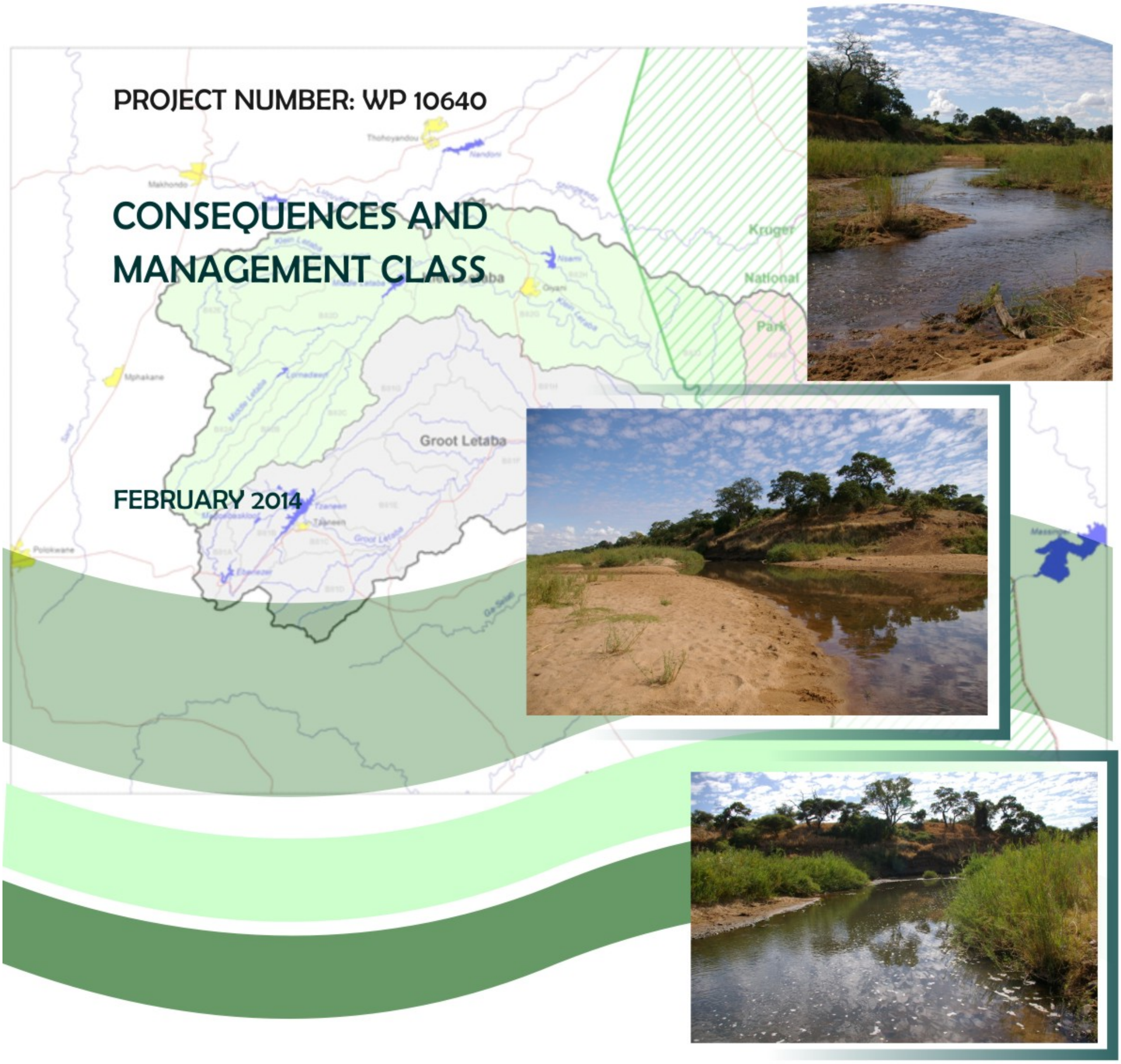
IMPLEMENTATION OF THE WATER RESOURCES CLASSIFICATION SYSTEM AND DETERMINATION OF THE RESOURCE QUALITY OBJECTIVES FOR SIGNIFICANT WATER RESOURCES IN THE LETABA CATCHMENT

PROJECT NUMBER: WP 10640

CONSEQUENCES AND MANAGEMENT CLASS

FEBRUARY 2014



water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

RDM/WMA02/00/CON/CLA/0114

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DEPARTMENT OF WATER AFFAIRS

CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE RESOURCE QUALITY OBJECTIVES IN THE LETABA CATCHMENT

CONSEQUENCES AND MANAGEMENT CLASS

Report Number: RDM/WMA02/00/CON/CLA/0114

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DEPARTMENT OF WATER AFFAIRS
CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE RESOURCE QUALITY OBJECTIVES IN THE LETABA CATCHMENT

CONSEQUENCES AND MANAGEMENT CLASS

Report Number: RDM/WMA02/00/CON/CLA/0114

Approved for Rivers for Africa by:

…………………………………….

Delana Louw
Project Manager

…………………………………….

Date

DEPARTMENT OF WATER AFFAIRS (DWA)

Approved for DWA by:

…………………………………….

Chief Director: Water Ecosystems

…………………………………….

Date

AUTHORS

The report was authored by:

Author	Company
Deacon, Andrew	*Private Consultant*
Huggins, Greg	*Nomad Consulting*
Koekemoer, Shael	*Koekemoer Aquatic Services*
Kotze, Pieter	*Clean Stream Biological Services*
Louw, Delana	*Rivers for Africa*
Mackenzie, James	*Mackenzie Ecological and Development Services*
Rountree, Mark	*Fluvius Environmental Consultants*
Scherman, Patsy	*Scherman Colloty and Associates*
Seago, Caryn	*WRP*
Van Rooyen, Pieter	*WRP*
Mullins, William	*Conningarth Economists*

Report editor and compiler: Shael Koekemoer
Internal Review: Shael Koekemoer and Delana Louw

Contributions in analysis were supplied by:
Deacon, Andrew (Private Consultant)
Koekemoer, Shael (Koekemoer Aquatic Services)
Kotze, Pieter (Clean Stream Biological Services)
Mackenzie, James (Mackenzie Ecological and Development Services)
Rountree, Mark (Fluvius Environmental Consultants)
Scherman, Patsy (Scherman Colloty and Associates)

Development of a Multi Criteria Decision Analysis tool to determine the Management Class:
Overall:
Pieter van Rooyen (WRP)
Ecological submodel:
Deacon, Andrew (Private Consultant)
Kotze, Pieter (Clean Stream Biological Services)
Louw, Delana (Rivers for Africa)
Mackenzie, James (Mackenzie Ecological and Development Services)
Economic submodel:
William Mullins (Conningarth Economists)
Ecosystem Services:
Huggins, Greg (Nomad Consulting)

ACKNOWLEDGEMENTS

Comments were provided by:

REPORT SCHEDULE

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EXECUTIVE SUMMARY

INTRODUCTION

The Chief Directorate: Resource Directed Measures (CD: RDM) of the Department of Water Affairs (DWA) initiated a study for the provision of professional services to undertake the implementation of the Water Resources Classification System (WRCS) and determination of the Resource Quality Objectives (RQOs) for significant water resources in the Letaba River catchment. Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study with support from various specialist consultancies as outlined in DWA (2012 – Section 8).

This task is associated with step 4 and 5 of the Water Resource Classification System. In summary, this task forms ***part*** *of Step 4 within the integrated approach adopted for this study, i.e. the identification and evaluation of scenarios within the Integrated Water Resource Management Process. The purpose of this report is to recommended operational scenarios and preliminary Management Classes for stakeholder evaluation.*

INTEGRATED CONSEQUENCES EVALUATION APPROACH

Considering that the core purpose of the Classification process is to select the Management Class (DWA, 2007) for a water resource, the scenario evaluation process provides the information needed to assist in arriving at a recommendation that will be consideration by the Minister of the Department of Water Affairs or delegated authority to make the final decision.

The overarching aim of the scenario evaluation process is to find the appropriate balance between the level of environmental protection and the use of the water to sustain socio-economic activities. Once the preferred scenario has been selected the Management Class is defined by the level of environmental protection embedded in that scenario.

There are three main elements (variables) to consider in this balance, namely the ecology, ecosystem services and the economic benefits obtained from the use of a portion of the water resource. The scenario evaluation process therefore estimates the consequences of a set of plausible scenarios will have on these elements by quantifying selected metrics to compare the scenarios on relative bases with one another.

The sequential activities carried out to evaluate the scenarios are presented in Figure 2.1, starting with the vision setting and describing the scenarios to be analysed. The status quo information was applied to identify the components requiring evaluation and defining the relevant parameters to be quantified. Water availability analyses were carried out for the scenarios, which feeds into the activity to determine the consequences on the Ecology, Ecosystem Services, Economy and None-Ecological Water Quality. The scenarios were ranked, first, for the individual variables and secondly an overall integrated ranking was derived based on multi-criteria analysis methods.

The results of the initial set of scenarios were interpreted to identify alternative release rules to improve the integrated scores with the objective to find and recommend an optimised scenario.

Six scenarios were identified for discussion and consideration by the stakeholders as described below.

SCENARIO DESCRIPTION

The Letaba River System is highly developed and regulated, both physically through various large storage dams, weirs, river abstractions and conveyance infrastructure as well as institutionally *through water user associations, municipalities and irrigation boards whom all untimely reports to the Department of Water Affairs.*

The scenarios considered for evaluation were identified in context of the prevailing water resource management and planning activities in the Letaba River System. To this end the possible development options identified in the parallel study, Development of a Reconciliation Strategy for the Luvuvhu and Letaba Water Supply System form the basis for the selection of the preliminary list of scenarios. This list was presented to the Project Steering Committee for their consideration and a final list was taken further by the study team for analysis and evaluation. The full list of scenarios is described in Chapter 3 and the detail definition of each scenario is presented in Table 3.1. Short narrative descriptions of the six scenarios that will be discussed with stakeholders are presented below:

Maintain Present Ecological State (PES or Scenario 1)

This scenario assumes no further water resource developments will be taking place in the Letaba System and the flow regime in the rivers is to maintain the Present Ecological State. The socio-economic parameters are quantified in accordance with the present conditions. This can be seen as the status quo scenario prepared for reference purposes.

Recommended Ecological Category (REC) – Scenario 7d

This scenario implements all the identified water resource development options and introduces releases from the existing and proposed dams in accordance with the flow requirements specified for the Recommended Ecological Category. This scenario represents the case where the ecology would score the highest while the water available for abstraction is reduced below the current levels of supply. Due to the reduction in the water availability (compared to Scenario 1) this scenario results in reduced economic activity.

Full water resource development with no releases for the ecological (Scenario 5)

This scenario represents the situation where the maximum volume of water is made available for abstraction from the system for economic activities without any releases for the ecology. This scenario evaluates conditions that are directly opposed to what is assumed in Scenario 7d.

Scenarios 6, 9 and 10 (alternative ecological release strategies):

These scenarios apply different ecological release regimes exploring alternatives to find a balance between protection and use. Scenario 6 is where releases are made to provide the low flow component of the PES (no high flows were released). Scenario 9 apply the low flow component of the REC scenario as well as one high flow event in each year except when Tzaneen and Nwamitwa dams were near empty. Scenario 10 introduced high flow events in three months (January, February and March) in addition to the PES low flow releases. The high flows were not releases when Nwamitwa Dan is below the 17% level for Scenario 10.

ECONOMIC CONSEQUENCES

The economic evaluation of the impact of the different scenarios as evaluated is based on the broad assumption that the utilisation of any additional or current water allocation is utilised at maximum efficiency.

Any economic evaluation takes place within the specific current situation, not an empty space, and it is necessary that the current situation be taken into consideration in the evaluation of any of the operational scenarios.

An economic baseline was established and the estimated deviation from the baseline was determined with water as the main driver. Three economic activities were used in the evaluation process, namely:

- *Irrigation.*
- *Light Industry; and*
- *Domestic Household Use.*

The current economic situation in the project area was also used in the final evaluation process of the different scenarios. The Groot Letaba section of the project area falls mostly in the Greater Tzaneen Local Municipality (LM) and the Greater Letaba LM areas. The rural area of Tzaneen LM was part of the previous Lebowa and the Letaba LM area part of the previous Venda. The Klein and Middel Letaba rural areas fall mostly under the Greater Giyani LM which previously was part of Gazankulu. All three LMs are part of the Mopane District Municipality, which consists of five local municipalities. According to the "Local Government Handbook" and the Statistics South Africa "Municipality Data" publication table 2.2 reflects the current situation in the three Local Municipalities.

Impact of the identified Scenarios on GDP

Scenario 7d, 7c, 8 and 8b will have a very negative impact on the baseline GDP of the irrigation sector while the other scenarios will have a slight positive impact in terms of the current baseline GDP.

All the scenarios will have a positive impact when compared to the current baseline for the domestic service sector, with Scenario 5b and 9 providing the most positive results.

All the scenarios will have a positive impact when compared with the current baseline for the light industry sector, with Scenario 5b and 9 providing the most positive results.

Scenario 5b has the greatest positive impact on the overall GDP, while Scenario 7c and 7d will present overall negative results with Scenario 8a and 8b marginally positive and the rest all very positive.

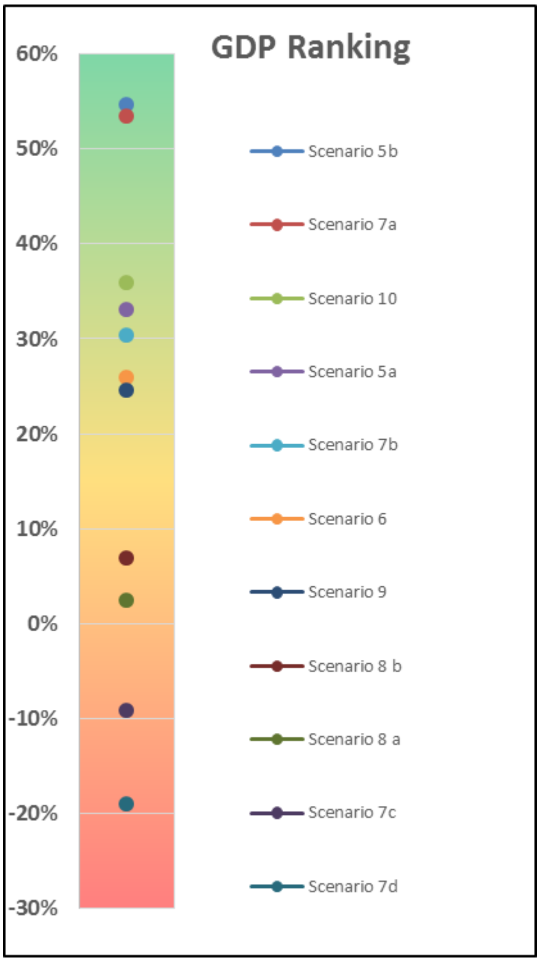
Impact of the identified Scenarios on Employment

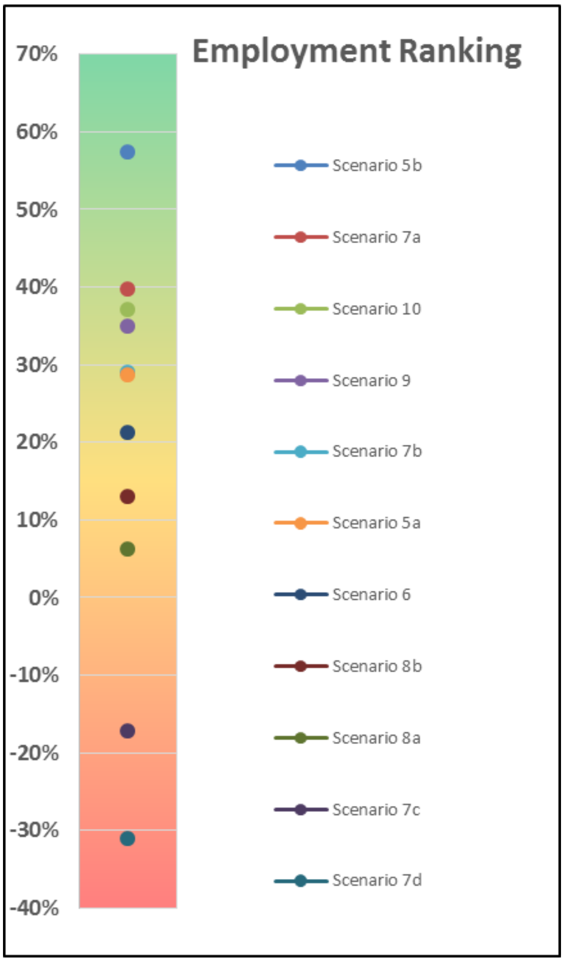
Scenario 7d and 7c will have a very negative impact on the baseline employment of the irrigation sector and Scenario 8a and 8b smaller negative impact with the other scenarios having a positive impact in terms of the current baseline employment.

In terms of additional jobs created, only Scenario 7c and 7d will create fewer jobs than the current baseline for the domestic service sector and the light industry sector.

Scenario 5b, 7a, 10 and 9 would be the most beneficial in terms of job creation for the domestic and light industry service sector as well as the irrigation sector.

In the next figure the scenarios are compared in terms of economic benefits that can flow from the different scenarios.





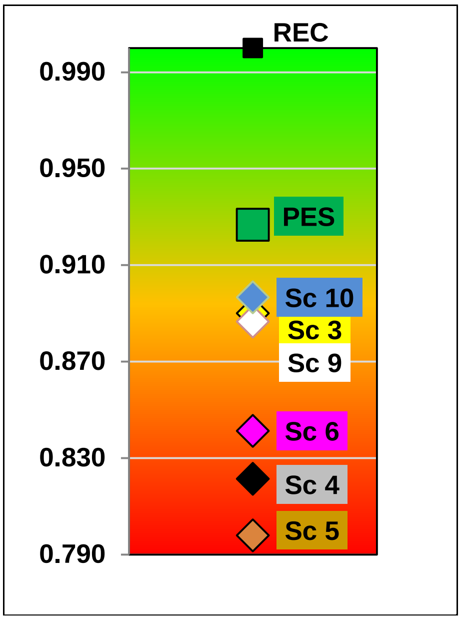
The comparison shows that the first three scenarios in each analysis are the same namely 5b, 7a and 10. The order only changes from the forth position where Scenario 9 in the case of employment creation moves upwards and 5a and 7 changes positions. In economic terms Scenarios 7d, 7c, 8a and 8b will have a negative impact on the economy of the region.

ECOLOGICAL CONSEQUENCES

The analysis of the consequences of operational scenarios was done in three steps as follows:

- *During the first step, an initial set of scenarios (Sc 2, 3, 4, 5 and 6) were evaluated and, during a specialist meeting, the consequences were determined. The results are provided in Report 4.2 (DWA, 2014) which serves as an information document for this report.*
- *A second set of scenarios (Sc 7a, b, c, d and Sc 8a, b) were designed with the aim to test sensitivity and lead to the design of optimised scenarios. Ecological consequences were broadly tested to aid in the design of optimised scenarios*
- *This information was used to generate a further set of operational scenarios with the aim of designing scenarios that potentially minimises the impacts (Sc 9 and 10). These scenarios were compared to the results generated during the first step and the ecological consequences determined (Section 5.2).*

The integration of the ecological consequences into a single ecological ranking for the Letaba River is supplied below.



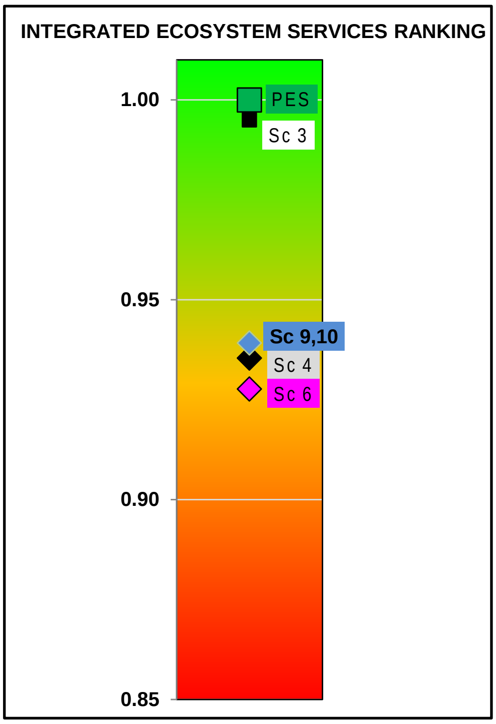
This ranking shows that none of the scenarios meet the Recommended Ecological Category and Present Ecological State for the system. The highest ranking Scenario is Sc 10 followed closely by Sc 3 and 9. As the Nwamitwa Dam will be built, the consequences are a given and the scenarios without Nwamitwa Dam cannot be considered. Therefore, the optimised Sc 10 is possibly the best option to consider depending on the socio-economic impacts.

ECOSYSTEM SERVICES

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

An analysis of the EWR sites 1, 2, 3, 4, 5, and 7 was undertaken. Ecosystem Services associated with the sites, bearing in mind that they represent a wider area, were listed and where they were deemed to generate value they were evaluated against the scenarios applicable to the site. Each site was evaluated under the impact against a base value of 1, representing the status quo. Anticipated change was evaluated against the base value with a negative impact represented as a score lower than 1 and an overall positive score represented as greater than 1. The process to determine an integrated ranking of the different scenarios required determining the relative importance of the different EWR sites. Here the perceived vulnerability of households dependent on the provisioning aspect of Ecosystem Services played a major role. EWR sites 3 and 4 and to a lesser extent EWR 2 were thus given a higher ranking.

The integration of the consequences of operational scenarios on Ecosystem Services into a single ranking for the Letaba River is supplied below.



Overall Scenario 3 was deemed to have least negative impact, followed in order of least negative impact, by Scenarios 9 and 10, then Scenario, 4 and lastly Scenario 6.

INTEGRATED MULTI-CRITERIA RESULTS

The scenario scores for the four variables, ecology ecosystem services, economy and employment are presented graphically in Figure 7.1. The relative weight applied to each variable for calculating the overall ranking is indicated numerically at the bottom of each graph.

The graph show the scenario with the highest ecological health metric (the REC scenario) reduces the water availability (compared to the current yield) to the extent that the economic and employment metric is the lowest of all the scenarios. This represents a curtailment (reduction) of the economy and employment in comparison with the present situation (PES scenario). At the other extreme, the scenario where no provision is made for releases, ecology scores the lowest (Scenario 5) while the available water for socio-economic development is high with corresponding high socio-economic benefits which results in the score of Scenario 5 for the economy and employment being the highest among all the scenarios. The scores for the other scenarios fall within these extremes and various alternative scenarios were evaluated in an attempt to find an optimum balance.

The final step in the multi-criteria analysis was to determine the integrated and overall rank of the scenarios and this is depicted in Figure 7.2a and Figure 7.2b for two alternative ranking methods. These results as well as the sensitivity analysis results presented in Table 7.2 indicate that Scenario 10 has the highest integrated rank of all the scenarios.

The resulting Management Classes for the six scenarios were determined by applying the criteria defined in Table 8.1 and is shown in Table 8.2.

CONCLUSIONS AND RECOMMENDATIONS

Given the results presented in Chapter 7 (summarised above) it can be concluded that Scenario 10 is the preferred scenario that achieves the best balance between protection and use among the scenarios considered. However, one of the characteristics of Scenario 10 is the inclusion of *additional abstractions out of Ebenezer Dam for possible transfer to Polokwane. This transfer is causing a reduction in the Ecological Category at EWR 1 (downstream of Ebenezer Dam) changing from a C Ecological Category for the PES Scenario to a C/D Ecological Category for Scenario 10. This reduction also results in a Management Class of III for IUA 1 for Scenario 10 compared to Management Class of II for the PES Scenario (see Table 8.2.). Furthermore, it was shown in the scenarios prepared for the Reconciliation Strategy Study that there is not sufficient water to supply the current and likely future water needs in the Letaba River System making further transfer to Polokwane infeasible from a water availability perspective.*

Therefore, it is recommended that Scenario 10 without the additional transfer to Polokwane be selected as the preferred scenarios which will imply the configuration of ECs and Management Classes for the IUAs as presented in Table 8.3.

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ACRONYMS

AZ	*Allocation Zones*
CD: RDM	*Chief Directorate: Resource Directed Measures*
CS	*Current State*
DWA	*Department of Water Affairs*
EC	*Ecological Category*
EI	*Ecological Importance*
EIS	*Ecological Importance and Sensitivity*
ES	*Ecological Sensitivity*
EWR	*Ecological Water Requirements*
ER	*Economic Region*
GIS	*Geographic Information System*
GLWUA	*Groot Letaba Water Users Association*
GDP	*Gross Domestic Product*
IUA	*Integrated Unit of Analysis*
KNP	*Kruger National Park*
LM	*Local Municipality*
MC	*Management Class*
MDG	*Millennium Development Goal*
PD	*Present Day*
PES	*Present Ecological State*
PSP	*Professional Service Provider*
REC	*Recommended Ecological Category*
RQOs	*Resource Quality Objectives*
Sc	*Scenario*
SQ	*Sub-quaternary (may also be termed a quinary)*
WIM	*Water Impact Model*
WMA	*Water Management Area*
WRCS	*Water Resources Classification System*

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Resource Directed Measures (CD: RDM) of the Department of Water Affairs (DWA) initiated a study for the provision of professional services to undertake the implementation of the Water Resources Classification System (WRCS) and determination of the Resource Quality Objectives (RQOs) for significant water resources in the Letaba catchment. Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study.

1.2 STUDY AREA OVERVIEW

The study area is the catchment of the Letaba River and illustrated in Figure 1.1.

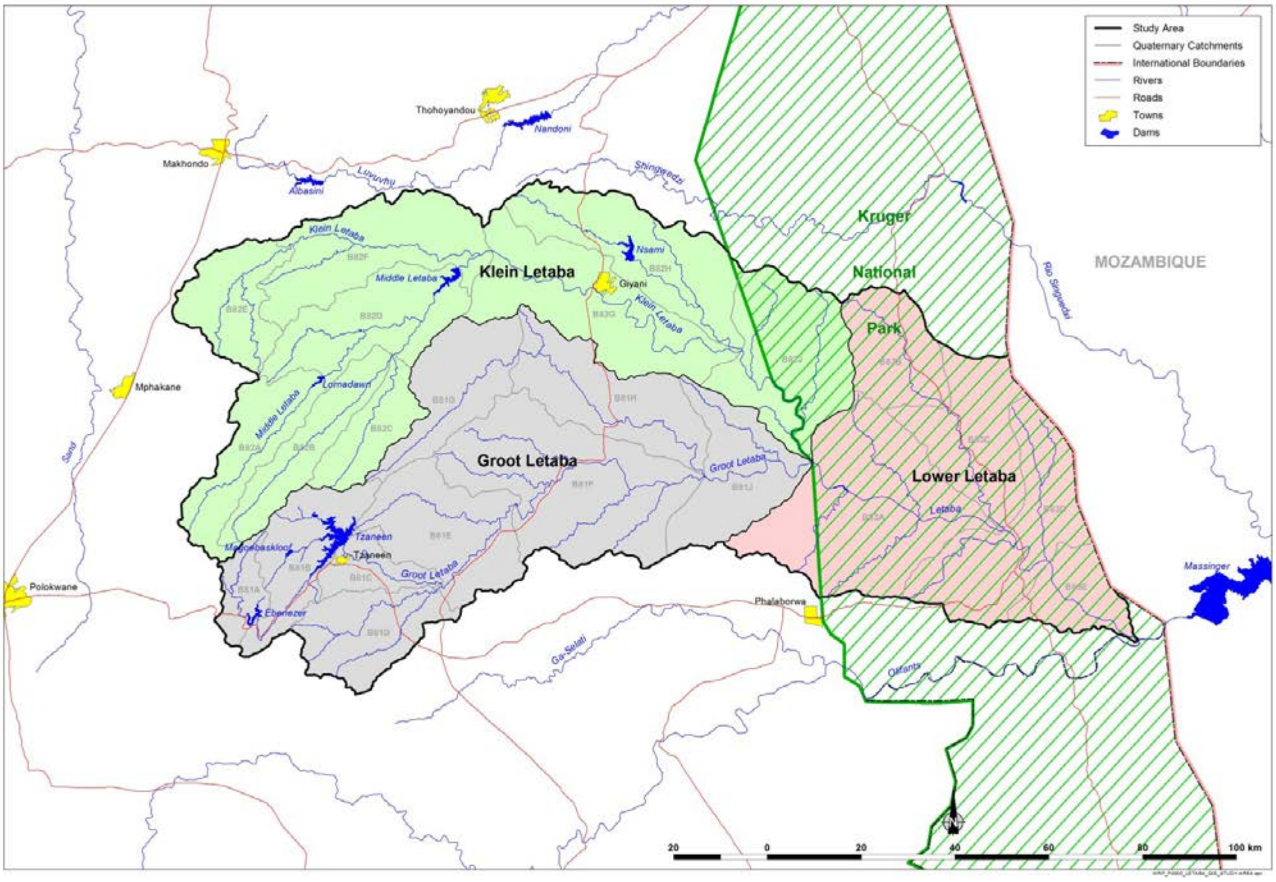

Figure 1.1 Study area: Letaba River Catchment

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	*Quantify the Ecological Water Requirements and changes in non-water quality ecosystem.*
4	**Identification and evaluate scenarios within the Integrated Water Resource Management process.**
5	**Evaluate the scenarios with stakeholders and determine Management Classes.**

Step	Description
6	*Develop draft RQOs and numerical limits.*
7	*Gazette and implement the class configuration and RQOs.*

This task forms ***part*** *of Step 4, i.e. the identification and evaluation of scenarios within the Integrated Water Resource Management Process. This step is closely linked to the next step where the scenarios are tested with stakeholders and the draft Management Classes (MCs) are determined. Using the results of the status quo assessment (DWA, 2013a) (Step 1), the next steps were initiated and the results of Step 4 is documented in this report.*

1.4 TASK D4: ID AND EVALUATION OF OPERATIONAL SCENARIOS TO IDENTIFY CONSEQUENCES

This task is associated with step 4 and 5 of the WRCS. In practice, these two steps function as one and are integrated as Task 4 (or step 4 within the integrated approach) (DWA, 2012). The objective of this task was to describe and document the following:

- *Identification of operating scenarios in accordance with the Reconciliation Strategy Study.*
- *River ecological consequences of the operational scenarios at the key biophysical nodes (Ecological Water Requirements (EWR) sites) by evaluating and determining the impact on the Ecological Category (EC).*
- *Economic consequences of operational scenarios by determining the impact of any water allocation changes.*
- *Assessment of the impacts of the various scenarios on Ecosystem Services of operational scenarios to identify the direction of change (either positive or negative) and estimate the magnitude of the change in benefits and costs that may be experienced within the river system.*
- *Water quality consequences (other than water quality consequences associated with the ecological component).*
- *Integrate the consequences to provide preliminary Management Class (MC) for stakeholder evaluation.*

The process described above is illustrated in Figure 1.2 and Figure 1.3. Figure 1.2 illustrates the broad conceptual process from the determination of the Status Quo (Integrated Step 1) through to the determination of Management Classes. Within these steps there are further sub-steps that pertain to integrated step 4 which are described in Figure 1.3.

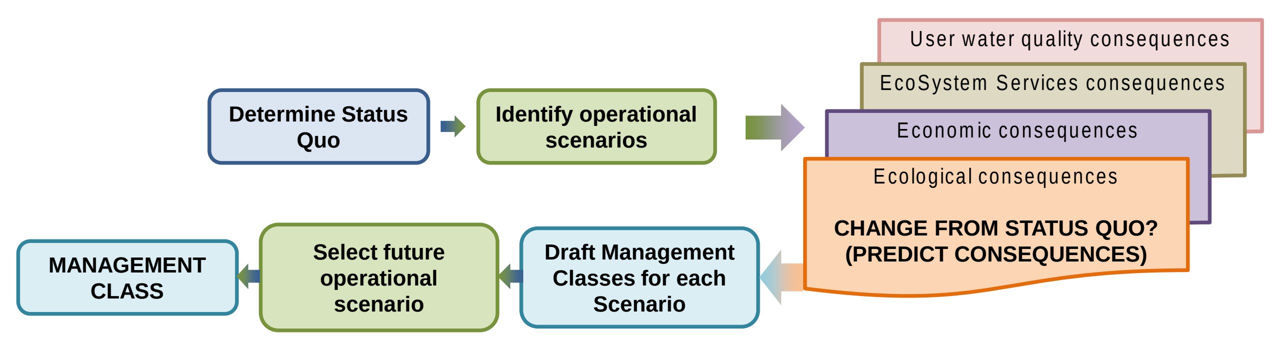

Figure 1.2 The process in Step 4 and 5: Identification of scenarios to the gazetted Management Class

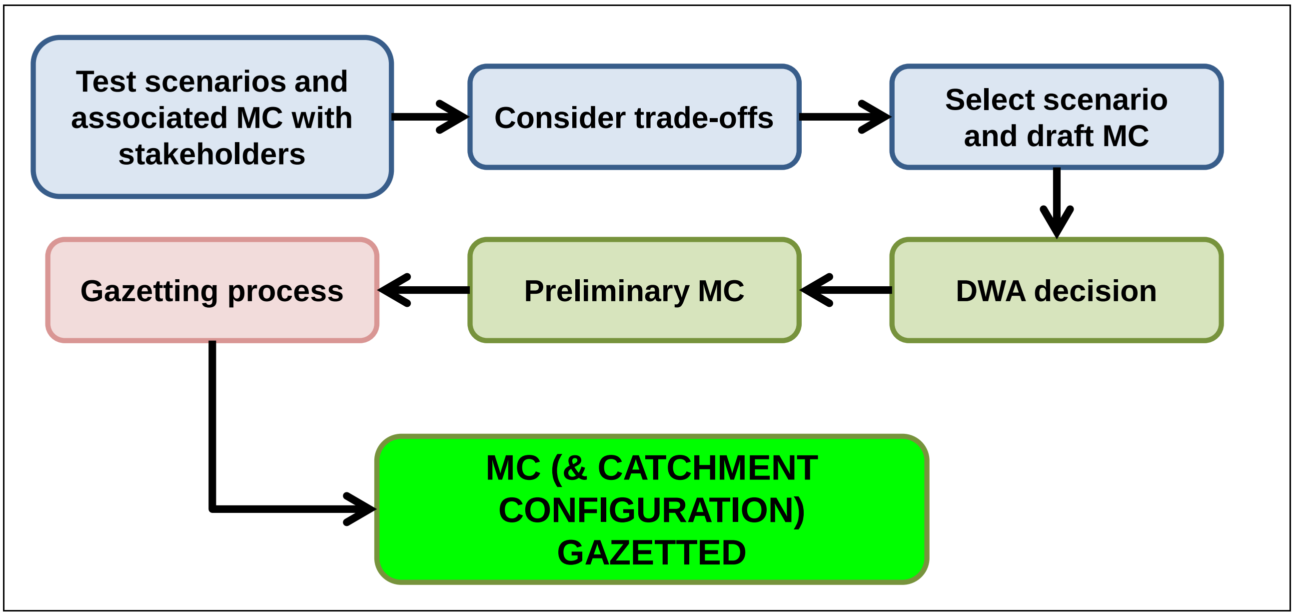

Figure 1.3 **Step 5: Illustrates the steps from the testing of scenarios with stakeholders to a final gazetted Management Class and catchment configuration**

1.5 PURPOSE AND OUTLINE OF THIS REPORT

The purpose of this report is to recommended operational scenarios and preliminary Management Classes for stakeholder evaluation.

The report outline is provided below.

Chapter 1: Introduction
This Chapter provides general background to the project Task.

Chapter 2: Integrated Consequences Evaluation Approach
This chapter provides an overview of the scenario evaluation process. Ecology, Ecosystem Services and the economic benefits are compared when determining the degree of achieving the appropriate balance between ecological objectives the socio-economic benefits and this chapter provides an expanded description of how the metric for each of the three components were derived.

Chapter 3: Scenario Description
The scenarios considered for evaluation are discussed.

Chapter 4: Economic Consequences
The results of different scenarios as it impacted on the different economic sectors are presented in this Chapter.

Chapter 5: Ecological Consequences
The results of the ecological consequences of the various scenarios are presented in this Chapter.

Chapter 6: Ecosystem Services
The results of impact of the different scenarios on Ecosystem Services are presented in this Chapter.

Chapter 7: Integrated Multi-Criteria Results

The results of the rating, weighting and scoring for the three variables, economy, ecology and Ecosystem Services presented in Chapters 4 – 6 were integrated to obtain the overall ranking of the scenarios and described in this chapter.

Chapter 8: Management Class Results

The recommended Management Classes among the scenarios are presented. Conclusions and recommendations are provided

Chapter 9: References

Chapter 10: Appendix A: Water Resource Modelling

The Water Resources Yield Model (WRYM) configuration was obtained from the Letaba-Luvuvhu Reconciliation Strategy Study Team for use in this study. The Appendix provides further detail regarding model configuration and schematic network diagrams.

Chapter 11: Appendix B: Water Quality in terms of User Requirements - Consequences of Scenarios

This Appendix presents the approach undertaken to include non-ecological water quality into the consequences evaluation and the results of this assessment.

Chapter 12: Appendix C: Report Comments

2 INTEGRATED CONSEQUENCES EVALUATION APPROACH

2.1 OVERVIEW OF THE SCENARIOS EVALUATION PROCESS

Considering that the core purpose of the Classification process is to select the Management Class (DWA, 2007) for a water resource, the scenario evaluation process provides the information needed to assist in arriving at a recommendation that will be consideration by the Minister of the Department of Water Affairs or delegated authority to make the final decision.

The overarching aim of the scenario evaluation process is to find the appropriate balance between the level of environmental protection and the use of the water to sustain socio-economic activities. Once the preferred scenario has been selected the Management Class is defined by the level of environmental protection embedded in that scenario.

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

During the evaluation process stakeholder are engaged at various stages, initially by providing their respective visions for the catchments (Integrated Units of Analysis - IUA), then defining and selecting the scenarios for evaluation and finally to assess the consequences with the aim to make a recommendation of which Management Class should be implemented.

The scenario evaluation process entails a sequence of activities followed during the Letaba River Classification Study and are illustrated schematically in Figure 2.1.

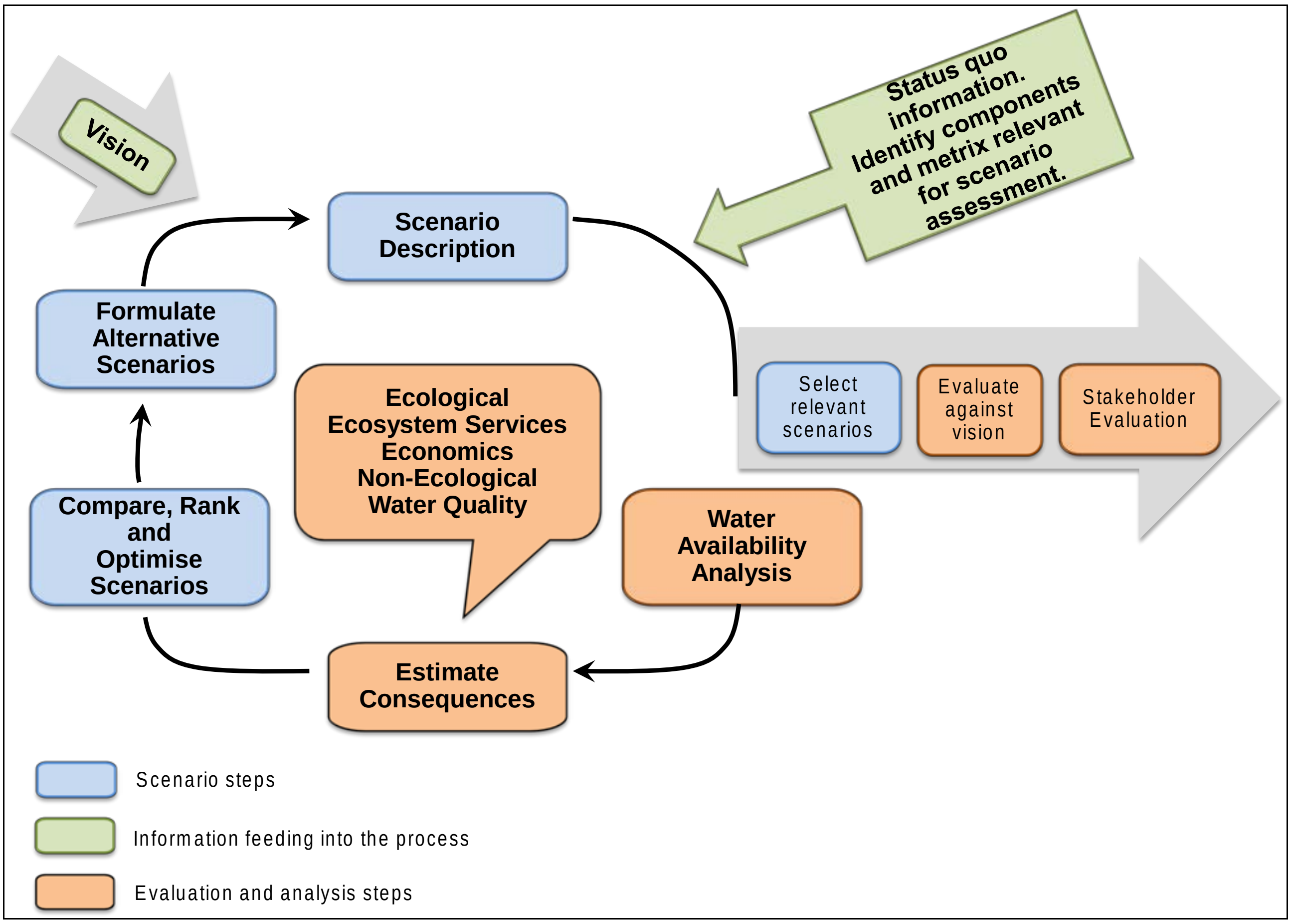

Figure 2.1 Schematic representation of the scenario evaluation process

Each activity presented in Figure 2.1 is briefly described in the following sections.

2.1.1 Vision

The visioning activity was carried out through interactive engagements with stakeholders where their respective views as to what the desired future state of the water resources should be were obtained. These visions were documented in the form of narrative descriptions and captured for the twelve delineated Integrated Units of Analysis (DWA, 2013a,b).

2.1.2 Scenario description

The definition and evaluation of scenarios were undertaken in context of the prevailing and proposed water resource management activities in the Letaba River System. With the understanding that a scenario, in context of water resource management and planning, are plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in a catchment and the system as a whole – the preliminary list of scenarios were derived from the parallel study Development of a Reconciliation Strategy for the Luvuvhu and Letaba Water Supply System. This preliminary list was presented to stakeholders for their consideration after which a final list was compiled for evaluation (see Section 3.3 for a description of the scenarios that were evaluated).

2.1.3 Assign attributes to EWR nodes

Applying the Status Quo information (DWA, 2013a) all the relevant properties (attributes) were defined for the biophysical nodes with respect to the Ecology, Ecosystem Services as well as the economic characteristics (in context of the IUA). A key aspect of this activity was to incorporate these nodes into the water resource simulation model to enable the generation of monthly time series of flow data for the scenarios where appropriate. At selected nodes (key biophysical nodes *or EWR sites) the flows required to achieve a particular ecological state were also defined, along with rules to make releases from upstream weirs and dams.*

2.1.4 Water availability analysis

This activity applied the water resource simulation model to determine the volume of water that is available for abstraction from the water resource for economic use, given that the flow regime in the river is maintained to achieve a certain ecological state. The ecological state is defined by the particular Ecological Category (EC) specified for the scenario under consideration, which could be the Recommended Ecological Category (REC), Present Ecological State (PES) or any other appropriate EC.

2.1.5 Estimate consequences

The simulated flow regimes at the nodes and the water available for abstraction form the basis for evaluating and estimating the consequences of each scenario. The text box in the centre of Figure 2.1 indicates the aspects that were evaluated. Table 2.1 lists these aspects and provides a brief description of the evaluation method and purpose as well as references to where further detail information are provided.

Table 2.1 Variables considered in the scenario comparison and evaluation process

Variable	Evaluation purpose and method	Reference to further detail information
Ecological	*Determine the EC and indicate the degree in which the scenario achieves the REC.*	*Report 4.2; Chapter 5*
Ecosystem Services	*Determine the extent that each scenario changes the Ecosystem Services relative to the PES conditions.*	*Chapter 6*
Economy	*Determine the economic benefit of utilising the available water (abstractions) in terms of Gross Domestic Product (GDP) and Employment (Jobs).*	*Chapter 4*
Non-ecological Water Quality	*Consider the consequences of having to achieve elevated water quality standards for users other than the ecology (fitness for use or Userspecs). This may involve determining the economic implications of such elevated standards.*	*Appendix B*

2.1.6 Compare, rank and optimise

The consequences from the abovementioned activity are expressed numerically for the scenarios and compared separately for each variable and then the results are combined for all variables to derive overall scores which give effect to the ranking of scenarios. The methodology employed for this is based on Multi Criteria Analysis approach where weighting factors are applied, firstly to give effect that certain nodes are more important than others and secondly that the variables listed in Table 2.1 may differ in their relative importance (see Section 2.2 for further details on the Multi Criteria Analysis methodology).

When the results of the first set of scenarios were evaluated it was identified that there were possible alternative EWR release methods that may achieve a more optimised overall solution. All the scenarios are described in Chapter 3.

2.1.7 Formulate alternative scenarios

This activity involves the formulation of alternative scenarios, usually consisting of adjustment to the initial list (rather than completely different scenarios) for further consideration. The other steps *are then repeated as indicated by the circular arrows depicting the information flow from one activity to the next.*

2.1.8 Select scenario subset for stakeholder evaluation

The technical study team assessed several scenarios of which the results defined the boundaries of the variable settings and point to the aspects that are important to consider in the Letaba River System. A relevant subset of the full list of scenarios was selected for discussion with stakeholders.

2.2 MULTI CRITERIA ANALYSIS FOR SCENARIO EVALUATION AND COMPARISON

2.2.1 Evaluation variables

As explained in Section 2.1 there are three main aspects that are compared when determining the degree of achieving the appropriate balance between the ecological objectives on the one hand and the socio-economic benefits on the other.

The ecological state (or health) rating is expressed relative to how the scenario achieves the REC. This is quantified as a numerical ratio ranging usually between 1 and 0, where a score of 1 indicates the scenario achieves the REC and zero when the scenario is typically in an F Ecological Category.

The rating of the Ecosystem Services for a scenario is expressed numerically and relative to the baseline Ecosystem Services available under current conditions (2013). A score of 1 indicates the scenario will provide the same services as under present conditions where a score of 1.2 imply there is 20% more utility in terms of Ecosystem Services. A score of 0.8 indicates a reduction of 20% in the services provided by the scenario.

In terms of the socio-economic component, two aspects are evaluated, namely the GDP and employment (the number of jobs) that will be supported by the volume of water that can be abstracted from the system for the scenario. The GDP is expressed in monetary terms (Rand) and employment in the number of jobs supported.

The following sections provide an expanded description of how the metric for each of the three components presented above were derived.

2.2.2 Ecological Metric

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

- *Scenarios at each EWR site are ranked on the basis of the degree to which the scenarios meet the REC.*
- *Comparing the impact of the scenarios at the different EWR sites to determine a ranking from a system context depends both on the degree to which the scenario meets the REC, as well as the relative ecological importance of the sites.*

To further explain this, if a scenario is ranked highest at a site of low importance, but lower at a site of high importance, this scenario will not carry the same weight as the scenario that scored the highest at the sites of high importance.

The steps and sub-steps to derive a single number are illustrated in Figure 2.2 and Figure 2.3 and described in the bulleted list below:

- **Step 1: Rank scenarios at each EWR site (Figure 2.2 and Figure 2.3)**
  - *Apply the EcoClassification (Kleynhans and Louw, 2007) process at each EWR site where the scenario influences the flow or water quality to determine the EC for each component*[1]*.*
  - *Provide the associated percentage that represents the category.*
  - *Calculate the degree to which the scenario meets the ecological objectives which is represented by the REC. I.e., if the REC for a component is 62% and the scenario results in this component being at 62%, then the resulting score would be a 1 (or a 100% successful in meeting the REC). If a scenario's rating for the component is 48%, then the score would be 0.77 (or 77% successful in meeting the REC).*
  - *Average the score at each component to obtain a score for the scenario at the site.*
  - *Each site's score is then normalised to obtain a rating that is 1 if the REC is achieved, above one if the REC is exceeded (i.e. 1.1) or between 1 and zero if the score (EC) is below the REC.*
  - *Rank the scenarios in terms of a numerical scale with values zero and one (typically, where one (1) indicates the scenario achieves the REC and a zero (0) represents the situation where the scenario results in a "F").*

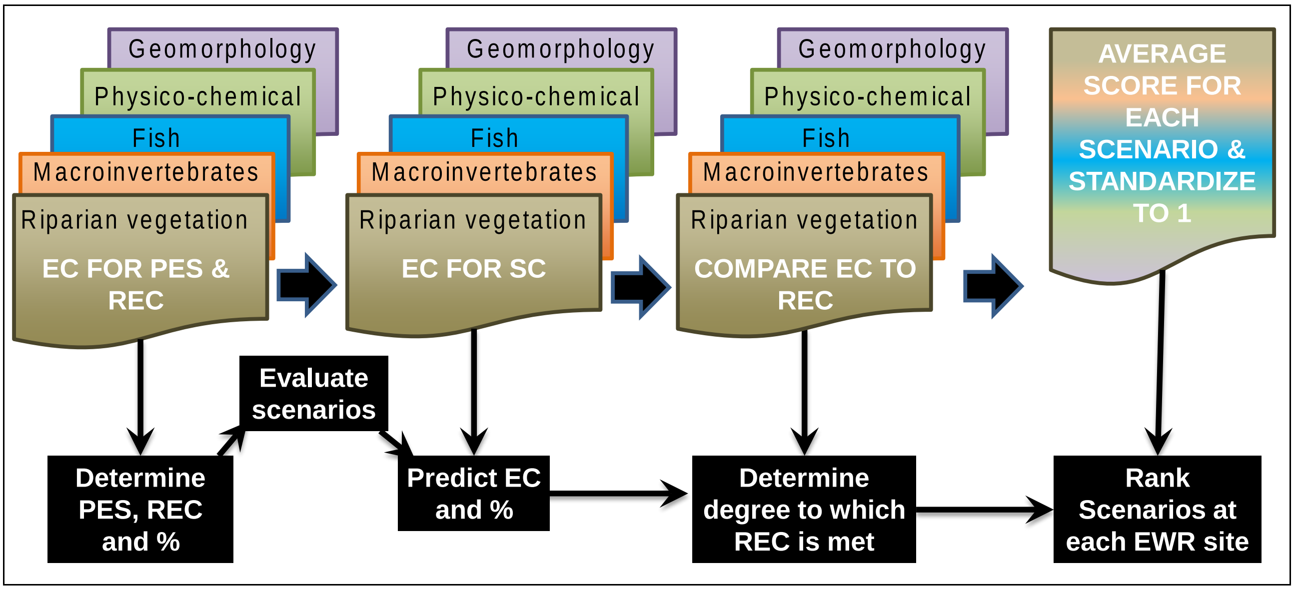

Figure 2.2 Process to rank scenarios at each EWR site

- **Step2: Determine the relative importance of EWR sites to each other (Figure 2.3)**

  The following aspects are considered when determining the relative importance of the EWR sites to each other:
  - *PES: The higher the PES the more important the EWR site. The PES percentage is used in this calculation.*
  - *Ecological Importance and Sensitivity (EIS): The higher the EIS rating, the more important the EWR site. The EIS score is used in this calculation.*
  - *Conservation importance: The locality of the site within a declared conservation area is highlighted. A site within a Transfrontier park or a Wilderness Area will be more important than a National Park which in turn will be more important than a provincial nature reserve.*

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1 Component: Habitat drivers (geomorphology and water quality (hydrology is a given)); Biological responses (fish, macroinvertebrates, riparian vegetation).

The above metrics are averaged and the score is then normalised out of one.

- **Step 3***:* **Rank the scenarios in a system context (Figure 2.3)**
  All the scores from the EWR sites are then combined into a single score by accounting for the above site importance ranking. This is achieved by assigning different weights (factors) to each site to reflect the importance relative to the others.

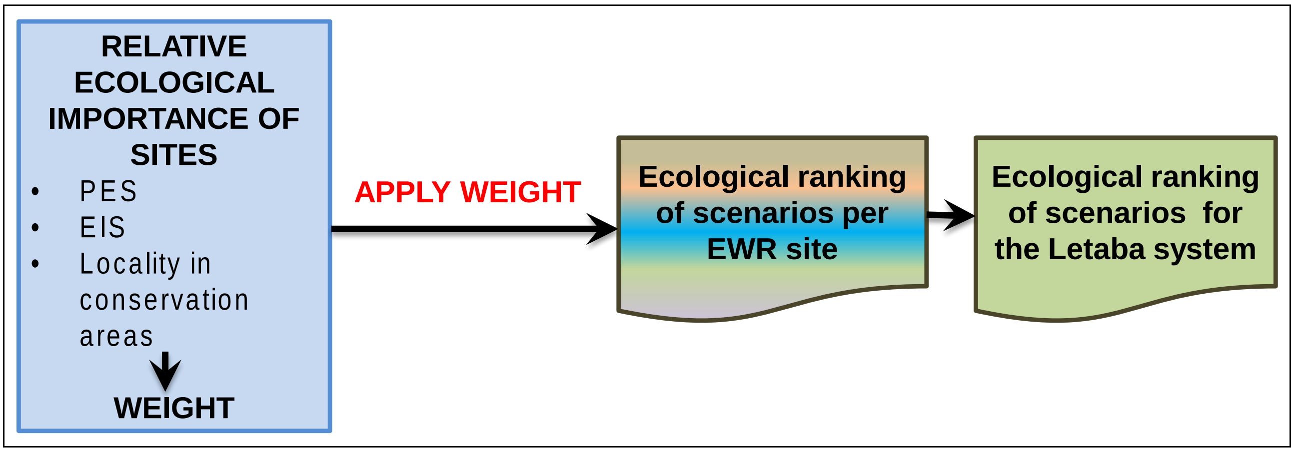

Figure 2.3 Process to achieve the ecological ranking of all scenarios on the Letaba system

The output of the application of these processes result in an ecological ranking of each scenario for the Letaba system. The individual ranking and consequences at each EWR site have therefore been integrated into one ranking and consequences applicable to the Letaba system.

2.2.3 Ecosystem Services metric

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

For operational purposes this study follows the approach defined in the 2005 Millennium Ecosystem Assessment and classifies Ecosystem Services along functional lines using categories of provisioning, regulating, cultural, and supporting services.

Provisioning services are the products obtained from ecosystems, including food and fibre. This includes the fish in the river as well as materials such as wood and fibres for timber and fuel as well as for items of utilitarian or craft value. Provisioning services also includes natural medicines, and pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.

Regulating services are the benefits obtained from the regulation of ecosystem processes and include:

- *Water regulation: The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.*

- *Erosion control: Vegetative cover plays an important role in soil retention and the prevention of landslides.*
- *Water purification and waste treatment: Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes*
- *Regulation of human diseases: Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.*
- *Cultural Services: The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including spiritual and religious values. Many religions attach spiritual and religious values to ecosystems or their components.*
- *Aesthetic values: Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, "scenic drives," and the selection of housing locations.*
- *Sense of place: Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.*
- *Recreation and ecotourism: People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.*

Supporting services are those that are necessary for the production of all other Ecosystem Services. They differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. Some examples of supporting services are primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitats.

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

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

This requires technical and food security interventions as well as interventions that offset market, policy and institutional failures. A poor understanding of the value of environmental goods and services will continue to encourage their overuse and degradation, the poor internalisation of the associated costs and benefits of their use, and sub-optimal allocation among competing users, thus further exacerbating development constraints.

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

Based on the literature research, as well as site visits, the key Ecosystem Services that form a part of community reliance, livelihoods and subsistence, or provide key non-market related economic functions, have been examined and form part of a separate report (DWA, 2013a).

DWA (2013a) addresses this component of the study, and the list of Ecosystem Services are further scrutinised to generate an overview of the likelihood that they will change given anticipated trajectories of modification to the system once flow scenarios are developed.

In the first part of the approach the Sub Quaternary (SQ) catchments were analysed and evaluated against each other. In this regard the most important step was to provide and integrated assessment of the current population of the study area. Analysis was undertaken using four primary tools. These were:

- *The 2001 census as adjusted and the 2011 census data that is available.*
- *The 2006 Letaba Catchment – Reserve Determination Study, undertaken for the Department of Water Affairs, included an overview of ecological goods and services (DWAF, 2006). This has been examined and updated.*
- *Geographic Information System (GIS) overlays of quaternary catchments and the census “sub place name” data. “Sub place name” data fields are the most detailed subsets of data released by Statistic South Africa. This allows for the population for each quaternary to be calculated and a profile of the population for each unit to be analysed. Data was analysed to select areas in which populations likely to be dependent on riverine goods and services were possibly or probably present.*
- *Cross check of the GIS data sets with available mapping to determine likely livelihood styles and profiles.*
- *Site visits to likely “hot spots”.*

A second level of analysis based on the typology of settlements in the area and their likely associated dependence on Ecosystem Services for livelihoods was undertaken for this report (DWA, 2013a). This was sourced from information available from Statistics South Africa and cross referenced with an examination of aerial photography, largely that provided by Google Earth. This allowed for an analysis of land use types associated with the settlement typology.

Based on the Status Quo analysis (DWA, 2013a) the catchment has been divided into zones that reflect the ecological goods and services attributes as a direct dependent of land use attributed. For the purposes of this catchment five different land use forms that reflect types of ecological goods and services that might be associated with the usage have been identified. It should be noted that as the building block for the analysis is the SQ, a judgment call has to be made as to which land form dominates in the section under consideration. In some instances there are multiple land uses that apply to the SQ. The land use based zones are:

- *Commercial Agriculture and Plantation: This is largely given over to zones dominated by commercial farming entities. Utilisation of Ecosystem Services tends to be low and restricted often to farm workers or incidental recreational aspects.*
- *Subsistence agriculture: These areas are dominated by subsistence agriculture but in areas where population densities are relatively low. Utilisation of Ecosystem Services tends to be higher here and the populations that make use are often poor and marginal.*
- *Rural Closer Settlement - Subsistence: These are the former homeland areas that have generally higher population densities than the purely subsistence areas. In some instances densities are high enough to be categorised as closer settlement/informal urban. Utilisation of Ecosystem Services tends to be higher here and the populations that make use are often poor*

and marginal. However, the population densities are such that resources tend to be under pressure.

- *High Density Formal Urban: These are the SQs heavily influenced by the town of Tzaneen. The utilisation of Ecosystem Services tends to be low as the populations tend to be urbanised and alienated from direct use of the resources.*
- *Recreational/Dams/Game Farms: These are areas given over to game farms (notably the KNP) as well as SQs dominated by dams. Recreational usage tends to dominate Ecosystem Services attributes.*

Further, each quaternary catchment of the Letaba system has been examined in detail and scored. The score was based on an earlier analysis of Socio Cultural Importance (SCI) and was determined from (a) a site visit that covered points along the river, (b) extrapolation to sites not visited by reference to available literature as well as to existing mapping. Given the size of the budget and the geographical scope of the work most of the information used to influence the score was derived from direct observation and consideration of the literature available. A limited number of direct interviews were held with people who were resident proximate to the river. The provisioning, regulating, cultural, and supporting services were considered in turn and rated per SQ from 1 (no importance wither in terms of magnitude or significance) to 5 (extreme importance in both magnitude and significance). The ratings were given weights to generate an overall score (also on a scale of 1 – 5) as follows:

- *Provisioning services: Given a weight of 0.5 or half the overall Ecosystem Services score. This is done so as to ensure that where there are vulnerable communities dependent on the direct consumption of goods for livelihoods due cognisance is given to this requirement. The Letaba catchment is relatively highly populated and includes a number of vulnerable communities.*
- *Cultural services: Given a weight of 0.25. These services include recreational aspects and again are of relatively high importance in the Letaba catchment.*
- *Supporting and regulating services: Given a weight of 0.125 each. While not to downplay these services they are given lesser importance in the overall Letaba catchment given the nature of the overall socio-political makeup that contains a number of vulnerable communities for whom provisioning services are critical.*

This analysis generates a weighted ranking of the overall importance of the SQs when compared to each other.

A further round of analysis was undertaken in a specialist workshop. It should be noted that the objective in describing and valuing the use of aquatic ecosystems is to determine the way in which aquatic ecosystems are currently being used in each socio-economic zone (represented by an EWR site), and to estimate the value generated by that use. This provides the baseline against which the socio-economic and ecological implications of different catchment configuration scenarios can be compared. It is important to point out that while Ecosystem Services were identified and described in qualitative terms, a baseline value can often only be described for some of these, as the information required is not available without investing in a costly survey.

A list of the relevant ecological Ecosystem Services that were found in the various reaches examined, and deemed to be significant, was generated as a table. These were cross checked with the biophysical experts that formed part of the project team at a specialist workshop held in October 2013.

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

The scenario impact on various Ecosystem Services (including botanical or fish species) were then amalgamated into overall categorisation of provisioning, regulating, cultural, and supporting services. The scenarios are also weighted with respect to the importance of the services at each EWR site. As such the score given to each of the services when the SQs are evaluated is examined against the nature of the particular EWR site and associated area. In an instance where regulating services, for example are deemed to be important, then these services are given a higher weight. The same goes for the other services.

2.2.4 GDP and employment metric

The economic evaluation of the impact of the different scenarios as evaluated is based on the broad assumption that the utilisation of any additional or current water allocation is utilised at maximum efficiency.

Any economic evaluation takes place within the specific current situation, not an empty undeveloped or river catchment, and it is necessary that the current situation be taken into consideration in the evaluation of any of the operational scenarios.

Currently the following main water users are identified in a catchment or Water Management Area (WMA), or are dependent on the water in the river. The main users are:

- *Irrigation.*
- *Commercial forestry.*
- *Mining.*
- *Electricity Generation.*
- *Heavy Industry.*
- *Urban and Domestic Household Use.*
- *Light Industry; and*
- *Tourism.*

The tourist activity depends on the availability and quality of the water in the river or estuary and the overall condition of the environment.

As the main aim of the classification process is to stabilise the river or estuary class, the possibility that the water in the river will be reduced is not always an acceptable option. Therefore, the tourist activities can only be positively impacted on, the worst case option is that the sector will remain as it is at present.

The commercial forestry sector is regulated by a permit system, and we could not find any evidence that any reduction in the commercial plantation area is considered. For this reason it was accepted that on the medium term the forestry sector will not be impacted on by any operational scenario.

The irrigation, mining, electricity and heavy industry sectors will only be impacted by scenarios which results in available volumes increasing or decreasing.

Measuring Parameters

It was decided to use, in both the baseline as well as the different scenarios, two macro-economic indicators, namely Gross Domestic Product (GDP) and employment and in some cases also low-income household payments. Although the use of the GDP created is generally accepted as an economic growth indicator, it sometimes does not present the full picture. In the case of irrigation agriculture irrigated maize provides a very large GDP contribution, maize is a very strategic product in the national food security picture as well as household food security. However, because of the high levels of mechanisation very few jobs are created in the primary sector. If the area is highly rural and impoverished then job creation is perhaps more important than GDP creation.

A second factor to consider is the value added process in the production area, as an example, sugar cane mills create a service point in the primary area of production. Many social services start to concentrate around sugar cane mills, such as health clinics, pension pay points and police stations.

On the opposite side is, possibly, citrus production which creates a large number of jobs in the primary production activity, but very little value added takes place in the primary production area as most of the fruit is exported. This is not always the complete picture as juice facilities and other value added processes can be added. However, it has a positive impact on the Balance of Payments.

In the final instance it is necessary to take into consideration the current situation, a certain economic sector is in operation while some of the others are based on assumptions and projections. There is always the risk that the projected benefits will not materialise because of a number of reasons, e.g. government policy, economic circumstances or lack of entrepreneurial skills.

Economic Modelling

The model, as is currently constructed, is in the form of a dynamic computerised water entitlement model which can be used to identify and quantify the following indicators:

- *Economic benefits.*
- *Maximum possible water reduction.*

The first step is to calculate the macro-economy of each of the Economic Regions (ERs) in the project area and to identify and establish the detailed water users in terms of volume used. In the case of irrigation and commercial forestry the detailed areas in production are determined together with the different crops produced.

A Water Impact Model (WIM) was constructed for the catchment which included the identified ERs. The model is water driven and gives the direct and indirect/induced results for the following sectors: irrigation agriculture, commercial forestry, heavy and light industries, mining, electricity generation and urban and household use and eco-tourism. Regarding agriculture the model can accommodate up to twenty different products and for forestry it makes provision for pine, gum and wattle sub-species.

The following impacts are estimated by the WIM:

- *Gross Domestic Product (GDP).*
- *Low Income Households and Total Households.*
- *Employment Creation.*

A group of economic multipliers was then developed for comparing different water use activities in terms of GDP (GDP/m^3), employment creation (number/million m^3) and the low-income households. As the economy entails a number of mechanisms and linkages between sectors, definitions of the economic impacts used in the economic results are described below in terms of the direct, indirect and induced effects explained by means of the agricultural sector:

- *Direct effect: Refers to effects occurring directly in the agriculture sector such as the hectares cultivated impacts.*
- *Indirect effects: Refers to those effects occurring in the different economic sectors that link backward to agriculture due to the supply of intermediate inputs, i.e. fertiliser, seed, etc.*
- *Induced effects: Refers to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumption expenditure.*

Project area specific considerations

In the evaluation of the different users it was identified that the following sectors in the project area could be affected by a change in the water allocation:

- *Irrigation.*
- *Urban and Domestic Household Use.*
- *Light Industry.*

An additional urban allocation as proposed by a number of scenarios will impact positively on the household sector as well as the light industry sector, if the urban centres of Tzaneen and Giyani experienced the future growth as expected.

An economic baseline was established and the estimated deviation from the baseline was determined with water as the main driver. Three economic activities are used in the evaluation process, namely:

- *Irrigation.*
- *Light Industry; and*
- *Domestic Household Use.*

The current economic situation in the project area was also used in the final evaluation process of the different scenarios. The Groot Letaba section of the project area falls mostly in the Greater Tzaneen Local Municipality (LM) and the Greater Letaba LM areas. The rural area of Tzaneen LM was part of the previous Lebowa and the Letaba LM area part of the previous Venda. The Klein and Middel Letaba rural areas fall mostly under the Greater Giyani LM which previously was part of Gazankulu. All three LMs are part of the Mopane District Municipality, which consists of five local municipalities. According to the "Local Government Handbook" and the Statistics South Africa "Municipality Data" publication Table 2.2 reflects the current situation in the three Local Municipalities.

Table 2.2 Local Municipality Data -2011/2012

Municipality	Population	Rural (%)	Population Growth Rate	Unemployment Rate
Tzaneen LM	*390 095*	*80%*	*0.38%/annum*	*36.7%*
Letaba LM	*212 701*	*85%*	*-0.29%/annum*	*40.3%*
Giyani LM	*244 217*	*80%*	*0.14%*	*47.0%*

Table 2.2 shows a mainly rural population with a high unemployment rate and low population growth rates. Letaba LM actually shows a negative population growth rate. It is not the purpose of this document to analyse the reasons for this, however, it is generally accepted that urbanisation by the younger generation is one of the main drivers. The two main urban areas, Tzaneen and Giyani, are experiencing a population growth rate considerably higher than the official rate, also an indication of the urbanisation process.

This reality contributes to the decision to specifically measure the possible impact of the different operational scenarios on the GDP representing the economic growth, the impact on employment and the possible impact on the low-income households as an indication of the contribution made to poverty alleviation.

Approach

In the formulation process of the different scenarios the projected available volume of water was calculated. In Table 2.3 the scenarios with the relevant water volumes are reflected.

Table 2.3 Estimated water allocation per Scenario

	Supply (million m^3/a)					
Scenarios (Sc)	**Groot Letaba system supply**	**Urban allocation**	**Irrigation allocation**	**Groot Letaba additional urban allocation**	**Additional ground water**	**Klein Letaba additional urban allocation**
1 (PES)	*82.60*	*16.20*	*66.40*			
2a						
2b						
3a						
3b	*82.60*	*16.20*	*66.40*	*0.00*		
3c						
4a						
4b					*64.00*	
5a					*64.00*	*12.00*
5b	*100.50*	*16.40*	*68.10*	*16.00*		*12.00*
6					*64.00*	*11.00*
7a	*90.70*	*16.40*	*69.20*	*5.00*		*2.00*
7b	*87.00*	*16.40*	*69.60*	*1.00*		*2.00*
7c	*57.20*	*16.40*	*40.80*	*0.00*		*2.00*
7d (REC)	*45.60*	*16.40*	*29.20*	*0.00*		*2.00*
8a	*67.20*	*16.40*	*50.80*	*0.00*		*7.00*
8b	*72.60*	*16.40*	*56.20*	*0.00*		*8.00*
9	*87.60*	*15.90*	*66.70*	*5.00*		*9.00*
10	*88.20*	*16.10*	*67.10*	*5.00*		*11.00*

The scenario Sc 1 (PES) refers to the current or present water allocation in the Groot Letaba catchment. Where no values are provided the water allocation per scenario is the same as the PES. The Scenarios highlighted in green in Table 2.3 were the only scenarios analysed from an economic perspective as these were the only scenarios where a change in water allocation was evident. In the case of the other scenarios it was accepted that the water allocation remained the same as the base line allocation and was not analysed. The ground water was not used at all.

In the following sections the assumptions used in the different sectors are discussed.

Irrigation Agriculture

Currently irrigation is the major user of water and also the largest economic enterprise in the Groot Letaba catchment. In analysing the possible impact of a specific operational scenario the following assumptions were made.

1. *Only the water provided by the Groot Letaba Water Users Association (GLWUA) as well as water provided by the canals and "run of river". It was accepted that the water used by the diffuse irrigators will be unaffected and was therefore not used.*
2. *The estimated irrigation demand is set at 88.17 million m^3, but the long term average supply is 66.4 million m^3. The following economic interpretation was used based on the average supply versus the demand: Effectively the "assurance of supply" is 75.31%, or over a 100 year period the full "demand" of irrigators will only occur for 75 years.*
3. *It was assumed that the current irrigation development is based on this long term water volume provision and that the management practises of the irrigators have been adapted to this reality.*
4. *Modern irrigation equipment is used in all crops.*
5. *The long term crop yields were adapted to be in line with the average long term water supply and not the irrigation demand assuring a 100% crop yield. In practical terms this is interpreted as follows: If a 100% water supply in a certain crop under perfect conditions in the Groot Letaba would yield 80 tons, then the long term average yield will be 60 tons per hectare. In Table 2.4 an indication of the long term yields is provided, compared with the theoretical 100% water supply.*
6. *In the case of Scenarios 7a, 7b and 9, where small increases in water provision were expected, the average crop yields where adapted upwards.*
7. *In the case of Scenarios 7c, 7d, 8a and 8b, where available irrigation water was reduced significantly, the hectares in production were reduced to be in line with the expected water supply, the crop yields retained, calculated for the average long term water provision. Average rule being, retain as much of the citrus, avocado and banana orchards.*

Table 2.4 Long term crop yield in comparison with theoretical 100% water supply

Crop	Yield with 100% water supply (tons/ha)	Estimated long-term yield (tons/ha)
Summer Vegetables - cucurbits	*22*	*20.93*
Winter Vegetables- brassicas	*80*	*72.4*
Macadamias	*6*	*4.77*
Citrus – Valencias	*48.5*	*40.53*
Bananas	*35*	*33.79*
Citrus – Grape fruit	*40.57*	*33.9*
Litchis'	*3.62*	*3.04*
Mangoes	*10*	*9.15*
Avocados	*13*	*11.04*
Tomatoes	*70*	*52.72*

In Table 2.5 the crop aggregation as used in the calculations is presented. It was necessary to add a number of different vegetable varieties together in order to limit the number of different crops to 10. It is not the ideal situation, but by grouping them in a winter and summer categories makes the modelling more acceptable. The winter category is represented by the Brassica group and the *summer category by the Cucurbit group. It is also presented in the so-called allocation zones as used to establish the original economic baseline. The different allocation zones (AZs) are as follows:*

- *AZ1 – Area above the Tzaneen dam.*
- *AZ 2 – Area below the dam up to the confluence with Letsitele River.*
- *AZ3 – Groot Letaba River from the confluence with the Letsitele River to the confluence with the Klein Letaba River.*
- *AZ4 – Letsitele River.*

Table 2.5 Division of Crops in the GLWUA provision area

Crop	AZ 1	AZ 2	AZ 3	AZ 4	Total
	Hectares	Hectares	Hectares	Hectares	Hectares
Bananas	*121.98*	*287.48*	*306.95*	*0.31*	*716.72*
Citrus (Valencias)	*1.55*	*1 196.54*	*3 558.96*	*1 367.29*	*6 124.34*
Avocados	*1 627.96*	*123.86*	*595.14*	*-*	*2 346.97*
Macadamias	*75.20*	*21.74*	*34.82*	*6.05*	*137.81*
Mangos	*78.76*	*341.44*	*447.42*	*612.37*	*1 479.99*
Tomatoes	*-*	*1.04*	*-*	*-*	*1.04*
Brassicas	*32.17*	*166.81*	*66.79*	*431.50*	*697.26*
Litchis	*234.71*	*90.12*	*118.09*	*28.75*	*471.67*
Cucurbits	*19.02*	*210.52*	*112.39*	*488.75*	*830.67*
Citrus (Grapefruit)	*0.66*	*1 185.45*	*447.94*	*585.98*	*2 220.04*
Total	*2 192.00*	*3 625.00*	*5 688.50*	*3 521.00*	*15 026.50*

Light Industry Sector

The light industry sector is relatively small and includes:

- *Saw Mills.*
- *Orange and other juice facilities.*
- *An Atchar producing unit in Letsitele.*

In some of the proposed operational scenarios the urban sector is allocated additional water, this allocation is for analytical purposes sub-divided into a 10% allocation for light industry and 90% for domestic use.

It was also accepted that the forestry sector will not expand; therefore the production from the saw mills will be static, with no growth at all. It was assumed that the irrigation based product light industry sector can expand, but no specific products were investigated as the baseline and specific multipliers were already determined in the previous phases of the study. It was also assumed that additional light industrial development can take place not based on the irrigation based products, but in the irrigation service sector. In line with this it was accepted that an expanding local urban population will also add to a growing informal economic sector.

Currently mostly agriculture and forestry related light industrial activities are taking place in the three LM areas. In estimating the possible impact of additional water being available, the assumption was made that as part of the Government's National Development Plan, initiatives will be launched to expand the activities. It is not the intention of this study to try to identify any such possible activities, but in the light of the large unemployment rate it is believed to be a reasonable assumption. In this analysis no difference was made between light industrial activities and informal activities, as they very often support one another in a small urban area.

The macro-economic multipliers used are representative of the light industry sector as drawn from the Limpopo Social Accounting Matrix and applied in the calculation of the GDP, labour and household income.

As the current WIM model is set up for light industry and heavy industry only, the informal sector was incorporated into the light industry sector multipliers.

Domestic Sector

The third activity identified and analysed is the Household Sector and its contribution to economic growth. Should more water be allocated to households and the living standards start improving, the household as such contributes to economic growth by using more water, paying larger accounts and using the service sector increasingly.

During 2012 a project[2] *was completed by Conningarth which estimated the value of this sector by differentiating between Urban High Income, Urban Low Income and Rural Households. The multipliers developed were updated to 2013 prices, incorporated into the WIM and applied to estimate the additional GDP and employment opportunities created by the additional water.*

Although this sector was not originally incorporated into the baseline it became necessary to incorporate it in order to estimate a value for the sector in terms of GDP and employment, when the additional water is allocated.

Tourism Sector

In analysing the sector the following groups were identified:

- *The Kruger National Park (KNP) where animals concentrate around the rivers, two of the main camps identified is the Olifants Camp and the Letaba Camp.*
- *The Eiland resort, which is situated on an island in the Letaba River.*
- *The tourists on their way to the KNP or from the KNP who overnight in the many facilities in the Magoebaskloof.*
- *The tourists just visiting the Magoebaskloof because of the beautiful scenery; and*
- *The business tourists.*

As discussed the tourism sector consists of a number of sections. In the case of the KNP all the proposed scenarios will improve the instream water flow in the river part that is in the National Park. Secondly the current unit occupation rate of the all the Kruger camps during the 2012/2013 was 77.7%, with a peak during the winter months. The two camps close to the river, Letaba and Olifants, actually recorded slightly higher unit occupancy rates than the average.

The question, whether there is actually scope for increased occupancy at the two camps should the volume of the water in the river increase, then arises. Our deduction was that the "experience" of the visitors will improve but not necessarily the number of visitors. We came to the same conclusion for the Eiland Resort and the Magoebaskloof facilities and therefor did not estimate the possible impact on tourism for any of the facilities.

2.2.5 Overall Ranking Metric

The first aspect to consider in deriving the overall ranking for each scenario is the method employed to normalise each variable's results. This is necessary to remove the effect of the

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[2] Development Bank of Southern Africa (DBSA) - Construction of the National Social Accounting Matrix for South Africa – updated in 2012.

different dimensions (Rand for the economy, number of jobs for employment and the different rating scales for the ecology and Ecosystem Services) and make the scores of each variable comparable. The second aspect is to make provision to vary the importance each variable has in the overall ranking. Both these are described further below.

Relative Importance

The relative importance (among the variables) is defined by assigning relative weights to each of the four variables. Examples of how different weights would result in a preselected bias are presented in Table 2.6 for illustration purposes. The actual weight scheme applied in the study is discussed in Section 7.3.

Table 2.6 Explanation of the application of variable weights

Pre-selected Importance Bias	Weights assigned (Sum of weights for the four variables must add up to one)			
	Ecological Protection	Ecosystem Services	Economic Indicator (GDP)	Employment Indicator (Jobs)
Neutral[1]	*0.5*	*0.1666*	*0.1666*	*0.1666*
Preference for ecology	*0.7*	*0.1*	*0.1*	*0.1*
Preference for socio-economy	*0.3*	*0.2333*	*0.2333*	*0.2333*
Preference for socio-economy with emphasis on employment	*0.3*	*0.2*	*0.2*	*0.3*
Preference for socio-economy with emphasis on economy	*0.3*	*0.2*	*0.3*	*0.2*

1 This weights scheme is neutral because all the socio-economic variables together carry the same weight as the ecology variable.

Normalising methods

The **first method** *normalise the score to a scale between 0 and 1, where the scenario with the best score is 1 and lowest score is 0. This is carried out for each variable respectively. The* **second method** *applies the rank order (1 for the one with the lowest score and 6 for the one with the highest score) of the scores of each variable. Both these methods were applied in the analysis and the results are described in Chapter 7.*

The overall rank for a scenario is therefore determined by the sum of the products of each variable's metric multiplied with importance weight of the variable.

2.3 MANAGEMENT CLASS DETERMINATION

In accordance with the WRCS Guidelines (DWAF, 2007), the MC for an IUA is defined by the distribution of the selected ECs for the biophysical nodes in an IUA. In general, if the nodes are in "A" or "B" ECs the IUA is in a Class I, a Class II will be assigned if most nodes are in a C EC and if the nodes mostly falls into a D EC the IUA is in a Class III.

The guidelines recommend the scheme presented in Table 2.7 as the criteria to determine the MC. The "units" applied in the table is the percentage of river length (associated with a biophysical node) falling into each of the indicated ECs.

The following is an example interpretation to illustrate the application of the guideline scheme.

An Integrated Unit of Analysis (IUA) is in Management Class I if the following applies:

- *40% or of the units must be greater than or equal to an A/B Ecological Category.*
- *60% of the units should be greater or equal to and B Ecological Category.*
- *80% of the units should be greater or equal to and C Ecological Category.*
- *99% of the units should be greater or equal to and D Ecological Category.*
- *Less than 1% of the units can be in an E EC.*

Table 2.7 Preliminary guidelines for the calculation of the IUA Class for a scenario (DWAF, 2007)

		% EC representation at units represented by biophysical nodes in an IUA				
		≥ A/B	**≥ B**	**≥C**	**≥ D**	**< D**
Class 1		*40*	*60*	*80*	*99*	-
Class 2			*40*	*70*	*95*	-
Class 3	**Either**			*30*	*80*	-
	Or				*100*	-

The results presented in Chapter 8 lists the IUA MCs for the indicated scenarios. The specific scheme (adjusted from the guideline scheme presented here) are also presented and discussed in Chapter 8.

3 SCENARIO DESCRIPTION

The Letaba River System is highly developed and regulated, both physically through various large storage dams, weirs, river abstractions and conveyance infrastructure as well as institutionally through water user associations, municipalities and irrigation boards whom all untimely reports to the Department of Water Affairs.

The scenarios considered for evaluation were identified in context of the prevailing water resource management and planning activities in the Letaba River System. To this end the possible development options identified in the parallel study, Development of a Reconciliation Strategy for the Luvuvhu and Letaba Water Supply System form the basis for the selection of the preliminary list of scenarios. This list was presented to the Project Steering Committee for their consideration and a final list was taken further by the study team for analysis and evaluation.

3.1 WATER RESOURCE MANAGEMENT MEASURES

At the Screening Workshop held with stakeholders during April 2012 as part of the Reconciliation Strategy Study, intervention options were identified for consideration as measures to reconcile the water requirement and availability. These consisted of options to reduce the water requirements as well as those that increase the water supply.

The identified options are listed below for the indicated catchment areas:

- **Groot Letaba River Catchment Options:**
  - *Water Conservation & Water Demand Management.*
  - *Raising of Tzaneen Dam[3].*
  - *Construction of Nwamitwa Dam[2].*
  - *Bulk Water Supply Infrastructure to distribute water from Nwamitwa Dam[2].*
  - *Artificial recharge at Mulele on the Molototsi River.*
  - *Groundwater regional scheme in conjunction with surface scheme.*
- **Middel and Klein Letaba River Catchment Options:**
  - *Water Conservation & Water Demand Management.*
  - *Development of groundwater resource.*
  - *Replacement of Middel Letaba canal with pipeline – reduce canal losses.*
  - *Transfer Scheme from Nandoni Dam.*
  - *Construction of new dam on Klein Letaba River:*
    - *Majosi Dam, or*
    - *Crystalfontein Dam*

3.2 ECOLOGICAL WATER REQUIREMENT SCENARIOS

Three primary EWR scenarios were identified for evaluation as listed below:

- *Maintain a minimum flow rate of 0.6 m^3/s in the Letaba River into the KNP (EWR 7). This represents the primary target release operation that was applied by the system operators and confirmed with the flow measurements over the past few years. This release option is an estimate (approximation) of a dynamic release rule method monitored by personnel of the KNP and system operators of the Department of Water Affairs (DWA, 2009).*
- *Make releases from upstream dams to maintain the PES low flows at respective EWR sites. The rationale of this scenario is that the high flows will be satisfied from high incremental runoff*

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[3] These options were approved by the Minister on December 2012 for implementation.

and spills from the dams while the low flows are maintained through releases. This scenario also takes into consideration that the release capacities from the existing dams are insufficient to make high flow releases.

- *Releases are made from upstream dams to maintain the REC low flows at the respective EWR sites.*
- *A further option where the PES and REC with high flows are implemented. This assumes the river release capacity of new dams will be constructed to enable meeting the flow requirements for the high flow events.*
- *In addition to the above, derivatives of high flow releases events were also considered in an attempt to find an optimum solution. The full list of scenarios and there driver variables are explained in the following section.*

3.3 CONSOLIDATED DEFINITION OF THE SCENARIOS

Table 3.1 summarises the scenario definition in the form of a matrix, where each row represents a scenario and the columns indicate each of the driver settings applicable for the scenario. Those drivers applicable for a scenario are indicated with a "Yes" and those not applied are indicated by a "No". The drivers are grouped into those affecting the Groot Letaba and Middel Letaba systems as well as the required flow regime for each EWR site. Several variations of EWR flow scenarios were analysed and the explanation of those are presented in the notes below Table 3.1.

Details of the modelling assumptions for each scenario analysed are presented in Appendix A (Chapter 11), along with the description of the network configuration and the data applied in the model for the simulations.

The consequences (resulting effect) of the scenarios on the Economy, Ecology and Ecosystem Services are described in respectively in Chapters 4, 5 and 6.

Table 3.1 Scenario definition matrix

Scenario	Groot Letaba Drivers								Middel Letaba Drivers			EWR Drivers						
	Restriction rule included	Raised Tzaneen Dam	Nwamitwa Dam	Letsitele River Dam	Mulele Dam GW[1] Recharge	Additional Allocation to Polokwane	Max GW use	Court order releases from Dap Naude	Crystalfontein Dam	Max GW use	Transfer from Nandoni Dam	KNP EWR of 0.6 m^3/s	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 7
1 (PES)	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
2a	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*Low*	*Low*	*Low PES*	*Low PES*	*Low*	*Low PES*
2b	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*Low*	*Low*	*Low REC*	*Low REC*	*Low*	*Low REC*
3a	*No*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
3b	*Yes*	*Yes*	*No*	*No*	*No*	*Yield*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
4a	*No*	*Yes*	*Yes*	*No*	*No*	*Request*	*No*	*Yes*	*No*	*No*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
4b	*No*	*Yes*	*Yes*	*No*	*No*	*Request*	*Yes*	*Yes*	*No*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
4c	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*No*	*No*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
5	*No*	*Yes*	*Yes*	*Yes*	*No*	*Request*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*No*	*No*	*No*
6	*No*	*Yes*	*Yes*	*Yes*	*No*	*Request*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*No*	*Low*	*Low*	*Low PES*	*Low PES*	*Low*	*Low PES*
7a	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*Low PES*	*Low PES*	*Total*	*Low PES*
7b	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*Low REC*	*Low REC*	*Total*	*Low REC*
7c	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*Total PES*	*Total PES*	*Total*	*Total PES*
7d (REC)	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*Total REC*	*Total REC*	*Total*	*Total REC*
8a	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*2High REC*	*2High REC*	*2High REC*	*2High REC*
8b	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*1High REC*	*1High REC*	*1High REC*	*1High REC*
9	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*1High PES/REC*	*1High PES/REC*	*1High REC*	*1High PES/REC*
10	*Yes*	*Yes*	*Yes*	*No*	*No*	*Yield*	*No*	*No*	*Yes*	*No*	*Yes*	*No*	*Low*	*No*	*3High PES*	*3High PES*	*Low*	*3High PES*

Notes:	
1	*Ground Water*
Label	**Description**
Low	*Low flow requirements (PES and REC are the same).*
Total	*High and low flow requirements (PES and REC are the same).*
Low PES	*Low flow requirements for the PES scenario.*
Total PES	*High and low flow requirements for the PES scenario.*
Low REC	*Low flow requirements for the REC scenario.*
Total REC	*High and low flow requirements for the REC scenario.*
2High REC	*Highest two flow months retained in each year in addition to the Low flow requirements for the REC scenario.*
1High REC	*Highest flow month retained in each year in addition to the Low flow requirements for the REC scenario.*
1High PES / REC	*Highest flow month retained in each year for the PES scenario in addition to the Low flow requirements for the REC scenario.*
3 High PES	*High flows in January, February and March for the PES scenario in addition to the Low flow requirements for PES.*
Request and Yield	*Additional allocation to Polokwane: Request = Additional water requested, an increase from 16.2 million m^3/annum current to 27 million m^3/annum.* *Yield = Total yield available from Ebenezer Dam, 32 million m^3/annum.*

4 ECONOMIC CONSEQUENCES

The results of different scenarios as it impacted on the different economic sectors are presented in this Chapter. The impact on GDP and then on labour is provided and in the final instance the sectors are combined to produce a final integrated in the final result.

4.1 GROSS DOMESTIC PRODUCT

Irrigation

In Table 4.1 the GDP results of the different scenarios are presented.

Table 4.1 GDP created per Scenario and percentage change if compared with the Baseline (2013 prices)

Scenario	GDP (Rand Million)	Percentage change from baseline
Baseline	*1 655*	
5b	*1 682*	*1.6%*
7a	*1 702*	*2.8%*
7b	*1 709*	*3.2%*
7c	*1 145*	*-30.8%*
7d	*938*	*-43.3%*
8a	*1 321*	*-20.2%*
8b	*1 522*	*-8.0%*
9	*1 677*	*1.3%*

Table 4.1 indicates that Sc 7c, 7d, 8a and 8b have a negative impact on GDP with 7d the largest negative impact when compared to the baseline. Figure 4.1and Figure 4.2 highlight the results.

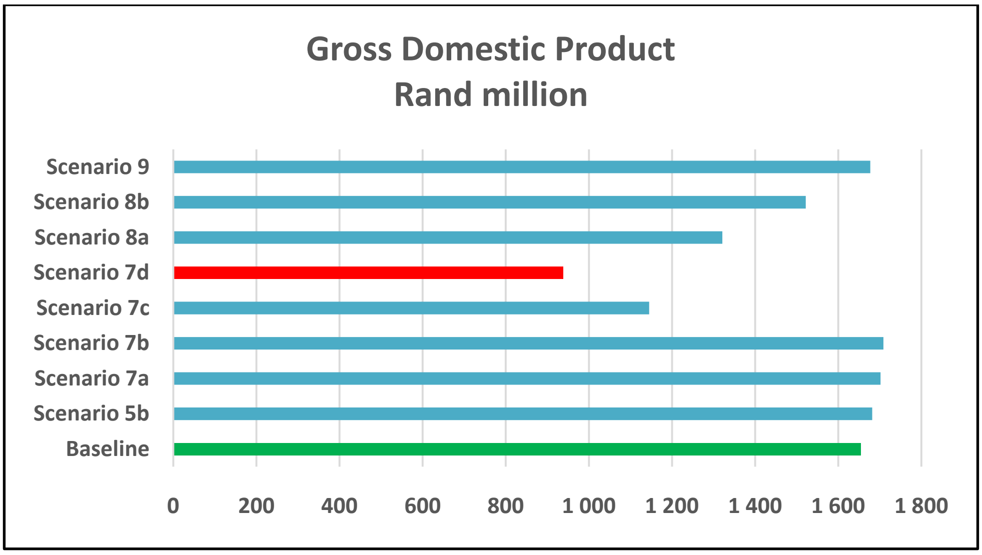


Figure 4.1 The GDP created by each Scenario

The comparative change of the impact of each of the scenarios when compared with the baseline is presented in Figure 4.2.

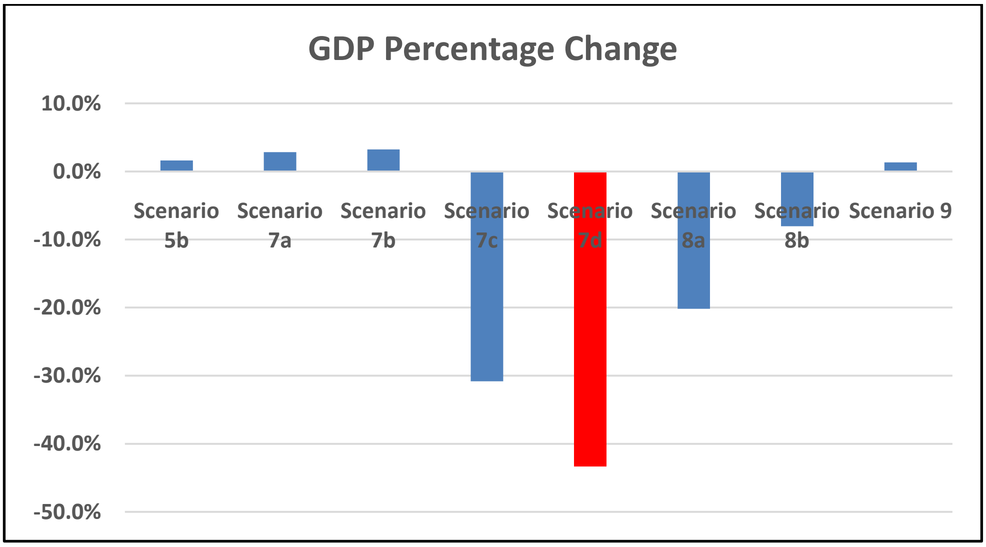


Figure 4.2 Comparative percentage of the impact of each scenario with the Baseline

Figure 4.1and Figure 4.2 show that Scenario 7d will have the severest negative impact followed by Sc 7c, 8a and 8b. Scenario 5b, 7a, 7b and 9 will increase the GDP of the irrigation sector.

4.2 URBAN DOMESTIC SECTOR

In Table 4.2 and Figure 4.3 the GDP impact is illustrated.

Table 4.2 GDP created per scenario (2013 prices)

Scenario	GDP (Rand mil.)	Additional GDP (Rand mil.)
Baseline	*89.75*	
5b	*218.33*	*128.59*
7a	*448.06*	*358.32*
7b	*191.14*	*101.39*
7c	*256.56*	*166.81*
7d	*273.33*	*183.58*
8a	*142.20*	*52.45*
8b	*142.20*	*52.45*
9	*169.39*	*79.64*
Baseline	*174.83*	*85.08*
5b	*305.70*	*215.95*

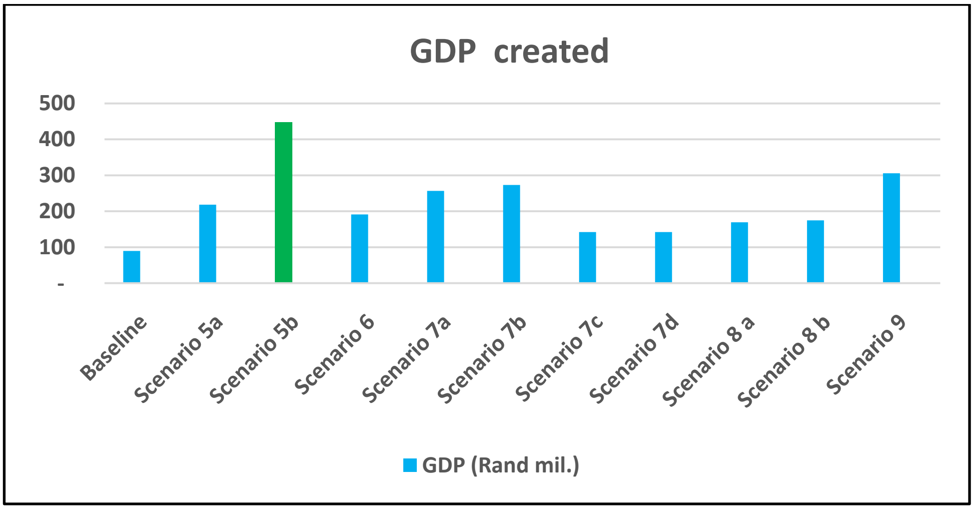


Figure 4.3 GDP created per Scenario (2013 prices)

Figure 4.3 shows that Scenario 5b will create the most additional GDP, if fully utilised, followed by Sc 9.

4.3 LIGHT INDUSTRY

In Table 4.3 the estimated potential GDP created per scenario is shown.

Table 4.3 Estimated Potential GDP created per Scenario

Scenario	GDP (Rand mil.)
Baseline	*354.08*
5b	*2 427.23*
7a	*4 460.59*
7b	*1 781.44*
7c	*1 261.53*
7d	*753.03*
8a	*619.03*
8b	*619.03*
9	*1 264.82*
Baseline	*1 393.97*
5b	*1 915.94*

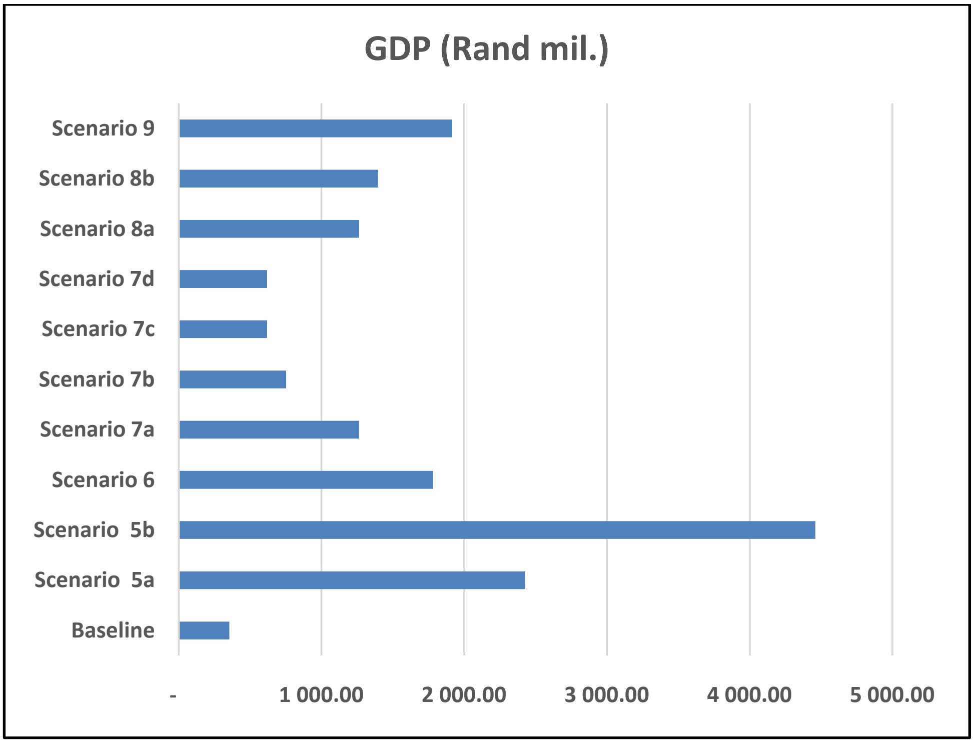


Figure 4.4 Estimated GDP per Scenario generated by the Light Industry Sector

4.4 TOTAL GDP

In Table 4.4 the total estimated GDP per Scenario is presented.

Table 4.4 Estimated total GDP per Scenario (2013 prices)

Scenario	Total GDP (Rand mil.)
Baseline	*2 098.82*
5a	*2 791.85*
5b	*3 244.89*
6	*2 641.19*
7a	*3 219.83*
7b	*2 734.90*
7c	*1 906.17*
7d	*1 699.37*
8 a	*2 149.33*
8 b	*2 243.28*
9	*2 613.91*
10	*2 852.46*

In Figure 4.5 the deviation from the baseline of the total GDP is presented.

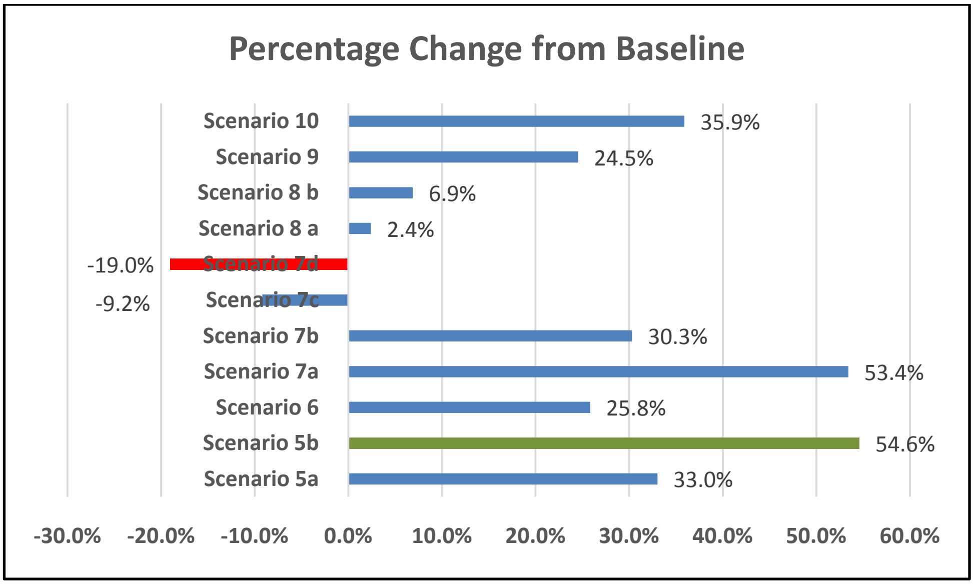


Figure 4.5 Percentage deviation from Baseline per Scenario

Figure 4.5 shows that Sc 5b presents the largest positive deviation from the baseline, 54.6%, with Sc 7d with the most negative impact namely -19% deviation from the baseline. In Table 4.5 the results are ranked in terms of its economic benefits expressed in GDP terms.

Table 4.5 Scenarios ranked in terms of GDP contribution

Scenario	Deviation from Baseline	Ranking
5b	*54.6%*	*1*
7a	*53.4%*	*2*
10	*35.9%*	*3*
5a	*33.0%*	*4*
7b	*30.3%*	*5*
6	*25.8%*	*6*
9	*24.5%*	*7*
8b	*6.9%*	*8*
8a	*2.4%*	*9*
7c	*-9.2%*	*10*
7d	*-19.0%*	*11*

4.5 EMPLOYMENT

4.5.1 Irrigation

In Table 4.6 the impact on employment for the different scenarios are compared with the baseline.

Table 4.6 Employment created per Scenario and projected job gains or losses per Scenario

Scenario	Total Labour	Job Losses
Baseline	*19 379*	
5b	*22 540*	*3 161*
7a	*22 945*	*3 566*
7b	*23 084*	*3 705*
7c	*14 235*	*-5 144*
7d	*11 297*	*-8 082*
8a	*17 612*	*-1 767*
8b	*19 193*	*-186*
9	*22 104*	*2 725*

Table 4.6 shows that Sc 5b, 7a, 7b, 9 and 10 can be beneficial for the irrigation farmers with 7a the best and 7d potentially having the largest negative impact.

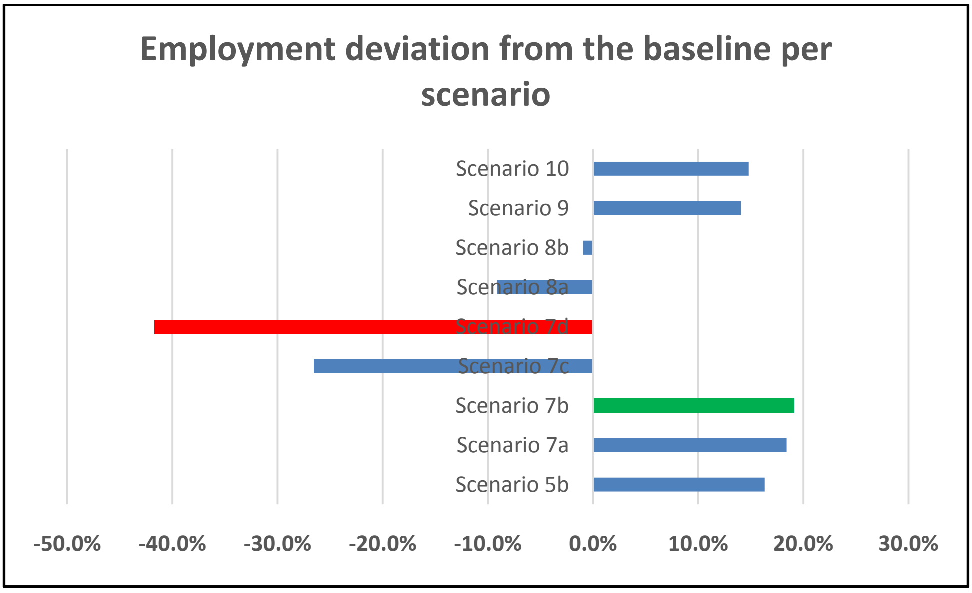


Figure 4.6 Employment deviation from Baseline in percentage

Figure 4.6 illustrates the deviation from the baseline in terms of percentage and very clearly shows that Sc 7d, 7c and 8a can have a very negative impact on the current irrigation activities.

4.5.2 Urban domestic sector

Table 4.7 presents the estimated jobs created per scenario.

Table 4.7 Estimated Employment created per Scenario

Scenario	Employment	Number of Jobs above current Baseline
Baseline	*274*	
5a	*671*	*397*
5b	*1 363*	*1 089*
6	*588*	*314*
7a	*781*	*508*
7b	*832*	*559*
7c	*438*	*164*
7d	*438*	*164*
8a	*521*	*247*
8b	*538*	*264*
9	*899*	*625*
10	*932*	*658*

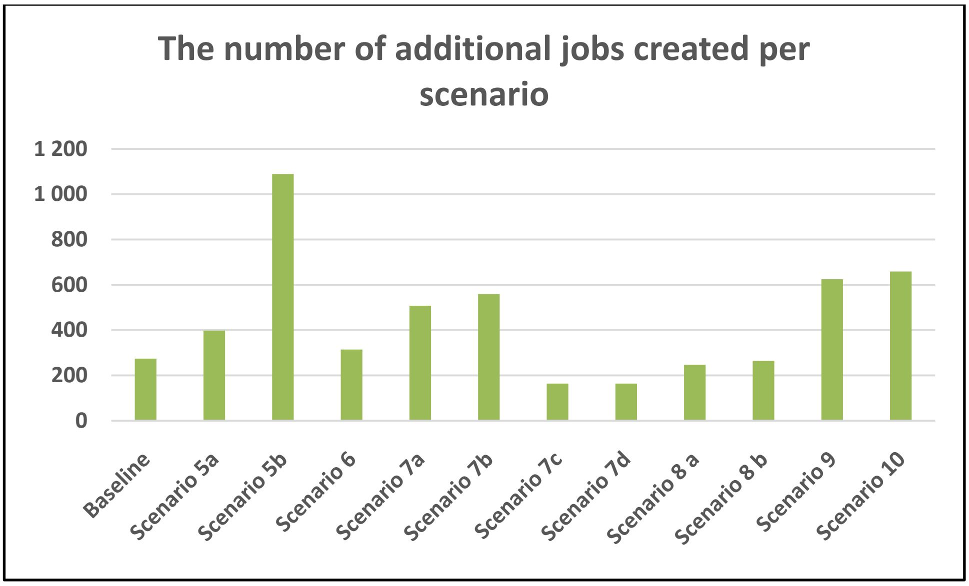


Figure 4.7 Number of additional Employment created per Scenario

In the evaluation of the above results (Figure 4.7) it is necessary to keep in mind that the additional jobs will only realise once all the water allocated has been used and the expected economic growth has taken place. This is a service sector and the additional jobs will depend on the expected higher standard of living of the urban population. Table 4.7 shows that Sc 5b has the potential to create the most jobs over a period of time with 7c and D to create the least number of jobs.

4.5.3 Light Industry

In Table 4.8 the estimated potential additional number of jobs created per scenario is presented.

Table 4.8 Additional Jobs created per Scenario compared to Baseline

Scenario	Additional Jobs created
Baseline	*1 718*
5a	*5 709*
5b	*8 021*
6	*4 217*
7a	*4 392*
7b	*1 935*
7c	*1 285*
7d	*1 285*
8a	*2 849*
8b	*2 702*
9	*4 093*
10	*4 376*

In Figure 4.8 the additional jobs are presented.

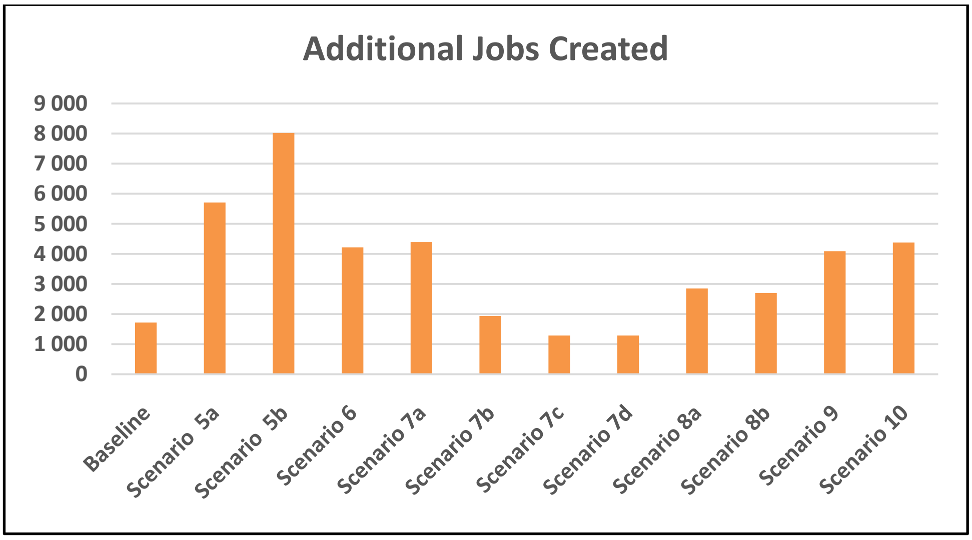


Figure 4.8 Additional Employment created

Table 4.8 and Figure 4.8 shows that Sc 5b has the potential to provide the most employment opportunities with 7c the least number of employment opportunities. In the evaluation of these numbers it is necessary to keep in mind that a number of assumptions apply, namely:

- *That the additional water will eventually be used.*
- *That the light industry sector will develop in the urban areas in the catchment.*

4.5.4 Total Employment

In Table 4.9 and Figure 4.9 the total estimated employment created per sector per scenario is presented.

Table 4.9 Estimated Total Employment per Scenario

Scenario	Employment per Scenario
Baseline	*21 370*
5a	*27 477*
5b	*33 641*
6	*25 901*
7a	*29 837*
7b	*27 569*
7c	*17 675*
7d	*14 738*
8 a	*22 699*
8 b	*24 150*
9	*28 813*
10	*29 272*

Table 4.9 shows that Sc 5b can potentially create and support the most employment opportunities with Sc 7d the least.

In Figure 4.9 the deviation from the baseline per scenario is presented.

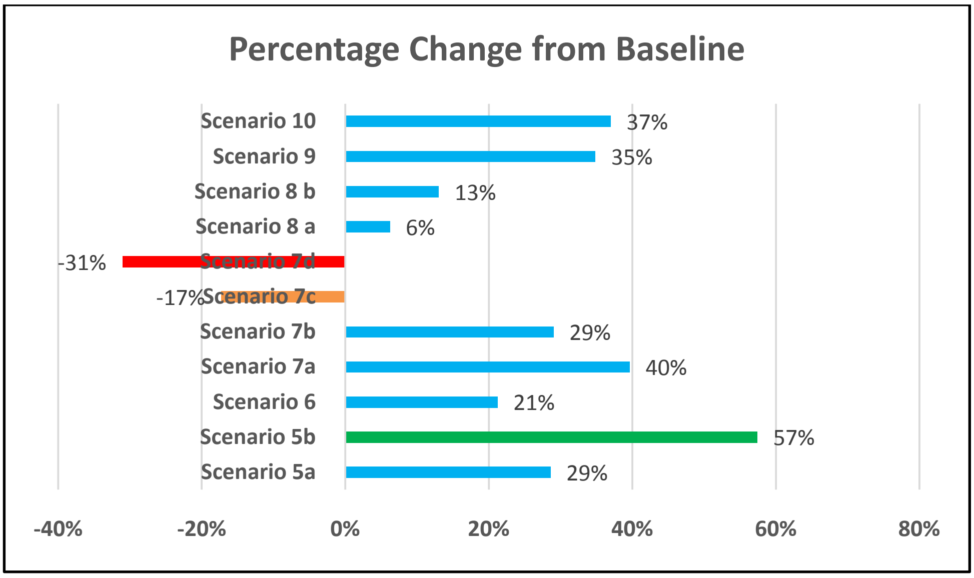


Figure 4.9 Percentage Employment change from the Baseline per Scenario

Figure 4.9 indicates that Sc 5b has the potential to create the most jobs, followed by 7a with 7d being the one that can destroy about 31% of the current employment. In Table 4.10 the scenarios are ranked in order of acceptability in terms of the economic evaluation, with one the most acceptable and rank 10 the least acceptable.

Table 4.10 Employment ranking per scenario

Scenario	Rank
5b	*1*
7a	*2*
10	*3*
9	*4*
7b	*5*
5A	*6*
6	*7*
8b	*8*
8a	*9*
7c	*10*
7d	*11*

Table 4.10 indicates that in terms of employment economic evaluation 5b will be most beneficial with 7d the least.

4.6 FINAL RANKING

As mentioned and discussed in the final evaluation process to determine the ranking it is necessary to take the following into consideration:

- *Irrigation which is currently the major driver of the economy in the project area.*
- *As the unemployment rate in the project varies around 40% it is important to maintain as many as possible jobs.*
- *The importance of the informal sector has not been investigated in detail therefore the Urban and Household sectors are important indicators.*
- *The risk associated with the light industry sector.*

A weighing process was used to determine the ranking of the different scenarios as presented in Table 4.11.

Table 4.11 Weights used to determine final ranking

Sector	Gross Domestic Product	Employment
Irrigation	*0.50*	*0.60*
Urban and Household Sector	*0.25*	*0.25*
Light Industry	*0.25*	*0.15*
Total	*1.00*	*1.00*

In Figure 4.10 the ranking of the GDP and Employment contribution per scenario is compared. Sc 5b, 7a and 10 fills the first three positions, it is in the rest of the middle order that some positions change. Scenario 7c and 7d are the least acceptable.

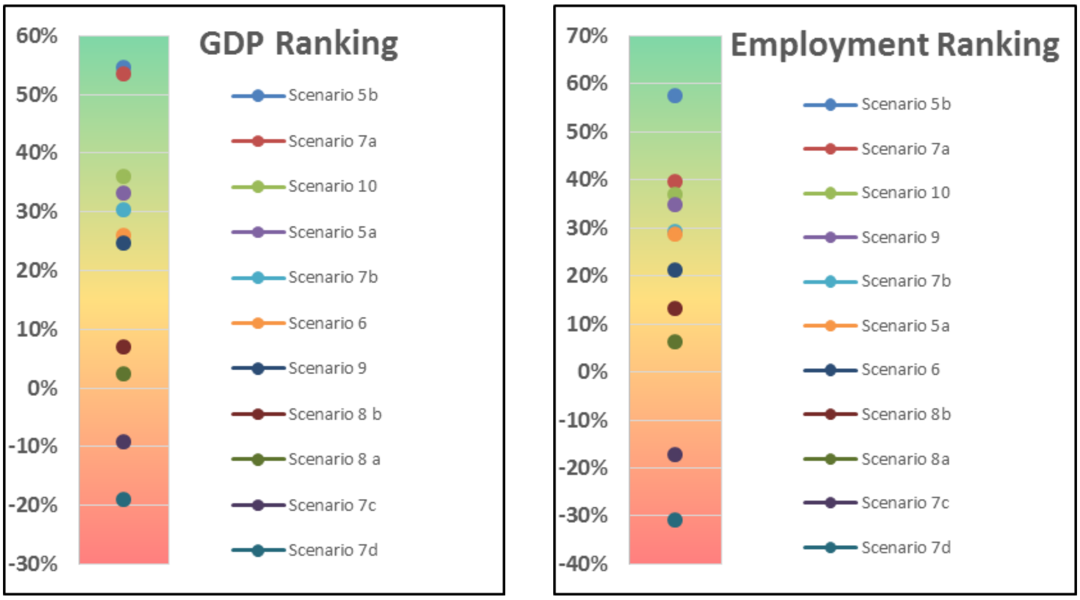


Figure 4.10 Traffic diagram illustration the impact of Scenarios on the GDP and Employment

5 ECOLOGICAL CONSEQUENCES

This chapter focuses on the results of the evaluation of the various scenarios. The analysis was done in three steps as follows:

- *During the first step, an initial set of scenarios (Sc 2, 3, 4, 5 and 6) were evaluated and, during a specialist meeting, the consequences were determined. The results are provided in Report 4.2 (DWA, 2014) which serves as an information document for this report. The results are also summarised in section 5.1 below.*
- *A second set of scenarios (Sc 7a, b, c, d and Sc 8a, b) were designed with the aim to test sensitivity and lead to the design of optimised scenarios. Ecological consequences were broadly tested to aid in the design of optimised scenarios*
- *This information was used to generate a further set of operational scenarios with the aim of designing scenarios that potentially minimises the impacts (Sc 9 and 10). These scenarios were compared to the results generated during the first step and the ecological consequences determined (Section 5.2).*

The integration into a single ecological ranking for the Letaba River is supplied in Section 5.3.

5.1 ECOLOGICAL CONSEQUENCES OF SCENARIOS 2, 3, 4, 5 AND 6[4] AT THE EWR SITES

The scenarios are described in Table 3.1. The ecological consequences are summarised in Table 5.1. The first column provides the ECs for each component at the EWR site. The second column provides the ranking of the scenarios. The third column includes a short explanation of the consequences and ranking.

5.2 ECOLOGICAL CONSEQUENCES OF SCENARIOS 9 AND 10 AT THE EWR SITES

The optimised scenarios are also described in Table 3.1. These optimised scenarios used Sc 6 as a basis as and the ecological consequences are compared to those as determined for Sc 6 and Present Day (PD). The ecological consequences at EWR 3, 4 and 7 in the Letaba River are summarised in Table 5.2. The first column provides the ECs for each component at the EWR site. The second column provides the ranking of the scenarios. The third column includes a short explanation of the consequences and ranking.

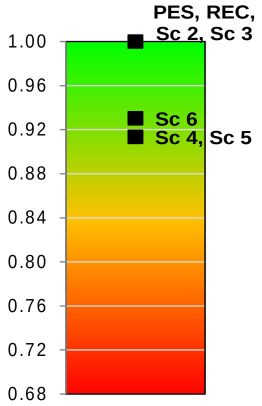
The consequences of the EWR sites at EWR 1 (Appel), EWR 2 (Letsitele) and EWR 5 (Klein Letaba) are assumed as follows:

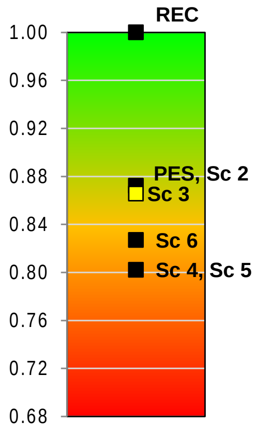
- *EWR 1 (Appel): The consequences are the same as Sc 6 as there are minimal changes to the upper Letaba operation under Sc 9 and 10.*
- *EWR 2 (Letsitele): The consequences are the same as the PES and NOT Sc 6. Scenario 6 includes the proposed Letsitele Dam, whereas Sc 9 and 10 does not. These scenarios do not change the PES.*
- *EWR 5 (Klein Letaba): Scenario 6 includes Crystalfontein Dam with a low PES/REC flow release. Scenario 9 and 10 are the same and the consequences are the same as for Sc 6.*

---

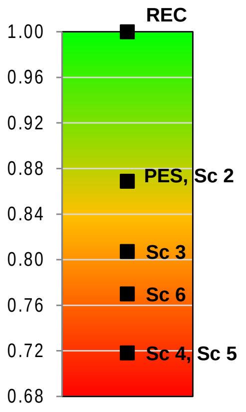
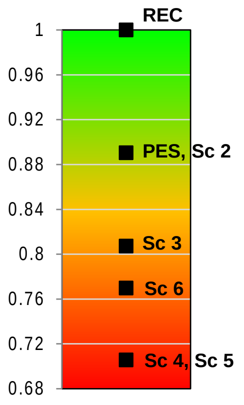
[4] Sc 2 = Sc 2a; Sc 3 = Sc 3b; Sc 4 = Sc 4b; Sc 5 = Sc 5a

Table 5.1 Summary of the detailed ecological consequences determined for Sc 3, 4, 5 and 6

<table>
<tr><th>Ecological consequences as ECs</th><th>Ecological consequences description</th><th>Ranked scenarios</th><th>Ranked scenarios rationale</th></tr>
<tr><td colspan="4">EWR 1 (APPEL, LETABA RIVER)</td></tr>
<tr><td>
<table>
<tr><th>Component</th><th>PES (REC)</th><th>Sc 3</th><th>Sc 4, 5</th><th>Sc 6</th></tr>
<tr><td><i>Physico chemical</i></td><td>B</td><td>B</td><td>B/C</td><td>B/C</td></tr>
<tr><td><i>Geomorphology</i></td><td>C/D</td><td>C/D</td><td>D</td><td>D</td></tr>
<tr><td><i>Fish</i></td><td>C</td><td>C</td><td>C/D</td><td>C/D</td></tr>
<tr><td><i>Invertebrates</i></td><td>C</td><td>C</td><td>C/D</td><td>C/D</td></tr>
<tr><td><i>Riparian vegetation</i></td><td>C</td><td>C</td><td>C/D</td><td>C/D</td></tr>
<tr><td><i>EcoStatus</i></td><td>C</td><td>C</td><td>C/D</td><td>C/D</td></tr>
</table>
</td><td><i>Sc 3 is similar to the present day flows and therefore maintains the PES and REC.
Sc 5 and 6 have lower floods than present day as well as lower base flows. This results in decreased fast habitats impacting on instream habitat and increased stress on the biota. Vegetation is likely to encroach in lower and marginal zones.</i></td><td>


</td><td><i>The results illustrate that Sc 3 meets the PES and REC but Sc 4, 5 and 6 will fall below the PES/REC. The ecological objectives are unachievable under Sc 4, 5 and 6 due to the decreased flooding regime (i.e. decreased spills) as there is no impact on low flows as they are generally higher than the PD hydrology. Sc 6 is marginally better than Sc 4 and 5 due to a smaller impact on the fish and macro-invertebrate components.</i></td></tr>
<tr><td colspan="4">EWR 3 (PRIESKA, LETABA RIVER)</td></tr>
<tr><td>
<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>Sc 3</th><th>Sc 4, 5</th><th>Sc 6</th></tr>
<tr><td><i>Physico chemical</i></td><td>B/C</td><td>B</td><td>B/C</td><td>C</td><td>C</td></tr>
<tr><td><i>Geomorphology</i></td><td>D</td><td>C/D</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td><i>Fish</i></td><td>C</td><td>B/C</td><td>C</td><td>C/D</td><td>C</td></tr>
<tr><td><i>Invertebrates</i></td><td>C</td><td>B/C</td><td>C</td><td>C/D</td><td>C</td></tr>
<tr><td><i>Riparian vegetation</i></td><td>C/D</td><td>C</td><td>C/D</td><td>D</td><td>C/D</td></tr>
<tr><td><i>EcoStatus</i></td><td>C</td><td>B/C</td><td>C/D</td><td>C/D</td><td>C/D</td></tr>
</table>
</td><td><i>Sc 3: Small change in low flows result in additional encroachment of vegetation. Very similar to PES.
Sc 6: Decrease in EC for all components due to reduced high flows. This will reduce substrate quality and suitability and species with a preference for this type of habitat may deteriorate.
Sc 5: Decreased low and high flows. Reduced fast habitats impact on rheophilic fish species and lack of floods cause deterioration in habitats. Reduced vegetation cover, and lack of recruitment.</i></td><td>


</td><td><i>The results illustrate that none of the scenarios meet the REC or maintain the PES. Sc 3 is very similar to the PES. Sc 6 is a slight improvement from Sc 5 (and 4) due to improved base flows and better condition of the biota compared to Sc 5 (and 4).</i></td></tr>
</table>

<table>
<tr><th>Ecological consequences as ECs</th><th>Ecological consequences description</th><th>Ranked scenarios</th><th>Ranked scenarios rationale</th></tr>
<tr><th colspan="4">EWR 4 (LETABA RANCH, LETABA RIVER)</th></tr>
<tr>
<td>
<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>Sc 3</th><th>Sc 5</th><th>Sc 6</th></tr>
<tr><td>Physico chemical</td><td>B/C</td><td>B</td><td>C</td><td>C</td><td>B/C</td></tr>
<tr><td>Geomorphology</td><td>C/D</td><td>C</td><td>C/D</td><td>D</td><td>D</td></tr>
<tr><td>Fish</td><td>C</td><td>B/C</td><td>C/D</td><td>D</td><td>C/D</td></tr>
<tr><td>Invertebrates</td><td>C</td><td>B</td><td>C/D</td><td>D</td><td>C/D</td></tr>
<tr><td>Riparian vegetation</td><td>C</td><td>B/C</td><td>C</td><td>C/D</td><td>C</td></tr>
<tr><td>EcoStatus</td><td>C</td><td>B/C</td><td>C</td><td>D</td><td>C/D</td></tr>
</table>
</td>
<td>Sc 3: Flows slightly less than PD. Impact on instream biota during the wet season. Marginal vegetation will reduce.
Sc 6: Reduced high flows will reduce substrate quality for instream biota. Lack of floods will promote marginal zone vegetation encroachment.
Sc 5: Further reduced baseflows and reduced wet season duration. Decrease in quality of fast habitat as well as significant impact on marginal vegetation in wet season will impact on instream biota.</td>
<td>
</td>
<td>The results illustrate that none of the scenarios meet the REC or maintain the PES. Although Sc 3 results in the same EcoStatus, only the vegetation EC is the same as the PES while the instream components are worse. Scenario 6 results in worse consequences than Sc 3 due to the reduction of baseflows with Sc 5 (and 4) being worse than Sc 6</td>
</tr>
<tr><th colspan="4">EWR 7 (LETABA BRIDGE, LETABA RIVER)</th></tr>
<tr>
<td>
<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>Sc 3</th><th>Sc 5</th><th>Sc 6</th></tr>
<tr><td>Physico chemical</td><td>B</td><td>B</td><td>C</td><td>C</td><td>C</td></tr>
<tr><td>Geomorphology</td><td>C</td><td>C</td><td>C/D</td><td>D</td><td>D</td></tr>
<tr><td>Fish</td><td>C</td><td>B</td><td>D</td><td>D</td><td>C/D</td></tr>
<tr><td>Invertebrates</td><td>C</td><td>B</td><td>C/D</td><td>D</td><td>C/D</td></tr>
<tr><td>Riparian vegetation</td><td>C</td><td>B</td><td>C</td><td>C/D</td><td>C</td></tr>
<tr><td>EcoStatus</td><td>C</td><td>B</td><td>C/D</td><td>D</td><td>C</td></tr>
</table>
</td>
<td>Sc 3: Impacts are on low flows. Reduced fast habitat and delay in onset of set season. Decreased vegetation in marginal zone.
Sc 6: Impacts on floods and low flows during the wet season. Similar to Sc 3 but the emphasis will be on decreased floods with resulting decrease in riffle quality.
Sc 5: Reduction in floods and low flows. Similar to Sc 3 with greatly reduced vegetation as cover impact on survival of some species.</td>
<td>
</td>
<td>The results illustrate that none of the scenarios meet the REC or the PES. Sc 3 and 6 impacts the instream biota due to reduced low flows as well as floods. Scenario 4 and 5 result in worse consequences due to the further reduction in low flows and floods.</td>
</tr>
</table>

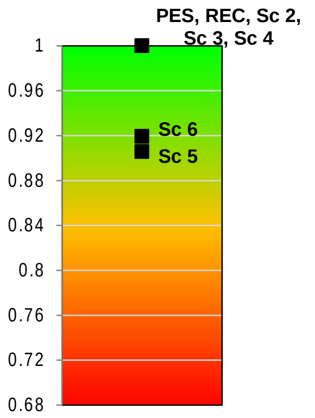
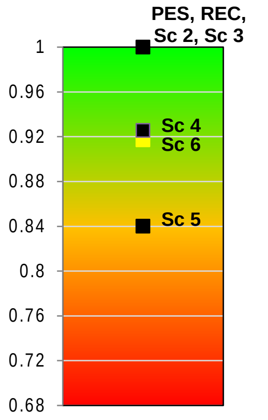
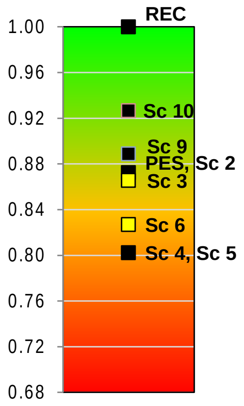
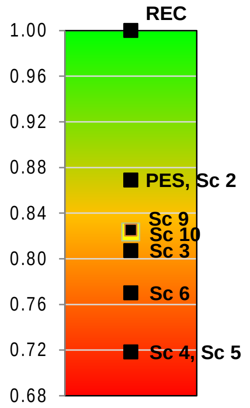
<table>
<tr><th>Ecological consequences as ECs</th><th>Ecological consequences description</th><th>Ranked scenarios</th><th>Ranked scenarios rationale</th></tr>
<tr><td colspan="4">EWR 2 (LETSITELE RIVER)</td></tr>
<tr>
<td>
<table>
<tr><th>Component</th><th>PES</th><th>Sc 4</th><th>Sc 5</th><th>Sc 6</th></tr>
<tr><td><i>Physico chemical</i></td><td>C</td><td>C</td><td>C</td><td>C</td></tr>
<tr><td><i>Geomorphology</i></td><td>D</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td><i>Fish</i></td><td>C/D</td><td>C</td><td>C/D</td><td>C/D</td></tr>
<tr><td><i>Invertebrates</i></td><td>C</td><td>C</td><td>D</td><td>D</td></tr>
<tr><td><i>Riparian vegetation</i></td><td>D</td><td>D</td><td>D/E</td><td>D/E</td></tr>
<tr><td><i>EcoStatus</i></td><td>D</td><td>D</td><td>D</td><td>D</td></tr>
</table>
</td>
<td><i>Sc 4: Similar to PD flows.
Sc 6: Includes a dam with a low flow EWR release. Reduced flows in the wet season will reduce abundance and suitability of fast habitat. Vegetation encroachment expected.
Sc 5: Includes a dam - reduced flows in wet season and floods. Similar to Sc 6 with slightly worse conditions.</i></td>
<td>
</td>
<td><i>The ecological objectives are met under Sc 4 (and Sc 3) and therefore the PES/REC is maintained. Under Sc 5 and 6 the ecological objectives are not met due to reduced baseflows and floods and the resulting impact on the instream biota and riparian vegetation. Riparian vegetation will degrade to a D/E which is unsustainable.</i></td>
</tr>
<tr><td colspan="4">EWR 5 (KLEIN LETABA RIVER)</td></tr>
<tr>
<td>
<table>
<tr><th>Component</th><th>PES</th><th>Sc 3</th><th>Sc 4</th><th>Sc 5</th><th>Sc 6</th></tr>
<tr><td><i>Physico chemical</i></td><td>B/C</td><td>B/C</td><td>C</td><td>C</td><td>C</td></tr>
<tr><td><i>Geomorphology</i></td><td>C/D</td><td>C/D</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td><i>Fish</i></td><td>C</td><td>C</td><td>C/D</td><td>D</td><td>C</td></tr>
<tr><td><i>Invertebrates</i></td><td>C/D</td><td>C/D</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td><i>Riparian vegetation</i></td><td>C</td><td>C</td><td>C/D</td><td>D</td><td>C/D</td></tr>
<tr><td><i>EcoStatus</i></td><td>C</td><td>C</td><td>C/D</td><td>D</td><td>C/D</td></tr>
</table>
</td>
<td><i>Sc 3: Similar to PD.
Sc 4: Lower flows during the wet season leading to some impact on the instream biota.
Sc 6: Lack of floods result in deterioration of substrate quality and loss of pools.
Sc 5: Decreased flows in wet seasons (severe) will result in impact on biota with preference for fast habitats and pools.</i></td>
<td>
</td>
<td><i>The ecological objectives of the PES/REC are met under Sc 3 as it is similar to PD. The ecological objectives of Sc 4, 5 and 6 are however not met. The consequences of Sc 4 and 6 are of a similar nature whereas Sc 5 has the worst impact due to reduced baseflows and floods.</i></td>
</tr>
</table>

Table 5.2 Summary of the detailed ecological consequences determined for the optimised Sc 9 and 10 at EWR 3, 4 and 7

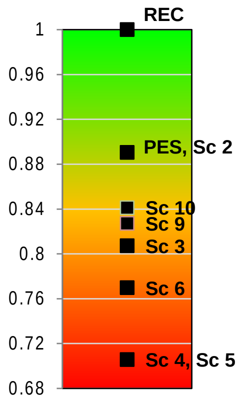
<table>
<tr><th>Ecological consequences as ECs</th><th>Ecological consequences description</th><th>Ranked scenarios</th><th>Ranked scenarios rationale</th></tr>
<tr><td colspan="4">EWR 3 (PRIESKA, LETABA RIVER)</td></tr>
<tr>
<td>
<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>Sc 6</th><th>Sc 9</th><th>Sc 10</th></tr>
<tr><td><i>Physico chemical</i></td><td>B/C</td><td>B</td><td>C</td><td>B/C</td><td>B/C</td></tr>
<tr><td><i>Geomorphology</i></td><td>D</td><td>C/D</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td><i>Fish</i></td><td>C</td><td>B/C</td><td>C</td><td>C</td><td>C</td></tr>
<tr><td><i>Invertebrates</i></td><td>C</td><td>B/C</td><td>C</td><td>C</td><td>C</td></tr>
<tr><td><i>Riparian vegetation</i></td><td>C/D</td><td>C</td><td>C/D</td><td>C/D</td><td>C</td></tr>
<tr><td><i>EcoStatus</i></td><td>C</td><td>B/C</td><td>C/D</td><td>C</td><td>C</td></tr>
</table>
</td>
<td><i>Sc 6: Decrease in EC for all components due to reduced high flows. This will reduce substrate quality and suitability and species with a preference in this type of habitat may deteriorate.
Sc 9: All categories except for geomorphology improve from Sc 6 due to the improvement in baseflows (positive for fish with a preference for fast habitat) as well as some smaller floods. Riparian vegetation improvement is in the marginal and lower zones as these floods will reduce encroachment on the macro-channel floor and promote zone health.
Sc 10: An improvement from Sc 9 due to the managed EWR floods included as a release.</i></td>
<td> </td>
<td><i>The results illustrate that none of the scenarios meet the REC. Both Sc 9 and 10 maintain and/or improve the PES.</i></td>
</tr>
<tr><td colspan="4">EWR 4 (LETABA RANCH, LETABA RIVER)</td></tr>
<tr>
<td>
<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>Sc 6</th><th>Sc 9</th><th>Sc 10</th></tr>
<tr><td><i>Physico chemical</i></td><td>B/C</td><td>B</td><td>B/C</td><td>B</td><td>B/C</td></tr>
<tr><td><i>Geomorphology</i></td><td>C/D</td><td>C</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td><i>Fish</i></td><td>C</td><td>B/C</td><td>C/D</td><td>C</td><td>C</td></tr>
<tr><td><i>Invertebrates</i></td><td>C</td><td>B</td><td>C/D</td><td>C/D</td><td>C/D</td></tr>
<tr><td><i>Riparian vegetation</i></td><td>C</td><td>B/C</td><td>C</td><td>C</td><td>C</td></tr>
<tr><td><i>EcoStatus</i></td><td>C</td><td>B/C</td><td>C/D</td><td>C</td><td>C</td></tr>
</table>
</td>
<td><i>Sc 6: Reduced high flows will reduce substrate quality for instream biota. Lack of floods will promote marginal zone vegetation encroachment.
Sc 9 and 10: Improved baseflows are offset against decreased spills. The releases of small floods do improve these scenarios from Sc 6.</i></td>
<td> </td>
<td><i>The results illustrate that none of the scenarios meet the REC or maintain the PES. Sc 9 and 10 results in the same EcoStatus, but the macro-invertebrate component is half a category lower. Scenario 9 and 10 is an improvement of Sc 6 and the consequences are virtually the same with Sc 9 being marginally better than Sc 10.</i></td>
</tr>
</table>

EWR 7 (LETABA BRIDGE, LETABA RIVER)

Component	PES	REC	Sc 6	Sc 9	Sc 10
Physico chemical	B	B	C	B/C	B
Geomorphology	C	C	D	C/D	C/D
Fish	C	B	C/D	C/D	C/D
Invertebrates	C	B	C/D	C/D	C/D
Riparian vegetation	C	B	C	C	C
EcoStatus	C	B	C	C	C

Sc 6: Impacts on floods and low flows during the wet season. Similar to Sc 3 but the emphasis will be on decreased floods with resulting decrease in riffle quality.

Sc 9 and 10. Impacts are similar than at EWR 3 and 4 with Scenario 10 showing the most improvement from Sc 6 due to the release of PES base flows and some EWR floods.



The results illustrate that none of the scenarios meet the REC or maintain the PES. Sc 9 and 10 results in the same EcoStatus, but the invertebrate and fish components are half a category lower. Scenario 9 and 10 is an improvement of Sc 6 with Sc 10 being the best option.

5.3 INTEGRATED ECOLOGICAL CONSEQUENCES ON THE LETABA SYSTEM

A summary of the predicted ecological consequences in terms of ECs are provided in Table 5.3. These results are based on the EcoStatus as calculated for each scenario.

Table 5.3 Summary of the ecological consequences for each scenario based on the EcoStatus

Site	PES	REC	Sc 3	Sc 4	Sc 5	Sc 6	Sc 9	Sc 10
EWR 1	C	C	C	C/D	C/D	C/D	C/D	C/D
EWR 3	C	B/C	C/D	C/D	C/D	C/D	C	C
EWR 4	C	B/C	C	D	D	C/D	C	C
EWR 7	C	B	C/D	D	D	C	C	C
EWR 2	D	D		D	D	D	D	D
EWR 5	C	C	C	C/D	D	C/D	C/D	C/D

The process to determine an integrated ranking of the different scenarios is described in Section 2.2.2. The first step was to determine the relative importance of the different EWR sites. As illustration, EWR 7 has a high ecological importance and is situated in the KNP which is a Transfrontier park and is therefore afforded the highest ranking. Both EWR 3 and 4 are also situated in provincial and private nature reserves and are ranked less than EWR 7 due to the higher importance of a national park than a provincial reserve amongst others.

The weights are provided in the Table 5.3. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 5.4 Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Conservation importance based on locality in nature reserves	Weight
EWR 1	*C*	*Moderate*	*1*	*0.14*
EWR 3	*C*	*High*	*3*	*0.19*
EWR 4	*C*	*High*	*2*	*0.18*
EWR 7	*C*	*High*	*5*	*0.23*
EWR 2	*D*	*Moderate*	*1*	*0.13*
EWR 5	*C*	*Moderate*	*1*	*0.14*

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the scenario for the Letaba system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. These results are provided in Table 5.5. The individual ranking compared per EWR sites (as per the *traffic diagrams in Table 5.1 and Table 5.2) are illustrated in Figure 5.1 and compared to the integrated ranking for the system.*

Table 5.5 Ranking value for each scenario resulting in an integrated score and ranking

EWR site	REC	PES	Sc 3	Sc 4	Sc 5	Sc 6	Sc 9	Sc 10
EWR 1	*0.14*	*0.14*	*0.14*	*0.12*	*0.12*	*0.13*	*0.13*	*0.13*
EWR 3	*0.19*	*0.17*	*0.16*	*0.15*	*0.15*	*0.16*	*0.17*	*0.18*
EWR 4	*0.18*	*0.16*	*0.14*	*0.13*	*0.13*	*0.14*	*0.15*	*0.15*
EWR 7	*0.23*	*0.21*	*0.18*	*0.17*	*0.17*	*0.18*	*0.19*	*0.20*
EWR 2	*0.13*	*0.13*	*0.13*	*0.13*	*0.11*	*0.12*	*0.13*	*0.13*
EWR 5	*0.14*	*0.14*	*0.14*	*0.14*	*0.12*	*0.12*	*0.12*	*0.12*
Integrated ranking	**1**	**0.93**	**0.89**	**0.83**	**0.81**	**0.84**	**0.89**	**0.9**

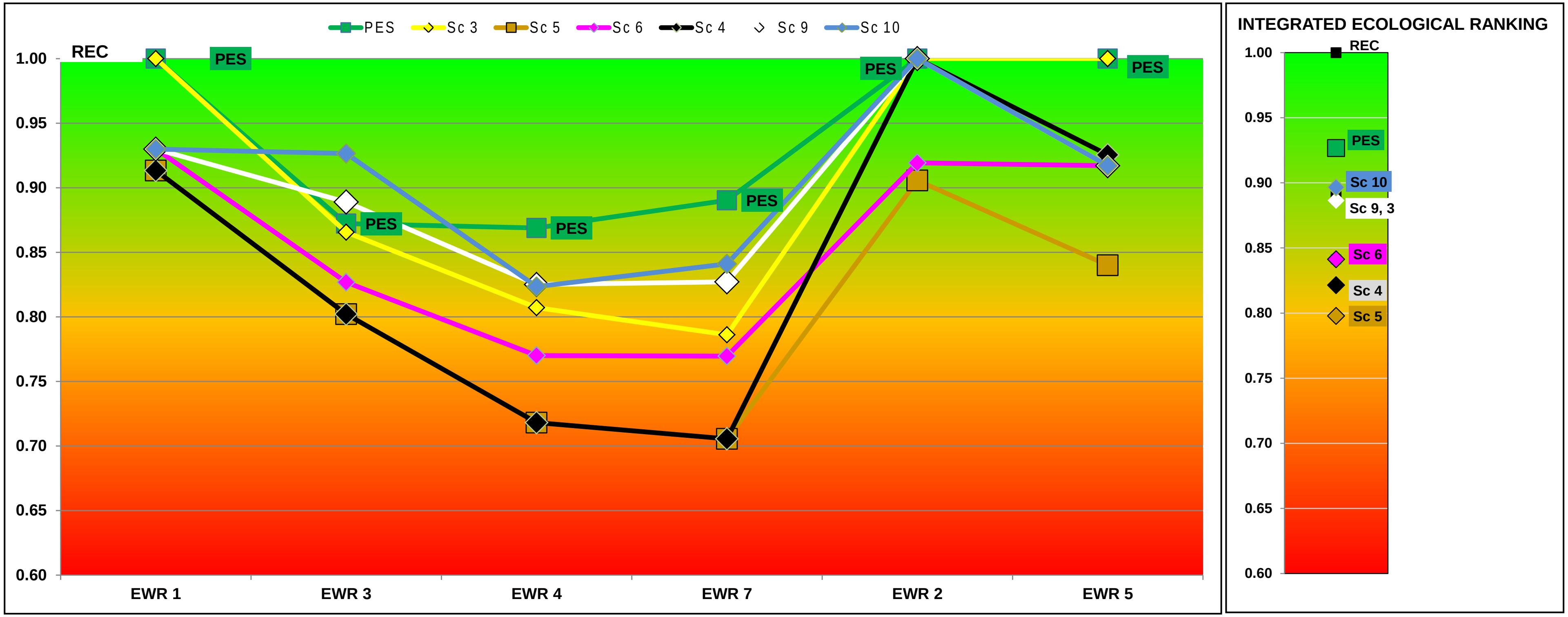


Figure 5.1 Individual ranking per EWR site and per scenario (prior to weighing) (left) compared to the integrated ranking for the EWR system with the weights applied (right)

5.4 CONCLUSIONS

The integrated ecological ranking for the Letaba system that will be taken forward in the decision-making process on scenarios and Management Class determination is summarised in Figure 5.2.

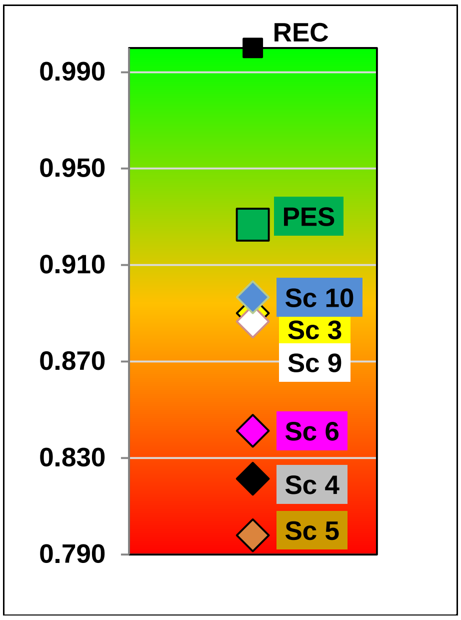


Figure 5.2 Integrated ecological ranking for the Letaba system

This ranking shows that none of the scenarios meet the REC and PES for the system. The highest ranking Scenario is Sc 10 followed closely by Sc 3 and 9. As the Nwamitwa Dam will be built, the consequences are a given and therefore scenarios without Nwamitwa Dam cannot be considered. The optimised Sc 10 is possibly the best option to consider depending on the socio-economic impacts.

6 ECOSYSTEM SERVICES

An analysis of the EWR sites 1, 2, 3, 4, 5, and 7 was undertaken. Ecosystem Services associated with the sites, bearing in mind that they represent a wider area, were listed and where they were deemed to generate value they were evaluated against the scenarios applicable to the site. It should be noted that Sc 9 and 10 were developed after the workshop was held and as such were not tested at that time. The trend in terms of results was however used to evaluate Sc 9 and 10 and to extrapolate scoring.

6.1 EWR 1

This site was in a stretch of river which was exclusively rural, and no nearby towns or village were noted. The upper reaches fall within the Ebenezer Dam, and includes the discharge point from the dam wall. The remaining extent was nearly exclusively comprised of formal plantation forestry, formal agriculture and natural vegetation. All services were given equal weight in scenario evaluation. Scenarios evaluated were 3, 4b/5 and 6 and results are provided in Table 6.1.

Table 6.1 Results for EWR 1

Service	Sc 3	Sc 4b and 5	Sc 6	Weight
Provisioning services	*1*	*1.03*	*1.03*	*0.25*
Regulating services	*1*	*0.88*	*0.88*	*0.25*
Cultural services	*1*	*1*	*1*	*0.25*
Supporting services	*1*	*1*	*1*	*0.25*
Weighted Score	**1**	**0.98**	**0.98**	

Scenario 3 was almost exactly the same with respect to anticipated changes as PD (Status Quo) although sedges are expected to be marginally less prevalent while some grazing grasses may fare marginally better. Scenario 4b and 5 were evaluated as the same scenario. Scenario 6 was evaluated separately although the impacts on Ecosystem Services were deemed to be very much the same as Sc 4b and 5. All of these scenarios were deemed to have an overall marginally negative impact. Provisioning services would potentially improve, and this was related to the more favourable conditions for sedges, reeds, Cynodon dactylon (grazing grass), Syzygium cordatum (Water berry), Breonadia salicina (Matumi) as well as some of the harvested alien species. Regulating services on the other hand, particularly those associated with waste assimilation, dilution and groundwater recharge would be compromised. Cultural services as well as supporting services would potentially not be impacted under the scenarios envisaged.

6.2 EWR 2

This stretch of river was rural in nature, however the Mariveni Township forms much of the north bank, and the Shinhungu Township is located on it south bank. Land-use other than the townships included both subsistence and formal agriculture. Provisioning and cultural services were given comparatively more weight at this site than the other two services. This was as a result of the perceived direct relationship between the communities living close to the site and these services.

Table 6.2 Results for EWR 2

Services	Sc 3	Sc 4b	Sc 5	Sc 6	Weight
Provisioning services	*1*	*1*	*0.99*	*0.99*	*0.3*
Regulating services	*1*	*1*	*0.97*	*0.97*	*0.2*
Cultural services	*1*	*1*	*1.00*	*1.00*	*0.3*
Supporting services	*1*	*1*	*0.93*	*0.93*	*0.2*
Weighted Score	**1**	**1**	**0.98**	**0.98**	

All scenarios were evaluated separately. Scenario 3 and 4 were deemed to be absent of any real impact with respect to Ecosystem Services. Scenario 5 and 6 had similar results and were regarded as being marginally negative. Here the provisioning and regulating services as well as supporting services were regarded as being negatively impacted. With regard to provisioning services the yellowfish and labeos were expected to decline under Sc 5 and 6. Sedges, reeds and Cynodon dactylon are expected to marginally increase in abundance, while Leersia hexandra would decrease slightly. Sand winning would decline slightly while transmission of Malaria might be expected to increase slightly. Cultural and supporting services would remain unchanged under all scenarios.

6.3 EWR 3

This stretch of river was exclusively rural. There was a narrow band of formal agriculture along a 8 km stretch, and thereafter the river flows into the Ndzalama/Hans Merensky Nature Reserve. The Makhwivirini and Prieska-A townships are located near the river however they cover a limited extent of the river. Cultural services, given the presence of the reserve, were elevated in weight and regulating services were reduced marginally.

Table 6.3 Results for EWR 3

Service	Sc 3	Sc 4b and 5	Sc 6	Weight
Provisioning services	*1.02*	*0.95*	*0.91*	*0.25*
Regulating services	*1.00*	*0.83*	*0.75*	*0.2*
Cultural services	*1.00*	*1.00*	*1.00*	*0.3*
Supporting services	*1.00*	*0.95*	*0.95*	*0.25*
Weighted Score	*1.01*	*0.94*	*0.91*	

Scenario 3 was almost exactly the same with respect to anticipated changes as PD (Status Quo). Scenario 4b and 5 were evaluated as the same scenario and were marginally negative. Scenario 6 was evaluated separately and was less favourable to Ecosystem Services than Sc 4b/5. Under Scenario 3 provisioning services would improve slightly. This was due to the more favourable conditions for sedges, as well as reeds, C. dactylon (grazing grass), S cordatum (Water berry), as well as Breonadia salicina (Matumi). No other services were impacted under Sc 3. Scenario 4b/5 were largely negative, albeit marginally, as a result in the anticipated decline in sedges, reeds, Cynodon dactylon (grazing grass), S. cordatum (Water berry), B. salicina (Matumi) and L. hexandra. Yellowfish and labeos were expected to decline under Sc 4b and 5. Regulating services, particularly those associated with waste assimilation and dilution, as well as stream flow regulation were anticipated as being compromised under Sc 4b and 5 as well as, and to a greater extent, Sc 6. Under Sc 6, and for provisioning services, the impacts on the botanical species were similar to those for Sc 4b and 5 but not anticipated as being an impact on the fish.

6.4 EWR 4

This stretch of river was exclusively rural and entirely located in the Letaba Game Reserve. No towns or villages were noted. Recreational/tourism activities and infrastructure are important on this stretch of the river. Given the nature of the stretch, provisioning services were irrelevant. Cultural services, given links to tourism were given greater weight as was regulating and supporting services.

Table 6.4 Results for EWR 4

Service	Sc 3	Sc 4b and 5	Sc 6	Weight
Provisioning services	*1*	*1*	*1*	*0.01*
Regulating services	*0.97*	*0.8*	*0.87*	*0.3*
Cultural services	*1*	*1*	*1*	*0.4*
Supporting services	*1*	*1*	*1*	*0.29*
Weighted Score	*0.99*	*0.94*	*0.96*	

All scenarios were seen as potentially negative. This was driven by the impact on regulating services. Regulating services, particularly those associated with waste assimilation and dilution, as well as stream flow regulation were anticipated as being compromised under Sc 4b/5 and 6 as well as, and to a greater extent, Sc 3.

6.5 EWR 5

This stretch of river had rural and urban elements. The river extent included 7 townships and 1 formal town (Giyani), the latter being the district municipal capital. Land-use is a mosaic of open unutilised land and informal agricultural fields/smallholding associated with the townships. There was some, but limited, formal agriculture accounting for less than 10% of the river extent. Provisioning services were given the greatest weight at this site.

Table 6.5 Results for EWR 5

Service	Sc 3	Sc 4b and 5	Sc 6	Weight
Provisioning services	*1*	*0.96*	*0.96*	*0.99*
Regulating services	*1*	*0.89*	*0.74*	*0.77*
Cultural services	*1*	*0.88*	*0.88*	*0.90*
Supporting services	*1*	*0.98*	*0.95*	*0.95*
Weighted Score	**1**	**0.92**	**0.89**	**0.91**

Scenario 4b, 5 and 6 all had negative impacts associated with altered flow regimes. Under these scenarios some of the critical fish species, notably yellowfish would be negatively impacted. The impact was potentially most severe under Sc 5. Impacts on botanical species would be slightly negative under Sc 4b and unchanged, or marginally positive with regard to recruitment of reeds and sedges. Under the scenarios regulating services, particularly those associated with waste dilution and assimilation would be negatively impacted. Again Sc 5 was least desirable. Given the overall impact on the system, cultural services would also be negatively impacted. Supporting services showed some negative change as well. Here deposition of sand and opportunities for sand winning were deemed to be at risk.

6.6 EWR 7

This is a stretch of river was exclusively rural, and entirely comprised of unutilised/open terrain (associated with the KNP). Recreational/tourism features as well as the Letaba Campsite were *noted as part of the stretch. Given the nature of the stretch provisioning services were not relevant. Cultural services, given links to tourism were given greater weight as was regulating and supporting services.*

Table 6.6 Results for EWR 7

Service	Sc 3	Sc 4b and 5	Sc 6	Weight
Provisioning services	*1*	*1*	*1*	*0.01*
Regulating services	*0.96*	*0.80*	*0.82*	*0.3*
Cultural services	*1*	*1*	*1*	*0.4*
Supporting services	*1*	*1*	*1*	*0.29*
Weighted Score	**0.98**	**0.90**	**0.91**	**1**

Results were similar to those found at EWR 4. All scenarios were seen as potentially negative. This was driven by the impact on regulating services. Regulating services, particularly those associated with waste assimilation and dilution, as well as stream flow regulation were anticipated as being compromised under Sc 4b/5 and 6 as well as, and to a lesser extent, Sc 3.

6.7 INTEGRATED CONSEQUENCES OF SCENARIOS ON ECOSYSTEM SERVICES IN THE LETABA SYSTEM

The ranking of the scenarios per site are provided in Table 6.7 and Figure 6.1. As indicated Sc 9 and 10 were evaluated after the specialist biophysical workshop and as such results were extrapolated from the trend generated by results.

Table 6.7 Summarised results of scenario ranking

EWR Site	Scenario	Rank
EWR 1	*PES, Sc 3*	*1*
	Sc 4, 5, 6, 9, 10	*0.98*
EWR 2	*PES, Sc 3, 4b, 9, 10*	*1*
	Sc 5, 6	*0.98*
EWR 3	*Sc 3*	*1.01*
	PES	*1*
	Sc 4b, 5, 9, 10	*0.94*
EWR 4	*PES*	*1*
	Sc 3	*0.99*
	Sc 6, 9, 10	*0.96*
	Sc 4b, 5	*0.94*
EWR 5	*PES, Sc 3*	*1*
	Sc 4b	*0.92*
	Sc 6, 9, 10	*0.91*
	Sc 5	*0.89*
EWR 6	*PES*	*1*
	Sc 3	*0.98*
	Sc 9, 10	*0.93*
	Sc 6	*0.91*
	Sc 4b, 5	*0.90*

The process to determine an integrated ranking of the different scenarios required determining the relative importance of the different EWR sites. Here the perceived vulnerability of households dependent on the provisioning aspect of Ecosystem Services played a major role. EWR sites 3 and 4 and to a lesser extent EWR 2 were thus given a higher ranking. The importance of cultural services at the EWR sites linked to game parks meant that they were also accorded a degree of importance, albeit lower than those in other parts of the study area. This was cross referenced with the SCI score discussed in Section 2.2.3. The weights are provided in the Table 6.8.

Table 6.8 Weights allocated to EWR sites relative to each other

EWR site	SCI	Ecosystem Services Rank	Weight
EWR 1	*Low*	*4*	*0.133*
EWR 3	*High*	*1*	*0.223*
EWR 4	*High*	*2*	*0.191*
EWR 7	*Low*	*4*	*0.134*
EWR 2	*Moderate*	*3*	*0.185*
EWR 5	*Low*	*5*	*0.134*

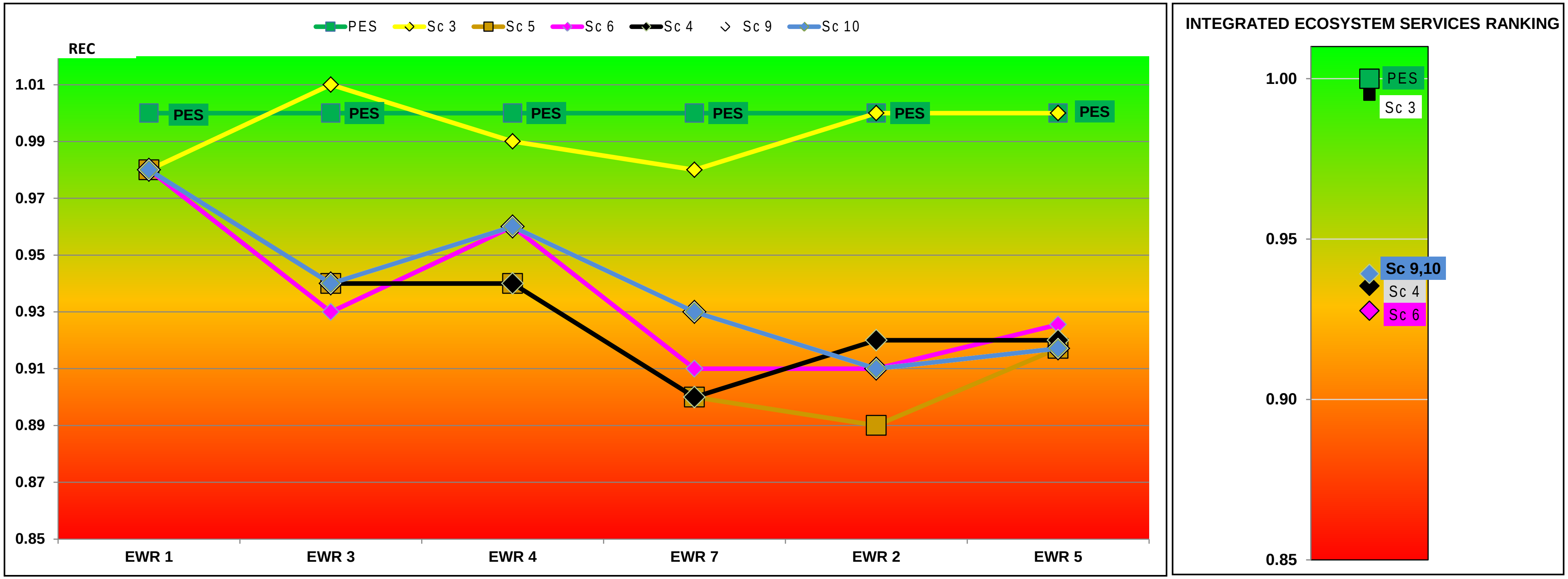


Figure 6.1 Individual ranking per EWR site and per scenario (prior to weighing) (left) compared to the integrated ranking for the EWR system with the weights applied (right)

7 INTEGRATED MULTI-CRITERIA RESULTS

The results of the rating, weighting and scoring for the three variables, economy, ecology and Ecosystem Services presented in the previous chapters were integrated to obtain the overall ranking of the scenarios and described in this chapter. Provision was made in this process to incorporate all the biophysical nodes in each of the IUAs.

7.1 ECOLOGICAL SCORING MATRIX RESULTS

Table 10.18 (Appendix A) provides an example (extract) of the full scoring carried out for the ecological component. The elements of the table are described below in accordance with the respective column alphabetic labels:

Column *a*: *National biophysical node label identifier, where the first 4 characters "B83A" refers to the quaternary catchment in which the node is located. The remaining numbers represent the SQ reach number. The SQ river reaches as indicated in http://www.dwa.gov.za/iwqs/gis_data /river/rivs500k.html and http://www.dwa.gov.za/iwqs/gis_data/river/River_Report_01.pdf, forms the basis of the Desktop Present Ecological State (PES) and Ecological Importance (EI) - Ecological Sensitivity (ES) (DWA 2013c) assessment (referred to PES (11)). A SQ changes when a significant tributary joins it. This means that a SQ may potentially be subdivided into various EcoRegions, geomorphic zones (slope zones) resource units (natural or management), etc. Such subdivisions are not addressed on a desktop level, and may be required when higher confidence assessments are done. The version of the 1:500 000 coverage that was used for the PES (11) (DWA, 2013c), was a version used by the National Freshwater Ecosystem Priority Areas (NFEPA) project in 2009 (Nel et al., 2011).*

The EWR sites are indicated as "EWR1" where the numerical number refers to the particulate site. These are the river sites where high confidence Reserve determination studies were undertaken and serve as the drivers for the water resource modelling and availability analysis.

Column *b*: *River or stream name.*

Columns *c* and *d*: *These columns are the weights assigned to each node. Column c reflects the relative ecological importance of each node and* **Column d** *is the length of river reach the node represents. The length of river is a measure of the extent of the ecological habitat of the river reach (associated with the nodes) relative to each other. These two weights are combined into one weight, see description of* **Column g** *below.*

Columns *e, f* and *g*: *The weights of* **Columns c** *and* **d** *are respectively normalised in these columns.*

Columns *e* and *f* *(divide each nodes weight by the sum of the weights)***:** *The combined weight in* **Column *g*** *is determined by the sum of the product of the normalised values with the factors given in grey shading above the column labels. These factors must add up to one and represents the relative contribution of the "Importance" and the "Length" in the combined weight.*

Columns *h* to *l*: *This is the rating of the ecological status of each node as it is influenced by the scenario. Since most of the biophysical nodes are in tributary catchment and not affected by the scenarios their ratings are one, indicating the REC is achieved.*

Columns *m* to *q*: *This is the score, the product of the weight in* **Column g** *and respective ratings in* **Columns h** *to* **i***. The sum of the scores of all the nodes for a scenario is listed at the bottom of each column. This is the metric representing the ecology for the scenario and taken into account when determining the integrated ranking of scenarios.*

7.2 ECOSYSTEM SERVICES SCORING MATRIX RESULTS

The same calculation methodology as described in Section 7.1 is applied for the Ecosystem Services component and presented in Table 10.19 (Appendix A).

7.3 INTEGRATED SCENARIO RANKING RESULTS

The scenario scores for the four variables, Ecology, Ecosystem Services, Economy and Employment are presented graphically in Figure 7.1. The scenarios presented are identified in accordance with their labels presented in Table 3.1. Note that only the scenarios that are relevant for the discussion and decision making process are listed. The scenarios not shown provided intermediate perspectives for evaluation purposes and were superseded by other scenarios during the analysis process.

The four individual graphs shown in Figure 7.1 have the following interpretation:

- **Ecological Status relative to REC:** *This is the measure of how each scenario's ecological status is ranked relative to the REC. As indicated* **Scenario 5a** *has the lowest ecological score while* **Scenario 10** *has the third highest score with the* **REC scenario** *the highest and the* **PES scenario** *the second highest.*
- **Ecosystem Services:** *The score indicates to what extent each scenario changes the Ecosystem Services relative to the PES conditions. The ranking follows largely the same ranking order as that for the ecological status.*
- **Economic Indicator (GDP):** *This metric represents GDP in Rands with* **Scenario 5a** *ranking the highest and the* **REC scenario** *lowest.*
- **Employment:** *The number of people employed is indicated by the metric with* **Scenario 5a** *ranking the highest and the* **REC scenario** *the lowest.*

The relative weight applied to each variable for calculating the overall ranking is indicated numerically at the bottom of each graph. Each weight has a value between zero and one and a set of selected weights for all four variables must add up to one. The rationale for the weights selected is to assess what the balance is between the ecological health and the socio-economic benefits, therefore a weight of 0.5 (or 50%) is assigned to the ecology and the remaining 50% is divided among the other three variables; Ecosystem Services (15%), economy (15%) and employment (20%).

The lines depicted in Figure 7.1 connect the variable points for a scenario and when opposing consequences are observed (among the variables) the lines cross. This indicates opposing outcomes and a compromise between ecological health and socio economic benefits will most likely result in the optimum solution – "the desired balance between protection and use".

The graph show the scenario with the highest ecological health metric (the **REC scenario***) reduces the water availability (compared to the current yield) to the extent that the economic and employment metric is the lowest of all the scenarios. This represents a curtailment (reduction) of the economy and employment in comparison with the present situation (***PES scenario***). At the other extreme, the scenario where no provision is made for releases, ecology scores the lowest (***Scenario 5a***) while the available water for socio-economic development is high with* *corresponding high socio-economic benefits which results in the score of* **Scenario 5a** *for the economy and employment being the highest among all the scenarios.*

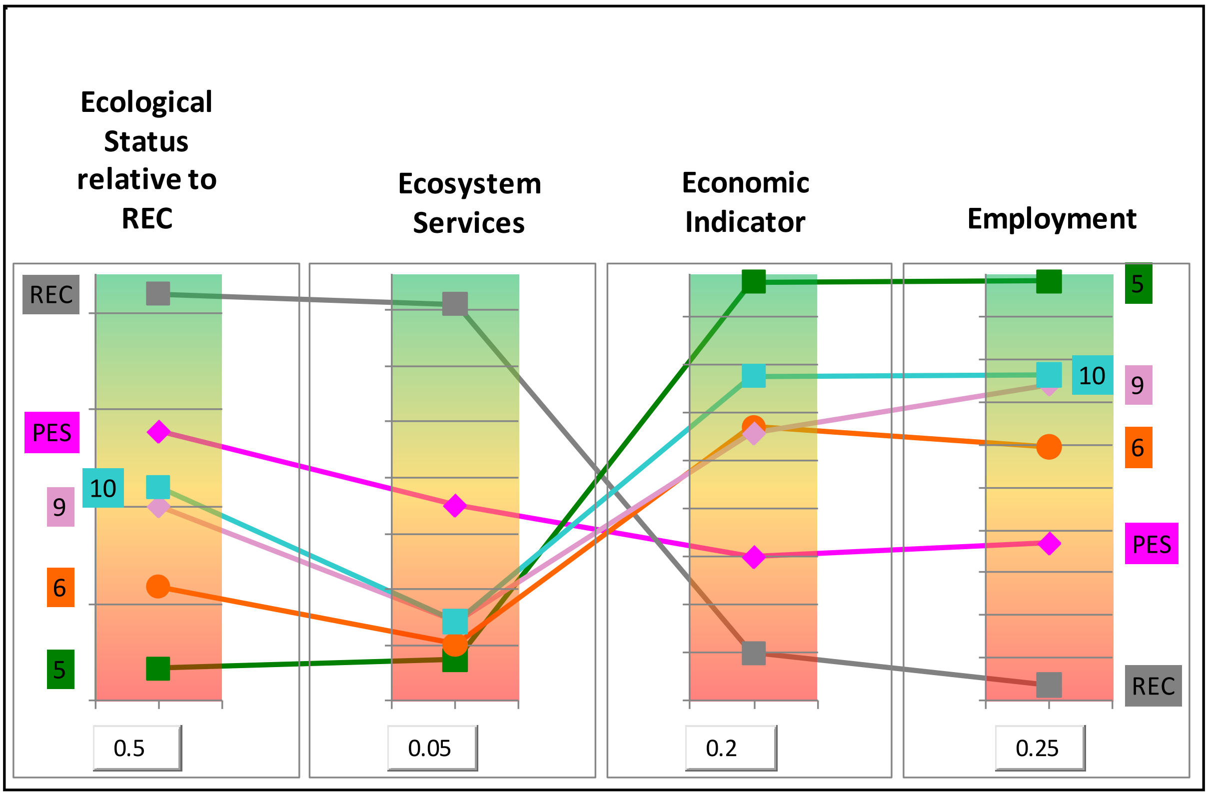


Figure 7.1 Graphical results of individual variables

The scores for the other scenarios fall within these extremes and various alternative scenarios were evaluated in an attempt to find an optimum balance.

The final step in the multi-criteria analysis was to determine the integrated and overall rank of the scenarios and this is depicted in Figure 7.2a and Figure 7.2b.

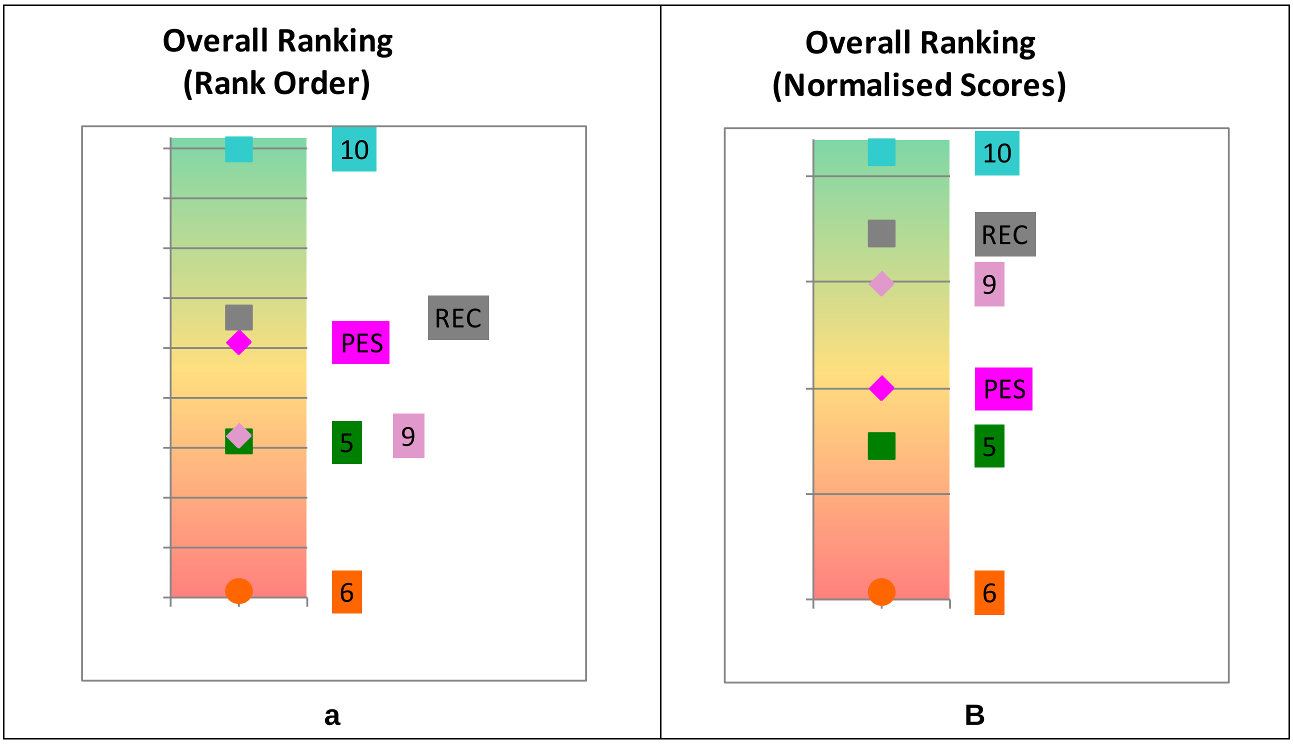


Figure 7.2 Graphical results of overall ranking from the multi-criteria analysis

Figure 7.2a rank the scenarios according the rank order of the scores while the normalised scores of the scenarios (scores made none dimensional) are applied to rank the scenarios in Figure 7.2b.

The integrated ranking calculations which give rise to the ranking order shown in Figure 7.2a are presented in Table 7.1 and explained below by using the column and row labels.

Column *a*: *This column contains headings describing the different sections in the table as well as labelling the variables for which the calculated data of the scenarios are provided in the subsequent columns.*

Columns *b* and *c*: *Contain parameters applied in the calculations, either the best and highest and lowest scores of the weights associated with each variable. The application of these parameters in the calculations is described below.*

Columns *d* to *i*: *Represent the values calculated for each of the scenarios.*

Rows *A* to *D*: *This is the numerical results (scores) of the scenarios.*

Row *A* *is the Ecological Scores for the scenarios, which originate from the calculations in Table 10.18 (Appendix A) and is obtained from the last row in that table.*

Row *B* *is the Ecosystem Services score which is calculated in Table 10.19 (Appendix A) and obtained from the last row in that table.*

Rows *C* and *D*: *Contains respectively the Economic Indicator (GDP in Rand) and the Employment numbers for each scenario. The calculations to derive these variables were described in Chapter 4.*

Rows *E* to *O*: *This section of the table shows the calculation results for the Rank Order method of determining the overall scenario rank.*

Rows *E* to *H*: *Contains the rank order position of each variable's score derived from the scored in* **Rows *A* to *D***.

Row *I*: *This is the sum of the rank positions of the scenario (note this is before the variable weight are applied.* **Row *J*** *is the ranked position of* **Row *I***. *Note that both* **Rows *I*** *and* ***J*** *are before the variables weights are applied.*

Rows *K* to *N*: *These rows show the scores where the Weights indicated in* **Column *b*** *is multiplied with the respective rank positions given in* **Rows *E*** *to* ***H***.

Row *O*: *This is the sum of the scenario values of* **Rows *H*** *to* ***N*** *– the overall score of the scenarios for the Rank Order method.*

Row *P*: *This is the rank order of the scenarios for the Rank Order method, indicating* **Scenario 10** *is the best (rank if one) and Scenario 6 ranks the lowest with a rank of six.*

Rows Q to *AB*: *The results for the normalisation calculation are presented in these rows.*

Rows *Q* to *T*: *Shows the normalised values for the variables determined from* **Rows *A* to *D*** *respectively.*

Rows *Q* to *T*: *This is the normalised values calculated by assuming the worst scenario will have a normalised value of zero and the best scenario a value of one. All the other values then transposed to fit the zero to one normalised scale.*

Rows *U* and *V*: *This is the sum of the scores for the normalised values for each scenario and the rank order of the scores. Note that both* **Rows *U*** *and* ***V*** *are before the variables weights are applied.*

Rows *W* to *Z*: *These rows show the scores where the Weights indicated in Column b is multiplied with the respective rank positions given in* **Rows *Q*** *to* ***T****.*

Row *AA*: *This is the sum of the scenario values of* **Rows *W*** *to* ***Z*** *– the overall score of the scenarios for the Normalisation Method.*

Row *AB*: *This is the rank order of the scenarios for the Normalisation Method, indicating* **Scenario 10** *is the best (rank if one) and Scenario 6 ranks the lowest with a rank of six.*

Rows *AC* to *AF*: *This is the respective results (integrated scores and rank positions) of the two ranking methods repeated for easy comparison.*

*In order to determine how sensitive the ranking results are for alternative weight settings, Table 7.2 provides scenario ranking results for a range of variable weights. Nine alternative weight alternatives were evaluated labelled as such in the column with the heading "***Alternatives***". The weights are as presented in* **Columns *a*** *to* ***I****, with* **Column *e*** *showing the sum of the weights which must be one.*

Both the scores and the rank order (pairs of results) for the scenarios are provided in **Columns *f*** *to* ***q****. The results for the Rank Order Method are presented in* **Rows *A*** *to* **I** *while the results for the Normalisation Method is shown in* **Rows *J*** *to* ***R****. Note that the same alternative weight settings is used for the alternatives with the same label.*

It can be observed that the Rank Order Method result is mostly consistent by indicating **Scenario 10** *is the preferred scenario (except for* **Alternative 7** - **Row *H****).*

The Normalisation Method is more sensitive with 4 out of the 9 alternatives indicating **Scenario 10** *ranks second. Of those,* **Alternatives 2** *and* **3** *indicate the* **REC Scenario** *is preferred while for* **Alternatives 7** *and* **8**, **Scenario 5** *is preferred. The weights for* **Alternative 8** *are also highly biased against the ecology and can be rules out due to the importance of the KNP as a conservation area of international standing.*

Considering that the **REC Scenario** *and* **Scenario 5** *represent the boundary cases or the extremes (***REC Scenario** *= full protection and* **Scenario 5** *least protection) these scenarios will not be selected when a compromised solution is to be attained i.e. a "balance between protection and use" need to be find. Therefore the results of both ranking methods points to* **Scenario 10** *being the preferred choice.*

Table 7.1 Integrated ranking calculations for the two ranking methods

Row	Description	Parameters		Scenarios:					
				PES	**REC**	**5**	**6**	**9**	**10**
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
	Variable Scores:								
		Highest	*Lowest*						
A	Ecological Status	1.00	0.81	0.93	1.00	0.81	0.85	0.89	0.90
B	Ecosystem Services	1.07	0.94	1.00	1.07	0.94	0.95	0.96	0.96
C	Economic Indicator (GDP) (R Millions)	3245	1699	2099	1699	3245	2641	2614	2852
D	Employment	33641	14738	21371	14738	33641	25901	28813	29272
	Rank Order Method:								
	Ranked order of variables (6 = higest, 1 = lowest, equals = average):								
E	Ecological Status			5.0	6.0	1.0	2.0	3.0	4.0
F	Ecosystem Services			5.0	6.0	1.0	2.0	3.5	3.5
G	Economic Indicator (GDP) (R Millions)			2.0	1.0	6.0	4.0	3.0	5.0
H	Employment			2.0	1.0	6.0	3.0	4.0	5.0
I	Total:			14.000	14.000	14.000	11.000	13.500	17.500
J	Rank (1 = best, 6 = worsed)			3	3	3	6	5	1
	Rank order x Weights:	Weights							
K	Ecological Status	0.50		2.50	3.00	0.50	1.00	1.50	2.00
L	Ecosystem Services	0.05		0.25	0.30	0.05	0.10	0.18	0.18
M	Economic Indicator (GDP) (R Millions)	0.20		0.40	0.20	1.20	0.80	0.60	1.00
N	Employment	0.25		0.50	0.25	1.50	0.75	1.00	1.25
O	**Total:**			**3.650**	**3.750**	**3.250**	**2.650**	**3.275**	**4.425**
P	**Rank (1 = best, 6 = worsed)**			**3**	**2**	**5**	**6**	**4**	**1**
	Normalisation Method:								
	Normilized (0 = minimum, 1 = maximum):								
Q	Ecological Status			0.632	1.000	0.000	0.219	0.433	0.483
R	Ecosystem Services			0.434	1.000	0.000	0.045	0.109	0.109
S	(R Millions)			0.259	0.000	1.000	0.609	0.592	0.746
T	Employment			0.351	0.000	1.000	0.591	0.745	0.769
U	Total:			1.676	2.000	2.000	1.464	1.879	2.107
V	Rank (1 = best, 6 = worsed)			5	2.5	2.5	6	4	1
	Normiliaed x Weights:	Weights							
W	Ecological Status	0.50		0.316	0.500	0.000	0.109	0.217	0.242
X	Ecosystem Services	0.05		0.022	0.050	0.000	0.002	0.005	0.005
Y	Economic Indicator (GDP) (R Millions)	0.20		0.052	0.000	0.200	0.122	0.118	0.149
Z	Employment	0.25		0.088	0.000	0.250	0.148	0.186	0.192
AA	Total:			**0.477**	**0.550**	**0.450**	**0.381**	**0.527**	**0.589**
AB	**Rank (1 = best, 6 = worsed)**			**4**	**2**	**5**	**6**	**3**	**1**
AC	**Overall Score (Rank Order method)**			3.65	3.75	3.25	2.65	3.275	4.425
AD	Rank (1 = best, 6 = worsed)			**3**	**2**	**5**	**6**	**4**	**1**
AE	**Overall Score (Normalisation Method)**			0.4772	0.5500	0.4500	0.3811	0.5265	0.5885
AF	Rank (1 = best, 6 = worsed)			**4**	**2**	**5**	**6**	**3**	**1**

Table 7.2 Sensitivity analysis of scenario ranking for alternative variable weights

Row	Alternative	Weighs					Scenarios											
							PES		REC		5		6		9		10	
		Ecological	Ecosystem Services	Economy (GDP)	Employment	Total	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
		a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
		Rank Order Method:																
A	**1**	**0.50**	**0.05**	**0.20**	**0.25**	**1.00**	**3.650**	**3**	**3.750**	**2**	**3.250**	**5**	**2.650**	**6**	**3.275**	**4**	**4.425**	**1**
B	2	0.50	0.10	0.20	0.20	1.00	3.800	3	4.000	2	3.000	5	2.600	6	3.250	4	4.350	1
C	3	0.50	0.15	0.15	0.20	1.00	3.950	3	4.250	2	2.750	5	2.500	6	3.275	4	4.275	1
D	4	0.50	0.05	0.15	0.30	1.00	3.650	3	3.750	2	3.250	5	2.600	6	3.325	4	4.425	1
E	5	0.50	0.05	0.30	0.15	1.00	3.650	3	3.750	2	3.250	4	2.750	6	3.175	5	4.425	1
F	6	0.25	0.25	0.25	0.25	1.00	3.500	2	3.500	2	3.500	2	2.750	6	3.375	5	4.375	1
G	7	0.20	0.10	0.40	0.30	1.00	2.900	5	2.500	6	4.500	2	3.100	4	3.350	3	4.650	1
H	8	0.15	0.10	0.45	0.30	1.00	2.750	5	2.250	6	4.750	1	3.200	4	3.350	3	4.700	2
I	9	0.50	0.05	0.20	0.25	1.00	3.650	3	3.750	2	3.250	5	2.650	6	3.275	4	4.425	1
		Normalisation Method:																
J	**1**	**0.50**	**0.05**	**0.20**	**0.25**	**1.00**	**0.477**	**4**	**0.550**	**2**	**0.450**	**5**	**0.381**	**6**	**0.527**	**3**	**0.589**	**1**
K	2	0.50	0.10	0.20	0.20	1.00	0.481	4	0.600	1	0.400	5	0.354	6	0.495	3	0.556	2
L	3	0.50	0.15	0.15	0.20	1.00	0.490	3	0.650	1	0.350	5	0.326	6	0.471	4	0.524	2
M	4	0.50	0.05	0.15	0.30	1.00	0.482	4	0.550	2	0.450	5	0.380	6	0.534	3	0.590	1
N	5	0.50	0.05	0.30	0.15	1.00	0.468	4	0.550	2	0.450	5	0.383	6	0.511	3	0.586	1
O	6	0.25	0.25	0.25	0.25	1.00	0.419	5	0.500	2	0.500	2	0.366	6	0.470	4	0.527	1
P	7	0.20	0.10	0.40	0.30	1.00	0.379	5	0.300	6	0.700	1	0.469	4	0.558	3	0.637	2
Q	8	0.15	0.10	0.45	0.30	1.00	0.360	5	0.250	6	0.750	1	0.489	4	0.566	3	0.650	2
R	9	0.50	0.05	0.20	0.25	1.00	0.477	4	0.550	2	0.450	5	0.381	6	0.527	3	0.589	1

8 MANAGEMENT CLASSES

8.1 IUA MANAGEMENT CLASSES FOR EACH SCENARIO

A range of alternative Management Class Criteria settings (alternative to the guideline criteria presented in Table 2.6) were evaluated by the study team leading to the recommended criteria parameters presented in Table 8.1.

Table 8.1 Recommended Management Class Criteria Table

		% EC representation at units represented by biophysical nodes in an IUA				
		≥ A/B	≥ B	≥C	≥ D	< D
Class 1		*0*	*60*	*80*	*95*	*5*
Class 2			*0*	*70*	*90*	*10*
Class 3	**Either**			*0*	*80*	*20*
	Or				*100*	

When applying the criteria presented in Table 8.1 to the resulting Ecological Categories for each scenario as presented in Table 10.20 (Appendix A), the Management Classes for the 12 IUAs are as listed in Table 8.2.

Table 8.2 Resulting IUA Management Classes for each scenario

IUA	Scenarios and Management Class					
	PES	REC	5	6	9	10
1	*II*	*II*	*III*	*III*	*III*	*III*
2	*III*	*III*	*III*	*III*	*III*	*III*
3	*III*	*II*	*III*	*III*	*III*	*III*
4	*II*	*II*	*III*	*III*	*III*	*III*
5	*I*	*I*	*I*	*I*	*I*	*I*
6	*III*	*III*	*III*	*III*	*III*	*III*
7	*XXX*	*III*	*XXX*	*XXX*	*XXX*	*XXX*
8	*II*	*II*	*II*	*II*	*II*	*II*
9	*II*	*II*	*III*	*III*	*III*	*III*
10	*I*	*I*	*I*	*I*	*I*	*I*
11	*II*	*I*	*III*	*II*	*II*	*II*
12	*I*	*I*	*I*	*I*	*I*	*I*

Following on from the discussion at the end of Chapter 7, the recommended Management Classes among the scenarios presented is therefore as indicated for **Scenario 10***. Further concluding remarks and the recommended Management Classes are discussed and presented in the following section. The result for IUA 7, indicated by "XXX" implies the scenarios did not comply with the criteria for a Class III. This is due to a large % of the biophysical nodes being in an E EC due to water quality problems as well as barriers and inundation impact.*

8.2 CONCLUSIONS AND RECOMMENDATIONS

Given the results presented in Chapter 7 (summarised above) it can be concluded that **Scenario 10** *is the preferred scenario that achieves the best balance between protection and use among the scenarios considered. However, one of the characteristics of* **Scenario 10** *is the inclusion of additional abstractions out of Ebenezer Dam for possible transfer to Polokwane. This transfer is causing a reduction in the Ecological Category at EWR 1 (downstream of Ebenezer Dam) changing from a C Ecological Category for the PES Scenario to a C/D Ecological Category for* **Scenario 10***. This reduction also results in a Management Class of III for IUA 1 for* **Scenario 10** *compared to Management Class of II for the PES Scenario (see Table 8.2.). Furthermore, it was shown in the scenarios prepared for the Reconciliation Strategy Study that there is not sufficient water to supply the current and likely future water needs in the Letaba River System making further transfer to Polokwane infeasible from a water availability perspective.*

Therefore, it is recommended that **Scenario 10** *without the additional transfer to Polokwane be selected as the preferred scenarios which will imply the configuration of ECs and Management Classes for the IUAs as presented in Table 8.3 is recommended.*

These results and the recommendations will be presented at the Project Steering Committee Meeting to be held in April 2014 for comments after which the final scenario and results will be prepared for gazetting.

Table 8.3 Recommended Ecological Categories and Management Classes for the Letaba River System

Nodes	River	IUA	EC	MC
B81A-00242	Broederstroom	1	C	II
B81A-00256			D	
B81A-00263			D	
B81A-00270	Broederstroom		C	
B81B-00233	Mahitse		C	
B81B-00234	Mahitse		C	
B81B-00246	Politsi		C	
B81B-00251			D	
B81B-00269	Morudi		B	
B81B-00227	Mahitse		D	
B81B-00240	Politsi		C	
B81B-00247	Great Letaba		C/D	
EWR1	Great Letaba		C	
B81D-00277	Thabina	2	D	III
B81D-00280	Bobs		B	
B81D-00296	Mothlaka-Semeetse		B	
EWR2	Letsitele		D	
B81D-00272	Letsitele		C	
B81C-00245	Great Letaba	3	C/D	III
B81E-00213	Nwanedzi		D	
B81E-00244	Great Letaba		C/D	
EWR3	Great Letaba	4	C/D	II
B81F-00212	Great Letaba		C/D	
B81F-00215	Great Letaba		C/D	
B81F-00218	Great Letaba		C/D	
B81F-00231	Great Letaba		C/D	
B81J-00209	Great Letaba		C/D	
EWR4	Great Letaba		C/D	
B81F-00228	Reshwele	5	B	I
B81F-00232	Makwena		B	
B81F-00189	Merekome	6	C	III
B81F-00203	Lerwatlou		C	
B81G-00164	Molototsi		D	
B81H-00162	Metsemola		C	
B81H-00171	Molototsi		D	
B81J-00187	Mbhawula		C	
B82A-00168	Middel Letaba	7	C	III
B82B-00173	Koedoes		D	
B82C-00175	Brandboontjies		E	
B82D-00163	Lebjelebore		C	
B82D-00154	Middel Letaba		D	
B82D-00166	Mosukodutsi		D	
B82D-00146	Middel Letaba		E	
B82E-00149	Khwali	8	B	III
B82E-00150	Little Letaba		C	
B82F-00141	Soeketse		C	
B82F-00128	Little Letaba		C	
B82F-00137	Little Letaba		D	
EWR5	Little Letaba	9	C/D	III
B82J-00165	Little Letaba		C/D	
B82J-00178	Little Letaba		C/D	
B82J-00201	Little Letaba		C/D	
B82J-00207	Little Letaba		C/D	
B82H-00127	Nsama	10	C	I
B82H-00139	Magobe		B	
B82H-00157	Nsama		B	
B82J-00153	Nalatsi		A/B	
B82J-00159	Byashishi		A/B	
B82J-00197	Ka-Malilibone		B	
B83A-00220	Letaba	11	C/D	II
B83A-00230	Letaba		C	
EWR6	Letaba		C	
B83A-00252	Letaba		C	
B83D-00250	Letaba		C	
EWR7	Letaba		C	
B83E-00265	Letaba		A/B	
B83A-00193	Shipikani	12	A/B	I
B83A-00238	Nharhweni		A/B	
B83A-00254	Ngwenyeni		A/B	
B83B-00161	Tsende		A/B	
B83D-00204	Manyeleti		A/B	
B83D-00208	Makhadzi		A/B	

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10 APPENDIX A: WATER RESOURCES MODELLING

10.1 CONFIGURING THE WATER RESOURCES YIELD MODEL

The Water Resources Yield Model (WRYM) configuration was obtained from the Letaba-Luvuvhu Reconciliation Strategy Study Team for use in this study. The model was updated to include all required biophysical nodes and EWR sites. Each site and node was configured as a specific channel which represented the simulated flow past that point under various conditions. Table 10.1 presents the details of the sites configured into the model, and relates to the schematic network diagrams presented in Figure 10.1 – Figure 10.3.

Table 10.1 Channel numbers assigned to biophysical nodes and EWR sites

Quaternary catchment	WRYM Channel no.	Sub-quaternary reach/EWR site
B81A	*208*	*B81A_00242*
B81A	*216*	*B81A_00256*
B81A	*207*	*B81A_00263*
B81A	*212*	*B81A_00270*
B81B	*23*	*B81B_00227*
B81B	*19*	*B81B_00233*
B81B	*154*	*B81B_00234*
B81B	*42*	*B81B_00240*
B81B	*38*	*B81B_00246*
B81B	*65*	*B81B_00247*
B81B	*36*	*B81B_00251*
B81B	*60*	*B81B_00269*
B81C	*151*	*B81C_00245*
B81D	*142*	*B81D_00272*
B81D	*147*	*B81D_00277*
B81D	*138*	*B81D_00280*
B81D	*131*	*B81D_00296*
B81E	*446*	*B81E_00213*
B81E	*444*	*B81E_00244*
B81F	*469*	*B81F_00189*
B81F	*472*	*B81F_00203*
B81F	*468*	*B81F_00212*
B81F	*499*	*B81F_00215*
B81F	*473*	*B81F_00218*
B81F	*493*	*B81F_00228*
B81F	*463*	*B81F_00231*
B81F	*495*	*B81F_00232*
B81G	*489*	*B81G_00164*
B81H	*539*	*B81H_00162*
B81H	*498*	*B81H_00171*
B81J	*569*	*B81J_00187*
B81J	*503*	*B81J_00209*
B82A	*297*	*B82A_00168*
B82B	*295*	*B82B_00173*
B82D	*301*	*B82D_00154*
B82D	*298*	*B82D_00163*
B82D	*302*	*B82D_00166*

Quaternary catchment	WRYM Channel no.	Sub-quaternary reach/EWR site
B82E	*308*	*B82E_00149*
B82E	*307*	*B82E_00150*
B82F	*312*	*B82F_00128*
B82F	*311*	*B82F_00137*
B82F	*313*	*B82F_00141*
B82H	*327*	*B82H_00127*
B82H	*329*	*B82H_00139*
B82H	*340*	*B82H_00157*
B82J	*336*	*B82J_00165*
B82J	*335*	*B82J_00178*
B82J	*334*	*B82J_00197*
B82J	*339*	*B82J_00201*
B82J	*337*	*B82J_00207*
B83A	*507*	*B83A_00220*
B83A	*508*	*B83A_00230*
B83A	*509*	*B83A_00252*
B83D	*510*	*B83D_00250*
B83E	*567*	*B83E_00265*
B81A	*225*	*EWR 1*
B81D	*144*	*EWR 2*
B81F	*475*	*EWR 3*
B81J	*504*	*EWR 4*
B82G	*319*	*EWR 5*
B83A	*511*	*EWR 6*
B83D	*512*	*EWR 7*

10.2 PREPARATION OF NATURAL AND PRESENT DAY FLOWS

10.2.1 Natural flows

The natural hydrology was received from the Letaba-Luvuvhu Reconciliation Strategy Study Team for use in this study, and covered the period October 1920 to September 2011. Two sets of natural hydrology were received. The first included natural flows without any groundwater abstractions, and the second included flows including groundwater abstractions. The first of the two sets was used to develop the natural flows at each of the biophysical nodes and EWR sites. Table 10.2 presents a breakdown of the portion of natural hydrology included at each site, as well as a summary of the average natural flow per site. The time series of historical natural flows at each of the sites was handed over to the EWR team for further use.

Table 10.2 Details of Natural flows development

Sub-quaternary reach/EWR site	Hydrology name and factors contributing to natural flows at site	Natural MAR[1] at site
B81A_00242	*B81A:0.22, B81ADN:1.00*	*23.83*
B81A_00256	*B81A: 0.25*	*16.35*
B81A_00263	*B81A: 0.09*	*5.76*
B81A_00270	*B81A: 0.53, B81ADN: 1.00*	*44.47*
B81B_00227	*B81B30: 0.49*	*13.60*
B81B_00233	*B81B30: 0.10*	*2.70*
B81B_00234	*B81B30: 0.37*	*10.13*
B81B_00240	*B81B01: 0.14, B81B20: 1.00*	*38.98*

Sub-quaternary reach/EWR site	Hydrology name and factors contributing to natural flows at site	Natural MAR[1] at site
B81B_00246	B81B01: 0.07, B81B20: 1.00	36.26
B81B_00247	B81A: 1.00, B81ADN: 1.00, B81B01_A: 1.00, B81B10_16: 1.00	109.97
B81B_00251	B81B01: 0.03	1.34
B81B_00269	B81B01_A: 0.41	1.95
B81C_00245	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00	238.71
B81D_00272	B81D2: 1.00	91.27
B81D_00277	B81D1: 1.00	25.28
B81D_00280	B81D2: 0.20	18.51
B81D_00296	B81D2: 0.12	10.53
B81E_00213	B81E1: 1.00, B81E2: 1.00	17.28
B81E_00244	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E10: 0.82	364.04
B81F_00189	B81F1020: 0.56	4.73
B81F_00203	B81F1020: 0.44	3.75
B81F_00212	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 0.12	396.76
B81F_00215	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00	406.89
B81F_00218	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 0.71, B81F1020: 0.44	389.56
B81F_00228	B81F2: 0.31	3.53
B81F_00231	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 0.63	385.54
B81F_00232	B81F2: 0.24	2.75
B81G_00164	B81G: 1.00, B81H: 0.06	16.72
B81H_00162	B81H: 0.07	0.64
B81H_00171	B81G: 1.00, B81H: 1.00	25.84
B81J_00187	B81J10: 0.28	2.53
B81J_00209	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 0.61	438.26
B82A_00168	B82A: 1.00, B82D: 0.14	31.12
B82B_00173	B82B: 1.00	23.13
B82D_00154	B82A: 1.00, B82D: 0.59	40.52
B82D_00163	B82D: 0.24	4.90
B82D_00166	B82B: 1.00, B82C: 1.00, B82D: 0.09	42.25
B82E_00149	B82E: 0.40	4.51
B82E_00150	B82E: 0.31	3.48
B82F_00128	B82E: 1.00, B82F: 0.92	32.12
B82F_00137	B82E: 1.00, B82F: 0.10	13.64
B82F_00141	B82F: 0.32	7.31
B82H_00127	B82H: 0.59	6.91
B82H_00139	B82H: 0.27	3.10
B82H_00157	B82H: 1.00	11.72
B82J_00165	B82A: 1.00, B82B: 1.00, B82C: 0.95, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 0.56	157.39

Sub-quaternary reach/EWR site	**Hydrology name and factors contributing to natural flows at site**	**Natural MAR[1] at site**
B82J_00178	B82A: 1.00, B82B: 1.00, B82C: 0.95, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 0.02	149.56
B82J_00197	B82J: 0.05	0.66
B82J_00201	B82A: 1.00, B82B: 1.00, B82C: 0.95, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00	163.71
B82J_00207	B82A: 1.00, B82B: 1.00, B82C: 0.95, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 0.92	162.55
B83A_00220	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 0.22	610.74
B83A_00230	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 0.49	616.00
B83A_00252	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 0.86	623.17
B83D_00250	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 1.00, B83BC: 1.00, B83D: 0.01	643.51
B83E_00265	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 1.00, B83BC: 1.00, B83D: 1.00, B83E: 1.00	658.42
EWR 1	B81A: 1.00, B81ADN: 1.00, B81B10_16: 0.82	99.84
EWR 2	B81D1: 1.00, B81D2: 1.00	116.56
EWR 3	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 0.88, B81F1020: 1.00	394.93
EWR 4	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 0.96	441.40
EWR 5	B82A: 1.00, B82B: 1.00, B82C: 0.95, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 0.12	124.18
EWR 6	B81A: 1.00, B81ADN: 1.00, B81B01: 1.00, B81B01_A: 1.00, B81B10_16: 1.00, B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 0.72	620.38
EWR 7	B81A:1.00, B81ADN:1.00, B81B01:1.00, B81B01_A: 1.00, B81B10_16: 1.00’ B81B20: 1.00, B81B30: 1.00, B81C: 1.00, B81D1: 1.00, B81D2: 1.00, B81E1: 1.00, B81E10: 1.00, B81E2: 1.00, B81F1: 1.00, B81F1020: 1.00, B81F2: 1.00, B81G: 1.00, B81H: 1.00, B81J10: 1.00, B82A: 1.00, B82B: 1.00, B82C: 1.00, B82D: 1.00, B82E: 1.00, B82F: 1.00, B82G: 1.00, B82H: 1.00, B82J: 1.00, B83A: 1.00, B83BC: 1.00, B83D: 0.28	646.29

10.2.2 Present Day flows

The model was configured to mimic present day flows based on the following assumptions:

- *The current releases of 0.048 million m^3/month were placed on Dap Naude Dam, and not the full court order releases.*
- *All irrigation demands were set at present day abstractions for the entire simulation period, 1920 - 2010. The canal infrastructure, where applicable, was simulated based on actual sizes. Limits were placed on irrigation abstractions equal to their allocations for irrigators forming part of a scheme.*
- *All urban and industrial demands were set at an average of the last four years of abstractions for the entire simulation period, 1920 – 2010.*
- *The current operating rule of restrictions for users from the Tzaneen Dam system was not included, and supply failures only occurred when the dam was empty.*
- *Ebenezer Dam was set to support Tzaneen Dam when Tzaneen Dam reached 15% of its storage capacity.*
- *A minimum flow of 0.6 m^3/s at Letaba Ranch was simulated based on current operation.*

A simulation was carried out, and the time series of flows at each of the biophysical nodes and EWR sites was stored. Again, these time series were handed over to the EWR team for further use. Figure 10.1, Figure 10.2 and Figure 10.3 present the simulated historical plots obtained for the main dams from the present day scenario simulation.

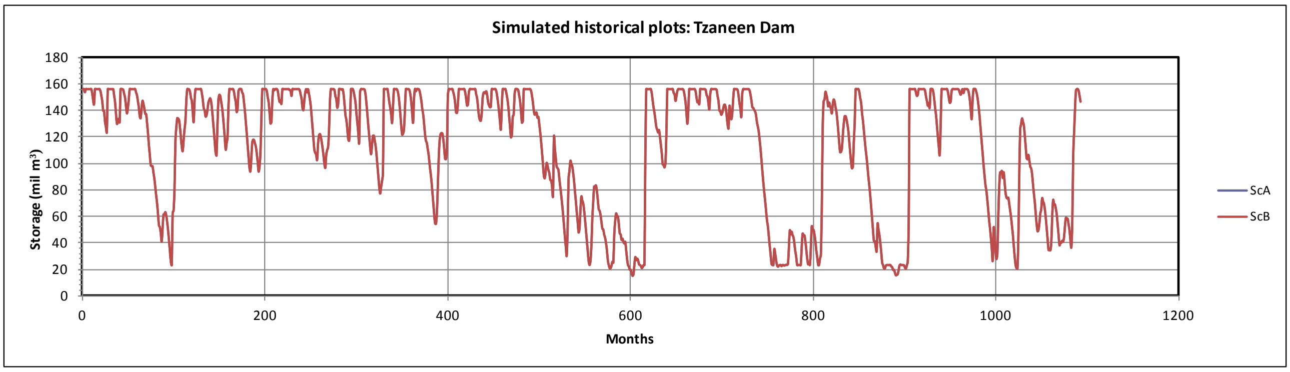

Figure 10.1 Historical behaviour of Tzaneen Dam under present day conditions

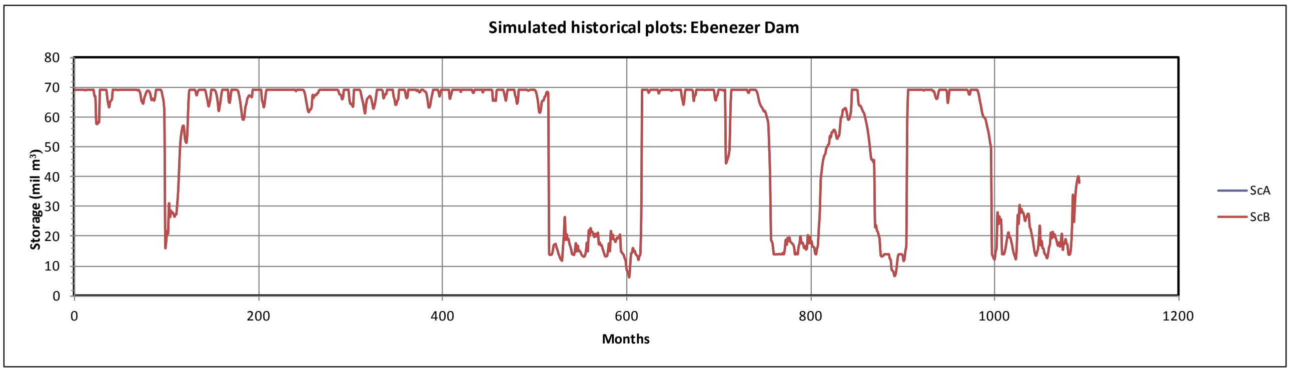

Figure 10.2 Historical behaviour of Ebenezer Dam under present day conditions

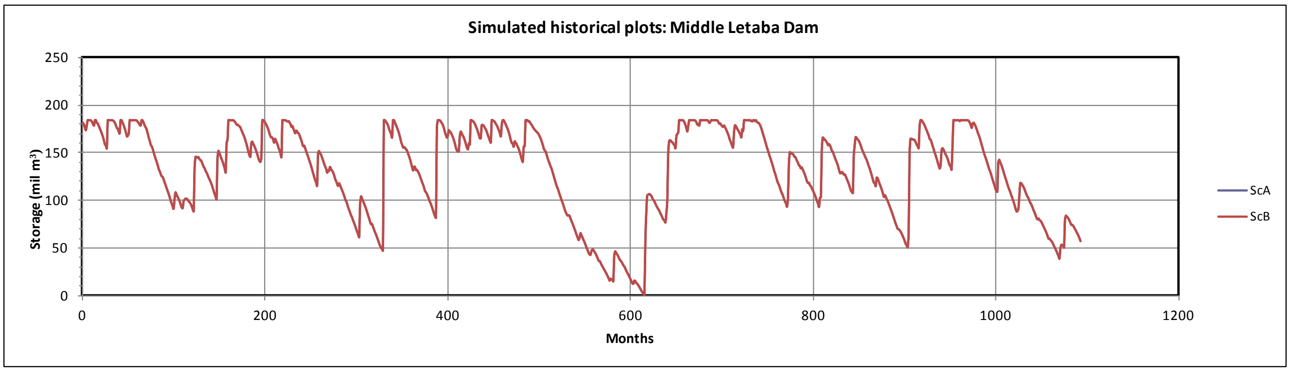

Figure 10.3 Historical behaviour of Middle Letaba Dam under present day conditions

10.3 SCENARIOS ANALYSED

A set of scenarios was selected based on inputs from the Reconciliation Strategy Study. Table 3.1 (Chapter 3) has presented the summary scenario matrix and it is not repeated here. The sections which follow present the detailed descriptions.

Restrictions to users from Tzaneen Dam are referred to in the scenario descriptions. The current restriction rule for irrigators in the scheme supplied from Tzaneen Dam is that when the dam level drops below 95%, the irrigators are only allowed 50% of their allocation. When the dam is below 15%, irrigators are not allowed any water, and urban users are restricted to 70% of their allocation. This rule results in irrigators receiving on average approximately 62% of their allocated water, which is currently the case in reality.

10.3.1 Scenario 1

Scenario 1 is the present day flows scenario as described in Section 10.2.2.

10.3.2 Scenario 2

Scenarios 2a and 2b were based on Sc 1, however, the minimum flow at Letaba Ranch was excluded. For Sc 2a, EWR flows were simulated for Sites 1, 2, 3, 4, 5 and 7 based on the low flow Present Ecological State (PES) EWR structures received from the EWR team. For Sc 2b, EWR flows were simulated for Sites 1, 2, 3, 4, 5 and 7 based on the low flow REC EWR structures. Table 10.6 to Table 10.17 present the EWR structures for each EWR simulated. The natural flows configured into the structures are the natural flows including groundwater abstractions as those are what are simulated by the model. Table 10.3 presents the EcoStatus for the PES and REC per EWR site.

Table 10.3 EWR EcoStatus per site

EWR site	PES	REC
1	*C*	*C*
2	*D*	*D*
3	*C*	*B*
4	*C*	*B*
5	*CD*	*CD*
7	*C*	*B*

10.3.3 Scenario 3

Scenario 3a was based on Sc 1, with the only difference being the raised Tzaneen Dam capacity was included in the simulations. The dam was raised by 3m and added an additional storage of 27 *million m^3 to the dam's capacity. Scenario 3b was identical to Sc 3a, however, the current restriction rule was placed on the Tzaneen users, and the maximum yield (32 million m^3/annum) was removed from Ebenezer Dam instead of the present day use of 16.2 million m^3/annum.*

10.3.4 Scenario 4

Scenario 4 was divided into two scenarios. Scenario 4a was based on Sc 3a, with the addition of Nwamitwa Dam. An additional demand of 15 million m^3/annum was removed from Nwamitwa Dam. An additional allocation of 10.9 million m^3/annum for Polokwane was removed from Ebenezer Dam. This brought the total abstraction by Polokwane to 27 million m^3/annum where previously it had been 16.2 million m^3/annum (in Sc 3a). The required Court Order releases from Dap Naude Dam were included. This differed from the previously simulated releases in that all inflows to the dam in the months of August, September and October were released.

Scenario 4b was identical to Sc 4a, however an additional maximum groundwater abstraction was removed from all catchments where groundwater is applicable. The additional abstraction was determined by the groundwater specialist based on the potential that could be abstracted due to the recharge. This new abstraction was simulated in the Pitman model, and a new natural hydrology flow file was generated representing the natural flows including maximum groundwater use. This additional abstraction and modified natural flows are summarized in Table 10.4.

Table 10.4 Details of current and maximum groundwater abstractions

Hydrology	Current groundwater abstraction	Maximum groundwater abstraction	Current catchment MAR	Reduced catchment MAR due to increased groundwater abstraction)
MIDDLE LETABA CATCHMENT				
B82A	*2.93*	*4.42*	*26.67*	*25.66*
B82B	*16.26*	*16.26*	*12.79*	*12.79*
B82C	*10.1*	*10.1*	*10.91*	*10.91*
B82D	*4.52*	*7.08*	*17.85*	*17.85*
B82E	*1.45*	*4.49*	*11.16*	*10.6*
B82F	*1.43*	*8.44*	*22.49*	*21.27*
B82G	*0.6*	*7.72*	*15.2*	*14.88*
B82H	*0.16*	*5.93*	*11.71*	*11.51*
B82J	*0*	*4.49*	*14.36*	*14.28*
EBENEZER CATCHMENT				
B81ADN	*0*	*0*	*9.53*	*9.53*
B81A	*0.15*	*1.36*	*66.03*	*64.89*
TZANEEN DAM CATCHMENT				
B81B10-16	*0*	*0*	*29.43*	*29.43*
B81B30	*0.73*	*1.49*	*27.26*	*26.85*
B81B20	*0*	*0*	*33.64*	*33.64*
B81B01_A	*0*	*0*	*4.83*	*4.83*
B81B01	*1.91*	*3.91*	*37.96*	*37.18*
LOWER GROOT LETABA CATCHMENT				
B81C	*5.31*	*5.31*	*26*	*26*
B81D1	*2.28*	*3.01*	*23.75*	*23.16*
B81D2	*1.85*	*2.45*	*90.54*	*90.26*
B81E10	*5.64*	*5.64*	*10.43*	*10.43*
B81E2	*4.86*	*4.86*	*6.97*	*6.97*
B81E1	*5.25*	*5.25*	*9.83*	*9.83*

Hydrology	Current groundwater abstraction	Maximum groundwater abstraction	Current catchment MAR	Reduced catchment MAR due to increased groundwater abstraction)
B81F1	*1.51*	*1.92*	*3.67*	*3.59*
B81F2	*2.91*	*3.70*	*11.45*	*11.41*
B81F1020	*3.52*	*4.47*	*8.36*	*8.3*
B81G	*5.06*	*5.06*	*15.98*	*15.98*
B81H	*2.62*	*5.61*	*9.64*	*9.48*
B81J10	*0*	*4.52*	*9.05*	*8.87*
B83A	*0*	*8.46*	*19.63*	*19.37*
B83BC	*0*	*5.78*	*17.42*	*17.35*
B83D	*0*	*4.65*	*10.31*	*10.2*
B83E	*0*	*1.49*	*4.73*	*4.71*
TOTAL	**81.03**	**147.87**	**552.15**	**544.58**

Note: All values are provided in million m^3/annum.

From Table 10.4 it is evident that an increase in groundwater abstraction of 64.3 million m^3/annum from 81.03 million m^3/annum to 147.9 million m^3/annum only results in a decrease of natural inflows into the system from catchments where groundwater is applicable of 7.6 million m^3/annum from 552.2 million m^3/annum to 544.6 million m^3/annum.

Scenario 4c was similar to Sc 4a, however, the Court Order release from Dap Naude was excluded. The Tzaneen restriction rule was included for Sc 4c, and the Ebenezer abstraction was set at the maximum million m^3/annum.

10.3.5 Scenario 5

Scenario 5 was based on Sc 4b with a few additional potential future schemes. A new dam, the Letsitele River Valley Dam was included upstream of EWR 2. No abstraction was removed from the Dam, and it was only included to improve the current assurance of supply to irrigators in the area. A new dam, Crystalfontein Dam, was included in a tributary of the Middle Letaba. A transfer up to a capacity of 10.4 million m^3/annum was included from Crystalfontein Dam to Middle Letaba Dam.

10.3.6 Scenario 6

Scenario 6 is identical to Sc 5, except that the minimum flow requirement at Letaba Ranch was excluded and the Low PES EWRs for sites 1 - 5 and 7 were included.

10.3.7 Scenario 7

Scenario 7 contained four sub-scenarios for the various EWR options. All sub-scenarios were identical to Sc 6, except that the restriction rule was included, Letsitele River Valley Dam was removed, the full yield of 32 million m^3/annum was removed from Ebenezer Dam, the Dap Naude Court order was excluded and the groundwater use was set back to present day. Crystalfontein Dam was included and in all cases with an abstraction of 2 million m^3/annum removed. The site 5 EWR was set at the total EWR requirements and the site 1 EWR was set to the Low EWR requirements. Site 2 EWR was excluded. For the other sites, the EWRs were varied as follows: Sc 7a used the Low PES option, Sc 7b used low REC, Sc 7c used total PES and Sc 7d used total REC. For Sc 7a, 5 million m^3/annum was abstracted from the Tzaneen system and Sc 7b included an abstraction of 1 million m^3/annum for Sc 7c and 7d, no additional abstraction was possible from the system, and in fact the supply to users had to be reduced.

10.3.8 Scenario 8

Scenario 8a and b attempted to improve the supply to users that had dropped significantly when the total EWRs were included in Sc 7c and 7d. Instead of the total EWRs at sites 3, 4, 5 and 7, a modification to the EWR was made that for Sc 8a, only the highest 2 months' flows were requested based on the REC total flow requirements and for scenario 8b, only the single highest month's flow was requested based on the REC total flow requirements. All the other months merely requested the low REC base flow requirements. The additional abstraction from the Tzaneen system was again set to zero, however an additional abstraction from Crystalfontein Dam of 7 million m^3/annum was included for Sc 8a and 8 million m^3/annum was included for Sc 8b.

10.3.9 Scenario 9

Scenario 9 was identical to scenario 8b with a single total flow requested and the remaining months low REC, however, this time the single total flow was the PES total. In addition to this, the high flow was removed in months when the Tzaneen and Nwamitwa dam levels went low, and in those cases, only the low flow REC requirements were supplied. An additional 5 million m^3/annum was abstracted from the Tzaneen system and an additional 8 million m^3/annum from Crystalfontein Dam.

10.3.10 Scenario 10

Scenario 10 was similar to Sc 9, however, this time three months of total flows (PES) were included, and these three months were always set at January, February and March. In the remaining months, the low flows were set to PES as opposed to Sc 9 which was set at the REC. The high flows were again stopped when Nwamitwa Dam dropped below 17%. EWR 5 was also adjusted back to just the low requirement. An additional 5 million m^3/annum was abstracted from the Tzaneen system and an additional 11 million m^3/annum from Crystalfontein Dam.

10.4 RESULTS

The results were stored as time series files of flows past each EWR site (1 - 5, and 7). A spreadsheet was developed in order to read in the results and present distribution plots of the flows for each scenario, for each month for comparison purposes. The time series files and the spreadsheets were all provided to the EWR team for further analysis. Figure 10.4 to Figure 10.9 present the annual average distribution plots for selected scenarios for each EWR site.

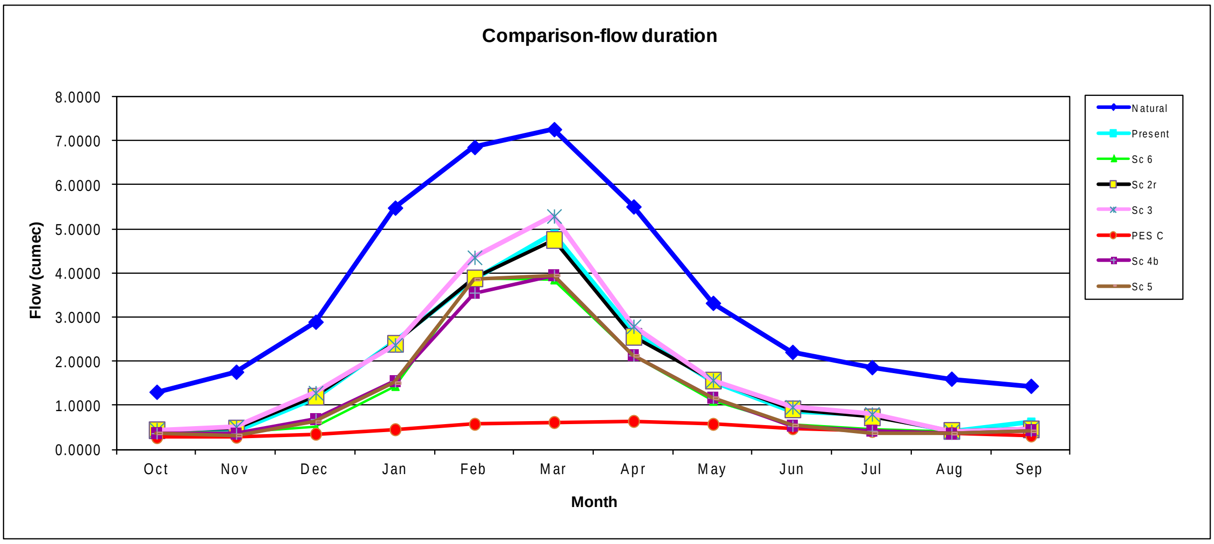

Figure 10.4 Monthly average flows occurring at EWR 1 for selected scenarios

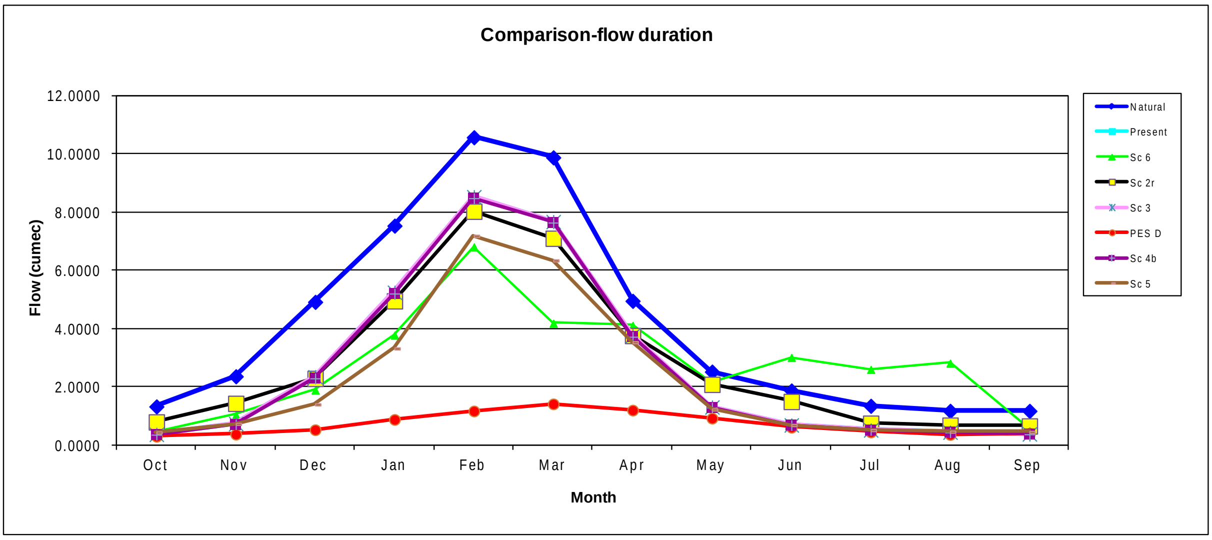

Figure 10.5 Monthly average flows occurring at EWR 2 for selected scenarios

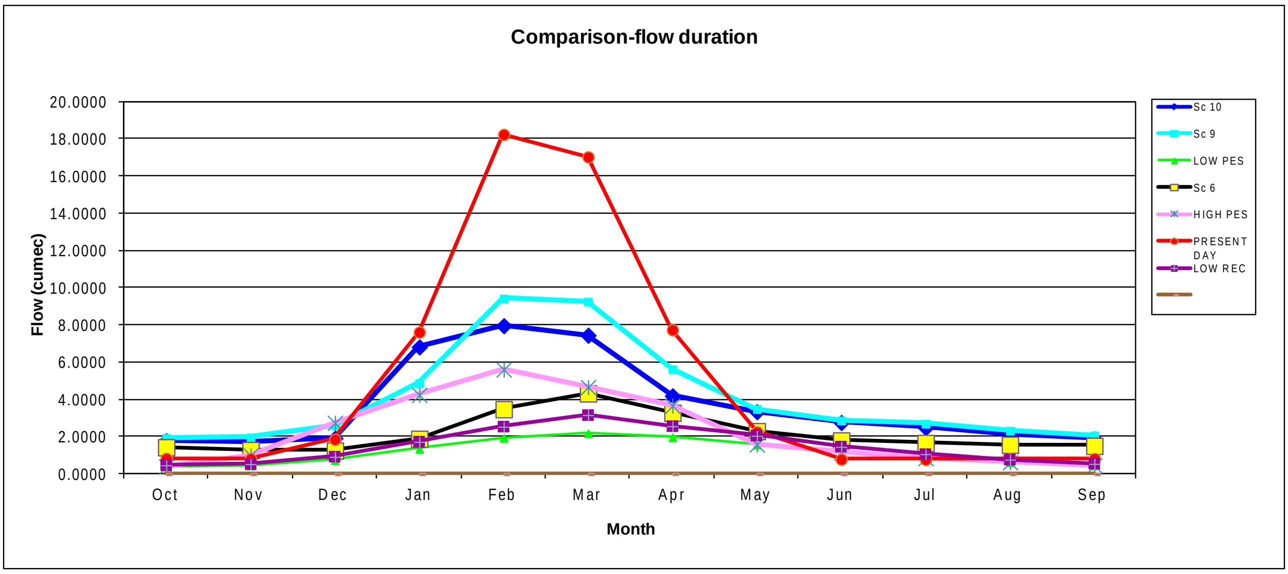

Figure 10.6 Monthly average flows occurring at EWR 3 for selected scenarios

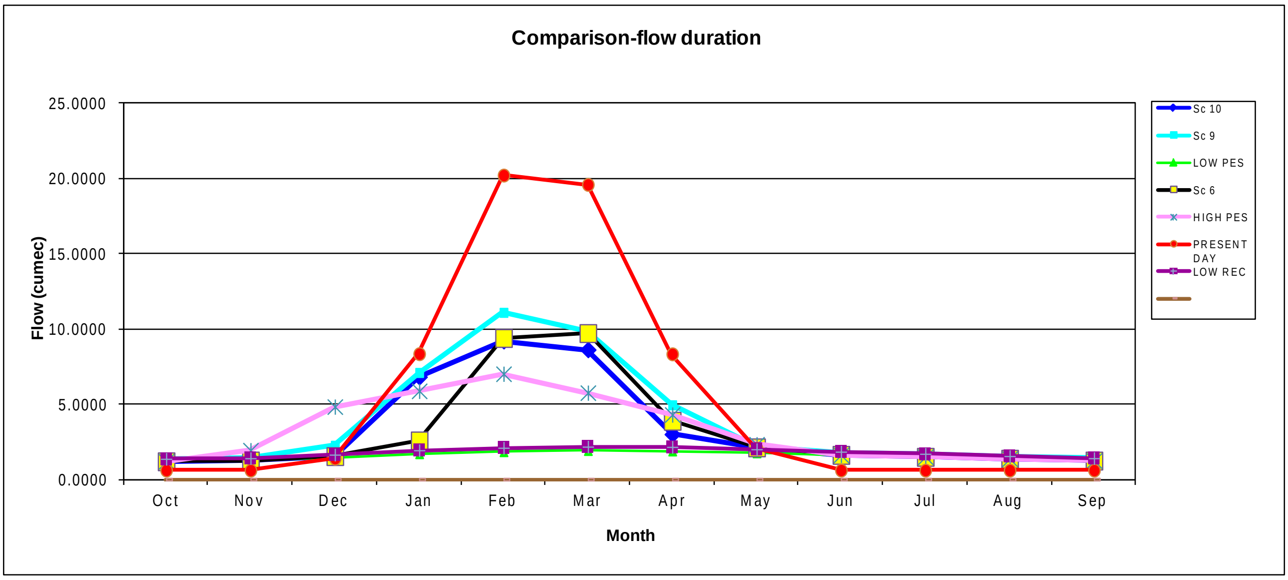

Figure 10.7 Monthly average flows occurring at EWR 4 for selected scenarios

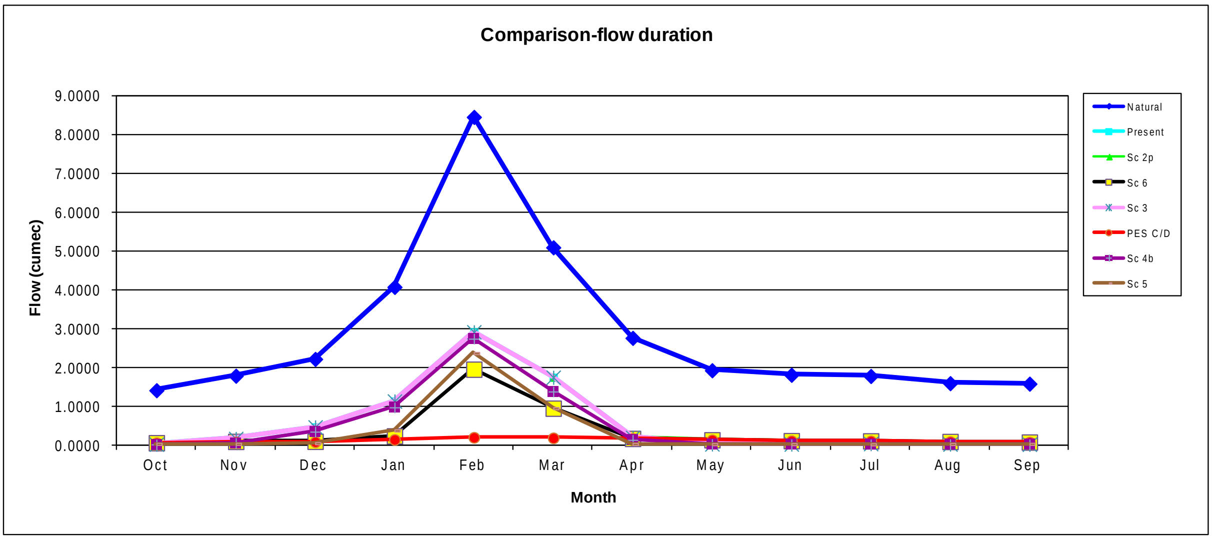

Figure 10.8 Monthly average flows occurring at EWR 5 for selected scenarios

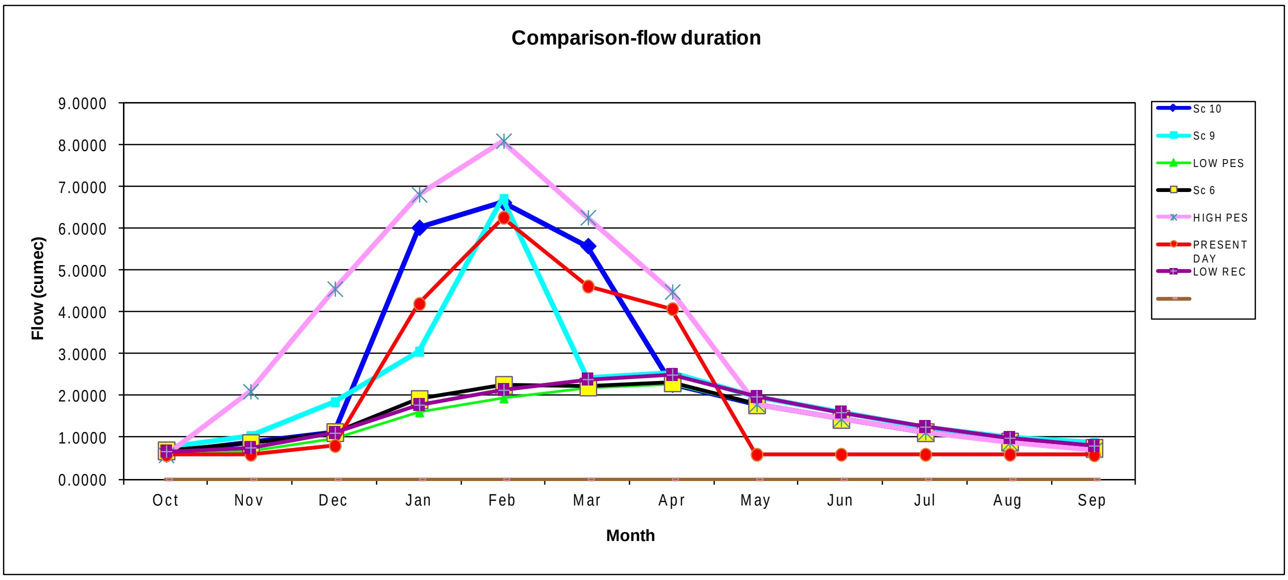

Figure 10.9 Monthly average flows occurring at EWR 7 for selected scenarios

The purpose of the WRYM scenario analysis was to achieve an optimised scenario whereby the existing users would not be adversely affected, however, the environment would be supplied the full, or as close to full, requirement. From the scenarios analysed, it appears that this has been achieved with Sc 10, which supplies the low PES requirement for 9 months of the year and the total PES requirement for the months of January, February and March. The total flow requirement is however stopped when the level of Nwamitwa Dam drops below 17%. Table 10.5 presents a summary of the supply to existing and future users for the various scenarios. These results were handed to the economic team for assessment of economic impacts under the various scenario conditions.

Table 10.5 Summary of supply to users for selected scenarios

Scenario	Supply to Tzaneen / Nwamitwa irrigators	Supply to Tzaneen / Nwamitwa current urban	Additional supply to Tzaneen / Nwamitwa urban	Total Supply to Tzaneen / Nwamitwa	Additional supply to Crystalfontein urban
3b	*66.4*	*16.2*	*0.0*	*82.6*	*N/A*
5	*68.1*	*16.4*	*16.0*	*100.5*	*12*
7a	*69.2*	*16.4*	*5.0*	*90.7*	*2*

Scenario	Supply to Tzaneen / Nwamitwa irrigators	Supply to Tzaneen / Nwamitwa current urban	Additional supply to Tzaneen / Nwamitwa urban	Total Supply to Tzaneen / Nwamitwa	Additional supply to Crystalfontein urban
7b	*69.6*	*16.4*	*1.0*	*87.0*	*2*
7c	*40.8*	*16.4*	*0.0*	*57.2*	*2*
7d	*29.2*	*16.4*	*0.0*	*45.6*	*2*
8a	*50.8*	*16.4*	*0.0*	*67.2*	*7*
8b	*56.2*	*16.4*	*0.0*	*72.6*	*8*
9	*67.7*	*16.1*	*5.0*	*88.9*	*8*
10	*67.1*	*16.1*	*5.0*	*88.1*	*11*

10.5 WATER RESOURCES MODELLING – ADDITIONAL INFORMATION

The schematic network diagrams are provided in Figure 10.10 to Figure 10.13. Table 10.6 to Table 10.17 present the EWR structures for each EWR simulated. The natural flows configured into the structures are the natural flows including groundwater abstractions as those are what are simulated by the model.

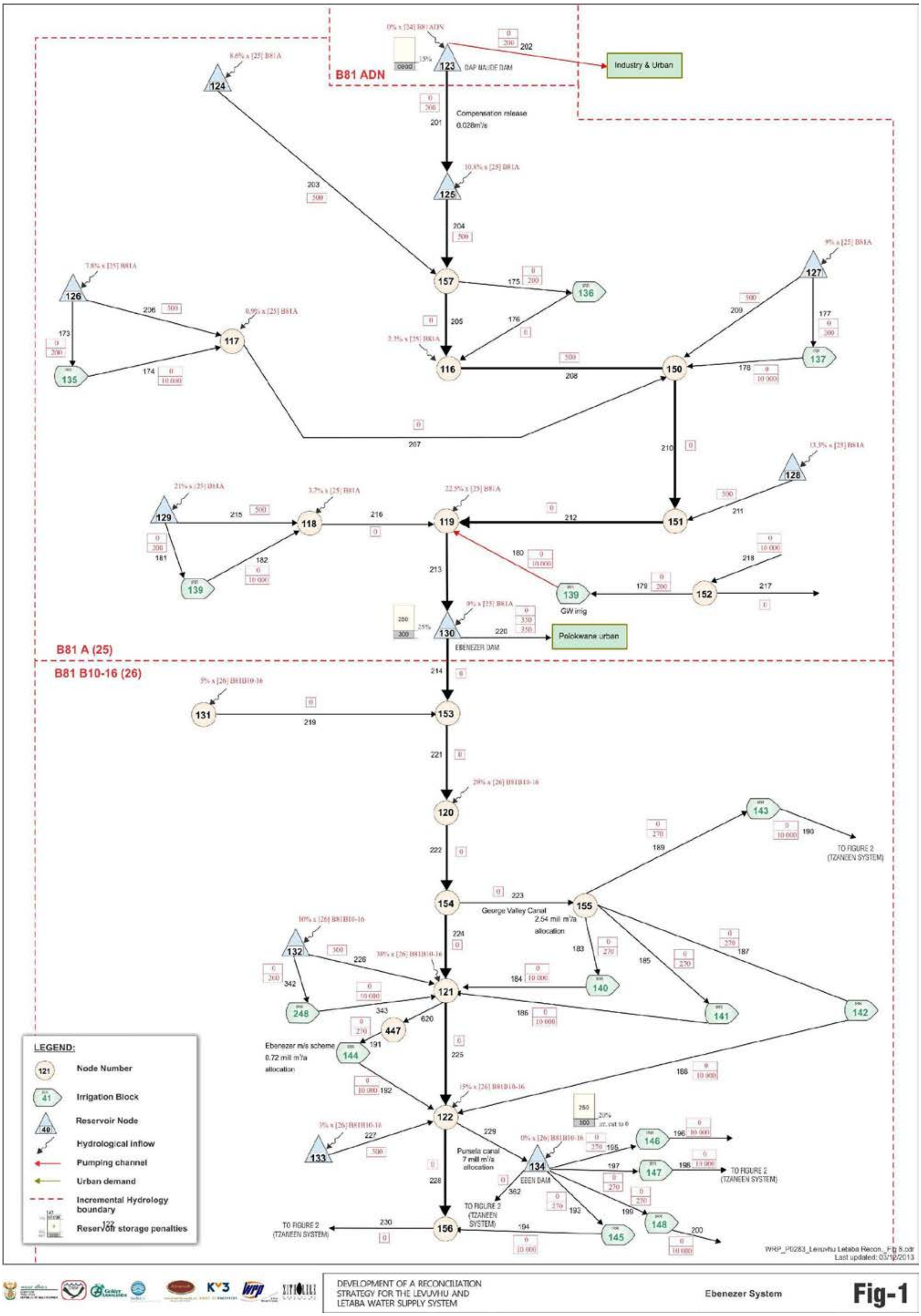

Figure 10.10 Schematic network for Ebenezer Dam

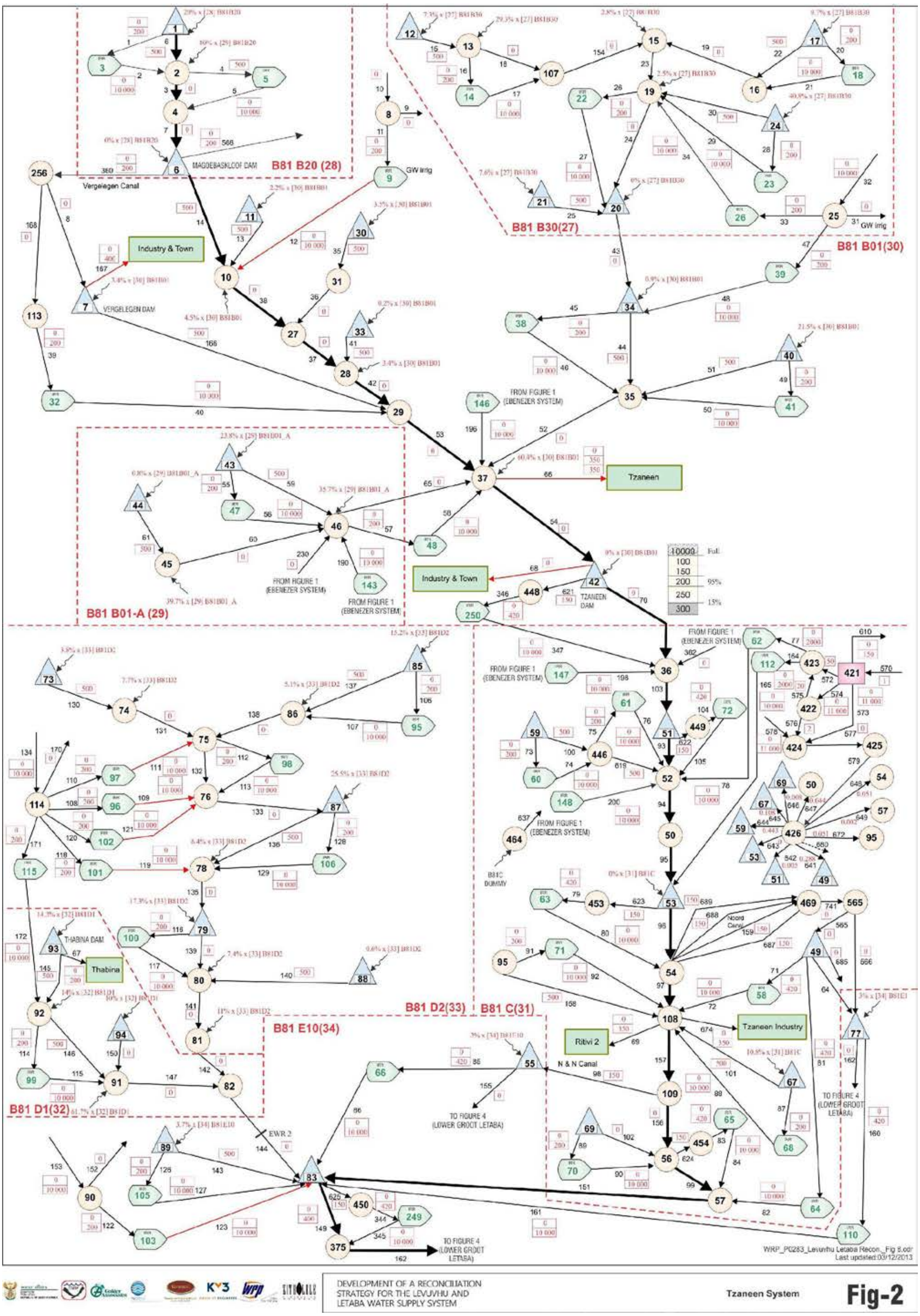

Figure 10.11 Schematic network for the Tzaneen system

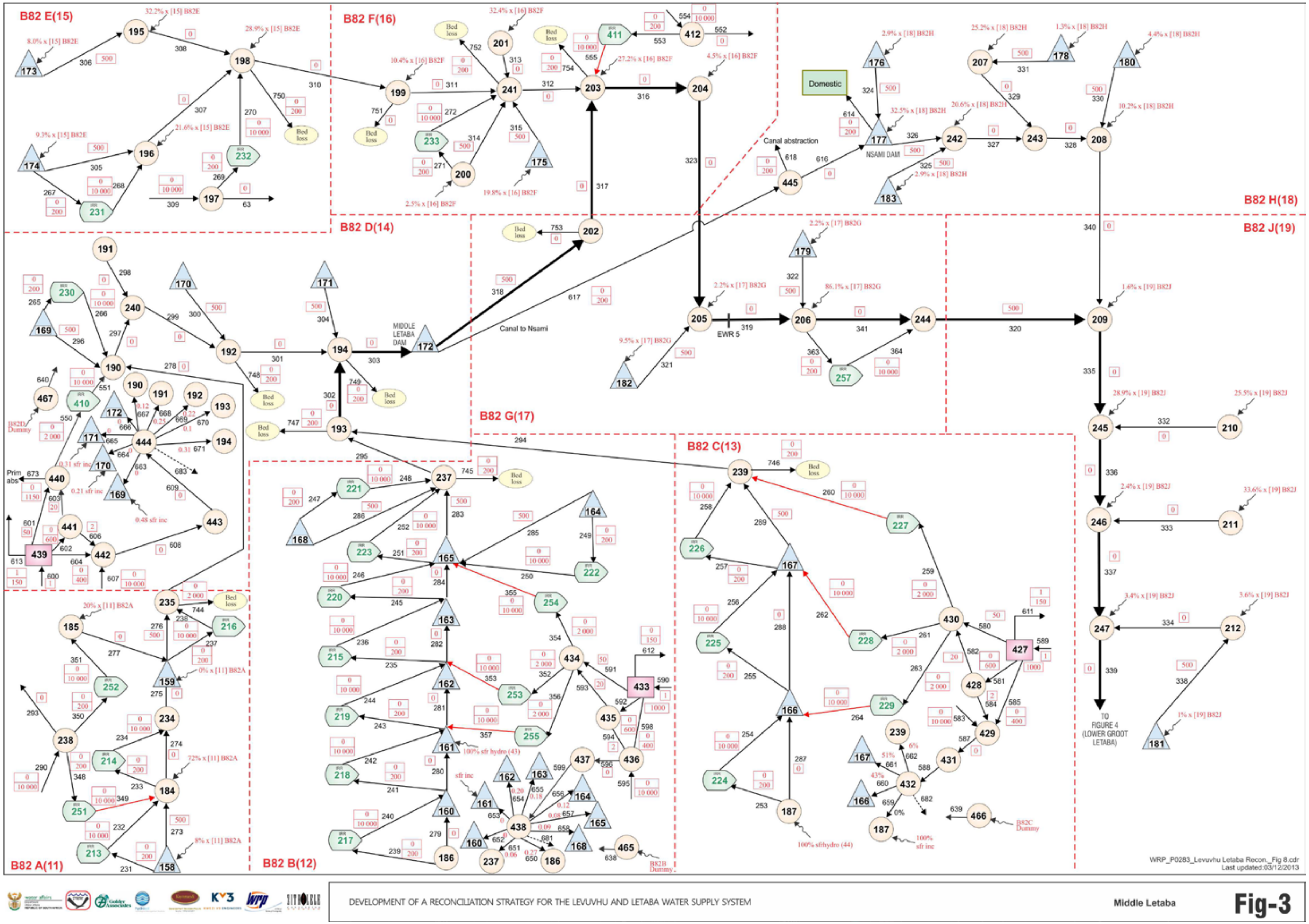

Figure 10.12 Schematic network for the Middle Letaba

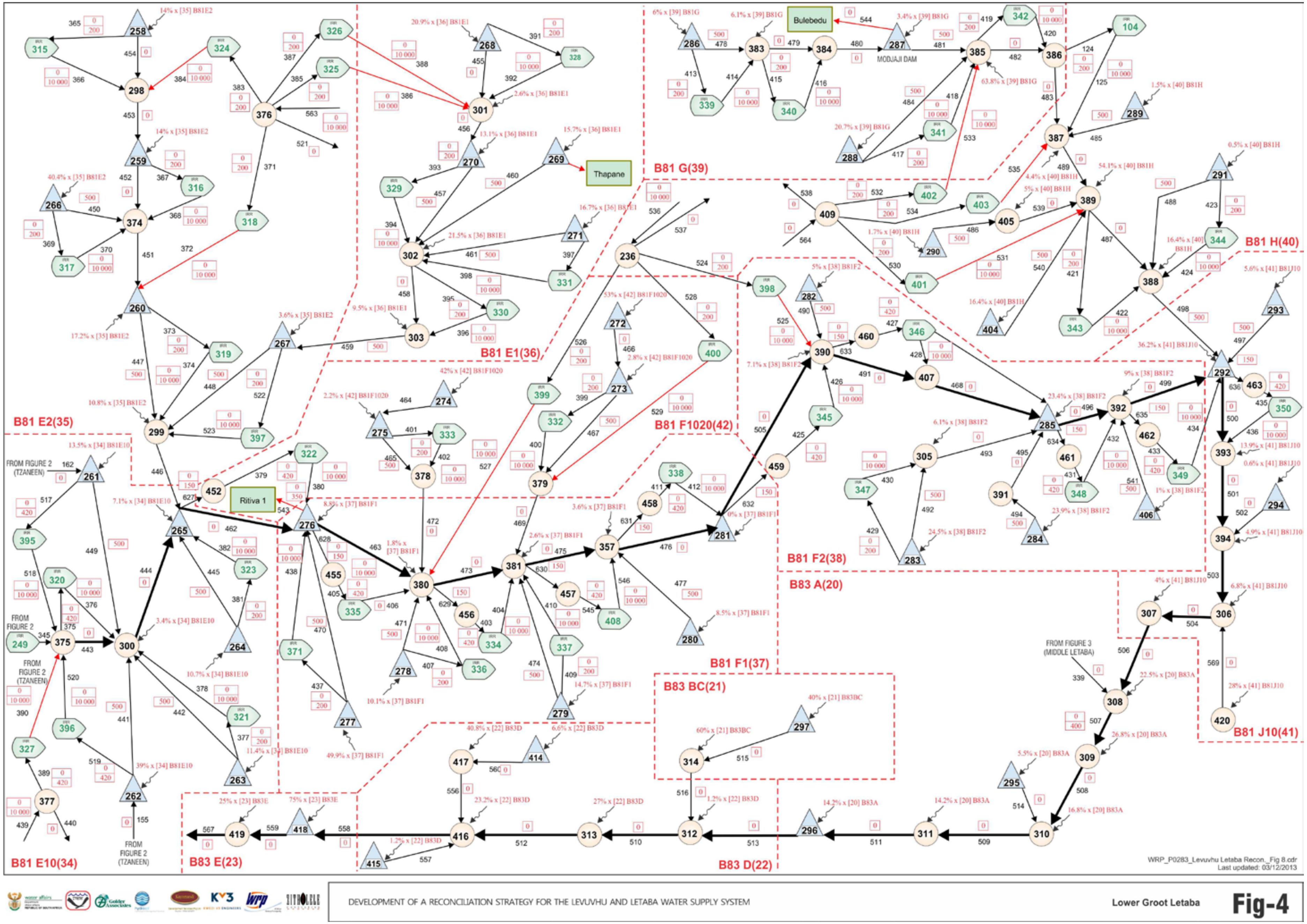

Figure 10.13 Schematic network for the lower Great Letaba system

Table 10.6 EWR Structure – EWR 1: PES C

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.578	0.109	0.556	0.112	0.600	0.120	0.820	0.130	1.137	0.149	1.127	0.156	1.029	0.157	0.814	0.155	0.718	0.147	0.625	0.139	0.542	0.126	0.489	0.115
0.755	0.116	0.767	0.115	1.033	0.130	1.350	0.149	1.867	0.158	1.745	0.182	1.784	0.178	1.539	0.179	1.380	0.173	1.170	0.169	0.985	0.152	0.837	0.126
0.809	0.127	0.940	0.129	1.237	0.146	1.891	0.185	2.566	0.203	2.216	0.212	2.121	0.218	1.723	0.215	1.502	0.206	1.285	0.195	1.104	0.174	0.934	0.142
0.939	0.141	1.088	0.149	1.534	0.170	2.144	0.211	3.08	0.244	2.751	0.263	2.400	0.278	1.913	0.265	1.679	0.257	1.416	0.235	1.251	0.203	1.051	0.162
1.015	0.161	1.208	0.169	1.784	0.200	2.740	0.249	3.741	0.322	3.247	0.344	2.778	0.359	2.127	0.344	1.838	0.323	1.545	0.291	1.340	0.251	1.163	0.193
1.081	0.189	1.377	0.196	2.104	0.231	3.429	0.313	04.847	0.393	04.480	0.424	3.578	0.456	2.483	0.426	1.989	0.392	1.637	0.354	1.415	0.293	1.267	0.235
1.173	0.225	1.490	0.237	2.381	0.283	3.952	0.395	5.496	0.442	5.472	0.522	04.586	0.554	2.923	0.504	2.111	0.438	1.785	0.388	1.528	0.327	1.349	0.267
1.301	0.273	1.756	0.282	2.882	0.350	5.456	0.451	6.852	0.575	7.250	0.615	5.498	0.640	3.311	0.573	2.205	0.475	1.859	0.413	1.598	0.373	1.436	0.311
1.401	0.332	1.938	0.340	3.516	0.389	7.842	0.513	11.681	0.649	11.022	0.735	7.115	0.702	3.766	0.609	2.376	0.513	1.914	0.453	1.677	0.404	1.520	0.358
1.664	0.401	2.205	0.423	04.774	0.465	10.078	0.626	19.526	0.982	17.559	1.116	09.176	0.763	04.735	0.705	2.725	0.579	2.174	0.542	1.853	0.483	1.681	0.425
999.0	0.401	999.0	0.423	999.0	0.465	999.0	0.626	999.0	0.982	999.0	1.116	999.0	0.763	999.0	0.705	999.0	0.579	999.0	0.542	999.0	0.483	999.0	0.425

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.7 EWR Structure – EWR 2: PES D

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.182	0.033	0.276	0.039	0.460	0.057	0.851	0.084	0.896	0.104	0.953	0.110	0.923	0.105	0.672	0.102	0.482	0.082	0.377	0.062	0.282	0.050	0.246	0.039
0.441	0.042	0.669	0.050	1.05	0.081	1.495	0.124	1.526	0.148	1.342	0.165	1.224	0.130	1.036	0.151	0.749	0.116	0.631	0.093	0.524	0.069	0.394	0.055
0.515	0.056	0.810	0.073	1.437	0.110	2.128	0.175	2.295	0.232	1.946	0.254	1.749	0.238	1.334	0.221	1.069	0.167	0.824	0.128	0.684	0.097	0.526	0.063
0.684	0.074	1.223	0.105	1.708	0.183	2.641	0.289	2.782	0.357	2.648	0.376	2.183	0.340	1.534	0.330	1.204	0.247	0.923	0.171	0.823	0.126	0.676	0.081
0.869	0.100	1.458	0.154	2.077	0.252	3.199	0.416	04.131	0.453	3.043	0.529	2.719	0.446	1.823	0.438	1.300	0.321	1.057	0.213	0.896	0.158	0.833	0.115
0.976	0.136	1.703	0.193	2.696	0.331	04.628	0.532	5.261	0.629	04.111	0.768	3.302	0.589	2.156	0.568	1.491	0.397	1.169	0.279	1.032	0.213	0.922	0.150
1.120	0.183	1.836	0.260	3.436	0.404	5.674	0.643	6.828	0.864	6.184	1.083	3.958	1.02	2.309	0.710	1.642	0.459	1.259	0.321	1.081	0.247	1.020	0.210
1.340	0.321	2.322	0.393	04.748	0.545	7.417	0.898	10.478	1.188	09.691	1.432	04.919	1.218	2.505	0.942	1.863	0.631	1.359	0.467	1.185	0.382	1.160	0.423
1.485	0.576	2.496	0.670	5.455	0.830	12.058	1.283	16.395	1.586	13.614	1.744	7.173	1.468	2.955	1.125	2.030	0.900	1.505	0.730	1.291	0.615	1.389	0.557
1.816	0.709	04.242	0.770	8.406	0.970	17.764	1.546	32.578	2.506	20.920	1.985	09.191	1.711	3.760	1.243	2.389	0.988	1.843	0.883	1.566	0.756	1.537	0.601
999.0	0.709	999.0	0.770	999.0	0.970	999.0	1.546	999.0	2.506	999.0	1.985	999.0	1.711	999.0	1.243	999.0	0.988	999.0	0.883	999.0	0.756	999.0	0.601

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.8 EWR Structure – EWR 3: PES C

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.492	0.129	1.586	0.133	1.941	0.150	2.658	0.161	3.285	0.174	3.336	0.174	3.139	0.196	2.434	0.183	2.168	0.169	1.902	0.159	1.585	0.148	1.474	0.133
2.177	0.139	2.630	0.145	3.488	0.166	5.084	0.195	6.409	0.206	5.321	0.215	5.240	0.223	4.264	0.216	3.704	0.204	3.223	0.194	2.665	0.173	2.413	0.149
2.543	0.153	3.140	0.164	4.614	0.198	6.753	0.254	7.718	0.293	6.479	0.304	6.742	0.293	5.329	0.289	4.468	0.265	3.678	0.234	3.177	0.205	2.690	0.167
2.838	0.173	3.931	0.191	5.700	0.263	7.580	0.364	09.812	0.426	8.00	0.465	7.548	0.412	5.814	0.444	5.031	0.399	4.197	0.323	3.683	0.264	3.158	0.199
3.345	0.201	4.459	0.238	6.954	0.345	09.972	0.455	12.279	0.620	10.971	0.724	8.593	0.703	6.591	0.656	5.740	0.552	4.672	0.440	3.967	0.322	3.430	0.238
3.728	0.241	5.044	0.302	8.313	0.412	12.267	0.686	17.423	0.895	14.199	1.096	11.748	0.902	7.671	0.952	6.208	0.779	5.143	0.622	4.594	0.452	4.070	0.311
4.026	0.301	5.748	0.362	09.897	0.544	16.105	0.995	21.177	1.273	19.410	1.560	15.150	1.239	09.011	1.212	6.700	0.909	5.491	0.754	4.752	0.540	4.387	0.385
4.574	0.396	7.081	0.450	11.905	0.752	23.160	1.346	31.623	1.940	28.685	2.180	19.059	1.959	09.905	1.588	7.228	1.155	5.880	0.855	5.051	0.629	4.702	0.459
4.943	0.562	7.897	0.625	15.130	0.936	34.076	1.983	54.803	3.467	41.594	4.487	22.729	3.269	11.410	2.139	8.062	1.417	6.295	1.089	5.372	0.794	4.992	0.621
5.799	0.904	09.802	1.026	21.261	1.263	49.615	2.536	96.126	4.526	74.039	5.237	30.780	3.850	13.675	2.309	8.628	1.677	7.288	1.450	6.134	1.176	5.612	1.07
999.0	0.904	999.0	1.026	999.0	1.263	999.0	2.536	999.0	4.526	999.0	5.237	999.0	3.850	999.0	2.309	999.0	1.677	999.0	1.450	999.0	1.176	999.0	1.07

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.9 EWR Structure – EWR 4: PES C

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.492	0.139	1.586	0.146	1.941	0.153	2.744	0.155	3.285	0.155	3.340	0.142	3.139	0.187	2.434	0.164	2.168	0.153	1.902	0.155	1.585	0.153	1.474	0.143
2.177	0.183	2.630	0.188	3.488	0.195	5.084	0.193	6.409	0.193	5.321	0.178	5.243	0.209	4.264	0.190	3.704	0.191	3.223	0.195	2.665	0.196	2.413	0.189
2.543	0.249	3.140	0.259	4.617	0.280	6.877	0.291	7.718	0.288	6.482	0.280	6.744	0.304	5.329	0.290	4.468	0.291	3.678	0.287	3.177	0.280	2.690	0.260
2.838	0.343	4.209	0.358	5.725	0.413	7.907	0.459	09.875	0.474	8.02	0.485	7.552	0.548	5.814	0.506	5.031	0.471	4.197	0.437	3.683	0.407	3.158	0.364
3.345	0.471	4.482	0.507	7.054	0.596	10.195	0.663	12.924	0.753	11.085	0.811	8.626	0.806	6.594	0.771	5.744	0.716	4.672	0.651	3.967	0.573	3.430	0.507
3.732	0.645	5.087	0.711	09.065	0.801	13.084	0.982	17.886	1.124	14.841	1.216	11.755	1.217	7.676	1.130	6.209	1.036	5.145	0.930	4.594	0.815	4.070	0.710
4.093	0.878	5.805	0.941	10.971	1.078	16.895	1.373	23.452	1.509	19.424	1.610	15.186	1.698	09.016	1.475	6.704	1.312	5.492	1.214	4.752	1.072	4.387	0.955
4.574	1.182	7.123	1.228	13.118	1.430	24.811	1.691	37.091	1.829	31.210	1.910	19.600	1.856	09.913	1.750	7.232	1.608	5.880	1.482	5.051	1.350	4.702	1.231
4.964	1.517	8.332	1.610	15.791	1.858	37.492	2.214	58.682	2.270	44.552	2.090	22.938	2.238	11.417	2.230	8.066	2.053	6.298	1.907	5.372	1.733	4.992	1.597
5.923	2.094	10.459	2.217	23.346	2.513	56.871	3.210	117.192	5.368	84.393	2.174	31.968	3.122	13.683	3.125	8.635	2.807	7.308	2.635	6.134	2.372	5.626	2.179
999.0	2.094	999.0	2.217	999.0	2.513	999.0	3.210	999.0	5.368	999.0	2.174	999.0	3.122	999.0	3.125	999.0	2.807	999.0	2.635	999.0	2.372	999.0	2.179

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.10 EWR Structure – EWR 5: PES C/D

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.153	0.013	0.143	0.022	0.193	0.027	0.278	0.027	0.256	0.028	0.337	0.035	0.314	0.032	0.257	0.030	0.243	0.030	0.220	0.031	0.215	0.029	0.190	0.025
0.359	0.016	0.310	0.022	0.404	0.027	0.598	0.027	0.877	0.032	0.750	0.035	0.601	0.032	0.542	0.030	0.537	0.030	0.516	0.031	0.446	0.029	0.383	0.025
0.479	0.019	0.502	0.022	0.656	0.027	0.996	0.034	1.056	0.039	0.897	0.037	0.876	0.037	0.729	0.036	0.715	0.034	0.665	0.033	0.601	0.029	0.545	0.025
0.623	0.024	0.704	0.027	1.039	0.029	1.319	0.044	1.361	0.052	1.168	0.048	1.073	0.047	0.945	0.043	0.905	0.042	0.805	0.040	0.734	0.035	0.653	0.027
0.721	0.030	1.040	0.037	1.290	0.044	1.596	0.059	1.735	0.072	1.510	0.069	1.296	0.064	1.086	0.055	1.054	0.052	0.963	0.049	0.874	0.043	0.783	0.036
0.853	0.040	1.188	0.051	1.594	0.066	1.960	0.093	2.468	0.104	2.09	0.096	1.680	0.088	1.297	0.085	1.198	0.072	1.030	0.062	0.930	0.054	0.891	0.047
1.051	0.053	1.370	0.063	1.824	0.078	2.440	0.106	4.914	0.150	2.823	0.143	2.090	0.124	1.567	0.102	1.464	0.091	1.349	0.085	1.193	0.071	1.088	0.064
1.428	0.075	1.764	0.094	2.218	0.099	4.03	0.158	8.380	0.213	5.077	0.199	2.709	0.185	1.946	0.149	1.817	0.127	1.791	0.121	1.611	0.105	1.537	0.091
1.646	0.107	2.307	0.147	3.121	0.143	09.835	0.280	16.691	0.463	8.725	0.360	3.628	0.272	2.522	0.214	2.451	0.191	2.285	0.183	2.071	0.156	1.914	0.128
2.337	0.158	3.590	0.181	6.038	0.203	20.180	0.387	28.440	0.767	15.111	0.530	5.711	0.323	3.135	0.262	2.993	0.241	2.844	0.233	2.587	0.212	2.483	0.187
999.0	0.158	999.0	0.181	999.0	0.203	999.0	0.387	999.0	0.767	999.0	0.530	999.0	0.323	999.0	0.262	999.0	0.241	999.0	0.233	999.0	0.212	999.0	0.187

1 Natural flows (m^3/s) *2 Environmental Water Requirement (m^3/s)*

Table 10.11 EWR Structure – EWR 7: PES C

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.673	0.517	1.741	0.520	2.261	0.576	3.140	0.609	3.956	0.720	3.966	0.743	3.978	0.636	3.096	0.640	2.643	0.627	2.242	0.609	1.948	0.575	1.737	0.531
2.588	0.521	3.117	0.538	3.974	0.601	6.737	0.673	7.865	0.720	6.380	0.774	6.059	0.693	4.864	0.691	4.100	0.670	3.622	0.649	3.266	0.612	2.861	0.548
3.102	0.528	3.957	0.558	5.856	0.664	8.622	0.770	09.556	0.844	7.656	0.921	7.488	0.826	6.134	0.796	5.428	0.768	4.549	0.708	3.905	0.641	3.278	0.559
3.480	0.538	5.022	0.618	7.134	0.759	10.559	0.940	11.605	1.064	09.496	1.083	8.419	1.090	6.960	1.062	5.965	0.949	4.996	0.811	4.377	0.702	3.741	0.579
4.104	0.553	5.965	0.645	8.956	0.884	12.269	1.212	15.803	1.376	12.580	1.469	10.095	1.554	8.035	1.381	6.664	1.139	5.604	0.951	4.850	0.780	4.412	0.635
4.874	0.576	6.929	0.652	11.010	0.979	16.736	1.612	21.669	1.948	17.212	2.201	13.810	2.272	8.938	1.793	7.496	1.442	6.250	1.120	5.630	0.869	5.266	0.694
5.366	0.613	7.803	0.716	14.487	1.061	20.628	1.872	30.470	2.500	23.050	2.265	17.557	2.840	10.919	2.190	8.649	1.625	6.823	1.227	6.100	0.923	5.566	0.706
5.961	0.680	09.400	0.804	17.733	1.125	35.498	2.253	53.892	2.628	43.124	2.679	22.399	3.030	12.408	2.192	09.521	1.640	7.876	1.327	6.770	1.014	6.288	0.796
6.964	0.809	10.306	0.915	22.276	1.243	53.973	2.465	95.507	3.180	64.807	3.208	27.010	3.261	13.246	2.356	09.985	1.648	8.583	1.348	7.478	1.098	6.817	0.885
7.768	1.119	15.421	1.255	31.583	1.604	78.878	3.024	154.930	5.388	113.511	4.908	43.225	3.811	16.701	2.368	10.786	1.829	09.230	1.598	8.235	1.383	7.932	1.260
999.0	1.119	999.0	1.255	999.0	1.604	999.0	3.024	999.0	5.388	999.0	4.908	999.0	3.811	999.0	2.368	999.0	1.829	999.0	1.598	999.0	1.383	999.0	1.260

1 Natural flows (m^3/s) *2 Environmental Water Requirement (m^3/s)*

Table 10.12 EWR Structure – EWR 1: REC C

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.578	0.109	0.556	0.112	0.600	0.120	0.820	0.130	1.137	0.149	1.127	0.156	1.029	0.157	0.814	0.155	0.718	0.147	0.625	0.139	0.542	0.126	0.489	0.115
0.755	0.116	0.767	0.115	1.033	0.130	1.350	0.149	1.867	0.158	1.745	0.182	1.784	0.178	1.539	0.179	1.380	0.173	1.170	0.169	0.985	0.152	0.837	0.126
0.809	0.127	0.940	0.129	1.237	0.146	1.891	0.185	2.566	0.203	2.216	0.212	2.121	0.218	1.723	0.215	1.502	0.206	1.285	0.195	1.104	0.174	0.934	0.142
0.939	0.141	1.088	0.149	1.534	0.170	2.144	0.211	3.08	0.244	2.751	0.263	2.400	0.278	1.913	0.265	1.679	0.257	1.416	0.235	1.251	0.203	1.051	0.162
1.015	0.161	1.208	0.169	1.784	0.200	2.740	0.249	3.741	0.322	3.247	0.344	2.778	0.359	2.127	0.344	1.838	0.323	1.545	0.291	1.340	0.251	1.163	0.193
1.081	0.189	1.377	0.196	2.104	0.231	3.429	0.313	4.847	0.393	4.480	0.424	3.578	0.456	2.483	0.426	1.989	0.392	1.637	0.354	1.415	0.293	1.267	0.235
1.173	0.225	1.490	0.237	2.381	0.283	3.952	0.395	5.496	0.442	5.472	0.522	4.586	0.554	2.923	0.504	2.111	0.438	1.785	0.388	1.528	0.327	1.349	0.267
1.301	0.273	1.756	0.282	2.882	0.350	5.456	0.451	6.852	0.575	7.250	0.615	5.498	0.640	3.311	0.573	2.205	0.475	1.859	0.413	1.598	0.373	1.436	0.311
1.401	0.332	1.938	0.340	3.516	0.389	7.842	0.513	11.681	0.649	11.022	0.735	7.115	0.702	3.766	0.609	2.376	0.513	1.914	0.453	1.677	0.404	1.520	0.358
1.664	0.401	2.205	0.423	4.774	0.465	10.078	0.626	19.526	0.982	17.559	1.116	09.176	0.763	4.735	0.705	2.725	0.579	2.174	0.542	1.853	0.483	1.681	0.425
999.0	0.401	999.0	0.423	999.0	0.465	999.0	0.626	999.0	0.982	999.0	1.116	999.0	0.763	999.0	0.705	999.0	0.579	999.0	0.542	999.0	0.483	999.0	0.425

1 Natural flows (m^3/s) *2 Environmental Water Requirement (m^3/s)*

Table 10.13 EWR Structure – EWR 2: REC D

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.182	0.033	0.276	0.039	0.460	0.057	0.851	0.084	0.896	0.104	0.953	0.110	0.923	0.105	0.672	0.102	0.482	0.082	0.377	0.062	0.282	0.050	0.246	0.039
0.441	0.042	0.669	0.050	1.05	0.081	1.495	0.124	1.526	0.148	1.342	0.165	1.224	0.130	1.036	0.151	0.749	0.116	0.631	0.093	0.524	0.069	0.394	0.055
0.515	0.056	0.810	0.073	1.437	0.110	2.128	0.175	2.295	0.232	1.946	0.254	1.749	0.238	1.334	0.221	1.069	0.167	0.824	0.128	0.684	0.097	0.526	0.063
0.684	0.074	1.223	0.105	1.708	0.183	2.641	0.289	2.782	0.357	2.648	0.376	2.183	0.340	1.534	0.330	1.204	0.247	0.923	0.171	0.823	0.126	0.676	0.081
0.869	0.100	1.458	0.154	2.077	0.252	3.199	0.416	4.131	0.453	3.043	0.529	2.719	0.446	1.823	0.438	1.300	0.321	1.057	0.213	0.896	0.158	0.833	0.115
0.976	0.136	1.703	0.193	2.696	0.331	4.628	0.532	5.261	0.629	4.111	0.768	3.302	0.589	2.156	0.568	1.491	0.397	1.169	0.279	1.032	0.213	0.922	0.150
1.120	0.183	1.836	0.260	3.436	0.404	5.674	0.643	6.828	0.864	6.184	1.083	3.958	1.02	2.309	0.710	1.642	0.459	1.259	0.321	1.081	0.247	1.020	0.210
1.340	0.321	2.322	0.393	4.748	0.545	7.417	0.898	10.478	1.188	09.691	1.432	4.919	1.218	2.505	0.942	1.863	0.631	1.359	0.467	1.185	0.382	1.160	0.423
1.485	0.576	2.496	0.670	5.455	0.830	12.058	1.283	16.395	1.586	13.614	1.744	7.173	1.468	2.955	1.125	2.030	0.900	1.505	0.730	1.291	0.615	1.389	0.557
1.816	0.709	4.242	0.770	8.406	0.970	17.764	1.546	32.578	2.506	20.920	1.985	09.191	1.711	3.760	1.243	2.389	0.988	1.843	0.883	1.566	0.756	1.537	0.601
999.0	0.709	999.0	0.770	999.0	0.970	999.0	1.546	999.0	2.506	999.0	1.985	999.0	1.711	999.0	1.243	999.0	0.988	999.0	0.883	999.0	0.756	999.0	0.601

1 Natural flows (m^3/s) *2 Environmental Water Requirement (m^3/s)*

Table 10.14 EWR Structure – EWR 3: REC B

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.492	0.185	1.586	0.190	1.941	0.213	2.658	0.227	3.285	0.245	3.336	0.244	3.139	0.276	2.434	0.256	2.168	0.237	1.902	0.225	1.585	0.211	1.474	0.191
2.177	0.195	2.630	0.203	3.488	0.230	5.084	0.264	6.409	0.278	5.321	0.288	5.240	0.300	4.264	0.289	3.704	0.275	3.223	0.263	2.665	0.238	2.413	0.208
2.543	0.211	3.140	0.223	4.614	0.264	6.753	0.327	7.718	0.368	6.479	0.381	6.742	0.373	5.329	0.364	4.468	0.339	3.678	0.305	3.177	0.272	2.690	0.227
2.838	0.231	3.931	0.252	5.700	0.332	7.580	0.442	09.812	0.508	8.00	0.549	7.548	0.505	5.814	0.529	5.031	0.480	4.197	0.398	3.683	0.334	3.158	0.261
3.345	0.260	4.459	0.302	6.954	0.419	09.972	0.537	12.279	0.711	10.971	0.821	8.593	0.800	6.591	0.749	5.740	0.640	4.672	0.521	3.967	0.394	3.430	0.302
3.728	0.302	5.044	0.368	8.313	0.487	12.267	0.779	17.423	1.00	14.199	1.211	11.748	1.015	7.671	1.060	6.208	0.878	5.143	0.711	4.594	0.530	4.070	0.379
4.026	0.365	5.748	0.432	09.897	0.626	16.105	1.104	21.177	1.396	19.410	1.698	15.150	1.372	09.011	1.332	6.700	1.014	5.491	0.850	4.752	0.622	4.387	0.456
4.574	0.465	7.081	0.535	11.905	0.940	23.160	1.742	31.623	2.561	28.685	3.174	19.059	2.573	09.905	2.067	7.228	1.483	5.880	1.072	5.051	0.771	4.702	0.546
4.943	0.638	7.897	0.709	15.130	1.063	34.076	2.239	54.803	3.895	41.594	5.02	22.729	3.674	11.410	2.420	8.062	1.617	6.295	1.235	5.372	0.901	4.992	0.705
5.799	0.997	09.802	1.130	21.261	1.388	49.615	2.749	96.126	4.889	74.039	5.573	30.780	4.188	13.675	2.512	8.628	1.833	7.288	1.589	6.134	1.293	5.612	1.110
999.0	0.997	999.0	1.130	999.0	1.388	999.0	2.749	999.0	4.889	999.0	5.573	999.0	4.188	999.0	2.512	999.0	1.833	999.0	1.589	999.0	1.293	999.0	1.110

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.15 EWR Structure – EWR 4: REC B

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.492	0.215	1.586	0.223	1.941	0.230	2.744	0.228	3.285	0.221	3.340	0.199	3.139	0.272	2.434	0.236	2.168	0.222	1.902	0.230	1.585	0.230	1.474	0.217
2.177	0.262	2.630	0.269	3.488	0.276	5.084	0.266	6.409	0.263	5.321	0.240	5.243	0.299	4.264	0.258	3.704	0.261	3.223	0.269	2.665	0.276	2.413	0.270
2.543	0.336	3.140	0.348	4.617	0.370	6.877	0.376	7.718	0.364	6.482	0.352	6.744	0.386	5.329	0.369	4.468	0.374	3.678	0.375	3.177	0.370	2.690	0.349
2.838	0.438	4.209	0.457	5.725	0.517	7.907	0.560	09.875	0.572	8.02	0.579	7.552	0.675	5.814	0.611	5.031	0.571	4.197	0.541	3.683	0.510	3.158	0.463
3.345	0.579	4.482	0.620	7.054	0.719	10.195	0.791	12.924	0.882	11.085	0.939	8.626	0.938	6.594	0.901	5.744	0.846	4.672	0.778	3.967	0.694	3.430	0.620
3.732	0.771	5.087	0.846	09.065	0.945	13.084	1.141	17.886	1.291	14.841	1.387	11.755	1.399	7.676	1.298	6.209	1.199	5.145	1.086	4.594	0.961	4.070	0.844
4.093	1.027	5.805	1.099	10.971	1.251	16.895	1.574	23.452	1.717	19.424	1.823	15.186	1.953	09.016	1.682	6.704	1.507	5.492	1.401	4.752	1.245	4.387	1.114
4.574	1.334	7.123	1.389	13.118	1.618	24.811	1.915	37.091	2.079	31.210	2.155	19.600	2.106	09.913	1.983	7.232	1.820	5.880	1.677	5.051	1.527	4.702	1.392
4.964	1.840	8.332	1.907	15.791	2.210	37.492	2.670	58.682	2.728	44.552	2.628	22.938	2.747	11.417	2.689	8.066	2.454	6.298	2.271	5.372	2.056	4.992	1.892
5.923	2.432	10.459	2.600	23.346	2.957	56.871	3.857	117.192	6.501	84.393	2.904	31.968	3.848	13.683	3.729	8.635	3.320	7.308	3.106	6.134	2.787	5.626	2.555
999.0	2.432	999.0	2.600	999.0	2.957	999.0	3.857	999.0	6.501	999.0	2.904	999.0	3.848	999.0	3.729	999.0	3.320	999.0	3.106	999.0	2.787	999.0	2.555

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.16 EWR Structure – EWR 5: REC C/D

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.153	0.013	0.143	0.022	0.193	0.027	0.278	0.027	0.256	0.028	0.337	0.035	0.314	0.032	0.257	0.030	0.243	0.030	0.220	0.031	0.215	0.029	0.190	0.025
0.359	0.016	0.310	0.022	0.404	0.027	0.598	0.027	0.877	0.032	0.750	0.035	0.601	0.032	0.542	0.030	0.537	0.030	0.516	0.031	0.446	0.029	0.383	0.025
0.479	0.019	0.502	0.022	0.656	0.027	0.996	0.034	1.056	0.039	0.897	0.037	0.876	0.037	0.729	0.036	0.715	0.034	0.665	0.033	0.601	0.029	0.545	0.025
0.623	0.024	0.704	0.027	1.039	0.029	1.319	0.044	1.361	0.052	1.168	0.048	1.073	0.047	0.945	0.043	0.905	0.042	0.805	0.040	0.734	0.035	0.653	0.027
0.721	0.030	1.040	0.037	1.290	0.044	1.596	0.059	1.735	0.072	1.510	0.069	1.296	0.064	1.086	0.055	1.054	0.052	0.963	0.049	0.874	0.043	0.783	0.036
0.853	0.040	1.188	0.051	1.594	0.066	1.960	0.093	2.468	0.104	2.09	0.096	1.680	0.088	1.297	0.085	1.198	0.072	1.030	0.062	0.930	0.054	0.891	0.047
1.051	0.053	1.370	0.063	1.824	0.078	2.440	0.106	4.914	0.150	2.823	0.143	2.090	0.124	1.567	0.102	1.464	0.091	1.349	0.085	1.193	0.071	1.088	0.064
1.428	0.075	1.764	0.094	2.218	0.099	4.03	0.158	8.380	0.213	5.077	0.199	2.709	0.185	1.946	0.149	1.817	0.127	1.791	0.121	1.611	0.105	1.537	0.091
1.646	0.107	2.307	0.147	3.121	0.143	09.835	0.280	16.691	0.463	8.725	0.360	3.628	0.272	2.522	0.214	2.451	0.191	2.285	0.183	2.071	0.156	1.914	0.128
2.337	0.158	3.590	0.181	6.038	0.203	20.180	0.387	28.440	0.767	15.111	0.530	5.711	0.323	3.135	0.262	2.993	0.241	2.844	0.233	2.587	0.212	2.483	0.187
999.0	0.158	999.0	0.181	999.0	0.203	999.0	0.387	999.0	0.767	999.0	0.530	999.0	0.323	999.0	0.262	999.0	0.241	999.0	0.233	999.0	0.212	999.0	0.187

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.17 EWR Structure – EWR 7: REC B

Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep	
NF[1]	EWR[2]	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR	NF	EWR
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.673	0.606	1.741	0.610	2.261	0.691	3.140	0.743	3.956	0.889	3.966	0.915	3.978	0.822	3.096	0.812	2.643	0.785	2.242	0.749	1.948	0.691	1.737	0.630
2.588	0.610	3.117	0.634	3.974	0.723	6.737	0.837	7.865	0.890	6.380	0.948	6.059	0.880	4.864	0.871	4.100	0.833	3.622	0.796	3.266	0.739	2.861	0.649
3.102	0.617	3.957	0.659	5.856	0.792	8.622	0.936	09.556	1.023	7.656	1.105	7.488	1.017	6.134	0.973	5.428	0.933	4.549	0.852	3.905	0.763	3.278	0.661
3.480	0.627	5.022	0.721	7.134	0.891	10.559	1.107	11.605	1.257	09.496	1.274	8.419	1.290	6.960	1.254	5.965	1.119	4.996	0.953	4.377	0.822	3.741	0.676
4.104	0.643	5.965	0.748	8.956	1.018	12.269	1.386	15.803	1.570	12.580	1.675	10.095	1.769	8.035	1.576	6.664	1.304	5.604	1.092	4.850	0.900	4.412	0.735
4.874	0.666	6.929	0.754	11.010	1.104	16.736	1.784	21.669	2.140	17.212	2.412	13.810	2.510	8.938	1.975	7.496	1.601	6.250	1.256	5.630	0.985	5.266	0.797
5.366	0.705	7.803	0.810	14.487	1.157	20.628	1.960	30.470	2.578	23.050	2.453	17.557	2.893	10.919	2.280	8.649	1.725	6.823	1.322	6.100	1.019	5.566	0.803
5.961	0.774	09.400	0.901	17.733	1.227	35.498	2.341	53.892	2.693	43.124	2.840	22.399	3.084	12.408	2.282	09.521	1.738	7.876	1.428	6.770	1.115	6.288	0.894
6.964	0.907	10.306	1.020	22.276	1.370	53.973	2.658	95.507	3.466	64.807	3.496	27.010	3.436	13.246	2.478	09.985	1.752	8.583	1.462	7.478	1.215	6.817	0.988
7.768	1.227	15.421	1.374	31.583	1.759	78.878	3.340	154.930	5.929	113.511	5.402	43.225	4.230	16.701	2.599	10.786	2.08	09.230	1.752	8.235	1.515	7.932	1.380
999.0	1.227	999.0	1.374	999.0	1.759	999.0	3.340	999.0	5.929	999.0	5.402	999.0	4.230	999.0	2.599	999.0	2.08	999.0	1.752	999.0	1.515	999.0	1.380

1 Natural flows (m^3/s) 2 Environmental Water Requirement (m^3/s)

Table 10.18 Example extract of the rating, weights and scoring table for the ecological component

Nodes	River	Weights		Normalisation		Combined	Scenario Rating					Scenario Score				
		Importance	Length (km)	Importance	Length		PES	REC	5	6	10	PES	REC	5	6	10
				1	0											
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
B81A-00242	*Broederstroom*	*1.0*	*21.9*	*0.009*	*0.0120*	*0.009*	*0.8235*	*1.000*	*0.8235*	*0.8235*	*0.8235*	*0.008*	*0.009*	*0.008*	*0.008*	*0.008*
B81A-00256	*0*	*1.0*	*5.3*	*0.009*	*0.029*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81A-00263	*0*	*1.0*	*5.1*	*0.009*	*0.028*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81A-00270	*Broederstroom*	*1.0*	*20.2*	*0.009*	*0.0111*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00233	*Mahitse*	*1.0*	*3.2*	*0.009*	*0.018*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00234	*Mahitse*	*1.0*	*7.1*	*0.009*	*0.039*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00246	*Politsi*	*1.0*	*14.7*	*0.009*	*0.080*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00251	*0*	*1.0*	*3.7*	*0.009*	*0.020*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00269	*Morudi*	*1.0*	*6.5*	*0.009*	*0.035*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00227	*Mahitse*	*1.0*	*11.0*	*0.009*	*0.060*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00240	*Politsi*	*1.0*	*10.2*	*0.009*	*0.056*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00247	*Great Letaba*	*1.0*	*12.5*	*0.009*	*0.068*	*0.009*	*1.000*	*1.000*	*0.9133*	*0.9301*	*0.9301*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
EWR1	*Great Letaba*	*135.6*	*25.7*	*0.1269*	*0.0141*	*0.1269*	*1.000*	*1.000*	*0.9133*	*0.9301*	*0.9301*	*0.1269*	*0.1269*	*0.1159*	*0.1181*	*0.1181*
B81D-00277	*Thabina*	*1.0*	*36.6*	*0.009*	*0.0200*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81D-00280	*Bobs*	*1.0*	*12.9*	*0.009*	*0.071*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81D-00296	*Mothlaka-Semeetse*	*1.0*	*9.7*	*0.009*	*0.053*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
EWR2	*Letsitele*	*126.4*	*4.4*	*0.1184*	*0.024*	*0.1184*	*1.000*	*1.000*	*0.9134*	*0.9270*	*1.000*	*0.1184*	*0.1184*	*0.1081*	*0.1097*	*0.1184*
B81D-00272	*Letsitele*	*1.0*	*31.4*	*0.009*	*0.0172*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81C-00245	*Great Letaba*	*1.0*	*36.8*	*0.009*	*0.0202*	*0.009*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.008*	*0.009*	*0.008*	*0.008*	*0.009*
B81E-00213	*Nwanedzi*	*1.0*	*43.2*	*0.009*	*0.0236*	*0.009*	*0.7143*	*1.000*	*0.7143*	*0.7143*	*0.7143*	*0.007*	*0.009*	*0.007*	*0.007*	*0.007*
B81E-00244	*Great Letaba*	*1.0*	*24.1*	*0.009*	*0.0132*	*0.009*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.008*	*0.009*	*0.008*	*0.008*	*0.009*
EWR3	*Great Letaba*	*189.2*	*18.7*	*0.1772*	*0.0102*	*0.1772*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.1545*	*0.1772*	*0.1421*	*0.1465*	*0.1641*
B81F-00212	*Great Letaba*	*1.0*	*9.5*	*0.009*	*0.052*	*0.009*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.008*	*0.009*	*0.008*	*0.008*	*0.009*
B81F-00215	*Great Letaba*	*1.0*	*9.7*	*0.009*	*0.053*	*0.009*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.008*	*0.009*	*0.008*	*0.008*	*0.009*
B81F-00218	*Great Letaba*	*1.0*	*6.6*	*0.009*	*0.036*	*0.009*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.008*	*0.009*	*0.008*	*0.008*	*0.009*
B81F-00231	*Great Letaba*	*1.0*	*21.9*	*0.009*	*0.0120*	*0.009*	*0.8723*	*1.000*	*0.8022*	*0.8269*	*0.9265*	*0.008*	*0.009*	*0.008*	*0.008*	*0.009*
B81J-00209	*Great Letaba*	*1.0*	*21.3*	*0.009*	*0.0117*	*0.009*	*0.8689*	*1.000*	*0.7182*	*0.7735*	*0.8234*	*0.008*	*0.009*	*0.007*	*0.007*	*0.008*
EWR4	*Great Letaba*	*178.4*	*11.1*	*0.1670*	*0.061*	*0.1670*	*0.8689*	*1.000*	*0.7182*	*0.7735*	*0.8234*	*0.1451*	*0.1670*	*0.1200*	*0.1292*	*0.1375*

Nodes	River	Weights		Normalisation		Combined	Scenario Rating					Scenario Score				
		Importance	Length (km)	Importance	Length		PES	REC	5	6	10	PES	REC	5	6	10
				1	0											
Several nodes not listed for presentation purposes																
B83A-00252	Letaba	1.0	0.5	0.009	0.003	0.009	0.8904	1.000	0.7055	0.7697	0.8411	0.008	0.009	0.007	0.007	0.008
B83D-00250	Letaba	1.0	4.0	0.009	0.022	0.009	0.8904	1.000	0.7055	0.7697	0.8411	0.008	0.009	0.007	0.007	0.008
EWR7	Letaba	234.6	16.1	0.2196	0.088	0.2196	0.8904	1.000	0.7055	0.7697	0.8411	0.1955	0.2196	0.1550	0.1690	0.1847
B83E-00265	Letaba	1.0	29.1	0.009	0.0159	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83A-00193	Shipikani	1.0	38.3	0.009	0.0210	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83A-00238	Nharhweni	1.0	28.8	0.009	0.0157	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83A-00254	Ngwenyeni	1.0	33.9	0.009	0.0186	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83B-00161	Tsende	1.0	77.4	0.009	0.0424	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83D-00204	Manyeleti	1.0	19.3	0.009	0.0106	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83D-00208	Makhadzi	1.0	17.7	0.009	0.097	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83D-00261	Nwanedzi	1.0	38.4	0.009	0.0210	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
B83D-00236	Makhadzi	1.0	17.3	0.009	0.095	0.009	1.000	1.000	1.000	1.000	1.000	0.009	0.009	0.009	0.009	0.009
Note: The full table (calculation sheet) is available electronically as a MS Excel spreadsheet.									Ecological Scores:			0.929	1.00	0.807	0.849	0.900

Table 10.19 Example extract of the rating, weights and scoring table for the Ecosystem Services component

Nodes	River	Weights	Length (km)	Normalisation		Combined	Scenario Rating					Scenario Score				
		Importance		Importance	Length		PES	REC	5	6	10	PES	REC	5	6	10
				1	0											
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
B81A-00242	*Broederstroom*	*1.0*	*21.9*	*0.009*	*0.0120*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81A-00256	*0*	*1.0*	*5.3*	*0.009*	*0.029*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81A-00263	*0*	*1.0*	*5.1*	*0.009*	*0.028*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81A-00270	*Broederstroom*	*1.0*	*20.2*	*0.009*	*0.0111*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00233	*Mahitse*	*1.0*	*3.2*	*0.009*	*0.018*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00234	*Mahitse*	*1.0*	*7.1*	*0.009*	*0.039*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00246	*Politsi*	*1.0*	*14.7*	*0.009*	*0.080*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00251	*0*	*1.0*	*3.7*	*0.009*	*0.020*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00269	*Morudi*	*1.0*	*6.5*	*0.009*	*0.035*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00227	*Mahitse*	*1.0*	*11.0*	*0.009*	*0.060*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00240	*Politsi*	*1.0*	*10.2*	*0.009*	*0.056*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81B-00247	*Great Letaba*	*1.0*	*12.5*	*0.009*	*0.068*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
EWR1	*Great Letaba*	*133.0*	*25.7*	*0.1245*	*0.0141*	*0.1245*	*1.000*	*1.000*	*0.9783*	*0.9783*	*0.9783*	*0.1245*	*0.1245*	*0.1218*	*0.1218*	*0.1218*
B81D-00277	*Thabina*	*1.0*	*36.6*	*0.009*	*0.0200*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81D-00280	*Bobs*	*1.0*	*12.9*	*0.009*	*0.071*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81D-00296	*Mothlaka-Semeetse*	*1.0*	*9.7*	*0.009*	*0.053*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
EWR2	*Letsitele*	*185.0*	*4.4*	*0.1732*	*0.024*	*0.1732*	*1.000*	*1.000*	*0.9793*	*0.9793*	*1.000*	*0.1732*	*0.1732*	*0.1696*	*0.1696*	*0.1732*
B81D-00272	*Letsitele*	*1.0*	*31.4*	*0.009*	*0.0172*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81C-00245	*Great Letaba*	*1.0*	*36.8*	*0.009*	*0.0202*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81E-00213	*Nwanedzi*	*1.0*	*43.2*	*0.009*	*0.0236*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81E-00244	*Great Letaba*	*1.0*	*24.1*	*0.009*	*0.0132*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
EWR3	*Great Letaba*	*223.0*	*18.7*	*0.2088*	*0.0102*	*0.2088*	*1.000*	*1.2000*	*0.9410*	*0.9305*	*0.9440*	*0.2088*	*0.2506*	*0.1965*	*0.1943*	*0.1971*
B81F-00212	*Great Letaba*	*1.0*	*9.5*	*0.009*	*0.052*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81F-00215	*Great Letaba*	*1.0*	*9.7*	*0.009*	*0.053*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81F-00218	*Great Letaba*	*1.0*	*6.6*	*0.009*	*0.036*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81F-00231	*Great Letaba*	*1.0*	*21.9*	*0.009*	*0.0120*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81J-00209	*Great Letaba*	*1.0*	*21.3*	*0.009*	*0.0117*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B81F-00228	*Reshwele*	*1.0*	*28.3*	*0.009*	*0.0155*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
Several nodes not listed for presentation purposes																

B83A-00252	*Letaba*	*1.0*	*0.5*	*0.009*	*0.003*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83D-00250	*Letaba*	*1.0*	*4.0*	*0.009*	*0.022*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
EWR7	*Letaba*	*134.0*	*16.1*	*0.1255*	*0.088*	*0.1255*	*1.000*	*1.1000*	*0.9020*	*0.9129*	*0.9265*	*0.1255*	*0.1380*	*0.1132*	*0.1145*	*0.1162*
B83E-00265	*Letaba*	*1.0*	*29.1*	*0.009*	*0.0159*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83A-00193	*Shipikani*	*1.0*	*38.3*	*0.009*	*0.0210*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83A-00238	*Nharhweni*	*1.0*	*28.8*	*0.009*	*0.0157*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83A-00254	*Ngwenyeni*	*1.0*	*33.9*	*0.009*	*0.0186*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83B-00161	*Tsende*	*1.0*	*77.4*	*0.009*	*0.0424*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83D-00204	*Manyeleti*	*1.0*	*19.3*	*0.009*	*0.0106*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83D-00208	*Makhadzi*	*1.0*	*17.7*	*0.009*	*0.097*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83D-00261	*Nwanedzi*	*1.0*	*38.4*	*0.009*	*0.0210*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
B83D-00236	*Makhadzi*	*1.0*	*17.3*	*0.009*	*0.095*	*0.009*	*1.000*	*1.000*	*1.000*	*1.000*	*1.000*	*0.009*	*0.009*	*0.009*	*0.009*	*0.009*
Note: The full table (calculation sheet) is available electronically as a MS Excel spreadsheet.								*Ecosystem Services Scores:*				*1.00*	*1.072*	*0.945*	*0.950*	*0.958*

Table 10.20 Ecological Categories of all biophysical nodes for the scenarios

Nodes	River	IUA	River Length (km)	Ecological Category					
				PES	REC	5	6	9	10
a	*b*	*c*	*d*	*h*	*i*	*i*	*k*	*l*	*m*
B81A-00242	Broederstroom	1	21.9	C	B	C	C	C	C
B81A-00256	0	1	5.3	D	D	D	D	D	D
B81A-00263	0	1	5.1	D	D	D	D	D	D
B81A-00270	Broederstroom	1	20.2	C	C	C	C	C	C
B81B-00233	Mahitse	1	3.2	C	C	C	C	C	C
B81B-00234	Mahitse	1	7.1	C	C	C	C	C	C
B81B-00246	Politsi	1	14.7	C	C	C	C	C	C
B81B-00251	0	1	3.7	D	D	D	D	D	D
B81B-00269	Morudi	1	6.5	B	B	B	B	B	B
B81B-00227	Mahitse	1	11.0	D	D	D	D	D	D
B81B-00240	Politsi	1	10.2	C	C	C	C	C	C
B81B-00247	Great Letaba	1	12.5	C	C	C/D	C/D	C/D	C/D
EWR1	Great Letaba	1	25.7	C	C	C/D	C/D	C/D	C/D
B81D-00277	Thabina	2	36.6	D	D	D	D	D	D
B81D-00280	Bobs	2	12.9	B	B	B	B	B	B
B81D-00296	Mothlaka-Semeetse	2	9.7	B	B	B	B	B	B
EWR2	Letsitele	2	4.4	D	D	D	D	D	D
B81D-00272	Letsitele	2	31.4	C	C	C	C	C	C
B81C-00245	Great Letaba	3	36.8	C	B/C	C/D	C/D	C	C
B81E-00213	Nwanedzi	3	43.2	D	C	D	D	D	D
B81E-00244	Great Letaba	3	24.1	C	B/C	C/D	C/D	C	C
EWR3	Great Letaba	4	18.7	C	B/C	C/D	C/D	C	C
B81F-00212	Great Letaba	4	9.5	C	B/C	C/D	C/D	C	C
B81F-00215	Great Letaba	4	9.7	C	B/C	C/D	C/D	C	C
B81F-00218	Great Letaba	4	6.6	C	B/C	C/D	C/D	C	C
B81F-00231	Great Letaba	4	21.9	C	B/C	C/D	C/D	C	C
B81J-00209	Great Letaba	4	21.3	C	B/C	D	C/D	C	C
EWR4	Great Letaba	4	11.1	C	B/C	D	C/D	C	C
B81F-00228	Reshwele	5	28.3	B	B	B	B	B	B
B81F-00232	Makwena	5	22.4	B	B	B	B	B	B
B81F-00189	Merekome	6	35.9	C	C	C	C	C	C
B81F-00203	Lerwatlou	6	34.9	C	C	C	C	C	C
B81G-00164	Molototsi	6	58.1	D	D	D	D	D	D
B81H-00162	Metsemola	6	13.2	C	C	C	C	C	C
B81H-00171	Molototsi	6	61.5	D	D	D	D	D	D
B81J-00187	Mbhawula	6	36.8	C	C	C	C	C	C
B82A-00168	Middel Letaba	7	73.0	C	C	C	C	C	C
B82B-00173	Koedoes	7	61.4	D	D	D	D	D	D
B82C-00175	Brandboontjies	7	37.9	E	D	E	E	E	E
B82D-00163	Lebjelebore	7	34.2	C	C	C	C	C	C
B82D-00154	Middel Letaba	7	15.6	D	D	D	D	D	D
B82D-00166	Mosukodutsi	7	10.5	D	D	D	D	D	D
B82D-00146	Middel Letaba	7	28.5	E	D	E	E	E	E
B82E-00149	Khwali	8	23.9	B	B	B	B	B	B
B82E-00150	Little Letaba	8	32.3	C	C	C	C	C	C

Nodes	River	IUA	River Length (km)	Ecological Category					
				PES	REC	5	6	9	10
a	b	c	d	h	i	i	k	l	m
B82F-00141	Soeketse	8	26.8	C	C	C	C	C	C
B82F-00128	Little Letaba	8	33.5	C	C	C	C	C	C
B82F-00137	Little Letaba	8	31.4	D	D	D	D	D	D
EWR5	Little Letaba	9	90.3	C	C	D	C/D	C/D	C/D
B82J-00165	Little Letaba	9	22.8	C	C	D	C/D	C/D	C/D
B82J-00178	Little Letaba	9	7.2	C	C	D	C/D	C/D	C/D
B82J-00201	Little Letaba	9	7.8	C	C	D	C/D	C/D	C/D
B82J-00207	Little Letaba	9	4.5	C	C	D	C/D	C/D	C/D
B82H-00127	Nsama	10	60.7	C	C	C	C	C	C
B82H-00139	Magobe	10	25.5	B	B	B	B	B	B
B82H-00157	Nsama	10	18.3	B	B	B	B	B	B
B82J-00153	Nalatsi	10	27.1	A/B	A/B	A/B	A/B	A/B	A/B
B82J-00159	Byashishi	10	36.2	A/B	A/B	A/B	A/B	A/B	A/B
B82J-00197	Ka-Malilibone	10	12.0	B	B	B	B	B	B
B83A-00220	Letaba	11	11.8	C	B/C	D	C/D	C	C
B83A-00230	Letaba	11	16.9	C	B	D	C	C	C
EWR6	Letaba	11	20.0	C	B	D	C	C	C
B83A-00252	Letaba	11	0.5	C	B	D	C	C	C
B83D-00250	Letaba	11	4.0	C	B	D	C	C	C
EWR7	Letaba	11	16.1	C	B	D	C	C	C
B83E-00265	Letaba	12	29.1	A/B	A/B	A/B	A/B	A/B	A/B
B83A-00193	Shipikani	12	38.3	A/B	A/B	A/B	A/B	A/B	A/B
B83A-00238	Nharhweni	12	28.8	A/B	A/B	A/B	A/B	A/B	A/B
B83A-00254	Ngwenyeni	12	33.9	A/B	A/B	A/B	A/B	A/B	A/B
B83B-00161	Tsende	12	77.4	A/B	A/B	A/B	A/B	A/B	A/B
B83D-00204	Manyeleti	12	19.3	A/B	A/B	A/B	A/B	A/B	A/B
B83D-00208	Makhadzi	12	17.7	A/B	A/B	A/B	A/B	A/B	A/B
B83D-00261	Nwanedzi	12	38.4	A/B	A/B	A/B	A/B	A/B	A/B
B83D-00236	Makhadzi	12	17.3	A/B	A/B	A/B	A/B	A/B	A/B

11 APPENDIX B: WATER QUALITY IN TERMS OF USER REQUIREMENTS - CONSEQUENCES OF SCENARIOS

11.1 INTRODUCTION

Steps 4 and 5 of the WRCS function as one step and are integrated as such into Step 4 of the Integrated Approach. One of the objectives of this task was to describe and document an approach as to how operational scenarios may impact on water quality for non-ecological users (i.e. water quality related to users other than ecology, for example: Domestic Use, Agriculture - Stock Watering, Agriculture – Irrigation, Industrial - Category 3 and Recreation - Intermediate Contact).

This Appendix therefore presents the approach undertaken to include non-ecological water quality into the consequences evaluation and the results of this assessment.

11.2 APPROACH

The approach undertaken is listed below as bullet points.

- *Identify the river reaches or EWR sites which may potentially be impacted by the scenarios.*
- *Gather background information on water users in the catchment.*
- *Use land use information and the Water Quality Status Quo task (DWA, 2013a) conducted for the Letaba study to identify the users in the study areas.*
- *Link users to the river reaches which may potentially be impacted by the scenarios.*
- *Identify the user group's water quality requirements and drivers of water quality.*
- *Provide an impact rating of selected scenarios on water quality at identified sites. This step may be done qualitatively (as in the case of the Letaba study area) or quantitatively if a water quality model has been set up for the catchment.*
- *Rank scenarios per site.*

Figure 11.1 is a diagrammatic representation of the steps shown in the approach. The various steps are referred to as Phases 1 to 5. This notation is followed during the explanation of data collection and results.

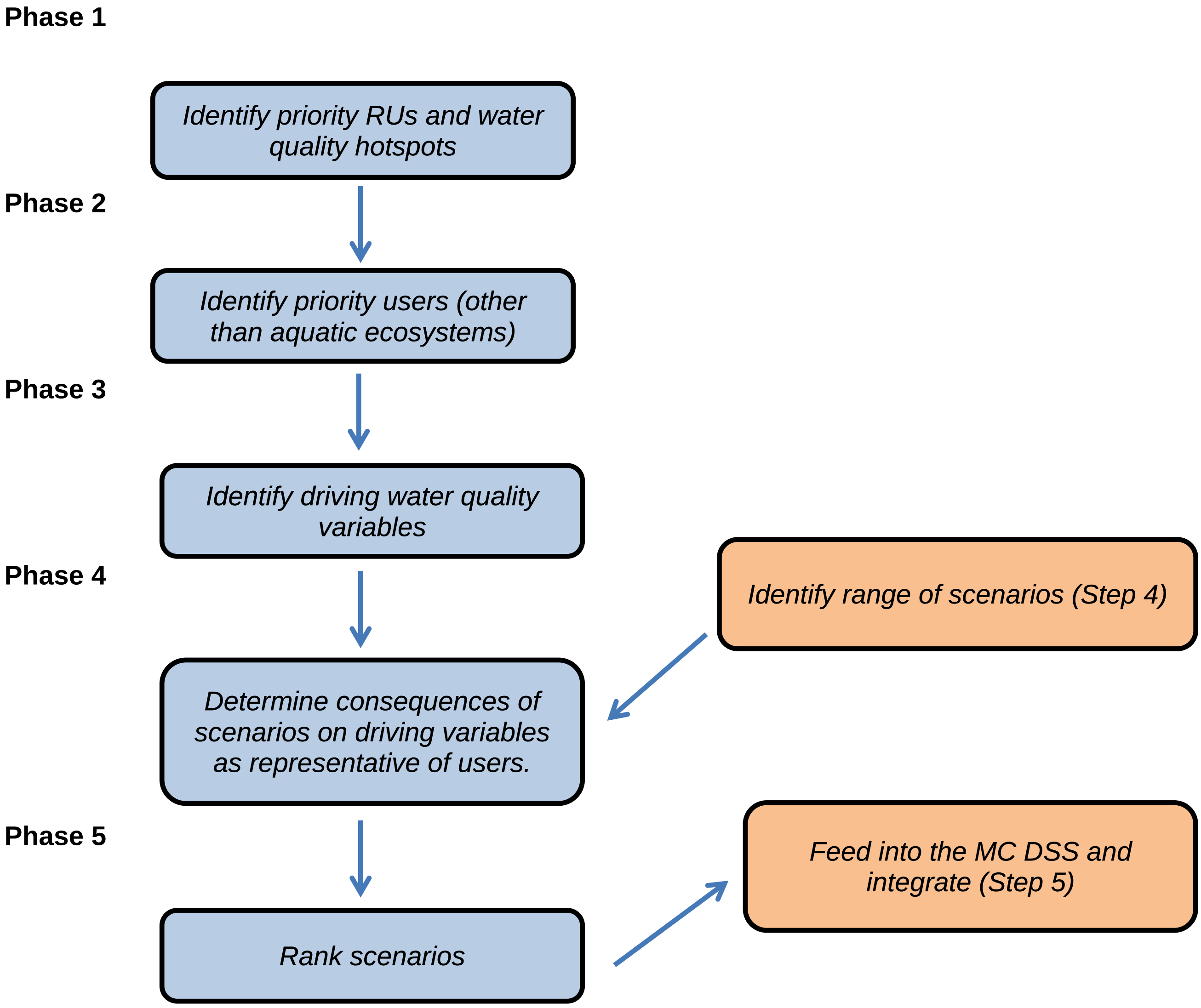

Figure 11.1 A diagrammatic representation of the approach followed for determining consequences of scenarios to non-ecological water quality

11.3 DATA COLLECTION

Data collection steps are provided for Phases 1 to 3.

11.3.1 Phase 1: Identify priority RUs and water quality hotspots

Priority RUs for the determination of consequences to non-ecological users are those reaches containing the EWR sites, which are listed below. Note that the impact of operational scenarios has been assessed at the key biophysical nodes in the study area, i.e. the EWR sites. All consequences, i.e. ecological, economic, ecological services and user (or non-ecological) water quality, were therefore been assessed at these driving nodes or reaches of the rivers.

- *Letaba River: Downstream Ebenezer to above Tzaneen Dam. This reach includes EWR 1 (Appel).*
- *Letsitele River. This reach includes EWR 2.*
- *Letaba River: SQs B81F-00200, B81F-00218 and B81F-00231. This reach includes EWR 3 (Prieska weir).*
- *Letaba River: SQ B91J-00219. This reach includes EWR 4 (Letaba Ranch).*
- *Little Letaba River: SQ B82G-00135. This reach includes EWR 5.*
- *Great Letaba River: Letaba River within the Kruger National Park. This reach includes EWR 6 in B83D-00255.*

11.3.2 Phase 2: Identify primary water users in priority reaches

Primary user groups in the priority river reaches are shown in Table 11.1.

Table 11.1 Primary users groups in river reaches considered during the scenario impact assessment process

Reach number	Priority river reaches	Primary (non-ecological) user group
1	*Letaba River: Downstream Ebenezer to above Tzaneen Dam.*	*Forestry (and some agriculture).*
2	*Letsitele River.*	*Citrus plantations and irrigation.*
3	*Letaba River: SQs B81F-00200, B81F-00218 and B81F-00231.*	*Irrigation of agricultural land and citrus plantations.*
4	*Letaba River: SQ B91J-00219.*	*Settlements; irrigation.*
5	*Little Letaba River: SQ B82G-00135.*	*Settlements; subsistence farming; Giyani urban area.*
6	*Great Letaba River: Letaba River within the KNP.*	*National Park - conservation and biodiversity.*

11.3.3 Phase 3: Identify driving water quality variables per primary non-ecological user

Driving water quality variable per user group are shown in Table 11.2.

Table 11.2 Driving water quality variable per primary user groups in identified river reaches

Reach number	Priority river reaches	Primary (non-ecological) user group	Driving water quality variable	Current State
1	*Letaba River: Downstream Ebenezer to above Tzaneen Dam.*	*Forestry and some agriculture.*	*Nutrients.*	*Good*
2	*Letsitele River.*	*Citrus plantations and irrigation.*	*Nutrients, salts, potential toxics.*	*Fair - Moderate*
3	*Letaba River: SQs B81F-00200, B81F-00218 and B81F-00231.*	*Irrigation of agricultural land and citrus plantations.*	*Nutrients, salts, potential toxics.*	*Moderate - Good*
4	*Letaba River: SQ B91J-00219*	*Settlements; irrigation.*	*Nutrients, turbidity (linked to erosion).*	*Moderate - Good*
5	*Little Letaba River: SQ B82G-00135.*	*Settlements; subsistence farming; Giyani urban area.*	*Nutrients, salts, turbidity (linked to erosion).*	*Moderate - Good*
6	*Great Letaba River: Letaba River within the KNP.*	*National Park - conservation and biodiversity.*	*Nutrients, salts, turbidity (related to irrigation and settlements upstream the KNP).*	*Good*

11.4 RESULTS

Results are presented as bar diagrams (Figure 11.2). Note the following explanatory points:

- *No scale is shown on the bars as the process undertaken was qualitative and in relation to Current State (CS).*
- *CS shown on the bar relates to the water quality state, for example, a Good CS will be located along the upper third and in the green portion of the bar.*
- *CS per river reach can therefore be assessed comparatively, that is, if CS is lower on one bar than the other, then water quality is assumed to be poorer at that site.*
- *The impact of operational scenarios (denoted as Sc x) have been considered in relation to CS. So therefore, if Sc 1 (for example) results in a small impact on the water quality of the primary*

user in the river reach, the small impact of that scenario will be shown by placing the symbol for the scenario close or alongside that denoting the CS.

- *It is expected that if a scenario has little impact on ecological water quality, it is unlikely to have a large impact on the water quality linked to any user.*
- *Scenarios relevant to the site are shown on the bars. See Section 3 for an explanation of operational scenarios.*
- *As a water quality model and load calculations are not available for the Letaba catchment, and water quality state across the catchment is generally good, a qualitative assessment was conducted for the scenario assessment.*

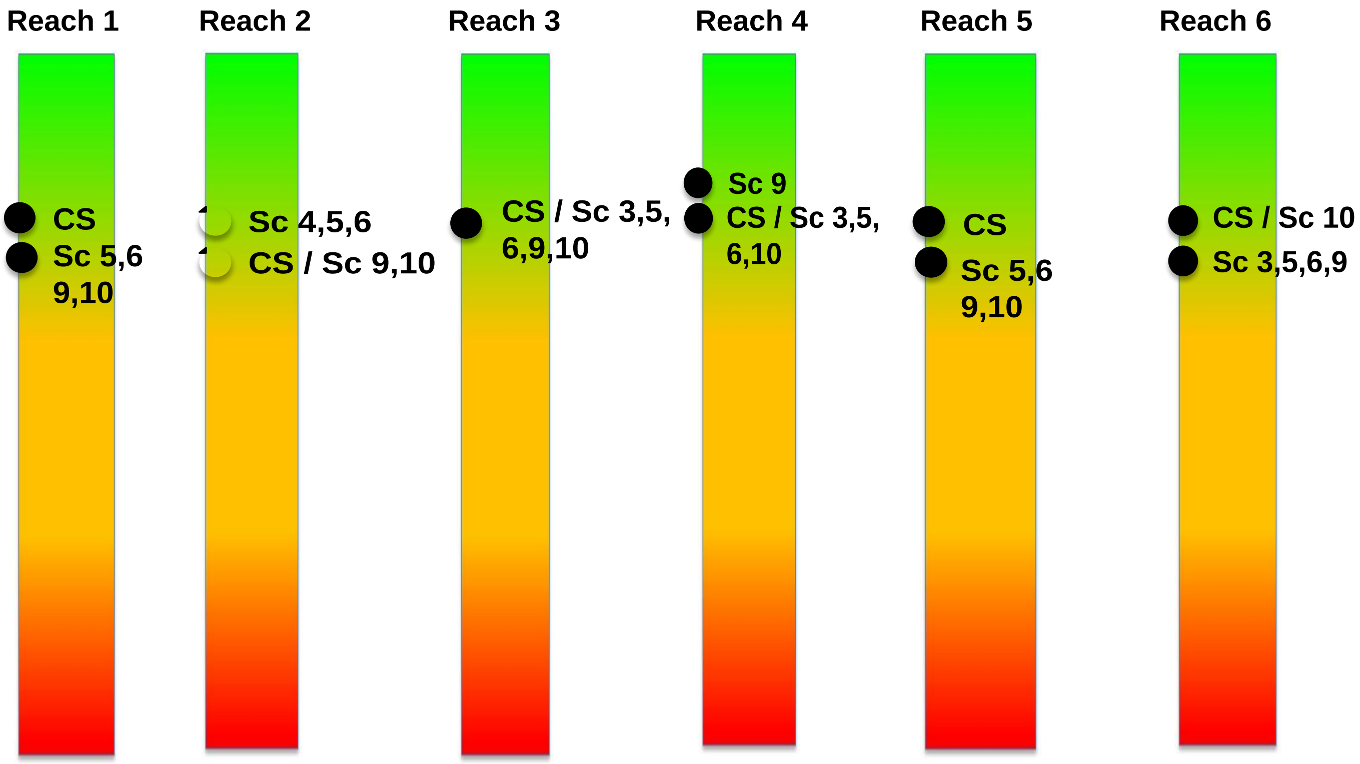

Figure 11.2 Consequences of selected scenarios on non-ecological water quality drivers of Reaches 1 - 6

11.5 CONCLUSION

The qualitative assessment of the consequences of operational scenarios on non-ecological water quality, i.e. users such as agriculture – irrigation and stock-watering to urban and rural settlements, shows that little impact is expected under any of the operational scenarios for these users. Phase 5 of the process would be to rank the scenarios. This step was not undertaken for the Letaba study due to the small differences and lack of resolution to actually differentiate between the scenarios for the various sites.

12 APPENDIX C: REPORT COMMENTS

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Comments from				