**Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment Project (WP10987)**

# LINKING THE VALUE AND CONDITION OF THE WATER RESOURCE

DWS REPORT NO: RDM/WMA9/00/CON/CLA/0117

Date:  March 2017

water & sanitation

Department:
Water and Sanitation
**REPUBLIC OF SOUTH AFRICA**

**Department of Water and Sanitation
Chief Directorate: Water Ecosystems**

Published by


Department of Water and Sanitation
Private Bag X313
Pretoria, 0001
Republic of South Africa


Tel: (012) 336 7500/ +27 12 336 7500
Fax: (012) 336 6731/ +27 12 336 6731


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This report is to be cited as:

Department of Water and Sanitation, South Africa. March 2017. Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment: Linking the Value and Condition of the Water Resource. Project Number WP10987. DWS Report No: RDM/WMA9/00/CON/CLA/0117

Prepared by:

Aurecon South Africa (Pty) Ltd in sub-consultancy association with Southern Waters Ecological Research and Consulting, Anchor Environmental and Delta-H Water Systems Modelling

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|---|---|
| *Title:* | *Linking the Value and Condition of the Water Resource Report* |
| *Author:* | *Dr Jane Turpie, Dr Karl Reinecke, Dr Barry Clark, Helen Seyler, Dr James Cullis, Erik van der Berg, Prof André Görgens.* |
| *Project Name:* | *Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment: WP 10987* |
| *DWS Report No:* | *RDM/WMA8/00/CON/CLA/0117* |
| *Status of Report*: | *Final* |
| *First Issue:* | *December 2016* |
| *Final Issue:* | *March 2017* |

**Professional Service Providers:** Aurecon South Africa (Pty) Ltd, Southern Waters Ecological Research and Consulting, Anchor Environmental and Delta-H Water Systems Modelling

**Approved for the PSP by:**

…………………………………………… ……………………………………………

Erik van der Berg                                                        Date

Technical Director

**DEPARTMENT OF WATER AND SANITATION**

**Chief Directorate: Water Ecosystems**

**Approved for DWS by:**

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Ndileka Mohapi

Chief Director: Water Ecosystems

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# List of Abbreviations

| | |
|---|---|
| AECs | Alternate Ecological Categories |
| CD: WE | Chief Directorate: Water Ecosystems |
| CMS | Catchment management strategy |
| DWA | (Previous) Department of Water Affairs |
| DWAF | (Previous) Department of Water Affairs and Forestry |
| DWS | Department of Water and Sanitation |
| EC | Ecological Category |
| EGSA | Ecological goods, services and attributes |
| EI | Ecological Importance |
| EIS | Ecological importance and sensitivity |
| ES | Ecological Sensitivity |
| EWR | Ecological water requirements |
| GDP | Gross Domestic Product |
| IEI | Environmental importance index |
| IUA | Integrated Unit of Analysis |
| MAR | Mean annual runoff |
| MCA | Multi-criteria Assessment |
| NFEPA | National Freshwater Ecosystem Priority Areas |
| NPV | Net present value |
| NWA | National Water Act |
| PES | Present Ecological Sate |
| RDM | Resource Directed Measures |
| REC | Recommended Ecological Category |
| RQOs | Resource Quality Objectives |
| RUs | Resource Units |
| SAM | Social Accounting Matrix |
| SCI | Socio-Cultural Importance |
| SEZ | Socio-Economic Zones |
| TDS | Total dissolved solids |
| WARMS | Water Allocation Registration Management System |
| WCWSS | Western Cape Water Supply System |
| WC/WDM | Water conservation and water demand management |
| WRCS | Water Resource Classification System |
| WMA | Water Management Area |
| WRC | Water Resource Class |
| WReMP | Water Resources Modelling Platform |
| WRSM2000 | Water Resources of South Africa 2012 |
| WRYM | Water Resources Yield Model |
| WRPM | Water Resources Planning Model |
| WRUI | Water Resource Use Importance index |
| WUA | Water User Association |

# Executive Summary

## INTRODUCTION

The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned a study to determine the Water Resource Classes (WRC) and associated Resource Quality Objectives (RQO) in the Berg Catchment.

Following the *Resource Units and IUA Delineation* and *Status Quo* reports, the *Linking the Value and Condition of the Water Resource Report* is the next report required for this study. In terms of the deliverables required for the water resource class determination task of this study, the following separate (but linked) reports will be required, of which this is the first:

1. *Linking the Value and Condition of the Water Resource* Report
2. *Quantification of the Ecological Water Requirements (EWR) and changes in EGSAs (ecological goods, services and attributes)* Report
3. *Ecological Base Configuration Scenarios* Report
4. *Evaluation of Scenarios* Report

Figure E1 illustrates the broad conceptual process from the determination of the Status Quo (integrated Step 1) through to the determination of Water Resource Classes.
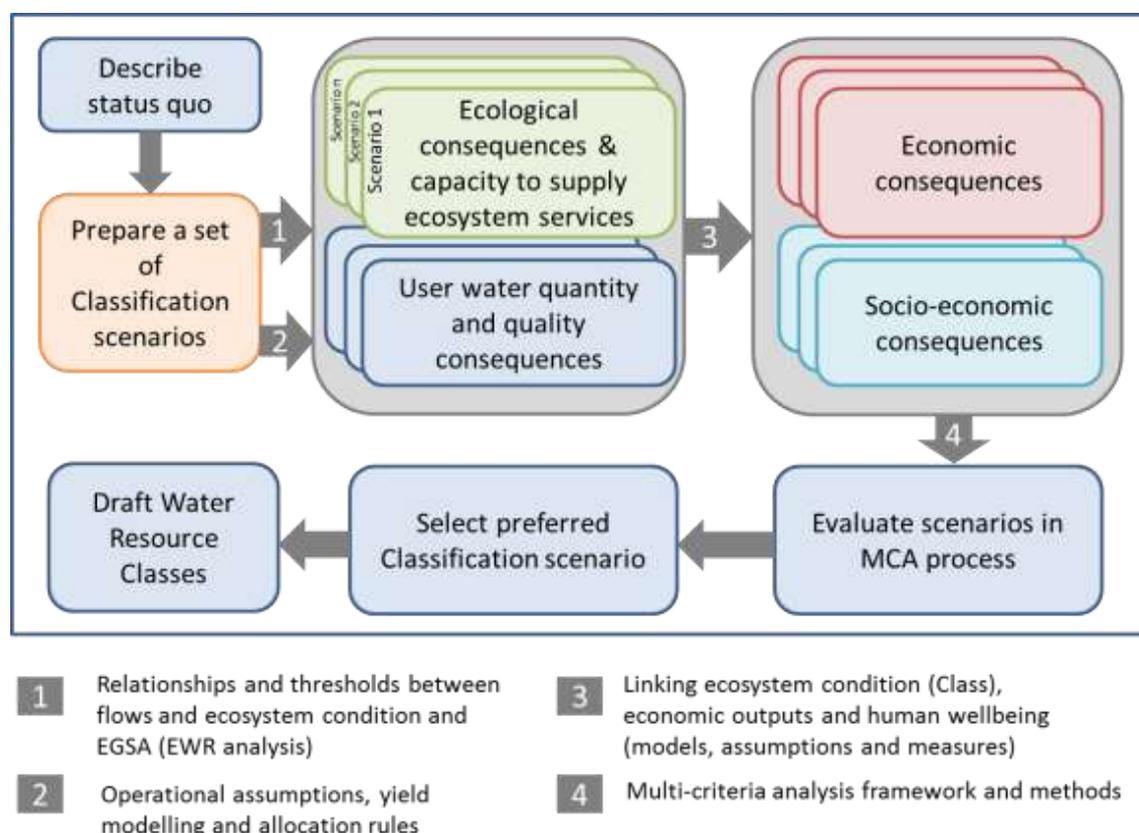


**Figure E1: The process in Step 4 and 5: Identification of scenarios to the gazetted Water Resource Class**

Within these steps there are further sub-steps that pertain to the development of the relationships and assumptions used in each step. This report describes the broad conceptual classification process, as well as the sub-steps of the four 'Scenario'-linked reports (defined as reports 1-4 above).

## SCENARIO EVALUATION PROCESS

The overarching aim of the scenario evaluation process is to find the appropriate balance between the level of environmental protection possible and the use of the water to sustain socio-economic activities. There are three main elements (variables) to consider in this balance, namely the ecology, economic and societal benefits obtained as a result of the Classification choices made.

The sequential activities carried out to evaluate the scenarios starts with the vision setting per Integrated Unit of Analysis (IUA) and describing the scenarios to be analysed. The *status quo* information will be applied to identify the components requiring evaluation and defining the relevant parameters to be quantified. Water availability analyses will be carried out for the scenarios, and this feeds into the activity to determine the consequences on Water Quality, Ecology, Ecosystem Services, Economy and Society. The scenarios will be ranked, first, for the individual variables and secondly an overall integrated ranking will be derived based on multi-criteria analysis methods.

The scenario evaluation process entails a sequence of activities to be followed as illustrated schematically in Figure E2.
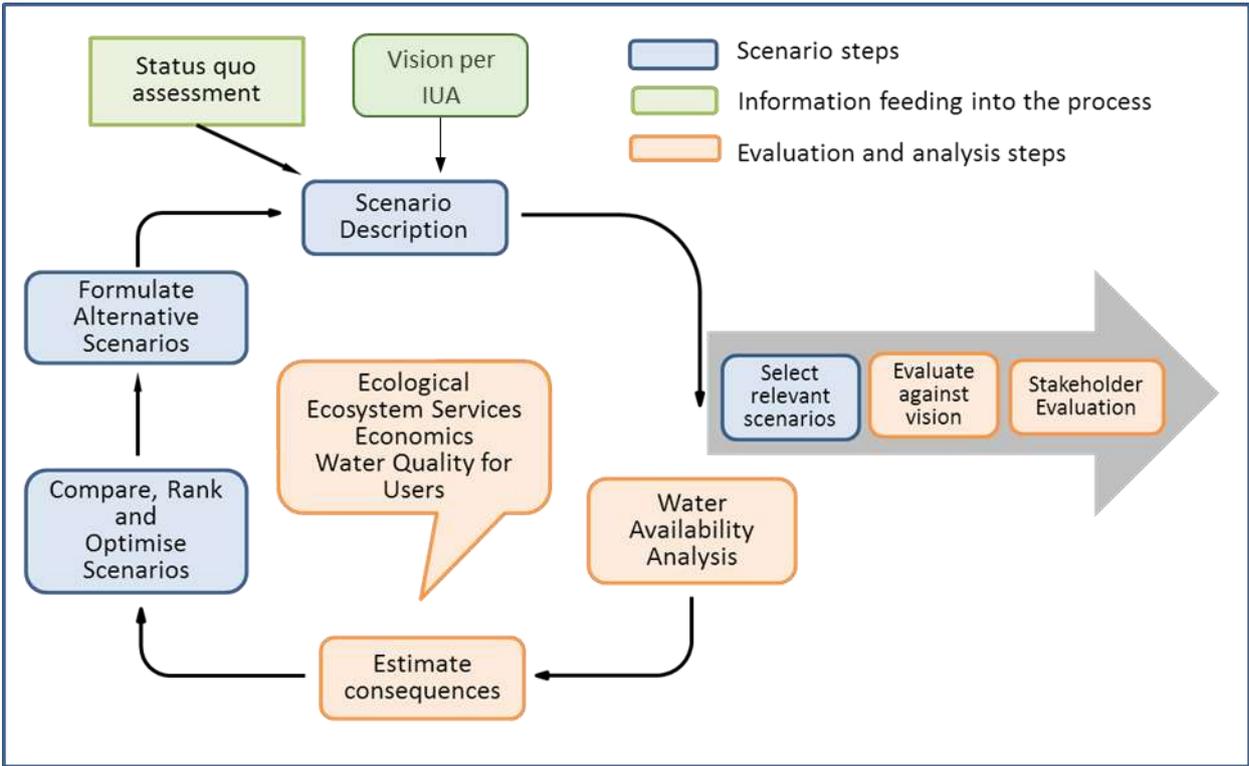


**Figure E2: Schematic presentation of the scenario evaluation process**

## PRELIMINARY IDENTIFIED SCENARIOS

The approach for establishing the suite of scenarios to be provided for hydrological analysis will consider different EC configurations in which environmental flows vary spatially and in their overall levels. Some of the spatial configurations would be driven by conservation priorities for freshwater systems and estuaries.

The preliminary range of scenarios to be developed is as shown in Table E1. The only variation will be (a) the ecological water requirements (EWRs) and (b) the water demands that have to be met. This will allow evaluation of the trade-offs between ecological and socio-economic consequences.

**Table E1: Preliminary Identified Scenarios**

| # | Scenario | Description |
|---|---|---|
| 1A | **Maintain Present Ecological State (PES) + low growth (=Baseline)** | River, wetland and estuary systems are maintained in their present condition. |
| 1B | **Maintain PES + high growth** | |
| 2A | **Bottom line + low growth** | The maximum volume of water is made available for abstraction from the system for economic activities, with the provision that all water resources are just maintained in a D Ecological Category (EC) (the ecological "bottom line"). |
| 2B | **Bottom line + high growth** | |
| 3A | **RECs + low growth** | The Recommended Ecological Categories (RECs) determined for rivers, wetlands and estuaries based on present water resource health and conservation importance (but without any consideration of socio-economic effects) are applied in these scenarios. |
| 3B | **RECs + high growth** | |
| 4A | **Targeted conservation + low growth** | High ECs are given to areas of high conservation importance, but for other areas, the ECs can be below REC. It may end up that this scenario set is similar to the above. |
| 4B | **Targeted conservation + high growth** | |
| 5A | **High conservation + low growth** | This scenario represents the situation where conservation targets are met, with an emphasis on a tourism-based economy, with most resources in a good condition and a significant proportion in an EC of A or B. |
| 5B | **High conservation + high growth** | |

The further development of the scenarios will be done in the form of a matrix, where each row will represent a scenario and the columns will indicate each of the scenario element settings applicable for that scenario. More than one variation of a scenario can be analysed if necessary. The modelling assumptions for each scenario will be presented.

The consequences (resulting effect) of the scenarios on Water Quality, Ecology and Ecosystem Services, Economy and Society will be described in reports 2-4 (i.e. *Quantification of the EWR and changes in EGSAs; Ecological Base Configuration Scenarios*; and *Evaluation of Scenarios* reports).

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# 1  INTRODUCTION

## 1.1     Background

Chapter 3 of the National Water Act (NWA: No. 36 of 1998) lays down a series of measures which are together intended to ensure protection of the water resources.  In accordance with these measures, the Department of Water and Sanitation (DWS) in line with Section 12 of the NWA, established a (Water Resource Classification System (WRCS) that is formally prescribed by Regulations 810 dated 17 September 2010. The WRCS provides guidelines and procedures for determining Water Resource Classes, Reserve and Resource Quality Objectives.

Section 13 of the NWA states that "as soon as reasonable practicable after the Minister prescribed a system for classifying water resources, the Minister must, subject to subsection (4), by notice in the Gazette, determine for all or part of every significant water resource-

    a)        A Class in accordance with the prescribed classification system; and
    b)        Resource quality objectives based on the class determined in terms of paragraph (a).

The Chief Directorate: Water Ecosystems has therefore commissioned a study to determine Water Resource Classes (WRCs) and associated Resource Quality Objectives (RQOs) for all significant water resources in the Berg-Olifants Water Management Area (WMA) that lie outside the Olifants-Doring parts of the WMA. This study therefore covers the area of the former Berg WMA (i.e. former WMA 19).

The Berg River is the largest catchment in the study area, which also includes a number of smaller catchments such as the Diep, Kuils, Eerste, Lourens, Sir Lowry's, Steenbras, as well as various small catchments on the Cape Peninsula and along the West Coast, as shown in                 Figure 1.1.

The 7-step WRCS procedure is prescribed in the WRCS Overview Report (DWAF, 2007) leading to the recommendation of the Class of a water resource (the outcome of the Classification Process).

## 1.2     Objectives of the Study

The main objectives of the Study are to undertake the following:

- Co-ordinate the implementation of the WRCS, as required in Regulation 810 in Government Gazette 33541, by classifying all significant water resources in the Berg Catchment.
- Determine RQOs using the DWS Procedures to Determine and Implement RQOs for all significant water resources in the Berg Catchment.

In addition the project will require extensive stakeholder engagement and capacity building of relevant DWS and proto-Catchment Management Agency (CMA) staff.

The final outcome from the study will be the recommendations for the desired Water Resource Classes and associated RQOs presented to DWS for gazetting.
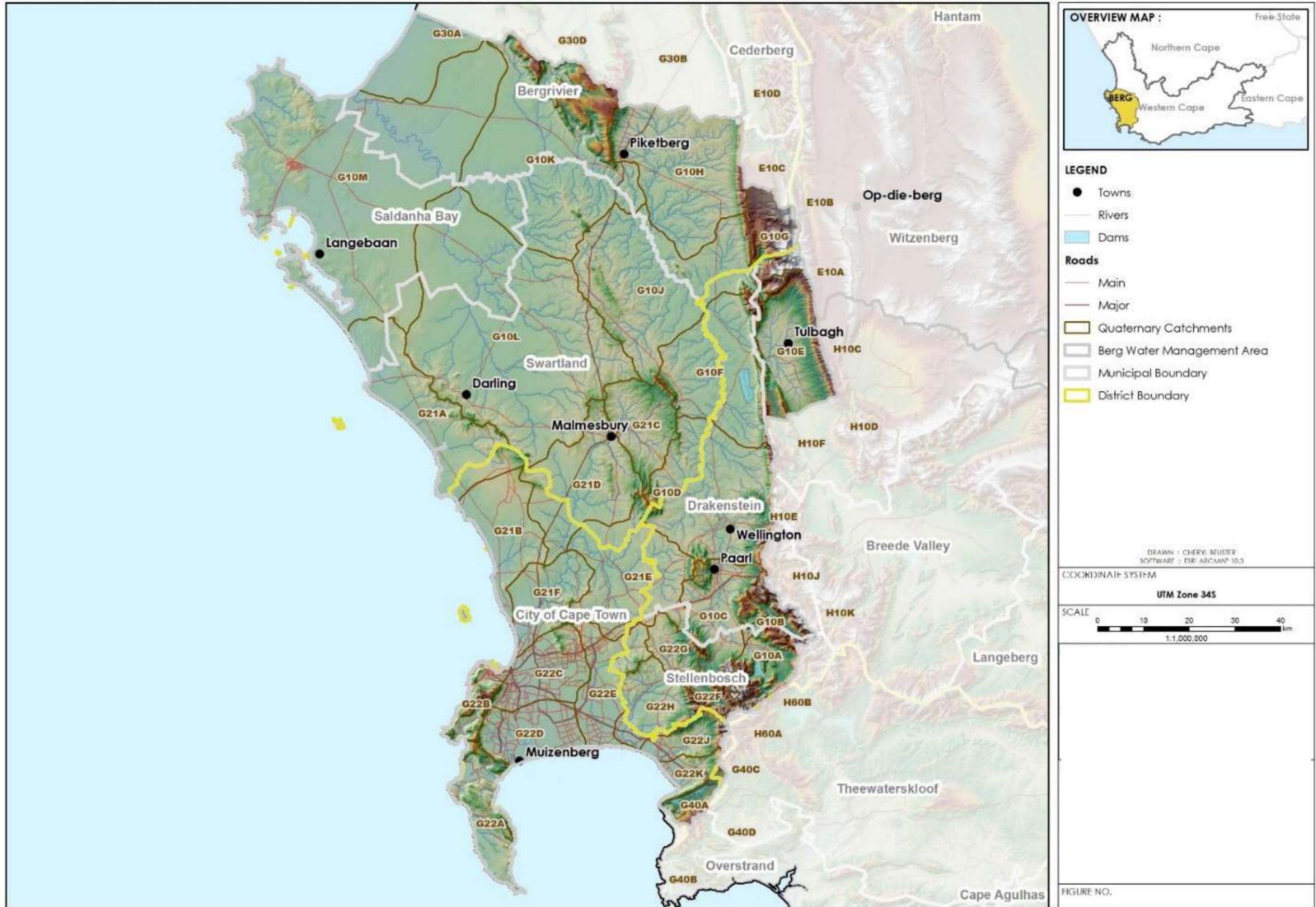
**Figure 1.1:** Map of the study area

## 1.3    Purpose of this Report

Following *delineation of resource units* and *describing the status quo of water resources*, *linking the value and condition of water resources* is the next step required in terms of the Classification Procedure for Water Resources, as shown in Figure 1.2.  In terms of the deliverables required for this study, the following separate reports will be required:

1. Linking the Value and Condition of the Water Resource

2. Quantification of the EWR (Ecological Water Requirement) and changes in EGSAs (ecological goods, services and attributes)

3. Ecological Base Configuration Scenarios

4. Evaluation of Scenarios

STEP 1: Delineate Resource Units & describe Status Quo of water resource

STEP 2: Link value & condition of water resource

STEP 3: Quantify EWRs and changes in non-water quality EGSAs

STEP 4: Determine scenarios

STEP 5: Evaluate scenarios within IWRM process

STEP 6: Evaluate scenarios with stakeholders

STEP 7: Gazette & Class configuration
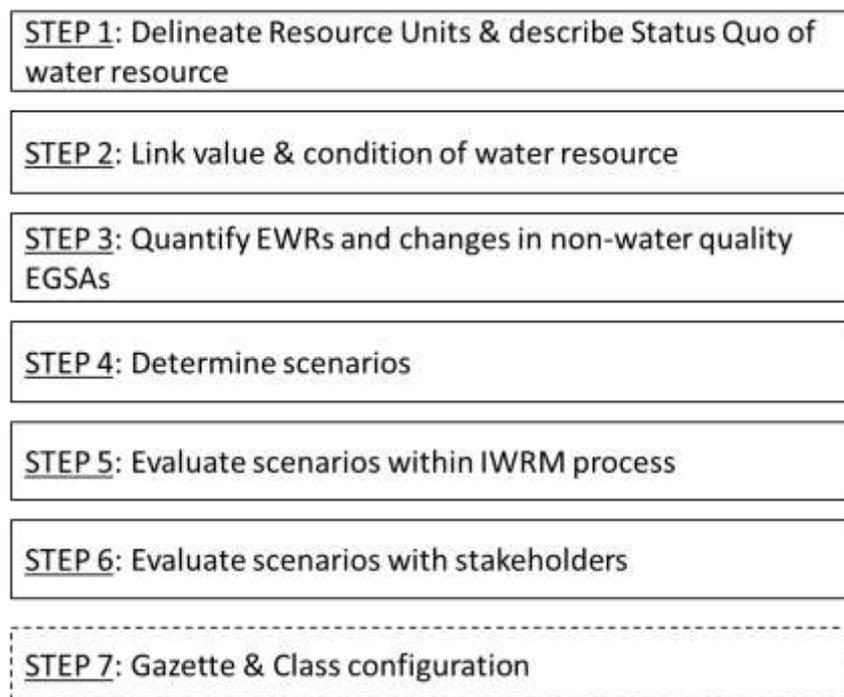
**Figure 1.2:  7 Step Procedure to determine Water Resource Classes**

Step 2, related to this report, is associated with and provides the introduction for Steps 4 and 5 (Figure 1.2). Steps 4 and 5 are closely linked to Step 6 whereby the scenarios are evaluated with stakeholders and the draft Water Resource Classes (WRCs) are determined.

The objective of step 2 of the WRCS, Linking the Value and Condition of the Water Resource, is to describe and document the following:

- Identification of Classification scenarios.

- Water quality consequences (water quality for users).

- River ecological consequences of the operational scenarios at the key biophysical nodes (EWR sites) by evaluating and determining the impact on the Ecological Category (EC) and capacity to supply ecosystem services

- Economic consequences of Classification scenarios by determining the sectoral impacts of scenarios on yield and ecosystem services.

- Socio-economic consequences of Classification scenarios by determining the impacts of any water allocation changes on poorer households. .
- Integrating and evaluating the consequences to provide preliminary WRCs for stakeholder evaluation.

The process described above is illustrated in Figure 1.3. This illustrates the broad conceptual process from the determination of the *status quo* (Integrated Step 1) through to the determination of Water Resource Classes. Within these steps there are further sub-steps that pertain to the development of the relationships and assumptions used in each step. The first of these is the determination of the flow – ecosystem condition relationships which allow the determination of the class threshold flow requirements. These relationships are described in the EWR report. The second is the defining of the operational assumptions, yield models and allocation assumptions and water quality models used to determine the impacts of each scenario on the quantity and quality of water available to water users. The third is to link the ecosystem condition (or Class) to economic outputs and societal wellbeing in order to estimate changes in these criteria under different Classification scenarios. The fourth is to define the framework with which to evaluate the scenarios in conjunction with stakeholders in order to come up with a preferred Classification scenario. This would form the basis for recommended Classes for each of the integrated units of assessment (IUAs) of the study area.

This report provides an overview of the second, third and fourth elements described above.
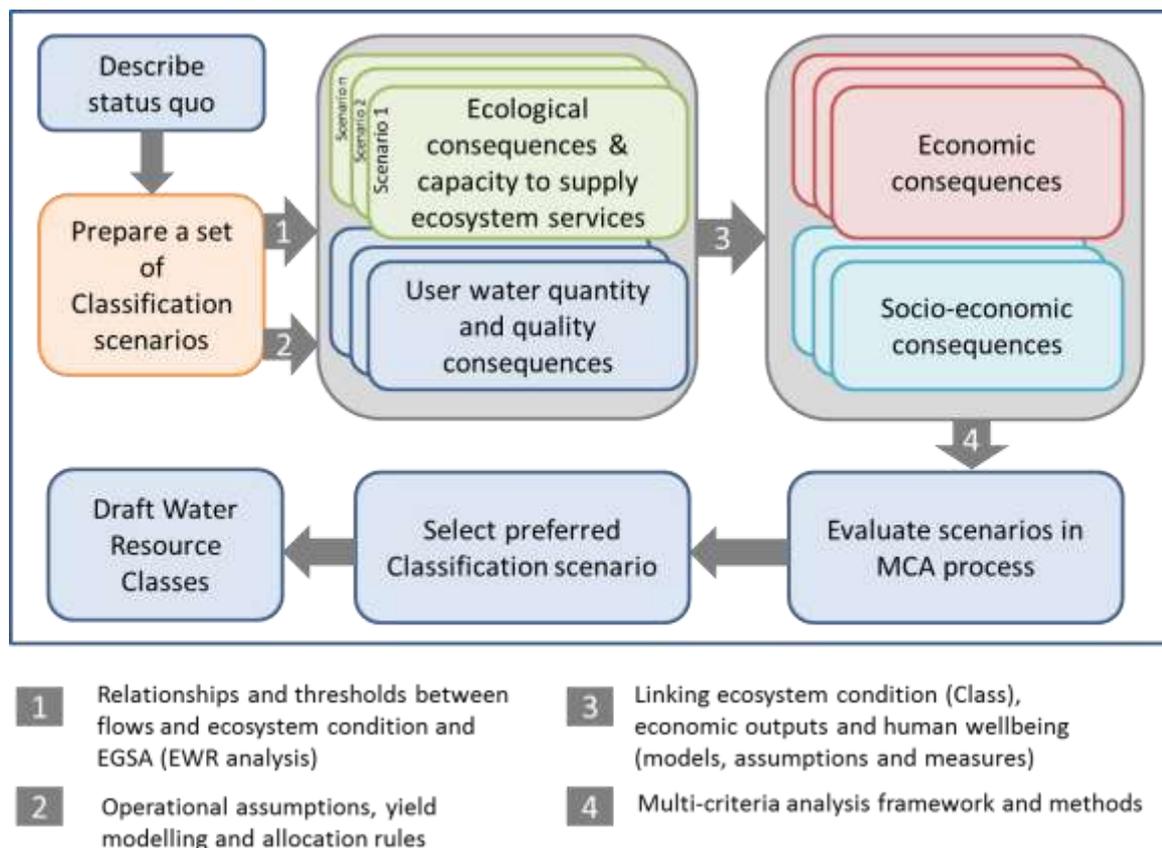


Figure 1.3:  The process in Step 4 and 5: Identification of scenarios to the gazetted water resource class

# 2 OVERVIEW OF CONDITION-ECONOMY-SOCIETY LINKAGES

The Classification of water resources will define their intended condition and the amount and quality of water required to maintain that condition. This in turn will determine the volume of water available for use. The Classification of water resources in the study area will be decided at the IUA scale on the basis of an analysis of a range of alternative scenarios in which the classes of each IUA are varied in different combinations. This report lays out the methods and assumptions used in estimating the changes in economic output and societal wellbeing as a result of changes in water use and ecosystem services under the different water allocation scenarios.

The economic impacts are considered in terms of changes in the two main macro-economic indicators of Gross Domestic Product (GDP) and employment, as well as changes in cost savings due to changes in specific types of ecosystem services. This requires estimating the relationships between water use and economic outputs as a result of production in water user sectors, stream flow reducing sectors and sectors relying on ecosystem services. The social impacts are considered in terms of a composite index of societal wellbeing that takes impacts on household income, health and happiness into account.
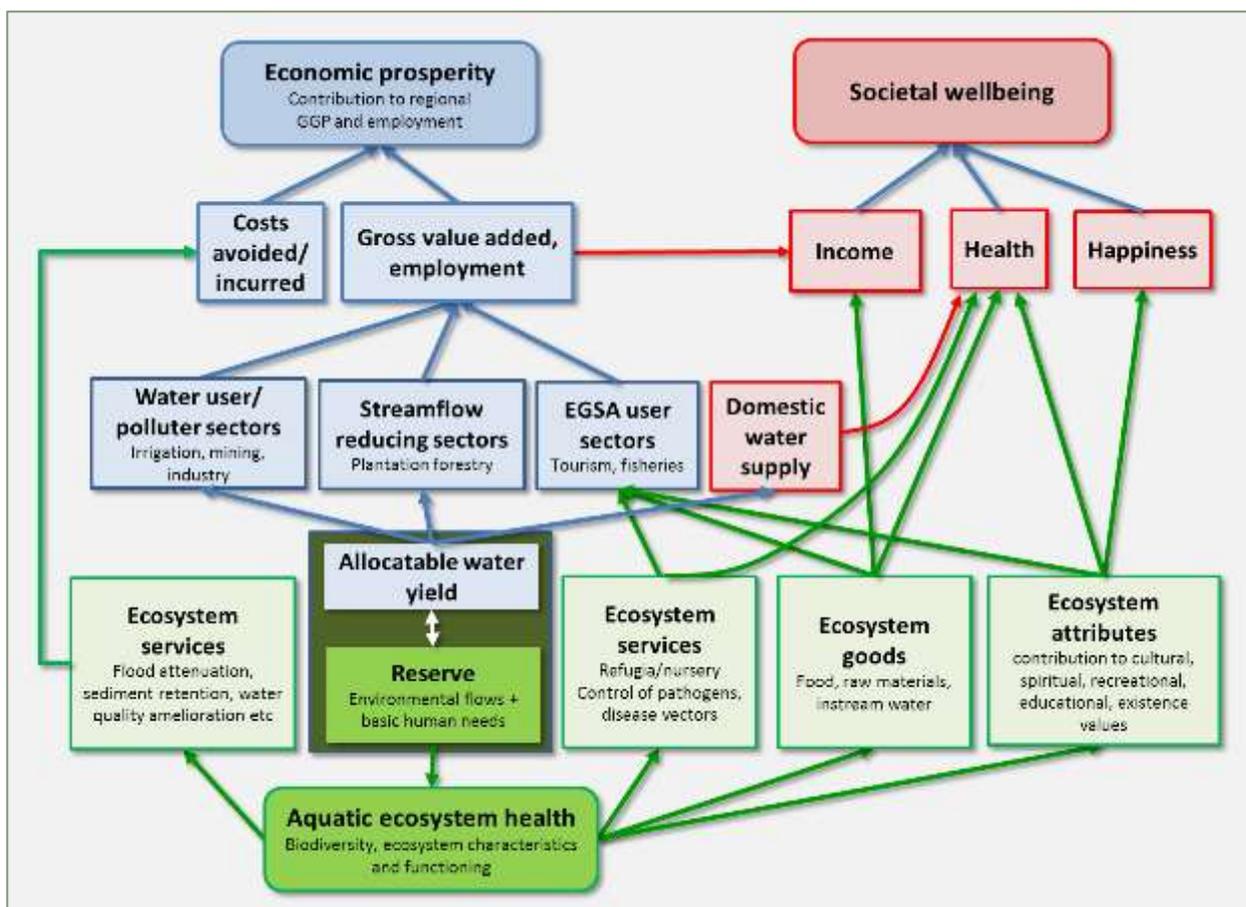


**Figure 2.1: Linkages arising from the trade-off between water abstracted for use and water retained for the Reserve (source: modified from Turpie et al. 2006)**

# 3 INTEGRATED SCENARIO EVALUATION APPROACH

## 3.1 Overview of the Scenario Evaluation Process

Considering that the core purpose of the Classification process is to select the WRCs (DWA, 2007) for all significant water resources in the Berg Catchment, the scenario evaluation process provides the information needed to assist in arriving at a recommendation that will be considered by the Minister of Water and Sanitation, 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 WRC 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, economic and societal benefits obtained as a result of the Classification choices made. The scenario evaluation process therefore estimates the consequences that a set of plausible scenarios will have on these elements by quantifying selected metrics to compare the scenarios with one another.

The sequential activities carried out to evaluate the scenarios are presented in Figure 3.1.
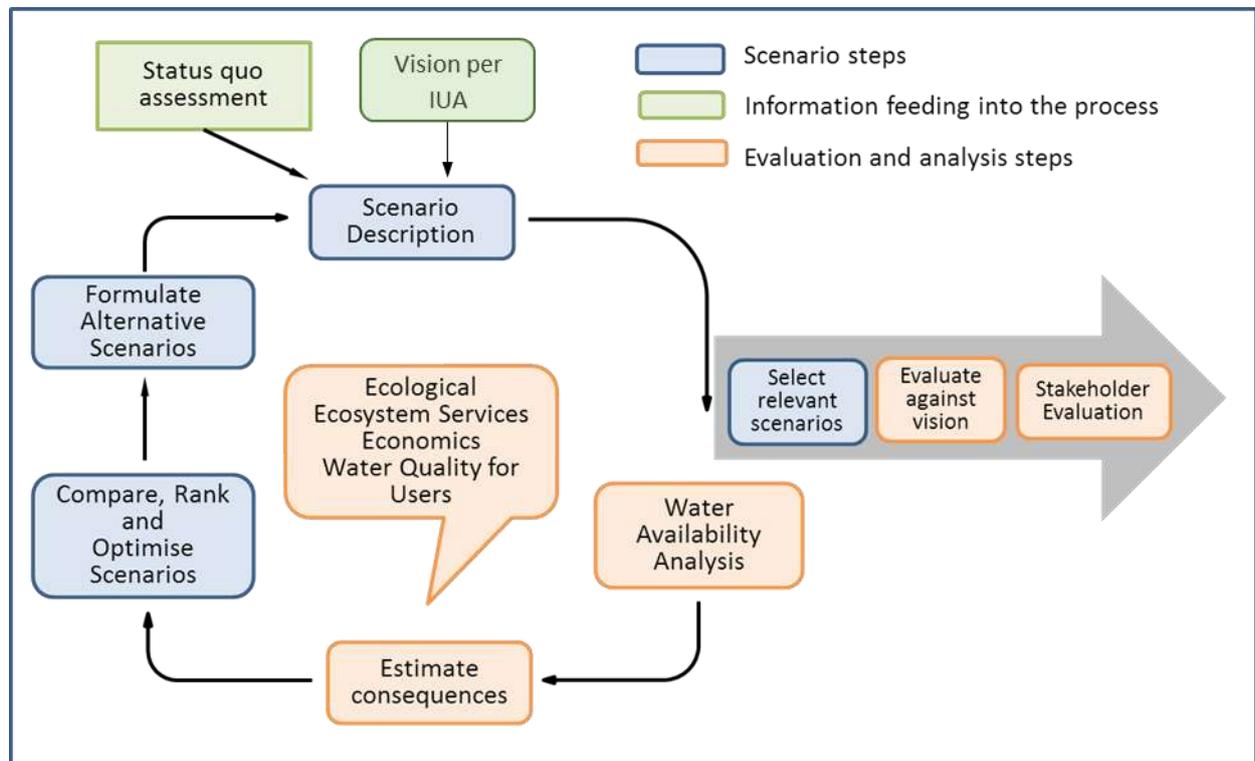


Figure 3.1: Schematic presentation of the scenario evaluation process

The status quo information will be applied to identify the components requiring evaluation and defining the relevant parameters to be quantified. Water availability analyses will be carried out for the scenarios, and this feeds into the activity to determine the consequences on Water Quality, Ecology, Ecosystem Services, Economy and Society.

The scenarios will be ranked, first, for the individual variables and secondly an overall integrated ranking will be derived based on multi-criteria analysis methods. The results of the initial set of scenarios will be interpreted to identify alternative release rules to improve the integrated scores with the objective to find and recommend an optimised scenario.

## 3.2      Scenario Description

The definition and evaluation of scenarios will be undertaken in the context of the prevailing and proposed water resource management activities in the Berg Catchment. With the understanding that a scenario, in the context of water resource Classification, comprises a potential configuration of classes for the water resources in each IUA, together with plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in the catchment – the preliminary list of scenarios were derived by consultant team working sessions. This preliminary list will be discussed with DWS, and will be presented to stakeholders for their consideration and inputs, after which a final list will be compiled for evaluation.

## 3.3      Determine Flows and Water Availability for Use

By applying the relationships defined in the EWR report, all the relevant flow and water quality requirements will be determined for each of the biophysical nodes relating to the significant rivers, estuaries and wetlands, for each scenario.  In order to do this, the flows required to achieve a particular ecological state will be defined at selected nodes (key biophysical nodes or EWR sites).  Another key prerequisite for this activity will be to incorporate these nodes into the water resource simulation model to enable the generation of monthly time series of flow data at the nodes for the scenarios where appropriate.

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 appropriate EC between A and D.  Some portion of the flow (to maintain a particular EC) is derived from surface water (runoff), and some from groundwater (via the groundwater contribution to base flow). Use of groundwater can reduce base flow hence impact the flow (and EC), and surface water use clearly impacts runoff hence flow (and EC). In order to relate the flow requirement per EC to surface and groundwater availability for use, information is required on the contribution to flow from groundwater and surface water.

The water resource simulation model incorporates groundwater contribution to base flow, and these numbers will be verified against all available information to establish likely groundwater contribution to base flow per quaternary catchment, and where possible disaggregated to the biophysical nodes. Knowing what portion of flow derives from groundwater and surface water enables a decision to be taken as to whether to meet the required flow from groundwater (impacting on groundwater availability for abstraction) versus surface water (impacting on surface water availability for abstraction), or whether a combination of both is required.

The water resource simulation model will be applied to determine the volume of surface water that is available for abstraction from the water resource for economic use, given that particular flow regime in the river is required to achieve a certain EC. A groundwater balance model will be used to relate the change in base flow per EC to groundwater availability in the aquifers surrounding a biophysical node and contributing to base flow.

Note that depending on how the scenarios are set up, the present EC configuration may be used to define flow requirements, which then determine how much surface and groundwater is available for use, or a development scenario may be defined and related to particular water requirements, in which case the resultant EC configuration would be derived, subject to a constraint of minimum flows to maintain D category.

## 3.4    Characteristics of Rivers, Wetlands and Estuaries

By applying the relationships defined in the EWR report, all the relevant ecosystem characteristics, including those relating to ecosystem health, biodiversity conservation targets and the delivery of EGSAs, will be determined for each of the biophysical nodes relating to the significant rivers, estuaries and wetlands, for each scenario.

## 3.5    Describe the Consequences

The ecosystem characteristics 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 3.1 indicates the aspects that will be evaluated. Table 3.1 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 3.1:    Variables to be considered in the scenario comparison and evaluation process

| Variable | Components | Evaluation method and purpose |
|---|---|---|
| **Ecological** | <ul><li>Overall state of aquatic ecosystem health (a weighted measure / 100)</li><li>% of freshwater conservation targets met (national obligation)</li><li>% of estuary conservation targets met (national obligation)</li></ul> | Determine the EC and indicate the degree in which the scenario achieves the REC. |
| **Water Quality for Users** | <ul><li>Empirical impacts on salinity and nutrient enrichment</li><li>Qualitative impacts on constituents of concern in a particular IUA</li><li>Microbial pollution</li></ul> | 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. |
| **Economic** | <ul><li>Losses / gains in Total Value Added + Costs saved/incurred</li><li>Losses/gains in Total Employment</li></ul> | Determine the economic benefit of utilising the available water (abstractions) in terms of Gross Domestic Product (GDP) and Employment (Jobs). |
| **Society** | <ul><li>Impact on livelihoods</li><li>Income to poor households</li><li>Intangible benefits to society</li><li>Water allocation reform</li></ul> | Determine the extent that each scenario changes the livelihoods, income to poor households, and intangible benefits to society. |

## 3.6    Compare, Rank and Optimise

The consequences from the above mentioned 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 the Multi Criteria Analysis (MCA) 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 3.1 may differ in their relative importance (see Chapter 10 for further details on the MCA methodology). When the results of the

first set of scenarios were evaluated it was identified that there were possible alternative EWR release methods (refer to section 4) that may achieve a more optimised overall solution.

## 3.7 Formulate Alternative Scenarios

After evaluation of the first set of scenarios, it is possible that alternative or revised scenarios may be devised in order to develop an improved overall solution. This activity involves the formulation of alternative scenarios, usually consisting of adjustment to or refinement of the initial list (rather than completely different scenarios) for further consideration.

## 3.8 Select Scenario Subset for Stakeholder Evaluation

The technical study team will assess several scenarios of which the results will define the boundaries of the variable settings and will point to the aspects that are important to consider in the study area. A relevant subset of the full list of scenarios will be selected for discussion with stakeholders.

# 4 PRELIMINARY DESCRIPTION OF SCENARIOS

## 4.1    Introduction

The river systems within the study area are generally 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, all of whom ultimately report to the DWS. Of critical importance is the future development scenarios for the City of Cape Town and the surrounding District Municipalities including future development opportunities such as the Saldanha Bay Industrial Development Zone (IDZ), agriculture and mining opportunities.

A preliminary list of scenarios considered for evaluation was identified in the context of the prevailing water resource management and planning activities in the study area. This preliminary list will be further refined before being presented to the Project Steering Committee for their consideration. A final list will then be taken further by the study team for analysis and evaluation.

The aim of the scenario analysis is to evaluate the consequences of allocating different volumes and quality of water to the environment, by evaluating the costs and benefits thereof.  The benefits of allocating more water to the Reserve are in the form of biodiversity conservation and ecosystem services which contribute to the economy and societal wellbeing, e.g. through eco-tourism, while the costs would take the form of increased cost of supplying water for use in economic activities (e.g. by having to build new infrastructure and adopt other, potentially more expensive, technologies sooner), reducing overall value added in the economy from water using activities.

This requires evaluating different EC configurations, in the context of different scenarios of economic development, and in the context of expected changes in climate, over a defined planning time frame, with a given set of options for augmenting water supply as demand increases over time.

The factors to be considered in the formulation and evaluation of the scenarios are described below.

## 4.2    Overview of the Scenario Approach

A range of Water Resource Classification Scenarios will be defined that describe alternative Class and EC configurations for the study area (Figure 4.1). The outcomes of these scenarios will be analysed over a defined time period, under a range of assumptions regarding climate change, projected population and economic growth, water demand management measures and overall water demand.

The result will be to estimate the costs of additional water supply measures that would need to be brought on line in order to meet the demands. This cost will be compared to the benefits of the Reserve.

Given the objectives of the study, most scenarios are likely to be set in terms of the EC configurations, from which the available water for use will be determined, based on the EWRs for the specified ECs. In some cases, scenarios could be development-focused, in which case the water requirements for development will be met, and the resultant ECs will be determined (Figure 4.2).
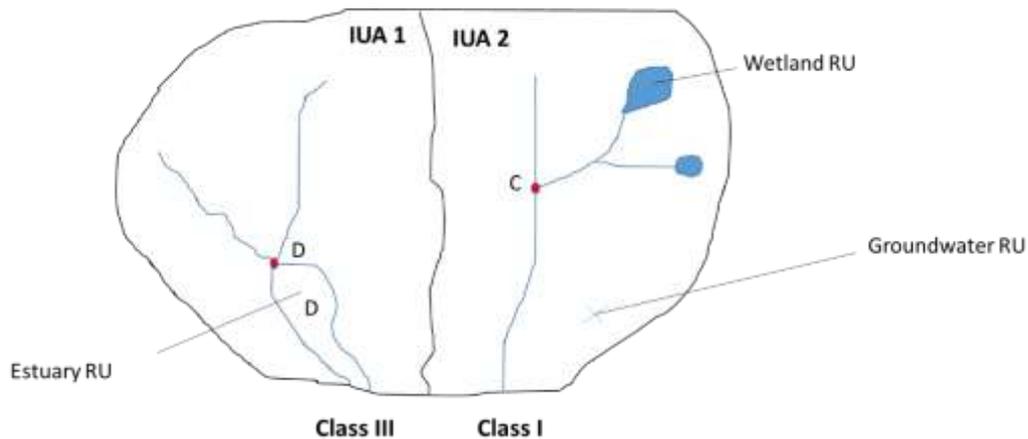
**Figure 4.1: Example of WRC and EC configuration of a catchment with two IUAs.**
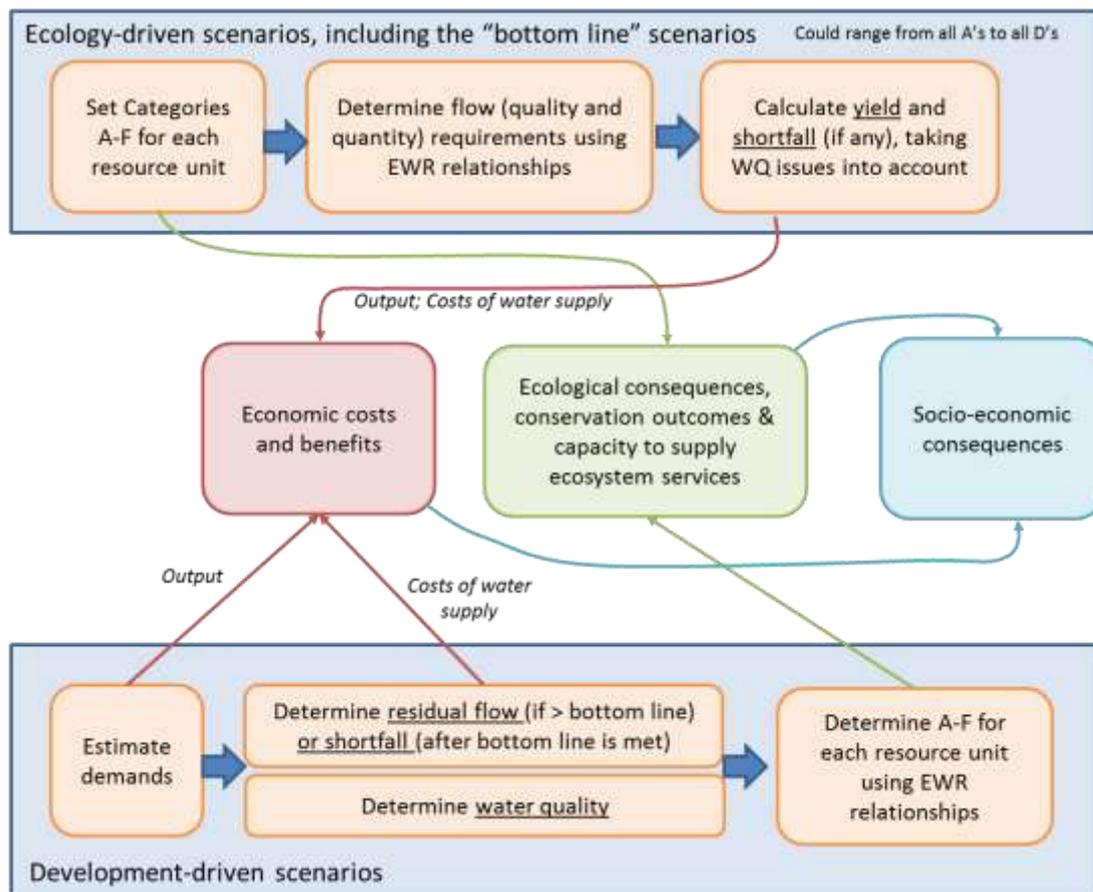


**Figure 4.2: Summary of technical processes for classification scenario assessment.**

For ecology-driven scenarios, the ecology team will provide three outputs from the Desktop model (Hughes, and Hannart, 2003) - a rule curve, a summary table and a monthly time series, which the hydrologists will use to determine the full flow distribution, and from this the surface and groundwater available for use will be determined. For surface water availability this requires consideration of the existing water supply infrastructure.

For development-driven scenarios, a set of groundwater and surface water requirements will be established related to a development scenario, and the resultant flow and hence EC configuration would be derived, subject to a constraint of minimum flows to maintain a D Category.

Defined scenario categories can be met either by river flows from upstream areas or incremental flows, a portion of which can be met by groundwater (0-100% depending on case), by return flows, spills from in-stream dams, or releases made from in-stream dams. High flows will be satisfied by high river flows and spills from dams while low flows will be satisfied by river flows and releases from dams. The release capacities from most dams in the study area are insufficient to make high flow releases. It is expected that the release capacities of (significant) new in-stream dams will be able to meet flow requirements for high flow events. Few in-stream dams are however being planned, as these are strongly discouraged by DWS, due to significant in-stream and other impacts. The implication of this is that in terms of environmental releases from dams, the dams within the study area will still be largely unregulated. The exception is the Berg River Dam which has been specially designed and equipped to make environmental releases.

## 4.3      Water Supply Infrastructure

This is fixed as at the current infrastructure situation for 2017, for all scenarios. The need for new infrastructure is then calculated for each scenario based on the shortfall calculated (refer to Section 4.7).

## 4.4      Time Frame

The time horizon for the analysis is also important. Most water-demand forecasting studies use a time horizon of about 25 years (e.g. the "All Towns Reconciliation Strategies"). Furthermore, economic forecasts beyond the short (3-4 years) or medium term (5-10 years) are very difficult because of unknown technological innovation etc. In this study it is proposed to use a time horizon of 2016 to 2035 (20 years). In all cases, the scenarios would be evaluated in the near term (as if the change was already in place), and the long term (after 20 years).

## 4.5      Climate

Water resources modelling will be carried out for present-day conditions using the available time series of historic climate information and for projected future climate conditions as at the final date (2035).

## 4.6      Current and Future Water Demand

Current water use was described by Water Resource Zone in the *Status Quo* Report. Future water requirements growth projections will be taken from the latest reconciliation strategy Status Report for the Western Cape Water Supply System (WCWSS). The Reconciliation Strategy takes potential growth in future urban water requirements into consideration through the development of future water requirements scenarios. Typically, a low-growth, medium-growth, and high-growth scenario is developed (Figure 4.3), but in this study we will just consider low and high growth scenarios to start with. Domestic water requirements are typically a function of economic circumstances and population growth.

It is not expected that significant further allocations for irrigation will be made, except to meet transformation targets. Farmers typically expand their irrigation practices horizontally by becoming more efficient on-farm, and vertically by planting higher-value crops. (Geo)hydrological water resource zones where surplus water balances are identified may be targets for the expansion of irrigation, or where bulk water infrastructure such as dams can be cost-effectively developed to allocate water for new irrigation, should suitable soils and other enabling conditions be in place, or can be put in place. There are however extremely few options available, if any, to develop additional yield cost-effectively for irrigation purposes, unless farmers are subsidised.

If completed in time, the initial results of the Verification and Validation (V&V) of Water Use study for the Berg-Olifants WMA will be taking into account in terms of estimates of future water demands for the study area.
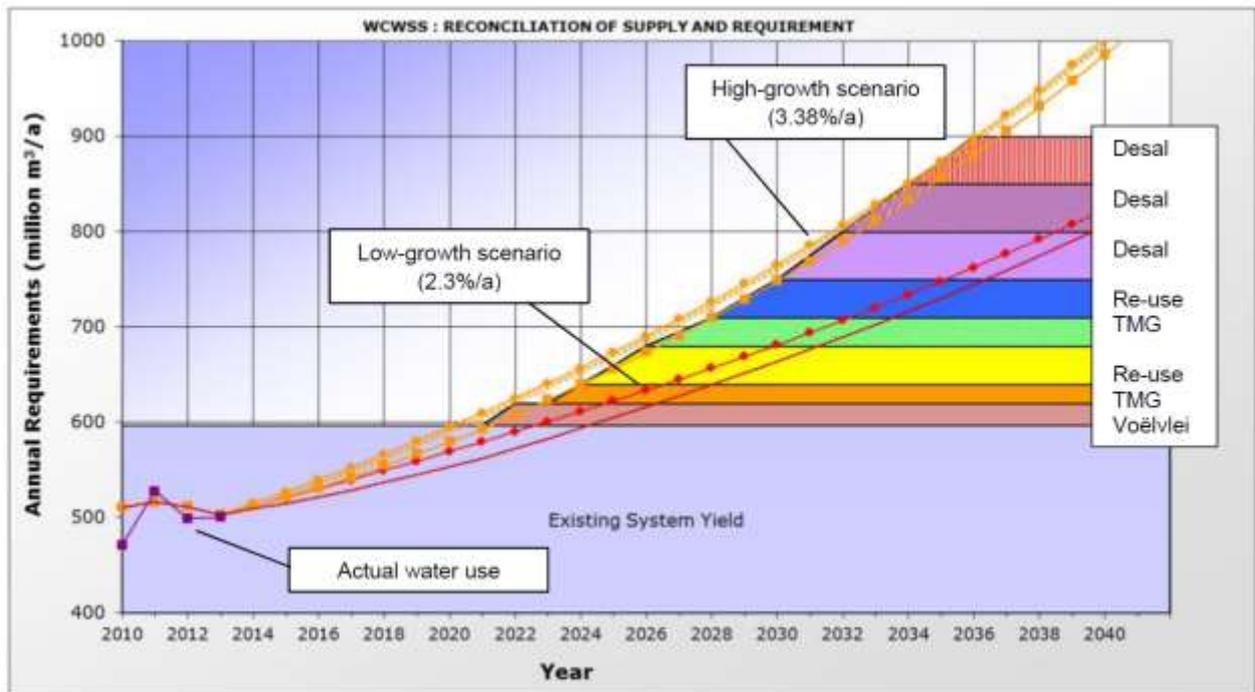


**Figure 4.3: Reconciliation of future water demands and interventions for the WCWSS (DWS, 2015).**

## 4.7    Options for Meeting water Supply Shortfall

Based on the difference between system yield using current infrastructure and projected growth in water requirements, the shortfall in meeting demands will be estimated (after meeting the Reserve), which is then translated into the costs of augmenting water supply to the level required in 2035.

Water supply infrastructure comes on line in relation to the projected rate of growth in water requirements relative to current water requirements.  So it will be necessary to work out an equation (or set of area-specific equations) to estimate the cost of water supply under the different scenarios.

Under the Reconciliation Strategy Study for the Western Cape Water Supply System and the All-Towns Reconciliation Strategy Studies, intervention options have been identified for consideration as measures to reconcile potential future water requirements with availability. An intervention is a measure that must be timeously implemented, either by reducing water requirements or by increasing water availability, to prevent the risk of a water shortage or the implementation of unitive water restrictions to reduce demand becoming unacceptable.

**Interventions options** that were considered can include the following potential interventions:

- Water conservation and water demand management (WC/WDM), reducing water demand as a result of increasing water use efficiency.
- Reuse of effluent, reducing water demand from other sources, i.e. providing treated effluent in lieu of water previously provided from other water sources.
- Improved operational practices of existing water infrastructure, reducing water demand as a result of improved operational efficiency.
- New or increased run-of-river diversions/abstractions from rivers
- Construction of new dams (instream or off-channel)
- Raising of existing dams

- Increased demands placed on existing supply sources, that are not yet fully utilised
- Increased groundwater abstraction from existing sources, within he safe aquifer yields
- New groundwater development
- Artificial recharge of aquifers
- Conjunctive use of surface and groundwater
- Transfer schemes, either transferring water in or out of the WMA
- Augmentation through desalination of brackish river water, groundwater or seawater

A list of potential intervention options, and potential implementation dates (if available) will be compiled, following scrutiny of the Reconciliation Strategy studies and other potential sources, such as known initiatives by municipalities that may not yet be fully integrated into the Reconciliation Strategies.

## 4.8 Proposed Ecological Classification Scenarios

The approach for establishing the suite of scenarios to be provided for hydrological analysis will consider different EC configurations in which environmental flows vary spatially and in their overall levels. Some of the spatial configurations would be driven by conservation priorities for freshwater systems and estuaries.

The preliminary range of scenarios to be developed is as shown in Table 4.1. The only variation will be (a) the EWR requirements and (b) the water demands that have to be met. This will allow evaluation of the trade-offs between ecological and socio-economic consequences.

**Table 4.1: Preliminary Scenarios**

| # | Scenario | Description |
|---|----------|-------------|
| 1A | **Maintain PES + low growth (=Baseline)** | River, wetland and estuary systems are maintained in their present condition. |
| 1B | **Maintain PES + high growth** | |
| 2A | **Bottom line + low growth** | The maximum volume of water is made available for abstraction from the system for economic activities, with the proviso that all water resources are just maintained in a D class (the ecological "bottom line"). |
| 2B | **Bottom line + high growth** | |
| 3A | **RECs + low growth** | The RECs determined for rivers, wetlands and estuaries based on present health and conservation importance (but without any consideration of socio-economic effects) are applied in these scenarios. |
| 3B | **RECs + high growth** | |
| 4A | **Targeted cons+ low growth** | High ECs are given to areas of high conservation importance, but for other areas, the ECs can be below REC. It may end up that this scenario set is similar to the above. |
| 4B | **Targeted cons+ high growth** | |
| 5A | **High conservation + low growth** | This scenario represents the situation where conservation targets are met, with an emphasis on an eco-tourism-based economy, with most resources in a good condition and a significant proportion in Classes A or B. |
| 5B | **High conservation + high growth** | |

# 5    ENVIRONMENTAL FLOWS

By applying the relationships defined in the EWR report, all the relevant flow and water quality requirements will be determined for each of the biophysical nodes relating to the significant rivers, estuaries and wetlands, for each scenario.  In order to do this, the flows required to achieve a particular ecological state will be defined at selected nodes (key biophysical nodes or EWR sites), along with rules to make releases from upstream weirs and dams.  Another key prerequisite for this activity will be 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.

Note that depending on how the scenarios are set up, the present EC configuration may be used to define flow requirements, which then determine how much water is available for use, or a development scenario may be defined, in which case the resultant EC configuration would be derived, subject to a constraint of minimum flows to maintain a Class D category

The methods used to generate the EWR data to construct the EC scenarios will be described in the "*Quantification of the EWR and changes in the EGSAs*" report, which will be accompanied by an electronic appendix of all the EWR data files; *.tab files, *.rul and *.mrv files as they are only useful for hydrological modelling. As the regions within the WMA are so diverse, it will be necessary to consider defining hydrological water resource zones of similar characteristics across which to generalise the EWR models to be applied for each Resource Unit.

The scenarios and the methods used to generate the time series\ of scenario flows will be described in the "*Ecological Base Configuration Scenario*" report. A "flow/condition" tool will be created in Excel to allow for "balancing and routing" of flows at a monthly time-step from source to sea, to ensure that downstream targets and flow requirements are met and to make provision for setting minimum low flow requirements. This tool allows the user to set Reserve requirements for different reaches of river that maintain a target ecological category in that section. Thus, the volumetric and distribution requirements will differ from reach to reach. This is often most evident in a mismatch between the estuary and the river reach immediately upstream.

In practice, once the Reserve is gazetted, Reserve allocations need to be sufficient to meet the river reach to which the Reserve is allocated, as well as downstream allocations. The Reserve allocations in the upper reaches are generally set to be higher than what is required to maintain the ecological condition in order to balance flows across a catchment. In order to meet downstream Reserve allocations it is often necessary to source additional water from undeveloped tributaries by both increasing these tributaries Reserve requirements and by limiting increases in more developed areas to the winter months. In this case winter allocations are often limited to certain months (i.e. July, August and September) due to farms dams delaying the onset of first winter flows in June and reducing the duration of the winter flows in October. This means that higher Reserve requirements in July, August and September should not reduce the existing yield from farm dams.

# 6 WATER AVAILABLE FOR USE

## 6.1 Overview of Surface Water Resources Models

### 6.1.1 Models for Surface Water Decision Support

The rainfall-runoff catchment and water resources system analysis models that have been configured in previous studies for all or parts of the study area are outlined in Table 6.1.

Table 6.1: Surface water decision support models configured in previous studies

| Model | Year Configured | Catchments and River Systems | Project Owner |
|-------|-----------------|------------------------------|---------------|
| WRYM | 2014 | The entire WCWSS area. | DWS |
| WRPM | 2014 | The entire WCWSS area. | DWS |
| WR2012 Pitman | 2013/2014 | The entire study area. | WRC |

The DWS updated earlier WCWSS configurations of the Water Resources Yield Model (WRYM) and Water Resources Planning Model (WRPM) system models as part of the recently-completed Study: *Development of Integrated Annual and Real Time Operating Rules for the Western Cape Water Supply System* (2014). In this Study, the 2014 configuration of the WRYM system yield model is used for yield analysis relating to all the relevant components of the WCWSS.

For the lesser coastal catchments that do not form part of the WCWSS, the WR2012 Pitman model configurations for those catchments were employed. The WR2012 configurations of the Pitman model for the present-day case include all bulk water resources infrastructure, demands, clusters of farm dams, run-of-river abstractions, afforestation, invasive alien plants, return flows from irrigated areas and treated effluent return flows.

### 6.1.2 Incorporation of Biophysical Nodes into Water Resource Models

In total, 47 biophysical / allocation river nodes and 22 estuary nodes have been identified across the study area. The river nodes that fall within the WCWSS were incorporated into the WRYM configuration at the applicable locations. The original WR2012 configurations of the Pitman model were structured around Quaternary catchment delineations. The WR2012 configurations located outside the WCWSS were further sub-divided to reflect the contributing catchments to both the biophysical/allocation river nodes and the estuary nodes.

### 6.1.3 Proportioning of Incremental Stream Flows at Nodes.

Because the locations of the biophysical and allocation river nodes occasionally did not coincide with locations of existing modelling nodes in both the WRYM and Pitman configurations, streamflows at each such river node had to be derived by proportioning of the incremental streamflows at the immediately downstream existing modelling node on the basis of the Mean Annual Precipitation (MAP) and area of the incremental catchment of the river node and the well-established WR90 MAP-Mean Annual Runoff (MAR) (in mm) regionalised curves. The incremental MAPs of river node incremental catchments were derived

from the WR2012 gridded MAP coverage of the whole country through Geographic Information System (GIS) applications.

Estuaries of major rivers usually represent the outflow point of the most downstream Quaternary of their catchments, whereas the catchments of minor estuaries sometimes comprise only a portion of a Quaternary. For various minor estuaries a similar proportioning exercise to that described above for river nodes, was conducted.

### 6.1.4 Improvement of Existing WR2012 Pitman Model Configurations

In the course of incorporation of the biophysical and allocation river nodes into the existing WR2012 Pitman model configurations, a number of incorrect aspects of these configurations were noticed and corrected. These aspects include occasionally incorrect items relating to bulk infrastructure details, demands, irrigation areas, model routes and sub-catchment interlinkages. The WR2012 configurations were improved by correcting all the above aspects.

## 6.2 Surface Water Availability

### 6.2.1 Definition of Surface Water Yield

The evaluation of ecological consequences of changes in water availability under different catchment development / conservation scenarios should be conducted for conditions of relative surface water scarcity, rather than of relative surface water abundance. Surface water availability is generally expressed as *yield at a selected percentage assurance of annual supply* (or annual recurrence interval of failure of supply) at system or sub-system level. Typically, in integrated planning of bulk system augmentation schemes to meet future increases in water requirements, a 98% assurance of annual supply (i.e.1:50 year recurrence interval of failure) is used to express water availability. However, such a high assurance of water supply represents a situation of extreme relative surface water scarcity (i.e. a severe drought) for which provision of domestic water supply must still be ensured, but would therefore not be appropriate for this study. Instead, values for assurance of annual supply of 90% or 80% (i.e. recurrence intervals of failure of 1:10 and 1:5 years, respectively) are more appropriate because they represent more common climate conditions of relative surface water scarcity, without being unrealistically severe.

### 6.2.2 Scaling Down to IUA Level

The consequences of changes in water availability are evaluated at the Integrated Unit of Analysis (IUA) scale. However, given that the simulated yield usually represents the integrated contributions of various components of the surface water system, while IUAs do not necessarily constitute logical surface water system units, the changes in yield will be disaggregated to the IUA scale. This process will also include spatial proportioning of domestic versus irrigation water requirements.

### 6.2.3 Inclusion of the Potential Impacts of Climate Change

The changes to surface water availability due to the potential impacts of climate change have been projected by application of a wide range of climate change impact models for different emission scenarios (Cullis et al, 2015). The results for a "moderately dry" scenario (for example, the 75th percentile) will be selected from the "drying" side of the spectrum of outcomes from the above study and super-imposed on one of the development/conservation scenarios.

### 6.2.4 WRYM Modelling Approach

As stated earlier, the WCWSS will be modelled as an integrated system by means of the existing WRYM configuration. For each scenario the existing configuration and/or the operating rules will be changed as required by that scenario. The resulting integrated system yield as well as sub-system yields (at 90%/80%

assurance (to be decided) will be determined stochastically as per the usual application of the stochastic streamflow generation utility included in the WRYM.

### 6.2.5    WR2012 Pitman Approach

As stated earlier for the smaller coastal river systems the WR2012 Pitman model configuration, as improved for this study, will be used. For each scenario the existing configuration and/or the operating rules will be changed as required by that scenario and the resulting 100 years of monthly stream flows simulated at each node of interest in each IUA. The determination of the (90% or 80%) yields at all points of interest in each affected IUA will be determined by the annual volume of water abstracted with either 10 or 20 actual failures of supply.

## 6.3    Groundwater Yield 'Model'

In order to relate flow (and resultant EC) to surface and groundwater availability, information is firstly required on the contribution to base flow and resulting flow per biophysical node. Groundwater contribution to base flow is incorporated in the (updated) WR2012 based on the Pitman model. These datasets will be compared with all available data from other sources (GRAII, existing numerical models in the area, all relevant previous studies in the area) to establish the groundwater contribution to base flow (and hence flow and EC), per biophysical node.

Groundwater use can reduce base flow, hence relationships are required to relate changes in groundwater use in particular aquifers, to base flow at the nodes. Groundwater balance equations incorporating recharge, existing use, and base flow will be established per aquifer per groundwater resources unit, and related to biophysical nodes. The limitations and over-simplifications incorporated in this approach (necessary for largescale investigations) will be specifically documented. To support groundwater balance equations, numerical model(s) will be developed. This information will be documented in the *Ecological Base Configuration Scenarios* report.

# 7 QUANTIFYING CONSEQUENCES FOR BIODIVERSITY AND CAPACITY TO SUPPLY ECOSYSTEM SERVICES

## 7.1 Introduction

The relationships between flows water quality and ecosystem condition, biodiversity and functioning will be described in the report "*Quantification of the EWR and changes in EGSAs*". A short summary of the general approach and data pertinent to the overall process of scenario evaluation is provided in this section.

## 7.2 Biodiversity and Ecosystem Condition

A total of 47 biophysical nodes were allocated in the study area, as described in the "*Resource Units* and *IUA Delineation*" Report. Routing flows through so many nodes may be cumbersome and it will be necessary to prioritise nodes for the scenario analysis. A range of biophysical data are useful to quantify biodiversity that can help guide the prioritisation of nodes for scenario evaluation and analysis and be used to determine the outcome of the scenario evaluation (see Section 10). Some of these data have already been summarised in the reports already completed and much is contained in the *Status Quo* Report. A summary of these data and their use in this process is provided below.

The index of Water Resource Use Importance (WRUI) to identify priority areas is shown in Figure 7.1.

The PES, EI and ES data used in this process were summarised in the PESEIS study (DWS 2014). The usefulness of the SCI and WRUI data in this process can only be assessed once the tool is provided to the study team, therefore it is not considered further here.

The Resource Unit Prioritisation tool will be used as described in the Inception Report. In general though, whether the Resource Unit Prioritisation tool is used or not, nodes must be prioritised in a way that captures:

- The location of EWR sites
- Sites that maintain links with other important aquatic ecosystems, such as nodes for floodplain wetlands, lakes or estuaries
- Sites linked to important areas of water supply and demand
- Sites where National Freshwater Ecosystem Priority Areas (NFEPAs) are located (but see below).

NFEPAs were delineated across South Africa by Nel et al. (2011). NFEPAs were selected based on a range of criteria, similar to that used to determine the type of rivers in the S*tatus Quo* Report, including flow, geomorphological zonation, the presence of aquatic organisms, such as fish, and rivers in good condition, normally an A- or B-category PES. Since this process was undertaken prior to the publication of the PES/EIS data (DWS 2014) the part of the selection process based on ecological condition must be checked against the new PES scores. In some instances it is also not clear in the documentation or data provided with the NFEPAs what criteria or aquatic organisms were the basis for the selection of a particular river reach as an NFEPA. Despite this NFEPAs still represent the most comprehensively gathered database for river types and importance and so provide a good starting point. The data therein must just be verified prior to use.

Linking the Value and Condition of the Water Resource | Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment

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The location of the NFEPAs will be cross-referenced into the PESEIS database and any NFEPAs located on rivers in poorer condition than A or B-categories will not be removed as NFEPAs from the analyses. The location of Phase 2 FEPAs, currently in a C-category, will also be checked in the same way. Changes in the ecological condition of the remaining NFEPAs and Phase 2 FEPAs will be monitored through the evaluation of scenarios as a measure of meeting river biodiversity performance targets.
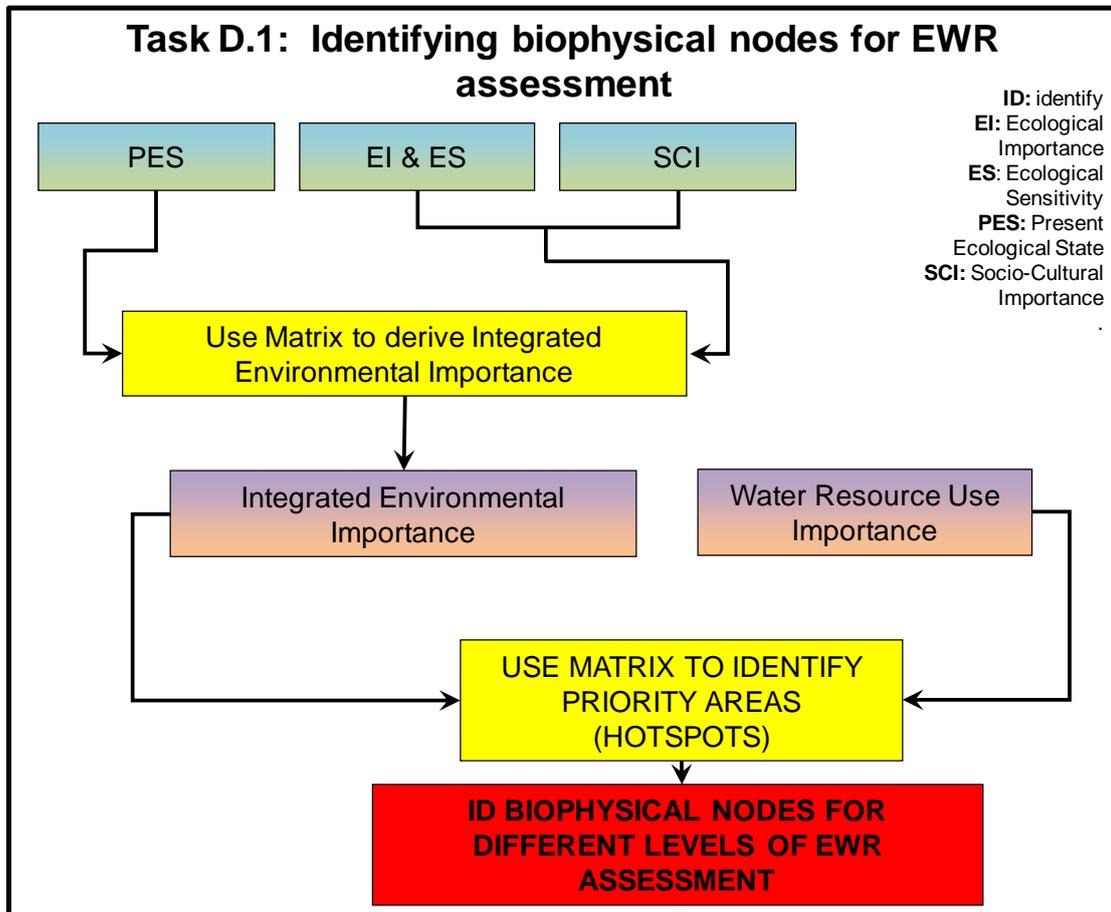


**Figure 7.1: Summary of the process to prioritise nodes for scenario evaluation and analysis (DWS 2013)**

The data summarised in the *Status Quo* Report that was used to type the rivers in order to create river Resource Units will be used to facilitate extrapolation of EWR data from EWR sites to nodes on rivers of the same type. This means that nodes that are on rivers of the same type and in close proximity to EWR sites will have the same configuration of flows for a range of ecological conditions, normally described as the REC and two Alternate Ecological Categories (AECs). In some instances, nodes are too different or too far away from EWR sites for extrapolation of EWR data. In both instances and for all nodes, Reserve allocations will be generated for a range of ecological conditions, normally B, C and D-categories, using the Desktop Reserve Determination Model of Hughes and Hannart (2003).

The Desktop Model (Hughes and Hannart, 2003) is based on the assumption that total water requirements for a river decrease as the ecological category changes from A through to D. The model consists of three components; estimation of the maintenance/drought and high/low flows, estimation of the seasonal distribution of annual total flows based upon the natural flow regime separated into high/low flows, and estimation of the rules that combine the maintenance drought requirements into continuous assurance frequency curves. The final output of these magnitude data is a table of flows for each month of the year

for a range of percentage assurances. The flows are expressed as volumes ($m^3 \times 10^6$) or as mean monthly flow rates ($m.s^{-1}$).

At sites where there was no existing EWR data in close enough proximity to justify extrapolation of EWR data a straight desktop model run, for either a Western Cape wet or dry season will be used. All the data generated in this way will produce valid comparative monthly flows between different ecological categories using the standard assurance level settings in the desktop model for classes B through D.

For each node the following data will be presented in turn. A summary of the desktop estimate (*.tab) will be followed by the assurance table (*.rul) and finally the time series of monthly flows (*.mrv) for each determined ecological category. In most cases there will be data for three ecological categories, B through D. There will be some instances where other categories are determined, for example a BC or CD and other cases where only one or two classes will be determined.

In this way ecological condition is linked directly with a time series of monthly flows so in all the scenario analyses that will be undertaken changes in flow will be translated back into categories of ecological condition as a consequence of these flow changes. The balancing tool (see Section 5) will be useful in some respects of this but it may be necessary to create an updated version to deal with the inputs required for the multi-criteria analysis of scenarios (see Section 10).

NFEPAs are not linked specifically with time series of flows but that their ecological conditions are specified means that flows can be allocated to monitor the performance of NFEPAs in this same way. Similarly, estuarine Reserve allocations are described in terms of time series of monthly flows and therefore the flows themselves become the common currency between the different components of the assessment of ecological performance with respect to changes in ecological condition.

In this way ecological condition is linked directly with a time series of monthly flows.  Thus, changes in flow in the scenarios will be translated back into categories of ecological conditions as a consequence of these flow changes. The flow/condition tool (see Section 4.4) is being updated to accommodate this assessment (see Section 10).

## 7.3 Ecosystem Services

The changes in ecosystem structure and functioning that occur as a result of changes in flows will impact on their attributes and capacity to supply ecosystem services. These relationships will be described as part of the EWR determination task, as they are elements of the ecosystem structure and functioning. The variables required as inputs into the sectoral and societal components of the assessment will be identified and assumptions regarding their relationship to ecosystem health will be described.

For example, EWR studies may provide information on the status of fish populations, but the ecosystem service of interest might be the status of a certain subset of these fish populations, e.g. for recreational fisheries in estuaries or for nursery outputs to marine fisheries. The assumptions made about how the fish resources of interest vary with ecosystem health will be described. For some ecosystem services, such as cultural services, it might be necessary to find a proxy for more intangible properties such as aesthetic appeal.

# 8 IMPACTS ON WATER QUALITY

## 8.1 Introduction

As part of the scenario evaluation, the classification process requires that water quality for users be assessed at two levels:

- The present-day water quality requirements for all water users (fitness for use).

- The water quality implications of different scenarios for different users.

## 8.2 Present Day Water Quality Status

In order to assess the water quality consequences of different catchment scenarios, it is necessary to assess the present water quality status and the degree to which the water quality requirements of users are satisfied. This then forms the basis of predicting how a specific catchment scenario would change the water quality, and then assess how this change would affect water user requirements.

The present day water quality assessment for water users was conducted for the S*tatus Quo* Report (DWS, 2016). The assessment used water quality data collected in the study area by DWS over the past five to six years (2010 to 2015/2016) to describe the present water quality status. The fitness for use was rated into the following four categories, namely "Ideal", "Acceptable", "Tolerable", and "Unacceptable".

- The Ideal category describes a water quality that is fit for all uses and that would have no impacts on any of the users.

- The Acceptable category describes water that is fit for most uses but the most sensitive users or crops might be slightly affected.

- The Tolerable category describes water quality that is moderately fit for use but impacts such as a reduction in crop yield may occur.

- The Unacceptable category describes water that is unfit for most users and that will definitely have a negative impact on water users. Users that were considered were domestic water use, agricultural (irrigation) water use, recreation, and aquatic ecosystem requirements.

A descriptive summary will be compiled of the key findings of the present water quality status assessment, describing the key water quality trends, the water quality issues, and the concerns identified in the different IUAs within the study area (DWS, 2016).

## 8.3 Water Quality Impacts of Different Catchment Scenarios

This component of the WRCS process requires assessing the change a particular scenario would have on water quality and specifically the implications on the fitness for use for the key water users in an IUA.

The concentrations of chemical constituents and values of physical variables are often dependent on flow. For example, salinity is often inversely related to flow in a river (as the flow increases the salt concentrations decrease) while phosphates or suspended sediments are often directly related to flow (as the flow increases so do the phosphate or suspended sediment concentrations). Likewise, use of greater volumes of groundwater would reduce base flow, and where groundwater has a significantly different quality to surface water, the changing groundwater use could impact on surface water quality.

Therefore, a change in the flow regime (scenarios) could cause a change in water quality.

The WRCS methods recommend that water quality be modelled along with the flows if a water quality model has been set up alongside the flow assessment model. However, the WRSM2000-Pitman model that will be used to assess the flow scenarios in the study area, has not been configured to simulate water quality.

The empirical water quality related changes and impacts will be estimated for Total Dissolved Solids (TDS), and nutrients. This would entail the following steps:

- Determine an empirical relationship between average daily flow and constituent concentrations for the key monitoring points. The FLUX32 program of the USACE will be used to determine the relationship. This approach requires a paired data set of concentration and flow on the day a particular water sample was collected and can only be used for sampling points where flow and water quality data are available.

- Use the Flow: Concentration relationship with the predicted flow duration curve for each catchment scenario at the outflow of the IUA to estimate a constituent concentration distribution.

- Calculate the 95th percentile concentrations for a specific scenario.

- Compare the percentiles for each scenario to the user requirements to assess the potential water quality impacts.

- Confirm if the catchment scenario being evaluated results in a change in the overall fitness-for-use category, or the fitness-for-use category for a specific user sector.

- If there is insufficient data to develop the Flow: Concentration relationship, or if there is no relationship between a constituent concentration and flow, the present-day 95th percentile will be used in the assessment. The 95th percentile value was selected because it is the statistic that DWS uses to assess compliance to a specific water quality target or objective (DWAF, 2006).

For other constituents a qualitative assessment of the water quality impacts for each scenario will be done based on knowledge of the behaviour of the constituent with flow, and local conditions in the IUA that may affect the in-stream concentration (e.g. presence of point or non-point sources of pollution). Likewise, quantification of the relationship between groundwater use and groundwater or surface water quality is not possible on regional scale within the project. Nevertheless, where groundwater quality is known to differ significantly from the surface water in the specific area, a qualitative assessment of the potential impacts of groundwater use on surface water may be possible.

By default the water quality management objective is to not allow further deterioration in water quality, that is, maintain water user requirements in at least their present state. If a specific catchment scenario results in a poorer water quality category for users, then the catchment scenario can be modified by changing a combination of three options. These are:

- Reduce the constituent loads from the point and non-point sources (implying management intervention to reduce loads).

- Provide more water for dilution (implying a better ecological category).

- Change water user requirements (implying water users have to accept poorer quality water and cope with the consequences).

Using the above analysis, the water quality specialist will adjust the information on water available for use to provide detail on changes of availability of water for use in different sectors and subsectors, based on their water quality requirements. This will be fed into the economic analysis.

# 9 SOCIO-ECONOMIC IMPACTS

## 9.1 Introduction

The Guidelines for conducting the Classification Process noted that whereas the ecological component drew on years of experience of practitioners, the socio-economic component was breaking new ground, and drew on a very limited number of studies. The guidelines for the socio-economics component (Volume 3), highlighted the complex relationships between water, ecosystem services, the economy and human wellbeing, and outlined possible methods for the valuation of water use and ecosystem services and the development of an index of human wellbeing. They suggest development of a suitable socio-economic evaluation framework to link changes in (1) yield, (2) water quality and (3) ecosystem characteristics to socio-economic values. The Guidelines also propose the use of a Social Accounting Matrix (see Box 9.1) to model macro-economic and social implications of different scenarios. The guidelines were not overly prescriptive, however, recognising that this is a rapidly-evolving field, where future studies would benefit from the increasing availability of good quality data and build on national and global progress in development of suitable approaches for evaluations of this nature. It is also recognised that in the highly competitive consulting environment, budget constraints for these kinds of studies would be an issue.

Assessment of the socio-economic impacts of water allocated to the Reserve began before the gazetting of the Classification Process and commencement of Classification studies. Since the mid-2000s, studies of this nature have been carried out as part of Resource Directed Measures studies or Classification studies in several catchment areas. These include:

- 2006 – RDM study of the Letaba River
- 2006 – RDM study of the Kromme River
- 2011 – Classification of the Olifants WMA
- 2012 – Classification of the Olifants-Doorn WMA
- 2013 – Classification of the Mokolo/Matlabas Catchment: Limpopo WMA and Crocodile (West) Marico WMA
- 2014 – Classification of the Mvoti to Umzimkulu WMA
- 2014 – Classification of the Letaba catchment
- 2016 – Classification of the Usutu to Mhlatuze WMA

The socio-economic component of these different studies has been carried out by a few groups of socio-economics specialists, and they have used different approaches. Among past studies, there tends to be a reasonable amount of convergence in the approaches to estimate the economic impacts pertaining to water user sectors. The approaches on ecosystem services differ quite widely, however. In some studies they are estimated separately and then added to sectoral GDP estimates, and in others they are not quantified and form part of the more qualitative social assessment. The methods for assessing economic and social impacts were reviewed in the development of the approach for this study.

## 9.2 Economic Impacts

### 9.2.1 Sectors Considered

The following sectors are the main water users or are dependent on the ecosystem services generated by aquatic ecosystems:

- Water users:
    - Urban and Domestic Household Use.
    - Non-urban industry;
    - Irrigation;
    - Commercial forestry;
- Dependent on aquatic ecosystem services :
    - Tourism;
    - Property, and
    - Lagoon and marine inshore fisheries

There is a hierarchy for water allocation. Apart from the Reserve, the needs of strategic development projects and households are met before those of non-strategic industry and agricultural users. For this reason, it is assumed that domestic needs are fully taken care of, and that changes in water availability for use would most likely affect industrial and/or agricultural users, if anyone.

### 9.2.2 Measures

The economic impacts are described in terms of (1) value added[1] to the economy (= contribution to GDP) and (2) employment. These impacts are described in terms of direct and total impacts (which include multiplier effects).

It should be noted that the economic indicators selected do not always provide the full picture of the impacts of changes on the economy. For example, some activities may not generate high outputs but might be important for food security of job creation. Some activities such as citrus fruit production may create large numbers of jobs in the primary activity but have little in the way of knock on effects because most of the fruit is exported. However these exports are very important at a national scale for the Balance of Payments.

It should also be noted that it is very difficult to predict economic impacts with any degree of certainty. The eventual outcomes will be affected by a number of factors including government policy, exchange rates, economic circumstances and the state of education systems. It is important to remember that economic analysis of alternative scenarios works on the premise that all other things are equal.

### 9.2.3 Linking Water Supply to Production Outputs/Costs

Current sectoral economic outputs were estimated on the basis of national accounting data (municipal level data disaggregated to socio-economic zones and IUAs), for the year 2015. Since national accounting data do not disaggregate the Agriculture, Forestry and Fisheries sector, values generated in Agriculture and Forestry were estimated on the basis of highly detailed spatial data on land use. These are described in the *Status Quo* Report. In order to link these outputs to water supply, current water use in the different sectors was estimated based on the Water Allocation and Registration Management System (WARMS) data on allocations and on detailed estimates of crop water requirements.

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[1] Value added is the sum of wages, company profits, taxes paid and interest earned.

Demand for domestic household water use was expected to grow with the population growth of the study area, while the demand for irrigation and industrial uses is expected to grow in line with general economic growth. For this study, it was assumed that there would be no change in the forestry sector in the medium term, and that this sector would not be impacted on by any operational scenarios. Forestry is a relatively minor water using activity in the study area, and is more likely to diminish than to grow over the longer term.

Water supply infrastructure will also grow in order to keep pace with increasing demands. Over time, additional water is supplied at ever increasing marginal costs, because the system has to take on more expensive surface and groundwater options and more expensive technologies such as recycling of water and desalination of sea water (Figure 9.1).
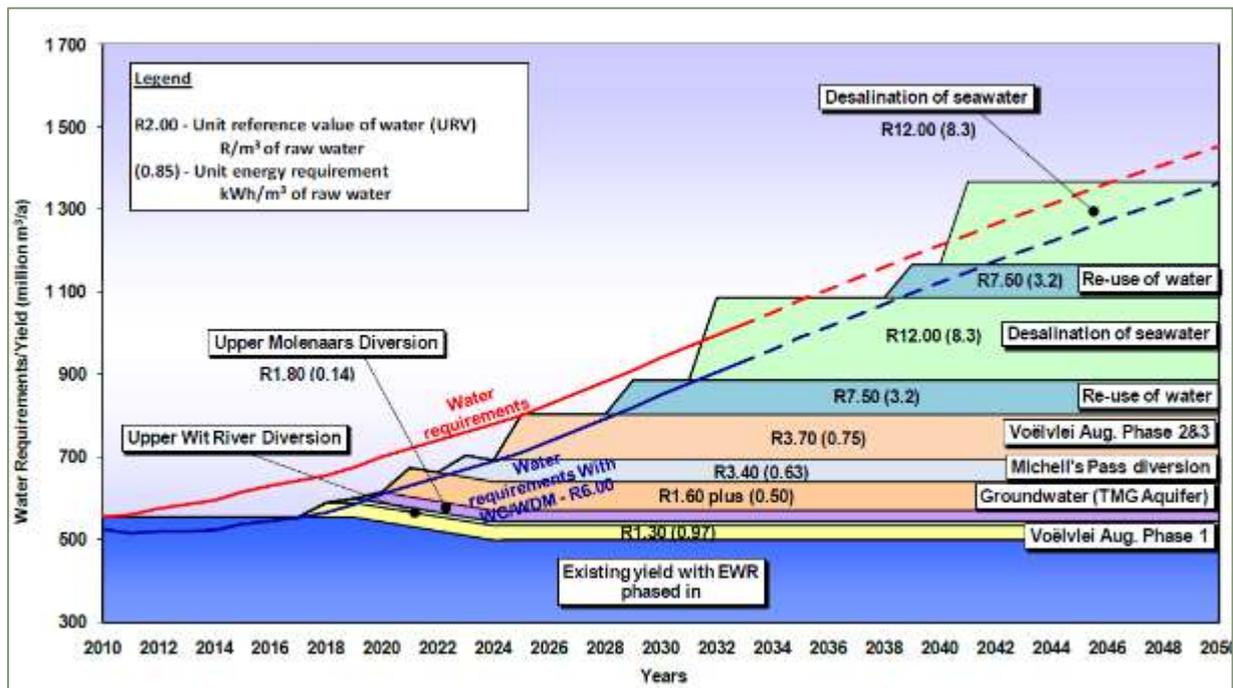


Figure 9.1: Augmentation Options for the Western Cape Water Supply System (WCWSS)

The demands of the Reserve are just another one of those demands. If everything else is held constant and the Reserve is increased, this could either result in a reduction in the quantity of water allocated to certain users, or in the establishment of further infrastructure in order to be able to continue to meet the existing allocations. In this study the latter is assumed, since the former is publically non-feasible. In the latter case, there are three options all of which involve increasing the cost of water to users.

These are (1) the deliberate increases in water tariffs to force the adoption of more water-efficient water distribution and use in municipalities, farming methods and associated technological innovation, (2) introduction of water trading to achieve the same ends more efficiently, but involving the devolution of water rights and control to the users, and (3) the augmentation of water supply at increasing cost. In this study, we have used the latter to estimate the costs of increasing the Reserve, where appropriate (note that it could turn out that the next infrastructural development is able to meet all of the demands). In other words, none of the water user sectors was expected to be limited by water availability *per se*, but they would be impacted by increasing costs under scenarios involving increased allocation to the Reserve as a result of supply augmentation costs or demand management.

Note that water may not be used efficiently in the study area, because water is allocated rather than traded on the open market. Nevertheless, it is beyond the scope of this study to investigate the impacts of proper water pricing on efficiency and trade-offs involved in classification.

If the availability of water to discretionary sectors increases under any scenarios, then potentially more water could be allocated to one or more of these (in this case irrigation or general industry). Whether this affects irrigation, industry or both may be dictated by location to some extent, but for a given location, should be dictated by the relative potential value of supplying water to each of those sectors. Where there are multiple users, such as different irrigation subsectors and industry, the social planner should allocate water to the sector that delivers the highest GDP and/or employment benefits, until the marginal benefit of water in each use is equal.

Understanding marginal changes in production ideally requires estimating a production function (Nahman and de Lange 2012). This is often difficult for a desktop study. Previous Classification studies have mostly used the average value added per $m^3$ water used, and the average number of people employed per million $m^3$, calculated on the basis of the estimated (presumably direct) value added per activity in relation to the amount of water used in different socio-economic zones or catchment areas (Mullins 2014). In other words, it is assumed that the additional production resulting from a unit increase in water would be the same as the average production. This is not strictly correct, as the change in production at the margin (whether an increase or decrease) is likely to be lower than the average production. Nevertheless, the only study that estimated the marginal changes resulting from an increase in water availability for irrigation farming estimated an increasing marginal benefit.

Kleynhans & Hoffman (2012) used an enterprise modelling approach to estimate changes in income and employment at the farm level. This was achieved by describing a typical farm (in terms of size and nature of farming operations, expenses, production and income) in each of the socio-economic zones in which irrigation farming would be affected. The farm model captured the capital costs, operating costs and income involved in establishment of the production system and ongoing costs and revenues, in order to work out the net present value (NPV) of the net income stream over 25 years.

The assumption was that increasing the available irrigation water would allow an increase in irrigation area, which would lead to a disproportional increase in profit due to the increased scale of production, or *vice versa*. For example, for the wine grape and vegetable production area of the lower Olifants, a typical farm was described as 50 ha, of which 47 ha were irrigated, using 6400 $m^3$/ha/year, generating a NPV of R3.8 million. A 6.4% increase in irrigation area would increase the NPV to R7.4 million. For the table grape farming area near Clanwilliam Dam, a typical farm was described as 50 ha, of which 43 ha were irrigated, using 7600 $m^3$/ha/year, generating a NPV of R8.6 million. A 9.3% increase in irrigation water would increase the NPV to R12.6 million. The basis for these assumptions was not given, however.

In the case of increasing water availability, this study uses a similar approach to Conningarth Consultants. The magnitude of change was first determined for each water user individually, these were then ranked according to the magnitude of each entity's contribution to the economy, and then the allocation of the water rights was adjusted accordingly before arriving at the final estimate of the impact of the change.

### 9.2.4 Linking Ecosystem Services to Production Outputs/Cost Savings

The sectors dependent on aquatic ecosystem services could either shrink or expand as a result of moving to a lower or higher ecological class, respectively. The availability and quality of water in rivers, wetlands and estuaries and the overall condition of these natural systems influences their capacity to deliver aquatic ecosystem services. These, in turn, will influence the value of final goods and services generated by activities that depend on them.

In this study, the main sectoral impacts considered are tourism, property and inshore fisheries. These sectors and their linkages to the aquatic ecosystem services in the study area are explained in more detail in the *Status Quo* Report. Estuaries are the main freshwater-dependent ecosystems that impact on all three of these sectors. Impacts on these sectors were estimated on the basis of the relationships derived in Turpie & Clark (2007) between ecosystem condition and these values.

### 9.2.5 Estimating Contribution to GDP and Employment

Multipliers extracted from the provincial Social Accounting Matrix (SAM) were used to estimate value added to GDP as a proportion of the gross output value of production, and to estimate income accruing to poor households. The Western Cape SAM was initially developed in 2006 and has since been updated to 2014 values.

**Box 9.1: Social Accounting Matrix and economic multipliers (source: Prime Africa 2011)**

A SAM is a matrix that summarises the linkages that exist between the different role players in the economy i.e. business sectors, households and government. Thus, a SAM reflects all of the inter-sectoral transactions in an economy and the activities of households. A household is a very important economic definition, as it is the basic unit where significant decisions regarding important economic variables such as expenditure and saving are taken. A SAM combines households into meaningful groups, and thus enables analysis of different household groups, and its dependence on the rest of the economy. A SAM thus enables modelling of changes in economic activity on economic growth (i.e. the impact on GDP); job creation (i.e. the impact on labour requirements); impact on capital formation; and income distribution (i.e. the impact on low-income, poor households and the total income households).

A SAM enables the simulation of changes in sector turnover to estimate macro-economic impacts using economic multipliers. Economic models fundamentally incorporate a number of "multipliers" that form the nucleus of the modelling system. A multiplier specifies the nature and extent of the impact of a change in a specific economic quantity (e.g. agriculture) on another economic quantity or quantities (e.g. food manufacturing or employment). Multipliers consist of direct, indirect and induced multipliers. The direct multiplier measures an economic effect occurring in a specific sector, whilst the indirect multiplier measures those effects occurring in the different economic sectors that link backwards and forwards to this sector. The induced effect measures the additional economic activity generated by the spending of additional salaries and profits generated. Sectoral multipliers are calculated using information contained in the Sectoral SAMs and data obtained from the Reserve Bank of South Africa and Stats SA.

The Development Bank of South Africa has published SAMs for each of the nine Provinces of South Africa. The Western Cape SAM was produced in 2006 and updated by Conningarth Economists in 2014.

### 9.2.6 Accounting for Water quality impacts

Following Prime Africa (2011), the impacts of changes in water quality were estimated as the cost of restoring water quality to an A class based on the costs of removal of Nitrogen and Phosphorus loads in wastewater treatment works. The load that had to be removed was estimated using the concentrations at each class from water quality guidelines, and virgin MAR for each sub-catchment. The value was used as a proxy for the costs of implementing pollution charges to achieve RQOs, as envisaged by the Waste Discharge Charge System. Consideration will also be given to approaches developed in the Olifants River for estimating the costs associated with pollution prevention measures to that required to treat polluted water resources, especially with respect to salinity, nutrient enrichment and microbial pollution (de Lange et al, 2012, Oelofse et al., 2011).

## 9.3 Social Impacts

It is particularly difficult to describe and quantify changes in societal wellbeing. Peoples' wellbeing is affected by a very wide range of factors, only a few of which are being considered in this study, while the rest are 'held constant' as for the economic analysis. The proportional influence of the factors being considered in this study is fairly subjective.

Several past Classification studies have incorporated a qualitative assessment of the change in ecosystem services as a proxy for social impacts. In this study we have incorporated changes in ecosystem services into both the economic and social analysis, since ecosystem services can impact on both.

The social impacts of water allocation will come from changes in employment, changes in the abundance of harvested resources, changes in human health risks as a result of water quality, and the more intangible amenity values associated with natural systems.

Changes in income to poor households are estimated based on changes in economic outputs and multipliers derived from the Western Cape SAM.

In the study area, there are very few communal land areas and few areas where there are concentrations of rural poor that are dependent on the environment. Nevertheless, many households use rivers, wetlands and estuaries to harvest a range of natural resources. Impacts on the capacity of these ecosystems to deliver these resources would impact on those households. These impacts are estimated in terms of value, based on the estimated changes in the harvested populations derived from the ecological models.

The *status quo* description includes statistics on the proportion of poor households, the proportion of households that have piped water, and the proportion that depend on rivers for their water supply. Access to piped water is about municipal service provision, and is not expected to change as a result of Classification. For those few households depending on river water, however, changes in the quantity and quality of dry season flows may have an impact. This impact is described in qualitative terms.

The cultural, spiritual and recreational values associated with natural systems are extremely difficult to measure, but very important for peoples' health and wellbeing. Changes in these benefits are described qualitatively using a scoring system in order to evaluate relative changes under the different scenarios.

# 10   MULTI-CRITERIA ASSESSMENT

## 10.1   Overview

The study will examine the potential implications of a range of alternative flow scenarios on biodiversity, the economy and human wellbeing (Figure 5.1).  Each scenario will be compared to the <u>baseline</u> to estimate change in a range of ecological, economic and social measures and/or indices which are referred to as criteria or indicators.  Not all of these can be measured in comparable units such as money.  Therefore the Classification Process uses a multi-criteria assessment (MCA) approach in which both monetary and non-monetary impacts can be assessed.

This study will express values in monetary terms where relevant and other units or scales for those criteria for which monetary values are irrelevant or impractical to measure.  For example, ecological and social variables may be described in terms of state, e.g. % of biodiversity targets met; % of households that are poor, while economic variables will be described in terms of gains or losses of income.

## 10.2   Evaluation Variables

Three main aspects will be considered, i.e. ecological, social and economic:

- The **ecological condition** (or health) rating. This is expressed as a score out of 100 that indicates % similarity to the natural or reference condition.  The weighted sum of the scores for each node, gives the overall health at the IUA- or catchment- scales.  A second ecological criterion is the degree to which biodiversity targets are met under the different scenarios.

- In terms of the **economics 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 **social component** evaluates impacts on wellbeing of the population of the study area. This is expressed in terms of changes in income to poor households, impacts on health and impacts on amenity benefits to households. The first is estimated in monetary terms, the latter in terms of indicators. It should be noted upfront that impacts on health are minor in this WMA, because of the low level of reliance on rivers for direct run-of-river domestic water abstraction.

The main criteria described for each spatial unit in the study area and for the study area as a whole are summarised in Table 9.1.  This report focuses on the economic and social measures.

Table 9.1: Main criteria indicators to be included in the multi-criteria analysis

| Ecological | Economic | Social |
|---|---|---|
| Overall state of aquatic ecosystem health (a weighted measure / 100) | Losses/gains in Total value added | Impacts on livelihoods |
| % of freshwater conservation targets met (national obligation) | Losses/gains in Total employment | Impacts on health |
| % of estuary conservation targets met (national obligation) | Costs saved/incurred | Impacts on intangible benefits (recreation etc.) |

## 10.3    Ranking and Rating of Scenarios

The scenarios should be considered in terms of the performance with respect to each criterion separately, but an overall summary ranking is also a useful consideration.

An overall ranking can only be derived if the values on each criterion are converted to "comparable" scales, firstly by normalising the scores and secondly by deriving appropriate weights for combining them.

Thus the different measures (Rand for the economy, number of jobs for employment and the different rating scales for the ecology and Ecosystem Services) should all be converted to the same unitless scale (e.g. 0 to 1 or 0 to 100), and the relative "importance" of the scales are made comparable by the weights applied to each.

The overall rank for a scenario is determined by the sum of the products of the score for each variable or criterion multiplied with importance weight of the variable.

## 10.4    Weights

The relative importance of the criteria is defined by assigning weights to each. These weights should, for the technical analysis in particular, consider the relative importance of the effects of the criterion, rather than reflecting a purely subjective "pro-development" or "pro-conservation" or any other "pro" or "anti" position. In other words, the weights used should be "swing weights" (Belton and Stewart, 2002). In absence of the time and resources required to "workshop" these weights with the technical team and/or with stakeholders it is proposed that a two-pronged approach be used:

- A wide range of weights are applied so as to perform a sensitivity analysis reflecting the extent to which changes in weights would have an effect on overall performance (i.e. how robust the overall scores or ranks are to changes in weights);

- Stakeholders are requested (in an appropriately facilitated meeting or via email) to provide weights, and this range of weights is similarly employed to determine the robustness of scenarios, and also to evaluate the preferred scenarios for various stakeholders.

The above assessments will provide a rich picture of the scenarios for examination by DWS.

# 11 WATER RESOURCE CLASS

In accordance with the WRCS Guidelines (DWAF, 2007), the Water Resource Class (WRC) 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 Figure 11.1 as the criteria to determine the WRC.

| | | % 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 | - |

Figure 11.1: Preliminary guidelines for the calculation of the IUA Class for a scenario (DWAF, 2007)

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 results of the scenarios evaluation will present the IUA WRCs for the indicated scenarios. The specific scheme (adjusted from the guideline scheme presented here) will further be presented and discussed.

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