DEVELOPMENT OF THE WATER RESOURCE CLASSIFICATION SYSTEM (WRCS)

Decision-analysis (including the stakeholder engagement process) guidelines for the 7-step classification procedure - February 2007







1st Edition

Chief Directorate
Resource Directed Measures

Volume 4

water & forestry

Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

THE DEVELOPMENT OF THE WATER RESOURCE CLASSIFICATION SYSTEM (WRCS)

First Edition: February 2007
Volume 4

Decision-Analysis (Including the Stakeholder Engagement Process) Guidelines for the 7 – Step Classification Procedure

Chief Directorate: Resource Directed Measures

Technical Guidelines for
DEVELOPMENT OF THE WATER RESOURCE CLASSIFICATION SYSTEM (WRCS)

First Edition

Department: Water Affairs and Forestry

Development of the Water Resource Classification System (WRCS)
February 2007
First Edition
Department: Water Affairs and Forestry
Private Bag X313
Pretoria 0001
Republic of South Africa
Chief Directorate: Resource Directed Measures
Water Resource Classification

This document should be cited as:
Department: Water Affairs and Forestry.2007. Development of the Water Resource Classification System (WRCS). By Chief Directorate: Resource Directed Measures

Preface

The Water Resource Classification System (WRCS) was established in response to the South African National Water Act of 1998. The WRCS is a set of guidelines and procedures that, when applied to a specific catchment, will ultimately assist in the process of maintaining a balance between protecting our national water resources and using them to meet economic and social goals. The procedures are to be applied as part of a consultative ‘Classification Process’, the final outcome of which is a decision about the set of desired characteristics for each of the water resources in a given catchment.

The Classification Process sets a ‘Class’, which defines objectives for every significant water resource—watercourse, surface water, estuary, or aquifer. There are three classes, ranging from the minimally used to the heavily used. These objectives describe the desired condition of these resources and the extent to which they can be utilised.

The Classification Process is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use. A key component of classification is therefore the ongoing process of evaluating options with stakeholders in which the economic, social and ecological trade-offs will be clarified and decided upon.

Volumes 1 to 5 of these reports build on an earlier version of the classification system and meet the terms of reference as set out in the inception report (DWAF, 2005a). The development of the new system was completed in twelve months using the Olifants/Doring catchment as a ‘proof of concept’ catchment. The Olifants/Doring system was chosen for two reasons: 1) A recent Reserve determination study had provided much of the required information. 2) Most of the WRCS project team had been involved in the determination study.

It was initially planned that once the draft WRCS had been developed, it would be tested, refined and possibly streamlined using two other, more complex catchments (such as Thukela and Incomati). This turned out not to be possible. The description of the classification procedure has therefore been left as generic as possible so that future applications of the WRCS can build on and improve the procedures and guidelines presented in these volumes.

The classification system regulations will be developed from these volumes.

Acknowledgements

The following persons and organisations are thanked for their contributions to this project.

PROJECT TEAM

Project leader:

Dr ESJ Dollar, Natural Resources and Environment, CSIR

Project team leaders:

Dr CA Brown, Southern Waters Ecological Research and Consulting cc.
Dr JK Turpie, Anchor Environmental Consultants cc.
Dr AR Joubert, Department of Statistical Sciences, University of Cape Town
Dr CR Nicolson, University of Massachusetts
Prof DA Hughes, Institute for Water Research, Rhodes University
Mr SM Manyaka, Zitholele Consulting (Pty) Ltd
Dr G Pegram, Pegasys Strategy and Development

Project team:

Ms C Colvin, Natural Resources and Environment, CSIR
Mr J Conrad, Geohydrological and Spatial Solutions International (Pty) Ltd
Ms E Engelbrecht, Zitholele Consulting (Pty) Ltd
Ms J Ewart-Smith, Freshwater Consulting Group
Dr JA Goldin, Take Away Poverty cc.
Mr D Grobler, Blue Science Consulting cc.
Mr J Hallowes, Clear Pure Water cc.
Ms D Louw, Water for Africa (Pty) Ltd
Mr R Magoba, Southern Waters Ecological Research and Consulting cc.
Dr H Malan, Freshwater Research Unit, University of Cape Town
Mr S Mallory, Water for Africa (Pty) Ltd
Dr W Mullins, Conningarth Consulting Economists
Mr N Rossouw, Ninham Shand Consulting Services
Dr A Turton, Natural Resources and Environment, CSIR
Ms L van Niekerk, Natural Resources and Environment, CSIR
Dr C von der Heyden, Pegasys Strategy and Development

DWAF project manager

Ms M Kadiaka, Chief Directorate: Resource Directed Measures

STEERING COMMITTEE

Ms C Bosman, DWAF: Resource Protection and Waste
Ms R Cronje, DWAF: Water Resource Management Systems
Dr Q Espey, DWAF: Resource Quality Services
Mr P Herbst, DWAF: Gauteng Regional Office
Mr B Hibbert, National Department of Social Development (NDSD)
Ms M Hinsch, DWAF: Water Allocation

Ms M Kadiaka, DWAF: Resource Directed Measures
Mr B Madikizela, DWAF: Resource Quality Services
Mr D Masemola, DWAF: Resource Directed Measures
Ms T Mhlabane, DWAF: Resource Directed Measures
Mr C Moseki, DWAF: Integrated Water Resource Planning
Mr S Naidoo, DWAF: Resource Protection and Waste
Ms S Oelofse, DWAF: Resource Protection and Waste
Mr H Pienaar, DWAF: Resource Directed Measures
Ms W Ralekoa, DWAF: Resource Directed Measures
Mr B Rowlston, DWAF: Policy and Strategy Co-ordination
Mr A Seetal, DWAF: Water Allocation
Mr P Shoba, DWAF: Water Services Regulation
Mr P van Niekerk, DWAF, Integrated Water Resource Planning
Mr J van Rooyen, DWAF: National Water Resource Planning
Mr N van Wyk, DWAF: National Water Resource Planning
Mr P van Wyk, DWAF: Integrated Water Resource Planning
Mr P Viljoen, DWAF: Water Resource Planning Systems
Mr D Weston, DWAF: Water Management Institutions Governance
Mr N Zulu, DWAF: Resource Directed Measures

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

ACRONYMS

ASCE	American Society of Civil Engineers
CBA	Cost-Benefit Analysis
CMP	Catchment Management Plan
CMS	Catchment Management Strategy
Cons.	(Freshwater) Conservation (Target)
DWAF	Department: Water Affairs and Forestry
EC	Ecological Category
EGSAs	Ecosystem Goods, Services and Attributes
EI	Ecosystem Index
EIS	Ecological Importance and Sensitivity
ELU	Existing Lawful Use
ESBC	Ecological Sustainability Base Configuration (scenario)
EWRs	Ecological Water Requirements
GDP	Gross Domestic Product
GGP	Gross Geographic Product
I&AP	Interested and Affected Parties
IUAs	Integrated Units of Analysis
IV	Intangible Value
IWRM	Integrated Water Resources Management
MC	Management Class
MCDA	Multi-Criteria Decision-Analysis
NDSD	National Department of Social Development
NGOs	Non-Governmental Organizations
NWA	National Water Act
OEI	Overall Ecosystem Index
OREP	Overall Regional Economic Prosperity
OSWB	Overall Social Wellbeing
PES	Present Ecological Status
PSP	Professional Service Provider
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REP	Regional Economic Prosperity
RQOs	Resource Quality Objectives
SAM	Social Accounting Matrix
SWB	Social Wellbeing
TC1	Test Catchment 1
TGP	Total GGP Effects
VISA	Visual Interactive Sensitivity Analysis
WRCS	Water Resource Classification System
WRM	Water Resources Management

1 INTRODUCTION

1.1 The Water Resource Classification System (WRCS)[1]

The WRCS is required by the National Water Act (NWA) (No. 36 of 1998), and consists of a set of guidelines and procedures for determining the different classes of water resources (Chapter 3, Part 1, Section 12). Desired characteristics of the resource are represented by a Management Class (MC) which outlines the attributes required of different water resources by the resource custodian (Department: Water Affairs and Forestry (DWAF)) and by society.

The WRCS will be used in a consultative process (i.e. the Classification Process) to classify the water resources within a geographic region in order to facilitate finding a balance between protection and use of the water resources. The actual process of *applying* the WRCS procedures described in this volume to a catchment is called the Classification Process i.e. establishing the MC. The economic, social and ecological implications of choosing a MC need to be established and communicated to all Interested and Affected Parties (I&AP) during the Classification Process.

The outcome of the Classification Process will be the setting of the MC, Reserve and Resource Quality Objectives (RQOs) by the Minister or delegated authority for every significant water resource (watercourse, surface water, estuary, or aquifer) under consideration. This will be binding on all authorities or institutions when exercising any power, or performing any duty under the NWA. This MC, which will range from Minimally to Heavily used (Table 1.1), essentially describes the desired condition of the resource, and concomitantly, the degree to which it can be utilised. In other words, the MC of a resource sets the boundaries for the volume, distribution and quality of the Reserve and RQOs, and therefore informs the determination of the allocatable portion of a water resource for use. This has considerable economic, social and ecological implications.

Table 1.1 Proposed water resource classes

Class I: Minimally used
The configuration of ecological categories of the water resources within a catchment results in an overall water resource condition that is minimally altered from its pre-development condition.
Class II: Moderately used
The configuration of ecological categories of the water resources within a catchment results in an overall water resource condition that is moderately altered from its pre-development condition.
Class III: Heavily used
The configuration of ecological categories of the water resources within a catchment results in an overall water resource condition that is significantly altered from its pre-development condition.

1.2 Objective of this report

This report presents the decision-making (including the stakeholder engagement process) guidelines for the 7-step classification procedure (see Section 1.3) through a 'proof of concept' application to the Olifants/Doring catchment (Test Catchment 1 (TC 1)). The context to the WRCS, the definition of the classes and description of the overall classification procedure are presented in

[1] This section has been adapted from DWAF (2006a).

Volume 1 of this series (Dollar *et al*., 2007). The guidelines and procedures for the ecological and socio-economic components of the classification procedure and their application to the Olifants/ Doring catchment are presented in Volumes 2 (Brown *et al*., 2007) and 3 (Turpie *et al*., 2007) respectively.

1.3 7-step classification procedure

A seven-step procedure to recommending the class of a resource (the outcome of the Classification Process) is proposed (Figure 1.1). The seven steps which may be embedded in other DWAF processes are:

Step 1: Delineate the units of analysis and describe the status quo of the water resources:-

a. Describe the present-day socio-economic status of the catchment;
b. Divide the catchment into socio-economic zones;
c. Identify a network of significant resources, describe the water resource infrastructure and identify the water user allocations;
d. Define a network of significant resources and establish the biophysical and allocation nodes.
e. Describe communities and their wellbeing;
f. Describe and value the use of water;
g. Describe and value the use of aquatic ecosystems;
h. Define the Integrated Units of Analysis (IUA);
i. Develop and/or adjust the socio-economic framework and the decision-analysis framework; and
j. Describe the present-day community wellbeing within each Integrated Unit of Analysis.

Step 2: Link the value and condition of the water resource:-

a. Select the ecosystem values to be considered based on ecological and economic data;
b. Describe the relationships that determine how economic value and social wellbeing are influenced by the ecosystem characteristics and the sectoral use of water; and
c. Define the scoring system for evaluating scenarios.

Step 3: Quantify the Ecological Water Requirements and changes in non-water quality Ecosystem Goods, Services and Attributes:-

a. Identify the nodes to which Resource Directed Measures data can be extrapolated and make the extrapolation;
b. Develop rule curves, summary tables and modified time series for all nodes for all ecological categories; and
c. Quantify the changes in relevant ecosystem components, functions and attributes for each ecological category for each node.

Step 4: Determine an Ecologically Sustainable Base Configuration scenario and establish the starter configuration scenarios:-

a. Determine an Ecologically Sustainable Base Configuration (ESBC) scenario that meets feasibility criteria for water quantity, water quality and ecological needs;
b. Incorporate the planning scenarios (future use, equity considerations and existing lawful use); and

c. Establish the Resource Directed Measures configuration scenarios.

Step 5: Evaluate scenarios within the Integrated Water Resource Management (IWRM) process:-

Steps 5 and 6 form part of the 'Larger Process' where the economic, social and ecological trade-offs will be made. Trade-offs will also need to be made between Existing Lawful Use (ELU) and equity considerations. Emerging from this 'Larger Process' will be the recommended MC, Reserve and RQOs, CMS, allocation schedule, modelling system and the monitoring, auditing and compliance strategy. A number of key questions will need to be addressed in this 'Larger Process'. These include:

- at what level will the trade-offs be negotiated?
- in what institutional setting will they be negotiated?
- what types of scenarios will inform the process of negotiation?; and
- since the recommended MC, Reserve, RQOs, CMS and allocation schedule will impact on specific groups of people in different ways, what processes will guide decisions about who benefits and who pays the social and economic cost?

These key questions should be framed (and assessed) in the context of equity, efficiency and sustainability as required by the NWA, and by the core objectives of the present government which are, amongst others, to halve poverty and unemployment by 2014, to reduce the regulatory burden on small and medium businesses, and to eliminate the second economy[2]. Step 5 should therefore contribute to meeting government's objective of '…reduce(ing) inequality and virtually eliminating poverty'.[3] To address these objectives and to fit within the larger DWAF institutional context, Classification Procedure Step 5 needs to include the following sub-steps:

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

Step 6: Evaluate the scenarios with stakeholders:-

a. Stakeholders evaluate scenarios and agree on a short-list; and
b. Recommend classes for the Integrated Units of Analysis.

Step 7: Gazette the class configuration:-

a. Populate the Integrated Water Resource Management summary template and present to the Minister or his/her delegated authority;

[2] www.info.gov.za/issues/asgisa/.
[3] www.info.gov.za/issues/asgisa/.

b. Decision by the Minister or his/her delegated authority on the Integrated Unit of Analysis classes, nested ecological category configurations, Reserve(s), allocation schedule(s) and the Catchment Management Strategy;
c. Set the resource quality objectives;
d. Gazette Integrated Unit of Analysis classes, nested ecological category configurations, Reserve(s) and resource quality objectives; and
e. Develop a plan of action for implementation of the recommended scenario which must include a monitoring programme.

1.4 Structure of this report

The report is structured and aligned with the 7-step classification procedure presented in Figure 1.1. The decision-making component guidelines (including the stakeholder engagement process) of the 7-steps are presented, together with an example of application of the guidelines to the ‘proof of concept’ catchment, the Olifants/Doring. Prior to this, however, a discussion is presented on the background to the decision-analysis component of the classification procedure, as well as a brief discussion on the recommended decision-analysis framework.

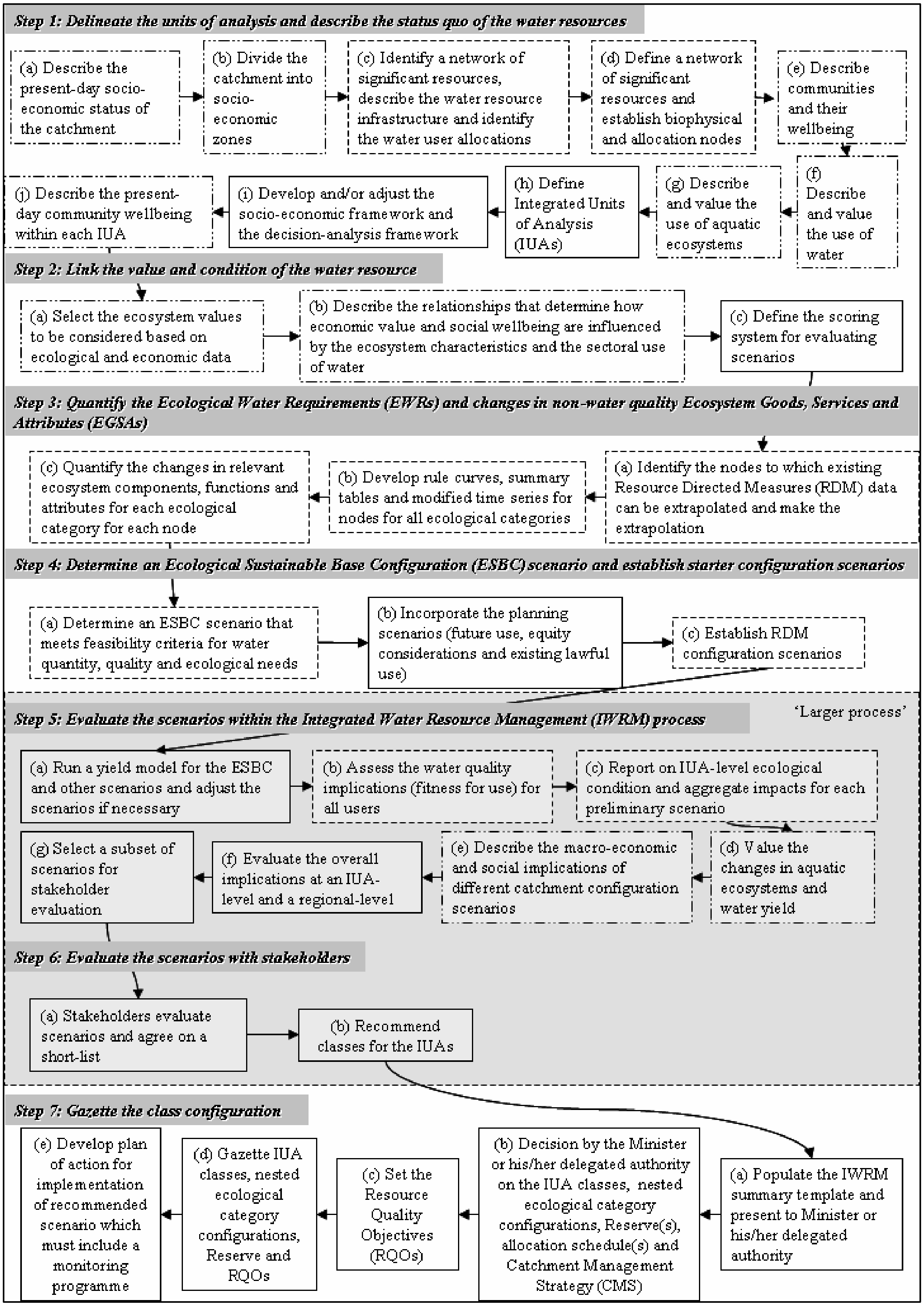


Figure 1.1 Outline of the 7-step classification procedure.

2 BACKGROUND TO THE DECISION-ANALYSIS COMPONENT OF THE CLASSIFICATION PROCEDURE

The decision-analysis component of the classification procedure needs to be aligned with the NWA which calls for the efficient, equitable and sustainable use of the nation's water resources. These economic, social and ecological goals respectively, are embodied in DWAF's official motto, '*ensuring some, for all, for ever, together*'. The economic goal of efficiency relates to maximising economic returns from water resources, or achieving the maximum net benefit. The social goal of equity seeks to allocate and distribute the costs and benefits of utilising the resource fairly, while the ecological goal of sustainability seeks to promote the use of resources in a way that meets the needs of current generations, but does not compromise the economic opportunities and social wellbeing of future generations. In addition to this, provision needs to be made for the redress of historic inequity. The decision-analysis component of the classification procedure therefore requires a framework that allows for the assessment of the economic prosperity, social wellbeing and ecosystem health implications of different catchment configuration scenarios (see Section 3) within the context of historic redress of past imbalances. In addition to this, these assessments may need to be considered at various scales.

A decision-analysis framework is therefore required to incorporate the objectives, criteria, value tree, indices and scoring systems that are needed for the overall evaluation of the catchment configuration scenarios (see Brown *et al*., 2007; Volume 2 for a discussion on catchment configuration scenarios) in terms of DWAF's mandate and the letter and spirit of the NWA. The decision-analysis framework developed for the 'proof of concept' catchment (the Olifants/Doring catchment) is presented in Section 3.3. However, in order to avoid being prescriptive, provision has been made in the classification procedure (Step 1i – see Section 3) for the development and/or adjustment of the decision-analysis framework during the Classification Process.

The following sections present the technical background to the decision-analysis component (in this case, Multi-Criteria Decision-Analysis (MCDA) and Cost-Benefit Analysis (CBA)) (see Section 2.1), describe the decision-analysis framework recommended for the classification procedure (see Section 3), and describe the recommended decision-analysis component steps for the 7-step classification procedure (see Section 3 onwards).

2.1 Background to MCDA and CBA

MCDA[4] and CBA are techniques which, in different ways, try to weigh up the pros and cons of alternatives. In situations where costs and benefits cannot justifiably all be converted to monetary units, MCDA is an appropriate alternative.

MCDA and CBA may be considered as complementary methods, and both have been separately or jointly widely applied in water resource management (see for example the *Journal of Water Resources Planning and Management* (American Society of Civil Engineers (ASCE)), *Water Resources Development* (Carfax), *Water Resources Research* (American Geophysical Union) and *Ecological Economics* (Elsevier)). A flow chart suggesting when to use which method and some of the more obvious associated assumptions and caveats is given in Figure 2.1. Many authors have compared aspects of MCDA and CBA (cf. Joubert *et al*., 1997; Joubert, 2003;

[4] The terms Multi-Criteria Analysis, Multi-Criteria Decision Aid and Multi-Criteria Decision Making are also often used, sometimes interchangeably.

Hajkowicz, 2006). Most authors, however, agree that there are few instances where solely CBA can be used, and that the use MCDA is often required or recommended.

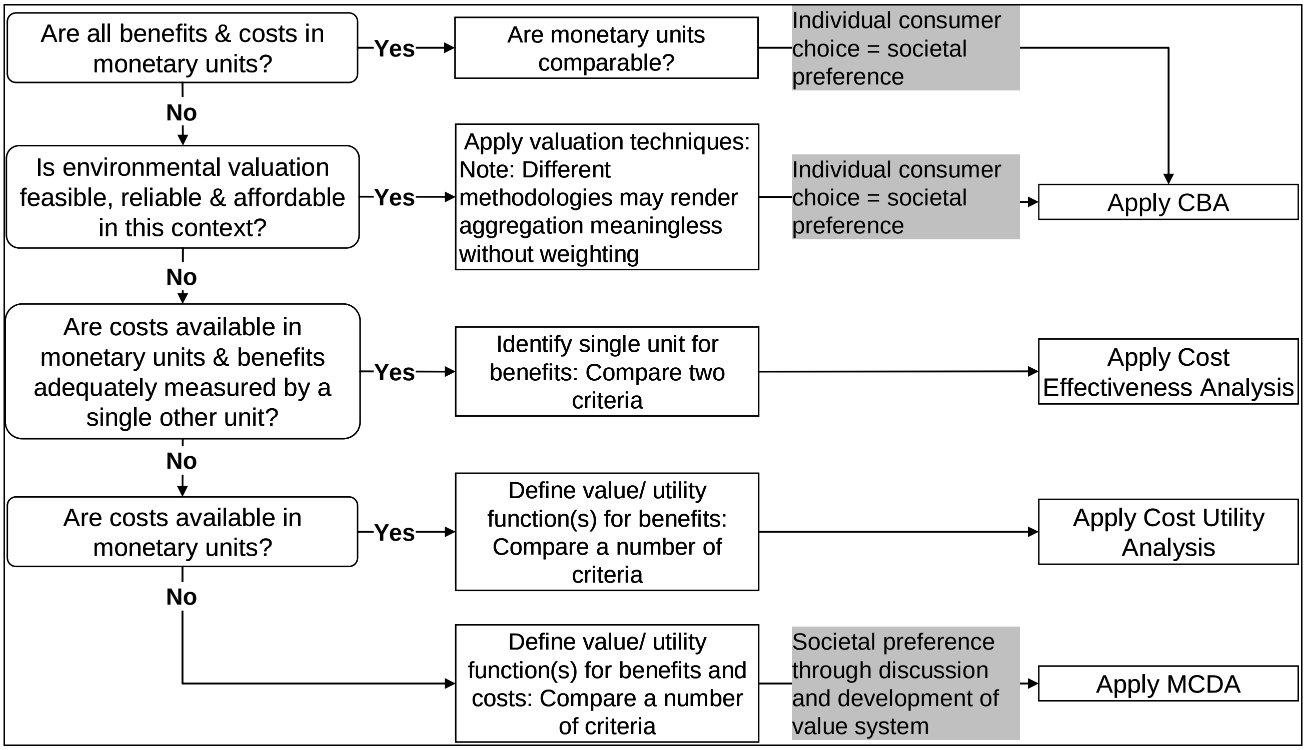


Figure 2.1 Choosing techniques (adapted from Hajkowicz, 2006 and Joubert, 2003)

There are a large number of MCDA techniques. Perhaps the simplest is a weighted summation approach, as it is easy to understand and apply and is flexible and therefore applicable in a number of situations. It can also be combined with other MCDA approaches, for example, by including min-max, if-then-else, or other decision rules.

Weighted summation is the basic approach recommended for the classification procedure with some rule-based MCDA included where appropriate. Any monetary valuations undertaken during an application of the WRCS could be integrated into the overall MCDA weighted summation framework. In other words, although a resource or environmental economics valuation may produce a monetary value for something, it can be converted to a score consistent with all the others as described later (see Section 4). Any criteria that are included in the generic system which are irrelevant in a particular application can be given a zero weight. Weighted summation is usually represented as (Equation 1):

$$V(a) = \sum_{i=1}^{n} w_i v_i(x_i)$$

Equation 1

Where:
$V(a)$ is the overall value of alternative a;
w_i is the weight of criterion i;
x_i is attribute or criterion i; and
$v_i(x_i)$ is the value of attribute or criterion x_i.

Such an approach can easily be implemented in a spreadsheet, while there is also a plethora of dedicated MCDA software available, two of which are VISA (Visual Interactive Sensitivity Analysis, © Belton), and DEFINITE (IVM, 2002).

There are some basic assumptions and implications of weighted summation:

1. Criteria need to be preferentially (or judgementally) independent*:* This means that one should not change the preference ordering according to one criterion if the level of another criterion should change. An example where preferential independence is not met is: If one is evaluating the choice of an office, two of the criteria might be street level exposure and suburb. In a ‘good’ suburb one might want street exposure, but in a ‘bad’ suburb one might prefer not to have street exposure.

2. The mathematical operation of weighted summation means that the criteria are compensatory and by implication the criteria are comparable. Two conditions need to be satisfied to allow summation:

   a) The scoring for each criterion needs to be on an *interval scale*. This means, for example, if a scoring scale of 0-100 were used for a particular criterion, that a change from 10-20 should have the same value as a change from 80-100.

   b) Even if all criteria are on a 0-100 scale, this does not mean that the scales are equivalent or comparable. They need to be weighted (stretched or shrunk) to make them comparable and aggregatable. The weights need to have the ‘swing weight’ meaning. When choosing weights the importance of a ‘swing’ from worst to best on one criterion should be compared to the importance of a swing from worst to best on another criterion. In other words, not only the intrinsic importance of an issue or criterion should be considered but also the range of alternatives under consideration. Examples are given in Box 1. The scoring and weighting *together* make the scales comparable and adjust for appropriate trade-offs. The steps are shown Figure 2.2.

Box 1 Swing weights and intrinsic weights

Example 1: A proposal has been put forward to build a new factory and two of the important issues are job creation and ecosystem impact. Generally speaking, in South Africa, society as a whole would probably agree that poverty alleviation/job creation is more important than ecosystem impact. However, in this example, the factory will only create 5 jobs whereas a biodiversity hotspot will be permanently and extensively damaged through extreme levels of air, water and land pollution. Ecosystem impact may then be considered more important in this case.

Example 2: A number of tests and an exam are set for a subject. Marks for each are given as percentages out of 100. However when the overall year mark is calculated, the different tests and exams contribute more or less to the final mark, therefore they are weighted.

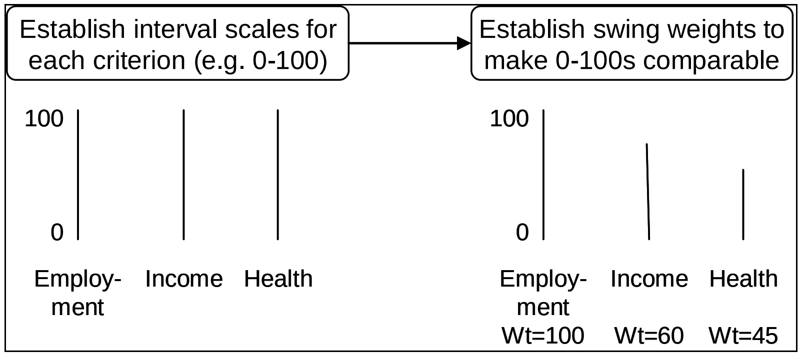


Figure 2.2 Concepts of weighting and scoring

Besides these concepts, other relevant terminology is defined below:

- Value tree: A hierarchy of criteria with broad level objective or goals at the top and (quantitatively or qualitatively) measurable criteria or indicators at the bottom. The implications of the structure of the tree are: (a) the criteria or indicator at the bottom in some way contributes to the higher level criteria or goal to which it is linked; (b) lower level criteria can be aggregated in some way so as to provide a measure of achievement on the higher level goal. More importantly, the value tree provides an invaluable visual aid for structuring thinking about the evaluation of alternatives and scenarios (see the example in Section 3).

- Value function: A function which translates the attribute levels to criterion values. These are often used for quantitative criteria. A shortcoming of many MCDA applications is the assumption that there is a linear relationship between an attribute and its value. A value function translating an attribute x, is often represented as $v(x)$. Examples of value functions recommended for the WRCS are shown in Section 4.

- Scoring system: A system of value functions, scores with associated definitions for specified levels and weights defined for a set of criteria or indices.

- Indices: In this context, indices are criteria (together with their scoring systems) which are intended to be repeatedly used.

MCDA consists of a number of iterative stages as shown in Figure 2.3. These stages are described in more detail below.

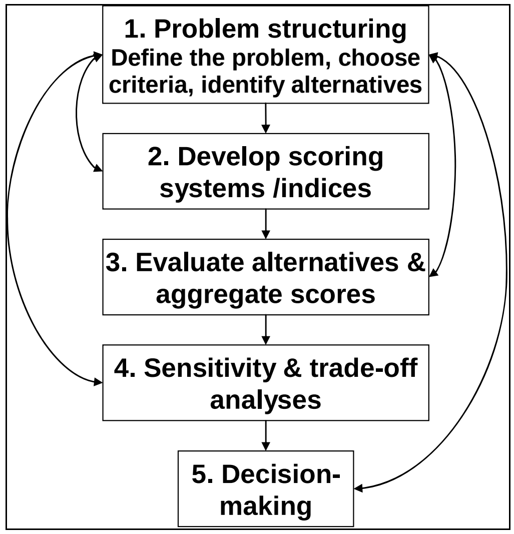


Figure 2.3 Stages of MCDA

1. *Problem structuring.* During this stage, the 'problem' is explored, and the criteria and alternatives for evaluation are selected or defined. This normally takes place in a workshop setting with a facilitator using a number of techniques to elicit the appropriate information in the appropriate format for the particular MCDA technique to be used. The problem structuring stage is the most important and most neglected stage of any decision-making process. A universal complaint of decision analysts is that too little time is allowed for or attention given to the first stage and that this shortcoming may be more important than choice of method or rigour in later stages (e.g. Janssen, 2001).

   The criteria are the measures by which the alternatives are evaluated – they are often organised into a 'value tree' (see earlier definition and example in Figure 3.1).

   In many cases the alternatives are not pre-defined. The development or definition of an appropriate set of alternatives for evaluation is therefore also required. Although guidelines exist (e.g. Belton and Stewart, 2002), these need to include a wide enough range to include a best and second best for different points of view.

2. *Develop scoring systems or indices and elicit weights*. When a weighted summation approach is used, the criteria need to be preferentially independent[5] and on an interval or cardinal scale and the weights need to be swing weights. Swing weights were described earlier.

   There should not be 'too many' criteria, but they need to capture all the main concerns, and there should not be double counting.

   Value scales for criteria may be defined on global (including the entire range that is likely to be encountered in repeated applications of the system) or local (including the range to be encountered in a single application of a once-off system) scales. *Indices are developed on global scales*.

[5] See earlier definitions of terminology.

For quantitative criteria or indices, value functions for translating attribute levels into scores can be defined. For qualitative criteria or indices for each level there needs to be a clear definition of the meaning so that scores are uniformly applied (in effect a qualitative value function). In either case, care should be taken that the scores are on an interval scale (not merely ordinal) and that any non-linearities between attribute level and score are considered.

Scoring systems and weights are usually developed in a workshop setting with the relevant specialists or stakeholders.

Examples of scoring systems and weights developed as part of this project are given in Section 4.

Guidelines exist for questioning procedures to elicit value functions and swing weights (e.g. von Windterfeldt and Edwards, 1986; Belton and Stewart, 2002).

3. *Evaluate scenarios and aggregate scores*. Scenarios are evaluated according to the system developed and overall scores and ranks determined. Where 'objective' attribute measures are available and value functions have been defined, there may be an automatic process of translating them to scores. However, where this is not the case, specialists or stakeholders may provide the scores, again usually in a workshop setting with analyst guidance. Once the alternatives have been evaluated, an overall ranking or rating emerges through, in the case of weighted summation, the aggregation of criterion scores into an overall score. The alternative with the highest overall score may be chosen as the 'best'. However, consideration should also be given to the alternatives' performance on lower level criteria. For example, if the alternative with the highest overall score has the worst score on one particular criterion; one might prefer a second best alternative which does not perform worst on any one criterion (i.e. is more 'balanced'). In addition, rankings according to different stakeholders can be compared.

4. *Sensitivity and other analyses*. The sensitivity of results to changes in scores and weights needs to be examined. This is particularly important where different groups of stakeholders exist or emerge and therefore where differences arise in, for example, weights. In order to avoid forcing a compromise weight which may be meaningless, the different weight systems of different stakeholders can be recorded, and the overall rankings of different stakeholder groups compared. The ranges of ranks recorded can be used to guide a sensitivity analysis. Other analysis may include determining the trade-offs implied by the scores and weights given (e.g. the scores and weights elicited may mean that a gain of 10 jobs will compensate for a loss of R100 000 in turnover).

5. *Decision making*. The overall ranking, ranking according to subsidiary criteria, ranking according to different stakeholders, sensitivity and other analyses need to be taken into account when the decision-maker makes his/her final choice among the alternatives.

When an evaluation system is being developed for repeated application, as is the case in the development of the WRCS, the stages described above also should be followed. The integrative evaluation system, which includes the value tree, scoring and weighting framework and guidelines developed should be generic (i.e. applicable in all catchments).

2.2 Decision-analysis conceptual framework for the classification procedure

The overall decision-analysis conceptual framework for the classification procedure is presented diagrammatically in Figure 2.4. This figure presents a summarised version of the 7-step classification procedure highlighting only the MCDA-related steps, together with the recommended MCDA/CBA phases or tasks. A summarised description of this is provided below.

Step 1. Delineate units of analysis and describe the status quo of the water resources. As part of this step, a conceptual decision-analysis framework for linking attributes of interest to the relevant criteria is required as part of the classification procedure. Although a generic framework has been developed as part of this project (described in Section 3), it should be checked and adjusted if shortcomings are encountered during the Classification Process. This is Step 1(i).

Step 2. Link the value and condition of the water resource. The decision-analysis component of this step requires that the generic framework established in Step 1i be populated by defining and formalising the relationships between changes in Ecosystem Goods, Services and Attributes (EGSAs)[6] , water yield, the attributes of interest and the scores/index values. Some of these relationships may be generic, but some may be IUA or catchment specific, therefore during each application of Step 2, the relationships need to be verified and updated.

Steps 1 and 2 of the classification procedure together relate to the MCDA phases of problem structuring and the development of scoring systems (Figure 2.4). The framework and relationships established ultimately link to the indices being used to evaluate the catchment configuration scenarios, therefore during Steps 1 and 2, the indices, scoring systems, etc. need to be checked and refined where necessary. The indices selected and scoring systems recommended for the classification procedure are described in Section 4.

Step 3. Quantify the Ecological Water Requirements (EWRs) and changes in non-water quality EGSAs. There were no particular MCDA related tasks here. If comprehensive EWR methodologies are used in later applications of the WRCS, scoring and weighting of ecological components becomes relevant.

Step 4. Set the Ecological Sustainability Base Configuration (ESBC) scenario and establish starter configuration scenarios. There were no MCDA related tasks here.

Step 5. Evaluate scenarios within Integrated Water Resource Management (IWRM) process. The decision-analysis component of this step relates primarily to the evaluation of the catchment configuration scenarios (See Volume 2, Brown *et al*., 2007 for further explanation), the sensitivity analyses MCDA phases, the selection of scenarios (for the technical analysis of scenarios in the WRCS context) and the selection of a subset of alternatives for stakeholder evaluation. Step 5 MCDA activities are described in Section 5.

Step 6. Evaluate the scenarios with stakeholders. The decision-analysis component of this step primarily involves the evaluation by stakeholders of the subset of scenarios selected by DWAF in the Step 5 and agreement by them on a scenario or on a shortlist of scenarios for presentation to the Minister. These are therefore the scenario evaluation and sensitivity analyses MCDA phases. MCDA and other stakeholder related activities for Step 6 are described in Section 8.

[6] See Volume 3 (Turpie *et al*., 2007) for a full description of EGSAs.

Step 7. Gazette the class configuration. The results of the technical and stakeholder evaluations should be presented in a consistent and readily accessible format to the Minister for consideration. A template has been developed as part of the WRCS (see Section 11). Some of the MCDA outputs discussed in this Volume may be included in this template (Section 11).

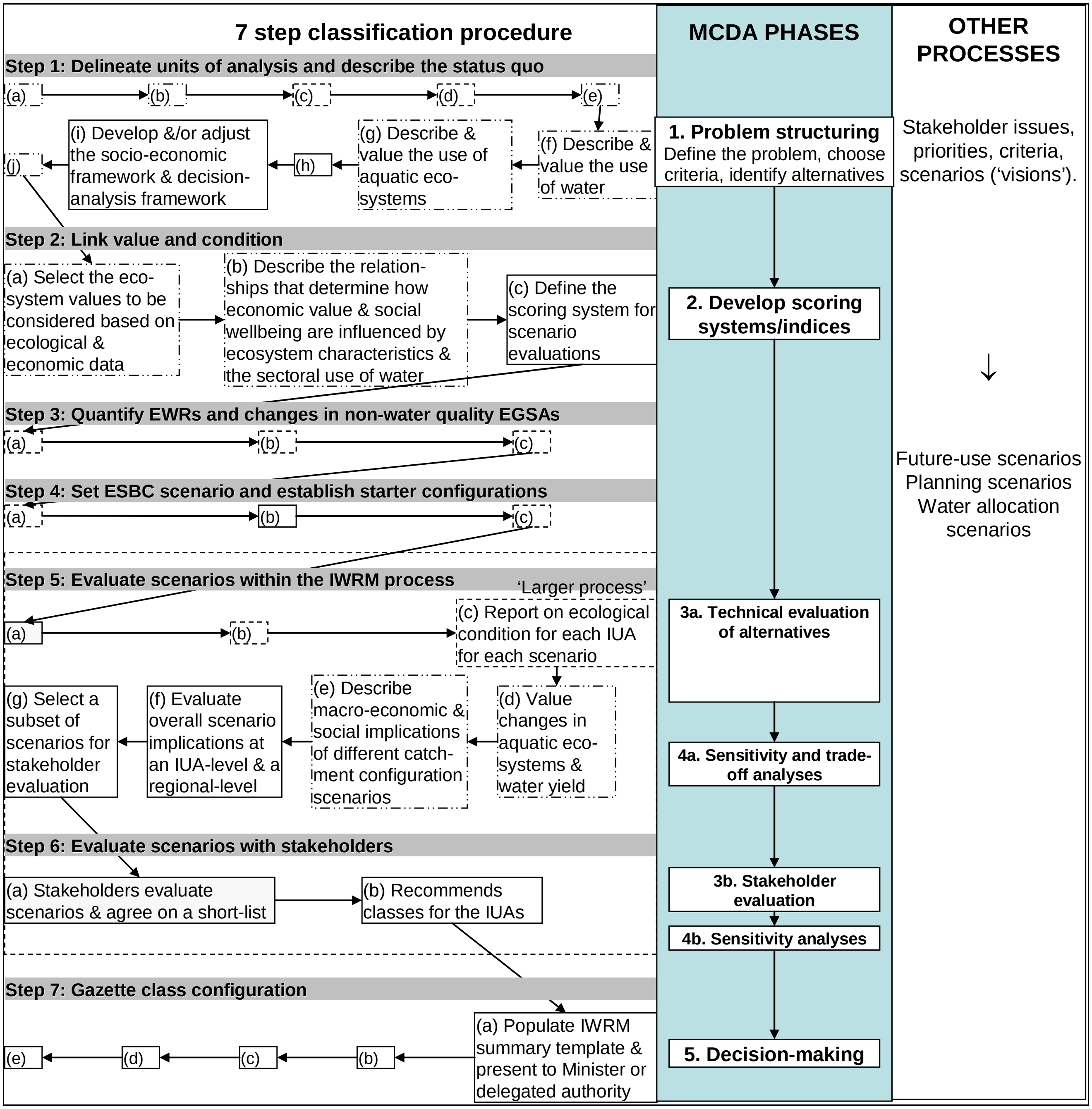


Figure 2.4 7-steps of the classification procedure, associated MCDA stages and other external activities

The following section describes the decision-analysis component steps required for the 7-step classification procedure. The decision-analysis component steps of the classification procedure is summarised in Table 2.1. Steps that require input from the decision-analysis component, but are not the exclusive domains of the decision-analysis component are highlighted in *italics*.

Table 2.1 Summary of the decision-analysis components of the 7-step classification procedure

Step	Description	Section
1i	*Develop and/or adjust the socio-economic framework and the decision-analysis framework*	*3*
2c	*Define the scoring system for evaluating scenarios*	*4*
5f	*Evaluate the overall scenario implications at an IUA-level and a regional-level*	*6*
5g	*Select a subset of scenarios for stakeholder evaluation*	*7*
6a	*Stakeholders evaluate scenarios and agree on a short-list*	*9*
6b	*Recommend classes for the IUAs*	*10*
7a	*Populate the IWRM summary template and present to Minister or his/her delegated authority*	*11*
7b	*Decision by Minister or his/her delegated authority on the IUA classes, nested ecological category configurations, Reserve(s), allocation schedule(s) and Catchment Management Strategy (CMS)*	*12*
7c	*Set the Resource Quality Objectives (RQOs)*	*13*
7d	*Gazette IUA classes, nested ecological category configurations, Reserve(s) and RQOs*	*14*
7e	*Develop plan of action for implementation of recommended scenario which must include a monitoring programme*	*15*

3 STEP 1I: DEVELOP AND/OR ADJUST THE SOCIO-ECONOMIC FRAMEWORK AND THE DECISION-ANALYSIS FRAMEWORK

3.1 Introduction

The broad decision-analysis phases were described in Section 2.2 as they relate to the seven steps of the classification procedure. The detail of the decision-analysis framework for evaluation of scenarios is described in this Section. The objective of the decision-analysis component of this sub-step is to either develop a new decision-analysis framework for the catchment targeted for classification, or to apply or adjust the decision-analysis framework recommended in this report (in this Section). This decision will depend on the specific characteristics of the targeted catchment, and/or the preference of DWAF and/or the team appointed for the Classification Process. Which ever of the two options is chosen (i.e. develop a new decision-analysis framework or adapt or apply the decision-analysis framework presented here), the framework must allow for the assessment of the economic prosperity, social wellbeing and ecosystem health implications of different catchment configuration scenarios within the context of historic redress of past imbalances, and must allow for assessments to be considered at various scales.

The decision-analysis component of Step 1i requires either applying or adjusting the existing framework, specifically in terms of the criteria selected and the value tree developed (i.e. problem structuring).

3.2 Procedure

3.2.1 Problem structuring: selecting criteria and developing the value tree

Step 4 of the classification procedure requires the establishment of a suite of 'starter' catchment configuration scenarios for each Integrated Unit of Analysis (IUA)[7] and for the catchment as a whole (Figure 1.1). These need to be evaluated at the IUA-level and at the catchment-level (Steps 5 and 6) (Figure 1.1). 'Trade-offs' will need to be made between IUAs in order to establish the preferred scenario for the catchment as a whole (Step 6). It is therefore recommended that the value tree be established at the IUA-level.

The system of criteria and value tree should be (Stewart and Joubert, 2006):

- Judgmentally independent: It should be possible to think about tradeoffs between any two criteria, all other things being equal, without having to know levels of achievement on the other criteria
- Value relevant: Stakeholders should be able to link each criterion to their goals, thereby enabling them to specify preferences directly in terms of the criterion
- Understandable: Stakeholders should share a common understanding of the concepts underlying each criterion
- Measurable: the performance of alternatives in terms of each criterion should be able to be measured in a consistent manner.
- Non-redundant: More than one criterion should not be addressing essentially the same concerns, perhaps just in different words or on different branches of the value tree.
- Operational: The decision model based on the chosen criteria should be usable with reasonable effort, i.e. not place excessive demands on decision makers.
- Balance completeness and conciseness: The value tree should be complete, i.e. all important aspects of the problem should be captured, but should also be concise, keeping the level of detail to the minimum required.
- Balance simplicity and complexity: One should strive for the simplest tree which adequately captures the problem for decision makers.

3.3 Example: Olifants/Doring catchment

A value tree was developed for the 'proof of concept' catchment, the Olifants/Doring, which illustrates the evaluation approach for each IUA (Figure 3.1). The evaluations for each IUA can be integrated to give an overall catchment evaluation (with the same value tree structure). It has become conventional to evaluate impacts of scenarios, alternatives etc. on the basis of three main groups of criteria: social, ecological and economic and the same approach was adopted for the 'proof of concept' catchment. These groups of criteria relate in turn to the objectives of equity, sustainability and efficiency, respectively (see Section 2).

[7] See Brown *et al*., (2007) and Turpie *et al*., (2007) for a definition and description of IUAs.

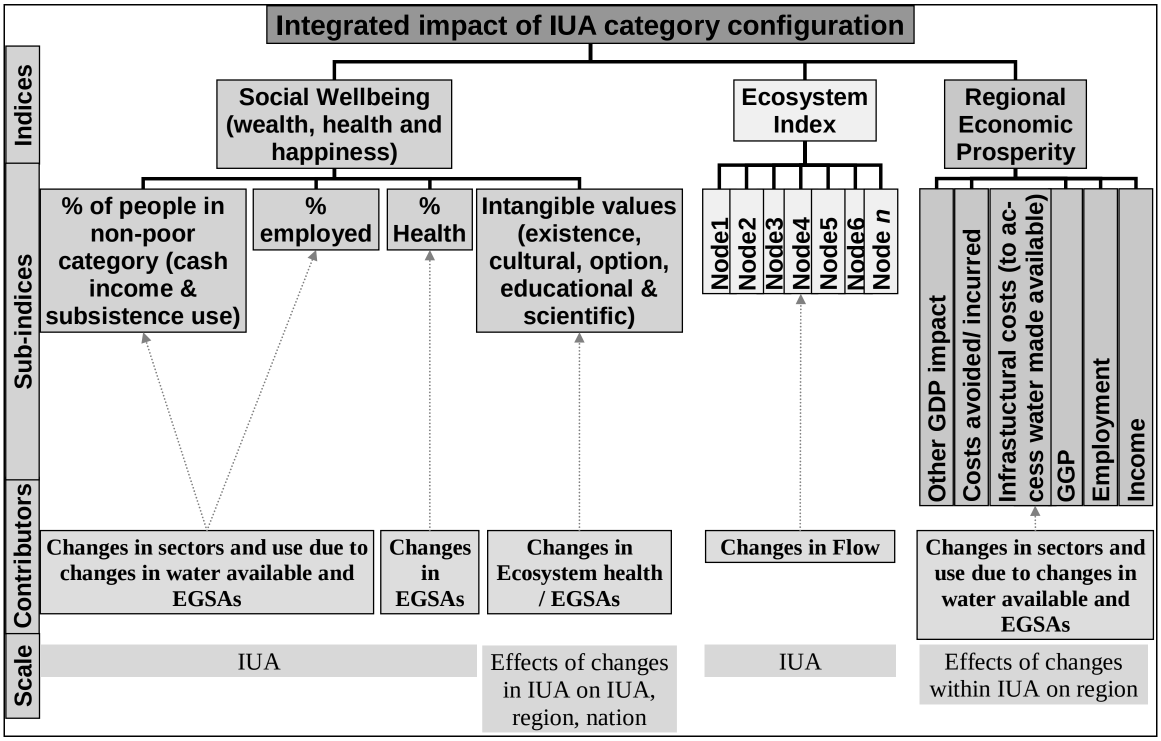


Figure 3.1 Value tree developed for the Olifants/Doring catchment for evaluating catchment configuration scenarios for each IUA and the catchment

An important feature of IUA value tree must be noted: the Ecosystem Index (EI) and most of the social criteria measure the impacts of the catchment configuration scenarios within the particular IUA, but the 'Intangible Values' social criterion and the Regional Economic Prosperity (REP) criteria, measure the impact of the change in the IUA as felt locally or regionally (see Figure 3.1). This is because (a) the macro-economic impacts determined by a model such as the Social Accounting Matrix (SAM) may include industries and multiplier effects in the relevant province and (b) existence and other values included in the Intangible Values index may be felt by people in the IUA and catchment, but also nationally and even internationally, particularly, for example, if the IUA included a biodiversity hotspot.

It is important to note, however, that data were not available for several of the measures contributing to the indices, and so the results for the Olifants/Doring catchment cannot be considered reliable or comprehensive, nor do they provide the basis for any actual decision-making. Figure 3.2 shows the value tree in the form of the impact matrix in Excel, using results from the Olifants/Doring catchment for the Doring-Rangelands IUA.

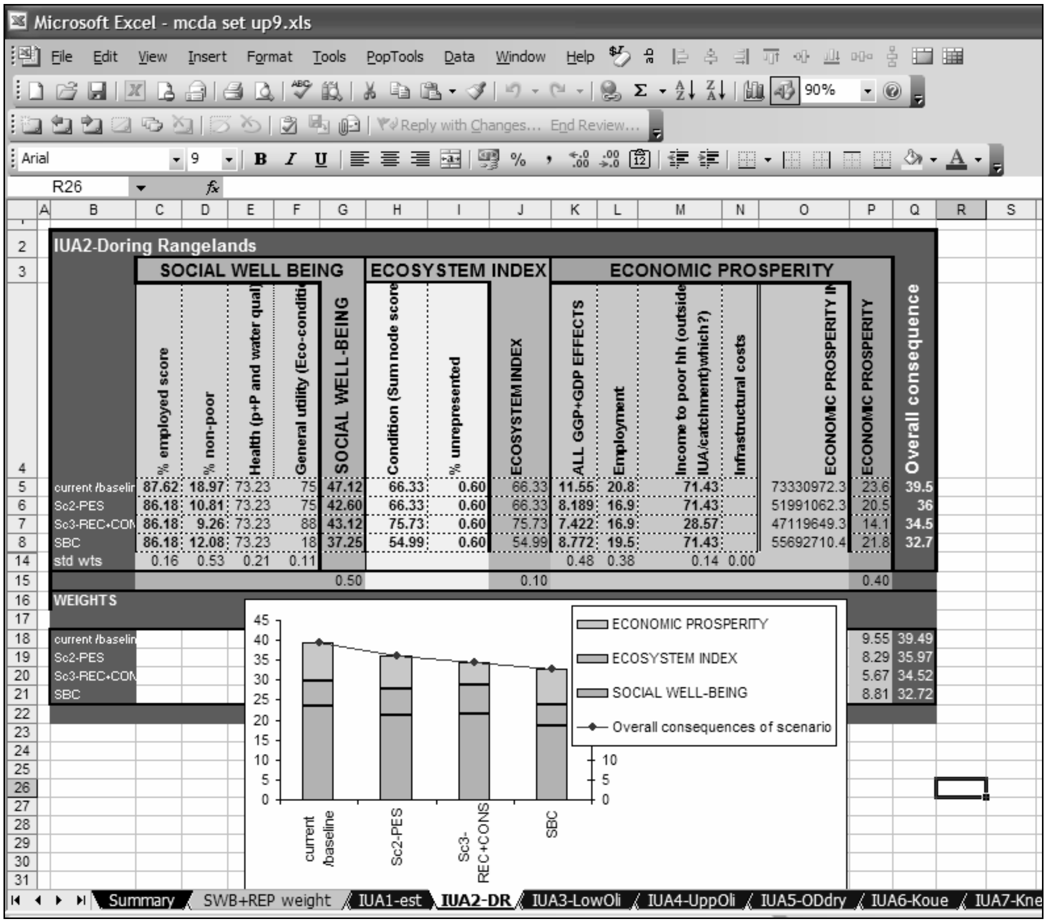


Figure 3.2 Print-screen view of the impact matrix Excel implementation of the value tree

4 STEP 2C: DEFINE THE SCORING SYSTEM FOR EVALUATING SCENARIOS

4.1 Introduction

The objective of this sub-step is to adjust or redefine the scoring systems that will be used to evaluate the catchment configuration scenarios in Steps 5 and 6 of the classification procedure. As mentioned earlier, it has become convention to evaluate the implications of scenarios, alternatives etc. on the basis of three main groups of criteria: social, ecological and economic. For this and other reasons, Step 5 of the classification procedure was designed to evaluate the implications of catchment configuration scenarios in terms of social wellbeing, ecosystem health and economic prosperity. The scoring systems for scenario evaluations therefore reflect this position. The sections below therefore describe the recommended scoring systems together with examples for the Olifants/Doring catchment for:

- social wellbeing (Section 4.1.1);
- ecosystem health (Section 4.1.2); and
- regional economic prosperity (Section 4.1.3).

In what follows the indices are intended to be generic, however, particular relationships may be specific to the Olifants/Doring catchment, in which case this is made clear in the text. In all cases, the sub-indices are aggregated to give the index scores using an equation of the form of Equation 1.

4.1.1 Scoring system for social wellbeing

The rationale behind the selection of the sub-indices (or criteria) contributing to the Social wellbeing (SWB) index is described elsewhere (Turpie *et al*., 2007). A position was taken that Income, Employment, Health and Intangible Values (see Turpie *et al*., 2007) were felt to be the most important criteria to be included in a SWB index, and that these would be applicable to all catchments.[8] For each of these criteria an index could be created with scores from 0-100, where 100 is the highest level and 0 the lowest. The SWB score of a catchment configuration scenario in an IUA could be the weighted sum of these four (or fewer/ greater) sub-indices. Equation 2 presents an example of how the SWB index might be calculated:

$$\mathrm{SWB}_i(a) = w_{\mathrm{NP}}\, v(\mathrm{NP}) + w_{\mathrm{Emp}}\, v(\mathrm{Emp}) + w_{\mathrm{Hlth}}\, v(\mathrm{Health}) + w_{\mathrm{EI}}\, v(\mathrm{EI})$$

Equation 2

Where:

$\mathrm{SWB}_i(a)$ is the Social-Wellbeing score for scenario a in IUA i;

NP = % in non-poor category;

Emp = % employed;

EI = Ecosystem Index;

w_{NP} is the weight applied to the % non-poor category sub-index and so on for the other three sub-indices; and

$v(\mathrm{NP})$ is the value function translating % non-poor to the value of % non-poor to SWB and so on for the other three sub-indices.

The weighting and aggregation of the SWB sub-indices is described in Section 6. This section describes the separate indices.

4.1.1.1 Percentage of households in the non-poor category in the IUA

Non-poor households can be defined as those earning more than R 38 000/yr (Turpie *et al*., 2007). In order to determine the scores, a series of calculations are required. First, average income per household and the percentage of people in the non-poor category should be calculated for each IUA (this gives the value for the current situation). A relationship exists between average income and percentage in the non-poor category and a regression equation can be found for the catchment.

The regression equation can then be used to translate changes in overall average income (through effects of the scenarios on turnover and therefore cash income in various sectors (irrigation agriculture, tourism, etc.) as well as on subsistence activities to changes in the percentage of those in the non-poor category. The values arising from this relationship are therefore already on a scale of 0-100 (although it is likely that only a portion of this scale will be used).

While the 0-100 scale arises naturally and has a natural meaning (as a %), this does not necessarily mean that it directly reflects the value that we place on different levels of achievement along the scale: i.e. it does not necessarily relate linearly to value. For example, it might be of

[8] However, these four criteria are recommendations; others may be included (or excluded) during the Classification Process.

more importance or value to SWB to increase from 0 to 20% in the non-poor category than it would be to increase from 80-100% in the non-poor category. Although linear relationships between attributes and values (score) are often used as the 'easiest'; misspecification of non-linear relationships as linear can have a bigger influence on final aggregate scores than weights (Stewart, 1996). Two possible value functions, linear and logarithmic, are shown in Figure 4.2.

4.1.1.1.1 Example: Olifants/Doring catchment

Various examples were tested for the Olifants/Doring catchment and different relationships might arise in other catchments. The relationship has to have a zero or near-zero y-axis intercept (there cannot be a negative % of people in a category). The best fit equation for the Olifants/ Doring catchment based on r^2 values and on the most likely (or least unlikely) actual relationship was chosen as a 2nd order polynomial: $y = 0.0000000118\,x^2 + 0.0001931\,x$ ($r^2 = 0.695$) (Figure 4.1).

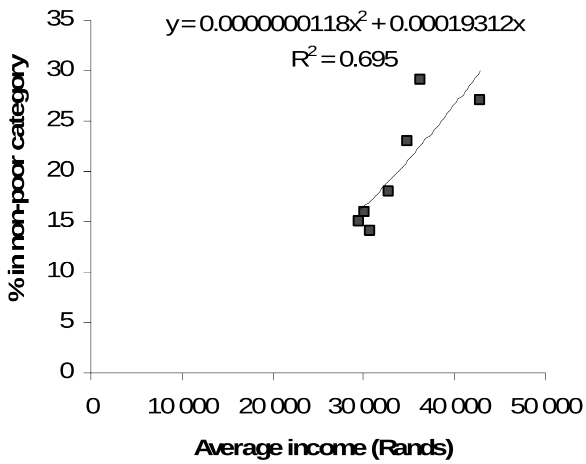


Figure 4.1 Relationship between average income and the % of people in the non-poor category. The graph on the left represents the Olifants/Doring catchment data and regression line. Each point is for one of the Olifants/Doring IUAs. The graph on the right shows the same relationship extended over the range R0 to R80 000, (showing that the relationship is non-linear although this is not apparent on the left where the curve is only over a short range)

The linear value function was used for the Olifants/Doring catchment. Figure 4.2 illustrates the difference in score that would result for the estuary IUA depending on whether a linear or log relationship was used.

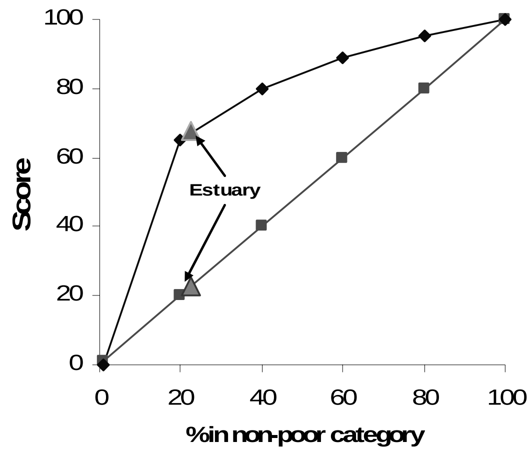


Figure 4.2 Two possible value functions relating the % of people in the non-poor category to score /value, showing, as an example, the different scores resulting for estuary.

4.1.1.2 Percentage of the IUA population employed

The current figures for percentage employment are available from the Census data. The number of (local) jobs created or lost by the various catchment configuration scenarios need to be converted to % employment. Estimation of the number of jobs created or lost is described in Turpie et al. (2007). This index is therefore also directly available on a naturally understood 0-100 scale. Consideration should also be given to whether there is a linear or non-linear relationship between % employment and contribution to SWB.

4.1.1.2.1 Example: Olifants/Doring catchment

A linear value function was used for the Olifants/Doring catchment.

4.1.1.3 Human health in the IUA

The health index still needs to be refined. However, it could be based on data which is available at a municipal scale (Turpie *et al*., 2007).

The overall health status of people in an IUA can be related to four groups of health problems (Table 4.1). These are: general nutrition (indicated by the percentage of children under 5 who are malnourished), the prevalence of infectious diseases (indicated by the prevalence of HIV/AIDS, TB and hepatitis), the prevalence of water-related diseases (malaria and bilharzia), the prevalence of water quality-related diseases or problems (diarrhoea in under 5 year olds, skin and eye irritations, cholera and typhoid). While cholera and typhoid are water-borne they were included in the latter group as they relate more to the general quality of sanitation, reliance on instream water and water quality. Only water-related and water quality-related diseases are likely to be directly affected by the catchment configuration scenarios in question (although co-morbidity of HIV and diarrhoea may also be considered).

Table 4.1 Recommended elements of a Health Index

Sub-indices	Descriptors			
General nutrition	Malnutrition in under 5 year olds			
Infectious diseases	HIV prevalence in population		TB prevalence in population	Hepatitis occurrences
Water-related diseases	Malaria occurrences		Bilharzias occurrences	
Water quality diseases	Diarrhoea in under 5 year olds	Cholera occurrences	Typhoid occurrences	Skin and eye irritations

All of these factors can be expressed as prevalence (as a % of population) or occurrences in a year (as a % of population). Therefore, the overall amount of disease or unhealthiness in an area could be calculated as the sum of these separate percentages. As two of the measures relate to under 5 year olds, the figure could be adjusted by multiplying by the % of under fives in the population. The separate indices could also be weighted by the severity of the illness in question (e.g. HIV may be weighted higher than malaria). Therefore there are three possible approaches for aggregation of the health sub-indices to give an indication of overall disease or disease burden (DB_i) for an IUA i:

1. Unweighted summation:
   DB_i = % malnutrition + % HIV + % TB + % hepatitis + % malaria + % bilharzia + % diarrhoea + % cholera + % typhoid + % skin & eye irritations.

2. Weighted by % of children under five:
   DB_i = % malnutrition (x % under 5s) + % HIV + % TB + % hepatitis + % malaria + % bilharzia + % diarrhoea (x % under 5s) + % cholera + % typhoid + % skin & eye irritations.

3. Weighted by severity of disease:
   DB_i = % malnutrition (x % under 5s) (x severity of malnutrition) + % HIV (x severity of HIV) + % TB (x severity of TB) + % hepatitis (x severity of hepatitis) + % malaria (x severity of malaria) + % bilharzia (x severity of bilharzia) + % diarrhoea (x % under 5s x severity of diarrhoea) + % cholera (x severity of cholera) + % typhoid (x severity of typhoid) + % skin & eye irritations (x severity of s&e).

The level of health in IUA i (Hi) can then be taken as: $H_i = 100 - DB_i\%$.

4.1.1.3.1 Example: Olifants/Doring catchment

The first summation option was used for the Olifants/Doring catchment. Malnutrition in children is understood to be a good indicator of the health of the population in general, and therefore it was decided that it should not be down weighted by the percentage of under five year olds in the IUA. There was no expertise on the team for deciding on ‘severity’ weights.

4.1.1.4 Intangible Values arising from changes in the IUA

Intangible Values arise from a number of sources such as existence value, option value, education value, cultural value and spiritual values. These values are more or less important to different people both within and outside the IUA or catchment (e.g. an area with high biodiversity importance may be valued nationally). The values to greater or lesser degrees, and potentially in different ways relate to the ecological condition of the resource.

The simplest approach is to combine all Intangible Values into one index relating to the ecological condition of the resources. It is assumed that there is a non-linear S-shaped relationship between ecological condition and intangible value (IV). Ecological condition was represented by the

Ecosystem Index (EI) as described in Section 4.1.2. A relationship which captures the S-shape is presented in Equation 3.

$IV = IV_{max} \times EI^{Q} / (K^{Q} + EI^{Q})$

Equation 3

Where:
IV = Intangible value;
IV_{max} = maximum intangible value (105.033);
K = the value at which IV is half IV max (55);
Q = is a parameter which controls the slope near K (5); and
EI= Ecosystem Index value.

This equation, with parameters as shown above in brackets gives the shape shown in Figure 4.3.

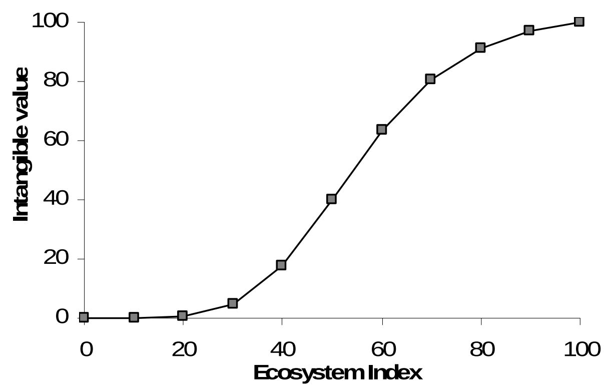


Figure 4.3 Relationship between the EI of ecosystem health and intangible values

Two other options exist for this sub-index. First, if there were a clear link between a particular EGSA and one of the Intangible Values, then a separate value function could be developed for this Intangible Value which could subsequently be added to the rest. Second, if budget and time were to permit, in a particular application of the WRCS, various valuation techniques could be used to obtained monetary estimates of the separate values. However, it cannot be over-emphasised that these values cannot be assumed to be comparable with each other if different techniques were used for different components of intangible value nor with other monetary criteria within the WRCS value tree (e.g. GGP effects) (Joubert, 2003). The values cannot be directly compared or aggregated, although a preference ordering of scenarios *within* each criterion would be determined. The preference orderings and relative differences between scenarios could be used to estimate a resulting score for the particular component of IV.

A number of ways of determining overall IUA ecosystem health, i.e. the EI required for determining IV, were explored. It is recommended that System 1 as described in Section 4.1.2 be used to derive the IV score as System 3 (used to define the resulting Class) will be too coarse.

4.1.1.4.1 Example: Olifants/Doring catchment

The relationship of Equation 3 (and Figure 4.3) was used in the Olifants/Doring catchment using the EI derived using System 1 (as described in Section 4.1.2).

4.1.2 Scoring system for ecosystem health

A scoring system for representing ecosystem health at the level of an IUA is required for Steps 5 and 6 of the classification procedure. An Ecosystem Index (EI) was developed as part of the 'proof of concept' decision analysis framework to represent the ecosystem health of an IUA. It is recommended that the score used to represent the ecosystem health of an IUA (in this case the EI) be translated to (or directly be) the Classes of the IUAs. These will become the gazetted classes.

The overall ecosystem health of an IUA can be based on the condition of the resources represented by each of the nodes. A number of alternatives are possible; however it is first necessary to translate the ecological categories of A to E (see Kleynhans, 1999) to scores. In this case, the classes A to E were given scores from 5-0[9]. In all cases, the percentage of the total length of the resource (in the case of the Olifants / Doring this is the river) within an IUA that a node represents should be determined. The percentage resource length that each node represented of the *represented* portion, in turn, should be calculated[10].

System 1. The category score of a node can be multiplied by the percentage length which the node represents. The sum of these 'length-weighted' scores can then be taken as the total ecosystem health score of that IUA.

In mathematical notation the EI value of IUA_i can be calculated as (Equation 4):

$$EI_{\mathrm{i}}(a) = \left(\sum_{j=1}^{m} \mathrm{N}_j(l_j) \right) \times 20$$

Equation 4

Where:
N_j = the category score of node j in IUA i; and
l_j = the percentage length of the represented portion of the river that node j represents.

Multiplication by 20, brings the score to a value out of 100, where 100 means that all reaches are in an A category.

For example, consider an IUA_i with three nodes in categories A, B, and B, representing 20%, 30% and 35% of the total IUA river length, respectively (15% is unrepresented). Of the represented portion then, 24% (20/85) of the river is in A category and 76% is in a B condition ((30/85) + (35/85)). The overall EI is therefore:

EI_i = (5 x 0.24 + 4 x 0.76) x 20 = 84.7

The condition of the IUA can be represented graphically in either the form presented in the left of Figure 4.4 which also shows the unrepresented portion of the river, or in the form presented in the right of Figure 4.4 which shows the score out of 100 of the represented portion of the river.

[9] The ecological condition of the nodes can be considered as the sub-indices of the EI index. Once again, more attention could be given here to the potentially non-linear relationship between category and score: e.g. maybe A = 10, B = 9, C = 7, D = 5, E = 3, F = 0 would better reflect the ecological meaning of the categories than 5-0. However, for the sake of simplicity at this stage, 5-0 was felt to be appropriate. In future, the relevant specialists should refine this.
[10] The percentage of resource length which is not represented by a node can be retained as a measure of uncertainly.

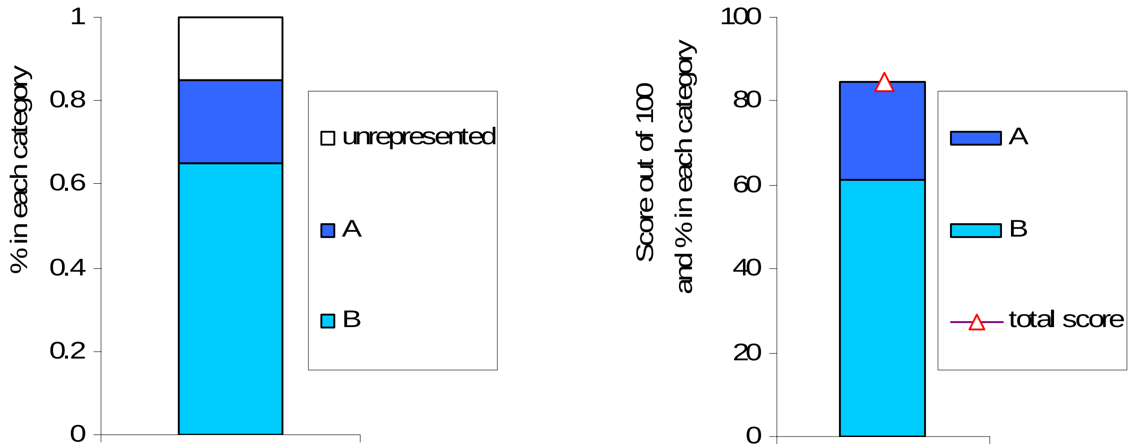


Figure 4.4 Possible graphical representations of IUA ecosystem health

System 2. The contribution of the nodes to the overall score could be weighted by the Ecosystem Importance and Sensitivity (EIS) of the resource (EIS_i) represented by the node with or without also being weighted by the percentage of river represented by the node (Equation 5):

$$EI_i(a) = \sum_{j=1}^{m} N_j(l_j)(EIS_j)$$

Equation 5

System 3. The degree to which defined Freshwater Conservation (Roux *et al*., 2006) targets are achieved could be used to rate the IUA. Conservation targets could be defined such that in order for an IUA to obtain a particular overall score it must have at least a particular percentage of river length in a particular category. As for Systems 1 and 2, the resulting score or value could ultimately be the Class of the chosen scenario.

Initial suggestions for such Class definitions are given in Table 4.2.

Table 4.2 Preliminary guidelines for determining the IUA class for a scenario (after DWAF, 2006a)

IUA Class		**Percentage Ecological Category (EC) representation at units represented by biophysical nodes in an IUA**				
		≥A/B	**≥B**	**≥C**	**≥D**	**<D**
Class I		≥40	≥60	≥80	≥99	-
Class II		-	≥40	≥70	≥95	-
Class III	Either	-	-	≥30	≥80	-
	Or		-	-	100	-

Of these three systems, System 3 was considered the preferred one for defining Classes, but not for an EI. The rules and the translation of nodal categories into only three resulting scores (i.e. the resulting three Classes) would be inadequate for the purposes of an EI for the comparison and evaluating of scenarios according to the value tree in Figure 3.1. In other words while the three Class definitions may be adequate for the final classification of a resource once scenarios have been evaluated, they are not useful as an evaluation tool for two main reasons:

1. A small change in a scenario may cause the Class to change from one class to another, or several nodes may change category but the Class may remain unchanged. In comparing scenarios on the basis of this criterion, decision-makers or stakeholders will not be in a position to tell if there has been a large or slight change. The examples in Table 4.3 illustrate these problems. Scenario 1 and 2 differ very slightly. In scenario 1, 46% of the river is in category B, and for scenario 2, 39% of the river is in a category B, yet System 3 places scenario 1 in Class II and scenario 2 in Class III. The System 1 scores are, however, very close (69 and 68). In contrast, scenario 2 and 3 are very different: 39% of scenario 2 is in B and 61% in C, while 100% of scenario 3 is in D. However, both are placed in Class III by System 3. The System 1 scores, however, do show that they are rather different: they score 68 and 40 respectively. The final example has scenario 3 with all Ds and scenario 4 with all Cs. Both are in Class III, but their scores are 40 and 60 respectively, reflecting their relative condition. Thus, the System 1 scores better reflect the changes in node categories than do the System 3 classes.

Table 4.3 Category configuration scenarios showing Classes arising from applying System 3 (definitions in Table 4.2) and scores arising from applying System 1 an IUA within the Olifants/Doring catchment

Node configuration scenarios (13 nodes) 1	2	3	4	% of *represented* IUA river length
C	C	D	C	12
B	B	D	C	9
B	C	D	C	6
B	B	D	C	7
C	B	D	C	5
B	B	D	C	6
B	C	D	C	9
C	C	D	C	6
C	C	D	C	7
C	C	D	C	12
C	B	D	C	7
B	C	D	C	9
C	B	D	C	6

Category	1: Cumulative % in category	1: Number in each category	2: Cumulative % in category	2: Number in each category	3: Cumulative % in category	3: Number in each category	4: Cumulative % in category	4: Number in each category
A	0	0	0	0	0	0	0	0
B	46	6	39	6	0	0	0	0
C	100	7	100	7	0	0	100	13
D	100	0	100	0	100	13	100	0
E	0	0	0	0	0	0	0	0

Results	**1**	**2**	**3**	**4**
System 3: Class	**II**	**III**	**III**	**III**
System 1: EI score	**69.3**	**67.9**	**40.0**	**60.0**

2. Besides providing a measure of IUA ecosystem health, the EI value can also used to obtain the Intangible Value score (see Section 4.1.1.4 and Figure 4.3). The Intangible Value score would similarly only have three values if a three Class EI were used, and this would be inadequate.

Therefore, a more responsive and finer-scaled scoring system than System 3 may be required for the EI. The EI recommended for the classification procedure is System 1 (or System 2 if the information were available). Once a scenario has been chosen, System 3 (the rules suggested in Table 4.2), could be refined and applied to obtain the final IUA Class of the chosen catchment configuration scenario. Ultimately, it should be possible to integrate System 1 (or 2) and System

3, such that, for example, a score of above 80% from System 1 can be placed in Class 1 from System 3.[11]

4.1.2.1 Example: Olifants/Doring catchment

For the purposes of the 'proof of concept' catchment, System 1 was applied to the Olifants/Doring catchment. The results of applying System 1 and System 3 (using the rules of Table 4.2) were applied to the three catchment configuration scenarios (see Brown *et al*., 2007) developed for the Olifants/Doring catchment for comparison (Appendix A).

4.1.3 Scoring system for regional economic prosperity

There are six macro-economic sub-indices that can be used to measure the economic implications of different catchment configuration scenarios. Many of these describe the implications at a regional or provincial scale, while some describe impacts at a national scale (see Volume 3; Turpie *et al*., 2007):

1. **Effect on Gross Geographic Product (GGP)** (measured in R/year): this is made up of contributions from all the relevant sectors.
2. **Other Gross Domestic Product (GDP) effects**: only carbon sequestration contributes to this criterion (also measured in R/year).
3. **Costs avoided/incurred** (measured in R/year): this is made up of costs avoided or incurred through flood attenuation, sediment control, waste treatment and invasive exotic species and/or pests.
4. **Infrastructural costs** – (measured in annualised capital and maintenance costs in R/year): these are the costs that would arise, for example, from a particular catchment configuration scenario which increases yield, in order to make that yield available for use (e.g. through building a dam, canal, or other infrastructure). These costs are really a subset of 3, but should be kept separate as the source of information or data would be quite different to 3.
5. **Income to poor households** – R/year: this is determined through the changes occurring in the same sectors as 1.
6. **Jobs** – the number of jobs created outside of the IUA or catchment: this is determined through the changes occurring in the same sectors as 1.

Criteria 1, 5, and 6 are outputs from a macro-economic model (e.g. a SAM) which are usually run at a provincial level. Criterion 4 should be available from planning and future-use scenarios (Step 4b of the classification procedure – see Brown *et al*., 2007) and depending on the type of infrastructure would be a national, provincial or local government cost. Criterion 2 could, similarly, be a government cost at any of the three tiers of government.

A problem arises with the macro-economic criteria as there is no clearly defined global maximum as there was with the SWB criteria.[12] Several approaches exist, three of which are described here:

---

[11] See research needs, Section 16.

[12] In contrast, all of the SWB criteria can be related to a 100% maximum - theoretically possible amount. For example, 100% of the population in the non-poor category, 100% employment, 100% healthy, and 100% of potential Intangible Value. It must be noted, however, that there are different likelihoods of these "100%" ever actually being achieved, and so the SWB indices use different parts and extents of the 0-100 scales. See comment in Section 16 regarding future research.

System A: The values obtained from the SAM (or other macro-economic model) could be translated to a percentage of the maximum of the scenarios across all IUAs.
System B: One could translate values as a percentage of the maximum of scenarios within each IUA.
System C: One could determine the percentage change relative to the current/ baseline scenario in each scenario and then translate this to a score relative to the maximum improvement from the status quo across all IUAs.

System A has the affect that a very small IUA which nevertheless has a high level of economic activity for its size may have a low resulting score. However, given the purpose of the macro-economic criteria – to allow the Minister to, for example, examine which scenarios have the larger regional GDP impact – either System A or C seem more appropriate[13] rather than System B. System C presents the relative improvement in economic prosperity arising from an IUA rather than the absolute size of the contribution to regional economic prosperity which System A presents.

For the purposes of the 'proof of concept' catchment, values obtained from the SAM were translated to a percentage of the maximum of the scenarios across all IUAs – i.e. System A was applied.

As with the other indices, for each of the sub-indices 1-6, one should then consider whether there is a linear relationship between the percentage obtained and its contribution to economic prosperity. For example, for effect on GDP, is it more important to move from 10% to 20% of the maximum than moving from 80% to 90% of the maximum?

Once a final 0-100 value scale is obtained indices 1-4 can be added directly as they are similar types of values measuring similar things (costs or benefits to national, regional or local government). The summed value is now called Total GGP effects (TGP). (There may be reasons why, in an application of the WRCS these four sub-indices are not added directly, but swing weights applied to all six sub-indices).

The overall Regional Economic Prosperity (REP) index for IUA i can be made up of the weighted sum of the TGP with sub-indices 5 and 6 (Equation 6):

$$\text{REP}_i(a) = w_{\text{TGP}}\, v(\text{TGP}) + w_{\text{Income}}\, v(\text{Income}) + w_{\text{Jobs}}\, v(\text{Jobs})$$

Equation 6

Where:
$\text{REP}_i(a)$ is the Regional Economic Prosperity of IUA i of scenario a;
TGP = total GGP effects;
w_{TGP} is the weight applied to the GGP index; and
$v(\text{TGP})$ is the value function translating TGP impact to value, etc. for the other two indices.

Deriving the weights and aggregating the sub-index scores is described in Section 6.

4.1.3.1 Example: Olifants/Doring catchment

System A was applied in the Olifants/Doring catchment. At the time of writing, information from the SAM was not available for the Olifants/Doring catchment in the format required (i.e. back-

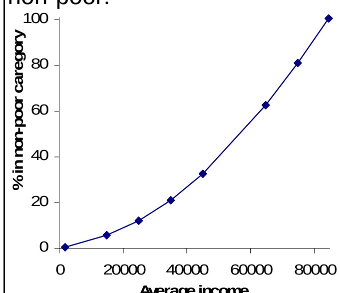
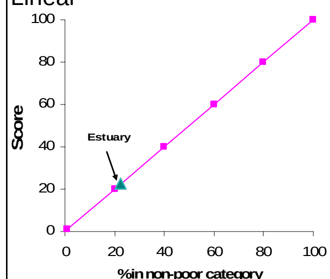
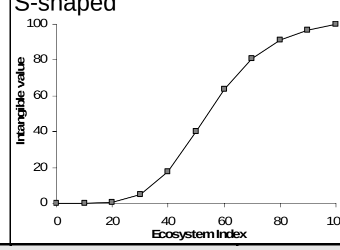
[13] Either way, this reminds one of the importance of ensuring that one has a realistic 'worst' and 'best' scenario from each main point of view.

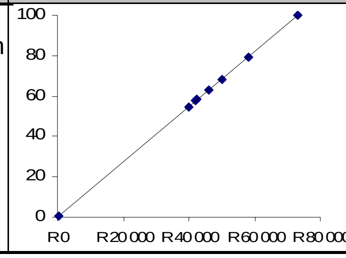
calculated to the IUA level from the provincial outputs), and so the sectoral turnover values (see Turpie *et al*., 2007; Volume 3) were used as an interim substitute in order to demonstrate the system. Information regarding changes in employment and income to poor households at the macro level were obtained from the SAM for the catchment as a whole and were not disaggregated to the IUA level. The same proportional changes were therefore applied to all IUAs for these two indices. It was decided to use linear value functions for all the economic prosperity indices for the Olifants/Doring catchment, given that the contribution of the Olifants/Doring catchment to GGP is relatively small and therefore, only a small portion of a hypothetical larger non-linear value function may be being used, and this might be considered linear.

4.2 Summary of indices for the Olifants/Doring catchment

A summary of the ecosystem health, SWB and REP indices and their scoring systems as applied in the Olifants/Doring catchment is given in Table 4.4.

Table 4.4 Summary of indices and scoring systems for the Olifants/Doring catchment

	Approach and/or Baseline/reference point	Scale	Value function	Overall
SOCIAL WELLBEING (SWB)				
% in non-poor category	% households earning <R38 000/yr. Average income translated to % non-poor: 	IUA	Linear 	SWB$_i(a)$ = w_{NP} v(NP) + w_{Emp} v(Emp) + $w_{Hlth}v$(Health) + w_{EI} v(EI)
% employed	% of people employed within the IUA	IUA	Linear	
Health	"% health" = 100-%prevalence or % occurrence of four groups of health problems	IUA	Linear	
Intangible values	EI score translated to IV: **IV** = IV$_{max}$ x EI^Q / (K^Q + EI^Q)	Effects of changes in IUA on the IUA, region, nation	S-shaped 	
ECOSYSTEM INDEX (EI)				
Ecosystem index	System 1 as described above	IUA		$EI_i(a)=\left(\sum_{j=1}^{m} N_j(l_j)\right)\times 20$
REGIONAL ECONOMIC PROSPERITY (REP)				
Total GGP effects	Percentage of maximum scenario across all scenarios & IUAs (System A) (sum of indices 1-4)	Effects of changes in IUA on the region.	Linear, e.g.	REP$_i(a)$ = w_{TGP} v(TGP) +

	Approach and/or Baseline/reference point	Scale	Value function	Overall
Jobs	Percentage of maximum scenario across all scenarios & IUAs (System A)	(Can compare IUAs but not with other catchments)		w_{Inc} v(Income) + w_{Jobs} v(Jobs)
Income to poor house-holds	Percentage of maximum scenario across all scenarios & IUAs (System A)			

5 STEP 5: EVALUATE SCENARIOS WITHIN THE IWRM PROCESS

5.1 Introduction

Step 5 of the classification procedure (see Figure 1.1) involves the evaluation of 'starter' catchment configuration scenarios as part of the Integrated Water Resource Management (IWRM) process. Besides enabling DWAF to assess the desirability of catchment configuration scenarios in an integrated way, this step will also provide the information necessary to add additional scenarios and to select a suitable subset of scenarios for further evaluation by stakeholders. In terms of the decision-analysis component of the classification procedure, the following needs to be noted:

- A sufficient range of scenarios should be evaluated to enable the selection of a range of them for evaluation by stakeholders in Step 6. This should include all their (stakeholders) 'best' scenarios, and preferably also their second best scenarios. Thus, Step 5 involves an iterative process to select and evaluate scenarios before selecting a subset for stakeholder evaluation in Step 6.

- In order to evaluate the scenarios, the decision-analysis framework developed in Step 1i and the scoring system developed in Step 2c should be applied.

- An overall evaluation of the catchment configuration scenarios requires that the indices are aggregated at a number of different levels of the value tree and geographic scales. Therefore, weights need to be found for each of these aggregation steps. The elicitation of weights or the development of a weighting system is part of the development of the scoring system (Step 1i). Their derivation however, is described as part of Step 5f, where it more comfortably fits in the context of the classification procedure.

- In addition to scoring and weighting, during Step 5f, once the scoring and weighting has been done, sensitivity analyses (and other analyses) of the results could be undertaken. Sensitivity analysis could be undertaken to ensure that the more robust alternatives are selected for further evaluation, or in order to anticipate the likely preferred scenarios of identified stakeholder groups. These should then be included for further evaluation.

- Finally, during Step 5g, based on the scoring, weighting, aggregate scores and sensitivity analyses, a subset of (about 5-10) scenarios needs to be selected for further evaluation by the stakeholders.

5.2 Context

During Step 4 of the classification procedure, the ESBC scenario can be established as a 'bottom-line' from an ecological point of view[14], while the Recommended Ecological Category (REC) plus the Freshwater Conservation targets (Cons.) (REC+Cons.) scenario can be established as a 'best' from the ecological point of view (see Brown *et al*., 2007 for a full discussion on Step 4 of the classification procedure). Bests and 'second bests' from the ecological and economic points of view also need to be developed. It is envisaged that at least some of these catchment configuration scenarios and those for particular stakeholder groups (if their 'bests' are likely to differ from these), will arise from the broader IWRM process which takes place alongside the Classification Process; including for example allocation scenarios and future use scenarios (Step 4b). As mentioned earlier, these 'starter' catchment configuration scenarios should be evaluated in terms of their economic, social and ecological implications for different users at different scales. This occurs in Steps 5a, 5b, 5c, 5d and 5e of the classification procedure.

Each of the 'starter' catchment configuration scenarios should be compared in the same way: i.e. the scenarios should be evaluated using the same decision-analysis evaluative framework. This can either be the decision-analysis framework recommended in this report, or a DWAF-approved framework designed during a specific application of the WRCS.

During the iterative process of developing a rich set of scenarios, the evaluation of the scenarios on the basis of the value tree provides the information necessary to fine-tune scenarios or select new ones. For example, if a scenario performs well on most criteria but very poorly on one criterion, it could be adjusted so as to improve its performance overall. Ultimately, the full rich set is evaluated using the evaluation framework and from them a subset for stakeholder evaluation could be selected.

The following two sections (Sections 6 and 7) discuss Steps 5f and 5g in more detail.

6 STEP 5F: EVALUATION OF THE OVERALL SCENARIO IMPLICATIONS AT AN IUA-LEVEL AND A REGIONAL-LEVEL

6.1 Recommended procedure for Step 5f

The objective of Step 5f is to utilise the outputs of Step 5c (see Brown *et al*., 2007), 5d (see Turpie *et al*., 2007) and 5e (see Turpie *et al*., 2007) and the decision-analysis framework (Step 2i – see Section 3) and scoring systems (Step 2c – see Section 4) to evaluate the overall implications of different catchment configuration scenarios at an IUA-level and a regional-level. The following steps are required:

- gives scores to scenarios;
- apply weights to criteria; and
- aggregate scenario scores.

If the appropriate quantitative data are available (i.e. generated in Steps 5a to 5e), scoring of scenarios can be more-or-less an automatic step, as the data can be directly converted to scores for the various indices (i.e. EI, SWB and REP), based on the framework developed in Step 1i and

[14] It is possible, depending on the process used to develop the ESBC, that it may in fact be better than the PES, in which case the PES becomes the 'worst case' scenario.

the scoring system developed in Step 2c. There may be situations where the data are unavailable for criteria which nevertheless should be included. In this case, the relevant specialist input could be obtained. The specialist should give a score directly, based on the likely achievement on the particular index.

There are a number of aggregation steps in terms of levels of the value tree and geographic scales, and at each of these steps weights could be defined. At the IUA-level aggregation and weighting steps may include:

- the aggregation of the four indices contributing to the SWB index;
- the aggregation of node level categories to give an IUA-level EI (already described (Section 4.1.2));
- the aggregation of the indices contributing to REP; and
- the SWB, REP and EI values can be aggregated to obtain an overall evaluation of the scenarios for the IUA.

At the catchment-level aggregation and weighting steps may include:

- the aggregation of the IUA-level SWB to get a catchment-level Overall SWB (OSWB) score;
- the aggregation of the IUA-level REP indices to get a catchment-level Overall REP OREP) score;
- the aggregation of the IUA-level EI to get a catchment-level Overall EI (OEI) score; and
- the aggregation of the catchment-level SWB, REP and EI values (i.e. OSWB, OEI and OREP) to obtain an overall evaluation of the scenarios at the catchment-level.

While, ideally, there should be a consistent set of criteria applied in all applications of the WRCS (with irrelevant ones given a zero weight), the weights will probably differ from IUA to IUA, from catchment to catchment and from stakeholder group to stakeholder group. Thus, in contrast to the value tree and indices, the weights applied are likely to be context specific (defined at IUA- or catchment-level rather than nationally). For the technical level evaluation of scenarios, it is recommended that the guidelines given here and in Box 2 are used to derive swing weights (noting that stakeholders may offer different weights during Step 6, and therefore that sensitivity analyses need to anticipate possible ranges in these weights).

6.2 IUA-level overall scenario evaluations: weighting and aggregation

This section describes the recommended procedure for the aggregation of the sub-indices contributing to the three main indices (i.e. SWB, REP and EI) within an IUA, and aggregating them to give an overall IUA-level assessment of the catchment configuration scenarios. Section 6.3 presents the procedure for the catchment-level assessments.

6.2.1 Social wellbeing

The four SWB indices should be aggregated to obtain an overall IUA-level SWB score. The weighted summation equation is Equation 2 in Section 4.1.1. The swing weighting approach should be applied to obtain the relevant weights.

A question arises as to whether the indices should be aggregated using IUA specific weights or weights derived for the catchment as a whole. The former approach may be preferable because

(a) different issues will be important in different catchments, (b) there will be a different range of scenario effects on different criteria within different IUAs, and (c) during the stakeholder process, stakeholders in different IUAs may have different priorities. Therefore, with swing weighting, the weights are likely to be different for different IUAs. In the evaluation of scenarios at the IUA-level, IUA-level priorities should be taken into account and it suggested that IUA specific weights should be applied.

During an application of the WRCS, DWAF could decide on these weights, based on the available information for each IUA and the guidelines for swing-weight elicitation given in Box 2.

6.2.1.1 Example: Olifants/Doring catchment

An example of the elicitation of swing weights for the SWB index in the Doring Rangelands IUA is shown in Box 2.

Different IUA-level weights were used in the Olifants/Doring catchment, but there was no opportunity to do a swing-weighting exercise for this technical evaluation of the Olifants/Doring catchment scenarios. However, IUA 'dummy' weights (based loosely on some interaction with the project team using the process in Box 2) were applied for illustrative purposes. An example for the Doring Rangelands SWB index is illustrated in Table 6.2. Aggregate SWB indices for all IUAs are shown in Section 6.2.4. Results for the Olifants/Doring catchment are shown in full in Appendix A, B and C.

Box 2 Elicitation of swing weights

Information such as that presented in Table 6.1 is presented to stakeholders or specialists. This shows the worst and best attribute levels (as opposed to the derived scores) obtained for the scenario in that IUA (the Doring Rangelands was used in this example). All attribute values (and scores in this case) are from 0-100. (It must be noted that it is unlikely that the full ranges of these scores are likely ever to be used, and in different catchments different portions of the scale might be used.)

* The respondent is asked: "Imagine a scenario where all criteria are at the worst level. Now considering the swing from this worst level to the best, which one criterion would you choose to move to its best level if you could change just one criterion in this way?"
* Whichever criterion is chosen is ranked 1. The question is repeated until all criteria are ranked in order of importance.
* Then the criterion ranked 1 is given a weight of 100. The respondent is asked how important the rank 2 criterion is relative to this (e.g. "What is the percentage importance of criterion 2 relative to criterion 1?").
* In this way all criteria are weighted. The weights are then normalised to sum to 1.

Table 6.1 Eliciting weights for the SWB criteria for Doring Rangelands IUA							
SWB criteria	**Worst scenario**	**Comment**	**Best scenario**	**Comment**	**Rank**	**Weight**[15]	**Sum to 1**
% employed	85%		88%		3	30	0.16
% non-poor	17.3%		19%		1	100	0.53
Disease burden	73	rough estimate of % of people well	73	rough estimate of % of people well	2	40	0.21
Intangible values	18	29%B, 16%C, 54%D	87	35%A, 9%B, 56%D	4	20	0.11

Table 6.2 Aggregation of SWB criteria to obtain an overall SWB score for the Doring Rangelands IUA

Scenario	**SOCIAL WELLBEING**				
	% employed	**% non-poor**	**Health**	**Intangible Values**	**SWB**
Current/baseline	87.6	19.0	73	75	47.1
Scenario 2: PES	84.7	17.6	73	75	44.3
Scenario 3: REC+Cons.	84.7	17.3	73	88	45.1
Scenario 4: ESBC	84.7	17.9	73	18	38.7
Weights	0.16	0.53	0.21	0.11	

6.2.2 Ecosystem Index

The aggregation of the node level ecological categories to an IUA-level EI has already been described (Section 4.1.2).

6.2.2.1 Example: Olifants/Doring catchment

EI values for all IUAs of the Olifants/Doring catchment are shown in Section 6.2.4. Results for the Olifants/Doring catchment are shown in full in Appendix A, B and C.

6.2.3 Regional Economic Prosperity

The six REP indices can be aggregated to obtain an overall IUA-level REP score. The weighted summation of Equation 6 was used. Therefore the swing weighting approach should be applied to obtain the weights.

In the case of the REP, as mentioned, the scenarios were scored relative to the best scenario across all IUAs (there being no ‘natural’ maximum as there was for the SWB criteria). Also, the impacts are not felt within each IUA, but regionally. For these two reasons, there is no real basis for having different weights for different IUAs as there is for SWB indices. In this case, government priorities - applied in a swing weighting sense – could be used to guide the weighting of the REP indices. DWAF could decide on these weights, interacting perhaps with other government departments, based on the worst and best levels for the catchment.

The worst and best levels for the scenarios across all IUAs in the Olifants/Doring catchment are given in Table 6.3 to illustrate, once again, the swing weighting approach.

[15] Hypothetical ‘dummy’ weights supplied by the authors, but based on ranges from worst to best and input from the team.

Table 6.3 Eliciting weights for the REP index. The 'swings' are from worst to best level achieved (contribution to REP) in the whole catchment. Attribute values are hypothetical as the macro-economic implications of the scenarios were not available at the time of writing.

	Worst scenario	Best scenario	Rank	Weight[16]	Sum to 1
Total GDP effects	R 5 050 500	R 634 860 000	1	100	0.48
Jobs	37 215	54 557	2	80	0.38
Income to poor households (total)	R 505 090 000	R 861 210 000	3	30	0.14

6.2.3.1 Example: Olifants/Doring catchment

The weights shown in Table 6.3 were used for the Olifants/Doring catchment. An example for the Doring Rangelands REP index is shown in Table 6.4. Regional economic prosperity indices for all IUAs are shown in Section 6.2.4. Results for the Olifants/Doring catchment are shown in full in Appendix A, B and C.

Table 6.4 Aggregation of REP criteria to obtain an overall REP score for the Doring Rangelands IUA. Scores are hypothetical as the macro-economic impacts were not available at the time of writing[17].

Scenario	REGIONAL ECONOMIC PROSPERITY				
	GDP effects	Regional employment	Income to poor households	Infrastructural costs	REP
Current/baseline	11.6	100.0	100.0	Not available	57.9
Scenario 2: PES	8.19	77.0	80.5		44.7
Scenario 3: REC+Cons.	7.42	68.4	58.6		38
Scenario 1: ESBC	8.77	76.7	78.7		44.6
Weights	0.48	0.38	0.14	0	

6.2.4 Aggregate IUA score

It is useful to have an aggregate IUA score with which to broadly compare scenarios within an IUA. Therefore the three indices can be aggregated using swing weights within the
Equation 8:

$$V_i(a) = w_{\mathrm{SWB}i}\ \mathrm{SWB}_i(a) + w_{\mathrm{REP}i}\ \mathrm{REP}j(a) + \mathrm{w}_{\mathrm{EI}i}\ \mathrm{EI}i(a)$$

Equation 7

Where:
$V_i(a)$ is the overall value of scenario a in IUA i;
$w_{\mathrm{SWB}i}$ is the weight applied to SWB in IUA i; *and*
$\mathrm{SWB}_i(a)$ is the SWB score of scenario a in IUA i (Equation 2), etc.

[16] These are hypothetical examples only. "Dummy" weights supplied by author, but based on ranges from worst to best and input from the team.
[17] Macro-economic information was not available per IUA. IUA turnover was used to represent Total GGP effects per IUA. Proportional changes in income to poor households and employment were calculated for scenarios, and the same proportions applied to all IUAs.

6.2.4.1 *Example: Olifants/Doring catchment*

Aggregate SWB, EI, REP IUA values are shown in Table 6.5, Table 6.6 and Table 6.7. Overall IUA results are shown in Table 6.8. The swing weights used were SWB = 0.5, EI = 0.1 and REP = 0.4. The results for the Olifants/Doring catchment are shown in full in Appendices A, B and C. IUA-level results for the Doring Rangelands IUA as displayed by VISA (© Belton) are shown in Figure 6.1.

Table 6.5 Aggregate SWB values for the IUAs in the Olifants/Doring catchment

Scenario	IUA 1 Estuary	IUA 2 Doring Range-lands	IUA 3 Lower Olifants	IUA 4 Upper Olifants	IUA 5 Dryland Farming	IUA 6 Koue Bokkeveld	IUA 7 Knersvlakte
Current	51.2	47.1	45.4	45.2	49.2	41.3	43.5
Scenario 1: PES	51.2	44.3	30.9	42.4	52.4	35.7	38.1
Scenario 2: REC+Cons.	58.4	45.1	35.0	49.4	58.5	53.6	38.2
Scenario 3: ESBC	38.5	38.7	30.3	34.1	37.3	36.2	31.2

Table 6.6 Aggregate EI values for the IUAs in the Olifants/Doring catchment

Scenario	IUA 1 Estuary	IUA 2 Doring Rangelands	IUA 3 Lower Olifants	IUA 4 Upper Olifants	IUA 5 Dryland Farming	IUA 6 Koue Bokkeveld	IUA 7 Knersvlakte
Current	60.0	66.3	42.2	45.5	68.9	42.7	60.0
Scenario 1: PES	60.0	66.3	42.2	45.5	68.9	42.7	60.0
Scenario 2: REC+Cons.	80.0	75.7	100.0	75.9	92.4	93.2	60.0
Scenario 3: ESBC	40.0	55.0	40.0	45.3	42.3	67.7	51.5

Table 6.7 Aggregate REP index values for the IUAs in the Olifants/Doring catchment[18]

Scenario	IUA 1 Estuary	IUA 2 Doring Rangelands	IUA 3 Lower Olifants	IUA 4 Upper Olifants	IUA 5 Dryland Farming	IUA 6 Koue Bokkeveld	IUA 7 Knersvlakte
Current	52.8	57.9	100.0	88.2	57.9	84.2	54.0
Scenario 1: PES	41.2	44.7	68.0	76.5	48.2	70.6	41.1
Scenario 2: REC+Cons.	34.8	38.0	34.4	66.1	42.9	66.3	34.8
Scenario 3: ESBC	40.8	44.6	67.6	68.3	45.9	71.1	40.7

Table 6.8 Aggregate performance for the IUAs in the Olifants/Doring catchment (weighted in anticipation of aggregation to a catchment level score)

Scenario	IUA 1 Estuary	IUA 2 Doring Rangelands	IUA 3 Lower Olifants	IUA 4 Upper Olifants	IUA 5 Dryland Farming	IUA 6 Koue Bokkeveld	IUA 7 Knersvlakte
Current	5.54	7.18	13.16	10.76	7.42	7.60	5.18
Scenario 1: PES	4.88	6.22	9.11	9.77	7.05	6.48	4.27
Scenario 2: REC+Cons.	5.14	5.98	8.51	10.39	7.50	7.62	3.91
Scenario 3: ESBC	4.11	5.73	8.98	8.38	5.56	6.69	3.93

The IUA level results show, for example, that generally the current scenario is preferred and REC+Cons. is preferred to PES except in the Doring Rangelands and Lower Olifants. The latter two catchments are particularly affected by changes in water available for irrigation implied by

[18] Hypothetical value.

Rec+Cons. The REC+Cons. Scenario also negatively affects other catchments, but not enough to result in overall scores that are lower than for PES[19], because the SWB and EI scores are much higher for REC+Cons.

Figure 6.1 VISA results for the Doring Rangelands IUA

6.3 Catchment-level overall scenario evaluations: weighting and aggregation

This section describes the recommended procedure for the aggregation of the sub-indices contributing to the three main indices (i.e. SWB, REP and EI) to obtain catchment-level SWB, EI and REP scores. Different rationales may pertain for the aggregation within the three different indices. In general, however, it is recommended that the swing weighting approach be used in guiding these rationales.

The three catchment level indices can, in turn, be aggregated to get a one number summary of the scenario impacts. The aggregation of the IUA scores to get a catchment-level perspective allows for an overall evaluation of the scenarios. However, the lower level (on the value tree) or smaller scale (geographically) impacts need to be referred to at all times.

6.3.1 Social wellbeing

The weights used in the weighted summation of the IUA-level SWB scores could be based on:

1. The population of the IUA: More people are affected by changes in SWB in populous IUAs than in those were few people live.
2. The percentage of poor people in the IUA: An IUA whose population is wealthy, might receive a lower weight than an IUA with the same number of people but who are all

[19] Remembering always that some of the data could not be disaggregated to IUA level.

poor. This would have the effect of making impacts on poor people more important than impacts on wealthy people.
3. Both 1 and 2.

The equation (Equation 8) for aggregation according to 3 above might therefore be as follows:

$$OSWB(a) = (p_1 \times \% \ poor_1 \times SWB_1) + (p_2 \times \% \ poor_2 \times SWB_1) + \ldots + (p_n \times \% \ poor_n \times SWB_n)$$

Equation 8

Where:
OSWB is the overall SWB score;
SWB_n is the SWB score of IUA_n;
P_n is the population of IUA_n; and
% $poor_n$ is the percentage of the population who are in the poor category.

6.3.1.1 Example: Olifants/Doring catchment

Equation 8 was the approach adopted for the Olifants/Doring catchment. The weights were derived as shown in Table 6.9.

Table 6.9 Deriving weights for the SWB IUA-level weights

Scenario	IUA 1 Estuary	IUA 2 Doring Rangelands	IUA 3 Lower Olifants	IUA 4 Upper Olifants	IUA 5 Dryland Farming	IUA 6 Koue Bokkeveld	IUA 7 Knersvlakte	Total
IUA population	3 500	11 242	29 076	18 872	9 461	9 703	4 852	86 706
Population weight (IUA pop/total pop)	0.040	0.130	0.335	0.218	0.109	0.112	0.056	
IUA % poor	77.3	81.1	70.0	78.9	84.0	83.3	84.6	559
Poor weight (IUA % poor/total % poor	0.138	0.145	0.125	0.141	0.150	0.149	0.151	
poor weight x population weight	0.006	0.019	0.042	0.031	0.016	0.017	0.008	0.139
Combination weight IUA comb/ total	0.040	0.136	0.303	0.221	0.118	0.120	0.061	

6.3.2 Ecosystem index

An overall assessment of the ecosystem health of a catchment can be obtained by aggregating the IUA level EI scores. The IUA scores could be weighted by the (average) ecosystem importance and sensitivity (EIS) of the IUAs (Equation 9). The EIS values were obtained from the ecological data available from this project (Brown *et al*., 2007):

$$OEI(a) = \sum_{i=1}^{n} EI_i(\overline{EIS}_i)$$

Equation 9

Where:
OEI is the overall EI score, and
$\overline{EIS}_i$ is the average EIS across the nodes in IUAi.

6.3.2.1 Example: Olifants/Doring catchment

Equation 9 was the approach adopted for the Olifants/Doring catchment. The weights were derived as shown in Table 6.10.

Table 6.10 Deriving weights for the EI IUA-level weights

	IUA 1 Estuary	**IUA 2** Doring Rangelands	**IUA 3** Lower Olifants	**IUA 4** Upper Olifants	**IUA 5** Dryland Farming	**IUA 6** Koue Bokkeveld	**IUA 7** Knersvlakte
Average EIS	4.00	1.57	2.00	2.37	2.77	1.00	2.00
EIS weight	0.26	0.10	0.13	0.15	0.18	0.06	0.13

6.3.3 Regional economic prosperity

An overall assessment of the combined IUA effects on REP of the scenarios can be obtained by aggregating the IUA-level REP scores. Because of the scoring approach adopted (i.e. scores were given as a percentage of the maximum across all scenarios in all IUAs), the IUA REP scores are directly comparable to each other and no weighting need apply to REPs from different IUAs.

It is worth noting that there are two options for aggregation to the catchment level. One can aggregate the IUA REP score or one can aggregate the IUA REP sub-indices scores and then aggregate those at the catchment level.[20] In the case of the REP index, either approach will have the same final outcome as they are arithmetically the same (because of the scoring approach and the same weights applying in each IUA). The former format is maintained for consistency with the SWB and EI indices (refer to Section 6.2.3 for the swing weight approach to the IUA-level REP) (Equation 10):

$$OREP(a) = \sum_{i=1}^{n} w_i(REP_i),$$

Equation 10

Where:

OREP is the overall REP score; and

the IUA-level REPs are equally weighted (i.e. $w_1=w_2=\ldots=w_n$) as there is no basis for differently weighting them, given the approach used for scoring.

6.3.3.1 Example: Olifants/Doring catchment

Equation 10 was the approach adopted for the Olifants/Doring catchment. The IUAs were given equal weights.

6.4 Overall catchment scores and summaries

The catchment-level OSWB, OREP and OEI values can be aggregated to obtain a single number summary of the performance of the scenarios at the catchment-level, noting again the need to refer back to sub-indices and IUA-level measures. The catchment level overall score ($\mathcal{V}(a)$) can be found using Equation 11:

[20] In the case of the SWB index, it might be worthwhile to aggregate the sub-indices to catchment-level for reporting purposes (e.g. overall there is X% unemployment), but for the overall assessment summing the IUA SWB score by population weights is probably better than summing the catchment-level aggregated sub-indices using some 'global' set of swing weights.

$$V(a) = W_{OSWB}\, OSWB + W_{OREP}\, OREP + W_{OEI}\, OEI$$

Equation 11

As for the IUA-level indices, a swing weighting exercise needs to be undertaken to estimate the weights of the catchment level indices. It becomes more difficult to assess swing weights meaningfully once one is dealing with a very aggregated score, however in this case (depending on the value functions and weights actually applied), because there are not too many criteria, the 'natural' scales of the sub-indices could perhaps provide a basis for the swing weighting. For example, Table 6.11 shows the overall worst and best levels for each sub-index across all IUAs, and hypothetical weights for them, aggregated to obtain the index weight. Note that it is a well-known problem of weight elicitation that the number of (sub)criteria within a group criterion may influence the overall weight derived if the approach illustrated in Table 6.11 is used. Two other alternative approaches exist: (a) the sub-index perceived to be the most important from each of the three indices are compared, or (b) the three catchment-level indices are compared holistically.

Table 6.11 Deriving swing weights to allow for aggregation of the IUA-level scores to obtain overall catchment-level weights

Sub-index	Minimum	Maximum	Rank order	Weight	Sum to 1	Index weight
SWB						
% employed	18	93	1	100	0.1923	0.50
% non-poor	13	30	2	90	0.1731	
Disease burden	73	73	8	30	0.0577	
Intangible value	18 (100% D)	100 (100% A)	7	40	0.0769	
EI	40.0 (100% D)	100 (100% A)	6	50	0.0962	0.10
REP						
Total GGP effect	R 5 050 500	R 634 860 000	3	80	0.1538	0.40
Jobs	37 215	54 557	4	70	0.1346	
Income to poor hh	R 505 090 000	R 861 210 000	5	60	0.1154	

6.4.1 Example: Olifants/Doring catchment

Equation 11 was the approach adopted for the Olifants/Doring catchment for aggregating the three indices. The weights used were those shown in Table 6.11 and the results are shown in Table 6.12. Various graphical presentations of the results are shown in Figure 6.2 and more are given in Section 9.2.2. While it would be useful for the technical team to look at all of this different formats, when presenting results to stakeholders and the Minister, it may be necessary to consistently use one or two versions.

Table 6.12 Catchment-level results for the Olifants/Doring catchment

Scenario	SWB	EI	REP	OVERALL
Current	45.67	56.64	70.72	56.84
Scenario 1: PES	39.63	56.64	55.75	47.77
Scenario 2: REC+Cons.	45.70	81.98	45.34	49.04
Scenario 3: ESBC	34.21	45.94	54.13	43.38

The catchment level results show that in terms of SWB and EI the REC+Cons. scenario is the preferred scenario, but in terms of REP this scenario does not perform well, and overall this Current scenario has the highest score.

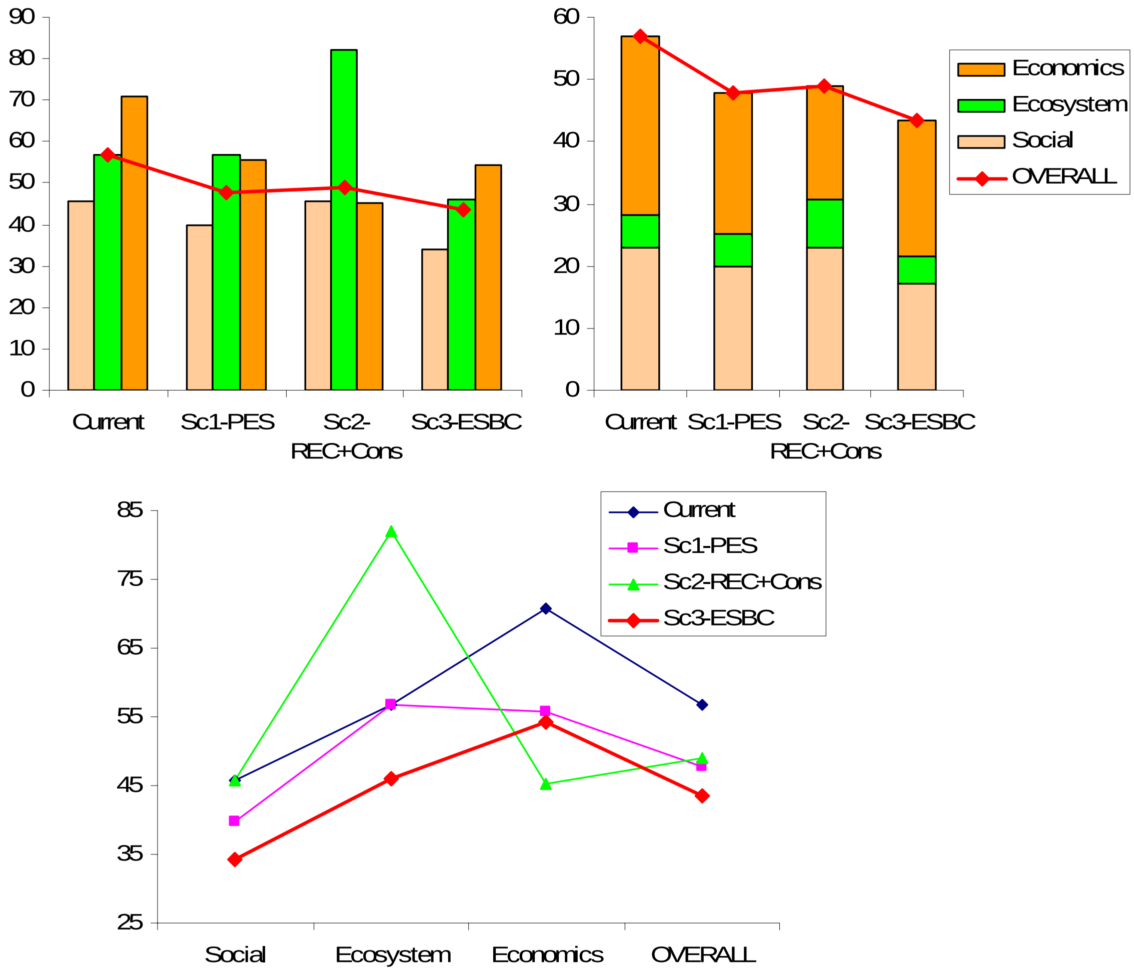


Figure 6.2 Some ways of graphically presenting results: (top left) Unweighted bar graph results, (top right) weighted bar graph results and (bottom) 'value profile' results. These show the overall results for the Olifants/Doring catchment

The results are reported in full in Appendices A, B and C. Figure 6.3 shows the bar graph summaries for each IUA and for the catchment as a whole. This shows, for example (and remembering that the REP data are partially hypothetical), that whereas in the Lower Olifants IUA, the REC+Cons. scenario is worst overall because of the severe REP consequences, this effect does not make it the worst scenario for the catchment as a whole.

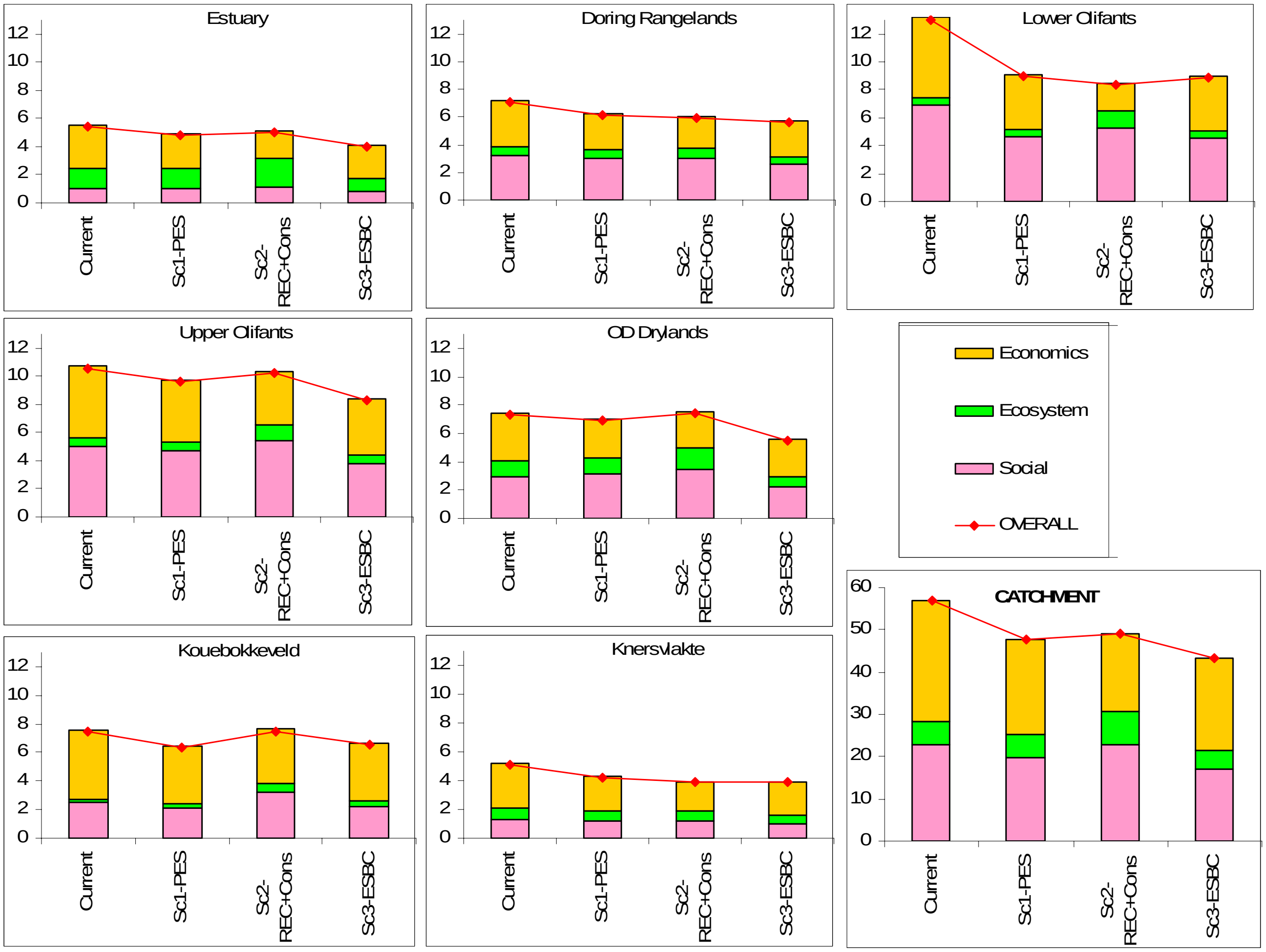


Figure 6.3 Graphical summaries of IUA-level and catchment-level results

6.5 Sensitivity and other analyses

The sensitivity of results to the weights should be examined. While comprehensive assessments can be implemented with simulations such as randomly changing weights and recording the top or top three ranking catchment configuration scenarios for each simulation, smaller scale assessments can also be implemented. For example, the results with the weights as selected can be compared with using 'equal' weights in all instances.

6.5.1 Example: Olifants/Doring catchment

Table 6.13 shows the results of using the derived weights and 'equal' weights for the Olifants/Doring catchment. As can be seen the overall rank order and the rank orders for the SWB, EI and REP indices remained the same under these two different weights sets. However, the scores show that the preferred scenario for SWB with swing weights was just marginally the REC+Cons., but it is more clearly preferred with the 'equal' weights. This is unsurprising as, with 'equal' weights, a change from, say, 20% to 30% in terms of EI is the same as a change from 20% to 30% in the non-poor category. It is unlikely that this would be an acceptable trade-off.

Table 6.13 Sensitivity to two different weight sets for the Olifants/Doring catchment

Scenario	Swing weights				Equal weights			
	Social	*Ecosystem*	*Economics*	*Overall*	*Social*	*Ecosystem*	*Economics*	*Overall*
Current	45.67	56.64	70.72	56.84	46.14	55.09	70.72	56.93
Scenario 1: PES	39.63	56.64	55.75	47.77	42.14	55.09	55.75	48.88
Scenario 2: REC+Cons.	45.70	81.98	45.34	49.04	48.31	82.46	45.34	50.39
Scenario 3: ESBC	34.21	45.94	54.13	43.38	35.19	48.83	54.13	44.15

Another useful analysis is to see whether a weight set exists which would cause a particular scenario to be the most or least preferred option overall. For example, Solver in Microsoft Excel was set up to change the weights used in Equation 2, Equation 6, Equation 7 and Equation 11 in order to maximise the overall catchment score of the ESBC (noting that the ESBC was the worst scenario overall with the two weight sets in Table 6.13). It was found that there was no set of weights which made the ESBC the best scenario, but it could be weighted such that it scored second highest (ahead of REC+Cons.). This would indicate the ESBC should not really be taken forward for further evaluation. (Please recall that this assessment is based on ‘dummy’ values for some of the indices). However, setting up Solver to find the weight set that maximises the overall score of REC+Cons., reveals that with a particular weight set REC+Cons. can become the best scenario (but not the worst). The weights required (shown in Table 6.11), suggest that REC+Cons. is unlikely to be ultimately as there is unlikely to be a consensus set of stakeholder weights matching these.

Table 6.14 Weights which make REC+Cons. the lowest scoring option

Index	Criteria	Estuary	Doring Rangelands	Lower Olifants	Upper Olifants	Olifants/Doring catchment	Koue-bokkeveld	Kners-vlakte
SWB	**% employed**	0.13	0.42	0.13	0.42	0.13	0.13	0.31
	% non-poor	0.13	0.08	0.13	0.08	0.13	0.13	0.06
	Disease burden	0.13	0.08	0.13	0.08	0.13	0.13	0.31
	Intangible values	0.63	0.42	0.63	0.42	0.63	0.63	0.31
REP	**Total GGP effect**	0.14				**OSWB**	0.71	
	Jobs	0.71				**OEI**	0.18	
	Income to poor households	0.14				**OREP**	0.11	

It is worth emphasising that the sensitivity analyses are not intended to provide a set of weights to support particular prejudices, but to explore scenarios *after* scores and weights have been assigned.

As mentioned in Section 2.1, the weighted summation implies ‘perfect compensation’ between the sub-indices. Once value functions and weights have been defined, one can ‘back calculate’ exactly what the trade-off implied actually is. This is a useful reality check on weights. In a situation where all of the value functions are linear, the trade-offs implied by the weights are easier to calculate (if the value functions are non-linear, different trade-offs apply at different points along the curve). In comparing attributes x and y, a 1 unit increase of y is exactly compensated for by a (Equation 12):

$$\left(\left(\max(x)-\min(x)\right) \Big/ \left(\max(y)-\min(y)\right) \right) \times \left(w_y \big/ w_x \right) \text{ unit decrease in } x$$

Equation 12

For example, using the weights in Table 6.3, a change of 1 job (attribute y) is exactly compensated for by a (R 634 860 000/ 147.89) (0.38/0.48) = R 34 343.41 change in total GDP effects.

6.6 Implied Management Class

Each scenario for an IUA has an associated implied IUA Management Class (MC) arising from applying System 3 as described in Section 4.1.2.

6.6.1 Example: Olifants/Doring catchment

For example, the MCs associated with the four scenarios for the Olifants/Doring catchment per IUA are shown in Table 6.15 (together with the EI scores from System 1).

Table 6.15 Implied IUA level management class arising from applying System 3 and associated EI score (System 1) for the Olifants/Doring catchment scenarios

	PES	REC+Cons.	ESBC		PES	REC+Cons.	ESBC
Estuary	60	80	40		Class II	Class I	Class III
Doring Rangelands	66.3	75.7	55.0		Class III	Class II	Class III
Lower Olifants Irrigation	42.2	100.0	40.0		Class III	Class I	Class III
Upper Olifants Irrigation	45.5	75.9	45.3		Class III	Class II	Class III
Olifants/Doring Dryland Farming	68.9	92.4	42.3		Class II	Class I	Class III
Knersvlakte	60	60	51.5		Class III	Class III	Class III
Koue Bokkeveld	42.7	93.2	67.7		FAIL[21]	Class I	Class II

7 STEP 5G: SELECT A SUBSET OF SCENARIOS FOR STAKEHOLDER EVALUATION

7.1 Introduction and procedure

The objective of this step is to select a subset of scenarios from the full suite of catchment configuration scenarios (considered in Step 5f - see Section 6) for stakeholder evaluation. As with other steps, to avoid being prescriptive, results from the 'proof of concept' catchment are used to demonstrate that a number of tools can assist is assessing the overall implications of different catchment configuration scenarios. However, as general guideline, when scenarios are evaluated to select a subset for further evaluation by stakeholders, it is recommended that the best and second best scenarios need to be included, and that any clearly 'dominated' scenarios should be excluded (dominated scenarios are those which perform worse than the other scenarios on all criteria). (However, if a dominated scenario is in fact a first or second best of a particular stakeholder group it should be retained. Further, it would be useful for DWAF to anticipate stakeholders' needs or to have prior knowledge of these through the broader IWRM process.

7.2 Example: Olifants/Doring catchment

A number of tools can be used to assist in selecting a subset of scenarios. For example, a *value profile* such as that shown in Figure 6.2 and Figure 7.1 can assist in assessing whether a scenario is dominated. For example, for the 'proof of concept' catchment, it can be seen in Figure 7.1 that the Current/baseline and PES both dominate the ESBC[22].

[21] This IUA 'fails' in terms of achieving a management class of better than or equal to Class III because of the percentage of river length in particular category.

[22] Note that both Figure 6.2 and Figure 7.1 are 'unweighted' value profiles; weighted profiles can also be created.

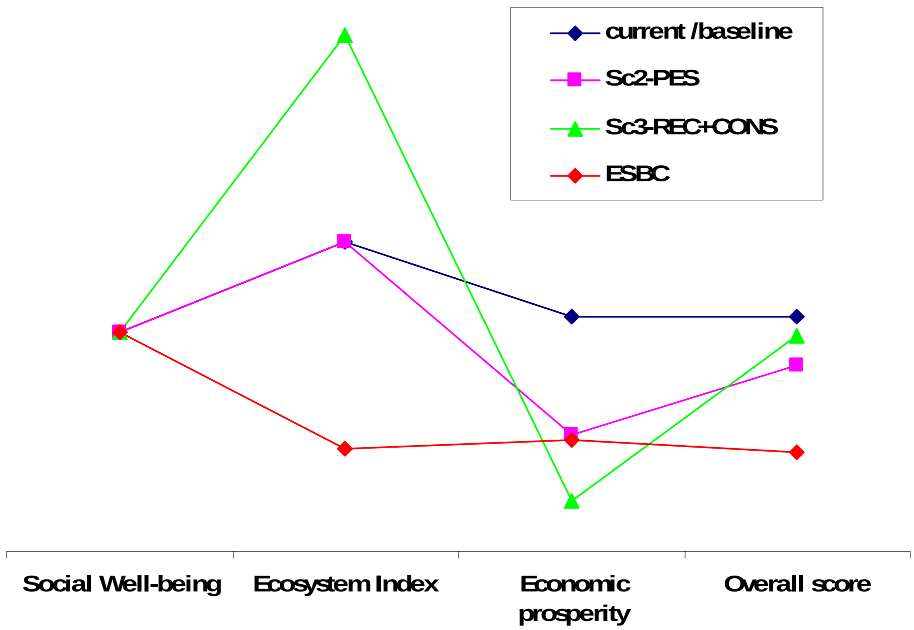


Figure 7.1 Unweighted value profile of the Estuary IUA scores

Sensitivity analyses can be also used to inform the selection of scenarios. For example, in the case of the Olifants/Doring catchment, the sensitivity analysis showed that the ESBC scenario could be second worst rather than worst scenario. However, if no weight set existed which raised the rank of this scenario; one would not take this scenario forward for further assessment.

The *value profile* can also help in that it can indicate where a 'second best' scenario may be preferred to the 'best' scenario in terms of overall score. For example, while the REC+Cons. scenario performed well overall in the Estuary IUA (Figure 7.1), it performs worst on the REP index. Therefore, the PES scenario could be considered preferable to REC+Cons. scenario because it is not the worst on any one of the indices.

The *VISA* (© Belton) presentation of weight sensitivity, in this case using only the sensitivity to weights on catchment-level SWB, EI and REP scores is shown in Figure 7.2 using hypothetical figures (not the same as those in other figures and tables). This shows that the results are slightly sensitive to the weight on the EI. If the weight were to increase from its current level (indicated by the dotted vertical line) to about 0.2 the REC+Cons. scenario would have the highest score. Similarly, if the weight on REP were to decrease by about a half, the REC+Cons. scenario would have the highest score. Analyses such as these showed that the REC+Cons. scenario was the scenario most sensitive to changes in weights, whereas the current scenario was best from the REP and SWB points of view and less sensitive.

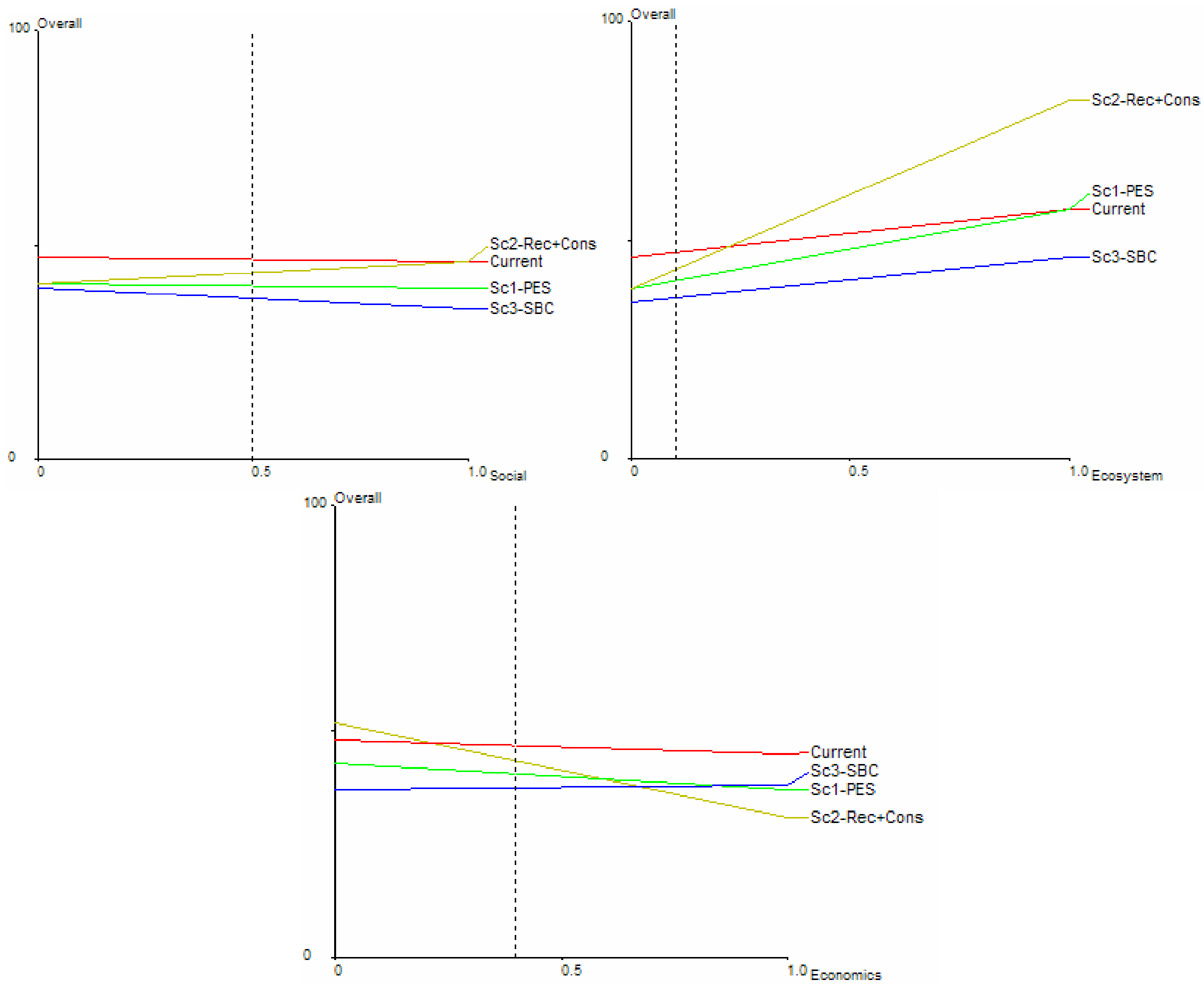


Figure 7.2 VISA weight sensitivity analysis graphics. The graph on the top left indicates sensitivity to the weight on SWB, the graph on the top right indicates sensitivity to the weight on EI, while the graph at the bottom-centre indicates sensitivity to the weight on REP

Incidentally, this discussion of sensitivity and selection of subsets illustrates why it is necessary to have several scenarios at this stage. If, for example, there were only three scenarios it would make it very difficult to pick up subtleties which could help to find a scenario which would satisfy the bulk of stakeholders as one tends to end up with scenarios at the top– middle- and bottom levels of each of the three indices.

8 STAKEHOLDER ENGAGEMENT FRAMEWORK

8.1 Introduction

The objective of Step 6 of the classification procedure is to evaluate the subset of scenarios selected in Step 5g (see Section 7) together with the stakeholder[23] scenarios, and to agree on an overall preferred catchment configuration scenario or a shortlist of scenarios for the Minister's

[23] The terms "stakeholders" and "interested and affected parties (I&APs)" are used interchangeably in this section.

consideration (Step 6a) in Step 7 (see Section 9). This is followed by DWAF recommending the IUA classes in Step 6b (see Section 10). It is important to point out, however, that Step 6 is not the only point of contact with the stakeholders in the classification procedure. Stakeholder involvement occurs from Step 1, but as part of the larger compulsory licensing process. A description of the stakeholder process for the compulsory licensing process is beyond the scope of this report, but will need to be incorporated into the classification procedure as and when it becomes available. The recommended procedure described in this report for Step 6 therefore focuses specifically on the classification component of stakeholder process (which forms part of the larger compulsory licensing process).

For the purposes of this report, a generic description of the stakeholder engagement process prior to Step 6 is presented for completeness. This is followed by a description of the procedure recommended for Steps 6a (see Section 9) and 6b (see Section 10). As no stakeholder engagement process was followed for the 'proof of concept' catchment, no examples are presented for the Olifants/Doring catchment.

8.2 Stakeholder engagement process

8.2.1 Identify broader body of stakeholders

8.2.1.1 Objectives

The first step in any stakeholder engagement process is to identify interested and affected parties (I&APs), and to afford them the opportunity to become involved by nominating one or more stakeholders to represent their specific sector of society in the multi-stakeholder group. A second objective of this step is to identify key stakeholders whose involvement must be pro-actively ensured.

Although challenging, it is useful to identify in advance those stakeholders who should be directly informed about the opportunity to contribute, and then to inform them by way of letters addressed to them by name, rather than by relying on media or impersonal flyers. Unless stakeholders indicate that they do not wish to remain on the mailing list, they receive all further announcements for comment even though they may not have "formally" registered by returning their first reply sheet.

It is not necessary to list countless people on the mailing list. What is, however, necessary, is to provide the broadest possible range of sectors of I&APs the opportunity to contribute, and to be able to prove this. Like-minded people often organise themselves into a group with an assigned spokesperson, e.g. a religious group, environmental group, women's group or tribal community. Sectors of society do the same, such as local Chambers of Commerce, Farmers' Unions, environmental non-governmental organisations (NGOs) and others. It is necessary to obtain the group's or the sector's involvement, and not that of every individual or organisation in the group or sector.

At the same time, checks and balances must be built into the process to ensure that it is defensible. This is to ensure that:

- those included in the mailing list are not only the spokesperson's for a group or sector (e.g. a tribal leader), but include individual members of that group or sector (e.g. a religious leader in that group, and some women and youth leaders);
- there is a good geographic representation;
- urban as well as rural communities are included;

- a good gender and race balance is achieved; and
- a multi-pronged approach is used to announce the opportunity for stakeholders to contribute (i.e. direct mail as well as print and broadcast media advertisements/ announcements).

8.2.1.2 Methodology

Existing, recent stakeholder mailing lists should be used as far as possible to avoid duplication of effort and cost. The list should be verified for accuracy since databases go out of date by roughly 10% every two to three months. In addition, the list should be verified for representivity by cross-checking that all relevant sectors are included (see Box 3). This is very important, since to overlook sectors and stakeholder bodies will cause process difficulties and rework later on. Should a stakeholder mailing list be found to be inadequate, a process of mainly telephonic networking and referral should be followed to ensure that the list is adequate. This involves one or two dedicated people making telephone calls for a day or two and adding stakeholders to the list.

Box 3 Examples of sectors of I&APs	
• Government (national, provincial and local, all relevant departments, including local councillors) • Traditional leaders • Conservation and environmental bodies • NGOs (environmental and development-focused) • Commerce and business • Industry • Mining • Agriculture • Forestry • Transport • Tourism and recreation	• Civil society (voluntary organisations, community groupings, religious and welfare organisations, residential organisations, women's organisations, youth organisations) • Local communities leaders in addition to tribal leaders • Labour unions • Researchers and consultants • Local media (print and broadcast) • Water management institutions • Education bodies • Health bodies • Departmental personnel in the DWAF National as well as Regional Offices.

An electronic database of stakeholders' contact details is recommended from which mail merges can be done. The database should be categorised by sector of society, and containing title, correctly spelled first name, initials, surname, position, organisation, province, address, telephone, fax and email. If more than one language is to be used, categorise the database into language preference of stakeholders. Allow for "creep" in the database when budgeting. As stakeholders respond to media releases and or through contact with colleagues and friends, their names should be added to the database, and they should receive subsequent letters along with all others. Record-keeping is a very important component of stakeholder engagement.

8.2.1.3 Key stakeholders

Key stakeholders should be identified at the start of the process. They will include anyone whose involvement would be crucial to the project and include people who stand to be directly affected, influential people, respected people, spokespeople for their sectors, people with the authority to say "yes" or "no," people whose local knowledge is important, people who may want to derail the process for personal gain, and all those who *think* they are key stakeholders.

The easiest way to initially identify key stakeholders is to ask other stakeholders. The mandate of key stakeholders to speak for their constituents can only be established as the process evolves,

but their early involvement ensures that the views of all sectors are accommodated, and that certain sectors cannot later say that they were not involved.
The stakeholder engagement process must make special efforts to obtain the contributions of these stakeholders. They may either be very busy people (in which case they may not respond to written invitations to comment), or they may be people not familiar with the topic at hand, or people suspicious of the process. Therefore, extra effort is needed to accommodate them.

8.2.1.4 Announcing the opportunity to participate

The next step in the stakeholder engagement process entails announcing the opportunity to participate. Participation by the broader body of stakeholders will comprise firstly the nomination of members to the representative group and secondly by being able to request milestone discussion documents for written comment, or alternatively to comment via a member of the group.

The objective is to ensure that stakeholders are aware of the process and the opportunity to contribute. The more thorough this initial announcement, the more defensible the process, and the less likely the chances for surprises during the process. A multi-pronged approach works best, using both verbal and written communication. Initial information to stakeholders should be easy and fairly quick to read and should give them the opportunity to decide whether they want to contribute.

Various announcement methodologies could be used:

- A short letter of invitation addressed to stakeholders by name, accompanied by a Discussion Document and a reply sheet with space to indicate the following:

    - whether they want to remain on the mailing list;
    - issues that they wish to see considered;
    - their comment on the scenarios;
    - the sector of I&APs they represent; and
    - the name and contact details of the person they wish to nominate to participate in the stakeholder workshops.

- Electronic forwarding of the Discussion Document and reply sheet to stakeholder organisations for onward forwarding to their members.

- Short advertisements or announcements in the printed as well as broadcast media known to be read by stakeholders. The higher the public sensitivity, the more prominent the announcement or advertisement should be.

9 STEP 6A: STAKEHOLDERS EVALUATE SCENARIOS AND AGREE ON A SHORT-LIST

9.1 Introduction

The objective of Step 6a is to evaluate scenarios and agree on a short-list. This involves assessing the subset of scenarios selected for evaluation in Step 5g (see Section 7), as well as scenarios generated/requested by stakeholders. As this evaluation process is as yet untested, the procedure recommended has been kept as generic as possible. A number of guidelines are, however, suggested.

9.2 Procedure

A number of stakeholder workshops are likely. These will include a suite of workshops aimed at presenting the subset of scenarios (selected during Step 5g) to stakeholders. People nominated by their sectors as spokespersons in each catchment may attend this round of workshops. One or more of these workshops will involve an open house component wherein information will be presented visually (see e.g. Section 9.2.2 for examples of presentation formats) to small groups of people in local languages before and after the workshop and/or during tea and lunch.

Critical requirements for a successful and useful workshop include:

- clear definition of the aims and objectives of the workshop and the sharing of these with the I&APs in advance of the workshop;
- advance notification, i.e. four to six weeks, to advise I&APs of the workshop;
- formal advance registration procedures, including acknowledgement to I&APs that they are registered to attend;
- advance provision of workshop materials to registered I&APs;
- providing the client with a presentation strategy; and
- a dry-run workshop with the client to strategise for questions that may be raised and to align presentations.

Following the first information sharing workshop(s), stakeholders should be encouraged to go away, think about the scenarios and submit comments on them. The comments may refer to a number of different issues, but those of concern are whether the catchment configuration scenarios include a wide enough range for the stakeholders, and whether the criteria cover all the relevant issues of concern. It is recommended that the stakeholders are assisted to develop the capacity to comprehend the scenarios, since the short-listing of scenarios and their signing-off depends on their ability to understand and comprehend the implications of the different catchment configuration scenarios. If necessary, pre- or post- workshop briefings should be considered for members with difficulties. In the interest of efficiency and cutting costs, such briefings could be scheduled for the day before or after the workshop.

DWAF could use these comments to guide the generation of additional catchment configuration scenarios if necessary, and to obtain the necessary information regarding issues of concern if these have not been adequately covered.

Following the stakeholder response to the first suite of workshops, a second set of workshop(s) may be required where a revised set of catchment configuration scenarios (including those requested by the stakeholders) could be presented to the stakeholders and further comment elicited. During these workshops, the stakeholders could be asked to assess whether the suite of scenarios being assessed covers the range of options they require. If the range of scenarios sufficiently covers the stakeholders' preferred options and the criteria cover the issues of concern, the stakeholders may proceed to evaluate the scenarios (Section 9.2.1). If the scenarios do not cover the range of options for the stakeholders, additional scenarios need to be generated iteratively.

It is recommended that the workshops be facilitated with empathy and care to bring about convergence in viewpoints and consensus as far as possible. Further, where individuals in the group have widely divergent views, the following could be considered:

- more than one workshop may be required; or
- technical specialists may have to gather additional technical information; or
- technical specialists work may have to be peer-reviewed by independent specialists nominated and trusted by the stakeholder group; or
- the facilitator may need to create opportunities for additional deliberations, capacity building and satisfying process objectives.
- where convergence is not possible, two or more evaluation models (systems of scores and weights) may need to be developed by the analyst in order to capture the differences.

Once the stakeholders have agreed that the suite of scenarios that require evaluation cover the range of options they require, the scenarios need to be evaluated by the stakeholders (by scoring or ranking them, see Section 9.2.1). From this process, the workshop facilitator/technical team may select a scenario that best satisfies all concerned (based on these scores) or generate a short-list that best represents the broad views of the stakeholders. Ideally, the short-list should be presented to the stakeholders directly at this workshop (i.e. the scenario scores should be captured and analysed at the workshop) for initial comment. Depending on the degree of trust and credibility of the process, the document containing the preferred scenario or short-list must first be distributed as a draft for comment, and another workshop may be necessary in order to finalise it. Alternatively, if there has been general consensus on the preferred scenario, stakeholders may only wish to receive a copy of this document. The technical specialists should also clearly indicate the results of the stakeholder engagement process and stakeholders' views of the scenario to be recommended to the Minister. This document then gets 'signed-off' by the stakeholders and by DWAF.

9.2.1 Guidelines for the rating of scenarios by stakeholders

The overall decision-analysis framework (value tree, scores and weights) applied should be presented to the stakeholders together with the resulting ratings or rankings according to the different indices within IUAs, overall IUA scores and overall catchment scores. The stakeholders may wish to adjust some of the weights. Stakeholders may also be given the opportunity to give their overall evaluation of the scenarios (i.e. give their overall scores to the scenarios) on the basis of this information. The stakeholders (interacting with the facilitator who may be capturing the information interactively or at subsequent workshops) may then select a preferred scenario or a short-list from which the Minister may choose a scenario. A short-list rather than a single scenario may be necessary when there are very divergent views.

9.2.2 Guidelines for the presentation of scenarios to stakeholders

Great care needs to be taken in presenting the scenarios that the material is simple and accessible. It may also be necessary to have smaller group or individual sessions to work through the material. Only essential information should be presented, but all details need to be available in order to address any queries that might arise.

The value tree has proved to be a very useful tool for communicating an evaluation system and it is suggested that this would be a good 'starting point' for presenting information once the basic background information to the classification procedure and the catchment has been presented.
In terms of presentation of results, there are many possible approaches. While there has been a tendency to use simple icons (e.g. smiley and frowning faces) and colour (e.g. red=bad, green=good) to represent *degree* or rating or bad to good, it is doubtful whether these measures are simpler to digest and consistently interpret than *size*. Therefore, although bar graphs are

considered ‘complex’ or ‘sophisticated’, they may be simpler to (consistently across various groups) interpret. Colours or shades of colour are not necessarily immediately accessible to stakeholders, are recognized differently by different linguistic groups (e.g. Roberson, 2005), are more difficult to categorise or order than size and may be differently interpreted (e.g. dark means good instead of bad) (e.g. Rheingans, web document).

It is suggested that bar graphs of the sort shown in Figure 9.1 can be a useful and reasonably widely accessible presentation format. Which of these formats is more suitable will have to be decided by the facilitators. The graph on the left (Figure 9.1) shows a catchment level summary with the three main indices unweighted, and the figure on the right shows weighted catchment level scores.

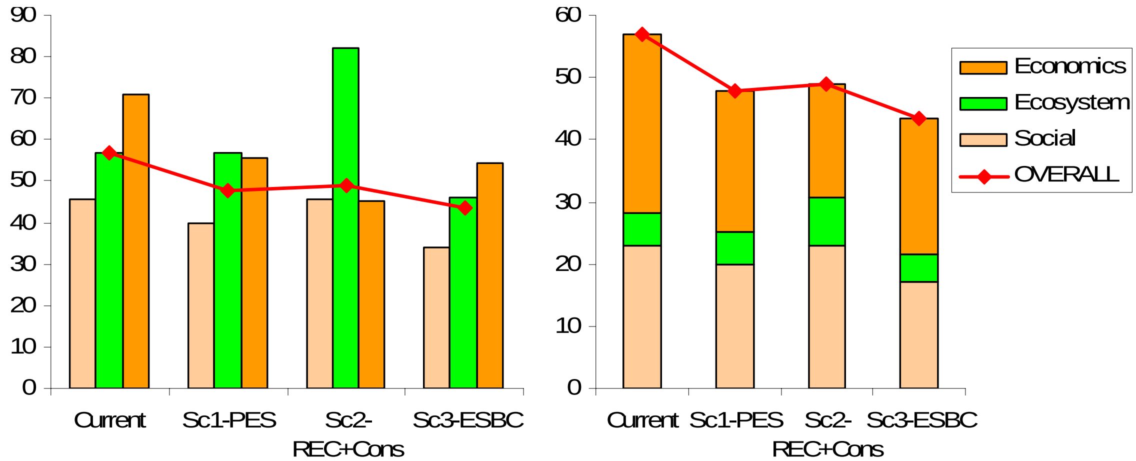


Figure 9.1 Bar graph summaries of the overall catchment three index summaries

A useful and informative way to present some of the information would be to present them on maps. For example, IUA summary bar graphs of the type showed in Figure 9.1 could be shown together with the map of the catchment and the relevant IUAs (e.g. Figure 9.2 shows some results for the Olifants/Doring catchment). Maps can also be difficult to understand and stakeholders may need assistance.

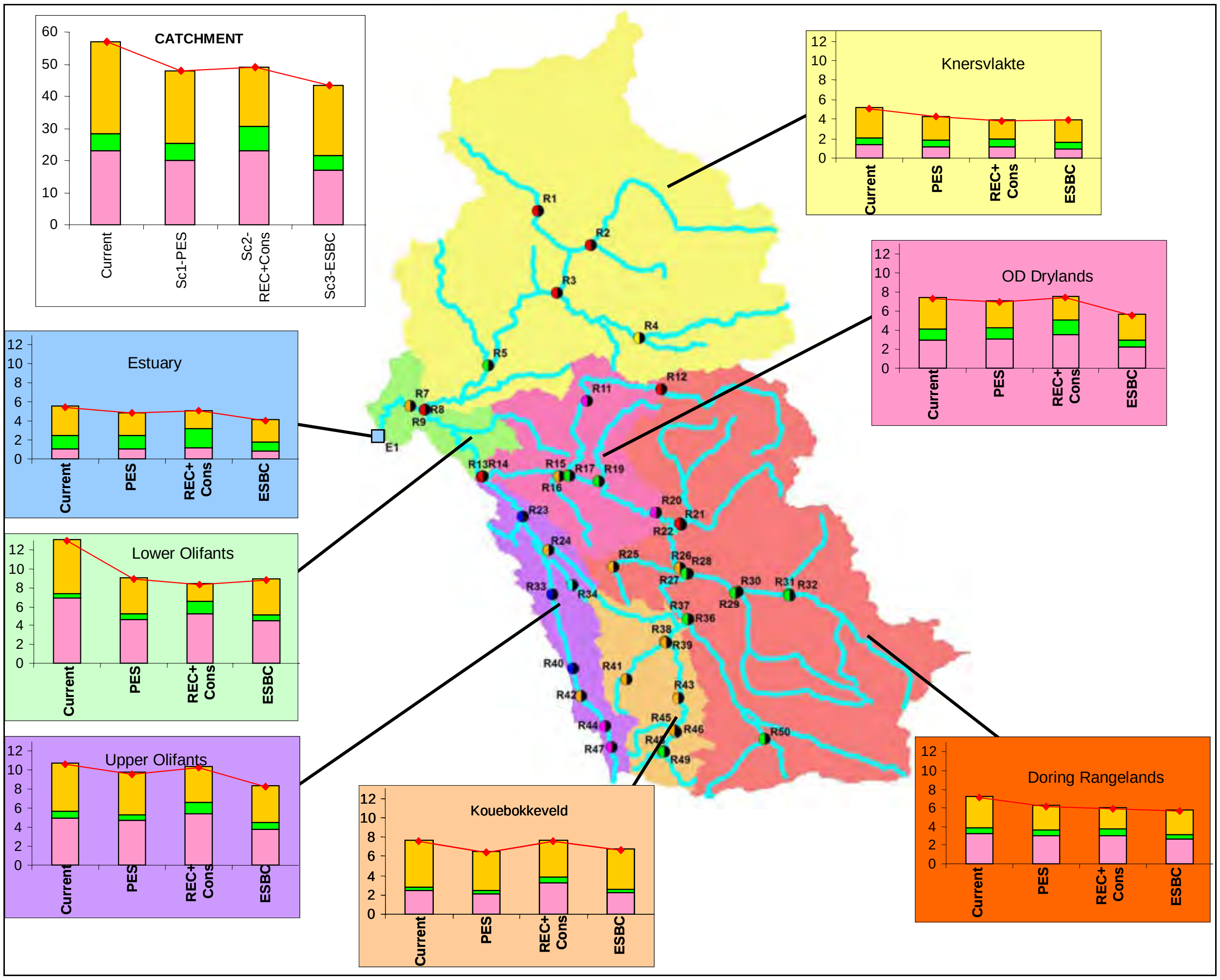


Figure 9.2 Map and bar graph summaries for IUAs in the Olifants/Doring catchment

9.2.3 Guidelines for eliciting stakeholder weights

Stakeholders may want to adjust the weights applied by DWAF during the technical analysis in order to better reflect their priorities. This should only be necessary for the sub-index weights within the SWB index (Equation 2), for the weights to aggregate IUA-level SWB, EI and REP (Equation 7) and the weights to aggregate catchment-level SWB, EI and REP (Equation 11). If the stakeholders wish to adjust the weights, the process should be carefully facilitated so that weights are elicited in the simplest possible way while still closely resembling swing weights. A process such as that shown in Box 2 could be used, with the facilitator emphasizing the swing concept. The stakeholders could respond as a group with the facilitator recording the agreed weights or recording different weights if there were no agreement, or the stakeholders could respond individually (on pieces of paper prepared beforehand). If this process were perceived to be too complex by the facilitator, a more simple approach could be to ask the stakeholders to (individually or in interest groups) to distribute a fixed number of sticky stars among the sub-indices (for SWB) and again for the indices at IUA-level and catchment-level.

People often feel very uncomfortable at the prospect of eliciting weights from stakeholders, and worry that it is ‘subjective’ and that there will be big disagreements among the stakeholders. First, it must be pointed out that not explicitly applying weights, simply means that one particular set of weights (so-called 'equal weights') have been chosen. 'Equal' weights may in fact be the least suitable weights. Secondly, weights must be subjective as they (together with the scores) should reflect societal values, which are not objective. However, using swing weighting means that while the weights are still subjective, they relate specifically to the matter in hand, and are not purely intrinsic weights (e.g. see Box 2). Thirdly, in practice it has often been the case that, in contrast to the expectation of large differences in weights from different interest groups, there is little conflict, particularly in rank order. Fourthly, as mentioned, where different weights emerge for different interest groups, these should be recorded for use in sensitivity analyses and for presentation to the decision-maker.

The stakeholder weights, when inserted into the system prepared for the technical evaluation of scenarios, will automatically produce a preferred scenario overall or, where there are different weights from different groups, there may be several preferred scenarios.

9.2.4 Guidelines for scoring of scenarios

Besides this 'automatic' selection of scenarios once the weights are adjusted and inserted into the evaluation system, the stakeholders could be given the opportunity to holistically rate the scenarios themselves based on the information they have been given. Note that it is not technically necessary for stakeholders to give both weights and holistic scoring, but given the context, it may be useful to do both. Stakeholders may not be comfortable accepting the scenarios emerging from the evaluation framework developed (although by the time they have been exposed to the information, the value tree, indices, etc. they might well be) and therefore might want to give their own evaluation. On the other hand, given the large amount of information presented, their holistic assessments are likely to be flawed (e.g. when people rate holistically, they tend to refer mainly to the most recently heard information) and their weights (as part of the technical evaluation system) give the Minister more detailed information about their priorities and preferences.

Stakeholders find the 'thermometer' scoring approach accessible. In this approach, stakeholders position scenarios along a 0-100 scale (i.e. they actually indicate on a scale rather than just providing a number) (Figure 9.3). This approach helps stakeholders to visualise the differences between scenarios. Otherwise, stakeholders could just be asked to give a score out of a 100 or 10 for each scenario.

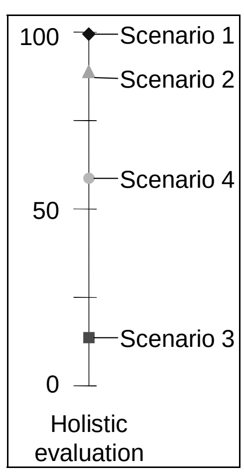


Figure 9.3 Holistic (thermometer) scoring of scenarios by stakeholders

9.2.5 Guidelines for recording and analysing stakeholder inputs

The technical team will need to record all stakeholder inputs in terms of weights and scores. Weights will need to be inserted into the system prepared as part of Step 5f (see Section 5). As mentioned, this will automatically produce a preferred scenario (or short-list if different weights sets are used). This should be compared to the holistic assessments if the latter were obtained. As before, the sensitivity of results to weights should be assessed.

10 STEP 6B: RECOMMEND CLASSES FOR THE IUAS

The objective of Step 6b is to assess the outputs of Step 6a (see Section 9), and to put forward recommendations for the catchment configuration scenarios and IUA classes. This process has not been prescribed, as it will be developed during the early applications of the WRCS in the Classification Process.

11 STEP 7A: POPULATE THE IWRM SUMMARY TEMPLATE AND PRESENT TO MINISTER OR HIS/HER DELEGATED AUTHORITY

The objective of Step 7a is to populate a summary template with DWAF's recommendations for the catchment configuration scenarios and IUA classes derived from Step 6b (see Section 10) and present this to the Minister or his/her delegated authority for his/her consideration. This summary template is not prescribed here, as it will be developed during the early applications of the WRCS in the Classification Process (and other aligned processes – e.g. compulsory licensing). However, a number of recommendations can be made in this regard, and these are presented in Table 11.1 It is important to note, however, that the summary template should include information from the larger IWRM process (e.g. compulsory licensing), and therefore the outline of the IWRM summary template presented in Table 11.1 serves only as a starting point.

Table 11.1 Proposed IWRM summary template for Step 7a of the classification procedure

Section	Sub-section	Comment
1. Introduction	Description of catchment and IUAs.	Map of study area with nodes and IUAs depicted. Will include geographical area (i.e. co-ordinates), quaternary catchments and flow gauging weirs.
	Description of current water use in the catchment.	Broad summary of current equity, social conditions and economic activities in the catchment.
	Description of the generic classes.	The classes gazetted as part of the WRCS gazette.
2. Record of decision	Nature of the proposed authorisation to be undertaken (water use applications).	A description of why the Classification Process was undertaken. Note that this may also include a description of why the compulsory licensing process was undertaken, but this recommended IWRM template focuses on the classification component. The compulsory licensing component of the IWRM template will need to be added as and when it becomes available.
	Scope of the study.	Confidence of the results of the classification study.
3. Description of the stakeholder consultation process	Overall description of the process.	Narrative.
	Key aspects informing the class for each IUA.	
	Summary of catchment configuration scenarios short-listed by stakeholders.	
	Summary of key economic, social and ecological implications for stakeholders.	
	List of key stakeholder concerns about catchment configuration scenarios.	List specific concerns and potential conflict amongst users and potential conflict with decision to be taken by the custodian.
4. Recommended classes for each IUA	Recommended classes.	Validity and period of revision of classes.
	Water balance for the catchment.	Described.
	Category configurations for the recommended classes.	IUA classes and nested category configurations making up the IUA class. Possibly also presented as a system/network diagram (see Brown *et al*., 2007; Figure 11.2 as an example).
	Socio-economic implications of the recommended classes.	Describe how they will deviate from the present socio-economic conditions.
	Allocation schedules.	Refer to Water Allocation Reform process for details as to how equity is addressed.
	Other relevant information.	Described.

5. Reserves (using existing Reserve template)	Description of water resource(s).	For a defined geographical area including the water management area (WMA), drainage region(s) and a short description of the resources and their location.
	Overall summary of quantity Reserve (%nMAR).	Described for each node for the configuration making up the class.
	Overall summary of quality Reserve.	General chemistry recommended, nutrient, physical, toxics and complex mixtures. This should be described at least at the IUA outlet node or at a finer scale where relevant and supported by information.
	Basic Human Needs.	Described for each node for the configuration making up the class.
	Applicability.	Section 21 of the NWA.
	Technical reports.	List of technical reports on the Reserve determination process including the level of confidence in the determination of the water quantity and quality Reserve, cumulative/incremental Reserves, location, implications and relative to nMAR, and .rul and .tab files.
6. Resource Quality Objectives	RQOs for each nested ecological category for each significant water resource (i.e. not just the IUA).	Listed.
7. Applicability to Section 21 of the NWA	Applicable sections of NWA.	Listed.
	Action required for extensions of applicability.	Listed.
8. Special conditions and limitations	Resources not considered.	Listed.
	Limitations.	Listed.
	Data limitations.	Listed (e.g. flooding).
	Punitive measures associated with class configuration.	List the proposed punitive measures that should be gazetted to assist DWAF and CMA to enforce class configuration.
	Restrictions of study.	Listed.
9. Methods applied	Classification procedure.	Listed and described.
	Reserve method.	Listed and described.
	Water quality method.	Listed and described.
	Basic Human Needs method.	Listed and described.
	Resource Quality Objectives method.	Listed and described.
10. Administrative information	Project management team	Listed.
	Peer review information.	To demonstrate scientific validity and good practice.
	RDM team and Professional Service Providers (PSP).	Listed.

11. Aspects included in the catchment management strategy (CMS) and catchment management plan (CMP)	Flow-related.	Listed and described.
	Non-flow related.	Listed and described.
	Operation rules.	Listed and described.
	Monitoring programme and implementation plan.	Listed and described.
12. Monitoring	Monitoring locations (geographical co-ordinates).	Listed and described.
	Aspects to be monitored.	Listed and described, but may include resource monitoring compliance to RQOs, water quality and allocation.
13. References	Specialist reports.	Listed and referenced.

12 STEP 7B: DECISION BY THE MINISTER OR HIS/HER DELEGATED AUTHORITY ON THE IUA CLASSES, NESTED ECOLOGICAL CATEGORY CONFIGURATIONS, RESERVE(S), ALLOCATION SCHEDULE(S) AND CATCHMENT MANAGEMENT STRATEGY (CMS)

The objective of Step 7b is for the Minister to decide on IUA classes and nested ecological category configurations, Reserve(s), allocation schedule(s) and Catchment Management Strategy (CMS) based on a suite of catchment configuration scenarios (and other information from other DWAF IWRM processes) presented to her in the form of the IWRM template (Step 7a - see Section 11). This is procedure is not prescribed, as it depends on the discretion of the Minister or his/her delegated authority.

13 STEP 7C: SET THE RESOURCE QUALITY OBJECTIVES (RQOS)

The objective of Step 7c is to set the Resource Quality Objectives (RQOs) for the IUA classes and nested ecological category configurations following a decision on these by the Minister. It is recommended that the RQOs be established at this point, as it would be inefficient to establish RQOs for the suite of catchment configuration scenarios that are presented to the Minister in Step 7b (see Section 12) The process for determining RQOs is well established (cf. DWAF, 1999, DWAF, 2006b), and will not be repeated here. The RQOs established in Step 7c will need to be put forward for gazetting in Step 7d (see Section 14).

14 STEP 7D: GAZETTE IUA CLASSES, NESTED ECOLOGICAL CATEGORY CONFIGURATIONS, RESERVE(S) AND RQOS

The objective of Step 7d is to gazette the IUA classes, nested ecological category configurations, Reserve(s) and RQOs. The NWA lays out clear guidelines for the gazetting of the class and RQOs:

Section 13.

(1) The Minister having prescribed a system for classifying water resources, must as soon after as is reasonably practicable, subject to subsection (4), by notice in the *Gazette,* determine for all or part of every significant resource:
  (a) a class in accordance with the prescribed classification system;
  (b) RQOs based on the class determined in terms of paragraph (a).

(2) A notice in terms of subsection (1) must state the geographical area in respect of which RQOs will apply, the requirements for achieving the objectives, and the dates from which the objectives will apply.

(3) The objectives determined in terms of subsection (1) may relate to:
  (a) the Reserve;
  (b) the instream flow;
  (c) the water level;
  (d) the presence and concentration of particular substances in the water;
  (e) the characteristics and quality of the water resource and the instream and riparian habitat;

(f) the characteristics and distribution of aquatic biota;
(g) the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resources; and
(h) any other characteristic of the water resource in question.

(4) The Minister needs to publish in respect of each water resource a notice in the *Gazette* setting out the details of the above (paraphrased), invite and consider written comments.

15 STEP 7E: DEVELOP PLAN OF ACTION FOR IMPLEMENTATION OF RECOMMENDED SCENARIO WHICH MUST INCLUDE A MONITORING PROGRAME

The objective of Step 7d is to develop a plan of action for implementation of the recommended scenario, as well as the development of a monitoring programme. This plan will need to be developed with the objectives of the larger IWRM process in mind. This recommended procedure for developing this implementation plan could therefore be developed during the early applications of the WRCS in the Classification Process (and other aligned processes – e.g. compulsory licensing).

16 AREAS REQUIRING REFINEMENT, ADDITIONAL INPUT OR RESEARCH

16.1 Mismatch of information format, inputs, outputs and scales of information between disciplines

A challenge during this project was the mismatch between inputs and outputs in terms of data requirements, final index format and geographic scale of the different disciplines and sources of information. It is imperative that the specialists involved in an application of the WRCS meet together in the same room several times in order to ensure that the data requirements of the various specialists and stages of the classification procedure are understood. For example, the macro-economists are expected to provide information which either is, or needs to be 'back-calculated' to be, at the IUA scale

Another example concerns the requirements of the environmental economist in terms of EGSA data and the data routinely provided by ecologists particularly from a Reserve determination. During Step 1 and 2 of the classification procedure, the more important EGSAs from a socio-economic point of view need to be identified and it needs to be verified whether these data are available, and if not, whether the project will be meaningful without them. For example, if it is known that subsistence fishing of a particular fish is a very important component of local livelihoods, yet available Reserve or other data provides no information on stocks or yield, then it may be necessary to conduct an additional study. In other cases, the required information may easily be included within a Reserve study or provided by specialist input or direct scoring.

This essential process of specialists agreeing and repeatedly verifying formats, inputs, outputs and scales, forms part of the problem structuring MCDA stage. While this requirement may increase the implementation expense, without it, the application will risk being flawed because the results it produces are unreliable and/or irrelevant.

16.2 Scaling of the SWB scores

As mentioned, for the SWB indices, different parts and extents of the 0-100 scales may be in use. This may unduly influence the results or at least the *perception* of the results and in turn the elicitation of swing weights. In this study 100% was taken as the natural maximum and scores scaled accordingly. However, it might be better to determine the probable highest point for each of these sub-indices (e.g. 90% employment, 50% in the non-poor category) rather than using the theoretically possible highest point (100% employment, 100% in the non-poor category) which are unlikely to ever be achieved in the real world. There is therefore a need to determine for South Africa as a whole what these probable maxima are.

16.3 Ecological Category and Ecological Importance and Sensitivity scores

The scores given to the Ecological Categories (0-5 for category E to A) (used to calculated the EI and the IV, Sections 4.1.2 and 4.1.1.4) and to the EIS (used to weight IUAs when aggregated to catchment level, Section 6.3.2) might need to be adjusted to better reflect the relative ecological value of these categories or perhaps to help the matching of System 1 and 3 (below).

16.4 Matching System 3 (Class definition) and System 1 (Ecosystem Index)

The rules of System 3 (see Section 4.1.2) will need fine-tuning in consultation with other ecologists. It would be useful to see if the adjustments to the rules for System 3 and the category scores for System 1 (see Section 4.1.2) could be made in such a way that the two systems better 'match'. One might be able to develop a system whereby EI scores of greater than 80 correspond to a Class I, those between 60 and 80 correspond to a Class II and those less than 60 correspond to Class III. At the moment, as was seen in Table 4.3 and Section 4.1.2 the two approaches are not completely compatible. There are transition areas of the EI scores between about 58-65 where the Class could be II or III and between about 80 and 87 where the Class could be either II or I. Assessing these two systems to bring about a better match would be a relatively short but worthwhile investment of time.

17 REFERENCES

Belton, V. and **Stewart, T.J.**, 2002: *Multiple Criteria Decision Analysis: An Integrated Approach*. Kluwer Academic Publishers, Dordrecht, Netherlands.

Brown, C.A., Ewart-Smith, J., Conrad, J., Rossouw, N. Dollar, E.S.J. and **Nicolson, C.R.** 2007: *The development of the water resource classification system (WRCS). Volume 2. Ecological, hydrological and water quality guidelines for the 7-step classification procedure*. CSIR Report No. CSIR/NRE/WR/ER/2006/0187B/C. Department of Water Affairs and Forestry, Pretoria, 134pp.

Department of Water Affairs and Forestry (**DWAF**) 1999: *Resource Directed Measures for Protection of Water Resources,* Version 1.0. Department of Water Affairs and Forestry, Pretoria.

Department: Water Affairs and Forestry (**DWAF**) 2005: *The development of a national water resource classification system. Inception report.* Contract Report for Department of Water Affairs and Forestry, by ESJ Dollar Consulting cc, Cape Town, 277pp.

Department of Water Affairs and Forestry (DWAF) 2006a: *Class definitions for gazetting: Draft discussion document.* Department: Water Affairs and Forestry, Pretoria, 16pp.

Department of Water Affairs and Forestry (DWAF), 2006b: *Guideline for determining Resource Water Quality Objectives (RWQOs), Allocatable Water Quality and the Stress of the Water Resource*. Version 2.3. Water Resource Planning Systems Series, Sub-Series No. WQP 1.4.3.1, Resource Directed Management of Water Quality. Pretoria.

Dollar, E.S.J., Brown, C.A., Turpie, J.K., Joubert, A.R., Nicolson, C.R. and **Manyaka, S.M**. 2007: *The development of the Water Resource Classification System (WRCS). Volume 1. Overview and 7-step classification procedure.* CSIR Report No. CSIR/NRE/WR/ER/2006/0187A/C. Department of Water Affairs and Forestry, Pretoria, 74pp.

Hajkowicz, S.A., 2006: Taking a closer look at multiple criteria analysis and economic evaluation. SEA News, Issue 21, July 2006. http://www.crcsalinity.com.au/newsletter/sea/SEANews21 .html (SEA= Sustainability and Economics in Agriculture)

IVM, 2002: DEFINITE V3.0. copyright, IVM 2002-2002. Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Janssen, R., 2001: On the Use of Multi-Criteria Analysis in Environmental Impact Assessment in The Netherlands. *Journal of Multi-Criteria Decision Analysis* 10, 101-109.

Joubert, A.R., 2003: Multi-attribute value measurement and economic paradigms in environmental decision making. PhD thesis: University of Cape Town.

Joubert, A.R., Leiman, A., de Klerk, H., Katua, S. and **Aggenbach, J.-C.**, 1997: Fynbos (fine bush) vegetation and the supply of water: A comparison of multi-criteria decision analysis and cost-benefit analysis. *Ecological Economics* 22, 123-140.

Kleynhans C.J. 1999: A procedure for the determination of the ecological reserve for the purposes of the national water balance model for South African River. Institute of Water Quality Studies, Department of Water Affairs & Forestry, Pretoria**.**

Rheingans, P., (undated web document): *Task-based color scale design*, Department of Computer Science and Electrical Engineering, University of Maryland Baltimore County, Baltimore MD 21250. www.cs.umbc.edu/~rheingan/pubs/scales.pdf.gz

Roux D., Nel J.L.; **MacKay H.M.** and **Ashton P.J.,** 2006: *Cross-sector policy objectives for conserving South Africa's inland water biodiversity*. Report to the Water Reseach Commission. Report Number: TT 276/06.

Stewart, T.J., 1996: Robustness of additive value function methods in MCDM. *Journal of Multi-Criteria Decision Analysis* 5, 301-309.

Steward, T.J. and **Joubert, A.R.** 2006: *Multicriteria support for decision-making in the ecosystem approach to fisheries management. Report to the Benguella Current Large Ecosystem Project. 27 October 2006*. Department of Statistical Sciences. University of Cape Town. 36pp.

Turpie, J.K., Dollar, E.S.J., Goldin, J., Mullins, W., Mallory, S., Rossouw, N. Joubert, A.R. and **Nicolson, C.R**. 2007: *The development of the water resource classification system (WRCS). Volume 3. Socio-economic guidelines for the 7-step classification procedure*. CSIR Report No. CSIR/NRE/WR/ER/2006/0187C/C. Department of Water Affairs and Forestry, Pretoria, 111pp.

VISA, Visual Interactive Sensitivity Analysis for Multicriteria Decision Making. Copyright and design Val Belton, Visual Thinking International: http://www.simul8.com/

von Winterfeldt, D. and **Edwards, W.**, 1986: *Decision Analysis and Behavioural Research*. Cambridge University Press, Cambridge. 604pp.

APPENDIX A: CATEGORY CONFIGURATION SCENARIOS USED IN THIS VOLUME, ECOSYSTEM INDEX VALUES AND ASSOCIATED CLASS

Category configuration scenarios for the Olifants/Doring catchment, EI scores and Classes

IUA	Node	PES	Rec+ Cons	SBC	PES	Rec+ Cons	SBC	PES	REC+ CONS	SBC
Doring Rangelands	R12	C	A	b	66.33	75.73	54.99	Class III	Class II	Class III
Doring Rangelands	R20	B	B	D						
Doring Rangelands	R21	C	C	D						
Doring Rangelands	R22	C	C	D						
	R25	B	A	b						
Doring Rangelands	R27	C	C	D						
Doring Rangelands	R28	B	A	D						
Doring Rangelands	R29	C	C	D						
Doring Rangelands	R30	C	C	c						
Doring Rangelands	R31	C	C	D						
Doring Rangelands	R32	C	C	b						
Doring Rangelands	R36	B	A	c						
Doring Rangelands	R50	C	C	b						
Estuary	E1	C	B	D	60	80	40	II	I	III
Knersvlakte	R1	C	C	c	60	60	51.50	Class III	Class III	Class III
Knersvlakte	R2	C	C	c						
Knersvlakte	R3	C	C	D						
Knersvlakte	R4	C	C	b						
Knersvlakte	R5	C	C	D						
Knersvlakte	R8	C	C	D						
Koue Bokkeveld	R37	B	A	c	42.73	93.17	67.69	FAIL	Class I	Class II
Koue Bokkeveld	R38	B	B	b						
Koue Bokkeveld	R39	B	B	D						
Koue Bokkeveld	R41	B	B	a						
Koue Bokkeveld	R43	B	A	c						
Koue Bokkeveld	R45	F	A	b						
Koue Bokkeveld	R46	F	A	c						
Koue Bokkeveld	R48	F	A	b						
Koue Bokkeveld	R49	F	A	c						
Lower Olifants Irrigation	R7	C	A	D	42.17	100.0	40.00	Class III	Class I	Class III
Lower Olifants Irrigation	R9	D	A	D						
Olifants/Doring Dryland Farming	R11	B	A	D	68.86	92.38	42.34	Class II	Class I	Class III
Olifants/Doring Dryland Farming	R14	C	A	D						
Olifants/Doring Dryland Farming	R15	C	A	D						
Olifants/Doring Dryland Farming	R16	C	B	D						
Olifants/Doring Dryland Farming	R17	C	B	D						
Olifants/Doring Dryland Farming	R19	B	B	D						
Olifants/Doring Dryland Farming	R26	B	A	c						
Upper Olifants Irrigation	R13	F	A	D	45.51	75.92	45.29	Class III	Class II	Class III
Upper Olifants Irrigation	R23	D	D	D						
Upper Olifants Irrigation	R24	D	D	c						
Upper Olifants Irrigation	R33	D	A	D						
Upper Olifants Irrigation	R34	B	B	D						
Upper Olifants Irrigation	R40	C	C	D						
Upper Olifants Irrigation	R42	B	A	c						
Upper Olifants Irrigation	R44	C	B	D						
Upper Olifants Irrigation	R47	C	B	D						

APPENDIX B: TABULATED SCENARIO RESULTS FOR IUAS IN OLIFANTS/DORING CATCHMENT

IUA1-Estuary

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed	% non-poor	Health	Intangible Values	SOCIAL WELL-BEING	Condition	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh (regional)	Infrastructural costs	Economic prosperity in Rands	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	53	22	73	64	51	60	0	60	0.8	100	100		5050500	53	
Sc2-PES	53	22	73	64	51	60	0	60	0.8	77	80		5040500	41	
Sc3-REC+Cons.	53	22	73	91	58	80	0	80	0.7	68	59		4612057	35	
ESBC	52	22	73	18	38	40	0	40	0.7	77	79		4217986	41	
Sub-index weights	0.38	0.23	0.12	0.27					0.48	0.38	0.14	0.0			
Index weights					0.50			0.10						0.40	

IUA2-Doring Rangelands

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed	% non-poor	Health	Intangible Values	SOCIAL WELL-BEING	Condition	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh (regional)	Infrastructural costs	Economic prosperity in Rands	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	88	19	73	75	47	66	0.6	66	11.6	100	100		73330972	58	
Sc2-PES	86	14	73	75	44	66	0.6	66	8.2	77	80		51991062	45	
Sc3-REC+Cons.	86	13	73	88	45	76	0.6	76	7.4	68	59		47119649	38	
ESBC	86	15	73	18	39	55	0.6	55	8.8	77	79		55692710	45	
std wts	0.16	0.53	0.21	0.11					0.48	0.38	0.14	0.0			0.16
std wts					0.50			0.10						0.40	

IUA3-Lower Olifants

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed	% non-poor	Health	Intangible Values	SOCIAL WELL-BEING	Condition	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh (regional)	Infrastructural costs	Economic prosperity in Rands	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	74	30	73	22	45	42	0.5	42	100.0	100	100		634860001	100	
Sc2-PES	63	6	73	22	31	42	0.5	42	57.0	77	80		361870201	68	
Sc3-REC+Cons.	46	1	73	100	35	100	0.5	100	0.0	68	59		1	34	
ESBC	63	6	73	18	30	40	0.5	40	57.0	77	79		361870201	68	
std wts	0.29	0.48	0.10	0.14					0.48	0.38	0.14	0.00			
std wts					0.50			0.10						0.40	

IUA4-Upper Olifants

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed	% non-poor	Health	Intangible Values	SOCIAL WELL-BEING	Condition	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh (regional)	Infrastructural costs	Economic prosperity in Rands	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	86	21	73	31	45	46	0.4	46	75.3	100	100		477741618	88	
Sc2-PES	76	21	73	31	42	46	0.4	46	74.9	77	80		475602130	76	
Sc3-REC+Cons.	76	13	73	88	49	76	0.4	76	66.5	68	59		422439091	66	
ESBC	76	8	73	18	34	45	0.4	45	58.5	77	79		371296033	68	
std wts	0.27	0.45	0.09	0.18					0.48	0.38	0.14	0.00			
std wts					0.50			0.10						0.40	

IUA5-Olifants Doring Drylands

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed score	% non-poor	Health (P+P and water qual.)	General utility (Eco-condition)	SOCIAL WELL-BEING	Condition (Sum node score x length)weighted by length	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh	Infrastructural costs	ECONOMIC PROSPERITY IN RANDS	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	82	17	73	78	49	69	0.2	69	11.7	100	100		74176005	58	
Sc2-PES	81	24	73	78	52	69	0.2	69	15.5	77	80		98129312	48	
Sc3-REC+Cons.	82	28	73	98	59	92	0.2	92	17.7	68	59		112449849	43	
ESBC	81	16	73	18	37	42	0.2	42	11.4	77	79		72101102	46	
std wts	0.24	0.48	0.10	0.19					0.48	0.38	0.14	0.00			
std wts					0.50			0.10						0.40	

IUA6-Kouebokkeveld

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed score	% non-poor	Health (P+P and water qual.)	General utility (Eco-condition)	SOCIAL WELL-BEING	Condition (Sum node score x length)weighted by length	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh	Infrastructural costs	ECONOMIC PROSPERITY IN RANDS	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	93	17	73	22	41	43	0.6	43	66.8	100	100		424229551	84	
Sc2-PES	83	10	73	22	36	43	0.6	43	62.5	77	80		396754934	71	
Sc3-REC+Cons.	83	17	73	98	54	93	0.6	93	67.0	68	59		425085945	66	
ESBC	83	13	73	18	36	68	0.6	68	64.3	77	79		408502835	71	
std wts	0.24	0.48	0.10	0.19					0.48	0.38	0.14	0.00			
std wts					0.50			0.10						0.40	

IUA7-Knersvlakte

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						
	% employed score	% non-poor	Health (P+P and water qual.)	General utility (Eco-condition)	SOCIAL WELL-BEING	Condition (Sum node score x length)weighted by length	% unrepresented	ECOSYSTEM INDEX	ALL GGP+GDP EFFECTS	Employment	Income to poor hh	Infrastructural costs	ECONOMIC PROSPERITY IN RANDS	ECONOMIC PROSPERITY	Overall consequences of scenario
Current /baseline	69	16	73	64	43	60	0.6	60	3.5	100	100		21934463	54	
Sc2-PES	64	8	73	64	38	60	0.6	60	0.7	77	80		4374697	41	
Sc3-REC+Cons.	64	8	73	64	38	60	0.6	60	0.8	68	59		4972190	35	
ESBC	64	7	73	18	31	51	0.6	51	0.5	77	79		2921580	41	
std wts	0.29	0.48	0.10	0.14					0.48	0.38	0.14	0.00			
std wts					0.50			0.10						0.40	

APPENDIX C: SUMMARISED IUA- AND CATCHMENT-LEVEL RESULTS

Aggregate Social well being index values for the IUAs in the Olifants/Doring catchment.

	IUA1 Estuary	IUA2 Doring Rangelands	IUA3 Lower Olifants	IUA4 Upper Olifants	IUA5 Dryland farming	IUA6 Koue Bokkeveld	IUA7 Knersvlakte
Current /baseline	51.2	47.1	45.4	45.2	49.2	41.3	43.5
Sc2-PES	51.2	44.3	30.9	42.4	52.4	35.7	38.1
Sc3-REC+Cons.	58.4	45.1	35.0	49.4	58.5	53.6	38.2
ESBC	38.5	38.7	30.3	34.1	37.3	36.2	31.2

Aggregate Ecosystem Index values for the IUAs in the Olifants/Doring catchment.

	IUA1 Estuary	IUA2 Doring Rangelands	IUA3 Lower Olifants	IUA4 Upper Olifants	IUA5 Dryland farming	IUA6 Koue Bokkeveld	IUA7 Knersvlakte
Current /baseline	60.0	66.3	42.2	45.5	68.9	42.7	60.0
Sc2-PES	60.0	66.3	42.2	45.5	68.9	42.7	60.0
Sc3-REC+Cons.	80.0	75.7	100.0	75.9	92.4	93.2	60.0
ESBC	40.0	55.0	40.0	45.3	42.3	67.7	51.5

Aggregate Regional economic prosperity index values for the IUAs in the Olifants/Doring catchment[24].

	IUA1 Estuary	IUA2 Doring Rangelands	IUA3 Lower Olifants	IUA4 Upper Olifants	IUA5 Dryland farming	IUA6 Koue Bokkeveld	IUA7 Knersvlakte
Current /baseline	52.8	57.9	100.0	88.2	57.9	84.2	54.0
Sc2-PES	41.2	44.7	68.0	76.5	48.2	70.6	41.1
Sc3-REC+Cons.	34.8	38.0	34.4	66.1	42.9	66.3	34.8
ESBC	40.8	44.6	67.6	68.3	45.9	71.1	40.7

Aggregate performance for the IUAs in the Olifants/Doring catchment.

	IUA1 Estuary	IUA2 Doring Rangelands	IUA3 Lower Olifants	IUA4 Upper Olifants	IUA5 Dryland farming	IUA6 Koue Bokkeveld	IUA7 Knersvlakte
Current /baseline	5.54	7.18	13.16	10.76	7.42	7.60	5.18
Sc2-PES	4.88	6.22	9.11	9.77	7.05	6.48	4.27
Sc3-REC+Cons.	5.14	5.98	8.51	10.39	7.50	7.62	3.91
ESBC	4.11	5.73	8.98	8.38	5.56	6.69	3.93

Catchment level results for the Olifants/Doring catchment.

	Social well-being	Ecosystem Index	Regional economic prosperity	OVERALL
Current /baseline	45.67	56.64	70.72	56.84
Sc2-PES	39.63	56.64	55.75	47.77
Sc3-REC+Cons.	45.70	81.98	45.34	49.04
ESBC	34.21	45.94	54.13	43.38

[24] Hypothetical values.