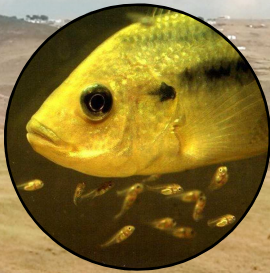


PROCEDURES TO DEVELOP AND IMPLEMENT RESOURCE QUALITY OBJECTIVES

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EXECUTIVE SUMMARY

1. Introduction

The National Water Act (No. 36 of 1998) (NWA) sets out to ensure that water resources are used, managed and controlled in such a way that they benefit all users. In order to achieve this, the Act prescribes a series of measures which are intended to ensure comprehensive protection of water resources so that they can be used sustainably. The Act states that these measures are to be developed progressively within the context of the National Water Resource Strategy and catchment management strategies. In particular the Act provides for:

- The development of a Classification System for water resources
- The setting of a Management Class and Resource Quality Objectives
- Determination of the Reserve

Resource Quality Objectives capture the Management Class of the Classification System and the ecological needs determined in the Reserve into measurable management goals that give direction to resource managers as to how the resource needs to be managed.

The National Water Act states that the purpose of RQOs is to establish clear goals relating to the quality of the relevant water resources and stipulates that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to use them (Chapter 3 part 2). The Act further states that the RQOs may “*relate to the Reserve; the instream flow; the water level; the presence and concentration of particular substances in the water; the characteristics and quality of the water resource and the instream and riparian habitat; the characteristics and distribution of aquatic biota; the regulation or prohibition of instream or land-based activities which may affect the quantity and quality of the water resource; and any other characteristic*”. The Act also states that “once the Class of a water resource and the Resource Quality Objectives have been determined they are binding on all authorities and institutions when exercising any power or performing any duty under this Act.”

2. Context for RQOs

Early thinking on RQOs emerged in the extensive 1999 publication of guidelines for resource directed measures. The RDM Integrated manual noted that “*the Resource Quality Objectives for a water resource are a numerical or descriptive statement of the conditions which should be met in the receiving water resource, in terms of resource quality, in order to ensure that the water resource is protected*.” This manual also states that RQOs are scientifically derived criteria based on best available scientific knowledge and that they should be set for each Resource Unit for instream and riparian habitat and aquatic biota.

The National Water Resources Strategy (NWRS) identified the linkages between the Class of the Resource, Ecological Reserve and Resource Quality Objectives. This document recognised that while the Reserve includes the quantity and quality of water required to meet basic human needs and to protect aquatic environments, Resource Quality Objectives provide numerical and/or descriptive statements about the biological, chemical and physical attributes that characterise a resource for the level of protection defined by its Class. The NWRS therefore stipulates that “*Resource Quality Objectives might describe, among other things, the quantity, pattern and timing of instream flow; water quality; the character and condition of riparian habitat, and the characteristics and condition of the aquatic biota*”.

3. User and Ecological Requirements

The National Water Act requires that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to use them. The first stage in the

protection of water resources, according to the National Water Act, is the development of a system to classify the nation's water resources. The Water Resources Classification System (WRCS) (DWAF, 2007) is a key framework into which the Reserve and RQOs both fit. The WRCS provides a seven-step process which balances the needs of the environment and those of users and reflects this information in a Management Class.

The Ecological Reserve on the other hand, defines the quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. The data which is produced by the Ecological Reserve process, which details the objectives to be met for the protection of the ecosystem have been called EcoSpecs. These are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity), which define the Class (natural, good or fair) and serve as an input to Resource Quality Objectives.

A range of users are also defined in the National Water Act. These users all have needs of the water resource, which vary in terms of both quality and quantity and which give rise to the development of UserSpecs.

The RQO determination procedure works to balance the requirements of the environment with those of the ecosystem within the framework of the Water Resource Classification. Palmer et al. (2004b) noted that RQOs can be more protective than EcoSpecs if there is a particularly sensitive user need, but normally the EcoSpecs defines the level of protection. They went on to say that when a user has a more sensitive flow or water quality requirement than the ecosystem, and if the UserSpec will not impair the ecosystem's condition, then the UserSpec becomes the RQO.

4. Format of RQOs

In line with earlier thinking, the outputs of the RQO determination procedure include both *descriptive statements* and attendant numerical values.

The RQOs themselves are essentially narrative and qualitative but sometimes broadly quantitative statements that describe the overall objectives for the catchment, IUA or Resource Unit. For example, an RQO for a river may state "the water quality from this Resource must be acceptable for irrigation of crops". In addition, the RQOs may say that "the endemic yellowfish in this river should be maintained as a viable population to support the ecosystem and also for recreational angling". These RQOs are aligned with the Vision for the resource, and because they are essentially narrative, are less subject to change as the understanding of the ecosystem changes. Because they are descriptive, and generally easy to understand, they are also meaningful to stakeholders, as well as the responsible managers, and give direction for whatever action is necessary to achieve the vision for the resource. These RQOs are gazetted and are thus supported by law.

Numerical limits however are generally quantitative descriptors of the different components of the resource such as the water quantity, quality, habitat and biota. These descriptors give a quantitative measure of the RQOs that can be used for monitoring e.g. following the examples above, the RQO numeric limits for water suitable for irrigation may include the concentration of dissolved solids at $x \text{ mg l}^{-1}$, and for the yellowfish may include that "there should be 20 fish $>300\text{mm}$ in length collected in a two hour collection effort using an electro-fishing apparatus". However, because there is a high uncertainty in the scientific information that says that a particular concentration of dissolved solids is suitable for irrigation at a level suitable for the users of that water, and also that 20 fish is indeed the correct number to quantify the narrative RQO (i.e. to maintain a viable population and support recreational angling), these numeric limits are NOT gazetted and thus may be more easily changed if

found to be inaccurate. This process of changing the Numerical Limits should not be taken lightly and needs to follow the guidelines given in this document. At the end of the day, the limits will still need to be able to demonstrate that the vision and the RQO is being achieved, and thus need to be maintained with absolute integrity.

5. Seven step process for determining RQOs

A seven step procedure has been provided for the determination of Resource Quality Objectives. Each of the steps has detailed directions, with two Excel spreadsheet tools in attendance to assist with decision-making. These two tools are:

- **Resource Unit Prioritisation Tool** – this tool assists with the selection of Resource Units which should be considered as important for monitoring. To some extent this will be influenced by the resources that are available for long-term monitoring, but those with the highest priority are clearly identified.
- **Resource Unit Evaluation Tool** – this tool guides the RQO determination through a number of decisions in order to produce a prioritised short-list of indicators that can be used for monitoring of a particular Resource Unit.

The seven step process is outlined below and forms part of a classic adaptive management cycle (see Figure 1) which adds a further three steps. Overall the procedure involves defining the resource, setting a vision, determination of RQOs and Numerical Limits, gazetting this and then moving to implementation, monitoring and review before starting the process all over again.

Step 1. Delineate the Integrated Units of Analysis (IUAs) and define the Resource Units (RUs)

- 1.1 Gather and map available information for IUA and RU determination
- 1.2 Describe the present day socio-economic status (Step 1a of WRCS)
- 1.3 Divide the catchment in socio-economic zones (Step 1b of WRCS)
- 1.4 Define the Integrated Units of Analysis (Step 1h of WRCS)
- 1.5 Delineate Resource Units using RDM methodology
- 1.6 Align Resource Units with IUA boundaries
- 1.7 Understand how the Resource Units relate to the Water Resource Classification river nodes.

Step 2. Establish a vision for the catchment and key elements for the IUAs

- 2.1 Select a geographical area
- 2.2 Workshop preparation
- 2.3 Develop a Vision

Step 3. Prioritise and select preliminary Resource Units for RQO determination

- 3.1 Extract and map catchment and Resource Unit level information
- 3.2 Determine the position of each Resource Unit within the IUA
- 3.3 Assess the importance of each Resource Unit to users
- 3.4 Determine the level of threat posed to water resource quality for users
- 3.5 Assess the importance of each Resource Unit to ecological components
- 3.6 Determine the level of threat posed to water resource quality for the environment
- 3.7 Identify Resource Units for which management action should be prioritised
- 3.8 Assess practical considerations associated with RQO determination for each Resource Unit
- 3.9 Evaluate the relative ranking and weighting of each criterion
- 3.10 Select Preliminary Resource Units for RQO determination using prioritisation scores
- 3.11 Complete the information sheet for the Resource Unit Prioritisation Tool

Step 4. Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change

- 4.1 Identify and assess the impact of current and anticipated future use on water resource components
- 4.2 Identify requirements of important user groups
- 4.3 Selection of sub-components for RQO determination
- 4.4 Establish the desired direction of change for selected sub-components
- 4.5 Complete the information sheet for the Resource Unit Evaluation Tool

Step 5. Develop draft RQOs and Numerical Limits

- 5.1 Carry over sub-component and indicator information from the Resource Unit Evaluation Tool
- 5.2 Extract available data to determine the present state for selected sub-components and indicators
- 5.3 Assess the suitability of the data
- 5.4 Where necessary, collect data to determine the Present State for selected indicators
- 5.5 Determine the level at which to set RQOs
- 5.6 Set appropriate draft RQOs
- 5.7 Set appropriate draft Numerical Limits in line with the draft RQO
- 5.8 Determine confidence in the RQOs and process

Step 6. Agree Resource Units, RQOs and Numerical Limits with stakeholders

- 6.1 Notify stakeholders and plan the workshop
- 6.2 Present and refine the Resource Unit selection with stakeholders
- 6.3 Present the sub-components and indicators selected for the RQO determination
- 6.4 Present the proposed direction of change and associated rationale
- 6.5 Present and revise RQOs and Numerical Limits

Step 7. Finalise and Gazette RQOs

6. RQOs for rivers, wetlands, estuaries and groundwater

The RQO determination procedure has been designed in such a way that it can be used to develop RQOs for rivers, wetlands and estuaries. The process of determining the RQOs remains constant, but the prioritisation of components and indicators will vary as different variables are of significance to rivers, wetlands and estuaries. Drivers of change in the catchments will also impact differently on these three system types. The model thus comes in three variants, for rivers, wetlands and estuaries, but these are essentially very similar. Differences are indicated in the text describing the seven steps and also in the two different Excel tools that are appended.

Groundwater is dealt with separately as not only are the Resource Units completely different to the surface water systems, so are the variables of concern. Two systems for undertaking RQO determination for groundwater resources already exists (Colvin et al., 2004; Parsons and Wentzel, 2006). These processes have been aligned to this generic RQO procedure.

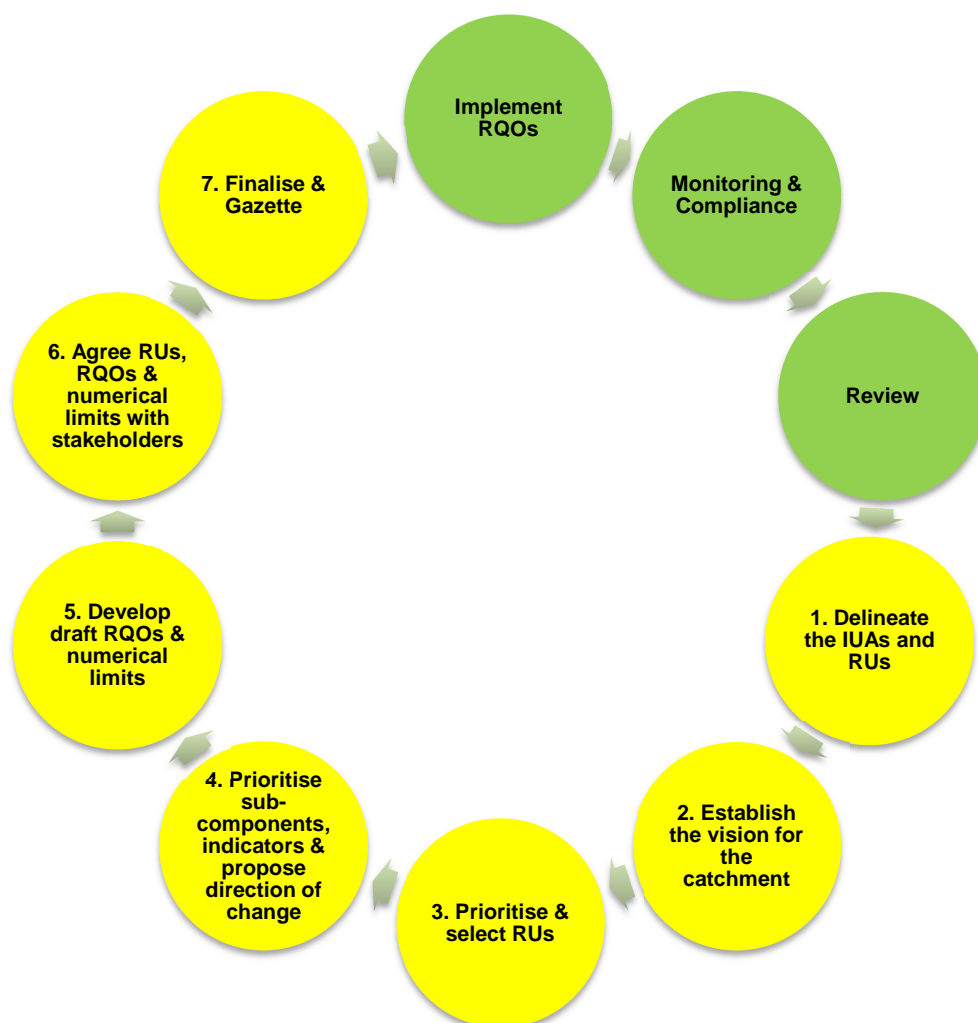


Figure 1. Management of water resources using RQOs; incorporating the seven steps for determination of RQOs and three additional steps to implement the Adaptive Management Cycle.

7. Management, Monitoring and Compliance

Following the gazetting of the RQOs comes the process to complete the Adaptive Management Cycle. Adaptive Management is defined basically as ‘learning by doing’, suggesting that management should be on a continual learning cycle, learning from their mistakes and rectifying these mistakes. In terms of the setting and management of RQOs following the Adaptive Management approach, RQOs should always be seen as ‘first generation’ RQOs, which will be subject to scrutiny as implementation progresses and will be changed if found not to be aligned with the vision for the resource.

Monitoring and compliance entails a systematic process to measure and manage performance in management of the water resource towards RQOs. Compliance with RQOs would be achieved when the resource is equal to or in a “better” condition than indicated by the RQOs or Numerical Limits, or when there is evidence that the resource quality is moving towards the objective and not away from it.

In the event that there is a change in direction away from the RQOs, then it indicates that the measures in place to protect the water resource are not sufficient to bring the resource into alignment with the objectives, or alternately that the RQOs are not reasonable. Consideration needs to be given to understanding which of these two are at play and that appropriate measures are instituted to better the situation.

8. Conclusion

This procedure for the determination and implementation of RQOs forms a vital part of the water resources management cycle, as only when managers of the water resource have clear objectives for their work, will protection of the resource become a reality. While these procedures have been written to be as comprehensive as possible, there will undoubtedly be situations where intelligence and adaptation need to be applied to ensure a proper outcome. In the end, it is the spirit of what is intended here that is important, more so than the fineness of the detail.

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I. INTRODUCTION

The National Water Act (No. 36 of 1998) (NWA) recognises that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users. In order for this to be possible, it is necessary firstly to know what water resources are available, secondly to have a vision for how they can be used, and then thirdly to have a set of targets in place in order to know if the vision is being achieved. As the saying goes – *“if you don’t know where you are going, then any direction will do”*.

In order to achieve this, the National Water Act prescribes a series of measures which are intended to give effect to the above mission, and to ensure the comprehensive protection of water resources so that they can be sustainably used. The Act states that these measures are to be developed progressively within the context of the National Water Resource Strategy and catchment management strategies. In particular the Act provides for:

- The development of a Classification System for water resources
- The setting of a Management Class and Resource Quality Objectives
- Determination of the Reserve

The Water Resource Classification establishes the Management Class *i.e.* the Class towards which the resource must be managed. This Class must capture a long term balance between protection of water resources, optimal water use, equity between generations and current equitable access including international obligations. In some situations, this may result in the resource being heavily utilised and degraded to some extent but still within the resilience of the water resource, while in others the resource may be put aside for conservation. The Ecological Reserve describes the needs of the ecosystem, the protection of which is needed to ensure sustainable use. These all come together in the description of Resource Quality Objectives (RQOs) which provide measurable management goals that give direction to resource managers and how the resource needs to be managed. These managers give effect to this via the allocation of licenses, with the total of the resulting impacts being constrained by the overall quality of the resource as described by the RQOs.

The above is represented in Figure 1.

A. RQOs in the South African Context

It is necessary to review a number of documents that are pivotal to the understanding of Resource Quality Objectives. Not only do these documents describe the origins of the RQO thinking, but they also give detail on how RQOs fit into other arms of the management of water resources. The most important documents to consider are:

- The National Water Act (1998)
- RDM Integrated Manual (1999)
- The National Water Resources Strategy (DWAF, 2004)
- Water Resource Classification System (DWAF, 2007)
- Resource Water Quality Objectives (DWAF, 2006)
- Ecological Reserve, EcoClassification, EcoStatus and EcoSpecs

a) The National Water Act (No. 36 of 1998)

The National Water Act (No. 36 of 1998) states that the purpose of RQOs is to establish clear goals relating to the quality of the relevant water resources and stipulates that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to use them (Chapter 3 part 2).

The Act further states that the RQOs may “*relate to the Reserve; the instream flow; the water level; the presence and concentration of particular substances in the water; the characteristics and quality of the water resource and the instream and riparian habitat; the characteristics and distribution of aquatic biota; the regulation or prohibition of instream or land-based activities which may affect the quantity and quality of the water resource; and any other characteristic*”. The Act also states that “*once the Class of a water resource and the Resource Quality Objectives have been determined they are binding on all authorities and institutions when exercising any power or performing any duty under this Act.*”

The Act defines Resource Quality as the quality of all aspects of a water resource including:

- (a) the quantity, pattern, timing, water level and assurance of instream flow
- (b) the water quality including the physical, chemical, and biological characteristics of the water
- (c) the character and condition of the instream and riparian habitat; and
- (d) the characteristics, condition and distribution of the aquatic biota.

Note that the Act does not specifically define RQOs, but only Resource Quality

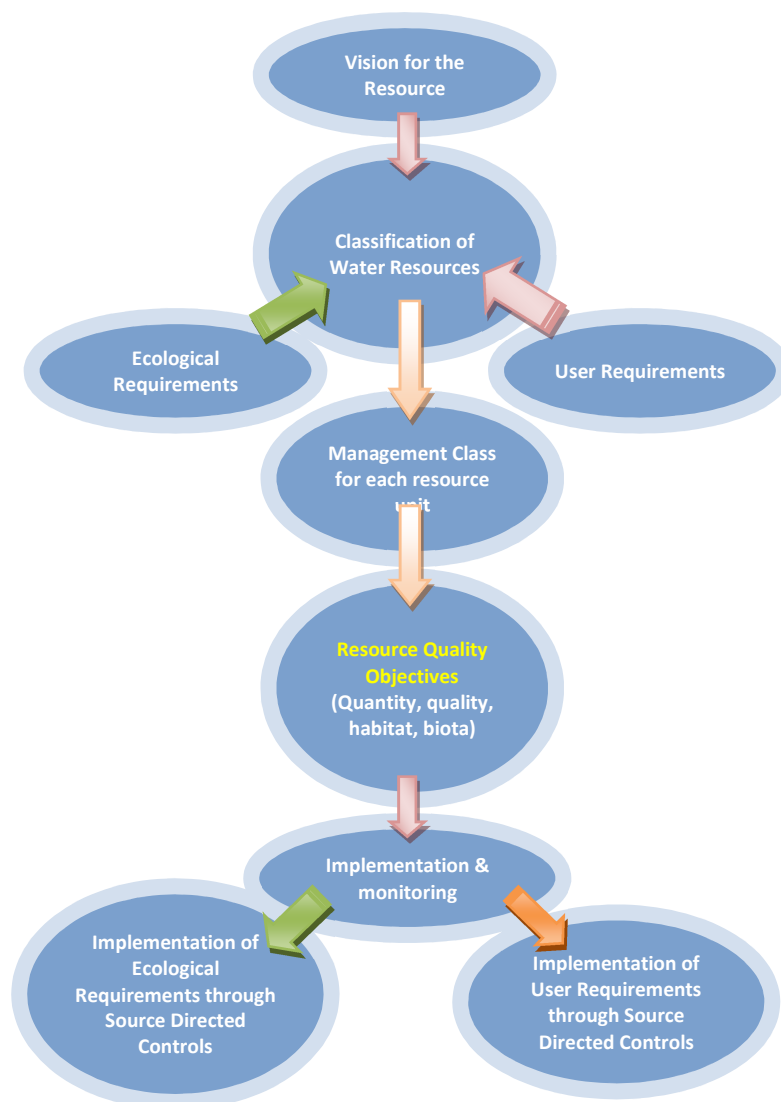


Figure 1. Context of the RQOs in relation to other aspects of resource management

b) RDM Integrated Manual (1999)

Early thinking on RQOs emerged in the extensive 1999 publication of guidelines for resource directed measures. For example the RDM Integrated Manual (DWAF, 1999a) noted that *“the Resource Quality Objectives for a water resource are a numerical or descriptive statement of the conditions which should be met in the receiving water resource, in terms of resource quality, in order to ensure that the water resource is protected.”*

The same Manual notes that RQOs are scientifically derived criteria based on best available scientific knowledge. The purpose and application of objectives is documented as follows (shortened in this case):

- They represent a goal for desired protection towards which management can be directed.
- They provide a clearly understood line between which activities and impacts are acceptable and not. This includes the impacts of point sources, non-point sources, land use and development, water abstraction, etc.
- They are a baseline for measuring the success of management and for reviewing the effectiveness of source directed control and regulatory activities.
- They provide a stable framework for a time period, for both resource managers and the regulatory community to undertake decision-making and planning.

The Manual continues in Section (6b) that there is the intention to *“set Resource Quality Objectives for each Resource Unit”* for instream and riparian habitat and aquatic biota. Habitat was noted to contain both quantity and quality of water. It also suggested that the impacts of other activities should also be considered, such as when land-based activities are impacting on sedimentation of the river, then requirements relating to the land-based activities may also be included in the RQOs.

This approach is given more detail in Volume 29 (DWAF, 1999b). A worked example provides an indication of the type of RQOs that would go into this table. These would include what are subsequently called EcoSpecs, such as SASS scores for invertebrates, etc. It also contains the outputs of the Ecological Reserve process, i.e. the complete table of monthly flow recommendations for maintenance, drought and flood flows. It also contains information on the water quality for each of the variables that is of importance, also considering the different months of the year where this is relevant.

While these documents were landmarks in the development of knowledge on resource directed measures, much of their content has been overtaken by evolutionary developments in the science. Nevertheless, they form an important reference that enables a better understanding of just what resource directed measures are, which can become obscured by the volumes of detail now available.

c) The National Water Resources Strategy (DWAF, 2004a)

In Section 3.1.2.3 it notes that *“the Class of a resource, the Reserve and its Resource Quality Objectives are intimately related to one another. The Reserve includes the quantity and quality of water to meet basic human needs and to protect aquatic ecosystems. Resource Quality Objectives provide numerical and/or descriptive statements about the biological, chemical and physical attributes that characterise a resource for the level of protection defined by its Class. Thus Resource Quality Objectives might describe, among other things, the quantity, pattern and timing of instream flow; water quality; the character and condition of riparian habitat, and the characteristics and condition of the aquatic biota”*.

It also states that *“Resource Quality Objectives must take account of user requirements and the Class of the resource. Accordingly, the determination of the Management Class of a resource and the related Ecological Reserve and Resource Quality Objectives will usually be undertaken as an integrated exercise. This will be done once the Resource Classification System is established”*.

d) Water Resource Classification System (DWAF, 2007)

The first stage in the protection of water resources, according to the National Water Act, is the development of a system to classify the nation's water resources. The Water Resources Classification System (WRCS) (DWAF, 2007) is a key framework into which the Reserve and RQOs both fit. The National Water Act makes provision for the Classification of resources and the setting of Management Classes (see Table 1). These Classes give direction to the setting of RQOs.

Volume 1 of the WRCS (DWAF, 2007) noted that *"the Water Resource Classification System is a defined set of guidelines and procedures for determining the different Classes of water resources. A key component of classification is an iterative process of evaluating catchment configuration options (scenarios) with stakeholders where the economic, social and ecological trade-offs will be made, and out of which will emerge the allocation schedule, installed modelling system, Class, Ecological Reserve, RQOs and the Catchment Management Strategy (CMS). This process is referred to as the 'Larger Process', or the Compulsory Licensing Process"*.

"Accordingly, co-operation with all three spheres of Government, participation of stakeholders and engagement with civil society is required to ensure appropriateness and acceptability of the WRCS and, ultimately, of the proposed Class. This implies that the Water Resource Classification is founded on consensus seeking, participation and co-operative governance to ensure socio-economic balance and sustainability in addition to the technical elements of ecological sustainability".

The WRCS provides a seven step procedure (DWAF, 2007), and as RQOs are by design required to respond to the Water Resource Classification, they are closely integrated. The seven step procedure for the classification of water resources is not provided here but needs to be understood in order to fully understand the origin of RQOs. For example, the WRCS has a process to describe the geographic areas that the Water Resource Classification applies to (IUAs and Resource Units). These areas by necessity become the same as those to which RQOs should apply. The last of the seven steps of the WRCS takes the Management Class produced by earlier steps, and gives it effect by gazetting, determining RQOs and then providing a plan for implementation.

Table 1. Summary of Management Classes produced by the Classification System (note that Class 1V is not permissible as a Management Class)

Management Class	Description
Class 1	Natural – minimal impact of humans, natural water quality and safe for most uses, of high significance. Other Classes are defined in terms of degree of deviation from the Natural Class
Class 11	Moderately used/impacted – slightly altered from natural due to human activity.
Class 111	Heavily used/impacted – significantly changed from natural due to human activity but nevertheless ecologically sustainable.
Class 1V	Unacceptably degraded resources – due to overexploitation. The Management Class is set higher in order to rehabilitate.

e) Resource Water Quality Objectives (DWAF, 2006a,b,c,d,e,f)

Resource Water Quality Objectives (RWQOs) are a component of RQOs. Because of the importance of water quality issues for resource management, and the complexity of water quality assessment, DWA proactively addressed this issue by developing procedures for the determination of RWQOs. The procedures for doing this are documented in a number of reports (DWAF, 2006a,b,c,d,e,f). These RWQOs form an input to the derivation of RQOs in much the same way that the Ecological Reserve

EcoSpecs are incorporated. In the end, the RQOs must provide the framework for the RWQOs but as the definition below suggests, RWQOs may be set in greater detail than RQOs: *Resource Water Quality Objectives (RWQOs) are defined as numeric or descriptive (narrative) instream (or in-aquifer) Water Quality Objectives typically set at a finer resolution (spatial or temporal) than RQOs that provide greater detail upon which to base the management of water quality* (DWAF, 2006a).

The DWAF (2006a,b,c,d,e,f) series of reports address policy, strategy, institutional arrangements and management instruments and relate specifically to management of the use and protection of the water quality component of inland water resources. The focus of the study was the determination of RWQOs for surface water resources; however the approach is considered generic and as such was developed with the other water resources, *i.e.* groundwater, estuaries, wetlands, lakes and reservoirs in mind. The primary product is a guideline document which outlines an approach for:

- Determining Resource Quality Objectives as they relate specifically to water quality for South African fresh water resources.
- Determining the allocatable water quality and the water quality stress of a water resource;
- Integrating catchment visioning, Water Resource Classification and the Ecological Reserve process into the water resource management process, through the determination of RWQOs.

These documents provide a systematic step wise process for the determination of RWQOs. Included is detail on the processes to integrate the different components of the RWQOs, including the ecological as well as the user requirements. They then give guidance on the time frame for RQOs, suggesting that a review period is necessary. They also discuss the spatial scale of the RWQOs, the area to which they apply, noting that a monitoring site should be situated at the lower extremity of the Resource Unit. The value of these documents in the management of RQOs is addressed later in this report.

f) Ecological Requirements - the Ecological Reserve, EcoClassification, EcoStatus and EcoSpecs

The Ecological Reserve is defined by the National Water Act as “*the quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource*”. The Ecological Reserve is not intended to protect the aquatic ecosystem as an end, but to maintain aquatic ecosystems in such a way so that they can continue to provide the goods and services required by society. The Reserve (ecological and basic human needs) is the only right to water; all other water uses are subject to authorisation.

The data which is produced by any Ecological Reserve process, which details the objectives to be met for the protection of the ecosystem have been called EcoSpecs. These are clear and measurable specifications of ecological attributes (*e.g.* water quality, flow, biological integrity), which define the Class (natural, good or fair) and serve as an input to Resource Quality Objectives. EcoSpecs refer explicitly and only to ecological information, whereas RQOs include economic and social objectives (DWAF, 2002).

A component process of the Ecological Reserve, the EcoClassification process (Kleynhans and Louw, 2008), determines the Present Ecological State (PES) (health or integrity) of various biophysical attributes of the resource compared to the natural or close to natural reference condition. The purpose of EcoClassification is to gain insights into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This process considers both the *drivers* (*e.g. hydrology*) and the *responses* (*e.g. fish*). Each of these ‘components’ has an attendant suite of methods that are used for the assessment of the state of a resource which may range from Natural to Critically Modified. The evaluation is done by comparison of the present state with the reference or

original state. All of the biophysical components are then integrated to provide a single Ecological Status or EcoStatus for the river. The EcoStatus can be defined as follows: *"the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services"* (Iversen *et al.*, 2000).

An important aspect of these documents (summarised in Kleynhans and Louw, 2008), is that they outline the importance of response monitoring in particular the monitoring of the biotic component of aquatic resources, as a valid measure of the overall state of the ecosystem. They note that it is desirable to have endpoint indicators that express this. They suggest that the endpoint of monitoring should express three dimensions:

- Physical integrity would imply habitat conditions of the water body that would sustain a balanced biological community.
- Physico-chemical integrity (referring to both chemical and physical properties of the water) would refer to water and sediments that would not be injurious to the aquatic biota.
- A composition of aquatic biota that would be balanced and resembling or approaching that of unaffected similar aquatic systems in the same ecoregion without invasive species, thus representing biological integrity.

What is pivotal about this document is that it introduces the need to integrate the different response indicators so that an overall picture of the state of the resource can be gained and represented by a single outcome. This need has arisen from those situations where one response indicator may indicate that a Resource Unit is in good condition and another in a bad condition. This does not necessarily mean that the indices are failing in their function, but rather that only certain drivers have dominated the system, and do not reflect equally in the different responses.

These documents provide guidance for generation of much of the information representing the ecosystem, that are the inputs to the determination of RQOs.

Box 1. Present Ecological State for Estuaries

The estuary health assessment determines the Present Ecological Status (PES) of an estuary using a simple scale of A to F. Estimating the health of an estuary involves (a) estimating what the estuary was like in its natural condition (the Reference condition) in terms of physical and biological characteristics and processes, (b) scoring the present condition relative to this estimated Reference state using the Estuary Health Index, which provides a score out of 100, and (c) converting the score to its Present Ecological Status category. The rationale for the method is explained in detail in Turpie *et al.* (2008) and is a step in the method used to determine the ecological water requirements of estuaries.

B. Relation of RQOs to User Requirements

The National Water Act is somewhat vague on how RQOs are to relate to User Requirements. All that is stated in the Act is that the purpose of Resource Quality Objectives is to establish clear goals relating to the quality of the relevant water resources and stipulates that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to **use** them.

The National Water Act requires that "in respect of each class of the water resource" that procedures are established "which are designed to satisfy the water quality requirements of water users as far as

is reasonably possible, without significantly altering the natural water quality characteristics of the resource" and "set out water uses for instream or land-based activities which activities must be regulated or prohibited in order to protect the water resource" (Chapter 3, Part 1). The procedure for the Classification of resources documents user requirements without actually defining their measurement.

Palmer *et al.* (2004b) noted that RQOs can be more protective than EcoSpecs if there is a particularly sensitive user need, but normally the EcoSpecs defines the level of protection. They went on to say that when a user has a more sensitive flow or water quality requirement than the ecosystem, and if the UserSpec will not impair the ecosystem's condition, then the UserSpec becomes the RQO.

The range of water uses are clearly defined in Section 21 of the NWA. These include taking water from a water resource, storing water, impeding or diverting the flow of water in a watercourse, engaging in a stream flow reduction activity, engaging in a controlled activity (irrigation, power generation, discharge of waste etc), altering the bed, banks, course or characteristics of a watercourse, removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people: and using water for recreational purposes. These users all have needs of the water resource, which vary in terms of both quality and quantity and which give rise to the development of UserSpecs.

The National Water Resources Strategy also describes users of the water resource in terms of the need to balance water requirements and water availability. It notes that "the determination of water availability must take account of the requirements of Resource Quality Objectives and the Reserve, which will be determined for each possible Management Class, water to meet international rights and obligations, a 'contingency' to meet projected future water requirements including possible transfers of water to another water management area, and water use of strategic importance, all of which are the Minister's responsibility".

The procedure for setting of RWQOs has included the determination of Water Users (from a water quality point of view) (DWAF 2006c). Section 3.3 outlines the water use requirements procedure and covers basic human needs as well as the needs of other users (note the ecosystem is not included).

The list of users is given in the Table 2 below.

Table 2. List of water users

Domestic <ul style="list-style-type: none"> • Drinking (health) • Food preparation • Bathing • Laundry 	Industry <ul style="list-style-type: none"> • Category 1 (High water quality requirement) • Category 2 (Intermediate water quality requirement) • Category 3 (At least domestic water quality requirement) • Category 4 (Low water quality requirement)
Agriculture <ul style="list-style-type: none"> • Livestock watering • Irrigation • Aquaculture 	Recreation <ul style="list-style-type: none"> • Full contact • Intermediate contact • Non-contact

It must be noted that only the major water user sectors are presented here. More detailed information may be collected on the user sector, e.g. under agriculture: irrigation - maize, tobacco, vegetables,

etc. Certain water users may have specific water quality requirements, e.g. tobacco is sensitive to elevated chloride concentrations.

Not all users have a requirement for the water resource to be in a particular condition *other* than to use the resource as a point of discharge of their waste. The National Toxicity Monitoring Programme (under development) is one strategy that is to be used to co-ordinate the potentially detrimental inputs of a broad suite of users. It plans to do this by developing a Source Classification *i.e.* “one that categorises sources of pollution according to the level of threat or risk posed by the source to the water resource” (National Toxicity monitoring programme, Record of Decision - anonymous). The approach recognises five main sectors, namely mining, industry, agriculture, settlements (urban and rural/dense) and national infrastructure (e.g. contaminated land, railway and shipping activities and natural processes). These are then classified on the basis of the risk or threat posed to water resources, *i.e.* the potential of the source to have a serious detrimental impact on the water quality of the resource. Various source management options are proposed that depend on the Class (A, B or C) assigned to each activity.

C. Involving stakeholders in the RQO process

a) Level of stakeholder involvement

The NWA (Section 13.4a) requires as a minimum that draft RQOs are published for comment in a gazette, and that the Minister consider all comments before finalising the Class and RQOs for a water resource. Meeting this minimum implies that the public are excluded from the process of setting RQOs and merely provided with an opportunity to comment on the draft RQOs. Given the value of including stakeholders in establishing water management objectives the following level of involvement is proposed.

There are generally five levels of public participation:

- i. Inform: The objective is to provide the public with balanced and objective information to enable people to understand the problem, alternatives and/or solution. This is primarily a one way process.
- ii. Consult: The objective is to obtain public feedback on analysis, alternatives and/or decisions. It involves acknowledging concerns and providing feedback on how public input has influenced the decision. This is a two way process. It provides opportunity for comment but no involvement in decision-making.
- iii. Involve: The objective is to work directly with the public throughout the process to ensure that public issues and concerns are understood and considered at every stage. This process involves more intensive involvement by stakeholders, where they are involved throughout the process to ensure that public issues are consistently understood and considered.
- iv. Collaborate: The objective is to work as a partner with the public on each aspect of the decision, including the development of alternatives and the identification of the preferred solutions.
- v. Empower: The objective is to place the final decision-making in the hands of the public (Dore *et al.*, 2010).

It is immediately clear that certain of these levels are not appropriate for the purposes of setting RQOs. For example, the NWA assigns responsibility for decision-making to the Minister and therefore the ‘Empowerment’ level of participation is not an option. Collaboration would also suggest a level of involvement that exceeds the intention of the Act because it involves ‘participatory decision-making’. The capturing of information from stakeholders is considered an important aspect of the RQOs process. The lowest level of participation *i.e.* ‘consult’ is therefore also considered

inappropriate because it provides limited options for involvement and feedback. The level of participation therefore falls between the options 'consult' and 'involve'. The level considered appropriate for the setting of RQOs is to 'consult' for the following reasons:

- It is unlikely that stakeholders will be involved at 'each stage' of the process as is the case where one 'involves'. Involvement in every step is unlikely due to the highly technical nature of certain steps and the cost associated with involving a wide range of stakeholders in a relatively lengthy process.
- There is a need to avoid stakeholder fatigue. Although stakeholders have an interest, they do not have capacity to be involved in every aspect. Furthermore, involvement of a broad range of stakeholders throughout the process is intensive and likely to be prohibitively expensive.

In view of the above, it is important to select appropriate points in the process that allow for the optimisation of stakeholder involvement with the resources. The first of these is the setting of a catchment vision to guide the process.

b) Establishing a Vision for the Resource

Unless there is a picture of the desired state of the resource, then it is impossible to set objectives to achieve this. Visioning is a process of articulating society's aspirations for the future. A vision statement must be converted into and explicitly linked with objectives that are useful at the operational level – which is where RQOs are relevant.

To some extent, the vision for a resource is expressed by the Management Class determined in the Water Resource Classification. However there is a need to expand this in order to capture the spirit of what is meant by the Management Class. The process of setting the vision is as important as the final outcome because it requires stakeholders to develop a better understanding of the needs of other users and the impacts of their use on the resource. The WRCS does not however include a visioning process. Consequently, the visioning guideline from the RWQO procedure (DWAf, 2006b) has largely been adopted for the purposes of setting RQOs.

The RWQO procedure points out that a license must reflect consensus. This is an important point which requires that stakeholders together set the vision and thus the objectives. Otherwise water resource protection and use will be disconnected from societal consensus and is therefore without context. In the same vein - water resource allocation is a social process of ongoing dialogue and the balancing of levels and types of water use, in a constant effort to achieve equitable, efficient and sustainable distribution of costs and benefits to society. License conditions, the resulting resource use patterns and the consequent state of the resource, must therefore collectively reflect the catchment the views and decisions of stakeholders. The development of a vision is the first point of direct involvement with stakeholders in the RQO process however stakeholders are also involved in various other steps in the process. The method for this involvement is detailed throughout the document with guidance provided as to the tools that can be applied to ensure the stakeholder consultation achieves the required outcomes.

D. A Procedure for the Determination and Implementation of RQOs

There is a need for an objective, unambiguous and consistent way of determining and implementing RQOs so that the eventual goal of sound management of the water resources is secured. This document attempts to provide such a procedure and should be closely followed (see Figure 6). There are however, many options available during implementation of the procedure, largely based on the availability of necessary information such as may be provided by an existing Water Resource Classification and Ecological Reserve. The procedure below provides guidance to ensure that determination of RQOs does not become immobilised by this varying availability of information.

a) A seven step process to determine RQOs

This document details the seven steps that are required to determine RQOs for a Resource Unit. Each of the steps has detailed directions, with two Excel spreadsheet tools in attendance to assist with decision-making. These two tools are:

- **Resource Unit Prioritisation Tool** – this tool assists with the selection of Resource Units which should be considered as important for monitoring. To some extent this will be influenced by the resources that are available for long-term monitoring, but those with the highest priority are clearly identified.
- **Resource Unit Evaluation Tool** – this tool guides the RQO determination through a number of decisions in order to produce a prioritised short-list of indicators that can be used for monitoring of a particular Resource Unit.

The seven step process is documented in detail later in this report and will not be discussed here, suffice to say that it forms part of a classic adaptive management cycle (see Figure 6) which would be a further three steps longer. Overall the procedure involves defining the resource, setting a vision, determining of the RQOs and Numerical Limits, gazetting these and then moving to implementation, monitoring and review before starting the process all over again. The process of adaptive management is discussed in greater detail below.

b) Levels of confidence in the RQO determination

The level of confidence in the RQO determination is an important consideration. The model presented here does not have different approaches based on the desired level of confidence in the output, as is the case with the Ecological Reserve. Instead it is the inputs to the process which will determine the level of confidence in the output.

Factors impacting on the level of confidence in the output will include:

1. The synthesis of socio-economic information that is used as the framework for the derivation of IUAs, will have an impact on the outcome. Complex and important catchment situations may require a greater level of investigation to ensure that the spatial demarcation is realistic.
2. There will be a level of confidence in the vision that is determined for the resource, even where this was done via the Water Resource Classification. The vision should reflect the consensus view of the stakeholders in the area, something which is never going to be perfect.
3. The input models (e.g. the Ecological Reserve) are determined at a particular level of confidence, and thus the data and information that they produce for use in the RQO determination may be variable. Where a Comprehensive Reserve has been carried out, then the RQOs produced will be of higher confidence. The opposite also applies.
4. The prioritisation of Resource Units and of components/indicators that are worthy of being used as RQOs for a resource, will depend on the information that is used in running the model.
5. The RQOs and their adjacent Numerical Limits may either be set stringently or with room for uncertainty – which will depend on issues such as the ecological importance and sensitivity or the importance of the users.

c) Seasonal variation in RQOs

The RQOs and attendant Numerical Limits for any Resource Unit will be subject to seasonal variation, which in some systems becomes extreme. For those perennial systems, the guidance given in the Ecological Reserve process should be followed and the corresponding EcoSpecs used, including any variations for seasonal purposes. For non-perennial systems, guidance should be taken from the Ecological Reserve documentation describing that situation (Seaman *et al.*, 2009). This may

necessitate RQOs and Numerical Limits which are entirely different for the different seasons and in some systems they will only apply when there is water in the river!

d) RQOs for rivers, wetlands, estuaries and groundwater

The model which has been developed is designed to be applicable, with minor variations, to rivers, wetlands and estuaries. The process of determining the RQOs remains constant, but the prioritisation of components and indicators will vary as different variables are of significance to rivers, wetlands and estuaries. Drivers of change in the catchments will also impact differently on these three system types. The model thus comes in three variants, for rivers, wetlands and estuaries, but these are essentially very similar. Differences are indicated in the text describing the seven steps and also in the two different Excel tools that are appended.

Groundwater is dealt with separately as not only are the Resource Units completely different to the surface water systems, so are the variables of concern. Section 3.1.4.3 of the National Water Resources Strategy (DWAF, 2004a) deals with RQOs for groundwater saying that “*Resource Quality Objectives for groundwater resources are considered crucial for the effective protection of groundwater. Numeric or descriptive statements for a groundwater resource will be set in order to guide the use and management thereof. Typically these will relate to - groundwater levels or gradients (time and locality specific); groundwater abstraction rates; groundwater quality; spring flow; and targets for the health of terrestrial ecosystems that are dependent on groundwater*”.

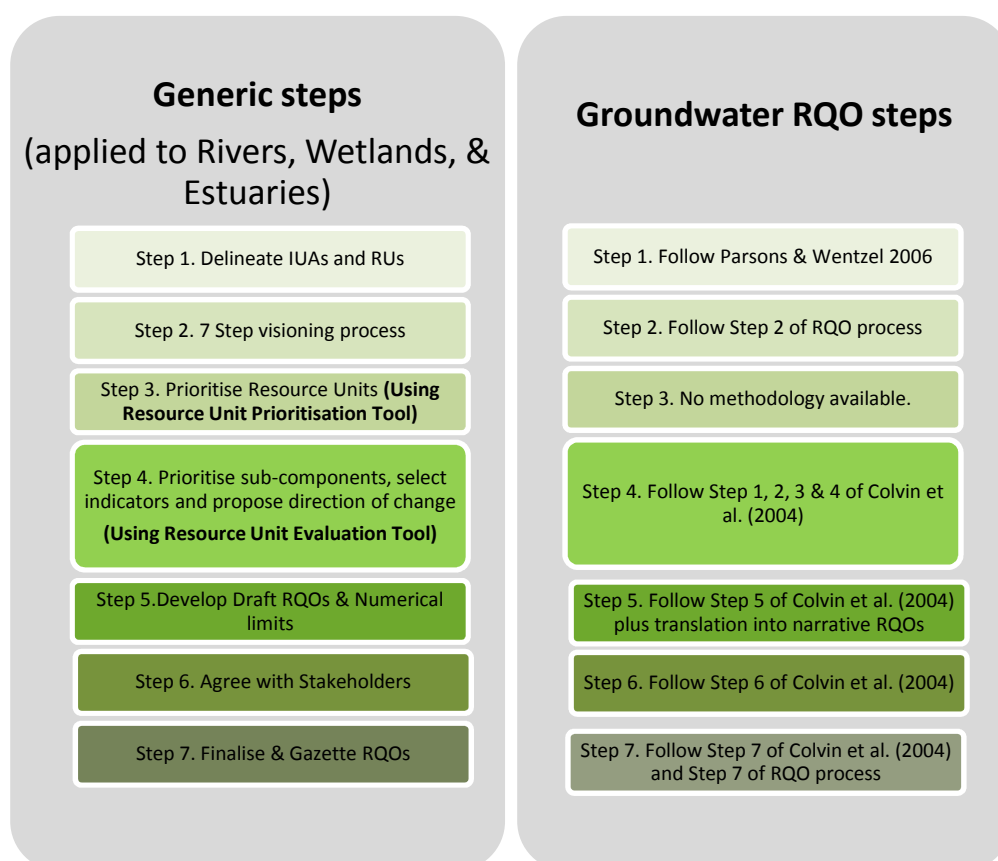


Figure 2. Diagram to illustrate the alignment between the RQO determination process to be followed for rivers, wetlands and estuaries, with that of groundwater.

Two systems for undertaking RQO determination for groundwater resources already exists (Colvin *et al.*, 2004; Parsons and Wentzel, 2006). These processes have been aligned to this generic RQO procedure as indicated in Figure 2. The most important change introduced by this procedure takes place in Step 5 and relates to the description of RQOs as narrative and with attendant Numerical Limits. This will naturally have an impact on Steps 6 and 7.

e) Alignment between the WRCS and the RQO procedure

As indicated earlier, the proper place for the determination of RQOs is in response to the Water Resource Classification and the resulting Management Class following the implementation of the WRCS. Where this is done, then several steps in the RQO process become redundant as they are already done by Water Resource Classification. These steps are indicated in Table 3 and are also highlighted in each of the steps in the procedure to follow.

There will however be situations where the WRCS has not been implemented. The National Water Act indicates that it is acceptable to determine *preliminary* RQOs which will be the situation where the Water Resource Classification has not been done. The RQO procedure which follows thus makes allowance for this by introducing steps which correspond to some of the WRCS steps. In the absence of the Water Resource Classification, what is clearly missing is the Management Class which is the main output of the intense and detailed Water Resource Classification procedure. This has been replaced by a Visioning process which achieves a similar outcome but with less confidence. Its advantage is that a vision can be derived in a short space of time with less information. The Visioning process embraces stakeholders in order to determine the vision for the resource, against which the RQOs can then be determined.

Table 3. Illustration of the relationship between the WRCS and the RQO determination processes. Those steps in *italics* indicate where the information may be carried over directly from the Water Resource Classification into the RQO procedure.

Water Resource Classification System		RQO Procedure	
1	<i>Delineate the Integrated Units of Analysis</i>	1	<i>Delineate the Integrated Units of Analysis and Resource Units</i>
		2	Establish the catchment vision (the Management Class is used here) and key elements for each IUA
2	Link the value and condition of the water resources	3	Prioritise Resource Units using Tool
3	Quantify the EWR and changes in non-water quality EGSA's		
4	Determine the ESBC and establish starter configuration scenarios		
5	Evaluate the scenarios within the IWRM process		

		4	Prioritise sub-components, select indicators and propose direction of change using Tool
		5	Develop draft RQOs and Numerical Limits
6	Evaluate the scenarios with stakeholders	6	Agree Resource Units, RQOs and Numerical Limits with stakeholders
7	Gazette the Class configuration	7	Finalise and Gazette RQOs

E. Principle Characteristics of RQOs

According to the National Water Resources Strategy (DWAF, 2004a) “RQOs may include chemical and physico-chemical, biological and hydro-geomorphological attributes. Social and economic considerations will be included in the Water Resource Classification to ensure a decision that provides a balance between protection and utilisation. Each Management Class will allow for a range of values for each parameter as well as for different resource types. The boundaries between Classes will be determined in the Water Resource Classification and represent points selected along a continuum of change. For certain resources, water use requirements (for agriculture, for instance) may require stricter standards than those required for ecological protection, and these standards will be captured in the Resource Quality Objectives for that water resource”.

The RDM Integrated Manual (DWAF, 1999) suggested that RQOs are set on the basis of acceptable risk, that is, the less risk we are prepared to accept of damaging the Resource Base and possibly losing the services provided by the water resource, the more stringent should be the objectives. The level of risk is thus associated with the value or importance given to a resource. But, it stresses that this should be accepted by all stakeholders, including impactors and water users, who should have a clear and common understanding of the possible long term consequences. This provides a nationally consistent basis for deciding on the acceptability of impacts while at the same time allowing natural site-specific differences to be taken into account.

The risk of irreversible damage to an aquatic ecosystem relates to the overall integrated risk due to stresses on the ecosystem arising from changes in the driving factors or stressors. The Resource Quality Objectives which are then set with the intention of maintaining the level of risk/protection associated with an assigned Class must have three characteristics:

- They must be set in an integrated way, allowing for the combined and inter-dependent effects of the stressors;
- They must allow for the high variability in natural hydrological, chemical and biological conditions which is observed within South Africa;
- They must be implementable, measurable and verifiable.

One of the RWQO documents provides a useful set of Guiding Principles for setting of RWQOs (DWAF, 2006c) which should also apply to the setting of RQOs. They provide the following useful insight:

The determination of RWQOs is underpinned by the principle of sustainable development and was informed by the principles which formed the foundation for the following instruments:

- The Precautionary Principle (DEAT, 1997),
- The default rule described in the Resource Directed Measures documentation (DWAF, 1999),
- The National Water Resource Strategy (DWAF, 2004a), and
- Environmental rights as described in the South African Constitution (Act No. 108 of 1996)

The implications of these principles highlighted in this report (DWAF, 2006c) are that:

- The Department may not accept a deterioration in water quality from the present state, at least when determining RWQOs using a low confidence method, which due to the low level of confidence in the approach, by default adopts the Precautionary Principle,
- In areas of deteriorated water quality, the quality should be improved from an Ecological Category of an 'E/F' to an ecological category of 'D' and the Management Class of 'Heavily used/Impacted' (as a minimum). A 'D' category is considered the minimum sustainable Ecological Category,
- The default rule for other users is that the minimum desired category should be 'Tolerable', and
- RWQOs should be determined to that of meeting the Ecological and Basic Human Need Reserve (or better).

The UNDP have provided useful guidance on the selection of indicators as is required in the management of RQOs (Cap-Net, 2008). This guidance is reflected below:

Definition of an indicator – *the representation of the trend tracking the measureable change in a system over time.* Generally an indicator focuses on a small, manageable set of information that gives a sense of the bigger picture. From this it can be seen that there is no need to measure everything and the choice of indicator is important as to whether it gives sufficient 'sense of the bigger picture'.

Criteria for indicators:

1. Simple, easily measured, understood and applied
 - a. The data used for indicators should be in a format that is easy to use, can be measured using standard techniques, explained using established principles, and easily used for analytical purposes. The more complex the indicator the less useful it will be. The data collected should be reliable and collected using standard, defensible methods.
2. As few as necessary
 - a. The capacity to measure and report is usually limited by financial and human resources, especially in developing countries. Being burdened with an excessive number of indicators may mean that the system fails to achieve the expected benefits or does not work at all.
 - b. Indicators reduce the number of measurements and parameters that normally would be required to give an exact description of a situation. As a consequence, the number of indicators and the level of detail contained in the indicator set need to be limited. A set with a large number of indicators will tend to clutter the overview it is meant to provide.
3. Using existing information where possible
 - a. It is preferable that the information needed to measure an indicator is available through existing data sources and monitoring programs or that data collection can occur through existing programs. This will improve the cost effectiveness of the system.
4. Relate at the appropriate scale
 - a. An indicator should relate to the specific situation it is 'indicating' information about. The indicator should be measurable at an appropriate scale, both temporarily and spatially. For example, if a monthly time step has been chosen as the temporal scale for assessing water quantity, then all the indicators chosen for this parameter, be they base flow, stream flow, etc. should have data that are available on the same temporal scale or another indicator

considered. Similarly at the spatial level if data are expected to represent the river basin then the indicator information has to be collected at that level.

5. Detect change

- a. The indicator should be able to detect change and thus be useful for identifying progress with a management objective or performance of a system or the River Bain Organisation. If the indicator does not reflect changes because it was poorly selected or the situation has changed then another indicator should be identified.

6. Comparable, repeatable and defensible between sites and times

- a. IWRM is implemented using a set of common principles and the progress and performance of IWRM implementation is best measured using indicators that are comparable between river basins and even between countries. This will improve transboundary water resource management as well as national measures of progress with water sector reform.

Cap-Net (2008) and Walmsley *et al.* (2001).

Additional criteria for the selection of RQOs could also include:

- RQOs need to include, where appropriate, the quantity of water, quality of water, habitat and biota.
- They need to reflect the requirements of the ecosystem as well as of users.
- RQOs may be narrative or numerical statements. In keeping with the setting of objectives from countries around the world, at a high level these are usually narrative descriptions of the objective state of the resource, which may then be described by the use of quantitative numeric limits.
- The present and future characteristics of the water resource where the RQOs are being determined need to be considered.
- RQOs need to consider seasonal and annual variability.
- The RQO must be implementable when it is taken into resource management, *i.e.* the method should be cost effective and it should not require a high level of skill for monitoring.
- They must be meaningful in terms of the objectives of the Act which are about Resource Protection through the means of ecosystem protection, and should also provide protection for water users.
- There needs to be a balance between the ecological importance and sensitivity of the resource (which includes biodiversity, rarity, uniqueness and fragility, from habitat, species and community perspectives), the intrinsic ecological value of the resource and its importance to the functioning of neighbouring ecosystems and the importance of the resource for human use.
- There may be a tradeoff between the requirements of one user (or the ecosystem) and another. Depending on importance and risk, this may not favour the most sensitive user.
- Driver and Response indicators may both be appropriate. Indicators of drivers are useful as management are only in control of drivers, but response indicators give a better indication of achievement of goals, so both may be included in RQOs.
- RQOs may be set for temporary rivers, but naturally when a river has no water, then the RQOs that were set for the flowing condition cannot apply. Such variability should be indicated in the setting of the RQOs which should be season specific. In this instance, RQOs may also be set for conditions where a river has no water. Even under these conditions, the

quality aspects of the biota and habitat still require protection as informed by the Class of the resource.

- It should be acknowledged that the interactions between the stressors themselves and the responses of the biota to these stressors are complex and also subject to a degree of inherent uncertainty (as most ecological processes are). The system should make allowance for this uncertainty through two main approaches:
- RQOs are generally set as narratives and so are less subject to this uncertainty:
- A process of Adaptive Management needs to be implemented, where there is potential to adapt quantitative values as understanding improves.
- RQOs need to be site-specific since a numerical objective which provides a certain level of protection in one region of the Country may not provide that same level of protection in another region where the ecosystem conditions are quite different. Also, reference conditions may differ from region to region. Reference conditions provide the upper limit for the setting of Numerical Limits. No RQO may be set at a level better than those that are defined by reference conditions.
- The EcoClassification procedure (Kleynhans & Louw, 2008) proposes a number of layers of information that can be used, starting with independent variable endpoints for monitoring (e.g. habitat indices, hydrology), followed by indications of catchment stress (e.g. land use changes) and then dependent variables and biotic assessment endpoints.
- The biological responses in an aquatic ecosystem are determined through linkages of drivers to processes and to habitat effects. The essence of this interpretation is that the direct assessment of the biological response (e.g., using a biological indicator) identifies where ecosystem functions have been impaired, and may suggest causes of impairment (Beechie *et al.*, 2003). There is merit in utilising any or all of these levels for the determination of RQOs as each level offers useful information. But, where resources are limited, there is a strong motivation to target response indicators.
- Jooste and Rossouw (2002) reasoned that maintaining ecosystem integrity, with the reference as the standard, was the best that we could do to ensure the continued supply of goods and services. This measurement of integrity can be of both biotic and abiotic descriptors but they acknowledge that the response of the environment to water quality stressors and the resulting biotic species is a complex issue that is not well understood. They do nominate species as the suitable end point however, and provide some information on how species would be used for interpreting the end point of this investigation. For chemical substances, the Ecological Reserve end point may be population survival.

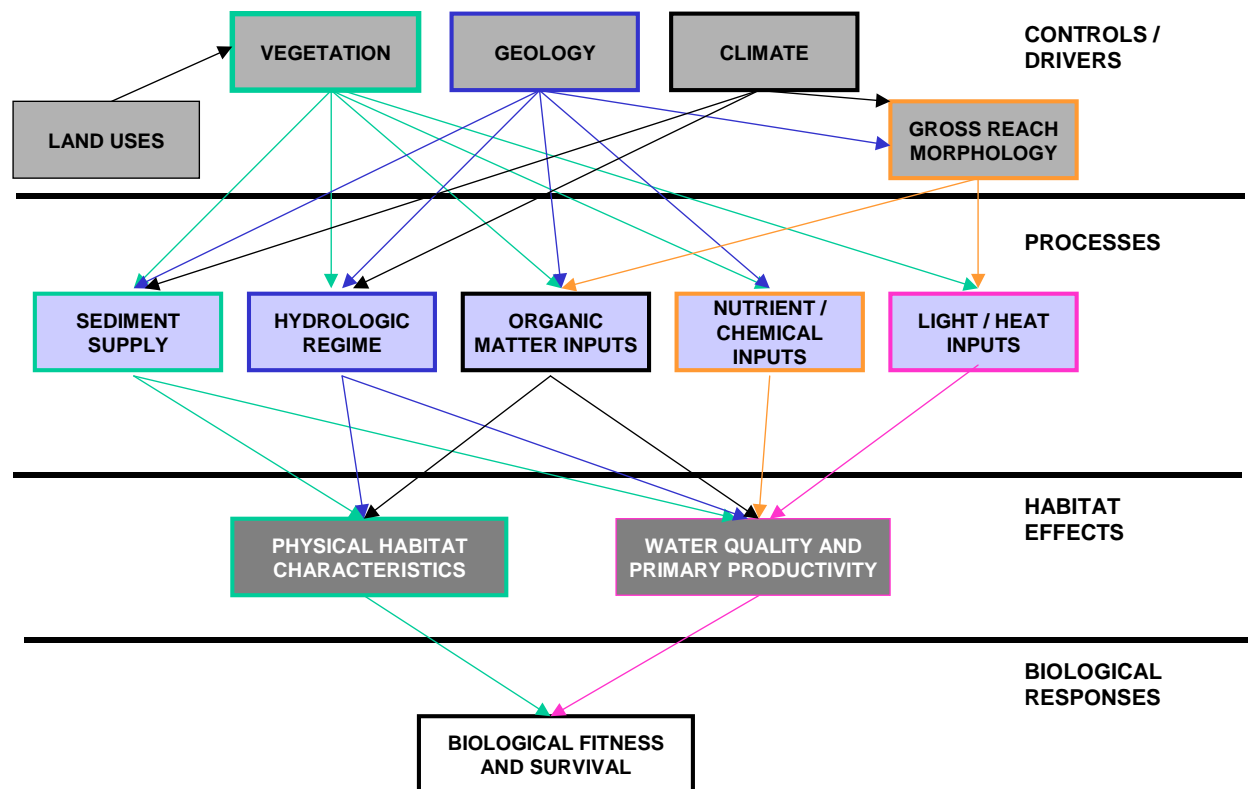


Figure 3. Schematic diagram of relationships between drivers of catchment processes, effects on habitat conditions, and aquatic biota survival and fitness (adapted by Kleynhans & Louw, 2008, from Beechie and Bolton 1999).

Criteria for RQOs – land-based activities and other characteristics

The National Water Act (1998) states that RQOs can be comprised of criteria that represent the ecosystem, in particular the quantity, quality, habitat and biota. But it also states that land-based activities and any other characteristics may be incorporated. By including these ‘not so obvious’ criteria, the Act is seeking to ensure that the water resource is not negatively impacted by activities that may take place on the land and indeed by any other undescribed activities.

The Department of Water Affairs has adopted this responsibility by influencing several land-based activities with a view to protecting water resource quality. For example, DWA have been heavily involved in the allocation of permits for afforestation, because it is known that forestry uses significant amounts of the water resource before it even reaches the river. They have also been involved in the regulation of industrial activities particularly where these activities may have an impact on the water quality. The procedure for the determination and management of RQOs takes the approach that it is the impact on the water resource which is the final arbiter of whether the land-based activity is having an impact or not and it is the actual impact on the water resource which needs to be regulated as an objective. Where such an impact is recorded, then DWA has the responsibility to influence the land-based activity to either reduce or eliminate this impact. But, if there is no impact, then such responsibility is void. The detail of what is implemented on the land thus remains the responsibility of land based operatives as well as other government departments, until such time that this infringes on the water resource.

In order to follow through with the implementation of the above provisions of the Act, the procedure to determine RQOs takes cognisance of land-based activities and anticipates the impacts that these activities may have on the water resource. For example, if there is a metal-plating industry in a

catchment, then it is likely that RQOs will be set that include the monitoring of heavy metal pollution in the water resource. In turn, this will influence the setting of discharge licenses to discharge the heavy metal to the environment. By exercising control at this point, DWA is effectively implementing a control on the industrial process to ensure that the water resource is not contaminated. This approach is indeed followed, and in Step 4 the models consider a variety of land based activities which may impact the water resource which in turn informs those sub-components which should be selected for RQO determination.

The Water Act in Section 13(3) also notes that “any other characteristic” of the water resource may also form part of the RQOs. This part of the Act opens the possibility that any other characteristic of the water resource, as yet unanticipated or undefined, may also form an objective for the management of the resource. The procedure for the determination of RQOs makes allowance for these “other characteristics” as they could be recorded under the column for the most closely related sub-component and then carried through the model where an appropriate indicator could be identified and an RQO set.

Box 2. Sensitivity and importance of estuaries

Sensitivity versus Importance in estuaries

In rivers importance and sensitivity often equate to each other, however estuaries that have average to low biodiversity importance can be extremely sensitive to flow reduction. More than 70% of South Africa's estuaries close periodically to the sea. These medium to small systems rely on river runoff to keep their mouths open, thus they are highly sensitive to reductions in runoff. However these estuaries support less species due to their smaller size and have a lower biodiversity importance score compared to permanently open estuaries.

Estuary Importance Index

Estuary Importance scores are available for all South African estuaries (Turpie et al., 2002; Turpie and Clark, 2007). The score reflects the importance of an estuary to the maintenance of biological and ecological diversity and functioning on a national scale. Factors taken into account in the importance index are: Size, Rarity of Estuary Type with regard to Geographic Position, Habitat Diversity and Biodiversity Importance. The importance score together with the present ecological status is used to assign the recommended ecological category to an estuary.

F. Formatting of RQOs

The procedure followed in this document introduces the concept of RQOs together with Numerical Limits that give detailed description of those RQOs.

RQOs – these are essentially narrative and qualitative but sometimes broadly quantitative statements that describe the overall objectives for the catchment, IUA or Resource Unit. For example, an RQO for a river may state *“the water quality from this Resource must be acceptable for irrigation of crops”*. In addition, the RQOs may say that *“the endemic yellowfish in this river should be maintained as a viable population to support the ecosystem and also for recreational angling”*. These RQOs are aligned with the Vision for the resource, and because they are essentially narrative, are less subject to change as the understanding of the ecosystem changes. Because they are descriptive, and generally easy to understand, they are also meaningful to stakeholders, as well as the responsible managers, and give direction for whatever action is

necessary to achieve the vision for the resource. These RQOs are gazetted and are thus supported by law.

Numerical Limits – these are the generally quantitative descriptors of the different components of the resource such as the water quantity, quality, habitat and biota (but may also include other characteristics). These descriptors give a quantitative measure of the RQOs that can be used for monitoring e.g. following the examples given above, the RQO numeric limits for water suitable for irrigation may include the concentration of dissolved solids at $x \text{ mg l}^{-1}$, and for the yellowfish may include that “*there should be 20 fish >300mm in length collected in a two hour collection effort using an electro-fishing apparatus*”. However, because there is a high uncertainty in the scientific information that says that a particular concentration of dissolved solids is suitable for irrigation at a level suitable for the users of that water, and also that 20 fish is indeed the correct number to quantify the narrative RQO (*i.e.* to maintain a viable population and support recreational angling), these numeric limits are NOT gazetted and thus may be more easily changed if found to be inaccurate. This process of changing the numeric limits should not be taken lightly and needs to follow the guidelines given in this document. At the end of the day, the limits will still need to be able to demonstrate that the vision and the RQO is being achieved, and thus need to be maintained with absolute integrity.

Because the Numerical Limits are responding to RQOs which are intentionally descriptive and qualitative, it does not mean that a wide range of limits needs to be accommodated within the RQOs. However there is a need for the Numerical Limits to be more quantitative, in a similar way to EcoSpecs. The relationship between these quantitative and qualitative aspects of RQOs is illustrated in Figure 4, showing how there is a change from a qualitative description, through a more quantitative measure and back to a qualitative perspective

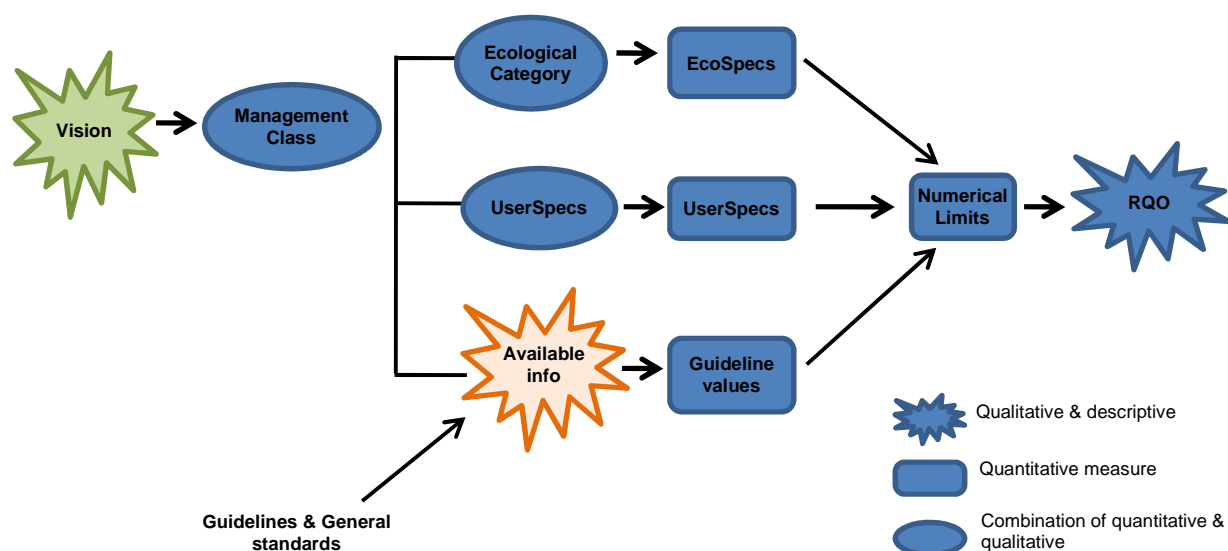


Figure 4. Quantitative and qualitative steps followed during RQO determination and implementation

Box 3. What RQOs are NOT!!!

It is important to appreciate that the RQO procedure is NOT a “catch-all” for resource management, but it has certain limitations. These include:

1. RQOs are not determined for an individual user, but for a Resource Unit as a whole. As such, they cannot be part of a license issued to a particular user.
2. RQOs do not replace the need for other monitoring programmes. Programmes such as the water quality, microbial, eutrophication, aquatic ecosystems health etc all have objectives which are different to the setting of RQOs. These programmes should continue following their own objectives.
3. RQOs do not include every resource quality variable of interest, but only those which are determined necessary to ensure the overall protection of the resource.
4. RQO Numerical Limits should not be considered as absolute “truths”. It needs to be acknowledged that they are the product of imperfect science trying to quantify an uncertain and variable environment.

G. Monitoring of RQOs

In general the monitoring of RQOs will need to be designed for the catchment being managed, yet it is possible to provide basic guidelines. A useful reference to the principles of monitoring design that are appropriate for the local RQO monitoring programme is DWAF (2004b). This report suggests that the following steps be followed (see Table 4). These have been considered alongside the RQO process to identify the specific needs of RQO monitoring.

Table 4. Monitoring of RQOs (Adapted from DWAF (2004b))

Step in monitoring Described in DWAF (2004b)		Application to RQO monitoring
Phase 1 Step 1	Identify primary users of the information	In the case of RQOs, this will be water resource managers within DWA and CMAs.
Phase 1 Step 2	Identify the information products required by the primary information users	This will be available as the gazetted RQO with the attendant Numerical Limits for the Resource Unit. It is important to appreciate that while the RQOs are generally narrative, the Numerical Limits are quantitative and are the object of the monitoring programme.
Phase 1 Step 3	Design the information generation protocols	Much of this is encapsulated in gazetted RQOs.
Phase 2 Design the monitoring network	Select and finalise the water resource quality attributes to be included in the monitoring programme	This process has been done in the Resource Unit Evaluation Tool. Some of the selected indicators may be unique and will require development of a monitoring procedure. Note that the RQOs and Numerical Limits do not always prescribe the specific method but rather the indicator itself. For example, phosphorus may be an indicator, but the actual chemical analytical method will not be prescribed. Suffice to say that where possible the methods used should be rigorous and should meet the appropriate quality assurance

		standards.
	Selecting the data acquisition (sampling) sites	<p>While the Resources Units have been prioritised, specific sites remain to be selected. These should be selected with the following guidelines:</p> <ol style="list-style-type: none"> 1. they should be at or near the outlet of the RU 2. if possible, they should be the same as sites from other monitoring programmes in particular the Ecological Reserve. Where there is conflict, this should be resolved in the most efficient manner. 3. sites should be suitable for the sub-components that are being monitored. 4. sites should be accessible
	Frequency of data acquisition (sampling frequency)	<p>This will vary for the different sub-components being monitored and could range from weekly/monthly to only every five years. Guidance in this should come from the monitoring procedures themselves and/or from the Ecological Reserve process. Note that there will be situations where less frequent but more intensive monitoring would provide better information. Trade-offs between these two will be necessary.</p>
Phase 3 Design the operational requirements for the programme	Information generation and dissemination	<p>What needs to be done, by whom and by when.</p> <p>This will be case specific.</p>
	Data management and storage	<p>Data collected especially for management of RQOs (data and information including Numerical Limits) will need to be filed in a central repository within DWA. This will need the appropriate institutional support.</p> <p>Data collected by other monitoring programmes needs to be accessed on a routine basis. All data required for management of RQOs will need to be collated together to allow interpretation of the RQOs.</p>
	Data acquisition	<p>This step will require that the data is collected in the field in a reliable way, at the right time and at the right frequency. This will need to be determined on a case specific basis. A key aspect here will be acknowledging which sub-components or variables are already being sampled by other monitoring programmes. There will need to be synchronisation of these efforts.</p>

There is more detailed guidance on the monitoring and auditing of RWQOs available in Department of Water Affairs and Forestry (DWAf, 2006e).

Box 4. Monitoring guidelines for estuaries

Monitoring guidelines are available in the following reports:

Taljaard, S., Van Niekerk, L., Huizinga, P. and Joubert, W. (2003) Resource Monitoring Procedures for Estuaries. For application in the Ecological Reserve Determination and Implementation Process. Water Research Commission Report No.1308/1/03. Pretoria.

McGwynne, L. and Adams, JB. (2004) Protocols contributing to the management of estuaries in South Africa, with a particular emphasis on the Eastern Cape province. Volume II, Report E, A Monitoring Protocol for South African estuaries. Water Research Commission Report No. TT 237/04.

H. RQOs in the Management of the Water Resource

Once RQOs have been determined and are installed within the system as objectives for the management of water resources, there are a number of considerations that need to be taken into account.

It was stated in DWAf (2006e) that *“RQOs and RWQO are the most important management objectives against which monitoring data will be assessed. This will indicate whether the Management Class is being maintained. In general, RQOs will be the most important sustainability indicators for water resource management”*. This report goes on to stress that RQOs nevertheless CANNOT provide all of the information needed for management of water resources. They cannot provide any information on what management actions are required to achieve the RQOs, information which is provided in other procedures. As they state, managers will need more holistic information than just resource quality to properly manage

- the resource
- those impacting on the resource
- those impacted by the resource.

This cannot be stressed enough! The function of RQOs is simply to provide limits or boundaries from which it can be deduced whether the resource is being stressed by existing management practices or not. They do not provide detailed information on causal linkages between particular users and ecological responses or the many other issues that require monitoring in order to understand the situation in the water resource. Such information comes from the variety of other monitoring programmes that are conducted each of which has its own very different objectives.

According to Volume 1 of the WRCS (DWAf, 2007), the following provisions of the Act (amongst others) are of significance to the WRCS and thus implementation of RQOs:

1. The WRCS is the platform for the Resource Directed Measures to ensure resource protection and effective management, including the Reserve and RQOs.
2. The NWRS must give effect to the Class in terms of the Reserve and Water Quality Objectives. CMSs (Catchment Management Strategies) must take account of (and give effect to) the Class of the water resources in the Water Management Area (WMA), particularly in terms of the water allocation plan.
3. Any water use licenses or general authorisations issued or allowed under the Act must take account of the Class. Regulations on water use may differentiate between different Classes of

water use. An existing water user who has applied for a license may be restricted without compensation to provide for the Reserve.

4. The pricing strategy for water use charges may differentiate between Classes, while the Minister must consider the Class in setting the pricing strategy.

The same document goes on to say that in order to implement the Act, DWA makes use of seven types of strategies/regulatory activities:

1. CMSs.
2. NWRS.
3. Allocation plans.
4. Resource Directed Measures (RDM) – defining the desired level of protection for a water resource, and on that basis, setting the Reserve as well as clear numerical or narrative goals of the resource (the RQOs). These measures focus on the quality of the resource itself.
5. Source Directed Controls (SDCs) – controlling impacts on the water resource through the use of regulatory measures such as registration, permits, directives and prosecution, and economic incentives such as levies and fees, in order to ensure that RQOs are met. These measures contribute to defining the limits and constraints that should be imposed on the use of water resources to achieve the desired level of protection.
6. Managing demands on water resources to keep utilisation within the limits for protection; including water conservation and demand management.
7. Monitoring the status of the Country's water resources to ensure the RQOs are being met, and to enable the modification of programmes for resource management and impact control as and when necessary.

The National Water Resources Strategy (DWAF, 2004a) notes that *“the output from the compulsory licensing process will, in most cases, be the publication for comment of a proposed allocation schedule, representing the preferred reconciliation solution, the associated management Class(es), the Reserve(s) and Resource Quality Objectives for the resource, and a proposed catchment management strategy”*.

It is important that those responsible for water resources management have strategies and action plans to manage water resources and are guided by the RQOs. For example the use of RQOs needs to be part of Catchment Management Strategies, Water Use management, *etc.* as guided by the Department of Water Affairs (DWAF, 2006f). For example, in relation to water quality issues, a water quality allocation plan should allocate the Source Management Objective (SMO) load reductions to priority sectors in the catchment, and these must be based on the RQOs.

1. Management using RQOs

The setting of RQOs is intimately related to the management of the water resources through the implementation of Source Directed Controls (SDC) (see Figure 5). RDM (including RQOs) provide descriptive and quantitative goals for the state of the resource, while SDC specify the criteria for controlling impacts such as waste discharge licenses and abstraction licenses. As illustrated in Figure 5, a variety of sources could be impacting on a single resource, which is monitored by only a single set of RQOs.

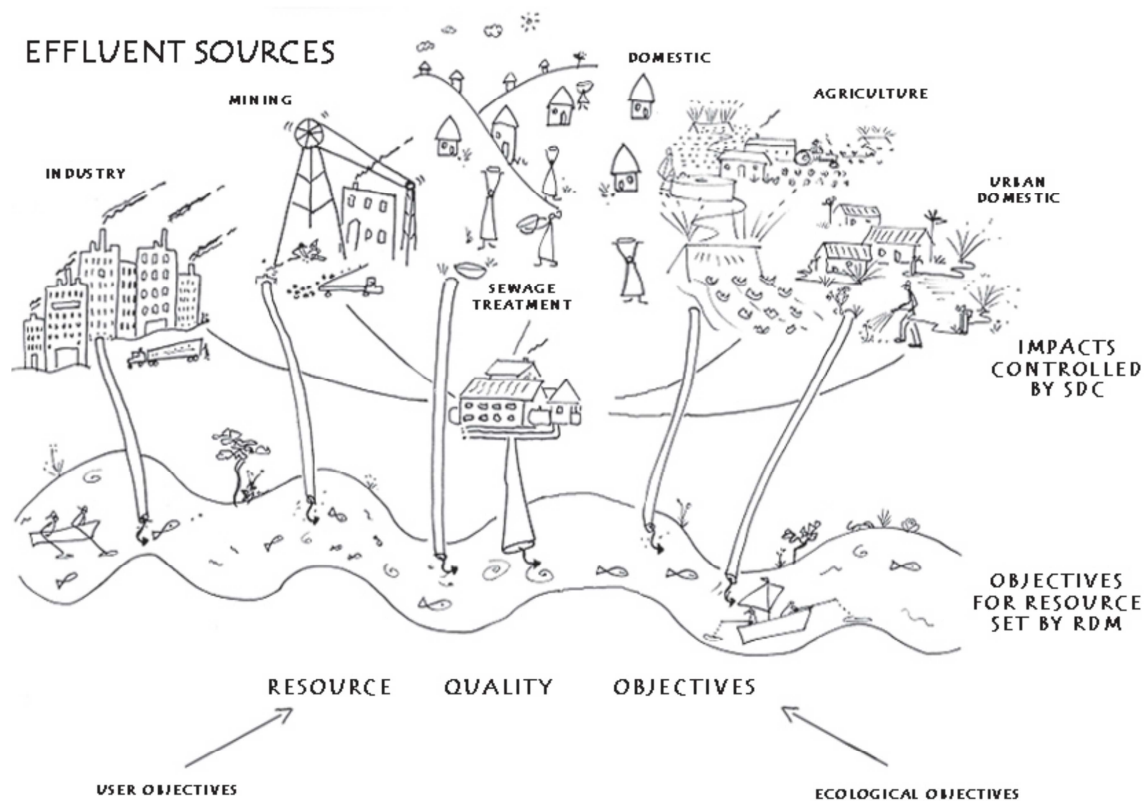


Figure 5. The relation between RQOs and Source Directed Controls (from Palmer *et al.*, 2004a)

Note that no single user can be responsible for the achievement of RQOs in a Resource Unit. This responsibility lies with the local water resource authority (DWA or CMA) who needs to allocate the privilege to stress the system between the various users in the Resource Unit, so that their combined impact results in the achievement of the RQOs. For this reason, it needs to be acknowledged that RQOs can never form a part of a license for a single user.

2. Adaptive Management

The Department of Water Affairs' policy (DWAf, 2006a) embraces the concept of adaptive management and learning by doing – in particular the RDM Policy for Water Quality which states that “the Department subscribes to a cyclical adaptive management approach often categorised as *plan, implement, check and review*”. Section 1.3.5 on Adaptive Management gives a short description stating that the Government has an imperative to deliver and that sometimes there is insufficient information, so adaptive management becomes necessary by bringing in flexibility that allows for change when circumstances demand this. In the spirit of this the Department will use “*pragmatic instruments and guidelines (typically associated with low confidence) as the basis for decision-making in the interim transition phase. The objective is to avoid unnecessary delays in decision-making. These instruments will be progressively replaced with more accurate instruments when the demand arises. When using approximate methods of calculation as the basis for decision-making, the Department will acknowledge the unknown underlying assumptions, and use independent sources of information or methods (multiple lines of evidence) whenever this is feasible and cost effective*”. The same document stresses the importance of monitoring including the monitoring of RQOs. It states that monitoring objectives must be reviewed regularly, after not more than five years, which is the start at simple adaptive management.

The adoption of Adaptive Management practice is appropriate based on the fact that the science that provides the data and information used for water resource management is imperfect. In the context of RQOs, this means that the science that gives support to the numerical description of any RQOs may be misguided and that unless there is a continuous learning process, the resource and the society making use of the resource, could be severely disadvantaged.

Adaptive Management is defined basically as 'learning by doing', suggesting that management should be on a continual learning cycle, learning from their mistakes and rectifying these mistakes. Yet, Adaptive Management has progressed far beyond this simplistic view, trying to penetrate the reasons that management so often fails in its attempts to manage the environment by being rigid and prescriptive. If taken seriously, Adaptive Management has significant implications for policy and management. According to Pahl-Worstl (2007), a systematic approach to learning under conditions of high uncertainty *should be perceived as the guiding paradigm for the design of adaptive policy processes*. This type of mind-set in managers is required if they are going to be able to embrace adaptive management and by so doing, manage the natural resource.

In terms of the setting and management of RQOs following the Adaptive Management approach, RQOs should always be seen as 'first generation' RQOs, which will be subject to scrutiny as implementation progresses and will be changed if found not to be aligned with the vision for the resource.

In many respects Adaptive Management seems to state the obvious and there are perceptions that this is 'business as usual'. Yet a look at the state of the environment and of society as a whole is ample enough evidence that the obvious and traditional ways of doing things in the past have not succeeded in preventing a decline. Allen (2007) points to the problem saying that there is a strong desire to manage complexity and uncertainty (*i.e.* the natural environment) through reduction and simplification. She notes that there is a strong tendency for adaptive management to slide towards conventional management which is understandable given the constraints on managers' *e.g.* strong expectations on managers, long history of rational planning, and reliance on scientific expertise. These expectations include that problems can be clearly defined and that responses can be equally clearly articulated to allow targets and milestones to be set. Short time frames, rigid targets and focus on success prompt managers to continue with conventional, reductionist and controlled management approaches even when encouraged by government rhetoric to manage more adaptively. Allen points out that the fear of failure prevents more adaptive approaches from being developed. For this reason, a new generation of water resource managers will need courage to do what is right for the right reasons.

Box 5. Adaptive management

Adaptive Management (Walters and Holling, 1990) is an approach to natural resource and ecosystem management that acknowledges the uncertainty and complexity inherent in natural systems and which limits our knowledge and understanding of ecosystem functioning. Adaptive management offers a means of dealing with this uncertainty by incorporating research into conservation action. Specifically, it is the integration of design, management, and monitoring to *systematically test assumptions in order to adapt and learn*.

According to Pahl-Worstl (2007) adaptive management is *"a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies"*.

3. Compliance with RQOs

Remembering that RQOs do not apply to a single user of the water resource and do not form part of a license condition, but rather aggregate the objectives for an entire Resource Unit, it would be unreasonable to expect 100% compliance with the numerical scale of the objectives on the part of the water resources manager (DWA or CMA). 'Exceedance' of RQOs should thus not be seen as a punitive issue or as a failure of a Key Performance Area for the manager, as this would encourage inappropriate activities such as undue influence on the setting of the RQOs, failure to monitor, passing the blame, *etc.* Rather, effective management in terms of RQOs should be seen as moving in the direction of the RQOs. For example, in a severely degraded catchment, RQOs could be set which are presently unachievable. Compliance with these Objectives would mean that the manager can demonstrate that the direction of change is towards these objectives. Such change may be protracted, as can be expected where licenses have been issued that last for several years, but nevertheless, the manager needs to be as creative as possible to ensure that the quality of the resource is moving towards the objectives.

Compliance with RQOs would be achieved when the resource is equal to or in a "better" condition than indicated by the RQOs or Numerical Limits, or when there is evidence that the resource quality is moving towards the objective and not away from it.

As indicated above, achievement of RQOs should be considered positive if the direction of change over time is towards the objective and not away from it. Provided that the direction is positive, then lack of having actually attained the RQOs should not be considered as a failure.

There will be situations where the RQOs that have been set are persistently not achieved for a site. The National Water Resources Strategy (DWAF, 2004a) in Section 3.1.2.1 notes that in "*some cases the present levels of resource use (existing lawful use) may fail to comply with the Resource Quality Objectives. These situations will need to be addressed progressively, over realistic periods of time, to allow users to adjust their activities, by attaching appropriate conditions of use to licenses. Regular monitoring will be required to assess changes in the condition of the resource, and to determine the extent to which Resource Quality Objectives are being achieved. Successful resource rehabilitation will therefore require the application of source-directed controls, embodied in licenses as conditions of use, that are guided by the Resource Quality Objectives derived from the determination of resource-directed measures*". For example, resource sediments may act as a source of pollutants when the equilibrium of a parameter between the dissolved state and the sediment shift towards dissolution of the sediment. Thus even with efficient effluent management it will still be difficult to realise the achievement of RQOs. It is therefore clear that non-achievement of RQOs does not suggest that the RQOs need to be changed, but rather that there needs to be improved management of the sources of impact. Yes it may on occasion be appropriate to alter the RQOs, but only through a stakeholder consultation process as stakeholders would have to accept that the vision that had previously been agreed to is being changed. This would need to be part of a conscious adaptive management strategy.

In the event that there is a change in direction away from the RQOs, then it indicates that the measures in place to protect the water resource are not sufficient to bring the resource into alignment with the objectives, or alternately that the RQOs are not reasonable. It is important that urgent consideration be given to understanding which of these two are at play and that appropriate measures are instituted to better the situation.

4. Practical issues in the management of RQOs

A water resources manager now has the responsibility of managing activities in a catchment or Resource Unit in a way that their combined impacts do not exceed the measures described by the RQOs. This will be dependent on the characteristics of a site/catchment, as the nature of the stressors and of the aquatic resource will vary. There are however a number of pointers that may be considered.

a. Institutional issues

It is important that a formal structure within DWA and its allied institutions be established for the purpose of management of RQOs. While this is beyond the mandate of this procedure, it is useful to consider a number of principles on which this structure should be based:

1. Given that this procedure includes the adoption of a vision for the resource, it is important that institutional involvement is at a high level to ensure that the mandate of DWA is exercised. This would suggest that ultimate responsibility for RQO management should rest at Head Office.
2. A suitable location within Head Office needs to be established and full responsibility for the implementation of RQOs given to that office. These persons would be required to direct the determination of RQOs, be responsible for the review and custodianship of a RQO database, and ensure that regional implementation of RQOs is taking place.
3. A National Database to house RQO information would need to be established. This database would house the actual approved RQOs and Numerical Limits for each Resource Unit. It would also present notices of intention to change RQOs and Numerical Limits. This database would need to be available to DWA personnel who are responsible for management of water resources, and also to stakeholders in order for them to be able to comment.
4. Also at a National level, it will be necessary to establish an adjudicator of proposed alterations to RQOs and in particular to Numerical Limits. In order to ensure impartiality, such persons should be structurally separated from those who would benefit from adjustment of the Numerical Limits. These persons would also reside over an expert panel which would assist with making decisions to alter Numerical Limits.
5. It is important to engage Regional Offices as they will be required to manage water resources in order to achieve RQOs. RQOs will become a vital part of Regional Office existence and they should thus be appropriately resourced. It is imperative to have achievement of RQOs as a key performance area for the relevant catchment management personnel.

b. Trends in ecological data

Given that the definition of achievement of RQOs includes ***evidence that the resource quality is moving towards the objective and not away from it***, the science of trend analysis in data will be important. This does necessitate that data be of sufficient quality and quantity to be able to determine trends with some level of accuracy.

c. Allocation of the water resource

The responsibility of catchment management personnel will be to allocate the loadings and stresses which are put by users onto the resource, in a way that the RQOs are not negatively exceeded. This subject will not be documented in detail here however it is a subject where the creativity of catchment managers can be brought to bear. In summary:

i) Management of water quantity

In those systems where upstream dams allow for the discharge of water in order to meet quantity RQOs, then this issue may be relatively simple. Complexity will emerge in situations where there are

competing users of water or where downstream water releases are not made. But, as indicated by the National Water Act, protection of the resource takes first priority together with water for basic human needs.

More complex will be situations where the loss of water from a system is due to multiple users who may each be abstracting water in relatively small amounts but the total of which exceeds the available quantity. In such situations, the distribution of licenses needs to be done in a way which does not conflict with the overall allocatable amount of water. The need to be adaptive has to be stressed here, where both water resource managers and users need to make allowance for imperfect knowledge and for changes to be made.

ii) Management of water quality

The presence of almost all forms of human society in a catchment will inevitably result in a stress on the water quality. The task of the responsible authority is to apportion the stress emanating from all of the users in a catchment so that the net effect is that the water quality of the resource does not negatively exceed the RQOs. This may mean the allocation of the privilege to discharge polluting substances into the water resource, but as controlled via the issue of discharge permits. The apportionment of these permits can be a complex issue as there are a number of issues which will affect compliance with the RQOs, the most obvious of which is to apportion the stress loading between the different users which is complicated by the river ecosystem which has the ability to remove some types of pollutants from the water-column by assimilation into the food chain. There are also many variations of interaction between different chemical pollutants in water, thus altering the overall impact on the system. Non-point source pollutants will also challenge the understanding of the water quality. The water resource manager thus needs to have some understanding of these issues in order to wisely allocate loadings to different users.

Guidance for the process of managing water quality in relation to RQOs is available in the form of documents published by Department of Water Affairs and Forestry (see text box below).

Box 6. Resource Directed Management of Water Quality

In South Africa, a comprehensive guide to management of water quality in relation to RQOs exists in the form of a number of documents published by the Department of Water Affairs and Forestry (2006).

Appropriate reports in this context include:

- Volume 4.1: Guidelines on Catchment Visioning for the Resource Directed Management of Water Quality (DWAF, 2006b)
- Volume 4.2: Guideline for Determining Resource Water Quality Objectives (RWQOs), Allocatable Water Quality and the Stress of the Water Resource (DWAF, 2006c)
- Volume 4.3: Guideline on Monitoring and for the Resource Directed Management of Water Quality (DWAF, 2006e)

These reports provide detailed practical assistance in the management of water to achieve water quality objectives and should be used in order to meet RQOs.

iii) Management of habitat

Habitat refers to the 'home' for the biota in an ecosystem. While the quantity and quality of water is equally part of this 'home', these have been separated out for consideration. Remaining to be considered as habitat, is the physical nature of the ecosystem, the movement of sediments, the shape of the river channel, the abundance of vegetation on the river bank and across a wetland, etc.

Management of such habitat may be achieved by a number of approaches which would need to be considered for a Resource Unit:

1. Alteration of the flow regime may change habitat, in particular flood events.
2. Management of sediment movement in a river may play an important role, as sediments may be intercepted by instream structures.
3. Land use activities also play a pivotal part in management of habitats, by impacting on the habitat by for example, grazing pressure, burning of vegetation, harvesting, generation of sediment, *etc.*
4. Activities may directly impact on the instream habitat and need to be managed e.g. construction activities, stream crossings.

iv) Management of biota

The management of the biotic composition of an aquatic ecosystem is determined by a number of aspects:

1. The natural biota occurring in the resource
2. The presence of introduced species
3. The habitat and how this has changed from its natural condition
4. The quantity and quality of water that is available, as compared to its natural condition.

Generally it is recognised that if the quantity and quality, as well as the habitat of an ecosystem are managed, then the biota will be taken care of. This is generally true but there are many exceptions, in particular where alien species are involved. The requirements to provide the necessary habitat for an ecosystem will have been determined by the Ecological Reserve process. This process will have described specifications (EcoSpecs) for each aspect of the ecosystem that need to be maintained in order to maintain the overall state of the ecosystem. There will however, be situations where direct interventions in biotic composition may be necessary.

d. Periodic review of RQOs

It is noted in the National Water Act that RQOs are set for a time period. The practical implementation of Adaptive Management in water resources management means that RQOs should be set for a time that is within the expectations of significant change to that resource. So, RQOs in heavily developed areas should have a shorter existence than those in a wilderness setting. However, given the complexity that this would entail for management, it is recommended that the RQOs for all catchments (as a whole) should be reviewed after not more than five years. There will be situations which trigger a review before the review period has run its course. Examples of such triggers will be where:

- a) There have been substantial changes to the activities in the catchment which will pose an increased threat to the resource.
- b) Where the RQOs that have been put in place are demonstrated to be failing to protect the resource and where it would not be wise to wait for the completion of the review period.
- c) There has been a substantial change to the information that is available, e.g where Ecological Reserve information becomes available.

Responsibility for identifying that a trigger has occurred rests with the resource manager and stakeholders alike. This requires that stakeholders have access to the outputs of the monitoring process, and emphasises the need for effective data management and dissemination of information. This access and the opportunity to engage the resource manager maintains the link to the original process and entrenches the collective responsibility developed in the setting of the RQOs.

While the passing of the review time period would demand that a review is initiated, the triggers would be less definite but identifying them would include consideration of the following questions:

1. Has the vision for the Catchment, the IUA and each Resource Unit been met or is progress to this end being made?
2. Has there been a change in the drivers of stress to the aquatic ecosystem in any Resource Unit?
3. Is there a need to re-prioritise the selection of Resource Units for monitoring?
4. Is there any need to re-prioritise the selection of components for monitoring?
5. Is there a need to change the RQOs and/or the Numerical Limits describing each component?

2. Review of the RQOs

If answers to the above suggest that the RQOs and/or the Numerical Limits are no longer a fair reflection of the objectives for the resource, then it is important that the RQO procedure be re-run to adapt the RQOs. Re-running the entire RQO procedure will guide the decision-making process, however it will only be necessary to make changes to the existing documentation and the Excel models. Only if there are recommended changes to the Vision and/or the narrative RQOs will it be necessary to engage with stakeholders. Note that this level of change will require amendment to the RQOs that have been gazetted. Where there is a requirement to change the Numerical Limits, this needs to follow the guideline below.

Review of Numerical Limits

There will be situations where there is a need to adjust the Numerical Limits that have been set without having to change the corresponding RQOs. For example, the RQOs for a RU may state that the water quality needs to be suitable for irrigation of crops. The Numerical Limits will then provide, amongst other variables, the salt concentration acceptable for irrigation at a level appropriate for the specific users, which would also be agreed to by the users. This concentration of salts will be based on the best available scientific information, but over time it may become apparent that the concentration was inappropriate. This may be the result of new scientific information being produced or could be the result of users finding the quality unacceptable for their crops. It would thus be appropriate to change the Numerical Limit for salt concentration. Because of the potential to abuse this process, the following recommendations are provided:

- a. All changes must be motivated, which can be done by stakeholders or by DWA personnel.
- b. Motivations for change should be considered within DWA by an 'honest broker' who is impartial to the local situation. This person would be mandated to undertake this function for all parts of the Country and would be able to call on expert advice where necessary. He/she would be expected to evaluate the scientific merits of the proposed change e.g. that the guidelines for salt concentration for irrigation of crops has been changed.
- c. All recommended changes should be submitted for approval to a review panel comprising knowledgeable and suitable persons that would meet from time to time to review national changes to Numerical Limits. Full justification for any decisions must be given with detailed records of the decision being produced and kept. However, it should be noted that despite these possible review loops, RQOs will always ensure that the resource Class determined through the National Water Resource Classification is being met.
- d. Changes to the Numerical Limits should be lodged in the appropriate database and published on the DWA web site for comment. Changes should also be formally communicated with the responsible catchment manager who needs this information for implementation. Stakeholders should also be notified of these changes and given an opportunity to comment on them.

Given the importance of this phase of RQO management, it is suggested that a formal procedure be developed to govern this exercise. There is unfortunately scope for abuse of this procedure which thus needs to be carefully undertaken.

The seven step procedure for RQO determination

The procedure which follows for the determination of RQOs, fits within the Adaptive Management cycle for the management of water Resource Quality Objectives (See Figure 6). It is important that this process should be seen within this cyclic process as the process does NOT end with the gazetting of the RQOs!



Figure 6. Management of water resources using RQOs; incorporating the seven steps for determination of RQOs and three additional steps to implement the Adaptive Management Cycle.

II. SEVEN STEP RESOURCE QUALITY OBJECTIVE DETERMINATION PROCEDURE – IN BRIEF

The procedure for determination of RQOs has been summarised into seven steps. These are summarised below and then are given more detail in the successive sections. Note that some of these steps will be integrated with the Water Resource Classification if this has been previously done or if the two processes are being carried out simultaneously. Where the Water Resource Classification has not been done, then all steps become necessary. Table 3 indicates the relationship between the two processes.

1 Delineate the Integrated Units of Analysis (IUAs) and define the Resource Units (RUs)

- 1.1 Gather and map available information for IUA and RU determination
- 1.2 Describe the present day socio-economic status (Step 1a of WRCS)
- 1.3 Divide the catchment in socio-economic zones (Step 1b of WRCS)
- 1.4 Define the Integrated Units of Analysis (Step 1h of WRCS)
- 1.5 Delineate Resource Units using RDM methodology
- 1.6 Align Resource Units with IUA boundaries
- 1.7 Understand how the Resource Units relate to the Water Resource Classification river nodes.

2 Establish a vision for the catchment and key elements for the IUAs

- 2.1 Select a geographical area
- 2.2 Workshop preparation
- 2.3 Develop a Vision

3 Prioritise and select preliminary Resource Units for RQO determination

- 3.1 Extract and map catchment and Resource Unit level information
- 3.2 Determine the position of each Resource Unit within the IUA
- 3.3 Assess the importance of each Resource Unit to users
- 3.4 Determine the level of threat posed to water resource quality for users
- 3.5 Assess the importance of each Resource Unit to ecological components
- 3.6 Determine the level of threat posed to water resource quality for the environment
- 3.7 Identify Resource Units for which management action should be prioritised
- 3.8 Assess practical considerations associated with RQO determination for each Resource Unit
- 3.9 Evaluate the relative ranking and weighting of each criterion
- 3.10 Select Preliminary Resource Units for RQO determination using prioritisation scores
- 3.11 Complete the information sheet for the Resource Unit Prioritisation Tool

4 Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change

- 4.1 Identify and assess the impact of current and anticipated future use on water resource components
- 4.2 Identify requirements of important user groups
- 4.3 Selection of sub-components for RQO determination
- 4.4 Establish the desired direction of change for selected sub-components
- 4.5 Complete the information sheet for the Resource Unit Evaluation Tool

5 Develop draft RQOs and Numerical Limits

- 5.1 Carry over sub-component and indicator information from the Resource Unit Evaluation Tool
- 5.2 Extract available data to determine the present state for selected sub-components and indicators

- 5.3 Assess the suitability of the data
- 5.4 Where necessary, collect data to determine the Present State for selected indicators
- 5.5 Determine the level at which to set RQOs
- 5.6 Set appropriate draft RQOs
- 5.7 Set appropriate draft Numerical Limits in line with the draft RQO
- 5.8 Determine confidence in the RQOs and process

6 Agree Resource Units, RQOs and Numerical Limits with stakeholders

- 6.1 Notify stakeholders and plan the workshop
- 6.2 Present and refine the Resource Unit selection with stakeholders
- 6.3 Present the sub-components and indicators selected for the RQO determination
- 6.4 Present the proposed direction of change and associated rationale
- 6.5 Present and revise RQOs and Numerical Limits

7 Finalise and Gazette RQOs

1. DELINEATE THE INTEGRATED UNITS OF ANALYSIS AND DEFINE THE RESOURCE UNITS

Integrated Units of Analysis (IUAs) are finer-scale units aligned to watershed boundaries, in which socio-economic activities are likely to be similar. These homogenous units provide a useful indication of similar impacts in different areas of the catchment which should be considered in the determination of RQOs. A Resource Unit (RU), on the other hand, is a stretch of river that is sufficiently ecologically distinct to warrant its own specification of Ecological Water Requirements. Resource Units are nested within IUAs and in the RQO process, are aligned to IUA boundaries. Resource Units provide the smallest discrete, manageable unit (see example in Box 8).

The IUA delineation process prescribed in the Water Resource Classification System has been applied in the RQO determination procedure. The incorporation of this delineation process into the RQO procedure ensures that in the event of RQOs being developed in the absence of Water Resource Classification, the RQOs and their associated information will be aligned in terms of scale with the Water Resource Classification that will eventually be done. This should eliminate confusion in terms of the areas of applicability of the two processes and also prevent duplication of work. The Water Resource Classification also makes use of Resource Units developed in the Ecological Reserve process. Consequently, the RQO procedure has incorporated the methodology for defining Resource Units from the Ecological Reserve. This ensures that the Ecological Reserve, Water Resource Classification and RQO procedures are all aligned.

The sub-steps below set out the procedure to delineate Integrated Units of Analysis and define Resource Units. However, where the Water Resource Classification and/or an Intermediate or Comprehensive Ecological Reserve has been undertaken, these sub-steps may not always be necessary. Furthermore, it is possible to determine RQOs for a reach of river and not the entire catchment. In such cases, defining IUAs and Resource Units for the whole catchment is not appropriate. Table 5 sets out the sub-steps which should be undertaken based on the available information and the scale at which RQOs are being set.

Table 5. Sub-steps which should be undertaken to delineate IUAs and RUs based on available information and the scale of RQO determination

Available information	Scale of RQO determination	
	River reach	Catchment
WRC & Intermediate/Comprehensive Reserve	Only sub-step 1.7	Only sub-step 1.7
Intermediate/Comprehensive Reserve only	Omit all sub-steps	Do sub-steps 1.1 – 1.4
No WRC or Reserve information exists	Omit all sub-steps	Do all sub-steps

1.1 Gather and map available information for IUA and RU determination

The objective of this sub-step is to gather all available information for the selected catchment for use in the subsequent sub-steps of Step 1. The information required for this sub-step may be contained in a variety of different sources including Statistics South Africa, Conservation agencies, Department of Water Affairs and South African Weather Services. Where possible, this information should be obtained in a spatial format to enable an integrated analysis using Geographic Information Systems. A summary of the data requirements is provided in the Table 6 below.

Table 6. Data requirements for delineation of Integrated Units of Analysis and Resource Units

Sub-step needed	Data required
All sub-steps	Catchment boundaries
Sub-step 1.2	Population characteristics (e.g. numbers, gender)
Sub-steps 1.2 and 1.3	Land use (e.g. irrigation, farming, mining, forestry)
Sub-step 1.2	Proportional contribution by different water user sectors to the catchment and national economy
Sub-step 1.3	Land tenure
Sub-step 1.3	Ecoregions
Sub-step 1.3	Rainfall patterns
Sub-step 1.3	Location of rivers, wetlands and estuaries
Sub-step 1.5	Stream classification
Sub-step 1.5	Geomorphological classification
Sub-step 1.5	Habitat Integrity
Sub-step 1.5	Water quality delineation into units
Sub-step 1.5	Groundwater units (if applicable or available)
Sub-step 1.5	Operation of the system

1.2 Describe the present day socio-economic status (=Step 1a of WRCS)

The objective of describing the present-day socio-economic status of the catchment is to describe the target catchment's population, land use and economy as part of the status quo assessment. It is also required to divide the catchment into different socio-economic zones as part of sub-step 1.3. This information can be accessed from a variety of sources, including the Census data from Statistics South Africa (StatsSA) and the CD: IWRP Information Management System (IMS) database. Information should be collected on:

- population characteristics (e.g. numbers, gender);
- land use (e.g. irrigation farming, mining, forestry); and
- proportional contribution by different water user sectors to the catchment and national economy (e.g. agriculture contributes ~35% to Olifants/Doring catchments gross geographic product (GGP)).

The outcome of sub-step 1b may include:

1. A table containing a list of important population descriptors for the catchment.
2. A map showing the target catchment land use, together with a table listing the different land uses and their relative areas.
3. A table containing the proportional contribution by water user sector to the target catchment and national economy.

1.3 Divide the catchment into socio-economic zones (=Step 1b of WRCS)

The objective of dividing the catchment into socio-economic zones (in the RQO process) is to inform the development of Integrated Units of Analysis in sub-step 1.4. This sub-step requires dividing society into relatively homogenous communities through delineating socio-economic zones and describing community wellbeing within each zone. It is recommended that:

- the process be done spatially in such a way that any individual could identify his/her community;
- the process reflect communities' relationships to water and aquatic resources;

- the delineation of socio-economic zones include the following considerations:
 - land tenure;
 - predominant land use;
 - aquatic ecosystems and rainfall patterns; and
 - any other pertinent variables that create a pattern.

The outcome of sub-step 1c may include:

1. A table containing a list of socio-economic zones for the target catchment including:
 - a. an appropriate name; and
 - b. A description of each zone that should include at least the dominant land tenure, land use, aquatic ecosystems, rainfall patterns and any other pertinent variables that create a pattern.

1.4 Define the Integrated Units of Analysis (=Step 1h of WRCS)

The purpose of defining IUAs is to establish broader-scale units which may be subjected to similar anthropogenic impacts. This delineation of IUAs also ensures that the areas considered in the RQO process are aligned with those in the Water Resource Classification. IUAs are a combination of socio-economic zones defined in sub-step 1.3 and watershed boundaries, within which ecological information is provided at a finer scale. Once the delineation process is complete (undertaken in sub-step 1.3), the final socio-economic boundaries should be aligned with the quaternary catchment boundaries thereby defining the IUAs. An example of the IUAs delineated for the Mzimkhulu are provided in Box 8.

The outcome of sub-step 1e should include a defined set of IUAs for a target catchment

1.5 Delineate Resource Units using RDM methodology

From an ecological perspective, rivers should be viewed as continuous longitudinal systems. Impacts that occur in upstream reaches are likely to affect downstream processes. However, different sections of rivers can have different natural flows and may react differently to stresses depending on their sensitivity (Louw, 2004). In order to facilitate the effective management of a river, it is necessary to break the river down into discrete, manageable units. These discrete units are generally ecologically homogenous in nature.

The RDM methodology for delineating Resource Units for the purpose of determining the Reserve, is done primarily on a biophysical basis according to the occurrence of different ecological regions or EcoRegions. The delineation process also considers geohydrological response units as well as the results of Habitat Integrity. Overlaying this data does not necessarily provide a clear delineation and expert judgment is required for the final delineation.

The following are considered when delineating RUs (DWAF, 2004c)

- EcoRegions
- Stream classification (Geomorphological classification to zone level)
- Habitat Integrity
- Water quality delineation into units
- Groundwater units (if applicable or available)
- Operation of the system

The method for RU delineation of river RUs is detailed in DWAF 1999, Volume 3, and can be applied in this sub-step of the RQO determination procedure. For non-perennial systems, some differences may occur as clusters of pools in the river may be treated as separate RUs. Guidance is available from Seaman *et al.* (2009).

Box 7. Delineating Resource Units for wetlands

The challenge here is to prioritise and select wetlands that are important and significant at the scale of the assessment being undertaken. Using the Decision Support System for Wetland Reserve Determinations (DWAF, 1999c) as a basis, wetlands meeting the following criteria should be considered as a minimum:

- Ramsar wetlands or wetlands with potential Ramsar status;
- Wetlands with national or provincial protected status;
- Large wetlands providing important ecological services (e.g. flood attenuation, crop production etc);
- Large freshwater lakes;
- Large wetlands fed by water sources on which major developments are planned which could cause irreversible damage to the wetlands; and
- Wetlands supporting important populations of endangered species.

In some instances, it may be necessary to identify wetland groupings (e.g. in the case of many small but important wetlands) based on their similarity (e.g. wetland type). Further guidelines, including examples of additional prioritisation criteria based on the specific objective of the study are included in Rountree *et al.* (2008) and should be considered particularly where few wetlands meet the criteria outlined above.

1.6 Align Resource Units with IUA boundaries

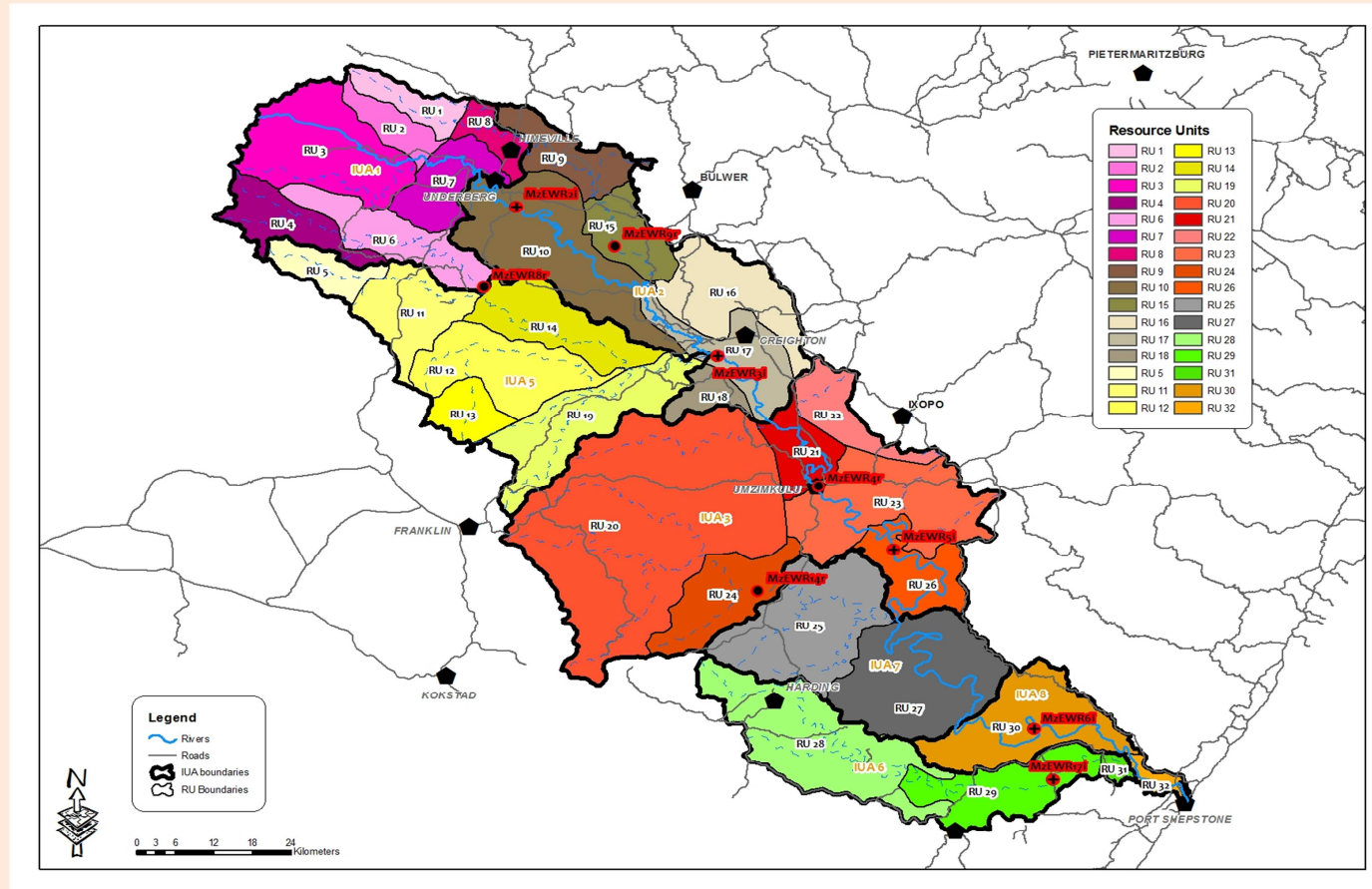
The delineation of Resource Units is based on the occurrence of different ecological regions whereas the delineation of IUAs is determined by the location of socio-economic zones which are aligned to watershed boundaries. It is therefore possible, that a Resource Unit may overlap two IUAs. The purpose of this sub-step is to ensure that all Resource Units are aligned with IUA boundaries. Any Resource Unit which transcends two IUAs should be split into two and its endpoints aligned with the IUA boundaries. An example of the Resource Units delineated for the Mzimkhulu are provided in Box 8.

1.7 Understand how the Resource Units relate to the Water Resource Classification river nodes

The Water Resource Classification System also develops Water Resource Classification river nodes which are used as modeling points within the Water Resource Classification. The Water Resource Classification river nodes may encompass one or more RDM Resource Units. The primary outcome of the Water Resource Classification is a selected scenario which provides the desired ecological category (Nested Ecological Category) for each reach of river upstream of a river node. It is therefore necessary to understand how the Water Resource Classification river nodes or modeling points relate to the Resource Units. Where a river node encompasses one or more RDM Resource Units, the same NEC should be applied to both.

Box 8. Example of IUAs and Resource Units delineated for in the Mzimkhulu catchment

Seven Integrated Units of Analysis were identified for the Mzimkhulu catchment. These are denoted by the broad coloured areas (e.g. pink area in the north of the catchment). The various shades within these areas indicate the different Resource Units. A total of 32 Resource Units were identified for the Mzimkhulu catchment.



2. ESTABLISH A VISION FOR THE CATCHMENT AND INTEGRATED UNITS OF ANALYSIS

Resource Quality Objectives set out to balance the need to protect and sustain water resources on the one hand, with the need to use and develop them on the other. A key step in the RQO process is therefore to align the diverse and competing interests in the resource into a collective desired future state. Visioning is the consensus-building process which articulates society's aspirations into a common future purpose. The visioning process serves as a tool to involve multiple stakeholders in the strategic planning process of water resource management (DWAF, 2009). It aims to achieve the following:

- To generate a sense of cohesion and common purpose amongst people with diverse interests in the water resource
- To direct activities related to diverse interests towards that common purpose
- To continuously improve water resource management practices and the state of the resource
- To promote a culture of co-operation and consensus-building
- To promote a chain of accountability that links the vision to management objectives, so that it is possible to track whether or not the actions contribute to achieving the overall vision
- To provide clusters of objectives that allow operational managers to interpret license applications and to formulate and recommend license conditions in a strategic fashion (DWAF, 2006b).

The visioning process should provide stakeholders with an opportunity to voice their desires regarding the future state of water resource characteristics. It is vital that all interest groups are identified and included in this process, not just the ones that are visible and well-organised. The visioning process proposed for "Resource Directed Management of Water Quality" is based on participation by key stakeholders as opposed to a comprehensive suite of stakeholders (DWAF, 2006b). The Department of Water Affairs proposes an ongoing, iterative process where the confidence in the vision is improved as more stakeholders are involved (DWAF, 2006b). Given the importance of RQOs in terms of its implications for users over and above water quality considerations and the need to optimise resources, is proposed that the level of consultation is expanded beyond key stakeholders, and that it includes as many participants as is required to effectively represent users identified in the previous step. This will increase the level of confidence in the RQOs established and will minimise the risk of negative feedback when they are published for comment.

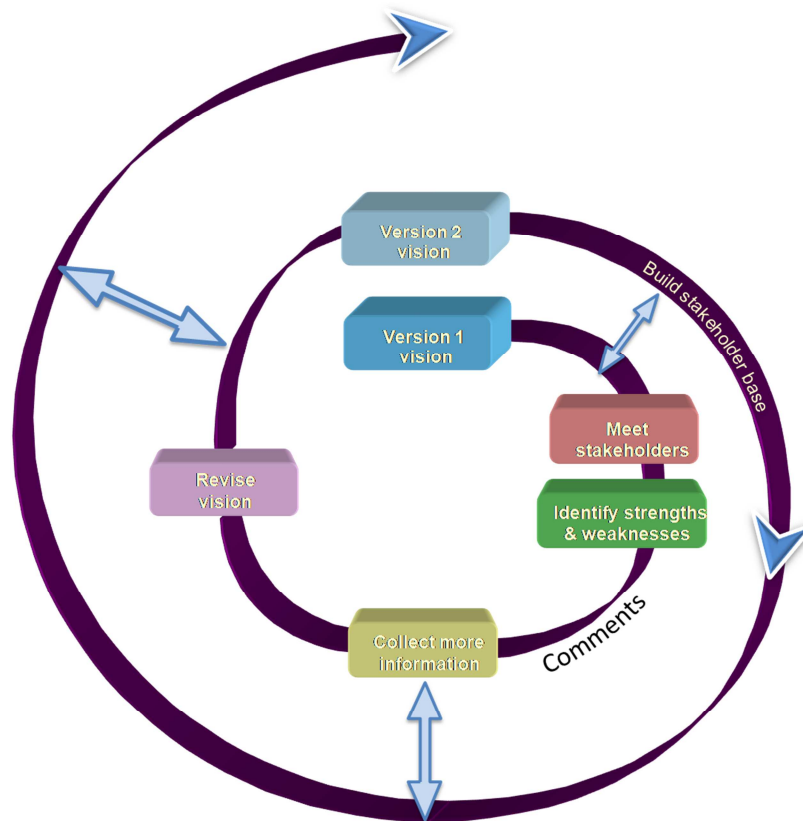


Figure 7. The relationship between different rounds of visioning (Source: DWAF, 2006b)

The approach and steps to developing a vision are as follows:

2.1 Select a geographical area

A vision must correspond to some defined geographical area. In the case of RQOs, the vision should be established for the catchment as a whole and for each IUA.

2.2 Workshop Preparation

2.2.1 Prepare baseline situation assessment

A baseline understanding developed by the project team will be presented as a basis for refining and amending the catchment context in line with stakeholders knowledge and perceptions of the status quo. This baseline context should be compiled from the following sources .

- *Gather baseline information*

This sub-step will draw on the baseline information gathered and used to delineate the Integrated Units of Analysis in Step 1 of the RQO process. The following information is important in generating catchment context within the visioning process. This information should be provided for the catchment as a whole and also for each Integrated Unit of Analysis.

- Maps of the vegetation types, topography, *etc.*
- Type and condition of water resources
- Distribution of people and land use types
- Interest groups and organisations using the water resources
- Aquatic goods and services of interest

- *Identify any existing visions*

Any existing visions or objectives for the study area or parts of the study area should be sourced. Although these may not have been developed with the RQO process in mind, there is still value in drawing from the knowledge and insights of other visioning processes (DWAF, 2006) and it is also important that the RQO vision should be aligned to other visions, or if not, then a process needs to be considered to reconcile different visions. Examples of documents which may contain existing visions include:

- Water Resource Classification
- Catchment Management Strategy
- Existing water planning processes
- Integrated Development Plans
- Spatial Development Initiatives
- Strategic Environmental Assessments
- Visions generated by other catchment forums (DWAF, 2006b).

Stakeholders will often have been involved in the development of other visions and objectives. The identification and consideration of such processes demonstrates to stakeholders that the project team has investigated the situation thoroughly and that there is not unnecessary duplication of effort, thereby contributing to improved confidence in the team and the process.

2.2.2 Invite stakeholders to the workshop

The list of stakeholders should represent the understanding as developed in Step 1 in terms of rights, rewards, responsibilities and risks associated with water resource management. A Background Information Document (BID) should be prepared and circulated to stakeholders with an invitation at least four weeks prior to the workshop. The BID should provide an outline of the purpose of RQOs and some context information (including maps) on the catchment in question. The BID should also include some detail on the broader RQO process. Early notification of the workshop is important for securing participation. It also provides:

- Space for dealing with capacity building needs among stakeholders prior to the workshop, where this is necessary.
- Time to follow up with stakeholders to ensure that the correct representative will be attending the workshop.

The list of stakeholders will need to account for the diversity within the catchment and the spatial variation *i.e.* there should be representation from the range of stakeholder groups and account for the various IUAs.

2.2.3 Select a facilitator and plan the workshop

An appropriate facilitator, as defined in the following text box should be identified and the workshop planned under their guidance. The timing, participatory techniques and format will be informed by the stakeholder profile and any feedback (questions, requests for additional information) received in response to the invite or subsequent follow up.

Box 9. Selecting a Facilitator

The facilitator's role in the visioning process is critical, because they are not simply the driver of the process, but can influence the spirit within which process is conducted (DWAF 200b). Given the importance of this role, Dore *et al.* (2010) list various attributes of the person selected to this role:

- **Listener:** Ability to listen and create an atmosphere where others will listen.
- **Enabler:** Ability to see who is/not participating and apply techniques to enable participants to contribute in an authentic way. This includes stopping any individual or group from dominating discussions. A simple option is to ensure that each person gets an opportunity to have input.
- **Linker:** It is important for the facilitator to link the steps in process to maintain some direction and focus, whilst still being adaptable to the needs of participants.
- **Respectful:** Respect and empathy for different people and world views they may hold.
- **Energetic:** To maintain enthusiasm of the participants to persist and work through what may be difficult tasks, the facilitator requires personal energy.
- **Familiarity and Experience of Facilitator Techniques:** The facilitator needs to draw on different techniques to achieve the overall objective of the vision. Techniques may vary depending on the number of stakeholders and the range in their level of understanding, technical capacity and even language. This should be considered prior to the workshop and potential options should be anticipated.

Principles of Facilitation

The following principles are summarised from DWAF (2006b):

- Facilitators must **create an environment that promotes new insights and shared understanding** – This requires that each perspective is respected and given a chance for audience.
- It is the facilitator's responsibility that **discussion is inclusive** i.e. everyone is given an equal opportunity to express their view or opinion.
- Co-evolution of perspectives and interests can only take place in an **atmosphere of mutual trust** and openness. This requires that the facilitator encourages disclosure of interests and agendas.
- The facilitator needs to **keep interaction and dialogue constructive** in order to move towards consensual agreement. The opposite is to pursue counter arguments in pursuit of identifying a 'winner'.
- The **future should remain the focus** throughout in order that the process is not bogged down in the past or present. Looking to the future provides greater opportunity for creativeness and opportunity.

2.2.4 Undertake Capacity Building

Any capacity building required to ensure effective participation at the visioning workshop needs to be undertaken prior to the workshop. This capacity building could range from merely providing additional to improve the understanding, to a preliminary workshop where there is a need to better understand the purpose to RQOs, the relationship with other water management tools and some of the technical aspects. Depending on the need, it may be run immediately before the workshop for purposes of efficiency, or alternatively take place a few weeks prior to the workshop.

2.3 Develop a Vision

The primary purpose of sub-step 2.3 is to establish a vision for the catchment. This sub-step should be undertaken in a workshop format with stakeholders who have an interest in the catchment.

2.3.1 Generate collective catchment context

In order to generate a vision, it is necessary to have some level of understanding of the current state of area in question. Current state includes not only the state of the resource but also the current state of societal issues affecting the use of the water resource. It is important to involve stakeholders and to encourage them to describe their water resource issues. This will provide a description of the context as stakeholders see it. A shared understanding of the context of the selected area, its people and their water resource issues at various scales (local, regional, national and international) and from different perspectives (ecological, socio-economic, governance, policy and legal) can be developed.

The value of this process can't be overemphasised as it establishes the common understanding between users of their relationship between other users and the resource and how their decision and activities impact other users. Furthermore, a large amount of valuable information will emerge regarding priority areas (reaches, systems) and aspects of the system (resources, flow) for the different users. It is critical to capture this information which will inform the prioritisation of UserSpecs and EcoSpecs. The spatial orientation of key sites and or aspects is important and is facilitated by having applications such as GIS available on which to discuss and capture the information presented.

Practically the process should commence with a summary of the baseline information collected in Step 1. The facilitator should then develop the catchment context by asking stakeholders to explain their issues *i.e.* how is the current situation affecting their use or benefits derived from the system. All information and understanding must be captured and spatially referenced on GIS or a map. This will help build up a spatial overview. It is also important to:

- Identify the interdependencies of the issues and views raised (so stakeholders understand how they are impacting others).
- Trajectories of change *i.e.* is the situation getting worse or better, and where possible the rate of change (this will help prioritise issues).

An example of how to capture interdependencies from DWAF (2006c) is provided in Table 7. As discussed in DWAF (2006b) this structure will assist in highlighting which groups are directly dependent on the water resource for their livelihood, and which groups are more interested from a purely economic or business perspective. It should highlight non-consumptive use of the water resource, an aspect of water resource use that is often overlooked when categorising use according to sectors (These aspects relate to ensuring equity and, through equity, ensuring sustainability).

Discussing and generating a joint perception around the context and current state leads to a common understanding of issues, problems and points of strength. A range and diversity of issues is generated often highlighting that the status quo is not acceptable. This forms the basis for working towards a desired future state in the form of the vision.

Table 7. Example of analysis of stakeholders issues in a catchment and interdependencies (Source DWAF 2006c).

Interest and beneficiaries	Aquatic ecosystem services	Impacts on other users/interested parties	Impacted on by other users	Notes about interdependencies
Fly-fishing in river headwaters (Fly fishing club)	Trout fishing and scenic beauty	Access to certain parts of the main stem river headwaters restricted or blocked.	Harvesting activities of upstream forestry affecting TDS and trout survival. Sawmill settling ponds discharging into river – water quality impacts.	River water turbidity at times of timber harvesting seems to be the impact of greatest concern here.
Scenic beauty and safety of resource. Town inhabitants and tourists	Attractive riparian zone and close contact with this through picnic sights on river bank.	None	Upstream sewerage works not well managed and spills occur at times	Spills are sporadic but safety issues (high <i>E.coli</i> levels) warrant high priority attention to this issue.
Irrigation water (adequate quality and assurance of supply) for subtropical fruit production.	Water provision.	Affects flow and quality of water use by downstream irrigators. Downstream protected area with RAMSAR wetland dependant on flows downstream of irrigation.	Affected by upstream water use by forest plantations. Some farms affected by upstream sewerage spills.	This is both a volume and quality issue. Flow levels noticeably higher during dry season since forestry removed plantation trees from riparian zone.
Informal agriculture – growing madumbi's in riparian zone.	Moisture in riparian zone soils; medicinal plants.	Unknown.	Probably all upstream water use	Need better information on this use type to understand interdependencies.

2.3.2 Formulate a Vision

- *Define Focal Priorities*

Building on the combined context, the next step is to identify those aspects of the system or the uses it supports that are a priority to stakeholders and which should be included in the vision. This is accomplished using Table 8 below. A generic list of economic sectors and uses is provided along with aspirations in terms of protecting the resource. The list of uses is proposed because they are aspects/definitions which people can relate to. Furthermore, these categories facilitate that link between uses and UserSpecs. A generic list has been provided, which may not always be applicable to the catchment in question. They should and can be amended as deemed appropriate.

The focal areas are selected and prioritised through a voting process. Each stakeholder group should be allocated a single vote and be required to vote against each aspect selected. This ensures that no single stakeholder group is afforded unfair weight in the process (it also highlights the importance of ensuring that all stakeholders holders are represented, preferably by more than one representative). The outcomes of the voting will be used to guide the formulation of the vision. It is also important to document the link between the rating and the catchment context through comments that summarise the motivation for the selection or exclusion of focal areas. The rationale as it emerges through discussion should also be captured. This will serve as a record of the process and ensure transparency in the process.

Table 8. Stakeholder voting on Preferred Focal Areas

Water Resource Use	Strongly Agree	Agree	Disagree	Strongly Disagree	Comments
Use Aspirations					
Rural domestic (treated)					
Rural domestic (BHN)					
Industrial					
Urban and residential					
Commercial irrigated agriculture					
Commercial livestock production					
Subsistence livelihood					
Recreation					
Strategic use					
International use					
Real estate and property					
Afforestation					
Dryland sugarcane					
Mining					
Conservation					
Ecotourism					
Protection Aspirations					
Maintain Present Ecological State					
Improve Present Ecological State					
Allow deterioration of present status (overall, in certain areas, for certain components, short or long term)					

Alternatively the table may be amended to categories according to broad aspects such as sustainability, equity and efficiency. In the case of the Orange River process the following table was used (Table 9). It requires that stakeholders select broad socio-economic objectives and then rank the sectors and state of the resource that should be prioritised to achieve the broad objectives. The potential risk is that there will always be strong agreement for economic empowerment, maximising job security, *etc.*

Table 9. Example of alternative categories for prioritising focal areas for inclusion in the vision

Strengths	Strongly Agree	Agree	Disagree	Strongly Disagree	Comment
Economic and social objectives					
Economic empowerment		x			
Maximise job creation	x				
Maximise capital growth		x			
Social upliftment	x				
Beneficial use of water resources	x				
Promote the following sectors to achieve the above					
Agriculture (maize, wheat)	x				
Eco tourism	x				
Subsistence farming	x				
Ecological Water Requirement of the water resource					
Maintain overall present status	x				
Improve present status		x			
Allow deterioration of present status			x		
Allow deterioration of selected water resources in the short term		x			

- *Convert the Focal Areas to a Descriptive Vision*

Regardless of the categories selected, the aim is to identify and prioritise aspects that stakeholders consider a priority in the catchment in the future. The facilitator then needs to manage a process of converting these priorities to a vision that captures them in terms of a desired future state. This process needs to be repeated for each IUA. An example of the vision developed for the Mzimkhulu catchment and one of the IUAs in the process of testing the RQO methodology is provided below. Examples for both wetland and estuarine systems are also provided.

The process should culminate with an overview of how the project team will take the vision and understanding provided by the stakeholders forward, and an indication of how and when stakeholders will be involved in the remaining steps.

The proceedings and a summary of the main outputs, *i.e.* the catchment and IUA visions need to be compiled and forwarded to the stakeholders for comment.

Box 10. Example of visions for the Mzimkhulu

Vision for the catchment

The vision is to have a well-managed catchment which is used sustainably and equitably by its people. The resource has unique characteristics which are not compromised and should be promoted for ecotourism. Certain areas should be developed to promote social upliftment, e.g. forestry, which may mean localised deterioration. Any development should not compromise the overall functioning and integrity of the resource system. Where there is uncertainty, the resource should be managed with a precautionary approach.

Vision for IUA 2

This IUA supports mixed agriculture particularly irrigated pastures for livestock, and forestry. The water resource remains in good condition, with both good quantity and quality of water, with diverse habitats and biota and usage thereof, supporting a thriving ecotourism sector. The upper catchment supports important wetlands, including The Swamp, which continue to provide valuable ecosystem services. The vision is thus to support sustainable agriculture and ecotourism in the IUA whilst maintaining the health of the water resource, in particular the quantity and quality of water, in a good condition.

Box 11. Vision for estuaries

For some estuaries the vision will be available from the Estuary Management Plan (EMP). The Integrated Coastal Management Act (No. 24 of 2008) requires the development and implementation of EMPs for all South African estuaries. The vision is a statement describing how the stakeholders envisage the estuarine environment. The vision statement should be brief and concise, directing future efforts and driving the change required to attain the goals. For example:

“We, the custodians, strive for the equitable, integrated and sustainable protection and use of the marine and other resources of the estuary, recognising that the resources are finite and tradeoffs between users are essential to achieving benefits for residents and the environment at a local, regional and national level.”

Box 12. Vision for Wetlands

As for estuaries, visions may be available from Wetland Management Plans. This is particularly likely where the wetland occurs within a protected area or is a designated Ramsar site, for which a management plan is routinely developed. An example of a vision for the Ntsikeni wetland which occurs within a protected area and is a designated Ramsar site is included, below:

“Look after the soil, water, plants and animals (i.e. maintain the hydrological and biotic integrity) of the Ntsikeni Nature Reserve, particularly of the Ntsikeni wetland, within the context of the Maloti-Drakensberg Transfrontier Park, while at the same time optimising the benefits of the Reserve to local communities, especially through nature-based tourism and livestock grazing.”

3. PRIORITISE AND SELECT PRELIMINARY RESOURCE UNITS FOR RQO DETERMINATION

This step should be undertaken using the Resource Unit Prioritisation Tool

The Water Resource Classification System proposes that RQOs are set for each Resource Unit. In reality however, this may not be possible as there may be a large number of Resource Units within a selected catchment. A rationalisation process may therefore be necessary to prioritise and select the most useful Resource Units for RQO determination. The objective of Step 3 is therefore to prioritise and select preliminary Resource Units which will then be discussed and agreed with stakeholders during Step 6. A decision support tool has been developed to guide this selection process. Note that it is expected that at least one RU should be monitored to represent each IUA.

The **Resource Unit Prioritisation Tool** is used to assess a range of criteria that would indicate the importance of monitoring each RU as part of management operations. This would include the position of Resource Units within an IUA, user and ecological considerations, practical constraints and management considerations. Although the tool can be applied using desktop information, local knowledge and a thorough understanding of the catchment are recommended. The assessment should therefore ideally be undertaken in conjunction with the relevant catchment managers and other key individuals with a good understanding of the area. The Resource Unit Prioritisation Tool can be used to prioritise Resource Units for rivers, wetlands and estuaries. Currently no methodology exists for prioritising groundwater Resource Units.

A number of sub-steps are proposed in undertaking Step 3. These are briefly described below. For further information, and detail relating to applying the Resource Unit Evaluation Tools, users are encouraged to consult the supporting information included in Annexure 1.

Box 13. Applying the Resource Unit Prioritisation Tool to Estuaries

The Resource Unit Prioritisation Tool considers all Resource Units for the entire catchment. An estuary is considered to be a Resource Unit on its own and will therefore be included as such in the tool. The sub-steps detailed below and applied to river Resource Units should thus also be followed for estuaries.

Box 14. Applying the Resource Unit Prioritisation Tool to Wetlands

The Resource Unit Prioritisation Tool considers all Resource Units for the entire catchment. Each wetland identified in Section 1.5 is considered to be a Resource Unit on its own and will therefore be included as such in the tool. The sub-steps detailed below and applied to river Resource Units should also be followed for wetlands.

3.1 Extract and map catchment and Resource Unit level information

The objective of sub-step 3.1 is to gather all available information for the selected catchment necessary to inform the prioritisation process. The relevant information may be contained in a range of different sources. The Water Resource Classification is a key document which should include much of the required ecological and socio-economic data necessary for the determination of Resource Quality Objectives. In many instances however, the Water Resource Classification may not have been completed. In such cases, the Ecological Reserve documentation (even if only from the Desktop database) should be sought to obtain key ecological data whilst the socio-economic information should be gathered from various sources including the Catchment Management Strategy, Integrated Development Plans and stakeholder consultation. Local knowledge and understanding of the catchment is vital and should be used where detailed information is not available or is not suitable.

Table 10 below provides a guideline as to where information could be accessed from. Where possible, information should be summarised at a Resource Unit level. A detailed description of each of the information requirements is provided under the relevant sub-step where it is needed. ***Note that it may not be necessary to document this information exhaustively and that expert local knowledge may be used as a quicker and more meaningful substitute.***

Table 10. Summary of the information needed and potential sources of information for the different steps in RU prioritisation. Note that those in italics should if possible be represented spatially.

Needed	Information needed	Source
Sub-step 3.2	<i>Integrated Units of Analysis</i>	Detailed in Step 1 above or extracted from Water Resource Classification
Sub-step 3.2	<i>Resource Units</i>	Detailed in Step 1 above or extracted from Water Resource Classification
Sub-step 3.3.1	Cultural services	Water Resource Classification Tourism authorities Integrated Development Plans Catchment Management Strategy Stakeholder consultation
Sub-step 3.3.2	Ecosystem services supporting livelihoods of significant vulnerable communities	Water Resource Classification Integrated Development Plans Catchment Management Strategy Land use information
Sub-step 3.3.3	Ecosystem services for strategic requirements and international obligations	DWA and/or Eskom
Sub-step 3.3.4	Regulating and supporting services	Water Resource Classification National Wetland Coverage Ecosystem services maps from Municipalities or scientific papers
Sub-step 3.3.5	Activities reliant on water resources and contributing to the economy	Water Resource Classification Land cover map (afforestation and commercial agriculture)

		Integrated Development Plans Water institutions
Sub-step 3.4 and 3.6	<i>Location of polluting industries or activities</i>	DWA Water institutions
Sub-step 3.5.1	EIS ratings	Water Resource Classification DWA Desktop EIS ratings Reserve Determination (Extrapolation?)
Sub-steps 3.5.2 and 3.7	Nested Ecological Category	Water Resource Classification If no Water Resource Classification then use PES
Sub-steps 3.5.2 and 3.7	Present Ecological State	Water Resource Classification Reserve Determination Desktop PES (Extrapolation?)
Sub-step 3.5.3	<i>National Freshwater Ecosystem Priority Areas</i>	NFEPA database
Sub-step 3.5.4	<i>Irreplaceability value of Resource Units</i>	Provincial aquatic conservation plans
Sub-step 3.6	<i>Location of water resource infrastructure</i>	DWA
Sub-step 3.8.1	<i>Location of EWR sites or other monitoring points</i>	Reserve determination River Health Programme DWA gauging weirs Microbial Monitoring Programme Water institutions
Sub-step 3.8.2	Accessibility	Road infrastructure maps Topography maps Local knowledge

3.2 Determine the position of the Resource Unit within the IUA

The first criterion of the Resource Unit Prioritisation Tool assesses the location of the Resource Unit within the IUA.

Resource Units on large mainstem rivers at the downstream end of the IUAs are located at the edge of socio-economic zones where user requirements are likely to differ. Such Resource Units also aggregate the upstream impacts from the entire IUA and thus enable the assessment of management performance at meeting objectives (including the gazetted IUA Class) for the upstream catchment. These Resource Units thus receive high prioritisation in the Tool. It is important to note that estuaries will always be prioritised in this way.

3.3 Assess the importance of each Resource Unit to users

The second criterion to be assessed is the importance of the Resource Unit to users. This assessment should consider both current and anticipated future use. The tool assesses a number of sub-criteria relevant to different user considerations. Note that ratings applied are subjective and should be informed by gathered information and local knowledge. Details of each sub-criteria evaluated as part of this assessment are included below.

3.3.1 Resource Units which provide cultural services

Cultural services are less tangible than material services but nonetheless may be highly valued by society. Relevant benefits may include recreational use, tourism or scientific benefits, and aesthetic, cultural or spiritual values. Resource Units which provide these benefits should be protected as they contribute to the wellbeing of society. User groups for which this service is likely to be particularly important include subsistence users, recreation and tourism and real estate and property owners/developers.

Although it is rarely possible to quantify the actual value that these services contribute to society, an assessment of the importance of this service may be informed by land uses, levels of use for recreation and tourism activities, knowledge of community values and activities and use by educational groups.

3.3.2 Resource Units which support the livelihoods of significant vulnerable communities

Many poor communities are directly reliant on water resources for domestic water use, food, grazing, medicine, and building materials. Poor communities are particularly vulnerable to changes in the water resource as these changes affect their livelihoods directly. The level of vulnerability determines the degree of impact caused by changes in the level of service provision. Resource Units which support significant vulnerable communities should therefore be prioritised. Potential user groups who should be considered in this assessment are limited to subsistence users.

3.3.3 Resource Units used for strategic requirements or international obligations

The National Water Act stipulates that all water use except the Reserve, international rights and obligations, strategic water use and Schedule I use, must be authorised by license. Strategic water use is important in meeting service delivery targets in the Country while South Africa is often bound by law to meet certain international obligations. These uses are therefore given preference over other uses. Resource Units which are used for strategic purposes or are important in meeting international obligations should be prioritised to ensure that obligations are met.

3.3.4 Resource Units which provide supporting and regulating services

The Millennium Assessment identifies four categories of ecosystem services including regulating and supporting services. The intangible nature of some of these services makes them difficult to measure and as a result they are often overlooked. However, they are important to a large number of users at a regional or even international scale. A range of supporting and regulating services are supplied, for example, by large wetland systems.

3.3.5 Resource Units which support activities which contribute to the economy

Resource Units which support activities (e.g. irrigated agriculture, industrial abstractions and bulk abstractions by water institutions) that add value to the South African economy should be prioritised. These activities contribute to the GDP, create jobs and affect household income and distribution. Potential user groups who should be considered in this assessment include industrial users, commercial agriculture and water institutions.

Box 15. Assessing the importance of wetlands to users

It is worth noting that tools have been developed to assess the importance of benefits provided by wetland systems. Wet-Ecoservices (Kotze *et al.*, 2007) is particularly useful in this respect, which allows wetland benefits to be broadly characterised at a desktop level or assessed in more detail using a wide range of criteria. If such information is available, it should be used to inform the assessment process.

Box 16. Applying the 'Importance to users' section of the Resource Unit Prioritisation Tool to the Mzimkhulu catchment

The Resource Unit Prioritisation Tool was applied in the Mzimkhulu catchment. The figure below provides the scores applied to Resource Units in the Upper Mzimkhulu IUA for the "importance to users section" of the tool.

RESOURCE UNIT PRIORITIZATION TOOL			Upper Mzimkhulu					
Criterion	Sub-criteria	Rating Guideline	9 - The Swamp	10 - Below Underberg	15 - Lower Phudela	16 - Tributaries N of Mzimkhulu	17 - Mzimkhulu	18 - Southern Tributary
Importance for users (Current & anticipated future use)	Resource units which provide important cultural services to society	0 - RUs with no known / limited provision of cultural services 0.5 - RUs providing some cultural services 1 - RUs providing very important or numerous cultural services		0.5			0.5	
	Resource units which are important in supporting livelihoods of significant vulnerable communities	0 - RUs which do not support / provide limited support for vulnerable communities 0.5 - RUs providing some support for vulnerable communities 1 - RUs playing an important role in supporting vulnerable communities					0.5	0.5
	Resource units which are important in meeting strategic requirements and international obligations	0 - RUs not used for strategic purposes or to meet international obligations 0.5 - RUs moderately important for strategic purposes or are somewhat useful for verifying compliance with international obligations 1 - RUs extremely important for strategic purposes or are ideally suited for verifying compliance with international obligations						
	Resource units that provide supporting and regulating services	0 - RUs which supply limited supporting and regulating services 0.5 - RUs which supply moderate supporting and regulating services 1 - RUs which supply extensive supporting and regulating services	1	0.5				
	Resource units most important in supporting activities contributing to the economy (GDP & job creation) in the catchment (e.g. commercial agriculture, industrial abstractions and bulk abstractions by water authorities)	0 - RUs which do not directly support any activities which contribute to the economy 0.5 - RUs which support activities which provide a moderate contribution to the economy 1 - RUs which support activities which contribute significantly to the economy	1	1	0.5	1	1	0

3.4 Determine the level of threat posed to water resource quality for users

This assessment should consider the risk of the water resource to users in each Resource Unit. Resource Units which are threatened or are likely to be threatened by current or planned future activities (e.g. mines, towns, industries, dams, intensive agriculture) should be monitored. Emphasis should be placed on selecting those Resource Units most likely to be impacted by high risk activities and which could therefore have serious implications for users if not effectively managed. This may include threats which are located outside of the Resource Unit but which are still likely to impact the Resource Unit in question.

3.5 Assess the importance of each Resource Unit to ecological components

As with anthropogenic users, there are a range of attributes that affect the importance of setting RQOs for different Resource Units. In order to help highlight Resource Units that are important from an ecological perspective, four sub-criteria have been included namely:

- Ecological Importance and Sensitivity (EIS) Categories
- Present Ecological State (PES) and Nested Ecological Category (NEC)
- National Freshwater Ecosystem Priority Areas; and
- Priority habitats / species identified in provincial conservation plans

3.5.1 Resource Units which have a high or very high EIS category

Resource Units with high or very high Ecological Importance and Sensitivity Category require special attention to prevent deterioration of these Resource Units. These areas are considered vital for protecting important or sensitive species and maintaining aquatic biodiversity.

3.5.2 Resource Units which have an A/B NEC and /or PES

Resource Units with an A/B PES or an agreed A/B NEC (in the case where Water Resource Classification has been undertaken) need to be carefully managed to prevent deterioration of these reaches. This is particularly relevant given the poor state of South Africa's rivers and the need to protect aquatic biodiversity.

3.5.3 Resource Units which have been identified as a National Freshwater Ecosystem Priority Area

Resource Units identified as National Freshwater Ecosystem Priority Areas, have been identified using spatial modelling and expert review, and include rivers, wetlands and estuaries. This has included a focus on free-flowing rivers and national freshwater rehabilitation priority areas. Such areas are regarded as priority for protection and monitoring from an ecological perspective.

3.5.4 Resource Units which have been identified as a priority in provincial aquatic systematic conservation plans?

Provincial systematic conservation plans have been developed throughout South Africa and are based on the concept of irreplaceability. Irreplaceability reflects the planning units ability to meet set 'targets' for selected biodiversity 'features' and ranges from 0 (not important) to 1 (critically important). Where a planning unit has an irreplaceability value of 0, all biodiversity features recorded in that unit are conserved to the target amount and, consequently, there is unlikely to be concern from a biological perspective if that area were impacted by anthropogenic activities. Resource Units with a high irreplaceability value in terms of provincial systematic aquatic conservation plans (where available) represent areas of important aquatic biodiversity and should be protected. In some cases, systematic conservation plans may have been used to develop biodiversity sector plans or bioregional plans. In such cases, outputs of these assessments should also be considered.

3.6 Determine the level of threat posed to water resource quality for the environment

Resource Units which are threatened or are likely to be threatened by current or planned future upstream activities (e.g. mines, towns, industries, dams, intensive agriculture) should be monitored due to the potential risk posed to ecological elements of the water resource. Emphasis should be placed on selecting those Resource Units most likely to be impacted by high risk activities and which could therefore have serious implications for the environment if not effectively managed. This assessment need only be undertaken for those Resource Units which received a score in the 'ecological importance' assessment.

3.7 Identify Resource Units for which management action should be prioritised

Where the PES category of a reach is currently lower than a D category or the accepted gazetted category (NEC), actions are clearly required to improve the sustainability of these Resource Units (Default rule in DWAF, 1999a). Such reaches should therefore be prioritised to monitor the effectiveness of measures implemented to improve the status quo. Equally, where PES is greater than the NEC and controlled degradation of the resource is expected - such Resource Units are not regarded as a priority for monitoring due to residual assimilative capacity of the Resource Unit.

3.8 Assess practical considerations associated with RQO determination for each Resource Unit

Apart from the criteria already considered, there are additional practical considerations which are worth considering during the Resource Unit prioritisation process. These include the availability of data to inform RQO determination and practical constraints associated with accessibility and security risks. Details of sub-criteria considered are detailed below.

3.8.1 Resource Units which contain an existing monitoring site (EWR, RHP, DWAF gauging weirs) and associated data

Resource Units with existing Ecological Water Requirement (EWR) sites typically have EcoSpecs defined for sub-components which can be used to inform the setting of RQOs. These reaches are therefore regarded as more suitable than reaches for which no EWR sites are available and data must be extrapolated or new data obtained to set realistic RQOs. It is also important to note that a prioritisation process has typically been undertaken in selecting EWR sites to account for a range of requirements. Reaches with existing monitoring points are regarded as preferable as they could (i) cut down on costs for monitoring compliance with RQOs and (ii) are likely to have data which can be used to inform the setting of RQOs in the reaches concerned. Those sites with data considered to be 'current' or where the proper EWR procedures have been used, should be ranked higher than those sites where data no longer represents the current situation or where inappropriate monitoring techniques have been used.

3.8.2 Resource Units which are accessible to visit for monitoring

Reaches which are not accessible will be difficult to monitor and as a result are less appropriate for the determination of RQOs.

3.8.3 Resource Units which are safe to monitor

Safety is a key concern in the selection of Resource Units for ongoing monitoring. Resource Units which are not considered to be safe to monitor are less desirable for RQO determination than other Resource Units. Although safety concerns can be overcome by hiring security staff to accompany monitoring teams, this adds to the cost of monitoring. It is therefore preferable to select Resource Units which do not have safety concerns.

3.9 Evaluate the relative ranking and weighting of each criterion

Standardised rankings and weightings have been proposed for each of the seven criteria used above in the prioritisation process. However, there may be strong motivation to alter these values. The purpose of this sub-step is to review the ranking and weighting of each criterion and determine whether these values are appropriate in the current context.

3.10 Select Preliminary Resource Units for RQO determination using prioritisation scores

The purpose of this sub-step is to finally select those Resource Units which should be considered for RQO determination. Summary scores are provided for each of the sub-criteria. The scores for users

and the environment integrate both the importance for users/environment and the threats to users/environment in order to calculate an overall 'concern score' for each Resource Unit. . These 'concern scores' help to highlight those Resource Units that are both important and subject to a high level of threat by anthropogenic activities and which are therefore likely to be a priority for users and the environment.

The scores for all four criteria are then combined into a priority rating which scores the Resource Units relative to each other. This provides an integrated measure to inform the selection of Resource Units. Resource Units with high scores should generally be prioritised for RQO determination however there may be good reason for selecting alternative Resource Units. A rationale for the selection of specific Resource Units should be provided particularly where Resource Units with low priority ratings are selected above those with higher ratings. It is also strongly recommended that at least one Resource Unit be selected within each IUA to ensure that management requirements within each of these units are adequately considered. Note that the number of RUs selected for a catchment may depend on the available resources of the implementing agent.

3.11 Complete the information sheet for the Resource Unit Prioritisation Tool

An information sheet for the Resource Unit Prioritisation Tool has been included on the "information sheet" tab in the tool. This sheet records the catchment name and date of the assessment together with the names and details of the people who undertook the prioritisation process. This information lends credibility and confidence to the prioritisation process and should be completed once the prioritisation process has been undertaken.

Box 17. Summary scores for the Resource Unit Prioritisation Tool applied in the Mzimkhulu catchment

The Resource Unit Prioritisation Tool summarises the information for each criterion into a prioritisation score per Resource Unit. The figure below provides an example of these scores for the Upper Mzimkhulu IUA in the Mzimkhulu catchment. Resource Unit 9 (Mzimkhulu) has the highest priority rating of 1, which can be attributed to its location in the IUA and its importance for users. Similarly, Resource Unit 9 (the swamp), which is an important wetland system and was delineated as a Resource Unit, has received a priority rating of 0.5 based largely on its importance from a conservation perspective. These two Resource Units have therefore been selected for RQO determination. Additional Resource Units could be selected depending on the nature of the system and available resources.

		Upper Mzimkhulu					
		9 - The Swamp	10 - Below Underberg	15 - Lower Phulela	16 - Tributaries N of Mzimkhulu	17 - Mzimkhulu	18 - Southern Tributary
PRIORITIZATION SCORES	Position in IUA	0.0	0.0	0.0	0.0	0.3	0.0
	Concern for users	0.0	0.0	0.0	0.0	0.1	0.0
	Concern for environment	0.2	0.2	0.2	0.1	0.1	0.0
	Management and practical considerations	0.1	0.1	0.1	0.1	0.1	0.0
	Total Prioritization Score	0.34	0.30	0.27	0.24	0.64	0.07
	Priority Rating	0.5	0.5	0.4	0.4	1.0	0.1
Select Resource Unit for RQO determination?		Y				Y	
Rationale for selection of resource units		Most important from a conservation and ecological support perspective				Lower-most point in IUA & identified as important for users (particularly irrigation)	

4. PRIORITISE SUB-COMPONENTS FOR RQO DETERMINATION AND SELECT INDICATORS FOR MONITORING

This step should be undertaken using the Resource Unit Evaluation Tools

RQOs should be quantifiable, measurable, verifiable, and enforceable and ensure protection of all components of the resource, which make up ecological integrity. There are numerous properties of a water resource that can be quantified, measured and enforced.

Chapter 14 of the National Water Act provides for the monitoring, recording, assessing and disseminating of information on water resources in the Country. In response to this, numerous monitoring programmes have been established across the Country at national, provincial and local scales. These monitoring programmes facilitate the continued and co-ordinated monitoring of various aspects of water resources by collecting relevant information and data, through established procedures and mechanisms, from a variety of sources including organs of state, water management institutions and water users. These programmes provide valuable information on the status and trends of different aspects of water resources and help to assess the effectiveness of measures to protect water resources.

Although this information may be useful in the development of RQOs, the presence of a monitoring programme for a particular aspect or sub-component in an area does not necessarily mean that this aspect or sub-component will be selected as an RQO. The purpose of RQOs is to establish clear goals relating to the quality of the water resource and which balances social needs and ecological requirements. The RQO process is therefore an objectives driven approach which provides a short list of variables for RQO monitoring based on their ecological and social importance. These variables will be case and region specific and may be non-traditional but meaningful in the context (e.g. pan water depth may be an important variable in a floodplain but will not be used in other locations). It is important to note that RQOs will not replace the various monitoring programmes.

Step 4 of the RQO process has two key objectives. Firstly, to identify and prioritise sub-components that may be important to either users or the environment and secondly to select those sub-components and associated indicators for which RQOs and Numerical Limits should be developed. This step in the RQO process bears particular relevance to the consideration of the impacts of land-based activities on the water resource.

Although there is wide range of sub-components for which RQOs can be set, it is not necessary or practical to set RQOs for all sub-components in all selected Resource Units. A rationalisation process is therefore required to evaluate and prioritise sub-components for RQO determination. A decision support tool has been developed to guide this prioritisation process. The **Resource Unit Evaluation Tool** has two primary functions (i) to determine the level of threat posed to each of the sub-components by impacting activities in the catchment and secondly (ii) to identify which sub-components should be protected in order to support water resource dependent activities and/or maintain the integrity and ecological functioning of the water resource. This information is then used to prioritise sub-components for RQO determination.

Although the tool can be applied using desktop information, local knowledge and a thorough understanding of the catchment is recommended. The assessment should therefore ideally be done in conjunction with the relevant catchment managers and other key individuals with a good understanding of the area and also the ecosystem.

A number of sub-steps are proposed in undertaking Step 4. These are briefly described below. For further information, and detail relating to applying the Resource Unit Evaluation Tools, users are encouraged to consult the supporting information included in Annexure 2.

Box 18. Resource Unit Evaluation Tool for Estuaries

The Resource Unit Evaluation Tool has been customised for estuaries by including sub-components relevant to estuarine environments. The process outlined for rivers is however directly relevant for estuaries. The steps detailed below and applied to river Resource Units should also be followed for estuaries.

Box 19. Resource Unit Evaluation Tool for wetlands

The Resource Unit Evaluation Tool has been customised for wetland Resource Units by including sub-components relevant to wetland areas. The process outlined for rivers is however directly relevant for wetlands. The steps detailed below and applied to river Resource Units should also be followed for wetlands.

4.1 Identify and assess the impact of current and anticipated future use on water resource components (Impacting activities tab)

The first sub-step in prioritising sub-components for RQO determination involves building an understanding of current impacts and future pressures on the Resource Unit. This is important in that there is likely to be a greater urgency to set RQOs for water resource quality components that are heavily impacted and / or threatened by impacting activities than components that are largely unaffected or unlikely to deteriorate with future development. This sub-step should be undertaken using the 'Impacting activities' worksheet in the Resource Unit Evaluation Tool. An example of the impact assessment applied in the Mzimkhulu is provided in Box 20.

4.1.1 Assess the importance of activities in driving resource change

Consideration should be given to current users (existing and authorised water use) and anticipated future use (within next 10 years) within *and upstream* of the RU. The importance of activities that impact on the water resource is determined by the anticipated level of impact to the water resource and the contribution of the activity to the economy. The anticipated level of impact to the water resource should be informed by an understanding of the impacting activity (e.g. nature and extent of activities, duration, intensity and magnitude of anticipated impacts). Those activities which are considered to have a significant impact should be rated as very important users irrespective of their contribution to the economy. The economic contribution of activities should be assessed in terms of their contribution to GDP, the number of jobs that they provide and whether they are a strategic water user. A brief description and rationale for the rating assigned to each user should be provided.

4.1.2 Determine the anticipated level of impact on each sub-component

Each of the listed activities (e.g. irrigated agriculture, urban areas, rehabilitation, etc.) has the potential to impact the components and sub-components of the water resource in a variety of different ways. The purpose of this sub-step is to identify those sub-components which are threatened as a result of high levels of impact as such sub-components should be prioritised over those sub-components which are experiencing a low level of impact. This assessment is undertaken by capturing the anticipated level of impact for each important or very important user group identified above. Here, consideration is given to both current activities and *planned* future uses (within the next 10 years) which could impact on water resource components. The assessment should be based on

the scale, location and intensity of the current and future activities in the Resource Unit and/or catchment.

4.1.3 Determine the cumulative level of impact on each sub-component

The purpose of sub-step 4.1.3 is to identify the cumulative effect of all of the impacting activities on each sub-component. Cumulative effects are commonly understood as the impacts which combine from different activities and which result in significant change, which is larger than the individual impacts. Based on a review of impact scores, a 'cumulative level of impact' score for each sub-component should be selected using the impact rating guidelines. In doing so, it is important to differentiate between those components with a high and low anticipated level of impact and associated threat to water resource quality. It is recommended that specialists are included in this process. This information is then used to automatically determine an Impact Class for each sub-component.

4.1.4 Determine the anticipated consequences of the impacting activities on each sub-component

Once an understanding of key impacts driving current and future impacts to the Resource Unit have been assessed, this is used to help inform an assessment of the anticipated consequences of impacting activities on water resource quality. This is expressed as a projected trajectory of change for each sub-component and is informed by the 'cumulative level of impact' score. The potential impact of activities on the various sub-components is not always obvious and it is therefore recommended that specialists are included in this assessment to ensure that potential impacts on all sub-components are adequately identified and captured.

Box 20. Example of the 'Impacting activities' worksheet of the Resource Unit Evaluation Tool applied in the Mzimkhulu catchment (Note that not all columns and user groups have been displayed)

Identify and assess impact of current and anticipated future use			Quantity		Quality					Habitat		Biota							
			Low Flows (Maintenance Flows)	High Flows (Floods)	Nutrients	Salts	System variables	Toxics	Pathogens	Instream habitat	Riparian habitat	Fish	Aquatic & riparian plant species	Mammals	Birds	Amphibians & reptiles	Periphyton	Aquatic Invertebrates	Diatoms
User Group Type	User Group	Relative importance in driving resource change (current & future)	Anticipated level of impact (current & future use) Impact rating: Very High: -1; High: -0.75; Moderate: -0.5; Low: -0.25; None: 0 Note: Positive scores are allocated where an improvement in PES is anticipated																
Activities that impact on water resource.	Afforestation	Not important users																	
	Alien vegetation	Important users	-0.25	0	0	0	0	0	0	-0.25	-0.5	-0.25	-0.5	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
	Concentrated livestock operations	Important users	0	0	-0.75	0	-0.25	-0.25	-0.75	-0.25	-0.25	-0.5	0	0	0	-0.5	-0.5	-0.25	-0.25
	Dams	Very important users	-0.5	-0.25	0	0	0	0	0	-0.75	-0.25	0	-0.25	0	0	0	-0.25	-0.25	-0.25
	Dryland agriculture (including sugarcane & other crops)	Not present																	
	Irrigated agriculture	Important users	-0.5	0	-0.25	0	-0.25	0	0	0	0	0	0	0	0	-0.25	-0.25	-0.25	-0.25
	Livestock grazing	Important users	0	0	-0.25	0	-0.25	0	-0.25	0	-0.5	0	-0.5	0	0	0	0	0	0
	Sewage works and solid waste sites	Not important users																	
	Urban areas	Important users	-0.25	0	-0.25	0	0	-0.25	-0.25	0	0	0	0	0	0	0	0	-0.25	-0.25
	Urban Informal settlements	Not important users																	
	Rehabilitation activities	Not important users																	
	Other	Not present																	
	Cumulative level of impact		-1.00	-0.25	-1.00	0.00	-0.75	-0.50	-1.00	-1.00	-1.00	-0.75	-1.00	-0.25	-0.25	-1.00	-1.00	-1.00	-1.00
	Impact Class		VH (-)	L (-)	VH (-)	N/A	H (-)	M (-)	VH (-)	VH (-)	VH (-)	H (-)	VH (-)	L (-)	L (-)	VH (-)	VH (-)	VH (-)	VH (-)
			Anticipated consequences (trajectory of change) resulting from current and future impacting activities																
			↓	→	↓	→	→	↓	↓	↓	↓	→	→	→	→	→	↓	↓	↓

4.2 Identify requirements of important user groups

The second sub-step in prioritising sub-components for RQO determination entails identifying which groups are using the resource, classifying the importance of these groups and determining which sub-components are important to them. This sub-step should be undertaken using the 'User requirements' worksheet in the Resource Unit Evaluation Tool.

4.2.1 Identify important user groups within the 'protection of the water resource' and 'water resource dependent activity' user group types

The purpose of this sub-step is to identify water users that need to be considered when setting RQOs. This is done by assessing the relative importance of user groups within the Resource Unit. Ideally, those user groups who are identified as 'important' or 'very important' should have a greater say in deciding the desired direction and magnitude of change of each of the water resource components. The relative importance of user groups is therefore assessed and recorded with a supporting rationale in the Resource Unit Evaluation Tool. An example of the template used for this assessment in the Mzimkhulu catchment is provided in Box 21.

4.2.2 Rate the importance of sub-components for the 'protection of the water resource' and 'water resource dependent activities'

The purpose of sub-step 4.2.2 is to determine which sub-components are important and / or of concern to different user groups. This is determined by rating the importance of sub-components for users who have been identified as important or very important and is used to calculate an importance score for each sub-component. This helps to highlight sub-components of primary concern to different user groups, thus reflecting aspects of the water resource that they feel need to be closely monitored.

4.2.3 Summarise the aspirations of each important user group

Opportunity is provided to summarise relevant aspirations of conservation agencies and users dependent on the water resource. In the case of conservation agencies and users dependent on the water resource, stakeholders may highlight specific components or attributes of the water resource which are of concern to them. These aspirations effectively provide a justification for assigning a particular rating or score in the previous importance assessment. This justification, particularly specific attributes, should be captured in narrative format in the appropriate column in the Tool as it may be useful in selecting indicators in later steps of the RQO process. For example, subsistence users may have ranked water quality as an important ecosystem service and component because of elevated levels of *E. coli* which are detrimental to their health. This rationale should be captured as *E. coli* could be selected later on as an appropriate indicator.

4.2.4 Review Present State information

Sub-step 4.2.4 requires that the Present State information is documented for each sub-component. This is necessary to inform the desired direction of change for users. From a protection perspective, this entails the collection of Present Ecological State information, while for water resource dependent activities, present state is expressed in terms of 'fitness for use'.

When completing the information for the 'protection of the water resource' user group, the Ecological Category should first be recorded for each sub-component. This data may be obtained from a range of sources such as the Ecological Reserve or River Health Programme data. Where the Present Ecological State has not been determined, expert judgement should be applied. However, in these instances, the confidence in the data should be scored as low. Categories for 'confidence in the data' may be scored as high, moderate, low or very low.

The 'fitness for use' category for each sub-component for the 'water resource dependent activities' user group must then be recorded. At a low confidence level, this simply entails selecting an appropriate use category from Table 11 below based on available information and user requirements. By default, the most stringent user requirements or most sensitive user is used to inform the selection of an appropriate category. For further information on linking user categories for water quality components refer to the Guideline for Determining Resource Water Quality Objectives, Allocatable Water Quality and the Stress of the Water Resource (DWAF, 2006c).

Table 11. User categories used to define the present state for users (DWAF, 2006c)

Fitness for use category	User category and effect
Ideal	No risk to user (e.g. no health risk; no aesthetic risk)
Acceptable	Very low risk to user (e.g. slight health risk for sensitive individuals, noticeable aesthetic effect but acceptable)
Tolerable	Slight risk to user (e.g. Slight health risk for most individuals, objectionable aesthetic effect to sensitive persons)
Unacceptable	Significant risk to user (e.g. Severe health risks, aesthetically unacceptable)
Totally unfit for use	Gross pollution or deviation from the norm

The current trajectory of change for each component is also estimated. This is informed by the assessment of impacting activities (undertaken in sub-step 4.1) but may be over-written based on more reliable information.

4.2.5 Propose the desired direction and magnitude of change for each sub-component for important user-groups

For 'water resource dependent activities' and organisations responsible for protecting the natural environment, an assessment of the desired direction of change is undertaken to provide an indication of whether stakeholders would like a particular sub-component of the water resource to be improved or whether some level of degradation may be acceptable.

Both the importance ratings for each of the sub-components and present state / fitness for use information can be used to guide this assessment. Sub-components which are perceived to be of high importance and are either in a poor state / unacceptable condition or are threatened by current or future activities, provide strong motivation to improve the management of the water resource, while maintaining the status quo may be acceptable where importance is scored as moderate or low and present state / fitness for use is acceptable. For example, subsistence users who are entirely reliant on water from the river (high importance) which currently have moderate *E. coli* levels, may require a reduction in these levels and therefore an improvement in water quality to minimise the risk to health. However, use of the riparian zone may be limited and despite being degraded current state of habitat may be still be acceptable to this user group.

Box 21. Example of the 'User requirements' worksheet of the Resource Unit Evaluation Tool applied in the Mzimkhulu (Note that not all columns and user groups have been displayed)

Below is an example of the application of the user assessment for Resource Unit 10 in the Mzimkhulu. This example only shows the application for the 'protection of the water resource' user group type however a similar assessment would be undertaken for 'water resource dependent activities'. It is important to note that some sub-components have not been shown.

Identify requirements of important user groups				Quantity	Quality					Habitat		Biota				
				Low Flows (Maintenance Flows)	Nutrients	Salts	System variables	Toxics	Pathogens	Instream habitat	Riparian Habitat	Fish	Amphibians & reptiles	Periphyton	Aquatic Invertebrates	Diatoms
User Group Type	User Group	Relative importance of user group	Rationale for rating importance of user groups	Rating of importance of components for protection of the water resource Very High:1; Moderate:0.5; Not important:0												
Protection of the resource	Conservation	Not important users	EIS only moderate - no known important red data species or habitats of specific conservation value	0	0	0	0	0	0	0	0	0	0	0	0	0
	Maintenance of ecosystem characteristics	Important users	The water resource is in reasonable condition and supports basic ecological processes. It is characterised by a number of features.		0.5	0.5	0.75				0.5				0.5	
	Importance Score			0.00			0.38	0.00	0.00							
	Review of Present Ecological State Information															
	Present ecological state			B/C	A	A	A	A	A/B	B	B	A	?	?	B	B
	Trajectory of change			↓	↓	→	→	↓	↓	↓	↓	→	→	↓	↓	↓
	Confidence in data			High	High	High	High	High	High	Moderate	Moderate	Moderate	Very Low	Very Low	Moderate	Moderate
	Desired direction & magnitude of change in PES to ensure protection of water resource															
	Direction of change			→	↑	→	→	→	→	→	↑	→	→	→	→	→

4.3 Selection of sub-components for RQO determination

The purpose of this sub-step is to select the key sub-components for RQO determination and identify appropriate indicators to monitor them. This sub-step should be undertaken using the 'Indicator selection' worksheet in the Resource Unit Evaluation Tool. An example of the template used for this assessment in the Mzimkhulu catchment is provided in Box 22.

4.3.1 Review the Ecosystem and User Prioritisation ratings

Two prioritisation ratings, one for the ecosystem and the other for users, are automatically calculated. These prioritisation ratings are based on how important a sub-component is from an ecological or user perspective and whether this sub-component is threatened by anthropogenic activities occurring in the catchment. The overall prioritisation ratings range from very low to very high. Very high ratings highlight those sub-components which are both important from an ecological and/or user perspective and which are threatened by anthropogenic activities. Such sub-components are logical choices for RQO determination

4.3.2 Select sub-components and associated indicators for RQO determination

The overall priority ratings should be used to guide the selection of sub-components for RQO determination. Sub-components with high scores should generally be selected first. A rationale for selecting each sub-component should also be provided. Based on the rationale for sub-component selection, the selection of a sub-component as a 'UserSpec', 'EcoSpec' and/or 'Integrated measure' should be documented. This should be informed by the Ecosystem and User Prioritisation ratings. For example, if the Ecosystem Prioritisation rating for a particular sub-component was high, then it is likely that this sub-component has been selected as an 'EcoSpec'.

Once sub-components have been selected, suitable indicators for monitoring should be identified. Again, the selection of this indicator should be informed by the Ecosystem and User Prioritisation rating and the associated aspirations of the user group which was captured in sub-step 4.2.3. For example, faecal coliforms may have been selected as an appropriate indicator for setting RQOs and monitoring them because the Resource Unit is important for recreation and under threat by the expansion of informal settlements. The rationale for selecting the indicator should then be captured in the appropriate column in the Resource Unit Evaluation Tool.

Box 22. Example of the ‘Indicator selection’ worksheet of the Resource Unit Evaluation Tool applied in the Mzimkhulu catchment (Note that not all columns and user groups have been displayed)

Selection of sub-components for RQO determination			Quantity	Quality			Habitat		Biota			
			Low Flow: (Maintenance flows)	Nutrients	Salts	Pathogens	Instream habitat	Riparian habitat	Fish	Aquatic & riparian plant species	Aquatic invertebrates	Diatoms
Selection guidance	EcoSpec Selection	Importance Rating	VL	L	L	VL	VL	L	VL	VL	L	VL
		Impact Class	VH (-)	VH (-)	N/A	VH (-)	VH (-)	VH (-)	H (-)	VH (-)	VH (-)	VH (-)
		Ecosystem prioritization rating	Low	Moderate	Very Low	Low	Low	Moderate	Very Low	Low	Moderate	Low
	UserSpec Selection	Importance Score (Water Dependant Activities)	1	0.75	1	1	0.75	0.75	0.75	0	0	0
		Importance Rating	VH	VH	VH	VH	VH	VH	VH	VL	VL	VL
		Impact Class	VH (-)	VH (-)	N/A	VH (-)	VH (-)	VH (-)	H (-)	VH (-)	VH (-)	VH (-)
		User prioritization rating	Very High	Very High	Low	Very High	Very High	Very High	High	Low	Low	Low
Documenting selection process & rationale	Select for RQO Determination		Y	Y		Y		Y				Y
	EcoSpec							Y				
	UserSpec		Y	Y		Y		Y				
	Integrated Measure											Y
	Indicators Selected for RQO determination		Flow (m ³ /sec)	SRP (µg/litre)		E. coli / 100ml		Density of infestation by wattle				Specific Pollution Index (SPI) Score

4.4 Establish the desired direction of change for selected sub-components

Once sub-components and relevant indicators have been selected, it is important to establish the level at which RQOs will be set. Where Water Resource Classification has been undertaken, any decisions need to be aligned with the decisions made as part of that process and relevant information needs to be interrogated accordingly. In the absence of such a study, the direction of change needs to be decided through consultation with key stakeholders and experts. Decisions taken are captured on the 'Desired direction of change' worksheet in the Resource Unit Evaluation Tool. An example of the template used for this assessment in the Mzimkhulu catchment is provided in Box 23.

4.4.1 Where applicable, understand the tradeoffs that have been made between user groups in the Water Resource Classification

Before applying the tool and proposing a particular direction and magnitude of change, it is first important to establish whether decisions have already been made regarding the future management of selected Resource Units. This sub-step therefore requires investigating any decisions made within the Water Resource Classification. This sub-step can be omitted where the Water Resource Classification has not been undertaken.

The Water Resource Classification models a range of possible scenarios for the catchment. Based on the implications of these scenarios, a preferred scenario is selected. This scenario stipulates the required state of each Resource Unit within the catchment and associated IUAs. The required state of each RU is termed the Nested Ecological Category (NEC). The NECs are gazetted and are legally binding. It is therefore vital that the aspirations of stakeholders are managed within the framework of the Water Resource Classification. For example, where the Water Resource Classification has stipulated that the PES will be degraded to a D category for a particular Resource Unit, it may not be possible for stakeholders participating in the RQO process to request a significant improvement in water quality to meet water quality requirements for sensitive biota. The purpose of this sub-step is therefore to ensure that the direction and magnitude of change in components requested by stakeholders in the RQO process is aligned with the outcomes of the Water Resource Classification.

Step 5 of the Water Resource Classification System determines where economic, social and ecological tradeoffs will be made in the catchment. The social, economic and ecological information is presented per scenario for each IUA. Using this information and comparing it against the Present Ecological State, it is possible to assess which of these three categories are considered to be most important in the selected scenario. An example of this information is provided in Table 12 below.

Table 12. Examples of trade-offs between user groups undertaken in the Water Resource Classification for IUA2 – Doring Rangelands (extracted from DWAF, 2007)

	SOCIAL WELL BEING					ECOSYSTEM INDEX			ECONOMIC PROSPERITY						Overall consequences of scenario
	0% 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	
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-EC+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	1.1			0.16
std wts					0.50			0.10						0.40	

In this example, if Scenario 3 (REC + Cons.) is accepted and compared to Scenario 2 (PES) it can be seen that the social well-being score is maintained (44 in Scenario 2 vs 45 in Scenario 3) while the Ecosystem Index increases (66 in Scenario 2 vs 76 in Scenario 3) and the Economic Prosperity score decreases (45 in Scenario 2 vs 38 in Scenario 3). These changes in scores indicate that the protection of ecological aspects have been prioritised at the expense of economic prosperity in this IUA.

Although a general improvement in ecological aspects may be accepted for the IUA, this may not be so for individual Resource Units. Indeed, there may only be a few Resource Units where specific protection measures are advocated to protect particularly important species. The Resource Units in which such changes are required can be identified by comparing the Present Ecological State with the desired future state reflected in the Nested Ecological Category. Where, the Present Ecological State is lower than the Nested Ecological Category, the present state of the water resource will need to be improved whereas if the NEC is lower than the Present Ecological State some level of controlled degradation may be permissible. Table 13 provides an indication of situations where the Present Ecological State should be improved, maintained or allowed to degrade.

Table 13. Information from the WRCS used to determine if the Present Ecological State should be improved, maintained or allowed to degrade

		RU NEC			
		A	B	C	D
RU PES	A	Maintain	Controlled degradation	Controlled degradation	Controlled degradation
	B	Improve	Maintain	Controlled degradation	Controlled degradation
	C	Improve	Improve	Maintain	Controlled degradation
	D	Improve	Improve	Improve	Maintain
	<D	Improve	Improve	Improve	Improve

In the example below, there are thirteen Resource Units in the Doring-Rangelands IUA (see Table 14). However, when the PES and NEC (for the REC+Cons Scenario) are compared, only four Resource Units (R12, R25, R28 and R36) require an improvement in their PES while the PES of the remainder of the Resource Units can simply be maintained. The desired direction and magnitude of change in the sub-components should therefore be set in line with the results of this assessment (e.g. if R12 is being considered then an improvement in the ecological elements is necessary, whereas if R30 is being considered then the status quo must be maintained).

Table 14. Scenarios for the Olifants/Doring catchment (taken from the WRCS (DWAF, 2007a)

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	R 12	C	A	b	66.33	75.73	54.99	Class III	Class II	Class III
Doring Rangelands	R 20	B	B	D						
Doring Rangelands	R 21	C	C	D						
Doring Rangelands	R 22	C	C	D						
	R 25	B	A	b						
Doring Rangelands	R 27	C	C	D						
Doring Rangelands	R 28	B	A	D						
Doring Rangelands	R 29	C	C	D						
Doring Rangelands	R 30	C	C	c						
Doring Rangelands	R 31	C	C	D						
Doring Rangelands	R 32	C	C	b						
Doring Rangelands	R 36	B	A	c						
Doring Rangelands	R 50	C	C	b						

4.4.2 Propose an acceptable direction of change for each selected sub-component

The 'Desired direction of change' worksheet in the Resource Unit Evaluation Tool provides a summary of the desired and / anticipated magnitude and direction of change in the present state / fitness for use of each sub-component for each activity type. This information is used as a basis for discussion and seeking consensus regarding an acceptable direction of change. Where the Water Resource Classification has already been applied, decisions must be in line with the Water Resource Classification outcomes. This includes the overall management objective and trade-offs between user groups identified in sub-step 4.4.1. Similarly, special limit values may have been applied in some catchments. These values are legally binding and must be considered in deciding the acceptable direction of change.

It is recommended that the precautionary approach be applied in proposing an acceptable direction of change. However, there may be instances where controlled degradation of the water resource is permissible (e.g. in the vicinity of a mine (see DWAF, 2007b))

A rationale for proposing a particular direction and magnitude of change should be documented in the appropriate column of the model.

4.4.3 Align the outcomes of each RU assessment across the catchment

The purpose of sub-step 4.4.3 is to align the proposed direction and magnitude of change between Resource Units. Because management decisions affect downstream water resources, the proposed direction of change of a component in one Resource Unit may impact the proposed direction of change of a component in an adjacent or downstream Resource Unit. For example, water quality may not be an issue to users in one Resource Unit and are therefore prepared to accept some level of degradation in water quality however users in a neighbouring downstream Resource Unit may require

a major improvement in water quality. It is therefore necessary for the expert group to review and align the outcomes of the Resource Unit assessments across the catchment. The refined direction of change based on the alignment of Resource Units should be captured in the Resource Unit Evaluation Tool. The catchment and IUA visions should also be carefully considered during this process as key areas identified in these visions should be given preference in terms of their requirements.

4.5 Complete the information sheet for the Resource Unit Evaluation Tool

An information sheet for the Resource Unit Evaluation Tool has been included on the “information sheet” tab in the tool. This sheet records the relevant catchment name, IUA and Resource Unit and the date of the assessment. It also requires that the names and details of the people who undertook the prioritisation process and their associated role in the assessment are detailed. This information lends credibility and confidence to the evaluation process and should be recorded once the process has been completed.

Box 23. Example of the 'Desired direction of change' worksheet of the Resource Unit Evaluation Tool applied in the Mzimkhulu catchment (Note that not all columns and rows have been displayed)

Establishing desired change for selected sub-components			Quantity		Quality			Habitat		Biota					
			Low Flows (Maintenance Flows)	Nutrients	Salts	System variables	Toxics	Pathogens	Instream habitat	Riparian habitat	Fish	Amphibians & reptiles	Periphyton	Aquatic invertebrates	Diatoms
Guidance information	Selected Indicators		Y	Y				Y		Y					Y
	Ensuring Protection of resource	Present ecological state	B/C	A				A/B		B					B
		Trajectory of change	↓	↓				↓		↓					↓
		Desired direction & magnitude of change in PES in line with protection priorities and aspirations	→	↑				→		↑					→
	Water Resource dependent activities	Fitness for use for users	Acceptable	Ideal				Acceptable		Tolerable					N/A
		Trajectory of change	↓	↓				↓		↓					N/A
		Desired direction & magnitude of change in fitness for use in line with user priorities and aspirations	→	↑				↑		↑					N/A
Documenting direction & magnitude of change & supporting rationale	Proposed direction of change		→	→				→		↑					→
	Refined direction of change		→	→				→		↑					→

5. DEVELOP DRAFT RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS

The National Water Act requires that Resource Quality Objectives, which may relate to all components of the water resource including quantity, quality, habitat and biota, are set for all or part of every significant water resource. The Act also stipulates that RQOs include the requirements for achieving the objectives. These Resource Quality Objectives are then published by way of government notice in the government gazette.

As described in Section F of the Introduction, RQOs are essentially narrative but sometimes broadly quantitative descriptions of the resource. These are gazetted and are supported by Numerical Limits which are not.

5.1 Carry over sub-component and indicator information from the Resource Unit Evaluation Tool

From the Resource Unit Evaluation Tool, carry over the list of sub-components and indicators selected for monitoring, identifying whether they have been selected as an 'EcoSpec', 'UserSpec' or 'Integrated measure' and detailing the rationale for considering these. This information will be used as the basis for Step 5. This sub-step must be undertaken for each Resource Unit.

Box 24. Example of indicators identified for RU 10 in the Mzimkhulu catchment

The indicators identified for Resource Unit 10 in the Mzimkhulu example are provided in the table below. In addition, the rationale for their selection and whether they are considered to be an EcoSpec, UserSpec or Integrated measure is provided.

Sub-component	UserSpec	EcoSpec	Integrated measure	Rationale	Indicator
Low flows	√			Agricultural and animal production enterprises are reliant on a steady supply of base flows. Recreational, tourism & real estate benefit from a river characterised by good dry season flows. If future abstractions are un-checked, this could result in a significant deterioration in base flows, negatively affecting existing users and habitat for aquatic biota.	Flow (m ³ /sec)
Nutrients	√			This water resource is naturally characterised by very low nutrient levels. Trends in monitoring indicate that nutrient levels are increasing which could impact on ecosystem health and aesthetic quality along the river reach.	SRP (ug/litre)
Pathogens	√			There is a clear trend of increasing <i>E. Coli</i> levels in the system. This poses a risk to recreational activities and livestock watering.	<i>E. coli</i> / 100ml
Riparian habitat	√	√		The density of Wattle infestation is impacting on the condition of the riparian habitat (and affecting aesthetics)	Density of infestation by wattle
Diatoms			√	Diatoms provide a useful composite measure of ecosystem health, particularly where water quality is an important issue.	Specific Pollution Index (SPI) Score

5.2 Extract available data to determine the present state for selected sub-components and indicators

All available data which may assist in determining the present state of selected indicators should be gathered. This information, or lack thereof, can also be used to identify where additional data collection may be necessary. The Present Ecological State (PES) of sub-components is usually determined through EcoClassification as part of the Reserve process and may be an invaluable source of information. This information assists in determining the level at which to set RQOs, as it relates the present state of each sub-component to reference conditions.

The Present Ecological State of a water resource is expressed in terms of its bio-physical components.

- Drivers (Physico-chemical, geomorphology, hydrology) which provide a particular habitat template
- Biological responses (fish, riparian vegetation and aquatic invertebrates)

The Ecological Status or EcoStatus represents the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna. The EcoStatus provides an integrated measure of the drivers and biological response components.

Different EcoClassification models are used to assign an Ecological Category to each component. The Ecological Category is used to define and type the ecological condition of a river in terms of the deviation of the biophysical components from the natural reference condition. Weighted scores, obtained from the respective EcoClassification models, are expressed as a percentage of the maximum. This value indicates the deviation away from the expected reference condition. These values are then used to place a component into a particular Ecological Category ranging from A to F where 'A' is an unmodified state and 'F' is critically modified.

Table 15. Generic ecological categories for EcoStatus components (modified from Kleynhans, 1996, 1999)

ECOLOGICAL CATEGORY	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of moderate habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

Within each of the respective EcoClassification models, the driver and response components are further sub-divided into metric groups. Metrics are systems of parameters and define what needs to be measured. For example, the metrics considered in the VEGRAI model include cover, abundance, population structure and recruitment for both woody and non-woody vegetation. Ecological specifications, or EcoSpecs, can be linked to either the Ecological Category and/or to different metrics

and metric groups within each component. If the EcoClassification process has been undertaken, EcoSpecs should already be detailed for each of the Ecological Categories. The EcoSpecs which relate to a selected indicator for the Present Ecological State can therefore simply be extracted from this documentation.

Box 25. Present ecological status for estuaries

The Estuarine Health Index is used to determine the PES of an estuary. The Estuary Health Score represents the degree to which an estuary resembles its pristine ecological state.

Example of the Estuary Health Index:

VARIABLE	WEIGHT	SCORE
<u>Abiotic (habitat) variables</u>		
Hydrology	25	41
Hydrodynamics and mouth condition	25	80
Water quality	25	59
Physical habitat	25	80
1. Habitat health score = weighted mean	50	65
<u>Biotic variables</u>		
Microalgae (minimum score of phytoplankton or benthic microalgae)	20	60
Macrophytes	20	60
Invertebrates (minimum score of Zooplankton, Benthic invertebrates, Macrocrustaceans)	20	70
Fish	20	60
Birds	20	90
2. Biological health score = weighted mean	50	70
ESTUARY HEALTH SCORE = weighted mean of 1 and 2		68.5

An estuary is assigned to a Present Ecological Status, which indicates six broad categories of estuary health, as indicated below. Thus in the example calculated above, an estuary scoring 68.5 points would be classified as 'C'.

Recommended guidelines for the classification of the Present Ecological Status (PES) of an estuary.

ESTUARINE HEALTH INDEX (EHI) SCORE	PRESENT ECOLOGICAL STATUS	DESCRIPTION
100 - 91	A	Unmodified, natural
76 – 90	B	Largely natural with few modifications
61 – 75	C	Moderately modified
41 – 60	D	Largely modified
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

The EcoClassification process however, only considers ecological requirements and does not take cognisance of user needs. Ideally, the Water Resource Classification, which balances both user and ecological requirements, should provide a breakdown of the sub-component Ecological Categories which contribute to the overall EcoStatus of both the Present Ecological State and the Nested Ecological Category for each Resource Unit (e.g. The NEC for RU 1 is in a C category which comprises Hydrology in a C category, Water Quality in a B category, Geomorphology in a C category, Riparian vegetation in a C category, Aquatic Invertebrates in a C category and Fish in a B category). The NEC and its associated Ecological Categories for its sub-components effectively establish the limits within which RQOs can be set. This information can then be linked to EcoSpecs (which should be detailed per Ecological Category in the EcoClassification) to establish the present and required state for the selected indicators.

In many instances however, EcoClassification data may not be available or may not be suitable for determining the present state of selected indicators. In these cases, data for the present state of selected indicators should be gathered from alternative sources. These may include the River Health Programme, National Water Resource Monitoring Programmes (National Chemical and Salinity Monitoring Programme, National Eutrophication Monitoring Programme, National Microbial Monitoring Programme, National Toxicity and Toxicant Monitoring Programme), National Freshwater Priority Assessment data, and data contained in specialist reports compiled as part of Environmental Management Frameworks or Environmental Impact Assessments.

Where available, data should also be extracted from the Resource Water Quality Objectives model which is particularly useful for determining the level at which to set UserSpecs.

5.3 Assess the suitability of the data

The purpose of this sub-step is to evaluate the suitability of available data for determining the present state of each of the selected indicators. Where the data is deemed to be suitable, it can then be used to determine the present state of the selected indicators. Alternatively, additional data collection may be required before the present state can be determined. Factors which should be considered in evaluating the adequacy of the data include:

- The age of the data
- The techniques and methods used
- The format of data
- The season in which it was collected
- Whether the data has been extrapolated

Kleynhans and Louw (2006) provide guidance on how to assess the suitability of data. It is recommended that this document be consulted during this sub-step.

5.4 Where necessary, collect data to determine the Present State for selected indicators

In setting RQOs, it is important to have a good understanding of the present state of the indicators that have been selected for RQO determination. This information provides a baseline against which aspirations and/or management objectives can be compared thereby ensuring that the RQOs are set at an appropriate level.

Where data is available and suitable (as determined in sub-steps 5.2 and 5.3) it can be used to establish the Present State for each of the selected indicators. However where there is no available data or the data is deemed to be inadequate, it may be necessary to collect present data for the selected indicators. Prior to collection, it is necessary to identify an appropriate monitoring site and

determine the most appropriate method for collecting this information. For example, if the indicator is the size and number of yellowfish, then a survey to collect data on the size and numbers of yellowfish will need to be undertaken. It is not however necessary to complete a comprehensive assessment of the fish using the FRAI model. The results of this sampling exercise can then be used to determine the present state of the selected indicators.

For Resource Units where sub-components of water quality have been selected as UserSpecs, the Present State should be determined for all present and future Water Users by calculating water quality statistics, assessing the fitness for use of each variable of concern and classifying it as Ideal, Acceptable, Tolerable and Unacceptable (this can be automated using the RWQM model).

5.5 Determine the level at which to set RQOs

5.5.1 Carry over the proposed direction of change from the Resource Unit Evaluation Tool

Step 4 of the RQO process entailed proposing the most appropriate and feasible direction and magnitude of change for each of the selected sub-components. This information should be carried forward to this sub-step as it provides an indication of the level at which to set the respective RQOs.

5.5.2 Consider the requirements defined by the Water Resource Classification

The Nested Ecological Category and Management Class as defined by the Water Resource Classification need to be considered first. The NEC should be matched with the EcoStatus from the Ecological Reserve. The composition of the NEC should then be informed by the Ecological Reserve. For example, if the NEC is a B, then the Ecological Reserve should provide a breakdown of the EcoStatus B into its various components e.g. water quality is in an C, aquatic invertebrates are in a B riparian vegetation is in a B, hydrology is a C, *etc.* The Reserve should also provide a breakdown of each of these sub-components into smaller sub-components. For example, Nutrients, Toxics, Pathogens, *etc* may all have an Ecological Category which can be extracted, as can the actual EcoSpecs which have been set during the Reserve process. Where these EC's have been determined, the Resource Quality Objectives should be set in line with the sub-component Ecological Categories. These ECs (and EcoSpecs) define the upper and lower limits for the RQOs and associated Numerical Limits.

5.5.3 Review the stakeholder aspirations and translate into Numerical Limits

During Step 4, the aspirations of stakeholders for management of specific components were identified. These aspirations informed the 'proposed direction of change' for each of the components and also influenced the final selection of sub-components for RQO determination. These aspirations have also been captured, in part, in the rationales for selecting a particular sub-component. For example, Faecal coliforms were selected as an indicator for pathogens as full contact recreation is an important activity in the Resource Unit.

The first task in this sub-step is to ensure that the aspirations for each selected sub-component are understood and expressed numerically. Guideline documents should be used to inform the translation of management aspirations into Numerical Limits, for example the DWAF Water Quality Guidelines have been used to categorise water quality as Ideal, Acceptable, Tolerable and Unacceptable for each water user category. Where no reliable information or guideline documents are available, expert judgment should be used to determine the required level of a selected indicator. In such cases, these indicators should be assigned a low confidence rating but can be refined over time through an adaptive management process.

The Reserve Information should also be considered in this sub-step. Specialist may need to translate the aspirations into Ecological Category and extract the relevant EcoSpecs from the Ecological Reserve.

Box 26. Examples of aspirations and guideline levels for two indicators selected for Resource Unit 10 in the Mzimkhulu catchment

E. coli and low flows were selected as indicators for Resource Unit 10 in the Mzimkhulu catchment. *E. coli* was selected as the river is used for contact recreation. The guideline level for *E. coli* for contact recreation has therefore been extracted from the South African Water Quality Guidelines. Similarly, low flows were selected as an indicator as users would like the low flows maintained. The Ecological Reserve value has therefore been used as the guideline level.

Type	Aspiration	Guideline Level	Source
<i>E. coli</i>	There is a requirement for low risk for contact recreation.	The median is 130 <i>E. coli</i> /100 ml for contact recreation but discussions with SA Canoeing indicate that instantaneous levels of 2000 are acceptable. The 80 th ile is <1000.	SA WQ guidelines
Low flows	To maintain low flows.	The minimum requirement as determined by the Ecological Reserve is 0.289 m ³ /s in August but there is no information for requirements for trout or other users but these cannot transgress the Reserve. <i>Natural flow in August is 0.86 m³/s</i>	Ecological reserve

5.5.4 Based on PES, assess the feasibility of achieving the desired state

Although stakeholders may have expressed their aspirations in respect of a particular indicator, the attainment of this aspiration may in fact not be possible. The purpose of this sub-step is to evaluate the management aspirations in line with the present state and the component visions. The present state of the selected indicator (determined in Step 5.4) should be compared against guideline information and/or the reference condition to determine whether it is feasible to meet the aspiration. This sub-step should also address any conflicts which may exist between 'EcoSpecs', 'UserSpecs' and 'Integrated measures'. In addition, conflicts may also exist between the required magnitude and direction of change of an indicator to meet an aspiration and the agreed direction and magnitude of change expressed in the component vision. Expert judgment should be used in addressing these conflicts.

In cases where an EcoSpec and UserSpec exists for a single determinand, RQOs are determined through the integration of the ecological and water user requirements, with the most stringent water quality or most sensitive water user defining the RQO. For example certain water users may have

more stringent water quality requirements than the ecological requirements – e.g. tobacco is sensitive to elevated chloride concentrations. A UserSpec can therefore be more protective than an EcoSpec if there is a particularly sensitive user need (and if the UserSpec will not impair the ecosystem's condition), but normally EcoSpecs define the level of protection

An example of a comparison between the present state and guideline documents/reference conditions for 'EcoSpecs', 'UserSpecs' and 'Integrated measures' is provided below (see Box 27).

Box 27. Example of the two indicators, their present state and the possibility of achieving stakeholder aspirations for Resource Unit 10 in the Mzimkhulu catchment

The Present State of each of the two indicators, *E.coli* and low flows identified for RU10 in the Mzimkhulu is then compared with stakeholder aspirations. Specialists felt that it was possible to improve the present state of *E. coli* to achieve the stakeholder request. However, it may be more difficult to achieve stakeholder aspirations for low flows.

Indicator	Present state	Possibility of achieving aspiration
<i>E. coli</i>	Currently <i>E. coli</i> median is 510 over the past 3 years, thus improvement is needed to reach 130 to provide for contact recreation. The highest instantaneous value is 19 860 and improvement is needed to reduce maximum to <2000. The 80 th %ile for livestock watering is 1400 and similarly an improvement is needed to reach <1000.	Catchment practices would need to be improved to achieve this RQO. This is attainable.
Low flow	Lowest flow months is August, and average present day flows are 0.47 m ³ /s (1920 – 2007).	The Reserve requirement is 0.289 and even this is not always met with present day flows. This it will be difficult to even meet the Ecological Reserve. It will be more difficult to meet additional user requirements.

5.6 Set appropriate draft RQOs

Resource Quality Objectives are largely narrative statements which may relate to the components, sub-components and selected indicators of each selected Resource Unit in the catchment. The RQOs may reflect the direction of change of a particular sub-component and/or indicator. They may also include the reason for the selection of component, sub-component and/or indicator and the rationale for the level at which it has been set. RQOs should not however include detailed numerical information. The RQOs should be captured in the RQO template. An example of this template is provided in Box 1.

Example of completed draft RQO template for Mzimkhulu

1. Vision for the catchment

The vision is to have a well-managed catchment which is used sustainably and equitably by its people. The resource has unique characteristics which are not compromised and should be promoted for ecotourism. Certain areas should be developed to promote social upliftment, e.g. forestry, which may mean localised deterioration. Any development should not compromise the overall functioning and integrity of the resource system. Where there is uncertainty, the resource should be managed with a precautionary approach.

1.1 IUA 2.

Vision: *This IUA supports mixed agriculture particularly irrigated pastures for livestock, and forestry. The water resource remains in good condition, with both good quantity and quality of water, with diverse habitats and biota and usage thereof, supporting a thriving ecotourism sector. The upper catchment supports important wetlands, including The Swamp, which continue to provide valuable ecosystem services. The vision is thus to support sustainable agriculture and ecotourism in the IUA whilst maintaining the health of the water resource, in particular the quantity and quality of water, in a good condition.*

RQOs for RU10

a) Quantity

- River low flows continue to supply adequate water to maintain agricultural and animal production enterprises as well as recreational (canoeing and angling), tourism and real estate uses.
- River flows continue to protect the Ecological Reserve in a sustainable condition

b) Quality

- The river is ideal for contact recreation and is acceptable for livestock watering.
- The water contains low concentrations of nutrients thus avoiding instream nuisance condition.

c) Habitat

- The density of Wattle does not significantly affect the condition of the riparian habitat or the aesthetic characteristics of the resource

d) Biota

- The instream ecosystem supports a diversity of biota including those which are sensitive to water quality perturbations.

5.7 Set appropriate draft Numerical Limits in line with the draft RQOs

Numerical Limits provide a quantifiable 'worst' point along a continuum of change in selected environmental indicators. This point represents the level at which the desired state of the environmental indicator can no longer be achieved.

Numerical Limits translate the narrative RQOs into numerical values which can be monitored and assessed for compliance. These Numerical Limits must be based on the feasibility assessment undertaken in sub-step 5.5.4 which compared the present state of selected indicators with guideline documentation or applied expert judgment to determine whether the stakeholder aspirations were feasible. This feasibility assessment determined the level at which RQOs should be set thereby

providing a Numerical Limit. It is recommended that Numerical Limit be set as a fixed point rather than a range, as the system will usually be managed to the lowest point in this range anyway. Thresholds of Potential Concern (TPCs) should be set at a level which is 'better' than the Numerical Limit.

The Numerical Limits are then captured into the RQO template (see Box 29)

Box 29. Example of draft numerical limits which underpin the selected indicators for Resource Unit 10 in the Mzimkhulu catchment

The narrative RQOs for water quantity and quality for Resource Unit 10 in the Mzimkhulu catchment were then translated into numerical limits. These numerical limits are provided for each of the key indicators selected for Resource Unit 10. Examples of the numerical limits are provided in the tables below.

Resource Unit 10:					
QUANTITY					
Low Flow	Measure	Numerical criteria	compliance	TPC	Sampling frequency & method
	Indicator: Low flows				
	February	2.198 m ³ /s	average	N/A	These values are for the EWR site and need to be scaled back to gauging weir
	June	0.479	average	N/A	
	July	0.333	average	N/A	
	August	0.289	average	N/A	
September	0.324	average	N/A		

Water quality					
	Measure	Numerical criteria	Statistic	TPC (inst.value)	Sampling frequency and method
Pathogen	E.coli	<130 E.coli/100ml	50		Monthly sampling
	E.coli	<1000	80		Monthly sampling
	E.coli	<2000	100	1500	Monthly sampling
Nutrient					
	SRP	<15 ug/l	average	20	Monthly sampling

5.7.1 Determine appropriate measures, sampling methods and sampling frequency

Expert judgment should be used to determine the appropriate measure, sampling method and sampling frequency for each of the selected indicators. Much of this information will be available from the Reserve process and from other monitoring programmes. The sampling method is likely to be influenced by the site at which the sampling is being undertaken while the sampling frequency will depend on the nature of the indicator and the level of threat in the catchment or RU. For example, invertebrates are more sensitive to short term ecological change than plants or fish and may therefore need to be monitored more frequently. The frequency of monitoring will also be influenced by the need for confidence in the data. Monitoring should be undertaken more frequently in cases where there is a high level of importance attached to the data and assessment.

5.7.2 Determine the percentile compliance with the Numerical Limits

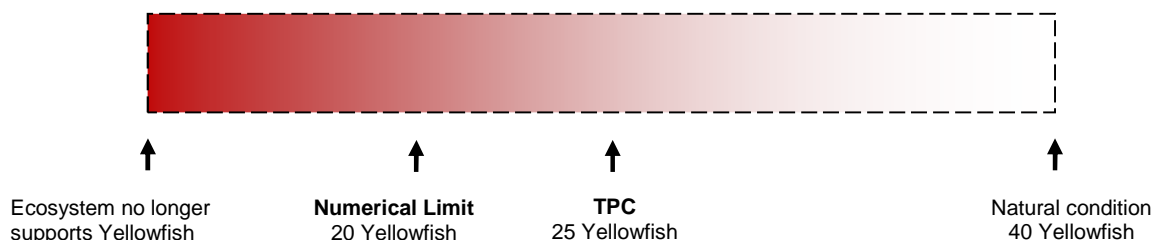
The percentile compliance should be based on the implications of changes in the Numerical Limit for users and the environment. For example, if *E. coli* levels exceed those of the Numerical Limit, there could be serious implications for human health. The percentile compliance with this Numerical Limit should therefore be high and more than one statistic may be recommended to be used, for example compliance may be required to be calculated against a 95th percentile, a 99th-percentile and a maximum. Similarly, additional statistics such as 99th-percentiles or maxima may also be recommended for EcoSpecs. Compliance for 95 percent of the time would not be adequately protective of the aquatic environment in the case of a highly polluted toxic spill which may have a devastating consequence on the river.

5.7.3 Determine the Thresholds of Potential Concern

Thresholds of Potential Concern (TPCs) may be upper and lower levels along a continuum of change which provide an early warning that the desired level (in this case the Numerical Limit) is in danger of being exceeded. When the TPC is reached, it prompts an assessment of the causes and extent of the change. This assessment provides the basis for determining whether management action is necessary or whether the TPC should be recalibrated. TPCs provide strategic goals or endpoints within which to manage the system and form the basis of adaptive management. They hypothesise the limits of acceptable change in ecosystem structure, function and composition and their validity and appropriateness are open to challenge and may be adaptively modified as knowledge and understanding of the system increases (Rogers & Bestbier, 1997).

While the Numerical Limit represents the lowest or 'worst' level of a desired category band, the TPC should be set at a point before this lowest level reached *i.e.* at a 'better' level. The proximity of the TPC to the Numerical Limit should be determined by the confidence in the data. Where the Numerical Limit is based on reliable data and the location of this endpoint is considered to be quite accurate then the TPC can be set at a level that is relatively close to the Numerical Limit. However, if only expert judgment has been used in determining the Numerical Limit, then there is usually low confidence in the location of this endpoint and it is pertinent to set TPCs at a level that is significantly better than the RQO. Note that in some situations *e.g.* for a toxin, the TPC will be at a lower concentration than the Numerical Limit, while in others *e.g.* a SASS score, the TPC will be at a higher score indicating better conditions.

Depending on the nature of the environmental indicator, it may be necessary to set either an upper or lower threshold or TPC, or both. For example, if the Numerical Limit requires that 20 yellowfish are caught per net haul, then the manager should be concerned when he starts approaching this value and is only catching 25 yellowfish. The TPC should therefore be set at 25. However, he is not concerned if there are greater numbers of yellowfish being caught.



However, if the Numerical Limit has been set for pH in order to provide the correct habitat for Yellowfish, then an increase or decrease in this pH may be detrimental to this fish species. An upper and lower TPC should therefore be set.

The trajectory of change which is assessed during the Present State assessment should also be considered when setting TPCs. Most Water Quality TPCs are based on the 95th percentile of the RQO. This is often too late to implement corrective action and consequently the chance of exceeding the TPC when you have reached the 95th percentile is great. When the trajectory of change is significant, it is recommended that TPCs are set at lower levels such as the 80th percentile, which still allows time for interventions.

If the EcoClassification has been undertaken, then TPCs may already be available and can simply be extracted from this documentation. However, if this information is not available or does not address the selected indicators, then TPCs will need to be determined. The process for determining TPCs for most components is detailed in Kleynhans and Louw (2006). This document does not however provide guidance for determining TPCs for high and low flows, pathogens, birds, amphibians, periphyton and diatoms or for determining TPCs for UserSpecs. In these cases, expert judgment should be used to determine TPCs.

Box 30. EcoSpecs, TPCs and monitoring requirements for estuaries

If the ecological reserve study has been completed for an estuary then EcoSpecs, TPCs and monitoring requirements would be available particularly for recently completed intermediate and comprehensive studies.

5.8 Determine confidence in the RQOs and process

The purpose of sub-step 5.8 is to assess the confidence in both the RQOs and in the process followed in determining these narrative statements. Obviously, the confidence in the RQOs will be dependent on the accuracy of information used in the process. For example, if the Water Resource Classification and a Comprehensive Reserve has been done, it is likely that the confidence in the RQOs will be high as they are based on reasonable information.

The assessment of confidence should be undertaken for the processes applied and associated outputs at both the catchment and Resource Unit scale. Thus, it will be necessary to apply this assessment to all selected Resource Units as well as the catchment as a whole.

The assessment of confidence at the catchment level should consider confidence in the outputs of the:

- Delineation of the IUAs and Resource Units?
- Visioning Process
- Selection of Resource Units

An example of the template to be completed for the catchment level assessment is provided in Table 16.

Similarly, the assessment of confidence at a Resource Unit level should consider confidence in the:

- Selection of sub-components
- Resource Quality Objectives
- Numerical Limits

An example of the template to be completed for the catchment level assessment is provided in Table 17.

The guideline for assessing confidence in the EcoClassification has been adapted for use in the RQO process. This guideline stipulates that confidence can be considered low where there is derived or very scarce data whereas confidence is regarded as high where observed information and ecological information on the ecosystem is available (Kleynhans and Louw, 2008). The following rating system has been adapted from the EcoClassification process and should be applied in the confidence assessments for RQOs.

- Low confidence should be scored as 1
- Low to medium confidence should be scored as 2
- Medium confidence should be scored as 3
- Medium to high confidence should be scored as 4
- High confidence should be scored as 5

Table 16. Template for catchment level assessment of confidence

		Confidence
Catchment level process	Delineation of IUAs & RUs	
	Visioning process	
	Selection of RUs	

Table 17. Template for Resource Unit level assessment of confidence

		Confidence			
		RU1	RU2	RU3	RU4
RU level	Selection of sub-components				
	Description of RQOs				
	Level of Numerical Limits				

6. AGREE RESOURCE UNITS, RQOS AND NUMERICAL LIMITS WITH STAKEHOLDERS

Having involved stakeholders in the setting of the vision, it is important to provide them with an opportunity to review how their input has been considered and taken forward in the process. Much work is done by the project team between the setting of the vision (Step 2) and this point is of a technical nature. Given the amount and nature of the work it is appropriate that stakeholders are again formally engaged in a direct manner.

This step therefore involves the presentation of the outcomes from Steps 3, 4 and 5 in a workshop process. The aim of this step is to verify and refine:

- The prioritisation of Resource Units for RQO determination.
- The selection of sub-components and indicators for RQOs, and the proposed direction of change for these.
- The Draft RQOs and Numerical Limits.

In terms of continuity it is important to build on the visioning process and involve the same set of stakeholders. To obtain effective input it is important that stakeholders are provided with sufficient information. In line with this, the following sub-steps are proposed.

6.1 Notify stakeholders and plan the workshop

An invitation should be sent to stakeholders at least four weeks in advance of the proposed date. The invitation should clearly articulate the purpose of the workshop and provide a broad agenda. The draft RQOs should also be made available to stakeholders for review prior to the workshop. This can be achieved by including a summary circulated with the invitation indicating:

- The RUs selected for RQO determination
- The sub components selected per RU.
- The proposed direction of change and the Draft RQOs and Numerical Limits.

This summary can also be made available via a website. Where effective in the visioning process, the same facilitator should be used as they will already have a relationship with stakeholders. The process, timing, format and mediums used in the presentation should be designed based on the capacity and level of understanding of stakeholders, which will be better understood following the engagement in Step 2. To avoid any surprises and plan appropriately, stakeholders should be contacted beforehand to establish whether they have initial concerns with the draft.

6.2 Present and refine the Resource Unit selection with stakeholders

In Step 3 of the RQO process, the Resource Unit Prioritisation Tool was applied and a number of Resource Units were prioritised for RQO determination. It is important that stakeholders are afforded an opportunity to comment on the selected Resource Units. The aim of sub-step 6.2 is to explain the purpose and process of RU selection, present the selected Resource Units and where necessary, refine this selection. This process requires that stakeholders have a thorough understanding of each of the Resource Units within their respective IUA.

This sub-step should therefore commence with an overview of the location of each Resource Unit within the catchment and the respective IUAs. An introduction to the Resource Unit Prioritisation Tool should then be provided. This should include a broad description of the criteria used to inform the selection of Resource Units. Each of the resulting prioritisation scores should then be discussed. These include the following:

- Position in the IUA
- Concern for users
- Concern for the environment
- Management and practical considerations

Following this, the total prioritisation score, final prioritisation rating and final Resource Unit selection should be discussed and changes made where necessary.

6.3 Present the sub-components and indicators selected for RQO determination

The purpose of sub-step 6.3 is to inform stakeholders of the sub-components and indicators that were selected for RQO determination and the process that was followed in doing so. This requires that the information contained on the 'Indicator selection' worksheet of the Resource Unit Evaluation Tool is presented and discussed. It is important to work through the Ecosystem and User Prioritisation ratings and ensure that stakeholders understand that the selection of sub-components was based on two key criteria:

- (i) the importance of the sub-components to important and very important user groups and
- (ii) the anticipated level of impact denoted by the Impact Class.

It is not necessary to refer to the 'User Requirement' and 'Impacting activities' worksheets unless there is a specific query. The final selection of sub-components and associated indicators should also be discussed. This should include the rationale for selection.

6.4 Present the proposed direction of change and associated rationale

The summary information contained on the 'Desired direction of change' worksheet should be discussed with stakeholders. In particular, it is important that stakeholders understand that although their needs may have been considered in the initial analyses, the direction and magnitude of change proposed is the consensus that is reached based on all important user requirements, impacting activities and the feasibility of achieving these.

6.5 Present and revise RQOs and Numerical Limits

The draft RQOs should be presented to stakeholders as the final step of the workshop. The review and amendments to any of the RQOs will constitute the final activity in the process.

Stakeholders should be informed of the final step in the process, which effectively provides them with a final opportunity to engage in the process.

7. FINALISE AND GAZETTE RQOS

The National Water Act requires that Resource Quality Objectives are published by way of notice in the Government Gazette. The Act specifically states that:

The Minister must in respect of each water resource—

a) publish a notice in the Gazette—

(i) Setting out—

(aa) the proposed Class;

(bb) the proposed Resource Quality Objectives;

(cc) the geographical area in respect of which the objectives will apply;

(dd) the dates from which specific objectives will apply; and

(ee) the requirements for complying with the objectives

(ii) Inviting written comments to be submitted on the proposed Class or proposed Resource Quality Objectives specifying an address to which and a date before which the comments are to be submitted, which date may not be earlier than 60 days after publication of the notice

(iii) Consider what further steps, if any, are appropriate to bring the contents of the notice to the attention of interested persons and take those steps which the Minister considers to be appropriate

(iv) Consider all comments received on or before the date specified in paragraph a(ii)

It is important to note that Resource Quality Objectives can only be gazetted once the Water Resource Classification has been undertaken. RQOs are included for gazettement in the proposed Integrated Water Resources Management (IWRM) template set out in the WRCS (DWA, 2007). The IWRM template makes specific provision for RQOs under Section 6 which requires that “RQOs for each nested ecological category for each significant water resource (i.e. not just the IUA)” are detailed. However, the RQOs will only have been determined for each prioritised Resource Unit and not all Resource Units in the catchment. It is recommended that the template for Resource Quality Objectives for each prioritised RU is prepared and included under this section of the IWRM template.

In addition to the RQOs, the IWRM template requires additional information which is relevant to RQOs. This includes the following:

- A description of the overall stakeholder consultation process
- Data limitations and resources not considered
- Methods applied in the determination of RQOs
- The project management team should be listed under administrative information
- Details on the monitoring of RQOs including monitoring locations (geographical co-ordinates) and aspects to be monitored
- Resource Quality Objectives and Numerical Limits for prioritised RUs.

Once the IWRM template has been completed, it will follow the gazettement process as stipulated in the Water Resource Classification System. The RQOs may be reviewed and amended at a different time period to that of either the Ecological Reserve or Water Resource Classification. It should therefore be possible to follow an amendment process to alter the RQOs without having to alter the outcomes of the Water Resource Classification or Ecological Reserve.

The template for the Numerical Limits will not be gazetted but should still be published on the DWA website for comment. These Numerical Limits also need to be signed-off by DWA and it is recommended that the approval process set out below is followed to achieve this.

Where the Water Resource Classification has not been undertaken, the Act does allow for the determination of preliminary Resource Quality Objectives. However, these preliminary RQOs and Numerical Limits will still need to be agreed and signed off with DWA. An approval process for Catchment Management Strategies is set out in DWAF (2007). It is recommended that the broad steps detailed in this document are followed for the approval of RQOs. These steps have been adapted for the RQO process and include:

- Preparation of a notice calling for public comment
- Revision and consideration of public comments and amendment of RQOs and Numerical Limits
- Revision by DWA of how the public comments have been considered and the RQOs and Numerical Limits revised
- Preparation by DWA of submission for approval of RQOs
- Written consent by DWA

IMPLEMENTATION, MONITORING, COMPLIANCE AND REVIEW

Following the gazetting of the RQOs comes the process to complete the Adaptive Management Cycle. Direction given in Section 1 (Management of Water Resource Quality Objectives) and summarised in Figure 6, shows how this all fits together into the full Adaptive Management Cycle. Following the Determination of RQOs as outlined in the seven step process above, management of water resources needs to continue as follows:

- Implementation – this process entails decision making by water resource managers on how to allocate water resources to different users so as to maintain the RQOs, followed by the implementation of this.
- Monitoring & Compliance – the systematic process to measure and manage performance in management of the water resource towards RQOs
- Review – the periodic process to review whether management actions are indeed achieving the objectives for the resource or at least are moving in that direction. Following the review, the entire cycle starts again, with a re-consideration of the RQOs and Numerical Limits for each RU.

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ANNEXURE 1. APPLICATION OF THE RESOURCE UNIT PRIORITISATION TOOL

While the direction in Step 3 above gives an overview of how the Resource Units are prioritised, this Appendix gives detailed guidance to working with the Excel based Resource Unit Prioritisation Tool. The purpose of this Appendix is to provide explanation where there is difficulty in understanding the Tools.

3.2 Determine the position of the Resource Unit within the IUA

The position of the Resource Unit within the IUA should be scored as follows:

- Resource Units located on a mainstem river and at the base of the IUA should be scored as 1
- Resource Units which are not on a mainstem river or at the base of the IUA should be scored as 0

3.3 Assess the importance of each Resource Unit to users

Consideration of the importance of a Resource Unit to users entails the assessment of a number of sub-criteria. The definitions and scoring of these sub-criteria is provided in more detail below.

3.3.1 Resource Units which provide cultural services

Cultural services address the use of ecosystems for spiritual enrichment and cultural activities. Examples of cultural services are detailed below.

a) *Recreational use, tourism or scientific benefits*

Aquatic resources provide opportunities for a range of recreational activities including boating, fishing, hunting and various tourism initiatives. High levels of biodiversity often contribute to the value of recreation and tourism as many people specifically seek to visit areas which support rare or unusual species or habitats, support particular species targeted for recreational hunting or fishing or offer scenic beauty. However, high levels of biodiversity and recreational and tourism value do not always correlate as some activities, e.g. trout fishing, may be in conflict with natural biodiversity.

Aquatic ecosystems provide an opportunity for both formal and informal education and training. For example, wetlands are unique ecosystems which contain both aquatic and terrestrial elements and as a result are of high value for education and research. This service can be measured by the presence and accessibility of features with special educational or scientific value or interest and the number of classes visiting or scientific studies undertaken on these features (de Groot *et al.*, 2010).

b) *Aesthetic, cultural or spiritual values*

Aesthetic value refers to the appreciation of natural scenery other than through deliberate recreational activities. It encompasses the aesthetic quality of the landscape including structural diversity, 'greenness' and tranquility (De Groot *et al.*, 2010).

Many religious, historical or traditional practices are directly linked to aquatic ecosystems and may be important to local communities or contribute to national heritage. This non-consumptive use is often difficult to quantify but can be measured by the presence of culturally important landscape features or species and the number of people who attach religious or spiritual significance to these ecosystems (de Groot *et al.*, 2010).

Although it is rarely possible to quantify the actual value that these services contribute to society, an assessment of the importance of these services may be informed by land uses, levels of use for recreation and tourism activities, knowledge of community values and activities and use by educational groups. This value should form part of the qualitative assessment.

The following scoring system should be applied in the assessment of cultural services:

- Resource Units with no known cultural services or which provide limited cultural services should be scored as 0;
- Resource Units which provide some cultural services should be scored as 0.5; and
- Resource Units which provide very important or numerous cultural services should be scored as 1.

3.3.2 Resource Units which support the livelihoods of significant vulnerable communities

Many poor communities are directly reliant on water resources for domestic water use, food, grazing, medicine and building materials. A description of each of these services is provided below.

a) Water

Water is often extracted directly from rivers, wetlands and groundwater for domestic, agricultural and other purposes. However, the use of water as an ecosystem services in this assessment relates only to subsistence users who may be directly reliant on aquatic resources for their water supply. The importance of water supply as an ecosystem service can therefore be inferred by the level of water services available to local communities.

b) Food and grazing

Aquatic and riparian plants and animals often provide an important source of food for both humans and livestock. These include fish, shellfish, bait, edible plants and grazing. In addition, some areas such as wetlands and floodplains may be used for the cultivation of food crops. In this way, these riparian areas contribute to food security and livelihoods. These services are of particular importance to poor communities.

c) Raw materials

A wide variety of raw materials may be obtained from aquatic resources. Many of these are important from a livelihood perspective and include sedges for crafts and mats, reeds for thatching and fencing, wood for construction and firewood and medicinal plants.

The following scoring system should be applied in the assessment of significant vulnerable communities:

- Resource Units which do not support or provide limited support to the livelihoods of significant vulnerable communities should be scored as 0;
- Resource Units which provide some support to the livelihoods of significant vulnerable communities should be scored as 0.5; and
- Resource Units which play an important role in supporting the livelihoods of significant vulnerable communities should be scored as 1.

3.3.3 Resource Units used for strategic requirements or international obligations

Strategic water use is important in meeting services delivery targets in the Country while South Africa is often bound by law to meet certain international obligations. Examples of both strategic water use and international obligations are provided below.

a) Strategic water use

During the development of the first edition of the National Water Resource Strategy (NWRS), DWA defined a number of users including strategic requirements. Strategic water use refers exclusively to water used in the power process, typically the cooling of South Africa's coal-powered stations.

b) International obligations

DWAF (2002) define international obligations as those requirements stipulated in agreements with neighbouring countries. In the current context, this definition is expanded to include any water-related agreements with international bodies such as the RAMSAR convention.

The following scoring system should be applied in the assessment of strategic requirements and international obligations:

- Resource Units which are not important for strategic purposes or in meeting international obligations should be scored as 0;
- Resource Units which are moderately important for strategic purposes or are somewhat useful for verifying compliance with international obligations should be scored as 0.5; and
- Resource Units which are extremely important for strategic purposes or are ideal for verifying compliance with international obligations should be scored as 1.

3.3.4 Resource Units which provide supporting and regulating services

The Millennium Assessment identifies four categories of ecosystem services including regulating and supporting services. A selection of these services is described in more detail below:

a) Flood attenuation

Some ecosystems may help to alleviate the impacts of floods on human systems and infrastructure. Inland waters, including dams, floodplains and wetlands are key agents of energy dissipation of runoff peaks. Although an isolated wetland may perform a flood protection function, it is generally the cumulative effect of multiple wetlands within a particular catchment that provide effective flood control. Most flood benefits are derived from extensive wetland systems, in particular floodplain wetlands. Coastal areas, including estuaries and mangroves also play a role in reducing the impact of coastal storm events.

b) Water purification

Water purification is the process of removing unwanted or excess chemicals, pathogens, nutrients, salts and sediments from surface and groundwater. Ecosystems with extensive vegetation cover and root systems, such as riparian forests and wetlands, are considered to be effective in improving water quality. This vegetation reduces the speed of water, physically traps sediments and the contaminants adhered to these particles, and absorbs water and nutrients through the root zone. Aquatic ecosystems also play a key role in water purification through dispersion (the dilution process) and advection (the movement of water downstream). Both these processes reduce the concentration of the pollutants at their point of entry into the ecosystem (Millennium Ecosystem Assessment, 2005).

c) Stream flow regulation

Stream flow regulation refers to the timing of water supply and ensures that water is available throughout the year. The continuous availability of water is often more important than the total annual water yield, particularly in areas with seasonal rainfall. Wetlands and floodplains are purported to play an important role in stream flow regulation as they act as natural sponges; absorbing excess water during heavy rains and gradually releasing this water throughout the dry season thereby maintaining base flows. These base flows are critical to aquatic ecosystem health and many human populations who rely on this water for domestic use, agriculture and livestock watering.

d) Erosion control and sediment retention

Wetland, floodplain and riparian vegetation play an important role in reducing soil erosion and retaining sediments. This vegetation reduces the speed at which the water is travelling resulting in the deposition and trapping of sediments. The capture of these sediments can potentially reduce costs of water treatment for downstream users and reduce siltation of water supply infrastructure thereby increasing their capacity and lifespan. Sediment retention also reduces the impact to aquatic ecosystems as high silt loads in rivers may decrease light penetration which in turn negatively affects primary production and thus fisheries.

e) Disease and pest control

Disease regulation refers to the biological regulation of disease populations through trophic relations. This results in a reduction in human diseases and livestock pests. Some aquatic ecosystems support organisms which control the populations of certain pests (e.g. fish eat disease vectors) or themselves provide conditions which regulate diseases. For example, interference with wetland hydrology has exacerbated the incidence of mosquito-borne diseases (Millennium Ecosystem Assessment, 2005)

The following scoring system should be applied in the assessment of supporting and regulating services

- Resource Units which supply limited supporting and regulating services should be scored as 0;
- Resource Units which supply moderate supporting and regulating services should be scored as 0.5; and
- Resource Units which supply extensive supporting and regulating services should be scored as 1.

3.3.5 Resource Units which support activities which contribute to the economy

The following scoring system should be applied in the assessment of activities which contribute to the economy:

- Resource Units which do not directly support any activities which contribute to the economy should be scored as 0;
- Resource Units which support activities which provide a moderate contribution to the economy should be scored as 0.5; and
- Resource Units which support activities which contribute significantly to the economy should be scored as 1.

3.4 Determine the level of threat posed to water resource quality for users

The following scoring system should be applied in the assessment of the threat posed to water resource quality for users:

- Resource Units where the potential threat posed to users is very low should be scored as 0;
- Resource Units where the potential threat posed to users is moderate should be scored as 0.5; and
- Resource Units where the potential threat posed to users is very high should be scored as 1.

3.5 Assess the importance of each Resource Unit to ecological components

Consideration of the importance of a Resource Unit to ecological components entails the assessment of a number of sub-criteria. The scoring system for each of these sub-criteria is provided in more detail below.

3.5.1 Resource Units which have a high or very high EIS category

The following scoring system should be applied in the assessment of EIS categories:

- Resource Units which have a low or moderate EIS Category should be scored as 0;
- Resource Units which have a high EIS Category should be scored as 0.5; and
- Resource Units which have a very high EIS Category should be scored as 1.

3.5.2 Resource Units which have an A/B NEC and /or PES

The following scoring system should be applied in the assessment of NEC and/or PES:

- Resource Units with a PES or NEC lower than a B should be scored as 0;
- Resource Units with a B PES or NEC should be scored as 0.5; and
- Resource Units with an A PES or NEC should be scored as 1.

3.5.3 Resource Units which have been identified as a National Freshwater Ecosystem Priority Area

The following scoring system should be applied in the assessment of NFEPA:

- Resource Units not associated with any 'freshwater ecosystem priority areas' or 'freshwater ecosystem support areas' in terms of NFEPA should be scored as 0;
- Resource Units located within 'freshwater ecosystem support areas' in terms of NFEPA should be scored as 0.5; and
- Resource Units located within 'freshwater ecosystem priority areas' in terms of NFEPA should be scored as 1.

3.5.4 Resource Units which have been identified as a priority in provincial aquatic systematic conservation plans?

The following scoring system should be applied in the assessment of provincial aquatic systematic conservation plans:

- Resource Units with a low irreplaceability value (0-0.5) should be scored as 0;
- Resource Units with a moderate irreplaceability value (0.51 – 0.99) or located within an 'Ecological Support Area' should be scored as 0.5; and
- Resource Units with a high irreplaceability value (1) or located within a 'Critical Biodiversity Area' should be scored as 1.

3.6 Determine the level of threat posed to water resource quality for the environment

The following scoring system should be applied in the assessment of the threat posed to water resource quality for the environment:

- Resource Units where the potential threat posed to ecological components is very low should be scored as 0;
- Resource Units where the potential threat posed to ecological components is moderate should be scored as 0.5; and
- Resource Units where the potential threat posed to ecological components is very high should be scored as 1.

3.7 Identify Resource Units for which management action should be prioritized

The following scoring system should be applied in the assessment of management action:

- Resource Units with a PES higher than a C category or a PES higher than the NEC should be scored as 0; and
- Resource Units with a PES lower than a D category or with a PES lower than the NEC should be scored as 1.

3.8 Assess practical considerations associated with RQO determination for each Resource Unit

Apart from the criteria already considered, there are additional practical considerations which are worth considering during the Resource Unit prioritisation process. This entails the assessment of a number of sub-criteria. The scoring system which should be applied to each of these sub-criteria is provided below.

3.8.1 Resource Units which contain an existing monitoring site (EWR, RHP, DWAF gauging weirs) and associated data

The following scoring system should be applied in the assessment of existing monitoring sites and associated data:

- Resource Units for which no resource quality information exists should be scored as a 0;
- Resource Units for which a moderate level of resource quality information exists should be scored as a 0.5; and
- Resource Units for which there is good availability (containing “current” data and where appropriate monitoring methods have been used) of resource quality information should be scored as 1.

3.8.2 Resource Units which are accessible for monitoring

The following scoring system should be applied in the assessment of accessibility:

- Resource Units which have very poor accessibility should be scored as 0;
- Resource Units which have a moderate accessibility should be scored as 0.5; and
- Resource Units which have good accessibility should be scored as 1.

3.8.3 Resource Units which are safe to monitor

The following scoring system should be applied in the assessment of safety:

- Resource Units which are not safe to monitor should be scored as 0;
- Resource Units where safety is questionable should be scored as 0.5; and
- Resource Units where safety is not a concern should be scored as 1.

3.9 Evaluate the relative ranking and weighting of each criterion

Standardised rankings and weightings have been proposed for each of the seven criteria used above in the prioritisation process. However, where there is strong motivation to alter these, the following process should be applied. Of the criteria considered, the most important criterion should be ranked as 1 with the second most important ranked as 2 and so on. The criterion which has been ranked 1 is then assigned a weighting of 100% and the others are assigned a weighting relative to this. If a decision is taken to amend the default rankings and weightings for the criteria, a detailed rationale for altering these values must be provided.

Note: Standardised ratings and weightings have also been included for each of the sub-criteria considered. It is strongly recommended that these ratings and weightings remain fixed rather than modifying them for each catchment. Where there is a strong motivation for altering these scores, appropriate justification must be provided.

3.10 Select Preliminary Resource Units for RQO determination using prioritisation scores

The purpose of this sub-step is to finally select those Resource Units which should be considered for RQO determination.

The scores for each of the sub-criteria are weighted and summed to provide a summary score for each of the four criteria (Position within IUA, Concern for users, Concern for environment,

Management and Practical considerations). The summary scores highlight which Resource Units are important from different perspectives. It is important to note that the scores for users and the environment integrate both the importance for users/environment and the threats to users/environment in order to calculate an overall 'concern score' for each Resource Unit. These 'concern scores' help to highlight those Resource Units that are both important and subject to a high level of threat by anthropogenic activities and which are therefore likely to be a priority for users and the environment.

The scores for all four criteria are then combined into a priority rating which scores the Resource Units relative to each other. This provides an integrated measure to inform the selection of Resource Units. Resource Units with high scores should generally be prioritised for RQO determination however there may be good reason for selecting alternative Resource Units. A rationale for the selection of specific Resource Units should be provided particularly where Resource Units with low priority ratings are selected above those with higher ratings. It is also strongly recommended that at least one Resource Unit be selected within each IUA to ensure that management requirements within each of these units are adequately considered.

3.11 Complete the information sheet for the Resource Unit Prioritisation Tool

The information sheet included on the "Information sheet" tab in the Resource Unit Prioritisation Tool, should be completed at the end of the prioritisation process.

ANNEXURE 2. APPLICATION OF THE RESOURCE UNIT EVALUATION TOOL

While the direction in Step 4 above gives an overview of how the Components of the resource are prioritised for monitoring, this Appendix gives detailed guidance to working with the Excel based Resource Unit Evaluation Tool. The purpose of this Appendix is to provide explanation where there is difficulty in understanding the Tool.

Components of the aquatic ecosystem

The National Water Act stipulates that RQOs should address four key components of an aquatic ecosystem to ensure that structure and function is protected. These include the following:

- **Water quantity:** Water quantity requirements are stated as the flow requirements of a river reach or estuary and/or the water level requirements for standing water or groundwater necessary to maintain spring flows, base flows and other ecological features.
- **Water quality:** The requirements for water quality include the chemical and physical characteristics of the water.
- **Habitat:** The requirements for habitat integrity reflects the physical structure of in-stream and riparian habitats, including various aspects of the vegetation
- **Biota:** Biotic integrity encompasses the health, community structure and distribution of aquatic and semi-aquatic biota.

The water quantity, water quality and habitat aspects are generally regarded as the primary drivers of the aquatic ecosystem whilst the biotic characteristics are usually dependent on the interaction between these key drivers. Although the biotic characteristics tend to be used as the principal indicators of the functioning of an ecosystem, the RQO process enables both driver and response components to be selected for RQO determination.

A number of sub-components have been identified within each of the four broad component categories. These are listed in more detail in below.

Quantity

- **Low flows (maintenance flows)**

Low flow requirements refer to flows which can be managed in almost all situations. These are the maintenance flows in the Reserve approach.

- **High flows (floods)**

High flow requirements can usually not be managed without large dams in place. These are the flood flows in the Reserve approach.

Quality

- **Nutrients**

Nutrients are generally not toxic but stimulate eutrophication if present in excess. Nutrients are monitored to assess the trophic status of the resource (degree of nutrient enrichment), and include inorganic nitrogen (nitrate, nitrite, ammonium), soluble phosphorus and the N:P ratio.

- **Salts**

Salts can impact the functioning and productivity of ecological systems at elevated levels and include the cations such as Na, K, Mg, Ca, anions such as Cl, SO₄, HCO₃, CO₃, NO₃, PO₄, OH and calculated inorganic salts such as MgSO₄, Na₂SO₄, MgCl₂, CaCl₂, NaCl, CaSO₄.

- **System variables**

System variables include temperature, pH, dissolved oxygen, total dissolved solids, turbidity/suspended solids, all of which may play a substantial role in ecosystem processes. Biota are usually adapted to the natural seasonal and diurnal cycles of changing system variables. Changes in the amplitude, frequency and duration of these cycles may cause severe disruptions to the ecological and physiological functions of aquatic organisms and hence the ecology of the system.

- **Toxics**

Toxic substances are monitored to assess toxicity of the resource to humans, fish, invertebrates, plant, and birds. Toxics seldom occur in high concentrations in unimpacted systems and include inorganic and organic constituents such as un-ionised ammonia, manganese, iron, aluminium, arsenic, atrazine, cadmium, chromium, copper, cyanide, mercury and others. They may include toxics of industrial origin.

- **Microbial determinands**

Microbiological determinands are monitored to assess the levels of microbial contamination of the resource and include bacteria, viruses and pathogens. For societal reasons, there may be a particular emphasis on microbes of human gut origin.

Habitat

- **Geomorphology**

Geomorphology and its associated processes contribute to the habitat integrity of a water resource. The habitat integrity status is based on a combination of biological and physical criteria. Physical criteria include the erosion status of the catchment, measures of bed modification due to siltation or erosion and channel modification such as result of from a change in flow or bank erosion.

- **Riparian habitat**

Riparian habitat includes the physical structure and associated vegetation of the areas associated with a watercourse. This habitat is generally characterised by alluvial soils and is inundated to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from the adjacent land areas.

- **Instream habitat**

Instream habitat includes the physical structure of a watercourse and the associated vegetation in relation to the bed of the watercourse.

Biota

- **Fish**

Fish include both the diversity of species as well as particular species which may have specific requirements for flow, cover, velocity-depth Classes and modified physico-chemical conditions of the water column. Species may include those indigenous fish important from an ecological perspective or exotic and indigenous species important to users for recreational angling or food.

- **Birds**

Aquatic habitats provide habitat for a variety of bird species. Aquatic birds often provide important indicators of the health of the habitats they occupy. Different species may be ecologically or recreationally important. Depending on the situation, it may be important to consider specific species, species diversity and/or population size.

- **Amphibians**

Amphibians are a class of vertebrates that include frogs and toads. They provide a good indication of ecosystem health as they breathe through their skin which allows toxins and/or chemicals to be absorbed into their body. Consideration could be given to particular species, population size and/or species diversity.

- **Periphyton**

Periphyton refers to aquatic plants, especially algae that live attached to submerged surfaces in the aquatic environment. Periphyton are primary producers and are sensitive to changes in water quality. Responses in this community can be measured in a variety of different ways ranging from physiological to community level changes. Possibly the most common measure is the chlorophyll content of a standard sample which is used as a measure of biomass and thus eutrophication.

- **Aquatic invertebrates**

A wide range of invertebrate organisms (e.g. insect larvae, beetles, snails, crabs and worms) require specific habitat types and conditions for different parts of their life cycles. A change in structure in aquatic communities therefore provides an indication of changes in overall river condition. In addition, most aquatic species are short lived and remain in one area during their aquatic life phase. Consequently, they act as good indicators of localised conditions in a river over the short term (River Health Programme website accessed in June 2010).

- **Diatoms**

Diatoms are microscopic algae that are either single-celled or in colonies but of the class *Bacillariophyceae*. Their cell walls consist of interlocking parts and contain silica, making them resistant to decay when dead and thus they can be investigated even when dead. Diatoms have variable sensitivity to different aspects of water quality and thus are useful indicators of water quality.

Box 31. Description of sub-components identified for estuaries

Quantity

- **Low Flows:** In temporarily open/closed estuaries baseflow keeps the mouth of the estuary open to the sea. Baseflow maintains the longitudinal salinity gradient from the mouth to the head of the estuary.
- **High Flows (Floods):** are important in resetting estuaries and maintaining an open mouth. Floods influence the sediment erosion/deposition equilibrium and can alter important features such as bathymetry (e.g. channel depth or the size of intertidal areas) and sediment composition (e.g. sand or mud).
- **Hydrodynamics (Mouth Condition):** Three mouth states are recognised closed, open and semi-closed when the estuary is perched above sea level and water flows from the estuary into the sea.
- **Hydrodynamics (Abiotic states):** River inflow ranges are related to typical 'abiotic states'. The four dominant states are: freshwater-dominated, freshwater pulsed/recovery state, marine-dominated and the closed mouth state

Quality

- **Salinity** distribution patterns in estuaries are important indicators of changes in freshwater inflow. Vertical and horizontal salinity gradients are modified by the river inflow, tidal range and mouth condition.
- **Dissolved inorganic nitrogen and dissolved inorganic phosphate:** Nutrients are monitored to assess the trophic status of the resource (degree of nutrient enrichment).
- **Water clarity:** Levels of suspended particles, colloidal material and coloured, dissolved organic matter influence water clarity.
- **Dissolved oxygen:** Low oxygen or anoxic conditions may develop when the die-off and subsequent bacterial decomposition of algae results in the depletion of dissolved oxygen in the water column, which can cause large-scale fish and invertebrate mortalities. Anoxic conditions can also create aesthetically unacceptable odours associated with decomposition.
- **Toxic substances** Toxic substances (*i.e.* trace metals, petroleum hydrocarbons, herbicides and pesticides) are important to monitor in those estuaries which receive runoff from urban and industrial areas and contaminated agricultural runoff. Sediment samples are collected and analyzed for toxic substances.
- **Pathogens** Organisms used as indicators of micro-biological contamination include faecal coliforms (*e.g. E. coli*), enterococci, coliphages and human viruses.

Physical Habitat

- The intertidal habitat occurs between the high and low tide mark whereas the subtidal habitat is permanently submerged. The percentage of sand relative to mud indicates available habitat for different benthic invertebrates.

Biota All biotic components are described in terms of species richness, abundance and community composition.

- **Microalgae:** Phytoplankton biomass is an index of eutrophication while changes in the dominant phytoplankton groups indicate changes in response to water quality and quantity.
- **Macrophytes:** Macrophytes represent both habitat and food for the estuarine fauna. Habitat types include submerged macrophytes, salt marsh, mangroves, swamp forest, reeds & sedges and macroalgae.
- **Invertebrates:** include zooplankton, nektonic (swimming) and benthic (bottom-dwelling) invertebrates.
- **Fish** contain many life forms and functional guilds and are likely to cover a number of components of aquatic ecosystems affected by change. Fish are divided into the following groups; estuary residents, estuary dependent marine fish, marine migrants, euryhaline freshwater species and catadromous species.
- **Birds** are good indicators of water quality, habitats and fish abundance. Some of the important bird groups are waders, waterfowl and piscivores.

Box 32. Description of sub-components for wetlands

Quantity

In the case of wetlands, two components are important in determining the hydrological functioning as described below:

- **Water Inputs**
The formation of a wetland and the maintenance of wetland habitat are largely dependent on the input of water from the wetlands upstream catchment. Changes in water inputs can therefore have a significant impact on wetland integrity and associated functions. It is not only the amount of water entering a wetland that is important, but also the pattern of water inputs (timing and intensity of flows) as alterations to these characteristics can significantly affect the hydrological functioning of these systems.
- **Water distribution and retention patterns**
This refers to the way in which water is distributed and retained within the wetland. A change in water distribution generally results in altered wetness regimes, which in turn affects the biophysical processes and the vegetation patterns.

Quality

- The same sub-components identified for rivers are also relevant for wetlands.

Habitat

- **Geomorphology**
Geomorphology refers to the origin and development of landforms and in the context of wetlands, is concerned with processes of weathering, erosion and deposition that affects the three-dimensional structure of the wetland surface. The assessment of geomorphic integrity is based on both diagnostic features and on-site indicators of erosion and deposition (Macfarlane *et. al.*, 2007).
- **Wetland Vegetation**
Wetland vegetation has compositional and structural characteristics that provide specialised habitats for a range of important wetland dependent species.

Biota

- The same groups of biota identified for rivers are typically relevant for wetland areas.

User group types

A key sub-step of Step 4 is to identify important user groups and their respective requirements within each Resource Unit. Important user groups should be considered in determining the appropriate direction and magnitude of change for each of the sub-components. Three separate user group types are considered in order to try and develop a balanced view about the desired future state of the water resource.

The National Water Act aims to ensure that water resources are protected, used, developed, conserved, managed and controlled in such a way that they promote the efficient, sustainable and beneficial use of water whilst simultaneously protecting aquatic and associated ecosystems and their biodiversity. The term 'protection' includes both the prevention of degradation of the water resource and the maintenance of the quality of the water resource to ensure that it may be used in an ecologically sustainable manner.

Three user group types are therefore considered in the RQO process:

- **Protection of the resource:** This user group gives voice to organisations mandated to maintain ecosystem functioning and to meet biodiversity conservation objectives.
- **Water resource dependent activities:** Those activities that are reliant on goods and services provided by water resources and that would usually benefit from the improved health of these ecosystems. Examples include recreation, ecotourism and real estate.
- **Activities that impact on water resources:** Those activities that impact on flow, water quality, habitat or biota and which often result in a negative impact on ecosystem health. Examples include abstraction of water for mining and irrigation and effluent discharges from waste water works which cause water quality to deteriorate (DWAF, 2003 Volume 3).

There are also a range of user groups with a potential to impact on water resources. Descriptions of each user group are outlined in Table 18 below.

Table 18. Description of user groups potentially impacting on water resources

Activity	Description of impact
Afforestation	Although forestry does not specifically utilise surface water resources, it intercepts rainfall and increases evapotranspiration thereby reducing river flow and the water available to other users.
Alien vegetation	Typical impacts include alteration of riparian vegetation, reducing water temperature, <i>etc.</i>
Concentrated livestock operations	Intensive livestock operations include feedlots and dairies. These operations can have a significant impact on water quality. Nutrients (nitrogen and phosphorus), microorganisms (e.g. bacteria, faecal coliforms, <i>Cryptosporidium</i> , <i>Giardia</i>) and organic material such as livestock wastes may impact receiving streams and aquatic life and also pose a risk to downstream users.
Dams	Dams have the potential to affect water resources in a number of ways. They create barriers to the movement of migratory species (e.g. fish) and reduce the movement of sediment to downstream areas. Dams also alter the natural stream flow thereby affecting downstream habitat and biota and the consequent supply of ecosystem services.
Dryland agriculture (including sugarcane and other crops)	The impact of dryland sugarcane and other crops is similar to that of forestry. Dryland sugarcane and other crops intercept rainfall thereby increasing evapotranspiration and reducing streamflow. The application of pesticides and fertilisers may result in the pollution of water resources.
Industrial areas	Run-off and effluent from industrial areas is often discharged directly into the water resource or may be discharged via on-site treatment facilities. This results in the pollution of surface water which has consequent impacts on aquatic habitat and biota.
Infrastructure	Infrastructure, including roads and power-lines, has the potential to impact on water resources particularly wetlands. Impacts include the re-direction of water flow and consequent sedimentation of water resources and the

	destruction of riparian vegetation.
Inter-basin transfers	Inter-basin transfers result in altered stream flow thereby affecting aquatic habitat and biota.
Irrigated agriculture	Impacts associated with activities such as abstraction, irrigation return flows, pesticide & fertiliser application.
Livestock grazing	The impacts of formal livestock grazing in riparian areas include the deposition of manure and urine directly into the water resource. Unmanaged grazing may also accelerate erosion and increase sediment inputs into the system.
Mining activities	The removal of vegetation for the purposes of mining may result in increased run-off, erosion and sedimentation. Acid mine drainage and the presence of other toxins may also result in the contamination of ground and surface water.
Recreation and ecotourism	Typical impacts include erosion of banks from wave action (speed boats), disturbance of vegetation and banks by fishing or recreational activities, litter, <i>etc.</i>
Rural settlements practicing subsistence resource use	Rural settlements practicing subsistence resource use impact directly on the habitat and biotic components of the resource through the harvesting of natural resources. Fishing is often common practice and reeds and sedges are harvested as building and weaving material. Cultivation and informal grazing of riparian areas also results in increased erosion and sedimentation of the water resource.
Sewage works and solid waste sites	Wastewater treatment works have the potential to significantly impact on water quality and flow in the receiving river. Leakages and effluent discharges from these plants may result in the pollution of ground and surface water.
Urban areas	Polluted run-off from streets, roofs and parking areas enters receiving waters directly and/or results in the overloading of wastewater treatment works. Malfunctioning and leaking sewage systems may result in the contamination of ground- and surface water (note that wastewater treatment is considered in a separate category).
Urban informal settlements	Urban informal settlements often have poor water supply and sanitation services. Untreated wastes are thus often discharged directly into rivers thus contaminating the water.
Rehabilitation activities	These activities are aimed at improving the current state of the water resource (e.g. Working for Water)
Other	This category addresses any other activity, not listed above, which may impact the Resource Unit in question.

4.1 Identify and assess the impact of current and anticipated future use on water resource components (Impacting activities tab)

4.1.1 Assess the importance of activities in driving resource change

The following table should be applied in the assessment of the importance of impacting activities:

	Anticipated level of impact on the water resource				
Economic contribution		Very low	Low	Moderate	High
	Very low	Not important	Not important	Important	Very important
	Low	Not important	Not important	Important	Very important
	Moderate	Not important	Important	Important	Very important
	High	Not important	Important	Very important	Very important

A rationale for assigning the importance rating should be provided in the relevant column in the Resource Unit Evaluation Tool.

4.1.2 Determine the anticipated level of impact on each sub-component

Impact scores are typically negative but in some cases may be positive if rehabilitation, refurbishment or better management is anticipated. In such cases, the same scoring system should be applied however the impacts should be scored as positive rather than negative.

The following scoring system should be applied in assessing the anticipated level of impact:

- Sub-components which are likely to experience a very high level of impact should be scored as -1
- Sub-components which are likely to experience a high level of impact should be scored as -0.75
- Sub-components which are likely to experience a moderate level of impact should be scored as -0.5
- Sub-components which are likely to experience a low level of impact should be scored as -0.25
- Sub-components which are likely to experience a very low level of impact should be scored as 0.

4.1.3 Determine the cumulative level of impact on each sub-component

Based on the anticipated level of impact of the activities on each of the sub-component, expert judgment should be used to determine the 'cumulative level of impact score'. As with the anticipated level of impact, scores may be positive in certain situations.

The following scoring system should be applied in assessing the cumulative level of impact:

- Sub-components which are likely to experience a very high level of impact should be scored as -1
- Sub-components which are likely to experience a high level of impact should be scored as -0.75
- Sub-components which are likely to experience a moderate level of impact should be scored as -0.5
- Sub-components which are likely to experience a low level of impact should be scored as -0.25
- Sub-components which are likely to experience a very low level of impact should be scored as 0.

The 'cumulative level of impact' score is then automatically translated into an Impact Class. Impact Class categories include very high, high, moderate, low and none. Impact Classes are determined automatically based on the following rating system:

Cumulative impact score	Corresponding Impact Class
-1	Very high
-0.75	High
-0.5	Moderate
-0.25	Low
0	None

4.1.4 Determine the anticipated consequences of the impacting activities on each sub-component

The following rating system should be applied in the assessment of anticipated consequences of the impact activities:

- ↓↓ indicates that a significant deterioration in the PES of the sub-component is anticipated
- ↓ indicates that a slight deterioration in the PES of the sub-component is anticipated
- → indicates that the PES of the sub-component is unlikely to change
- ↑ indicates that a slight improvement in the PES of the sub-component is anticipated
- ↑↑ indicates that a significant improvement in the PES of the sub-component is anticipated

4.2 Identify requirements of important user groups

4.2.1 Identify important user groups within the 'protection of the water resource' and 'water resource dependent activity' user group types

The purpose of this sub-step is to determine the relative importance of user groups within the Resource Unit. The following rating tables should be applied in determining the importance of user groups.

- **Identifying important user groups involved in the protection of the water resource**

EIS rating	Importance of user group
Low EIS value	Not present
Moderate EIS value	Not important
High EIS value	Important
Very high EIS value	Very important

- **Identifying important water resource dependent activities**

Size of user group and contribution to social wellbeing and economic prosperity	Anticipated level of dependence on the water resource				
		Very low	Low	Moderate	High
	Very small	Not important	Not important	Not important	Important
	Small	Not important	Not important	Important	Important
	Large	Not important	Important	Important	Very important
	Very large	Not important	Important	Very important	Very important

4.2.2 Rate the importance of sub-components for the protection of the water resource and water resource dependent activities

The rating of sub-components for the protection of the water resource should be undertaken for two key users, namely:

- **Conservation** - This user group relates to the protection of the natural environment to meet biodiversity conservation objectives (species and habitat conservation) and should be informed by Conservation Targets, EIS & NFEPA
- **Maintenance of ecosystem characteristics** – This user group relates to the importance of the natural physical, chemical or biodiversity properties of the water resource in defining its uniqueness or character and maintaining its biological functioning

A range of user groups have been included for water resource dependent activities. These are outlined in more detail in Table 18. Some sub-components which are not obviously used by users in the 'water resource dependent activities' user group type, have been excluded from this assessment. These include periphyton, aquatic invertebrates and diatoms.

Each sub-component should be scored as follows:

- Sub-components which are not considered to be important to the user group should be scored as a 0;
- Sub-components which are considered to be of moderate importance to the user group should be scored as a 0.5; and
- Sub-components which are considered to be very important to the user group should be scored as 1.

Note: The 'maintenance of ecosystem characteristics' user group is always considered to be either important or very important. It can therefore only be scored as 0.5 or 1.

A rationale for assigning the importance rating should be provided in the relevant column in the Resource Unit Evaluation Tool.

This information is then used to determine an importance score for each sub-component which is calculated as a weighted average of the importance scores for the user groups. Very important and important users will be weighted more heavily than not important users. This importance score is then translated into an Importance Rating based on the following system:

Importance score	Importance rating
1	Very high
0.75	High
0.5	Moderate
0.25	Low
0	Very low

4.2.3 Summarise the aspirations of each important user group

The relevant aspirations of different user groups should be summarised in the appropriate column of the Resource Unit Evaluation Tool. This information is important as it informs the level at which to set Numerical Limits later on in the process.

4.2.4 Review Present Ecological State and 'Fitness for use' information

The review of the Present Ecological State and 'Fitness for use' information considers three key aspects, namely the Ecological Category or Fitness for Use category, the Trajectory of change and the confidence in the data. These should be scored as follows:

- ***Ecological category and Fitness for use***

For Protection of the Water Resource, the appropriate Ecological Category should be recorded for each sub-component in the model. This data may be obtained from a range of sources such as the Ecological Reserve or River Health Programme data. Where the Present Ecological State has not been determined, expert judgement should be applied.

For Water Resource Dependent activities, the appropriate fitness for use category should be recorded for each sub-component. At a low confidence level, this simply entails selecting an appropriate user category from Table 8 based on available PES information and user requirements. By default, the most stringent user requirements or most sensitive user is used to inform the selection of an appropriate category. For further information on linking user categories for water quality components refer to the Guideline for Determining Resource Water Quality Objectives, Allocatable Water Quality and the Stress of the Water Resource (DWAF, 2006).

- ***Trajectory of change***

The trajectory of change should be scored as follows:

- ↓↓ denotes a significant deterioration in the current state
- ↓ denotes a slight deterioration in the current state
- → denotes that no change in the current state is anticipated
- ↑ denotes a slight improvement in the current state
- ↑↑ denotes a significant improvement in the current state

- **Confidence in the data**

Confidence in the data may be scored as high, moderate, low or very low.

4.2.5 Propose the desired direction and magnitude of change for each sub-component for important user groups

The following rating system should be applied in the assessment of the magnitude and direction of change:

- ↓↓ indicates that a significant deterioration in the sub-component is acceptable to the user group
- ↓ indicates that a slight deterioration in the sub-component is acceptable to the user group
- → indicates that the the current state of the sub-component is acceptable to the user group
- ↑ indicates that a slight improvement in the sub-component is desirable for the user group
- ↑↑ indicates that a significant improvement in the sub-component is desirable for the user group

4.3 Selection of sub-components for RQO determination

4.3.1 Review the Ecosystem and User Prioritisation ratings

This sub-step should be undertaken using the 'Indicator selection' worksheet in the Resource Unit Evaluation Tool.

Two prioritisation ratings, one for the ecosystem and the other for users, are automatically calculated. These prioritisation ratings are based on how important a sub-component is from an ecological or user perspective and whether this sub-component is threatened by anthropogenic activities occurring in the catchment. The Ecosystem prioritisation rating is automatically calculated by combining and averaging the importance scores provided for important and very important user groups for 'protection of the water resource' (completed in sub-step 4.2) and the 'Impact Class' (calculated in sub-step 4.1). Similarly, the User prioritisation rating is calculated by combining and averaging the importance scores for important and very important user groups for 'water resource dependent activities' and the 'Impact Class'. The overall prioritisation ratings range from very low to very high. Very high ratings highlight those sub-components which are both important from an ecological and/or user perspective and which are threatened by anthropogenic activities. These sub-components should be prioritised for RQO determination.

4.3.2 Select sub-components and associated indicators for RQO determination

This sub-step should be undertaken using the 'Indicator selection' worksheet in the Resource Unit Evaluation Tool. The overall priority ratings should be used to guide the selection of sub-components for RQO determination. Sub-components with high scores should be selected first. The number of sub-components selected for RQO determination should be based on the importance of the overall catchment and the level of confidence in the assessment. The selection of a sub-component as a 'UserSpec', 'EcoSpec' or 'Integrated measure' should be documented. This should be informed by the Ecosystem and User Prioritisation ratings. For example, if the Ecosystem Prioritisation rating for a

particular sub-component was high, then it is likely that this sub-component has been selected as an 'EcoSpec'.

A suitable indicator for monitoring this sub-component should then be proposed. Again, the selection of this indicator should be informed by the Ecosystem and User Prioritisation rating and the associated aspirations of the user group which was captured in sub-step 4.5. For example, faecal coliforms may have been selected as an appropriate indicator for setting RQOs and monitoring them because the Resource Unit is important for recreation and under threat by the expansion of informal settlements. The rationale for selecting the indicator should then be captured in the appropriate column in the Resource Unit Evaluation Tool.

4.4 Establish the desired direction of change for selected sub-components

The purpose of this sub-step is to determine the level at which to set RQOs. This sub-step should be undertaken using the on the 'Desired direction of change' worksheet in the Resource Unit Evaluation Tool.

4.4.1 Where applicable, understand the tradeoffs that have been made between user groups in the Water Resource Classification

Before applying the tool, a range of information should be gathered and interpreted. Details of the required information and associated interpretation are detailed in the associated section in the main body of this Report.

4.4.2 Propose an acceptable direction of change for each selected sub-component

The 'Desired direction of change' worksheet in the Resource Unit Evaluation Tool provides a summary of the Present Ecological State / Fitness for use information, trajectory of change and the desired direction and magnitude of change for each sub-component for each activity type. This information is used as a basis for discussion and seeking consensus regarding an acceptable direction of change.

A rationale for proposing a particular direction and magnitude of change should be documented in the appropriate column of the model.

4.4.3 Align the outcomes of each RU assessment across the catchment

The purpose of sub-step 4.4.3 is to align the proposed direction and magnitude of change between Resource Units. Because management decisions affect downstream water resources, the proposed direction of change of a component in one Resource Unit may impact the proposed direction of change of a component in an adjacent or downstream Resource Unit. Expert judgment should be applied in determining the appropriate direction of change. The following scoring system should be used to capture the outcomes of the alignment process:

The following rating system should be applied in the assessment of the refined direction of change (in the 'Desired direction of change' worksheet):

- ↓↓ indicates that a significant deterioration in the sub-component is possible and proposed
- ↓ indicates that a slight deterioration in the sub-component is possible and proposed
- → indicates that the the current state of the sub-component is possible and proposed
- ↑ indicates that a slight improvement in the sub-component is possible and proposed
- ↑↑ indicates that a significant improvement in the sub-component is possible and proposed

4.5 Complete the information sheet for the Resource Unit Evaluation Tool

The information sheet included on the “Information sheet” tab in the Resource Unit Evaluation Tool, should be completed at the end of the evaluation process.