REPORT NO. RDM/WE/00/CON/ORDM/0816

DEVELOPMENT OF PROCEDURES TO OPERATIONALISE RESOURCE DIRECTED MEASURES

PROJECT NO: WP 10951

WATER QUALITY TOOL ANALYSIS AND STANDARDISATION REPORT

SEPTEMBER 2016

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Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEVELOPMENT OF PROCEDURES TO OPERATIONALISE RESOURCE DIRECTED MEASURES

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Authors: ***Scherman, P-A, Koekemoer, S.***

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REPORT AND DELIVERABLE INDEX

Index Number	DWS Report Number	Report Title and Deliverables
1	RDM/WE/00/CON/ORDM/0116	Lessons Learnt Report
2		Inception meeting
3	RDM/WE/00/CON/ORDM/0216	Inception Report
4		Integrated framework Workshop
5	RDM/WE/00/CON/ORDM/0316	Integrated framework Milestone Report
6		Reserve, Classification, RQO Frameworks Workshop
7	RDM/WE/00/CON/ORDM/0416	Reserve, Classification, RQO Frameworks Report
8		River tool analysis and standardisation Workshop
9		Wetland tool analysis and standardisation Workshop
10		Estuaries and Marine tool analysis and standardisation Workshop (outcomes report)
11		Water quality tool analysis and standardisation Workshop
12		Groundwater, Hydrology, Hydraulics tool analysis and standardisation Workshop
13		Socio-economics and Ecosystem services tool analysis and standardisation Workshop
14	RDM/WE/00/CON/ORDM/0516	River tool analysis and standardisation Report
15	RDM/WE/00/CON/ORDM/0616	Wetland tool analysis and standardisation Report
16	RDM/WE/00/CON/ORDM/0716	Estuaries and Marine tool analysis and standardisation Report
17	**RDM/WE/00/CON/ORDM/0816**	**Water quality tool analysis and standardisation Report**
18	RDM/WE/00/CON/ORDM/0916	Groundwater, Hydrology, Hydraulics tool analysis and standardisation Report
19	RDM/WE/00/CON/ORDM/1016	Socio-economics and Ecosystem services tool analysis and standardisation Report
20	RDM/WE/00/CON/ORDM/1116	Stakeholder involvement and communication tool analysis and standardisation Report
21	RDM/WE/00/CON/ORDM/1216	RDM Communications Framework Report
22	RDM/WE/00/CON/ORDM/0117	Main Report
23	RDM/WE/00/CON/ORDM/0217	Capacity Building Report
24	RDM/WE/00/CON/ORDM/0317	Project Close-Up Report

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The following consultants participated in the 18 - 21 July 2016 workshop and contributed to the report in terms of method identification and evaluation:

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Maila, Dineo	Prime Africa
Moodley, Priya	Golder Associates (18th July only)
Scherman, Patsy	Scherman Colloty and Associates
Taljaard, Susan	CSIR
Wade, Peter	Private Consultant

The following DWS representatives participated at the specialist meeting and therefore contributed to the information in the report.

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Jooste, Sebastian	D: Resource Quality Information Services
Khoza, Philani	CD: Water Ecosystems (21st July only)
Machaba, Thapelo	D: Resource Directed Measures
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Mosoa, Lebo	CD: Integrated Water Planning: Water Resource Planning Systems: Water Quality Planning (18th July only)
Viljoen, Pieter	CD: Integrated Water Planning: Water Resource Planning Systems: Water Quality Planning

The following persons/groups provided comments on the report:
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REPORT SCHEDULE

Version	Date
First draft	September 2016
Final	October 2016

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

ALARM	Automated Land-based Activity Risk assessment Method
BHNR	Basic Human Needs Reserve
BBM	Building Block Methodology
CD:WE	Chief Directorate: Water Ecosystems
DWS	Department of Water and Sanitation
DWA	Department Water Affairs (Name change applicable after April 2009)
DWAF	Department Water Affairs and Forestry
DAP	Diatom Assessment Protocol
DM	District Municipality
EC	Ecological Category
EWR	Ecological Water Requirements
IUA	Integrated Units of Analysis
IWRM	Integrated Water Resource Management
NWRCS	National Water Resource Classification System
PAI	Physico-Chemical Assessment Index
PES	Present Ecological State
PESEIS	Present Ecological State and Ecological Importance-Ecological Sensitivity
PSP	Professional Service Provider
PMC	Project Management Committee
PSC	Project Steering Committee
RDM	Resource Directed Measures
RQIS	Resource Quality and Information Services
RQO	Resource Quality Objective
RU	Resource Unit
RWQO	Resource Water Quality Objectives model
SSD	Species Sensitivity Distribution
SSP	Species Sensitivity Distribution
SPI	Specific Pollution Index
SQ	Sub quaternary reach
TEC	Target Ecological Category
TTG	Technical Task Group
ToR	Terms of Reference
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TDS	Total Dissolved Solids
WMS	Water Management System
WQ	Water Quality
WQSAM	Water Quality Systems Assessment Model
WRUI	Water Resource Use Importance

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the Development of Procedures to Operationalise Resource Directed Measures (RDM). Rivers for Africa eFlows Consulting (Pty) Ltd., in association with supporting specialists, was appointed as the Professional Service Provider (PSP) to assist the Department in undertaking this study.

1.2 STUDY OBJECTIVES

The study objectives as defined by the Terms of Reference (ToR) are as follows:

- Develop a framework for Reserve determination.
- Standardise methodologies for Reserve determination.
- Develop a framework for Water Resource Classification.
- Develop a framework for Resource Quality Objectives (RQOs).
- Develop a RDM Communications Framework.

In the ToR, the CD: WE also identified the need for the development of an Integrated RDM framework. The term operationalise was not defined clearly as part of the TOR, apart from the objectives stated above. However, a definition was presented by DWS and agreed by all as follows:

Provide the frameworks and tools to allow CD: WE to give effect to the Reserve, Classification and RQOs (i.e. give effect to RDM). It therefore includes the frameworks, steps, processes, tools and implementation and monitoring information. The operationalisation of RDM starts at planning and ends at corrective actions (though the continuum of the plan, do, check, act cycle) which will include implementation and monitoring guidelines and the provision of information for various line functions.

NB: Care should be taken to distinguish between the term “operationalise" as it is defined above and “operating” rules for dams etc. OR with operational scenarios.

1.3 PURPOSE OF THIS TASK

The aims and objectives for this task as addressed at the specialist workshops to consolidate and standardise RDM methods are provided below:

Aim: Standardise methodologies for Reserve determination. Note, methodologies required for Classification and RQO determination not covered through the Reserve methodologies will also be included.

Objectives:

- Identify and standardise input and output for every sub-step (if relevant) of the Integrated Framework.
- Identify the range of tools and methods used in DWS and DWS related studies for each sub-step (if relevant).
- Evaluate the tools and methods according to a range of agreed criteria.

Approach:

These objectives were addressed during a workshop for river specialists in July 2016. Standardisation of methods focussed on standardising the inputs and outputs of the tools used in the sub-steps to define the information and data that is required to ensure continuity between the processes and steps. This will ensure that during all phases of the frameworks, the methods comply with the standardised inputs and outputs and that the linkages through the whole process are seamless.

1.4 PURPOSE OF THIS REPORT

During a range of specialist meetings (July 2016), available tools and methods for each of the sub-steps were identified, evaluated and documented in a range of reports (RDM/WE/00/CON/ORDM/0516 to RDM/WE/00/CON/ORDM/01116). This report serves to document the outcomes of the Water quality tool analysis and standardisation workshop specialist meeting (18 to 21 July 2016) (RDM/WE/00/CON/ORDM/0816).

2 APPROACH

2.1 BACKGROUND

Currently Resource Directed Measures (RDM) consists of three major processes:

- Water Resource Classification System (DWAF, 2006a).
- Determination of the Reserve (Louw and Hughes, 2002).
- Determination of RQOs (DWA, 2011).

Each of these processes consist of steps which were designed in 2002 (Reserve, Louw and Hughes, 2002), 2006 (Classification, DWAF, 2006a) and 2011 (DWA, 2011). These steps were gazetted (Gazette No. 19182, Notice No. 1091) on 17 September 2010. This gazette provides procedures (in the format of steps) for each of the RDM processes, which are largely similar to the initially designed steps for the Reserve and Classification. It must be noted however that the RQO steps and guideline appeared during 2011, i.e. after the gazette and differs significantly from the gazetted steps. During this project, the gazetted steps and the RQO guideline steps will all be referred to.

Therefore, each of the RDM processes consists of gazetted steps, guidelines, methodologies and approaches and various methods and tools supporting the methodologies. There are inherent links, overlaps and complexities within all of the above. This situation is further complicated by having to deal with large study areas with many nodes (points of interest) requiring answers that may be either at a desktop level and/or more detailed level. Issues regarding confidence, uncertainty and decision-making on various aspects such as where the areas of focus should be in study areas, add to the complexities.

2.2 INTEGRATED FRAMEWORK

During a February 2016 specialist meeting, an Integrated Framework was designed and subsequently finalised. The Integrated Framework consists of 8 steps. Each step is broken down into sub-steps described through a list of actions grouped together under various labels. The format is described below:

Each individual step within the Integrated Framework is broken down according to sub-steps which represent the different components that need to be investigated during the process. Sub-steps are labelled and required actions are listed below each sub-step. The format is described below:

- Actions are listed in clear (not coloured) blocks which are labelled. The first numbering of the label will refer to the Step number and the second a sequential number. For example, a block numbered and labelled ‘1.4 Rivers’ will mean that the block represents the river component under step 1. The four implies that this is the fourth block in the flow diagram. Essentially each block represents a sub-step which consists of a label and a list of actions. Reference is made to Step 1.4 and that as this is a secondary tier number, it represents a sub-step.
- These blocks are sometimes grouped together within a grey block which may have its own heading. The individual clear blocks are then labelled according to a next tier in the numbering, e.g. 1.4.1. This would mean that this block is part of Step one, grouped within a grey block numbered 1.4 and would form the first block in the grey block, i.e. 1.4.1
- The descriptions for these blocks are sub-steps. The reference in the report refers to these as Steps; however the numbering if a second tier (e.g. 1.1) will indicate that it is a sub-step. The numbering corresponds to the relevant flow diagram representing the relevant Integrated step.
- The actions that must be undertaken in each block are numbered from ‘1’ on.

- The descriptions of the actions in the report use a set of bullets as well as the numbers that can be cross-referenced to the flow diagram.
- Blocks with no numbers and shaded a light blue refer to KEY outputs (not all the outputs) of the step. These key outputs are those that are essential for use in the next step. This reflects the sequential manner of the Integrated Framework steps.

The integrated steps are provided in Figure 2.1, and are shown here after discussion and review by the DWS.

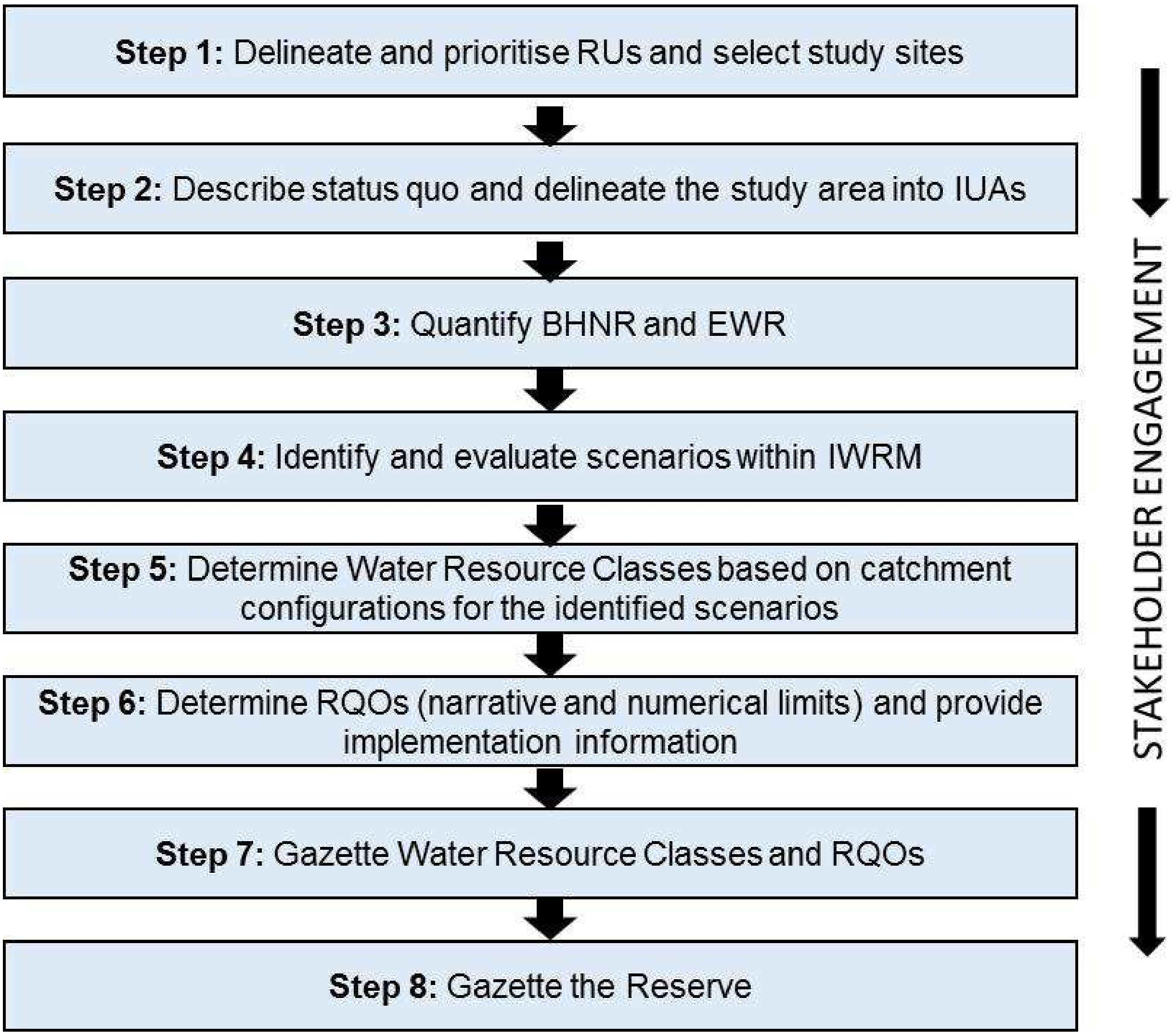

Figure 2.1 Integrated steps for the determination of the Reserve, Classification and Resource Quality Objectives

All numbering in this report will refer to the numbering in the flow diagram of each step illustrating the sub-steps as blocks and actions as a numbered list in the block.

2.3 STANDARDISATION OF TOOLS, METHODOLOGIES, METHODS AND APPROACHES

Since 1987, Instream Flow Requirements (known now as the Ecological Reserve) were considered by DWS in most water resource evaluations and investigations. Methods for determining environmental flow requirements were world-wide in its infancy. South Africa undertook research projects to evaluate existing projects and also developed one of the first holistic methods (King and Louw, 1998), the Building Block Methodology (BBM) which catered for South African circumstances and the requirements of DWS for Integrated Water Resource Management (IWRM). Since then, many methods and new methodologies have been developed to what has since 1999 become known as the Reserve – specifically the Ecological Reserve. This method development largely focussed on rivers and estuaries.

During the last five years, application of Classification studies has resulted in further expansion of the Ecological Reserve methods as well as developing additional methods through application to cater for the demand set by the complexities of Classification and then RQOs.

The myriad of methods and tools being applied have presented challenges, mostly as the output of methods did not necessarily comply to standard requirements and could not be seamlessly used between different phases of related studies. It must be noted Reserve, Classification and RQO studies are undertaken under the auspices of IWRM and results of these studies must be compatible with the prevailing IWRM practices. This of course also implies that the input used in tools, especially around the driver components (hydrology, geohydrology, water quality etc.), require standardisation.

As many methods in some cases are available for application within these studies, the focus of this work would not be to select specific methods that may be used in RDM work, but to indicated whether these methods comply to a range of requirements and whether the input and output comply to the required standard. Tools that will be evaluated are those methods that have been in use in environmental flow requirement studies in South Africa with the specific emphasis of those used for RDM. International methods that have not been used in South Africa will not be evaluated.

2.4 CONSIDERATIONS FOR STANDARDISATION

The focus is to be on the input and output, rather than the tool or method themselves. The key requirements for standardisation are:

- Aim to achieve coherent application throughout the RDM steps and processes.
- Application of RDM processes is part of Integrated Water Resource Management - the prevailing water resource management activities need to define the focus.

Examples of inputs and outputs are:

- Inputs: Hydrology time series datasets, or databases such as Present Ecological State and Ecological Importance-Ecological Sensitivity (PESEIS) (DWS, 2014a) etc.
- Outputs: Ecological Water Requirement (EWR) time series and rule definitions; Ecological Categories A to F.

The approach to the standardisation of methods will focus on standardising the inputs and outputs of the tools used in the sub-steps to define the information and data that will flow between the processes and steps. This will ensure that during all phases of the activities in the frameworks, the methods comply with the standardised inputs and outputs and that the linkages through the whole process are seamless. It must be noted that the Excel spreadsheet has been designed to include all sub-steps and all actions. However, this may not be relevant, necessary, or practical to provide the input and output at this level for a particular action.

Note: Not all sub-steps may require standardised inputs although most would require standardised outputs.

2.5 TOOL IDENTIFICATION

Studies carried out for DWS (directly or indirectly) were considered and tools were identified that has been applied for the Sub-steps and actions. Tools refer to any models, methods or systematic approaches and any of these will be referred to in this document as tools. The models could be detail hydrological models, spreadsheet formulas, methodical procedures and techniques.

If a Sub-step did not require a tool, it was noted that it is not applicable. If tools are not available, this was identified as a gap.

Note:

- **Not all sub-steps or actions required a tool.**
- **Actions were grouped in the sub-step if tools were applicable to these groups rather than per action.**
- Note that if there are tools that have been used extensively in the past but which are now obsolete, these tools will not be evaluated, but will be provided in this report including the reasons why they are obsolete (e.g. BBM). **TEACHA (Tool for Ecological Aquatic Chemical Habitat Assessment) is included in the water quality assessment as extensively used in the past and once it is upgraded, will be used in current and future studies.**
- **Standard computer packages such as Google Earth, Microsoft Office suite of programmes, Statistica etc. are not RDM tools within the context of this study. Methods or models can be written using Excel as per example, but the tool would be the method, not the computer package which is used.**

A generic set of criteria to rate the tools were identified and described (See Section 2.7). The tools were rated using an Excel spreadsheet. **Note that not all criteria will be applicable to a tool or method.**

2.6 SPECIALIST WORKSHOP APPROACH

During the workshop, a step by step approach was followed to provide the necessary information for each step of the Integrated Framework which was presented as a series of Excel spreadsheets. The approach followed is given below:

- Determine whether there is standardised input that is relevant for the sub-step.
- Decide whether the standardised input is for the sub-step as a whole or if it is linked to the listed actions.
- Define the standardised input.
- Define the standardised output.
- Identify all tools (referring to models, approaches, methods) used during the sub-step.
- Some sub-steps may not have any specific tools, as the output could be a qualitative description.
- Some actions within the sub-steps will often not have any action-specific tools and the specific actions can then be ignored.
- Evaluate the identified tools according to the given criteria. Note, that depending of the nature of the tool, all the criteria may not be valid and in these cases, the spreadsheet will not be populated.
- Transfer the information and all the added explanations in a MS Word report template.

Note the following in terms of water quality reporting:

- River water quality, wetland water quality tools and non-ecological water quality information can be found in this report, i.e. RDM/WE/00/CON/ORDM/0816.
- Further information regarding the use of wetland tools can be found in the Wetland Report, i.e. RDM/WE/00/CON/ORDM/0616.
- As water quality is embedded in the groundwater process and methods, water quality is covered in report RDM/WE/00/CON/ORDM/0916.
- As water quality is embedded in the estuary process and methods, water quality is covered in report RDM/WE/00/CON/ORDM/0716, where ecological water quality is embedded in Step 4: Estuary Ecological Component. The Specialist Workshop (in Step 4) is used to assess the consequences of operational scenarios on non-ecological uses (e.g. recreation, mariculture, industrial use). That information is captured in the Non-ecological water quality consequences report, together with the riverine results.
- The water quality component of Ecosystem services can also be found in that report, i.e. RDM/WE/00/CON/ORDM/1016.
- As the Planning Model is evaluated in the Groundwater/Hydrology/Hydraulics Report, see RDM/WE/00/CON/ORDM/0916 for an evaluation of the TDS module of the Planning Model tool.

2.7 EVALUATION CRITERIA

Table 2.1 outlines the tool evaluation criteria, evaluation manner and explanatory comments.

Table 2.1 Criteria and evaluation

Criteria	Evaluation	Explanatory comment
Frequency of application of use	1 - Very Low 2 - Low 3 - Medium 4 - High 5 - Very High	Supply supporting information. Provide year since it has been in use and approximate number of studies.
Can the method be applied at a catchment level?	Yes/No	Some methods can only be applied at a site and have to be repeated for every site, i.e. the method was not designed to deal with e.g. 200 nodes. Provide explanation using the following: 1. Node or site; 2 River reach, 3 Catchment; 4 Water Management Area
Is the method described?	Yes/No	If Yes, provide type of method description (user manuals, method description, spreadsheet)
Indicate the status of publication of the method.	1 N/A 2 None 3 Internal 4 National 5 International	Describe the type of publication
Are there existing training course?	Yes/No	If Yes, provide a description
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes/No	Note: Level refers to Desktop or Detailed and more specifically to the Reserve Levels of Desktop, Rapid, Intermediate, Comprehensive. Provide a description of the assessment level to which the method is applicable.
Time efficient (link to assessment level)	Provide evaluation in terms of a description in weeks and provide seasonality requirements if necessary.	Provide explanatory comment and explain time limitations.
Is the data available to	Always	Describe the reliance of method on monitored

Criteria	Evaluation	Explanatory comment
apply the method?	Usually Seldom Never	and/or measured data and pre-processing.
Compatibility	Yes/No	Can the method use the standardised input and does the method provide the results (output) according to the standardised requirements? In short, is the method compatible with the standardised input and output requirements? Please provide explanations
Must software be purchased?	Yes/No	If Yes, indicate the approximate costs and any associated conditions.
License requirements	None Simple Complex Duration limiting	Risk of use and administrative requirements.
Enhancement flexibility or adaptability of algorithms	1 Open script 2 Open source [Intellectual Property:] 3 DWS 4 WRC 5 Commercial	Purpose of criteria is to indicate the risk of keeping method relevant.
Is the method validated and verified?	Yes/No	Is the tool/method's results validated and can it be verified against the conditions on the ground? Provide an explanatory comment for the reasoning.
Description of mathematical algorithms and model structure	Algorithm based Detail explanation Conceptual description None	Provide an explanatory comment for the reasoning.
Is the model robust?	Yes/No	Will different numerical tools provide similar answers e.g.?
Does the method include an objective assessment of uncertainty such as may influence confidence?	Yes/No	If Yes, describe the process to quantify the uncertainty. If no, and there is a qualitative assessment of confidence (such as an rating by expert opinion): Please describe.

3 STEP 1: DELINEATE AND PRIORITISE RESOURCE UNITS AND SELECT STUDY SITES

Objective: The objective of Integrated Step 1 is to identify high priority areas (previously referred to as hotspots[1]) as these would be the areas where more detailed work for the rest of the steps would focus on. These high priority areas are selected based on ecological, socio-cultural and water resource use importance and are often areas of high ecological importance where water resources are stressed or may be stressed in future. This is a key step as the information that is gazetted are Resource Units (RUs) with measured information and potentially higher confidence output. The prioritisation therefore acts as a filter to allow one to focus on specific areas in the various ecosystems. Integrated Step 1 (Figure 3.1) therefore involves the delineation and prioritisation of RUs. Study sites where more detailed field work is undertaken are selected within High priority RUs, i.e. sites can only be selected after the prioritisation process.

This step has three sub-steps pertaining to water quality, and discussed below. Note that for easy reference, all sub-steps which are described with a second or third tier number (e.g. 1.1, 1.2) are referred to as e.g. Step 1.1. The numbering format implies that it is a sub-step.

[1] A biodiversity/ecological hotspot is a biogeographic region which is a significant reservoir of biodiversity which is threatened with destruction (http://en.wikipedia.org/wiki/Biodiversity_hotspot). In the context used in the Desktop EcoClassification, the hotspot represents a quaternary catchment with a high Integrated Importance which could be under threat due to its importance for water resource use. These hotspots indicate areas where Reserve assessments should ideally result in high confidence recommendations and requires appropriate methods.

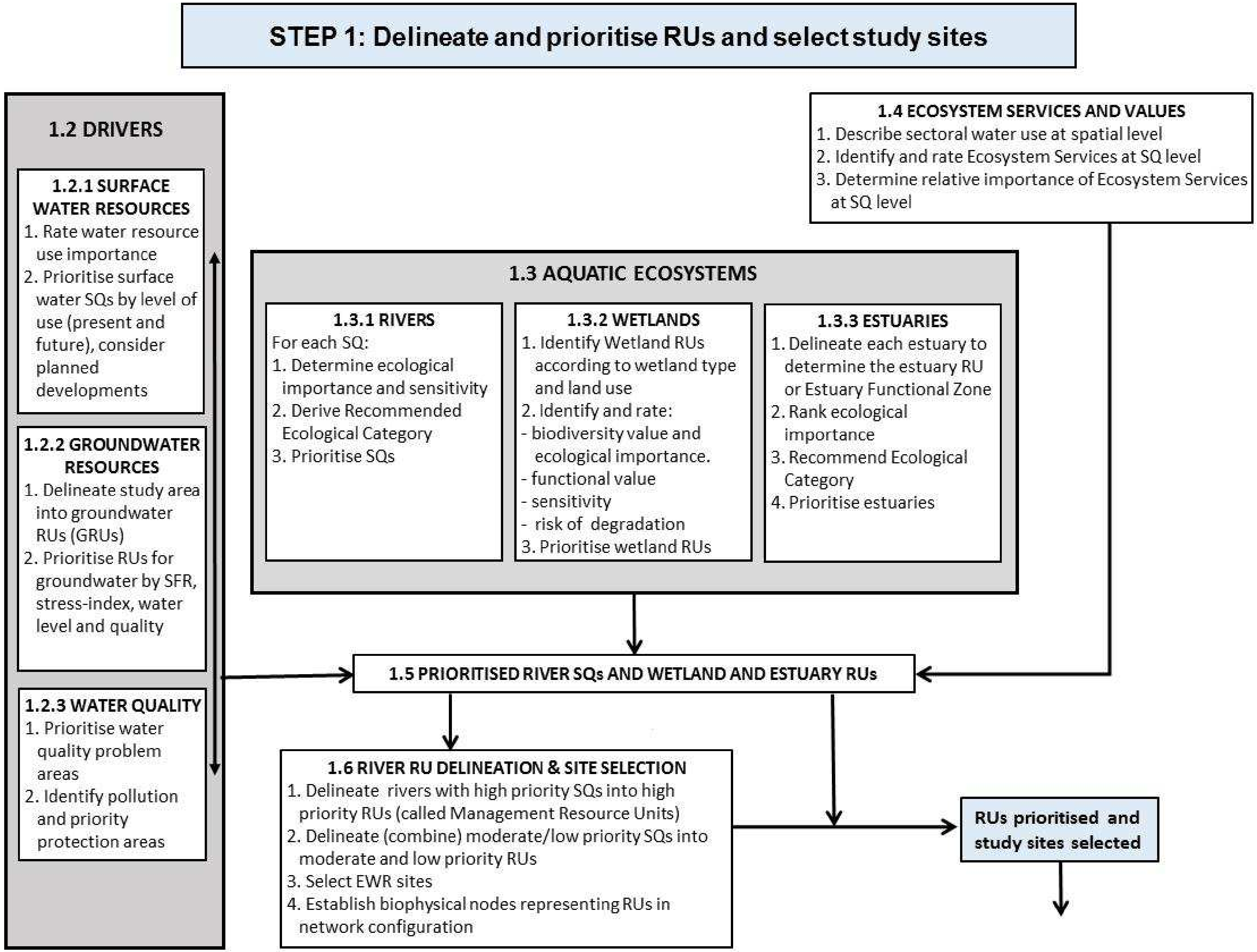

Figure 3.1 Illustration of the sub-steps for Step 1: Delineate and prioritise RUs and select study sites

3.1 STEP 1.2.3 WATER QUALITY: ACTIONS

Objective: Information collated during sub-step 1.2.3 is used to rate the Sub-Quaternary reaches (SQs) according to potential problem or protection areas. The identified land uses in the existing PESEIS (DWS, 2014a) and the refinement undertaken during Step 2, will lead to the potential causes and sources of water quality problems to be broadly identified.

The bullets below describe the actions required in this sub-step. Note that the numbers relate to the numbers in the flow diagram.

- **1. Prioritise water quality problem areas**
  a. Identify water quality role players, including non-ecological e.g. irrigation.
  b. Start identifying driving variables (e.g. elevated phosphate levels) associated with indicator water quality role players and metrics (e.g. nutrients).
- **2. Identify water quality priority areas**

These may be:

  a. Pollution priority area, i.e. high pollution level areas.
  b. Priority protection area, i.e. areas of sensitive water quality or those requiring protection on a water quality basis.

3.2 STEP 1.2.3 WATER QUALITY: STANDARDISED INPUT AND OUTPUT

The standardised input and output for relevant actions are provided in Table 3.1. Note that no tools or methods were used for the water quality step (Step 1.2.3), although the water quality information feeds into the *Catchment Reserve RU Priority Spreadsheet* tool used during Step 1.6. This tool is evaluated in the River Report (RDM/WE/00/CON/ORDM/0516).

Table 3.1 Standardised input and output per action

Action	Input	Comment/Process	Output
Identify water quality problem and protection areas (including non-ecological)	▪ Literature sources, e.g. Green Drop reports. ▪ Information from specialists, Water Quality Planning (DWS), stakeholders, authorities etc. ▪ Water quality rating from the Water Resource Use Importance (WRUI - rivers).	Process includes interviews and questionnaires, as required.	▪ Potential pollution sites and protection priority areas identified on a qualitative basis (as part of screening and prioritisation). ▪ Preliminary description of the study area in terms of water quality. ▪ Output is in the form of tables of identified SQs and associated stressors, and maps.

3.3 STEP 1.2.3 WATER QUALITY: IDENTIFIED TOOLS AND EVALUATION PER ACTION

No identified method or tool is followed or used for this step.

4 STEP 2: DESCRIBE STATUS QUO AND DELINEATE THE STUDY AREA INTO INTEGRATED UNITS OF ANALYSIS

Objective: The objective of Integrated Step is to define Integrated Units of Analysis (IUAs) and provide a status quo description of each IUA. An IUA is a homogenous catchment or linear section of river based on the similarity of ecological state, system operation, land use, etc. The status quo description therefore provides the information at a broad scale to inform the delineation of the IUAs. Basically, this step provides the baseline for the, National Water Resource Classification System (NWRCS) in the sense that it defines and describes the study area and its components. This step therefore includes the identification of the water resource operation in the study area, the identification of users and socio-economics issues, describing the status quo which represents the current condition of the various (components as illustrated in Figure 4.1), and then, through a process of comparing similar areas, to delineate IUAs. The status quo information for the study area is then used to describe the status quo for each IUA.

This step has three sub-steps pertaining to water quality, and discussed below. Note that for easy reference, all sub-steps which are described with a second or third tier number (e.g. 2.1, 2.2) are referred to as e.g. Step 2.1. The numbering format implies that it is a sub-step.

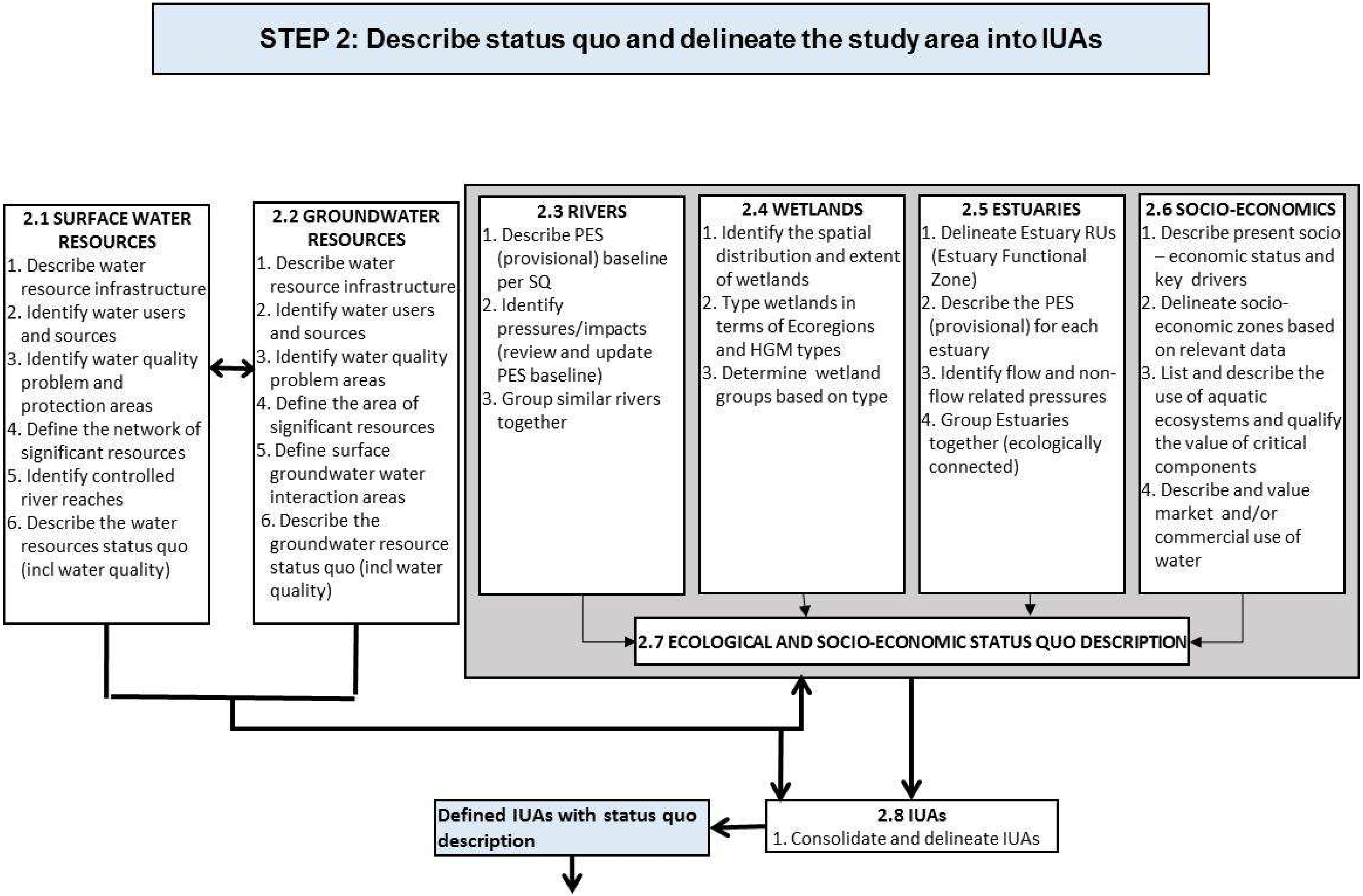

Figure 4.1 Illustration of the sub-steps for Step 2: Describe status quo and delineate the study area into IUAs

4.1 STEP 2.1 SURFACE WATER RESOURCES: WATER QUALITY ACTIONS

Objective: The water resource information must be packaged in such a way that the recommended IUA delineation can be determined after integrating the water resource information with the outputs from all the other sub steps under Integrated Step 2.1 (Figure 4.1.).

The bullets below describe the actions required in this sub-step. Note that the numbers relate to the numbers in the flow diagram.

- **Step 2.1.3: Identify water quality problem and protection areas (including non-ecological)**

Information collated during Step 1.2.3 is used as input to Step 2.1.3. The identified land uses and other information in the existing PESEIS database (DWS, 2014a; refer to Step 2.3: Rivers, Report RDM/WE/00/CON/ORDM/0516), and the refinement undertaken during subsequent steps, will lead to the potential causes and sources of water quality problems to be identified. This will feed into a description of water quality status quo for the study area (sub-step 2.1.6).

- **Step 2.1.6: Describe the water resources status quo (including water quality)**

The products from the sub steps of Integrated Step 2.1 are presented as relevant chapters of the status quo report covering the entire study area. The water quality status quo for the study area is provided as main output of this sub-step.

Available documents should be used to guide the information gathering process for study area description, for example:

- A guide to conduct water quality catchment assessment studies: In support of the water quality management component of a Catchment Management Strategy (DWAF, 2003);
- Assessing the impact of land-based activities on water resources: The automated land-based activity risk assessment method (ALARM) (DWA, 2014); and
- RDM: Water Quality Management report series of 2006 (DWAF, 2006b).

4.2 STEP 2.3 RIVERS: WATER QUALITY ACTIONS

Objective: Identify water quality hotspots on a desktop level, with associated reasons, and map the water quality hotspots. These hotspots, together with all other information gathered during Step 1.2.3, would then be used to delineate IUAs.

4.3 STEPS 2.1 AND 2.3: STANDARDISED WATER QUALITY INPUT AND OUTPUT

The standardised input and output for relevant actions are provided in Table 4.1.

Table 4.1 Step 2.1: Surface Water Resources - Standardised input and output per action

Action	Input	Comment/Process	Output	Tool	Comment/Gap
3. Identify water quality problem and protection areas (including non-ecological)	▪ Information from sub-step 1.2.3. ▪ Available spatial data e.g. shape files on wastewater treatment options; Google Earth coverages on land use. ▪ Information gathered from stakeholder interaction regarding users and stressors.	▪ This step follows on from sub-step 1.2.3. ▪ Use available documentation to guide data-gathering process. ▪ Process is extended to gather information from stakeholders at Project Management Committee (PMC), Project Steering Committee (PSC) and other meetings.	▪ Identification of problem and protection areas extended to include water quality overview and processes. ▪ List users and associated uses and water quality issues/problems that impact on use. ▪ Identify driving variables responsible for water quality state, or those needing protection (this information feeds into Integrated Step 6, the selection of RQOs for water quality). ▪ Set up a conceptual model to understand the chemistry or water quality processes in the study area. ▪ Output is in the form of tables identifying SQ, users and associated stressors, finalised maps and a conceptual model of the area.	Resource Unit Evaluation Spreadsheet (used primarily for RQO studies).	.
6. Describe the water resources status quo for water quality	Output from Action 3.		▪ Description of the study area in terms of water quality: Status quo and processes. ▪ Input to the Status Quo Report. ▪ Data output should contain the following: 1. Land use map. 2. Identify urban and industrial centres. 3. Locate wastewater treatment plants and associated Green Drop scores. 4. Locate agricultural areas. 5. Identify other land uses at an appropriate level of resolution to link impacts on water quality. 6. Assess natural and current state of systems and sensitivities (e.g. perenniality; naturally turbid or saline systems etc.). 7. Set up a geological template of the study area.		

One of the gaps in the approach followed by consultants to date is information on the process by which standardised outputs for water quality are reached, and the step assessing responses to stressors. This is necessary to inform prioritisation and water quality consequences of scenario steps.

Table 4.2 Step 2.3: Rivers - Standardised input and output per action

Action	Input	Output	Tool	Comment
1. Describe PES (provisional) baseline per SQ: Water quality component	PESEIS database (DWS, 2014a).	Desktop ecological physico-chemical impact ratings from the PESEIS database (DWS, 2014a) and land-use sources.		The PESEIS database tool is an existing database in a spreadsheet format. More information can be found in the River Report, i.e. RDM/WE/00/CON/ORDM/05 16.

4.4 STEP 2.1 SURFACE WATER RESOURCES: IDENTIFIED WATER QUALITY TOOLS AND EVALUATION PER ACTION

- **Action 3: Identify water quality problem and protection areas**

The Resource Unit Evaluation tool (Table 4.1) directs the evaluation of the user/eco-specifications and directs the user to the selection of components and sub-components with additional information to choose appropriate RQOs. In addition to using this tool in Step 6, it is also used to provide information linked to one of the outputs of Action 1, i.e. List users and associated uses and water quality issues/problems that impact on use.

The Resource Unit Evaluation tool has been used for a number of RQO studies by Dr O'Brien of the University of KwaZulu-Natal. It is included as part of Integrated Step 2 as preparatory work for Integrated Step 6, i.e. RQOs, as it includes the identification of variables for which RQOs will be prescribed.

Table 4.3 Assessment of the Resource Unit Evaluation spreadsheet

Evaluation criteria		Resource Unit Evaluation spreadsheet
Frequency of application use	Evaluation	4 – High
	Explanatory Comment	Used in numerous case studies (Olifants, Upper, Middle and Lower Vaal) for RQO determination in SA.
Can the method be applied at a catchment level?	Evaluation	No
	Explanatory Comment	Tool designed to be used on RU scale which for many RUs can be used to establish RQOs on a catchment scale.
Is the method described?	Evaluation	Yes
	Explanatory Comment	RQO guideline documents (DWA, 2011).
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	RQO guideline documents (DWA, 2011).
Are there existing training course?	Evaluation	No
	Explanatory Comment	Capacity building is available for the use of the tools through RQO case studies.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes. Note that although this tool can be used at different levels of assessment, these generally do not refer to Reserve studies, as the tool has been used mostly for setting RQOs.
	Explanatory Comment	Tool makes use of available information.
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	Tool can be used to select and describe RQOs for 4 - 6 sites comfortably in one day through a workshop process.
Is the data available to apply the method?	Evaluation	Always
	Explanatory Comment	Tool makes use of available information.
Compatibility	Evaluation	Yes
	Explanatory Comment	Transparent, flexible approach.

Evaluation criteria		Resource Unit Evaluation spreadsheet
Must software be purchased?	Evaluation	No
	Explanatory Comment	Excel based tool.
Licensing requirements	Evaluation	None
	Explanatory Comment	Free excel based tool.
Enhancement flexibility or adaptability of algorithms	Evaluation	1 – Open script
	Explanatory Comment	Simple excel based tool.
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	Tested in numerous case studies.
Description of mathematical algorithms and model structure	Evaluation	Algorithm based
	Explanatory Comment	Weighted excel based equations.
Is the model robust?	Evaluation	Yes
	Explanatory Comment	Weighted excel based equations.
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	n/a

4.5 METHOD DESCRIPTIONS AND PUBLICATIONS

All methods identified and used during Integrated Step 2 are listed below. The associated publications (e.g. source of a manual and/or description of the methods) are referenced in this section and not in Chapter 8.

- **Resource Unit Evaluation tool**

Department of Water Affairs (DWA). 2011. Procedures to Develop and Implement Resource Quality Objectives. Department of Water Affairs, Pretoria, South Africa. Prepared by Dickens, C; Pringle, C and Macfarlane, D of the Institute for Natural Resources.

Department of Water and Sanitation (DWS). 2014a. Determination of Resource Quality Objectives in the Olifants Water Management Area (WMA4): Resource Quality Objectives and numerical limits Report. Report No.: RDM/WMA04/00/CON/RQO/0214. Chief Directorate: Water Ecosystems. Study No.: WP10536. Prepared by the Institute of Natural Resources (INR) NPC. INR Technical Report No.: INR 492/14.(vi). Pietermaritzburg, South Africa.

Department of Water and Sanitation (DWS). 2014b. Determination of Resource Quality Objectives in the Upper Vaal Water Management Area (WMA8): Resource Quality Objectives and numerical limits Report. Report No.: RDM/WMA08/00/CON/RQO/0214. Chief Directorate: Water Ecosystems. Study No.: WP10535. Prepared by the Institute of Natural Resources (INR) NPC. INR Technical Report No.: INR 493/14.(vi). Pietermaritzburg, South Africa.

Department of Water and Sanitation (DWS). 2014c. Determination of Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10): Resource Quality Objectives and numerical limits Report. Report No.: RDM/WMA10/00/CON/RQO/0214. Chief Directorate: Water Ecosystems. Study No.: WP10535. Prepared by the Institute of Natural Resources (INR) NPC. INR Technical Report No.: INR 494/14.(vi). Pietermaritzburg, South Africa.

Lesotho Highlands Development Authority, (LHDA). 2016. Specialist Consultants to Undertake Baseline Studies (Flow, Water Quality and Geomorphology) and Instream Flow Requirement (IFR)

Assessment for Phase 2: Instream Flow Requirements for the Senqu River – Final report No 6001/2/e. Lesotho Highlands Development Authority, Maseru.

5 STEP 3: QUANTIFY BHNR AND EWR

Objective: The objective of Integrated Step 3 is to quantify the EWRs for different ecological states and set the Basic Human Needs Reserve (BHNR). These EWRs (ECs and associated flow regimes) are essential input into all the next steps and especially for the scenario evaluation. Once a recommendation is made regarding the Target Ecological Category (TEC), the EWR determined during this step which supports the TEC and the Class will become the flow or hydrology RQO. The water quality state associated with the TEC is then described as the ecological part of the water quality RQO.

Integrated Step 3 determines the BHNR and the EWR components that describe the Reserve once the IUAs have been classified. EWRs are set at desktop level for the desktop biophysical nodes and at detailed level at the study sites that are selected during Integrated Step 2. EWRs can be set for a range of ECs.

Note: Reference is made here to the EWR and not to the Ecological Reserve. The reason for this is that the Reserve can only be set once there is a decision on the EC which happens in later steps in the process.

This step has two sub-steps pertaining to water quality, and discussed below. Note that for easy reference, all sub-steps which are described with a second or third tier number (e.g. 3.1, 3.2) are referred to as e.g. Step 3.1. The numbering format implies that it is a sub-step.

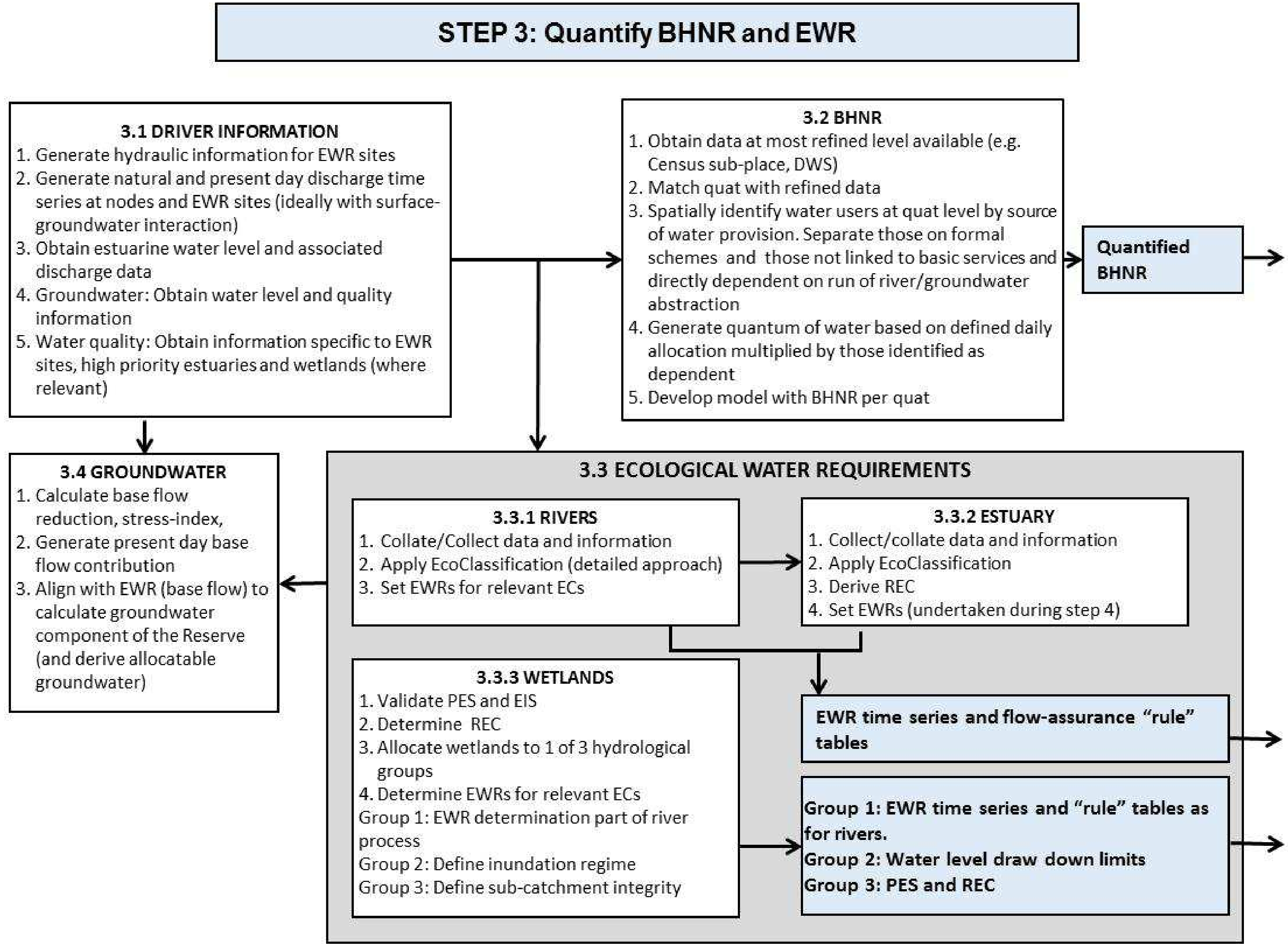

Figure 5.1 Illustration of the sub-steps for Step 3: Quantify BHNR and EWR

5.1 STEP 3.1 DRIVER INFORMATION: WATER QUALITY ACTIONS

Objective: The required water quality data is collated that is needed to determine the Present Ecological State (PES) for water quality.

The bullet below describes the action required in this sub-step. Note that the numbers relate to the numbers in the flow diagram.

- **Step 3.1.5. Water quality: Obtain information specific to EWR sites, high priority estuaries and wetlands (where relevant)**

This step involves the identification and collection of physico-chemical and other data that will be used in the EcoClassification step, i.e. setting the present state for water quality (part of Step 3.3).

5.2 STEP 3.1 DRIVER INFORMATION: STANDARDISED WATER QUALITY INPUT AND OUTPUT

The standardised input and output for relevant actions are provided in Table 5.1.

Table 5.1 Standardised input and output per action

Actions	Input	Comment/Process	Output	Tools	Comment/Gaps
5. Water quality: Obtain information specific to EWR sites, high priority estuaries and wetlands (where relevant)	DWS: Water Management System (WMS) database.	Refine the conceptual model from Step 2.1 of chemistry/quality processes in the study area.	Selected data/information for EWR sites and in preparation for EcoClassification.	Determination of the water quality part of the Ecological Reserve for rivers (DWAF, 2008): Data collection/processing step.	Note issues with WMS data, e.g. fluoride, pH.
	Other water quality databases, e.g. Umgeni Water, eThekwini District Municipality (DM), with data in WMS format for rivers data.		Understanding of the conceptual processes driving water quality at the EWR sites and selected estuaries and wetlands.	RapidMiner (for data quality assessment - to assist in refining the conceptual model of the catchment).	Resolution of rivers methods important and an assessment thereof needs to be done.
	Rules for data selection and use (see DWAF, 2008 for rivers; scientific standards).				Knowledge of the system is being used intuitively at present. Should this be formalised?
	International and other standards as needed.				
	Toxicological data (e.g. time-dependent Species Sensitivity Distribution (SSD) curves and toxicological data for acute and sub-acute responses)				
	Stressor distribution information (spatial and temporal)				
	Diatom data (particularly relevant for wetlands).				
	Qualitative clues from land-use, expert input and DWAF (2008) benchmark tables for rivers.				
	Process information on how the system operates (from Step 2.1).				
	Graphical representations for changes in selected variables over time				
	EWR site-specific data (incl. any in situ water quality data).				

5.3 STEP 3.1 DRIVER INFORMATION: IDENTIFIED WATER QUALITY TOOLS AND EVALUATION PER ACTION

- **Action 5: Water quality - Obtain information specific to EWR sites, high priority estuaries and wetlands (where relevant)**

Two tools are evaluated:

- RapidMiner 5.3: Used for data quality assessment and assisting in refining the conceptual model of the catchment (Table 5.2).
- Data collection step: Determination of the water quality part of the Ecological Reserve for rivers (DWAF, 2008) (Table 5.3).

Table 5.2 Assessment of RapidMiner 5.3

Evaluation criteria		RapidMiner
Frequency of application use	Evaluation	4 - High
	Explanatory Comment	Used by P. Wade for all desktop Reserves.
Can the method be applied at a catchment level?	Evaluation	n/a
	Explanatory Comment	n/a
Is the method described?	Evaluation	Yes
	Explanatory Comment	User manual; method description in (Wade, 2013).
Indicate the status of publication of the method.	Evaluation	5 – International
	Explanatory Comment	Widely used tool for assessment of data quality and other statistical procedures.
Are there existing training course?	Evaluation	No
	Explanatory Comment	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	Tool has only been used for desktop Reserves to date, but can be used at all levels of assessment.
Time efficient (link to assessment level)	Evaluation	
	Explanatory Comment	Very time efficient.
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	Used to interpolate from available data using rule-based decision making.
Compatibility	Evaluation	Yes
	Explanatory Comment	Input data is transformed to the required output format.
Must software be purchased?	Evaluation	Yes
	Explanatory Comment	The last freeware version was 5.0.
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or adaptability of algorithms	Evaluation	
	Explanatory Comment	Not open source.
Is the method validated and verified?	Evaluation	Yes
	Explanatory Comment	Tested and used in numerous studies.
Description of mathematical algorithms and model structure	Evaluation	Algorithm based
	Explanatory Comment	Statistics and informatics.
Is the model robust?	Evaluation	Yes

Evaluation criteria		RapidMiner
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	Yes
	Explanatory Comment	

Table 5.3 Assessment of the data collection/processing step of the Reserve water quality manual for rivers (DWAF, 2008)

Evaluation criteria		Reserve water quality method for rivers: Data collection/processing
Frequency of application use	Evaluation	4 - High
	Explanatory Comment	Used by numerous consultants and DWS for many Reserve studies.
Can the method be applied at a catchment level?	Evaluation	No
	Explanatory Comment	Methods designed to be used at a site-specific level .
Is the method described?	Evaluation	Yes
	Explanatory Comment	Draft user manual (DWAF, 2008); method description in numerous reports.
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	Widely used tool for data processing, although still a DRAFT document.
Are there existing training course?	Evaluation	No
	Explanatory Comment	Training has been provided through a number of courses and linked to Reserve and Classification studies.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes.
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	
Is the data available to apply the method?	Evaluation	Usually.
	Explanatory Comment	
Compatibility	Evaluation	Yes
	Explanatory Comment	Method uses available information.
Must software be purchased?	Evaluation	No
	Explanatory Comment	Excel may be used as a tool within the method.
Licensing requirements	Evaluation	None
	Explanatory Comment	Excel may be used as a tool within the method.
Enhancement flexibility or adaptability of algorithms	Evaluation	1 – Open script
	Explanatory Comment	Simple excel based tool, if excel is used as a tool within the method.
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	Tested in numerous case studies.
Description of mathematical algorithms and model structure	Evaluation	Algorithm based, if excel is used as a tool within the method.
	Explanatory Comment	
Is the model robust?	Evaluation	Yes
	Explanatory Comment	It has been tested widely.
Does the method include	Evaluation	No

Evaluation criteria		Reserve water quality method for rivers: Data collection/processing
an objective assessment of uncertainty such as may influence confidence?	Explanatory Comment	

5.4 STEP 3.3 ECOLOGICAL WATER REQUIREMENTS: WATER QUALITY ACTIONS

Objective: Quantify the EWRs for relevant ECs. EWRs per se are not determined during this step for estuaries as the process of estuarine EWR determination follows a top down approach based on scenario evaluation. Scenarios are generated during Integrated Step 4 and the assessment of these scenarios lead to the estuary EWR being determined.

The bullets below describe the actions required in this sub-step. Note that the numbers relate to the numbers in the flow diagram:

- **1. Collate/Collect data and information**

Also covered during Step 3.1 for water quality.

- **2. Apply EcoClassification methods (detailed approach)**

River (Step 3.3.1) and wetland (Step 3.3.3) water quality steps of the EcoClassification process are presented here.

- **3. Set EWRs for relevant ECs**

5.5 STEP 3.3.1 RIVERS: STANDARDISED WATER QUALITY INPUT AND OUTPUT

The standardised input and output for relevant actions are provided in Table 5.4.

Table 5.4 Standardised input and output per action

Actions	Input	Comment/Process	Output	Tool	Comment/Gaps
1. Collate/Collect data and information (including field survey)	Information from Driver Step 3.1.	Process data	Summary statistics for parameters/variables (using the specified data record) as defined by the methods manual (DWAF, 2008).	Determination of the water quality part of the Ecological Reserve for rivers: data collection and processing steps (evaluated in Table 5.3).	DWAF (2008) needs to be updated, reviewed and finalised, e.g. phosphate values need to be updated (current benchmarks are related to dams). Current work (e.g. agriculture and drinking water guidelines) needs to be assessed and included. Confidence important
				TEACHA.	TEACHA needs to be reprogrammed into a more user-friendly format and less costly platform.
	Available response data (e.g. diatom data; ecotoxicological SSD data).	Process data	Diatom species list, report and diatom-based Ecological Categories (ECs).	Diatom Ecological Reserve protocol (Koekemoer & Taylor, 2008), including the use of SA Diatom Assessment Protocol (DAP) (Taylor *et al.*, 2007a;b) and OMNIDIA software (LeCointe *et al.*, 1993) for diatom assessment (produces index scores associated with different ECs).	Diatoms are for present state. Cannot easily assess natural state.
2. Apply EcoClassification (detailed approach)	Information from Driver Step 3.1 (rivers), i.e. summary statistics and response data.				
	Benchmark tables and ratings (rivers; DWAF, 2008).		Integrated water quality category (rivers)	Determination of the water quality part of the Ecological Reserve for rivers: Physico Chemical Assessment Index (PAI) model (Kleynhans and Louw, 2007; DWAF, 2008).	
				Desktop Reserve tool for water quality of rivers.	

5.6 STEP 3.3.1 RIVERS: IDENTIFIED WATER QUALITY TOOLS AND EVALUATION PER ACTION

- **Action 1: Water quality, rivers – Data processing**

The Diatom Ecological Reserve protocol for processing diatom data and providing biological water quality categories (Table 5.5) is assessed.

Table 5.5 Assessment of the Diatom Ecological Reserve protocol for rivers and wetlands

Evaluation criteria		Diatom Ecological Reserve protocol
Frequency of application use	Evaluation	Rivers: 5 – Very high Wetlands: 2 - Low
	Explanatory Comment	Rivers: Diatom assessment has been used in most river Reserve assessments since 2004. Wetlands: Diatom assessments have been used, but studies have been limited. Method developed for channelled valley bottom wetlands.
Can the method be applied at a catchment level?	Evaluation	No
	Explanatory Comment	Rivers and wetlands: Site-specific tool which can be used across a catchment
Is the method described?	Evaluation	Yes
	Explanatory Comment	Manual (Taylor et al., 2007a;b), spreadsheet, method description and reports (e.g. Resource Directed Measures: Reserve Determination studies since 2004 e.g. Outeniqua (Knysna and Swartvlei), Upper Vaal, Mokolo, Inkomati, Mvoti and Gouritz catchments.
Indicate the status of publication of the method.	Evaluation	4 - National
	Explanatory Comment	WRC report. Rivers: DWS reports.
Are there existing training course?	Evaluation	No
	Explanatory Comment	Occasional training is provided upon request.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	Rivers and wetlands: Although the method can be applied to existing data on a desktop level, normally only used for Rapid to Comprehensive studies.
Time efficient (link to assessment level)	Evaluation	
	Explanatory Comment	Rivers and wetlands: Collection: Very time efficient. Analysis: Time and expertise-dependent.
Is the data available to apply the method?	Evaluation	Rivers and wetlands: Usually; but often few data points.
	Explanatory Comment	High reliance on field data.
Compatibility	Evaluation	
	Explanatory Comment	
Must software be purchased?	Evaluation	Yes
	Explanatory Comment	Rivers and wetlands: OMNIDIA (LeCointe *et al.*, 1993). Output cost is High.
Licensing requirements	Evaluation	Rivers and wetlands: Simple.
	Explanatory Comment	Included with software. Renewal not required.
Enhancement flexibility or adaptability of algorithms	Evaluation	Rivers and wetlands: Intellectual property.
	Explanatory Comment	
Is the method validated and verified?	Evaluation	
	Explanatory Comment	
Description of	Evaluation	Rivers and wetlands: Detail

Evaluation criteria		Diatom Ecological Reserve protocol
mathematical algorithms and model structure	Explanatory Comment	
Is the model robust?	Evaluation	n/a
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	Rivers and wetlands: Yes
	Explanatory comment	Rivers and wetlands: This dependent on available data, sampled data and confidence in assessment
Additional criterion: Applicability for monitoring	Explanatory comment	Rivers and wetlands: Standardised results (the Specific Pollution Index (SPI)) can be used for monitoring

- **Action 2: Water quality, rivers - Apply EcoClassification methods**

Three tools are evaluated:

- TEACHA (Tool for Ecological Aquatic Chemical Habitat Assessment): Used for data processing and derivation of water quality categories (Table 5.6).
- the PAI model: Production of an integrated water quality category, (Table 5.7).
- A Desktop Reserve tool for assessing the water quality of rivers (Table 5.8).

Table 5.6 Assessment of TEACHA ver 1_32 (Jooste, 2007)

Evaluation criteria		TEACHA
Frequency of application use	Evaluation	5 - Very high
	Explanatory Comment	Frequency of use was high, but currently not in use (approximately last 5 years) due to software and licensing issues.
Can the method be applied at a catchment level?	Evaluation	n/a
	Explanatory Comment	n/a
Is the method described?	Evaluation	Yes
	Explanatory Comment	Reserve water quality rivers manual (DWAF, 2008); TEACHA notes taken from Jooste (2007).
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	
Are there existing training course?	Evaluation	No
	Explanatory Comment	Training previously offered on demand.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	
	Explanatory Comment	Very time efficient.
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	The confidence in the output is very dependent on the quality and amount of data used.
Compatibility	Evaluation	Yes
	Explanatory Comment	The output is an integrated water quality category. The model also produces salts from salt ions.
Must software be purchased?	Evaluation	No
	Explanatory Comment	
Licensing requirements	Evaluation	Simple

Evaluation criteria		TEACHA
	Explanatory Comment	The MATLAB platform needs to be purchased at approximately R100 000 per license.
Enhancement flexibility or adaptability of algorithms	Evaluation	
	Explanatory Comment	TEACHA: DWS; MATLAB: commercial.
Is the method validated and verified?	Evaluation	n/a
	Explanatory Comment	n/a
Description of mathematical algorithms and model structure	Evaluation	Conceptual description
	Explanatory Comment	See original TEACHA ver 1_32 notes (Jooste, 2007).
Is the model robust?	Evaluation	n/a
	Explanatory Comment	n/a
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	Yes
	Explanatory Comment	
Additional comment	The model needs the correct interface with the operating system.	

Table 5.7 Assessment of the PAI model (DWAF, 2008)

Evaluation criteria		Reserve water quality method for rivers: PAI model
Frequency of application use	Evaluation	5 - Very high
	Explanatory Comment	Frequency of use is high since the tool has become available.
Can the method be applied at a catchment level?	Evaluation	No
	Explanatory Comment	Methods designed to be used at a site-specific level.
Is the method described?	Evaluation	Yes
	Explanatory Comment	Reserve water quality rivers manual (DWAF, 2008).
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	DWS draft report since 2008. Never reviewed or signed off by DWS.
Are there existing training course?	Evaluation	No
	Explanatory Comment	Training has been offered as part of two EcoClassification courses offered. Additional informal training as part of Reserve/Classification studies or as requested by CD: WE.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	
	Explanatory Comment	Running the PAI model is time efficient.
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	The confidence in the output is very dependent on the quality and amount of data used.
Compatibility	Evaluation	Yes
	Explanatory Comment	The output is an integrated water quality category.
Must software be purchased?	Evaluation	No
	Explanatory Comment	PAI is an excel spreadsheet model.
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or	Evaluation	n/a

Evaluation criteria		Reserve water quality method for rivers: PAI model
adaptability of algorithms	Explanatory Comment	
Is the method validated and verified?	Evaluation	n/a
	Explanatory Comment	
Description of mathematical algorithms and model structure	Evaluation	n/a
	Explanatory Comment	
Is the model robust?	Evaluation	n/a
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	Qualitative assessment of confidence.

Table 5.8 Assessment of a Desktop Reserve tool

Evaluation criteria		Desktop Reserve tool
Frequency of application use	Evaluation	5 - Very high
	Explanatory Comment	Used by P Wade for numerous desktop Reserve studies.
Can the method be applied at a catchment level?	Evaluation	No
	Explanatory Comment	
Is the method described?	Evaluation	Yes
	Explanatory Comment	Method description (Wade, 2014).
Indicate the status of publication of the method.	Evaluation	
	Explanatory Comment	Method statement produced for client and lodged with client.
Are there existing training course?	Evaluation	No
	Explanatory Comment	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	No
	Explanatory Comment	Only used for Desktop Reserve assessments for water quality.
Time efficient (link to assessment level)	Evaluation	
	Explanatory Comment	
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	The confidence in the output is very dependent on the quality and amount of data used.
Compatibility	Evaluation	Yes
	Explanatory Comment	The output is an integrated water quality category.
Must software be purchased?	Evaluation	No
	Explanatory Comment	Tool is an excel spreadsheet model.
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or adaptability of algorithms	Evaluation	n/a
	Explanatory Comment	
Is the method validated and verified?	Evaluation	n/a
	Explanatory Comment	
Description of mathematical algorithms and model structure	Evaluation	n/a
	Explanatory Comment	

Evaluation criteria		Desktop Reserve tool
Is the model robust?	Evaluation	n/a
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	Semi-quantitative assessment of confidence.

5.7 STEP 3.3.3 WETLANDS: STANDARDISED WATER QUALITY INPUT AND OUTPUT

Standardised input and outputs are provided for wetland water quality steps as follows:

- **1. Validate PES**

Tools are only available for Rapid wetland Reserve assessments.

The standardised input and output for this action is provided in Table 5.9.

Table 5.9 Standardised input and output per action

Action	Input	Comment/Process	Output	Tool
1. Validate PES	Data as previously collected (see Wetland Tools Report).	▪ Rapid Level. ▪ All hydrogeomorphic (HGM) types.	EcoStatus per wetland.	▪ Wetand water quality – landuse method: Appendix A7 of Rountree *et al.* (2013) refined in Malan and Day (2012) ▪ Diatoms: Appendix A6 of Rountree *et al.*, 2013) - use of the SPI diatom index scores which define condition.

The diatom tool has been assessed in Table 5.5.

5.8 STEP 3.3.3 WETLANDS: IDENTIFIED WATER QUALITY TOOLS AND EVALUATION PER ACTION

- **Action 1: Water quality, wetlands – Validate PES**

The Wetland water quality PES landuse method is assessed in Table 5.10.

Table 5.10 Assessment of the Wetland water quality PES landuse method

Evaluation criteria		Wetland water quality PES landuse method
Frequency of application use	Evaluation	1 – Very low
	Explanatory Comment	The method was only applied at the development stage.
Can the method be applied at a catchment level?	Evaluation	No
	Explanatory Comment	It can be used across catchments but on a wetland-by-wetland basis
Is the method described?	Evaluation	Yes
	Explanatory Comment	Appendix A7 of Rountree *et al.* (2013) refined in Malan and Day (2012)
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	WRC reports
Are there existing training course?	Evaluation	No
	Explanatory Comment	
Is the method applicable	Evaluation	No

Evaluation criteria		Wetland water quality PES landuse method
to all levels of assessment (Desktop to Comprehensive)?	Explanatory Comment	For Rapid assessments only
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	Assumed information and/or data are available
Is the data available to apply the method?	Evaluation	Usually (landscape information) Seldom (water quality data)
	Explanatory Comment	The landscape method was developed due to the dearth of water quality wetland data
Compatibility	Evaluation	Yes
	Explanatory Comment	
Must software be purchased?	Evaluation	No
	Explanatory Comment	
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or adaptability of algorithms	Evaluation	n/a
	Explanatory Comment	
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	
Description of mathematical algorithms and model structure	Evaluation	n/a
	Explanatory Comment	
Is the model robust?	Evaluation	Yes
	Explanatory Comment	A simple spreadsheet tool
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory comment	Uncertainty is only evaluated qualitatively

5.9 METHOD DESCRIPTIONS AND PUBLICATIONS

All methods identified and used during Integrated Step 3 are listed below. The associated publications (e.g. source of a manual and/or description of the methods) are referenced in this section and not in Chapter 8.

- **RapidMiner**

Wade, P.W. 2013. Data Mining and Statistical Analysis of Environmental Data – HBPD (2008-2012). Prepared for Menco Monitoring and Environmental Connections, Pretoria, 0060, South Africa. 148 pp.

- **Diatom Ecological Reserve Protocol**

Koekemoer, S. and Taylor, J.C. 2008. EcoClassification Report – Inkomati Comprehensive Reserve study: Appendix K. Diatom analysis. Draft report prepared for the Department of Water Affairs and Forestry, Pretoria, South Africa.

Appendix B
IN
Department of Water and Sanitation (DWS). 2014. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Rivers RDM

Report – Rapid Assessment. Prepared by Rivers for Africa eFlows Consulting (Pty) Ltd. for Scherman Colloty & Associates cc. Report no. RDM/WMA16/01/CON/1113.

Appendix B
IN
Department of Water and Sanitation (DWS). 2015. Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Rivers RDM Report – Intermediate Assessment. Prepared by Rivers for Africa eFlows Consulting (Pty) Ltd. for Scherman Colloty & Associates cc. Report no. RDM/WMA16/00/CON/1013.

- **Diatom Assessment Protocol (DAP)**

Taylor, JC, Harding, WR and Archibald, CGM. 2007a. A Methods Manual for the Collection, Preparation and Analysis of Diatom Samples. Version 1.0. WRC Report No. 281/07. Water Research Commission, Pretoria.

Taylor, JC, Harding, WR and Archibald, CGM. 2007d. An illustrated Guide to Some Common Diatom Species from South Africa. WRC Report No TT282/07. Water Research Commission, Pretoria.

- **OMNIDIA**

Lecointe, C, Coste, M and Prygiel, J. 1993. "Omnidia": Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

- **TEACHA**

Jooste, S. 2007. TEACHA 1.32 User Notes. Found in Appendix 2 of DWAF (2008).

- **Reserve water quality method for rivers: Data collection/processing and PAI**

Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Draft Report. Prepared by P-A Scherman of Scherman Consulting.

Appendix A
IN
Department of Water and Sanitation (DWS). 2014. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Rivers RDM Report – Rapid Assessment. Prepared by Rivers for Africa eFlows Consulting (Pty) Ltd. for Scherman Colloty & Associates cc. Report no. RDM/WMA16/01/CON/1113.

Appendix A
IN
Department of Water and Sanitation (DWS). 2015. Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Rivers RDM Report – Intermediate Assessment. Prepared by Rivers for Africa eFlows Consulting (Pty) Ltd. for Scherman Colloty & Associates cc. Report no. RDM/WMA16/00/CON/1013.

Scherman, P-A., Louw, D., Koekemoer, S., Kotze, P., Mackenzie, J., Rountree, M. and Palmer, R. 2016. Noordoewer/Noordoewer/Vioolsdrift Dam Feasibility Study: Ecological Water Requirements Report: volume 1 – River. Draft Report prepared for AECOM-WCE Joint Venture.

- **PAI method**

Kleynhans, C.J. and Louw, M.D. 2007. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 329/08.

- **Desktop Reserve tool**

Wade, P.W. 2014. Derivation of Numerical Values for Indicator Measures of Water Quality in Resource Units in the Upper Vaal, Lower Vaal and Olifants Catchments. Prepared for SA Institute of Natural Resources, Pietermaritzburg, 3201, South Africa, 24pp.

- **Wetland water quality PES method**

Malan, H.L. and Day, J.A. 2012. Water Quality and Wetlands: Defining Ecological Categories and links with land-use. Water Research Commission Report No. 1921/1/12.

Appendix A6: Diatom assessment – Koekemoer, S. and Taylor, J.C.
AND
Appendix A7: Water quality assessment – Malan, H.L., Batchelor, A., Scherman, P-A., Taylor, J., Koekemoer, S., and Rountree, M.W.
IN
Rountree, M.W., Malan, H.L., and Weston, B.C. 2013. Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0). Joint Department of Water Affairs/Water Research Commission Study. WRC Report No. 1788/1/12.

6 STEP 4: IDENTIFY AND EVALUATE SCENARIOS WITHIN IWRM

Objective: Integrated Step 4 consists of the preliminary identification and description of operational scenarios within Integrated Water Resource Management (IWRM). The objective of this step is to identify scenarios (operational) which are then modelled to provide the output of a model in the formats required to evaluate the scenarios. Note that these scenarios could consist of any changes to the water resource in terms of quantity and quality. As such, it can include groundwater scenarios as well as water quality scenarios (those associated with waste water treatment works) amongst others. These scenarios are then tested with stakeholders and an agreed list of scenarios are finalised for further analyses. The scenarios are modelled (yield and system models) and the outputs are evaluated to determine a range of consequences which is then compared in order to rank the scenarios.

This step has two sub-steps pertaining to water quality, and discussed below. Note that for easy reference, all sub-steps which are described with a second or third tier number (e.g. 4.1, 4.2) are referred to as e.g. Step 4.1. The numbering format implies that it is a sub-step.

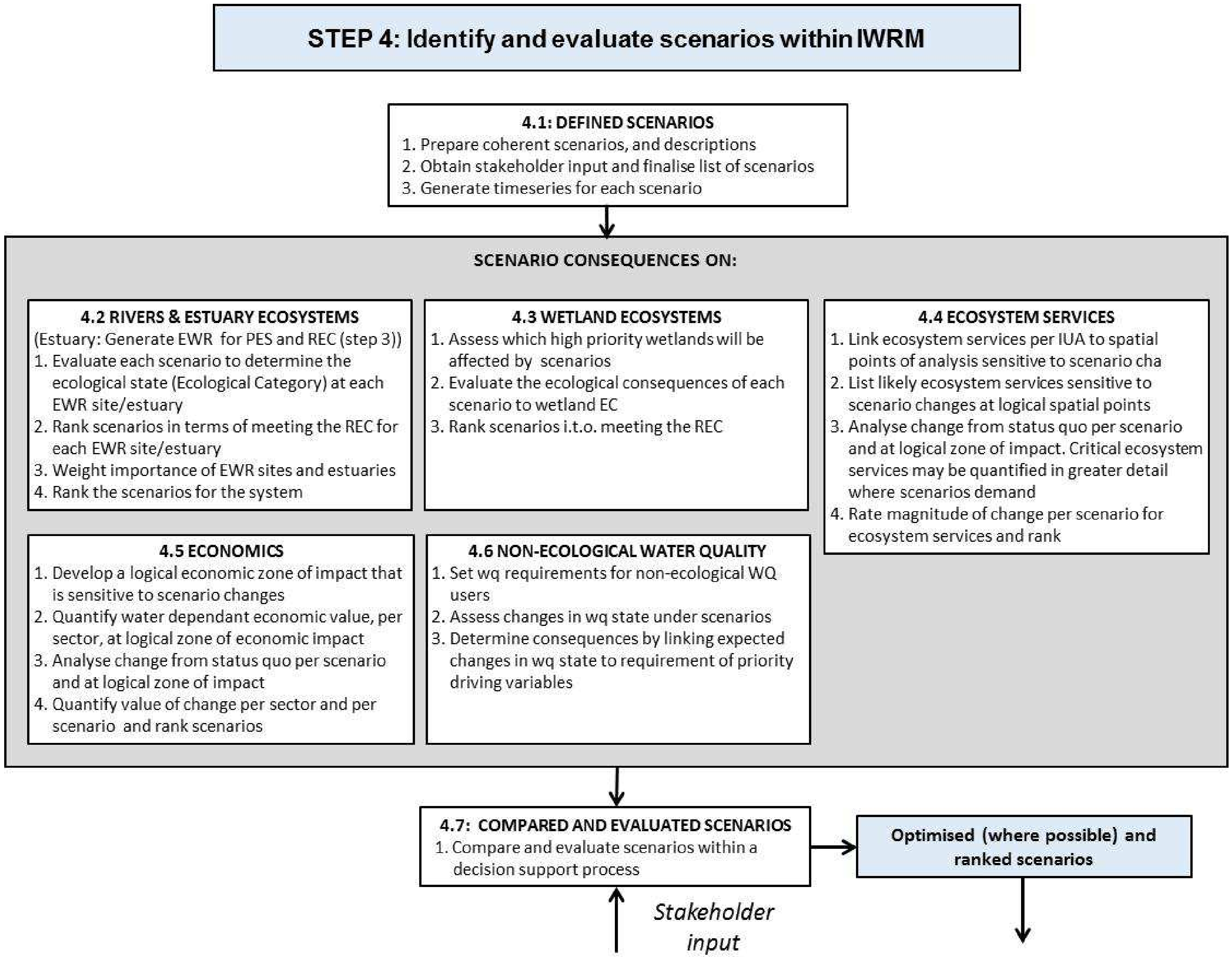

Figure 6.1 Illustration of the sub-steps for Step 4: Identify and evaluate scenarios within IWRM

6.1 STEP 4.2 RIVERS AND ESTUARY ECOSYSTEMS: RIVERS WATER QUALITY

Objective: Determine the ecological consequences of the scenarios for water quality.

The bullets below describe the actions required in this sub-step. Note that the numbers relate to the numbers in the flow diagram.

- **1. Evaluate each scenario to determine the ecological state (Ecological Category) at each EWR site and/or estuary**

Scenarios are evaluated to determine the predicted EC for each scenario for riverine water quality.

6.2 STEP 4.2 RIVERS AND ESTUARY ECOSYSTEMS: RIVERS WATER QUALITY

The standardised input and output for relevant actions are provided in Table 6.1.

Table 6.1 Standardised input and output per action

Actions	Input	Tools	Output	Comment: Tools under development/available
1. Evaluate each scenario to determine the ecological state (Ecological Category) at each EWR site/estuary	Hydrological time series as exceedence curves for present state and per scenario (rivers)	Regression technique for linking variables and flow time series (Examples: flow-concentration regression model (Malan *et al.*, 2003).	Water quality category under each scenario, and associated PAI assessment (rivers).	WQSAM (Water Quality Systems Assessment Model; Slaughter and Hughes, 2013: Institute for Water Research, Rhodes University).
	Processed water quality data (from Step 3) (rivers).	TDS module of the Planning Model (practitioners for Reserve studies: Coleman; van Rooyen)	Associated confidences (output of regression and of integrated category/result).	QUAL2K (Chapra *et al.*, 2008); derivative used for the Vaal Reserve (DWAF, 2009)
	Integrated ecological water quality category (from PAI model in Step 3) (rivers).	SenComp (Scenario comparison tool; Birkhead; 2014-2016).		QUAL2K
		PAI model (assessed as part of Step 3, Table 5.7).		USEPA BASINS model (United States Environmental Protection Agency Better Assessment Science Integrating point & Non-point Sources) .
				VENSIM PLE (VENSIM Personal Learning Edition; system dynamics simulation platform).
				PHREEQC (pH-REdox-Equilibrium, written in the C programming language) (speciation model; including chemical fate and transport).

Tools currently in development, e.g. WQSAM, are listed due to their potential future use in Reserve and Classification studies. Note the Planning Model is evaluated in the Groundwater/Hydrology/Hydraulics Report, RDM/WE/00/CON/ORDM/0916.

6.3 STEP 4.2 RIVERS AND ESTUARY ECOSYSTEMS: IDENTIFIED WATER QUALITY TOOLS AND EVALUATION PER ACTION

- **Action 1: Water quality, rivers – Consequences of scenarios**

Three tools are evaluated:

- Flow-Concentration (regression) Model of Malan *et al*. (2003) (Table 6.2).
- Scenario Comparison tool developed by Birkhead (2014 - 2016) (Table 6.3). This is a VBA (Visual Basic Application - Excel-based) tool that allows for the importing of multiple time-series or flow-duration tables (e.g. naturalised, present day and other scenarios), and then plots them on a series of graphs to facilitate comparisons. It also summarises the comparative data in tables.

Table 6.2 Evaluation of the Flow-Concentration Model (Malan *et al*., 2003)

Evaluation criteria		Flow Concentration Model
Frequency of application use	Evaluation	3 – Medium
	Explanatory Comment	
Can the method be applied at a catchment level?	Evaluation	Yes
	Explanatory Comment	The method has generally been used per EWR site
Is the method described?	Evaluation	Yes
	Explanatory Comment	
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	WRC and DWS reports
Are there existing training course?	Evaluation	No
	Explanatory Comment	Training has been provided as part of Reserve and other training as requested
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	Dependent on available data
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	Confidence is data dependent
Compatibility	Evaluation	Yes
	Explanatory Comment	Transparent, flexible approach.
Must software be purchased?	Evaluation	No
	Explanatory Comment	Excel based tool.
Licensing requirements	Evaluation	None
	Explanatory Comment	Free excel based tool.
Enhancement flexibility or adaptability of algorithms	Evaluation	1 – Open script
	Explanatory Comment	Simple excel based tool.
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	Tested in numerous case studies.
Description of mathematical algorithms and model structure	Evaluation	Algorithm based
	Explanatory Comment	Weighted excel based equations.
Is the model robust?	Evaluation	Yes
	Explanatory Comment	Weighted excel based equations.

Evaluation criteria		Flow Concentration Model
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	n/a

Table 6.3 Evaluation of the Scenario Comparison tool (Birkhead, 2014 – 2016)

Evaluation criteria		Scenario Comparison tool
Frequency of application use	Evaluation	3 - Medium
	Explanatory Comment	Used in a number of Reserve studies (Inkomati and Mvoti-Umzimkulu Classification studies; Vioolsdrift Dam Feasibility study: Reserve scenario comparison component (Scherman *et al*., 2016)
Can the method be applied at a catchment level?	Evaluation	Yes
	Explanatory Comment	
Is the method described?	Evaluation	Yes
	Explanatory Comment	The use of the tool is discussed in the Scherman *et al.* 2016
Indicate the status of publication of the method.	Evaluation	National
	Explanatory Comment	
Are there existing training course?	Evaluation	No
	Explanatory Comment	Tool was developed to assist Reserve practitioners to compare flow time series per scenario for a range of flow scenarios
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	Used during the ecological consequences step when assessing scenarios
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	
Is the data available to apply the method?	Evaluation	Always
	Explanatory Comment	
Compatibility	Evaluation	Yes
	Explanatory Comment	Transparent, flexible approach.
Must software be purchased?	Evaluation	No
	Explanatory Comment	Visual Basic Application - Excel-based
Licensing requirements	Evaluation	None
	Explanatory Comment	Visual Basic Application - Excel-based
Enhancement flexibility or adaptability of algorithms	Evaluation	1 – Open script
	Explanatory Comment	Visual Basic Application - Excel-based
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	Used in a number of Reserve studies to assess ecological consequences of flow scenarios.
Description of mathematical algorithms and model structure	Evaluation	Algorithm based
	Explanatory Comment	
Is the model robust?	Evaluation	Yes
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	n/a

6.4 STEP 4.6 NON-ECOLOGICAL WATER QUALITY

Objective: The evaluation is undertaken to determine the consequences of operational scenarios on identified non-ecological users or role players. This step is required as a separate step and actions as these aspects are not addressed through the water quality component which is part of the ecological systems (i.e. rivers, wetlands and estuaries).

The bullets below describe the actions required for consequences for non-ecological water quality (WQ) users. The full set of input and output is shown on Table 6.4.

- **1. Set WQ requirements for non-ecological WQ users**
  - Identify priority users and confirm driving variables (from Step 2).
  - Determine present state of water quality (from Step 3).
  - Access water quality guidelines of South Africa for identified users.
  - Access information on available Resource Water Quality Objectives from DWS Water Quality Planning.
  - Link condition of resource to user water quality targets (e.g. as per industrial or agricultural water quality guidelines). Note that some of this work is carried over from Steps 1 and 2.
  - Determine or confirm water quality requirements for identified priority user driving variables.
- **2. Assess changes in WQ state under scenarios**

The change in water quality state has to be determined under each scenario.

- **3. Determine consequences by linking expected changes in WQ state to requirement of priority driving variables**

Changes in water quality state under each scenario will be linked to changes in driving variables resulting in the changed overall state. These changes are evaluated against the requirements of identified users or role players.

6.5 STEP 4.6 NON-ECOLOGICAL WATER QUALITY: STANDARDISED INPUT AND OUTPUT

The standardised input and output for relevant actions are provided in Table 6.5.

Table 6.4 Standardised input and output per action

Action	Input	Comment/ Process	Output	Tool	Comment/Gaps
1. Set WQ requirements for non-ecological WQ users	Input from Step 2 in terms of: ▪ Description of the study area: Status quo and processes. ▪ Users, uses and water quality issues impacting on use. ▪ Users and associated stressors.	Non-ecological uses in estuaries mostly limited to Recreation, Mariculture and Industrial use (e.g. intake for desalination and seafood processing or cooling water).		Resource Unit Evaluation spreadsheet (assessed in Step 2, Table 4.1).	Use of Biointegrated Economic Model (Maila *et al*. 2015) to provide an assessment of financial implication associated with the exceedence of fitness for use. Model is an output of a WRC project (K5/2272) to evaluate water quality costs in a non-monetary way.
	Water quality guidelines for all users (e.g. DWAF, 1996a-c; DEA, 2012) or specifications obtained from actual users based on their process requirements.		List of water quality requirements for defined users.		
	Finalisation of users, stressors and driving variables from stakeholder input through Technical Task Group (TTG) meetings.	PSC drives the requirement for TTG meetings.			
2. Assess changes in WQ state under scenarios	▪ Input from Step 3 in terms of present state. ▪ Input from Step 4.2 regarding river and estuary water quality state conditions under operational scenarios. ▪ Changes in driving variables of non-ecological users under scenarios.				Regression technique for linking variables and flow time series of driving variables.
3. Determine consequences by linking expected changes in WQ state to requirement of priority driving variables	Select strictest user requirements.	Ecology: PAI model (Step 3). Non-ecological water use: compare to guideline for driving user and variable.	Rivers: Probability of exceedence of fitness for use for the driving user (and variable).	User water quality consequences protocol: Rivers.	This is a semi-quantitative assessment.
			Estuaries: Compliance/non-compliance of various scenarios for each estuary as it relates to water quality requirements of users/uses.		

6.6 STEP 4.6 NON-ECOLOGICAL WATER QUALITY: IDENTIFIED TOOLS AND EVALUATION PER ACTION

- **Action 3: Water quality, rivers – Determine consequences by linking expected changes in WQ state to requirement of priority driving variables**

One tool is evaluated; i.e. the User Water Quality Consequences protocol developed and used during the Letaba, Inkomati and Mvoti-Umzimkulu Classification studies (Table 6.5). References are shown in Section 6.7.

Table 6.5 Evaluation of the User Water Quality Consequences protocol (DWA, 2014; DWS, 2014; DWS, 2015)

Evaluation criteria		User Water Quality Consequences protocol
Frequency of application use	Evaluation	3 – Medium
	Explanatory Comment	Used in three Classification studies (Inkomati (DWS, 2014), Letaba (DWA, 2014) and Mvoti-Umzimkulu (DWS, 2015)).
Can the method be applied at a catchment level?	Evaluation	Yes
	Explanatory Comment	
Is the method described?	Evaluation	Yes
	Explanatory Comment	Method descriptions in DWS RQO reports
Indicate the status of publication of the method.	Evaluation	4 – National
	Explanatory Comment	DWS reports
Are there existing training course?	Evaluation	No
	Explanatory Comment	Training has taken place as part of Classification studies
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	Yes
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	
Compatibility	Evaluation	Yes
	Explanatory Comment	
Must software be purchased?	Evaluation	No
	Explanatory Comment	
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or adaptability of algorithms	Evaluation	n/a
	Explanatory Comment	
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	Output has not been tested against other protocols or tools
Description of mathematical algorithms and model structure	Evaluation	n/a
	Explanatory Comment	
Is the model robust?	Evaluation	Unknown
	Explanatory Comment	Output has not been tested against other protocols or tools

Evaluation criteria		User Water Quality Consequences protocol
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	Qualitative assessments of confidence and uncertainty only.

6.7 METHOD DESCRIPTIONS AND PUBLICATIONS

All methods identified and used during Integrated Step 4 are listed below. The associated publications (e.g. source of a manual and/or description of the methods) are referenced in this section and not in Chapter 8.

- **Flow-Concentration Model**

Malan, H.L. and Day, J.A. 2002. Development of numerical methods for predicting relationships between stream flow, water quality and biotic responses in rivers. WRC Report no. 956/1/02. Prepared for the Water Research Commission, Pretoria.

Malan, H., Bath, A., Day, J. and Joubert, A. 2003. A simple flow-concentration modeling method for integrating water quality and water quantity in rivers. Water SA 29 (3) 305-312.

Malan, H.L. 2004. Chapter 2: Integration of water quality and water quantity. pp 27 – 46 in Palmer, C.G., Scherman, P-A., Muller, W.J., Rossouw, J.N, Malan, H.L. and Jooste, S. Early development of water quality methods and approaches in ecological Reserve assessments. WRC Report no. 1108/1/04. Prepared for the Water Research Commission, Pretoria.

- **Scenario Comparison Tool**

Refer to Section 6.3
IN
Scherman, P-A, Louw, D; Koekemoer, S; Kotze, P; Mackenzie, J; Rountree M and Palmer, R. 2016. Noordoewer/Noordoewer/Vioolsdrift Dam Feasibility Study: Ecological Water Requirements Report: volume 1 – River. Draft Report prepared for AECOM-WCE Joint Venture.

- **Biointegrated Economic Model**

Maila, D., Naidoo, N., Visser, W., Mulders, J., Pearce, D., Crafford, J., Mitchell, S., Harris, K. and Magagula, T. 2015. Evidence-base analysis of environmental degradation: Impact of ecological degradation on water resources, ecosystems and socio-economic development. Deliverable 15: Case study of the Apies-Pienaars socio-ecological system. Water Research Project K5/2272. Prepared by Prime Africa.

- **WQSAM**

Slaughter, A.R. and Hughes, D.A. 2013. Development and application of a simple South African water quality model for management of rivers and reservoirs under current and future development and climate change scenarios. Water Research Commission Report No K5/2237/1. Prepared by the Institute for Water Research, Rhodes University, Grahamstown.

- **QUAL2K**

Chapra, S.C., Pelletier, G.J. and Tao, H. 2008. QUAL2K: A Modelling Framework for Simulating River and Stream Water Quality, Version 2.11: Documentation and User Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Department of Water Affairs and Forestry (DWAF). 2009. QUAL2K model for the Vaal River. Water Resource Planning Systems. Water Quality Planning.

- **USEPA BASINS**

US EPA. 2015. BASINS 4.1 (Better Assessment Science Integrating point & Non-point Sources) Modeling Framework. National Exposure Research Laboratory, RTP, North Carolina. https://www.epa.gov/exposure-assessment-models/basins.

- **User water quality consequences protocol**

Appendix B
IN
Department of Water Affairs (DWA). 2014. Classification of Water Resources and determination of the Resource Quality Objectives in the Letaba Catchment. Consequences and Management Class. Authored by Huggins, G, Louw, MD, Mullins, W, Seago, C, Scherman, P-A and Van Rooyen, P. Prepared by*:* Rivers for Africa eFlows Consulting (Pty) Ltd. DWA Report, RDM/WMA02/00/CON/CLA/0114.

Appendix C
IN
Department of Water and Sanitation (DWS), South Africa. 2014. The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area. Operational Scenarios and recommended Water Resource Classes. Authored by Huggins G, Louw MD, Mallory S, Van Jaarsveld P and Van Rooyen P. DWS Report, RDM/WMA05/00/CON/CLA/0214. September 2014. Authored by Scherman, P-A.

Department of Water and Sanitation (DWS). 2015. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 6: Supporting Information on the Determination of Water Resource Classes – User Water Quality Consequences of Operational Scenarios. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by Scherman, P-A.

7 STEP 6: DETERMINE RQOs (NARRATIVE AND NUMERICAL LIMITS) AND PROVIDE IMPLEMENTATION INFORMATION

Objective: ROQs (narrative and numerical) are specified for the Classes and catchment configuration per RU. RQOs are determined according to RU priority (as determined during Integrated Step 2.5). The output is to provide the appropriate level of RQOs for all RUs with the high priority RQOs being available for gazetting. High priority water quality sites identified in Steps 1 and 2 provide the input information into setting water quality RQOs, which will be in a numerical and narrative form.

This information informs the monitoring phase as well as the implementation of the Class configuration and the Reserve. According to the priorities of the RUs (determined during Integrated Step 1) different levels of detail is provided. High priority (including high priority water quality sites) and moderate priority RUs where water quality is a driver will require detailed RQOs for driving variables. High priority RUs and associated RQOs will be gazetted. All information is tested with stakeholders in preparation of gazetting the RQOs.

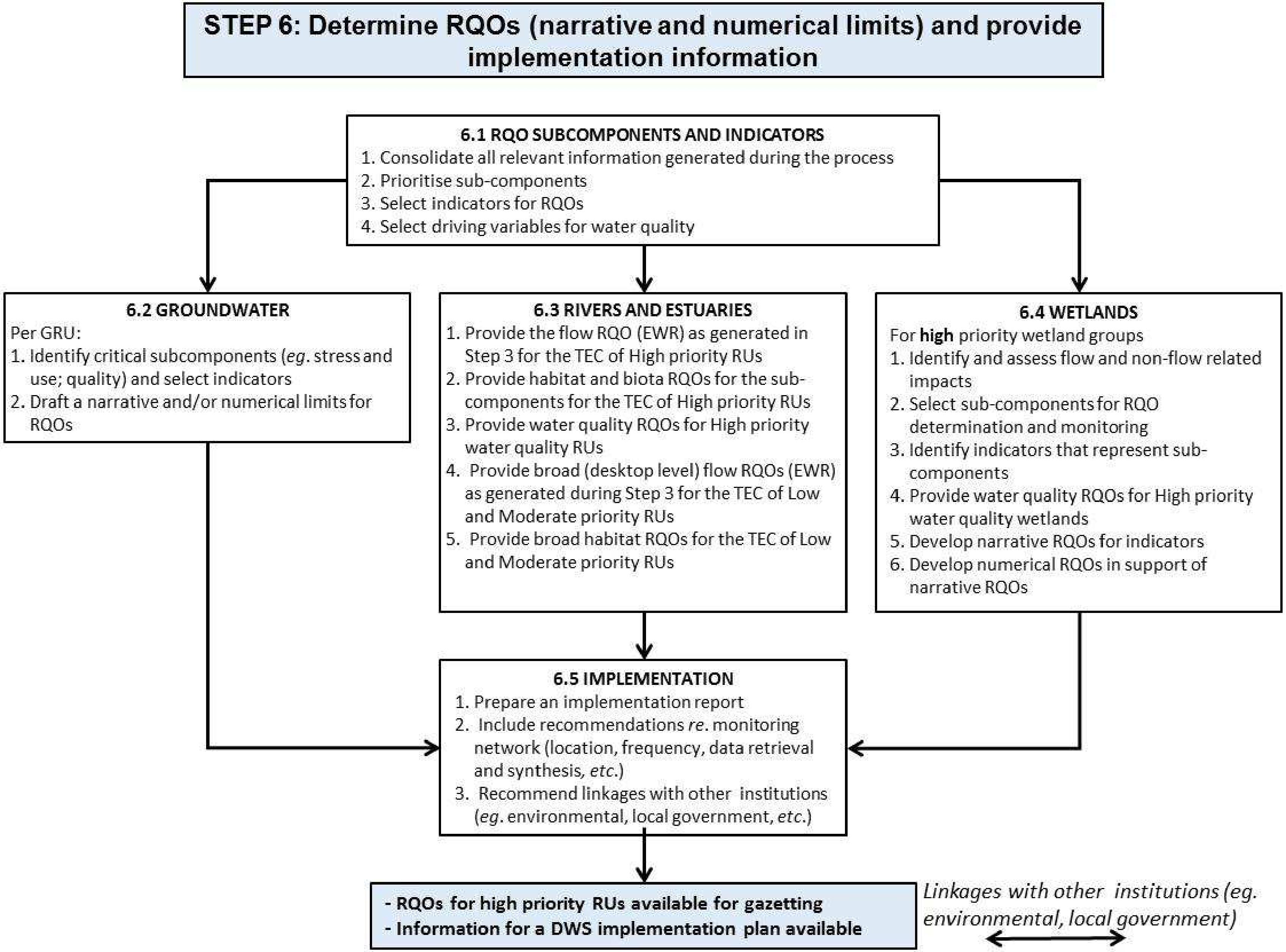

Figure 7.1 Illustration of the sub-steps for Step 6: Determine RQOs (narrative and numerical limits) and provide implementation information

7.1 STEP 6.1 RQO SUB-COMPONENTS AND INDICATORS: ACTIONS

Objective: Sub-components are identified and prioritised in each RU. With water quality this could relate to nutrients which are identified as a sub-component and phosphates as an indicator for a particular landuse.

The bullets below describe the actions required in this sub-step. Note that the numbers relate to the numbers in the flow diagram.

- **1. Consolidate all relevant information generated during the process**
- **2. Prioritise sub-components**
- **3. Select indicators for RQOs**
- **4. Select driving variables for water quality**

Most of the information required has been generated during Integrated Steps 1 to 4. During this step the information is consolidated, prepared in tabular form and forms the baseline for the determination of RQOs (numerical and narrative) for water quality.

7.2 STEP 6.3: RIVERS AND ESTUARIES

Objective: The objective of this step is to provide the RQOs for all RUs at the appropriate level. This information is then available to feed into the implementation report and the gazette. It must be noted that water quality is included in this step and addresses both the ecological aspects (in terms of habitat) **as well as those for the non-ecological user**.

The bullets below describe the actions required.

- **2. Provide habitat and biota RQOs for the subcomponents for the TEC of High priority RUs**

Water quality is presented here as habitat for biota. For estuaries, this would include water quality of river inflow, as well as that of the estuary itself.

- **Provide water quality RQOs for High priority water quality RUs**

This step encompasses the preparation of narrative and numerical RQOs for water quality, which would be represented by the driver variable(s) identified for the resource under investigation. Although ecological water quality is dealt with as a habitat RQO for rivers, provision has to be made for including non-ecological water quality, e.g. industry or recreational use, should these be the identified user. Driving variables for which RQOs need to be set must be identified. Cognisance must be taken as to whether RQOs are based on a database of monitored data (and RQOs may then be immediately applicable), or whether RQOs are preliminary, i.e. requiring data collection, and testing of monitored data against preliminary RQOs before the RQO becomes applicable. The following actions are required for determining RQOs for the water quality of rivers.

  - Use prioritisation (users and driving variables) from Integrated Step 4.6.
  - Use TECs from Integrated Step 5 for high priority RUs and moderate RUs where water quality is a driving variable.
  - Set RQOs (numerical in support of narrative, where available) based on the most stringent requirements, for the driving variables.

Standard DWS guidelines/databases are used as input. Additional sources are used as required. For rivers these sources may include (but are not limited to the following: (1) benchmark values for ecological categories as in DWAF (2008); (2) water quality ranges from water quality guidelines for users and the aquatic ecosystem (DWAF, 1996); and, (3) risk levels used by the DWS's National Microbial Monitoring Programme may be used for faecal coliforms and *Escherichia coli*. Estuarine information for users use guidelines such as: (1) water quality ranges from water quality guidelines (DWAF, 1995); and (2) recreational guidelines of DEA (2012).

7.3 STEP 6.4: WETLANDS

Objective: To determine the ecological consequences of the scenarios and provide a site and system ranking of scenarios.

The bullets below describe the actions required for each prioritised wetland for water quality.

- **4. Provide water quality RQOs for High Priority water quality wetlands**

7.4 STEPS 6.1, 6.3 AND 6.4 RQO SUB-COMPONENTS AND INDICATORS, RIVERS, ESTUARIES AND WETLANDS: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action (if relevant) are provided in Table 7.1.

Table 7.1 Standardised input and output per action

Action	Input	Comment/ Process	Output	Tool	Comment/Gaps
Step 6.1					
1. Consolidate all relevant information generated during the process	Information from Steps 1 – 4 for water quality.				
2. Prioritise sub-components	Undertaken during Step 2.5.				
3. Select indicators for RQOs	Undertaken during Step 2.5.				
4. Select driving variables for water quality	Output from Step 4 for rivers and estuaries, i.e. selection of driving variables linked to requirements of most sensitive user.	Tested with stakeholders during TTG meetings held as part of Integrated Step 4.		User water quality protocol: Rivers	This is a semi-quantitative approach.
				Resource Unit Evaluation Spreadsheet: Rivers	
Step 6.3					
Sub-steps/actions 2, 3 and 5: Water quality RQOs - EWR sites, sites where water quality is identified as part of Moderate priority RUs and High priority water quality RUs	Functional description of the catchment (from Steps 1 – 4) and its users, particularly detailed outputs from Step 4.6		Narrative and numerical (measurable) objectives for diving variables	Ecotoxicological approach to setting RQOs	
				Resource Water Quality Objectives Model (RWQO) approach (dashboard) (for non-ecological users): Rivers.	Although the RWQO model has been used extensively by DWS Water Quality Planning, its use by other practitioners has been limited.
			Identify variables which are a red flag but cannot yet be monitored as RQOs		
Step 6.4					
Provide Water Quality RQOs for the TEC of high priority wetlands	Key drivers of PES and threats for each prioritised wetland; data from EcoStatus assessments		Numerical (where possible) and narrative RQOs for water quality	Resource Unit Evaluation Tool - wetland module – evaluated in the Wetland Report, RDM/WE/00/CON/ORDM/0616	

7.5 STEPS 6.1, 6.3 AND 6.4 RIVERS, ESTUARIES AND WETLANDS WATER QUALITY IDENTIFIED TOOLS AND EVALUATION PER ACTION

- **Step 6.3 - Actions 2, 3, 5: Select driving variables for water quality**

Three tools are evaluated; i.e. 1) User Water Quality protocol developed and used during the Letaba, Inkomati and Mvoti-Umzimkulu Classification studies, 2) an Ecotoxicological approach to setting RQOs used for the Vaal and Olifants RQO studies (Table 7.2), and 3) Resource Water Quality Objectives model developed by DWS's Water Quality Planning and used for setting RWOs. Outputs were used for the Letaba, Inkomati and Mvoti-Umzimkulu RQO studies (Table 7.3). References are shown in Section 7.9.

The User Water Quality protocol and Resource Unit Evaluation spreadsheet were both assessed as tools in Step 4. An adaptation of the User protocol, i.e. the User Water Quality Consequences protocol, was also evaluated as a tool in Table 6.5 for assessing consequences of scenarios on non-ecological water quality users. As the principle steps and input data are the same, this modification of the protocol is not evaluated again. The reference section (Section 7.9) lists the RQO report where more detail can be sourced regarding the use of these protocols.

Table 7.2 Evaluation of an ecotoxicological approach to setting RQOs

Evaluation criteria		Ecotoxicological protocol
Frequency of application use	Evaluation	4 – High
	Explanatory Comment	The approach has been used for four RQO studies (3xVaal River; Olifants River).
Can the method be applied at a catchment level?	Evaluation	Yes
	Explanatory Comment	Scale independent
Is the method described?	Evaluation	Yes
	Explanatory Comment	Method descriptions in RQO reports
Indicate the status of publication of the method.	Evaluation	4 - National
	Explanatory Comment	DWS reports.
Are there existing training course?	Evaluation	No
	Explanatory Comment	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	N/a as used for RQOs.
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	Use of the tool is quick if all data are available
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	Information are available for most variables.
Compatibility	Evaluation	Yes
	Explanatory Comment	Uses standardized input and produces standardized output
Must software be purchased?	Evaluation	No
	Explanatory Comment	
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or adaptability of algorithms	Evaluation	n/a
	Explanatory Comment	

Evaluation criteria		Ecotoxicological protocol
Is the method validated and verified?	Evaluation	Yes
	Explanatory Comment	Based on international best practise in terms of toxicology
Description of mathematical algorithms and model structure	Evaluation	n/a
	Explanatory Comment	
Is the model robust?	Evaluation	n/a
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	Yes
	Explanatory Comment	Based on international best practise in terms of toxicology

Table 7.3 Evaluation of the Resource Water Quality Objectives model

Evaluation criteria		Resource Water Quality Objectives model
Frequency of application use	Evaluation	3 – Medium (outputs for the production of RQOs). 5 – Very high (by WQ Planning for the production of RWQOs).
	Explanatory Comment	Outputs from the RWQO model has been used for three RQO studies (Inkomati, Letaba and Mvoti-Uzimkhulu) .
Can the method be applied at a catchment level?	Evaluation	Yes
	Explanatory Comment	Scale independent
Is the method described?	Evaluation	Yes
	Explanatory Comment	User manual (DWAF, 2006); method descriptions in RQO reports (DWS, 2015).
Indicate the status of publication of the method.	Evaluation	4 - National
	Explanatory Comment	DWS reports.
Are there existing training course?	Evaluation	No
	Explanatory Comment	Training has been offered by WQ Planning to regional DWS offices.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Evaluation	N/a as used for RQOs.
	Explanatory Comment	
Time efficient (link to assessment level)	Evaluation	1
	Explanatory Comment	Use of the tool is quick if all data are available.
Is the data available to apply the method?	Evaluation	Usually
	Explanatory Comment	Dependent on the availability of data from WMS or other databases.
Compatibility	Evaluation	Yes
	Explanatory Comment	Some variables need correcting (e.g. NO_2+NO_3 should read NO_2+NO_3-N), and output therefore not standardised.
Must software be purchased?	Evaluation	No
	Explanatory Comment	
Licensing requirements	Evaluation	None
	Explanatory Comment	
Enhancement flexibility or adaptability of algorithms	Evaluation	n/a
	Explanatory Comment	
Is the method validated and verified?	Evaluation	No
	Explanatory Comment	
Description of	Evaluation	n/a

Evaluation criteria		Resource Water Quality Objectives model
mathematical algorithms and model structure	Explanatory Comment	
Is the model robust?	Evaluation	n/a
	Explanatory Comment	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Evaluation	No
	Explanatory Comment	
Additional comment	The model needs the correct interface with the operating system.	

7.6 STEP 6.5 IMPLEMENTATION: ACTIONS

Objectives: The rollout actions needed to implement the Water Resource Classes and RQOs are defined and described in this step. These should link to existing water quality monitoring programmes run by other DWS directorates, local authorities, Water Service Providers and other institutions are performing. A generic activity of this plan would involve soliciting support from relevant directorates to adjust or incorporate appropriate actions into their business plans for the benefit of implementing Water Resource Classes and RQOs.

The bullets below describe the actions required for each prioritised water resource.

- **2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)**

Provide a schedule of existing and additional proposed measuring requirements along with a description of all the organisations conducting monitoring in the catchments of water resource system.

7.7 STEP 6.5 IMPLEMENTATION: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action (if relevant) are provided in Table 7.4.

Table 7.4 Standardised input and output per action

Action	Input	Comment/Process	Output	Comment/Gaps
2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Knowledge of existing monitoring networks and monitoring data		Identify monitoring points for RQOs	Define and standardize monitoring points. E.g. if at downstream point in SQ, actually for downstream users
				Downstream cumulative impacts
				Define confidence; e.g. how many data points are appropriate for monitoring

7.8 STEP 6.5 IMPLEMENTATION: IDENTIFIED TOOLS AND EVALUATION PER ACTION

No water quality tools were identified for this action.

7.9 METHOD DESCRIPTIONS AND PUBLICATIONS

All methods identified and used during Integrated Step 6 are listed below. The associated publications (e.g. source of a manual and/or description of the methods) are referenced in this section and not in Chapter 8.

- **Ecotoxicological approach to setting RQOs**

Department of Water and Sanitation (DWS), 2014. Determination of Resource Quality Objectives in the Middle Vaal Water Management Area (WMA09): Resource Quality Objectives and Numerical Limits Report. Report No: RDM/WMA09/00/CON/RQO/0214. Prepared by: Golder Associates Africa in association with Wetland Consulting Services, Water Quality Consultants, WRP Consulting Engineers.

- **RWQO model**

Department of Water Affairs and Forestry (DWAF). 2006. Resource Directed Management of Water Quality: Management Instruments. Volume 4.2: Guideline for Determining Resource Water Quality Objectives (RWQOs), Allocatable Water Quality and the Stress of the Water Resource. Edition 2. Water Resource Planning Systems Series, Sub-Series No. WQP 1.7.2. ISBN No. 0-621-36793-1. Pretoria, South Africa.

- **User Water Quality Protocol**

Chapter 3.1.2
IN
Department of Water and Sanitation (DWS). 2014. The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area. Resource Quality Objectives. Authored by Deacon AR, Kotze PJ, Louw MD, Mackenzie JA, Scherman P-A,. DWA Report, RDM/WMA05/00/CON/CLA/0414.

Chapter 3.2
IN
Department of Water and Sanitation (DWS). 2015. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 1: River Resource Quality Objectives. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd.

- **Resource Unit Evaluation Spreadsheet**

Department of Water and Sanitation (DWS). 2014. Determination of Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10): Resource Quality Objectives and numerical limits Report. Report No.: RDM/WMA10/00/CON/RQO/0214. Chief Directorate: Water Ecosystems. Study No.: WP10535. Prepared by the Institute of Natural Resources (INR) NPC. INR Technical Report No.: INR 494/14.(vi). Pietermaritzburg, South Africa.

Lesotho Highlands Development Authority, (LHDA). 2016. Specialist Consultants to Undertake Baseline Studies (Flow, Water Quality and Geomorphology) and Instream Flow Requirement (IFR) Assessment for Phase 2: Instream Flow Requirements for the Senqu River – Final report No 6001/2/e. Lesotho Highlands Development Authority, Maseru.

- **Implementation and water quality**

Department of Water and Sanitation (DWS). 2015. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Implementation report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by Pieter van Rooyen, Delana Louw, Patsy Scherman, Lara van Niekerk, Susan Taljaard, Shael Koekemoer, Piet Kotze, James Mackenzie, Karim Sami.

8 CONCLUSIONS

The workshop conducted in July 2016 was considered a valuable step forward in standardizing water quality RDM methods for use in South Africa. A number of gaps exist; with a primary gap being the much needed DWS review, update and completion of the DWAF (2008) draft methods manual for rivers. The implication of long-term use of methods still not officially approved by DWS, although being used widely by DWS and practitioners conducting work for DWS, was discussed at length.

The workshop also provided an opportunity to discuss methods available and not widely known, but in use by practitioners for data analysis and manipulation, for example, the methods available to patch data. As water quality data can be patchy and of low confidence, these types of tools are considered invaluable. There was also the opportunity to “formalize” tools developed and being used during a number of water quality RDM studies, such as the diatom and user water quality protocols.

Exposure to new tools, e.g. the Biointegrated Economic Model, and those under development, such as the quality/quantity modelling tools that can be used for assessing water quality consequences, was an interesting component of the workshop. The value of regression techniques for linking variables and flow time series of driving variables, was again reiterated.

One of the gaps in the approach followed by consultants to date, is information on the process by which standardised outputs for water quality are reached, and the step assessing responses to stressors. This is necessary to inform prioritisation and water quality consequences of scenario steps. A useful contribution of the workshop was therefore the opportunity to formalize the way in which the water quality “context” of a catchment can be built up, and how relationship between the stressors can be responders can be evaluated. Although done for every study, this standardization/tools process could formalize the way in which this can be approached, guided by a number of useful documents produced by the Water Quality Planning directorate of DWS.

Additional gaps or points of importance identified can be listed as follows:

- TEACHA needs to be reprogrammed into a more user-friendly format and less costly platform.
- Although the RWQO model has been used extensively by DWS Water Quality Planning, its use by other practitioners has been limited.
- Data confidence still needs to be defined; e.g. how many data points are appropriate for monitoring.
- Determining cumulative downstream water quality impacts is still a challenge.

The interaction between water quality specialists from DWS divisions such as RDM, Water Quality Planning, Resource Quality and Information Services (RQIS), and practitioners was considered the most positive outcome of the workshop.

9 REFERENCES

Department of Environmental Affairs (DEA). 2012. South African water quality guidelines for coal marine waters. Volume 2: Guidelines for Recreational Use.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996a. South African water quality guidelines. Volume 2: Recreational Use.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996b. South African water quality guidelines. Volume 3: Industrial Use.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996c. South African water quality guidelines. Volume 7: Aquatic Ecosystems.

Department of Water Affairs and Forestry (DWAF). 2003. Water Quality Management Series, Sub-Series No. MS 8.2. A Guide to Conduct Water Quality Catchment Assessment Studies: In Support of the Water Quality Management Component of a Catchment Management Strategy. Edition 1. Pretoria.

Department of Water Affairs and Forestry (DWAF), 2006a. Development of the Water Resource Classification System (WRCS) Volume 1 Overview and 7-step classification procedure.

Department of Water Affairs and Forestry (DWAF), 2006b. Resource Directed Management of Water Quality: Introduction. Edition 2. Water Resource Planning Systems Series, Sub-Series No. WQP 1.7.6. ISBN: 0-621-36786-9. Pretoria, South Africa.
https://www.dwa.gov.za/projects/iwqms/Documents.aspx

Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the water quality component of the Ecological Reserve. Report prepared for Department of Water Affairs and Forestry, Pretoria, South Africa by P-A Scherman of Scherman Consulting.

Department of Water Affairs (DWA), South Africa. 2011. Procedures to Develop and Implement Resource Quality Objectives. Department of Water Affairs, Pretoria, South Africa.

Department of Water Affairs (DWA). 2014. Assessing the Impact of Land-based Activities on Water Resources: User Manual for the Automated Land-based Activity Risk Assessment Method version 1.01. No. WP 10255.

Department of Water and Sanitation (DWS). 2014a. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa.
Compiled by RQIS-RDM:https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.

King, J.M. and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management 1: 109-124.

Louw, M.D. and Hughes, D.A. 2002. Prepared for the Department of Water Affairs and Forestry, South Africa. Resource Directed Measures for Protection of Water Resources: River Ecosystems - Revision of a quantity component.

10 APPENDIX A: REPORT COMMENTS REGISTER

Page Number	Chapter /Section /Step	Comment	Addressed in report?	Comment/explanation
		Add a Conclusion chapter	Yes	Conclusions have been added to the report.
5-5	Table 5.2 re: RapidMiner	The latest version of RapidMiner is not free. The last free version of RapidMiner was version 5.0. KNIME is a useful alternative. It seems to have more functionality in the more advanced statistical applications, while RapidMiner is better for less advanced statistics.	Yes	Table 5.2 corrected. Note that although KNIME may be used as an alternative freeware method, it has not been included in the report or evaluated as it has not yet been used for RDM applications.
		Geomorphological processes are not covered specifically although habitat is. It should be considered as it is as important a driver as flow.		Point noted. Geomorphological methods are covered in the Rivers Tools Report, RDM/WE/00/CON/ORDM/0516.
		Interflow should be considered as a flow contributor to rivers and wetlands (and should be regarded more specifically than just as part of groundwater). A large quantity of water feeding wetlands and rivers are contributions from hillslope hydrology, water moving in the unsaturated zone (vadose zone) in the soil profile. This issue will have to be included in future when we assess intactness of flow drivers and to a certain extent water quality.		Point noted. Interflow is referred to in the Groundwater/Hydrology/Hydraulics Tools Report (RDM/WE/00/CON/ORDM/0916), as part of the groundwater/interflow Status Quo description requirement.