REPORT NO.: RDM/WE/00/CON/ORDM/0616

DEVELOPMENT OF PROCEDURES TO OPERATIONALISE RESOURCE DIRECTED MEASURES

PROJECT NO: WP 10951

WETLAND TOOL ANALYSIS AND STANDARDISATION REPORT

OCTOBER 2016

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REPUBLIC OF SOUTH AFRICA

DEVELOPMENT OF PROCEDURES TO OPERATIONALISE RESOURCE DIRECTED MEASURES

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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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Contributions to the report in terms of identifying methods and evaluating the methods were provided by:

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The following DWS representatives participated at the specialist meeting held on 18 - 19 July 2016 and contributed to the discussions and information in the report.

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Thirion, Christa	D: Resource Quality Information Services
Thwala, Mmaphefo	Water Resource Classification
Weston, Barbara	D: Resource Directed Measures

REPORT SCHEDULE

Version	Date	Comments
First draft	October 2016	No comments
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

BHNR	Basic Human Needs Reserve
CBA	Critical Biodiversity Area
CD: WE	Chief Directorate: Water Ecosystems
DRIFT	Downstream Response to Imposed Flow Transformation
DWA	Department Water Affairs
DWAF	Department Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Areas
HGM	Hydro-geomorphic
IBA	Important Birding Area
IUA	Integrated Units of Analysis
IWRM	Integrated Water Resource Management
NFEPA	National Freshwater Ecosystem Priority Area
NWRCS	National Water Resource Classification System
PES	Present Ecological State
PESEIS	Present Ecological State and Ecological Importance-Ecological Sensitivity
PSP	Professional Service Provider
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SQ	Sub quaternary reach
TEC	Target Ecological Category
ToR	Terms of Reference
VB	Valley Bottom wetland
WCS	Wetland Consulting Services
WMA	Water Management Area
WRC	Water Research Commission

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 methods 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, methods 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 workshop, are provided below:

Aim: Standardise methodologies for Reserve determination. Note, methodologies required for Classification and RQO determination, that are 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 of wetland specialists during 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 framework, 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 wetland tool analysis and standardisation workshop specialist meeting (18 to 19 July 2016) (RDM/WE/00/CON/ORDM/0616).

2 APPROACH

2.1 BACKGROUND

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

- Water Resource Classification System (DWAF, 2006).
- 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, 2006) 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 be addressed.

Each of the RDM processes therefore 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 the fact that the study area for these assessments is usually large with many nodes (points of interest) requiring varying levels of detail dependant on whether the study is undertaken 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, adds to the complexity of inputs, outputs and the methodologies required to achieve these outputs.

2.2 INTEGRATED FRAMEWORK

During a February 2016 specialist meeting, an Integrated Framework was designed and subsequently finalised (DWS, 2016). The Integrated Framework consists of eight steps. Each step is sub-divided into sub-steps described through a list of actions grouped together under various labels. The design and numbering of the flow diagrams are provided below:

Each individual step within the Integrated Framework is sub-divided 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 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 1, 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.

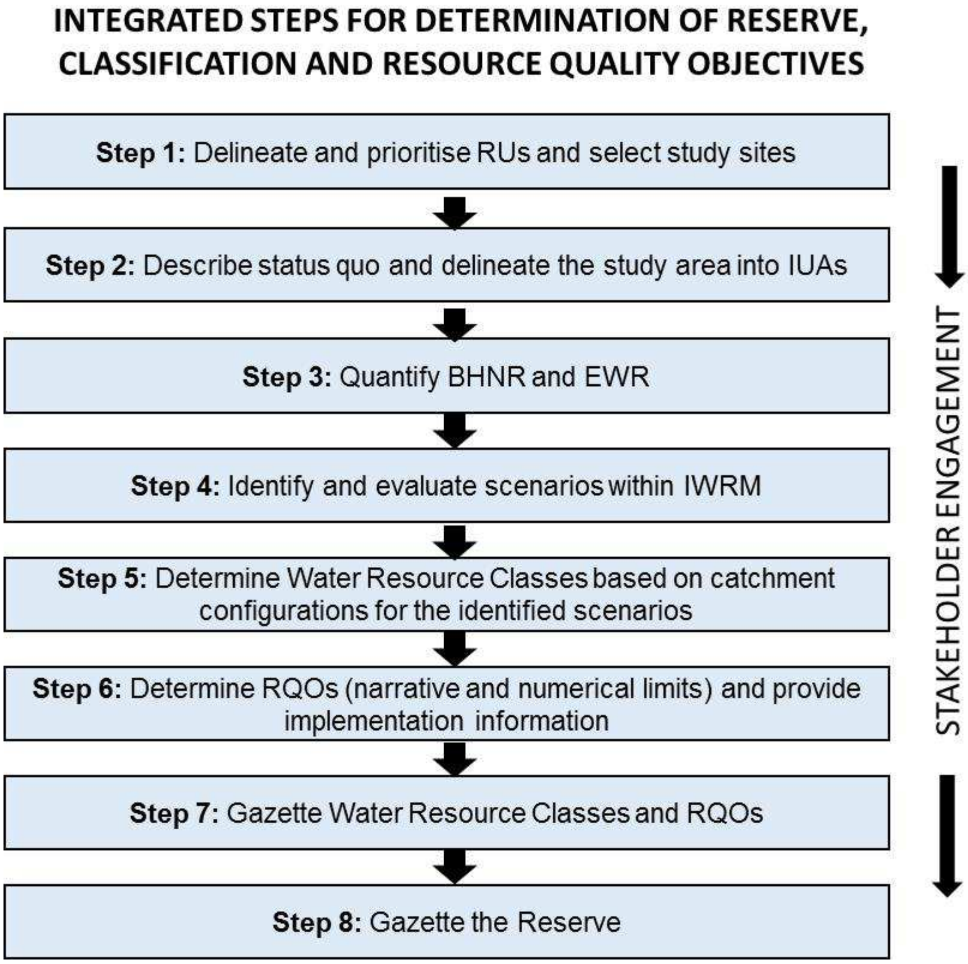

Figure 2.1 Integrated steps for the determination of the Reserve, Classification and Resource Quality Objectives

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 (now known as the Ecological Water Requirement) 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 methods and also developed one of the first holistic methods (King and Louw, 1998), the Building Block Methodology which catered for South African circumstances and DWS's requirements 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 Ecological Water Requirement which is used to determine 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 Resource Quality Objectives. For wetlands, Rapid Ecological Reserve Determination methods (Rountree *et al*., 2013) were developed during a 3-year study undertaken by a large multi-disciplinary team of wetland specialists, but higher confidence Reserve assessment methods for most wetland types remain poorly developed.

The myriad 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 that Reserve, Classification and RQO studies are undertaken under the auspices of IWRM and results of these studies must be compatible with 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 indicate whether these methods comply with a range of requirements and whether the input and output comply with 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 of this evaluation is on the standardisation of the inputs and outputs of each sub-step's actions rather than the 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 IWRM - 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 PESEIS etc.
- Outputs: 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, inputs and outputs may not be relevant for some sub-steps.

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 have been applied for the sub-steps and actions. Tools refer to any models, methods or systematic approaches and are collectively referred to as METHODS in this document. The models could be detail hydrological models, spreadsheet formulas, methodical procedures and techniques.

If a sub-step does not require a tool, this is noted as not applicable. If methods are not available, this was identified as a gap.

Note:
- **Not all sub-steps or actions required a method.**
- **Actions were grouped in the sub-step if methods were applicable to these groups rather than per action.**
- **Note that if there are methods that have been used extensively in the past but which are now obsolete, these methods will not be evaluated, but will be provided in this report including the reasons why they are obsolete (e.g. TEACHA and BBM).**
- **Standard computer packages such as Google Earth, Microsoft Office suite of programmes, Statistica etc. are not RDM methods within the context of this study. Methods or models can be written using Excel as per example, but the method would be the spreadsheet model, not the computer package which is used.**

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

TERMINOLOGY: TOOLS vs METHOD
The use of the word 'tools' created confusion as most people associated tools with computer models. Further in this report, the word '**method**' will rather be used to accommodate the confusion with regards to the tool terminology.
Tools refer to any models, methods or systematic approaches. The models could be detailed hydrological models, spreadsheet formulas, methodical procedures and techniques.

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) that are used for 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 on 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.

2.7 EVALUATION CRITERIA

The criteria for the method evaluation, the evaluation manner and an explanatory comment is provided in Table 2.1 below.

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, and 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 apply the method?	Always; Usually; Seldom; Never	Describe the reliance of method on monitored 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;	Purpose of criteria is to indicate the risk of keeping method relevant.

Criteria	Evaluation	Explanatory comment
	5 Commercial	
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 a rating by expert opinion): please describe.

3 STEP 1: DELINEATE AND PRIORITISE RUS AND SELECT STUDY SITES

Objective: The objective of this step 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 Integrated 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 Resource Units (RUs) information is gazetted 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.

Integrated Step 1 contains six sub-steps. Wetlands fall within sub-step 1.3 and sub-step 1.5 – Aquatic Ecosystems and is discussed in this Chapter.

[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.

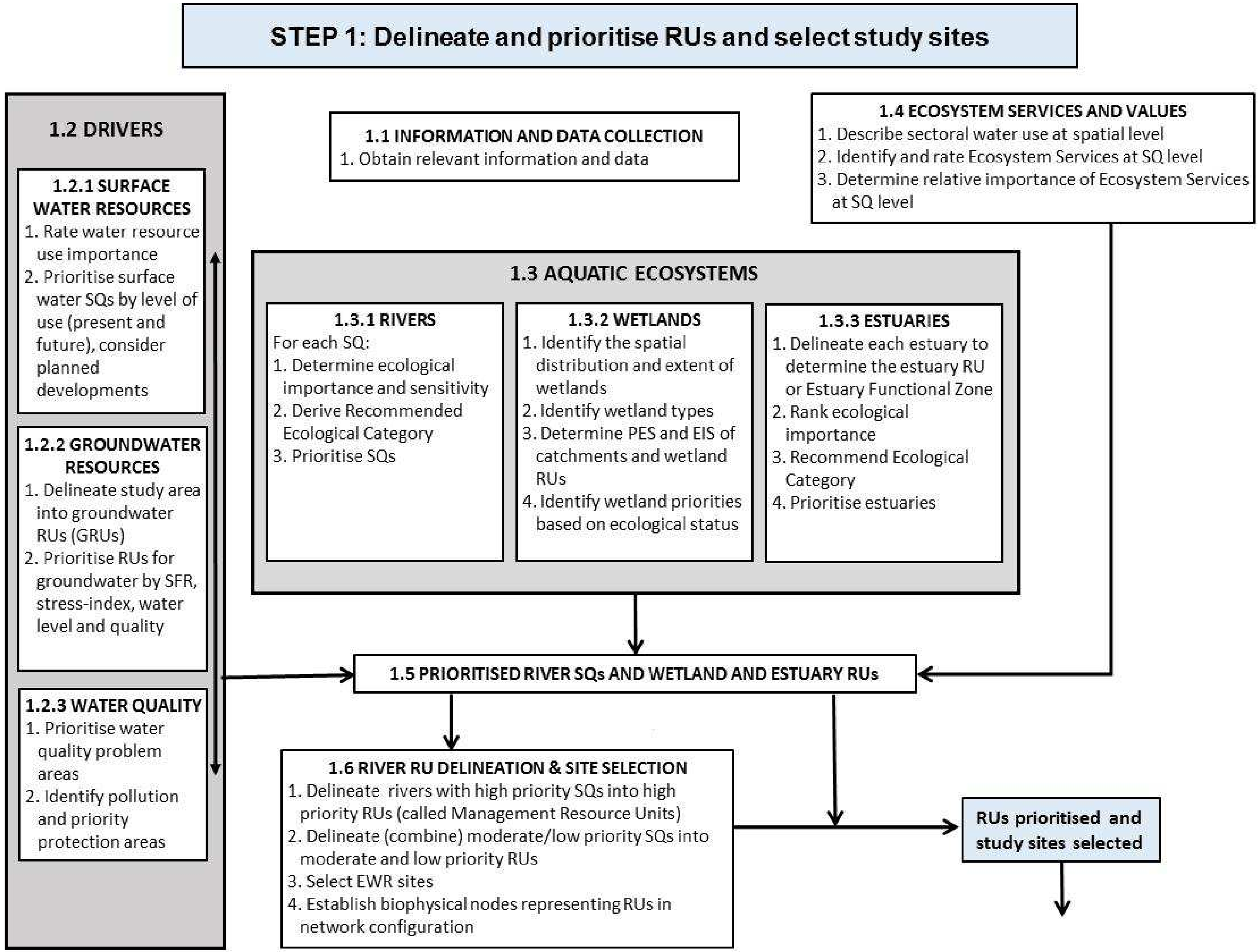

Figure 3.1 **Illustration of the sub-steps for Integrated Step 1: Delineate and prioritise RUs and select study sites**

3.1 STEP 1.3.2 WETLANDS: ACTIONS

Objective: The objective is to delineate RUs for wetlands and to prioritise these on the basis of ecological condition, as well as importance and sensitivity. Once wetlands have been prioritised in terms of ecological criteria, the list of prioritised wetlands is refined and updated to include considerations of water resource use and risk of degradation.

Considering the heterogeneity of wetland types and thus the inability to accurately extrapolate broadly between wetlands, wetland resource units (Wetland RUs) are given as individual wetlands or clusters of interconnected wetlands (such as pans and their associated seeps). Nevertheless, prioritisation takes place at different scales for different purposes. At the catchment scale, ecological condition and importance can be determined as an average for that area and prioritised accordingly. These are then the units for setting generic resource quality objectives (RQOs) as a final step in the RDM process. At a wetland RU scale, the actions within this step are applicable to specific wetlands and the prioritised list of wetlands is then the subject of more detailed investigation as part of the subsequent steps in the RDM process.

The bullets below describe the actions required.

- **1. Identify the spatial distribution and extent of wetlands.**
- **2. Identify wetland types based on primary HGM type and vegetation.**
- **3. Determine Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) of catchments and wetland RUs.**
- **4. Identify wetland priorities based on ecological status (which includes condition, importance and sensitivity).**
- **5. Refine wetland priorities by considering other factors, particularly current and expected resource demand and risk of degradation.**

The inputs required to fulfil these steps and the standardised outputs generated from these actions is provided in the next section.

3.2 STEP 1.3.2 WETLANDS: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action (if relevant) are provided in Table 3.1 and described in this section.

- **1. Identify the spatial distribution and extent of wetlands**

The identification of wetlands is based on existing spatial wetland data at a broad (study area) scale and should include national and provincial (or regional) data. The best available *national scale* spatial wetland database is currently the NFEPA layer which was finalised in 2011 (Nel *et al.,* 2011). In terms of wetlands, this layer identifies FEPAs, wetland ecosystem types and estimates condition on a national scale. Although the map augments wetlands from several different information sources obtained at different scales, there is significant under-mapping of wetlands, particularly isolated systems such as depressions, seeps and flats with a higher under representation in the more arid parts of the country (Skowno *et al*., 2014; Snaddon *et al.* 2015). In a comparative study with the national wetlands database and regional fine scale databases, van Deventer *et al.* (2015) found that the national data only represent 54% of wetlands mapped at a regional scale and inaccuracies in wetland types and condition classifications were also quantified. Similarly, the RDM study on the determination of RQOs in the Olifants WMA (DWS, 2014d) compared wetlands mapped as part of the NFEPA process and that mapped at a finder scale in the upper Olifants region from aerial imagery. That study clearly demonstrates the discrepancies between wetland spatial layers mapped at different scales and highlights the issues associated with using wetland data mapped at different scales in the same study area to provide the outputs required for RDM studies (DWS 2014d).

To improve confidence and data resolution, it is strongly recommended that this step involve some manipulation of the existing NFEPA map as well as some validation of wetlands within the study area. While some study areas may require more refinement than others, the level of refinement required should be considered during the planning stages of any RDM study.

As part of the National Wind and Solar PV Strategic Environmental Assessment for wetlands, Skowno *et al.* (2014) (Appendix 3) provides methods to edit the existing NFEPA wetlands layer to generate a map of natural wetlands only, as well as eliminate some inaccuracies and remove mapping artefacts. This method has not been used in RDM studies to date and is therefore not evaluated further. However, the protocol provides the same output required for this step in RDM studies and therefore it is recommended that this approach be adopted. In terms of verification of wetland delineation and typing, Google Earth and freely available SPOT imagery are useful resources for this process. 1: 50 000 topographical maps, the 1: 50 000 rivers and dam coverage, geology maps and the peat ecoregions are also useful information sources to verify wetlands. Furthermore, the national wetland map (NWM3), as well as various region-specific fine-scale maps should be used if available to improve confidence in the generation of the extent and typing of wetlands within the study area.

Despite the limitations of exiting wetland maps, key wetlands of a study area (those of national or provincial importance deserving of *detailed RDM studies*) are likely to be known - the NFEPA study has already indicated wetlands and wetland clusters in each WMA that are considered national conservation priorities (Nel *et al.,* 2011).

- **2. Identify the types of wetlands**

The typing of wetlands is based on HGM types and vegetation groupings given as the wetland ecosystem types within NFEPA database (Nel *et al.,* 2011). The HGM types are based on the National Wetland Classification System level 4 (SANBI, 2009) which has recently been updated (Ollis *et al.,* 2013) and vegetation groupings that are derived from the vegetation map of South Africa (Mucina and Rutherford, 2006). Wetland ecosystem types thus provide a basis for understanding the heterogeneity of wetland types at a broad scale that are used as a starting point for determining regional wetland groups. Although there are several classification types that have been used in RDM studies, these are not relevant at this step which is based on existing broad scale datasets.

- **3. Determine PES and EIS of catchments and wetland RUs**

At both a catchment and wetland RU scale, ecological condition, together with identified expert knowledge on features of conservation importance within the National Freshwater Ecosystem Priority Area (NFEPA) database (e.g. extensive intact peat wetlands, presence of rare plants and animals) as well as available spatial data on the occurrence of threatened amphibians and wetland-dependent birds (Nel *et al*., 2011) are used as a starting point to inform the ecological importance of wetlands. This coverage is always filtered to exclude all artificial wetlands. Considering that the NFEPA database provides a low confidence information source, it is recommended that other data sources be used to augment this data source. If available, the NFEPA wetland coverage is supplemented with wetlands indicated in local conservation plans, provincial wetland coverages or from other desktop or more detailed studies. In the case of river linked wetlands such as valley bottoms and floodplains associated with main stem rivers, the fact sheets of the Sub Quaternary (SQ) river reaches in the Present Ecological State and Ecological Importance-Ecological Sensitivity (PESEIS) database (DWS, 2014a) can be useful. Also, the national Land Use database can be useful to assist with determining wetland condition or sensitivity. In particular, Wetland Consulting Services (WCS) describes a landcover intersect method (Table 3.1) for PES estimation. In this method, individual wetland units are scored based on their intersection with various land-cover types, derived from the National Landcover dataset. A Present Ecological State (PES) Category is then assigned to each wetland based on a set of specific rules that translate landuse into PES categories. Although these methods are used for deriving PES at the desktop level at a regional scale, there are no specific methods or approaches for deriving Ecological Importance and Sensitivity (EIS) at the same level and EIS is generally inferred from various spatial datasets. Various approaches (see Table 3.1) are available to collate these inputs such that PES and EIS information is the standardised output of this action. In the case of catchments however, this information is then averaged for each catchment to provide catchment level PES and EIS information as the standardised output. In terms of wetland RUs, PES and EIS is not averaged but is given for each wetland as standardised output of this action.

- **4. Identify wetland priorities based on ecological status**

At a quaternary or sub-quaternary catchment scale, a combination of averaged PES and EIS is used to provide a list of priority catchments from an ecological perspective. In terms of wetland RUs, wetland PES and EIS, together with a list of criteria indicated as standardised input in Table 3.1 is used to:

- Identify and rate biodiversity value and ecological importance. Rate specific criteria that define biodiversity value based on desktop information (e.g. RAMSAR status, condition, habitat for rare and endangered species (birds, frogs etc.), Freshwater Ecosystem Priority Areas ((FEPA) status, wetland extent and provincial Critical Biodiversity Areas (CBAs)).
- Identify and rate functional value. Rate specific criteria that evaluate the functional value including socio-economic value; hydrological functioning (flow regulation, maintenance of base flows) and water quality amelioration.
- Identify and rate sensitivity of each wetland unit using size, type and landuse.

- **5. Refine wetland priorities by considering other factors, particularly resource demand and risk**

Once a preliminary list of wetland priorities at the catchment and RU scale is established, other considerations should be used to refine the final prioritised list. As a standard input, information that would help to determine resource demand and existing and future risks of degradation is specified. This information may be readily available from regional government departments but can be determined from information on landuse and water demand within the study area. Wetlands that support important ecosystem goods and services are listed as a standardised input to address the social importance of wetlands within the study area. Inputs from other project components including groundwater, rivers, social and water quality are listed as a standard input because these may assist with identifying links to important water resources that are considered priorities. For example, a high priority river may be sustained by upstream seep wetlands. The importance of these wetlands for the functioning of a priority river would automatically deem these seeps as a priority.

Table 3.1 Step 1.3.2: Standardised input and output per action

Action	Scale	Input	Output	Method	Comment
1. Identify the spatial distribution and extent of wetlands	Catchment	NFEPA wetland database (Nel *et al.*, 2011) or most recent National Wetlands Map from SANBI	Map of natural wetlands within the defined study area with a database of wetland ecosystem types (primary HGM types together with vegetation types)	None identified but see recommendations in text	The input map requires some processing to remove mapping artefacts and artificial systems; Some wetland validation is recommended considering the low confidence associated with this spatial database (see text).
2. Identify the types of wetlands (wetland ecosystem types)					
3. Determine PES and EIS of catchments and wetland RUs	Catchment	NFEPA database: wetland condition and key features	Catchment scale PES and EIS	Sub-quaternary based PESEIS tool (DWS, 2014a)	Various tools are currently being developed to improve the desktop approach to determining the PES. It is recommended that once these approaches have been finalised, the best approach and the standardised inputs required be revisited through a workshop of key wetland specialists. It should be noted that while the EIS is an important output of this step, there are no standard tools or approaches for determining the EIS at the desktop level at this stage.
				Quaternary-based PESEIS (DWAF, 2009; DWA 2010a,b; 2013a; DWS, 2015)	
	Wetland RU	NFEPA database: wetland condition and key features	Wetland RU PES and EIS	Land cover intersect method for PES estimation (WCS) – PES determination only	
4. Identify wetland priorities based on ecological status	Catchment	Catchment scale PES and EIS	List of ecologically important catchments	Broad-scale Wetland Prioritisation Approach (WCS)	The inputs for this action are the outputs of action 1 above at a catchment scale.
	Wetland RU	Wetland RU PES and EIS	List of ecologically important wetland RUs	Detailed Wetland Prioritisation Approach (WCS)	The first input for this action is the output of action 1 above at a wetland RU scale. While some of the inputs listed here may be included in the NFEPA database, fine-scale information may be available to inform these inputs and should be used if available. It should be noted that the NFEPA map includes ecologically important wetlands (FEPAs) and thus the inputs should be used to validate/verify these FEPAs and augment the list of ecological priorities if and where necessary.
		Important Birding Area (IBAs)			
		RAMSAR systems			
		Wetland threat status based on type and rarity			
		Unique/highly biodiverse systems			
		Landscape connectivity			
5. Refine wetland priorities by considering other factors,	Catchment	List of ecologically important catchments	Ranked list of priority catchments		
		Regional office information on			

particularly resource demand and risk		resource demands			
	Wetland RU	List of ecologically important wetland RUs	Ranked list of priority wetland RUs	Decision analyst (Escot)	
		Spatial information on priorities identified by other components of the study, particularly rivers, groundwater, social and water quality		RU prioritisation tool (DWS, 2014a)	
		Ecosystem goods and services data		Workshop with regional office/experts (DWAF, 2009; DWA, 2010b, DWS, 2015)	
		Regional office information on resource demands			

3.3 STEP 1.3.2 WETLANDS: IDENTIFIED METHODS AND EVALUATION PER ACTION

No methods have been applied to RDM studies for actions 1 and 2 to date. The input data for these two actions are largely based on existing information. As indicated in Section 4.2, application of methods used in other broad-scale wetland studies (e.g. Snaddon *et al.,* 2015) should be considered. In addition it should be recognised that existing databases may become redundant as they become replaced or improved and that the most up to date data should then be used. The methods applicable to the remaining actions relevant to this step are detailed below.

3.3.1 Action 3: Determine ecological condition and importance of wetlands

Two methods for determining ecological condition and ecological importance and sensitivity (PES and EIS) of wetlands were identified at the catchment scale (Table 3.1). Studies on the Outeniqua, Upper Vaal, Inkomati, and Gourtiz WMAs (DWAF, 2009; DWA, 2010b,a; 2013a and DWS, 2015) developed and applied an approach to estimate the average PES and EIS of all wetlands at the quaternary catchment scale. The Inkomati study (DWA, 2013a) describes an approach to determining sub-quaternary catchment scale EI and ES for wetlands based on data from the fact sheets and plant species lists of existing river PESEIS databases to rate a number of criteria. The median scores are then used to determine a general sub-quaternary catchment scale EI and ES for wetlands. Similarly, both approaches describe a desktop PES assessment of wetland based on rating a list of criteria that describe wetland condition at a quaternary or sub-quaternary catchment scale. While these approaches are very similar, there is some variation in the EIS and PES criteria lists used by the various studies. Also, the source of information for rating these criteria and the scale at which it is applied (i.e. sub-quaternary vs quaternary catchments) differs between these two desktop EIS and PES assessment tools. These tools are evaluated in Table 3.2.

At the scale of specific wetlands, a GIS-based landuse model for PES determination was developed by WCS. This is evaluated in Table 3.3. PES estimates for all wetlands are also available within the NFEPA database (Refer to Action 4 in Section 3.2 of this report).

Table 3.2 Action 3: Evaluation of Quaternary based PES and EIS tools

Criteria	Sub-quaternary based EI ES and PES tool		Quaternary based EIS and PES tool	
	Evaluation	Explanatory comment	Evaluation	Explanatory comment
Frequency of use of the application?	Very low	Has been used in Inkomati WMA.	Medium	Has been used in the Orange, Outeniqua, Mvoti, Inkomati, Upper Vaal and Gouritz WMAs.
Can the tool be applied at a catchment level?	Yes	Applied at the sub-quaternary catchment scale.	Yes	Applied at the quaternary catchment scale.
Is the method described?	Yes	Described in Inkomati WMA Status Quo Report (DWA, 2013a).	Yes	Described in the Orange, Outeniqua, Mvoti, Upper Vaal, Inkomati and Gouritz wetland studies.
Indicate the status of publication of the method	Internal	Described within RDM study reports.	Internal	Described within RDM study reports (DWAF, 2009; DWA 2010a,b; 2013a and DWS, 201a).
Are there existing training courses?	No		No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	This method is applicable at a desktop level.	Yes	This method is applicable at a desktop level.
Time efficient (link to assessment level)	1 week	The approach relies heavily on existing information although verification of input information is required.	< 1 week	The approach relies on Google Earth assessment of PES (using FEPA wetland maps) and available desktop information for the EIS.
Is the data available to apply the method?	Usually	The method is based on existing information although the accuracy of existing information is questionable and therefore requires verification during the study.	Always	The method is based on existing information although the accuracy of existing information is questionable and therefore requires verification during the study.
Compatibility?	Yes	The method is compatible with existing databases and approaches.	Yes	The method is compatible with existing databases and approaches.
Must software be purchased?	No		No	
Licencing requirements?	No		No	
Enhancement flexibility or adaptability of algorithms?	N/A		N/A	
Is the method validated and verified?	No	Although it has been used in RDM studies, the results have not been validated in the field.	Partially	Some testing and validation of results has been undertaken, most recently with data supplied by KZN-Ezemvelo for the Mvoti WMA (DWA, 2013b).
Descriptions available of mathematical algorithms and model structure?	No	EIS and PES criteria rated but the detail of rating and collation of information is not available	Yes	EIS and PES criteria and method provided in DWAF (2009); DWA (2010a,b).
Is the model robust?	No	In terms of the criteria used to evaluate the PES and EIS, the tool is relatively robust although the use of some criteria are questionable and should be rationalised, particularly the	No	In terms of the criteria used to evaluate the PES and EIS, the tool is relatively robust although the use of some criteria is questionable and should be rationalised. Also, in terms of PES assessment, the way in which the criteria are

Criteria	Sub-quaternary based EI ES and PES tool		Quaternary based EIS and PES tool	
	Evaluation	Explanatory comment	Evaluation	Explanatory comment
		density of wetlands. Also, the approach relies substantially on the use of data used for the generation of SQ EcoStatus for rivers. While these data may be valid for river-linked wetlands on the main system through an SQ, all other river-linked wetlands, as well as isolated systems are not included. This is a major limitation of the approach, particularly for catchments that are dominated by isolated wetlands or wetlands not on the mainstem river.		used is vague and thus the ability to reproduce similar results is questionable The tool excludes all quaternary catchments with less than 0.5% surface area of wetlands based on NFEPA mapped wetlands. The exclusion of catchment on this basis up front is questionable.
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	Does not include an evaluation of confidence although confidence is considered low.	Yes, (partially)	Confidence rating for data entry is included in the model.

The above evaluation indicates that neither approach is robust because some of the EIS and PES criteria considered are questionable and the approach to rating these criteria is vague. Essentially, the results generated are not easily replicable.

At the scale of individual wetlands or wetland RUs, a GIS-based landuse model (Land cover intersect method) for PES estimation was developed for assessing condition of individual wetlands and has been applied in several studies (Table 3.3). Unlike the quaternary-based PES and EIS methods evaluated in Table 3.2, this method can be applied at both the wetland RU level or at the catchment scale. However, this method only provides an indication of wetland condition (PES).

While this method provides a rapid way of categorising wetlands at a catchment scale, a major limitation is that the method may underestimate the PES Category. This is particularly the case where a minimal intersection of one low ranking land cover category causes the whole wetland to be categorised as lower in terms of PES. Although alternative measures are considered to improve confidence in the PES rating, this is considered time consuming to undertake at secondary catchment or higher level (such as a Water Management Area (WMA)) study as there are automation limitations associated with individual wetland Hydro-geomorphic (HGM) units. This tool is evaluated in Table 3.3.

Table 3.3 Action 3: Evaluation of Land cover intersect method for PES estimation (WCS)

Criteria	Evaluation	Explanatory comment
Frequency of use of the application?	Medium	Was used for Croc West Matlabas, Marico, Middle Vaal, Usuthu/Mhlatuze WMAs.
Can the tool be applied at a catchment level?	Yes	It is designed for assessing individual wetland RUs but the data can be summarised at the catchment scale.
Is the method described?	Yes	Briefly described in Reserve determination study of Ushutu-Mhlathuze: Wetland prioritisation report (DWS, 2014b).
Indicate the status of publication of the method	Internal	Described within wetland reserve reports (Usutu-Mhlathuze Reserve study).

Criteria	Evaluation	Explanatory comment
Are there existing training courses?	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	This method is a desktop approach.
Time efficient (link to assessment level)	1 week for regional scale studies (WMA)	Relies on modelling landuse data and wetland extent although some verification of data is required.
Is the data available to apply the method?	Usually	Relies on landuse data and wetland extent - the accuracy of the latter is questionable.
Compatibility?	Yes	The PES Categories align with existing PES Categories used in RDM studies.
Must software be purchased?	No	Evaluation of PES relies on analysis of spatial data for which free software is available (e.g. QGIS).
Licencing requirements?	No	
Enhancement flexibility or adaptability of algorithms?	N/A	
Is the method validated and verified?	No	Although it has been used in RDM studies, it is a desktop tool that has not been validated.
Descriptions available of mathematical algorithms and model structure?	None	The model to scores landuse activities to generate the PES category is not published or described in the available reports.
Is the model robust?	No	The quality of the output is reliant on the quality of the input data and, as described in the text, the level of accuracy associated with the input data is variable and unreliable. Also, the outputs are only robust if everyone uses the same scoring system (and as this is not shown in the report, it cannot be replicated).
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	No, but the confidence is assumed to be low.

There are currently a number of research based studies underway to develop methods for the determination of wetland EcoStatus at a desktop level. In particular, a Water Research Commission (WRC) project titled "*Development of a refined suite of tools for assessing the PES of wetland ecosystems in South Africa*" (WRC Project number K5/2549). As part of the suite of tools to be developed, included is a broad-scale desktop-based PES determination method which relies on existing mapped land cover categories (NLC2014) within a wetland and within its buffer and the broader catchment. This method will build on a preliminary version of a wetland ecological condition assessment tool based on land cover developed by D. Kotze in 2015. The method is currently being tested and refined, and will then be finalised within the WRC project currently underway. This tool will then provide a standardised, verified and tested approach particularly suited to the evaluation of EcoStatus at the desktop level and it is therefore recommended that this approach be considered in future RDM studies.

3.3.2 Actions 4 and 5: Identify wetland priorities based on ecological and other criteria

As with the determination of ecological condition and importance, the prioritisation process is scale dependant such that either catchments or wetlands RUs or both are prioritised. Firstly, priority catchments or wetland RUs are identified through the evaluation of various data inputs that define their ecological condition or importance (e.g. PES and EIS, RAMSAR, IBAs, wetland type and rarity). Thereafter, inputs from other components such as groundwater, river, water quality are considered, together with information on water resource use and socio-cultural importance to provide a ranked list of priority catchments and/or wetlands.

WCS describe a desktop wetland prioritisation approach applied in the Usuthu-Mhlatuze study (DWS, 2014b), that uses various spatial datasets as described above as a starting point for prioritisation (Tables 3.4 and 3.5). A first level of prioritisation is achieved by identifying wetlands indicated as priority (indicated as a WETFEPA in the attribute table) in the NFEPA dataset. Further prioritisation is then carried out based on the ecological importance of terrestrial areas (which intersect the wetlands, as indicated by the relevant provincial conservation plan datasets). These criteria are then used to prioritise wetlands as low, middle or high priorities. A more detailed wetland prioritisation process is also described by WCS where specific information on Ecological Importance based on various criteria ranging from biodiversity value to uniqueness, functional value and threatened status is used to refine the list of priorities within a study area (Table 3.5). One of the main limitations of these tools is that they attribute priority to wetlands low priority as the risks of degradation and resource demand may be low. These two criteria are introduced in action 3 when the list of priorities is further refined.

In most wetland components of RDM studies to date, the prioritisation process has not relied on standardised methods or approaches. The wetland component of the Upper Vaal (DWA, 2010b), Inkomati (DWA, 2010a), Mvoti (DWA, 2013b) and Gouritz (DWS, 2015) RDM studies for example relied on consultation regional DWS staff and other local experts to identify priority wetlands in the respective study areas.

In the classification study for the Inkomati WMA (DWA, 2013a), the “hotspot tool” developed specifically for identifying river priorities was used to identify wetland priorities (Tables 3.1 and 3.6). However, in that study *only river-linked wetlands* were considered in the prioritisation process. This is a critical limitation in a catchment where large important pan wetlands are present. In the Olifants WMA (DWS, 2014c) and Upper Vaal WMA RQO (DWS 2014d) studies, a rationalisation process based on a series of available desktop spatial data was adopted. These datasets were analysed using “Decision Analyst” to identify priority wetland RUs (Tables 3.1 and 3.6). In the case of the Olifants WMA study (DWS 2014c), the RU prioritisation tool was also applied to wetlands for the identification of priority wetland RUs. Thereafter, engagement with key stakeholders enabled verification of priority wetlands based on local knowledge.

Table 3.4 Action 4: Evaluation of ecological prioritisation tools for wetlands at the broad-scale

Criteria	Broad-scale Wetland Prioritisation Approach (WCS)	
	Evaluation	**Explanatory comment**
Frequency of use of the application?	Very low	Used in the Usuthu/Mhlatuze WMA.
Can the tool be applied at a catchment level?	Yes	Wetland RUs on a broad, catchment scale are prioritised.
Is the method described?	Yes	Described within the wetland prioritisation report for the Usutu-Mhlatuze RDM study (DWS, 2014b).
Indicate the status of publication of the method	Internal	Described within the wetland prioritisation report for the Usutu-Mhlatuze RDM study.
Are there existing training courses?	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	Applicable to all levels.
Time efficient (link to assessment level)	<1 week	This is a desktop analysis of existing spatial data (uses FEPAs i.e. existing priorities together with terrestrial areas of conservation importance to run an intersect of the spatial data so the process is relatively quick).

Is the data available to apply the method?	usually	Relies on NFEPA database and provincial conservation plans but the latter data is not available for the entire country.
Compatibility?	Yes	The outputs are compatible with inputs required in subsequent steps in the process.
Must software be purchased?	No	Application of the tool relies on GIS software.
Licencing requirements?	None	
Enhancement flexibility or adaptability of algorithms?	N/A	
Is the method validated and verified?	No	No, although it has been applied to identify wetland priorities, the approach has not been validated.
Descriptions available of mathematical algorithms and model structure?	Yes	Prioritisation criteria described.
Is the model robust?	Yes	Considering that the input data for the prioritisation process are standard, it is likely that the output priority list would be repeatable.
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	There is no evaluation of confidence included in the method.

Table 3.5 Action 4: Evaluation of ecological prioritisation tools for wetlands at a detailed scale

Criteria	Detailed Wetland Prioritisation Approach (WCS)	
	Evaluation	Explanatory comment
Frequency of use of the application?	Very low	Used in the Usutu/Mhlatuze WMA.
Can the tool be applied at a catchment level?	No	Designed to prioritise wetlands on a more detailed level and thus application at a catchment level would be too data intensive.
Is the method described?	Yes	Described within the wetland prioritisation report for the Usutu-Mhlatuze RDM study (DWA 2014b).
Indicate the status of publication of the method	Internal	Described within the wetland prioritisation report for the Usutu-Mhlatuze RDM study (DWA 2014b).
Are there existing training courses?	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	Applicable to all levels.
Time efficient (link to assessment level)	1 week	This is a desktop analysis of existing spatial data which considers a large number of ecological criteria.
Is the data available to apply the method?	Seldom	Relies on relatively detail local conservation plans and provincial wetland coverages that are not always available.
Compatibility?	Yes	The outputs are compatible with inputs required in subsequent steps in the process.
Must software be purchased?	No	Application of the tool relies on GIS software.
Licencing requirements?	None	
Enhancement flexibility or adaptability of algorithms?	N/A	N/A
Is the method validated and verified?	No	No, although it has been applied to identify wetland priorities, the approach has not been validated.
Descriptions available of mathematical algorithms and model structure?	Yes	Prioritisation criteria described.
Is the model robust?	No	Although this method offers a mechanism for prioritising wetland RUs based on existing spatial data layers, there is no standard requirement for which data should be included in the analysis and therefore, in its current form, the approach is subjective.

Criteria	Detailed Wetland Prioritisation Approach (WCS)	
	Evaluation	Explanatory comment
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	There is no evaluation of confidence included in the method.

Table 3.6 Action 5: Evaluation of prioritisation tools for resource use and risk

Criteria	Hotspot Tool		Decision Analyst		RU prioritisation tool	
	Evaluation	Explanatory comment	Evaluation	Explanatory comment	Evaluation	Explanatory comment
Frequency of use of the application?	Very low	Used in the Inkomati WMA.	Low	Used in the Upper Vaal and Olifants WMAs.	Very low	Used in the Olifants WMA for the determination of RQOs.
Can the tool be applied at a catchment level?	Yes	It was used to identify individual priority wetlands or areas (such as SQs), but evaluation criteria can be applied at a broader catchment level.	Yes	It was used to identify individual priority wetlands RUs. It could be used at a catchment scale to identify areas of importance.	No	The information required to apply it at a catchment scale would be too intensive.
Is the method described?	Yes	Described within wetland RQO report for the Inkomati catchment.	Yes	Described within wetland RQO reports for the Upper Vaal and Olifants catchments only.	Yes	Described in a user manual and a series of spreadsheets. It was originally developed for rivers and adapted for wetlands. An adapted version has been used at an IUA scale. It's useful but it requires refinement.
Indicate the status of publication of the method	Internal	Described within wetland RQO report for the Inkomati catchment.	Internal	Described within wetland RQO reports for the Upper Vaal and Olifants catchments only.	National	DWA (2011) report.
Are there existing training courses?	No		No		No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	Applicable to all levels.	Yes	Applicable at all levels.	Yes	Applicable at all levels.
Time efficient (link to assessment level)	1 week but depends on scale	This is a desktop analysis of existing data, so can range in terms of time taken to conduct depending on actual data and scale of assessment, but took less than 1 week for the Inkomati study.	Unknown but > 2 weeks	Not able to assess according to the number of weeks. However, it is data and time intensive.	Unknown but at > 2 weeks	Not able to assess according to the number of weeks. It is extremely data and time intensive.
Is the data available to apply the method?	Varies	National databases (such as NFEPA and PESEIS) are always available, but wetland specific data are seldom available.	Usually	Most of the data required are based on spatial data inputs which are generally available, although the quality of data may be questionable in some instances.	Seldom	In terms of the current method, the data required for application to wetlands are generally not available for large study areas with numerous wetlands.
Compatibility?	Yes	The outputs are compatible with inputs required in subsequent steps in the process.	Yes	The outputs are compatible with inputs required in subsequent steps in the process.	Yes	The outputs are compatible with inputs required in subsequent steps in the process.

Criteria	Hotspot Tool		Decision Analyst		RU prioritisation tool	
	Evaluation	Explanatory comment	Evaluation	Explanatory comment	Evaluation	Explanatory comment
Must software be purchased?	No	This is a simple spreadsheet comparison of stipulated wetland criteria.	No		No	
Licencing requirements?	None		None		None	
Enhancement flexibility or adaptability of algorithms?	N/A		N/A		N/A	
Is the method validated and verified?	No	Not applicable since this is a simple spreadsheet comparison of stipulated wetland criteria.	No	Only used in two projects to date.	Yes	Some field verification was undertaken during the development of the protocols.
Descriptions available of mathematical algorithms and model structure?	Yes	Prioritisation criteria described.	N/A		N/A	
Is the model robust?	No	Criteria are subjectively assessed to indicate priority or combinations of priority.	No	Although this method offers a mechanism for prioritising wetland RUs based on existing spatial data layers, there is no standard requirement for which data should be included in the analysis and therefore, in its current form, the approach is subjective.	Yes	The method is considered robust because it relies on specific data inputs that are standardised and described. However, the method can only be applied if the required data is available and this is unlikely at the scale required for prioritising wetlands within RDM studies.
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	Confidence of the method is reliant on the confidence of the input data.	No	Confidence of the method is reliant on the confidence of the input data. Without verification of the method, assessment of confidence is not possible.	No	Confidence of the method is reliant on the confidence of the input data. Although the method has been tested through groundtruthing, this was limited and thus assessment of confidence is not possible.

The evaluation in Tables 3.4, 3.5 and 3.6 suggests that there are existing methods that have been applied in various RDM studies to prioritise wetlands. In terms of prioritising wetlands on ecological criteria only, the two methods evaluated have only been applied in one RDM study and have not been verified or validated. Both methods rely on fairly sophisticated GIS spatial data analysis and it is questionable as to whether the output differs significantly from existing database information (NFEPA priorities). Also, in the case of the more detailed ecological prioritisation of wetlands approach (Table 3.5) may be limited by the data requirements.

In terms of the prioritisation tools which include both ecological criteria as well as input on resource demand and risk of degradation, the available methods are either bias towards specific systems (i.e. only river-linked wetlands in the Hotspot tool) or are data and time intensive. The prioritisation process in both the Upper Vaal and Olifants RQO studies (DWS, 2014d; DWS 2014c) used these data intensive methods and verified the outcome through stakeholder meetings. They found that these desktop models yielded a similar outcome to what had already been achieved in a stakeholder engagement process (Ian Bredin, INR, *Pers. Comm.*), the latter being far less time consuming, more cost effective and reliant on local knowledge rather than secondary datasets. However, there is the possibility that reliance on stakeholders and local knowledge to inform the prioritisation process may preclude wetlands that are unknown by stakeholders present at the workshop. Nevertheless, the existing methods available for prioritisation are currently fraught with some subjectivity, although they offer the potential for refinement into tools that may provide a more objective means of prioritisation. Such refinement may also limit the input datasets required and thus reduce the current data requirements and time necessary to apply the method. Although such refinement is beyond the scope of this assessment, it is recommended that the approach to prioritisation be investigated such that the operationalisation of RDM methods become standardised in future studies.

4 STEP 2: DESCRIBE STATUS QUO AND DELINEATE THE STUDY AREA INTO IUAs

Objective: The objective of this 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, delineate IUAs. The status quo information for the study area is then used to describe the status quo for each IUA.

Integrated Step 2 contains eight sub-steps. Wetlands fall within sub-step 2.4 and is discussed in this Chapter.

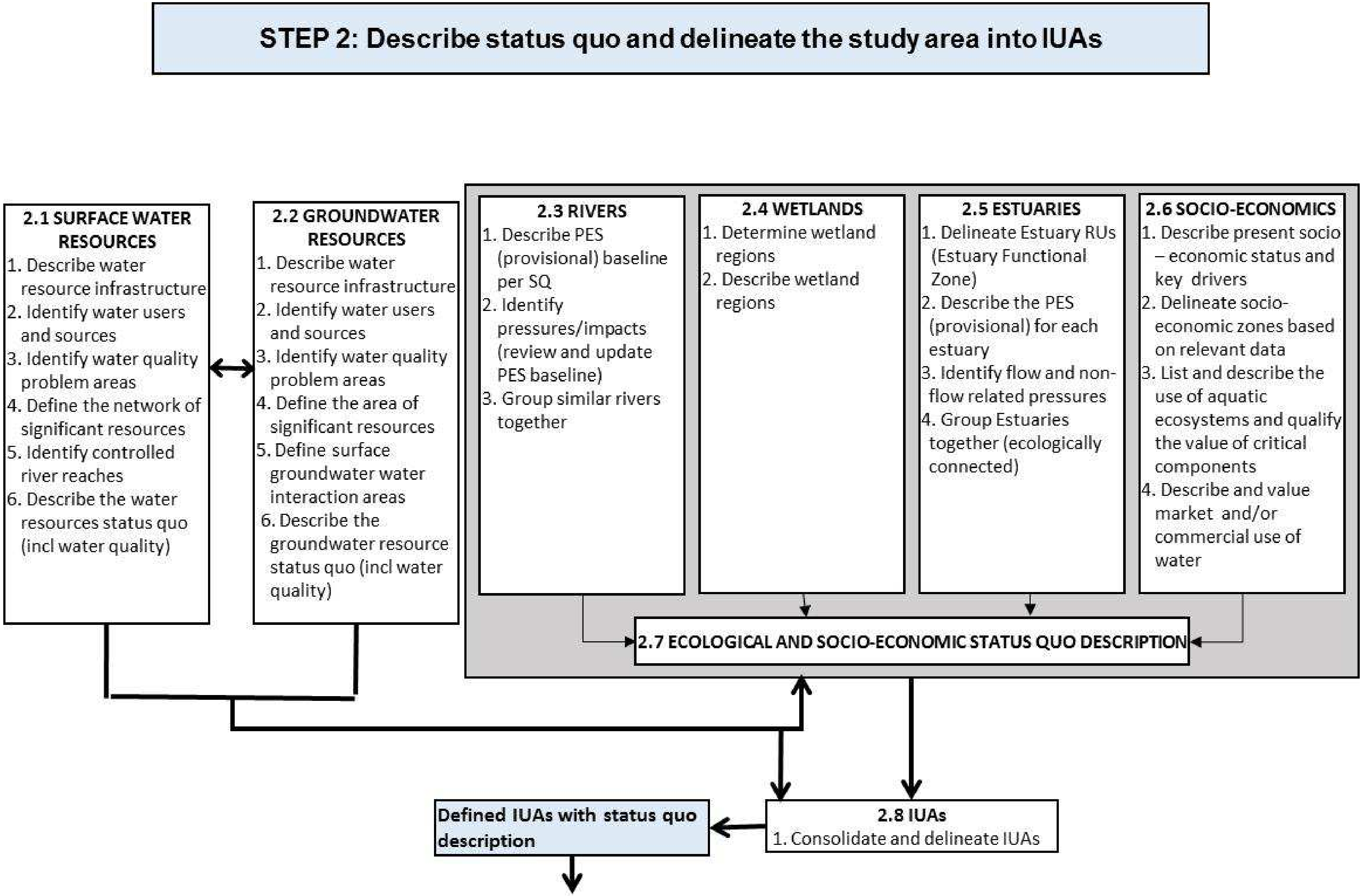

Figure 4.1 Illustration of the sub-steps for Integrated Step 2: Describe status quo and delineate the study area into IUAs

4.1 STEP 2.4 WETLANDS: ACTIONS

Objective: Identify, type and establish groups of wetlands. For each group, the ecological state must be broadly described.

The bullets below describe the actions required.

- **1. Determine broad wetland regions.**
- **2. Describe wetland regions.**

The inputs required to fulfil these steps and the standardised outputs generated from these actions are provided in the next section.

4.2 STEP 2.4 WETLANDS: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action (if relevant) are provided in Table 4.1 and described in this section.

- **1. Delineate regional wetland groups**

Broad wetland groups are determined from an evaluation of wetland ecosystem types, Level 1 and 2 EcoRegions, geology and ground water characteristics of the study area. Rountree *et al.* (2013) lists specific information sources used to define wetland resource units for small scale Rapid Reserve Determinations for wetlands and these were used largely to inform the standardised inputs for determining regional wetland groups (See Box 1) indicated in Table 4.1. Examples of regional wetland groupings in large scale studies, are provided by DWAF (2009) for the Outeniqua catchment, DWA (2010a) for the Inkomati WMA, DWA (2010b) for the Upper Vaal, DWA (2013b) for the Mvoti WMA and DWS (2015) for the Gouritz WMA.

Box 1: WETLAND REGIONS VS WETLAND RUs

Wetland regions delineate WMAs in to units that broadly define wetland characteristics on a similar scale to ecoregions – typically between Level 1 and Level 2 ecoregions. By contrast, wetland RUs are individual wetland systems (which may contain more than one HGM type) or wetland clusters (a group of more than one pan or seep that rely on their connectivity to maintain their ecological integrity).

At the Wetland Region scale, the characteristics of these regions are used to set broad recommendations and management conditions for wetlands, determined according to the landuse threats and risks of wetlands in each region.

- **2. Describe wetland regions**

The status quo descriptions of each wetland region augment information generated as part of Action 1 which uses wetland type and broad biophysical characteristics to define wetland regions, with information on the condition of wetlands provided within the NFEPA database. The confidence in the estimation of condition varies across regions, although Snaddon *et al.* (2015) found that the NFEPA wetland condition provided a relatively good representation of wetland condition for the eight landscape level regions across South Africa that were in that study. Although the NFEPA wetland condition estimate is considered as standardised input during this action, the confidence of these estimates should be verified for a specific study area and refined if necessary. Information from the SQ PESEIS (DWS, 2014a) fact sheets have been used in such instances in previous studies, however this approach is limited in that only wetlands on the main river are considered in the SQ database. Nevertheless, in some instances refinement of the PES determination has been undertaken based on consideration of landuse using other spatial data sources, particularly Google Earth.

Table 4.1 Step 2.4: Standardised input and output per action

Action	Input	Output	Method	Comment
1. Determine broad wetland regions	Wetland map (Action 1 output) Level 1 and 2 EcoRegions Geology (1:500 000) Groundwater Resources (from ground water component of the study)	Map of wetland regions	None identified	Examples of regional wetland groups identified for this step are given in DWAF (2009), DWA (2010a,b; 2013a and DWS (2015).
2. Describe wetland regions	NFEPA wetland condition (Nel *et al*., 2011); landuse	Broad descriptions per wetland region		The status quo descriptions are provided at a broad scale and summarised for each wetland region.

4.3 STEP 2.4 WETLANDS: IDENTIFIED METHODS AND EVALUATION PER ACTION

No methods have been applied to RDM studies for these actions to date. Although the input is largely based on existing information with some critical inputs from the groundwater component of the study, it is recommended that some manipulation of the information be undertaken to improve the accuracy of the information output which is the basis for all subsequent steps. As indicated in Section 4.2, application of methods used in other broad-scale wetland studies (e.g. Snaddon *et al.,* 2015) should be considered. In addition it should be recognised that existing databases may become redundant as they become replaced or improved and that the most up to date data should then be used.

5 STEP 3: QUANTIFY BHNR AND EWR

Objective: The objective of this step is to quantify the Ecological Water Requirements (EWRs) for different ecological states and set the Basic Human Needs Reserve (BHNR). These EWRs (Ecological Categories (ECs) and associated flow regime) 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.**

During Integrated Step 3 (Figure 5.1), the BHNR and the EWR components that describe the Reserve, once the IUAs have been classified, are determined. EWRs are set at desktop level for the desktop biophysical nodes and at detailed level for the study sites (EWR sites) that are selected during Integrated Step 1. 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 Target Ecological Category which happens in later steps in the process.

Integrated Step 3 contains four sub-steps. Wetlands fall within sub-step 3.3 – Ecological Water Requirements and is discussed in this Chapter.

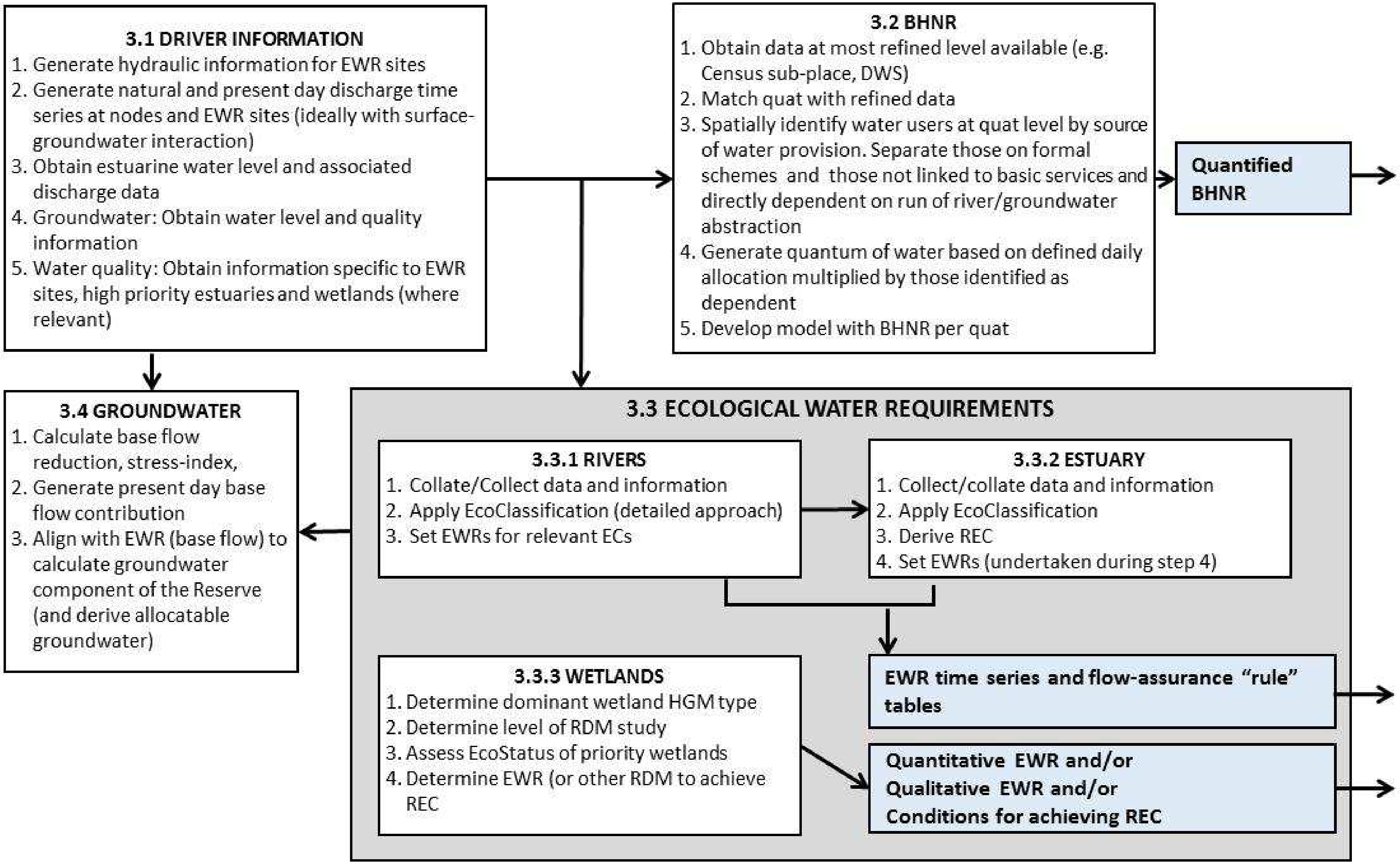

Figure 5.1 Illustration of the sub-steps for Integrated Step 3: Quantify BHNR and EWR

5.1 STEP 3.3.3 WETLANDS: ACTIONS

Objective: The objective is to provide conditions that support the hydrological functioning of wetlands for the maintenance of a desired ecological state. These conditions will vary depending on wetland type from quantified flow volumes and distribution or inundation regimes (i.e. quantification of the reserve) to setting of criteria for the protection of wetland condition where the hydrological requirements cannot be quantified.

The output from Integrated Step 1 is the identification of the prioritised catchments or wetland RUs within the study area. For each priority wetland RU where further detailed RDM work is to be undertaken, the necessary actions are addressed within this step. The bullets below describe the actions required.

- **1. Determine dominant wetland HGM type**

The HGM wetland type dictates the method of RDM study, as there are different types of assessment methods and EWR determination approaches for different types of wetlands (pans and lakes, for example, require different types of expertise and hydrological and hydraulic approaches to those used on floodplains). For the Rapid Reserve methods for wetlands, the DWAF (2007) and Rountree and Batchelor (2013) HGM wetland classification has been followed although the classification system for wetlands developed by Ollis *et al.* (2013) is being applied more widely as a standard approach to wetland classification throughout South Africa.

- **2. Determine appropriate level of RDM study for wetlands**

The document "*Guideline for identifying appropriate levels of Resource Protection Measures for Inland Wetlands*" (DWA, 2012) provides a framework for selecting the appropriate level of RDM study for wetlands. This approach uses the type of wetland and impact type or threat being considered to identify an appropriate level of RDM assessment. The RDM assessment may be either a quantitative EWR determination, a qualitative EWR determination or, in the most simple (low risk) situations, the determination of simple conditions to achieve the Recommended Ecological Category (REC).

- *Quantitative EWR*: Provision of a quantifiable water requirement in terms of volumetric water requirement. This approach would be applied to systems where the primary source of inflows is from a river, such as a floodplain. However, the approach takes into account more than just river inflows and might consider rainfall and evaporation. Outputs may, for example be a time series of river discharge, inflows, outflows and saturation of wetland units.
- *Qualitative EWR*: Provision of a non-volumetric water requirement. This would apply to wetlands where maintenance of inundation levels or extents (defined temporally) would reflect the hydrological functioning of a wetland required for the maintenance of a desired ecological condition. The output could, for example, be a time series of water levels.
- *Conditions for achieving REC:* Provision of simple ecological or site management conditions for the maintenance of wetland integrity to achieve the REC.

- **3. Assess EcoStatus of priority wetlands**

This is achieved through the following:

- Validating the PES.
- Determining the EIS.
- Determining the REC.

An overall PES of the wetland should be determined. Detailed driver and habitat component PES may be required to be determined and an overall PES calculated from the component scores. A variety of PES assessment methods exist for validating the low confidence desktop estimation of

PES and these can be selected based on the level of study and components that are relevant for each wetland type (Table 5.1).

It should be noted that WRC Project K5/2549 titled "*Development of a refined suite of tools for assessing the PES of wetland ecosystems in South Africa"* which is currently underway, will provide a refinement of these existing tools, taking cognisance of the problems that have been identified with using these tools to date. Of particular relevance to this sub-step are the following two proposed tools that will form part of this suite of tools:

- Site-scale, field-based very rapid PES determination by experts which would involve a short field datasheet, similar to the approach of 1999 RDM method (DWAF, 1999) for wetland PES assessment, although the approach will be more robust.
- Site-scale, field-based rapid PES determination by trained assessors. This method will be a refined version of WET-Health, representing a combination of the current "Level 1" and "Level 2" approaches, including an additional module for Water Quality PES.

Also, an approach to a comprehensive assessment of wetland PES based on detailed studies incorporating intensive biophysical data collection will be addressed in this WRC project. While no tools, as such, are envisaged for this level of assessment, guidelines will be produced for such assessments.

The EIS should be assessed using the Rountree and Kotze (2013) approach for wetlands, and REC can be determined according to the guideline in the Rapid Reserve Manual for Wetlands (Rountree *et al*., 2013).

Table 5.1 Action 3: Available methods for assessing the PES and EIS of wetlands

<table>
<tr><th rowspan="3">Wetland Type</th><th colspan="8">Step 3 EcoStatus determination methods</th></tr>
<tr><th rowspan="2">EIS</th><th rowspan="2">Overall PES</th><th colspan="6">PES Components</th></tr>
<tr><th>Vegetation</th><th>Hydrology</th><th>Geomorphology</th><th>Water Quality</th><th>Diatoms</th><th>Inverts</th></tr>
<tr><td>Seepage wetlands</td><td rowspan="7">Rapid Reserve EIS Method (Rountree and Kotze, 2013) is applicable for all wetland types.</td><td>MacFarlane et al. (2007)</td><td colspan="3" rowspan="4">MacFarlane et al. (2007)</td><td rowspan="3">Malan et al. (2013)
or
Malan and Day (2012)</td><td rowspan="6">Koekemoer and Taylor (2013)</td><td>n/a*</td></tr>
<tr><td>Pans</td><td>MacFarlane et al. (2007)
or
Marneweck (Pers. Comm.).</td><td>Farrell (Pers. Comm)</td></tr>
<tr><td>Wetland Flats</td><td rowspan="2">MacFarlane et al. (2007)</td><td rowspan="5">n/a*</td></tr>
<tr><td>Unchannelled Valley Bottoms (VBs)</td><td rowspan="3">DWAF (2007)
or
Malan et al. (2013)
or
Malan and Day (2012)</td></tr>
<tr><td>Channelled VBs</td><td rowspan="2">DWAF (2007)
or
MacFarlane et al (2007)</td><td colspan="3" rowspan="2">DWAF (2007)
or
MacFarlane et al. (2007)</td></tr>
<tr><td>Floodplains</td></tr>
<tr><td>Lakes</td><td>DWAF (1999)</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

*Most studies indicate that invertebrates are a poor water quality indicator in wetland environments. Diatoms are far better indicators and the Rapid Reserve Methods for Wetlands in South Africa (Rountree *et al.*, 2013) excluded invertebrate assessments in favour of diatoms.

- **4. Determine EWR (or other RDM) to achieve REC**

Dependent on the type of wetland and level of RDM assessment, a range of possible methods are available for application (Table 5.2). These vary according to the HGM type of wetland and level of study. Essentially, this sub-step for wetlands does not necessarily require the quantification of the reserve in the same sense that it is determined for rivers and thus, in some cases, may only require the setting of conditions for the maintenance of the hydrological functioning of a specific wetland RU. Guidance on the approach to setting EWRs for wetlands is determined during action 2.

Table 5.2 Step 3.3.3: Summary of methods for wetland RDM assessments (varying by type of wetland and level of RDM assessment)

Wetland type	Set conditions for achieving REC only		Determine EWR (Quantitative or Qualitative)		
	General conditions	Site specific conditions	Desktop Reserve	Rapid Reserve	Intermediate and Comprehensive Reserve
Seepage wetlands	Standard conditions/ RQOs (see DWA, 2012)	EcoStatus and site-specific RQOs (see DWA, 2012)	n/a	n/a	Nothing published or available in DWS reports, but some methods are under development for the Upper Olifants catchment (Marneweck, *Pers. Comm*).
Pans			Rountree (2013a) Fluvius (2007)	Wetland Rapid Reserve Manual (Rountree *et al.*, 2013)	
Wetland Flats			*No standalone wetland studies should be undertaken for wetlands that are primarily groundwater fed: Undertake Groundwater Reserve and use wetlands as indicator of groundwater resource condition.*		
Unchannelled VBs			Use (river) desktop model to estimate EWR, confirm % with previous wetland Rapid studies	Wetland Rapid Reserve Manual (Rountree *et al.*, 2013)	Nothing published or available in DWS reports, but some methods are under development for the Upper Olifants catchment (Marneweck, *Pers. Comm*).
Channelled VBs					Refer to approaches used on Frankinvlei (Rountree *et al*., 2006), Nyl (Birkhead *et al.*, 2007) or Bedford (Rountree, 2010) Wetland EWR studies.
Floodplains					No formal publication, but refer to approaches used at EWR 7 on the large Wilge Floodplain (DWA, 2010b) and Pongolo floodplain (DWS, 2014b – Mhlatuze WMA study).
Lakes			n/a	n/a	DWAF (1999) (but see also DWA, 2014b).

5.2 STEP 3.3.3 WETLANDS: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action are provided in Table 5.3.

Table 5.3 Step 3.3.3: Standardised input and output and methods per action

Action	Dominant Wetland (HGM) Type	Input	Tool/Approach	Output	Comment
1. Determine dominant wetland HGM type			Classification system for wetlands (Ollis *et al.* 2013) HGM type identification approach (Rountree and Batchelor, 2013)	Primary HGM wetland type	HGM type dictates RDM approach
2. Determine appropriate level of RDM study for wetlands		HGM wetland type List of identified threats and impact type	Guideline for RDM assessment level (DWA, 2012)	Required level of RDM assessment	
3a. Validate PES of priority wetland RUs	Floodplains and channelled VBs		Wetland IHI (DWAF, 2007): Vegetation, Geomorphology, Hydrology, Water Quality	Integrated PES of each wetland RU	Together, the integrated PES and EIS provides the EcoStatus of each wetland RU
	All		WET-Health (MacFarlane *et al*, 2007): Vegetation, Geomorphology, Hydrology		
	All		Water Quality: Malan *et al*. (2013), but refined in Malan and Day (2012) Wetland IHI (DWAF, 2007)		
	All		Diatoms: Koekemoer and Taylor (2013)		
	Pans		Invertebrates: Pan macro-invertebrate Assessment Method (Farrel, unpublished)		
3b. EIS of priority wetlands	All		Rapid EIS method (Appendix A3 in Rountree and Kotze (2013)	EIS category of each wetland RU	
3c. REC of priority wetlands		PES and EIS of each wetland RU	REC determination guidelines - Section 4.3 in Rountree *et al.* (2013)	REC of each wetland RU	
4. Determine EWR (or other RDM) to achieve REC			Various (see Table 5.4)	Qualitative AND/OR Quantitative EWRs for wetlands (see Table 5.4)	Output dependent on wetland type and level of RDM assessment

Table 5.4 Step 3.3.3: Input and outputs for Action 4: Wetland EWR determinations (described by wetland type and Level of Reserve)

Dominant Wetland (HGM) Type	Input	Tool/Approach	Output	Comment
For wetlands that are primarily groundwater fed, no standalone wetland studies should be undertaken. Groundwater study required.				
Wetland Flats	Groundwater table scenarios (from groundwater team)	Link wetland condition to groundwater scenarios	Estimate of PES of wetland under groundwater scenarios	Use wetlands as an indicator of groundwater resource condition
Desktop Reserve Determination				
Pans	Historical rainfall records and satellite imagery	Rainfall-inundation method - Rountree (2013a)	Wetting regime of pan (area of inundation)	Inundation regime simulates historical pattern
Unchannelled VBs Channelled VBs Floodplains	Wetland PES	Desktop Model	"Rule and Tab" EWR requirement	Use (river) desktop model to estimate EWR, confirm % with previous wetland Rapid studies
Rapid Reserve Determination				
Pans	Area-capacity relationship of pan; Historical rainfall records and satellite imagery	Rountree *et al*. (2013)	Wetting regime of pan (area/depth of inundation)	Inundation regime linked to ecological indicators
	Vegetation field survey	Kotze and Walters (2013)	Vegetation EWRs	
	Diatom field sample and lab analysis	Koekemoer and Taylor (2013)	Diatom PES and indication of WQ impacts	WQ impacts (indicated by diatoms) can inform EWR required for REC
Unchannelled VBs Channelled VBs Floodplains	Downstream river flow volumes (WRSM and ACRU)	Mallory (2010)	Historical flows for local wetland catchment	Wetlands are often in small ungauged catchments
	Historical rainfall records	Mallory (2013)	Water Balance for wetland	
	Site hydraulics (surveyed cross-section, water level)	Jordanova (2013); Birkhead (*et al*., 2007)	Rated cross section for vegetated channel	
	Vegetation field survey	Kotze and Walters (2013)	Vegetation EWRs	
	Diatom field sample and lab analysis	Koekemoer and Taylor (2013)	Diatom PES and indication of WQ impacts	WQ impacts (indicated by diatoms) can inform EWR required for REC
	Geomorphology field assessment	Rountree (2013b)	Habitat EWRs	

Dominant Wetland (HGM) Type	Input	Tool/Approach	Output	Comment
	Vegetation (and other habitat and biotic EWRs)		"Rule and Tab" EWR requirement, AND/OR Qualitative EWRs (e.g. flooding extent/depth)	EWR outputs are dependent on available data for catchment
Intermediate Reserve Determination				
Pans	Intensive field survey data (topography, soils, vegetation, logged pan water levels over a year or more)	Under development (surface and subsurface hydrological modelling approaches) plus water balance model for within pan	Wetting regime of pan/soil saturation index	Methods are still under development on non-perennial Highveld wetland systems. Wider testing required; methods not published (Marneweck, *Pers. Comm*)
Unchannelled VBs	Intensive field survey data (topography, soils, vegetation, flow records)	Under development (surface and subsurface hydrological modelling approaches)	Soil saturation Index scores, inflows and outflows of wetland	Methods are still under development on non-perennial Highveld wetland systems. Wider testing required; methods not published (Marneweck, *Pers. Comm*)
Channelled VB Wetlands	Downstream river flow volumes (WRSM and ACRU)	Mallory (2010)	Historical flows for local wetland catchment	Wetlands are often in small ungauged catchments
	Historical rainfall records	Mallory (2013)	Water Balance for wetland	
	Site hydraulics (surveyed cross-section, water level)	Jordanova (2013); Birkhead (reference)	Rated cross section for vegetated channel	
	Vegetation field survey	Kotze and Walters (2013)	Vegetation EWRs	
	Vegetation (and other habitat and biotic EWRs)		"Rule and Tab" EWR requirement, AND/OR Qualitative EWRs (e.g. flooding extent/depth)	EWR outputs are dependent on available data for catchment
Seepage wetlands	Rainfall and evaporation	Under development (surface and subsurface hydrological modelling approaches) Models suggested are: Hydrus (Šimůnek *et al*, 1999) PyTOKAPI (Sinclair and Pegram, 2013) SPRING (König, 2011)	Soil saturation index of seepage wetland	Methods are still under development on non-perennial Highveld wetland systems. Wider testing required; methods not published (Marneweck, *Pers. Comm*)

Dominant Wetland (HGM) Type	Input	Tool/Approach	Output	Comment
Lakes		DWAF (1999)	Qualitative EWRs (e.g. flooding extent/depth) AND/OR inflow requirements	
Comprehensive Reserve Determination				
Floodplains		Standard river EWR approaches can be followed for large floodplains, but a water balance to account for floodplain losses/requirements is recommended		

5.3 STEP 3.3.3 WETLANDS: IDENTIFIED TOOLS AND EVALUATION PER ACTION

5.3.1 Action 1: Determine dominant wetland HGM type

A simple description of wetland types and characteristics is provided in DWAF (2007) or Rountree and Batchelor (2013). The main HGM type of each priority wetland should be determined according to this or similar HGM descriptions in order to select the appropriate RDM method of assessment (Action 2).

5.3.2 Action 2: Determine appropriate level of RDM study for wetlands

Table 5.5 Step 3.3.3: Evaluation of the "Guideline for identifying appropriate levels of Resource Protection Measures for Inland Wetlands" (DWA, 2012) tool

Criteria	Evaluation	Explanatory comment
Frequency of use of the application?	2 - Low	Few wetland Reserves have been undertaken in SA.
Can the tool be applied at a catchment level?	No	Tool is to identify RDM level for individual wetlands.
Is the method described?	Yes	DWS report (DWA, 2012).
Indicate the status of publication of the method	4 National	Published as part of a suite of reports linked to the DWS/WRC's Rapid Reserve Manual for Wetlands.
Are there existing training courses?	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	No	
Time efficient (link to assessment level)	1	Very efficient - should take a few minutes only.
Is the data available to apply the method?	Usually	Need to get information on risks/likely pressures on wetland.
Compatibility?	n/a	
Must software be purchased?	No	
Licencing requirements?	None	
Enhancement flexibility or adaptability of algorithms?	n/a	
Is the method validated and verified?	No	Not yet widely tested.
Descriptions available of mathematical algorithms and model structure?	None	
Is the model robust?	Yes	
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	

5.3.3 Action 3a: PES of priority wetlands

A variety of PES determination methods are available for wetlands and the various ecosystem components within wetlands. These are evaluated below.

Table 5.6 Step 3.3.3: Evaluation of variety of EcoStatus Tools

Criteria	Evaluation					Comparative Notes
	WET-Health (MacFarlane *et al*, 2007): Vegetation, Geomorphology, Hydrology	Wetland IHI (DWAF, 2007): Vegetation, Geomorphology, Hydrology, Water Quality	Diatoms (Koekemoer and Taylor (2013)	Water Quality (Malan *et al.*, 2013/Malan and Day, 2012)	Pan invertebrates (Farrell, *Pers. Comm.*)	
Frequency of use of the application?	4	4	3	2	1	
Can the tool be applied at a catchment level?	Yes	No (only VB and floodplain wetlands)	Yes	Yes	No (only Highveld pan wetlands)	Yes indicates the tool is applicable for most wetland types
Is the method described?	Yes	Yes	Yes	Yes	No	
Indicate the status of publication of the method	4 (National publication)	4 (National publication)	4 (National publication)	4 (National publication)	2	
Are there existing training courses?	Yes (Rhodes University)	No	No	No	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes (Rapid and higher)	Yes (Rapid and higher)	Yes (Rapid and higher)	Yes	No (applicable only to Highveld pan wetlands)	
Time efficient (link to assessment level)	1	1	1	1	1	
Is the data available to apply the method?	Always	Always	Usually	Always	No (dedicated sampling required)	
Compatibility?	n/a	n/a	n/a	n/a	n/a	
Must software be purchased?	No	No	No	No	No	
Licencing requirements?	None	None	None	None	None	
Enhancement flexibility or adaptability of algorithms?	n/a	n/a	n/a	n/a	n/a	
Is the method validated and verified?	Yes	Yes	Yes	Unknown	Unknown	
Descriptions available of mathematical algorithms and model structure?	n/a	n/a	n/a	n/a	n/a	
Is the model robust?	Yes	Yes	Yes	Yes	Unknown	
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	Subjective scoring of confidence included	No	No	No	

5.3.4 Action 3b: EIS of priority wetlands

Table 5.7 Step 3.3.3: Evaluation of Wetland Importance Tool (Rountree and Kotze, 2013)

Criteria	Evaluation	Explanatory comment
Frequency of use of the application?	4	Used nationally in many DWS and consulting studies by a variety of users
Can the tool be applied at a catchment level?	No	Applicable at site scale, not catchment scale
Is the method described?	Yes	Briefly described in Rountree and Kotze (2013)
Indicate the status of publication of the method	4	Rountree and Kotze (2013)
Are there existing training courses?	No	Tool is simple and self-explanatory.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	
Time efficient (link to assessment level)	1	Less than 1 day to collate information and undertaken assessment
Is the data available to apply the method?	Usually	
Compatibility?	n/a	
Must software be purchased?	No	
Licencing requirements?	None	
Enhancement flexibility or adaptability of algorithms?	n/a	
Is the method validated and verified?	Yes	Tested on several sites
Descriptions available of mathematical algorithms and model structure?	Yes	Tool is available in electronic format.
Is the model robust?	Yes	Tested on several sites; limited variability
Does the method include an objective assessment of uncertainty such as may influence confidence?	Yes	Qualitative assessment of confidence (in input data) is included.

5.3.5 Action 3c: REC of priority wetlands

A simple guideline to determine the REC is provided in section 4.3 of Rountree *et al*. (2013). This guideline uses the PES (Action 3a) and EIS (Action 3b) of the wetland to determine the REC (Action 3c).

Table 5.8 Step 3.3.3: Evaluation of the REC determination (Section 4.3 in Rountree *et al*., 2013)

Criteria	Evaluation	Explanatory comment
Frequency of use of the application?	2 - Low	Few wetland Reserves have been undertaken in SA
Can the tool be applied at a catchment level?	Yes	
Is the method described?	Yes	Briefly described
Indicate the status of publication of the method	4 National	Published as part of a suite of reports linked to the DWS/WRC's Rapid Reserve Manual for Wetlands
Are there existing training courses?	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	

Criteria	Evaluation	Explanatory comment
Time efficient (link to assessment level)	1	Very efficient - should take a few minutes only
Is the data available to apply the method?	Yes	
Compatibility?	n/a	
Must software be purchased?	No	
Licencing requirements?	None	
Enhancement flexibility or adaptability of algorithms?	n/a	
Is the method validated and verified?	No	Not yet widely tested
Descriptions available of mathematical algorithms and model structure?	None	
Is the model robust?	Yes	
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	

5.3.6 Action 4: Determine EWRs for the relevant ECs

A variety of EWR determination methods for wetlands are available. These methods vary dependent on the type of wetland (according to the hydrological driver conditions) and the level of RDM study being undertaken. These various approaches are evaluated in Table 5.9.

Table 5.9 Step 3.3.3: Evaluation of Variety of overall EWR Determination approaches for Wetlands

Criteria	Overall Rapid Methods (Rountree *et al.*, 2013)		Intermediate Methods (Marneweck, *Pers. Comm.*) – under development			
			HYDRUS (Šimůnek *et al*, 1999)	PyTOKAPI (Sinclair and Pegram, 2013)	SPRING (König, 2011)	Comment
	Evaluation	Comment	Evaluation			
Frequency of use of the application?	3	Few wetland Reserves undertaken by DWS.	1	2	1	Only used in a few locations in Upper Olifants for EIAs related to mines.
Can the tool be applied at a catchment level?	No	Individual wetland scale.	No	No	Yes**	**SPRING can manage up to Quaternary catchments only.
Is the method described?	Yes		Yes	No	Yes	Basic models are sometimes described, but not changes to these.
Indicate the status of publication of the method	4	National (WRC) publication.	5	3	5	
Are there existing training courses?	No		Yes	No	Yes	Commercial training courses available.
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	No	Desktop (possibly intermediate with additional data) only.	No	No	No	The model is very data intensive and therefore is not suitable for Desktop or Rapid applications.
Time efficient (link to assessment level)	1 - Yes	Highly efficient.	1	4	2	Varying data inputs and requirements reflected in score.
Is the data available to apply the method?	Usually		Never	Never	Never	Detailed information about soils and other materials must be collected.
Compatibility?	Yes	Links to DWS hydrology (where volumetric EWRs are requested).	No	No (not yet – outflows may be possible in future)	No	Models cannot integrate with other study components. Cannot consider large scale scenarios.
Must software be purchased?	No		Yes (R35 000 fee)	No	Yes	
Licencing requirements?	None		Simple	None	Simple	Licence upon purchase.
Enhancement flexibility or adaptability of algorithms?	n/a		Commercial	Open Source	Commercial	
Is the method validated and verified?	Yes	This method has been tested in several case	No	No	No	No verification or publication of methods as yet.

Criteria	Overall Rapid Methods (Rountree *et al*., 2013)		Intermediate Methods (Marneweck, *Pers. Comm.*) – under development			
			HYDRUS (Šimůnek *et al*, 1999)	PyTOKAPI (Sinclair and Pegram, 2013)	SPRING (König, 2011)	Comment
	Evaluation	Comment	Evaluation			
		studies.				
Descriptions available of mathematical algorithms and model structure?	n/a		Algorithm based	Algorithm based	Algorithm based	
Is the model robust?	Yes					No verification or publication of methods as yet.
Does the method include an objective assessment of uncertainty such as may influence confidence?	No					No

Table 5.10 Step 3.3.3: Evaluation of EWR Determination Tools for ecosystem components

Criteria	Evaluation					
	Pan inundation (Rountree, 2013a; Fluvius, 2007)	Vegetation Assessment (Kotze and Walters, 2013)	Diatom Assessment (Koekemoer and Taylor, 2013)	Hydrology data (Mallory, 2010; 2013)	Hydraulics data (Jordanova, 2013)	Geomorph assessment (Rountree. 2013b)
Frequency of use of the application?	1	3	2	3	2	2
Can the tool be applied at a catchment level?	No (pans only)	Yes (all wetlands)	Yes (all wetlands)	Yes (most wetlands)	No (only valley bottom wetlands)	Yes (most wetlands)
Is the method described?	Yes	Yes	Yes	Yes	Yes	Yes
Indicate the status of publication of the method	Yes	Yes	Yes	Yes	Yes	Yes
Are there existing training courses?	No	No	No	No	No	No
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes (with increased data)	Yes (with increased data)	Yes (with increased data)	Yes (with increased data)	Yes (with increased data)	Yes (with increased data)
Time efficient (link to assessment level)	1	1	1	1	1	1
Is the data available to apply the method?	Usually	Yes	Usually	Yes	Yes	Yes
Compatibility?	No	n/a	n/a	usually	yes	yes

Criteria	Evaluation					
	Pan inundation (Rountree, 2013a; Fluvius, 2007)	Vegetation Assessment (Kotze and Walters, 2013)	Diatom Assessment (Koekemoer and Taylor, 2013)	Hydrology data (Mallory, 2010; 2013)	Hydraulics data (Jordanova, 2013)	Geomorph assessment (Rountree. 2013b)
Must software be purchased?	No	No	No	No	No	No
Licencing requirements?	None	None	None	None	None	None
Enhancement flexibility or adaptability of algorithms?	n/a	n/a	n/a	n/a	n/a	n/a
Is the method validated and verified?	Yes				Yes	
Descriptions available of mathematical algorithms and model structure?	n/a	n/a	n/a	n/a	n/a	n/a
Is the model robust?						
Does the method include an objective assessment of uncertainty such as may influence confidence?						

6 STEP 4: IDENTIFY AND EVALUATE SCENARIOS WITHIN IWRM

Objective: Integrated Step 4 consists of the preliminary identification and description of operational scenarios within 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 transfer 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.

Integrated Step 4 contains seven sub-steps. Wetlands fall within sub-step 4.3 and is discussed in this Chapter.

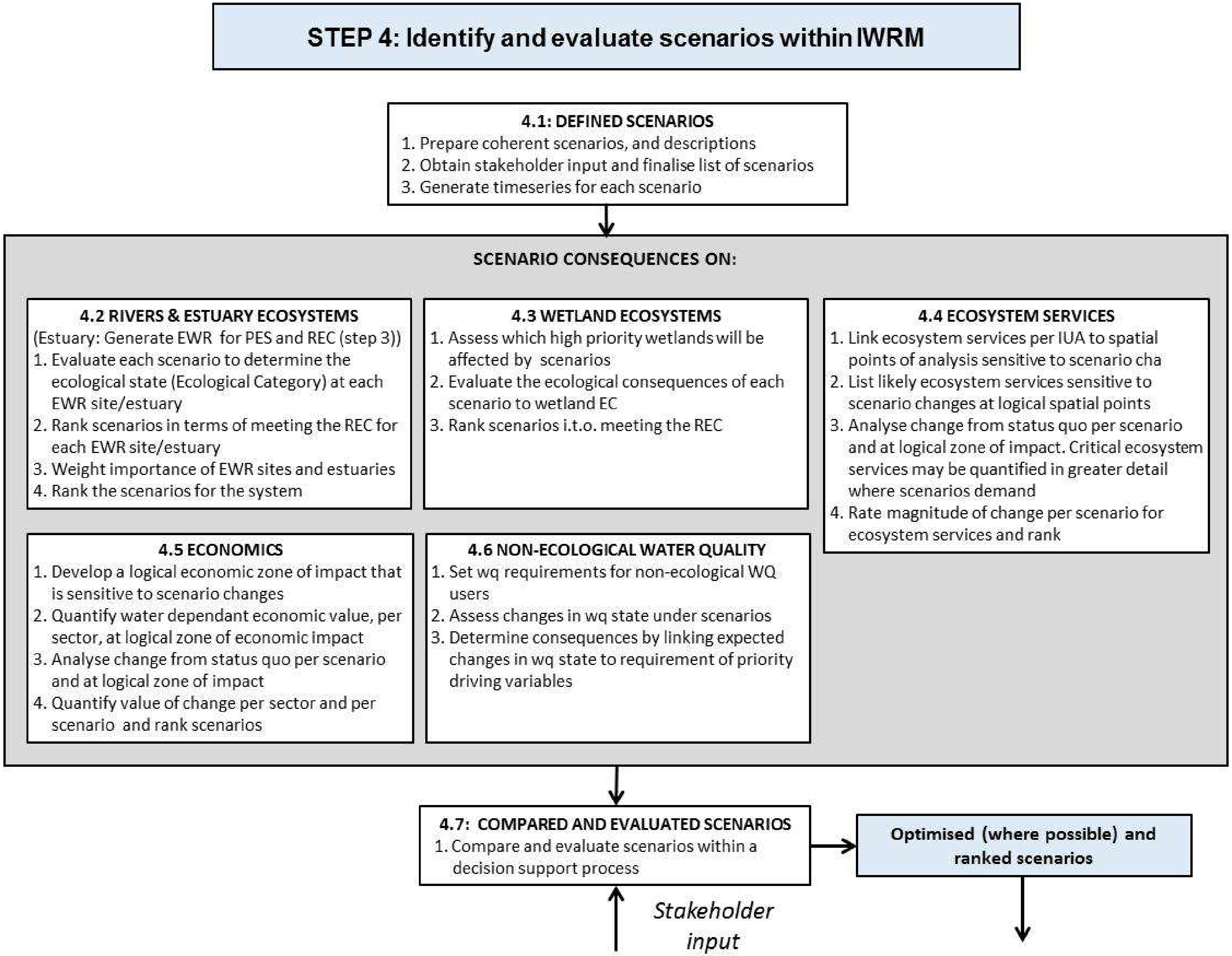

Figure 6.1 Illustration of the sub-steps for Integrated Step 4: Identify and evaluate scenarios within IWRM

6.1 STEP 4.3 WETLANDS: ACTIONS

Objective: To determine the ecological consequences of the scenarios and ranking of scenarios for high priority wetland RUs.

The bullets below describe the actions required.

- **1. Assess which high priority wetlands will be affected by scenarios**

Compare each scenario in terms of relation to spatial implication of each scenario to identify which wetlands will be affected.

- **2. Evaluate the ecological consequences of each scenario to wetland EC**

Evaluate both the non-flow related and flow related (including groundwater input) impacts associated with each scenario and determine the ecological consequences in relation to REC.

- 3. Rank scenarios in terms of meeting the REC

6.2 STEP 4.3 WETLANDS: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action (if relevant) are provided in Table 6.1.

Table 6.1 Step 4.3: Standardised input and output per action

Action	Input	Tool/Approach	Output	Comment
1. Assess which high priority wetlands will be affected by scenarios	Scenario information Priority wetlands		Subset of priority wetlands that may be impacted by scenario/s	
2. Evaluate the ecological consequences of each scenario to wetland EC	Wetland PES	Use existing PES models to predict scenario consequences	EC of priority wetland RUs under scenarios	
	Scenario hydrology (high confidence studies)	Downstream Response to Imposed Flow Transformation (DRIFT)		For high confidence studies, scenario hydrology may be used in this evaluation
3. Rank scenarios i.t.o meeting the REC	Wetland EC response to scenarios	Scenario ranking tool: Rank simply according to ability of scenario to meet REC	Scenarios ranked in terms of their ability to meet the REC (at each site and overall)	

The relevant PES tools that have been evaluated previously (see Table 5.6). The applicability of DRIFT for evaluation of scenarios is tabulated below (Table 6.2).

Table 6.2 Step 4.3: Evaluation of DRIFT for evaluation of scenarios

Criteria	Evaluation	Explanatory comment
Frequency of use of the application?	2 - Low	Few high confidence wetland Reserves have been undertaken in SA
Can the tool be applied at a catchment level?	Yes	
Is the method described?	Yes	Published internationally
Indicate the status of publication of the method	5	Published internationally. The method is endorsed by the World Bank.
Are there existing training courses?	Yes	

Criteria	Evaluation	Explanatory comment
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	
Time efficient (link to assessment level)	5	Only applicable for high confidence studies linked to hydrology.
Is the data available to apply the method?	Yes	
Compatibility?	n/a	
Must software be purchased?	No	
Licencing requirements?	Yes	DRIFT licence will be required for application
Enhancement flexibility or adaptability of algorithms?	n/a	
Is the method validated and verified?	Yes	
Descriptions available of mathematical algorithms and model structure?	None	
Is the model robust?	Yes	
Does the method include an objective assessment of uncertainty such as may influence confidence?	Yes	

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. Different RQO levels, according to the RU priority (as determined during Integrated Step 1), are determined. The output provides appropriate level of RQOs for all RUs. RQOs of High Priority RUs are available for gazetting. It must be noted that the RQO report must include as much numerical information as possible for all priorities as this serves as the numerical limits document used for monitoring. Moderate and low priority RUs and broad RQOs are used e.g. for licensing of small developments and in the gazetting of the Reserve (Integrated Step 8).

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 RUs will require detailed RQOs for a variety of components which will be gazetted while low and moderate priority RUs will require broad and mostly narrative RQOs. This information is then tested with stakeholders in preparation of gazetting the RQOs.

Integrated Step 6 contains five sub-steps. Wetlands fall within sub-step 6.4 and 6.5 and is discussed in this Chapter.

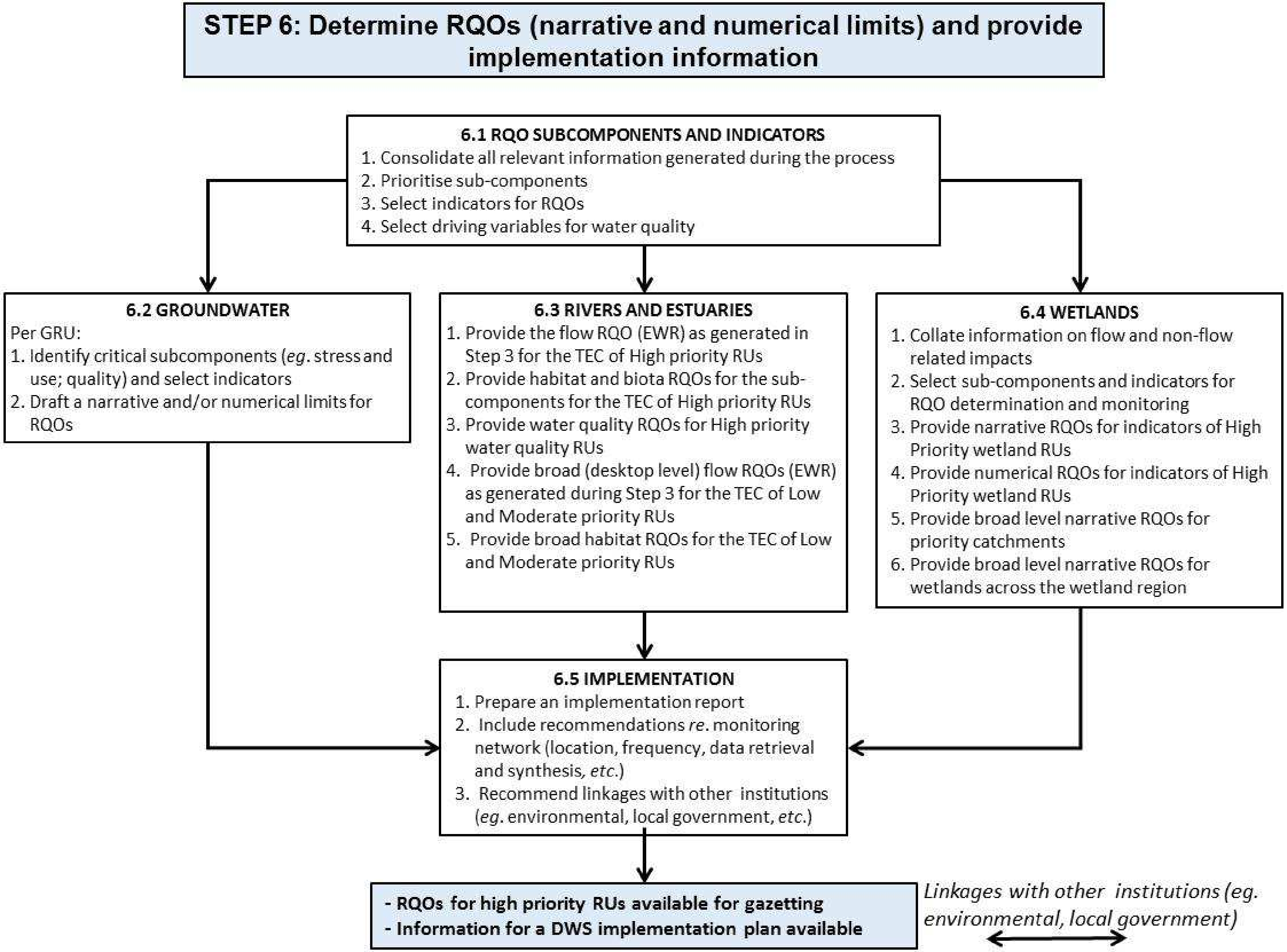

Figure 7.1 Illustration of the sub-steps for Integrated Step 6: Determine RQOs (narrative and numerical limits) and provide implementation information

7.1 STEP 6.4 WETLANDS: ACTIONS

Objective: The objective of this step is to specify RQOs for wetlands at both a catchment level as well as prioritised individual wetland RUs (as determined during Integrated Step 2). Catchment-level RQOs provide broad level objectives for wetland management within the WMA. RQOs for priority individual wetland RUs are determined using available baseline data. However, these data are often not available or so general that the RQOs become superfluous and vague. Where such data are available, this enables the specification of numeric as well as narrative RQOs to manage these systems according to the desired ecological condition.

The bullets below describe the actions required.

- **1. Collate information on flow and non-flow related impacts**

This requires collation of information on flow and non-flow related impacts identified in Integrated Step 2 as well as identification and assessment of potential future impacts on prioritised catchments or wetland RUs to inform which sub-components are indicative of the condition of the resource and are thus sensitive to current or potential future impacts.

- **2. Select sub-components and indicators for RQO determination and monitoring**

The main components of relevance to wetlands include quantity, quality, habitat and biota for which several sub-components are of relevance. The selection process at both the catchment and individual wetland RU scale involves consideration of both the potential current and future impacts as output from Action 1 above, as well as user requirements. Sub-components and indicators should reflect those that are sensitive to actual or potential impacts but can be measured and monitored to meet regional conservation targets as well as secure protection of critical ecosystem goods and services. In terms of catchment level sub-components and indicators, these may be individual wetland RUs, sub-components should reflect those that are threatened by impacting activities such that protection can be provided to maintain ecological functioning and integrity according the TEC. Indicators should then reflect change in response to impacts.

- **3. Provide narrative RQOs for indicators of High Priority wetland RUs**

This involves the preparation of narrative RQOs for sub-components and indicators identified as relevant in the previous action. For example, the specification of water quality RQOs will only apply to high priority wetland RUs where water quality is considered at risk of degradation and maintenance of water quality is identified as important in terms of specific users. Similarly, the water quantity requirements, based on the EWRs for different ECs during Integrated Step 3 will only be specified if water quantity sub-components are considered as key drivers of ecosystem integrity that are at risk of degradation.

It should be noted that water quality RQOs for high priority wetlands makes provision for both ecological water quality requirements as well as those required for recreational use if identified as a management objective.

- **4. Provide numeric RQOs for indicators of high Priority wetland RUs**

This involves the preparation of numerical RQOs to complement the narrative RQOs provided during Action 3. These may only be applicable to a sub-set of indicators where existing baseline data exists.

- **5. Provide broad level narrative RQOs for priority catchments**

Essentially, this involves the specification of generic management guidelines specific to the regional scale sub-components identified in Action 2 above. These should however be clear, unambiguous guidelines for specific sub-components that are sensitive to change and reflect the condition of the resource.

- **6. Provide broad level narrative RQOs for wetlands across the wetland region**

Generic management guidelines specific to the wetland regions should provide management and monitoring approaches for specific sub-components (relevant to the wetland types and risks of the relevant wetland region).

7.2 STEP 6.4 WETLANDS: STANDARDISED INPUT AND OUTPUT

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

Table 7.1 Step 6.4: Standardised input and output per action

Action	Scale	Input	Output	Methods	Comment
1. Collate flow and non-flow related impacts	Catchment and wetland RU	Scenario descriptions and flows Prioritised wetlands/prioritised catchments	Key drivers of PES and threats for each prioritised catchment or wetland RU		This requires identifying a list of potential impacts to establish which are the most relevant or likely to affect wetlands at a catchment scale or individual wetland RUs
2. Select sub-components and indicators for RQO determination and monitoring	Catchment and wetland RU	TEC for wetland RUs or catchments Key drivers of PES and threats for each prioritised catchment or wetland RU	List of relevant sub-components and associated indicators for priority catchments and wetland RUs	Wetland Ecosystem Evaluation Tool	Examples for catchments include catchment level EcoStatus. For specific wetlands, examples include wetland hydrology (water quality); nutrients, toxins, system variables (water quality); birds, fish, invertebrates, diatoms (biota), vegetation, geomorphology (habitat)
3. Provide narrative RQOs for High priority wetlands	Wetland RU	TEC, key drivers of PES and threats for each prioritised wetland and data from EcoStatus assessments	List of narrative RQOs for high priority wetlands		
4. Provide numeric RQOs for High priority wetlands	Wetland RU	TEC, Key drivers of PES and threats for each prioritised wetland and data from EcoStatus assessments	List of numeric RQOs for high priority wetlands		These are only applicable to wetlands where actual baseline data for specific indicators exists
5. Provide broad level narrative RQOs for priority catchments	Catchment	Key drivers of PES and threats for each prioritized catchment	List of narrative RQOs for high priority catchments		These are broad, generic and descriptive
6. Provide broad level narrative RQOS for wetland regions	Wetland regions	Key threats to wetland condition	List of narrative RQOs for wetland regions		

7.3 STEP 6.4 WETLANDS: IDENTIFIED METHODS AND EVALUATION PER ACTION

A method for the selection of appropriate sub-components indicators (the Wetland Ecosystem Evaluation Tool) within Action 2 was the only method identified for application during this sub-step.

The Wetland Ecosystem Evaluation Tool is an adaptation of the procedures for determining RQOs developed mainly for rivers (DWA, 2011). The tool has been applied for the selection of sub-components and indicators in the Upper Vaal and Olifants studies (DWS, 2014d;c - see Table 7.2). Although the tool is designed for application to specific wetlands, it was used at a broader catchment-scale in the Upper Vaal study (DWS, 2014d). In most wetland RDM studies to date, the selection of sub-components and indicators is not reliant on a specific tool at either the catchment or specific wetland scale but is guided by discussion with DWS and key wetland experts.

The Wetland Ecosystem Evaluation Tool has however been used to assist with the rationalisation process for selecting sub-components and indictors. The tool uses the output from Action 1 (i.e. the key driving current and future impacts) together with information on wetland condition as well as the requirements of important user groups (both from a protection perspective and water resource use perspective) to select specific sub-components and indicators (DWS 2014c and 2014d). Despite the availability of this tool for rationalisation of sub-component and indicator selection for wetlands, it has been found to be “cumbersome and time-consuming” (DWS 2014d).

Table 7.2 Step 6.4: Evaluation of the Wetland Ecosystem Evaluation Tool

Criteria	Evaluation	Explanatory comment
Frequency of use of the application?	Low	It has been used in the determination of RQOs in the Upper Vaal (DWS 2014d) and Olifants (DWS 2014c) WMAs.
Can the tool be applied at a catchment level?	Yes	The tool is designed for individual wetlands, although it was adapted to determine indicators for a regional evaluation in the Upper Vaal Study (DWS 2014d). The adaptation involved replacing the components and sub-components with ecosystem services provided by the specific wetlands under evaluation.
Is the method described?	No	Although it an adaptation of a described method (DWA, 2011), the actual tool in its adapted form is not described.
Indicate the status of publication of the method	None	See above.
Are there existing training courses?	No	
Is the method applicable to all levels of assessment (Desktop to Comprehensive)?	Yes	The method can be applied at all levels although it requires information on many different attributes and such information is not always available, especially at the desktop level.
Time efficient (link to assessment level)	Unknown	It is reportedly time consuming, although no specific timeframe is provided.
Is the data available to apply the method?	Seldom	The method is reliant on a large amount of attribute information that is not always available.
Compatibility?	Yes	Yes, the method is consistent with standardised inputs and outputs but the data inputs for the method itself extend beyond these standardised requirements.
Must software be purchased?	No	No

Criteria	Evaluation	Explanatory comment
Licencing requirements?	No	No
Enhancement flexibility or adaptability of algorithms?	DWS	The approach is an adaption of a method that was developed for DWS (DWA, 2011).
Is the method validated and verified?	Yes	Some validation and verification of the rationalisation process has been undertaken but only on a very limited basis.
Descriptions available of mathematical algorithms and model structure?	Yes	These are described in the spreadsheets for application of the tool.
Is the model robust?	No	In its current form, the method is reliant on a large amount of information that is not often available. The output of the method will vary depending on the information that is used in the rationalisation process and because this is not standardised, the outputs are not standardised.
Does the method include an objective assessment of uncertainty such as may influence confidence?	No	There is no quantitative or qualitative assessment of uncertainty built into the method.

7.4 STEP 6.5 IMPLEMENTATION: ACTIONS

Objectives: The rollout actions needed to implement the Water Resource Class and RQOs should be defined and describes in this step. This should include a schedule of measurement and monitoring requirements that are needed to periodically evaluate if the targeted ecological objectives are achieved. Cognisance should be taken if several of such implementation actions are already undertaken or is closely linked to functions what other DWS directorates, Local Authorities or Water Service Providers 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 Class and RQOs.

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

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

Besides the provision of a schedule of existing and additional proposed measurement and monitoring requirements, the implementation plan should describe the role and responsibility of role players, including all organisations conducting monitoring in the catchments of the water resource system, and any potential intervention actions required.

7.5 STEP 6.5 IMPLEMENTATION: STANDARDISED INPUT AND OUTPUT

The standardised input and output for each action (if relevant) is provided in Table 7.3.

Table 7.3 Step 6.5: Standardised input and output per action

Action	Input	Comment	Output
2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Measurable management goals	These recommendations are determined specifically for each RQO – monitoring scale, frequency and approach are specific for each ecosystem component and dependent on available baseline data	Wetland monitoring programme

The Institute for Natural Resources (INR) is currently involved in a WRC project (WRC project number: K5/2547) titled "*The development of a refined procedure for determining wetland RQOs,* *and the development of a wetland RQOs implementation manual".* Some of the key expected outcomes of this WRC project are:

- The development of a refined procedure for determining wetland RQOs; and
- the development of a wetland RQOs implementation manual which will provide guidance on how to implement monitor and review wetland RQOs.

Considering the expected outcomes of this WRC project, it is strongly recommended that the methods and guidelines provided by that research, which will involve field testing and verification as well as wetland specialist input from across the country, be used to update the standardised inputs, outputs and methods proposed in this document.

8 CONCLUSIONS

Through a workshop of wetland specialists, the standardised inputs, outputs and methods applicable to every step of the Integrated Framework for RDM studies were identified for wetlands as one of the three aquatic ecosystems considered in the process. Whereas the other two aquatic ecosystems, namely rivers and estuaries, have been the subject of numerous RDM studies, wetlands have not been included in such studies to the same extent. Indeed, wetland ecosystems *per se* were not considered in the initial design of the steps relevant to the three major RDM processes (i.e. Classification, Reserve Determination and RQO Determination). Wetland methods are therefore not well developed, neither have they been extensively applied in a standardised manner.

Furthermore, wetland ecosystems pose a number of complexities for application of RDM processes. In particular, wetlands within a study area at any given scale are generally numerous and heterogeneous in terms of wetland types and their functionality and thus the ability to extrapolate broadly poses a number of challenges for RDM studies not necessarily applicable to rivers and estuaries. Consequently, identification of the inputs, outputs and standardised methods for wetland ecosystems applicable to each of these steps within the Integrated Framework was challenging, particularly with regards to Steps 1 and 2. One of the biggest challenges was identifying inputs and outputs to address wetland ecosystems at different scales relevant to different RDM processes. This issue was overcome by stipulating the relevant scale applicable to different inputs, outputs and available methods where applicable.

The actions relevant to step 1 rely on databases of existing wetland data, mostly the NFEPA database which has been identified in several assessments as an unreliable, low confidence source of information. It is therefore strongly recommended that the extent of wetlands and the identification of wetland types as the basis for any further actions in this step involve some manipulation of the existing NFEPA database and some validation of wetlands within the study area.

In terms of Determining Ecological Importance and Present Ecological State of wetlands, a number of tools were identified and evaluated at both the catchment scale as well as the wetland RU scale although it is evident that these tools have been variously applied to previous studies. It is important to note that various tools are currently being developed to improve the desktop approach to determining wetland EcoStatus. It is recommended that once these approaches have been finalised, the best approach and the standardised inputs required be revisited through a workshop of key wetland specialists. It should be noted that while the EIS is an important output of this step, there are no standard tools or approaches for determining the EIS at the desktop level at this stage.

In terms of wetland prioritisation, several methods were identified but similar to the determination of ecological importance, the process of prioritisation is relevant to both the catchment scale as well as individual wetland RUs. Nevertheless, application of these methods is limited and has not been verified or validated adequately. Also, some of the available methods tend to be either bias towards specific systems (e.g. river-linked wetlands) or are data and time intensive. Evidently, the existing methods available for prioritisation are currently fraught with some subjectivity, although they offer the potential for refinement into tools that may provide a more objective means of prioritisation. Such refinement may also limit the input datasets required and thus reduce the current data requirements and time necessary to apply the method. It is therefore recommended that the approach to prioritisation be investigated such that the operationalisation of RDM methods become standardised in future studies.

With regards to wetlands, Step 2 is limited to two actions which involve the determination and status quo description of broad wetland regions as input to the determination of IUAs. No specific tools were identified for actions relevant to Step 2. Nevertheless, this step is interlinked with actions relevant to Step 1 and thus it is recommended that, from a wetland perspective, these two steps be run in parallel as far as possible and where relevant in terms of the specific objectives of a particular RDM study.

At Step 3 of the process, a number of methods were identified for the determination of EcoStatus relevant to specific wetland types but their applicability varies according to the relevant level of study. It is important to note that for wetlands, this sub-step does not necessarily require the *quantification* of the reserve in the same sense that it is determined for rivers. Consequently, this sub-step may only require the setting of conditions for the maintenance of the hydrological functioning of a specific wetland RU in some cases. Consequently, Step 4 involves the evaluation of both the non-flow and flow related impacts associated with each scenario and a subset of methods applicable to Step 3 for wetlands is relevant to Step 4.

As with previous sub-steps, setting of RQOs at Step 6 for wetlands is scale dependant. Only one applicable method was identified (i.e. the Wetland Ecosystem Evaluation Tool) and this method or tool is specific to the selection of sub-components and indictors for RQO determination and monitoring of wetlands. Nevertheless, limited application of this tool to specific RDM studies have found it be time consuming and difficult to use. Nevertheless, a research project is currently underway to refine the procedures for determining and implementing wetland RQOs. Considering the shortcomings of existing method, it is recommended that the methods and guidelines provided by that research, which will involve field testing and verification as well as wetland specialist input from across the country, be used to update the standardised inputs, outputs and methods proposed in this document.

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