REPORT NO.: RDM/WE/00/CON/ORDM/0117

DEVELOPMENT OF PROCEDURES TO OPERATIONALISE RESOURCE DIRECTED MEASURES

PROJECT NO: WP 10951

MAIN REPORT

FEBRUARY 2017

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Department:
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REPUBLIC OF SOUTH AFRICA

DEVELOPMENT OF PROCEDURES TO OPERATIONALISE RESOURCE DIRECTED MEASURES

MAIN REPORT

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Authors:	***Louw D, Birkhead, D, Ewart-Smith J, Huggins G, Koekemoer S, Lotter A, Mackenzie J, Mullins W, Sami, K, Scherman P, Van Niekerk L, Van Rooyen P.***

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Approved for the Professional Service Providers by:

……………………………………….. ………………………………….

Delana Louw *Date*

Project Manager

DEPARTMENT OF WATER AND SANITATION (DWS)

Directorate: Water Resource Classification

Approved for DWS by:

…………………………………….. ………………………………….

Ms Ndileka Mohapi *Date*

Chief Director: Water Ecosystems

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
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18	RDM/WE/00/CON/ORDM/0916	Groundwater, Hydrology, Hydraulics tool analysis and standardisation Report
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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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Authors	Company
Louw, Delana	Rivers for Africa (Pty) Ltd
Ewart-Smith, Justine	Freshwater Consulting
Huggins, Greg	Nomad Consulting
Lötter, Anelle	Private
Mullins, William	Mosaka Economists
Sami, Karim	WSM Leshika (Pty) Ltd
Scherman, Patsy	Scherman Colloty and Associates
Van Niekerk, Lara	Council for Scientific and Industrial Research
Van Rooyen, Pieter	WRP Consulting Engineers

The teams provided input at the specialist meetings and reviewed the individual component reports which were used as the baseline for this report. The teams are listed below:

Contributors	Company
GROUNDWATER, HYDROLOGY, HYDRAULICS TEAM	
Task leader: Van Rooyen, Pieter	WRP Consulting Engineers
Birkhead, Drew	Streamflow Solutions
Hughes, Denis	Institute for Water Research, Rhodes University
Sami, Karim	WSM Leshika (Pty) Ltd
WATER QUALITY TEAM	
Task leader: Scherman, Patsy	Scherman Colloty and Associates
Koekemoer, Shael	Koekemoer Aquatic Services
RIVERS TEAM	
Task leader: Louw, Delana	Rivers for Africa (Pty) Ltd
Brown, Cate	Southern Waters
Kotze, Piet	Clean Stream
Mackenzie, James	Mackenzie Ecological and Developmental Services
Rountree, Mark	Fluvius Consulting
ESTUARIES TEAM	
Task leader: Van Niekerk, Lara	Council for Scientific and Industrial Research
Adams, Janine	Nelson Mandela Metropolitan University
Lamberth, Stephen	Department of Agriculture, Forestry and Fisheries
Taljaard, Susan	Council for Scientific and Industrial Research
WETLAND TEAM	
Task leader: Ewart-Smith, Justine	Freshwater Consulting cc
MacKenzie, James	Mackenzie Ecological and Developmental Services
Rountree, Mark	Fluvius Consulting
SOCIO-ECONOMIC TEAM	

Task leader: Huggins, Greg	Nomad Consulting
Mullins, William	Mosaka Economists
STAKEHOLDER LIAISON TEAM	
Task leader: Lötter, Anelle	Private

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REPORT SCHEDULE

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Final	April 2017

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ACRONYMS AND ABBREVIATIONS

ACRU	Agricultural Catchment Research Unit
BBM	Building Block Methodology
BHN	Basic Human Needs
BHNR	Basic Human Needs Reserve
CD: LS	Chief Directorate Legal Services
CD: WE	Chief Directorate: Water Ecosystems
CD:WIM	Chief Directorate Water Information & Management
CD:WRP	Chief Directorate Water Resource Planning
CMA	Catchment Management Agency
CRR	Comments and Responses Report
D:RQIS	Directorate: Resource Quality Information Services
DAFF	Department of Agriculture, Forestry and Fisheries
DAP	Diatom Assessment Protocol
DDM	Daily Dam Model
DEA	Department of Environmental Affairs
DRIFT	Downstream Response to Imposed Flow Transformation
DRM	Desktop Reserve Model
DSS	Decision Support System
DWA	Department of Water Affairs (Name change applicable after April 2009)
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EcoSpecs	Ecological Specifications
EFZ	Estuary Functional Zone
EGSA	Ecosystem Goods, Services and Attributes
EIS	Ecological Importance and Sensitivity
EMP	Estuary Management Plan
EWR	Ecological Water Requirements
FFHA	Fish Flow Habitat Assessment
FIFHA	Fish Invertebrate Flow Habitat Assessment
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphological Driver Assessment Index
GDP	Gross Domestic Product
GIS	Geographic Information System (GIS)
GRA II	Groundwater Resource Assessment Phase II
GRDM	Groundwater Resource Directed Measures
GRU	Groundwater Resource Unit
GRYM	Groundwater Yield Model for the Reserve
GVA	Gross Value Added
HFSR	Habitat Flow Stressor Response
HGM	Hydrogeomorphic
ICM	Integrated Coastal Management
IHI	Index of Habitat Integrity
ISP	Internal Strategic Perspective
IUA	Integrated Units of Analysis
IWRM	Integrated Water Resource Management

MAR	Mean Annual Runoff
MCM	Million Cubic Metres
MIRAI	Macro Invertebrate Response Assessment Index
MIRAI	Macro Invertebrate Response Assessment Index
MRU	Management Resource Unit
NBA	National Estuaries Biodiversity Plan
NFEPA	National Freshwater Ecosystem Priority Area
NGA	National Groundwater Archive
NWA	National Water Act
NWRCS	National Water Resource Classification System
PAI	Physico-Chemical Assessment Index
PBMT	Potential Bed Material Transport
PES	Present Ecological State
PESEIS	Present Ecological State and Ecological Importance-Ecological Sensitivity
PSC	Project Steering Committee
PSP	Professional Service Provider
RDM	Resource Directed Measures
RDRM	Revised Desktop Reserve Model
REC	Recommended Ecological Category
REMP	River EcoStatus Monitoring Programme
RHAM	Rapid Habitat Assessment Method
RQO	Resource Quality Objective
RU	Resource Units
RWQO	Resource Water Quality Objective
SANBI	South African National Biodiversity Institute
SCI	Socio-Cultural Importance
SFR	Streamflow reduction
SLA	State Law Advisor
SPATSIM	Spatial and Time Series Modelling
SQ	Sub quaternary reaches
SSD	Species Sensitivity Distribution
TDS	Total Dissolved Solids
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TEC	Target Ecological Category
ToR	Terms of Reference
TTG	Technical Task Group
VEGRAI	Vegetation Response Assessment Index
WARMS	Water Use Authorisation and Registration Management System
WCS	Wetland Consulting Services
WMS	Water Management System
WRCS	Water Resource Classification System
WReMP	Water Resource Modelling Platform
WRPM	Water Resource Planning Model of DWS
WRSM2000	Water Resources Simulation Model 2000
WRYM	Water Resource Yield Model of DWS
WSAM	Water Situation Assessment Model
WUL	Water Use Licences
WULA	Water Use Licensing Administration
WWTW	Waste Water Treatment Works
ZQM	South Africa Water Quality Monitoring programme

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 REPORT

The purpose of this report is to summarise the technical outcomes of the study with the focus on:

- Providing the final integrated framework which includes all adjustments that were recommended during the study.
- Integrating all the methods and approaches for each step.
- Integrating all the standardised input and outcomes for each step. The individual reports were used as the basis, but in this main report only those inputs and outcomes that are relevant in terms of standardisation are highlighted.

2 INTEGRATED FRAMEWORK

The integrated framework steps as designed during the February 2016 specialist meeting and subsequently revised are provided in **Figure 2.1**. Abbreviations used are described in the acronyms and abbreviation list at the beginning of this report.

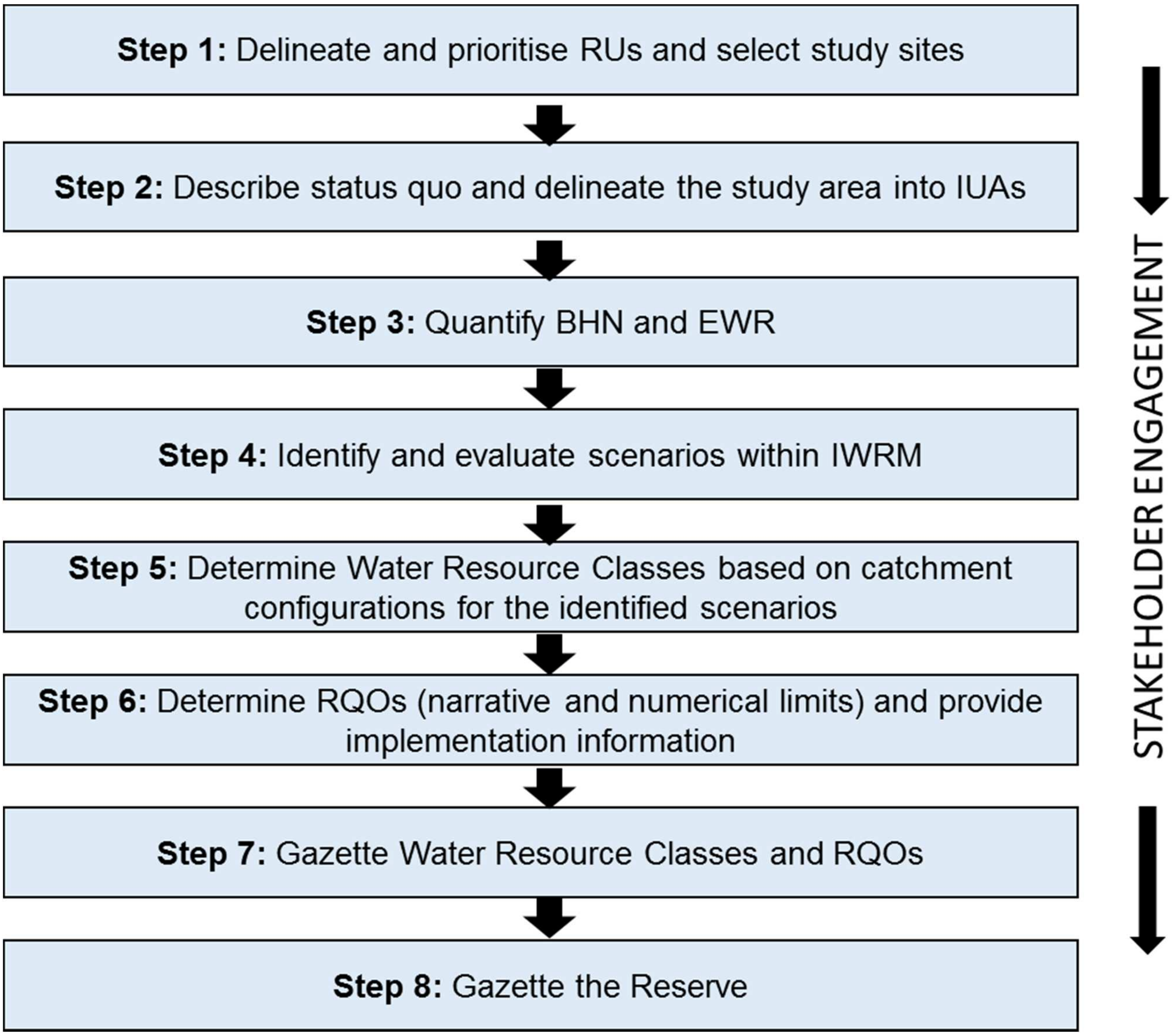

Figure 2.1 Integrated steps for the determination of the Reserve, Classification and Resource Quality Objectives

The incorporation of the individual gazetted steps[1] into the integrated framework is shown in **Figure 2.2**. It must be noted that the RQO gazetted steps (September 2010) are not similar to the RQO steps which were designed afterwards and documented in the RQO guideline document, 2011 (DWA, 2011). As such, the comparison of the RQO guideline steps and the Integrated Framework is provided in **Figure 2.3**.

Figure 2.2 and **Figure 2.3** must be interpreted through the colours of the individual blocks. Each step of the integrated framework is in a specific colour. **The blocks of the steps of each of the three RDM processes are coloured according to the corresponding steps in the Integrated**

[1] REGULATIONS FOR THE ESTABLISHMENT OF A WATER RESOURCE CLASSIFICATION SYSTEM
Published under Government Notice R 810 in Government Gazette 33541. Commencement date: 17 September 2010.

Framework. If the steps in the three RDM processes are represented by more than one colour, it means that the this double coloured (eg) step represents actions undertaken during more than one step in the Integrated framework.

These figures are supported by a narrative in **Table 2.1** which provides the motivation for the groupings of the RDM process steps into the integrated steps.

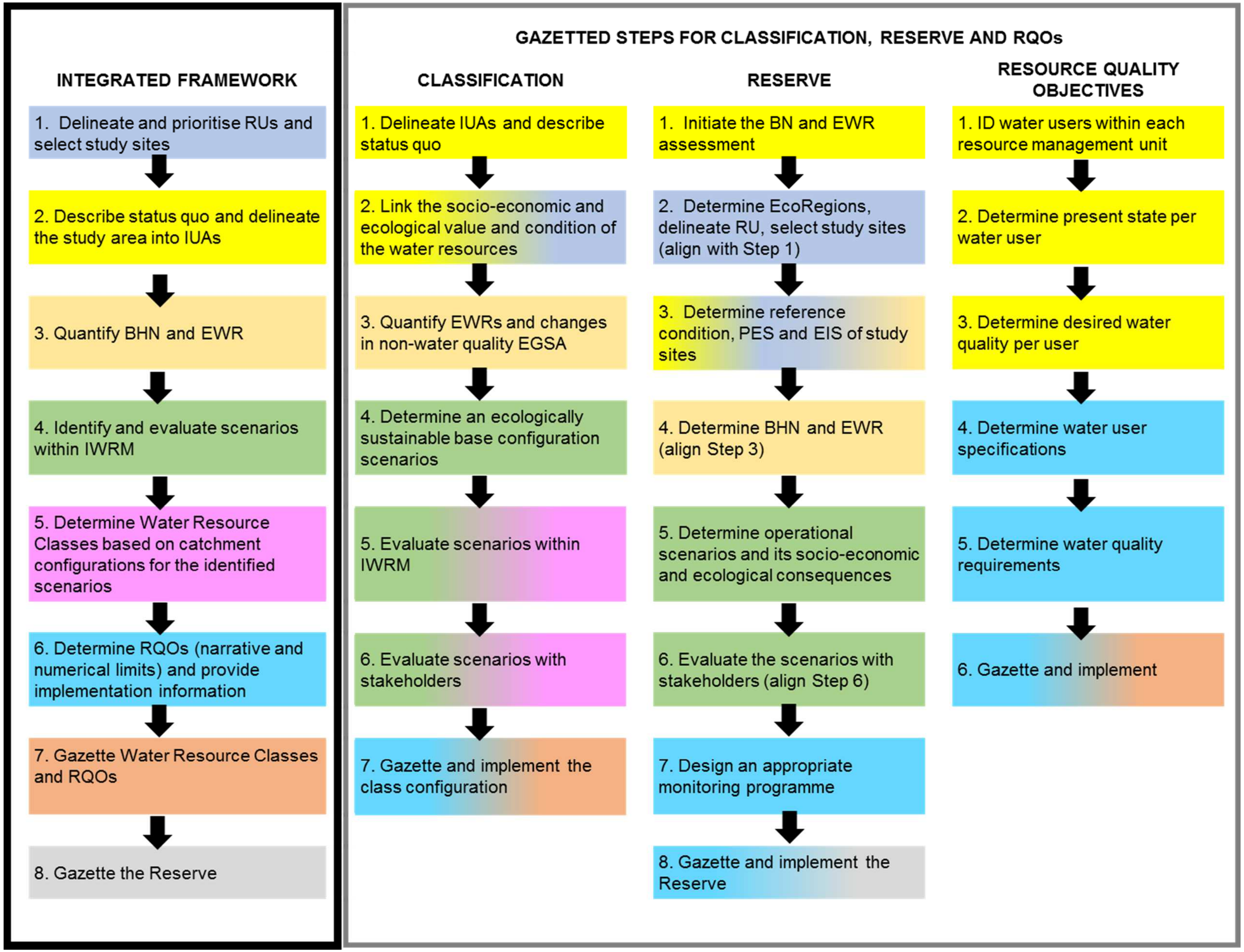

Figure 2.2 **Flow diagram illustrating how the gazetted steps for Classification, Reserve and RQO are incorporated in the Integrated Framework**

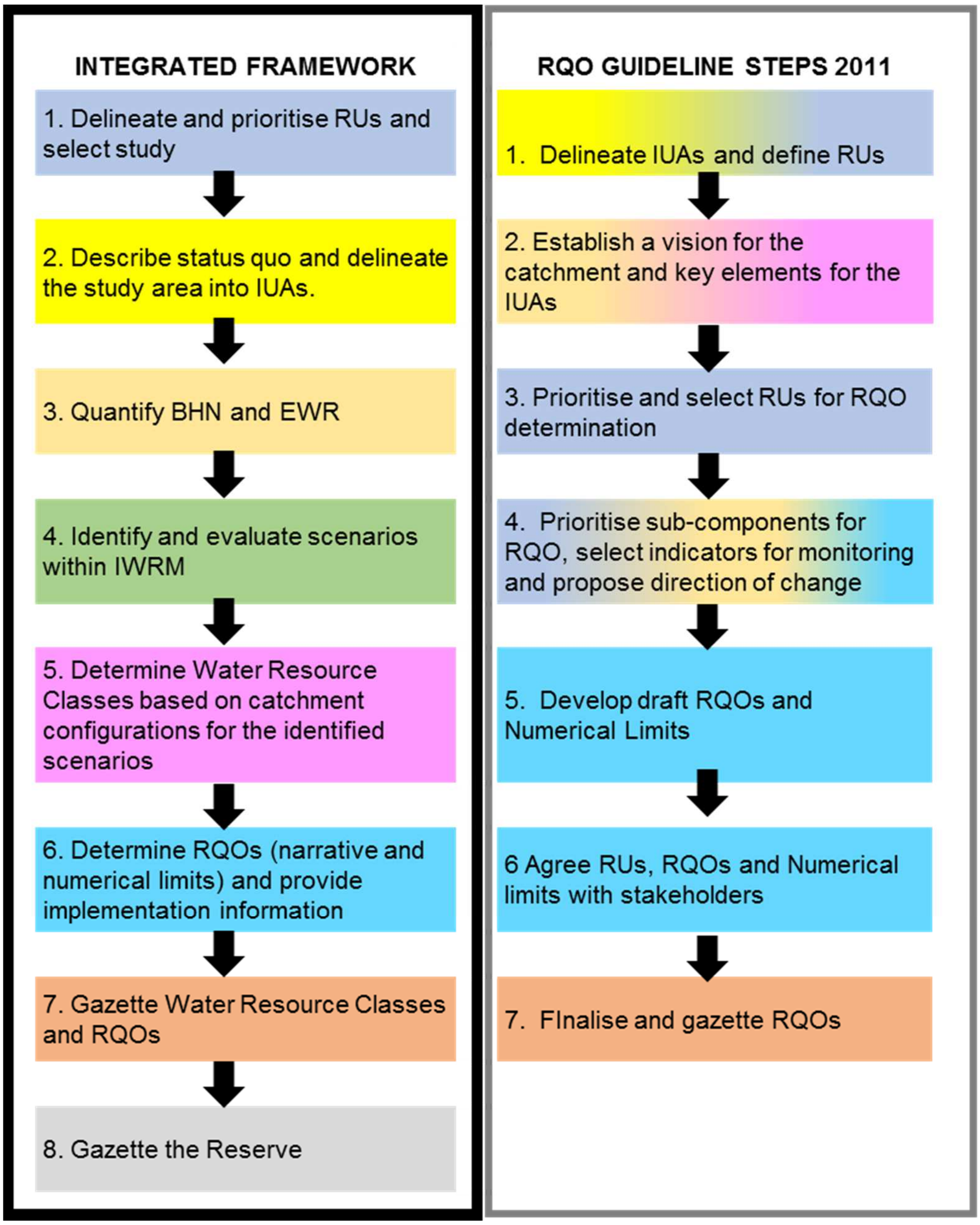

Figure 2.3 Flow diagram illustrating how the RQO guideline steps are incorporated in the Integrated Framework

Each of the Integrated steps were unpacked and depicted by a flow diagram consisting of steps, substeps and actions. The flow diagram and objectives and descriptions are provided at the start of the **Chapters 5 to 11**. This provides context for the methods and approaches that were identified for each step and substep.

3 INDIVIDUAL FRAMEWORKS

This chapter focusses on the outcomes of the Framework workshop held (22 to 25 February 2016) and addressed the development of individual frameworks for the RDM processes which were derived from the Integrated Framework (Report RDM/WE/00/CON/ORDM/0316).

The approach to design the individual frameworks was as follows:

- At the specialist meeting held on 22 to 25 February 2016 the integrated framework was discussed, formulated and subsequently documented. This was undertaken by considering the gazetted steps for each of the three RDM processes as well as the RQO steps from the guideline (DWA, 2011) which differ significantly from the gazetted steps. The integrated framework in use since 2013 (DWA, 2013a) served as the starting point and were revised during the meeting.
- Using the integrated framework as a basis (**Figure 2.1**), steps were allocated to the Reserve, Classification and RQO determination processes.
- Cognisance was taken of changes in the frameworks depending on the order in which specifically Reserve and Classification are undertaken.

The Reserve, Classification and RQO Frameworks are summarised in this chapter.

3.1 RESERVE FRAMEWORK

There are three situations that could trigger the need for Reserve studies. Situation 1 and 2 are where a Preliminary Reserve study is initiated prior to classification, which the National Water Act (NWA), section 17 makes provision for. Classification is then done at a later stage. All subs-steps in this framework are designed in such a way that all the output data from the preliminary process will be compatible and can be incorporated into the Classification framework when the Classification process is initiated.

The Preliminary Reserve process is divided into two sub-steps for Integrated Step 4, i.e. as follows:

- Situation 1 (RS1): The Preliminary Reserve determination is triggered by proposed developments (which means the operational scenario evaluation as part of Integrated Step 4 for Classification is required (Referred to as RS1 in figures and tables)).
- Situation 2 (RS2): The Preliminary Reserve determination is triggered to address an area that is stressed in terms of water supply or resource quality and requires a Reserve (mostly to aid with the evaluation of Section 21 water use licenses). No operational scenario evaluation (as required in Integrated Step 4) is required (Referred to as RS2 in figures and tables).

Situation 3 (RS3): The third situation (referred to as RS3 in figures and tables) is where a Reserve determination is undertaken after the Class has been determined, and as per Section 16 of the NWA, to enable gazetting of the Reserve. RS3 could be applied for new developments that may be identified after Classification and to address additional Ecosystems that were not prioritised during Classification, or to comply with the procedure of gazetting the Reserves post Classification.

To accommodate the above situations, three Reserve frameworks have been designed. Two of these will be Preliminary Reserve Frameworks (RS1 and RS2) and one will be a Reserve Framework (RS3). A Preliminary Reserve framework for when the Preliminary Reserve is undertaken as part of Classification process is not presented as a separate framework as these steps are embedded in the Integrated Framework (Report RDM/WE/00/CON/ORDM/0316).

Figure 3.1 illustrates the links between the Integrated Framework and the Preliminary Reserve (both versions) and the Reserve steps (i.e. following after Classification). **Figure 3.2** provides a comparison between the three Reserve frameworks and the gazetted Reserve steps and illustrates how they are included. In both **Figure 3.1** and **Figure 3.2** colour coding is used to indicate links between the various processes.

Note that the Integrated Framework (**Figure 3.1**) incorporates the Reserve steps in the Integrated steps as part of Step 1, 2, 3, 4, 6 and 8.

As indicated, RS3 includes two situations, i.e.

- where new Reserves are undertaken (additional to those already gazetted); or
- where the Preliminary Reserves are determined or formalised during Classification.

The RS3 framework refers to 'if relevant' in some of the steps which specifically pertains to the first bullet where additional EWR work and quantification is being undertaken. Many of these steps would not be relevant for the second bullet above as this would refer to the situation where all the quantification and evaluation of the Reserve has already been undertaken and the results are taken from the Classification and RQO study.

Figure 3.2 compares the individual framework to the gazetted Reserve steps. It must be noted that the gazetted Reserve Step 8 will apply once Classification has been undertaken. This Reserve determined prior to classification as per RS1 and RS2 will be signed off as the Preliminary Reserve and is not gazetted. Abbreviations used are described in the acronyms and abbreviation list at the beginning of this report.

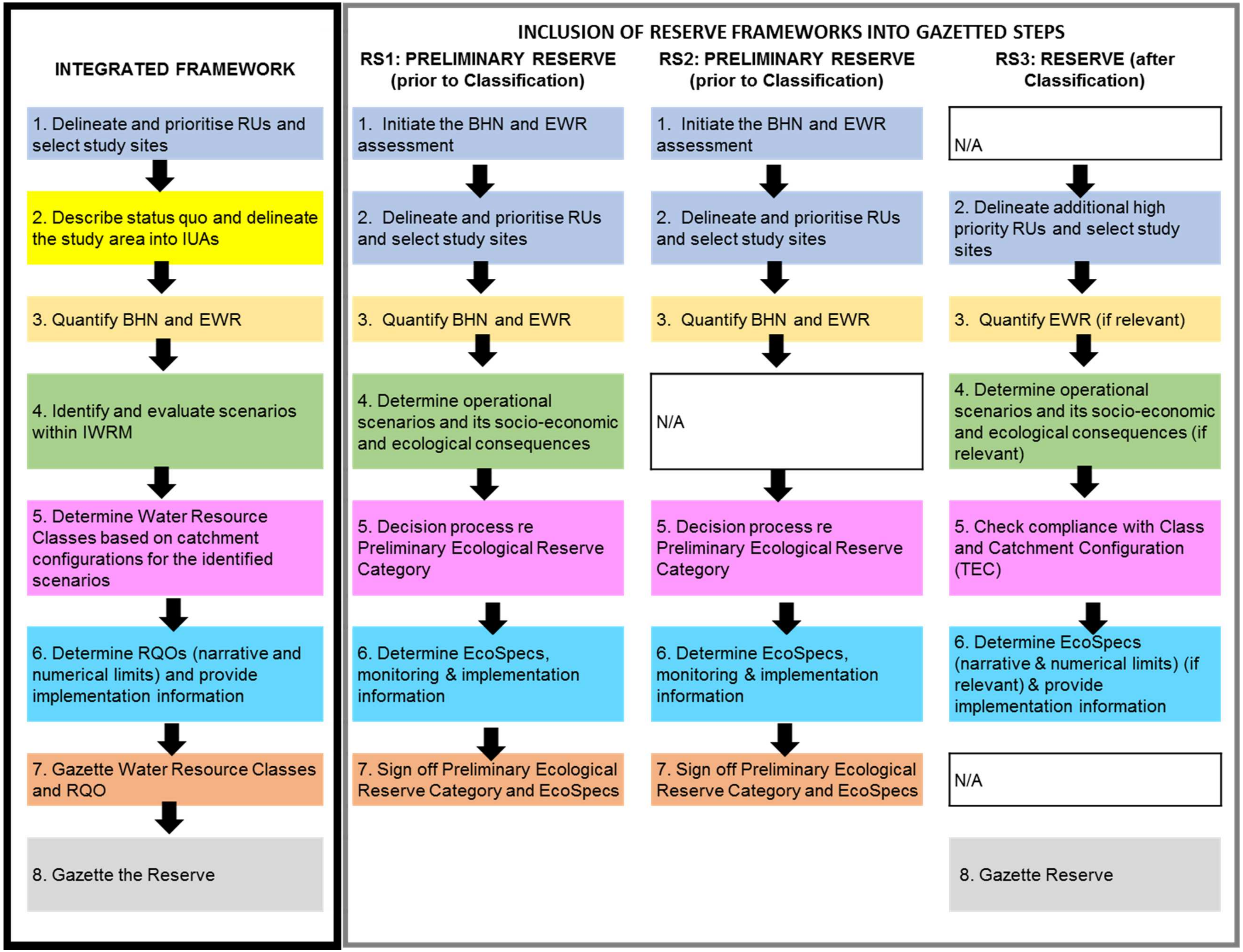

Figure 3.1 Reserve frameworks compared to Integrated Framework

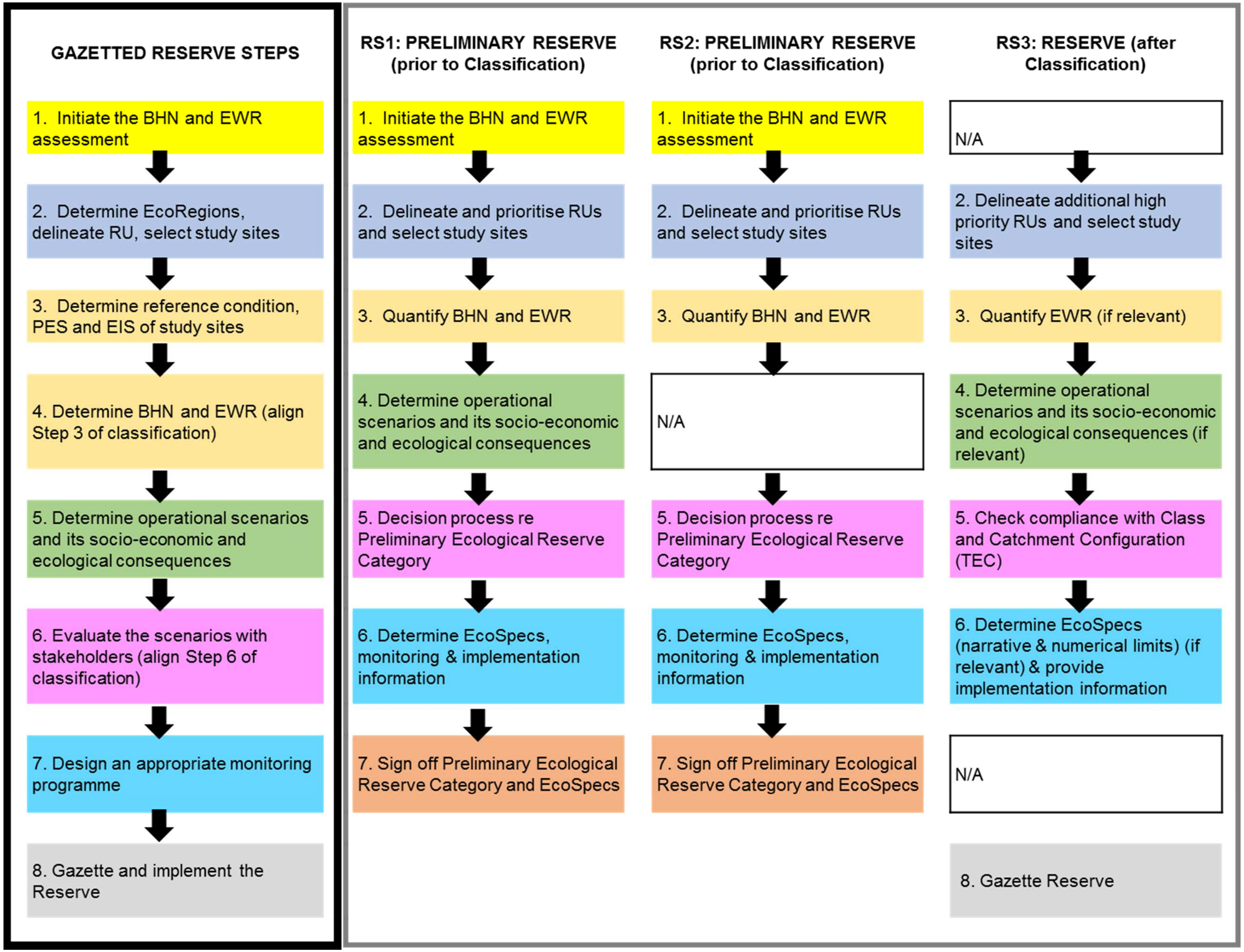

Figure 3.2 Reserve frameworks compared to the gazetted Reserve steps

3.2 CLASSIFICATION FRAMEWORK

The fourth framework is for Classification as a stand-alone study – the assumption is that:

- The Preliminary Reserve has already been undertaken/ and
- The RQOs will be done after Classification.

The existing classification steps include Preliminary Reserve steps and represent a partly integrated set of steps. Even when the Preliminary Reserve has been undertaken as a separate study, Classification incorporates the Preliminary Reserve results. In some cases the Preliminary Reserve studies undertaken prior to Classification may not address the same study area as Classification process. In this case, additional Reserve work may be required as part of Classification.

Therefore, irrespective of whether the Preliminary Reserve is undertaken as part of Classification, or prior to Classification, the results and analysis of the Reserve and the use of the results will still be part of Classification. As such, the Integrated Framework (Report RDM/WE/00/ CON/ORDM/0316) already established, is largely applicable as the Classification framework but excludes Step 6 of the Integrated Framework which refers to the RQOs. The Integrated Framework and Classification framework is provided in **Figure 3.3** and in **Table 3.1**.

Table 3.1 Classification Framework

Steps
1. Describe the status quo and delineate the study area into IUAs.
2. Delineate and prioritise RUs and select study sites
3. Quantify BHNR and EWR
4. Identify and evaluate scenarios within IWRM
5. Determine Water Resource Classes based on Catchment configurations for the identified scenarios
6. Gazette Water Resource Classes

Figure 3.3 illustrates the gazetted classification steps, the Integrated Framework and the Classification Framework. Colours have been used to indicate how the gazetted classification and Integrated Framework steps compare to the Classification Framework.

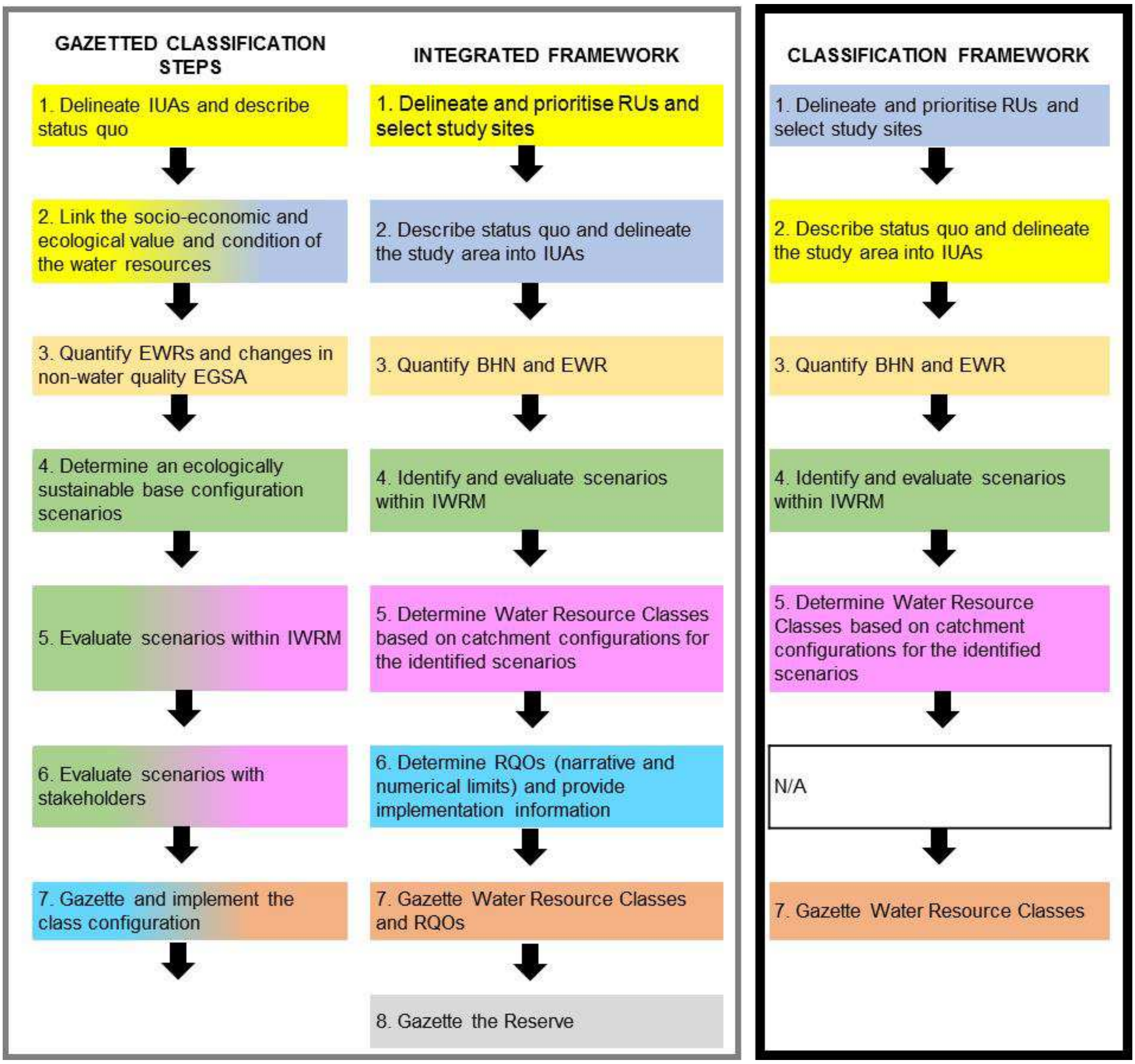

Figure 3.3 Classification Framework compared to the gazetted classification steps and the Integrated Framework

3.3 RQO FRAMEWORK

The RQO steps were gazetted (Gazette No. 19182, Notice No. 1091) on 17 September 2010 with the Classification and Reserve steps. 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 processes. It must be noted however that the RQO steps and associated guideline document were produced during 2011 (DWA, 2011), i.e. after the gazette and differs significantly from the gazetted steps. The gazetted RQO steps are based on water quality and drafted whilst the guidelines were still being prepared, and should therefore be reviewed and updated. The gazetted steps are sufficiently broad to address the RQO determination process as currently applied. The RQO guideline steps largely repeats steps addressed in Classification and the Reserve processes and provides insufficient detail of steps required to determine RQOs.

In this report, reference to the two sets of steps will be as RQO gazetted steps and RQO guideline steps. Although these two sets of steps differ from each other, both sets are addressed in the Integrated Framework (Report RDM/WE/00/CON/ ORDM/0316) and provided in **Figure 3.4** where they are also compared to the Integrated Framework. The colouring of the Integrated Framework steps is duplicated in the two sets of RQO steps to show where they have been addressed.

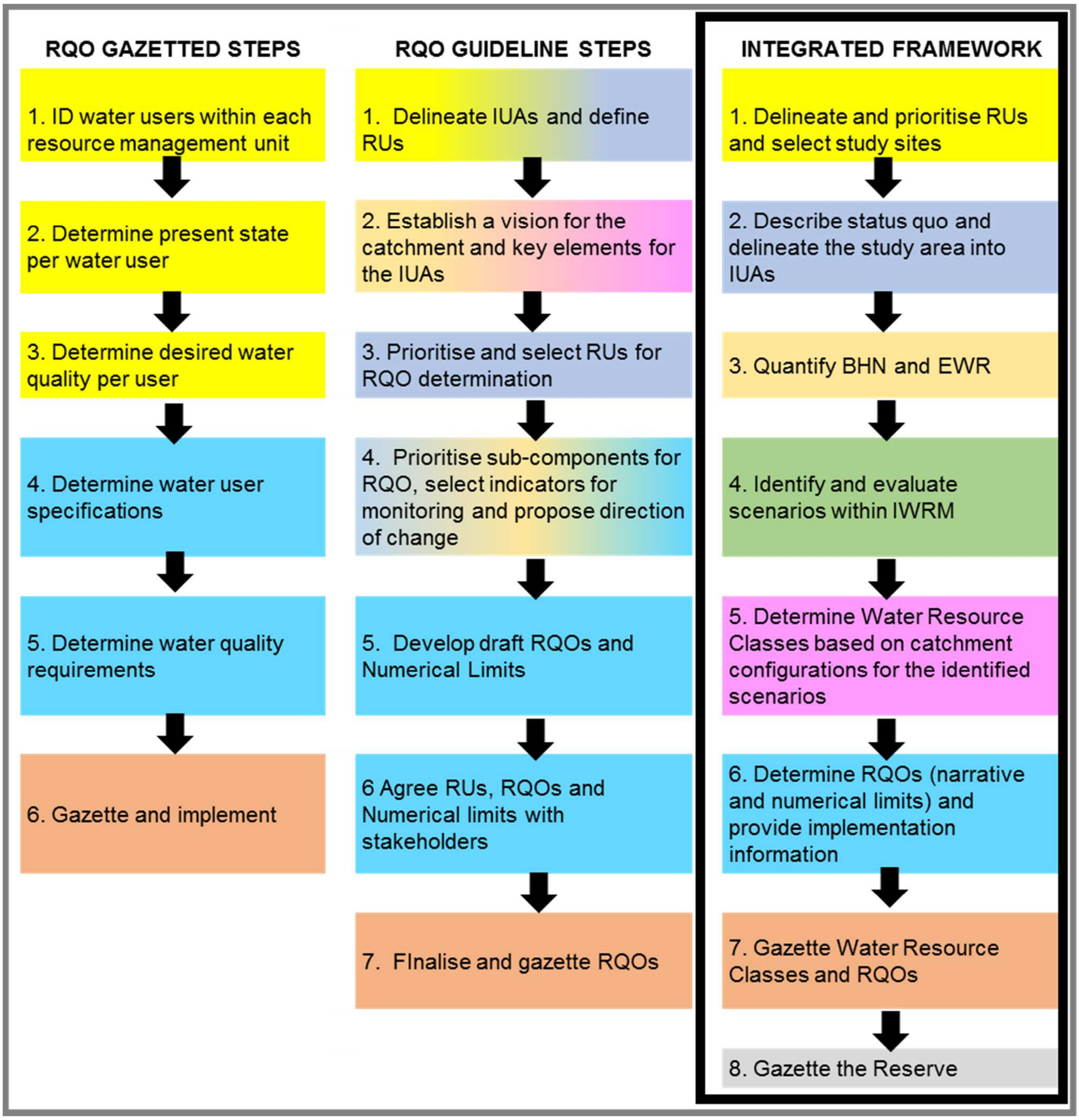

Figure 3.4 Gazetted and guideline RQO steps compared to the Integrated Framework

RQOs can only be determined after the Class (and ecological catchment configuration) has been determined[2] and therefore all information required for the determination of RQOs, which would also be relevant for Classification, and Reserve determination, must be included in those frameworks. This implies that all the steps provided in both the gazetted and RQO guideline steps, apart from the quantification and gazetting step itself, are not unique to RQOs but also part of Reserve and Classification. **The quantification of RQOs are therefore summarised within one step (Step 6) of the integrated framework. The quantification steps within the gazetted and guideline steps are also coloured blue**. All the other coloured steps (apart from the orange steps referring to RQO gazetting) are part of Reserve and Classification and not unique to the RQO process.

[2] According to DWS it is unlikely that stand-alone RQO studies will be undertaken in the future.

Setting up a RQO framework is therefore complex because of the links to Classification and the Reserve. Integrated Step 6 is a major step and this step itself should be broken down into a framework, together with the step pertaining to the gazetting of RQOs. It is recommended that when the RQO steps for the gazette are revised, specific studies to establish a final framework and a guideline be undertaken.

Figure 3.5 illustrates the RQO steps (third column) based on the Mvoti to Umzimkulu, the Inkomati and the Letaba Classification and RQO studies. This is compared with the first column (integrated framework) and the second column (RQO gazetted steps). Although these steps all form part of Step 6 and 7 of the Integrated Steps (see blue block corresponding with Integrated Framework Step 6), the individual block colouring shows the links and the Integrated Steps where the information necessary for determining RQOs are generated. Information generated during these Integrated Steps therefore feeds into the RQO determination step (Integrated Framework Steps 6 and 7) and essentially form the baseline for RQO determination

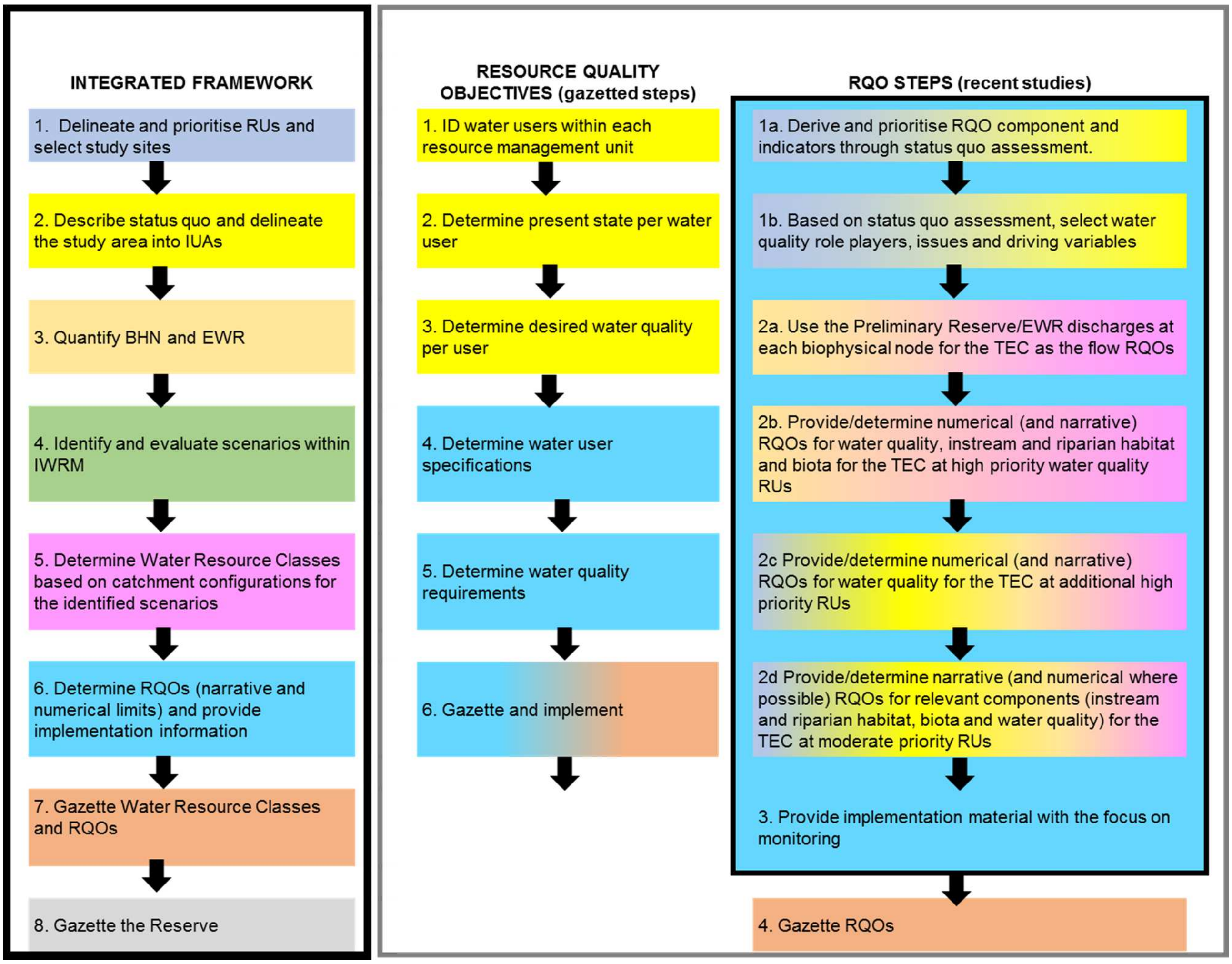

Figure 3.5 Steps in the Integrated Framework that produces essential information for RQO determination and links between the Integrated Framework and the RQO framework

Table 3.2 provides an explanation of each of the RQO steps (recent studies, third column) based on the Mvoti to Umzimkulu, the Inkomati and the Letaba Classification and RQO studies.
It must also be noted that there are duplication and overlap in terminology used in the Reserve and RQO processes regarding components, subcomponents, indicators and driving variables. These terminology issues have not been clarified but the explanation (second column in **Table 3.2**)

provides the terminology and clarification. The terminology issues and overlap must also be addressed when the RQO steps in the gazette are revisited.

Table 3.2 Explanation of suggested RQO framework steps

RQO steps	Explanation
1a. Derive and prioritise ROQ components and indicators	A database (spreadsheet) is compiled during Integrated Step 1 (RUs) that identifies the issues and users for each RU that have resulted in a change in ecological state. From these, the components (referring to riparian vegetation, instream biota and water quality) that must be addressed are identified. The indicators relevant to riparian vegetation and instream biota refer to specific species, taxa, guilds or metrics such as abundance and Frequency of Occurrence.
1b. Based on status quo assessment, select water quality role players, issues and driving variables.	The water quality users are identified (building on from the data base compiled during Integrated Step 1) and this aids in deriving specific water quality variables for which RQOs must be set.
2a. Use the Preliminary Reserve/EWR discharges at each biophysical node for the TEC as the flow RQOs.	EWRs (discharges) are set for each Ecological Category (EC) at different levels of confidence for each RU during Integrated Step 3. This information is carried over for the TEC at each biophysical node to present the flow RQOs.
2b. Provide/determine numerical (and narrative) RQOs for water quality, instream and riparian habitat and biota for the TEC at high priority water quality RUs	RQOs at high priority RUs which contain EWR sites, must be provided for all components and priority variables. These are usually provided at a detailed level and likely to be gazetted.
2c Provide/determine numerical (and narrative) RQOs for water quality for the TEC at additional high priority RUs	Water quality RQOs are provided for the driving users and variables, which may be different than the variables relevant for the ecological water quality. RUs that are prioritised as being of high priority due to water quality aspects therefore require detailed water quality RQOs.
2d Provide/determine narrative (and numerical where possible) RQOs for relevant components (instream and riparian habitat, biota and water quality) for the TEC at moderate priority RUs	Moderate priority RUs require narrative (with numerical RQOs where possible) and only for the relevant components, indicators and driving variables. Therefore, if it is shown that the impacts in the RU all relate to riparian vegetation and water quality; RQOs for these components only will be provided. All information is provided for the TEC. As these RQOs are set at lower confidence levels than those at EWR sites, it is unlikely to be gazetted but can be used for licensing and strategic planning.
3. Provide implementation material with focus on monitoring.	Information for a DWS implementation plan is provided at this step. The focus is on: ▪ Ensuring that RQOs are adhered to (requires compliance monitoring); ▪ monitoring to determine whether the ecological objectives are achieved (response monitoring); and ▪ adaptive management based on the results of the above actions. Required liaison and structures with other (than DWS) organisations are also recommended.
4. Gazette RQOs	High confidence RQOs set for high priority RUs are gazetted. Other RQOs are used for planning and management and will be updated if priorities of the RU change.

Table 3.3 provides the reasoning and further explanation of why actions required for RQO determination are addressed early in the integrated steps (and in the Classification and Reserve Reserves gazetted steps.

Table 3.3 Description of the information generated during Reserve and Classification for RQO determination

Integrated Step		Explanation
1. Delineate and prioritise RUs and select study sites. 2. Describe status quo and delineate the study area into IUAs	1a. Derive and prioritise ROQ components and indicators 1b. Based on status quo assessment, select water quality role players, issues and driving variables. 2c Provide/determine numerical (and narrative) RQOs for water quality for the TEC at additional high priority RUs 2d Provide/determine narrative (and numerical where possible) RQOs for relevant components (instream and riparian habitat, biota and water quality) for the TEC at moderate priority RUs.	RUs and prioritisation are essential for RQO determination as different level of RQOs are set for the different priorities of RUs. This step is an essential Reserve and Classification step as high priority RUs must be identified to select EWR sites where high priority RQOs will be determined. During this step the components for RQO determination at Moderate and Low priority RUs are also identified as part of the process to determine Recommended Ecological Categories. Water quality prioritisation and data collection starts in this step, i.e. identifying water quality role players and issue, and identification of driving variables
3. Quantify BHNR and EWR	2a. Use the Preliminary Reserve/EWR discharges at each biophysical node for the TEC as the flow RQOs. 2b. Provide/determine numerical (and narrative) RQOs for water quality, instream and riparian habitat and biota for the TEC at high priority water quality RUs 2c Provide/determine numerical (and narrative) RQOs for water quality for the TEC at additional high priority RUs 2d Provide/determine narrative (and numerical where possible) RQOs for relevant components (instream and riparian habitat, biota and water quality) for the TEC at moderate priority RUs.	EWRs will provide the baseline and quantified information for the flow, habitat and biota RQOs which will be set during Integrated Step 6.
5. Determine Water Resource Classes based on catchment configurations for the identified scenarios	2a. Use the Preliminary Reserve/EWR discharges at each biophysical node for the TEC as the flow RQOs. 2b. Provide/determine numerical (and narrative) RQOs for water quality, instream and riparian habitat and biota for the TEC at high priority water quality RUs 2c Provide/determine numerical (and narrative) RQOs for water quality for the TEC at additional high priority RUs 2d Provide/determine narrative (and numerical where possible) RQOs for relevant components (instream and riparian habitat, biota and water quality) for the TEC at moderate priority RUs.	The TEC is recommended during this step. This information is essential for RQO determination as RQOs are set for the TEC.

4 STANDARDISED METHODOLOGIES AND APPROACHES

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 listed below:

- RDM/WE/00/CON/ORDM/0516: River tool analysis and standardisation report.
- RDM/WE/00/CON/ORDM/0616: Wetland tool analysis and standardisation report.
- RDM/WE/00/CON/ORDM/0716: Estuaries and Marine tool analysis and standardisation report.
- RDM/WE/00/CON/ORDM/0816: Water quality tool analysis and standardisation report.
- RDM/WE/00/CON/ORDM/0916: Groundwater, Hydrology, Hydraulics tool analysis and standardisation report.
- RDM/WE/00/CON/ORDM/1016: Socio-economics and Ecosystem services tool analysis and standardisation report.
- RDM/WE/00/CON/ORDM/1116: Stakeholder involvement and communication tool analysis and standardisation report.

4.1 DESIGN OF SUB-STEPS FOR THE INDIVIDUAL FRAMEWORKS

During the February specialist meeting, the steps of the Integrated Framework were disaggregated into sub-steps. Sub-steps were provided for the original Classification (DWAF, 2006) and the Reserve (Louw and Hughes, 2002) steps but required revision. In terms of the Classification, the Lessons Learnt formed the basis of the revision.

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 subsequent chapters will provide the sub-steps and then the standardised input and output as well as listing the tools for each of the Integrated Steps.

4.2 BACKGROUND TO THE STANDARDISATION TASK

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.

The myriad of methods and tools being applied have presented challenges, mostly as the output of methods did not necessarily comply with 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 from these studies must be compatible with the prevailing IWRM practices. This of course also implies that the input used in methods, 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.

4.3 AIM OF STANDARDISATION OF METHODOLOGIES AND APPROACHES

The TOR required the standardisation of methodologies for Reserve determination. Note, methodologies required for Classification and RQO determination which were not covered through the Reserve methodologies were also included.

Specific objectives for this task of the study are provided below.

- 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.

Standardisation of methods focused on standardising the inputs and outputs of the various tools to define the information and data that flow between the processes and steps in order to ensure that during all phases of the frameworks, the methods comply with the standardised inputs and outputs and that the linkages through the whole process are seamless. The work was undertaken during a series of specialist work sessions.

4.4 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 focused on standardising the inputs and outputs of the methods 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. The Excel spreadsheets used to capture this information is available on the electronic data provided.

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

4.5 TOOL IDENTIFICATION

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

If a sub-step did not require a method, it was noted that it is 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.**
- **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 method, not the computer package which is used.**

A generic set of criteria to rate the methods were identified and described (**Section 4.6**). 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.

4.6 EVALUATION CRITERIA

The criteria for the method evaluation, the evaluation manner and an explanatory comment are provided in **Table 4.1** below.

Table 4.1 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	Yes/No	If Yes, indicate the approximate costs and any

Criteria	Evaluation	Explanatory comment
purchased?		associated conditions.
License requirements	None; Simple; Complex, Duration limiting	Risk of use and administrative requirements.
Enhancement flexibility or adaptability of algorithms	1 Open script; 2 Open source; [Intellectual Property:] 3 DWS; 4 WRC; 5 Commercial	Purpose of criteria is to indicate the risk of keeping method relevant.
Is the method validated and verified?	Yes/No	Is the tool/method's results validated and can it be verified against the conditions on the ground? Provide an explanatory comment for the reasoning.
Description of mathematical algorithms and model structure	Algorithm based; Detail explanation; Conceptual description; None	Provide an explanatory comment for the reasoning.
Is the model robust?	Yes/No	Will different numerical tools provide similar answers e.g.?
Does the method include an objective assessment of uncertainty such as may influence confidence?	Yes/No	If Yes, describe the process to quantify the uncertainty. If no, and there is a qualitative assessment of confidence (such as a rating by expert opinion): please describe.

The evaluation is not repeated in this document but is available as electronic data provided for this study. In this main report, all available methods evaluated are listed. The output of the first criteria in **Table 4.1** is provided in the list as it is arguably one of the most important and gives an indication of how well are methods used in RDM and IWRM processes in DWS.

5 INTEGRATED STEP 1: DELINEATE AND PRIORITISE RUs AND SELECT STUDY SITES: STANDARDISED INPUT, OUTPUT AND IDENTIFIED METHODS

Objective: The objective of this step is to identify high priority areas (previously referred to as hotspots[3]) as these would be the areas where more detailed work for the rest of the steps would focus on. These high priority areas are selected based on ecological, socio-cultural and water resource use importance and are often areas of high ecological importance where water resources are stressed or may be stressed in future. This is a key step as the gazetted information is RUs with measured information and potentially higher confidence output. The prioritisation therefore acts as a filter to allow one to focus on specific areas in the various ecosystems. Integrated Step 2 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.

The flow diagram illustrating the steps, sub-steps and actions for Integrated Step 1 is provided in **Figure 5.1**. Sub-steps are represented by second tier numbering e.g. Step 1.1. Note that abbreviations used are described in the acronyms and abbreviation list at the beginning of the document.

5.1 STEP 1.1 INFORMATION AND DATA COLLECTION

Objective: At the start of the study, all available data required to base this step and future steps on must be identified and obtained. Although data collation is an ongoing activity throughout the project, certain specific information must be obtained at the onset of the study. This information focusses on the aspects below. Note that standardised reference documentation or databases that must be used has been identified and provided.

[3] 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.

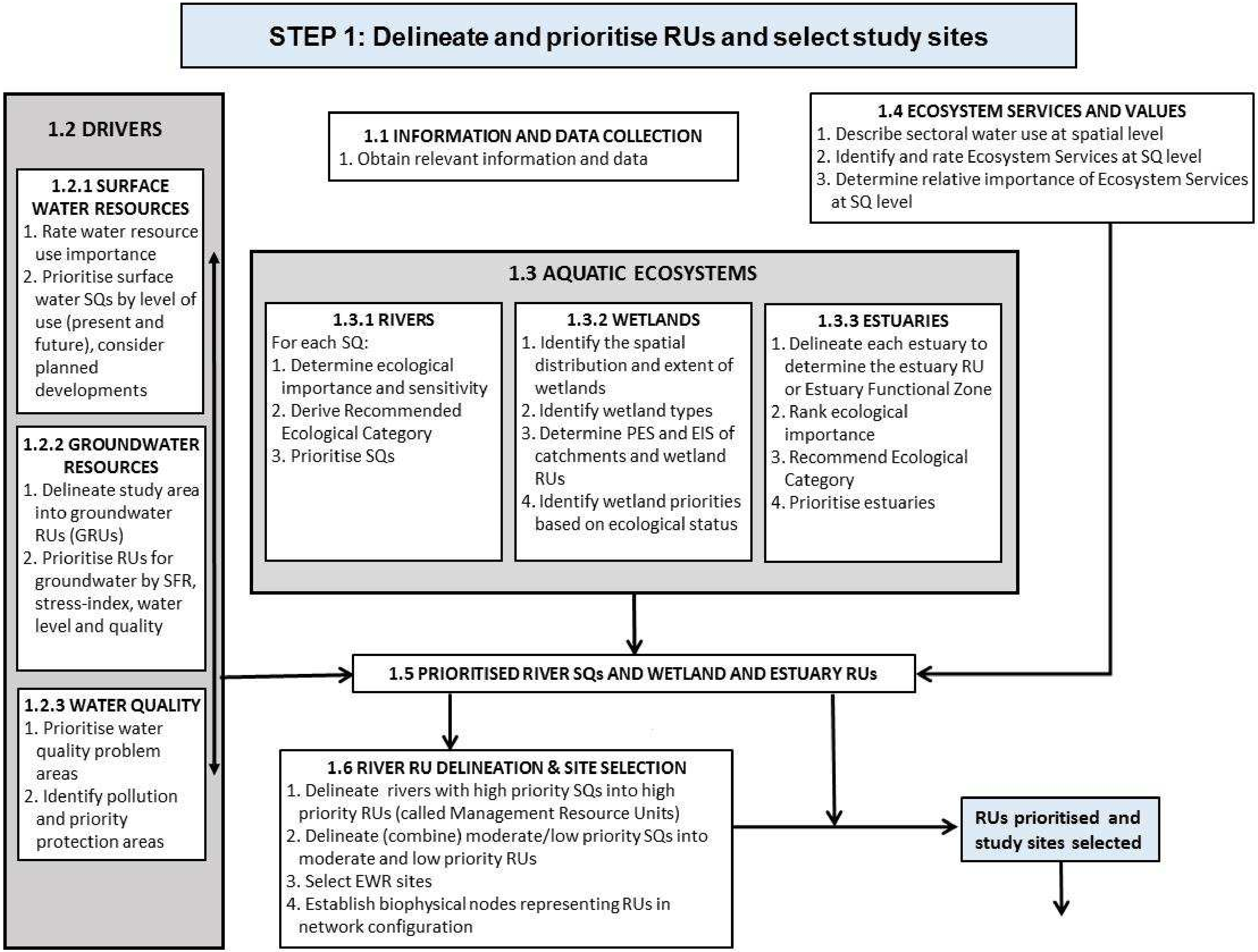

Figure 5.1 Illustration of the sub-steps for Integrated Step 1: Delineate and prioritise RUs and select study sites.

5.2 STEP 1.2 DRIVERS

Objective: Priority areas for the driving components must be provided to be integrated in a priority rating to determine the high priority areas. High priority areas or RUs in this step are the RUs that are currently under water resource stress or may be under future water resource stress due to planned developments. If these areas are in the same time of high ecological and socio-cultural importance, this will lead to a high priority rating. The driver assessments provide the information on the water resource stress.

Table 5.1 Step 1.2 Drivers: Standardised input and output per relevant action

Action	Output
Step 1.2.1 Surface Water Resources (RDM/WE/00/CON/ORDM/0916)	
1. Rate water resource use importance 2. Prioritise surface water SQs by level of use (present and future), consider planned developments	Relative rating of water use. Apply a typical five tier scale from limited use (1) up to Heavily used (5). Prioritise per relative ratings by applying appropriate integration methods and weights to obtain integrated scores if required.
Step 1.2.2 Groundwater Resources (RDM/WE/00/CON/ORDM/0916)	
1. Delineate study area into groundwater RUs (GRUs).	▪ Delineated GRUs with maps (GIS) and narrative description.
2. Prioritise RUs for groundwater by SFR, stress-index, water level and quality	▪ Time series of natural and present day baseflow. ▪ Aquifer vulnerability map. ▪ Stress index map. ▪ Plotted water levels and long term trends. ▪ Aquifer classification.
Step 1.2.3 Water Quality (RDM/WE/00/CON/ORDM/0816)	
Identify water quality problem and protection areas (including non-ecological)	Potential pollution sites and protection priority areas identified on a qualitative basis (as part of screening and prioritisation).

5.3 STEP 1.3 AQUATIC ECOSYSTEMS

Objective: The objective is to delineate RUs for estuaries and wetlands. Delineated RUs for estuaries and wetlands and river sub-quaternary reaches (SQs) are prioritised on the basis of ecological importance and sensitivity.

The aquatic ecosystem components which are assessed are outlined below and each of these require different actions:

- 1.3.1 Rivers;
- 1.3.2 Wetlands; and
- 1.3.3 Estuaries.

Table 5.2 Step 1.3 Aquatic Ecosystems: Standardised input and output per action

Action	Input	Output
Step 1.3.1 Rivers (RDM/WE/00/CON/ORDM/0516)		
1. Determine the ecological importance and sensitivity per SQ	PESEIS database	EIS rating (number (0 – 5) and description) per SQ.
3. Prioritise SQs		Ranked SQs in terms of EIS.
Step 1.3.2 Wetlands (RDM/WE/00/CON/ORDM/0616)		

Action	Input	Output
1. Identify the spatial distribution and extent of wetlands 2. Identify the types of wetlands (wetland ecosystem types)	Catchment scale: 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).
3. Determine PES and EIS of catchments and wetland RUs. 4. Identify wetland priorities based on ecological status 5. Refine wetland priorities by considering other factors, particularly resource demand and risk	NFEPA database.	▪ Catchment scale PES and EIS. ▪ Wetland RU PES and EIS. ▪ Ranked list of priority catchments and RUs based on ecological status.
Step 1.3.3 Estuaries (RDM/WE/00/CON/ORDM/0716)		
1. Delineate each estuary to determine the estuary EFZ	EFZ layer (SANBI BGIS). 1:100 year floodline.	Map delineating the EFZ per estuary.
2. Rank ecological importance	Turpie *et al*. (2002).	List of estuaries with importance evaluation following standard scoring resulting in 'Low, Medium, High and Very High' priorities
4. Prioritise estuaries		Estuaries prioritised according to a scoring system described as 'Low, Medium, High and Very High'.

5.4 STEP 1.4 ECOSYSTEM SERVICES AND VALUES

Objective: The objective is to determine the Socio-Cultural Importance (SCI) which will provide another layer for the prioritisation of RUs.

Table 5.3 Step 1.4 Ecosystem Services and Values: Standardised input and output per action (RDM/WE/00/CON/ORDM/1016)

Action	Input	Output
2. Identify and rate Ecosystem Services at SQ level		List of SQs with Ecosystem Services identified and rated using a score of 1 – 5.
3. Determine relative importance of Ecosystem Services at SQ Level		SQs with indicated relative importance rated 1 – 5.

5.5 STEP 1.5 PRIORITISED RIVER SQS AND WETLAND AND ESTUARY RUs

Objective: All relevant information focussing on the various components' importance are fed into an assessment procedure which rates the priority areas (a rule-based scoring system is usually used). At this point rivers, estuaries and wetlands under current and future pressures in need of intervention or protection have been identified. These systems should be targeted for higher confidence EWR assessments, the level of which depends on data availability. One would have therefore have mapped all the high priority systems and can now plan for the next sub-steps. Note that rivers are prioritised at SQ level as this information is required to undertake the delineation (Integrated Step 1.6).

5.6 STEP 1.6 RIVER RU DELINEATION AND SITE SELECTION

At this point, the assessment for rivers has been based on SQ scale. RUs have not yet been selected as, due to the number of SQs, a filtering process is required whereby detailed and desktop assessments of RU determination are undertaken. For this filtering process, the high priority RUs (previously referred to as hotspots) need to be identified first (Integrated Step 1.5).

Objective: The objective is to identify the main rivers with high priority areas and select EWR sites. EWR sites are the river study sites where surveys, measurements and observations are undertaken and are likely to be identified in high priority areas.

Table 5.4 Step 1.6 River RU Delineation and Site Selection: Standardised input and output per action (RDM/WE/00/CON/ORDM/0516)

Action	Input	Output
1. Delineate rivers with high priority SQs into high priority RUs (called MRUs)[4]	▪ EcoRegion Level II. ▪ Geomorphic zones[5].	Delineated MRUs.
2. Delineate (combine) moderate/low priority SQs into moderate and low priority RUs	n/a.	Delineated RUs.
3. Select EWR sites		Described and groundtruthed EWR sites.
4. Establish biophysical nodes representing RUs in network configuration		Nodes mapped at downstream end of RUs.

5.7 INTEGRATED STEP 1: IDENTIFIED METHODS/TOOLS

Table 5.7 lists the associated methods/tools for each action (if relevant).

Table 5.5 Integrated Step 1: Identified tools

Step	Action	Method/Tool	Frequency Rating
1.2.1: Drivers - Surface Water Resources		Water Resource Use Importance (WRUI) spreadsheet.	Very High. In use since 2004 and applied in most Reserve studies and four Classification studies.
1.2.2: Drivers - Groundwater Resources		DRASTIC tool.	High.
1.3.1: Aquatic Ecosystems - Rivers	2. Derive REC	Catchment Reserve RU priority spreadsheet (DWA, 2013b).	Very High. In use since 2004 and applied in most Reserve studies and four Classification studies.
	3. Prioritise SQs	Catchment Reserve RU priority spreadsheet (DWA, 2013b).	Very High (in use since 2004 and applied in most Reserve studies and four Classification studies).
		RU Prioritisation tool (original guideline version; DWA, 2011).	Low (used in two Classification studies).
		RU Prioritisation tool (case study version).	Low – Medium. Used in two RQO studies.
1.3.2: Aquatic Ecosystems - Wetlands	3. Determine ecological condition and importance of wetlands	Sub-quaternary based PESEIS tool (DWS, 2014a).	Medium. Used in one Classification study.
		Quaternary-based PESEIS (DWAF, 2009a; DWA 2010a,b; 2013c;	Medium. Used in four Reserve studies and one Classification study.

[4] For both rivers and estuaries, Step 1 and 2 in practice is usually addressed as one step as there are linkages and inter-dependencies between the different actions.

[5] Information available for the whole country.

Step	Action	Method/Tool	Frequency Rating
		DWS, 2015a).	
		Land cover intersect method for PES estimation (WCS) – PES determination only.	Medium. Used in three studies.
	4. Identify wetland priorities based on ecological status	Broad-scale approach to Wetland Prioritisation (WCS).	Very Low. Used in one Reserve study.
		Detailed approach to Wetland Prioritisation (WCS).	Very Low. Used in one Reserve study.
	5. Refine wetland priorities by considering other factors, particularly resource demand and risk	Decision analyst (Escot).	Very Low.
		RU prioritisation tool (DWS, 2014a).	Very Low – used in one RQO studies.
1.3.3: Aquatic Ecosystems - Estuaries	1. Delineate each estuary to determine the estuary RU or EFZ	EFZ method: Van Niekerk and Turpie (2012).	Very High. In use since 2009 for all EWR studies.
	2. Rank ecological importance	Ranking Ecological Importance of Estuaries (Turpie *et al.*, 2002)	Very High. In use since 1999 for all EWR studies.
	4. Prioritise estuaries	Proposed Rule-base method described in (DWA, 2013d).	Low. Designed for one Classification study – no alternative methods.
1.4 Ecosystem Services and Values		SCI Spreadsheet tool.	Very High. In use since 2001 and used in most Reserve studies.
1.6 River RU Delineation and Site Selection	1. Delineate rivers with high priority	MRU method (DWS) (DWAF, 2008a).	Very High. Formalised in 2008 (CJ Kleynhans and Louw). Used in all Reserve studies since then.
	3. Select EWR sites	EWR site selection process (DWA, 2013e).	Very High. Process formalised during 1997 (Louw and Kemper) and used for all EWR site selection.

5.8 STAKEHOLDER INVOLVEMENT AND COMMUNICATION

Objective: At the start of a study, establish a stakeholder database, announce the study, its objectives and the proposed study implementation process for stakeholder comments and contributions.

Stakeholder database:
Identify stakeholders in the study area according to sector and geographic representation and compile a stakeholder database consisting of full contact details of each person (organisation, designation, telephone number and email or postal address). An understanding of the dynamics of the study area will assist in the identification of stakeholders.

Announcement of the study:
The Study Inception Report should form that basis of the information which should be conveyed to stakeholders in the announcement of the study. The announcement can be conveyed through a number of methods, however in line with DWS best practices, the announcement should be:

- Advertised (radio and/or newspaper);
- communicated in written format through a document which can be easily understood (brochure, Background Information Document);
- published on the DWS web-site, and
- by means of meeting with stakeholders (e.g. a public meeting to announce the study).

The above-mentioned methods can take on many forms and should be determined by the requirements of the DWS, the stakeholders and the general dynamics of the study area (e.g. be sensitive to language use, customs of the area, preferences for communication).

The output required from Integrated Step 1 is:
- A stakeholder database.
- Stakeholders knowledge of the study, what it is all about; its implication and how they can participate.
- Comments on the Inception Report.

Recording of comments:
A record to capture contributions of stakeholders and responses from the DWS and technical team is essential for the study in terms of tracking stakeholder contributions and responses, but also to ensure transparency in the process. Any method can be used to compile a record of contributions and responses. A Comments and Responses Register (CRR) is a suggested method of recording such contributions and responses. Such a record has to be compiled and updated from the start of the study during Integrated Step 1.

Establishment of a Project Steering Committee (PSC):
It is recommended that a Project Steering Committee (PSC) be established during Integrated Step 1 of the process. A PSC must consists of a representative group of all stakeholders in the study area. The PSC is voluntary and all members should agree upfront on the ToR of the committee and the roles and responsibilities of all parties involved. The PSC does not replace the stakeholders; it is merely a representative body of the stakeholders who will assist in guiding the study.

6 INTEGRATED 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 6.2**), 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.

The flow diagram illustrating the steps, sub-steps and actions for Integrated Step 2 is provided in **Figure 6.1**. Sub-steps are represented by second tier numbering e.g. Step 2.1. Note that abbreviations used are described in the acronyms and abbreviation list at the beginning of the document.

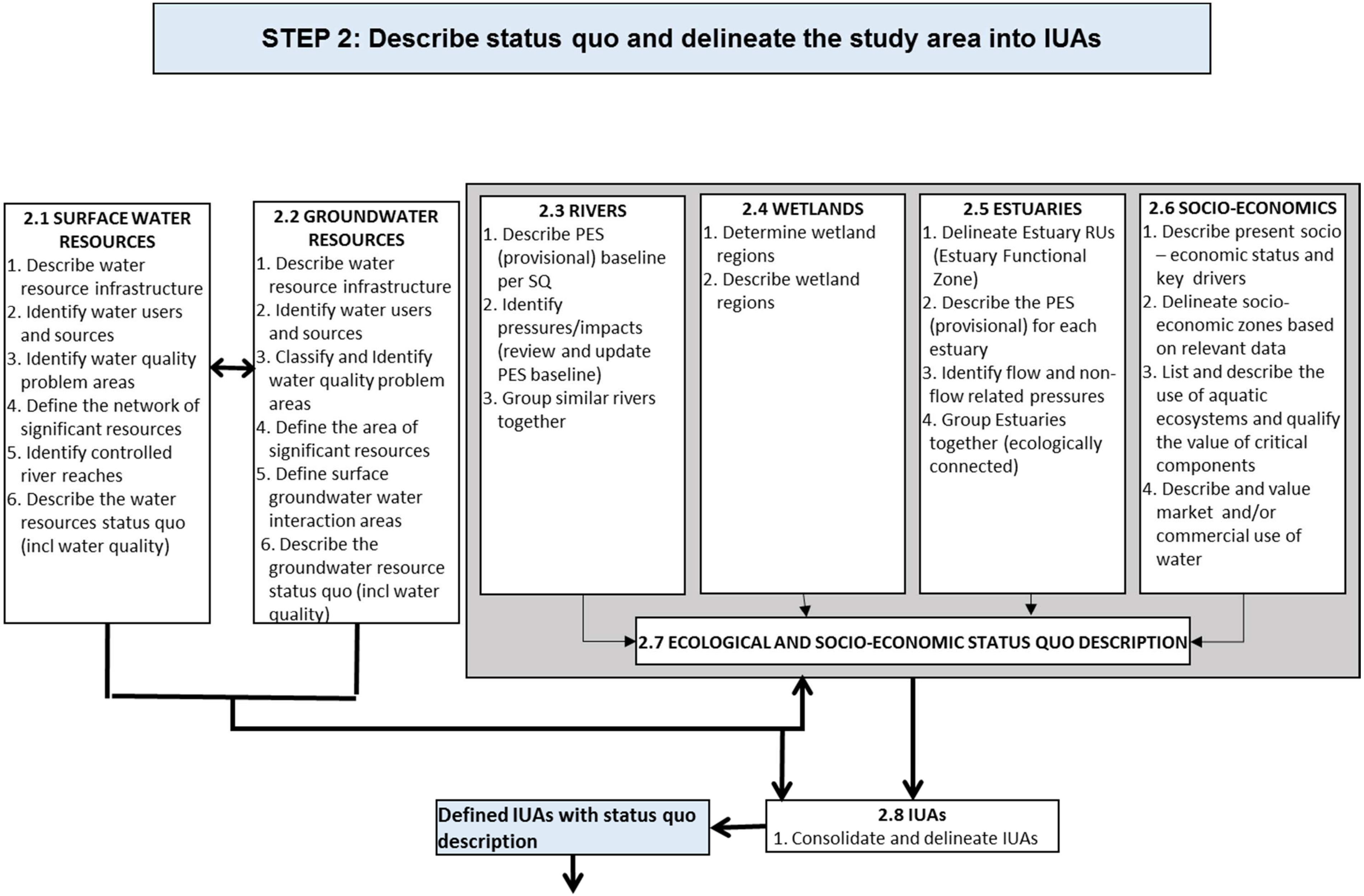

Figure 6.1 Illustration of the sub-steps for Integrated Step 2: Describe status quo and delineate the study area into IUAs

6.1 STEP 2.1 SURFACE WATER RESOURCES

Objective: Define and describe the surface water resources in the study area by following a catchment-by-catchment approach and identify key river reaches where flow is controlled by current or future operational activities. The information must be sourced from past hydrological and water resource assessment studies using the Quaternary Catchment definitions as the primary delineation for the descriptions. The descriptions should focus on where there are significant alterations of river flows caused by regulating water infrastructure and water use.

The status quo description must also present the hydrological data requirements and availability for application in subsequent steps, particularly for Integrated Step 3. The level of uncertainty associated with the hydrological information and data must be presented along with a qualitative rating which indicates how representative the data is and to what degree the available data could deviate from the actual conditions in the catchments.

The availability and status of water resource simulation models need to be documented with due reference to the resolution of the networks configured for the catchments in the study area. This review must reflect how the available models will be applied for the simulation of scenarios as part of Integrated Step 4.

Table 6.1 Step 2.1 Surface Water Resources: Standardised input and output per action

Action	Input	Output
Water quality (RDM/WE/00/CON/ORDM/0816)		
2. Identify water users and sources		▪ Water user type. ▪ Water source. ▪ If Irrigation: crop type, application system, areas, water use volume. ▪ Historical water use volume. ▪ Licenced water allocations. ▪ Future proposed water uses.
3.Identify water quality problem areas		▪ Tables identifying water quality priority SQs, users and associated stressors, finalised maps.
Groundwater, Hydrology, Hydraulics (RDM/WE/00/CON/ORDM/0916)		
4. Define the network of significant resources 5. Identify controlled river reaches		River reach and catchment on GIS map.

6.2 STEP 2.2 GROUNDWATER RESOURCES

Objective: The objective of this sub-step is to define and describe Groundwater Resources for the purpose of Groundwater Resource Unit (GRU) delineation.

Quaternary catchments form the basic unit of delineation. These can be grouped into similar geohydrological properties by aquifer type, or be further subdivided if significant geohydrological features cut through catchments. Areas of similar character are grouped and mapped into distinct units, termed GRUs. Criteria that can be utilised to group or disaggregate catchments to form GRUs include:

- Interaction with other components of the hydrological cycle such as wetlands and rivers.
- Nature of the aquifers (primary, secondary dolomitic, alluvial etc.).
- Groundwater depth.

- Lithology when it affects borehole yields and groundwater quality.
- Topography.
- Groundwater dependence and use.
- Groundwater quality.
- Recharge and available groundwater resources.
- For the status quo description, additional data requirements and shortcomings should be identified and stressed regions highlighted. The level of uncertainty associated with the data should be presented. The data should be presented in a manner suitable for GRU and IUA delineation.

Table 6.2 Step 2.2 Groundwater Resources: Standardised input and output per action (RDM/WE/00/CON/ORDM/0916)

Action	Input	Output
1.Describe water resource infrastructure		▪ Groundwater regions by aquifer type and hydraulic connection. ▪ Groundwater Dependent communities. ▪ Maps of borehole distribution, yield distribution, geology structures, catchments and groundwater schemes, recharge, baseflow.
2.Identify water users and sources	▪ WARMS. ▪ All Towns strategy reports and ISP reports. ▪ GRAII. ▪ Census data 2011 or later. ▪ DWS regional office information databases.	▪ Water use by sector. ▪ Licenced Water allocation.
3.Identify water quality problem areas	▪ ZQM data. ▪ WMS surface water quality at gauging stations. ▪ NGA. ▪ WSAM quality data (potability index).	Distribution of water quality classes for potability for TDS, Fluoride, Nitrates, metals etc.
4.Define the area of significant resources	▪ GRAII. ▪ Harvest Potential. ▪ Groundwater maps. ▪ Groundwater use.	Recharge and exploitable groundwater resources.
5. Define surface groundwater water interaction areas	▪ GRAII. ▪ GRDM software. ▪ Area and type of SFR activity. ▪ NFEPA wetlands database.	Natural and present day baseflow time series.
6. Describe the groundwater resource status quo (incl. water quality)	▪ Recharge. ▪ Exploitation or Harvest Potential. ▪ Groundwater use. ▪ Groundwater Quality by potability class.	▪ Groundwater baseflow and interflow. ▪ Water quality classification. ▪ Groundwater balance in terms of the mean annual volumes (or depths) of the components of the groundwater cycle (recharge, baseflow, abstraction, evapotranspiration, outflow, inflows from surface water).

6.3 STEP 2.3 RIVERS

Objective: Broadly determine the Present Ecological State (PES) for the study area in terms of the Ecological Categories (ECs: A to F) which informs the delineation of IUAs. A country wide database of the PES is used to allocate an EC to each of the Sub Quaternary (SQ) reaches (delineation forming the basis of the Present Ecological State and Ecological Importance-

Ecological Sensitivity (PESEIS) database (DWS, 2014b) and based on the 1:500 000 map scale). During this step, all assessments are made at SQ scale. An additional output of this step is to determine the desired EC (based on a set of DWS rules) (DWS, 2014c) called the **Recommended Ecological Category (REC) and also indicated what (broadly) would be required to achieve these ecological objectives where the REC represents an improvement of the PES**.

Table 6.3 Step 2.3 Rivers: Standardised input and output per action (RDM/WE/00/CON/ORDM/0516)

Action	Input	Output
1. Describe PES (provisional) baseline per SQ	PESEIS database (PES component).	Described and updated pressures /impacts based on land use and resulting ecological state.
2. Identify pressures /impacts (review and update PES baseline)		
3. Derive REC	▪ PESEIS database ▪ DWS rules.	REC per SQ including identification of actions required to achieve REC (desktop level).

6.4 STEP 2.4 WETLANDS

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

Table 6.4 Step 2.4 Wetlands: Standardised input and output per action (RDM/WE/00/CON/ORDM/0616)

Action	Input	Output
1. Determine broad wetland regions	Map of natural wetlands (Step 1, Action 1 output).	Identified wetland regions.
	Level 1 and 2 EcoRegions.	
	Geology (1:500 000).	
2. Describe wetland regions	▪ NFEPA database. ▪ Land use map.	Broad descriptions per wetland region.

6.5 STEP 2.5 ESTUARIES

Objective: Broadly determine the PES for all the estuaries in the study area in terms of the ECs (A to F) which informs the delineation of IUAs. This information is used in the grouping of estuaries and the delineation of the IUAs. An additional output of this step is to determine the desired EC (based on a set of DWS rules) (DWS, 2014b) called the **REC and also indicated what (broadly) would be required to achieve these ecological objectives where the REC represents an improvement of the PES**.

Table 6.5 Step 2.5 Estuaries: Standardised input and output per action (RDM/WE/00/CON/ORDM/0716)

Action	Input	Output
1. Describe the PES (provisional) for each estuary	National Estuaries Biodiversity Plan (NBA) 2011 (or any updates their off).	Desktop EWR PES of individual estuaries.
2. Identify flow and non-flow related pressures	▪ Estuary Management Plans (Under Integrated Coastal Management (ICM) Act). ▪ Historical Estuary EWR	List of flow and non-flow pressures.

Action	Input	Output
	studies (DWS).	
3. Provisional REC	National Estuaries Biodiversity Plan 2011 (or any updates thereof) (van Niekerk and Turpie, 2012).	Provisional REC for each estuary in terms of A-F ECs.
4. Group Estuaries together (ecologically connected)		Estuaries grouped into functional/management units.

6.6 STEP 2.6 SOCIO-ECONOMICS

Objective: The information needed to quantify and describe the socio-economic benefits that are derived from utilising the water resources in the study area is collated in this step.

It is advisable to undertake a cursory assessment of the likely alternative water resource management options and scenarios that will have to be evaluated in Integrated Step 4, prior to the collation of the *quantitative* socio economic data. The aim with this "forward-looking" approach is to ensure the data collation activity focusses on what will be relevant for the comparison of scenarios in Integrated Step 4 (It should be noted that, in general, information on possible options and alternatives are available from previous water resource planning investigations as well as catchment management and bulk water system reconciliation strategies.).

Table 6.6 Step 2.6 Socio-Economics: Standardised input and output per action (RDM/WE/00/CON/ORDM/1016)

Action	Input	Output
1 Describe the present socio-economic status and key drivers		Narrative overview of the catchment and key economic drivers, potential "hotspots" identified.
2 Delineate socio-economic zones based on relevant data		Narrative description of separate zones based on land use and socio-economic criteria and overview of communities associated with the zones - link to IUAs.
3 List and describe the use of aquatic ecosystems and qualify the value of critical components		Narrative description of expected ecosystems and their importance to communities, disaggregated by socio-economic zones.
4 Describe and value status quo market and/or commercial use of water		Quantitative analysis of value of water by sector expressed as Gross Value Added (GVA)/ Gross Domestic Product (GDP), employment and payment to households. The opportunity costs associated with the negative values attached to the Waste Water Treatment Works (WWTW) costs must be reflected here as well.

6.7 STEP 2.7 ECOLOGICAL AND SOCIO-ECONOMIC STATUS QUO DESCRIPTION

The ecological status quo for rivers, wetlands and estuaries are provided according to the relevant groupings for rivers and wetlands and per estuary. The economic status quo as well as the use of aquatic ecosystems and the value thereof is also described.

6.8 STEP 2.8 IUAs

During this step, all the data collated is consolidated and used to delineate the IUAs. The step therefore involves the synthesis of the information products from all components (steps 2.1 to 2.6) and entails, among other aspects, overlaying the GIS information of the pertinent catchment 'features' to define the IUAs. This is the motivation for the two arrows flowing into 1.9 as it illustrates the synthesis of all the work undertaken in Step 2.1 to 2.6. The synthesis is typically undertaken in the form of a work session where the various specialists motivate and agree on the proposed IUA delineations. The proposed IUAs are then presented to stakeholders for comments after which the final selection is made for application in subsequent steps.

6.9 INTEGRATED STEP 2: IDENTIFIED METHODS/TOOLS

Table 6.7 lists the associated methods/tools for each action (if relevant).

Table 6.7 Integrated Step 2: Identified tools

Sub-step	Action	Method/Tool	Frequency rating
2.1: Surface Water Resources	3. Identify water quality problem and protection areas (including non-ecological)	Resource Unit Evaluation Spreadsheet (used primarily for RQO studies).	▪ Very High.
2.2: Groundwater Resources	5. Define surface groundwater water interaction areas	Derive natural and present day time series of baseflow: ▪ WRSM2000 (Pitman model – Pitman *et al*., 2008). ▪ SPATSIM (Pitman model – Hughes *et al*., 2012). ▪ GRYM (DWA, 2010c). ▪ ACRU (Schulze and Pike, 2004).	▪ High. ▪ High. ▪ Low. ▪ Low.
2.3 Rivers	3. Derive REC	Catchment Reserve RU priority spreadsheet (DWA, 2013b).	Very High. In use since 2004 and applied in most Reserve studies and four Classification studies
2.5 Estuaries	4. Derive REC	Guidelines for setting REC as per DWAF (2008b) (or future updates).	Very High. In use since 1999 for all EWR studies.

6.10 STAKEHOLDER INVOLVEMENT AND COMMUNICATION

Objective: Obtain stakeholder comment on the draft IUAs and its Status Quo, and the prioritisation of RUs in IUAs.

Towards the end of Integrated Step 2, the work which has been done during Integrated Step 1 and Step 2 on the identification, delineation of IUAs and the prioritisation of the RUs within the IUAs and its status have to be presented to stakeholders for comment.

The information can be presented using a combination of the following methods:

- During a PSC meeting, (meeting 1).
- Notifications (of planned PSC and after the PSC to remind stakeholders of information on the DWS web site).
- Information document (compile a summary of the technical reports and distribute to stakeholders for their review).
- Minutes of PSC meeting.
- Distributions of the presentations delivered at the PSC.
- Publish information as presented on the DWS website.
- Update the Comments and Responses Register.

7 STEP 3: QUANTIFY BHNR AND EWR

Objective: The objective of this step is to quantify the EWRs for different ecological states and set the Basic Human Needs (BHN). These EWRs (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, and which supports the TEC and the Class, will become the flow or hydrology RQO.**

During Integrated Step 3 (**Figure 7.1**), the BHN and the EWR components that describe the Reserve, 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. In a similar way the BHN rather than the Basic Human Needs Reserve (BHNR) is referred to. At this stage the BHN is quantified for different daily allocations and it only becomes the BHNR once a decision is made on the allocation.

The flow diagram illustrating the steps, sub-steps and actions for Integrated Step 3 is provided in **Figure 7.1**. Sub-steps are represented by second and third tier numbering e.g. Step 3.1 and Step 3.1.1. Note that abbreviations used are described in the acronyms and abbreviation list at the beginning of the document.

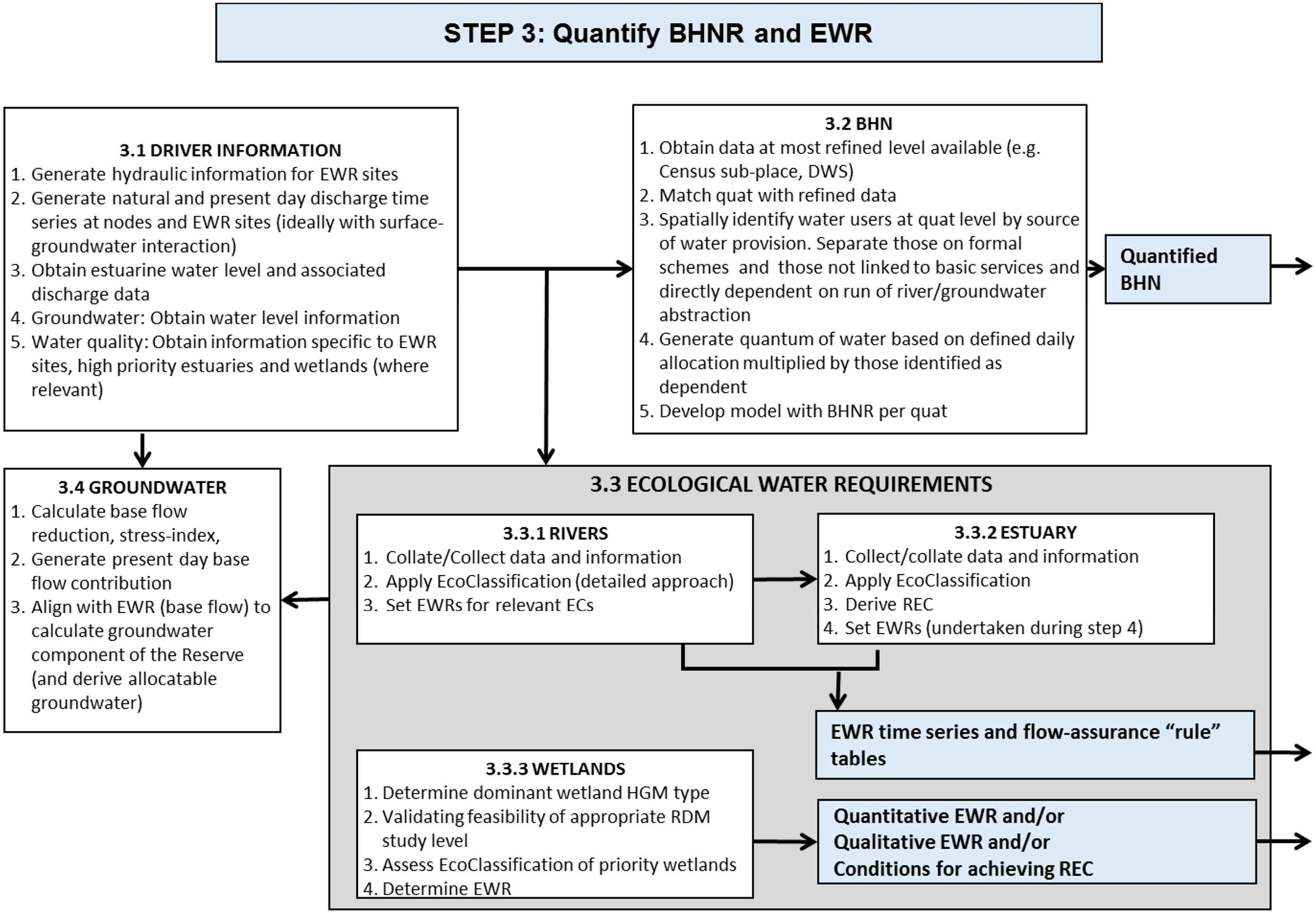

Figure 7.1 Illustration of the sub-steps for Integrated Step 3: Quantify BHN and EWR

7.1 STEP 3.1 DRIVER INFORMATION

Objective: The required hydrological and hydraulic data that is needed to determine the ecological water requirements is produced. The hydrological time series data is usually generated by a river-runoff and/or water resource simulation model assuming the catchment development is constant (stationary) over the simulation period. The time series data record period must cover several wet and dry periods that will ensure the derived EWRs are representative of the full spectrum of flow conditions.

Water quality objective: The required water quality data that is needed to determine the PES for water quality is collated.

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

Table 7.1 Step 3.1 Driver information: Standardised input and output per action

Action	Input	Output
Surface water (RDM/WE/00/CON/ORDM/0916)		
1. Generate hydraulic information for EWR sites		Rating data (Q and stage). Hydraulic habitat definitions in terms of Velocity Depth Classes (Fish) and Velocity Substrate Classes (Invertebrates).
2. Generate natural and present day discharge time series at nodes and EWR sites (ideally with surface-groundwater interaction)	Calibrated model for study area.	Monthly time series of natural flows and simulated present day flows. Estuarine analysis: Monthly data in m^3/s (in tabulated form and column format) summarised as ▪ Mean Annual Runoff (MAR). ▪ Average monthly flow (m^3/s) (Oct to Sep). ▪ Monthly volume (MCM) (Oct to Sep). ▪ 50%ile monthly flow (Median flows) (Oct to Sep). ▪ 75% monthly flow (Base flows) (Oct to Sep). ▪ 10%ile monthly flows (Drought Flows) (Oct to Sep). ▪ Monthly Standard deviation. ▪ The month in which the maximum flows occurs. ▪ The month in which the minimum flow occurs. ▪ Flood variance for both natural and present day flow, defined as the 95th percentile over the 25th percentile. ▪ Base flow variance for both natural and present day flow, defined as the 75th percentile over the 25th percentile for Oct to Sep. ▪ The duration of low flow (defined as the number of months from when the mean monthly flow drops below

Action	Input	Output
		6% of the MAR to the minimum flow month). ▪ The month in which high flows commence (the first month after the minimum flow month in which the monthly flow exceeds the mean monthly flow). ▪ Coefficient of variability (average monthly flow minus median monthly flow divided by the median monthly flow). ▪ An assessment of whether the flow is bimodal or not, that is, two wet periods and two dry periods. ▪ List 25 highest flow months as identified in Reference time series
3.Obtain estuarine water level, associated discharge data and other relevant information		▪ Topographical and bathymetric map. ▪ Sediment grain size as per DWS. Daily flows (if possible) which must be consistent with the monthly systems data, i.e. no new hydro can be generated at this point). ▪ River inflow coupled to abiotic states (e.g. mouth state, water levels, salinity regime, retention).
4: Groundwater: Obtain water level information		If required (dependant on estuary type), simulated groundwater inflow defined as a water level and a volume of input.
Water Quality (RDM/WE/00/CON/ORDM/0816)		
5. Water quality: Obtain information specific to EWR sites, high priority estuaries and wetlands (where relevant)	DWS: WMS database or data from other water quality databases, with data in WMS format.	
	Rules for data selection and use (see DWAF, 2008c for rivers; scientific standards).	
	Toxicological data (e.g. time-dependent Species Sensitivity Distribution (SSD) curves and toxicological data for acute and sub-acute responses).	
	Diatom data (particularly relevant for wetlands).	

7.2 STEP 3.2 BHN

Objective: The objective is to quantify the BHN from surface and/or groundwater.

Table 7.2 Step 3.2 BHN: Standardised input and output per action (RDM/WE/00/CON/ORDM/1016)

Action	Input	Output
1. Obtain data at most refined level available (e.g. Census sub-place, DWS)	SQ data as GIS shape files, Census data.	Populated catchment/project area with numbers of households and, by extrapolation, individuals as well as their primary source of water supply.
2. Match quaternary catchment with refined population data		Quaternary catchments showing numbers of households and individuals within each.
3. Spatially identify water users at quaternary level by source of water provision. Separate those on formal schemes and those not linked to basic services and directly dependent on run of river/groundwater abstraction		Quaternary catchments, or SQ catchments, showing numbers of people not serviced from a formal water supply scheme. Those not serviced must be disaggregated into those dependent on ground water through borehole abstraction and those directly dependant on surface water.
4. Generate quantum of water based on defined daily allocation multiplied by those identified as dependent		Quantify various demand parameters expressed in litres per capita per day.
5. Develop model with BHNR per quaternary catchment		Water required per quaternary catchment

7.3 STEP 3.3 ECOLOGICAL WATER REQUIREMENTS

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

The aquatic ecosystem components which are assessed are outlined below and each of these require different actions:

- 3.3.1 Rivers;
- 3.3.2 Estuaries; and
- 3.3.3 Wetlands.

Table 7.3 Step 3.3 Ecological Water Requirements: Standardised input and output per action

Action	Input	Output
Step 3.3.1: Rivers (RDM/WE/00/CON/ORDM/0516)		
2. Apply EcoClassification (detailed approach)	▪ Fish reference condition from River EcoStatus Monitoring Programme (REMP). ▪ Fish present: Frequency of Occurrence (FROC) from Fish Response Assessment Index (FRAI) generator.	Fish PES (categories per EWR site).
	▪ Reference list in Macro Invertebrate Response Assessment Index (MIRAI) version 2. ▪ Present day list from PESEIS (DWS, 2014b)	Aquatic Invertebrate PES (categories per EWR site).

Action	Input	Output
	and from Rivers database.	
		Geomorphology (categories per EWR site).
		Vegetation (categories per EWR site).
		Riparian and Instream habitat categories per EWR site.
		EcoStatus per EWR site (EC).
		EIS per EWR site (score and evaluation in terms of Low to Very High).
	REC rules.	REC per EWR site.
3. Set EWRs for relevant ECs (see also **Table 7.4**)		Time series and EWR rules for relevant ecological status at EWR sites. Time series must be generated using the facility included in SPATSIM in the specific appropriate models.
Step 3.3.1: Water Quality (RDM/WE/00/CON/ORDM/0816)		
1. Collate/Collect data and information (including field survey)		Summary statistics for parameters/variables (using the specified data record) as defined by the methods manual (DWAF, 2008c).
		Diatom species list, report and diatom-based ECs.
2. Apply EcoClassification (detailed approach)	Benchmark tables and ratings (rivers; DWAF, 2008c) required for running the Physico-Chemical Assessment Index (PAI) model.	Integrated water quality category (rivers).
Step 3.3.2: Estuaries (RDM/WE/00/CON/ORDM/0716)		
1. Collect/collate data and information on bathymetry	See Step 3.1, action 3.	
2. Apply EcoClassification		▪ Abiotic state distribution for reference and present as per DWAF (2008a). ▪ Health scores for abiotic and biotic components combined into overall PES score for each estuary (indicate if achieving EMP objectives, Nursery targets, Recreational targets) DWAF (2008b).
	▪ Ecological Importance Rating. ▪ Conservation priorities.	Ecological Importance rating.
3. Derive REC	▪ Requirements as specified in Estuary Management Plans (ICM Act). ▪ Requirements related to protection of nursery areas (Department of Agriculture Forestry and Fisheries - DAFF layers).	REC for each estuary (indicating whether EMP objectives and nursery targets, recreational targets will be achieved).
4. Set EWRs (see also **Table 7.4**)	Undertaken during Integrated Step 4.	
Step 3.3.3: Wetlands (RDM/WE/00/CON/ORDM/0616)		
1. Determine dominant wetland HGM type		Primary HGM wetland type.
2. Validate feasibility of appropriate level of RDM study	List of identified threats and impact type.	Required level of RDM assessment.

Action	Input	Output
3. Assess EcoClassification of priority wetlands		PES, EIS and REC of each wetland RU.[6]
4. Determine EWR		Qualitative AND/OR Quantitative EWRs AND/OR conditions for relevant EC[7]

For rivers and estuaries there are defined methodologies (DWAF, 1999b) which are linked to different levels of EWR determination. Each of these methodologies is linked to different detail of driver input, without which these methods cannot be applied. These driver inputs need to be associated with the different levels that are in turn associated with the different tools (**Section 7.5**). This information is provided in **Table 7.4**. For further information on differences of the different methodologies please refer to the reference.

Table 7.4 Step 3.3 Ecological Water Requirements: Standardised driver input and output for different EWR methodologies

<table>
<tr><th>Action</th><th>Input</th><th>Output</th></tr>
<tr><td colspan="3">Step 3.3.1: Rivers (RDM/WE/00/CON/ORDM/0516)</td></tr>
<tr><td colspan="2">3. Set EWRs for relevant ECs</td><td>Time series and EWR rules for relevant ecological status at EWR sites.</td></tr>
<tr><td>3.1 Desktop</td><td>Monthly time series for natural and present day at every desktop biophysical node.
EcoClassification information from PESEIS database.</td><td></td></tr>
<tr><td>3.2 Rapid</td><td>Monthly time series for natural and present day at the EWR sites.
Hydraulic information.</td><td></td></tr>
<tr><td>3.3 Intermediate</td><td rowspan="2">Monthly time series for natural and present day at the EWR sites.
Calibrated hydraulic information at the EWR site based on site surveys.
Diatom information to inform water quality.</td><td></td></tr>
<tr><td>3.4 Comprehensive</td><td></td></tr>
<tr><td colspan="3">Step 3.3.2: Estuaries (RDM/WE/00/CON/ORDM/0716)</td></tr>
<tr><td colspan="2">4. Determine EWRs for relevant ECs</td><td>Selected scenario that complies to relevant ecological status at the estuary.</td></tr>
<tr><td>4.1 Desktop</td><td>Monthly time series for natural and present day at a desktop level for each estuary.
EcoClassification information from National Biodiversity Assessment.</td><td></td></tr>
<tr><td>4.2 Rapid</td><td>Monthly time series for natural and present day at the head of each estuary.
Information on hydrodynamics (mouth conditions and salinity distribution)
Information on water quality.</td><td></td></tr>
<tr><td>4.3 Intermediate</td><td>Calibrated monthly time series for natural and present day at the head of each estuary.
Measured river inflow at head of estuary.
Information on hydrodynamics (long-term continuous record of mouth conditions (> 5 years) and salinity profile behaviour under various flow conditions).</td><td></td></tr>
</table>

6 Ideally, the Ecological Categories should be available for each component and then an integrated component (EcoStatus) generated. However, currently these tools are not available and the focus is on the EcoStatus.
7 Note that more detail on the standardised output for each type of wetland is available in the Wetland Report (RDM/WE/00/CON/ORDM/0616).

Action	Input	Output
	Seasonal information on water quality parameters: salinity, temperature, pH, oxygen, nutrients, turbidity, toxins. Information of sediment dynamics	
4.4 Comprehensive	Calibrated monthly time series for natural and present day at the head of each estuary. Measured river inflow at head of estuary. Information on hydrodynamics (long-term continuous record of mouth conditions (> 5 years) and salinity profile under various flow conditions). Seasonal information on water quality parameters: salinity, temperature, pH, oxygen, nutrients, turbidity, toxins) collated in field surveys. Measured / modelled sediment dynamics (especially if large infrastructure development)	

7.4 STEP 3.4 GROUNDWATER

Objective: The objective is to define, in a quantitative manner, the groundwater contribution to baseflow, which is required to calculate the groundwater component of the Reserve, and its contribution to the EWR.

Table 7.5 Step 3.4 Groundwater: Standardised input and output per action (RDM/WE/00/ CON/ORDM/0916)

Action	Input	Output
1 Calculate base flow reduction, stress-index	Calibrated time series of baseflow.	Naturalised baseflow time series.
2. Generate present day base flow contribution	Groundwater abstraction SFR activities.	▪ Baseflow time series at present day use. ▪ Stress at present day use.
3. Align with EWR (base flow) to calculate groundwater component of the Reserve (and derive allocatable groundwater)	EWR low (base) flows for PES and REC.	% of time baseflow is less than EWR.

7.5 INTEGRATED STEP 3: IDENTIFIED METHODS/TOOLS

Table 7.6 lists the associated methods/tools for each action (if relevant).

The list of methodologies associated with setting of EWRs in rivers and Estuaries are provided below:

Rivers:

- Desktop level: Desktop model: DRM (Hughes and Hannart, 2003; RDRM - Hughes *et al*., 2013) Very High frequency of use.
- Rapid level: RERM (Level III) (DWAF, 1999a) Very High frequency of use.
- Intermediate level: IERM (DWAF, 1999a) Very High frequency of use.
- Comprehensive level: CERM (DWAF, 1999) Very High frequency of use.

Estuaries:

- Desktop level (2013d) – Low frequency of use (new approach recently developed)
- Rapid, Intermediate and Comprehensive levels (DWAF, 2008b) – Very High frequency of use

Table 7.6 Integrated Step 3: Identified tools

Step	Action	Method/Tool	Frequency rating
3.1: Driver information	1. Generate hydraulic information for EWR sites	HABFLOW.	Very High: Used for all EWRs Rapid II and higher since about 2007.
	2. Generate natural and present day discharge time series at nodes and EWR sites (ideally with surface-groundwater interaction)	▪ Water Resource Yield Model (WRYM). ▪ Water Resource Planning Model (WRPM). ▪ WReMP – (Water Resources Modelling Platform). **Other tools:** ▪ The Daily Dam Model (DDM) is applied to perform a daily time step spill analysis of dams. ▪ Fish River Seasonal EWR method.	▪ Very High: Used for most water resource systems in RSA. ▪ High: All large water resource systems simulated with WRYM. ▪ Low. ▪ Medium: Used in three studies. ▪ Very Low – Used in Fish River (Namibia) as part of joint SA study.
	5. Water quality: Obtain information specific to EWR sites, high priority estuaries and wetlands (where relevant)	▪ DWAF (2008c). Data collection/processing step. ▪ RapidMiner (for data quality assessment - to assist in refining the conceptual model of the catchment).	▪ Very High. ▪ High: Used only by P Wade.
3.2: BHNR	Match quaternary catchment with refined population data	GIS Based Analysis tool.	Very High – used in all studies
3.3.1: Ecological Water Requirements - Rivers	2. Apply EcoClassification (detailed approach)	▪ FRAI Ver 2.0 (Level IV EcoClassification) (Kleynhans, 2007). ▪ MIRAI Ver 2.2 (Thirion, 2007, Thirion 2016). ▪ GAI IV (2006 version - Rowntree and du Preez, 2006). ▪ GAI III (2006 version - Rowntree and du Preez, 2006). ▪ GAI (Rowntree, 2013). ▪ Potential Bed Material Transport (PBMT) (Dollar and Rowntree, 2003) ▪ (VEGRAI (IV) (Kleynhans *et al.*, 2007). ▪ VEGRAI (III) (Kleynhans et al., 2007). ▪ IHI (Kleynhans *et al.*, 2009). ▪ IHI (Kleynhans, 1996, ver2). ▪ EcoStatus model (Kleynhans and Louw, 2007). ▪ EIS (2009, site based) (DWAF, 1999a; Louw and Koekemoer (eds), 2010).	▪ Very High: Since 2004 in all EWR studies. ▪ Very High: Since 2004 in all EWR studies. ▪ High: Since 2007 in all EWR studies. ▪ Low. ▪ Very Low – update of 2006 GAI in use as the standard. ▪ Very High – used in many studies since 2002. ▪ Very High: Since 2007 in all EWR studies. ▪ High: Since 2007 largely for river health practices. ▪ Very High: In use for detail studies since 2007. ▪ Very High: Original method and now updated. ▪ Very High: Used since 2007 in all EWR studies. ▪ High: Used since 2009.

Step	Action	Method/Tool	Frequency rating
		▪ EIS (1999) (DWAF, 1999a). ▪ EIS (2014 - PESEIS) (DWS, 2014b). ▪ PAI model (Kleynhans and Louw, 2007; DWAF, 2008c). ▪ Desktop Reserve tool for water quality of rivers. ▪ Tool for Ecological Aquatic Chemical Habitat Assessment (TEACHA - Jooste, 2007). ▪ Diatom Ecological Reserve protocol (Koekemoer and Taylor, 2008), SA Diatom Assessment Protocol (DAP) (Taylor *et al*., 2007a;b) and OMNIDIA software (LeCointe *et al*., 1993).	▪ Very High: used since 1999 but now obsolete. ▪ Very high (SQ level for SA). ▪ Very High: used since 2007 for most EWR studies. ▪ High: Only used by P Wade. ▪ Very High – currently not in use due to software issues. ▪ Very High: Used since 2004 in most rivers where EWRs undertaken.
	3. Set EWRs for relevant ECs	▪ Habitat Flow Stressor Response (HFSR) (O'Keeffe *et al*., 2002; Hughes and Louw, 2010). ▪ Downstream Response to Imposed Flow Transformation (DRIFT; King *et al*., 2003). ▪ Fish Invertebrate Flow Habitat Assessment (FIFHA - part of HFSR) (Kleynhans and Thirion, 2016 in press). ▪ Fish Flow Habitat Assessment (FFHA - part of HFSR). ▪ Building Block Methodology (BBM – King and Louw, 1998). ▪ Revised Desktop Reserve Model (RDRM - Hughes *et al*., 2013). ▪ Desktop Reserve Model (DRM - Hughes and Hannart, 2003).	▪ Very High (consistently used since 2000 for most EWR studies. ▪ High (mostly used in Western Cape and Lesotho). ▪ Very Low (recently developed). ▪ High: Developed in 2009 – may be replaced by FIFHA. ▪ Very High but now obsolete. ▪ Medium: Extensively used for desktop assessments and for all studies to produce EWR rule. Currently under revision. ▪ Very High: Extensively used since development for all desktop assessments and production of EWR rule.
3.3.2: Ecological Water Requirements - Estuary	2. Apply EcoClassification	▪ Estuarine Health Index - see DWAF (2008b) (or any updates thereof). ▪ Estuarine Importance Index (DWAF, 2008b). ▪ Turpie *et al*. (2012).	Very High: Used in all Estuary EWR studies since 1999.
	4. Set EWRs (undertaken during Integrated Step 4)	▪ DRIFT (Brown *et al*., 2013; 2006; King *et al*., 2003). ▪ Method for setting EWRs described in DWAF (2008b) (or any updates thereof).	▪ Very Low: Only used on St Lucia. ▪ Very High: Used in all EWR studies apart from the above.
3.3.3: Ecological Water Requirements - Wetlands	1. Determine dominant wetland HGM type	▪ Classification system for wetlands (Ollis *et al*., 2013). ▪ Wetland types in DWAF (2007). ▪ Rountree and Batchelor (2013).	▪ Low ▪ Low ▪ Medium

Step	Action	Method/Tool	Frequency rating
	2. Determine appropriate level of RDM study for wetlands	Guideline for RDM assessment level (DWA, 2012).	Low: Few wetland Reserves have been undertaken in SA.
	3a. Validate PES of priority wetland RUs	**All wetlands:** ▪ WET-Health (MacFarlane *et al*., 2007). ▪ Water Quality: Malan *et al*. (2013), but refined in Malan and Day (2012). ▪ Wetland IHI (DWAF, 2007). ▪ Diatoms: Koekemoer and Taylor (2013). **Pans:** ▪ Invertebrates: Pan macro-invertebrate Assessment Method (Farrel, unpublished)	▪ High ▪ Low ▪ High ▪ Medium ▪ Very Low
	3b. EIS of priority wetlands	Rapid EIS method (Appendix A3 in Rountree and Kotze (2013).	High
	3c. REC of priority wetlands	REC determination guidelines - Section 4.3 in Rountree *et al.* (2013).	Low (few wetland Reserves undertaken in RSA).
	4. Determine EWR (or other RDM) to achieve REC	**Desktop Reserve Determination:** ▪ Pans - Rainfall-inundation method - Rountree (2013a). **Rapid Reserve Determination:** ▪ Pans - Rountree *et al*. (2013); Kotze and Walters (2013) and Koekemoer and Taylor (2013). ▪ Unchannelled VBs, Channelled VBs, and floodplains - Mallory (2010). ▪ Mallory (2013); Jordanova (2013); Birkhead *et al*. (2007); Kotze and Walters (2013); Koekemoer and Taylor (2013) and Rountree (2013b). **Intermediate Reserve Determination:** ▪ Channelled VB Wetlands - Mallory (2010, 2013); Jordanova (2013); Birkhead *et al*. (2007) and Kotze and Walters (2013). ▪ Seepage wetlands: Hydrus (Šimůnek *et al*., 1999); PyTOKAPI (Sinclair and Pegram, 2013) and SPRING (König, 2011). **Comprehensive Reserve Determination:** ▪ Lakes - DWAF (1999b). ▪ Floodplains - Standard river EWR approaches.	▪ Very low ▪ Medium ▪ Medium ▪ Low ▪ Low ▪ Very Low ▪ Low. Applied on five lakes associated with the Mhlathuze system. ▪ Medium – Only few large wetlands done by this method.

7.6 STAKEHOLDER INVOLVEMENT AND COMMUNICATION

Objective: Obtain stakeholder comment on the BHNR and EWRs.

Towards the end of integrated step 3 the BHNR and the EWRs would have been preliminarily quantified and stakeholder inputs would be required. Comments on the information can be obtained using a combination of the following methods:

- During a PSC meeting, (meeting 2).
- During additional meetings to obtain specific technical information (e.g. Technical Task Group - TTG).
- Notifications (of planned PSC and after the PSC to remind stakeholders of information on the DWS web site).
- Information document (compile a summary of the technical reports and distribute to stakeholders for their review).
- Minutes of PSC meeting.
- Distributions of the presentations delivered at the PSC.
- Publish information as presented on the DWS website.
- Update the CRR.

8 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.

The flow diagram illustrating the steps, sub-steps and actions for Integrated Step 4 is provided in **Figure 8.1**. Sub-steps are represented by second tier numbering e.g. Step 4.1. Note that abbreviations used are described in the acronyms and abbreviation list at the beginning of the document.

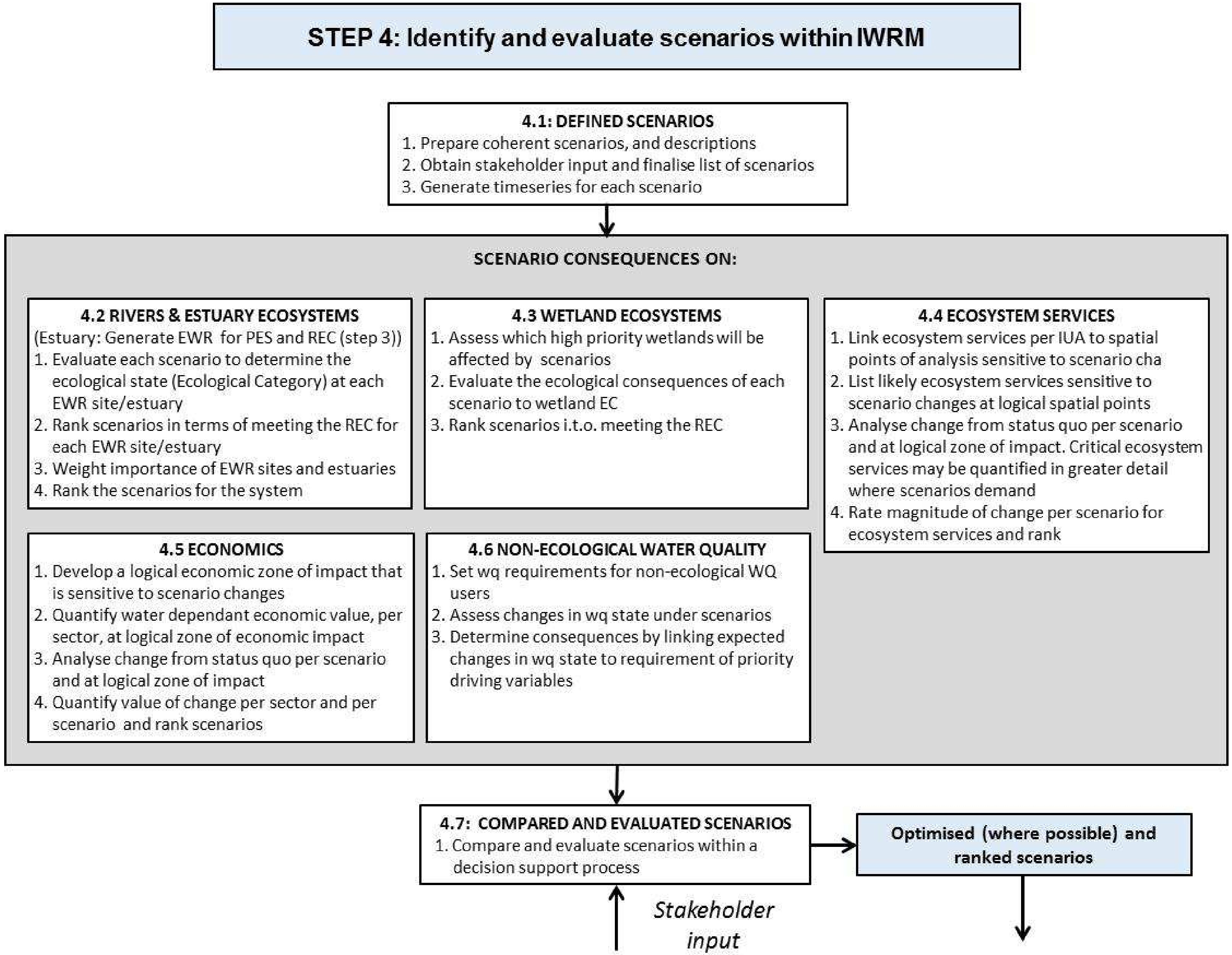

Figure 8.1 Illustration of the sub-steps for Integrated Step 4: Identify and evaluate scenarios within IWRM

8.1 STEP 4.1 DEFINED SCENARIOS

Objective: This step encompasses the identification and description of scenarios that will be evaluated to arrive at the desirable balance between the protection of the ecology and the utilisation of the water resource for socio-economic purposes.

The scenarios need to be coherent by appropriately accounting for the all relevant aspects (variables) in the catchment's water balance pertaining to each scenarios narrative.

Definition: Scenarios, in the context of water resource management and planning are plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in a catchment and the system as a whole.

The scenario narrative definitions are tested with stakeholders to ensure that a complete list of scenarios has been identified. Then the scenario narrative definitions are interpreted and applied to provide alternative hydrological flow time series for river reaches at relevant bio-physical nodes using water resource modelling tools. The modelling results are the base information used for quantifying the ecological and socio-economic consequences (implications) of each of the identified scenarios.

Table 8.1 Step 4.1 Defined scenarios: Standardised input and output per action

Action	Input	Output
Surface water (RDM/WE/00/CON/ORDM/0916)		
1. Prepare coherent scenarios, and descriptions	Water resource planning information and strategies.	Narrative descriptions and tubular scenario variable matrix.
3. Generate time series for each scenario		Monthly simulated flow time series for all relevant nodes affected by scenarios.
		Water availability (yield) information.
		Simulated water quality time series of the variables of concern.

8.2 STEP 4.2 RIVERS AND ESTUARIES ECOSYSTEMS

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

The process to determine EWRs for estuaries require that operational scenarios are identified and evaluated to determine the resulting EC during Integrated Step 4. The results are then compared to the present to determine the REC (Integrated Step 3) and the EWR (Integrated Step 4) in an iterative process. The step is therefore provided in brackets in the flow diagram. The detail is summarised in Step 3.3.2 (**Table 7.3**), but included here as a reminder that, for estuaries, this is one process.

Table 8.2 Step 4.2 Rivers and Estuaries ecosystems: Standardised input and output per action

Action	Input	Output
Rivers (RDM/WE/00/CON/ORDM/0516)		
1. Evaluate each scenario to determine the ecological state (Ecological Category) at each EWR site/estuary	▪ Monthly time series and flow duration tables. ▪ Daily data, Daily spill analysis (currently not readily available.	Impact on EC.
2. Rank scenarios in terms of meeting the REC for each EWR site/estuary		Ranked scenario for each EWR site.
3. Weight importance of EWR sites and estuaries	REC information.	Weight per EWR site.
4.Rank the scenarios for the system		Ranked scenarios for the system.
Water quality (RDM/WE/00/CON/ORDM/0816)		
1. Evaluate each scenario to determine the ecological state (Ecological Category) at each EWR site/estuary	▪ Monthly time series and flow duration tables (rivers). ▪ Daily data, Daily spill analysis.	Water quality category under each scenario, and associated PAI assessment (rivers).
	Processed water quality data (from Step 3) (rivers).	Associated confidences (output of regression and of integrated category/result).
Estuaries (RDM/WE/00/CON/ORDM/0716)		
1. Evaluate each scenario to determine the ecological state (Ecological Category) at each EWR site/estuary	Simulated monthly time series - Operational scenarios.	Abiotic state distribution for reference and present as per DWAF (2008a).
		Health scores for abiotic and biotic components combined into overall Operational Scenario scores for each estuary.
2. Rank scenarios in terms of meeting the REC for each EWR site/estuary		Relative rating per scenario.
3. Weight importance of EWR sites and estuaries	▪ Estuary size. ▪ Biodiversity Importance. ▪ Ecosystem services (nursery function). ▪ Connectivity (distance to nearest system/distance to next similar type system/temporal aspect mouth state).	Relative importance weight.
4.Rank the scenarios for the system		Relative ranking

8.3 STEP 4.3 WETLAND ECOSYSTEMS

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

Table 8.3 Step 4.3 Wetland ecosystems: Standardised input and output per action (RDM/WE/00/CON/ORDM/0616)

Action	Input	Output
1. Assess which high priority wetlands will be affected by scenarios		Subset of priority wetlands that may be impacted by scenario/s.
2. Evaluate the ecological consequences of each scenario to wetland EC	Wetland PES.	EC of priority wetland RUs under scenarios.
3. Rank scenarios in terms of meeting the REC	Wetland EC response to scenarios.	Scenarios ranked in terms of their ability to meet the REC (at each wetland and overall).

8.4 STEP 4.4 ECOSYSTEM SERVICES

Objective: The evaluation is undertaken to determine the consequences of operational scenarios on the current state of the Ecosystem Services.

Table 8.4 Step 4.4 Ecosystem Services: Standardised input and output per action (RDM/WE/00/CON/ORDM/1016)

Action	Output
1. Link ecosystem services per IUA to spatial points of analysis sensitive to scenario change	Narrative description of scenarios as they potentially relate to ecosystem services.
2. List likely ecosystem services sensitive to scenario changes at logical spatial points	Comprehensive and cohesive list of ecosystem services at points under consideration (EWR sites) with attention paid to those likely to change under mooted scenarios.
3. Analyse change from status quo per scenario and at logical zone of impact. Critical ecosystem services may be quantified in greater detail where scenarios demand	Populated spreadsheet/table with analysis of changes to key ecosystem services per scenario with narrative description of reasons for change.
4. Rate magnitude of change per scenario for ecosystem services and rank	Table that summarises the magnitude of change per scenario with narrative summary of reasons for change.

8.5 STEP 4.5 ECONOMICS

Objective: The response of the economic activities that rely on the water resource used in and from the catchments is estimated in this step for each identified scenario. Since the aim with the evaluation of scenarios is to draw comparisons, it is advisable to select appropriate economic parameters for numerical quantification that are relevant to the area and the defined scenarios. The focus of the economic analyses should be on estimating the relative economic changes (differences) that will be caused by the identified scenarios.

Table 8.5 Step 4.5 Economics: Standardised input and output per action (RDM/WE/00/CON/ORDM/1016)

Action	Output
1 Develop a logical economic zone of impact that is sensitive to scenario changes	Zone of economic input that is sensitive to change under possible scenarios.
2. Quantify water dependant economic value, per sector, at logical zone of economic impact	Quantified GVA value and employment per economic sector and per component of sector per zone.
3. Analyse change from status quo per scenario and at logical zone of impact	Analysis of impact model expressed as a change in GVA and employment.
4. Quantify value of change per sector and per scenario and rank scenarios	Quantified impact of scenarios per zone as output of macro-economic impact mode.

8.6 STEP 4.6 NON-ECOLOGICAL WATER QUALITY

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

Table 8.6 Step 4.6 Non-Ecological Water Quality: Standardised input and output per action (RDM/WE/00/CON/ORDM/0816)

Action	Input	Output
1. Set WQ requirements for non-ecological WQ users	Water quality guidelines for all users (e.g. DWAF, 1996a-c; DEA, 2012) or specifications obtained from actual users based on their process requirements.	List of water quality requirements for defined users.
3. Determine consequences by linking expected changes in WQ state to requirement of priority driving variables	Select strictest user requirements.	**Rivers:** Probability of exceedence of fitness for use for the driving user (and variable). **Estuaries:** Compliance/non-compliance of various scenarios for each estuary as it relates to water quality requirements of users/uses.

8.7 STEP 4.7 COMPARE AND EVALUATE SCENARIOS

Objective: The objective of this step is to carry out a systematic process of evaluating and comparing the identified scenarios and apply a form of decision support analysis to assist with the selection of the proposed Water Resource Classes. The activities of this decision support process are broadly twofold, firstly, an analytical approach is undertaken for comparing and ranking scenarios preferably by means of a set of quantitative metrics. Secondly, stakeholders are engaged to seek their views and preferences as to what Class would constitute as an appropriate balance between the protection and use for the water resources in question. Ultimately the full package of information (from the decision support process and all the other steps' outputs) is considered by the designated person(s) of the DWS as the delegated authority to set the Water Resource Class.

Table 8.7 Step 4.7 Compare and evaluate scenarios: Standardised input and output per action (RDM/WE/00/CON/ORDM/0916)

Action	Input	Output
1. Compare and evaluate scenarios within a decision support process	Coherent sets of quantitative results for each scenario, including: ▪ Consequence ratings of all bio-physical nodes ▪ Set of relative importance weights for the bio-physical nodes. ▪ Socio-Economic metric. ▪ Importance weights for each of the main comparison variables.	Individual variable and integrated rating of scenarios for comparison, ranking and selection of preferred (best) scenario.

8.8 INTEGRATED STEP 4: IDENTIFIED METHODS/TOOLS

Table 8.8 lists the associated methods/tools for each action (if relevant).

Table 8.8 Integrated Step 4: Identified tools

Step	Action	Method/Tool	Frequency rating
4.2: Rivers	1. Evaluate each scenario to determine the ecological state (Ecological Category) at each EWR site	▪ Scenario comparison Method (ScenComp - refer to RDM/WE/00/CON/ORDM/0916) ▪ Regression technique for linking variables and flow time series (Examples: flow-concentration regression model (Malan *et al*., 2003). ▪ TDS module of the Planning Model (practitioners for Reserve studies: Coleman; van Rooyen).	▪ High ▪ Medium ▪ Medium (four large systems)
	2. Rank scenarios in terms of meeting the REC for each EWR site. 3. Weight importance of EWR sites and estuaries. 4. Rank the scenarios for the system.	River Scenario evaluation ranking method (DWS, 2014d).	Very High: Qualitative approach since 2001 and quantitative approach developed for recent four classification studies and Comprehensive Reserve study.
4.2: Estuaries	1. Evaluate each scenario to determine the ecological state (EC) at each EWR site/estuary	DWAF (2008b) (or any updates thereof).	Very High. All studies since 1999.
	2. Rank scenarios in terms of meeting the REC for each EWR site/estuary. 3. Weight importance of EWR sites and estuaries 4. Rank the scenarios for the system	Method for ranking scenarios in terms of meeting the REC for each estuary, weighing and ranking is described in DWS (2015b).	Low. Developed for WMA 11 Classification study.
4.4: Ecosystem Services	3. Analyse change from status quo per scenario and at logical zone of impact. Critical ecosystem services may be quantified in greater detail where scenarios demand	Ecosystem Services Magnitude of Change per Scenario tool.	Medium.
4.5: Economics	2. Quantify water dependant economic value, per sector, at logical zone of economic impact 3. Analyse change from status quo per scenario and at logical zone of impact	Social Accounting Matrix based Econometric Impact tool.	Very High: Used in most studies during the last 15 years.
4.6: Non-Ecological water quality	1. Set WQ requirements for non-ecological WQ users	Resource Unit Evaluation spreadsheet.	Medium (three Classification Studies).
	3. Determine consequences by linking expected changes in WQ state to requirement of	User water quality consequences protocol: Rivers (DWA, 2014; DWS, 2014e; DWS, 2015c).	Medium (three Classification Studies).

Step	Action	Method/Tool	Frequency rating
	priority driving variables		
4.7: Compare and evaluate scenarios	1. Compare and evaluate scenarios within a decision support process	▪ Multi Criteria Decision Analysis. ▪ WRC determination tool.	▪ Medium: No tool existed. Tool developed and used in three large Classification studies.

8.9 STAKEHOLDER INVOLVEMENT AND COMMUNICATION

Objective: Obtain stakeholder comments on the draft identified scenarios.

Towards the end of Integrated Step 4 stakeholder inputs would be required on the following:

- The current status of the water resource (situation assessment), future possible management and development scenarios for the water resource.
- Expected impact of these scenarios.
- Establish what desired level resource protection stakeholders want to choose.

Comments on the information can be obtained using a combination of the following methods:

- During a PSC meeting, (meeting 3).
- During additional meetings to obtain specific technical information (e.g. Technical Task Group (TTG)).
- Notifications (of planned PSC and after the PSC to remind stakeholders of information on the DWS web site).
- Information document (compile a summary of the technical reports and distribute to stakeholders for their review.
- Minutes of PSC meeting.
- Distributions of the presentations delivered at the PSC.
- Publish information as presented on the DWS website.
- Update the CRR.

9 STEP 5: DETERMINE WATER RESOURCE CLASSES BASED ON CATCHMENT CONFIGURATIONS FOR THE IDENTIFIED SCENARIO

Objective: The objective of this step is to:

- Integrate the consequences to provide the resulting classes of each scenario, as well as Classes for the PES, REC and TEC for stakeholder evaluation during the next step; and
- with stakeholder input, arrive at Classes and the catchment configuration that will be available for the preparation of the legal notice.

Note that the PES, REC, TEC and operational scenarios all form part of the suite of identified scenarios that are evaluated.

The most important part of Integrated Step 5 is the determination of the Classes for each IUA under different operational scenarios as well for different ecological states at various biophysical nodes. An analysis is undertaken to determine the best balanced option between protection and use for each IUA and the biophysical nodes in the IUA (referred to as the Catchment Configuration). The implications of not meeting the ecological objectives represented by the REC are identified and the best balanced option, the TEC is selected with appropriate motivations.

After input from both internal and external stakeholders, as well as liaison with relevant government institutions that play a role in IWRM or who are affected, recommendations for the legal notice are made.

TEC definition:

Information Block:
Target Ecological Category (TEC)

The TEC is the resulting Ecological Category based on the Class. One will always strive to meet the REC, however once the balance between use and protection is considered, the TEC may be the PES, the REC or any other category.

The flow diagram illustrating the steps, sub-steps and actions for Integrated Step 5 is provided in **Figure 9.1**. Sub-steps are represented by second tier numbering e.g. Step 5.1. Note that abbreviations used are described in the acronyms and abbreviation list at the beginning of the document.

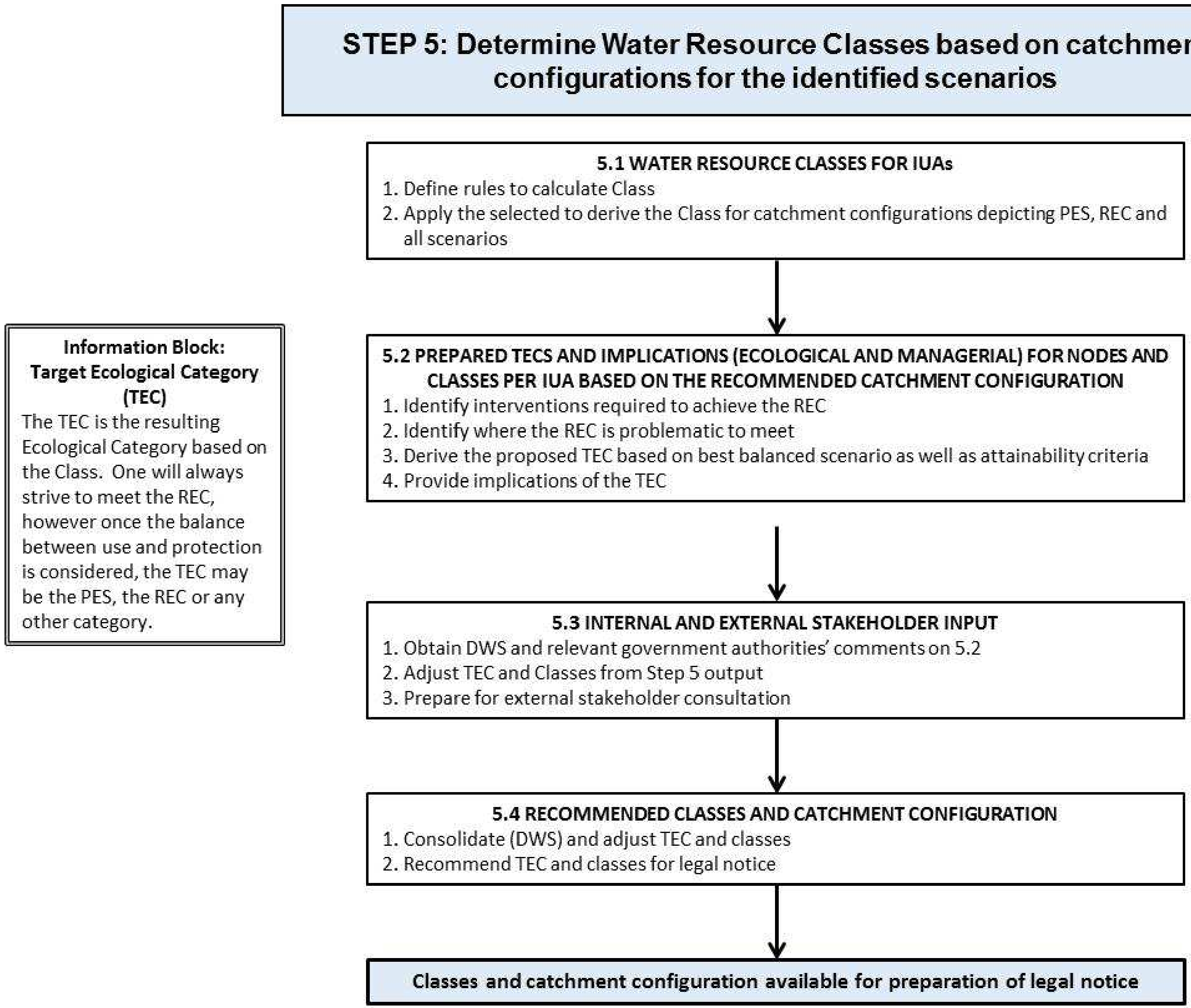

Figure 9.1 Illustration of the sub-steps for Integrated Step 5: Determine Water Resource Classes based on catchment configurations for the identified scenarios

Table 9.1 to 9.3 provides a summary of the standardised input and output per sub-step according to relevant actions.

Table 9.1 Step 5.1 Derive Water Resource Classes for IUAs: Standardised input and output per action

Action	Input	Output
Surface water (RDM/WE/00/CON/ORDM/0916)		
1. Define rules to calculate Class		Rules to calculate the Class.
2. Apply the selected rule to derive the Class associated with the PES, REC and all scenarios		Class for the various scenarios for each IUA.

Table 9.2 Step 5.2 Prepared TECs and implications (ecological and managerial) for nodes and classes per IUA based on the recommended catchment configuration

Action	Input	Output
Surface water (RDM/WE/00/CON/ORDM/0916)		
1. Identify interventions required to achieve the REC 2. Identify where the REC is problematic to meet		REC and actions required to meet REC for each SQ.
3. Derive the proposed TEC based on best balanced scenario as well as attainability criteria 4. Provide implications of the TEC		TEC for each RU and implications.
Estuaries (RDM/WE/00/CON/ORDM/0716)		
3. Derive the proposed TEC based on best balanced scenario as well as attainability criteria	DAFF critical nursery layer for exploited species.	Set the Estuary TECs.
	Estuary Management Plans (EMPs) ecological objectives (if available.	
	Transitional waters Requirements.	

9.1 STAKEHOLDER INVOLVEMENT AND COMMUNICATION

Objective: Obtain stakeholder comment on the consequences of scenarios, catchment visioning and the determination of the draft Water Resource Classes.

Towards the end of Integrated Step 5, the consequences of scenarios will be shared with stakeholders and co-operation from them will be required to do visioning of the catchment/s towards the determination of draft Water Resource Classes.

Comments on the information can be obtained using a combination of the following methods:

- During a PSC meeting, (meeting 4).
- During additional meetings to obtain specific technical information (e.g. TTG).
- Notifications (of planned PSC and after the PSC to remind stakeholders of information on the DWS web site).

- Information document (compile a summary of the technical reports and distribute to stakeholders for their review).
- Minutes of PSC meeting.
- Distributions of the presentations delivered at the PSC.
- Publish information as presented on the DWS website,
- Update the CRR.

10 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.

The flow diagram illustrating the steps, sub-steps and actions for Integrated Step 6 is provided in **Figure 10.1**. Sub-steps are represented by second tier numbering e.g. Step 6.1. Note that abbreviations used are described in the acronyms and abbreviation list at the beginning of the document.

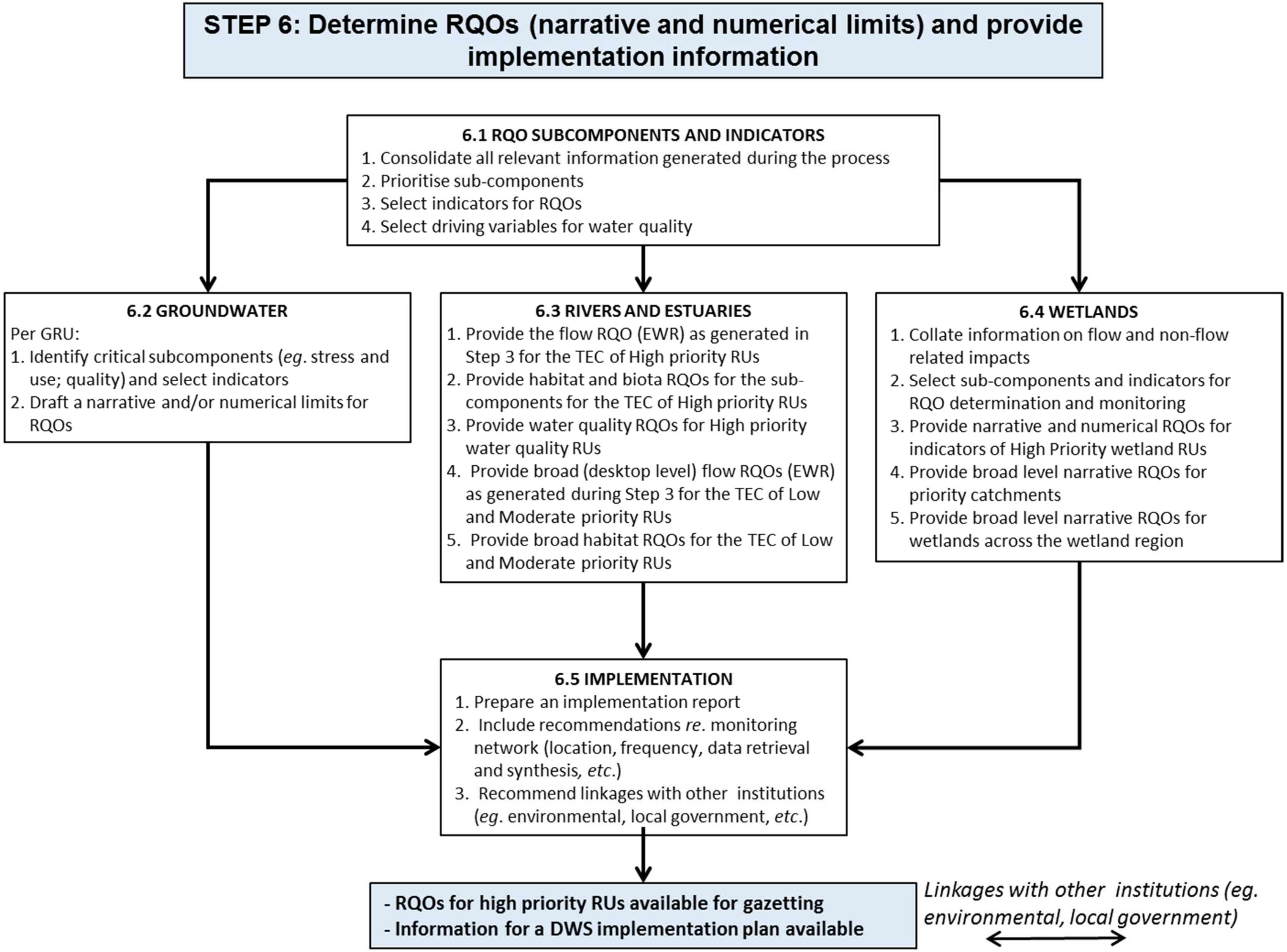

Figure 10.1 Illustration of the sub-steps for Integrated Step 6: Determine RQOs (narrative and numerical limits) and provide implementation information.

10.1 STEP 6.1 RQO SUB-COMPONENTS AND INDICATORS

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

10.2 STEP 6.2 GROUNDWATER

Objective: Identify critical subcomponents (e.g. stress and use; quality) and select indicators and draft a narrative and/or numerical limits for RQOs.

Table 10.1 Step 6.2 Groundwater: Standardised input and output per action (RDM/WE/00/CON/ORDM/0916)

Action	Input	Output
1. Identify critical subcomponents (e.g. stress and use; quality) and select indicators	Water use and recharge.	Threshold.
	Baseflow reduction.	Threshold.
	Water quality time series.	Threshold.
	Water levels time series.	Narrative output.
	Water level time series.	Thresholds for water level trends.
	Aquifer parameters.	Distance from a river at which to control abstraction.
2. Draft a narrative and/or numerical limits for RQOs		Simple and measureable RQOs.

10.3 STEP 6.3 RIVERS AND ESTUARIES

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

Table 10.2 Step 6.3 Rivers and Estuaries: Standardised input and output per action

Action	Input	Output
Rivers (RDM/WE/00/CON/ORDM/0516)		
1. Provide the flow RQO (EWR) as generated in Step 3 for the TEC of High priority RUs	EWR or yield model time series and flow duration table.	Numerical hydrology (EWR) RQO (time series and flow duration table).
2. Provide habitat and biota RQOs for the sub-components for the TEC of High priority RUs	TEC, EcoStatus models.	Fish, Riparian veg, Geomorphology, Water Quality, IHI, Invertebrate numerical RQOs that can be monitored.
4. Provide broad (desktop level) flow RQOs (EWR) as generated during Step 3 for the TEC of Low and Moderate priority RUs	EWR or yield model time series and flow duration table.	Numerical hydrology (EWR) RQOs (time series and flow duration table).
5. Provide broad habitat RQOs for the TEC of Low and Moderate priority RUs	TEC, PESEIS.	Broad qualitative habitat RQOs.
Water quality (RDM/WE/00/CON/ORDM/0816)		
Sub-steps/actions 2, 3 and 5: Water quality RQOs - EWR sites, sites where water		Narrative and numerical (measurable) objectives for diving variables.

Action	Input	Output
quality is identified as part of Moderate priority RUs and High priority water quality RUs		
Estuaries (RDM/WE/00/CON/ORDM/0716)		
1. Provide the flow RQO (EWR) as generated in Integrated Step 3 for the TEC of High priority RUs	Time series data (PES, Operational scenarios).	Defined EWR[8].
2. Provide habitat (including instream estuary water quality) and biota RQOs for the sub-components for the TEC of High priority RU		Numerical or narrative description of what the individual component TEC entails.
3. Provide water quality RQOs for other uses and high priority water quality RUs including the river upstream of the estuary		Numerical or narrative description of what the individual component TEC entails.
4. Provide broad (desktop level) flow RQOs (EWR) as generated during Step 3 for the TEC of Low and Moderate priority RUs		Narrative description of important flow parameters.
5. Provide broad habitat (Including instream estuary water quality) and biota RQOs (including water quality in estuary) for the TEC of Low and Moderate priority RUs		Broad qualitative habitat RQOs.

10.4 STEP 6.4 WETLANDS

Objective: 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.

Table 10.3 Step 6.4 Wetlands: Standardised input and output per action (RDM/WE/00/CON/ORDM/0616)

Action	Input	Output
1. Collate flow and non-flow related impacts		Key drivers of PES and threats for each prioritised catchment or wetland RU.
2. Select sub-components and indicators for RQO determination and monitoring	TEC for wetland RUs or catchments.	List of relevant sub-components and associated indicators for priority catchments and wetland RUs.

[8] It must be noted that currently the estuary process, being scenario based, does not set an EWR that consists only of flows required for the estuary. Currently the estuary EWR is representative of an operational flow scenario that meets the required EC. Further work on method development will be required to streamline the RQO hydrology output as well as to explicitly address the links between the river and estuary EWR.

Action	Input	Output
3. Provide narrative and numerical RQOs for High priority wetlands	TEC, key drivers of PES and threats for each prioritised wetland and data from EcoStatus assessments.	List of narrative and numerical RQOs for high priority wetlands.
4. Provide broad level narrative RQOs for priority catchments	Key drivers of PES and threats for each prioritized catchment.	List of narrative RQOs for high priority catchments.
5. Provide broad level narrative RQOS for wetland regions	Key threats to wetland condition.	List of narrative RQOs for wetland regions.
Water Quality (RDM/WE/00/CON/ORDM/0816)		
Provide Water Quality RQOs for the TEC of high priority wetlands	Key drivers of PES and threats for each prioritised wetland; data from EcoStatus assessments.	Numerical (where possible) and narrative RQOs for water quality.

10.5 STEP 6.5 IMPLEMENTATION

Objectives: The rollout actions needed to implement the Water Resource Class and RQOs should be defined and described 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 of 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.

Table 10.4 Step 6.5 Implementation: Standardised input and output per action

Action	Input	Output
Water resources (RDM/WE/00/CON/ORDM/0916)		
1. Prepare an implementation report		Define all processes within the Action>Monitor>Adaptation circular implementation framework.
2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)		▪ Describe existing monitor network. ▪ Present study area specific processes for monitoring. ▪ Prepare timeline programme of implementation activities.
3. Recommend linkages with other institutions (e.g. environmental, local government)		▪ Define the need for institutional business plans to incorporated requirements from RDM. ▪ Identify the institutional linkages and key liaison requirements.
Water quality (RDM/WE/00/CON/ORDM/0816)		
2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Standardised input according to DWS standards from existing monitoring networks.	Identify monitoring points for RQOs.
Rivers (RDM/WE/00/CON/ORDM/0516)		
2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Standardised input according to DWS standards.	Completed REMP.
Estuaries (RDM/WE/00/CON/ORDM/0716)		
2. Include recommendations	RQOs, DWAF (2008b).	Estuary Monitoring Programme that aligns

Action	Input	Output
regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)		the requirements of the various mandates of DWS, Department of Africulture, Fisheries and Forestry (DAFF) and Department of Environmental Affairs (DEA).
3. Recommend linkages with other institutions (e.g. environmental, local government, etc.)	TEC, Identified interventions, RQOs and monitoring plans.	List of actions for inclusion in the Estuarine Management Planning and implementation process under the Integrated Coastal Management Act (implemented by Provincial/Local Coastal Committees).
		Working Group 8 to facilitate inter-departmental collaboration (e.g. WWTW).
		Liaise with DEA (pollution), municipalities/industry on waste water discharge permits under the ICM Act.
		Engage with DAFF regarding Fisheries Management Protocols.
		Liaise with SANBI regarding relevant conservation targets.
Wetlands (RDM/WE/00/CON/ORDM/0616)		
2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Measurable management goals.	Wetland monitoring programme.

10.6 INTEGRATED STEP 6: IDENTIFIED METHODS/TOOLS

Table 10.5 lists the associated methods/tools for each action (if relevant).

Table 10.5 Integrated Step 6: Identified tools

Step	Action	Method/Tool	Frequency rating
6.1: RQO sub-components and indicators	4. Select driving variables for water quality	▪ User water quality protocol: Rivers. ▪ Resource Unit Evaluation Spreadsheet: Rivers.	See **Table 6.7**
6.3: Rivers	2. Provide habitat and biota RQOs for the sub-components for the TEC of High priority RUs	FRAI, MIRAI, IHI, VEGRAI, GAI analysed data for the TEC.	See **Table 6.7**
	4. Provide broad (desktop level) flow RQOs (EWR) as generated during Step 3 for the TEC of Low and Moderate priority RUs	RDRM or DRM.	See **Table 6.7**
6.3: Estuaries	1. Provide the flow RQO (EWR) as generated in Integrated Step 3 for the TEC of High priority RUs	WRYM and WRPM tools.	See **Table 6.7**
	2. Provide habitat (including instream estuary water quality) and biota RQOs for the sub-components for the TEC of High priority RUs 3.Provide water quality RQOs for other uses and high priority water quality RUs including the river upstream of the estuary	For guidance on RQOs see DWAF (2008b).	See **Table 8.8**
	Actions 2, 3 and 5: Water quality RQOs - EWR sites, sites where water quality is identified as part of Moderate priority RUs and High priority	▪ Ecotoxicological approach to setting RQOs. ▪ Resource Water Quality Objectives Model (RWQO)	▪ Medium: Vaal and Olifants Rivers ▪ Medium (output for the

Step	Action	Method/Tool	Frequency rating
	water quality RUs	approach (dashboard) (for non-ecological users): Rivers.	production of RQOs. Very high (by WQ Planning for production of RWQOs).
6.4: Wetlands	Provide Water Quality RQOs for the TEC of high priority wetlands	Resource Unit Evaluation Tool - wetland module.	Low.
6.5: Rivers	2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Rapid Habitat Assessment Method (RHAM – DWAF, 2009b).	High (used in more recent EWR studies).
6.5: Estuaries	2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	Determining estuary monitoring requirements (DWAF, 2008b).	Very High (in use since 1999).
	3. Recommend linkages with other institutions (e.g. environmental, local government, etc.)	Guidelines for the Development and Implementation of EMPs in terms of the National Estuarine Management Protocol (DEA, 2014).	Very High
6.5: Wetlands	2. Include recommendations regarding monitoring network (location, frequency, data retrieval and synthesis, etc.)	WRC project K5/2547 (in progress).	Development still taking place.

10.7 STAKEHOLDER INVOLVEMENT AND COMMUNICATION

Objective: Obtain stakeholder comment on the RQOs.

Towards the end of Integrated Step 6, comments on the draft Water Resource Classes and RQOs would be required from stakeholders.

Comments on the information can be obtained using a combination of the following methods:

- During a PSC meeting, (meeting 5).
- During additional meetings to obtain specific technical information (e.g. TTG).
- A public meeting.
- Notifications (of planned PSC and or public meeting and after the PSC and or public meeting to remind stakeholders of information on the DWS web site).
- Information document (compile a summary of the technical reports and distribute to stakeholders for their review).
- Minutes of PSC and or public meeting.
- Distributions of the presentations delivered at the PSC and or public meeting.
- Publish information as presented on the DWS website,
- Update the CRR.

11 STEP 7 AND 8: GAZETTE WATER RESOURCE CLASSES, RQOs AND THEN THE RESERVE

The details of gazetting and requirements are still being established.

Stakeholder involvement during the gazetting process is a legal requirement as per the legislation. The legislated process involves the publishing of a notice that provides access to the information to be gazetted and a 60-day public commenting period. Comments received are captured in the comment and Responses Register. Comments are considered and the final product (Water resources classes and the RQOs) is gazetted for public information.

12 RDM COMMUNICATIONS FRAMEWORK

12.1 PURPOSE OF COMMUNICATIONS FRAMEWORK

The purpose of the Communications Framework for RDM is to provide a guide that formulates the liaison and information exchange requirements in support of various RDM processes. Operational liaison is required between CD:WE and the Provincial Offices or proto-Catchment Management Agencies (CMAs)), CMAs and the following DWS components:

- Chief Directorate Water Resource Planning (CD:WRP).
- Chief Directorate Water Information and Management (CD:WIM) which includes the Directorate: Resource Quality Information Services (D:RQIS).
- Chief Directorate: Water Use Authorisation.

Objectives:

- ToR objective narrative: "Define roles and responsibilities between Chief Director: Water Ecosystems at DWS Head Office and the DWS Regional Office (through the development of the RDM Communications Framework)."
- Identify the communication needs as it relates to the roles and responsibilities of CD:WE and the above listed DWS components.
- List and describe the current and proposed liaison (communication) events.
- Highlight what the role of the Decision Support System (DSS), currently being developed (DWS, 2016), will be in fulfilling future communication needs.
- Make recommendations on how communication can be improved.

12.2 COMMUNICATIONS FRAMEWORK

Given that the RDM processes reside within the broader umbrella of Integrated Water Resource Management, the operationalisation of RDM requires collaboration, engagement (liaison) as well as exchange of information with other DWS components tasked with water resource management, planning, licencing and information services functions.

While the technical data requirements and information flow between the steps and sub-steps are presented in the other frameworks listed in **Section 1.2**, the broader communication needs of RDM is schematically depicted in **Figure 12.1** and described below. (This document should be read in conjunction with the other framework reports.)

The shaded boxes in **Figure 12.1** represent the relevant DWS components requiring communication, collaboration and information exchange with the Chief Directorate Resource Directed Measures: indicated at the top of the diagram. The arrows illustrate the direction of information flow between CD: WE and each of the shown DWS components. **Upward pointing arrows indicate information needed by RDM while downward pointing arrows are the products from RDM determination processes used by others**. The bidirectional arrows illustrate that the information to be exchanged originates from the other DWS component and is revised during the RDM determination work.

It should be noted that the information exchange elements (contained in the dashed box) are the primary items among other supportive data, models and information required for coherent management of the water resource. Essentially the exhaustive information exchange list is different for each study and depends on what previous investigations were carried out as well as the resolution and intensity thereof.

A brief explanation of the information elements listed in the dashed block of **Figure 12.1** is provided below:

Information exchange elements:	**Description:**
Area specific information	Considering the wealth of information generated by the CMA and Provincial Offices under their mandate, this information refers to all the data, models, reports describing the physical, temporal and geographical configuration of the water resource required for RDM determination work.
Stakeholder database	As part of the functioning of the CMA and Provincial Offices, various stakeholder liaison is taking place with a variety of interests relating to the protection and use of the water resource. This database of the officials (names and contact details) as well as their institutions should form the basis for the formation of the Project Steering Committee related to RDM determination studies.
Water Resource Classes	The primary product from the Water Resource Classification RDM activity is the Water Resource Class (I, II or II) for each of the Integrated Units of Analysis that were identified and agreed on in a particular catchment and study area. These Water Resource Classes need to be incorporated in the Catchment Management Strategies as the primary indicator of the degree of protection and use of the resource.
RQOs	The Resource Quality Objectives are the detailed information needed to give effect to the water resource class in general but also provide specific requirements for protection objective (ecological specifications) for each of the selected significant water resources. The RQOs should become part of the operational management of the water resource and serve as the target against which the ecological health of the resource is monitored, adaptive measures are recommended and implemented as an integral part of the ongoing management of the water resource.
RWQOs	Resource Water Quality Objectives refers to the water quality objectives as determined by the D: Water Quality Planning for National water resource planning purposes. In this context it is inclusive of the user water quality and quantity requirements from the water resource. Any information from investigations that were carried out by the Water Quality Planning component is required as source information for RDM determination work. Once the ecological and water user water requirements have been integrated the more stringent requirement should become the target for use in monitoring and management activities.
Use	Use is inclusive of all information (data, models and methods) applied in Water Resource Planning investigations that relates

Information exchange elements:	Description:
	to all water use (abstraction, discharge and storage) taking place in the catchment or study area.
Availability and hydrology	With “Availability”, what is meant is all information (data and models) that were applied for hydrological and system analyses studies in the water resource system in question. RDM processes mostly rely on the availability of this information from previous investigations that were carried out by the Water Resource Planning component.
EWR flow (hydrology data)	The flow definition of the determined Ecological Water Requirements at the selected driver nodes in a river system is the primary information that the Water Resource Planning component requires to undertake further planning investigations.
Ecological data	Ecological data from CD: WIM obtained from past studies is a valuable source of information for RDM processes.
WQ Data (WMS)	The comprehensive water quality database that is maintained by D:RQIS form the core dataset to apply in RDM determinations.
Methods	Considering that D:RQIS has the mandate to evaluate, develop and propose alternative methods for reserve determination, new methods need to be evaluated by RDM for possible application in the execution of RDM determination work. Other institutions may also recommend new methods given sound scientific backing and motivation.
PES/EIS Database*, and Water Resource Classes & RQOs*	The PES/EIS database originated from studies undertaken by D:RQIS and CD:WE. The initial database is used and updated as information became available through other RDM studies at a higher confidence level. The CD: WIM is responsible with the writing of the National State of Water Report, which requires sourcing of Water Resource Classes, Reserve and RQOs information.
WQ Discharge Standards	This is the prevailing discharge standards being applied for discharge Water Use Licences (WUL) and are being regulated by the Directorate: Resource Protection and Waste in the department. These requirements /conditions are essential input to the RDM processes to assess (understand) the cumulating effect of individual discharges on the water resource. The latter is normally expressed as part of current and future operational scenario (development). It forms part of RDM determinations through the ecological consequence evaluations, determination of the REC/TEC and setting

Information exchange elements:	Description:
	ecological specification which the WQ standards must meet.
Water Allocations	The schedule of water allocations in a water resource system is required in the assessment of the ecological implications through the scenario evaluations undertaken in the RDM determination works.
Reserve	The RDM determination process provides the required Reserve data and information that should accompany the documentation required for section 21 of water use licences.
Gazette: ▪ Preparation ▪ Vetting ▪ Recommendations by State Law Advisor	Communication requirements with the Chief Directorate Legal Services (CD:LS) and the State Law Advisor (SLA) involves: (a) submission of the prepared legal notice by CD:WE to CD: LS, (b) the CD:LS undertake the Vetting thereof and incorporate any recommendation from the State Law Advisor. (This element represents communication requirements for Step 7 and 8)

The above described framework focusses on the elements illustrated in **Figure 12.1** as the core communication requirements of RDM. Inevitably there are other communication channels, such as direct communication among the listed DWS components as well as liaison with all three tiers of government, local, provincial and national departments involved in water resource management. These external links need to be recognised in the RDM processes as and when required.

The form in which communication and information exchange takes place (method) is usually through direct person-to-person engagement, electronic methods (e-mail and the intranet) as well as dedicated scheduled meetings or standing coordination events.

One of the key success factors that have achieved high levels of integration and collaborations (a primary objective of Integrated Water Resource Management) in DWS's operational methods is the cooperation though cross attendance of PMC and Project Steering Committee meetings that consists of officials from different DWS components.

The interactions at these events provide theme focused engagements while allowing critical system wide interdependencies to be identified and addressed though timeous information sharing, data exchanges or appropriate collaborating management actions. The benefits of this cooperation go further than merely identifying and avoiding pitfalls; it also provides for the identification of cross cutting opportunities that if implemented provides immediate and long term benefits due to improved efficiencies gained by "at-the-right-time adjustments" to the prevailing workflow activities.

In lieu of the above, the communication events as currently being practiced, as well as the recommended additional liaison activities, are presented in the *RDM Communications Framework Report* (RDM/WE/00/CON/ORDM/1216).

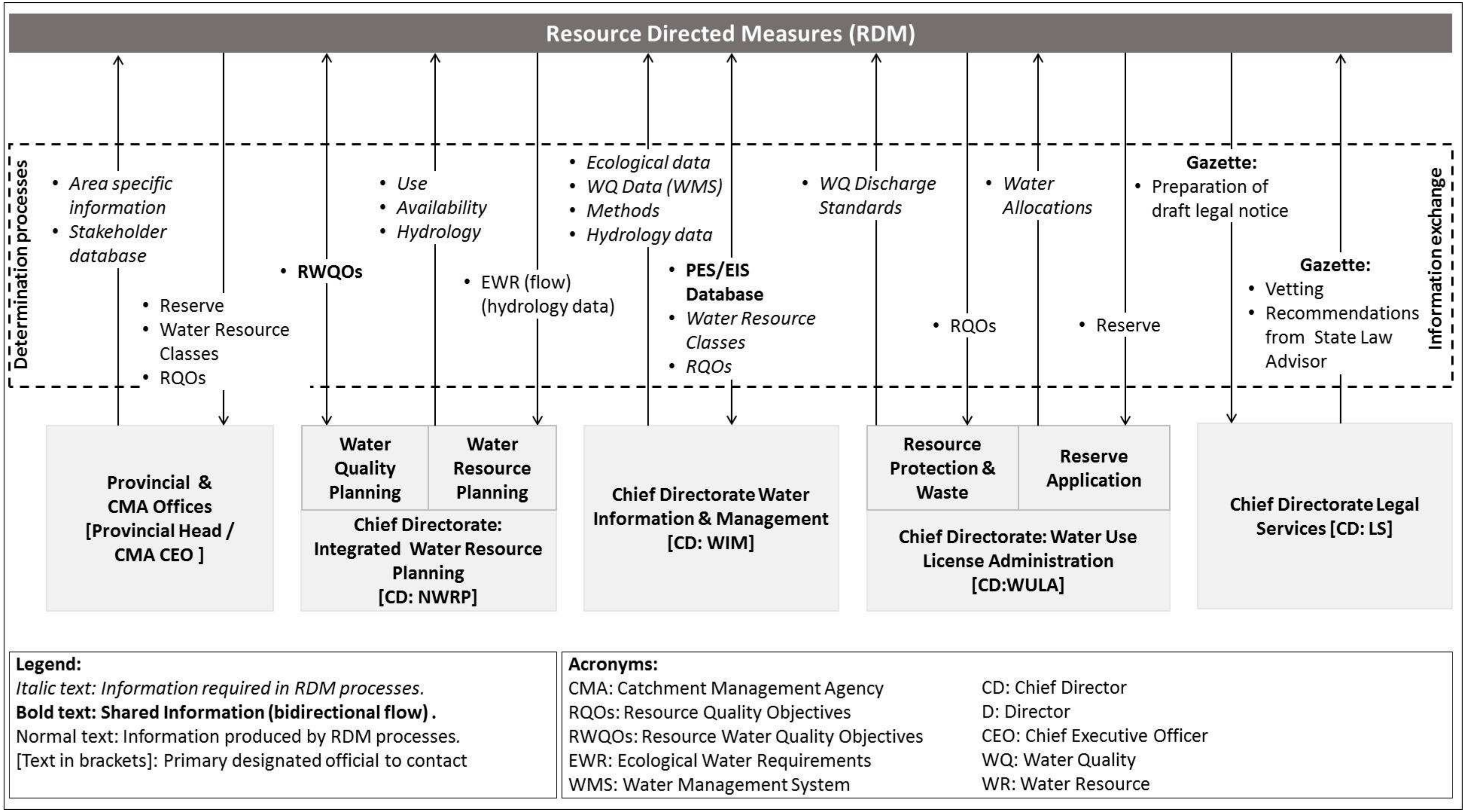

Figure 12.1 Communication Framework Schematic

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 HYDROLOGY AND GROUNDWATER

The following gaps (relating to surface and groundwater hydrology as well as hydraulic activities) have been identified which, if that is filled, will improve the effectiveness of RDM operationalisation:

Since hydrological information is one of the driver components of all RDM processes improvements in recorded data of rain fall, water use, river flow and water quality sampling to apply in the various assessments and for monitoring is considered to be the one key aspect that will enhance the effective implementation of RDM processes. The measuring requirement is study area and system specific and should be captured in the Implementation Report compiled as part of Step 7.5.

Going forward with RDM process applications, provision should be made for “orderly” evaluation and adoption of alternative or enhanced methods that aim to (a) improve productivity of application and (b) incorporate knowledge from ongoing research by integrating with what we have.

The transfer and multiplication of scientific skills for the application of all the specialist activities as well as process coordination expertise, to ensure coherent applications across all the steps, should receive a high priority in human resource and skills development strategies.

A current gap is the absence of integrated multi-constituent water quality models that are calibrated for study areas. This shortcoming hampers the ability to evaluate and compare scenario consequences of alternative water quality management measures.

The need for daily flow data that is consistent with the main stream monthly hydrological models has been identified as a gap. Current research is being carried out to address this requirement and once the methods have been proven, production tools (software) should be developed for application in RDM studies.

Overarching recommendations:
Ensure RDM processes are executed within Integrated Water Resource Management and the prevailing focus activities (other than RDM) should be guiding the intensity and extent of the human resource efforts.

13.2 WATER QUALITY

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

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

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

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

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

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

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

13.3 SOCIO-ECONOMIC AND ECOSYSTEM SERVICES

Tools for the socio-economic aspects of RDM operationalisation are available and used in a manner that is generally consistent with the level of effort required and the individual team members understanding of the resource areas or catchment in question.

For **Integrated Step 1** (Delineate and Prioritise Resource Units) there are no generally applicable tools but a Socio-Cultural Tool for comparative analysis of areas to determine comparative importance within the study area has been developed. Limited fieldwork may be undertaken to confirm assumptions. In some cases, more extensive fieldwork may be undertaken if the budget allows for this activity and if there is an identified requirement for more detailed and higher confidence analysis.

For **Integrated Step 2** (Description of the present socio-economic status and key drivers) a tool is not universally used but inputs are generally standardised. The inputs used will largely depend on the project and on available material. Although there are likely to be common elements in terms of available data across all parts of South Africa there may be some areas that have had recent focus and value added data over and above national or commonly available inputs could be found.

For **Integrated Step 3** (BHNR) an approach has been developed by the DWS and this is generally used. The approach is a simple mathematical model based on population present in the area and level of service delivery. Data needs to be obtained at the most refined level available. This can usually be sourced directly from StatsSA. DWS has some data for a limited number for regions that may be more refined than that available from StatsSA and needs to be determined at the outset of the project.

For **Integrated Step 4** (Identify and Evaluate Scenarios within IWRM) a range of tools are available. For Ecosystem Services these can be listed in a spreadsheet and categorised in terms of services as defined by the Millennium Ecosystem assessment (provisioning, supporting, regulating, and cultural). For some aspects of this analysis a consideration of different species and their potential reaction to change under scenarios can be considered. This is typically done in a specialist workshop with input from ecological specialist to guide an assessment of the types of changes associated with scenarios and reasons for such changes. For economic analysis an econometric model is available and this is based on the relevant provincial Social Accounting Matrix available from the Development Bank of Southern Africa.

13.4 RIVERS

In general, the rivers tools are well developed and most have been used extensively. The most obvious gap is clear and updated user manuals that integrate the tools into processes:

- **Step 1.3.1 Rivers:** In terms of the prioritisation, two tools are on the table. The Catchment Reserve RU priority spreadsheet has been in use since 2004. Another method was designed during 2010 to accommodate RQOs (RU Prioritisation tool). This tool is similar to the Catchment Reserve RU priority spreadsheet but is complex and time consuming. It has recently become clear that DWS requires the evaluation of SQs and in large catchments, the RU prioritisation tool does not accommodate this. As both tools comply with the standardised output, the choice would be based on the size of study area and resources that are available. Manuals for both tools would be essential as both tools in its current format are only explained in actual study specific reports.

- **Step 3 Ecological Water Requirements:** This step forms the basis of the quantification of the Ecological Reserve. The Comprehensive and Intermediate Ecological Reserve Methodologies have been in place and the two current methods have been well applied since about 2008. A current manual for the Habitat Flow Stressor Methodology is a gap that has been identified. To estimate EWRs at desktop level, the Desktop Reserve Model has been widely applied since the early 2000's. The update of this model (the Refined Desktop Reserve Model) has been extensively used, but the lack of a manual and complexities in the model has limited the use. These issues are currently being addressed through a WRC project.

- **Step 4 Evaluation of operational scenarios:** Tools to be used for this are built in within the EcoClassification models, the HFSR and the DRIFT. The issues regarding these processes are linked to the gaps described in the bullet above.

- **Step 6 Determine RQOs:** The determination of EcoSpecs and setting of monitoring programmes have been part of the HFSR from the design there-of. However, approaches and detail component specific methods are still lacking. With the design of the NWRCS as well as the guidelines of the RQOs, further attention has been given to these issues. However, these guidelines did not provide any reference to the quantification of EcoSpecs and just refers to the Reserve methodology. This is an important gap that should be addressed.

13.5 ESTUARIES

In general, the estuary methods and tools are well developed and most have been used extensively.

- **Step 1 Delineate and Prioritise RUs:** A method have been developed for the delineation of the EFZ for all estuaries in South Africa. This delineation is refined as part of the National Biodiversity Assessment to ensure coherence with other planning approaches. Most critical information is readily available for the ranking of estuaries based on their biodiversity importance, nursery function, conservation importance, and sensitivity/vulnerability to flow and pollution etc. Similarly, a provisional REC have been allocated to all estuaries in South Africa. An approach has been developed for the prioritisation of estuaries but it needs to be formalised.

- **Step 2 Describe status quo and delineate the study area into IUAs:** The National Biodiversity Assessment Management and Monitoring register for South Africa's estuaries provide an overview of all management responses (e.g. historical EWR studies, Estuary Management Plans) and monitoring activities (e.g. DWS monitoring sites) per estuary. It is therefore critical that this register be consulted for readily available information. Additional information should also be sourced from scientific publications and research reports. Similar to above, all critical information is readily available to describe the status quo and group the estuaries into logical units.

- **Step 3 Quantify the EWR:** This step forms the basis of the quantification of the Ecological Reserve. The Ecological Reserve Methodologies have been in place since 1999 and have been well applied over the past decade. A Desktop method have been developed as part of a WRC project and applied in a number of regional-scale studies since then. The DRIFT model has only been applied at St Lucia and needs further verification. At present there is no explicit guideline how to incorporate the requirements of the Estuary Management Plans (Integrated Coastal Management Act 24 of 2008) and DAFF /DEA targets such as maintaining/ensuring condition of nursery areas (Marine Living Resources Act 18 of 1998) formally into the EWR process. *The flow requirements of the marine environment is not addressed in any of the EWR/Classification studies and is a significant oversight as freshwater is critical for the maintenance of a number of coastal processes.*

- **Step 4 Evaluation of operational scenarios:** The tools to evaluate the operational scenarios are built into the DWS Estuary EWR methods. However current methods for the overall weighing and ranking of scenarios still need to be formally incorporated.

- **Step 6 Determine RQOs:** The determination of EcoSpecs and setting of monitoring programmes form part of the DWS Estuary EWR methods. However, approaches and detail component specific methods are still lacking. As part of the RQO process it is important to link the REC, mitigation measures required to meet the REC, and the role the other key lead agents (e.g. DEA, and DAFF) play in estuaries.

The following recommendations are made in this report:

- A proposed method has been developed for the grouping of estuaries in sub-step 1.6.4, but this approach needs to be confirmed by relevant specialists (e.g. workshop setting) and consolidate to set formal guidelines for inclusion in official DWS methodology documentation.
- Similarly, a proposed method has also been developed for the ranking, weighting and rating of scenarios. The approach needs to be confirmed by relevant specialists (e.g. workshop)

and consolidated to set formal guidelines for inclusion in official DWS methodology documentation. Connectivity (i.e. timing and duration of mouth closure in region) should explicitly be addressed.

- There is reservation regarding the ability of the DRIFT method to deal with estuarine complexity, especially in the case of transformed systems were flow is not the dominant driver. It is therefore recommended that the DRIFT method be evaluated by a team of estuarine specialists comprising all the relevant estuarine disciplines (e.g. hydrodynamics, water quality, physical habitat, microalgae, macrophytes, invertebrates, fish and birds) before it becomes accepted as part of the formal methods for estuaries.
- At present, there is no explicit guideline how to incorporate the requirements of the Estuary Management Plans (under Integrated Coastal Management Act 24 of 2008) and DAFF/DEA targets such as maintaining/ensuring condition of nursery areas (Marine Living Resources Act) and water quality modification in the Classification process.
- The fresh water requirements of South Africa's transitional water need to be incorporated in the Classification process. The loss of production and ecosystem services in the nearshore environment (fans and plume off large river systems) as a result of flow reduction need to be quantified and acknowledge in the Classification process. This includes aspects such as freshwater dependant coastal environments were groundwater feed the nearshore production.

13.6 WETLANDS

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.

13.7 STAKEHOLDER INVOLVEMENT AND COMMUNICATIONS

Stakeholder involvement and communication is critical to the development and implementation of the RDM processes. A standardised approach, which is in line with the DWS stakeholder and communication practices, should be the baseline for involving stakeholders as these practices are following international and national guidelines for public participation. Each process is unique and although methods and tools can be standardised, each process should consider the area of implementation and the needs of the stakeholders to be involved.

13.8 FRESHWATER REQUIREMENT OF THE TRANSITIONAL WATERS OF SOUTH AFRICA

13.8.1 Background

Freshwater flow reduction has severe consequences for transitional waters (i.e. estuarine, coastal and nearshore marine) biodiversity and resources through impacts on physical habitat, reduced nutrient inputs and alterations to important ecological processes (Van Niekerk and Turpie, 2012; Gillanders and Kingford, 2002; Lamberth and Turpie, 2003; van Ballegooyen *et al*., 2007; Lamberth *et al*., 2009; Porter, 2009). In South Africa, reduced river inputs have a significant impact on coastal and marine ecosystems around the entire South African coastline although impacts are expected to be more severe in the more nutrient poor marine environment of the east coast (van Ballegooyen *et al*., 2007). The impacts of altered fresh water flow reduction extend offshore with correlations between flow reduction and patterns in catches of commercial linefish documented more than 40 km offshore on the Thukela Banks (Lamberth *et al*., 2009).

Based on reductions in the 20 largest catchments in South Africa (those that contribute approximately 1% or more of total MAR in the region), the total freshwater flow to the marine environment has been reduced by about 40% (more than 11 000 million m^3/year) (see Table 13.1). The greatest reduction is on the west coast (approximately 7 000 million m^3/year) but there are significant reductions along both the south and east coasts. The larger river systems have experienced the greatest flow reduction and are therefore expected to have driven the most change in marine ecosystems. These include the Orange River on the west coast, the Thukela and Umzimvubu rivers in KwaZulu-Natal and the Breede River in the Agulhas Bioregion. The reduction of river flow leads to a reduced sediment supply to the coast with implications for beach and subtidal habitats. Reduced sediment input can change beach morphodynamic state, altering the beach biodiversity, accelerating beach erosion and can even lead to the loss of beach habitat (Harris *et al*., 2010). In the subtidal environment, riverine inputs provide important sediment inputs for the maintenance of unconsolidated sediment habitats. Reduced river inputs reduce the spatial extent of such habitats (van Ballegooyen *et al*., 2007).

Table 13.1 Summary of the 20 major catchments that play an important role in the development and productivity of South Africa's Transitional waters (Source: Van Niekerk and Turpie, 2012)

Catchment	MAR (Mill m^3/a)	% Change	% of SA Runoff
Orange	10 833.0	56	28.6
Thukela	3 753.6	27	9.9
Mzimvubu	2 893.8	10	7.7
Breëde	1 785.0	42	4.7
Umzimkulu	1 478.2	25	3.9
Olifants	1 070.1	34	2.8

Catchment	MAR (Mill m^3/a)	% Change	% of SA Runoff
Great Kei	1 064.1	15	2.8
Mkomazi	1034	15	2.7
Groot Berg	916.0	46	2.4
uMfolozi	885.0	19	2.3
Mbashe	836.0	10	2.2
Mgeni	682.9	61	1.8
Mhlathuze	645.0	20	1.7
Gouritz*	539.1	40	1.4
Great Fish	525.4	30	1.4
Gamtoos	500.6	35	1.3
Mvoti	482.0	25	1.3
St Lucia	417.9	30	1.1
Mtata	377.8	54	1.0
Mtamvuna	303.8	15	0.8

Many of these habitats are also important for ecological processes. For example the endemic and imperilled white steenbras *Lithognathus lithognathus* spawns on submarine fluvial fans, a localised habitat of limited extent, associated with mixed mud and sand banks deposited by rivers in the southeast Cape coast (Bennett, 1993). Changes in salinity and water temperature linked to flow alteration also impact thermohaline fronts which affects plankton feeding communities and the fish, birds and mammals that feed on the concentrated food associated with these habitats (van Ballegooyen *et al*., 2007).

Important processes that can be compromised through altered fresh water flow include nursery functions, environmental cues, productivity and food web processes. Increased frequency of estuary mouth closures and associated conditions due to reduced freshwater flow can also disrupt lifecycles and connectivity, and deprive fish and invertebrates of the important nursery function of estuaries (Whitfield, 1998). Sediment input leads to turbidity providing an important refuge for fish which is a key component of estuarine, coastal and offshore nursery areas (Whitfield, 1998; Lamberth *et al*., 2009). Reduced turbidity can alter predation pressure and the catchability of fisheries resources (van Ballegooyen *et al*., 2007). Altered freshwater flow leads to changes in important environmental cues such as those relevant for spawning, recruitment and migration (Lamberth *et al*., 2009). Changes in spawning intensity have been correlated with altered fresh water flow (QuiÑores and Montes 2001; Demetriades *et al*., 2000).

Catchment derived nutrients are an important component of coastal and marine foodwebs stimulating phytoplankton production. The impacts of reduced nutrient supplies will travel through coastal and marine ecosystems via foodwebs (van Ballegooyen *et al*., 2007). Reduced detritus may also impact on coastal and marine foodwebs as river-associated detritus and associated epiphytes are believed to be an important food source for microorganisms, filter feeders, detritivorous fish and invertebrates (Berry *et al*., 1979; Schleyer 1981; Berry and Schleyer 1983; Whitfield 1998; Porter, 2009). In KwaZulu-Natal, an isotope study showed that suspended riverine particulate organic matter (terrestrial, aquatic plant material and plankton) plays an important role in supporting inshore filter-feeder communities, i.e. intertidal and subtidal assemblages dominated by the sea-squirt known as red bait *Pyura stolonifera*, mussels *Perna perna*, and oysters *Striostrea margaritacea* and *Saccostrea cuccullata* (Porter, 2009). Porter (2009) found that between 8 and 33% of filter-feeder diets consisted of material introduced to the sea by rivers and concluded that rivers play an important trophic role in promoting filter-feeder biomass in the Natal Bioregion. He also demonstrated the links between river, inshore and pelagic ecosystems, highlighting the need for adequate freshwater supplies for the maintenance of the integrity of coastal and marine ecosystems.

Changes in freshwater flow and associated variations in turbidity, nutrients and sediment supply can impact fisheries resources, alter catch composition and reduce the economic returns of fisheries (Lamberth and Turpie, 2003; Lamberth *et al*., 2009). Fisheries resources in South Africa that have, or may have been compromised by reduced fresh water input include linefish (Lamberth *et al*., 2009), prawns (Demetriades *et al*., 2000), and filter feeding invertebrates in the intertidal and shallow subtidal (Porter, 2009).

Lamberth *et al*., (2009) identified significant relationships between flow and the catches of 14 linefish species (more than 90% of the total catch) on the Thukela Banks in KwaZulu-Natal. Most fish responded negatively, with reduced catches correlating with reduced flow (after a lag phase), slinger *Chrysoblephus puniceus* and squaretail kob *Argyrosomus thorpei*, the most important species in the fishery, showing the most marked response.

The ecological needs of South Africa's the Transitional waters (i.e. freshwater dependant coastal and marine environment) must be considered in the allocation of fresh water resources to ensure healthy functioning marine ecosystems that support productive and sustainable fisheries.

13.8.2 Recommendations for including the freshwater requirements of the transitional waters and coastal environment

Van Ballegooyen *et al*. (2007) developed a comprehensive assessment framework for the marine ecosystems that takes cognisance of their freshwater requirements. This study proposes to use a modified the version of the propose framework to evaluate a range of freshwater flow scenarios to the by means of the steps listed in Table 13.2.

- **STEP 1**

1.1 Define legislative obligations (in terms of **biodiversity protection, sustainable fisheries, coastal protection -beach development):** Review the policies and legislation of relevance to the assessment and management of the freshwater requirements of the marine environment, including particular obligations under various treaties and international agreements.

1.2 Define the ecosystem extent (biogeographic domain): The boundaries of ecosystem extent of relevance to the assessment need to be defined based on the extent of the marine ecosystem potentially impacted by change of freshwater inflow (i.e. an appropriate definition of the ecological "footprint").

1.3 Identify key ecosystem functions and services: Provide adequate description of key ecosystem function and services (i.e. key components) to ensure an appropriate ecosystem management approach and the appropriate maintenance of biodiversity.

1.4 Identify of resource utilization in ecosystem: The resource utilization needs to be identified in order that, as a minimum, appropriate keystone/indicator species can be selected for the assessment of the freshwater requirements of the marine environment.

- **STEP 2**

2.1 Identify biodiversity and resource use targets (e.g. fish nurseries, fisheries production, Marine Protected Areas, sediment requirement of beaches): Based on the identified policy and legislative requirements, resource utilisation and characteristics of the ecosystem under consideration, specific management and environmental quality objectives need to be developed.

- **STEP 3**

3.1 Determine ecosystem sensitivity to flow through:

3.1.1 **Identification relevant abiotic components (habitat) and assess the response to flow modification:** The critical abiotic drivers (e.g. salinity, nutrients, sediments, etc.) influencing the quality of the required habitats during the various life-cycle stages of the key biotic species need to be identified. For some species it may be required that other biotic drivers need to be selected as well. However, to limit the complexity of the assessment, this should be avoided if at all possible. This also includes an analysis of the temporal and spatial scales required to adequately characterise the drivers and their role in the biotic response of the species chosen. The various abiotic (and biotic) drivers need to be integrated and/or aggregated, such that they are relevant to determining the biotic response. Where the abiotic (and biotic) driver cannot be measured on the temporal and spatial scales required to adequately characterise the driver, an attempt should be made to characterise the driver based on a functional relationship based on a time series that has indeed been measured on the spatial and temporal scales required. Describe the changes in the past and present flow regime of the catchment to provide context to the assessment.

3.1.2 **Describe the implications of present flow regime on selected biological components (i.e. keystone/indicator species life-cycle and habitat requirements in terms of flow). Selection of keystone or indicator species:** Based on the management objectives, the defined ecosystem boundary and resource utilization, keystone and/or indicator species need to be identified that will minimise the complexity of the assessment, allow for the setting of clear and measurable environmental objectives and ensure practical and effective management advice. **Determination of life-cycle and habitat requirements:** An analysis of the various life-cycle stages of the identified keystone or indicator species is required to identify the habitat requirements for the various life-cycle stages and consequently the abiotic (and biotic) drivers of relevance.

- **STEP 4**

4.1 Assess hydrological operational scenario:

a) Describe the changes in the flow regime of the catchment to provide context to the assessment. Predicted the possible responses, if any, to predicted change in abiotic drivers.

b) Describe the implications of flow alteration on selected biological components (i.e. keystone/indicator species life-cycle and habitat requirements in terms of flow)

4.2 Evaluation of socio-economic importance of marine aquatic ecosystems and resource uses: The outcomes of the assessment of the potential impacts associated with changes in freshwater inflow into marine ecosystems need to be linked to the socio-economic implications of these changes as this is the primary basis upon which water resource allocations are likely to be made. Based on the outcome of this step, there may be modification of the recommended freshwater requirements for the marine ecosystems under consideration.

4.3 Recommendation of Freshwater Requirements: The adequacy of the scientific assessment will be determined by whether or not there is sufficient understanding and/or measurements to translate management and environmental quality objectives into specific freshwater requirements or target values, based on recognised usage of the marine environment as an existing or potential future resource. Typically this is only possible for a specific coastal and offshore region once existing and potential future resource utilisation in the region of interest has been mapped and there is a reasonable understanding of the functioning of the ecosystems of relevance.

- **STEP 5**

5.1 Include Transitional Waters EWR in the setting of the TEC for estuaries as part of a source protection measure: While the Water Act does not recognise South Africa's Transitional waters as a receiving environment, the Act does provide for "Source Protection". This, in turn, allows for the setting of EWR and RQOs for significant water resources or other ecosystem services. Therefore the requirements of the nearshore environment needs to be incorporated in the setting of the TEC for estuaries as it may well mean that an estuary must maintain or improve its current condition to meet the requirements of its Transitional Waters.

- **STEP 6**

6.1 Set RQOs (e.g. freshwater flow and river water quality): At a minimum set the RQOs for freshwater flow and river water quality to the transitional waters. RQOs for special habitats, e.g. sediment loads may also be defined if information is available.

Table 13.2 Actions required for including the flow requirement of the transitional waters of South Africa into the Classification processes

Classification	Comment
Step 1	1.1 Define legislative obligations (in terms of biodiversity protection, sustainable fisheries, coastal protection -beach development). 1.2 Identify ecosystem extent (delineation). 1.3 Identify key ecosystem functions and services. 1.4 Identify ecosystem resource use.
Step 2	2.1 Identify biodiversity and resource use targets (e.g. fish nurseries, fisheries production, Marine Protected Areas, sediment requirement of beaches).
Step 3	3.1 Determine ecosystem sensitivity to flow. Identify relevant abiotic components (e.g. habitat) and assess responses to flow modification. Describe the implications of present flow regime on selected biological components (i.e. keystone/indicator species life-cycle and habitat requirements in terms of flow).
Step 4	4.1 Assess hydrological operational scenario. Predicted the responses, if any, to predicted change in abiotic drivers. Describe the implications of flow alteration on selected biological components. 4.2 Evaluation of socio-economic importance of marine aquatic ecosystems and resource uses. 4.3 Recommend EWR.
Step 5	5.1 Include in TEC for estuaries as part of a source protection measure.
Step 6	6.1 Set RQOs (e.g. Flow and river Water Quality).

Table 13.3 include recommendations for including the coastal groundwater dependant systems in the Classification process.

Table 13.3 Actions required for including the flow requirement of the estuarine and coastal waters of South Africa into Step 3 of the Classification processes

Action	Input	Output	Methods/Tools
1.3.5 Define surface groundwater interaction areas (including estuaries and nearshore coastal environments)	Aquafer parameters. Climatic parameters. Recharge and rainfall.	Flows to estuary. Water levels. Seepage to sea (steady state or time series).	For more detail refer to RDM/WE/00/CON/ORDM/0916.

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15 APPENDIX A: REPORT COMMENTS REGISTER

Page Number	Chapter /Section /Step	Comment	Addressed in report?	Comment/explanation
PMC comments received: April 2017				
	Fig 3.4	Please check the colouring for step 6 of the RQO gazetted steps	Yes	
	4.1	You may need to refer the reader to the Lessons Learnt Report	Yes	
	3.3	It would help to recommend which of the two steps makes more sense	Yes	
	Fig 3.5	Extensive comments were provided in the report. This led to clarification and iterative adjustments of the figure and the rest of the chapter between the client and the author via Emails. The resulting agreement is included in the report.	Yes	
	Table 3.2	Remember some of the variables are not included due to resources constraints. Therefore if we say all driving variables we giving an impression that we must do all of them. I would be comfortable if we say priority variables. Even though this is vague however it gives an impression that one needs to prioritize the RQOs.	Yes	
	Table 3.2	Statement somehow amiss. Users other than ecological water quality???	Yes	
	Table 3.2	I would rather you remove licensing and say planning and management. We are always faced with a question of how to effect RQOs into licenses, if we say such statements, people may interpret it that RQOs can be used as license conditions.	Yes	
	Table 3.5 (New)	For consistency, why are you not using the colour codes as in other steps to show where the linkages are. These arrows are confusing. You can actually do the comparison the same way you did in fig 2.2 on page 2. Instead of the gazetted RQO step you put these proposed ones. I think it will make the picture better than what is projected here.	Yes	
	Table 3.3	I suggest you make an additional column where you project the information of the proposed RQO steps	Yes	

Page Number	Chapter /Section /Step	Comment	Addressed in report?	Comment/explanation
		rather than having it in the same block (explanation)		
	4.5	For DWS or RDM which is a component of DWS?	No	Studies that contains RDM work are sometimes carried out as part of larger studies managed by other directorates in DWS.
	10.7	Not sure if I understand this correctly. Stakeholder involvement happens throughout the process?	No	Stakeholder engagement happens throughout the process but not necessarily at each step. There are no specific stakeholder activities during Step 7
	Table 10.5	Shouldn't this be High; med or low? Why here we say previously evaluated, what does this tell us about frequency rating?	Yes	
	10.7	Not sure if I understand this correctly. Stakeholder involvement happens throughout the process?	Yes	This has been adjusted and the stakeholder information under Step 7 included here.
	12.1	What is the relevance/significance of adding this here?	Yes	Has been deleted
General		No Lessons learnt	No	Reference is made to the lessons learnt report.
General		No recommendations	Yes	There is a final chapter providing all the recommendations called conclusions. The name of the chapter has been changed.