Development of Decision-support Tools for Assessment of Wetland Present Ecological Status (PES)

Volume 2

DEVELOPMENT OF A DECISION-SUPPORT FRAMEWORK FOR WETLAND ASSESSMENT IN SOUTH AFRICA AND A DECISION-SUPPORT PROTOCOL FOR THE RAPID ASSESSMENT OF WETLAND ECOLOGICAL CONDITION

DJ Ollis, JA Day, HL Malan, JL Ewart-Smith & NM Job

WATER RESEARCH COMMISSION

TT 609/14

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Report to the

WATER RESEARCH COMMISSION

by

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This report emanates from a project titled *Consolidation and optimization of wetland health assessment methods through development of a Decision-Support Tree that will provide guidelines* (WRC Project No K5/2192)

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PREFACE

This report is one of the outputs of a directed Water Research Commission (WRC) project originally entitled “Consolidation and optimization of wetland health assessment methods through development of a Decision-Support Tree (DST) that will provide guidelines” (WRC Project K5/2192). The stated overall objective of the project was “To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision- support system applicable in all types of wetlands”.

This report forms Volume 2 of 2 in the pair of Final Reports compiled for WRC Project K5/2192. The two Final Reports are as follows:

- **Volume 1:** *Review of available methods for the assessment of the ecological condition of wetlands in South Africa* (by DJ Ollis and HL Malan) **(WRC Report No. TT 608/14)**.
- **Volume 2 (this report):** *Development of a decision-support framework for wetland assessment in South Africa and a Decision-Support Protocol for the rapid assessment of wetland ecological condition* (by DJ Ollis, JA Day, HL Malan, JL Ewart-Smith and NM Job) **(WRC Report No. TT 609/14)**.

The following ‘tools’ that were produced through WRC Project K5/2192 have both been packaged with this report:

- A generic decision-support Framework for Wetland Assessment in South Africa, which is a flow-chart showing the various steps in the process of identifying, delineating, classifying, assessing, managing and monitoring wetlands, and how these different aspects typically relate to one another; and
- A Decision-Support Protocol (DSP) specifically for the rapid assessment of Wetland Present Ecological Status (PES), in the form of a series of electronic spreadsheets compiled in a Microsoft Excel (.xls) format.

EXECUTIVE SUMMARY

RATIONALE

Government agencies (and other parties responsible for the management of wetlands) take the Present Ecological State (PES) of a wetland, as represented by the PES Score and associated Ecological Category, into account when making management decisions relating to the sustainable use and protection of wetlands. It is thus important for government agencies to ensure that appropriate methods, which generate reliable and comparable results, are used for wetland PES assessments.

The rationale for the current project was to:

(i) identify key areas for future research and development with regard to the assessment of wetland PES in South Africa (dealt with Final Report: Volume 1); and
(ii) provide interim decision-support tools to assist government agencies and wetland assessors in selecting appropriate wetland PES assessment methods and reporting the results in a transparent and consistent manner (dealt with in Final Report: Volume 2).

It is anticipated that the research and development needs identified, and the guidelines and decision-support tools produced through this project, should assist in demystifying what is currently an area of great confusion and uncertainty for South African government agencies and wetland assessors alike.

BACKGROUND AND CONTEXT

The ‘tools’ described in this document emanate from a directed Water Research Commission (WRC) project originally entitled “Consolidation and optimization of wetland health assessment methods through development of a Decision-Support Tree (DST) that will provide guidelines” (WRC Project K5/2192). The stated overall objective of the project was “To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision-support system applicable in all types of wetlands”.

The main deliverables that have been produced for WRC Project K5/2192 are a review of available methods for the assessment of the ecological condition of wetlands in South Africa (see Final Report: Volume 1), a Decision-Support Protocol (DSP) for the rapid assessment of the PES of wetlands, and an overarching decision-support Framework for Wetland Assessment in South Africa. The latter two deliverables form the focus of the current report.

APPROACH TAKEN TO DEVELOPING THE DECISION-SUPPORT TOOLS (METHODS)

The proposed decision-support Framework for Wetland Assessment was initially developed by reviewing and building upon a number of frameworks and procedures for various aspects of wetland assessment in South Africa that already exist.

The DSP for rapid wetland PES assessment was initially developed by considering the findings of a review of existing methods (as documented in Final Report: Volume 1) and taking some of the ideas from the updated manual for the rapid Ecological Reserve determination of inland wetlands (Rountree et al., 2013), particularly the mixed use of individual modules from the WET-Health (Level 1) and Wetland-IHI PES assessment 'tools'. A preliminary, integrated set of spreadsheet-based datasheets was created to assist with the completion of a rapid assessment of wetland PES. The results and recommendations stemming from the testing of existing wetland PES assessment methods (see Annexure of Final Report: Volume 1) served as major informants in the refinement and further development of the preliminary DSP tool.

A broadly similar approach was followed in the ongoing development of the DSP and the Framework for Wetland Assessment throughout the duration of the project, which involved *inter alia*:

- the holding of a number of mini-workshop sessions by members of the project team, to discuss the proposed tools;
- the delivery of presentations about the proposed tools at the annual SASAQS Conference and the National Wetlands Indaba in 2013, and discussions with delegates at these conferences to obtain input and suggestions for the improvement of the proposed tools;
- the holding of a dedicated workshop at the annual SASAQS Conference in July 2013 to discuss the proposed tools and to obtain input from workshop attendees;
- The delivery of presentations and discussion about the proposed tools at the Reference Group meetings for this project that were held in July 2013 and May 2014;
- the delivery of a presentation about the project and the proposed wetland assessment tools at the National Wetlands Task Group meeting held at DWA's offices in Pretoria in November 2013, followed by discussion (valuable input was received from DWA officials at this meeting);
- internal peer-review of draft versions of the DSP and Framework, and of the accompanying documentation, by members of the project team; and
- the dissemination of draft versions of the DSP and proposed Framework for Wetland Assessment, and the accompanying explanatory documentation, to members of the Review Group for this project, to relevant DWA officials, and to three external review consultants for their consideration and input.

PROPOSED FRAMEWORK FOR WETLAND ASSESSMENT IN SOUTH AFRICA

During the course of this project, it became apparent that in South Africa there is a lot of confusion about the tasks that should generally be carried out during a wetland assessment process and the correct methods to use for the various tasks. The prevalence of such confusion, which often leads to the inappropriate application of existing PES assessment methods, was one of the main motivating factors behind the development of the proposed Framework for Wetland Assessment as an additional deliverable in the current project. It is anticipated that the Framework that has been developed will minimise the incorrect application of wetland assessment tools, by guiding an assessor through the various steps that should typically be followed before and after conducting a wetland assessment, and by elucidating the different types of wetland assessments that can be undertaken.

The proposed Framework for Wetland Assessment in South Africa simply provides a visual summary of the process that is typically followed in the cycle of wetland identification, mapping (delineation), classification (typing), assessment, management and monitoring, by breaking the process down into five generic steps (see Figure A1). Each step in the Framework is described in the report and a summary table is provided. A description is given of the various tasks typically associated with each step in the Framework, and of relevant methods and/or guideline documents for each task, together with a list of references for the recommended methods/guidelines where such documentation exists.

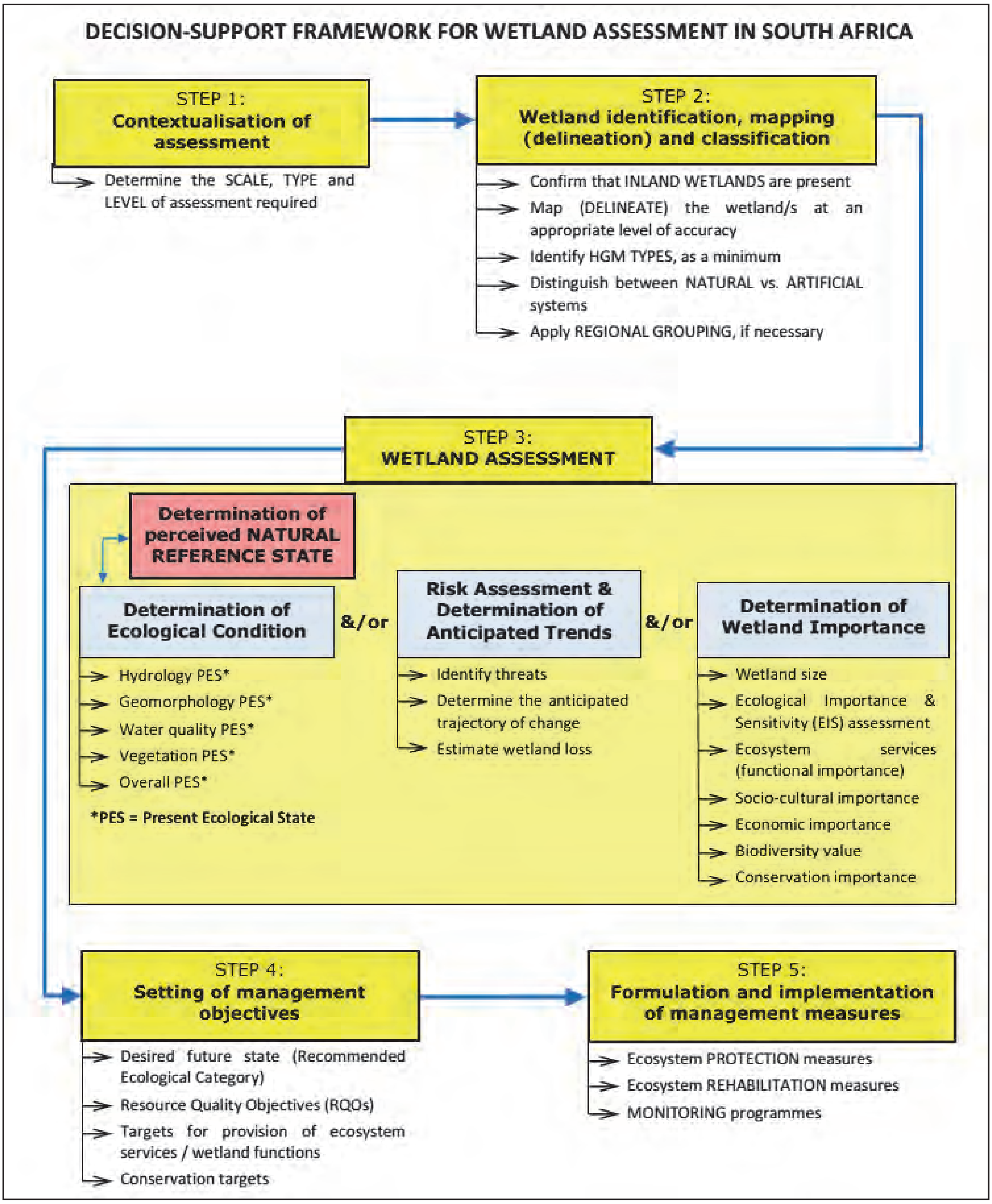

Figure A1: The proposed decision-support Framework for Wetland Assessment in South Africa

It is anticipated that that there is a wide range of potential areas of application for the proposed Framework for Wetland Assessment, due to its generic nature. At the same time it is important to bear in mind that the Framework is specifically intended for inland wetlands, and not for other types of inland aquatic ecosystems (such as rivers or open waterbodies). The Framework is not applicable to terrestrial, marine or estuarine ecosystems.

DECISION-SUPPORT PROTOCOL (DSP) FOR RAPID WETLAND PES ASSESSMENT

The DSP for the rapid assessment of wetland PES is the main deliverable that has been produced for the project. This tool is in the form of an electronic spreadsheet compiled in Microsoft Excel (.xls format). The Excel spreadsheet consists of a number of worksheets (designated by colour-coded, labelled tabs at the bottom of the screen), starting with an introductory worksheet ('INTRO' tab) with background information to contextualise the DSP and a worksheet that contains notes on the use of the DSP ('use-notes' tab). The main worksheet ('DSP Home') outlines the protocol that has been developed for the rapid assessment of wetland PES as a series of steps. This worksheet contains hyperlinks to the various worksheets that need to be filled in for each step when using the DSP.

The steps in the DSP have been purposefully formulated to align with the steps in the proposed Framework for Wetland Assessment (see Figure A1). The DSP, however, only includes aspects relating to Steps 1 to 3 of the Framework (up to 'wetland assessment') because this tool does not deal with Steps 4 or 5 (relating to the management of wetlands). It is also important to note that the DSP is only applicable to the rapid assessment of wetland PES and it does not, therefore, cater for other types of wetland assessment (such as 'risk assessment and determination of anticipated trends' or 'determination of wetland importance').

The protocol that has been developed for the rapid assessment of wetland PES (i.e. the DSP) guides an assessor through the following prescribed steps:

- Step 1: Determine the scale, type and level of assessment required.
- Step 2a: Confirm that the aquatic ecosystem is an inland wetland.
- Step 2b: Delineate the wetland, divide it into HGM Units (i.e. classify the wetland type/s) and identify "assessment units".
- Step 3a: Describe the perceived natural reference state of the (naturally-occurring) wetland assessment unit.
- Step 3b: Select and fill in score-sheets to derive PES Scores and Ecological Categories for individual components of wetland PES (by navigating via the main matrix table included in the 'DSP Home' worksheet).
- Step 3c: Select component weightings to derive an Overall PES Score and Ecological Category for the wetland assessment unit (using the second matrix table included in the 'DSP Home' worksheet).
- Step 3d: Generate a summary of results.

A detailed explanation of each step is provided in the report.

The inclusion of the initial step to provide an indication of the applicability of the DSP, based on the scale, type and level of assessment required in a particular situation, should prevent the inappropriate use of the WET-Health (Level 1) and Wetland-IHI assessment tools (and attempts to inappropriately conduct a rapid wetland PES assessment, in general).

The core of the DSP (Step 3b) is a matrix that allows users of the tool to select their preferred choice of applicable, existing rapid assessment method for each component of wetland PES (namely, Hydrology, Geomorphology, Vegetation, and Water Quality) (see Figure A2).

Wetland HGM type (reference state)	Components of wetland ecological condition			
	Hydrology	Geomorphology	Water quality	Vegetation
Floodplain wetland or **Channelled VB wetland**	WET-Health Level 1 Hydrology module **or** Wetland-IHI Hydrology module **and check against** (List of potential Hydrological Impacts)	WET-Health Level 1 Geomorphology module **or** Wetland-IHI Geomorphology module **and check against** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potential Vegetation Impacts)
Unchannelled VB wetland or **Seep**	WET-Health Level 1 Hydrology module **and check against** (List of potential Hydrological Impacts)	WET-Health Level 1 Geomorphology module **and check against** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potential Vegetation Impacts)
Depression or **Wetland flat**	WET-Health Level 1 Hydrology module **and check against** (List of potential Hydrological Impacts)	GAP (not covered by existing tools) **in interim check** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potental Vegetation Impacts)

Figure A2: A copy of the colour-coded matrix table included in the 'DSP Home' worksheet to assist with the selection of an appropriate rapid assessment method for determining the PES for the various components of wetland condition, according to the HGM type of the assessment unit

The separate modules from the WET-Health (Level 1) and Wetland-IHI assessment methods have been incorporated into Step 3b of the DSP, according to their relevance to different wetland HGM types (including the option to use the Vegetation and Water Quality modules of Wetland-IHI for all wetland types). For all wetland types, the Water Quality PES Score can be derived using either the Wetland-IHI water quality score-sheet or the 'landuse – water quality' spreadsheet developed by Malan et al. (2013).

In Step 3c, the DSP allows for the selection of the preferred weightings for the derivation of the overall Wetland PES by an assessor (i.e. the WET-Health default weightings or the Wetland-IHI default weightings, or customised weightings if neither of these are considered to be appropriate), until such time as the most appropriate weightings for different wetland types have been determined through rigorous testing. For depressions and wetland flats, the option is given of deriving the Overall PES Score using the RDM-99 method. This is because, for these wetland types, the Geomorphology PES cannot be determined using the existing methods and so it is not possible to derive an overall score by weighting and combining the various component scores.

Also included with the DSP are worksheets that were specifically developed for mapping HGM Units and assessment units (in Step 2b), for describing the perceived reference state of a wetland (in Step 3a), and for identifying (through the use of checklists) the most applicable potential impacts (and possible causes) that could be affecting the ecological condition of a wetland assessment unit (as part of Step 3b). It is anticipated that these additional features will help different assessors to 'calibrate' their assessment of impacts in relation to the perceived natural reference state of a wetland when using the DSP. The additional information that is recorded will also make PES assessments more transparent and should thus facilitate the identification of the main reasons for differences between the results generated by different assessors, where such inconsistencies do occur.

The score-sheets that are linked to the DSP ultimately generate an Ecological Category or PES Category, ranging from A to F, for the different components of wetland PES, following the PES rating system initially developed by Kleynhans (1996) that is commonly used for inland aquatic ecosystems in South Africa. To ensure that the Overall Ecological Category for a wetland assessment unit is generated in a consistent way, irrespective of which PES assessment methods are used to derive the PES% scores for the different components of wetland condition, the same scoring system is used (as shown in Table A1). The scoring system, which is based on the ranges of PES% scores used by DWA to derive an Ecological Category, allows for the derivation of intermediate categories (e.g. A/B or C/D).

Table A1: Ranges of PES percentage scores used in the DSP to derive an Overall Ecological Category from A to F, including intermediate categories, on the basis of the Overall PES% Score for a wetland assessment unit [after DWAF (2008b), as adapted from Kleynhans (1996)]

Ecological Category	Range of PES% scores
A	92-100%
A/B	87-91.9%
B	82-86.9%
B/C	77-81.9%
C	62-76.9%
C/D	57-61.9%
D	42-56.9%
D/E	37-41.9%
E	22-36.9%
E/F	17-21.9%
F	0- 16.9%

The final step in the DSP is to generate a summary of the results of the PES assessment for the wetland assessment unit. A summary table is provided for this purpose, which is accessed by clicking on the 'Go to summary of results' (Step 3d) hyperlink in the 'DSP Home' worksheet. The summary is generated by simply stipulating which assessment methods were used to generate the PES scores for the various components of wetland condition, and which scoring method was used to derive the Overall PES Score for the assessment unit (e.g. see the filled-in table for a hypothetical wetland assessment unit in

Figure A3). The final Ecological Categories presented in the summary table generated by the DSP, for the various components of wetland PES and for the Overall PES, are derived using the same scoring system based on ranges of PES% scores (as presented in Table A1). This ensures that there is consistency in the way that the final results are presented by different assessors, and makes it transparent to a reader as to which methods were used to generate the results.

SUMMARY OF PES RESULTS FOR WETLAND ASSESSMENT UNIT

Wetland name:	Hypothetical example	Back to DSP Home
Assessment unit [refer to HGM-map]:	HGM 1a	Look at Map/s
HGM Type:	Channelled VB wetland	
Date of assessment:	Date	
Name/s of assessor/s:	Name	

Components	**Method used for assessment** **[select using drop-down menus]**	**PES% Score**	**Ecological Category**
Hydrology PES	WET-Health Hydro Module	25 %	**E**
Geomorphology PES	Wetland-IHI Geomorph Module	26 %	**E**
Water quality PES	Landuse-WQ Model	86 %	**B**
Vegetation PES	WET-Health Veg Module	37 %	**E**
Overall Wetland PES	Wetland-IHI default weightings	36 %	**E**

Figure A3: Filled-in example of the summary table in the DSP, for a hypothetical assessment unit within a channelled valley-bottom wetland

To use the DSP, an assessor simply opens the Excel file (provided on the accompanying CD), goes to the first sheet ('INTRO' tab) and navigates from there. The main worksheet to work from when using the DSP is the one labelled 'DSP Home', which has a bright yellow-coloured tab. Most of the other worksheets have a 'Back to DSP Home' hyperlink that can be clicked on to navigate back to this worksheet. From the 'DSP Home' worksheet, the DSP is applied by going through the prescribed steps that are listed and clicking on the respective hyperlinks to navigate to the relevant worksheets, where applicable.

Limitations of the DSP and important provisos for its use

It is important to bear in mind that the DSP has some inherent limitations. Firstly, having been designed specifically to assist with the rapid assessment of wetland PES, the DSP is not applicable to the assessment of any other aspects such as the ecological importance and/or sensitivity of a wetland. Secondly, the DSP is only for inland wetlands, and is thus not applicable to rivers, lakes and other open waterbodies, or to marine and estuarine systems. A third and very important inherent limitation of the DSP is the fact that the PES scores that it generates are only as reliable as the existing wetland PES assessment methods included in the tool, namely WET-Health (Level 1), Wetland-IHI, the 'landuse – water quality' spreadsheet (developed by Malan et al., 2013) for water quality PES, and the RDM-99 method for the Overall PES Score of depressions and wetland flats.

The testing of the most widely-used, nationally-applicable, existing methods for the rapid assessment of wetland PES that was undertaken for this project revealed that there is an unsatisfactory degree of variability between the results generated by the different methods (i.e. WET-Health Level 1, Wetland-IHI, and the RDM-99 method) and by different assessors applying the methods to the same wetlands (see Annexure of Final Report: Volume 1). The implications of these findings are that the DSP could generate some dubious results if it is not applied with caution, taking cognisance of the fact that there are some gaps and limitations associated with the existing methods that have been included in the tool. This is an important proviso to bear in mind when using the DSP. A number of relatively minor refinements to the existing methods have been recommended to address some of the issues identified (see Final Report: Volume 1). As a longer-term solution, however, it has been strongly recommended that a new tool for the rapid assessment of wetland PES be developed from the existing tools so that there is a single, thoroughly-tested and scientifically validated rapid PES assessment tool for wetlands that can be used for all inland wetland types throughout the country.

CONCLUSIONS AND RECOMMENDATIONS

A Decision-Support Protocol for the rapid assessment of wetland PES and an overarching decision-support Framework for Wetland Assessment in South Africa have been produced as the main deliverables for the current project.

The use of the DSP, and of the existing methods included in the DSP (i.e. primarily WET-Health and Wetland-IHI), are considered to be the best available options for the rapid assessment of wetland PES at present. At the same time, however, there is clearly a dire need for the development of a single wetland PES assessment method (or a suite of similar assessment methods for different wetland types) in South Africa. The additional worksheets that were developed for the DSP could be used as a starting point in the development of such an integrated assessment method.

The decision-support Framework for Wetland Assessment in South Africa that has been produced, to accompany and encompass the DSP is considered to be, inherently, a relatively robust 'tool'. This is because the Framework, unlike the DSP that was developed specifically for rapid wetland PES assessment, is more conceptual in nature and is not dependent on the reliability or availability of particular methods/tools. On the contrary, it is anticipated that the Framework will assist in the identification of areas where specific 'tools' are currently lacking or where there is a need for more guidance to be provided by relevant government agencies for particular aspects relating to the identification, mapping (delineation), classification (typing), management and/or monitoring of wetlands in South Africa.

It is recommended that the DSP and proposed Framework for Wetland Assessment in South Africa should be distributed, with the accompanying documentation, to the wetland 'community of practice' throughout the country. There are a number of existing platforms that could be used to assist with this task.

It is anticipated that the DSP and overarching decision-support Framework for Wetland Assessment in South Africa will provide much-needed support and guidance for assessors and decision-makers involved in wetland assessment, management and/or monitoring throughout the country. At the same time, however, a number of major gaps and areas for future research and development still exist. The following pertinent recommendations that were documented in Final Report Volume 1 are reiterated here:

- The existing assessment tools (particularly WET-Health and Wetland-IHI) should be combined into a single assessment tool or an integrated suite of assessment tools for the categorisation of wetland PES for all HGM types.
- As an interim measure, a method for assessing the ecological condition of depressions and wetland flats (and possibly for seeps that are not connected to a drainage network) should be formulated as a matter of urgency.
- Written guidelines should be produced to assist with the determination of the natural reference state for wetlands that are to be assessed in terms of their PES.
- The characteristics of minimally-impacted reference wetlands in different geographical areas should be documented, following a standardised approach and reporting format.
- Field-guides should be developed for rating the extent and intensity of wetland impacts.
- Reporting guidelines and report templates should be produced for wetland PES assessments.

A copy of the Microsoft Excel file containing the Decision-Support Protocol for rapid wetland PES assessment can be found on the CD accompanying this report

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The authors would like to thank the Reference Group of the WRC Project K5/2192 for the assistance and the constructive discussions during the duration of the project:

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- Mark Rountree, Dr Donovan Kotze and Craig Cowden for reviewing a draft version of this report and draft versions of the accompanying 'tools'.

The project team for WRC Project K5/2192 would also like to acknowledge Bonani Madikizela (WRC Manager for Project K5/2192) for his central role in initiating this project, and for his ongoing support and encouragement during the course of the project.

Last, but by no means least, the project team wish to acknowledge the significance of the milestone that was attained through the development of the **Wetland-IHI** and **WET-Health** assessment methods. These tools have been extremely influential in the rapid advancement of wetland science that we have experienced in this country in the last decade. We would like to commend the developers of these tools for their achievements, the institutions that initiated the development of the tools for their foresight, and the scientists whose work paved the way for the development of the tools for their ground-breaking research.

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LIST OF ABBREVIATIONS

CD	Compact Disk
DSP	Decision-Support Protocol
DSS	Decision-Support System
DST	Decision-Support Tree
DWA	Department of Water Affairs
DWAF	Department of Water Affairs & Forestry
EIA	Environmental Impact Assessment
EIS	Ecological Importance & Sensitivity
EMC	Ecological Management Class
EWR	Environmental Water Requirements
FCG	The Freshwater Consulting Group
GIS	Geographical Information System
HGM	Hydrogeomorphic
IHI	Index of Habitat Integrity
MS	Microsoft
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act (Act No. 36 of 1998)
NWRC	National Water Resource Classification
NWRCS	National Water Resource Classification System
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
Ref	Reference
RQOs	Resource Quality Objectives
SANBI	South African National Biodiversity Institute
SASAQS	Southern African Society of Aquatic Scientists
SPI	Specific Pollution-sensitivity Index
UKZN	University of KwaZulu-Natal
US	United States (of America)
VB	Valley-bottom
WQ	Water quality
WRC	Water Research Commission
WULA	Water Use Licence Application

1 INTRODUCTION

1.1 Rationale

The Present Ecological State (PES) of a wetland refers to its present ecological condition relative to the perceived natural reference condition (pre-development/historical). The ability of a wetland to continue providing ecosystem goods and services is determined, to a large degree, by its present ecological condition. Government agencies (and other parties responsible for the management of wetlands) take the present ecological condition of a wetland, as represented by the PES Score and associated Ecological Category, into account when making management decisions relating to the sustainable use and protection of wetlands. It is thus important for government agencies to ensure that appropriate methods, which generate reliable and comparable results, are used for wetland PES assessments. Through their use over a number of years, gaps have been identified in the existing methods that are available for wetland PES assessment in South Africa. These shortcomings have been addressed through the *ad hoc* modifications of the existing assessment 'tools' by users, or through the development of additional (non-standardised) 'tools' for specific situations. This has created significant problems for government agencies in maintaining consistent standards of data collection and reporting, leading to a lack of confidence in the comparability of wetland PES assessment results generated by different assessors.

It is important for authorities (and assessors) to understand the limitations and gaps affecting the use of existing wetland assessment tools, as these have significant implications for decisions that are made with respect to the sustainable use and protection of wetland ecosystems. Furthermore, it has become evident that there is a dire need for clear guidelines and decision-support tools for the appropriate selection, use and reporting of results generated by the existing wetland assessment methods in South Africa. This was the motivation for the current project. In particular, the rationale for the project was to:

(i) identify key areas for future research and development with regard to the assessment of wetland PES in South Africa, so as to pave the way towards improving the existing methods [dealt with in Final Report: Volume 1 (Ollis and Malan, 2014)]; and
(ii) to provide interim decision-support tools to assist government agencies and wetland assessors in selecting appropriate wetland PES assessment methods and reporting the results in a transparent and consistent manner [dealt with in Final Report: Volume 2 (i.e. the current report)].

It is anticipated that the research and development needs identified, and the guidelines and decision-support tools produced through this project, should assist in demystifying what is currently an area of great confusion and uncertainty for South African government agencies and wetland assessors alike.

1.2 Background and context

The 'tools' described in this document emanate from a directed Water Research Commission (WRC) project originally entitled "Consolidation and optimization of wetland health assessment methods through development of a Decision-Support Tree (DST) that will provide guidelines" (WRC Project K5/2192). The stated overall objective of the project was, "To conduct gap analysis in wetland integrity assessment methods used in South Africa and develop a consolidated approach supported by a decision-support system applicable in all types of wetlands".

The main deliverables that have been produced for WRC Project K5/2192 are a review of available methods for the assessment of the ecological condition of wetlands in South Africa (see Final Report: Volume 1 by Ollis and Malan, 2014), a Decision-Support Protocol (DSP) for the rapid assessment of the PES of wetlands, and an overarching decision-support Framework for Wetland Assessment in South Africa. The latter two deliverables form the focus of the current report.

1.3 Brief description of the decision-support tools

The DSP that has been developed to assist with the rapid assessment of wetland PES in the South African context, as the primary deliverable for Project K5/2192, is in the form of an electronic spreadsheet compiled in Microsoft Excel (.xls format). The DSP represents a variation of the initially envisaged Decision-Support *Tree* (DST) or Decision-Support *System* (DSS) that was referred to in the initial aims for this project, with the name having been changed to convey a more accurate description of the final product that has been produced[1].

An additional product that has been developed for Project K5/2192 is a decision-support Framework for Wetland Assessment in South Africa, to contextualise the DSP and to provide users with a 'tool' to better understand how the rapid assessment of wetland PES relates to other aspects of wetland assessment. The decision-support Framework for Wetland Assessment is an important product for creating improved understanding of how the assessment of wetland condition relates to other aspects of wetland assessment. At the same time, however, it is important to note that the DSP for rapid wetland PES assessment has been developed in such a way that it can be applied as a stand-alone tool.

1.4 Structure of this report

The contents of this report have been structured as follows:

- An introduction is provided in **Section 1**, which includes an explanation of the background and context of the project (Section 1.1), an explanation of the rationale for the project (Section 1.2), and a brief description of the decision-support 'tools' that were produced as the main deliverables of the project (Section 1.3).

- The approach that was taken in developing the wetland assessment 'tools' presented in this report is described in **Section 2**.

[1] During the review that was undertaken for this project (see Final Report: Volume 1), it became apparent to the project team that none of the existing Wetland PES assessment methods are more suited to certain situations, compared with other methods (except for the obvious limitation that the Wetland-IHI method is only strictly applicable to floodplain and channelled-valley bottom wetland types, and the observation that a detailed "Level 2" WET-health assessment provides a more comprehensive assessment than the other, more rapid methods). As such, the development of a sophisticated DSS or DST was considered to be unfeasible and inappropriate.

- **Section 3** contains a detailed description of the proposed decision-support Framework for Wetland Assessment in South Africa (Section 3.1), together with an explanation of how to use the Framework (Section 3.2) and a discussion of the anticipated areas within which this ‘tool’ can be applied (Section 3.3). The proposed Framework itself is reproduced in **Appendix 1** for ease of reference.

- **Section 4** contains a description of the proposed DSP for the rapid assessment of wetland PES (Section 4.1), a step-by-step explanation of how to use the DSP (Section 4.2), and a discussion of the anticipated areas within which this ‘tool’ can be applied (Section 4.3). In Section 4.4, the limitations of the DSP and some important provisos for its use are dealt with. The DSP itself (an electronic spreadsheet on the accompanying CD) is included as **Appendix 2**. Comprehensive lists of potential impacts to the present ecological condition of wetlands, which have been incorporated into the DSP, are presented in **Appendix 3**.

- Conclusions and recommendations are given in **Section 4**.

2 APPROACH TAKEN TO THE DEVELOPMENT OF THE FRAMEWORK FOR WETLAND ASSESSMENT AND THE DECISION-SUPPORT PROTOCOL

The proposed decision-support Framework for Wetland Assessment was initially developed by reviewing and building upon a number of frameworks and procedures for various aspects of wetland assessment in South Africa that already exist. These primarily included the National Water Resource Classification System (NWRCS), Resource Directed Measures (RDM), EcoClassification and Reserve determination processes that have been formulated and refined by the Department of Water Affairs (DWA) through the years. Other, more recent frameworks/procedures that were given consideration included the proposed process for assessing offset requirements outlined in the Draft Wetland Offsets Guideline (DWA and SANBI, 2013)[2] and the proposed step-wise process within and through which it is recommended that buffer widths and other mitigation measures should be determined for water resources (wetlands, rivers and estuaries) in the DWA-WRC buffers project (pers. comm., Ian Bredin, Institute of Natural Resources: presentations at the SASAQS 2013 Conference and the 2013 National Wetlands Indaba)[3]. The presentations and discussions documented in a workshop report for an open meeting that was organised by the Western Cape Wetlands Forum in November 2008 to discuss the development of guidelines for standardising wetland assessment criteria in the Western Cape (Snaddon and Day, 2008) were also taken into account in the initial development of the proposed Framework for Wetland Assessment.

The DSP for rapid wetland PES assessment was initially developed by considering the findings of a review of existing methods (Ollis and Malan, 2014) and taking some of the ideas from the updated (Version 2.0) manual for the rapid Ecological Reserve determination of inland wetlands (Rountree et al., 2013), particularly the mixed use of individual modules from the WET-Health (Level 1) and Wetland-IHI PES assessment 'tools'. An integrated set of spreadsheet-based datasheets was initially created to assist with the completion of a rapid assessment of wetland PES. The results and recommendations stemming from the testing of existing wetland PES assessment methods (Ollis, 2014) served as major informants in the refinement and further development of the initially created DSP.

A broadly similar approach was followed in the ongoing development of the DSP and the Framework for Wetland Assessment throughout the duration of the project, which involved *inter alia*:

- The holding of a number of mini-workshop sessions by members of the project team, to discuss the proposed 'tools';

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[2] The recommended procedure for assessing the need for and required size of wetland offsets includes the steps of wetland mapping (delineation) and classification, and assessment of wetland condition, conservation importance and provision of ecosystem services (functional value).

[3] The recommended step-wise process for the formulation of mitigation measures and the determination of required buffer widths includes the steps of (1) defining the objectives and scope of assessment and determining the most appropriate level of assessment; (2) mapping (delineating) and classifying water resources in the study area; (3) determining the management objective for mapped water resources; (4) conducting risk assessments; (5) defining mitigation measures; (6) identifying and demarcating buffer zones; (7) documenting additional management measures that may be necessary; and (8) monitoring implementation and reviewing effectiveness.

- The delivery of presentations about the proposed DSP and overarching Framework for Wetland Assessment at the annual SASAQS Conference in July 2013 and the National Wetlands Indaba in October 2013, and discussions with delegates at these conferences to obtain input and suggestions for the improvement of the proposed 'tools';
- The holding of a dedicated workshop at the annual SASAQS Conference in July 2013 to discuss the proposed DSP [at that stage termed a Decision-Support Matrix] and overarching Framework for Wetland Assessment, and to obtain input from workshop attendees (fruitful discussions were held and valuable contributions were received at this workshop);
- The delivery of a presentation and discussion about the proposed 'tools' at the Reference Group meetings for this project that were held in July 2013 and May 2014;
- The delivery of a presentation about the project and the proposed wetland assessment 'tools' at the National Wetlands Task Group meeting held at DWA's offices in Pretoria in November 2013, followed by discussion (valuable input was received from DWA officials at this meeting);
- Internal peer-review of draft versions of the DSP and Framework, and of the accompanying documentation, by members of the project team; and
- The dissemination of draft versions of the DSP and proposed Framework for Wetland Assessment, and the accompanying explanatory documentation, to members of the Review Group for this project and to relevant DWA officials for their consideration and input.

A draft version of the current report was distributed to all members of the Review Group for WRC Project K5/2192, and an opportunity was given to provide comments and suggestions. In addition, a draft version of this document and the accompanying 'tools' were independently reviewed by three external consultants who have been involved in the development and/or testing of some of the more important wetland assessment methods that are currently in use in South Africa.

3 DECISION-SUPPORT FRAMEWORK FOR WETLAND ASSESSMENT

One of the issues that were identified in the review of wetland PES assessment methods (Ollis and Malan, 2014) was the misplaced use of PES assessment methods. Indeed, it is evident that PES assessment tools have, at times, been inappropriately used to ascertain the functional value or conservation importance of a wetland (or some other aspect). This has led to confusion and the perception that PES assessment methods are not adequate when, in reality, the incorrect type of wetland assessment 'tool' has been applied. Such confusion and inappropriate application of the existing PES assessment methods in South Africa was one of the main motivating factors behind the development of the proposed Framework for Wetland Assessment as an additional deliverable in the current project. It is anticipated that the Framework that has been developed will minimise the incorrect application of wetland assessment tools, by guiding an assessor through the various steps that should typically be followed before and after conducting a wetland assessment, and by elucidating the different types of wetland assessments that can be undertaken.

3.1 Description of the Framework and Explanation of the Steps

The decision-support Framework for Wetland Assessment in South Africa (see Figure 1, below) summarises the process that is typically followed in the cycle of wetland identification, mapping (delineation), classification (typing), assessment, management and monitoring into five generic steps. Each step in the Framework is sequentially described in the sub-sections below. For each step, a short description or list of key references is given for relevant methods and/or guideline documents that currently exist, where applicable.

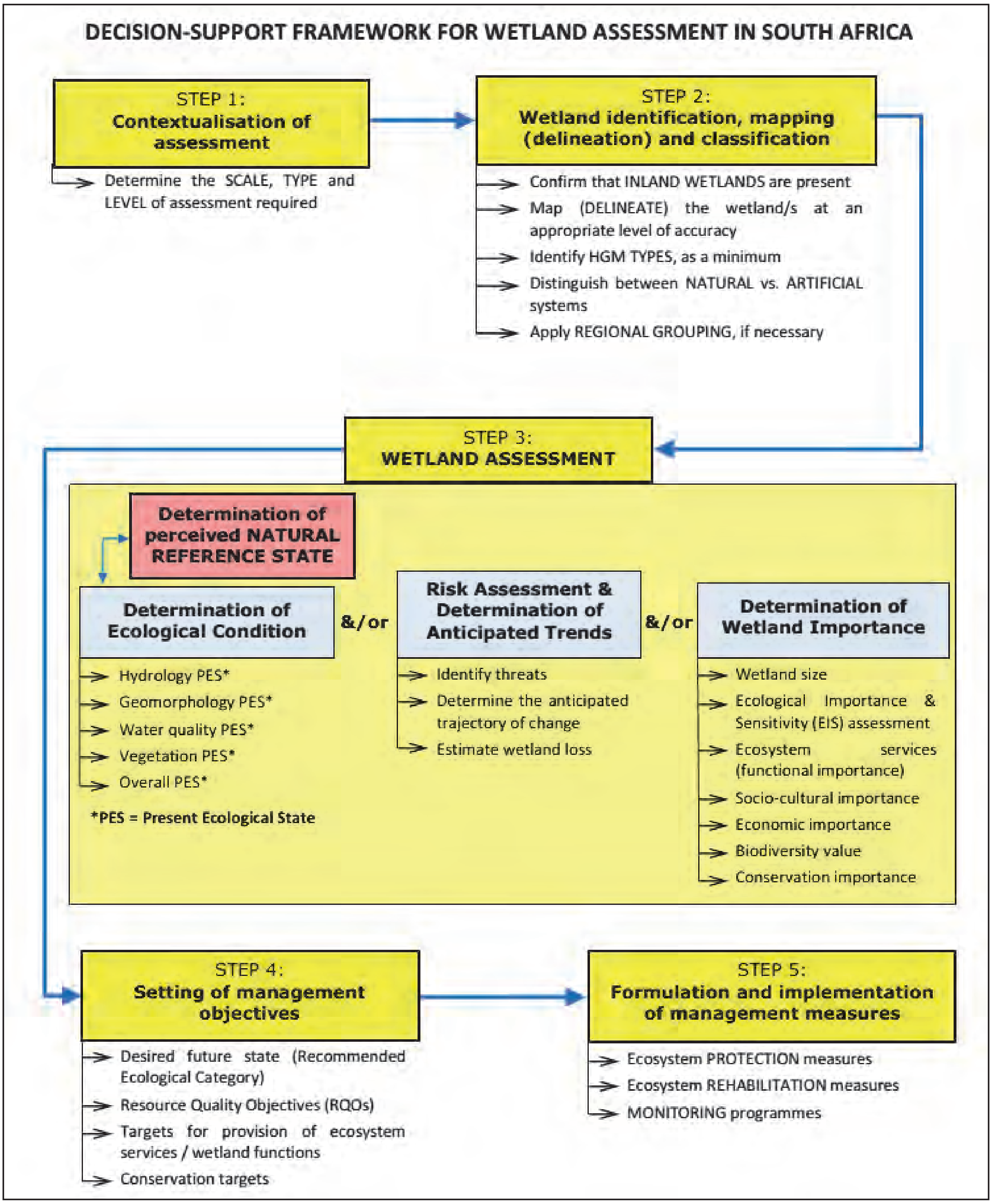

Figure 1: The proposed decision-support Framework for Wetland Assessment in South Africa

Whilst the steps in the Framework would generally be completed in a sequential manner, it is important to note that this would not always be the case. In reality, the steps are iterative and inter-related. In certain situations, a step in the process may need to be "re-visited" after completing a subsequent step – for example, the level of assessment (as determined in Step 1) may be dependent on the HGM type of the wetland that is being assessed (as determined in Step 2) for particular types of assessments. It is also important to note that it will not always be necessary to complete all the steps in the Framework; for example, in many cases a wetland study would stop at Step 3 (wetland assessment) or even at Step 2 (wetland delineation and classification), and it would not be necessary to complete Steps 4 or 5. At the same time, it is important to bear in mind that the preceding steps in the Framework typically need to be completed before a later step is initiated – for example, the management actions in Steps 4 and 5 generally require at least some of the activities in Steps 1 to 3 to be completed first.

The proposed decision-support Framework for Wetland Assessment in South Africa is presented again, for ease of reference, in ***Appendix 1*** *of the current report.*

3.1.1 Step 1: Contextualisation of assessment

Before a wetland assessment is initiated, the context and purpose of the assessment should be taken into consideration. At this stage, the *scale, type and level of assessment* should be determined. This will assist in selecting the most appropriate methods to use in the subsequent steps of the process.

One of the most important things to determine, upfront, is the *spatial scale of the assessment* that is required because this plays a major role in dictating what the most appropriate approach would be to follow. For example, for broad-scale initiatives, a largely desktop-based approach, with limited ground-truthing and a relatively low level of confidence or accuracy, would generally be followed but such an approach would usually be inappropriate for a site-specific study. The spatial scale can vary from a national (or supra-national) scale, to a regional or sub-regional scale (as in many fine-scale conservation plans), catchment scale, or at the scale of an individual wetland or even a particular portion of a wetland. Some assessment methods are only applicable at a wetland or site-specific scale, whereas other methods are specifically designed for broader-scale application or can be adapted for such use. These details are addressed in the sub-section of the current report that deals with the wetland assessment step (Section 3.1.3).

There are three broad *types of wetland assessment* that can be undertaken, namely (1) determination of the ecological condition or Present Ecological State (PES); (2) risk assessment and determination of anticipated trends; and (3) determination of wetland importance. In the majority of cases, it should be possible to determine at the start of a process which types of assessment are going to applicable. This is because the type of assessment required is, generally, dictated by the objectives of the particular wetland study that is being undertaken. For example, if the objectives of a study are to assess the ecological integrity of the wetlands within a certain area and to recommend rehabilitation measures for the degraded wetlands, then an assessment of the PES would be critical but an assessment of wetland importance may not be necessary. In a different situation, the main objective of a study may be to identify the wetlands that are of greatest functional value and/or conservation importance in a certain area, in which case an assessment of wetland importance (specifically of the provision of ecosystem services and of the overall conservation importance) would be most critical and an assessment of the PES may not be necessary. If an EcoClassification study is being undertaken, PES and Ecological

Importance & Sensitivity (EIS) assessments would always need to be undertaken as the basis for setting the Recommended Ecological Category (REC) for a wetland.
It is important to note that PES assessments are not applicable to artificial wetland systems because there is no natural reference state that can be used as the basis for such an assessment. This highlights a situation where Step 1 may need to be "revisited" after applying Step 2 of the Framework, i.e. if the type of assessment was determined to be a PES assessment in Step 1 but the classification of a wetland in Step 2 revealed that a particular wetland was artificial, then the need for a PES assessment would need to be reconsidered. Although an assessment of the ecological condition of an artificial wetland is not appropriate, many artificial wetland systems can be exceptionally valuable, from a functional (ecosystem service provision) and/or biodiversity perspective for example. There is thus often a need for an assessment of other aspects (such as the risks to the ecological functioning of the wetland or of its importance), instead of an assessment of PES, in the case of artificial systems.

The *level of detail required in a wetland assessment* will be determined, to a large degree, by the context of the study. For example, if an assessment of wetland PES is being conducted for a comprehensive Reserve Determination study for a particular wetland, then the PES assessment would need to be undertaken at a high level of detail with a relatively high degree of confidence. The methods required for Reserve studies must have a very high degree of accuracy and repeatability. Available data, time and budget are also considerations that should be taken into account in determining the most appropriate level of assessment – limited data may preclude rapid studies, whereas limited time/budget may lean the studies towards more rapid approaches (DWA, 2013). Four levels of detail are recognised by the Department of Water Affairs (DWA), in the context of Reserve determination studies – desktop, rapid, intermediate, and comprehensive levels. Increasing levels of confidence, and increasing amounts of time and resources, are associated with each successive level.

In the context of DWA's Resource Directed Measures (RDM) – collectively comprising of the NWRCS, the Reserve, and Resource Quality Objectives – it is recommended that the 'Guideline for identifying appropriate levels of Resource Protection Measures for Inland Wetlands' (DWA, 2013) be consulted for guidance in determining the appropriate level and type of Resource Directed Measures to be applied. This guideline recognises that the type of Resource Directed Measures that can be appropriately applied to wetland water resources is highly dependent on the type of wetland system that is being considered, since not all RDM methods apply to the various HGM wetland types. The first step in implementing the guideline is thus the determination of the primary (dominant) HGM wetland type in question, which forms part of wetland classification in Step 2 of the Framework for Wetland Assessment. This highlights another situation where the initial determination of the type and level of assessment in Step 1 may need to be "revisited" after the HGM types have been identified in Step 2.

Depending on the type of wetland that a RDM study intends to focus on, the DWA (2013) guideline provides a look-up table that indicates what type of RDM study is applicable for different purposes and for different levels of assessment. For example, the guideline indicates that comprehensive-level Reserve determination studies are generally not necessary for unchannelled valley-bottom wetlands or pans (a specific type of depression), and that Reserve determination studies at any level are generally not applicable to seeps. According to the guideline document, EcoStatus determination (i.e. PES assessment) and the setting of Resource Quality Objectives (RQOs) are potentially applicable to all wetland HGM types. For each HGM type, the DWA (2013) guideline also provides a rather convoluted tabular decision tree to aid in the selection of the most appropriate level of RDM assessment for the specific wetland and the water uses under consideration. The HGM-specific decision trees take into account the type of Water Use Licence Application (WULA) (consumptive vs. non-consumptive), the duration of surface disturbance (for non-consumptive water uses), the level of flow reduction (for consumptive water uses), the importance of the wetland, and the potential impact of the water use on vegetation, water quality and (for seeps only) subsurface inflows to the wetland. Clearly, the application of the specific guidelines provided by DWA (2013) for identifying the most appropriate type and level of RDM for particular wetland types requires completion of some of the activities in both Steps 2 and 3 of the Framework for Wetland Assessment developed as part of the current project (including an assessment of risks and determination of wetland importance).

3.1.2 Step 2: Wetland identification, mapping (delineation) and classification (typing)

One of the first steps that need to be taken for any study or management initiative relating to wetlands, once the context has been established, is to confirm that the ecosystems in question are actually wetlands. The most cited legal definition of a wetland in South Africa is the one contained in the National Water Act (Act No. 36 of 1998) (NWA) whereby, "*'wetland' means land which is transitional between terrestrial and aquatic systems, where the water table is usually at, or near the surface, or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support, vegetation adapted to life in saturated soil.*" It is thus recommended that this definition be used as the basis for establishing whether a particular ecosystem is a wetland or not. Other types of aquatic ecosystems that occur in South Africa, which are not wetlands according to the NWA definition, include rivers, open waterbodies (such as lakes or any other permanently inundated 'lentic' system) and marine ecosystems.

The identification of wetlands is often coupled with the delineation of the outer edge of ecosystems confirmed to be wetlands and/or the provision of a broad description of the most characteristic features of the areas identified to be wetlands (i.e. wetland characterisation). The official procedures prescribed by DWA for the identification and delineation of wetlands in South Africa are set out in 'A Practical Field Procedure for Identification and Delineation of Wetlands and Riparian Areas' (DWAF, 2005), and in the as-yet unpublished (DWAF, 2008a) update of this document. Other useful guideline documents for the identification and delineation of wetlands in South Africa include:

- An introduction to wetland hydrology, soils and landforms (Kotze, 1996).
- Guidelines for delineating the boundaries of a wetland and the zones within a wetland in terms of the South African Water Act (Marneweck and Kotze, 1999), as included in the original set of RDM documents for wetland ecosystems (DWAF, 1999a).

- Application of the Department of Water Affairs and Forestry (DWAF) wetland delineation method to wetland soils of the Western Cape (Job, 2009), which includes guidance on how to deal with wetland identification and delineation in sandy soils.
- The assessment of temporary wetlands during dry conditions (Day et al., 2010), which includes guidelines and lists of indicators that can be used to identify wetlands in the more arid parts of South Africa.
- Wetlands Delineation Manual of the US Army Corps of Engineers (Environmental Laboratory, 1987), which is one of the key guideline documents from the United States that is referred to internationally and which informed the development of all the guidelines produced in South Africa to date.

The above-mentioned guideline documents deal mostly with the identification and delineation of wetlands at a site-specific scale on the basis of field indicators. For initiatives that are undertaken at a broader spatial scale (such as national or regional conservation planning exercises), however, the identification and delineation of wetlands is largely carried out on a desktop basis, typically with a limited amount of field-based ground-truthing. In these cases, the field procedures for the identification and delineation of wetlands are generally not followed; instead, wetlands are mapped largely on the basis of visual (or automated, rule-based) interpretation of remote sensing imagery (e.g. satellite images or aerial photographs) using Geographical Information Systems (GIS). It is obviously possible to identify and delineate a lot more wetlands and to cover a larger geographical area using technologically advanced, desktop-based methods. At the same time, it is important to bear in mind that there will always be a lower level of accuracy and confidence in the mapping of wetlands following such an approach, compared to wetland mapping that is done through the use of field-based wetland identification and delineation techniques. The approach that is followed for the delineation of wetland boundaries should always be appropriate to the accuracy requirements of the end use (SANBI, 2012).

Once the wetlands that one is dealing with have been identified and delineated, at an appropriate level of accuracy, the next step (or concurrent step) that is generally taken is to classify the type/s of wetland that are present. It is important to recognise the difference in the use of the word ‘classification’ (or the phrase ‘classification system’), as used here, and that set out in the NWA, whereby ‘classification’ refers specifically to the process of categorising water resources into management classes, based on their present ecological condition and a number of other criteria, as part of a prescribed national Water Resource Classification System (see DWAF, 2007). In the current report and in the Framework for Wetland Assessment, the more commonly understood meaning of ‘classification’ (and ‘classification system’) has been assumed, and not the use of the term as adopted by the NWA.

It is recommended that wetlands are classified using the Classification System for Wetlands and other Aquatic Ecosystems in South Africa developed by SANBI (see User Manual for Inland Systems compiled by Ollis et al., 2013). Applying this classification system, following the guidance provided in the User Manual, will also assist in confirming whether a particular aquatic ecosystem is a wetland. When applying the SANBI Classification System to inland wetlands (using Ollis et al., 2013), it is recommended that, as a minimum, the HGM types making up each wetland are determined (at Level 4A of the Classification System) and each wetland is categorised as natural or artificial (using the 'Natural vs. Artificial descriptor' at Level 6). This will provide some of the critical information required for later steps in the Framework. Ideally, as much information as possible should be captured using the six 'levels' of the Classification System because this will assist in gaining a better understanding of the key characteristics of a particular wetland.

For certain applications, especially national- or regional-scale conservation planning initiatives, it would be necessary to apply some sort of regional grouping to the wetlands that have been identified and delineated within the study area, in addition to the classification of HGM types. In the SANBI Classification System (Ollis et al., 2013), this is catered for at Level 2 ('regional setting') and involves the selection of an appropriate spatial framework. As an example, for the National Freshwater Ecosystem Priority Areas (NFEPA) project, "wetland vegetation groups" derived by the grouping of vegetation types from the most recent vegetation map for South Africa (after Mucina and Rutherford, 2006) were used as the spatial framework to generate a national list of wetland types.

A guideline document entitled 'Wetland Mapping Guidelines for South Africa' has been produced by SANBI (2012). This document actually provides nationally-applicable guidelines for capturing and recording standardised spatial wetland information, rather than guidelines for wetland mapping *per se*. More specifically, the guideline is essentially a spreadsheet-based tool for recording (a) the procedures used to map a wetland boundary (and the spatial scale and inherent accuracy of the mapping); and (b) detailed attribute information relating to the wetland characteristics. The guideline is designed to record both the tool(s) and outputs used to map and describe the features of a wetland, with the reporting structure for attribute information based on the various levels of the National Wetland Classification System (after SANBI, 2009). It is applicable to both the desktop- and field-based mapping (delineation) and classification of wetlands, at a range of different wetland mapping scales (from individual sites to catchments or regions). Application of the tool involves the recording of different combinations of spatial and non-spatial attribute information in the spreadsheet that is provided, depending on the level of detail required. Three levels are recognised, namely: (1) Basic Level (mapping of wetland presence/absence); (2) Intermediate Level (for conservation planning); or Detailed Level (for site-specific wetland assessment). The guideline document (SANBI, 2012) stresses that the most appropriate mapping techniques to be used and the level of wetland site information that should be recorded are primarily informed by the objectives of a particular wetland mapping study (as would be determined in Step 1 of the proposed Framework for Wetland Assessment).

3.1.3 Step 3: Wetland assessment

After the wetlands of interest have been identified, mapped (delineated) and classified into wetland types, they can then be assessed. As explained in Step 1 (see Section 3.1.1), the most appropriate types and levels of assessment for a particular situation, and the spatial scale of the assessments, would typically be governed by the context and purpose of the assessment. The three broad types of wetland assessment (i.e. PES assessment, risk assessment and prediction of trends, and assessment of wetland importance) are separately discussed in the sub-sections below. It is important to recognise that in some cases all three types of assessment would be undertaken simultaneously, whereas in other cases only one or two of the broad types of assessment would be applicable or necessary.

(a) Determination of ecological condition (PES assessment)

Assessment of ecological condition and determination of the PES is only applicable to naturally-occurring wetlands because, as stated previously, the perceived natural reference state cannot be ascertained for an artificially created wetland (it does not exist). At the same time, it is important to remember that the assessment of PES is applicable to highly transformed wetlands that did occur naturally but are now far removed from their natural reference state (e.g. a naturally shallow, seasonally inundated endorheic depression with no inlet channels that has been transformed into a relatively deep, permanently inundated depression with channelised inflows).

The main, nationally-applicable methods that currently exist for the wetland- or site-specific assessment of Wetland PES in South Africa are the original RDM method developed by DWA in 1999 (Duthie, 1999a), the Wetland Index of Habitat Integrity (IHI) method for floodplain and channelled valley-bottom wetlands (DWAF, 2007a), and WET-Health (Macfarlane et al., 2007). A detailed comparison of these three methods was included in the review of wetland assessment methods undertaken for the current project (Ollis and Malan, 2014). All of these methods can be used for determining the PES of individual wetlands (or selected portions of individual wetlands), as long as their inherent limitations are taken into account.

The DSP that has been produced for the current project (see Section 4 of this report and the electronic spreadsheet included as Appendix 2) is a tool that can be applied in the *rapid assessment* of Wetland PES at a wetland- or site-specific scale. This tool relies mainly on the use of the individual modules of the WET-Health "Level 1" and the Wetland-IHI assessment methods to determine the Hydrology, Geomorphology, Vegetation and Water Quality PES of a wetland "assessment unit". The DSP also provides for the derivation of the overall PES of a wetland "assessment unit", with the procedure that is followed dependent on the HGM type that is being assessed. For specific guidance on the selection of the most appropriate PES components and methods that should be used in the context of a Rapid Ecological Reserve study, DWA's *Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)* (Rountree et al., 2013) should be consulted.

For wetland-specific PES assessments that need to be undertaken at a *comprehensive (and possibly intermediate) level of confidence*, the most appropriate tool currently available for such an assessment is probably the WET-Health "Level 2" assessment method. Alternatively, or in support of a WET-Health Level 2 assessment, detailed specialist studies could be conducted on various aspects of a particular wetland if a comprehensive PES assessment is required. Such specialist input could include specific studies on the hydrology/geohydrology, geomorphology, soils, vegetation, and/or water quality of the wetland, as well as bioassessment studies based on the biota associated with the wetland such as diatoms, fish, frogs, invertebrates, birds and/or semi-aquatic mammals.

For studies undertaken at a broader scale, where an estimate of wetland PES is required for multiple wetlands within a particular geographical area (such as a sub-catchment, catchment or region, or even across the country), it is obviously not feasible to apply site-specific wetland PES assessment methods. In these contexts, the PES of wetlands is often modelled (as in the case of the NFEPA project) or based on existing GIS layers that provide very coarse PES estimates for aquatic ecosystems at a Quaternary or Sub-Quaternary Catchment scale. It is important to bear in mind that these broad-scale wetland PES estimates are associated with very low levels of accuracy and confidence, and that the extrapolation of such PES estimates to specific wetlands (e.g. for an environmental impact assessment at a particular site where wetlands are present) is not appropriate.

Irrespective of which method is used, or at what spatial scale and level of detail a PES assessment is undertaken, the outcome is generally the determination of an Ecological Category (from A to F) for the overall ecological condition of the wetlands or "assessment units" within the study area. In the case of PES assessments of individual wetlands, separate Ecological Categories are typically determined for the hydrology, geomorphology, vegetation and possibly water quality components of wetland condition, in addition to the derived Overall Ecological Category for the wetland "assessment unit". It is important to note that the Ecological Categories determined through a PES assessment are (as the name implies) for the *present* ecological condition of the wetland, not the future state (that is dealt with in Step 4 of the Framework) or the previous state (that is taken into account in the assessment of anticipated trends). It is also very important to note that an assessment of PES does not provide an indication of the importance of a wetland, although it may be one of the factors taken into account in the determination of Wetland Importance (dealt with in subsection (c), below).

Determination of the perceived natural reference state

A critical component of any PES assessment, and one which is often omitted, is the determination and description of the perceived natural reference state (as shown in the flow diagram of the Framework for Wetland Assessment presented in Figure 1). The natural reference state offers a 'benchmark' from which change in condition can be evaluated. Interestingly, the importance of this aspect seems to be more entrenched for the assessment of river ecosystems in South Africa than it is for wetland assessment. For example, in the River EcoClassification Manual for EcoStatus Determination (Kleynhans and Louw, 2008), "Determine reference conditions for each component" is explicitly included as the first step in the EcoClassification process. As noted previously, it is not appropriate (or possible) to determine the natural reference state of an artificial system.

There is currently a lack of comprehensive guideline documentation relating specifically to the determination of the natural reference state for South African wetlands. A few guidelines are provided in the WET-Health (Macfarlane et al., 2007) and Wetland-IHI (DWAF, 2007a) manuals, but these are by no means comprehensive. The DSP that has been produced for the current project includes a list of criteria that should be considered in determining the natural reference state of a specific wetland (or wetland "assessment unit") for which a PES assessment is being undertaken (see Section 4.2.4 of the current document). As a minimum, when conducting PES assessments at a site-specific scale, the natural reference state of a particular wetland should be described in terms of its HGM type/s, hydroperiod, hydrological and geomorphological characteristics, water quality characteristics, and the vegetation in and surrounding the wetland. For PES assessments that are undertaken at a broader spatial scale than an individual wetland (e.g. for a catchment or a region), an attempt should be made to gain an understanding of the range of variability in the natural reference state of wetlands in the selected study area, using similar parameters to those typically used to describe the reference state of an individual wetland.

There is clearly a need for the development of scientifically rigorous, comprehensive and user-friendly guidelines for the determination of the natural reference state for wetlands in South Africa, as highlighted in the review of wetland assessment methods by Ollis and Malan (2014). Although determining the natural reference state of a wetland, or of a group of wetlands, is conceptually simple, in practice it is actually a relatively complex and difficult task. The natural reference state is a lot more tangible in situations where a relatively pristine wetland (or group of wetlands) with a very similar hydrogeomorphic setting, underlying geology and topography is available to refer to. However, in many cases one does not have this luxury, particularly in transformed landscapes. Another problem with defining the natural reference state is that the characteristic features of some wetlands are naturally highly variable (for example, there is often a large amount of spatial and temporal variability in the vegetation associated with wetlands that are naturally subject to periodic disturbance of one kind or another). Any guidelines that are developed for assisting with the determination of the natural reference state of wetlands would have to take complexities such as these into account.

(b) Risk assessment and determination of anticipated trends

For many situations, a risk assessment and determination of the anticipated trends needs to be undertaken for a wetland (or for groups of wetlands in studies undertaken at broader spatial scales). For example, this would typically be required in most Environmental Impact Assessment (EIA) and WULA processes involving wetlands.

The River EcoClassification Manual for EcoStatus Determination (Kleynhans and Louw, 2008), which includes "Determination of the trend for each component as well as for the EcoStatus" as an explicit step in the EcoClassification process for rivers, defines 'trend' as "*movement towards or away from the reference state*". This definition is also applicable to the assessment of anticipated trends for wetland ecosystems. An assessment of the anticipated trends in the ecological condition of a wetland generally involves the identification of the current threats to the ecological integrity of the wetland (i.e. a risk assessment) and an estimation of the anticipated trajectory of change.

The WET-Health assessment method explicitly requires an estimation to be made of the anticipated trajectory of change in the ecological integrity of a wetland by taking into account the threats to the wetland and the vulnerability of the wetland to particular impacts (i.e. by conducting a risk assessment). This evaluation is undertaken separately for the hydrology, geomorphology and vegetation components of wetland PES, and the anticipated trajectory of change is categorised into one of five “change classes”: substantial improvement (↑↑), slight improvement (↑), stable/remains the same (→), slight deterioration (↓), or substantial deterioration (↓↓). The overall “health” of the wetland is then reported for each module by jointly presenting the PES and likely Trajectory of Change. It is recommended that the WET-Health “change classes” be used to describe the anticipated trend in the PES of the various components of wetland PES, even if a WET-Health assessment is not being conducted.

In the WET-Health manual (Macfarlane et al., 2007), potential sources of change are listed for each component of assessment (in the individual sections for hydrology, geomorphology and vegetation), to assist the assessor in determining the “change class” for the anticipated trajectory of change for each module. The WET-Health manual thus includes some guidance for assessing risks and the anticipated trends in the PES of a wetland, and it highlights the point that (as in the case of the PES itself) the future threats to the ecological state of a wetland may arise from activities in the catchment upstream of the HGM unit and/or from within the wetland itself, or even from processes downstream of the wetland.

The WET-SustainableUse tool (Kotze, 2010) provides a means of assessing the risk that the current use(s) of a particular resource within a wetland are posing to the present ecological condition of the wetland, and predicting how future use(s) of that resource may potentially impact upon the ecological condition of the wetland and its ability to deliver ecosystem services. This tool focuses specifically on the grazing of wetlands by livestock, the cultivation of wetlands, and the harvesting of wetland plants for crafts and thatching. It enables an assessment to be made of the extent to which these uses of a wetland have altered the following five components of wetland condition: (1) the distribution and retention of water; (2) the erosion of sediment; (3) the accumulation of soil organic matter; (4) the retention of nutrients; and (5) the natural species composition of the vegetation in the wetland. WET-SustainableUse also provides guidance for setting “Thresholds of Potential Concern” for each of the five components of wetland condition, which define what are considered to be the limits of sustainable use for the wetland.

In the context of an EIA process, the potential impacts on wetlands that could result from a proposed development (or from several possible development alternatives) are identified, and an assessment is typically made of the predicted effect and significance of these impacts on the wetlands. This could be viewed as an assessment of the risks posed by the proposed development and of the anticipated trends in the ecological condition of the wetlands that are likely to result from the implementation of the development.

(c) Determination of wetland importance

There are several different aspects that can be evaluated to categorise the relative importance of wetlands, depending on the context and purpose of an assessment. These include assessments of:

- relative wetland size;
- the degree to which a wetland provides various ecosystem services (sometimes referred to as a ‘functional assessment’ or an assessment of wetland functions);
- the Ecological Importance & Sensitivity (EIS) of a wetland;

- the biodiversity importance/value of a wetland;
- the conservation importance/value of a wetland;
- the socio-cultural importance/value of a wetland; and/or
- the economic importance/value of a wetland.

The assessment of wetland importance is relevant to both natural and artificial wetland systems. It is a particularly critical step towards the formulation of management objectives for artificial systems because an assessment of the PES of such systems is not applicable (due to the lack of a natural reference state, as explained previously).

<u>Assessment of the provision of ecosystem services ('functional assessment')</u>

The most well-developed method currently available in South Africa for the qualitative assessment of the ecosystem services provided by a wetland is arguably WET-EcoServices (Kotze et al., 2007). This is an updated version of the Wetland-Assess tool (Kotze et al., 2004) for the qualitative assessment of the functional value of wetlands, which was loosely based on some of the concepts relating to the functional assessment of wetlands in South Africa that were put forward in the Wetland-Use tool (Kotze et al., 1994, 2000) and through the UKZN research project on the development of decision-support tools for wetland management (Kotze, 1999).

The WET-EcoServices assessment method is centred around an HGM approach to wetland classification, using the same classification system as WET-Health (Macfarlane et al., 2007). A WET-EcoServices assessment involves the rating of 15 potential ecosystem benefits, which include both direct and indirect benefits that can be derived from wetlands. The composite scores derived for each of the 15 specified ecosystem services are interpreted using rating guidelines to categorise the degree to which each ecosystem service is likely to be provided by the wetland, into one of five possible categories (low, moderately low, intermediate, moderately high, or high). A truncated version of the WET-EcoServices assessment method has been incorporated into the procedure developed by Rountree and Kotze (2013) for determining the overall importance of a wetland in the context of wetland RDM (Rountree et al., 2013), as explained below (under 'EIS assessment'). WET-EcoServices can (and should), however, still be used as a stand-alone tool for the qualitative assessment of ecosystem service provision by a wetland.

A new tool was recently developed for the rapid assessment of ecosystem services in the context of well-being, resilient social-ecological systems and Strategic Adaptive Management, as part of a WRC project entitled "Livelihoods and wetlands: restoration of wetland social-ecological processes to sustain the ecosystem services necessary to support livelihoods" (Project No. K5/1986.1) (pers. comm., Dr Donovan Kotze, UKZN). This tool aims to provide a means of rapidly assessing the regulating services and direct benefits (provisioning services) provided to the users of inland wetlands in South Africa. It has been designed to generate preliminary scores for several ecosystem services, as inferred from the HGM type/s and the broad vegetation types (including cultivated lands) present in a wetland. In the overall results, so-called "hectare-equivalents of ecosystem service supply" are calculated for each ecosystem service that is included in the assessment method. This new tool, which is due for release sometime in 2014, represents a novel addition to the main tools currently available for assessing the provision of ecosystem services by wetlands in South Africa.

Ecological Importance & Sensitivity (EIS) assessment

One of the earliest, formalised methods for categorising the EIS of a wetland in South Africa was the Intermediate Ecological Reserve EIS method for [floodplain] wetlands (Duthie, 1999b), which formed part of the DWAF (1999) documentation on Resource Directed Measures for Wetland Ecosystems (Version 1). This assessment method was originally developed for determining the EIS of floodplain wetlands but was later prescribed for broader application to all palustrine wetland types, except endorheic depressions (pans), according to the original Procedure for Intermediate Determination of RDM for Wetland Ecosystems (Duthie, 1999c). The wetland EIS method of Duthie (1999b) was based on, and is very similar to, the river EIS method of Kleynhans (1999). To conduct the assessment, a series of determinants for EIS are assessed and the median score is used to assign an Overall EIS Class according to four possible categories (very high, high, moderate, and low/marginal EIS).

The wetland EIS assessment method of Duthie (1999b) has been superseded by an adaptation of the method developed for the updated Wetland RDM Procedures, as described below. Ongoing use of the 1999 wetland EIS method is thus not recommended.

According to the Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0) (Rountree et al., 2013), when evaluating a water resource and providing recommendations for the future preliminary management class (or Recommended Ecological Category), the NWA requires consideration of the Ecological Importance of the resource (ecosystems and biodiversity), the ecological functions provided by the resource, and the role of the water resource in providing basic human needs. A rapid scoring system was developed by Rountree and Kotze (2013) for Wetland Importance assessment in the RDM context, to simultaneously evaluate (1) Ecological Importance and Sensitivity (after Kleynhans, 1999 and Duthie, 1999b); (2) Hydrological Functions (after Kotze et al., 2007); and (3) Direct Human Benefits (after Kotze et al., 2007). The prescribed procedure for implementing the integrated Wetland Importance assessment method is for a specialist team to complete the three scoring sheets (as shown in Figure 2, below), providing written motivations for the scores assigned to each criterion that must be rated and a confidence rating for each score. The highest score of the three assessments is then used to derive the overall importance category for a wetland (i.e. very high, high, moderate, or low/marginal).

Ecological Importance and Sensitivity	Score (0-4)	Confidence (1-5)	Motivation	Guideline
Biodiversity support	A (average)	(average)		
Presence of Red Data species	a			*Endangered or rare Red Data species presence*
Populations of unique species	a			*Uncommonly large populations of wetland species*
Migration/breeding/feeding sites	a			*Importance of the unit for migration, breeding site and/or a feeding.*
Landscape scale	B (average)	(average)		
Protection status of the wetland	b			*National (4), Provincial, private (3), municipal (1 or 2), public area (0-1)*
Protection status of the vegetation type	b			*SANBI guidance on the protection sutatus of the surrounding vegetation*
Regional context of the ecological integrity	b			*Assessment of the PES (habitat integrity), especially in light of regional utilisation*
Size and rareity of the wetland type/s present	b			*Identification and rareity assessment of the wetland types*
Diversity of habitat types	b			*Assessment of the variety of wetland types present within a site.*
Sensitivity of the wetland	C (average)	(average)		
Sensitivity to changes in floods	c			*floodplains at 4; valley bottoms 2 or 3; pans and seeps 0 or 1.*
Sensitivity to changes in low flows/dry season	c			*Unchannelled VB's probably most sensitive*
Sensitivity to changes in water quality	c			*Esp naturally low nutrient waters - lower nutients likely to be more sensitive*
ECOLOGICAL IMPORTANCE & SENSITIVITY	(max of A, B or C)	(average of A, B or C)		

		Hydro-Functional Importance	Score (0-4)	Confidence (1-5)	Motivation	Guideline
Regulating & supporting benefits		**Flood attenuation**				*The spreading out and slowing down of floodwaters in the wetland, thereby reducing the severity of floods downstream*
Regulating & supporting benefits		**Streamflow regulation**				*Sustaining streamflow during low flow periods*
Regulating & supporting benefits	Water Quality Enhancement	*Sediment trapping*				*The trapping and retention in the wetland of sediment carried by runoff waters*
Regulating & supporting benefits	Water Quality Enhancement	*Phosphate assimilation*				*Removal by the wetland of phosphates carried by runoff waters, thereby enhancing water quality*
Regulating & supporting benefits	Water Quality Enhancement	*Nitrate assimilation*				*Removal by the wetland of nitrates carried by runoff waters, thereby enhancing water quality*
Regulating & supporting benefits	Water Quality Enhancement	*Toxicant assimilation*				*Removal by the wetland of toxicants (e.g. metals, biocides and salts) carried by runoff waters, thereby enhancing water quality*
Regulating & supporting benefits	Water Quality Enhancement	*Erosion control*				*Controlling of erosion at the wetland site, principally through the protection provided by vegetation.*
Regulating & supporting benefits		**Carbon storage**				*The trapping of carbon by the wetland, principally as soil organic matter*
HYDRO-FUNCTIONAL IMPORTANCE			(average score)	(average confidence)		

	Direct Human Benefits	Score (0-4)	Confidence (1-5)	Motivation	Guideline
Subsistence benefits	*Water for human use*				*limited abstraction by a very few houses and lodges dotted around the lake*
Subsistence benefits	*Harvestable resources*				*very limited, if any, subsistence offtake*
Subsistence benefits	*Cultivated foods*				*no cultivation/agriculture in the wetland*
Cultural benefits	*Cultural heritage*				*very limited, if any*
Cultural benefits	*Tourism and recreation*				*very important recreational area*
Cultural benefits	*Education and research*				*important study area - protected area with unique wetland types*
DIRECT HUMAN BENEFITS		(average score)	(average confidence)		

Figure 2: Copies of the tables used in the *Rapid Ecological Reserve Determination Procedures for Wetlands* to determine Wetland Importance through assessment of wetland EIS (top table), hydro-functional importance (middle table) and direct human benefits (bottom table) [from Rountree and Kotze (2013)]

Assessment of conservation importance

The Freshwater Consulting Group (FCG) have developed a simple approach for the rapid categorisation of the conservation importance/value of a wetland, or any other inland aquatic ecosystem, on the basis of a list of criteria that are indicative of low, moderate or high conservation importance (see Table 1, below). When using this approach, which was developed in the context of EIA (after Ewart-Smith and Ractliffe, 2002), the highest category applicable to a particular wetland, based on any one criterion, is the one accorded the ecosystem as a whole. This method of assigning a conservation importance category to a wetland is intended to be applied by suitably qualified and experienced wetland ecologists, and it requires a written explanation of the criteria that are applicable to the wetland being assessed.

Table 1: List of criteria developed by the Freshwater Consulting Group (FCG) to assign low, moderate or high conservation importance to wetlands and other inland aquatic ecosystems (note that the highest category applicable to an aquatic ecosystem, based on any one criterion, is the one accorded the ecosystem as a whole) [after Ewart-Smith & Ractliffe (2002)]

Low importance: • does not provide ecologically or functionally significant aquatic habitat because of extremely small size or relatively high degree of degradation; and/or • of extremely limited importance as a corridor between systems that are themselves of low conservation importance.
Moderate importance: • provides ecologically significant aquatic habitat (e.g. locally important aquatic ecosystem habitat types); and/or • fulfils some functional roles within the catchment; and/or • acts as a corridor for fauna and/or flora between other aquatic ecosystems or ecologically important habitat types; and/or • supports (or is likely to support) fauna or flora that are characteristic of the region and/or provides habitat to indigenous flora and fauna; and/or • is a degraded but threatened habitat type; and/or • is degraded but has high potential for rehabilitation; and/or • has been identified as a Freshwater Ecosystem Priority Area (FEPA) in terms of the National Freshwater Ecosystem Priority Areas (NFEPA) project or as an aquatic Critical Biodiversity Area (CBA) in terms of a regional biodiversity conservation plan, but is in relatively poor present ecological condition; and/or • has been identified as an aquatic Critical Ecosystem Support Area (CESA) in terms of a regional biodiversity conservation plan; and/or • functions as a buffer area between terrestrial systems and more ecologically important aquatic ecosystems; and/or • is upstream of aquatic ecosystems that are of high conservation importance.
High importance: • supports a high diversity of indigenous plant/animal species; and/or • supports, or is likely to support, red data species; and/or; • supports relatively undisturbed aquatic communities; and/or • forms an integral part of the habitat mosaic within a landscape; and/or • is representative of a regionally threatened/restricted habitat type; and/or • has been identified as a FEPA in terms of the NFEPA project or as an aquatic CBA in terms of a regional biodiversity conservation plan, and is in fair to good present ecological condition; and/or • has a high functional importance (e.g. nutrient filtration; flood attenuation) in the catchment; and/or • is of a significant size (and therefore provides significant aquatic habitat, albeit degraded or of low diversity).

Approaches to the assessment of conservation importance such as that described above are appropriate for categorising the conservation importance of individual wetlands on a case-by-case basis. In the context of broader-scale initiatives (such as regional- or national-level biodiversity conservation planning), however, a different approach would need to be followed because one is dealing with many wetlands at the same time. The approach that is typically taken for such studies at a broader spatial scale is to develop criteria for assigning conservation importance ratings to relatively large geographical units of analysis (such as Quaternary Catchments or sub-catchments) or to groups of wetlands with similar characteristics (e.g. of the same vegetation type and level of threat).

<u>Assessment of socio-cultural and economic importance</u>

The following tools/protocols were developed through the WRC-funded Wetland Health and Importance Research Programme for the assessment of the socio-cultural and economic importance/value of wetlands:

- WRC Report TT 442/09: *A tool for the assessment of the livelihood value of wetlands* (Turpie, 2010).
- WRC TT 443/09: *A protocol for the quantification and valuation of wetland ecosystem services* (Turpie and Kleynhans, 2010).

These documents and the associated tools should be referred to if an assessment of the socio-cultural and/or economic importance of a wetland (or of multiple wetlands within a particular geographical area) is required.

3.1.4 Step 4: Setting of management objectives

Once an assessment has been made of the PES, the risks and anticipated trends, and/or the importance of a wetland (or group of wetlands) in Step 3 of the proposed Framework for Wetland Assessment, the management objectives for the wetland (or group of wetlands) can be determined using the information gained through the assessment phase.

Some examples of management objectives that can be determined in Step 4 include:

- Determination of the Recommended Ecological Category (REC) on the basis of the Wetland PES and Wetland Importance categories determined in Step 3, as required by DWA's EcoClassification process in the context of RDM (e.g. see Rountree et al., 2013) [not applicable to artificial wetlands].
- Setting of Resource Quality Objectives (RQOs) for wetlands in the context of RDM, following DWA's prescribed procedures to develop RQOs (DWA, 2011) and the associated 'Resource Unit Prioritisation' and 'Resource Unit Evaluation' Tools for wetlands.
- Setting of an Ecological Management Class (EMC) in terms of DWAF's (2007) NWRCS [not applicable for artificial wetlands].
- Setting of the vision for a wetland, as per DWA's water resource management cycle (presented, for example, in Rountree et al., 2013).
- Setting of rehabilitation objectives for a wetland, following guidelines such as those given in the WET-RehabPlan document (Kotze et al., 2009).
- Setting of targets for the provision of ecosystem services (i.e. functions) by wetlands. The detailed information about various wetland ecosystem services included in the WET-

EcoServices manual (Kotze et al., 2007) can be used to guide the formulation of such targets.
- Identification of priority wetlands for rehabilitation and/or conservation (e.g. see Rountree et al., 2009), and the setting of wetland conservation targets within a specified geographical area[4].

3.1.5 Step 5: Formulation and implementation of management measures

To give effect to the management objectives for a wetland (as determined in Step 4), specific measures need to be formulated for the protection, rehabilitation and/or monitoring of wetlands. These management measures must then be implemented.

Examples of some of the management measures that can be used for wetlands (in Step 5 of the proposed Framework) include:

- The determination of buffer widths and the establishment of buffer areas around wetlands. The Institute of Natural Resources are in the process of finalising a 'tool' for the determination of recommended wetland buffer widths, as a joint DWA-WRC project.
- The formulation and implementation of mitigation measures for potential development-related impacts on wetlands, typically in the context of an EIA[5].
- The formulation and implementation of rehabilitation measures for degraded wetlands, starting with the compilation of a Wetland Rehabilitation Plan. Generic wetland rehabilitation planning guidelines are provided in the WET-RehabPlan document (Kotze et al., 2009), while the WET-RehabMethods document (Russell, 2009) provides detailed guidance for the selection of the most appropriate wetland rehabilitation measures.
- The formulation and implementation of wetland offsets, as a last resort in situations where the *in situ* protection and/or rehabilitation of a particular wetland is not feasible. National guidelines for wetland offsets have been developed by DWA and SANBI, 2013).
- Determination of the Ecological Reserve or Environmental Water Requirements (EWR) for a wetland in the context of RDM (e.g. see guidelines for Rapid Ecological Reserve determinations for wetlands provided by Rountree et al., 2013), and implementation of the 'operating rules' formulated through the Reserve/EWR determination process.
- Setting of Ecological Specifications (EcoSpecs) for a wetland, against which the ecological condition of the wetland can be monitored in the context of DWA's EcoClassification process.
- Compilation and rollout of an Implementation Plan for wetland RDM (as recommended by Rountree et al., 2013).
- Formulation and implementation of conditions for water use authorisations, in the context of a WULA process.

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[4] Conservation planning and the identification of priority wetlands require the various steps of the proposed Framework for Wetland Assessment to be carried out at a relatively broad spatial scale.
[5] In an EIA, the formulation of recommended mitigation measures is generally completed together with an assessment of the significance of potential impacts on a wetland that could result from a proposed development (impact significance is typically rated "with mitigation" and "without mitigation" for a number of proposed development alternatives).

An important management measure for wetlands is to monitor progress against the management objectives that were determined in Step 4. This would typically involve the formulation and implementation of wetland monitoring programmes at appropriate levels of detail. There is currently a WRC project underway to develop the framework for a national wetland monitoring programme in South Africa (WRC Project K5/2269). It is anticipated that, besides consolidating information about the various wetland monitoring programmes currently in existence across the country, one of the outcomes of this project will be the provision of guidelines and 'tools' for the design and rollout of nationally-coordinated wetland monitoring initiatives in the future. At a more localised level, the WET-RehabEvaluate document (Cowden and Kotze, 2009) provides a framework and step-by-step guidelines specifically for the monitoring and evaluation of wetland rehabilitation projects. For a different purpose but for application relating to monitoring and evaluation at a similar spatial scale, the WET-EffectiveManage tool (presented in Kotze et al., 2009b and Appendix 4 of Kotze, 2010) provides a framework that can be used to evaluate how effectively a particular wetland is being managed. Application of this tool simply involves the rapid scoring of 15 key criteria/questions by selecting the most appropriate answer in each case, which then automatically assigns a score (of 0, 1, 2 or 3) to each criterion/question.

3.2 Explanation of how to use the Framework

The proposed Framework for Wetland Assessment is used by simply following the steps in the Framework, from Step 1 to Step 5, when dealing with any study or intervention that involves wetlands. The guidance provided in the descriptions above, and the guidelines or other documents that are referred to, should be consulted when applying the Framework. It is also important to provide an indication of the level of confidence in the 'results' generated at each step along the process outlined in the Framework.

When using the Framework for applications that cover a geographical area instead of an individual wetland (such as regional conservation planning or strategic environmental assessment relating to wetlands), each step in the Framework would need to be applied to a number of wetlands within the area under consideration. For these broader-scale applications of the Framework, the most appropriate methods to use in each step of the process would generally be different to those used for individual wetlands, as explained (where relevant) in the sub-sections above.

A summary of the various tasks associated with each of the steps in the Framework and the recommended methods or guideline documents for each task is presented in Table 2, together with a list of references for the recommended methods/guidelines. For ease of reference, this table is presented again in Appendix 1, together with the Framework. The portion of the table dealing with the determination of wetland PES, which is the focus of the current project and the scope of the Decision-Support Protocol (DSP) that has been produced, is highlighted in grey.

Table 2: Summary table listing the tasks typically associated with each of the steps in the proposed Framework for Wetland Assessment and the recommended methods or guidelines (with references) to use for these tasks [portion of table dealing with wetland PES assessment highlighted in grey]

	Step	Tasks	Recommended methods/guidelines	References
1	**Contextualisation of assessment**	Determine the scale of assessment	n/a	n/a
		Determine the type/s of assessment	*Rapid Reserve determination context*: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
		Determine the level of assessment	*RDM context*: Guideline for identifying appropriate levels of resource protection measures for inland wetlands	DWA (2013)
2	**Wetland identification, delineation and classification**	Wetland identification and delineation	DWA's official guideline for the identification and delineation of wetlands [and riparian areas]	DWAF (2005, 2008)
			Additional guideline documents published in South Africa	Kotze (1996); Marneweck & Kotze (1999); Job (2009); Day et al. (2010)
			Wetlands Delineation Manual of the US Army Corps of Engineers	Environmental Laboratory (1987)
		Wetland mapping (and classification)	SANBI's wetland mapping guidelines (guidelines for capturing and recording standardised spatial wetland information)	SANBI (2012)
		Classification of wetland types	SANBI's Classification System for wetlands and other inland aquatic ecosystems in South Africa	Ollis et al. (2013)
3	**Wetland assessment**	**Determine the Present Ecological State (PES):**		
		- rapid PES assessment	RDM-99 method	Duthie (1999)
			Wetland-IHI (for floodplain and channelled VB wetlands)	DWAF (2008)
			WET-Health (Level 1)	Macfarlane et al. (2007)
			Rapid Reserve determination context: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
			Decision-Support Protocol (DSP) for rapid wetland PES assessment	Ollis et al. (2014) [this report]
		- detailed PES determination	WET-Health (Level 2)	Macfarlane et al. (2007)
		Identify the risks and determine the anticipated trends	WET-Health guidelines for evaluation of the anticipated trajectory of change in hydrology/geomorphology/vegetation PES	Macfarlane et al. (2007)
			WET-SustainableUse	Kotze (2010)
		Determine wetland importance:		
		- Assessment of ecosystem service provision ('functional assessment')	WET-EcoServices	Kotze et al. (2007)
		- Assessment of Ecological Importance & Sensitivity (EIS)	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013), after Kleynhans (1999) and Duthie (1999b)
		- Assessment of hydrofunctional importance	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013), after Kotze et al. (2007)

Step		Tasks	Recommended methods/guidelines	References
		- Assessment of direct human benefits	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013), after Kotze et al. (2007)
		- Assessment of overall Wetland Importance	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013)
		- Assessment of conservation importance	Method developed by FCG for the rapid categorisation of the conservation importance of inland aquatic ecosystems	Ollis et al. (2014) [this report], after Ewart-Smith & Ractliffe (2002)
		- Assessment of socio-cultural and economic importance	A tool for the assessment of the livelihood value of wetlands	Turpie (2010)
			A protocol for quantification and valuation of wetland ecosystem services	Turpie and Kleynhans (2010)
4	**Setting of management objectives**	Determine the Recommended Ecological Category (REC)	*Rapid Reserve determination context*: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
		Set Resource Quality Objectives	Procedures to develop and implement RQOs	DWA (2011)
		Set the Ecological Management Class	National Water Resource Classification System (NWRCS)	DWAF (2007)
		Set wetland rehabilitation objectives	WET-RehabPlan	Kotze et al. (2009a)
		Set targets for provision of wetland ecosystem services	WET-EcoServices document contains useful info	Kotze et al. (2007)
		Set conservation targets and prioritise wetlands for conservation/rehabilitation	WET-Prioritise	Rountree et al. (2009)
5	**Formulation and implementation of management measures**	Determine buffer widths and establish buffer areas around wetlands	DWA-WRC 'tool' for the determination of recommended buffer widths for wetlands (to be published soon)	Macfarlane et al. (in prep.)
		Formulate and implement wetland rehabilitation measures	WET-RehabPlan	Kotze et al. (2009a)
			WET-RehabMethods	Russel (2009)
		Formulate and implement wetland offsets, as a last, if no other options are feasible	National guidelines for wetland offsets	DWA & SANBI (2013)
		Determine the Ecological Reserve and implement the 'operating rules'	*Rapid Reserve determination context*: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
		Set Ecological Specifications (EcoSpecs) for wetlands	Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0) contains a brief description of the process	Rountree et al. (2013)
		Compile and rollout an Implementation Plan for wetland RDM	Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0) contains a brief description of what this entails	Rountree et al. (2013)
		Formulate and implement conditions for wetland-related water use authorisations	[Internal DWA documents]	[not publicly available]
		Monitor wetlands	Documents and 'tools' from WRC project to develop the framework for a national wetland monitoring programme (WRC Project No. K5/2269)	[project still in progress]
			WET-RehabEvaluate for monitoring wetland rehabilitation projects	Cowden & Kotze (2009)
			WET-EffectiveManage for evaluating how effectively a wetland is managed	In: Kotze et al. (2009b); Kotze (2010)

3.3 Anticipated areas of application

It is anticipated that that there is a wide range of potential areas of application for the proposed Framework for Wetland Assessment, due to its generic nature. This includes *inter alia* water resource management areas of application (such as the RDM, EWR/Ecological Reserve, EcoClassification, and NWRC processes of DWA undertaken in terms of the NWA[6]), EIAs and strategic environmental assessments involving wetlands, the wetland component of State-of-Environment reporting, wetland rehabilitation planning, and systematic conservation planning. As indicated above, the Framework can be used for applications that require consideration of numerous wetlands in broad geographical areas, in addition to being used for individual wetlands on a case-by-case basis, but this must be taken into account at each step in the Framework. For example, Step 2 in a conservation planning application would typically involve the identification, rough delineation (mapping) and classification of numerous wetlands in a particular study area, largely using desktop-based methods.

It is important to bear in mind that the Framework is specifically intended for *inland wetlands*, and not for other types of inland aquatic ecosystems (such as rivers or open waterbodies). The Framework is not applicable to terrestrial, marine or estuarine ecosystems. If an attempt is made to apply the Framework to an ecosystem that is not an inland wetland, however, this should be revealed by properly following Step 2 of the process.

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[6] The proposed Framework has specifically been designed in such a way that it should be compatible with most of DWA's generic processes for various aspects of water resource management.

4 DECISION-SUPPORT PROTOCOL (DSP) FOR RAPID ASSESSMENT OF WETLAND PRESENT ECOLOGICAL STATE (PES)

The Decision- Support Protocol (DSP) for the rapid assessment of wetland PES is the main deliverable that has been produced for WRC Project K5/2192.

*The proposed Decision-Support Protocol (DSP) for the rapid assessment of Wetland PES is included as **Appendix 2** in the form of an electronic Microsoft Excel file (on the accompanying CD).*

4.1 Description of the DSP

The DSP that has been produced for this project (in place of the initially envisaged DSS or DST) is in the form of an electronic spreadsheet compiled in Microsoft Excel (.xls format). The Excel spreadsheet consists of a number of worksheets (designated by colour-coded, labelled tabs at the bottom of the screen), starting with an introductory worksheet ('INTRO' tab) with background information to contextualise the DSP and a worksheet that contains notes on the use of the DSP ('use-notes' tab). The main worksheet ('DSP Home'), presented in Figure 3, outlines the protocol that has been developed for the rapid assessment of wetland PES as a series of steps. This worksheet contains hyperlinks to the various worksheets that need to be filled in for each step when using the DSP.

Go to Intro Page Go to Notes on Use of DSP

DECISION SUPPORT PROTOCOL (DSP) FOR RAPID ASSESSMENT OF WETLAND ECOLOGICAL CONDITION

WATER RESEARCH COMMISSION

Project K5/2192

STEP 1: Determine the scale, type and level of assessment required

STEP 2a: Confirm that the aquatic ecosystem is an inland wetland
(the PES assessment methods in this DSP are not applicable to rivers or open waterbodies, nor to marine or estuarine systems)

STEP 2b: Delineate the wetland, divide it into HGM Units (i.e. classify the wetland type/s) and identify "assessment units"

STEP 3a: Describe the perceived natural reference state of the (naturally-occurring) wetland assessment unit
(PES assessment is not applicable to artificial wetland systems)

STEP 3b: Select and fill in score-sheets to derive PES Scores and Ecological Categories for individual components (using matrix table below)

Wetland HGM type (reference state)	Components of wetland ecological condition			
	Hydrology	Geomorphology	Water quality	Vegetation
Floodplain wetland or **Channelled VB wetland**	WET-Health Level 1 Hydrology module **or** Wetland-IHI Hydrology module **and check against** (List of potential Hydrological Impacts)	WET-Health Level 1 Geomorphology module **or** Wetland-IHI Geomorphology module **and check against** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potential Vegetation Impacts)
Unchannelled VB wetland or **Seep**	WET-Health Level 1 Hydrology module **and check against** (List of potential Hydrological Impacts)	WET-Health Level 1 Geomorphology module **and check against** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potential Vegetation Impacts)
Depression or **Wetland flat**	WET-Health Level 1 Hydrology module **and check against** (List of potential Hydrological Impacts)	GAP (not covered by existing tools) **in interim check** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potental Vegetation Impacts)

STEP 3c: Derive Overall PES Score and Ecological Category for the wetland assessment unit (using matrix table below)

Wetland HGM type	Overall ecological condition
Floodplain wetland or **Channelled VB wetland** or **Unchannelled VB wetland** or **Seep**	Wetland-IHI default weightings **or** WET-Health default weightings **or** (Custom weightings)
Depression or **Wetland flat**	Not possible to derive overall PES Score from individual component scores (because no geomorphology module currently exists that is applicable to depressions or wetland flats) **in interim use** RDM-99 overall score/category

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STEP 3d: Go to summary of results

Go to Intro Page

Figure 3: A copy of the 'DSP Home' worksheet

The steps in the DSP have been purposefully formulated to align with the steps in the proposed Framework for Wetland Assessment (see Figure 1). The DSP, however, only includes aspects relating to Steps 1 to 3 of the Framework (up to 'wetland assessment') because this tool does not deal with Steps 4 or 5 (relating to the management of wetlands). It is also important to note that *the DSP is only applicable to the rapid assessment of wetland PES* and it does not, therefore, cater for other types of wetland assessment (such as 'risk assessment and determination of anticipated trends' or 'determination of wetland importance', as included in Step 3 of the Framework). Each of the steps in the DSP are explained in Section 4.2, below.

The core of the DSP (Step 3b) is a matrix that allows users of the tool to select their preferred choice of applicable, existing rapid assessment method for each component of wetland PES (namely, Hydrology, Geomorphology, Vegetation, and Water Quality), according to HGM wetland type. For depressions and wetland flats, a PES score cannot be determined for the geomorphology component because none of the existing wetland PES assessment methods include a geomorphology 'module' that is applicable to these wetland types. An accompanying matrix (at Step 3c) allows users to select the set of weightings deemed to be most appropriate for the derivation of an overall Wetland PES score and category, for all wetland HGM types except depressions or wetland flats. In the case of depressions and wetland flats, it is not possible to derive an overall PES Score from individual component scores (because no geomorphology module currently exists that is applicable to these wetland types). In the interim, until such time as a suitable method is developed for assigning Geomorphology PES scores to depressions and wetland flats, the DSP allows for the use of the RDM-99 method (after Duthie, 1999a) to derive an overall Wetland PES score and category for these wetland types.

The DSP thus allows the user to apply a different existing tool/method to the assessment of each component of wetland PES, if so desired, and to derive an overall Ecological Category for a wetland based on the component scores generated by different methods using the selected set of weightings. This "mix-and-match approach" is similar to some of the approaches recommended by DWA for the assessment of the different components of wetland PES in the context of Rapid Ecological Reserve Determinations for wetland ecosystems (Rountree et al., 2013).

The primary matrix table of the DSP (at Step 3b) has hyperlinks to the data-entry forms for the selected assessment method in each case. The main wetland PES assessment methods included are WET-Health 'Level 1' (Macfarlane et al., 2007) and Wetland-IHI (DWAF, 2007a). For the derivation of an Ecological Category for the water quality PES component, the option is given (for all wetland types) of using the 'land-use – water quality spreadsheet' recently developed for use in Rapid Reserve determinations for wetlands (Malan et al., 2013). The RDM-99 wetland PES assessment method (Duthie, 1999a), which is the only other nationally-applicable wetland PES assessment method in South Africa besides WET-Health and Wetland-IHI (Ollis and Malan, 2014), was not included in the primary matrix table of the DSP because it does not have separate 'modules' for the different components of wetland PES. This method (and a hyperlink to the relevant score-sheet) has, however, been included in the matrix table of the DSP that deals with the derivation of an overall Wetland PES score/category, specifically for depressions and wetland flats.

For each component of Wetland PES, the primary matrix of the DSP includes hyperlinks to a comprehensive list of potential impacts relating to that component. These lists can be used, for a particular wetland that is being assessed, to check whether there are any specific impacts affecting a wetland that the selected assessment method does not take into consideration. This would assist in highlighting the need to possibly 'tweak' the score that is generated by the selected method[7] or to select another method that does take the unaccounted-for impact into account.

The DSP explicitly requires a description of the perceived natural reference state of a wetland that is being assessed to be provided, as the first step in the PES assessment process (Step 3a). A worksheet has been developed specifically to assist with this task ('Ref-state' tab) because the lack of explicit guidelines for describing the natural reference state was identified as one of the major gaps in all of the existing wetland PES assessment methods (see review by Ollis and Malan, 2014). The natural reference state cannot be described for artificial wetland systems and, with no reference point to serve as the basis for an assessment of the degree of wetland degradation, it is not possible to conduct a PES assessment of an artificial wetland. As such, *the DSP is not applicable to artificial systems*.

The DSP includes a worksheet for generating and presenting a summary of the results of a rapid wetland PES assessment that is completed using the DSP tool ('summary' tab in the Excel spreadsheet file).

4.2 Explanation of how to use the DSP

To use the DSP, simply open the Excel file (Appendix 2, provided on the accompanying CD), go to the first sheet ('INTRO' tab) and navigate from there. The INTRO sheet has hyperlinks to the overarching Framework for Wetland Assessment in South Africa and to the manuals for the WET-Health and Wetland-IHI PES assessment methods. This sheet also highlights the proviso that the DSP must be used with an understanding that there are gaps and limitations associated with the existing methods that have been incorporated into the tool. Notes on the use of the DSP are provided in the second worksheet ('use-notes' tab). These notes should be read through carefully before using the DSP for the first time.

The main worksheet to work from when using the DSP is the one labelled 'DSP Home' (see Figure 3), which has a bright yellow-coloured tab. Most of the other worksheets have a 'Back to DSP Home' hyperlink that can be clicked on to navigate back to this worksheet.

NOTE: When you hover the cursor over a hyperlink in the DSP worksheets, the cursor should change from a plus-sign (✚) to a pointing hand (☝).

From the 'DSP Home' worksheet, the DSP is applied by going through the prescribed steps that are listed and clicking on the respective hyperlinks to navigate to the relevant worksheets, where applicable.

[7] The 'tweaking' of the scores generated by one of the existing PES assessment methods is generally not recommended because the results that are produced by different users of the method cannot then be directly compared. There are, however, situations where some 'tweaking' may be necessary due to shortcomings in the existing methods (for example, if there is a particular impact that has a strong influence on the condition of a wetland but that impact is not taken into account by the assessment method). In these cases, written justification for the 'tweaking' of results must be given, together with a detailed explanation of how the scores were adjusted.

The protocol that has been developed for the rapid assessment of wetland PES (i.e. the DSP) guides an assessor through the following prescribed steps:

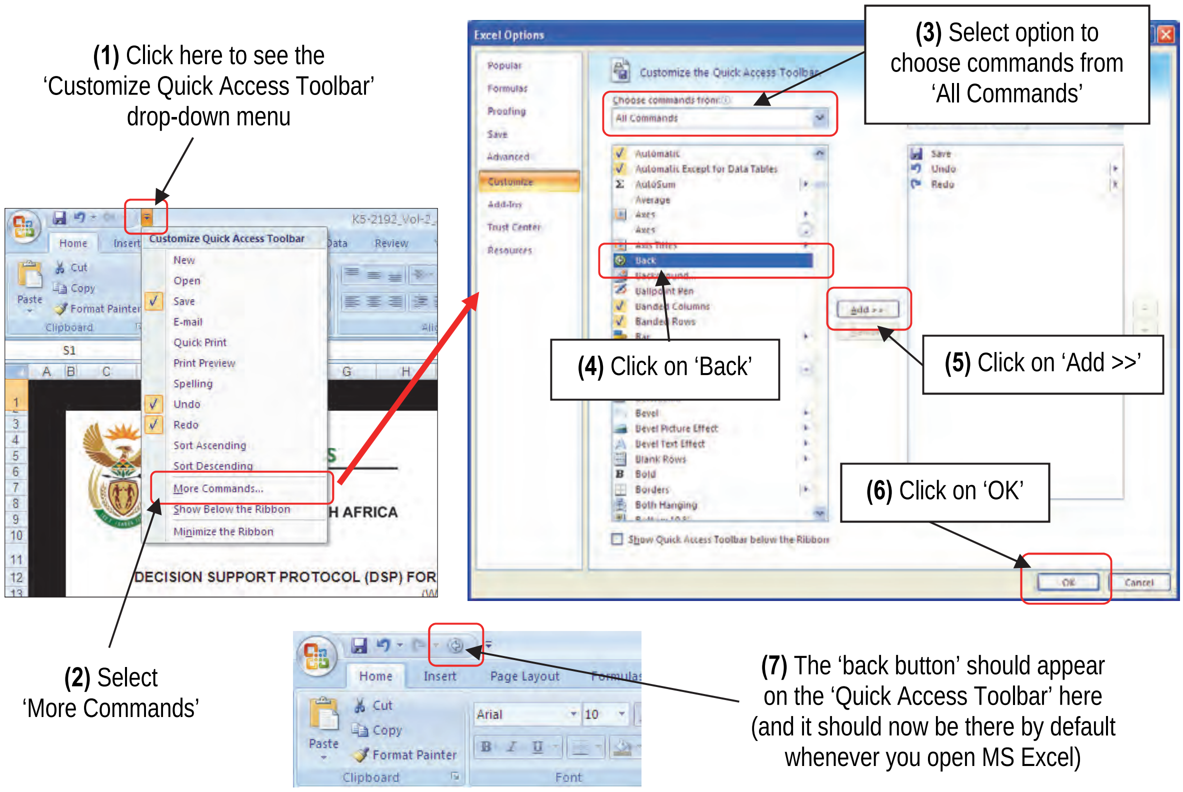
- **Step 1:** Determine the scale, type and level of assessment required.
- **Step 2a:** Confirm that the aquatic ecosystem is an inland wetland.
- **Step 2b:** Delineate the wetland, divide it into HGM Units (i.e. classify the wetland type/s) and identify “assessment units”.
- **Step 3a:** Describe the perceived natural reference state of the (naturally-occurring) wetland assessment unit.
- **Step 3b:** Select and fill in score-sheets to derive PES Scores and Ecological Categories for individual components of wetland PES (by navigating via the main matrix table included in the ‘DSP Home’ worksheet).
- **Step 3c:** Select component weightings to derive an Overall PES Score and Ecological Category for the wetland assessment unit (using the second matrix table included in the ‘DSP Home’ worksheet).
- **Step 3d:** Generate a summary of results.

These steps are explained in more detail in the sub-sections below.

A NOTE ABOUT ACTIVATING THE “BACK BUTTON” IN MICROSOFT EXCEL (2007)

In the DSP spreadsheet file, if you want to navigate back to the previous worksheet that was active before you clicked on a hyperlink and were directed to another worksheet, you can press the F5 key and then the Enter key on your computer keyboard.

Another way to navigate back to a previous worksheet in the DSP spreadsheet file is to use the “back button” in Microsoft Excel, once this has been activated. If you are using Microsoft Excel 2007, the “back button” can be activated via the ‘customize quick access toolbar’ drop-down menu in the top left corner of the screen, as illustrated below. The procedure for activating the “back button” may be different in other versions of Microsoft Excel.



4.2.1 Step 1: Determine the scale, type and level of assessment required

The first step in the DSP is to ensure that the DSP tool is appropriate for the scale, type and level of assessment required. A worksheet has been compiled to assist with this task ('scale-type-level' tab) and it is accessed by clicking on the hyperlink for Step 1 in the 'DSP Home' worksheet. The 'scale-type-level' worksheet includes a copy of the Framework for Wetland Assessment and some notes to clarify that the DSP is only applicable to the assessment of wetland PES. The most important part of the worksheet, however, is a table for indicating the scale, type and level of assessment required in a particular situation (as shown in Figure 4). The 'answers' that can be given for each of these 'questions', using the drop-down lists provided in the table, are as follows:

- Scale of assessment – *Site-specific* OR *Individual wetland/HGM Unit* OR *Catchment/sub-catchment* OR *Region/sub-region* OR *National* OR *Supra-national*
- Type of assessment – *PES assessment* OR *Risk assessment* OR *Anticipated trends* OR *Wetland importance*
- Level of assessment – *Desktop* OR *Rapid* OR *Intermediate* OR *Comprehensive*

As soon as an 'answer' has been selected, the table automatically provides an indication of whether or not the DSP is applicable to that particular scale, type or level of assessment. Once all three 'questions' have been answered (for the scale, type and level of assessment), the table automatically provides an indication of whether it is appropriate to continue with the DSP. Only if all three criteria (the scale, type *and* level of assessment) are appropriate for the DSP, does the table given an answer of YES for 'Continue with DSP?' (see Example 1 in Figure 4). The DSP has been developed specifically for the rapid PES assessment of an individual wetland or HGM Unit (or a specific 'site' representing a portion of a wetland HGM Unit). If the DSP is not applicable to the scale, type *or* level of assessment required, the table gives an answer of NO for 'Continue with DSP?' (see Example 2 in Figure 4). This would imply that another assessment 'tool' should be used, instead of the DSP, for the particular situation. In certain situations, the DSP could be used (with caution) for the wetland PES assessment of an individual wetland (or HGM Unit) at a desktop or intermediate level. If such a configuration is selected in the 'scale-type-level' table, an answer of "(with caution)" is given for 'Continue with DSP?' (see Example 3 in Figure 4).

Example 1: Situation for which it is appropriate to use the DSP

[select using drop-down menus below]		Applicability of DSP for rapid Wetland PES assessment	Continue with DSP?
Scale of assessment:	Individual wetland / HGM Unit	Applicable	**YES**
Type of assessment:	PES assessment	Applicable	
Level of assessment:	Rapid	Applicable	

Example 2: Situation for which it is not appropriate to use the DSP

[select using drop-down menus below]		Applicability of DSP for rapid Wetland PES assessment	Continue with DSP?
Scale of assessment:	Individual wetland / HGM Unit	Applicable	**NO**
Type of assessment:	Wetland importance	NOT applicable	
Level of assessment:	Rapid	Applicable	

Example 3: Situation for which it may be appropriate to use the DSP with caution

[select using drop-down menus below]		Applicability of DSP for rapid Wetland PES assessment	Continue with DSP?
Scale of assessment:	Site-specific	Applicable	**(with caution)**
Type of assessment:	PES assessment	Applicable	
Level of assessment:	Intermediate	???	

Figure 4: Filled-in examples of the table developed to indicate whether it is appropriate to use the DSP, based on the selected ‘answers’ for the scale, type and level of assessment required in a particular situation

The inclusion of the initial step to provide an indication of the applicability of the DSP, based on the scale, type and level of assessment required in a particular situation, should prevent the inappropriate use of the WET-Health (Level 1) and Wetland-IHI assessment tools (and attempts to inappropriately conduct a rapid wetland PES assessment, in general).

4.2.2 Step 2a: Confirm that the aquatic ecosystem is an inland wetland

A critical step in the application of the DSP is to confirm that the aquatic ecosystem that is being assessed is an inland wetland, before going on to the actual assessment in Step 3. This is because the PES assessment methods in the DSP are only appropriate for inland wetlands, and are specifically not applicable to rivers or open waterbodies, nor to marine or estuarine systems. Guidelines for distinguishing between inland systems and marine or estuarine systems, and for distinguishing wetlands from other types of inland aquatic ecosystems are given in the User Manual for the classification of inland aquatic ecosystems in South Africa (Ollis et al., 2013). The guideline documents for the identification and delineation of wetlands referred to in Step 2 of the Framework for Wetland Assessment (see Section 3.1.2 and Table 2) can also be used as aids in confirming whether a particular system “qualifies” as a natural wetland, especially those of DWAF (2005, 2008) and the US Army Corps of Engineers (Environmental Laboratory, 1987).

It is important to bear in mind that the DSP, and PES assessment in general, is only applicable to naturally-occurring systems, and not to any artificially created wetland systems.

4.2.3 Step 2b: Delineate the wetland, divide it into HGM Units and identify “assessment units”

Before embarking on the actual PES assessment for a particular wetland (in Step 3), the wetland should be mapped (i.e. delineated) at an appropriate scale and level of accuracy, the wetland should be divided into HGM Units (i.e. classification of the wetland types that are present should be completed), and the “assessment unit/s” should be identified and mapped. An assessment unit can be an entire HGM Unit or it can be a portion of an HGM Unit, depending on the purpose and focus of the assessment that is being undertaken. Each assessment unit that is identified, if there is more than one, must be separately assessed in Step 3 of the DSP. The DSP thus generates an individual PES Score and Ecological Category for each assessment unit.

If an overall, area-weighted PES score/category is required for a complex wetland made up of more than one HGM Unit (or for an HGM Unit that is divided into more than one “assessment unit”), the approach and guidelines of WET-Health should be used for this purpose (see pp. 34-35 of Macfarlane et al., 2009). This is undertaken once the DSP has been used to derive a PES% score for each assessment unit (the PES% scores would need to be converted to ‘impact scores’ by subtracting the PES% score from 100 and then dividing by 10). The procedure simply involves the calculation of an area-weighted impact score for each assessment unit based on the relative size of the assessment unit in relation to the relevant HGM Unit (= proportion of HGM Unit represented by the assessment unit/100 x impact score), and then summing the area-weighted scores across all assessment units within the HGM Unit. This is done separately for each component of wetland PES. If the assessment units are entire HGM Units, then the area-weighted impact scores are based on the relative size of each HGM Unit in relation to the whole wetland area.

From the above discussion, it should be clear that the compilation of a map showing the HGM Unit/s and the selected "assessment unit/s" within a wetland that is being assessed is of critical importance for any wetland PES assessment. The DSP includes a worksheet specifically for presenting such a map (‘HGM-map’ tab). This worksheet provides a space for a sketch map of the wetland that is being assessed to be inserted, and prompts the user to insert a map specifically showing the approximate delineation of HGM Units making up the wetland and the selected assessment units. For situations where a report exists that contains a map (or maps) of the HGM Units and the selected assessment units, the option is also provided of simply referring to the report and the relevant figure number/s therein.

In addition to the space provided for inserting a map, the ‘HGM-map’ worksheet of the DSP includes a table that must be filled in for the mapped wetland (as shown in Figure 5). This table allows for information to be captured for up to 5 HGM Units. For each HGM Unit, an indication must be provided of the HGM type (by using a drop-down list of possible HGM types from Ollis et al., 2013) and of whether the HGM Unit is an artificial system. If an HGM Unit is artificial, Step 3 of the DSP cannot be applied because it is not possible to conduct a PES assessment of an artificial system. The user must also provide an estimate of the approximate extent (in hectares) of each assessment unit that was identified and delineated on the map, allowing for up to three assessment units per HGM Unit. Once these area estimates have been entered, the table will automatically calculate the proportional extent of each assessment unit relative to the total extent of the relevant HGM Unit, and the proportional extent of each HGM Unit relative to the total extent of the entire wetland.

A filled-in example of the table in the ‘HGM-map’ worksheet of the DSP is presented in Figure 5, below. This hypothetical example is for a naturally-occurring wetland of 35 Ha in extent, which consists of two HGM Units making up 43% and 57% of the total wetland area, respectively. HGM Unit 1 is a channelled valley-bottom wetland, which was split into two “assessment units” of 10 and 5 Ha in extent, respectively. In the case of HGM Unit 2 (an unchannelled valley-bottom wetland), the entire HGM Unit of 20 Ha in extent was taken as the assessment unit. When conducting PES assessment in Step 3 of the DSP, a separate assessment should be completed for each assessment unit (i.e. separate PES assessments would be completed for “assessment units” HGM 1a, HGM 1b and HGM Unit 2 in this example).

Use the map showing HGM Units and "assessment units" within the wetland to fill in the following table:

HGM Unit	HGM Type	Artifical system?*	Assessment unit	Approximate extent (Ha)		Proportional extent (%) of assessment units: relative to HGM Unit	Proportional extent (%) of assessment units: rel. to entire wetland
1	Channelled VB wetland	NO	HGM 1a	10.0	15.0	67%	43%
			HGM 1b	5.0		33%	
			HGM 1c			%	
2	Unchannelled VB wetland	NO	HGM 2a	20.0	20.0	100%	57%
			HGM 2b			%	
			HGM 2c			%	
3			HGM 3a		0.0	#DIV/0!	%
			HGM 3b			#DIV/0!	
			HGM 3c			#DIV/0!	
4			HGM 4a		0.0	#DIV/0!	%
			HGM 4b			#DIV/0!	
			HGM 4c			#DIV/0!	
5			HGM 5a		0.0	#DIV/0!	%
			HGM 5b			#DIV/0!	
			HGM 5c			#DIV/0!	
			Total extent:	35.0 Ha		100%	
						[total must = 100%]	

*NOTE: If an HGM Unit is artificial, there is no natural reference state to use as the basis for a PES assessment

Figure 5: Filled-in example of the table in the ‘HGM-map’ worksheet of the DSP, for a hypothetical wetland of 35 Ha in extent that consists of two HGM Units

In the ‘HGM-map’ worksheet, a dedicated space is provided to enter the name of the wetland that is being assessed, the date of assessment, and the name/s of the assessor/s. It is important to fill this information in because it will automatically be copied to the other worksheets within the DSP.

4.2.4 Step 3a: Describe the perceived natural reference state of the wetland assessment unit

When undertaking a PES assessment of a wetland, it is important to start by determining and describing the perceived natural reference state of the wetland unit that is being assessed. As Step 3a in the DSP, a worksheet has been compiled specifically for this purpose (‘Ref-state’ tab, as shown in Figure 6). It is accessed by clicking on the hyperlink to ‘Describe the perceived natural reference state of the (naturally-occurring) wetland assessment unit’ on the ‘DSP Home’ worksheet. A note is included on the ‘DSP Home’ worksheet (under Step 3a) to highlight that PES assessment is not applicable to artificial wetland systems, and another note is included in the ‘Ref-state’ worksheet to remind the assessor that a description of the perceived natural reference state is not applicable to artificial wetlands. The relevant worksheet (‘Ref-state’) for describing the perceived natural reference state of the assessment unit is mostly completed by selecting the most appropriate “answers” for a number of criteria using drop-down menus that are activated by clicking on the relevant cell in the worksheet.

The first criterion that must be recorded is the wetland HGM type for the HGM Unit that is being assessed, as it would have been in its natural state, by selecting the most relevant ‘reference state’ HGM type of the six possible wetland types listed (following the classification system of Ollis et al., 2013)[8]. The rest of the criteria that must be described are grouped under four main headings, namely ‘Hydrology’, ‘Geomorphology’, ‘Vegetation’ and ‘Water quality’. At the bottom of the ‘Ref-state’ worksheet, under the heading ‘General’, a short written description must be provided of characteristic features of the wetland assessment unit in its perceived natural reference state.

In addition to the provision of a column for describing the perceived natural reference state of a wetland assessment unit, an optional column is also provided in the ‘Ref-state’ worksheet (shaded in pink) for describing the current state of the assessment unit using the same criteria. This additional column for the current state does not have to be filled in when using the DSP. If both the ‘perceived natural reference state’ and ‘current state’ columns are filled in, however, it does provide the assessor with an immediate ‘feel’ for the degree to which the current state of the wetland assessment unit has deteriorated from the perceived natural reference state, and highlights what some of the major impacts on the present ecological condition of the wetland are. An assessor should make sure that the major impacts identified by filling in the ‘current state’ column in the ‘Ref-state’ worksheet are taken into account in the PES assessment ‘modules’ selected in Step 3b of the DSP.

When selecting an ‘answer’ for each of the descriptive criteria included in the ‘Ref-state’ worksheet, for both the perceived natural reference state and the current state, the assessor is required to record their confidence rating (simply using the categories of high/medium/low) in the respective columns provided for this purpose.

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[8] If the aquatic ecosystem that is being assessed is a ‘river’ (a seventh type of inland aquatic ecosystem included as a possible HGM type in the SANBI classification system), then the DSP is not applicable and a more suitable ‘tool’ will have to be used for the rapid assessment of PES (e.g. the River IHI method of DWA).

DESCRIPTION OF PERCEIVED NATURAL REFERENCE STATE OF THE WETLAND ASSESSMENT UNIT

Wetland name:	Hypothetical example	Back to DSP Home
Assessment unit [refer to HGM-map]:		
Date of assessment:	Date	
Name/s of assessor/s:	Name	

>> Complete the table below (using the drop-down menus) and write in a description at the bottom, for the perceived natural reference state [and the current state]

Aspect	Perceived natural reference state*	Confidence	OPTIONAL: Current state	Confidence
WETLAND TYPE				
HGM type				
HYDROLOGY				
Inundation hydroperiod				
Permanently inundated				
Seasonally inundated				
Intermittently inundated				
Never/rarely inundated				
Maximum depth of inundation				
Saturation hydroperiod				
Permanently saturated				
Seasonally saturated				
Intermittently saturated				
Dominant water inputs (top 2 or 3)				
Dominant water outflows (top 2 or 3)				
GEOMORPHOLOGY				
Dominant substratum type (surface)				
Bedrock				
Boulders				
Cobbles				
Pebbles/gravel				
Sandy soil				
Silt (mud)				
Clayey soil				
Loamy soil				
Organic soil / peat				
Salt crust				
Other				
Dominant substratum type (subsoil)				
Bedrock				
Boulders				
Cobbles				
Pebbles/gravel				
Sandy soil				
Silt (mud)				
Clayey soil				
Loamy soil				
Organic soil / peat				
Other				
Erosional features (describe below)				
Depositional features (describe below)				
VEGETATION				
Approximate aerial cover (by vegetation)				
Dominant vegetation cover type				
Unvegetated (bare ground)				
Aquatic vegetation				
Shrubs/Thicket				
Forested wetland (swamp forest)				
Herbaceous: geophytes				
Herbaceous: grasses				
Herbaceous: herbs/forbs				
Herbaceous: sedges/rushes				
Herbaceous: reeds				
Herbaceous: restios				
Herbaceous: palmiet				
NFEPA WetVeg Group	<look up on relevant NFEPA map and enter info here>	n/a	<look up on relevant NFEPA map and enter info here>	n/a
Exposure to fires/burning				
Exposure to grazing/trampling by animals				
WATER QUALITY				
Salinity				
pH				
Turbidity/TSS				
Nutrient status				
Algal growth				
Water colour				
GENERAL	<enter written description below>		<enter written description below>	
Short written description of characteristic features of the wetland assessment unit				

* Not applicable to **artificial wetlands**

Back to DSP Home

Figure 6: A copy of the 'Ref-state' worksheet for describing the perceived natural reference state of the wetland assessment unit (and, optionally, the current state)

Most of the criteria in the ‘Ref-state’ worksheet, and the categories used for the drop-down “answers”, have been taken from the User Manual for the SANBI Classification System for inland aquatic ecosystems (Ollis et al., 2013). It is thus strongly recommended that an assessor consults the User Manual for the SANBI Classification System when filling in the ‘Ref-state’ worksheet of the DSP, especially the first time the DSP is used. Additional guidance for some of the criteria (e.g. erosional and depositional features, under the Geomorphology section) can be found in the manuals for WET-Health (Macfarlane et al., 2007) and Wetland-IHI (DWAF, 2007a).

The primary criteria in the ‘Ref-state’ worksheet of the DSP, by headings, are as follows:

- **Wetland type** – HGM type
- **Hydrology** – Inundation hydroperiod; Maximum depth of inundation; Saturation hydroperiod; Dominant water inputs (top 2 or 3); Dominant water outflows (top 2 or 3)
- **Geomorphology** – Dominant substratum type (surface); Dominant substratum type (subsoil); Erosional features; Depositional features
- **Vegetation** – Approximate aerial cover (by vegetation); Dominant vegetation cover type; NFEPA WetVeg Group; Exposure to fires/burning; Exposure to grazing/trampling by animals
- **Water quality** – Salinity; pH; Turbidity/TSS; Nutrient status; Algal growth; Water colour

Under the Hydrology, Geomorphology and Vegetation sections of the worksheet, the primary criteria are listed in bold text (e.g. ‘Maximum depth of inundation’ under the Hydrology heading). For some of these primary criteria (e.g. ‘Inundation hydroperiod’ under the Hydrology heading), there are a number of subordinate criteria listed below the primary criterion (in non-bold, indented text). In these cases, the “answers” for the subordinate criteria should first be filled-in, before the “answer” is selected for the relevant primary criterion. The following categories (from the ‘rating scale’ presented in Ollis et al., 2013) have been included as possible “answers” for estimating the proportion of the wetland assessment unit characterised by each of the subordinate criteria:

- not present (0%)
- rare (>0% - 5%)
- sparse (>5% - 25%)
- common (>25% - 50%)
- abundant (>50% - 75%)
- predominant (>75% - 95%)
- near-entire (>95% - 100%)

Once “answers” have been selected for the subordinate criteria, using the categories listed above (and making sure that the total proportional extent represented by the selected categories cannot add up to >100%), the assessor has a basis for selecting the dominant category for the relevant primary criterion. The “answers” that are selected for the subordinate criteria also provide an indication of the heterogeneity within the assessment unit for the relevant primary criterion. For wetland assessment units that are presumed to be very heterogeneous in their natural state with respect to a particular criterion, the option is given (at least for the Geomorphology and Vegetation criteria) to select an answer of ‘highly variable' as the dominance category for the primary criteria. The worksheet also provides the option of recording the dominant category as 'unknown', to cater for situations where there is insufficient information available about the natural reference state of a wetland to rate the proportional extents of the various categories.

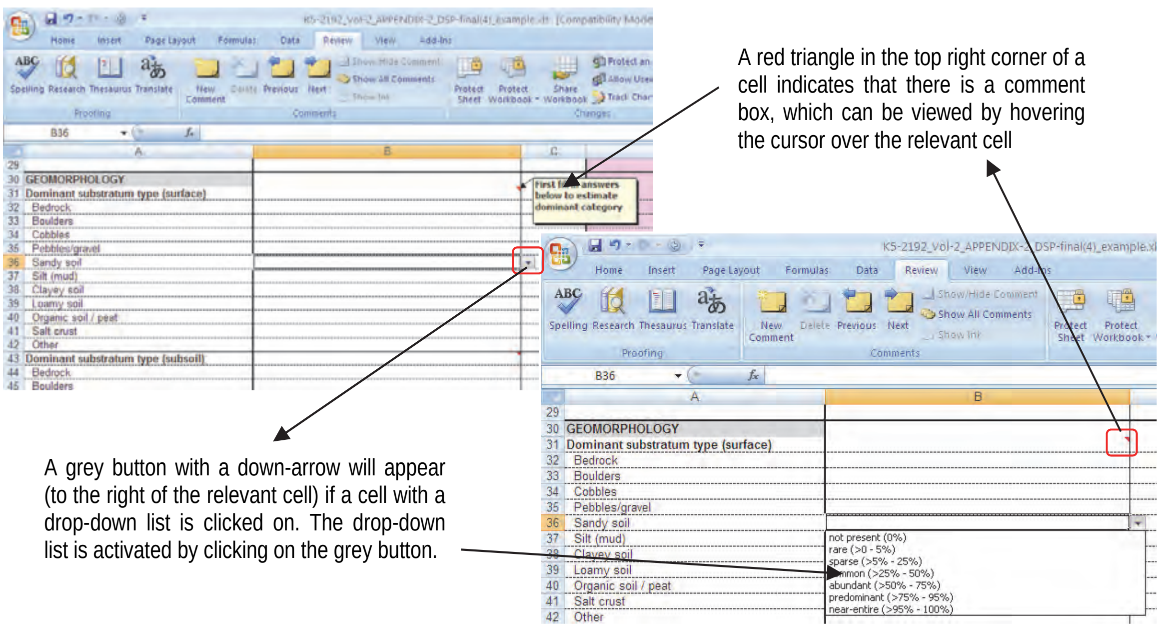
It is acknowledged that, while conceptually simple, the determination of the natural reference state of a wetland is a complex task, especially in transformed landscapes where there are very few (or no) pristine wetlands that can be used as reference sites. It is, nevertheless, important to describe and document the perceived natural reference state for any wetland PES assessment because the entire assessment revolves around the implicit assumptions made by an assessor as to what they perceive the natural reference state (and the natural variability) of a particular assessment unit to have been. The complexities of determining the natural reference state of an assessment unit, and the high levels of natural variability in certain wetlands, highlights the importance of indicating the level of confidence in the descriptions provided by an assessor.

In the 'Ref-state' worksheet, some guidelines and relevant references are provided for certain criteria, using "comment boxes" (as designated by a small red triangle in the top right-hand corner of the relevant cells).

A NOTE ABOUT COMMENT BOXES AND DROP-DOWN LISTS IN THE DSP WORKSHEETS

In some of the worksheets in the DSP, additional information is provided using "comment boxes". Where such additional information exists, the relevant cell in the relevant worksheet has a small red triangle in the top right-hand corner (as shown in the image below). The information is accessed by simply hovering the cursor over the relevant cell, which will make a comment box appear. When the cursor is moved away from the cell, the comment box will disappear again.

Most of the worksheets in the DSP include drop-down lists of possible "answers" for many of the cells that need to be filled in by an assessor. When clicking on a cell with a drop-down list, a square button with a down-arrow will appear to the right of the cell (as shown in the image below). The drop-down list is accessed by clicking on the button with the arrow. To fill in the relevant cell, click on the selected "answer" from the list that appears when the button with the arrow is clicked.



An example of a filled-in portion of the ‘Ref-state’ worksheet of the DSP, for the hydrology of a hypothetical channelled valley-bottom wetland assessment unit, is presented in Figure 7 (below). In this example, the columns for both the perceived natural reference state and the current state of the assessment unit were filled in, together with the respective confidence ratings for each criterion. Based on the selected “answers”, the inundation hydroperiod of the assessment unit, in its perceived natural reference state, would have been dominantly seasonally inundated to a maximum depth of 25-50 cm, with no permanently inundated areas but some intermittently inundated areas and a few patches that would never (or rarely) be inundated. These assumptions were made with a medium level of confidence. The perceived natural saturation hydroperiod, on the other hand, could only be described with a low level of confidence, as being dominantly seasonally saturated but with some areas that are permanently or intermittently saturated. Dominant water inputs into the assessment unit, in the natural state, were assumed to be overbank flooding and lateral seepage (from the adjacent channel) with a medium level of confidence, while the dominant water outflows from the assessment unit were assumed to be evapotranspiration and lateral seepage (with a low level of confidence).

DESCRIPTION OF PERCEIVED NATURAL REFERENCE STATE OF THE WETLAND ASSESSMENT UNIT

Wetland name:	Hypothetical example	Back to DSP Home
Assessment unit [refer to HGM-map]:	HGM 1b	
Date of assessment:	Date	
Name/s of assessor/s:	Name	

>> Complete the table below (using the drop-down menus) and write in a description at the bottom, for the perceived natural reference state [and the current state]

Aspect	Perceived natural reference state*	Confidence	OPTIONAL: Current state	Confidence
WETLAND TYPE				
HGM type	Channelled VB wetland	Medium	Channelled VB wetland	High
HYDROLOGY				
Inundation hydroperiod	**Dominantly seasonally inundated**	Medium	**Dominantly seasonally inundated**	High
Permanently inundated	not present (0%)	Medium	sparse (>5% - 25%)	High
Seasonally inundated	common (>25% - 50%)	Medium	common (>25% - 50%)	High
Intermittently inundated	common (>25% - 50%)	Medium	common (>25% - 50%)	High
Never/rarely inundated	sparse (>5% - 25%)	Medium	sparse (>5% - 25%)	High
Maximum depth of inundation	25-50 cm	Medium	50-100 cm	High
Saturation hydroperiod	**Dominantly seasonally saturated**	Low	**Dominantly intermittently saturated**	Medium
Permanently saturated	sparse (>5% - 25%)	Low	rare (>0 - 5%)	Medium
Seasonally saturated	abundant (>50% - 75%)	Low	sparse (>5% - 25%)	Medium
Intermittently saturated	sparse (>5% - 25%)	Low	abundant (>50% - 75%)	Medium
Dominant water inputs (top 2 or 3)	Overbank flooding	Medium	Overbank flooding	High
	Lateral seepage	Medium	Lateral seepage	High
			Surface runoff (overland flow)	High
Dominant water outflows (top 2 or 3)	Evapotranspiration	Low	Lateral seepage	Medium
	Lateral seepage	Low	Infiltration	Medium

Figure 7: Example of a filled-in portion of the ‘Ref-state’ worksheet for a hypothetical wetland assessment unit

In the hypothetical example above (see Figure 7), from the “answers” selected to describe the current state of the hydrology relative to the perceived natural reference state (all given with a medium to high level of confidence), it can be seen that the assessment unit currently has a similar inundation hydroperiod to its natural state (i.e. dominantly seasonally inundated) but the maximum depth of inundation is deeper (50-100 cm, versus 25-50 cm) and there are now some areas that are permanently inundated. At the same time, the saturation period has changed, from being dominantly seasonally saturated to being dominantly intermittently saturated. The dominant water inputs in the current state include surface runoff (overland flow), which was not a major contributor in the perceived natural reference state, and infiltration has become more dominant than evapotranspiration in terms of the outflows from the wetland assessment unit.

In all of the subsequent worksheets of the DSP, which incorporate the relevant score-sheets for determining the PES for the various components of wetland condition, a hyperlink is included to 'Check back to Reference State'. By clicking on this hyperlink, the assessor is taken back to the 'Ref-state' worksheet of the DSP so that they can check on their description of the reference state (and of the current state, if that section of the worksheet was filled in) for that particular component. This should assist with the formulation of a "picture" of the reference state in the mind of the assessor, which is required as a baseline for the PES assessment. An assessor can also revise their descriptions of the reference state (and of the current state) in the 'Ref-state' worksheet when checking back, if necessary, in the light of the insights gained through the PES assessment. In other words, there is an opportunity to iteratively refine the initial reference state descriptions while undertaking the PES assessment steps of the DSP.

4.2.5 Step 3b: Determine the PES Scores and Ecological Categories for individual components of Wetland PES

The next part of Step 3 in the application of the DSP to a wetland assessment unit, once the reference state has been described (in Step 3a), is to select and fill in the relevant score-sheets to derive PES% Scores and Ecological Categories for the individual components of wetland condition (i.e. Hydrology, Geomorphology, Water Quality, and Vegetation). A matrix table has been included in the 'DSP Home' worksheet (see Figure 8) to assist an assessor in navigating through this process.

NOTE:

The matrix tables in the 'DSP Home' worksheet have been colour-coded, to match the colour-coding used for the tabs for the various worksheets in the DSP spreadsheet file, as follows:

- Hydrology = light blue shading
- Geomorphology = light pink shading
- Water quality = light purple shading
- Vegetation = light green shading
- Overall Wetland PES = orange shading

This colour-coding has also been used to distinguish between the different components of wetland PES in the summary tables included in the DSP.

Wetland HGM type (reference state)	Components of wetland ecological condition			
	Hydrology	**Geomorphology**	**Water quality**	**Vegetation**
Floodplain wetland or **Channelled VB wetland**	WET-Health Level 1 Hydrology module **or** Wetland-IHI Hydrology module **and check against** (List of potential Hydrological Impacts)	WET-Health Level 1 Geomorphology module **or** Wetland-IHI Geomorphology module **and check against** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potential Vegetation Impacts)
Unchannelled VB wetland or **Seep**	WET-Health Level 1 Hydrology module **and check against** (List of potential Hydrological Impacts)	WET-Health Level 1 Geomorphology module **and check against** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potential Vegetation Impacts)
Depression or **Wetland flat**	WET-Health Level 1 Hydrology module **and check against** (List of potential Hydrological Impacts)	GAP (not covered by existing tools) **in interim check** (List of potential Geomorphological Impacts)	Wetland-IHI Water Quality module **or** Landuse/WQ spreadsheet **and check against** (List of potential Water Quality Impacts)	WET-Health Level 1 Vegetation module **or** Wetland-IHI Vegetation Alteration module **and check against** (List of potental Vegetation Impacts)

Figure 8: A copy of the matrix table included in the 'DSP Home' worksheet to assist with the selection of an appropriate rapid assessment method for determining the PES for the various components of wetland condition (note colour-coding), according to the HGM type of the assessment unit

Relevant PES score-sheets are selected primarily on the basis of the HGM type of the wetland unit that is being assessed (see column 1 of the relevant matrix), according to the HGM type of the assessment unit in its perceived natural state (as recorded for the first criterion in the 'Ref-state' worksheet). Three groupings of HGM types are provided for – (1) floodplain wetland or channelled valley-bottom (VB) wetland; (2) unchannelled VB wetland or seep; and (3) depression or wetland flat. For each grouping, the same options are applicable for the different components of wetland PES:

- To derive Hydrology and Geomorphology PES Scores (see columns 2 and 3 of the relevant matrix, respectively), the WET-Health (Level 1) or Wetland IHI score-sheets can be used for the first grouping (*floodplain and channelled VB wetlands*), whereas only the WET-Health (Level 1) score-sheet is applicable to the second grouping (*unchannelled VB wetlands and seeps*). This is because the Wetland-IHI method was strictly developed for floodplains and channelled VB wetlands only, and the application of the Hydrology and Geomorphology modules to other HGM types does not make sense (e.g. see Ollis, 2014). In the case of the third grouping (*depressions and wetland flats*), neither WET-Health nor Wetland IHI are really applicable to the derivation of Hydrology and Geomorphology PES Scores, although the Hydrology module of WET-Health can theoretically be applied to such wetland types (according to Macfarlane et al., 2009) but should be used with caution (thus this option has red text in the relevant matrix table on the 'DSP Home' worksheet). The lack of a module to determine the Geomorphology PES of depressions and wetland flats has been identified as a gap in the existing wetland PES assessment methods (Ollis and Malan, 2014).
- The Water Quality PES Score for a wetland (see column 4 of the relevant matrix) can be derived using either the Wetland-IHI water quality score-sheet or the 'landuse – water quality' spreadsheet developed by Malan et al. (2013) (see text box on the following page). The same approach is applicable to *all wetland types* in this case[9].
- The Vegetation PES Score for a wetland (see column 5 of the relevant matrix) can be derived using either the WET-Health (Level 1) or the Wetland-IHI vegetation score-sheet. Again, the same approach is applicable to *all wetland types* for this component of wetland PES[9].

Once an assessment method has been selected for a particular component of wetland PES, the relevant score-sheet is accessed by clicking on the relevant hyperlink in the first matrix table on the 'DSP Home' worksheet (in Step 3b).

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[9] Although the Wetland-IHI method was strictly developed for floodplain and channelled VB wetland types, the Water Quality and Vegetation Alteration modules are considered to be applicable to all wetland types (e.g. see Ollis, 2014).

Explanation of the Landuse – Water quality spreadsheet

Three basic complementary approaches have been recommended by Malan et al. (2013) for determining the water quality component of the Rapid Ecological Reserve for wetlands, namely: (1) Measurements of water quality parameters (either historical or new data); (2) The use of diatoms for inferring water quality; and (3) An impacts-based approach based on landuse in the catchment surrounding a wetland. The reason for proposing three different approaches, even at a Rapid level, is because no single approach is likely to give enough information based on our current understanding of wetlands in South Africa.

The standard procedure that has been recommended is to start by completing the Landuse/WQ spreadsheet (as included in the DSP for rapid Wetland PES assessment) by entering the approximate areal extent of different landuses in the catchment, and then to use expert judgement to answer the questions at the bottom of the spreadsheet in order to obtain a tentative PES Category. Thereafter, if possible, the Specific Pollution-sensitivity Index (SPI) should be used to generate an SPI score on the basis of the diatom community present in the wetland, and water quality measurements should be collected and analysed – the results of these additional assessments should be used to adjust the tentative Water Quality PES Category accordingly.

The above explanation is given to provide a better understanding of the context and original intention of the landuse – water quality spreadsheet produced by Malan et al. (2013). It is important to bear in mind, however, that only the spreadsheet-based component of the assessment, which is used to generate a tentative Water Quality PES Category, has been incorporated into the DSP.

The following guidelines have been provided by Malan et al. (2013) for completing the catchment landuse/water quality spreadsheet:

- For each landuse (irrigated cropland, etc.), the contaminants likely to be generated as runoff are rated in terms of the likely impact on the water quality of the wetland. The impact scores range from 0 (no impact) to 5 (major impact). Expert judgement was used to establish these scores, but if additional information is available, they can be altered at the user's discretion.
- A rough estimate of the extent major landuses must be made (as % of the total catchment area) and filled in on the spreadsheet (yellow column). The total landuse must equal 100%. A tentative PES Category is generated by the spreadsheet model.
- Note is made of other factors (e.g. the presence of a vegetation buffer around the wetland, presence of significant point sources of pollution in the catchment), which are used to alter the tentative PES Category that is obtained. The questions are simply answered "YES" or "NO" in the lower yellow column of the spreadsheet.
- The final PES Category is then automatically calculated by the spreadsheet model. It is important to note that this Category can still be modified if additional data (e.g. diatom SPI scores or water quality measurements) are available as described in the protocol.

Malan et al. (2013) provide additional recommendations for variations in the Water Quality PES assessment method to be followed for different wetland types, which in essence involve the application of river Water Quality PES assessment methods to wetlands that are more riverine in nature. These recommendations are more applicable to the overall assessment approach in a Reserve Determination study and so, for the purposes of the DSP, it has been assumed that the landuse – water quality spreadsheet that was developed for generating a tentative Water Quality PES Category for wetlands is applicable to all wetland HGM types.

For WET-Health, the score-sheets included in the DSP are the "Version 2" score-sheets for a 'Level 1' assessment that were packaged with the formally published manual (Macfarlane et al., 2007). The summary score-sheet that is used in WET-Health to derive an overall area-weighted "impact score" for each component of wetland condition in the case of complex wetlands made up of more than one HGM Unit (see note about this is Section 4.2.3 of the current document)[10] has, however, been excluded from the DSP. In the DSP, a column has been added to all the WET-Health score-sheets for a confidence rating to be given for each criterion that is scored (this was missing from the 'official' WET-Health score-sheets), and additional calculations have been added to derive a PES% Score and an Ecological Category from the 'impact score' that the 'official' WET-Health score-sheets generate for each component. For the WET-Health Hydrology score-sheet included in the DSP, two of the important look-up tables (Tables 5.3 and 5.12) have been placed in the relevant worksheet ('WET-H hydro' tab), at the bottom of the WET-Health Hydrology score-sheet. All the other look-up tables required for filling in the WET-Health score-sheets have been included as separate worksheets in the DSP, and hyperlinks have been added so that an assessor can easily navigate to the relevant look-up tables. The inclusion of the WET-Health look-up tables in the DSP, with hyperlinks to them, allows an assessor to complete a PES assessment without having to keep referring back to the manual to find these look-up tables.

In the case of Wetland-IHI, the score-sheets included in the DSP are the "Version 1.1" score-sheets that were issued (in June 2013) as an update to the score-sheets originally released with the manual (DWAF, 2007a). The Wetland-IHI score sheets already include the recording of confidence ratings and the derivation of overall PES% scores and Ecological Categories in the 'official' score-sheets. The 'official' Wetland-IHI score-sheets also already include all the necessary look-up tables and scoring guidelines, embedded into the relevant worksheets or in the form of "comment boxes".

When completing the WET-Health (Level 1) and Wetland-IHI score-sheets that are linked to the DSP, the relevant user manuals (Macfarlane et al., 20097 and DWAF, 2007b, respectively) should be consulted for guidance, especially when the assessor applying the DSP is not experienced in the use of these existing PES assessment methods. Hyperlinks to the websites from which the manuals can be downloaded are included in the 'INTRO' worksheet of the DSP (note: one must be connected to the internet for these particular hyperlinks to work). In the case of WET-Health, it is recommended (by Macfarlane et al., 2009) that the assessor complete at least one 'Level 2' assessment before attempting a 'Level 1' assessment so that they can become familiar with the factors that should be taken into account in the assessment of impacts.

The score-sheets that are linked to the DSP ultimately generate an Ecological Category or PES Category, ranging from A to F, for the different components of wetland PES, following the PES rating system initially developed by Kleynhans (1996) that is commonly used for inland aquatic ecosystems in South Africa (see Table 3, below).

[10] If an assessor wishes to derive an overall area-weighted Ecological Category for a complex wetland, the DSP can be used to derive component PES% Scores for each HGM Unit (or assessment unit). Once these scores have been converted to 'impact scores' of 0-10 (not necessary if WET-Health score-sheets have been selected), the relevant scores (and estimated areas of the individual HGM Units or assessment units) can simply be entered into the WET-Health summary score-sheet to generate automated results for each component of wetland PES.

Table 3: Description of Ecological (or PES) Categories from A to F and indication of range of PES% Scores used to derive a category for each component of wetland PES [from DWAF (1999), after Kleynhans (1996)]

Ecological Category	Description	PES Score (% of total)
A	Unmodified, natural.	90-100%
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90%
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79%
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59%
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39%
F	Modifications have reached a critical level and the ecosystem has been modified completely with an almost complete loss of natural habitat and biota.	0-19%

For each component of wetland PES (i.e. hydrology, geomorphology, water quality, and vegetation), the option is also provided in the DSP of using a checklist of common impacts to identify which ones are most relevant to the wetland that is being assessed. The checklists include a list of common impacts in each case (column 1 of the relevant worksheets) and subordinate lists of possible causes that typically result in the listed impacts for the specific component of wetland PES (column 2)[11]. Each of the possible causes must be individually rated in each case (column 3) and a confidence rating (high/medium/low) must be provided (column 4). The rating of impacts and/or causes simply involves assigning an 'applicability rating' to each criterion, using the categories of "highly applicable" (+++), "moderately applicable" (++), "slightly applicable" (+), or "not applicable" (-).

The main reason for including the option of checking the results of a PES assessment against the lists of potential impacts in the DSP is that it allows the assessor to identify the specific impacts (and causes) that are likely to be affecting a particular component of wetland PES. This should assist in the identification of impacts that are not adequately dealt with in the WET-Health (Level 1) or Wetland-IHI assessment methods, thus highlighting situations where there may be a need to "tweak" the PES assessment results generated by one of the existing methods. In these instances, the filled-in checklists also provide some sort of documented motivation for any "tweaking" of PES results that is undertaken.

The checklists in the DSP are colour-coded, to align with the colour-coding used in the relevant matrix table in the 'DSP Home' worksheet and in the summary tables. An example of a filled-in checklist, for a hypothetical wetland assessment unit, is presented in Figure 9. This example is for the list of potential hydrological impacts (thus shaded in light blue) and it can be seen that, for this hypothetical assessment unit, many of the potential causes of hydrological impacts were slightly to moderately applicable (rated as ++ or +) but none of the possible causes of hydrological impact were individually rated to be highly applicable. The filled-in checklist also shows that impacts resulting from damming or inter-basin transfers were not applicable to the hypothetical assessment unit. For the hypothetical assessment

[11] The lists of impacts and possible causes were compiled by members of the project team for Project K5/2192, using the criteria considered in the various modules/components of the WET-Health and Wetland-IHI assessment methods as a starting point and building on these.

unit, the filled-in checklist highlights, for example, that decreased water retention within the wetland as a result of infilling/increased deposition (rated to be of moderate applicability, ++) should be taken into account when scoring the hydrological impact of 'alteration of water distribution and retention patterns within the wetland' in the selected PES assessment method.

LIST OF POTENTIAL HYDROLOGICAL IMPACTS — Check back to Reference State

Impact	Possible causes	Applicability rating*	Confidence rating
Decreased/increased water inputs (quantity)	Decreased inflows		
	Diversion of flows that would have entered the wetland	+ +	Medium
	Water abstraction (of surface water and/or groundwater)	+	Medium
	Damming and obstruction of flow (upstream/up-slope of the wetland)	-	High
	Afforestation in the catchment	-	High
	Extensive evergreen crops (e.g. sugarcane) in the catchment	-	High
	Exotic (invasive alien) plant invasion in the catchment	+ +	High
	Increased inflows		
	Extensive loss of vegetation cover in the catchment	+ +	Medium
	Stormwater input	+	Medium
	Input of treated effluent	-	High
	Irrigation return flows	+ +	Medium
	Interbasin transfers into the catchment	-	High
Alteration of peak inflow magnitudes	Increased peak flow magnitudes		
	Extensive loss of vegetation cover in the catchment	+ +	Medium
	Catchment hardening (urbanisation)	+	High
	Decreased peak flow magnitudes		
	Damming and obstruction of flow (upstream/up-slope of the wetland)	-	High
	Diversion of flows that would have entered the wetland	+ +	Medium
Alteration of *frequency and/or timing* of water inputs (change in seasonality of inflows)	[same as for decreased/increased water inputs and alteration of peak inflow magnitudes (see above)]	+	Medium
Alteration of water distribution and retention patterns *within* the wetland	Decreased water retention		
	Artificial drainage (e.g. ditches, cut-off-drains)	+ +	High
	Enhanced drainage due to erosion gullies or channelisation of streams associated with the wetland	+	Medium
	Decreased surface roughness (e.g. through replacement of indigenous vegetation)	+ +	High
	Water abstraction from the wetland	+	Low
	Infilling / increased deposition	+ +	Medium
	Dams and other impeding features - downstream/down-slope effect	+	Medium
	Increased water retention		
	Excavation (incl. mining and prospecting)	+	High
	Dams and other impeding features - upstream/up-slope effect	-	High

Figure 9: A filled-in example for the checklist of potential hydrological impacts

The checklists that have been developed for the DSP (included for reference purposes in Appendix 3 of the current report) represent a good point of departure for the development of a single, integrated, rapid method for the assessment of wetland PES in South Africa (identified in the review by Ollis and Malan, 2014 to be an urgent need at present). These lists are considered to be relatively comprehensive in terms of the possible impacts that could affect the ecological integrity of a wetland.

As explained previously, in all of the individual score-sheets for determining the PES for the various components of wetland condition (including the worksheets containing the checklists of potential impacts), a hyperlink is included to 'Check back to Reference State'. By clicking on this hyperlink, the assessor is taken back to the 'Ref-state' worksheet of the DSP so that the description of the reference state for that particular component can be checked (and possibly revised) in relation to the current state. The inclusion of these hyperlinks in the PES score-sheets serves as a visible reminder to the assessor that the assessment must be made relative to the perceived natural reference state for the particular component of wetland PES that is being assessed. In addition, there are hyperlinks to 'Look at Map/s' (for navigating back to the map/s of HGM Units and assessment units identified within the wetland that is being assessed) and to 'Refer to Checklist' (for navigating to the relevant list of potential impacts). In the case of the WET-Health score-sheets, as mentioned previously, hyperlinks are included to navigate to all the look-up tables that need to be consulted when conducting a WET-Health (Level 1) assessment. There are also 'Back to DSP Home' hyperlinks at the top and bottom of each score-sheet, to navigate back to the "home worksheet" of the DSP (e.g. when a particular score-sheet has been filled in).

4.2.6 Step 3c: Determine the Overall PES Score and Ecological Category for the wetland assessment unit

The penultimate step in the application of the DSP to a wetland assessment unit is to select the preferred component weightings to derive an Overall PES Score and Ecological Category for the assessment unit, if required. This step can only be applied once a PES% Score and Ecological Category has been generated for each component of wetland PES using the selected methods. It simply involves selection of the set of default weightings that the assessor would like to use to generate the overall score/category, according to the HGM type of the assessment unit. A matrix table is included under Step 3c in the 'DSP Home' worksheet for this purpose (as shown in Figure 10, below). The relevant matrix table has hyperlinks to worksheets for generating the overall PES scores and categories, according to the selected scoring method.

Wetland HGM type	Overall ecological condition
Floodplain wetland or **Channelled VB wetland** or **Unchannelled VB wetland** or **Seep**	Wetland-IHI default weightings **or** WET-Health default weightings **or** (Custom weightings)
Depression or **Wetland flat**	Not possible to derive overall PES Score from individual component scores (because no geomorphology module currently exists that is applicable to depressions or wetland flats) **in interim use** RDM-99 overall score/category

Figure 10: A copy of the matrix table included in the 'DSP Home' worksheet for selecting an appropriate scoring method to derive the Overall PES Score and Ecological Category

For all wetland HGM types except depressions and wetland flats, the DSP allows for the use of the default weightings of either the Wetland-IHI or the WET-Health method (see comparison of default weightings in Table 4, below). Neither of these sets of default weightings have, however, been properly tested for their applicability to different wetland types. Therefore, in the interim, a third option is provided in the DSP of selecting user-defined custom weightings to derive the Overall PES Score and Ecological Category for a wetland assessment unit. In the long-term, it is recommended that research is initiated to test the use of different sets of weightings for different HGM types and to ultimately develop validated, standardised sets of weightings for specific wetland HGM types.

Table 4: Comparison of the weightings (as a percentage) given to component scores in the derivation of the overall Wetland PES Score (and category) by the Wetland-IHI and WET-Health methods

Component	Weightings allocated to each component by different assessment methods (as a %)	
	Wetland-IHI	WET-Health
Hydrology	26.4%	42.8%
Geomorphology	21.2%	28.6%
Vegetation/Biota	44.4%	28.6%
Water quality	8.0%	n/a

Once a set of weightings has been selected using the applicable hyperlink in the appropriate matrix on the 'DSP Home' worksheet, an assessor will be directed to the relevant score-sheet for generating the Overall PES% Score and Ecological Category for the wetland. In this score-sheet, the assessor simply needs to enter the selected methods that were used to derive each of the component PES% scores, using the drop-down menus, and the Overall PES% Score and Ecological Category will be automatically calculated. A filled-in example of the score-sheet, for a hypothetical wetland, is presented in Figure 11 (below). In this example, the Wetland-IHI default weightings were used to derive the Overall PES% (36%) and Ecological Category (Category E). For this hypothetical example, WET-Health was used to determine the hydrology and vegetation PES% scores, Wetland-IHI was used to determine the PES% score for the geomorphology component, and the landuse-WQ model was used to determine the PES% score for the vegetation component.

Wetland name:	Hypothetical example
Assessment unit:	HGM 1a
Date of assessment:	Date
Name/s of assessor/s:	Name

Components	Selected method	PES% scores	Default weighting	Overall PES%	Overall Ecological Category
Hydrology PES%	WET-Health Hydro Module	25	0.19	**36%**	**E**
Geomorphology PES%	Wetland-IHI Geomorph Module	26	0.24		
Water quality PES%	Landuse-WQ Model	86	0.07		
Vegetation PES%	WET-Health Veg Module	37	0.50		

Figure 11: Filled-in example of the worksheet included in the DSP to derive an Overall PES% Score and Ecological Category using the Wetland-IHI default weightings (for a hypothetical assessment unit within a channelled valley-bottom wetland)

To ensure that the Overall Ecological Category for a wetland assessment unit is generated in a consistent way, irrespective of which PES assessment methods are used to derive the PES% scores for the different components of wetland condition, the same scoring system is used (as shown in Table 5). The scoring system, which is based on the ranges of PES% scores used by DWA to derive an Ecological Category (e.g. DWAF, 2008b), allows for the derivation of intermediate categories (e.g. A/B or C/D).

Table 5: Ranges of PES percentage scores used in the DSP to derive an Overall Ecological Category from A to F, including intermediate categories, on the basis of the Overall PES% Score for a wetland assessment unit (these ranges are also used to derive the final Ecological Category for each component of wetland PES in the summary table of the DSP) [after DWAF (2008b), as adapted from Kleynhans (1996)]

Ecological Category	Range of PES% scores
A	92-100%
A/B	87-91.9%
B	82-86.9%
B/C	77-81.9%
C	62-76.9%
C/D	57-61.9%
D	42-56.9%
D/E	37-41.9%
E	22-36.9%
E/F	17-21.9%
F	0-16.9%

If a customised weightings are used to derive the Overall PES Score, the assessor must enter the custom weightings (as a proportion) into the relevant score-sheet (‘Custom weighting’ column in ‘Custom weightings’ worksheet), ensuring that the total adds up to 1. Written motivation must be given for the selected weightings. An example of a situation in which the use of customised weightings may be justifiable for the derivation of overall wetland PES scores is in the context of a rapid Reserve Determination process for a wetland. A set of recommended weightings has been provided for this purpose in the updated manual for rapid wetland Ecological Reserve determination processes (Rountree et al., 2013) (see Table 6, below[12]). It is suggested by Rountree et al. (2013) that these ‘default’ weightings could be adjusted up or down if the confidence in the assessment of individual components is very high or low respectively, but that they should remain broadly within the ranges of the default figures provided.

[12] It is recommended by Rountree et al. (2013) that diatoms be included in every wetland Reserve study as a relatively reliable surrogate for water quality, and that the diatom PES is weighted higher than water quality PES because the current approaches for assessing water quality in wetlands are not well tested. The recommended weightings for diatoms are not, however, included in Table 6 of the current report because the DSP does not make provision for diatom PES assessment, and to enable better comparison with the default weightings of WET-Health and Wetland-IHI (in Table 4).

Table 6: Recommended weightings (as a percentage) for deriving overall PES scores for a wetland in the context of a rapid Ecological Reserve determination, without the diatom and possible fish components included**

EcoStatus component	Floodplain and CVB wetlands	UVB wetlands	Pans (Depressions)	Wetland flats	Seeps
Hydrology	28.6%	27.8%	37.0%	37.0%	26.3%
Geomorphology	28.6%	27.8%	n/a	n/a	26.3%
Water quality	17.1%*	19.4%*	29.6%*	29.6%*	21.1%*
Vegetation	25.7%	25%	33.3%	33.3%	26.3%

* Weighting to be used if this component is included in the assessment; if it is not included, the weightings for the other components would have to be adjusted accordingly.

** NOTE: In the standardised EcoStatus (PES) assessment procedure in the context of a rapid Reserve determination process for wetlands, diatoms should be included as one of the EcoStatus components to be assessed and given a weighting that is generally greater than the water quality weighting in the derivation of overall PES scores (except for seeps, where the same weighting is recommended for water quality and diatoms). The inclusion of diatoms would obviously mean that all the weightings in the table above would have to be proportionally down-weighted.

In the case of assessment units that are depressions or wetland flats, it is not possible to derive an overall PES Score from the individual scores for the different components of wetland condition because no geomorphology module currently exists that is applicable to these wetland types. As an interim measure, until such time as a suitable 'module' is developed for the determination of a Geomorphology PES% Score for depressions and wetland flats, the DSP allows for the use of the RDM-99 wetland PES assessment method (Duthie, 1999a) to derive an Overall PES Score and Ecological Category for these wetland types. The score-sheet included for this method in the DSP ('RDM-99' tab) automatically generates the Overall PES% Score and Category, both with and without the prescribed "override" applied, once all the individual criteria have been scored. The prescribed scoring procedure for the RDM-99 method stipulates that the lowest score should be taken as the Overall PES Score, instead of the average, if any criterion in the score-sheet is given a score of <2. In the review of PES assessment methods by Ollis and Malan (2014), this approach, (whereby the average score is "overridden" by the lowest score when deriving the Overall PES Score if a very low score is recorded for one or more of the criteria) was found to be too extreme. The option is thus given in the DSP of applying the RDM-99 method without this "override", at the discretion of the assessor, to derive an Overall PES Score and Category.

4.2.7 Step 3d: Generate a summary of the results of the PES assessment

The final step in the DSP is to generate a summary of the results of the PES assessment for the wetland assessment unit. A summary table is provided for this purpose (in the 'summary' worksheet, as shown in Figure 12), which is accessed by clicking on the 'Go to summary of results' (Step 3d) hyperlink in the 'DSP Home' worksheet. The summary is generated by simply stipulating which assessment methods were used to generate the PES scores for the various components of wetland condition, and which scoring method was used to derive the Overall PES Score for the assessment unit (with the option of selecting either RDM-99 method with 'override' or RDM-99 method without 'override' in the case of depressions and wetland flats). Drop-down lists are provided to assist with this. Notes are included (using 'comment boxes') to remind the assessor where certain assessment methods are not applicable. For example, there is a note for the Hydrology PES stating that "Wetland-IHI Hydrology module only applicable to floodplain and channelled VB wetland types". A filled-in example is presented in Figure 12 (below) for a hypothetical wetland.

SUMMARY OF PES RESULTS FOR WETLAND ASSESSMENT UNIT

Wetland name:	Hypothetical example
Assessment unit [refer to HGM-map]:	HGM 1a
HGM Type:	Channelled VB wetland
Date of assessment:	Date
Name/s of assessor/s:	Name

Back to DSP Home
Look at Map/s

Components	**Method used for assessment** [select using drop-down menus]	**PES% Score**	**Ecological Category**
Hydrology PES	WET-Health Hydro Module	25 %	**E**
Geomorphology PES	Wetland-IHI Geomorph Module	26 %	**E**
Water quality PES	Landuse-WQ Model	86 %	**B**
Vegetation PES	WET-Health Veg Module	37 %	**E**
Overall Wetland PES	Wetland-IHI default weightings	36 %	**E**

Figure 12: Filled-in example of the summary table in the DSP, for a hypothetical assessment unit within a channelled valley-bottom wetland

The final Ecological Categories presented in the summary table generated by the DSP, for the various components of wetland PES and for the Overall PES, are derived using the same scoring system based on ranges of PES% scores (as presented in Table 5) and include intermediate categories. This ensures that there is consistency in the way that the final results are presented by different assessors, and makes it transparent to a reader as to which methods were used to generate the results.

4.3 Anticipated areas of application

The DSP developed through WRC Project K5/2192 is intended specifically for application to the *rapid assessment of wetland PES*, for all types of inland wetlands in South Africa. This 'tool' could be used in the context of RDM and the EcoClassification aspect of rapid Ecological Reserve determination studies for wetlands. It could also be used in the context of environmental and water use authorisation processes involving wetlands, or any projects where a rapid assessment of the ecological condition of a wetland is required. The DSP is primarily for use in *rapid* PES assessments, not comprehensive assessments, but it could possibly also be used for PES assessments at an intermediate or desktop level (as discussed in Section 4.2.1).

4.4 Limitations of the DSP and important provisos for its use

It is important to bear in mind that the DSP has some inherent limitations. Firstly, having been designed specifically to assist with the rapid assessment of wetland PES, the DSP is <u>*not* applicable to the assessment of any other aspects such as the ecological importance and/or sensitivity of a wetland</u>. Secondly, the DSP is only for inland wetlands, and is thus <u>*not*</u>

applicable to rivers, lakes and other open waterbodies, or to marine and estuarine systems. A third and very important inherent limitation of the DSP is the fact that the PES scores that it generates are only as reliable as the existing wetland PES assessment methods included in the tool, namely WET-Health (Level 1 assessment) and Wetland-IHI (and the RDM-99 method for the Overall PES Score of depressions and wetland flats).

The testing of the most widely-used, nationally-applicable, existing methods for the rapid assessment of wetland PES that was undertaken for this project revealed that there is an unsatisfactory degree of variability between the results generated by the different methods (i.e. WET-Health Level 1, Wetland-IHI, and the RDM-99 method) and by different assessors applying the methods to the same wetlands (see Ollis, 2014). The implications of these findings are that the DSP could generate some dubious results if it is not applied with caution, taking cognisance of the fact that there are some gaps and limitations associated with the existing methods that have been included in the tool (as the best-available methods at present). This is an important proviso to bear in mind when using the DSP. A number of relatively minor refinements to the existing methods have been recommended to address some of the issues identified (see Ollis, 2014; Ollis and Malan, 2014). As a longer-term solution, however, it has been strongly recommended that a new tool for the rapid assessment of wetland PES be developed from the existing tools so that there is a single, thoroughly-tested and scientifically validated rapid PES assessment tool for wetlands that can be used for all inland wetland types throughout the country (Ollis and Malan, 2014).

As an interim measure for improving the consistency between the results generated by different assessors and through the use of different existing methods, the DSP explicitly includes a worksheet for mapping and estimating the proportional extents of the HGM Units and selected "assessment units" within a wetland (see Section 4.2.3) and a worksheet for describing the perceived natural reference state of a wetland that is being assessed (see Section 4.2.4). The checklists of potential impacts (and potential causes of these impacts) that have been included in the DSP for the various components of wetland condition (see Appendix 3) should also assist by highlighting any impacts that have not been adequately accounted for by the existing methods. It is thus very important, when using the DSP, that the 'HGM-map' worksheet, the 'Ref-state' worksheet and the checklists of possible impacts (and causes) for the different components of wetland condition are filled in by an assessor. It is the inclusion of these additional 'tools' in the DSP that really distinguishes it from the existing methods in its application. The recording of this additional information also introduces more transparency to a wetland PES assessment, making the derivation of PES Scores and Ecological Categories less of a "black box", and should ultimately assist with the future refinement of the existing assessment methods.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A Decision-Support Protocol (DSP) for the rapid assessment of wetland PES and an overarching decision-support Framework for Wetland Assessment in South Africa have been produced as the main deliverables for WRC Project K5/2192.

The separate modules from the WET-Health (Level 1) and Wetland-IHI assessment methods have been incorporated into the DSP, according to their relevance to different wetland types (including the option to use the Vegetation and Water Quality modules of Wetland-IHI for all wetland types). The DSP allows for the selection of the preferred weightings for the derivation of the overall Wetland PES by an assessor (i.e. the WET-Health default weightings or the Wetland-IHI default weightings, or customised weightings if neither of these are considered to be appropriate), until such time as the most appropriate weightings for different wetland types have been determined through rigorous testing. For depressions and wetland flats, the option is given of deriving the Overall PES Score using the RDM-99 method. This is because, for these wetland types, the Geomorphology PES cannot be determined using the existing methods and so it is not possible to derive an overall score by weighting and combining the various component scores.

Also included with the DSP are worksheets that were specifically developed for mapping HGM Units and assessment units, for describing the perceived reference state of a wetland, and for identifying (through the use of checklists) the most applicable potential impacts (and possible causes) that could be affecting the ecological condition of a wetland assessment unit. It is anticipated that these additional features will help different assessors to 'calibrate' their assessment of impacts in relation to the perceived natural reference state of a wetland when using the DSP. The additional information that is recorded will also make PES assessments more transparent and should thus facilitate the identification of the main reasons for differences between the results generated by different assessors, where such inconsistencies do occur.

The use of the DSP, and of the existing methods included in the DSP (i.e. WET-Health and Wetland-IHI), are considered to be the best available options for the rapid assessment of wetland PES at present. At the same time, however, there is clearly a dire need for the development of a single wetland PES assessment method (or a suite of similar assessment methods for different wetland types) in South Africa. The additional worksheets that were developed for the DSP could be used as a starting point in the development of such an integrated assessment method. Extensive testing/validation and consultation with the wetland community across the country will be vital in the development of an adequately robust method that will be acceptable for widespread use throughout the country.

The decision-support Framework for Wetland Assessment in South Africa that has been produced, to accompany and encompass the DSP is considered to be, inherently, a relatively robust 'tool'. This is because the Framework, unlike the DSP that was developed specifically for rapid wetland PES assessment, is more conceptual in nature and is not dependent on the reliability or availability of particular methods/tools. On the contrary, it is anticipated that the Framework will assist in the identification of areas where specific 'tools' are currently lacking or where there is a need for more guidance to be provided by relevant government agencies for particular aspects relating to the identification, mapping (delineation), classification (typing), management and/or monitoring of wetlands in South Africa.

5.2 Recommendations

It is recommended that the DSP and proposed Framework for Wetland Assessment in South Africa should be distributed, with the accompanying documentation, to the wetland 'community of practice' throughout the country. This could be achieved by making the 'tools' and accompanying documentation available online (e.g. on the WRC website) and widely advertising their availability. Adverts could be sent out via the Wetlands Portal of South Africa, the Wetlands List Server, provincial Wetland Fora, the South African Wetlands Society, the SASAQS mailing list, and the WRC's bi-monthly Water *Wheel* magazine. In addition, presentations about the finalised decision-support 'tools' could possibly be given at appropriate national conferences such as the National Wetlands Indaba and the annual SASAQS Conference.

Although it is anticipated that the DSP and overarching decision-support Framework for Wetland Assessment in South Africa will provide much-needed support and guidance for assessors and decision-makers involved in wetland assessment, management and/or monitoring throughout the country, a number of major gaps and areas for future research and development still exist. The following pertinent recommendations that were documented in Final Report Volume 1 (Ollis and Malan, 2014) are reiterated here:

- The existing assessment tools (particularly WET-Health and Wetland-IHI) should be combined into a single assessment tool or an integrated suite of assessment tools for the categorisation of wetland PES for all HGM types.
- As an interim measure, a method for assessing the ecological condition of depressions and wetland flats (and possibly for seeps that are not connected to a drainage network) should be formulated as a matter of urgency.
- Written guidelines should be produced to assist with the determination of the natural reference state for wetlands that are to be assessed in terms of their PES.
- The characteristics of minimally-impacted reference wetlands in different geographical areas should be documented, following a standardised approach and reporting format. It is acknowledged that this will be challenging, in the light of the widespread disturbance of wetlands that has already taken place in the country, and would thus require innovative approaches to be pursued.
- Field-guides should be developed for rating the extent and intensity of wetland impacts.
- Reporting guidelines and report templates should be produced for wetland PES assessments.

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APPENDIX 1:

PROPOSED DECISION-SUPPORT FRAMEWORK FOR WETLAND ASSESSMENT IN SOUTH AFRICA

(and Summary Table listing recommended methods/guidelines for each step in the Framework)

DECISION-SUPPORT FRAMEWORK FOR WETLAND ASSESSMENT IN SOUTH AFRICA

STEP 1: Contextualisation of assessment

- Determine the SCALE, TYPE and LEVEL of assessment required

STEP 2: Wetland identification, mapping (delineation) and classification

- Confirm that INLAND WETLANDS are present
- Map (DELINEATE) the wetland/s at an appropriate level of accuracy
- Identify HGM TYPES, as a minimum
- Distinguish between NATURAL vs. ARTIFICIAL systems
- Apply REGIONAL GROUPING, if necessary

STEP 3: WETLAND ASSESSMENT

Determination of perceived NATURAL REFERENCE STATE

Determination of Ecological Condition

- Hydrology PES*
- Geomorphology PES*
- Water quality PES*
- Vegetation PES*
- Overall PES*

***PES = Present Ecological State**

&/or

Risk Assessment & Determination of Anticipated Trends

- Identify threats
- Determine the anticipated trajectory of change
- Estimate wetland loss

&/or

Determination of Wetland Importance

- Wetland size
- Ecological Importance & Sensitivity (EIS) assessment
- Ecosystem services (functional importance)
- Socio-cultural importance
- Economic importance
- Biodiversity value
- Conservation importance

STEP 4: Setting of management objectives

- Desired future state (Recommended Ecological Category)
- Resource Quality Objectives (RQOs)
- Targets for provision of ecosystem services/wetland functions
- Conservation targets

STEP 5: Formulation and implementation of management measures

- Ecosystem PROTECTION measures
- Ecosystem REHABILITATION measures
- MONITORING programmes

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(WRC Project K5/2192)

WATER RESEARCH COMMISSION

Summary table listing the tasks typically associated with each of the steps in the proposed Framework for Wetland Assessment and the recommended methods or guidelines (with references) to use for these tasks

	Step	Tasks	Recommended methods/guidelines	References
1	**Contextualisation of assessment**	Determine the scale of assessment	n/a	n/a
		Determine the type/s of assessment	*Rapid Reserve determination context*: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
		Determine the level of assessment	*RDM context*: Guideline for identifying appropriate levels of resource protection measures for inland wetlands	DWA (2013)
2	**Wetland identification, delineation and classification**	Wetland identification and delineation	DWA's official guideline for the identification and delineation of wetlands [and riparian areas]	DWAF (2005, 2008)
			Additional guideline documents published in South Africa	Kotze (1996); Marneweck & Kotze (1999); Job (2009); Day et al. (2010)
			Wetlands Delineation Manual of the US Army Corps of Engineers	Environmental Laboratory (1987)
		Wetland mapping (and classification)	SANBI's wetland mapping guidelines (guidelines for capturing and recording standardised spatial wetland information)	SANBI (2012)
		Classification of wetland types	SANBI's Classification System for wetlands and other inland aquatic ecosystems in South Africa	Ollis et al. (2013)
3	**Wetland assessment**	**Determine the Present Ecological State (PES):**		
		- rapid PES assessment	RDM-99 method	Duthie (1999)
			Wetland-IHI (for floodplain and channelled VB wetlands)	DWAF (2008)
			WET-Health (Level 1)	Macfarlane et al. (2007)
			Rapid Reserve determination context: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
			Decision-Support Protocol (DSP) for rapid wetland PES assessment	Ollis et al. (2014) [this report]
		- detailed PES determination	WET-Health (Level 2)	Macfarlane et al. (2007)
		Identify the risks and determine the anticipated trends	WET-Health guidelines for evaluation of the anticipated trajectory of change in hydrology/geomorphology/vegetation PES	Macfarlane et al. (2007)
			WET-SustainableUse	Kotze (2010)
		Determine wetland importance:		
		- Assessment of ecosystem service provision ('functional assessment')	WET-EcoServices	Kotze et al. (2007)
		- Assessment of Ecological Importance & Sensitivity (EIS)	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013), after Kleynhans (1999) and Duthie (1999b)
		- Assessment of hydrofunctional importance	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013), after Kotze et al. (2007)

Step		Tasks	Recommended methods/guidelines	References
		- Assessment of direct human benefits	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013), after Kotze et al. (2007)
		- Assessment of overall Wetland Importance	Specialist Appendix A3 of Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree & Kotze (2013)
		- Assessment of conservation importance	Method developed by FCG for the rapid categorisation of the conservation importance of inland aquatic ecosystems	Ollis et al. (2014) [this report], after Ewart-Smith & Ractliffe (2002)
		- Assessment of socio-cultural and economic importance	A tool for the assessment of the livelihood value of wetlands	Turpie (2010)
			A protocol for quantification and valuation of wetland ecosystem services	Turpie and Kleynhans (2010)
4	**Setting of management objectives**	Determine the Recommended Ecological Category (REC)	*Rapid Reserve determination context*: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
		Set Resource Quality Objectives	Procedures to develop and implement RQOs	DWA (2011)
		Set the Ecological Management Class	National Water Resource Classification System (NWRCS)	DWAF (2007)
		Set wetland rehabilitation objectives	WET-RehabPlan	Kotze et al. (2009a)
		Set targets for provision of wetland ecosystem services	WET-EcoServices document contains useful info	Kotze et al. (2007)
		Set conservation targets and prioritise wetlands for conservation/rehabilitation	WET-Prioritise	Rountree et al. (2009)
5	**Formulation and implementation of management measures**	Determine buffer widths and establish buffer areas around wetlands	DWA-WRC 'tool' for the determination of recommended buffer widths for wetlands (to be published soon)	Macfarlane et al. (in prep.)
		Formulate and implement wetland rehabilitation measures	WET-RehabPlan	Kotze et al. (2009a)
			WET-RehabMethods	Russel (2009)
		Formulate and implement wetland offsets, as a last, if no other options are feasible	National guidelines for wetland offsets	DWA & SANBI (2013)
		Determine the Ecological Reserve and implement the 'operating rules'	*Rapid Reserve determination context*: Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0)	Rountree et al. (2013)
		Set Ecological Specifications (EcoSpecs) for wetlands	Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0) contains a brief description of the process	Rountree et al. (2013)
		Compile and rollout an Implementation Plan for wetland RDM	Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0) contains a brief description of what this entails	Rountree et al. (2013)
		Formulate and implement conditions for wetland-related water use authorisations	[Internal DWA documents]	[not publicly available]
		Monitor wetlands	Documents and 'tools' from WRC project to develop the framework for a national wetland monitoring programme (WRC Project No. K5/2269)	[project still in progress]
			WET-RehabEvaluate for monitoring wetland rehabilitation projects	Cowden & Kotze (2009)
			WET-EffectiveManage for evaluating how effectively a wetland is managed	In: Kotze et al. (2009b); Kotze (2010)

APPENDIX 2:

DECISION-SUPPORT PROTOCOL (DSP) FOR THE RAPID ASSESSMENT OF WETLAND PRESENT ECOLOGICAL STATE (PES)

[provided in electronic format (Microsoft Excel spreadsheet file)]

APPENDIX 3:

COMPREHENSIVE LISTS OF POTENTIAL IMPACTS TO THE PRESENT ECOLOGICAL CONDITION OF WETLANDS

LIST OF POTENTIAL HYDROLOGICAL IMPACTS

Impacts	Possible causes
Decreased/increased water inputs (quantity)	<u>Decreased inflows</u> Diversion of flows that would have entered the wetland Water abstraction (of surface water and/or groundwater) Damming and obstruction of flow (upstream/up-slope of the wetland) Afforestation in the catchment Extensive evergreen crops (e.g. sugarcane) in the catchment Exotic (invasive alien) plant invasion in the catchment <u>Increased inflows</u> Extensive loss of vegetation cover in the catchment Stormwater input Input of treated effluent Irrigation return flows Interbasin transfers into the catchment
Alteration of peak inflow magnitudes	<u>Increased peak flow magnitudes</u> Extensive loss of vegetation cover in the catchment Catchment hardening (urbanisation) <u>Decreased peak flow magnitudes</u> Damming and obstruction of flow (upstream/up-slope of the wetland) Diversion of flows that would have entered the wetland
Alteration of *frequency and/or timing* of water inputs (change in seasonality of inflows)	[same as for decreased/increased water inputs and alteration of peak inflow magnitudes (see above)]
Alteration of water distribution and retention patterns *within* the wetland	<u>Decreased water retention</u> Artificial drainage (e.g. ditches, cut-off-drains) Enhanced drainage due to erosion gullies or channelisation of streams associated with the wetland Decreased surface roughness (e.g. through replacement of indigenous vegetation) Water abstraction from the wetland Infilling/increased deposition Dams and other impeding features – downstream/down-slope effect <u>Increased water retention</u> Excavation (incl. mining and prospecting) Dams and other impeding features – upstream/up-slope effect

LIST OF POTENTIAL GEOMORPHOLOGICAL IMPACTS

Impact	Possible causes
Alteration of sediment supply from the *catchment*	Increased sediment input
	Erosion in the catchment
	Extensive (currently active) open cast mining in the catchment
	Lots of gravel roads in the catchment
	Breaching of dam walls or weirs (upstream/up-slope)
	Extensive clearing of vegetation within the catchment (bare ground)
	Reduced sediment input
	Dams and/or weirs (upstream/up-slope from the wetland)
	Trapping of sediment behind causeways (road crossings)
	Canalisation of river channels
	Extensive catchment hardening (urbanisation)
	Increase in vegetation cover in the catchment
	Mining of sand (and other sediments) in the catchment
Alteration of sediment transport capacity (change in water yield and/or flood peaks)	Increased sediment transport capacity
	Increased runoff (e.g. though urbanisation and catchment hardening)
	Interbasin transfers with sustained high flows and large peak flow increases
	Sustained high-flow releases from large dams
	Channelisation (channel widening/deepening/straightening)
	Input of stormwater and/or treated effluent
	Extensive irrigation (irrigation return flows)
	Decreased sediment transport capacity
	Damming and obstruction of flows (upstream/up-slope from the wetland)
	Diversion of upstream flows
	Water abstraction and water use within the catchment
Diversion/straightening of natural channels associated with the wetland	
Increased erosion *within the wetland*	*Erosional features (not causes of increased erosion):*
	Formation of gullies/dongas in the wetland
	Incision of main channel associated with wetland
Increased deposition *within the wetland*	*Depositional features (not causes of deposition):*
	Alluvial fans
	Increase in vegetation robustness and/or cover
	Recent deposits of sediment
	Destruction of existing wetland features (e.g. disappearance of a deeply flooded area or a channel)
Loss of organic sediment *within the wetland*	Peat extraction
	Peat fires
	Tillage of organic soils
	Erosion
	Desiccation of wetland (reduction in period of saturation)

Impact	Possible causes
Topographic alteration *within the wetland*	Infilling
	Ploughing
	Excavation
	Construction of drainage features (e.g. drainage ditches and berms)
	Construction of dams/weirs within/across the wetland
Compaction/disturbance of sediments *within the wetland*	Ploughing
	Pugging and trampling by livestock

LIST OF POTENTIAL WATER QUALITY IMPACTS

Impact	Possible causes
Alteration of pH	Increased pH (alkalinisation)
	Cement and cement-contaminated water (construction)
	Excessive plant and/or algal growth (increased photosynthesis) – daytime effect
	Input of alkaline effluents from certain industries (e.g. food canning and textile production)
	Input/runoff of near-neutral water into naturally acidic systems
	FYNBOS BIOME: Removal/replacement of indigenous fynbos vegetation in the catchment
	Decreased pH (acidification)
	Acid mine drainage
	Acid rain
	Input of acidic effluents from certain industries (e.g. chemical, pulp/paper, and tanning/leather industries)
Alteration of TDS/conductivity	Increased TDS/conductivity (salinisation)
	Input of industrial effluents
	Runoff from fertlised land (e.g. cultivated agricultural areas, gardens, sports fields)
	Irrigation in the catchment (especially in semi-arid or arid regions)
	Input/runoff of relatively saline water into naturally fresh systems
	Reduction of inflows/water levels (e.g. through water abstraction)
	Clear-felling of trees in the catchment
	Re-use and recycling of water taken from natural systems
	Decreased TDS/conductivity ('freshening')
	Input/runoff of relatively fresh water into naturally saline systems (e.g. in arid or semi-arid regions)
	Increased baseflows and loss of seasonality
	Deep inundation of areas that were naturally shallowly inundated
Water temperature changes	Increased water temperatures
	Input of heated power station discharges
	Input of heated industrial discharges
	Decreased vegetation cover, esp. tree canopy cover (e.g. through removal of natural vegetation)
	Decreased flow rates/water levels
	Decreased groundwater input
	Runoff/input of irrigation return water
	Decreased turbidity of water column
	Overflows/releases from small dams
	Interbasin water transfer from a warmer system
	Decreased water temperatures
	Increased vegetation cover, esp. tree canopy cover (e.g. afforestation or invasive alien plant encroachment)
	Increased flow rates/water levels
	Increased turbidity of water column
	Bottom-releases from large (thermally stratified) dams
	Interbasin water transfer from a colder system

Impact	Possible causes
Alteration of dissolved oxygen concentrations	Decreased dissolved oxygen percentage saturation (oxygen depletion)
	Organic pollution (e.g. sewage contamination)
	Input of pollutants with a relatively high COD (e.g. sugar cane processing effluent)
	Re-suspension of anoxic sediments
	Release of anoxic bottom water
	Increased dissolved oxygen percentage saturation (super-saturation)
	Excessive plant and/or algal growth (increased photosynthesis) – daytime effect
	Increased turbulence in the water column
Alteration of TSS/turbidity	Increased TSS/turbidity (sedimentation)
	Dredging
	Input of mine tailings (incl. slimes)
	Trampling of wetland and surrounding areas by livestock
	Overgrazing of surrounding areas
	Excessive erosion in the catchment
	Open cast mining in the catchment
	Land-clearing in the catchment
	Agriculture or forestry activities in the catchment
	Extensive gravel roads in the catchment
	Road construction (current)
	Decreased water levels/flow rates
	Incision (down-cutting) of river channels
	Runoff/discharges from certain industries (e.g. breweries, paper mills, textile factories)
	Input of organic waste (e.g. sewage effluent, manure, fruit waste)
	Decreased TSS/turbidity
	Sediment trapping by dams and weirs (upstream/upslope)
	Sediment trapping by road crossings (upstream/upslope)
	Canalisation of river channels
	Catchment hardening (urbanisation)
	Increased water levels/flow rates
Nutrient enrichment	Sewage effluent
	Industrial discharges
	Intensive animal enterprises (e.g. cattle farms/dairies/feedlots, piggeries, chicken farms)
	Detergents
	Agricultural surface runoff
	Disturbance of soil mantle (e.g. through land clearing and ploughing)
	Addition of fertilizers
	Manure/bird droppings
	Urban runoff
	Abattoirs
Bacteriological contamination	Untreated sewage (point/non-point sources)
	Runoff from livestock farms
	Runoff/discharges from chicken farms and processing factories
	Runoff/dicharges from abattoirs

Impact	Possible causes
Heavy metal contamination	Industrial effluents
	Agricultural runoff
	Acid mine drainage
	Stormwater runoff from roads and urban areas
Oil pollution	Oil spillage into a wetland
	Runoff/input from industrial areas
	Runoff from roads
	Discharge of oil-contaminated effluents
Contamination/pollution by other toxicants	*Examples (<u>not</u> possible causes):*
	Biocides (pesticides, herbicides, fungicides, etc.)
	Endocrine disrupting contaminants (EDCs)
	Radioactive material

LIST OF POTENTIAL VEGETATION ALTERATION IMPACTS

Impact	Possible causes
Clearing/removal/smothering of natural vegetation	Land clearing (e.g. for urban development)
	Mining and excavation
	Infilling (incl. artificial levees)
	Deep and permanent/near-permanent back-flooding by dams/weirs
	Infrastructure development
	Removal of entire indigenous plants (e.g. through unsustainable harvesting practices)
	Very intensive grazing by high densities of livestock
Replacement of natural vegetation	Planting of agricultural crops (incl. pastures)
	Afforestation
	Establishment of residential gardens
	Establishment of sports fields
Historical agricultural transformation of land	Recently abandoned farmland
	Old abandoned farmland
Encroachment of alien/invasive plants into wetland	
Encroachment of terrestrial vegetation into wetland (due to drying out of wetland)	
Loss of diversity/shift in compositional structure	Loss of sensitive species
	Increased abundance of (and possible unnatural domination by) hardy/invasive indigenous species
	Transition from grassland to woodland
	Burning of wetland too frequently/infrequently
	Prevention or lack of natural grazing (e.g. by fencing of wetland or an absence of natural grazers)
	Unnaturally high levels of grazing by livestock/game
	Shallow and seasonal/intermittent back-flooding
	Seepage from dams causing more permanent soil saturation
Physical disturbance of natural vegetation	Trampling by livestock
	Footpaths through wetland
	Mowing of wetland vegetation
	Harvesting of indigenous plant species (incl. firewood collection)
	Stockpiling of material in wetland
	Excessive erosion/deposition in the wetland
	Intense fire through wetland (recently)
	Unnaturally intense flood events (e.g. from urban stormwater runoff or high-flow releases from upstream dams)