WET-EcoServices (Version 2)

A technique for rapidly assessing ecosystem services supplied by wetlands and riparian areas

Report to the
Water Research Commission

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EXECUTIVE SUMMARY

Background and aims of the project

Wetlands and riparian areas are globally threatened ecosystems and are well-recognized for the ecosystem services which they supply. Furthermore, these ecosystems make potentially important ecosystem services contributions to several broad-scale imperatives of government, including: water resource management; biodiversity conservation; human safety and disaster resilience; socio-economic development and poverty elimination; and climate change mitigation and adaptation.

Individual wetland/riparian areas differ according to their characteristics, contexts and the particular suite of ecosystem services which they supply to society. Thus, there is a need to assess and compare wetland/riparian areas in terms of ecosystem services delivery. Recognizing this need, a rapid assessment technique, termed WET-EcoServices (Version 1) was developed 10 years ago to help non-specialists assess the ecosystem services that individual wetlands supply. The technique has been revised through a Water Research Commission project to produce WET-EcoServices Version 2. The project addressed the following aims:

- Review WET-EcoServices against international best-practice and feedback from users of the technique.
- Comprehensively refine WET-EcoServices and its associated guideline document based on the above review and systematic field testing.
- Expand WET-EcoServices to include non-wetland riparian areas.
- Document some cases in order to showcase the application of WET-EcoServices across a range of applications and contexts.
- Provide recommendations for better integrating Wet-EcoServices outputs into the EIS (Ecological Importance and Sensitivity) tool.

Structure of the report

The main text of the document is given in three parts.

Part 1 begins by providing a short background to the technique and a brief description of each ecosystem service included in the technique in an attempt to clarify exactly what is represented by the particular ecosystem service. It then describes the technique, including its overall structure and the seven practical steps involved in applying the technique. This includes the rationale and method for assessing each indicator which is used together with the spreadsheet tool to undertake the assessment. A summary of the limitations of the technique are then given in order to discourage users from using the technique beyond its resolution/capability. Finally, guidance is provided on how the technique can be used to inform offset calculations.

Part 2 gives detailed background information on the technique, including key underpinning concepts, which are described with reference to relevant literature. It also describes how the technique was developed. Further, it elaborates more fully on the limitations of the technique given in Part 1, and provides specific recommendations for addressing these limitations in more detailed assessments and further research.

Part 3 provides selected case examples where the technique has been applied to a variety of different contexts and for a variety of different purposes.

Refinements carried out to the technique and other key outcomes of the project

The solicited comments on Version 1 of the technique and a review of international best practice were used to inform the development of an initial draft of Version 2, which was refined through application and testing. The testing included: (1) testing the consistency of the results when applied by different assessors, including experienced and less experienced assessors; and (2) validation testing on a few selected sites based on a comparison of the WET-EcoServices scores against the results produced by an independent panel of experts who scored the sites based on detailed information which was available for the sites.

The aims of the project (given at the beginning of the Executive summary) were achieved, and based on the review and feedback, together with the results of testing, several key changes/refinements were made to the technique, including the following:

- Non-wetland riparian areas have been included in the technique.
- The technique is now more explicit in terms of distinguishing ecosystem services supply and demand and the beneficiaries of the services, in particular the level of dependency of the beneficiaries on the services being assessed.
- Some of the indicators have been refined, e.g. instead of confining consideration of organic-rich soils to peat, this has been extended to include all organic soils, given the very limited occurrence of true peats in South Africa.
- A few of the indicators have been replaced with indicators better related to the ecosystem service or for which information is more readily available at a national level.
- Some key additional indicators have been added, e.g. catchment interception potential, for which wetland catchment size is taken as a proxy.
- The algorithms used to determine a score for each ecosystem service based on the scores for the relevant indicators have been refined so as to better account for the relative importance of the respective indicators.
- Improvements to ease of use of the technique, in particular with fuller explanations provided for tricky attributes, such as the surface roughness of the vegetation.
- Guidance provided on how the technique can be used to inform offset calculations.

The application of the technique at five different sites representing a diversity of land-use contexts has also been documented in order to demonstrate a variety of applications of WET-EcoServices Version 2.

In addition, recommendations for better integrating Wet-EcoServices outputs into the EIS tool were developed based on the review and stakeholder workshop with the Department of Water Affairs and Sanitation.

The refinements to WET-EcoServices listed earlier, together with the application of the technique to a diversity of cases, all represent important findings of the project and contribute significantly to the generation of new knowledge relating to assessing ecosystem services in South Africa's wetlands and riparian areas. This knowledge represents both the knowledge distilled into the technique itself as well as how the technique is anticipated to better equip practitioners and scientists in the future to add more effectively to the pool of knowledge on the ecosystem services of South Africa's wetlands and riparian areas. The application of the tool in other countries is also actively encouraged, particularly in regions for which techniques have yet to be developed.

An overview of WET-EcoServices Version 2

The overall purpose of WET-EcoServices is *to assist decision makers, government officials, planners, consultants and educators in undertaking rapid assessments of individual wetlands and riparian areas in order to reveal the importance of the ecosystem services* which the individual wetland/riparian areas provide.

The specific uses for which the results of a WET-EcoServices assessment might be applied include:

- Prioritise resource allocation for management and rehabilitation across a set of wetland/riparian areas.
- Assess ecosystem service outcomes and associated trade-offs of wetland rehabilitation projects by applying the technique to "with rehabilitation" and "without rehabilitation" situations.
- Flag important ecosystem services as part of an Environmental Impact Assessment or to help direct further investigations, including monetary valuation of key ecosystem services.
- Educate and raise awareness about the importance of wetland and riparian areas.
- Flag important ecosystem services to be considered when managing individual wetland/riparian areas.
- Inform offset planning, in particular offset calculations related to water resource management.
- Assist in Ecological Reserve Determinations, specifically where the importance of the wetland/riparian area needs to be accounted for when deciding on ecological flows.
- Assist in sustainability-of-use assessments.
- Determine the relative importance of individual wetland/riparian areas in a catchment context.

Users of WET-EcoServices should have good general experience and training, preferably with a minimum of a diploma or degree in the biophysical sciences. Further, they should have attended at least a basic introductory course on wetland functioning and values and should have had at least eight weeks experience in field assessment of wetlands. In addition, input is required of someone with specific local knowledge of the geographical area to which WET-EcoServices is to be applied.

WET-EcoServices Version 2 includes 16 different ecosystem services, which were selected for their specific relevance to the South African situation.

- Flood attenuation
- Streamflow regulation
- Sediment trapping
- Phosphate assimilation
- Nitrate assimilation
- Toxicant assimilation
- Erosion control
- Carbon storage
- Biodiversity maintenance
- Provision of water for human use
- Provision of harvestable resources
- Food for livestock
- Provision of cultivated foods
- Cultural and spiritual experience
- Tourism and recreation
- Education and research

WET-EcoServices Version 2 is specifically designed for rapid *field* assessment, generally taking no more than two people a half day in the field and requiring no more than a half day of office preparation and data analysis. WET-EcoServices provides a set of indicators (e.g. slope of the wetland) rated on a five-point scale of 0 to 4 that reflect the supply/capability of a wetland for each of the 16 different ecosystem services listed above. An Excel™ based spreadsheet tool has been developed to conduct the assessment.

For each ecosystem service, indicator scores are combined automatically in an algorithm given in the spreadsheet that has been designed to reflect the relative importance and interactions of the attributes represented by the indicators to arrive at an overall supply score. In addition, the demand for the ecosystem service is assessed based on the wetland's catchment context (e.g. toxicant sources upstream), the number of beneficiaries and their level of dependency, which are also all rated on a five-point scale. Again, an algorithm automatically combines the indicator scores relevant to demand to generate a demand score.

Applying WET-EcoServices Version 2 encompasses seven primary steps:

1. Define the objectives and scope of the assessment, based on, amongst others, the following key questions: How will the importance scores be used? What specific decisions are to be informed? and What are the specific information needs for these decisions?

2. Identify the Assessment Unit/s and their catchment/s and downstream service area/s. The Assessment Units within the mapped wetland/riparian area/s are identified by dividing these areas into Hydrogeomorphic (HGM) units – each HGM unit would generally constitute a separate Assessment Unit, but in some cases may be sub-divided or grouped together.

3. Prepare before going into the field. This involves becoming familiar with all of the indicators, and knowing which can be scored based on a desktop assessment and which need to be assessed in the field, and then planning the field visit.

4. Assess and score the indicators. All indicators need to be assessed and scored, and for each indicator, the Rationale underlying the indicator and the Methods which should be used to assess the indicator and decide on the score are provided. It is important that the Rationale provided be understood and that the Methods be followed closely in order to promote consistency of assessment.

5. Enter the scores in the spreadsheet. This is done on the first sheet of the spreadsheet, and the scores are then automatically carried through to the second sheet, where the calculations are carried out automatically.

6. Check and where necessary refine the Demand and Supply scores. A "Demand & Supply" tab is used to integrate the scores for relevant indicators into a Demand and Supply score for each ecosystem service. These scores should be reviewed, and where they are identified to poorly reflect the situation on the ground can be adjusted, provided that well documented justification is given.

7. Present and interpret the results, which are given as a summary table showing the supply, demand and overall importance scores for each ecosystem service and as a spider diagram showing supply and demand. Guidance is provided in terms of interpreting supply relative to demand.

A single overall importance score is generated for each ecosystem service by combining the supply and demand scores. Although a future scenario can also be scored, the focus here is the relative importance of the wetland/riparian area in currently providing ecosystem services. This aggregation therefore places somewhat more emphasis on supply than demand, with the supply score acting as the starting score for a "moderate" demand scenario. The importance score is, however, adjusted by up to one class up where demand is "very high" and by up to one class down where demand is "very low". The overall importance score can then be used to derive an importance category for reporting purposes. However, assessors are encouraged not to focus on the overall score (or importance category) alone as this will result in the "loss" of useful information.

Finally, guidance is also provided on how the WET-EcoServices technique can be applied in wetland offset calculations. This has particular relevance to assessments concerned with the impact of wetland loss and the consequent loss of wetland functions relevant to water resource management. The approach allows for an offset currency to be developed based on the local catchment context and uses a hectare equivalents approach to assess the gains in response to improvements anticipated with rehabilitation.

Limitations of the technique and recommendations for addressing these limitations

It is very important that anyone using the technique appreciate what it is not designed to do. Therefore, limitations of the technique have been identified, and some key limitations include:

Limitations in terms of scope of the technique

- Scores obtained using the technique have not been correlated with real economic values, and as such, cannot be used to infer an economic value for a wetland or riparian area.
- Given that scores for each service are relative to other wetlands for a specific service, a high importance score for flood attenuation, for example, cannot be equated with a high importance score for livestock grazing.

Limitations in terms of the technique's resolution and its representation of complexity

- It does not give a detailed description of a wetland site, including the direct description of hydrogeomorphic and biogeochemical processes, but instead uses coarse-scale proxies of these processes.
- It cannot be used to make fine-resolution distinctions in terms of ecosystem services provision.
- Demand for the ecosystem services takes into account number of users very coarsely with only a five-class scale.
- Level of dependency of users does not represent the diversity of dependency which may exist amongst users, and also does not explicitly account for the multiple socio-economic factors affecting dependency.

Limitations in terms of testing

- Application and testing within non-wetland riparian ecosystems was limited.
- Testing has not included unvegetated wetlands.
- Testing has been greater in the higher rainfall areas of the country than in semi-arid to arid areas.
- Testing has been limited for ecosystem services most difficult to validate.

Recommendations are provided in Part 2 of the main document for addressing these limitations for an intermediate-level assessment. For example, in order to carry out a somewhat higher resolution assessment of demand, a greater number of classes could be used, e.g. 10 classes instead of five classes, and for an intermediate resolution assessment, the approximate actual number of users would generally need to be estimated. Recommendations are also provided for further testing and refinement, particularly in those contexts listed above which have been most limited in terms of testing. For example, further testing and development of WET-EcoServices should focus on the under-represented types/contexts listed in the limitations. In addition, a particular effort should be made to use sites where data and understanding levels are relatively high and can therefore be used to help further validate the technique.

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ACRONYMS

DEA: Department of Environmental Affairs
DWAF: Department of Water Affairs and Forestry
DWS: Department of Water and Sanitation
EIS: Ecological Importance and Sensitivity
HGM: Hydrogeomorphic
IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
MEA: Millennium Ecosystem Assessment
NRC: National Research Council
PEDRR: Partnership for Environment and Disaster Risk Reduction
PES: Present Ecological State
SANBI: South African National Biodiversity Institute
TEEB: The Economics of Ecosystems and Biodiversity

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PART 1: GUIDELINE FOR APPLYING THE TECHNIQUE

1. Introduction

With today's high technology and global transport of food and other commodities, our attention has been diverted away from the ecosystems on which our well-being and long-term economic prosperity depend. Wetlands are among the most globally threatened and important ecosystems, providing a host of services to society (MEA, 2005; TEEB, 2010). Riparian areas are also threatened and well recognized for the ecosystem services which they supply (NRC, 2002; Capon and Pettit, 2018). As elaborated upon in Part 2, wetlands and riparian areas represent ecological infrastructure which can make potentially important ecosystem service contributions to several different broad-scale imperatives/objectives of government, both at the national and international scale, including:

- Water resource management
- Biodiversity conservation
- Human safety and disaster resilience
- Socio-economic development and poverty elimination
- Climate change mitigation and adaptation

Every wetland and riparian area is therefore likely to be of some importance. However, individual wetland/riparian areas differ according to their characteristics, contexts and the degree to which they supply different ecosystem services to society, as well as differing according to level of use. Thus, society may deem some wetland/riparian areas more important than others.

Thus, there is a need to assess and compare wetland/riparian areas in terms of ecosystem services delivery. Recognizing this need, the first version of WET-EcoServices (Kotze et al., 2008) was developed. While at the time, several different techniques existed for assessing ecosystem services, none of these were directly transferable to the South African situation. Many of the techniques were geared primarily for the developed world and mainly for wetlands in northern temperate regions, and thus, a locally relevant tool was developed. This first version of WET-EcoServices (Kotze et al., 2008) has now been refined and revised to produce WET-EcoServices Version 2 (this document). Version 2 has several additions (notably the inclusion of non-wetland riparian areas) and refinements (notably a more explicit separation of ecosystem service supply and demand), as elaborated upon in Part 2.

2. Purpose and scope of the technique

The overall purpose of WET-EcoServices is *to assist decision makers, government officials, planners, consultants and educators in undertaking rapid assessments of individual wetlands and riparian areas in order to reveal the importance of the ecosystem services* which the individual wetland/riparian areas provide.

For the purposes of the technique, wetlands and riparian areas are defined as they are categorized in the Water Act (Act No 36 of 1998), as follows:

“riparian habitat'' includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.

“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 typically adapted to life in saturated soil.

Where a stream is flowing through a wetland/riparian area then the stream is included as part of the area assessed. However, in the case of riparian areas, the assessment of regulating and supporting services is based on processes associated with the riparian area bordering the stream/river rather than the services provided by the active channel. This is due to the fact that instream processes and associated functions are very different to those provided by the riparian area and the fact that the active channel is highly dynamic in many instances, changing in response to prevailing climatic conditions and flood events."

The technique allows for importance in terms of ecosystem service provision to be compared across: (a) two or more different individual wetland/riparian areas (e.g. within a given catchment or management area); or (b) the same area under different management/rehabilitation scenarios. This will hopefully contribute to improved understanding and allow for more informed planning and decision-making.

Ecosystem services are defined as "*the aspects of ecosystems utilized (actively or passively) to produce human well-being* (Fisher et al., 2009: 645). Defined this way, ecosystem services include ecosystem organization or structure as well as process and/or functions if they are consumed or utilized by humanity either directly or indirectly" (Fisher et al., 2009: 645). WET-EcoServices includes the assessment of several different ecosystem services (Table 2.1) which, according to the categorization of ecosystem services by MEA (2005), encompass supporting services, regulating services, provisioning services and cultural services. For further elaboration on the definition of ecosystem services and different approaches for categorization of these services, see Part 2.

From Table 2.1 it can be seen that WET-EcoServices includes 16 different ecosystem services, which were selected for their specific relevance to the South African situation. Each of the 16 individual services is described in more detail in Section 7. It is recognized that, as listed in Appendix C, there are several additional ecosystem services not explicitly covered in the technique. If there is a specific need to assess any of the services missing from WET-EcoServices then the RAWES method (McInnes and Everard, 2017), which includes all of these services (but with less specific guidance than that provided by WET-EcoServices) is recommended.

Table 2.1: Ecosystem services included in WET-EcoServices.

Services contributing to indirect benefits	Regulating and supporting services	Flood attenuation		The spreading out and slowing down of floodwaters in the wetland/riparian area, thereby reducing the severity of floods downstream (Adamus et al., 1987; MEA, 2005)
		Streamflow regulation		Sustaining streamflow during low flow periods (McInnes and Everard, 2017)
		Water quality enhancement services	Sediment trapping	The trapping and retention in the wetland/riparian area of sediment carried by runoff water (Adamus et al., 1987)
			Phosphate assimilation	Removal by the wetland/riparian area of phosphates carried by runoff water, thereby enhancing water quality (O'Geen et al., 2010)
			Nitrate assimilation	Removal by the wetland/riparian area of nitrates carried by runoff water, thereby enhancing water quality (O'Geen et al., 2010)
			Toxicant assimilation	Removal by the wetland/riparian area of toxicants (e.g. metals, biocides and salts) carried by runoff water, thereby enhancing water quality (O'Geen et al., 2010)
			Erosion control	Controlling of erosion at the wetland/riparian area, principally through the protection provided by vegetation (MEA, 2005).
		Carbon storage		The trapping of carbon by the wetland/riparian area, principally as soil organic matter (Kumar et al., 2017)
	Biodiversity maintenance[1]			Through the provision of habitat and maintenance of natural process by the wetland/riparian area, a contribution is made to maintaining biodiversity (Liquete et al., 2016)
Services contributing to direct benefits	Provisioning services	Provision of water for human use		The provision of water which is taken directly from the wetland/riparian area for domestic, agriculture or other purposes (Kumar et al., 2017)
		Provision of harvestable resources		The provision of natural resources from the wetland/riparian area – including craft plants, fish, wood, etc. (McInnes and Everard, 2017)
		Food for livestock		The provision of grazing for livestock (McInnes and Everard, 2017)
		Provision of cultivated foods		The provision of cultivated foods from within the wetland/riparian area (McInnes and Everard, 2017)
	Cultural (non-material) services	Cultural and spiritual experience		Places of special cultural significance in the wetland/riparian area – e.g. for baptisms or gathering of culturally significant plants (McInnes and Everard, 2017)
		Tourism and recreation		Sites of value for tourism and recreation in the wetland/riparian area, often associated with scenic beauty and abundant birdlife (McInnes and Everard, 2017)[2]
		Education and research		Sites of value in the wetland/riparian area for education or research (McInnes and Everard, 2017)

[1]It is recognized that biodiversity maintenance is not an ecosystem service in the strict sense (Liquete et al., 2016), and is framed in less anthropocentric terms than all of the other services, but it underpins many other services and is widely acknowledged as having high value to society broadly, even in the absence of any local or downstream beneficiaries.

[2] WET-EcoServices focusses on recreational services which are specifically nature-based, e.g. bird watching. It does not account specifically for recreational services from wetland/riparian areas that have been converted into sports grounds, children's playgrounds or other built infrastructure.

3. Anticipated uses and users of the technique

There is no such thing as an ideal wetland assessment technique. The suitability of any technique depends on the particular wetland and the purpose of the assessment (Bartoldus, 1999). Nevertheless, the specific uses for which the results of a WET-EcoServices assessment might be applied include the following:

- Prioritise the allocation of resources for management and rehabilitation across a set of wetland/riparian areas.
- Assess potential and actual ecosystem service outcomes and associated trade-offs of wetland rehabilitation projects by applying the assessment to “with rehabilitation” and “without rehabilitation” situations and comparing the difference between the two situations and/or alternative rehabilitation scenarios.
- Flag important ecosystem services as part of an Environmental Impact Assessment that would need to be considered when assessing and planning different development options.
- Flag important ecosystem services to help direct further investigations including monetary valuation of key ecosystem services.
- Educate and raise awareness (influence perceptions about the values of wetlands and to substantiate why wetlands are important).
- Flag important ecosystem services that need to be considered when managing individual wetland/riparian areas.
- Inform offset planning, in particular offset calculations related to water resource management.
- Assist in Ecological Reserve Determinations, specifically where the importance of the wetland/riparian area needs to be accounted for when deciding on ecological flows.
- Assist in sustainability-of-use assessments.
- Determine the relative importance of individual wetlands in a catchment context to inform decision-making.

Users of WET-EcoServices should have good general experience and training, preferably with a minimum of a diploma or degree in the biophysical sciences, hydrology or agriculture. Further, they should have attended at least a basic introductory course on wetland functioning and values and should have had at least eight weeks experience in field assessment of wetlands. In addition, input is required of someone (e.g. a local extension worker or farmer) with specific local knowledge of the geographical area to which WET-EcoServices is to be applied. Anticipated users of WET-EcoServices include the following:

- Environmental consultants, particularly those undertaking specialist studies to inform development applications and offset planning.
- National and provincial government departments dealing with development applications, particularly those officials reviewing applications with a potential impact on water resources.
- Organizations involved in wetland and river restoration projects, particularly in determining the ecological importance and sensitivity of wetlands as part of the Reserve Determination process.
- Catchment Management Agencies.
- Provincial Nature Conservation Bodies.
- Municipalities, particularly those officials dealing with integration of the environment into decision-making processes.
- NGOs dealing with and lobbying for environmental matters.
- Educators interested in understanding and discussing the values of wetlands and riparian areas.

4. Limitations of the technique

It is important that anyone using the technique appreciate what it is not designed to do. Therefore, key limitations of the technique have been identified, and are listed below.

Limitations in terms of scope

- Whilst the assessment serves to quantify the services provided by wetlands, these scores are relative to other wetlands and riparian areas.
- Scores obtained using the technique have not been correlated with real economic values, and as such, cannot be used to accurately infer an economic value for a wetland or riparian area.
- Given that scores for each service are relative to other wetlands, a high importance score for flood attenuation cannot be equated with a high importance score for livestock grazing.
- The technique is not designed to assess ecological condition (health). Although it includes a few indicators relating to ecological condition, ecological health is dealt with very superficially, and WET-EcoServices does not yield an ecological health score. WET-Health (Macfarlane et al., 2020) provides a suitable technique for such an assessment.
- Although the technique assists in identifying key issues for a scoping report, it is not designed to quantify the significance of impacts of a current or proposed development. This requires specialist input and a much more holistic investigation than that provided by the technique.
- The technique is not exhaustive in its coverage of different types of ecosystem services but covers only those widely applicable to the South African context.

Limitations in terms of the technique's resolution and its representation of complexity

- The technique does not result in a detailed description of a wetland site, including the direct description of hydrogeomorphic processes, and therefore ecosystem services are assessed largely based on coarse-scale proxies.
- Given the above limitation, the technique is limited in its ability to make fine-scale resolution distinctions in terms of ecosystem services provision from similar wetland/riparian areas or from the same area under only slightly different rehabilitation scenarios.
- Although the assessment takes into account the number of users that may be potential beneficiaries of ecosystem services in order to gauge the demand for these services and incorporates this into the scoring system, it does so at a very coarse scale, using only five classes to represent the number of users.
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- The assessment of the level of dependency of users assumes a relatively uniform dependency amongst users of a particular service from a specific wetland/riparian area, which in some cases may be a poor representation of the actual situation.
- The technique assists in assessing individual wetland/riparian areas and does not address the cumulative contributions of a group of wetland/riparian areas. This can, however, be assessed for regulating and supporting services by applying a hectare equivalents approach (See Section 10).
- WET-EcoServices focuses on spiritual/religious practices (e.g. baptism ceremonies) as the primary way through which people engage wetland/riparian areas for their spiritual well-being and does not account for other ways of engagement that are less obvious. For example, when appreciating the beauty of a wetland, one may spontaneously experience a feeling of spiritual connection which one may not even consciously think of as a "spiritual experience" but which has contributed positively to one's spiritual well-being.
- The technique is limited in terms of its representation of the overlap between different services, as illustrated with the above example.
- The technique does not deal explicitly with culturally specific ways of expressing value and with relational values, described in more detail in Part 2, Sections 12.2 and 15.

- Whilst the technique has been expanded to include riparian areas, it accounts specifically for water quality enhancement services linked with lateral water inputs. As such, the importance of riparian areas which are regularly activated by floods from the upstream catchment or those that receive limited flows from lateral inputs (e.g. as might often be the case for riparian areas in arid environments) are not well accounted for.

Limitations in terms of testing

The technique has been designed for application to all inland wetlands and non-wetland riparian areas and has been subject to testing across a range of wetland/riparian types and social/land-use contexts. However, given the limited resources available for testing and the considerable diversity of types and contexts represented in South Africa, it is recognized that certain types and contexts have received less application and testing than others. The following are identified:

- Minimal testing and application within non-wetland riparian ecosystems has occurred in comparison to wetland ecosystems.
- Testing has been largely focussed on naturally vegetated wetland/riparian areas rather than unvegetated wetlands, which although unusual, occur extensively in certain arid portions of South Africa such as Bushmanland.
- Testing has been greater in the higher rainfall areas of the country than in semi-arid to arid areas.
- Certain services (e.g. streamflow regulation) are more difficult to validate than others, and these services have received less attention in the testing than those more easily validated and for which data are more readily available.
- The technique has been developed with reference to natural/semi-natural wetlands and its application for assessing constructed or heavily engineered wetland systems has not been tested. This includes engineered treatment wetlands where sections of the wetland are narrowly designed to address specific functions (e.g. sediment traps, bypass channels and treatment zones)

Part 2 Section 14 provides further details of the limitations of the technique in terms of its resolution and its representation of complexity and in terms of testing.

5. Overall structure of the technique

WET-EcoServices Version 2 is specifically designed for rapid *field* assessment, defined as taking no more than two people half a day in the field and requiring no more than half a day of office preparation and data analysis to carry out the full assessment (Fennessy et al., 2004). Users interested in a purely desktop method should refer to Appendix A, which provides a low-confidence way of inferring ecosystem services provision based on HGM type and broad climatic zone. It is worth noting, however, that certain indicators can be assessed at a regional scale and the principles associated with supply and demand have been successfully applied to regional assessments (e.g. Macfarlane and Atkinson, 2015).

WET-EcoServices provides a set of indicators (e.g. slope of the wetland) rated on a five-point scale that reflect the supply/capability of a wetland for each of the 16 different ecosystem services given in Table 2.1. Indicator scores are then combined automatically in an algorithm that has been designed to reflect the relative importance and interactions of the attributes represented by the indicators. In addition, the extent of the wetland providing the service is recorded, and the demand for the ecosystem service is assessed based on the wetland's catchment context (e.g. toxicant sources upstream), the number of beneficiaries and their level of dependency, which are also all rated on a five-point scale.

The primary basis for identifying the wetland/riparian area Assessment Unit is based on the Hydrogeomorphic (HGM) unit, together with its catchment and the downstream area that the unit supplies/provides services to.

Hydrogeomorphic (HGM) types are defined based on the geomorphic setting of the wetland in the landscape (e.g. hillslope or valley bottom, whether drainage is open or closed), water source (surface water dominated or sub-surface water dominated), how water flows through the wetland (diffusely or channelled) and how water exits the wetland (Ollis et al., 2013). The rationale behind characterizing the hydrogeomorphic types of a wetland is that areas belonging to the same HGM type and falling within a similar geological and climatic setting are likely to have a similar structure and exhibit similar processes (Ollis et al., 2013). Thus, HGM types provide a useful way of delimiting broad units of assessment which has relevance in terms of the ecological functioning of the units that are being assessed. There may, however, be situations where separate HGM units of the same type (and in similar contexts) are grouped together in a single Assessment Unit. There may also be situations where a single HGM unit is sub-divided into several Assessment Units.

6. A description of the step-by-step application of the technique

An assessment of a single Assessment Unit should generally take no more than a half day for two people in the field and a further half day of office preparation and data analysis. However, the length of time required for an assessment will vary depending on the diversity of uses (e.g. some wetlands are used for several provisioning services while others are not used for any provisioning services). It should also be noted that if several Assessment Units are assessed in the same landscape then after having completed the first Assessment Unit, subsequent assessment units are likely to require considerably less time for completion. This applies especially where the Assessment Units all supply the same downstream area. It is further noted that while two people carrying out the field assessment together promotes consistency of application of the technique and is sensible from a safety perspective, is not an essential requirement for applying the technique.

Applying the technique encompasses six primary steps:

1. Define the objectives and scope of the assessment;
2. Identify the Assessment Unit/s and their catchment/s and downstream service area/s;
3. Prepare before going into the field;
4. Assess and score the indicators;
5. Enter the scores in the spreadsheet;
6. Present and interpret the results.

6.1 Defining the objectives and scope of the assessment

Define clearly the objectives of your intended wetland assessment. State also how you intend to use the results of the assessment (e.g. to prioritise the allocation of limited resources for protecting the wetlands in a particular catchment for the purposes of enhancing water quality in that catchment). To do this you need to think carefully about how the information you collect will be used for supporting decisions. Some questions (adapted from Kumar et al., 2017) which might be useful to consider:

- How will the scores from the assessment be used?
- What are the issues and who has stakes?
- What specific decisions are to be informed?
- What are the specific information needs for these decisions?

Having considered the above questions and familiarized yourself with the capabilities and limitations of WET-EcoServices (Section 3 and 4), is the technique appropriate for your assessment objectives? If so, continue with the WET-EcoServices assessment.

6.2 Identify the Assessment Unit/s and their catchment/s and downstream service area/s

If the wetland/riparian area has already been mapped then proceed to identifying the HGM types in the mapped area, but if not then the wetland/riparian areas will need to be mapped. To do so refer to the delineation guidelines for wetlands and riparian areas (DWAF, 2006) and the mapping guidelines of Job et al. (2018). It is important to note, that for the purposes of a rapid ecosystem services assessment, a high level of mapping accuracy is not required and therefore, this can largely be carried out as desktop mapping, as described by Job et al. (2018).

Next, identify the Assessment Units within the mapped wetland/riparian area/s by dividing these areas into HGM units (as described in Section 5) – each HGM unit would constitute a separate Assessment Unit. In some cases, in order to improve the resolution of the assessment it may be advisable to sub-divide a single HGM unit into two or more Assessment Units, e.g. where half of the HGM unit is cultivation and the other half natural vegetation resulting in marked differences in hydrological flows and functionality between the two halves of the wetland. This is particularly important in situations where the assessment is being used to inform offset calculations and relatively fine-scale changes in wetland attributes need to be accounted for (See Section 10). However, in most cases the resources and time available for a rapid assessment would not allow for such sub-divisions, and in some cases very limited resources available for assessment may require that more than one HGM unit with similar attributes be grouped together into a single Assessment Unit.

Once all the Assessment Units have been identified and mapped then the catchment area of each of these should be mapped. If guidance is required for mapping of catchment areas, refer to the wetland mapping guidelines of Job et al. (2018).

Lastly, the distance that needs to be assessed in the downstream area is determined by the size of the Assessment Unit's catchment: if >1000 ha then 10 km is used and if <1000 ha than 5 km is used (as adapted from Adamus et al., 1987). It is recognized that the regulating services supplied by a wetland/riparian area may far exceed the 5 and 10 km distances downstream, and therefore they operate at a scale exceeding that of the assessment. However, with progressively larger distances downstream there is a progressive "dilution" of the service/s, particularly below confluences with other streams, and it becomes impractical to account for such greater distances in a rapid assessment. It is further recognized that not all water-related regulating services are generated at the same scale, but for the purposes of rapid assessment it is impractical to apply different downstream distances for different services (e.g. for flood attenuation and nitrate assimilation).

6.3 Preparations required before going into the field

Once desktop mapping has been completed, maps should be prepared for use in the field. Before proceeding into the field, it is important to be familiar with all of the indicators, and to know which of the indicators can be scored based on a desktop assessment (e.g. rainfall intensity which is based on the site's location in terms of a national rainfall intensity zone map) and those which need to be scored or verified based on field observations. This is indicated with colour-coding in the Score sheet of the Excel spreadsheet (downloadable from https://www.eco-pulse.co.za/download), where the data are entered. All desktop indicators can then be scored before or after the field visit. It is also useful to know whether the Assessment Unit is a riparian area or a wetland. While most of the indicators are applicable to both wetlands and riparian areas, there are some slight differences in terms of the indicators used. The need to assess indicators is indicated under the "Assess" column once a score for the first indicator has been selected ("Is a wetland or riparian area being assessed?). This can be used to customise the score sheet for the field visit.

When to visit the site? Ideally the site should be visited in both the dry and wet seasons. However, it is recognized that often this is not possible. If this is the case, then the wet season is preferable, but it is still feasible to carry out an assessment in the dry season. In all cases, it is important to bear in mind how hydrologically dynamic wetlands (and riparian areas) are, changing across a range of different time scales, e.g. in response to seasonal and inter-annual fluctuations (Box 1).

Box 1: The importance of considering climatic fluctuations when assessing ecosystem services South Africa is well known for its fluctuating climate, particularly in the drier portions of the country. Wetlands (and riparian areas) are generally hydrologically very dynamic, responding to these climatic fluctuations. This, in turn, often leads to fluctuations in the delivery of ecosystem services (e.g. the provision of reeds used for craft production may decrease in dry years and increase in wetter years). Climatic fluctuations may also profoundly influence the demand for these resources. For example, the demand for livestock grazing in a wetland/riparian area may increase during dry years as a result of greatly diminished grazing outside of the wetland, and in some cases the drier wetland being more accessible to livestock than in wetter years. Thus, although the total biomass production in a wetland/riparian area may be less during drier years than wetter years, the importance of grazing may, in fact, increase during drier years. Thus, where a high confidence assessment is required, the ecosystem services supplied by a wetland/riparian area should be assessed based on the consideration of seasonal variations that occur throughout a year (both the wet and dry season). Additionally, one should also consider variation that occurs between wetter and drier years, rather than limiting an assessment to the seasonal variations that occur within one year, which may produce inaccurate/atypical results for the unit being assessed. Aim to assess the average condition over the long-term if this information is available, unless the focus of the assessment was aimed specifically at assessing either a wet or dry period for the wetland/riparian area. This can be informed by the series of images typically available across a number of years in Google Earth™.

What to take with? Maps and score sheets should be taken into the field, together with a camera for collecting site photos that can be integrated into your report and/or cross-referenced when completing the assessment. Whilst not critical, the use of a GPS to note features of interest can be beneficial whilst activating "location tags" on your camera can also be used for this purpose. It is also critical to take a copy of Section 9 of this report, which lists all indicators and the rationale and methods given for each. Besides a soil auger, which is required to best assess a few key indicators, the technique requires limited equipment in the field. However, remember to wear sensible shoes and outdoor clothing as it is important to walk through the wetland/riparian area (which may be wet and muddy) rather than only observing the area from its fringes.

Which user groups to consider? The concept of ecosystem services demand (see Section 12.3 for further elaboration) requires that explicit attention be given to *who* is using the ecosystem services being assessed. When assessing the demand for ecosystem services, the following groups of users need to be considered:

1. People located downstream of the wetland who are potentially affected by flooding.
2. People who use water from downstream of the wetland, including the following categories of use:
    - domestic use;
    - subsistence use;
    - commercial agricultural/industrial/business use; and
    - use for recreation, e.g. swimming.
3. People who use the wetland directly for a variety of purposes, including the following
    - water for all of the uses listed under point 2, above;
    - livestock grazing;
    - natural resource use, including wood, grasses and sedges, medicinal plants, fish, etc.; and
    - cultivation of the wetland.

Who to contact? It is Important to obtain permission from the land-holder before visiting the site. It is also important to contact one or two key informants with a good local knowledge of the area and the different categories of use referred to above. The key informants may either be local people or people who have built up knowledge from visiting the area and from their networks. This local knowledge is especially relevant when assessing indicators dealing with downstream water use and provisioning and cultural services that benefit local communities (e.g. for water abstraction, livestock grazing, recreation, etc.). An ability to communicate in the local language (either directly or through an interpreter) is also important when visiting the Assessment Unit. Although it is beyond the scope of a rapid assessment to systematically interview individual users of the Assessment Unit, if such users are encountered during the course of the assessment then this presents an opportunity to opportunistically access additional local knowledge, which may be valuable for cross checking (triangulating) some of the information from the key informants. It is also recognized that broad stakeholder consultation (e.g. through a stakeholder workshop) is beyond the scope of a rapid assessment, but it would be very useful in a more comprehensive assessment to better quantify the demand for specific ecosystem services from the different user groups, especially where many different users are involved.

6.4 Assess and score the indicators

All applicable indicators need to be assessed and scored on a five-point scale from 0 to 4. Additional notes related to your observations or rationale for scores allocated should also be noted, particularly if the assessment is likely to be subject to external review. The ***Rationale*** underlying the selection of the indicator and the ***Method*** which should be used to assess the indicator and decide on the score are provided in Section 9. It is important that the Rationale be understood and that the Methods be followed closely.

As indicated in Section 6.3, the technique includes the following three ways of assessing indicators:

1. Assess the indicator in the office, based purely on desktop information.
2. Assess the indicator based on desktop information but verified / refined through field observations.
3. Assess the indicator based on direct field observations and/or by enquiring from someone with good local knowledge.

In order to improve confidence in the assessment, a combination of field observations and discussions to obtain local knowledge is recommended for some indicators, notably “Frequency with which storm flows are spread across the unit”. For this indicator, for example, it is important to check for direct evidence of flood debris as well as seeking local knowledge of flooding so as to cross-check these different sources of evidence.

When drawing on local knowledge it is important to be very clear about the boundary of the specific wetland/riparian area being assessed, the catchment of this area and the downstream service area. Thus, when questions are asked about these three respective areas, the local informant should be very clear on what area is being referred to. It is recommended that Google Earth and a basic map be used to clarify these boundaries when questioning a person with local knowledge.

6.5 Enter the scores in the spreadsheet

This is a straightforward step and simply involves entering the indicator scores into the first Tab of the spreadsheet, where indicators are given in the same five groupings and order as in Section 9. Also document any additional notes relevant to the assessment, particularly where substantiation of the score is warranted. The scores and additional notes are then automatically carried through to the second Tab of the spreadsheet where the calculations are carried out automatically.

At the end of the assessment, it is also important to identify if there are any key limitations in the assessment itself, i.e. over and above those limitations generally associated with WET-EcoServices as a rapid assessment technique (given in Section 4). This provides an indication of the confidence which can be placed in the assessment. One of the key limitations of the assessment most likely to be encountered would be not finding someone with good local knowledge of the Assessment Unit and downstream area. Another limitation might be that there was only sufficient time to directly observe a small portion of the Assessment Unit during the field assessment. Having noted the limitations, a brief assessment of the level of confidence (Low, Moderately Low, Intermediate, Moderately High, High) in the overall assessment should be given.

6.6 Check and, where necessary, refine the Demand and Supply scores

Whilst the assessment has been broadly tested, there will be situations where the supply and demand scores do not adequately reflect the situation on the ground. Thus, in the Supply and Demand sheet there is opportunity for reviewing the score and making an adjustment provided there is good justification for doing so and that this is well documented. Adjustments should not be seen as the norm but would typically be in cases where more detailed and/or direct evidence is available than that used by WET-EcoServices, e.g. as might be drawn from a geohydrological assessment that had fortuitously been done for the local area. For example, for streamflow regulation, the likelihood of groundwater connection is inferred based on a very broad-scale geology indicator, and it may be that this indicated that the Assessment Unit had no groundwater connection, but a geotechnical assessment showed that a local geological feature had resulted in a strong connection. In this case, there would be good grounds for an adjustment with justification.

6.7 Present and interpret the results

The final results of the assessment, calculated in the second sheet of the spreadsheet, are carried through to the third sheet where they are presented as a summary table showing the supply, demand and overall importance scores for each ecosystem service (Table 6.1). This table includes the supply, demand and integrated scores for each ecosystem service (See Section 8.3 for a description of how scores are integrated). This can be particularly useful for highlighting the relative importance of different ecosystem services and illustrating how these scores may change in response to future development or rehabilitation scenarios.

Table 6.1: Example of a condensed summary table for the Zaalklapspruit Wetland.

		Present State				Future State			
	ECOSYSTEM SERVICE	Supply	Demand	Importance Score	Importance	Supply	Demand	Importance Score	Importance
REGULATING AND SUPPORTING SERVICES	Flood attenuation	2.8	0.1	1.9	Moderate	2.8	0.1	1.9	Moderate
	Stream flow regulation	2.0	0.3	1.2	Low	2.6	0.3	1.8	Moderate
	Sediment trapping	2.8	1.0	2.3	Moderately High	3.5	1.0	3.0	High
	Erosion control	2.1	2.5	2.4	Moderately High	2.3	2.5	2.6	Moderately High
	Phosphate assimilation	2.4	1.0	1.9	Moderate	3.4	1.0	2.9	High
	Nitrate assimilation	2.0	1.0	1.5	Moderately Low	3.3	1.0	2.8	High
	Toxicant assimilation	2.2	2.0	2.2	Moderate	3.3	2.0	3.3	Very High
	Carbon storage	2.0	2.7	2.3	Moderately High	2.3	2.7	2.6	Moderately High
	Biodiversity maintenance	2.6	3.5	3.4	Very High	2.6	3.5	3.4	Very High
PROVISIONING SERVICES	Water for human use	1.6	0.0	0.6	Very Low	1.6	0.0	0.6	Very Low
	Harvestable resources	2.5	0.0	1.5	Moderately Low	2.5	0.0	1.5	Moderately Low
	Food for livestock	1.0	0.7	0.3	Very Low	0.8	0.7	0.1	Very Low
	Cultivated foods	2.5	0.0	1.5	Moderately Low	2.1	0.0	1.1	Low
CULTURAL SERVICES	Tourism and Recreation	0.5	0.0	0.0	Very Low	0.5	0.0	0.0	Very Low
	Education and Research	2.0	1.3	1.7	Moderately Low	2.0	4.0	3.0	High
	Cultural and Spiritual	1.0	0.0	0.0	Very Low	1.0	0.0	0.0	Very Low

The fourth sheet represents supply and demand scores graphically using spider diagrams (Figure 6.1). Both the output table and the spider diagram can be copied into a report presenting the findings of an assessment.

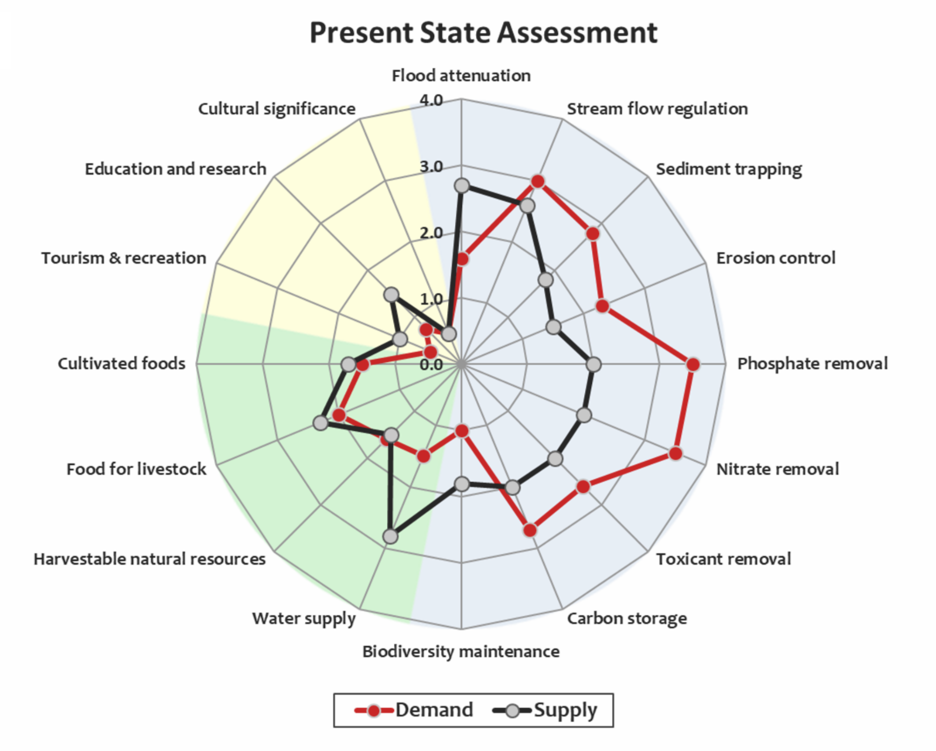
When interpreting the scores, it is generally useful to examine supply relative to demand for each service. In the first example provided in Figure 6.1, demand for water quality enhancement functions are high due to pollutants associated with urban runoff and poor sanitation management. In this instance, the channelled nature of the wetland limits the water quality enhancement functions currently provided and points to an opportunity to rehabilitate the wetland to enhance these services. Having ecosystem service supply and demand both expressed on the same scale allows for easy comparison and screening of potential risks and opportunities. Where supply is high relative to demand, then potential opportunities exist for increasing demand for of the service. Conversely, where demand is high relative to supply then potential risks to long-term supply may exist through overuse, but opportunities may also exist to enhance supply, e.g. through rehabilitation. It is important to emphasize, however, that this serves only as an initial screening, and that5 the specific features of an assessment unit and its context must be considered so that reasonable interpretations can be drawn.

In the second example in Figure 6.1, the demand for cultivated foods, food for livestock and harvestable natural resources are high, with the community making extensive use of the wetland for these purposes. Whilst the wetland provides high quality grazing, the graphic highlights limitations to cultivation and the availability of harvestable natural resources in the wetland. The graphic also illustrates the potential for the wetland to provide a broad suite of regulating and supporting services, but the low demand for these services in a well-managed rural catchment.

When interpreting the scores, it is very important to firstly bear in mind the limitations of the technique described in Section 4. In particular it needs to be remembered that the technique does not provide a high-resolution assessment, and therefore cannot be used for making fine distinctions, both in terms of ecosystem services supply and demand. It is also important to document the limitations associated with undertaking the assessment when presenting the results.

It is recognized that for certain reporting purposes, the single overall importance score which combines supply and demand is what is primarily required. How these scores are derived is elaborated upon in Section 8.3, but for now assessors are strongly encouraged not to focus on the integrated overall score alone as this will result in the "loss" of a lot of useful information. In many cases it may be better to present the supply and demand scores without any integrated score, as is represented in the spider diagram output of the technique.

(a)



(b)

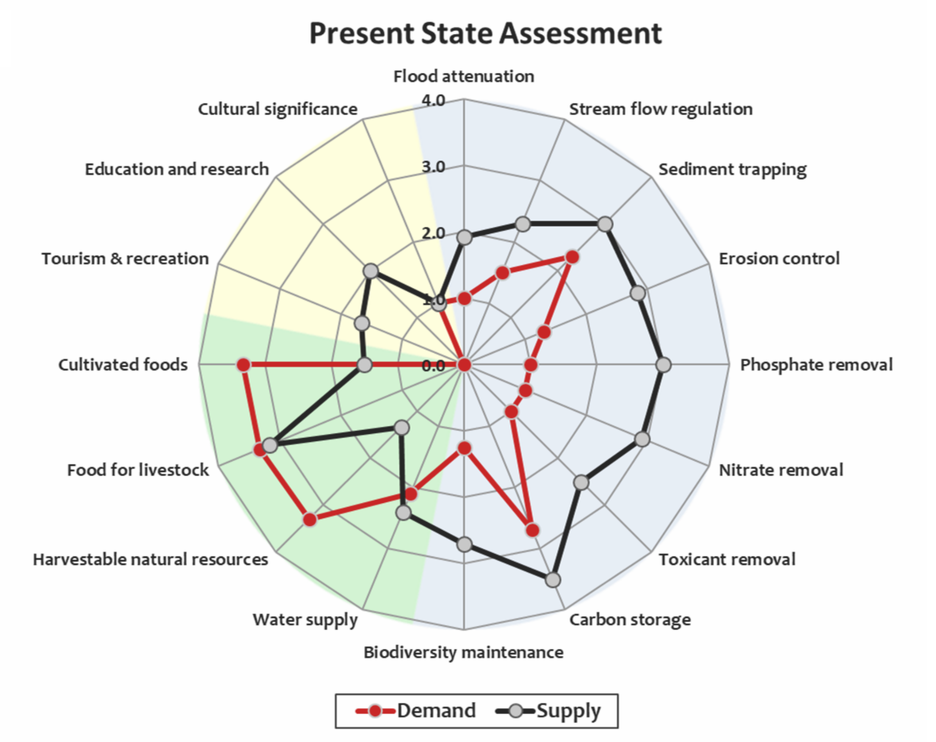


Figure 6.1: Examples of supply and demand scores represented in spider diagrams for (a) a channelled valley bottom wetland in an urban context with significant pollution inputs and (b) an unchannelled valley bottom wetland in a rural context.

7. Description of ecosystem services included in the technique

WET-EcoServices includes an assessment of 16 different ecosystem services, which were selected for their specific relevance to the South African situation (Table 2.1). This full suite of ecosystem services is assessed for both wetlands and riparian areas apart from streamflow regulation which is not included in the riparian assessment owing to a lack of relevant studies. This section provides a brief description of each ecosystem service included in the technique in an attempt to clarify exactly what is represented by the particular ecosystem service.

Flood attenuation

Flood attenuation refers to the spreading out and slowing down of flood waters, thereby reducing the severity of floods downstream and the potential damage to property and loss of human life that these floods may cause. The contribution that wetlands and riparian areas make to flood attenuation has been well demonstrated globally (Acreman and Holden, 2013; Capon and Pettit, 2018) and in South Africa, e.g. for the Kromme River wetland (Rebelo et al., 2015) and the Nylsvley wetland (Kleynhans et al., 2010). Generally, wetlands and riparian areas located low in the catchment, particularly floodplains, have a greater potential to reduce floods than headwater wetlands or riparian areas (Acreman and Holden, 2013).

Streamflow regulation

Streamflow regulation refers to the sustaining effect of a wetland on downstream flow during low-flow periods. Although Bullock and Acreman (2003) present evidence to show that wetlands generally do not sustain streamflows in the dry season, some wetlands have been shown to provide this service, e.g. the Kgaswane Nature Reserve wetland in North West Province (Smakhtin and Batchelor, 2005). A key influencing factor is whether, by virtue of its hydrogeological setting, a wetland has strong links with discharging groundwater. For these wetlands, it is important to emphasize that it is the hydrogeological and/or hydropedological processes in the wetland and its catchment rather than ecological processes in the wetland which are primarily responsible for the wetland's contribution. In addition, the evapotranspiration from a wetland constitutes a potentially major limitation over the contribution such areas might make to sustaining streamflows. However, in wetlands which have both a relatively low leaf area, e.g. short sedge or grass wet meadow and which become dormant in the dry season (Dye and Jarmain, 2004) this limitation is much less than areas with a relatively high leaf area remaining active over the dry season, as is typical of indigenous swamp forest (Clulow et al., 2012) and wetlands dominated by invasive alien trees such as black wattle (Dye and Jarmain, 2004). Specific reference to non-wetland riparian areas and streamflow regulation appear to be lacking, and as such, this ecosystem service is not scored for riparian areas.

Sediment trapping

Sediment trapping refers to the trapping and retention of sediment carried by runoff waters. Excess sediment not only diminishes water quality by increasing turbidity but also leads to significant loss of storage capacity in dams. Therefore, sediment trapping contributes to avoided sedimentation of dams. The contribution of intact wetlands and riparian areas to trapping sediment has been well demonstrated (Mitsch and Gosselink, 1986; NRC, 2002). For example, Turpie et al. (2014) calculated that maintenance of riparian buffers contributed to up to 36% reduction in sediment loads into Durban Harbour.

Erosion control

Erosion control refers to the control of erosion at the site through on-site factors that prevent the loss of soil from the HGM unit. The contribution of wetlands and riparian areas to controlling erosion is widely recognized (Capon and Pettit, 2016). A key factor contributing to this service is the dense natural vegetation typically associated with these areas. This contribution is most evident where this vegetation is removed, typically for cultivation purposes, and severe erosion results thereafter. A striking example of this is documented for the clearing of valley bottom wetlands dominated by Palmiet (*Prionium serratum*) (Rebelo et al., 2015). This service helps to safeguard existing biodiversity values and cultural and provisioning services provided by the wetland whilst also serving to protect the downstream environment and users from increased sediment loads. It should be added that by reducing downstream flooding intensity wetlands may also contribute to reducing the level of erosion downstream, but this downstream contribution is not included in this assessment.

Phosphate removal

Phosphate removal refers to the removal of phosphates carried by runoff waters, thereby enhancing the quality of water in the downstream catchment. The contribution of both wetlands and riparian areas to phosphate removal has been well demonstrated (Fisher and Acreman, 2004; Capon and Pettit, 2018). Phosphates are much less mobile than nitrogen and are generally strongly absorbed by sediments, and therefore phosphate removal tends to be strongly associated with the trapping of new sediment in both wetland and riparian environments (Hemond and Benoit, 1988; O'Geen et al., 2010; Capon and Pettit, 2018).

Nitrate removal

Nitrate removal refers to the removal of nitrates carried by runoff waters, thereby enhancing the quality of water in the catchment. As for phosphates, the contribution of both wetlands and riparian areas to nitrate removal has been well demonstrated (Fisher and Acreman, 2004). The contribution of wetlands to regulating nitrates at a catchment scale has been shown for catchments assessed in the Western Cape by Turpie et al. (2010a). The primary process by which nitrates are removed from runoff water in wetlands is denitrification, which requires prolonged saturation (seasonal to permanent) leading to anaerobic conditions (Sather and Smith, 1984). Non-wetland riparian areas, lack denitrification because of a lack of prolonged saturation, and are therefore taken to be generally less effective than wetlands in terms of nitrate uptake, but may nonetheless contribute significantly (Macfarlane and Bredin, 2016a; Capon and Pettit, 2018). Removal of nitrates (as well as phosphates, toxicants and pathogens) correlate well with hydraulic retention time: i.e. the more that water flows are spread out and held within a wetland or riparian area, the greater the opportunities for removal (Fisher and Acremen, 2004).

Toxicant and pathogen removal

Toxicant and pathogen removal refers to the removal of toxicants and pathogens carried by runoff waters, thereby enhancing the quality of water in the downstream catchment. Toxicants are defined very broadly to include biocides, metals (e.g. mercury), extreme pH and salts, while water-borne pathogens are agents causing disease or illness, including bacteria, viruses and protozoa.

Wetlands are generally effective in contributing to the removal of toxicants, through a wide variety of processes, including sorption onto sediment already immobile in the wetland or which is suspended and then is trapped in the wetland. Most metals are sorbed more efficiently by organic than mineral soils (Vestegaard, 1979). It must be emphasized, however, that certain potential toxicants (e.g. high levels of dissolved sodium and chloride) are not effectively removed by wetlands. The considerable contribution of wetlands to the removal of heavy metals has been well demonstrated for a few individual wetlands, notably the Klip River wetland in Gauteng (McCarthy and Venter, 2006) and the Zaalklapspruit wetland in Mpumalanga province (Maila et al., 2017). Given that non-wetland riparian areas encompass a narrower range of hydroperiods and therefore an associated lower diversity of biogeochemical environments, their capacity to remove a diversity of toxicants is likely to be lower than that for wetlands, as described by O'Geen et al. (2010).

The contribution of wetlands to reducing pathogen counts has been well demonstrated (Rogers, 1983; Weber and Legge, 2008). A wide variety of processes are involved in a wetland's removal and inactivation of pathogens in water, including sedimentation, natural die-off, inactivation or death related to temperature, oxidation, predation, inactivation or death related to unfavourable water chemistry, biofilm interaction, mechanical filtration, exposure to substances (e.g. from root secretions) which are toxic to the pathogens and UV radiation (Rogers, 1983; Weber and Legge, 2008). The importance of riparian areas in providing this service has also been well documented, together with the primary factors affecting performance (Macfarlane and Bredin, 2016a).

Carbon storage

Carbon storage refers to the trapping of carbon (notably as soil organic matter), thereby contributing positively as a carbon sink. The cumulative effect of natural carbon sinks (e.g. forests and peatlands) are of great significance for global climate change, lessening (but certainly not fully balancing) the potential catastrophic effect of carbon emissions from fossil fuel use. Given that organic matter decomposition is slowed down under waterlogged conditions, wetlands generally tend to have high capacities for storing organic carbon. This is highlighted by the fact that although wetlands occupy only 4-5% of the land area of the globe, they hold approximately 30% of the carbon in the terrestrial biosphere (Roulet, 2000; Joosten and Clark, 2002). Peatlands have particularly high levels of organic matter, and therefore they are particularly important for the storage of carbon. The global extent of peatlands is estimated at 4 000 000 km^2, but owing in particular to the dry climate over much of South Africa, peatlands are very limited in extent, and the total extent of peatlands in South Africa is estimated at 400 km^2 (P-L Grundling, 2018, personal communication) therefore representing a tiny fraction of the global extent. Non-wetland riparian areas lack the prolonged saturation (waterlogging) which characterizes wetlands and their generally high capacity to store carbon in the soil/sediment, and they are therefore generally less effective than wetlands in terms of carbon storage.

Biodiversity maintenance

Through the provision of habitat and maintenance of natural processes, wetlands and riparian areas contribute to maintaining biodiversity. Considered at a landscape scale, this contribution is potentially considerable (Preston and Bedford, 1988; Naiman et al., 1993; NRC, 2002). The capacity of a wetland or riparian area to provide this benefit depends strongly on the ecological condition of the area as well as on specific attributes of the site, including the diversity of habitats and the presence of habitats specifically required by Red listed species (Preston and Bedford, 1988; NRC, 2002).

Water supply

Water supply refers to the provision of water for direct human use and extracted directly from a wetland/riparian area for domestic, agricultural or other purposes. Although this provisioning service is related to some extent to the regulatory service that a wetland may have in regulating streamflow, the latter is considered separately in the assessment of streamflow regulation. Wetlands and riparian areas vary greatly in terms of perreniality and quality of surface and shallow sub-surface water available for domestic, agricultural or industrial use. The more sustained the availability of the water in the unit and the better the quality of this water, the greater will be the potential contribution of the unit to the supply of water for human use.

Harvestable natural resources

A wide variety of harvestable resources are potentially available in wetlands and riparian areas, including the following, which are often important from a livelihoods' perspective:

- Sedges and grasses for crafts, with certain provinces, notably KwaZulu-Natal having an extremely rich tradition of utilization of wetland plants for weaving of crafts (Kotze and Traynor, 2011).
- Reeds (*Phragmites australis* and *P. mauritianus*) and thatching grass (*Hyparrhenia* spp.) for construction, mainly for reed screens and thatching.
- Wood for construction and fuel, and in South Africa riparian areas are naturally often focal areas for woody plant growth (Rogers and Naiman, 1997).
- Medicinal plants, include herbaceous plants, e.g. *Gunnera perpensa* (River pumpkin) of which rhizomes are mainly used, and *Ranunculus multifidus* of which the leaves are used, and trees/shrubs, e.g. *Macaranga capensis* of which the bark is used.
- Fish and game for food, with riparian areas often serving as key resource areas for game (Rogers and Naiman, 1997).
- Flowers (e.g. arum lilies) for the florist industry.
- Edible plants (e.g. waterblommetjies).

Food for livestock

The high value of wetlands for livestock grazing has been well demonstrated for both private commercial farms and communal small-scale rural farms (Palmer et al., 2002; Lannas and Turpie, 2009). Riparian areas are also well recognized as important grazing areas for livestock (Rogers and Naiman, 1997; Capon and Pettit, 2018). Wetlands and riparian areas are key grazing resources, particularly in the context of a semi-arid climate, and are especially valuable in dry years and at the end of the dry season in most years, owing to their residual moisture (Rogers and Naiman, 1997; Fynn et al., 2015). Thus, wetlands and riparian areas are often critical forage sources over the dry season for both livestock and wild grazers (Rogers and Naiman, 1997; Fynn et al., 2015). However, the technique only directly covers grazing as food for livestock and not for wild grazers, although the presence of wild grazers would potentially influence the assessed importance of the wetland/riparian area for biodiversity maintenance and tourism and recreation.

Cultivated foods

Although excessive wetness (in the case of wetlands) and the risk of flooding may make wetland/riparian areas difficult and hazardous areas to cultivate, the residual moisture and generally high fertility of many these areas makes them attractive areas for cultivation. Riparian areas are widely cultivated through much of South Africa and extensive areas of wetland have historically been converted to commercial cultivated lands, particularly in the Western Cape and KwaZulu-Natal provinces. In southern Africa, wetlands and riparian areas are widely recognized for the contribution that they make towards food security of subsistence farmers, particularly in arid and semiarid areas (Kotze, 2002). It is recognized, however, that the cultivation of a wetland/riparian area requires the complete removal of the natural vegetation in the area cultivated, which often detracts considerably from the other ecosystem services provided by the area.

Tourism and recreation

Wetlands may have great value as sites for tourism and recreation, particularly in terms of the abundant wildlife (especially birds) that they often support, their scenic beauty and the open water that some wetlands provide for recreation. For example, the Nylsvley wetland and surrounding habitats attract about 10 000 visitors annually, mainly for bird watching (Scovronick and Turpie, 2010). By virtue of being associated with streams and rivers as well as being focal areas for wildlife (Naiman et al., 1993), riparian areas also have very high tourism and recreation potential.

Education and research

Education and research include use of the wetland/riparian area by schools, universities and other learning institutions for both formal research, as well as for more informal learning-orientated activities. Intact ecosystems generally offer good opportunity for intellectual interactions (e.g. research, education or historic records) between people and nature (Smit et al., 2017). Wetlands and riparian areas specifically contain elements of both terrestrial and aquatic systems. They are also generally good examples of ecological infrastructure and link to common challenges of water security and disaster risk management. They may therefore be of high value for education and research, particularly when they are readily accessible.

Cultural and spiritual experience

Cultural and spiritual experience of a site refers to the meanings and values that people attach to the site arising out of their interaction with the site (Barendse et al., 2016). What people do (e.g. fish from the bank of a river), feel (e.g. cool water), hear (e.g. the rustling of reeds in the wind) and see, all contribute to their experience (Barendse et al., 2016). Wetlands (and riparian areas by virtue of their association with streams and rivers) are recognized as having high cultural and spiritual significance for a diversity of different cultures in South Africa. This includes the culturally significant plants that they provide (for crafts, medicines and food) and the places of special cultural significance they represent (e.g. where baptisms or cleansing ceremonies take place) (WESSA, 2003a and b).

8. Use of the indicators to generate scores for the sixteen ecosystem services

8.1 A summary of the indicators used for each ecosystem service

An ecosystem services-by-indicators matrix is presented in Table 8.1 so that the user can see at a glance, for each specific service, which indicators are used for the assessment of supply and demand respectively. Section 8.2 elaborates on how these indicators are used to derive supply and demand scores for individual ecosystem services. In addition, all indicators given in the table are described in more detail in Section 9.

Table 8.1: A listing of all indicators used to assess the ecosystem services included in WET-EcoServices Version 2 (s= used to assess supply; d=used to assess demand, and S denoting an indicator which is heavily weighted in terms of its contribution to the supply score). The relevance of indicators for an assessment of wetlands and riparian areas is also indicated.

	Indicators	Riparian Area	Wetland	Flood attenuation	Stream flow regulation	Sediment trapping	Erosion control	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Carbon storage	Biodiversity maintenance	Water for human use	Harvestable natural resources	Food for livestock	Cultivated foods	Tourism & recreation	Education and research	Cultural & spiritual
1	Is a wetland or riparian area being assessed?	Y	Y																
2	Size of the contributing upstream topographically defined catchment.	Y	Y	**S**		**S**	**S**	**S**	**S**	**S**									
3	Link to the stream network	Y	Y	**S**	**S**	**S**		**S**	**S**	**S**									
4	Average slope of the Assessment Unit's catchment	Y	Y	d			d												
5	Inherent runoff potential of the soils in the Assessment Unit's catchment	Y	Y	d			d												
6	Rainfall intensity	Y	Y	d			d												
7	Contribution of catchment land-uses to increasing runoff intensity from the natural condition	Y	Y	d			d												
8	Contribution of catchment land-uses to increasing sediment inputs from the natural condition	Y	Y	d		d													
9	Extent of phosphate sources in the Assessment Unit and associated catchment	Y	Y					d											
10	Extent of nitrate sources in the Assessment Unit and associated catchment	Y	Y						d										
11	Extent of toxicant sources in the Assessment Unit and associated catchment	Y	Y							d									
12	Extent to which dams and other structures intercept flows from the upstream catchment	Y	Y	d		d	d	d											
13	Assessment Unit occurs on underlying geology with strong surface-groundwater linkages	N	Y		s														
14	Aquifer type, as mapped at a national scale by Colvin et al. (2007)	N	Y		s														
15	Longitudinal slope of the Assessment Unit (%)	Y	Y	s			s												
16	Vulnerability of the wetland to erosion given its slope and size.	N	Y				s												
17	Flow patterns of low flows within the wetland Assessment Unit	N	Y			**S**		**S**	**S**	**S**									
18	Current representation of different hydrological zones	Y	Y	s	s			s	s	s	s				s	s			
19	Frequency with which storm flows are spread across the Assessment Unit	Y	Y	**S**			**S**									s			
20	Extent of open water for tourism and/or recreation	Y	Y														s		

Indicators		Riparian Area	Wetland	Flood attenuation	Stream flow regulation	Sediment trapping	Erosion control	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Carbon storage	Biodiversity maintenance	Water for human use	Harvestable natural resources	Food for livestock	Cultivated foods	Tourism & recreation	Education and research	Cultural & spiritual
21	Acceptability of water for human consumption	Y	Y										s						
22	Periodicity of surface and shallow sub-surface water supply available for human use (domestic, agricultural or industrial)	Y	Y										s						
23	Occurrence of depressions in the Assessment Unit	Y	Y	s		s		s		s									
24	Reduction in water availability due to human-caused direct water losses from the wetland	N	Y		s														
25	Soil properties (permeability)	Y	Y	s		s		s	s	s									
26	Presence of organic soil	Y	Y		s						s					s			
27	Erodibility of the soil in the Assessment Unit based on the inherent erosion potential (K-factor) of catchment soils	Y	Y				s												
28	Current level of physical disturbance of the soil in the Assessment Unit	Y	Y				d				s								
29	Direct evidence of recent sediment deposition in the Assessment Unit	Y	Y			s		s		s									
30	Direct evidence of erosion in the Assessment Unit	Y	Y				s												
31	Lateral cross sectional (hill) slope of riparian area	Y	N	s		s	s	s	s	s									
32	Pattern of lateral flows through the riparian area	Y	N			s		s	s	s									
33	Extent of vegetation cover in the Assessment Unit	Y	Y			s	s	s	s	s									
34	Vegetation structure in terms of height and robustness	Y	Y	s		**S**	**S**	**S**		**S**	s								
35	Occurrence of grazable plants	Y	Y												s				
36	Availability of sedges, reeds and/or grasses for craft production and/or thatching	Y	Y											s					
37	Availability of wood for construction / combustion	Y	Y											s					
38	Availability of medicinal plants	Y	Y											s					
39	Reduction in evapotranspiration through frosting back of the wetland vegetation	N	Y		s														
40	Occurrence of fish and/or game for harvesting	Y	Y											s					
41	Bird-watching potential of the site	Y	Y														s		
42	Presence of charismatic species	Y	Y														s		
43	Scenic beauty of the Assessment Unit	Y	Y														s		
44	Accessibility of the Assessment Unit for education/research or	Y	Y														s	s	

Indicators		Riparian Area	Wetland	Flood attenuation	Stream flow regulation	Sediment trapping	Erosion control	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Carbon storage	Biodiversity maintenance	Water for human use	Harvestable natural resources	Food for livestock	Cultivated foods	Tourism & recreation	Education and research	Cultural & spiritual
	tourism/recreation purposes																		
45	Security risk associated with accessing the site for education/research or tourism/recreation purposes	Y	Y														s	s	
46	Threat status of the wetland or riparian type	Y	Y									d							
47	Priority in national and regional conservation plans	Y	Y									d							
48	Ecological condition of wetland / riparian vegetation	Y	Y									s		s					
49	Presence of threatened plant and/or animal species	Y	Y									s							
50	Diversity and heterogeneity of natural habitats	Y	Y									s							
51	Outstanding biodiversity attributes	Y	Y									s							
52	Ecological connectivity with other wetlands and aquatic habitats	Y	Y									s							
53	Width of intact buffer zone around the Assessment Unit	Y	Y									s							
54	Number of people downstream expected to be affected by flooding	Y	Y	d															
55	Level of risk that flooding poses to downstream users	Y	Y	d															
56	Number of people downstream of the Assessment Unit who are reliant on water for abstraction (run-of-river abstraction and/or from dams) livestock watering and/or recreational use.	Y	Y		d	d	d	d	d	d									
57	Dependence of downstream users on water for abstraction (run-of-river abstraction and/or from dams) livestock watering and/or recreational use.	Y	Y		d	d	d	d	d	d									
58	Ecological importance and sensitivity of rivers downstream of the Assessment Unit	Y	Y			d	d	d	d	d									
59	Presence of wetlands critical to meeting wetland conservation targets downstream of the Assessment Unit	Y	Y			d	d	d	d	d									
60	Presence and importance of downstream estuaries	Y	Y			d	d	d	d	d									
61	Number of people benefiting from carbon storage functions	Y	Y								d								
62	Dependence of users on carbon storage provided by the Assessment Unit	Y	Y								d								

Indicators		Riparian Area	Wetland	Flood attenuation	Stream flow regulation	Sediment trapping	Erosion control	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Carbon storage	Biodiversity maintenance	Water for human use	Harvestable natural resources	Food for livestock	Cultivated foods	Tourism & recreation	Education and research	Cultural & spiritual
63	Number of people making use of water from the wetland / river reach for commercial agriculture or industrial use	Y	Y										d						
64	Dependence of commercial agricultural / industrial users on abstracted water from the Assessment Unit	Y	Y										d						
65	Number of people using water from the Assessment Unit for domestic purposes	Y	Y										d						
66	Dependence of people using water from the Assessment Unit for domestic purposes	Y	Y										d						
67	Number of people reliant on harvestable natural resources (Cumulative across all resources)	Y	Y				d							d					
68	Dependence of people making use of harvestable natural resources from the Assessment Unit	Y	Y				d							d					
69	Number of people reliant on the Assessment Unit for livestock grazing	Y	Y				d								d				
70	Dependence of livestock owners on grazing provided by the Assessment Unit	Y	Y				d								d				
71	Number of people reliant on the Assessment Unit for growing cultivated foods	Y	Y				d									d			
72	Dependence of people sourcing cultivated foods provided by the Assessment Unit	Y	Y				d									d			
73	Number of people who access the Assessment Unit for tourism / recreational purposes on an annual basis	Y	Y														d		
74	Dependence of users on the Assessment Unit for tourism/recreation	Y	Y														d		
75	Suitability of the Assessment Unit as a reference and/or demonstration site	Y	Y															s	
76	Number of people who access the wetland for education/research purposes on an annual basis	Y	Y															d	
77	Dependence of users on the Assessment Unit as an education/research site	Y	Y															d	
78	Existing data & research	Y	Y															s	
79	Is the Assessment Unit in a rural communal area?	Y	Y																d
80	Known local cultural practices in the Assessment Unit	Y	Y																s

Indicators		Riparian Area	Wetland	Flood attenuation	Stream flow regulation	Sediment trapping	Erosion control	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Carbon storage	Biodiversity maintenance	Water for human use	Harvestable natural resources	Food for livestock	Cultivated foods	Tourism & recreation	Education and research	Cultural & spiritual
81	Known local taboos or beliefs relating to the Assessment Unit	Y	Y																s
82	Number of people who use the Assessment Unit for cultural and spiritual purposes on an annual basis	Y	Y																d
83	Dependence of users on the Assessment Unit for cultural and spiritual purposes	Y	Y																d

	Desktop assessment		Desktop with field verification		Field-based assessment

8.2 How the indicator scores are combined to generate supply and demand scores for individual ecosystem services

Demand and supply scores are calculated automatically in the spreadsheet tool. This automation is based on a conceptual understanding of the relative importance of different indicators in influencing the supply of and demand for each ecosystem service. This has been informed by available literature where possible but is largely based on expert interpretation of the authors. The supply and demand algorithms are not hidden in a "black box" and can be viewed by the user, who is also provided with a written rationale for the relative importance accorded different indicators, and how some might interact. The full rationale for integrating indicator scores can be seen in the "Supply and Demand" tab of the spreadsheet tool. For illustrative purposes, this section explains briefly, for three selected services, the rationale behind how the scores from the individual indicators are aggregated into the respective scores for supply and demand.

Flood attenuation:

The supply of this service is affected by both: (1) the Assessment Unit's setting and catchment context; and (2) on-site (local) attributes of the Assessment Unit. The catchment context is affected by two indicators: the size of the Assessment Unit's catchment and whether the Assessment Unit is linked to the stream network. Given the emphasis on benefits of flood attenuation to downstream users, this assessment is only relevant to assessment units that are directly linked to the stream network. As such, the supply score is taken as zero if there is no connection. If the upstream catchment feeding a wetland or riparian area is large (as is the case with most floodplains) then the land surface is great over which flood waters accumulate and are ultimately "delivered" to the downstream wetland. In contrast, if the upstream catchment is small (as is typical of hillslope seepage wetlands) then this land area over which flood water accumulate is small. As such, wetlands and riparian areas with the largest catchments receive the highest starting supply scores whilst those with smallest contributing catchments score lowest.

By far the most influential on-site indicator affecting flood attenuation functions, is the frequency with which stormflows are spread across the surface Assessment Unit. If this does not occur or is very infrequent then all of the other on-site indicators, which reflect the surface attributes of the Assessment Unit, will have little influence over floods. Thus, this influential indicator is used as the initial on-site score and is adjusted by the average of the three highest scoring other on-site indicators of the unit, namely slope, representation of different hydrological zones, occurrence of depressions, soil permeability, and vegetation structure in terms of height and robustness.

The demand for flood attenuation is based on (i) an assessment of 'at risk' users downstream of the Assessment Unit and (ii) an assessment of flooding risks stemming from the catchment directly upstream of the Assessment Unit. A starting demand score is calculated based on an assessment of potential beneficiaries downstream, based on indicators reflecting the number of people downstream expected to be affected by flooding and a further indicator reflecting the level of risk that flooding poses to these people (Table 8.2).

Table 8.2: Table indicating how a starting demand score is calculated based on information for downstream users.

		Number of people downstream expected to be affected by flooding				
		None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)
Level of risk that flooding poses to downstream users	None	0.0	0.0	0.0	0.0	0.0
	Low (Flooding occasionally causes minor inconvenience)	0.0	0.3	0.7	1.0	1.3
	Moderate (Flooding is an inconvenience but poses little risk to livelihoods, infrastructure or property)	0.0	0.7	1.3	2.0	2.7
	High (Flooding poses a moderate risk to livelihoods and property)	0.0	1.0	2.0	3.0	4.0
	Critical (Flooding poses a major risk to property and /or human life)	0.0	1.3	2.7	4.0	4.0

This starting demand score is then automatically adjusted by also considering the intensity of runoff from the Assessment Unit's catchment (Table 8.3). The latter is based on indicators reflecting the inherent runoff potential of the catchment (slope, runoff potential of the soils, and rainfall intensity) and indicators reflecting the human influence over runoff intensity (contribution of catchment land-uses such as hardened surfaces to increasing runoff intensity, and interception of flows by upstream dams). So, to illustrate, if flooding poses a high risk to 100 to 1000 people in the downstream area, the Assessment Unit would receive a starting demand score of three (Table 8.2). If runoff intensities upstream of the Assessment Unit are "Low", then it has limited potential to attenuate floods and the demand score is automatically adjusted down accordingly. If, on the other hand, the wetland receives intense runoff from urban development in the upstream catchment, and the catchment risk score would be "Very High", and a maximum demand score would be obtained (Table 8.3)

Table 8.3: Table indicating how the risk score for the Assessment Unit's catchment is integrated with the starting demand score to obtain a final demand score for flood attenuation.

		Risk based on attributers of the upstream catchment				
		None	Low	Moderate	High	Very High
Starting demand score (From Table 8.2)	0.0	0.0	0.0	0.0	0.0	0.0
	1.0	0.0	0.1	0.3	0.8	1.3
	2.0	0.0	0.2	0.7	1.5	2.7
	3.0	0.0	0.3	1.0	2.3	4.0
	4.0	0.0	0.3	1.3	3.0	4.0

Nitrate assimilation:

The supply of this service is affected by both: (1) the catchment context of the Assessment Unit (affected by the same two indicators given for flood attenuation); and (2) On-site features of the Assessment Unit. The primary on-site indicator affecting supply of the nitrate assimilation service is the pattern of low flows, as this has a critical effect on the level of contact between the wetland and the water, and much of the assimilation of nitrates takes place during low flow periods. Longitudinal and lateral slopes, hydrological zonation, extent of vegetation cover, which all influence detention time and biogeochemical processes contributing to nitrate assimilation, are additional indicators affecting supply.

The demand for nitrate assimilation is calculated in a similar manner to that for flood attenuation described above and includes an assessment of (i) potential downstream beneficiaries and (ii) risk based on the extent of nitrate sources in the Assessment Unit and its catchment. In the case of nitrate assimilation, downstream beneficiaries considered are broadened to include both human use and natural ecosystems. When assessing human use, consideration is given to both the number of people downstream who are reliant on water abstraction (run-of-river abstraction and/or from dams) for direct use. Natural ecosystems are accounted for by considering the ecological importance and sensitivity of rivers downstream of the Assessment Unit, presence of downstream wetlands critical to meeting wetland conservation targets and lastly the presence and importance of downstream estuaries.

Tourism and recreation:

The supply of this service recognizes that a wide variety of natural assets may attract people to wetland/riparian areas for tourism/recreation. In addition, the suitability of a site for tourism and recreation is influenced by access and security. To account for this interaction, the supply score is initially calculated by averaging the top two scores for the following five indicators: scenic beauty of the Assessment Unit, presence of charismatic species, outstanding biodiversity attributes, bird-watching potential of the site, and the extent of open water for tourism and/or recreation. This score is then down weighted based on the two indicators reflecting limitations associated with access and security risk, respectively.

The demand for this service is affected by the number of people who access the wetland/riparian area for tourism/recreation on an annual basis and the dependence of these users on the specific Assessment Unit for tourism/recreation. For the purposes of this assessment, dependence is rated by considering (i) the degree to which alternative sites providing similar opportunities are readily accessible and / or (ii) the frequency with which users make use of the site.

8.3 How the individual supply and demand scores are integrated into an overall importance score

The value or importance attributed to the ecosystem services provided by wetlands is dependent on both the ability of the ecosystem to provide the services (based on attributes of the wetland) and the demand for these services (based on social considerations). This is illustrated conceptually in Figure 8.1, with some authors arguing that without demand, the functions provided by an ecosystem cannot be described as a service (Burkhard et al., 2012).

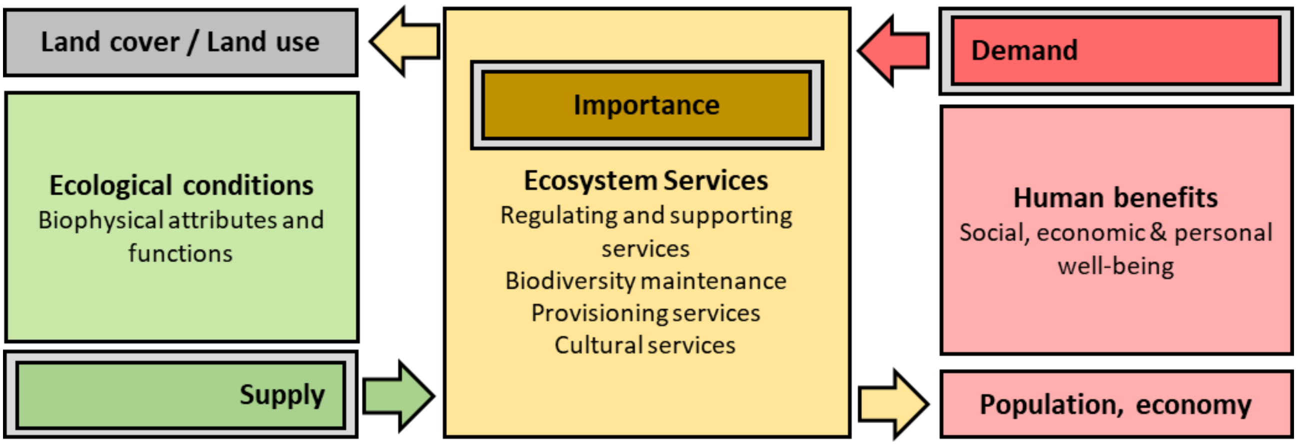


Figure 8.1: The links between ecosystem services' supply and demand (adapted from Burkhard et al., 2012)

This concept is integrated into the Wet-EcoServices assessment by calculating a single overall importance score by combining the supply and demand scores. Whilst it is acknowledged that demand is central to assessing the value of ecosystem goods and services provided, the focus here is to assess the relative importance of the wetland / riparian area in providing ecosystem services both now and into the future. By adopting such an approach, wetlands and riparian areas that currently supply services to a high degree but for which current demand is limited (e.g. due to limited development in the upstream catchment) can still be highlighted to inform decision-making processes.

The approach to aggregating supply and demand scores is presented in Table 8.4. This aggregation places somewhat more emphasis on supply than demand, with the supply score acting as the starting score for a "high" demand scenario. The importance score is, however, adjusted by up to half a class up where demand is "very high" and by up to one and a half classes down where demand is "very low". This reflects the need to take a longer-term view in decision-making by recognising both the current and future potential of wetlands and riparian areas to provide ecosystem services.

Table 8.4: Integrating the scores for ecosystem supply and demand into an overall importance score.

		Supply				
		Very Low	Low	Moderate	High	Very High
Demand		0	1	2	3	4
Very Low	0	0.0	0.0	0.5	1.5	2.5
Low	1	0.0	0.0	1.0	2.0	3.0
Moderate	2	0.0	0.5	1.5	2.5	3.5
High	3	0.0	1.0	2.0	3.0	4.0
Very High	4	0.5	1.5	2.5	3.5	4.0

The overall importance score can then be used to derive an importance category for reporting purposes (Table 8.5) which reflects the importance of the wetland in providing the service relative to other wetlands and riparian areas. This therefore allows different Assessment Units to be compared in terms of their relative importance. As emphasised in Section 6.6, assessors are again encouraged not to focus on the overall score (or importance category) alone as this will result in the "loss" of useful information.

Table 8.*5*: Categories used for reporting the overall importance of ecosystem services.

Importance Category		Description
Very Low	0-0.79	The importance of services supplied is very low relative to that supplied by other wetlands.
Low	0.8-1.29	The importance of services supplied is low relative to that supplied by other wetlands.
Moderately-Low	1.3-1.69	The importance of services supplied is moderately-low relative to that supplied by other wetlands.
Moderate	1.7-2.29	The importance of services supplied is moderate relative to that supplied by other wetlands.
Moderately-High	2.3-2.69	The importance of services supplied is moderately-high relative to that supplied by other wetlands.
High	2.7-3.19	The importance of services supplied is high relative to that supplied by other wetlands.
Very High	3.2-4.0	The importance of services supplied is very high relative to that supplied by other wetlands.

9. WET-EcoServices indicators, with rationale and method for each

This section describes all indicators included in the technique, with a description of: (1) the rationale underlying the indicator; and (2) the recommended method for its assessment given for each indicator. Where possible, indicators have been aligned with other existing tools such as the Buffer Zone Guidelines (Macfarlane and Bredin, 2016b) and those assessed when applying the WET-Health technique (Macfarlane et al., 2020). The indicator numbers provided in the spreadsheet tool, together with the broad approach taken to assessing indicators is also indicated based on the colour-coding below.

Desktop assessment	Desktop with field verification	Field-based assessment

TYPE OF ASSESSMENT						
1	Is a wetland or riparian area being assessed?	Wetland	Riparian area			

Rationale: The assessment caters for both wetlands and riparian areas. Once rated, indicators that need to be assessed are indicated in the spreadsheet.

Method: Simply select the score to reflect the relevant assessment being undertaken.

CATCHMENT CONTEXT OF THE ASSESSMENT UNIT						
2	Size of the contributing upstream topographically defined catchment.		Small local catchment (<10 ha) (WET: Typical of small seeps or small depressions) (RAs: Typical of 1st order streams)	Moderately sized upstream catchment (10-100 ha) (WET: Typical of unchannelled valley bottoms and small channelled valley bottoms) (RAs: Typical of 2nd and 3rd order streams)	Large upstream catchment (100-1000 ha). (WET: Typical of channelled valley bottoms & large unchannelled valley bottom systems) (RAs: Typical of 4th order streams)	Very large upstream catchment (>1000 ha). (WET: Typical of floodplain wetlands and very large channelled valley bottoms) (RAs: Typical of 5th & higher order streams)

Rationale: Whilst the importance of catchment size varies depending on the service being provided, wetlands with larger catchments are generally better located in terms of intercepting catchment runoff than headwater wetlands (Hansen et al., 2018). Thus, the size of the contributing upstream catchment is assumed to be relevant to all regulating services (except streamflow regulation, for which the relationship between catchment size and this service is poorly understood). Catchment size is also relevant to regulating services provided by riparian areas, although it is recognized that wetlands receive pollutants from the upstream catchment much more regularly than riparian areas which are typically only activated by flows from the main channel during high flow periods.

Note that this assessment is limited to the topographically defined catchment and therefore does not cater for water which is supplied by a regional aquifer that extends beyond the topographically defined catchment, e.g. as is common on coastal plain settings. As such, the benefit of wetlands in treating polluted water linked to any regionally connected groundwater source is not well addressed in this rapid method.

Method: The catchment of the Assessment Unit should be mapped, at least at a coarse level to inform various aspects of the assessment. This can be done using available tools (e.g. GIS, Google Earth Pro) and also informed by readily available GIS catchment datasets.

3	Link to the stream network	No link (i.e. hydrologically isolated. Includes flats & depressions with no channel outflow)				Linked to the stream system (includes all riparian areas)

Rationale: Quite simply, if a wetland is isolated from the stream system, as is the case for many depressions and some seepage slopes, then the wetland would not contribute any water to the stream system and the extent to which the wetland potentially regulates flows and water quality in the stream would generally be very limited. Thus, this indicator has implications for all regulating services affecting water quality and supply.

Method: Determine the connection to the stream system by examining aerial photos and inspecting on the ground to see if a stream is passing through, running adjacent to or leading from the HGM unit. It is important to note, however, that HGM units lacking such an obvious feature may, nevertheless, contribute to some degree through sub-surface water movement, but expert or local knowledge will be required to verify this. While depressions are generally isolated, there is some evidence to suggest that some depressions on the Highveld are "leaky", meaning that some of the water that collects in the depression leaks through the depression floor into the underlying substrata (Marneweck and Batchelor, 2002; Marneweck, 2003). Depressions that lie on drainage divides, particularly where the soils are sandy and streams are abundant, may suggest a possible link to flow regulation. Whether or not this actually is the case, is still to be determined.

4	Average slope of the Assessment Unit's catchment	<3%	3-5%	6-8%	9-11%	>11%

Rationale: Given all other factors being equal, the steeper the slope, the faster the runoff and the greater the runoff intensity, and therefore the greater the potential for floods and erosion.

Method: Average slope can be roughly calculated from available topographic maps, GIS datasets or Google Maps™ information. This is done by taking elevation readings from (i) the upper-most point of the catchment, and (ii) the site being assessed, and then calculating the altitudinal change. Thereafter, the distance between these points is measured and average slope estimated by dividing the altitudinal change by the distance from the upper reaches of the catchment. A more accurate measure can be calculated in Google Earth Pro by drawing a line feature from the site being assessed to the top of the catchment (along the stream line) and viewing the elevation profile (Figure 9.1). Where significant variation in slopes occur across the catchment, average slope should ideally be estimated from a number of sample transects.

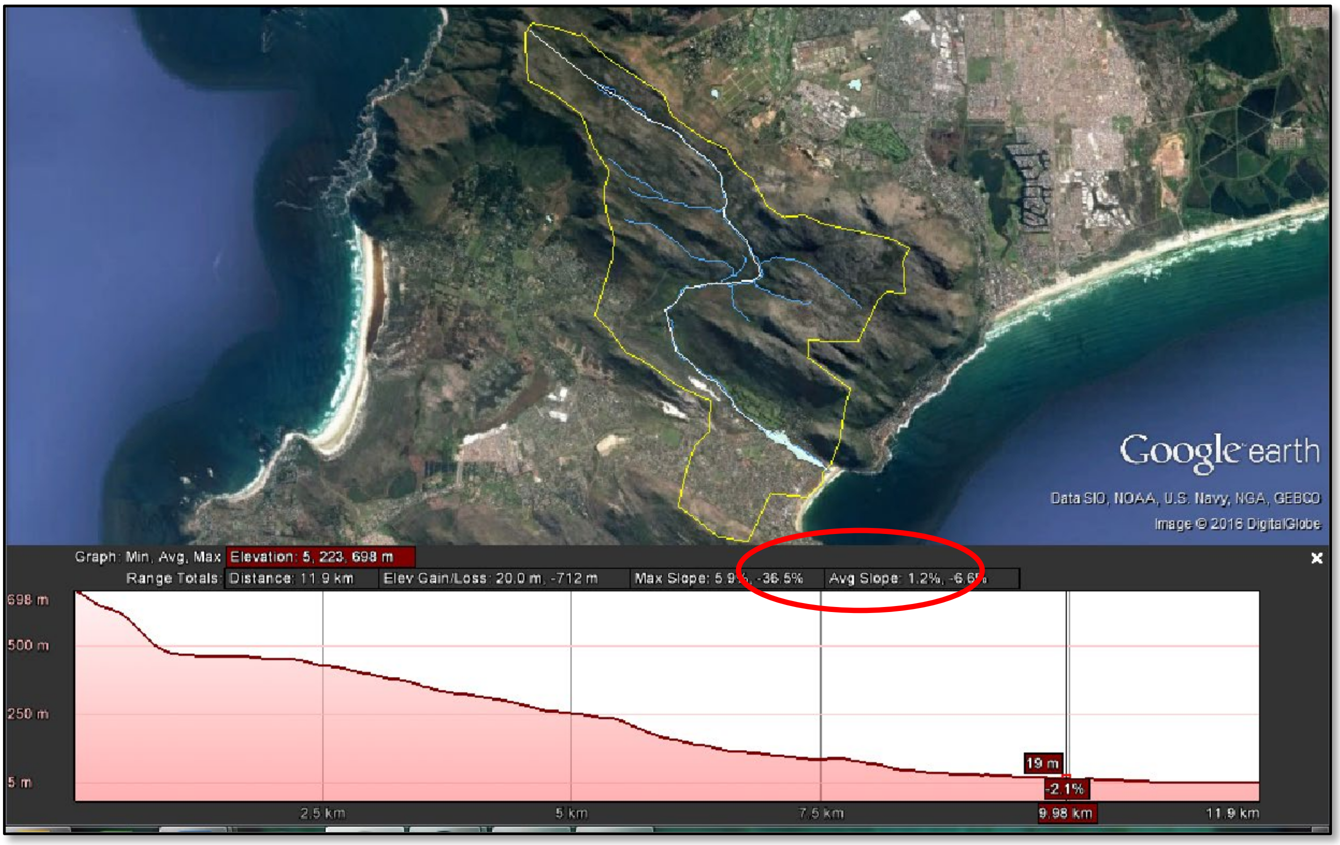


Figure 9.1: Illustration of how Google Earth can be used to determine an approximate average slope (Google Earth 2016 in: Macfarlane and Bredin, 2016b).

5	Inherent runoff potential of the soils in the Assessment Unit's catchment	Low	Moderately Low		Moderately High	High

Rationale: The higher the runoff potential of the soil, the slower will be the infiltration and the greater will be the runoff intensity (Schulze et al., 1989). Changes in runoff intensity has implications for both flood attenuation and erosion control.

Method: The Soil Conservation Services method for Southern Africa (SCS-SA) uses information on hydrologic soil properties to estimate surface runoff from a catchment (Schulze et al., 1989). Use the SCS-SA layer (Figure 9.2) available in either shapefile or KML format (https://sites.google.com/site/bufferzonehub/) to determine the appropriate hydrological soil group that best defines the wetland's catchment characteristics (Table 9.1).

Table 9.1: Runoff potential classes (after Schulze et al., 1989).

Low runoff potential	**Moderately Low runoff potential**	**Moderately high runoff potential**	**High runoff potential**
Infiltration and permeability rates are high. Deep, well drained to excessively drained sands and gravels.	Moderate infiltration rates, effective depth and drainage. Moderately fine to moderately coarse textures. Permeability slightly restricted.	Infiltration rate low. Permeability restricted by layers that impede downward movement of water. Moderately fine to fine texture.	Very slow infiltration and permeability rates. Clay soils with high shrink/swell potential. Soils with permanent high water table or with clay pan or clay layer at or near surface or shallow soils over fairly impervious material.

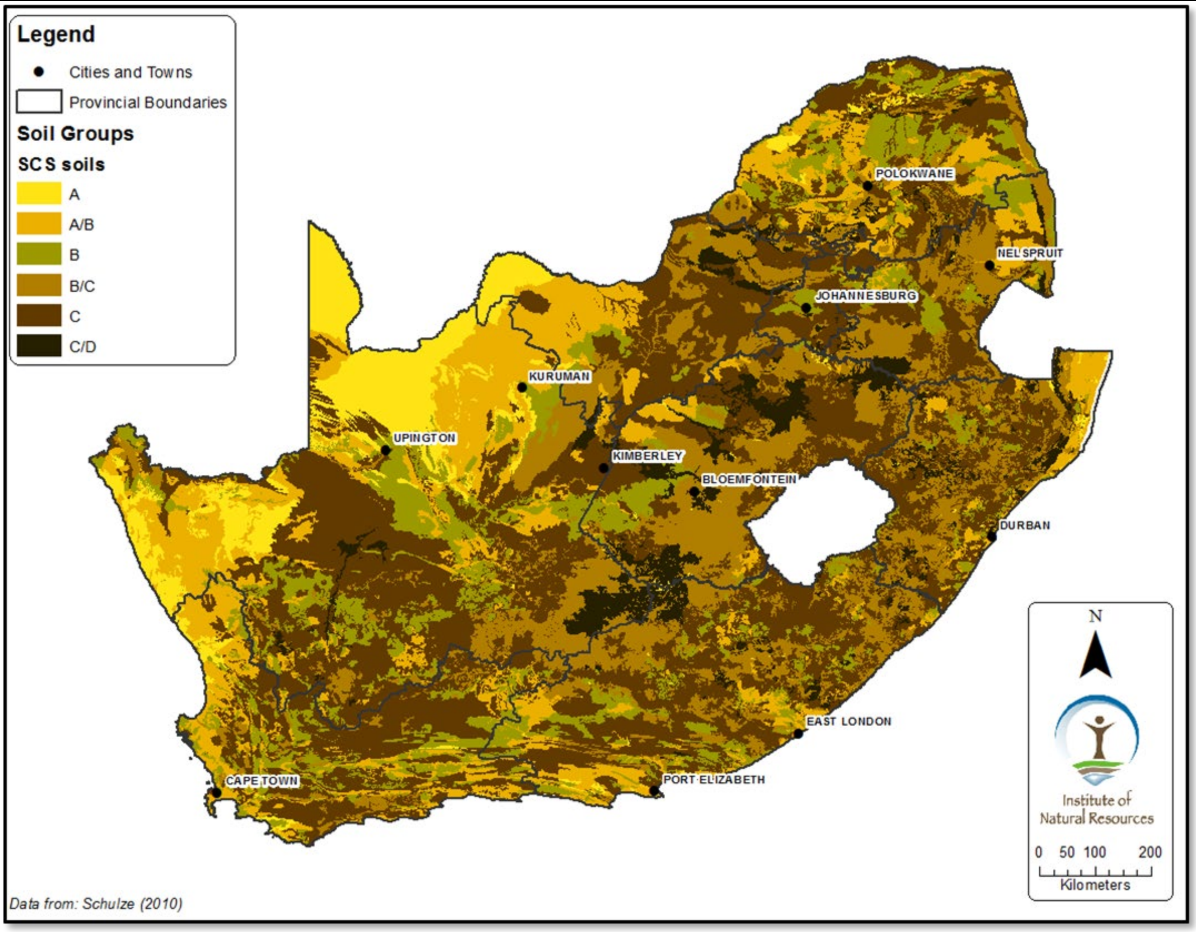


Figure 9.2: Distribution of SCS Soil Groups A to D over South Africa at a spatial resolution of land type polygons (Schulze, 2010 in: Macfarlane and Bredin, 2016b).

6	Rainfall intensity	Low (Zone I)	Moderately Low (Zone II)		Mod. high (Zone III)	High (Zone IV)

Rationale: Stormflows, which are directly relevant to flood attenuation and erosion control, result from rainfall. The rate or intensity of rainfall is usually more important than the total amount of rain. Rates are usually expressed in mm/hour(hr) or mm/24hr. From the map, it can be seen that the level of intensity of storms varies widely across South Africa, from Rainfall Zone 1 which has the lowest intensities to Rainfall Zone 4 with the highest.

Method: At a desktop level, determine the rainfall intensity zone that characterises the catchment of the Assessment Unit (Figure 9.3). For ease of use rainfall intensity can be accessed in both shapefile and KML format (https://sites.google.com/site/bufferzonehub/). Where such data is lacking, this should be assessed based on available climatic information.

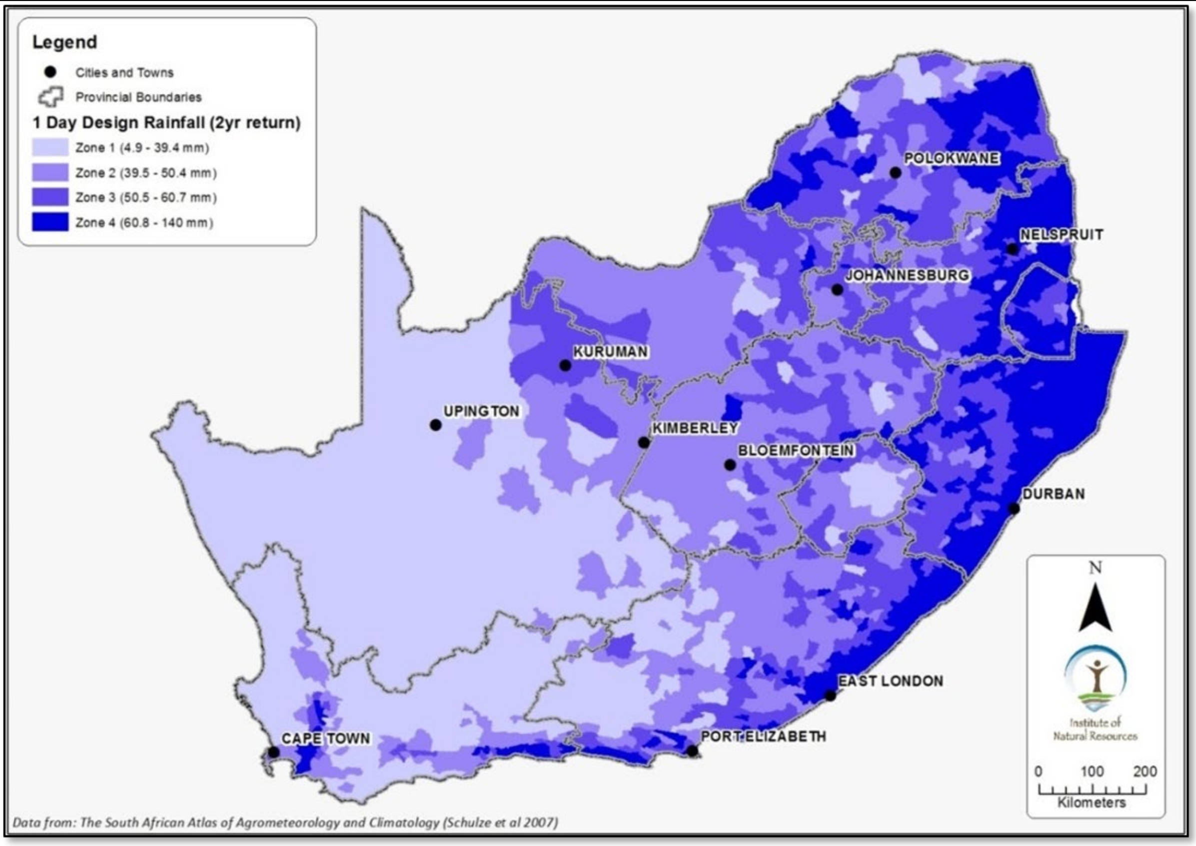


Figure 9.3: Rainfall intensity zones based on one day design rainfall over a two-year return (adapted from Schulze, 2007 in: Macfarlane and Bredin, 2016b).

7	Contribution of catchment land-uses to increasing runoff intensity from the natural condition	Negligible effect (e.g. Largely natural catchment)	Slight increase	Intermediate increase (e.g. Catchment characterized by widespread overgrazing with visible erosion)	Moderately High increase	High increase (e.g. Catchment dominated by urban housing and infrastructure)

Rationale: Catchment land-uses impact on flood peaks primarily through their influence over infiltration, which refers to the process by which water on the ground surface enters the soil. By reducing infiltration, land-use factors may have a very important influence on runoff intensity (Schulze et al., 1989), which has important implications for floods and erosion. Several land-use factors may reduce infiltration:

- Hardened surfaces in the catchment resulting from buildings, roads, footpaths, parking lots and other such developments. The greater the extent of hardened surfaces, the smaller the area available for infiltration to take place and the greater the runoff intensity will be. If hardened surfaces are extensive, the effect will be considerable (Neal, 1998). Most industrial and commercial areas have a high extent of hardened surfaces due to the large buildings and their roofs and extensive roads and parking lots.
- Poor conservation practices in cultivated lands (e.g. lack of contour tillage and contour banks, soil compaction, etc.) decrease infiltration and increase surface runoff, thereby increasing runoff intensity, while good conservation practices tend to prevent this (Schulze et al., 1989).
- Poor condition veld diminishes infiltration and increases runoff intensity compared with natural good condition veld (Schulze et al., 1989).

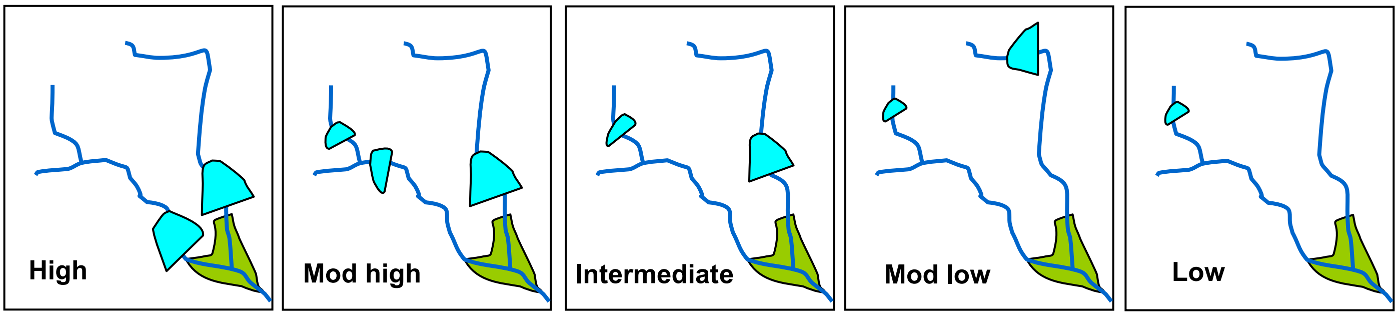
Method: It is important to note that this indicator excludes the influence of dams, the effect of which tends to counteract hardened surfaces, etc. and which is considered in a separate indicator. Examine the land cover map for the catchment (particularly in the case of large catchments not readily visible from the Assessment Unit during the field assessment) or undertake a reconnaissance in the field to identify land-uses such as those described above which decrease infiltration. If a WET-Health assessment of the HGM unit exists then the score for increased flood peaks as a result of changes in catchment landcover (1C-1 in the spreadsheet) can be used to score this indicator.

8	Contribution of catchment land-uses to increasing sediment inputs from the natural condition	Very Low (e.g. Largely natural catchment)	Low	Intermediate (e.g. Catchment with widespread agriculture but with buffer zones along most streamlines)	Moderately High	High (e.g. Catchment characterized by widespread overgrazing with visible erosion)

Rationale: The greater the extent of catchment land-uses (e.g. cultivated lands and gravel roads) which increase sediment input in the Assessment Unit's catchment and the closer these are located to the Assessment Unit, the greater will be the likely increased supply of sediment to the Assessment Unit. For example, where cultivated lands occupy 50% of the Assessment Unit's catchment and some of these occur within 10 m of the Assessment Unit, the potential supply of sediment to the Assessment Unit is likely to be high.

Method: Observe on maps and aerial photos and during the rapid visual appraisal, the extent and location of sediment sources. Sources of sediment to consider include: cultivated lands, particularly those poorly conserved; actively eroding gullies and bare areas of veld; forestry plantations on steep slopes or where planting and extraction practices are poor; and gravel roads, particularly where they are poorly designed. It is important that due account be taken of the effect that any dams

and/or natural vegetation areas may have in trapping the increased sediment, if the dams/natural vegetation are located between the sediment source/s and the Assessment Unit. If a WET-Health assessment of the Assessment Unit exists then refer to the end of the Water Quality module to see the predicted degree to which suspended solids are likely to have been changed from the natural reference state of the Assessment Unit to help inform this assessment of increased sediment. Note that classes are largely comparable except for "L-M" and "M" classes in WET-Health, which would translate to an "Intermediate" score above.						
9	Extent of phosphate sources in the Assessment Unit and associated catchment	Very Low (e.g. Largely natural catchment)	Low	Intermediate (e.g. Rural catchment dominated by intensive agriculture)	Moderately High	High (e.g. Urban catchment with Wastewater Treatment Works in close proximity upstream)
Rationale: The greater the extent of phosphate sources (point source and non-point source) in the Assessment Unit's catchment and the closer these are located to the Assessment Unit, the greater will be the likely supply of phosphates to the unit and the greater will be the demand for phosphorus trapping (Adamus et al., 1987). ***Method:*** Identify non-point sources of phosphate by considering areas (>0.5 ha) of fertilized crop or pasture land, urban/industrial areas and areas (>0.5 ha) where the density of houses with septic tanks or pit latrines exceeds 6 houses per ha. For fertilized lands, look out especially for loss of sediment because phosphorus tends to be strongly bound to sediment, and therefore loss of phosphorus from these areas is generally associated strongly with their loss of sediment. Identify point sources of phosphorus by considering sewage or industrial/mining outfalls, dairies, piggeries or feedlots. Speak to a key informant with good local knowledge about pollution sources, particularly point sources, which are often not visible on satellite images or aerial photographs or when the catchment is viewed from a distance. The local DWAS office may also have information concerning known pollution sources. If a WET-Health assessment of the Assessment Unit exists, then refer to the end of the Water quality module to see the predicted degree to which phosphates are likely to have been changed from the natural reference state of the Assessment Unit. Note that classes are largely comparable except for "L-M" and "M" classes in WET-Health, which would translate to an "Intermediate" score above.						
10	Extent of nitrate sources in the Assessment Unit and associated catchment	Very Low (e.g. Largely natural catchment)	Low	Intermediate (e.g. Rural catchment dominated by intensive agriculture)	Moderately High	High (e.g. Urban catchment with Waste Water Treatment Works in close proximity upstream)
Rationale: The greater the extent of nitrate sources (point source and non-point source) in the Assessment Unit's catchment, the greater the potential supply of nitrates will be to the unit and therefore the opportunity to enhance water quality (Adamus et al*.,* 1987). ***Method:*** Consider the following areas as non-point sources of nitrate pollution: areas (>0.5 ha) of fertilized crop or pasture land, urban/industrial areas, mined land and areas (>0.5 ha) where the density of houses with septic tanks exceeds 6 houses per ha. Point sources to consider include sewage or industrial/mining outfalls, leaking sewage lines, dairies, piggeries or feedlots. Speak to a key informant with good local knowledge about pollution sources. The local DWAS office may also have information concerning known pollution sources, as in the case of phosphates. If a WET-Health assessment of the HGM unit exists, then refer to the end of the Water quality module to see the predicted degree to which nitrogen is likely to have been changed from the natural reference state of the wetland. Note that classes are largely comparable except for "L-M" and "M" classes in WET-Health, which would translate to an "Intermediate" score above.						
11	Extent of toxicant sources in the Assessment Unit and associated catchment	Very Low (e.g. Largely natural catchment)	Low	Intermediate (e.g. Urban catchment dominated by residential land-uses)	Moderately High	High (e.g. Catchment characterized by extensive mining operations)
Rationale: Toxicants are defined very broadly to include biocides, metals (e.g. mercury), salts and disease-causing bacteria (e.g. *E. coli*). The greater the extent of toxicant sources (point source and non-point source) in the Assessment Unit's catchment and the closer these are located to the Assessment Unit, the greater will be the potential supply of toxicants to the unit and therefore the opportunity to enhance water quality (Adamus et al., 1987). ***Method:*** Consider the following areas to identify non-point sources of toxicant pollution: areas (>0.5 ha) of fertilized cropland (especially those likely to have high levels of pesticide application), urban/industrial and mining areas. Point sources to consider include sewage or industrial outfalls, leaking sewage lines, dairies, piggeries or feedlots. Speak to a key informant with good local knowledge about pollution sources. The local DWAS office or the local water management agency may also have information concerning known pollution sources, as in the case of phosphates. If a WET-Health assessment of the Assessment Unit exists, then refer to the end of the Water quality module to see the predicted degree to which toxics are likely to have been changed from the natural reference state of the Assessment Unit. Note that classes are largely comparable except for "L-M" and "M" classes in WET-Health, which would translate to an "Intermediate" score above.						
12	Extent to which dams and other structures intercept flows from the upstream catchment	High	Moderately High	Intermediate	Moderately Low	None / Low
Rationale: The greater the extent of dams and other structures in the Assessment Unit's catchment which act to detain sediment that would otherwise reach the Assessment Unit, the more limited would be the opportunity for the unit to receive and trap sediment. Such dams also act to intercept flood-flows and therefore reduce flood-peaks. ***Method:*** Observe on maps, aerial photos and/or satellite images and during the field assessment the location of dams in relation to the Assessment Unit. Now select that class given below which best describes the situation in the wetland's catchment in terms of the degree of interception by dams of the stream network entering the Assessment Unit.						



In addition, if the information is available, consider the collective volume of the dams and the level of abstraction from the dams, which both increase the dams' interception capacity. Also consider whether specific allowance is made for natural floods in the operating rules of the dam/s, which decrease the dams' interception capacity. Refer to the hydrology module of WET-Health for more information on the assessment of the three factors above. When assessing the influence of the interception of flows specifically on the sediment trapping services of the Assessment Unit, also consider whether the sediment in the Assessment Unit's catchment is predominantly sand (i.e. bedload) or clay (i.e. suspended load). If predominantly sand then dams generally trap most of the sediment which washes into the dam, but if predominantly clay (i.e. suspended load) then a lot of the sediment washing into a dam may remain in suspension and, depending on the level of outflow from the dam, will be carried out of the dam. Thus, for a predominance of clay consider adjusting down the influence of dam interception in reducing sediment by one or two classes. Refer to the Geomorphology module of WET-Health for more information on the determination of suspended load vs. bedload.

ON-SITE FEATURES OF THE ASSESSMENT UNIT						
13	Assessment Unit occurs on underlying geology with strong surface-groundwater linkages	No		Underlying geology quartzite	Underlying geology sandstone	Underlying geology dolomite or a coastal primary aquifer

Rationale: The occurrence of groundwater discharge areas (which would contribute to the regulation of streamflow) is likely to be high in geological provenances characterized by high levels of interaction between groundwater and surface water. This has important implications for streamflow regulation.

Method: Check for the presence of geological provenances characterized by high levels of groundwater-surface water interactions, including dolomitic terrain, sandstones and quartzitic terrain (includes the Cape Fold Mountains). A map of the underlying geology for the HGM unit and surrounding landscape should be obtained from Geological Survey (http://geoscience.org.za/cgs/ - RSA 1:1M Geological map of South Africa dataset).

http://geoscience.org.za/cgs/

14	Aquifer type, as mapped at a national scale by Colvin et al. (2007)	Inland aeolian (Kalahari) primary aquifer, Karoo Supergroup without dolerite dykes and sills	Extrusives, Other Fractured meta-sedimentary, Basement complex and younger granites	Other carbonate terrains, Alluvial primary aquifer, Karoo Supergroup with dolerite dykes and sills	Table Mountain Group	Coastal plain primary aquifer or karst landscape

Rationale: The Aquifer type, as mapped at a national scale by Colvin et al. (2007) provides a basis on which to draw some initial inferences in terms of hydrogeological characteristics that control aquifer discharge regimes to the unit. Specifically, as is the case with the previous indicator on underlying geology, they provide a preliminary identification of the likelihood that the unit is supplied by an aquifer, and therefore likely to be in a groundwater discharge area, with important implications for streamflow regulation.

Method: Identify in which aquifer type the wetland is located, by referring to the accompanying map (Figure 9.4).

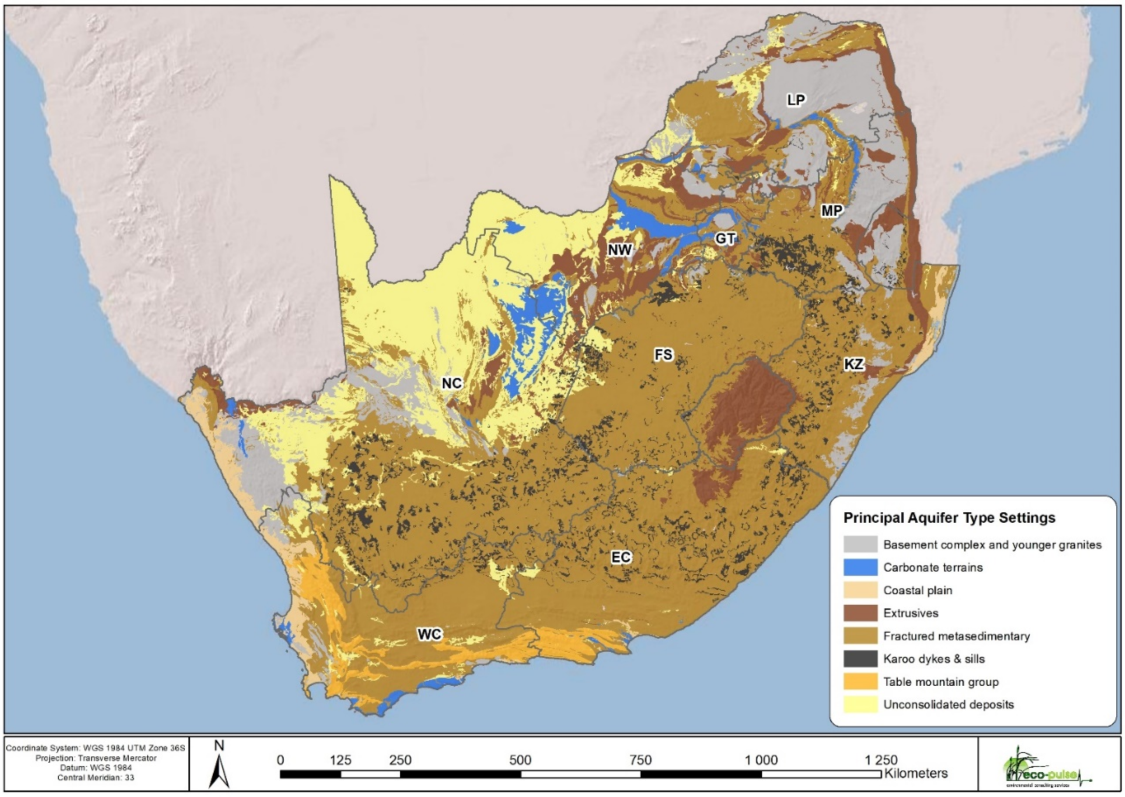


Figure 9.4: Map of main aquifer types based on primary lithology. (Source data – Council for Geoscience 1: 1000 000 lithology) (Adapted from Colvin et al., 2007).

15	Longitudinal slope of the Assessment Unit (%)	>5%	2-5%	1-1.9%	0.5-0.9%	<0.5%

Rationale: Given that the speed of water flow is directly influenced by slope, the gentler the slope the greater will be the attenuating ability of the HGM unit. This has implications for flood attenuation, erosion control, sediment trapping and water quality enhancement.

Method: This characteristic should be omitted from the assessment if the HGM unit is a depression because a depression's capacity to attenuate floods is not influenced by slope (i.e. it operates by capturing flows rather than slowing them down). For other HGM units, slope should preferably be estimated using a 1: 10 000 orthophoto or through available contour information. Slope should be expressed as a percentage (e.g. for a 1% slope, for every 100 m travelled horizontally, there is a vertical drop of 1 m). Where slope varies across the HGM unit, take the average slope. If a WET-Health assessment of the HGM unit exists, then refer to the Wetland attributes information where longitudinal slope would have been determined.

16	Vulnerability of the wetland to erosion given its slope and size.	Low (Vulnerability Score = 0)	Moderately Low (Vulnerability Score = 2)	Moderate (Vulnerability Score = 5)	Moderately High (Vulnerability Score = 8)	High (Vulnerability Score = 10)

Rationale: Vulnerability of a wetland to erosion increases with increasing steepness and discharge, for which wetland size may be used as a surrogate. Based on the occurrence (or not) of erosion in many observed wetlands in South Africa of varying longitudinal slope and size, Ellery et al. (2016) identified a means of predicting the vulnerability of a wetland to erosion based on slope and size (Figure 9.5). This rating therefore provides a useful indicator for assessing erosion risk.

Method: In order to identify vulnerability of a wetland, note the longitudinal slope (given in the previous indicator) and wetland size, and refer to the figure below.

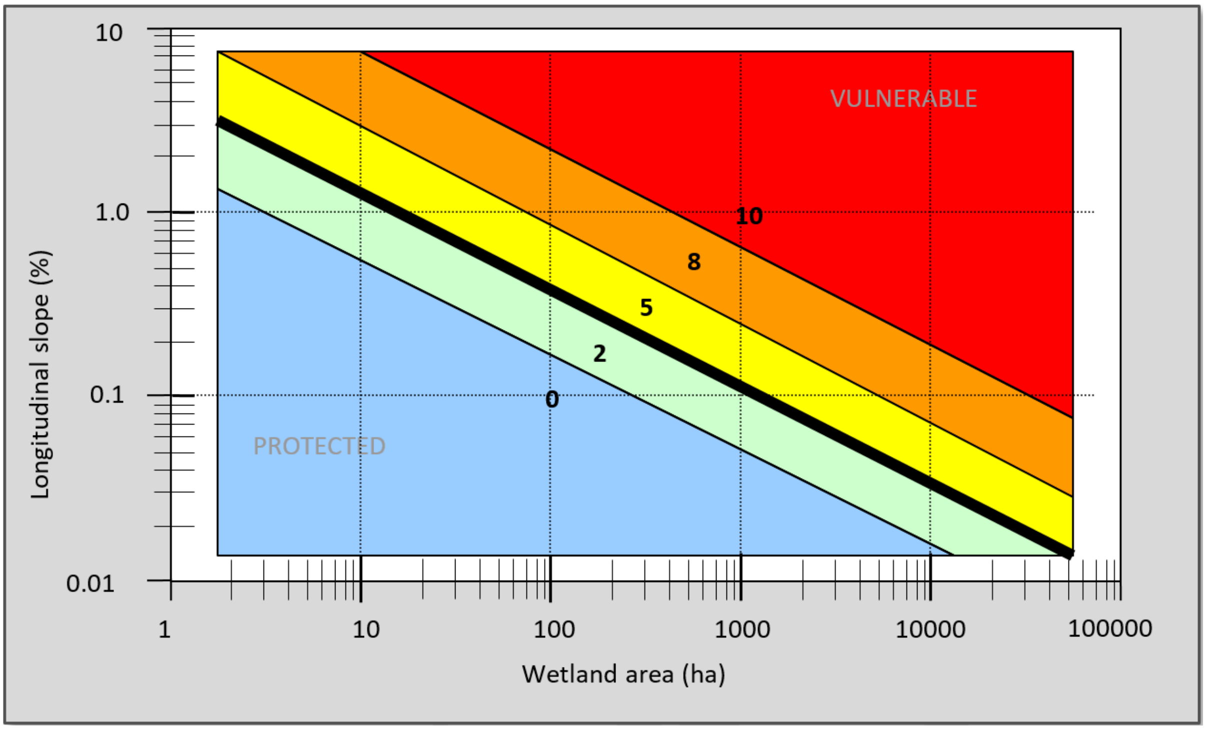


Figure 9.5: Vulnerability of HGM units to geomorphological impacts based on wetland size (a simple surrogate for mean annual runoff) and wetland longitudinal slope[1].

17	Flow patterns of low flows within the wetland Assessment Unit	Strongly confined: Low flows occur over < 5% of the unit (flows confined to active channel and/or drains)	Moderately confined: Low flows occur over 5-25% of the unit (flows strongly concentrated with limited interaction with the wetland floor)	Intermediate: Low flows occur over 25-50% of the unit (diffuse flows evident, but concentrated flow paths dominate)	Moderately unconfined: Low flows occur over 50-75% of the unit (flow is usually predominantly diffuse but preferential flow paths are evident)	Unconfined: Low flows occur over >75% of the unit (if any preferential flow paths are present, they are generally very localised)

Rationale: Much of a wetland's assimilation of pollutants, particularly those pollutants not carried by sediment, takes place during low flow periods. During these periods, waters are shallower and residency times in the wetland longer, which affords the wetland greater opportunity to assimilate pollutants contained in the water (Kadlec and Kadlec, 1979; Hammer, 1992). It is therefore important to determine this particular flow pattern. In some wetlands, low flows are spread diffusely over most of the wetland, allowing for considerable contact between water and the soil of the overall wetland. Conversely, in other wetlands flow is only spread across the wetland in very infrequent storm events, but under low flow conditions water is contained within a small part of the wetland in the active channel or drainage canals, allowing for little contact between wetland soil and surface water flows. The flow pattern of low flows has implications for sediment trapping and water quality enhancement services. Note, the active channel is the portion of a river/stream that is inundated at sufficiently regular intervals to maintain channel form (i.e. the presence of distinct bed and banks) and keep the channel free of terrestrial vegetation (Ollis et al., 2013). Active channels are typically filled during bankfull discharge (i.e. during the annual flood) except for intermittent rivers which do not flood annually (Ollis et al., 2013).

Method: It is important to note that low flows refer not only to flows during the dry season but also to regular flows during the wet season, i.e. excluding stormflows. Determine the pattern of low flows based on field observation of landform, examination of aerial photos and local knowledge. In particular, take note of the location and dimensions of any active stream channels, artificial drainage furrows, erosion gullies and other features which may confine low flows and therefore prevent these flows moving diffusely through the Assessment Unit.

18	Current representation of different hydrological zones	Non-wetland	Dominated by temporary zone	Mix of seasonal and temporary zone	Dominated by seasonal zone	Dominated by permanent zone

Rationale: Hydrology is central to how wetlands and riparian areas function and supply services. Therefore, the hydrological zones represented in the Assessment Unit have a key influence over the supply of almost all regulating services considered, e.g. the assimilation of nitrates and toxicants and attenuation of floods, as well as some of the provisioning services, e.g. food for livestock.

Method: It is very important to emphasize that the <u>*current situation*</u> is taken as that which occurs across all seasons in the year and not just as you see it on the particular day which you visit the wetland. The vegetation and the soil colour patterns should be examined as indicators of soil wetness over the seasons. The permanently saturated zone is typically dominated by tall sedges, reeds or bulrushes and the soils are typically grey, often with a sulphidic (rotten egg) smell. The seasonally saturated zone is typically dominated by medium height sedges and/or grasses and the soils are typically grey with many bright orange/yellow mottles, usually present close to the soil surface. The temporarily saturated zone is typically dominated by a mix of plants occurring predominantly outside of wetlands and hydric (water-loving) sedges and grasses, which are usually short growing. Non-wetland areas typically have brown soils and lack hydric plant species.

[1] Take note that the Y axis (longitudinal slope) makes use of a logarithmic scale.

It is important to also emphasize that the current situation may have been altered from the natural situation. For example, the area may have naturally been seasonally saturated, but drainage ditches or eucalypt trees in the unit have now reduced its level of wetness to temporary. In this case, the soils reflect the natural hydrological conditions under which they were historically formed rather than the current hydrological conditions.

For more information refer to Kotze (1996) ["How wet is a wetland?"] and DWAF (2006) [the DWAF guideline for delineating wetlands]. A soil auger and a Munsell colour chart will be required in order to examine colour patterns of the soil (e.g. purity of the colour and the presence of mottles) in the field as an indicator of hydrological zones.

19	Frequency with which storm flows are spread across the Assessment Unit		Never (Uncertain) OR unit occurs within the active channel of a river (includes banks)	Occasionally but less frequently than every 5 years	1 to 5 year frequency	More than once a year

Rationale: The greater the frequency with which stormflows exceed the capacity of any channel/s passing through the Assessment Unit and are spread across the Assessment Unit, the greater will be the effectiveness of the Assessment Unit in attenuating floods. Conversely, the greater the extent to which stormflows are contained within a channel passing through the Assessment Unit, the lower will be the effectiveness of the Assessment Unit in attenuating floods. The frequency with which stormflows are spread across the Assessment Unit, also influences sediment trapping, and the regulating services which are strongly associated with the trapping of sediment, e.g. phosphate removal.

Method: Use a rapid visual appraisal (look out for debris deposited by stormwater) and local knowledge of flooding. Pay particular attention to human modifications such as straightening, widening and deepening of the channel, and artificial levees, which serve to reduce the frequency with which flooding out of the channel takes place. Note also that incision of the natural stream channel may result in a floodplain/valley bottom no longer being actively flooded, even though the system developed under regular flooding in the past. In hillslope seepages and un-channelled valley bottoms, all major stormflows are generally spread across the unit, unless they have been cut off by human modifications.

20	Extent of open water for tourism and/or recreation	None	Present, but very limited (<10%)		Extent somewhat limited (11-50%)	Extensive (>50%)

Rationale: Open water is universally appreciated for its recreational potential, particularly if the water quality is good and there are no dangerous animals such as crocodiles. Recreation and tourism activities associated with open water includes swimming, fishing and boating.

Method: The extent of open water can generally be determined through direct observation in the field and/or observation of available satellite imagery. Note that open water includes the water surface of any stream/river flowing through the unit as well as any other open water areas such as standing water in oxbow lakes or other natural depressions in the unit and open water associated with any impoundments/dams. In instances where the open water declines considerably during the dry season, adjust the score down by one class. Similarly, if the open water is polluted and appears as discoloured and/or with an unpleasant odour or if the open water is largely obscured from view (e.g. by tall vegetation), adjust the score down by one class.

21	Acceptability of water for human consumption	Toxic	Not Acceptable	Tolerable / Easily Treatable	Acceptable	Ideal

Rationale: The water available in a wetland for direct human use may vary greatly in terms of the acceptability for use, and if it is of unacceptable quality then it is of little or no direct use. Therefore, it is important that the level of acceptability of the water quality be considered. The following five classes are used for the assessment:

Toxic - Acute health effects. Lethal toxicity may occur in highly polluted waters.

Not acceptable - Chronic health effects may occur after continuous use or in very young children and the immunocompromised, chronic and or acute health effects very likely to occur after contact or consumption. Once-off contact or use may not have severe adverse effects, but health risk increases exponentially after continuous use or contact. Lethal toxicity may occur in highly polluted waters.

Tolerable - The consumption of the water resource poses a moderate health risk to the general population. High aesthetic effects (taste) and likely adverse health effects expected in young children, sensitive individuals and those with compromised immune systems.

Acceptable - The consumption of the water resource poses a low health risk. Adverse aesthetic effects (taste) may be noted but no health effects after continuous exposure or consumption.

Ideal - The consumption of the water resource poses no health risk. No taste, other aesthetic or health effects associated with consumption and use. Generally pristine rivers with unpopulated catchments in headwater settings (source streams and springs).

Method: When undertaking this assessment, consideration should be given to a range of possible data sources including:

- Information gathered from local users regarding suitability for use and any known health effects
- Catchment land uses, particularly those posing a high threat to water quality (e.g. mining, industry, waste-water treatment works, etc.)
- Level and maintenance of sanitation services provided
- Direct indicators, including bad odours and visual observations of sewage, industrial or other discharges.

Water in the toxic or not acceptable classes will generally have a bad odour or discolouration. However, in the case of acid mine drainage or certain industrial toxicants, neither of these indicators would be apparent.

22	Periodicity of surface and shallow sub-surface water supply available for human use (domestic, agricultural or industrial)	None	Ephemeral supply	Seasonal supply	Seasonal-perennial supply	Perennial supply

Rationale: Surface and shallow sub-surface water is potentially available for domestic, agricultural or industrial use. Shallow sub-surface water excludes deep groundwater and refers to that which can be accessed by a shallow (<4 m deep) well. The more sustained the availability of the water in the unit, the greater will be the potential contribution of the unit to the supply of water for human use.

Method: The focus here is on areas of the Assessment Unit where water is most readily available (e.g. springs, depressions and channels). A key source of information concerning periodicity of supply is local knowledge of water supply over the year by users of the Assessment Unit. This can be verified by direct observations of the Assessment Unit (preferably in both the wet and the dry seasons). The representation of hydrological zones can provide additional supporting evidence. However, it is important that the dominance of a permanent zone, while suggesting a higher availability of water than a less wet zone, should not be assumed to always indicate that water for human use is supplied throughout the year. Similarly, the dominance of a temporary zone does not necessarily mean that the Assessment Unit does not provide a sustained supply, which may be from a localized spring or from a stream running through the Assessment Unit.

23	Occurrence of depressions in the Assessment Unit	None	Limited (<5%)	Intermediate (5-10%)	Moderately abundant (10-20%)	Abundant (>20%)

Rationale: Depressions refer to hollows in the ground in which water may collect. Depressions are usually rounded in shape, but may also be elongate, as is characteristic of oxbow lakes. Depressions may greatly increase the detention storage capacity of the wetland, depending on the extent and depth of the depressions. However, those depressions that remain filled to near maximum capacity throughout the year are unlikely to retain floodwaters, even if deep. Thus, depressions primarily influence flood attenuation, and, in turn, sediment trapping, and the regulating services which are strongly associated with the trapping of sediment, e.g. phosphate removal.

Method: Estimate the extent of depressions in the Assessment Unit based on interpretation of available satellite imagery and a rapid visual appraisal of the site. Where depressions remain full or close to capacity for much of the year, reduce the score by one class. This can be assessed by reviewing the time series of satellite images available for the site or through discussion with local stakeholders.

24	Reduction in water availability due to human-caused direct water losses from the wetland	Critical	Serious	Large	Moderate	None / Small

Rationale: Increased direct water losses from the Assessment Unit, including (1) increased loss of water to the atmosphere (e.g. as a result of a eucalypt plantation) and (2) artificial drainage furrows/ditches which cause water to flow more quickly out of the unit, can result in drying effects and reduce water availability for downstream areas.

Method: Common direct water losses are associated with alien plants, commercial afforestation and sugarcane within the Assessment Unit. The level of reduction would be based on the nature and extent of impacts and should include consideration of drainage since this can also promote desiccation of wetland areas. Some examples of land use impacts are provided to inform the assessment:

- Critical: Entire wetland planted to Eucalyptus trees / Wetland intensively drained and under sugarcane cultivation;
- Serious: Most of wetland under Pine trees / Wetland moderately drained and under sugarcane cultivation;
- Large: Entire wetland under sugarcane with good growth but limited drainage / 50% planted to Eucalyptus trees
- Moderate: Large portion of the wetland covered by alien invasive tree species
- None / small: Localized alien plant infestation.

25	Soil properties (permeability)	Very Low: Soils with a hard surface (e.g. compacted infill) or introduced hardened surfaces, e.g. tar roads	Low: Fine textured soils with low permeability (e.g. clay loam and clay) OR shallow (< 30 cm) soils with low to moderately ow permeability	Moderately Low: Moderately fine textured soils (e.g. loam & sandy clay loam) OR shallow (<30 cm) moderately drained soils	Moderate: Moderately textured soils (e.g. sandy loam) OR Shallow (<30 cm) well-drained soils.	High: Well-drained soils (e.g. sand and loamy sand).

Rationale: Soil properties can have a bearing on the Assessment Unit's ability to attenuate floods, trap sediments and provide water quality enhancement services. In the case of flood attenuation and sediment trapping, soils with good drainage properties promote infiltration, thus enhancing these services. For the purposes of this assessment, soil texture is used as the primary means of rating soil permeability.

Method: To undertake this assessment, take a small handful of soil (should fit in the palm of your hand) and add sufficient water to work it in your hand to a state of maximum stickiness, breaking up any lumps that may be present. Now try to form the soil into a coherent ball. If this is impossible or very difficult (i.e. the ball collapses easily), then soil is sand or loamy sand. If the ball forms easily but collapses when pressed between the thumb and the fore-finger, then soil is sandy loam. If the soil can be rolled into a thread but this cracks when bent, then soil is loam. If the thread can be bent without cracking and it feels slightly gritty, then soil is clay loam, but if it feels very smooth, then soil is clay (Figure 9.6) Once soil texture has been established, use this information, together with observations of soil surface conditions (e.g. shrinking cracks, earthworm channels) to place the soils into one of four classes. Soil depth is another important aspect affecting permeability and is therefore used to adjust the permeability class in instances where soil depth is shallower than 30 cm.

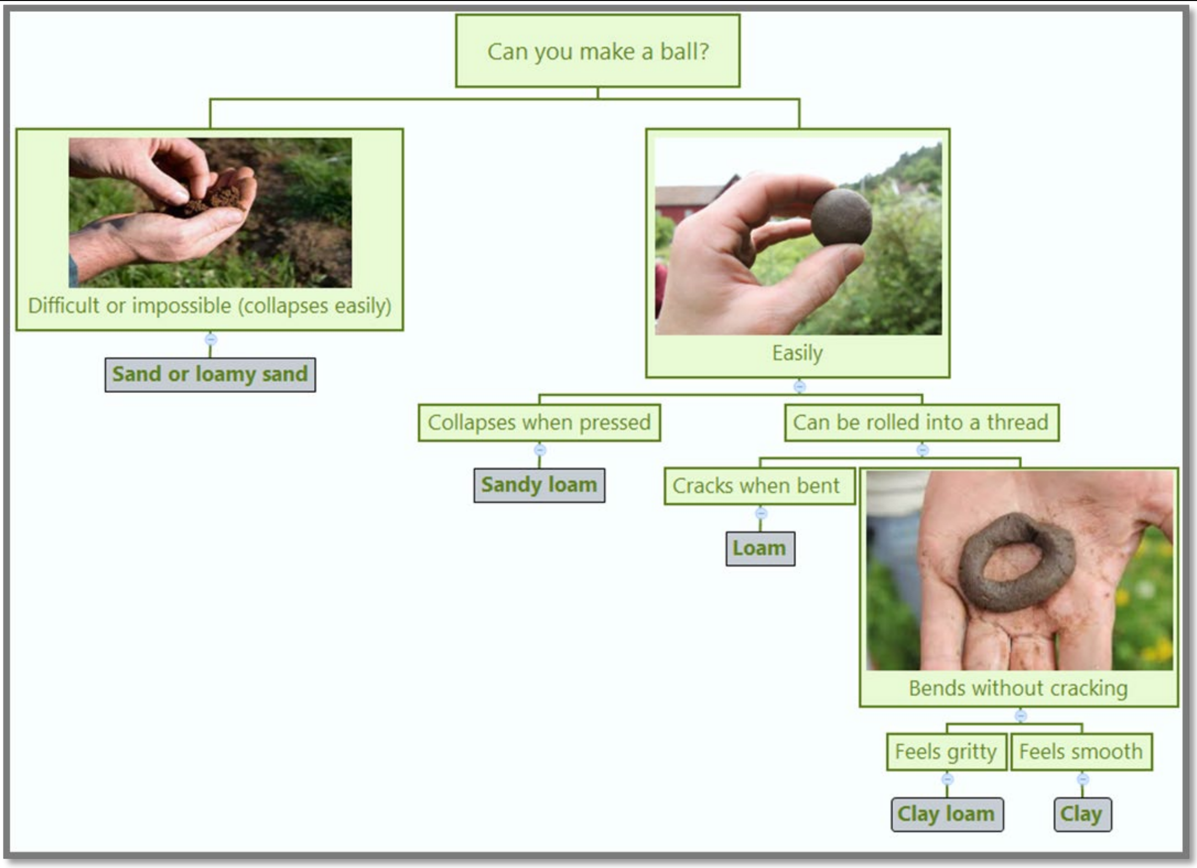


Figure 9.6: Flow chart to determine soil texture in the field (Macfarlane and Bredin, 2016b).

26	Presence of organic soil	Field indicators for organic or close to organic soils are absent, i.e. soils are clearly mineral	Soils appear to be possibly organic or close to organic but field indicators of organic character are not definitive	Organic soil is clearly visible but shallow (<0.2 m deep) and often also limited in extent within the unit	Organic soils moderately deep (0.2-0.8 m) and usually extensive within the unit	Organic soils deep (>0.8 m) and usually extensive within the unit

Rationale: The presence of organic soil has the most obvious implications for the carbon storage service of a wetland, as well as influencing streamflow regulation and the value of the soil for cultivation. Organic soil material is taken as soil material with an average carbon content of at least 10% dry mass (South African Soil Classification Working Group, 1991). Based on the fact that organic carbon generally constitutes between 52-56% of the mass of organic material (Chambers et al., 2011), this threshold translates into approximately 20% organic matter dry mass. The threshold for peat is set at 30% (Joosten and Clark, 2002). However, for the purposes of identifying organic-rich soils in South African catchments/landscapes, use the 20% organic material threshold. This threshold is recommended, given that the climate and topography of South Africa is generally not conducive to the accumulation of abundant soil organic matter, with the result that the occurrence of true peat is very rare (Grundling and Grobler, 2005).

Methods: In order to reliably establish whether soil material is organic requires laboratory analysis (as described in detail by the South African Soil Classification Working Group, 1991). However, a field determination can be undertaken based on the following field indicators. When dry, organic soil material is noticeably less heavy than mineral soil. If the organic material is fibrous then the preserved remains of plants can be seen by eye but be careful not to confuse the roots growing in the soil with the soil material itself. If the organic soil material is humified then it will consist of very fine particles which generally feel like clay. When water is squeezed out of organic material, it will often be discoloured but generally will not have a characteristically very milky appearance as is likely to be the case if it is clay. Finally, organic soil material is also characteristically very dark in colour but remember that some mineral soils may also be very dark. Also, take note of the hydrological zones in the wetland (assessed in another indicator) because organic soils, if present, tend to be confined to the permanently saturated zone. If the soils of the wetland have already been classified according to South African Soil Classification Working Group (1991) then organic soils can be distinguished as those classed as the Champagne soil form. Also refer to the National Peatland Database to check if peat has been recorded in the Assessment Unit.

27	Erodibility of the soil in the Assessment Unit based on the inherent erosion potential (K-factor) of catchment soils	Low (<0.13)	Moderately Low (0.13-0.25)	Intermediate (0.25-0.50)	Moderately High (0.50-0.70)	High (>0.70)

Rationale: An important factor determining the inherent erosion hazard of the site is the erodibility of the soil, which is defined by its resistance to two energy sources: the impact of raindrops on the soil surface, and the shearing action of runoff between soil clods in grooves or rills (Roose, 1996). As a general rule, fine sand is most erodible. For soil particles which are finer (i.e. silt and clay), cohesion develops between the particles, while coarser particles (i.e. coarse sand) and coarser clumps become increasingly heavy and therefore harder to transport (Roose, 1996).

Method: The inherent erosion potential of the soils in the Assessment Unit is inferred from the soil erodibility factor for the catchment area within which the Assessment Unit occurs, derived from the soil erodibility classes and K-factors given in the South African Atlas of Climatology and Agrohydrology (Schulze, 2007) (Figure 9.7). For ease of use, the soil erodibility K-factor map of Schulze (2007) is provided by Macfarlane and Bredin (2016b) in both shapefile and KML format (https://sites.google.com/site/ bufferzonehub/). For most wetland/riparian areas, detailed information on the soil types and their erodibility would not be available, but if such information was available then it could be used instead to score soil erodibility more directly than using the national-scale map of Schulze (2007).

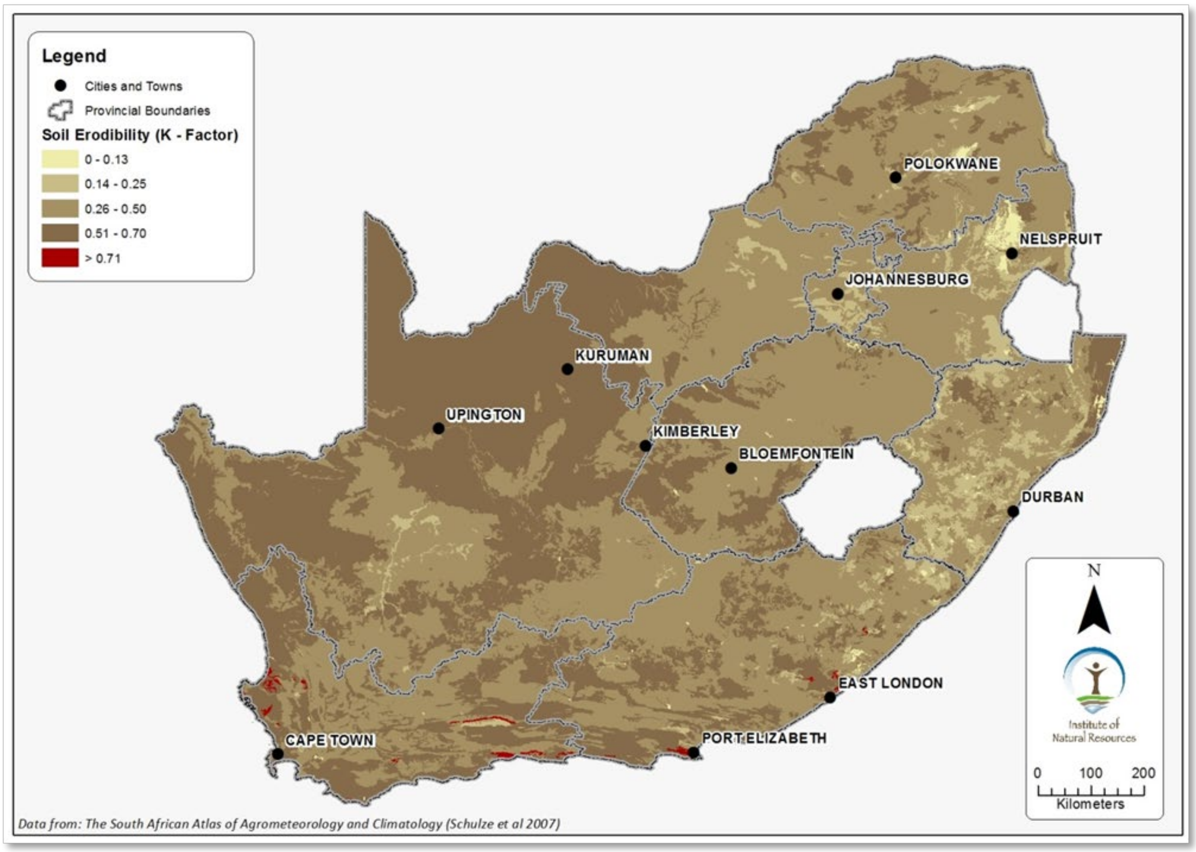


Figure 2.7: Soil erodibility (K-Factor) (Schulze, 2007 in: Macfarlane and Bredin, 2016b).

28	Current level of physical disturbance of the soil in the Assessment Unit	High (>50% of the area of the Assessment Unit)	Moderately High (26-50%)	Intermediate (11-25%)	Moderately Low (3-10%)	Low (<2%)

Rationale: The greater the current level of physical disturbance of the soil in the Assessment Unit, the more susceptible the unit will be to erosion. Disturbance reduces the strength and cohesion of the soil, and it also lowers vegetation cover and surface roughness, which have additional benefits described in the Rationale of these indicators. Soil disturbance also contributes to lowering soil organic matter levels. Tillage of the soil during cultivation accounts for much of the human disturbance of soil in wetlands. Other activities that may also contribute include sand winning, high levels of trampling by livestock, movement of vehicles, excavation for construction, etc.

Method: Assign an initial score based on the extent of current land-uses taking place in the Assessment Unit and which are typically associated with high levels of soil disturbance such as cultivation and earthworks. Where the frequency or intensity associated with cultivation practices is limited (e.g. as in the case of conservation tillage cultivation), adjust the score accordingly. Finally, refine the score with reference to other less intensive land-uses (e.g. livestock grazing).

29	Direct evidence of recent sediment deposition in the Assessment Unit	None	Low (present but <5% of the area of the Assessment Unit)	Intermediate (5-10%)	Moderately High (10-20%)	High (>20%)

Rationale: Direct evidence of sediment which has recently been deposited in the Assessment Unit would indicate that the unit is currently trapping sediment. This has further implications for erosion control as well the regulating services which are strongly associated with the trapping of sediment, i.e. phosphate removal and toxicant removal.

Method: The assessment is based initially on the extent (%) of direct evidence of recent sediment deposition in the Assessment Unit. Such features are often evident where catchment degradation (e.g. overgrazing) or transformation (e.g. rapid urban expansion) has significantly increased sediment inputs. Look particularly in areas where there is a change from a steeper to a gentler slope and/or from channeled flow into diffuse flow. The occurrence of terrestrial and/or pioneer species may also alert you to areas where large amounts of sediment have been deposited. Note too, that in an urban context, depositional features can often be identified through the accumulation of litter evident in recent sediment deposits. Also, look for signs such as sediment which is covering plant litter or low growing plants. In situations where sediment deposits are only evident as a thin coating over the vegetation, adjust the score down by one class whilst the score should be increased by a class where deep sediment deposits (>20 cm) are evident.

30	Direct evidence of erosion in the Assessment Unit	High (>20%)	Moderately High (10-20%)	Intermediate (5-10%)	Low (<5%)	None

Rationale: If there is a high level of erosion evident in the Assessment Unit then this is taken as direct evidence that the unit is not effectively controlling erosion. It is, however, acknowledged that erosion may be an integral part of the natural dynamics of a wetland/riparian area, e.g. those characterized by geomorphological cycles of cut and fill, as described by Pulley et al. (2018).

Method: Use airphoto/satellite imagery interpretation to assist in the identification of erosion gullies and areas of bare soil. The assessment is based initially on the extent (%) of the Assessment Unit affected. Where the depth of erosion gullies and/channel incision is high (e.g. >1 m) and / or there is evidence of active erosion (e.g. sods of soil recently broken off the head of an erosion gully), increase the score by at least one class.

31	Lateral cross sectional (hill) slope of riparian area	Steep (>40%)	Moderately steep (20.1-40%)	Moderate (10.1-20%)	Gentle (2.1-10%)	Very Gentle (0-2%)

Rationale: There is a direct relationship between slope and flow velocity, which, in turn, affects the potential of the riparian area to detain sediment, nutrients and toxicants, or conversely to lose sediment (and associated nutrients and toxicants) through erosion.

Method: Use a 1:10 000 topographic map or GIS with contour data of the study area to estimate the slope of the riparian area. Slope is calculated by measuring the ratio of the horizontal distance between the lowest and highest contour on the slope and the vertical distance (difference between contour elevations). Slope is then expressed as a percentage. For example, if the horizontal distance is 50 m and the vertical distance is 2 m then the slope is calculated as 2/50 x 100 = 4% (i.e. Gentle).

32	Pattern of lateral flows through the riparian area	-	Concentrated flow paths dominate.	Dominantly non-uniform topography	Dominantly uniform topography	Uniform topography

Rationale: The pattern of lateral flows through a riparian area vary considerably in terms of how concentrated flow is; thereby affecting sediment trapping as well as the regulating services, which are strongly associated with the trapping of sediment, e.g. phosphate removal. This is informed by the Literature Review and Buffer Zone Tools developed when compiling "Buffer Zone Guidelines for Wetlands, Rivers & Estuaries" (Macfarlane and Bredin, 2016b).

Method: Use a 1:10 000 topographic map or GIS with contour data of the unit and identify potential concentrated flow paths, taking particular note of drains, erosion gullies and/or rills. It is important to note that in most riparian areas lateral flows only occur with major storm events, and therefore are unlikely to be observed directly. Thus, they need to be inferred indirectly based on features such as erosion gullies which concentrate flows.

33	Extent of vegetation cover in the Assessment Unit	Low: Predominantly bare soil; vegetation sparse or present for only short periods	Moderately Low	Intermediate: Reasonably well covered with permanent vegetation but with noticeable bare areas lacking vegetation	Moderately High	High: Complete and permanent cover

Rationale: Vegetation cover has important direct effects on wetland functioning, in particular by the protection it provides to the soil surface from erosion. In addition, it provides a coarse indicator of the extent to which the soil is occupied by roots, which in turn bind the soil and contribute to soil organic matter and microhabitat for microbes which assist in the assimilation of nitrates and toxicants.

Method: Cover refers to the extent of aerial cover over the entire year. Therefore, it is best not to assess this indicator shortly after a fire as cover would have been temporarily reduced. Assign the Assessment Unit to one of the following five cover classes based on a visual appraisal of the canopy cover:

- Low cover: Predominantly bare soil; vegetation sparse or present for only short periods (i.e. periods less than 4 months)
- Moderately Low cover: Partially covered with permanent vegetation but with extensive bare areas or predominantly well covered but with extended periods when predominantly bare soil (e.g. between establishment of annual crops)
- Intermediate: Reasonably well covered with permanent vegetation but with noticeable bare areas lacking vegetation
- Moderately High cover: Predominantly well covered with permanent vegetation but with small bare areas lacking vegetation (although aerial cover may be temporarily reduced following burning)
- High cover: Complete and permanent cover (although aerial cover may be temporarily reduced following burning)

Note: Even in a complete and permanent cover, there will often be a certain amount of bare ground visible, but this will be as very small areas, generally less than 0.1 m^2. Also note that in some wetlands and riparian areas located in arid and semi-arid climates, the vegetation cover may be naturally much lower in drier years than in wetter years, and therefore it is generally best to take the average conditions represented by both a dry and wet year. If a VEGRAI (Kleynhans, 2007) assessment of the riparian vegetation exists then refer to the vegetation cover estimate for the present condition undertaken in this assessment.

34	Vegetation structure in terms of height and robustness	Very Low: Smooth surface with no vegetation to offer resistance, or if present if vegetation is present – very short (<0,05 m) or very sparse and or flimsy	Low: Smooth surface with Vegetation offering some resistance to water flow, but generally consisting of short plants (i.e. <0.5 m tall), e.g. creeping sedges such as *Pycreus mundii*	Intermediate: Generally dense, intermediate height (0.5-1.0 m) vegetation, e.g. *Imperata cylindrica* grass or *Juncus effusus*	High: Robust, tall vegetation (e.g. dense stands of reeds or sedges) offering high resistance to water flow	Very High: Very robust, tall vegetation (e.g. Swamp forest with dense understorey) and offering very high resistance to water flow

Rationale: Vegetation structure is described primarily in terms of surface roughness, which is related to height and robustness of the vegetation. The greater the surface roughness of a wetland, the greater is the frictional resistance offered to the flow of water and the more effective the wetland will be in slowing down the movement of water through the wetland. This, in turn, contributes positively to attenuating floods and trapping sediment, together with phosphates and toxicants adsorbed to the sediment (Reppert et al., 1979; Adamus et al., 1987).

Method: Assign the Assessment Unit to one of the five classes based on which class description best describes the situation in the unit (Figure 9.8). Note, reasonably sparse woody vegetation with low basal cover would generally be assigned to the Intermediate class. Where vegetation structure varies across the Assessment Unit, take the average condition. Where it varies during the year (e.g. in response to the growth cycles of plants) take the average condition during the wet season as this is when floods are most likely to be encountered.

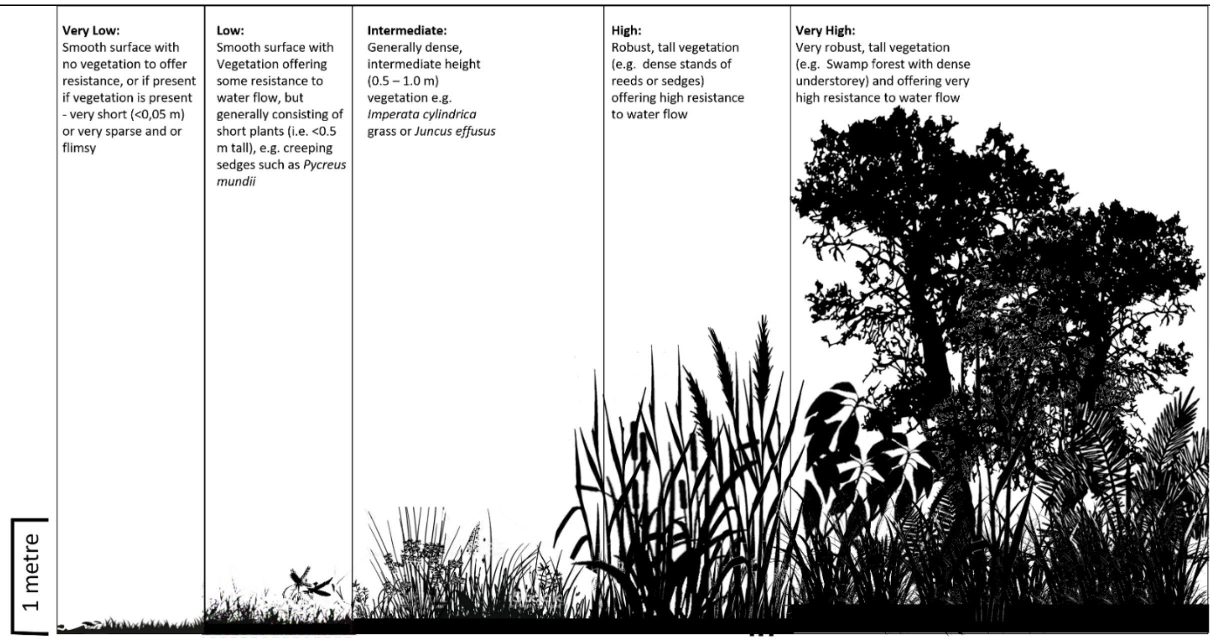


Figure 9.8: Guide for assessing the structure of vegetation.

35	Availability of grazable plants	None	Low (Present but covering <10% of the Assessment Unit)	Moderate (Covering 11-25% of the Assessment Unit)	High (Covering 25-50% of the Assessment Unit)	Very High (Covering >-50% of the Assessment Unit)

Rationale: Grazable plants refer to plants which can be grazed by livestock. Grasses, reeds and sedges can be assumed to generally be grazable, and many of South Africa's wetland/riparian areas support a high occurrence of grazable plants. However, some lack these plants, e.g. where dominated by plants such as eucalypt trees which are generally not eaten by livestock. If the palatability of the grazable plants is known to be low then lower the score by one class.

Method: The aerial cover of grazable plants is assessed by direct observation of the occurrence of grasses, sedges and reeds in the Assessment Unit. It is preferable to also speak to a key informant with local knowledge of the plants which are grazed.

36	Availability of sedges, reeds and/or grasses for craft production and/or thatching	None	Low (Present but covering <10% of the Assessment Unit)	Moderate (Covering 11-25% of the Assessment Unit)	High (Covering 25-50% of the Assessment Unit)	Very High (Covering >50% of the Assessment Unit)

Rationale: In certain parts of South Africa, notably KwaZulu-Natal, the Eastern Cape and Limpopo Province, a diversity of sedges are used for craft production and these sedges are largely confined to wetlands. Thus, the presence of these sedges positively affects the provision of natural resources. Grasses, in particular *Hyparrhenia* (thatch grass) species and the common reed (*Phragmites australis*) are widely used for thatching in South Africa. Thus, the presence of sedges, reeds and/or grasses positively affects the provision of natural resources. While the common reed and sedges are generally confined to wetlands, thatch grass and several grasses used for craft production (e.g. *Eragrostis plana* and *Digitaria eriantha*) occur widely in non-wetland riparian areas, temporary wetlands and elsewhere.

Method: The aerial cover of sedges, reeds and grasses potentially used for craft production and/or thatching is assessed by direct observation in the assessment area. In particular, look out for sedges which have reasonably robust, tall (>1 m) rounded stems, as these often are suitable for craft production. Sedges with robust tall leaves (e.g. *Cyperus latifolius*, ikhwane) may also be suitable for craft production. Thatch grass and the common reed are both conspicuous and easily noted through direct observation in the assessment area. In addition to direct observation, it is preferable to also speak to a key informant with local knowledge of the plants which are used for craft production.

37	Availability of wood for construction / combustion	None	Low (Present but covering <10% of the Assessment Unit)	Moderate (Covering 11-25% of the Assessment Unit)	High (Covering 25-50% of the Assessment Unit)	Very High (Covering >50% of the Assessment Unit)

Rationale: In South Africa, many riparian areas and some wetlands have woody plants suitable for construction and combustion. This includes both indigenous species (e.g. *Vachellia karroo*) and alien species (e.g. *Acacia mearnsii*, black wattle).

Method: Woody plants can be noted through direct observation in the Assessment Unit. A low availability refers to where these plants are limited to a very restricted area of the Assessment Unit. A high availability is where these plants occur widely across the unit, usually as one of the dominant plants in the unit.

38	Availability of medicinal plants	Unknown		Limited availability (Present but difficult to source)		Readily available (Easily sourced by users)

Rationale: In South Africa, many riparian areas and wetlands support medicinal plants, defined as "plants containing chemical compounds with therapeutic properties". These include herbaceous plants, e.g. *Gunnera perpensa* (River pumpkin) of which rhizomes are mainly used and *Ranunculus multifidus* (the common buttercup) of which the leaves are used, and trees/shrubs, e.g. *Macaranga capensis* (the river macaranga tree) of which the bark is used. Note that medicinal plants are typically available in smaller quantities than those used for grazing, thatching and crafts, and therefore have lower cover values than the latter for equivalent classes.

Method: For a listing of medicinal plants commonly associated with wetlands and riparian areas, refer to Wentzel and Van Ginkel (2012) on the distribution and use of medicinal plants of freshwater ecosystems in South Africa. Medicinal plants can be noted through direct observation in the Assessment Unit. However, many medicinal plants are not conspicuous and also may not be familiar to the assessor. Thus, the primary method for assessing their occurrence is generally to speak to a key informant with good local knowledge.

39	Reduction in evapotranspiration through frosting back of the wetland vegetation	Low	Moderately Low	Intermediate	Moderately High	High

Rationale: Whilst wetlands may be important in regulating streamflows, transpiration and evaporative losses from wetlands can affect the supply to downstream areas. This is particularly relevant in situations where wetland vegetation continues to transpire throughout the dry season. A key factor limiting the extent to which wetlands contribute to sustaining streamflow is that water is lost from the wetland through evapotranspiration. However, where natural winter dieback of the leaves takes place, as characteristically occurs in areas experiencing frequent winter frosts, then this loss is greatly reduced during winter. Following winter dieback, the amount of live transpiring plant material is very limited and the standing dead material greatly reduces evaporation from the wetland. This is particularly significant where the winter season coincides with the dry season, which pertains to the summer rainfall areas of South Africa. In the Free State, the Highveld, the Drakensberg foothills and Midlands of KwaZulu-Natal, for example, dry season dieback in wetlands is widespread owing to the high incidence of frosts. The higher the level of frosting back, the greater the reduction in potential loss of water through transpiration.

Method: A GIS coverage was generated to discount areas for anticipated transpiration losses during the dry season. This was achieved by developing a map based on the frequency of heavy frost days but discounted for winter rainfall areas using datasets in the South African Atlas of Climatology and Agrohydrology (Schulze et al., 2007). Rate this indicator with reference to the map provided (Figure 9.9) and refine through interactions with local stakeholders. If the class is High or Very High and frequent early winter burning occurs, then the protective vegetation is removed very soon after it is frosted back, and thus consider lowering the score by one class.

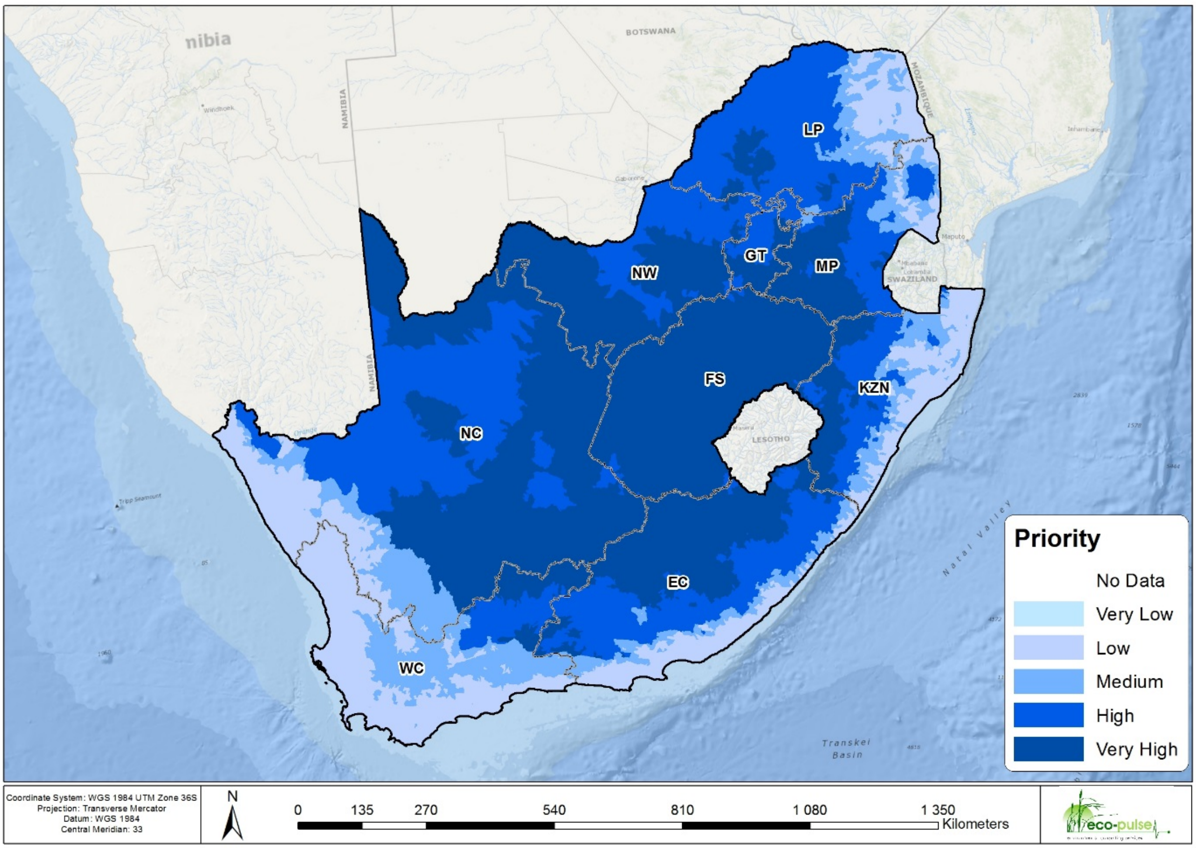


Figure 9.9: Map indicating the anticipated effect of frosting in reducing transpiration losses from wetland vegetation during the winter season (Macfarlane and Atkinson, 2015)

40	Availability of fish and/or game for harvesting	None	Low (Present but evidence of presence [e.g. dung or spoor] is limited)	Moderate (Moderate evidence)	High (Abundant evidence)	Very High (Very abundant evidence)

Rationale: Wetlands and riparian areas may support abundant fish, waterfowl, antelope (e.g. reedbuck, *Redunca arundinum*) and small game (e.g. cane rat, *Thryonomys swinderianus*) that can be sustainably harvested through fishing/hunting. The occurrence of fish and/or game positively affects the provision of natural resources. However, it is recognized that many inland South African wetland/riparian areas have a low potential from a hunting and fishing point of view, although there are some clear exceptions such as the Pongolo Floodplain in KwaZulu-Natal and Barberspan in the North West Province, which are well known for their good fishing opportunities.

Method: Occurrence of fish and/or game is assessed based on the frequency of encountering fish and/or game. Game and especially fish are often difficult to observe, and therefore it is usually not possible to properly assess their occurrence based on a single visit. Thus, the primary method for assessing the occurrence of fish and game is to speak to a key informant with good local knowledge.

41	Bird-watching potential of the site	Low (e.g. Highly disturbed / transformed sites sustaining few birds)	Moderately Low	Intermediate (e.g. Largely natural wetland but lacking diverse habitat)	Moderately High	High (e.g. Sites sustaining large bird populations / special species / a very diverse bird assemblage)

Rationale: Wetlands and riparian areas are well known for supporting a variety of different birds, including ducks, herons and waders, especially where a diversity of habitats is represented, including tall vegetation, very short vegetation, shoreline and some open water.

Method: Important birding sites are often well known and includes Important Bird Areas (Marnewick et al., 2015) and designated Ramsar sites. Whilst the regional context of the site is important to understand, the potential of the Assessment Unit for bird watching is dependent on suitable habitat, heterogeneity and disturbance. Where possible, the assessment should therefore be informed by visual observations and discussions with local stakeholders, particularly any birding clubs that may operate in the area. For direct observations, it is best to visit the site in the early morning or late afternoon when birds are most active.

42	Presence of charismatic species	None (Never encountered)	Low (Present but very seldom encountered)	Moderate (Occasionally encountered)	High (Frequently encountered)	Very High (Very frequently encountered)

Rationale: Nature appreciation often relates to the presence of conspicuous "charismatic" animal species that have wide appeal such as cranes, fish eagles and hippopotami. Therefore, the presence of these species contributes positively in terms of tourism and recreation.

Method: Determine if these are present by contacting the provincial Nature Conservation Department and visit the site or ask a key informant with good local knowledge.

43	Scenic beauty of the Assessment Unit	Low/negligible (e.g. Wetland with very low structural diversity / wetland with dumping and litter)	Moderately Low	Intermediate (e.g. Wetland with moderate diversity but which differs considerably from surrounding habitat)	Moderately High	High (e.g. Diverse wetland habitat within a well-maintained park)

Rationale: The scenic beauty of a site is a key element of its tourism and recreational potential, and many wetlands are well recognized for their high aesthetic value (Roggeri, 1995). Wetlands may have high scenic beauty depending on features such as the diversity of colours and textures, contrast with the surrounding landscape, presence of attractive flowers or open water, and absence of litter (Amman and Lindley-Stone, 1991).

Method: Visit the site and observe it from different vantage points, remembering that scenic beauty may change through the seasons, particularly in the case of wetlands supporting high abundances of attractive flowering plants. Score the wetland based on consideration of the following features.

- Diversity of colours, textures, tones and vegetation structure within the wetland: for example, a wetland with uniform short, light green vegetation would be visually much less diverse than one which had a variety of different heights, including short grass and tall reed clumps, a range of colours, including several different shades of green and brown as well as both light and dark tones.
- Contrast with the surrounding landscape: a wetland with high contrast with the surrounding landscape has more visual interest than a wetland that closely resembles the surrounding landscape. Even a wetland which has a low diversity may have a high contrast with the surrounding vegetation (e.g. a very dark green wetland surrounded by light green grassland or a wetland of any green surrounded by buildings).
- Bright and conspicuous flowers or leaves which turn vibrant colours (usually in the autumn): these add to the beauty of the wetland.
- Litter and other unsightly human developments (electrical pylons, security fences, dumping of building rubble, etc.): these may greatly diminish the overall visual quality of the wetland.

44	Accessibility of the Assessment Unit for education/research or tourism/recreation purposes	Very inaccessible (e.g. Located in an isolated setting and/or with serious access constraints)	Moderately inaccessible	Intermediate (e.g. Located within an urban area but with some practical access constraints)	Moderately accessible	Very accessible (e.g. Located within a public park or reserve with direct access)

Rationale: Access is necessary for any recreation/tourism or education/research benefits to be realized, and the more readily accessible the site, the lower will be the cost of gaining access (Amman and Lindley-Stone, 1991).

Method: Consider the following factors when assessing accessibility:

- Travel time to the nearest two primary/secondary education organizations and the nearest tertiary education organization
- Quality of the road to the site
- Availability of reasonable parking facilities
- Vegetation characteristics affecting access and visibility
- Land ownership (e.g. private land with restricted access vs. town commonage with open access)

45	Security risk associated with accessing the site for education/research or tourism/recreation purposes	High Security Risk (The incidence of crime in the general area is high and/or crime is known to have been committed within or adjacent		Some security risk (The incidence of crime in the general area is moderate and no crime is known to have been committed within or adjacent to the		Very Low security risk (The incidence of crime in the general area is low and no crime is known to have been committed within or adjacent to the

		to the Assessment Unit in the last year)		Assessment Unit in the last year)		Assessment Unit in the last year)

Rationale: Use of areas for recreation/tourism and education/research are strongly dependent on security risk. Where this risk is perceived to be high, many people are likely to avoid the area, irrespective of how ideal the area is in terms of all other relevant features.

Method: Speak to local people about the incidence of crime in the area and contact the local Policing Forum in order to obtain crime statistics information.

BIODIVERSITY INDICATORS

46	Threat status of the wetland or riparian type	Least Threatened (LT)		Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)

Rationale: Threat status is an indicator of how threatened an ecosystem type is in terms of its inherent rarity, present threats to existence and trends in integrity and spatial distribution. Ecosystem types are categorised as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Least Threatened (LT), based on the proportion of ecosystem type that remains in good ecological condition relative to a series of biodiversity thresholds such as the irreversible loss of natural habitat and level of ecosystem degradation (SANBI, 2016).

Method: The threat status of inland wetland ecosystem types is assessed at a national level as part of the National Biodiversity Assessment (NBA) (SANBI, 2017). For wetlands, the units of assessment in the freshwater component of the NBA are the 'wetland vegetation groups' produced as part of the National Freshwater Ecosystem Priority Areas (NFEPA) project (Driver et al., 2011). Until a more refined classification is developed, the threat status of the Wetland Vegetation Group should be applied as a basis for assessment. In the case of riparian areas, the threat status of the relevant azonal riverine, riparian and alluvial vegetation types may be used where available. Alternatively, the assessment should be based on the threat status of the terrestrial vegetation type in which the riparian area is embedded. In instances where threat status has been defined at a finer scale (e.g. provincial assessment), the higher threat status should be used.

47	Priority in national and regional conservation plans	Low priority: Wetlands or riparian areas not flagged as important		Moderate priority: Wetlands or riparian areas located in Ecological Support Areas, River FEPA Catchment or is part of a FEPA Wetland Cluster		High priority: Wetlands or riparian areas located within Protected Areas, Critical Biodiversity Areas or identified as a Wetland or River FEPA

Rationale: South Africa has consolidated considerable biodiversity information into Critical Biodiversity Area (CBA) maps that reflect priorities for biodiversity conservation. These CBA maps are spatial plans for ecological sustainability, and provide a coherent and systematically identified set of geographic priorities to inform planning, action and decision-making in support of sustainable development. They are typically developed at the provincial, district or metropolitan scale, and are based on a systematic biodiversity assessment or plan. CBA Maps divide the landscape into five main categories: Protected Areas, CBAs, ESAs (Ecological Support Areas), other natural areas and areas where no natural habitat remains. Such maps are available for all areas of the country and are being updated and refined on a regular basis. The latest information for South Africa can be obtained from SANBI's BGIS website in which a wide range of biodiversity data is stored and readily accessible (https://www.sanbi.org/link/bgis-biodiversity-gis/).

Much of the emphasis of CBA mapping in South Africa is on terrestrial ecosystems, and thus it is important to also consider complimentary processes that have sought to prioritise aquatic ecosystems. The Freshwater Ecosystem Priority Area (NFEPA) project involved a structured and systematic selection of priority wetlands and rivers required to meet national conservation targets (Nel, 2011). Until such time as wetlands and rivers are integrated more formally into CBA maps, this provides a useful complementary reference source for assessing the contribution of the site to national or regional conservation objectives.

Method: Identify if the wetland/riparian area is part of an existing Protected Area (PA) or is a CBA or ESA in a systematic biodiversity conservation plan, bioregional plan, or equivalent. PAs and CBAs rate most highly since they are required to meet conservation targets whilst ESAs support the maintenance of CBAs and receive a moderate rating. Also identify if the site is a wetland or river FEPA, in a FEPA catchment (a catchment important for maintaining a good condition main river reach) or in a Wetland cluster (a group of wetlands within 1 km of each other and embedded in a relatively natural landscape which allows for important ecological processes such as movement of amphibians between wetlands) (Nel, 2011). Maximum scores are allocated to wetland FEPAs and River FEPAs, and wetlands and riparian areas occurring within FEPA catchments or wetland clusters receive a score comparable to ESAs (i.e. moderate).

48	Ecological condition of wetland / riparian vegetation	Poor: Ecological function has been severely compromised or lost in addition to structure and composition (D-F PES Category)		Fair: Ecological function is maintained even though composition and structure have been compromised (C PES Category)	Good: Composition, structure and function are still intact or largely intact (A / B PES Category)	

Rationale: Ecological condition provides an indication of the extent to which the composition, structure and function (processes) have been modified from a reference condition of natural (SANBI, 2016) and is taken as a direct reflection of how well the wetland or riparian area is representative of its type. The focus here is specifically on vegetation since this provides the most direct indicator of habitat condition. Whilst areas in fair condition can contribute to meeting biodiversity targets for ecological processes, they generally cannot contribute to meeting biodiversity targets for representation of biodiversity pattern. Thus, wetland and riparian areas with vegetation in good ecological condition contribute most to meeting biodiversity targets, since they contain plant communities representative of reference conditions within a biogeographic region.

Method: Vegetation condition should be determined based on best-available information. If a VEGRAI (Kleynhans, 2007) assessment of the riparian vegetation exists then refer to the vegetation condition score which this assessment provides. Similarly, if a WET-Health assessment of the Assessment Unit exists then refer to the ecological condition score of the vegetation component of this assessment, with Level 2 providing a higher confidence assessment than Level 1, as it involves a higher level of field assessment. In the absence of a specific ecological condition assessment, a rapid assessment during the field visit is recommended based on expert judgement (substantiated opinion). Where the wetland is naturally un-vegetated (e.g. saline depressions and open water depressions) then use the condition of the wetland based on the hydrology, geomorphology and water quality components as a proxy for ecological condition.

49	Presence of threatened plant and/or animal species	No 'Endangered' or 'Critically Endangered' species present			One or more 'Endangered' species present	One or more 'Critically Endangered' species present

Rationale: The intention of this criterion is to indicate the rarity and conservation significance of biota present at the site. This is assessed by using the threat status of species present as a surrogate with an emphasis on species that face a high risk of extinction in the near future which includes Endangered and Critically Endangered species.

Method: This assessment should be based on best available information on the presence of Endangered and Critically Endangered species in the Assessment Unit. Where available, this should be informed by local knowledge and site-level species information collected during the past 10 years. Where such information is lacking, potential occurrence may be assessed based on habitat characteristics. If this is the only information available (i.e. occurrence is expected but not confirmed), score the indicator one class lower.

Lists of threatened species have been developed at various scales, ranging from International through to National and Regional assessments. South African conservation agencies use the internationally endorsed IUCN Red List Categories and Criteria to determine the conservation status of biota, which are published in various Red Lists for specific orders of animals and plants. Where there is a discrepancy in the threat status across scales, the highest threat status should be used. Note too that scoring is based simply on the threat status of the species without giving any consideration to the number of threatened species or the viability of populations. Whilst these are regarded as potentially useful inclusions, this is beyond the scope of this rapid assessment.

Note that Vulnerable and Least Threatened species are not specifically considered in order to focus and streamline the assessment. Where such information is available, and Vulnerable species are known to occur, a score of 1 should be assigned for this indicator.

50	Diversity and heterogeneity of natural habitats	Low habitat diversity and heterogeneity relative to other wetlands in the region.		Moderate habitat diversity and heterogeneity relative to other wetlands in the region.		Unusually high habitat diversity and heterogeneity relative to other wetlands in the region.

Rationale: Habitat diversity or heterogeneity refers to the variability in habitat types present within the wetland. In wetlands, this is driven largely by abiotic factors, most notably differences in hydrology (i.e. the supply, distribution and retention of water). Where such variability is high, the site is likely to support a wide range of niches and biota, whilst wetlands and riparian areas characterised by low variability tend to be characterised by low habitat diversity. It is important to emphasize that natural diversity or heterogeneity varies greatly across different regions. As such, one needs to be careful not to "penalize" sites in regions with inherently low diversity. Thus, the site should be assessed in relation to other wetlands or riparian areas in its vegetation group. It is important to note further that floral and faunal species diversity is not considered directly because it is difficult to assess without detailed sampling.

Habitat enhancement through human disturbance (e.g. introduction of artificial ponds) should also be carefully evaluated. Where such disturbance is done with due regard for the natural environment and increases the heterogeneity and diversity of naturally occurring plant communities, this may have a positive impact on biodiversity values. Where such activities destroy large areas of natural habitat, this is regarded as generally undesirable and should not attract a higher score. The presence of habitats associated with alien, pioneer or other species favoured by anthropogenic disturbance should not be considered favourably when undertaking this assessment.

Method: When rating this criterion, consideration should be given initially to the diversity of broad structural habitat types present (Ollis et al., 2013) within the wetland and the associated heterogeneity of habitats provided for plant and animal species. Structural habitat types to consider include:

- Aquatic (Floating, Submerged & Algal mats);
- Herbaceous (Geophytes, Grasses, Herbs/Forbs, Sedges/Rushes, Reeds, Restios, Palmiet);
- Shrubs/Thicket; and
- Forest (Riparian Forest, Forested Wetland /Swamp Forest).

The intention of this criterion is to specifically identify wetlands that either have noteworthy / unusually high habitat diversity or are of very low diversity relative to other wetlands in the region. In regions where habitat structure is typically quite uniform (e.g. naturally herbaceous wetlands), consideration should also be given to the variability in natural plant communities present. In this regard consideration of different topographical and hydro-geomorphic features within or surrounding the wetland should be considered that should correlate well with community variation, e.g. high relative variability in topographical surfaces and features like floodplain features (oxbow lakes, backswamps, alluvial ridges), erosion surfaces, valley bottom / basin variability, hummocks, depressions, alluvial fans, etc., and/or presence of springs. It is also important that the rating should be allocated in relation to other wetlands or riparian areas in the region, rather than by comparing across different types (e.g. focus on wetlands within a wetland vegetation group).

51	Outstanding biodiversity attributes	No				Yes

Rationale: Some wetlands and riparian areas have outstanding biodiversity attributes, which of themselves may make them of high biodiversity value. Features have been based on the Ramsar criteria and include the following:

- Supports unusually / uniquely large populations / numbers of plant and animal species in a particular biogeographical region.
- Provides critically important breeding, feeding and/or roosting sites for resident or migratory species.
- Regularly supports very large populations of waterbirds or 1% of the individuals in a population of one species or subspecies of waterbird.
- Supports a significant proportion of indigenous fish species or provides critical habitat for fish populations.
- Regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian species.

Method: Assess whether any of the attributes listed above are present in the Assessment Unit. Given that the criteria are aligned with the Ramsar criteria for identifying Wetlands of International Importance, all of South Africa's Ramsar sites are likely to qualify. There are, however, also likely to be many other wetland systems that qualify but have not yet been designated as Ramsar sites or are recognised as outstanding sites at the regional level.

52	Ecological connectivity with other wetlands and aquatic habitats	Low connectivity		Moderate connectivity		High connectivity

Rationale: Habitat fragmentation is widely recognised as one of the greatest threats to biodiversity worldwide, and climate change is expected to exacerbate these effects, as species' ranges shift across fragmented landscapes to track suitable conditions. Corridors are expected to mitigate the effects of habitat fragmentation and climate change by facilitating movement of individuals among patchy resources and among populations, providing buffering effects from local extinction processes, supporting gene flow and thus genetic diversity, maintaining ecological processes such as migration, and enabling species and ecological community adaptation in response to climate change (Plassmann, 2016). The purpose of this criterion is therefore to broadly rate the degree of spatial ecological connectivity of the Assessment Unit with other wetlands in the drainage network.

Method: Undertake the assessment based on the degree to which the Assessment Unit is connected to other wetlands and aquatic habitats in the landscape using Figure 9.10 (C) as a guide. Consideration should be given to (i) the proximity of other wetland and/or riparian habitat to the wetland of interest (particularly within 500 m of the wetland); (ii) the level of fragmentation of habitat and therefore connectivity that remains and (iii) the condition and associated biodiversity value (as supporting habitat) of adjacent or linked aquatic ecosystems (SANBI and DWS, 2016). These aspects can be assessed at a desktop level by examining available maps or aerial photography using a GIS or Google Earth and/or verified during the field visit and referring to the Picture guideline below. Then select which of the following three classes best describe the situation in the landscape surrounding the wetland.

Low connectivity: The Assessment Unit has very little surface connection with other aquatic, riparian or wetland ecosystems in the landscape (e.g. very high levels of fragmentation with few wetlands nearby).

Moderate connectivity: The Assessment Unit is moderately connected with other aquatic, riparian or wetland ecosystems in the landscape. (e.g. moderate levels of fragmentation but with reasonable connectivity to intact wetlands and /or riparian areas).

Good connectivity: The Assessment Unit is well connected with other aquatic, riparian or wetland ecosystems in the landscape. (e.g. limited fragmentation with good connectivity to intact wetlands and / or riparian areas via broad natural corridors).

It is worth noting that hazardous or restrictive barriers within or bordering the Assessment Unit may reduce the effectiveness of corridors present. If this is the case, there may be sufficient rationale to reduce the scoring by one class.

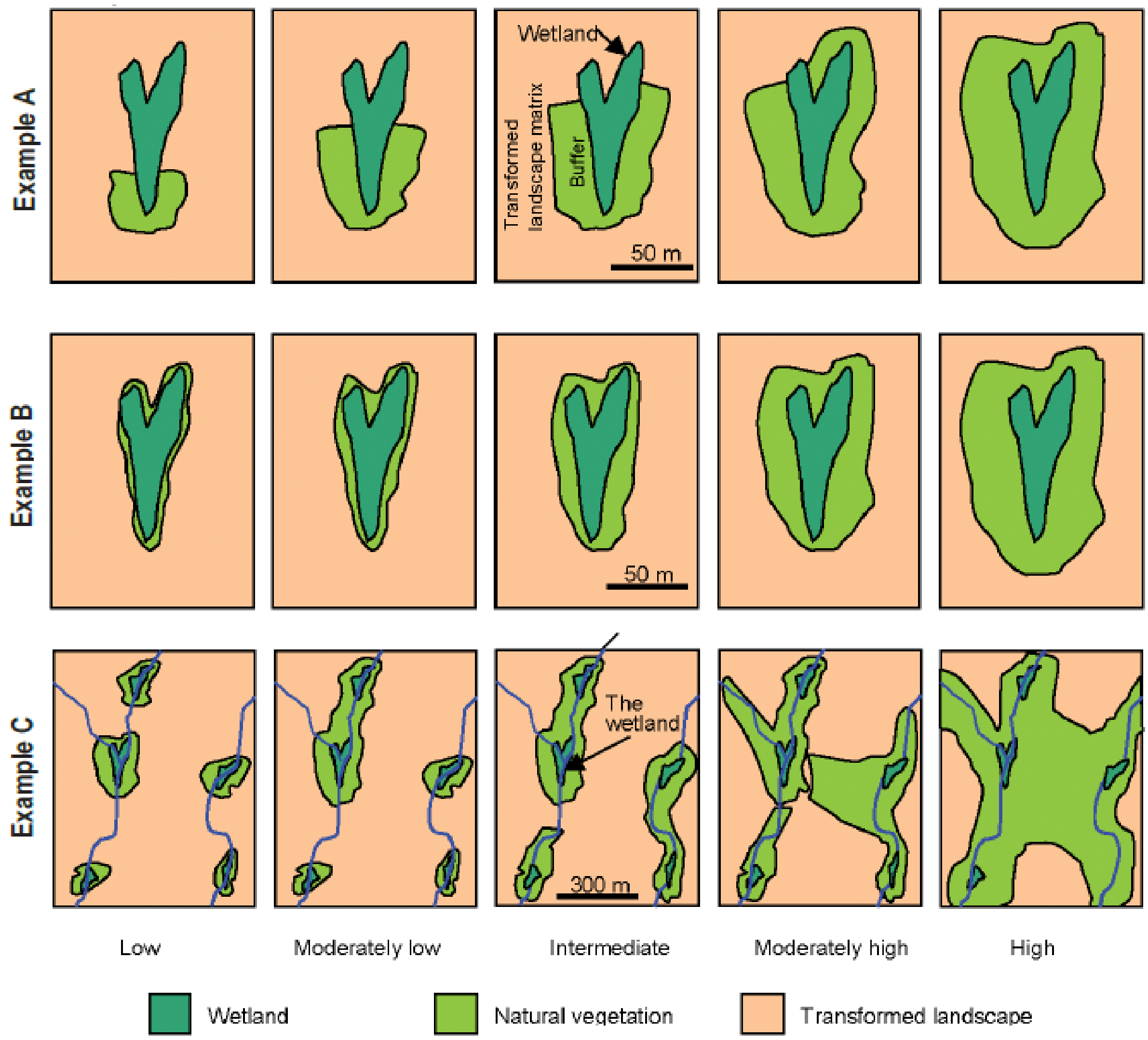


Figure 9.10: A picture guideline for the rapid assessment of (1) the level of buffering around a wetland (Examples A and B); and (2) the connectivity of the wetland with other natural areas in the landscape (Example C).

53	Width of intact buffer zone around the Assessment Unit	<15 m	15-30 m	30-50 m	50-100 m	>100 m

Rationale: A buffer zone refers to the area surrounding a wetland comprising natural or near-natural vegetation. This applies particularly to wetlands found in generally transformed landscapes (e.g. in urban areas or in areas under very intensive agricultural use). Intact terrestrial buffer zones support wetland hydrological functioning; provide a buffer for wetland-dependent species; screen wetlands from anthropogenic disturbances such as diffuse pollutant (nutrient and toxicant) inputs, elevated sediment inputs; and reduce impacts from human presence and traffic (e.g. noise and light pollution). Wetland species also depend on terrestrial habitats to varying degrees to complete their life cycles. For example, many semi-aquatic species rely on terrestrial habitats for the successful recruitment of juveniles and to maintain optimal adult survival rates. In addition, these areas provide potentially useful corridors, allowing the connection of breeding, feeding and refuge sites crucial to maintaining the viability of populations of semi-aquatic species.

Method: The extent of the adjacent terrestrial area that is of importance to species using aquatic habitats differs considerably from one species to the next. In general, however, the broader the buffer, the lower the levels of anthropogenic disturbance and greater the potential to support animals using the wetland or riparian area. For the purposes of this assessment, emphasis is placed on the extent of natural or semi-natural habitat within 100 m of the Assessment Unit. An average width is simply taken by assessing the variability in the distribution of buffers around the margins of the wetland or riparian area being assessed. These aspects can be assessed at a desktop level by examining available maps or aerial photography using a GIS or Google Earth and/or verified during the field visit. Refer to the picture guideline in the previous indicator (Figure 9.10) and select that class which best describes the situation in the landscape surrounding the wetland. In order to account for the quality of the buffer, if the buffer has been impaired (e.g. by heavy livestock pressure), then shift the score one class lower, and if the transformed area resembles the structure of the natural vegetation (e.g. planted pastures and natural grassland), then shift the score one class higher.

DOWNSTREAM USERS

54	Number of people downstream expected to be affected by flooding	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of users benefitting from flood attenuation, the greater the assumed demand for this service.

Method: Speak to a key informant with good local knowledge of the area and examine the 1 in 50-year flood area downstream of the Assessment Unit for infrastructure/property which would potentially be flooded. If the Assessment Unit's catchment is less than 1000 ha then the 1 in 50-year flood area should be examined for 5 km downstream of the Assessment Unit and if greater than 1000 ha then examine this area for 10 km downstream of the Assessment Unit (as adapted from Adamus et al., 1987). Next, estimate the number of people using this infrastructure.

55	Level of risk that flooding poses to the people downstream expected to be affected by flooding	None	Low (Flooding occasionally causes minor inconvenience)	Moderate (Flooding is an inconvenience but poses little risk to livelihoods, infrastructure or property)	High (Flooding poses a moderate risk to livelihoods and property)	Critical (Flooding poses a major risk to property and /or human life)

Rationale: The level of risk to people potentially affected by flooding may vary greatly. At one extreme where risk is low, flooding is largely an inconvenience (e.g. temporarily resulting in longer travel times) and lives are not at risk. At the other extreme, the risks in terms of damage to property and/or loss of lives of people affected by flooding is critical.

Method: Speak to a key informant with good local knowledge of the area and/or directly examine the downstream area. For the floodable property identified when determining the number of people affected, note whether this includes residences where people live.

56	Number of people downstream of the Assessment Unit who are reliant on water for abstraction (run-of-river abstraction and/or from dams) livestock watering and/or recreational use.	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The demand for streamflow regulation, sediment trapping and water quality functions provided by wetlands and riparian areas is strongly influenced by the number of people who make use of water resources downstream of the Assessment Unit. Such uses may include run-of-river abstraction (e.g. for agricultural or industrial use), direct use for domestic purposes, livestock watering or recreational activities. Dams also provide a critical resource for people, particularly dams which form part of a supply network for local communities or to address broader strategic uses. As such, it is important to establish the level of use in downstream areas when estimating the demand for a range of regulating services. In doing so, it is important to recognize that the contribution of the Assessment Unit is likely to decline as one moves further downstream. This is due to the contribution of water inputs from additional sources (e.g. tributaries) that are not intercepted by the Assessment Unit. Riparian areas and wetlands downstream also serve to provide complimentary services thus reducing the relative contribution of the Assessment Unit to regulating functions as one moves further downstream.

Method: This assessment should be informed initially by establishing the primary focal area downstream that needs to be assessed. If the Assessment Unit's catchment is less than 1000 ha then examine the river for 5 km downstream of the Assessment Unit and if greater than 1000 ha then examine the river for 10 km downstream of the Assessment Unit (as adapted from Adamus et al., 1987). Next estimate the number of people using water from this area including communities reliant on dams, run-of-river abstraction (e.g. for agricultural or industrial use) or direct use for domestic purposes (e.g. for drinking water where formal water infrastructure is lacking). In the case of dams, use can be established through discussions with local stakeholders and/or available information sources.

Run-of river abstraction for agricultural use is more difficult to establish but can be informed by identifying pump stations and/weirs along the river and noting the levels of irrigation in adjoining farmlands. Use for livestock watering can be inferred from prevailing land-use and typical agricultural uses in the area but should be refined where possible based on local knowledge. In the case of domestic use, this can be informed by obtaining an indication of communities living in the area and the degree to which formal piped water is supplied in the area through discussions with local stakeholders. Special note should be taken of poorly resourced communities including informal settlements where formal water supply is often lacking. It is important to note that in a scenario where a commercial farm or business is using the water, then the total number of people benefiting from such use is taken into account, this includes not only the farmer or owner of the business, but also the number of workers and members of each worker's household using the water. Recreational use should ideally be informed through discussions with local stakeholders.

Note that where limited use is evident in the assessment area but increases dramatically within 10-20 km downstream (e.g. large supply dam further downstream), consider modifying the score to reflect such use but reduce the scoring by at least one class.

57	Dependence of downstream users on water for abstraction (run-of-river abstraction and/or from dams) livestock watering and/or recreational use.	None	Low (There is a low level of reliance on water supply for household use, to support livelihoods and/or support income generating activities. Alternative water sources/services are readily available.)	Moderate (There is moderate reliance on water supply for household use, to support livelihoods and/or support income generating activities. Alternative water sources/services are accessible when needed.)	High (There is high reliance on water supply for household use, to support livelihoods and/or support income generating activities. Alternative water sources/services are accessible under critical circumstances.)	Critical (Water supply is critical for household use, to support livelihoods and/or support income generating activities. No alternative water sources/services are accessible under critical circumstances.)

Rationale: The dependence of users refers to the level to which users depend on water from the downstream river reach for their livelihoods and/or for their income generation and relates strongly to the presence of alternative water sources. The alternatives include other wetland/riparian/river areas as well as piped water sources. Dependence tends to be highest where alternative wetland/riparian/river areas are limited and the area is not serviced with a piped water supply or where piped supplies are largely dependent on abstraction from a dam or river in the downstream river reach. Ultimately, the greater the dependence of users, the greater the assumed demand for water quality enhancement services and flow regulation.

Method: A key part of assessing dependence is to consider alternatives available to the users. Generally, the more limited the alternatives, the lower the substitutability of the service provided by the unit and therefore the higher the dependence of the users on the services provided by the river reach and associated wetlands and riparian areas in the upstream catchment. Identifying the availability/accessibility of alternatives is generally achieved based on good local knowledge. In the case of domestic supply, reference can also be made to Figure 9.11, below which provides an indication of the reliance of communities on natural water resources based on the interpretation of the StatsSA 2013 dataset. This serves to highlight rural communities with limited formal water supply that are likely to have a high reliance on local water resources but this situation may have changed in response to investment in recent water supply schemes.

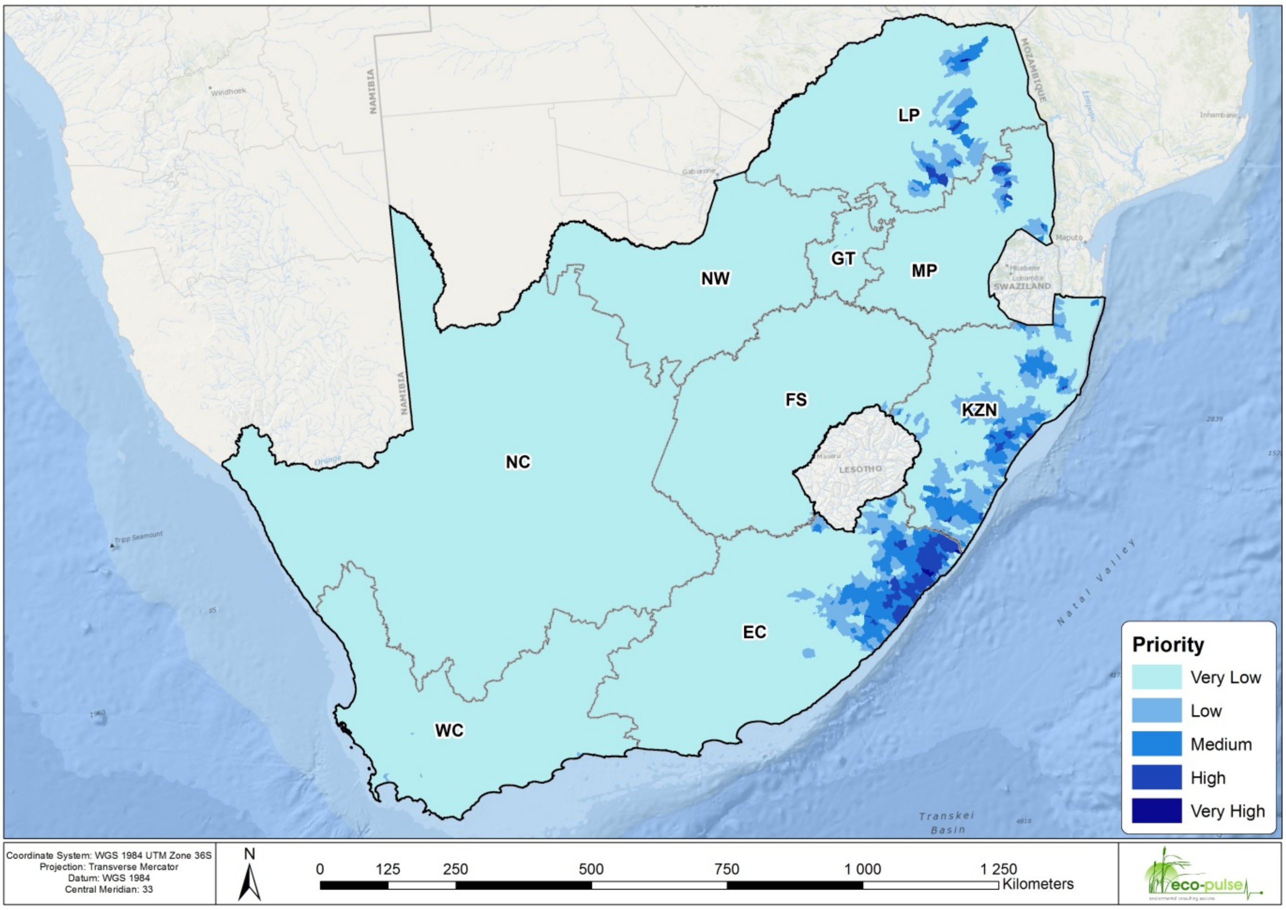


Figure 9.11: Importance of natural water sources for water provision based on available StatsSA 2013 data (Macfarlane and Atkinson, 2015).

58	Ecological importance and sensitivity of rivers downstream of the Assessment Unit	Very Low (Features are not ecologically important and sensitive at any scale)	Low	Moderate (Features that are considered to be ecologically important and sensitive at a local scale)	High	Very High (Features that are considered ecologically important and sensitive on a national or even international level)

Rationale: Rivers vary in their sensitivity to water quality modifications based on factors such as the ecological importance of biota and habitat represented and the sensitivity of rivers to changes in flows and water quality impacts. Where sensitivities are high, there is a greater demand for upstream ecosystems to assimilate pollutants whereas this is lower for systems regarded as being of lower ecological importance or which are less sensitive to anthropogenic impacts.

Method: As a starting point, determine the EIS of the main river of the sub-quaternary catchment (SQ) within which the Assessment Unit is located using the PES/EIS data that is available for most of the sub-quaternary catchments across the country generated as part of the most up-to-date national desktop river PES/EIS assessment (DWS, 2014). Whilst detail is available for EI and ES, the overall EIS class is regarded as a useful indicator for the purposes of this assessment and is available spatially for the entire country. This can simply be determined by selecting the SQ within which the wetland being assessed is located. The spatial data can be downloaded from the link: http://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx, and viewed in a GIS or Google Earth.

Where desktop PES/EIS data is lacking for the relevant sub-quaternary catchment, identify the relevant receiving river and consider the following key attributes of the river based on available spatial datasets and analysis of aerial photography in a GIS or Google Earth:

- Diversity and rarity of biota (fish, invertebrates, etc.) relative to other rivers in the region
- Condition of the river relative to reference conditions
- Habitat diversity and the importance for ecological processes

59	Presence of wetlands critical to meeting wetland conservation targets downstream of the Assessment Unit	No				Yes

Rationale: Maintaining the natural character of wetlands of high conservation value is recognised as an important conservation objective. Achieving this is, however, largely dependent on catchment management practices, and the ability of upstream aquatic ecosystems to assimilate pollutants.

Method: Identify the presence of any wetlands critical for meeting conservation targets located within 10 km downstream of the Assessment Unit. In the South African Context, this would include wetlands identified as CBAs in conservation plans or validated wetland Freshwater Ecosystem Priority Areas (FEPAs). If such an important wetland is picked up within 10 km downstream, this should be scored a 4.

In special circumstances, wetlands of especially high conservation importance (e.g. Ramsar sites) that are located beyond 10 km downstream of the Assessment Unit could still potentially be benefiting from the functions and services provided by the Assessment Unit. It is also thus important to identify any known Ramsar sites and wetlands within protected areas located within 10-20 km downstream of the Assessment Unit. If such an important wetland is picked up within 10-20 km downstream, this should be scored a 2 or a 3 with relevant substantiation.

It is important to note that in some regions, sub-provincial level systematic conservation assessments and plans have not been undertaken. In such regions, therefore, there is a possibility that important wetlands may not have been picked up as CBAs or wetland FEPAs due to the coarse resolution of the assessments. Similarly, it is important to consider the resolution of bioregional plans that are often coarse in resolution due to budgetary constraints. In such circumstances, local knowledge or previous assessments of known important wetlands within 10 km downstream of the assessment site should be interrogated to inform wetland EIS and rated accordingly.

For wetlands that are not connected to the drainage network, allocate a score of 0 for this criterion.

60	Presence and importance of downstream estuaries	No			Other Estuary	Priority estuary

Rationale: Estuaries are recognised for the important role they play in providing a range of critical ecological functions such as providing nursery functions for marine life, habitat for a range of species, and recreational opportunities for communities. Estuaries are also particularly sensitive to changes in catchment hydrology and water quality.

Method: Identify the presence of any estuaries located within 10 km downstream of the Assessment Unit. Where an estuary occurs downstream of the Assessment Unit, this criterion should be scored based on whether the estuary has been prioritised to meet conservation targets. This should be informed by the best available information (Turpie et al., 2002). It is important to note that all estuaries are assumed to be important, with priority estuaries scoring a maximum of 4 and non-priority estuaries a 3. This scoring approach means that the highly relevant ecological sensitivity of estuaries will also be factored into the scoring by default with no estuary scoring below a 3.

Where an especially important estuary (i.e. Ramsar / world heritage site) is located beyond 10 km downstream of the Assessment Unit but could still potentially be benefiting from the functions and services provided by the Assessment Unit, it is important to consider these sites. Therefore, especially important estuaries should be identified within 10-20 km downstream of the Assessment Unit. If such an important wetland is picked up, this should be scored a 3 or a 4 with relevant substantiation.

GLOBAL USERS (CONNECTED THROUGH THE ATMOSPHERE)

61	Number of people benefiting from carbon storage functions					Very High (>1000 people)

Rationale: Owing to the connectedness of the atmosphere at a global level, the beneficiaries of carbon storage are potentially global in scale and therefore the score for the number of beneficiaries is by default set at the maximum.

Method: Given the rationale above, the default score should always be used, and therefore no guidance is required for scoring.

62	Dependence of users on carbon storage provided by the Assessment Unit			Moderate (There is a moderate level of dependence of users on the wetland for providing this service)		

Rationale: Owing to the fact that South Africa's wetlands contain only a very small proportion of the global store of wetland carbon, the specific dependency on South Africa's wetland carbon storage is assumed not to be high, and by default is rather set at moderate.

Method: Given the rationale above, the default score of moderate should be used. However, if the site is recognized as a nationally significant peat store (see the National Peatland Database) then with motivation, the dependence score can be increased to high.

ON-SITE USERS OF PROVISIONING SERVICES

63	Number of people making use of water from the wetland / river reach for commercial agriculture or industrial use	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of agricultural or industrial users of water from the Assessment Unit or a river flowing through the unit, the greater the assumed demand for water provisioning by the unit.

Method: Speak to a key informant with good local knowledge of the area concerning commercial agriculture and industrial use if present. Where a key informant is not available, evidence of use should be based on the presence of abstraction points and the size of industrial and agricultural areas supplied. It is important to note that in a scenario where a commercial farm or business is using the water, then the total number of people benefiting from such use is taken into account, this includes not only the farmer or owner of the business, but also the number of workers and members of each worker's household using the water.

64	Dependence of commercial agricultural / industrial users on abstracted water from the Assessment Unit	None	Low (There is a low level of reliance on water supply for commercial / industrial use. Alternative water sources/services are readily available.)	Moderate (There is moderate reliance on water supply for commercial / industrial use. Alternative water sources/services are accessible when needed.)	High (There is high reliance on water supply for commercial / industrial use. Alternative water sources/services are accessible under critical circumstances.)	Critical (Water supply is critical for commercial / industrial use. No alternative water sources/services are accessible under critical circumstances.)

Rationale: The dependence of users refers to the level to which users depend on water from the Assessment Unit for their livelihoods and/or for their income generation and relates strongly to the presence of alternative water sources. Ultimately, the greater the dependence of users, the greater the assumed demand for water quality enhancement services and flow regulation.

Method: A key part of assessing dependence is to consider alternatives available to the users. Generally, the more limited the alternatives, the lower the substitutability of the service provided by the unit and therefore the higher the dependence of the users on the Assessment Unit for the particular service being considered. Identifying the availability/accessibility of alternatives is generally achieved based on good local knowledge and by assessing if any alternatives are practically available.

65	Number of people using water from the Assessment Unit for domestic purposes	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of domestic users of water from the Assessment Unit or a river flowing through the unit, the greater the assumed demand for water provisioning by the unit.

Method: Speak to a key informant with good local knowledge of the area to determine whether or not any direct use of water is made for domestic purposes (includes drinking and washing). Where stakeholder engagement is not possible, estimates of use should be inferred based on proxies such as the size of human settlement and land tenure/use in the area surrounding the Assessment Unit (generally consider 1 km from the Assessment Unit), availability of substitute sources (e.g. piped water), the suitability of water for abstraction, and direct evidence of use (e.g. water pumps / springs protected for abstraction).

66	Dependence of people using water from the Assessment Unit for domestic purposes	None	Low (There is a low level of reliance on water supply for household use, to support livelihoods and/or support income generating activities. Alternative water sources/services are readily available.)	Moderate (There is moderate reliance on water supply for household use, to support livelihoods and/or support income generating activities. Alternative water sources/services are accessible when needed.)	High (There is high reliance on water supply for household use, to support livelihoods and/or support income generating activities. Alternative water sources/services are accessible under critical circumstances.)	Critical (Water supply is critical for household use, to support livelihoods and/or support income generating activities. No alternative water sources/services are accessible under critical circumstances.)

See previous Rationale and Methods for assessing dependence. Note however that where local information on dependence is lacking, this must be inferred based on other proxies, in particular the land tenure/use in the area surrounding the Assessment Unit. In the urban context, alternative sources of water supply are generally readily available (bottled / piped water). In a rural context, dependence will be strongly affected by the location and accessibility of alternative sources relative to affected communities. As a general rule, dependence on provisioning services is highest in communal rural area.

67	Number of people reliant on harvestable natural resources (Cumulative across all resources)	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of users of harvestable natural resources from the Assessment Unit, the greater the assumed demand for harvestable natural resources in the unit.

Method: Speak to a key informant with good local knowledge of the area to obtain an indication of the number of people harvesting natural resources from the wetland on an annual basis. Users include not only those directly harvesting the natural resources in the Assessment Unit but also members of their households who benefit from these resources. Where a key informant is not available, this must be estimated based on observations in the field including direct evidence of use, the proximity and size of local communities, access to alternative products (typically high in urban settings) and evidence of natural resources incorporated in local structures.

68	Dependence of people making use of harvestable natural resources from the Assessment Unit	None	Low (There is a low level of reliance on the site to support livelihoods and/or support income generating activities. Alternative sites containing targeted harvestable natural resources are readily available.)	Moderate (There is moderate reliance on the site to support livelihoods and/or support income generating activities. Alternative sites containing targeted harvestable natural resources are accessible when needed.)	High (There is high reliance on the site to support livelihoods and/or support income generating activities. Alternative sites containing targeted harvestable natural resources are available but are difficult to access.)	Critical (Harvestable natural resources supplied by the site are critical for household use, to support livelihoods and/or support income generating activities. No alternative sites containing targeted harvestable natural resources are available.)

See previous Rationale and Methods for assessing dependence.

69	Number of people reliant on the Assessment Unit for livestock grazing	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of users using the Assessment Unit for grazing, the greater the assumed demand for grazing from the unit.

Method: Speak to a key informant with good local knowledge of the area to obtain an indication of livestock numbers utilizing the Assessment Unit and ownership. When rating this indicator, note that users include not only those directly owning the livestock but also members of their households who would benefit either directly or indirectly from such ownership. Where a key informant is not available, this must be estimated based on proxies such as ownership, prevailing land-uses and the suitability of the wetland in providing grazing to livestock.

70	Dependence of livestock owners on grazing provided by the Assessment Unit	None	Low (There is a low level of reliance on the site for grazing to support livelihoods and/or support income generating activities. Alternative sites providing suitable grazing are readily available.)	Moderate (There is moderate reliance on the site for grazing to support livelihoods and/or support income generating activities. Alternative sites providing suitable grazing are accessible when needed.)	High (There is high reliance on the site for grazing to support livelihoods and/or support income generating activities. Alternative sites providing suitable grazing are available but are difficult to access.)	Critical (Grazing supplied by the site is critical to support livelihoods and/or support income generating activities. Alternative sites containing suitable grazing are not available in critical periods.)

Rationale: The dependence of users, refers to the level to which users depend on the service provided by the assessment area for their livelihoods and/or for their income generation. The greater the dependence of users on the service supplied by the Assessment Unit, the greater the assumed demand for this service. A key factor affecting dependence is the availability of alternative areas. Generally, the more limited the alternatives, the lower the substitutability of the service provided by the unit and therefore, the higher the dependence of the users on the Assessment Unit for the particular service being considered. In terms of grazing, dependency on wetland/riparian areas is generally greatest in arid and semi-arid areas, where wetlands and riparian areas often provide key grazing resources in the dry season (especially towards the end of the season) and in droughts, when usually grazing is naturally very limited in the surrounding areas (Fynn et al., 2015).

Method: Speak to a key informant with good local knowledge of the area. Where such interaction is not possible, dependence should be assessed by considering proxies such as the availability and quality of alternative grazing areas.

71	Number of people reliant on the Assessment Unit for growing cultivated foods	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of people using the Assessment Unit for growing cultivated food, the greater the assumed demand for this service from the unit.

Method: Speak to a key informant with good local knowledge of the area. Users include not only those directly cultivating the Assessment Unit but also members of their households who benefit from the cultivated food. Where a key informant is not available, this must be estimated based on proxies such as the extent and nature of cultivation present (subsistence / commercial) and an understanding of land use allocations / ownership.

72	Dependence of people sourcing cultivated foods provided by the Assessment Unit	None	Low (There is a low level of reliance on the site to support livelihoods and/or support income generating activities. Alternative sites providing cultivated foods are readily available.)	Moderate (There is moderate reliance on the site to support livelihoods and/or support income generating activities. Alternative sites providing cultivated foods are accessible when needed.)	High (There is high reliance on the site to support livelihoods and/or support income generating activities. Alternative sites providing cultivated foods are available but are difficult to access.)	Critical (Cultivated foods supplied by the site are critical for household use, to support livelihoods and/or support income generating activities. No alternative sites providing cultivated foods are available.)

Rationale: The dependence of users, refers to the level to which users depend on the service provided by the assessment area for their livelihoods and/or for their income generation. The greater the dependence of users on the service supplied by the Assessment Unit, the greater the assumed demand for this service. A key factor affecting dependence is the availability of alternative areas. Generally, the more limited the alternatives, the lower the substitutability of the service provided by the unit and therefore, the higher the dependence of the users on the Assessment Unit for the particular service being considered.

Method: Speak to a key informant with good local knowledge of the area. Where such interaction is not possible, dependence should be assessed by considering proxies such as land tenure/use within a 1 km area of the Assessment Unit, the availability of alternative sources such as markets and cultivated areas and the economic status of local users which affects their ability to purchase products from alternative sources.

ON-SITE USERS OF CULTURAL SERVICES

73	Number of people who access the Assessment Unit for tourism / recreational purposes on an annual basis	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The dependence of users, refers to the level to which users depend on the service provided by the assessment area for their livelihoods and/or for their income generation. The greater the dependence of users on the service supplied by the Assessment Unit, the greater the assumed demand for this service. A key factor affecting dependence is the availability of alternative areas. Generally, the more limited the alternatives, the lower the substitutability of the service provided by the unit and therefore, the higher the dependence of the users on the Assessment Unit for the particular service being considered.

Method: Speak to a key informant with good local knowledge of the area. Where such interaction is not possible, proxies such as accessibility to the site, size of local communities and proximity to other tourism sites can be used to obtain an informed estimate.

74	Dependence of users on the Assessment Unit for tourism/recreation	None	Low (Alternative sites providing similar opportunities are readily accessible and / or users access the site on a very infrequent basis (e.g. less than once per year))	Moderate (Alternative sites providing similar opportunities are accessible and / or users access the site on a fairly regular basis (e.g. once per year))	High (Alternative sites providing similar opportunities are not easily accessed and / or users access the site on a very regular basis (e.g. once per month))	Critical (Alternative sites providing similar opportunities are not available and / or users access the site on a weekly basis)

Rationale: The dependence of users refers to the level to which users depend on the service provided by the assessment area for their tourism/recreation experience. The greater the dependence of users on the service supplied by the Assessment Unit, the greater the assumed demand for this service. A key factor affecting dependence is the availability of alternative areas.

Method: Speak to local tourism operators/initiatives as well as to a key informant with good local knowledge of the area. Where such interaction is not possible, dependence should be assessed by considering proxies such as land tenure/use within a 1 km area of the Assessment Unit and the availability of alternative tourism/recreation sites in the area.

75	Suitability of the Assessment Unit as a reference and/or demonstration site	Low (e.g. Degraded site with no special attributes)	Moderately Low	Intermediate (e.g. Good condition wetland but lacking interesting features)	Moderately High	High (e.g. Natural wetland with special features / rehabilitated wetland with supporting research)

Rationale: A reference wetland/riparian site refers to a site that represents a good example of the type/s of wetland/riparian areas common or unique to a region. These systems are typically in a good or near natural state (i.e. their biotic integrity is high). Such sites serve as useful baselines for scientific understanding and research and may also provide valuable sources of information for conservation and catchment planning and management (Roggeri, 1995; Brinson and Rheinhardt, 1996). A demonstration site is used particularly for education. It may have a relatively low ecological integrity but generally represents a variety of habitats and species, which contribute to its value for demonstrating a variety of ecological principles and features.

Method: To establish whether the site has a high biotic integrity check for an existing assessment of integrity, and if this is not available then land-use can be used as a proxy for integrity (refer to Macfarlane et al., 2020). Other attributes to consider include accessibility and uniqueness relative to other wetlands in the landscape.

76	Number of people who access the wetland for education/research purposes on an annual basis	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)

Rationale: The greater the number of people using the Assessment Unit for tourism/recreation, the greater the assumed demand for this service from the unit. ***Method:*** Speak to local stakeholders to establish levels of use for education / research purposes. Where such interaction is not possible, this should be assessed with reference to the use of other wetlands in the region.						
77	Dependence of users on the Assessment Unit as an education/research site	None	Low (Alternative sites providing similar opportunities are readily accessible and / or users access the site on a very infrequent basis (e.g. once less than once per year))	Moderate (Alternative sites providing similar opportunities are accessible and / or users access the site on a fairly regular basis (e.g. once per year))	High (Alternative sites providing similar opportunities are not easily accessed and / or users access the site on a very regular basis (e.g. once per month))	Critical (Alternative sites providing similar opportunities are not available and / or users access the site on a weekly basis.)
Rationale: The dependence of users refers to the level to which users depend on the service provided by the assessment area for their education/research experience. The greater the dependence of users on the service supplied by the Assessment Unit, the greater the assumed demand for this service. A key factor affecting dependence is the availability of alternative areas. ***Method:*** Speak to a key informant with good local knowledge of the area. Where such interaction is not possible, dependence should be assessed by considering proxies such as land tenure/use within a 1 km area of the Assessment Unit and the availability of alternative research/education sites in the area.						
78	Existing data & research	None	Moderately Low	Intermediate	Moderately High	Comprehensive data over long period
Rationale: Wetlands are inherently dynamic systems, changing over periods of days, seasons and years (Mitsch and Gosselink, 1986). Thus, to best understand these systems requires comprehensive, long-term data and research effort. Thus, the research potential of a wetland would be enhanced by the fact that it already has an existing research base and data gathered, and the more comprehensive and long-term, the greater the value. ***Method:*** Undertake an internet search to check for the availability of research/data on the site. Also contact the nearest tertiary education institute, DWAS and/or water management institute for information on existing data and research.						
79	Is the wetland in a rural communal area?	No		Yes		
Rationale: In many rural communal areas wetlands still have cultural significance for a variety of reasons, as elaborated further in the rationale of the next indicator. ***Method:*** Refer to an up-to-date cadastral map or consult local people.						
80	Known local cultural practices in the Assessment Unit	None				Yes
Rationale: A wide variety of cultural/religious practices take place in wetlands, including traditional cleansing ceremonies, baptisms, traditional fishing practices (e.g. the fonya drives of the Pongolo Floodplain, KwaZulu-Natal), harvesting of plants for traditional crafts, and harvesting of plants for traditional medicines (WESSA, 2003a and b). ***Method:*** Visit the HGM unit and observe any activities or evidence of recent activities (e.g. the stems of reeds that have been cut) and speak to local people, particularly older members of the community, about any cultural practices specifically taking place in the Assessment Unit.						
81	Known local taboos or beliefs relating to the Assessment Unit	None				Yes
Rationale: Important taboos and beliefs are still associated with some wetlands, and many of these taboos and beliefs help to support the sustainable utilization of the wetland (WESSA, 2003a and b). ***Method:*** Speak to local people, particularly older members of the community, about any taboos or beliefs relating specifically to the Assessment Unit. Remember that this may be a time-consuming operation, particularly if no previous contact has been made with the local people. Also refer to relevant literature (e.g. WESSA, 2003a and b). Where such interaction is not possible, assume that local taboos and beliefs are not present unless available and accessible research on other wetlands in the region suggests otherwise.						
82	Number of people who use the Assessment Unit for cultural and spiritual purposes on an annual basis	None	Low (1-10 people)	Moderate (11-100 people)	High (101-1000 people)	Very High (>1000 people)
Rationale: The greater the number of people using the Assessment Unit for cultural purposes, the greater the assumed demand for this service from the unit. ***Method:*** Speak to a key informant with good local knowledge of the area on their observations of the number of people that use the Assessment Unit for cultural purposes over a one-year period. Where such information is lacking, this can be informed by other proxies including an understanding of general reliance of communities on wetlands / riparian areas for such use in the region and the proximity and accessibility of the site to local communities.						

83	Dependence of users on the Assessment Unit for cultural and spiritual purposes	None	Low (Alternative sites providing similar opportunities are readily accessible and / or users access the site on a very infrequent basis (e.g. less than once per year))	Moderate (Alternative sites providing similar opportunities are accessible and / or users access the site on a fairly regular basis (e.g. once per year))	High (Alternative sites providing similar opportunities are not easily accessed and / or users access the site on a very regular basis (e.g. once per month))	Critical (Alternative sites providing similar opportunities are not available and / or users access the site on a weekly basis.)

Rationale: The dependence of users refers to the level to which users depend on the service provided by the Assessment Unit as an area for having cultural experience/s. The greater the dependence of users on the service supplied by the Assessment Unit, the greater the assumed demand for this service. A key factor affecting dependence is the availability of alternative areas providing similar experiences.

Method: Speak to a key informant with good local knowledge of the area. Where such interaction is not possible, dependence should be assessed by considering proxies such as land tenure/use within a 1 km area of the Assessment Unit and the availability of alternative cultural sites in the area.

10. Use of WET-EcoServices for assessing the Ecological Importance and Sensitivity (EIS) of wetlands

The term Ecological Importance and Sensitivity (EIS) is well entrenched in water resource management in South Africa. Ecological Importance (EI) is the expression of the importance of wetlands and rivers in terms of the maintenance of biological diversity and ecological functioning at a local and landscape level. Ecological Sensitivity (S) refers to ecosystem fragility or the ability to resist or recover from disturbance (Rountree and Kotze, 2013). The purpose of assessing ecological importance and sensitivity of water resources like wetlands, and rivers is to be able to identify those systems that provide valuable biodiversity support functions, regulating ecosystem services, or are especially sensitive to impacts. Knowing what ecosystems are valuable enables the appropriate setting of management objectives (i.e. recommended ecological category − REC) and the prioritization of management actions and interventions to promote effective water resource management.

The tool currently used for assessing wetland EIS (Rountree and Kotze, 2013) is somewhat outdated but is typically informed by a WET-EcoServices assessment. The implication is that practitioners involved in wetland assessments typically have to complete both a WET-EcoServices assessment and a stand-alone EIS assessment to inform decision-making processes. Recommendations to refine the wetland EIS tool have been documented (Macfarlane et al., 2019) and includes the need to revise and update the wetland EIS assessment framework to simply integrate the key outputs of the WET-EcoServices tool to produce an overall ecological importance (EI) score.

Specific recommendations for integrating the WET-EcoServices outputs into the wetland EIS assessment have also been documented. These include grouping of ecosystem service scores into broad categories which would then be integrated into an overall ecological importance (EI) score:

- ***Biodiversity maintenance importance***: This is the importance score derived from the biodiversity maintenance component of WET-EcoServices.
- ***Regulating services importance***: This would be calculated as the maximum score of all the importance scores for regulating services considered in WET-EcoServices.
- ***Provisioning and cultural services importance***: This would be calculated as the maximum score of all the importance scores for provisioning and cultural services considered in WET-EcoServices.

The EI would be simply derived based on the maximum of these scores and could then be integrated with the ecological sensitivity (ES) score to produce an overall EIS score. A simple schematic of the proposed Wetland EIS framework is shown in Figure 10.1 below whilst the proposed approach to integrating EI and ES is included in Table 10.1.

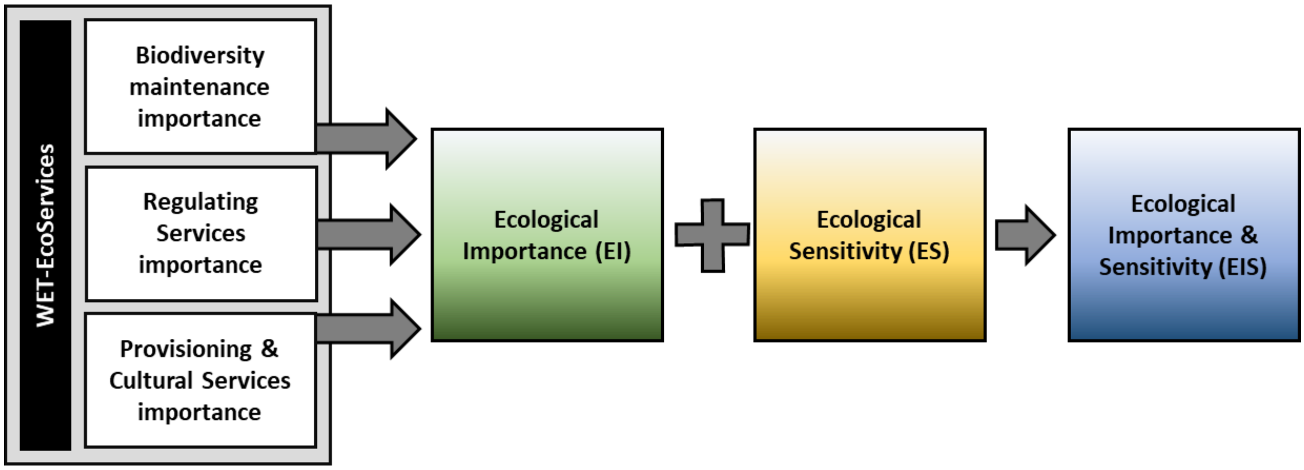


Figure 10.1: Schematic of the recommended Wetland EIS framework.

Based on this proposal, the EIS score would be calculated by using the EI score for a system with moderate sensitivity as a starting (benchmark) score and adjusting scores up or down by up to one class based on actual sensitivity. It is hoped that this concept will be taken forward by regulating authorities in due course.

Table 10.1: Proposed table for integrating EI and ES into a composite EIS score.

		Ecological Importance (EI)				
		Very Low	Low	Moderate	High	Very High
Ecological Sensitivity (ES)		0	1	2	3	4
Very Low	0	0.00	0.00	1.00	2.00	3.00
Low	1	0.00	0.50	1.50	2.50	3.50
Moderate	2	0.00	1.00	2.00	3.00	4.00
High	3	0.50	1.50	2.50	3.50	4.00
Very High	4	1.00	2.00	3.00	4.00	4.00

Note that whilst there may also be opportunities to adopt a similar approach for rivers, the current emphasis on river assessment in South Africa is strongly focussed on instream habitat and biota rather than on the specific values of riparian habitat. As such, the above recommendations do not apply specifically to river assessments.

11. Use of Wet-EcoServices to inform offset calculations

11.1 Emerging national guidelines

A best practice guideline for wetland offsets in South Africa has been developed (SANBI and DWS, 2016), and has served to inform wetland offset planning over recent years. The overall approach advocated in this guideline, involves an evaluation of three key components: Water Resources and Ecosystem Services, Ecosystem Conservation, and Species of Conservation Concern. Each of these components needs to be evaluated to ensure that the significant residual impacts on the full range of values associated with wetland impacts are included. A policy advocating a "no net loss" requires that the project's impacts are balanced or outweighed by measures taken to avoid, minimise, rehabilitate on-site and offset, so that no loss remains.

Whilst a no net loss policy can serve to help ensure that the environment is no worse off than prior to development, this may not be an acceptable outcome in certain contexts, particularly where wetlands have been heavily degraded and restored functions are required to address water resource management challenges. Recent work undertaken in eThekwini Municipality (Macfarlane, 2016) has highlighted a number of critical considerations. Firstly, policy responses need to be tailored according to local and regional priorities. In the north of Durban, reinstating wetlands to help address water quality challenges is critical in building urban resilience and therefore needs to be prioritised. Secondly, in areas where the degradation of ecological systems (in this case wetland/riparian areas) has already exceeded sustainability thresholds, the offset policy should aim for a 'net gain' rather than applying a 'no net loss' policy as currently advocated in national guidelines. This suggests that offset policies should be responsive to local conditions in order to address sustainable development objectives (Figure 11.1). As such, careful consideration needs to be given to offset policy objectives when planning offset activities.

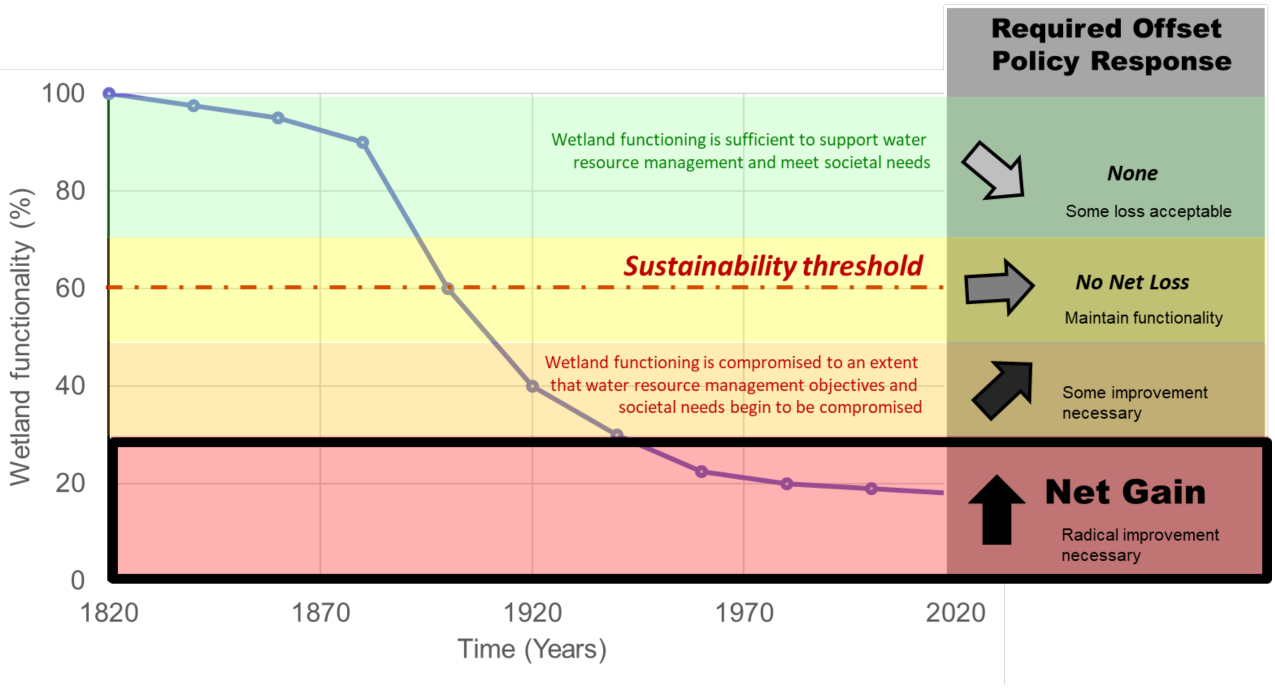


Figure 11.1: Diagram illustrating how wetland functionality has declined over time in the eThekwini study area, and indicating the shift in offset policy approaches that are required over time to ensure that sustainability objectives can be achieved (Douwes et al., 2018).

11.2 Determining offset requirements for water resource management

Accurate identification and evaluation of impacts is essential to enable adequate mitigation measures, including offsets to be determined. To enable the quantification of an appropriate offset, it is important to establish a common unit or currency that will allow residual losses (due to the proposed impacts) and gains (due to the proposed offset) to be consistently measured and compared.

The approach taken to assessing and quantifying the anticipated residual impacts on Water Resources and Ecosystem Services in the national guidelines, based on international best practice, incorporates a measure of ecological function, quality and/or integrity. The basic "hectare equivalents" of intact wetland used in this guideline are a combination of extent of wetland impacted and the change in condition or functionality (Figure 11.2). They are used as a surrogate for measuring residual loss and have been adopted as the primary currency for evaluating impacts of proposed development on wetland ecosystems.

Wetlands in some areas may be playing more valuable roles than those in other areas. The loss of these wetlands may thus have a greater relative impact on Water Resources and Ecosystem Services and would require an increased offset target to adequately compensate for the services to be lost. This is accounted for through the application of a Functional ratio to generate a final functional offset target, reported in terms of functional hectare equivalents (Figure 11.2).

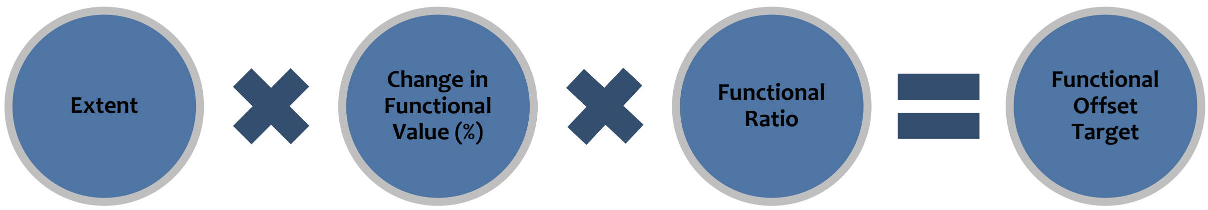


Figure 11.2: Offset calculation for determining offset requirements for Water Resources and Ecosystem Services.

11.3 Assessing change in functional value

The condition or quality of the affected wetland/riparian area can affect its capacity to provide regulating and supporting services for downstream users (e.g. drainage of a wetland may significantly reduce the ability of the wetland to provide a water quality enhancement function). In the absence of more suitable measurement systems, the national guidelines advocate using wetland condition to provide a surrogate measure for the impact on indirect services provided by wetland ecosystems (SANBI and DWS, 2016). The advancements made in Wet-EcoServices Version 2, have served to provide an estimate of the level of regulating and supporting services that can be compared on a hectare-by-hectare basis. As such, the updated tool can be used to provide a more direct indication of functional value than can be obtained by using wetland condition to inform such an assessment.

A complicating factor, however, is the fact that WET-EcoServices provides scores for a suite of different regulating and supporting services rather than providing a single functional value score that can be used for offset calculations. This is accounted for by integrating the scores into a composite score for offset calculations in the spreadsheet provided. This involves initially consolidating scores for sediment trapping and erosion control into a single score and consolidating scores for water quality enhancement functions (i.e. nitrate assimilation, phosphate assimilation and toxicant assimilation). An offset currency mix for the area in question is then defined by specifically weighting wetland Function / Service groups based on the catchment context. The importance of each Function / Service group must therefore be evaluated by assigning a weighting (%) relative to other groups and providing a supporting justification. This should be developed for the service area in question based on an understanding of the ecological context and water resource management challenges relevant to the study area as illustrated in Table 11.1.

Table 11.1: Rationale for weightings applied to service groups provided by wetlands in the eThekwini North Spatial Development Plan Area (Macfarlane, 2016).

Function / Service Groups	Weighting %	Rationale for weightings applied
Flood Attenuation	10	Although little information is available on changes in flooding regimes, existing studies suggest that there has been a moderate increase in mean annual runoff (MAR) from the oHlanga catchment (+67.5%) whilst little change has been reported for either the uMdloti (-16.2%) or Tongaat (+0.6%) estuaries (DWA, 2013). The project area is located just inland from the coastline, with little downstream infrastructure or communities within flood lines that could be negatively impacted by flood events. Given the minor risks associated with flooding in the study area, flood attenuation services provided by wetlands in the landscape are not regarded as particularly important. With plans to limit development around wetlands and main river systems, future flooding risk is likely to remain low. As such, a low weighting was applied to the flood attenuation functions provided by wetlands.
Streamflow Regulation	10	Stream flow regulation refers to the contribution that wetlands make towards sustaining stream flows during dry periods. This has implications for downstream water resources and downstream users, particularly if low flows have already been significantly impacted by catchment activities. Within the study area, existing studies suggest that base flows entering the oHlanga estuary have doubled while there has been a slight reduction of base flows reaching the Mdloti estuary and no noticeable change to flows reaching the Tongaat estuary (DWS, 2013). This suggests that base flows have not been impacted to a critical degree, as is the case with water quality, for example. Downstream users are also limited, with limited abstraction for agricultural or domestic use. It is also important to note that wetlands are conduits of water in the landscape, and that most wetlands in the landscape are unlikely to be particularly well suited to providing this function (they do not frost back during the winter months, are generally not characterized by peat accumulation and are not located on underlying geologies with strong surface-groundwater linkages). A low weighting was therefore applied to streamflow regulation functions.
Sediment Trapping & Erosion Control	20	Whilst little information is available on sedimentation of estuaries and downstream water resources, development and agricultural activities in the catchment are likely to have significantly increased soil loss from the catchment. Whilst such sediment would accumulate in estuaries, breaching during high flows is likely to flush out excess sediments, thus limiting the potential long-term impacts of increased sediment inputs. Sedimentation can increase turbidity, smother natural habitat and alter the profile of wetland areas however and as such, sediment trapping and erosion control functions of wetlands are still regarded as being relevant in the study area. A moderate weighting was therefore applied to sediment trapping and erosion control services provided by wetlands.
Water Quality Enhancement	60	Increased nutrient inputs from wastewater treatment have caused eutrophication across all the estuaries in the study area. Emergent species thrive under these conditions and invasive aquatic macrophytes such as water hyacinth (*Eicchornia crassipes*) and water cabbage (*Pistia stratiotes*) outcompete indigenous plants (DWS, 2013). Research suggests that these nutrient inputs have had far reaching impacts on other estuarine biota such as fish, with fish kills having been reported in recent years in both the Mdloti and oHlanga estuaries (Bundy et al., 2010). The small size of these estuaries also makes them sensitive to water quality impacts as pollutants accumulate during periods of mouth closure. Managing water quality impacts which includes improving the functioning of wetlands in the landscape is therefore regarded as critical to efforts to improve the condition of water resources in the study area. A heavy weighting was therefore placed on pollutant assimilation functions provided by wetlands in the project area.

These weightings are used to define the offset currency mix for the study area, as illustrated in Figure 11.3, below. In the example provided, water quality is regarded as the most important function, and as such, impacts to wetlands that provide this service to a high degree therefore give rise to the highest offset requirements.

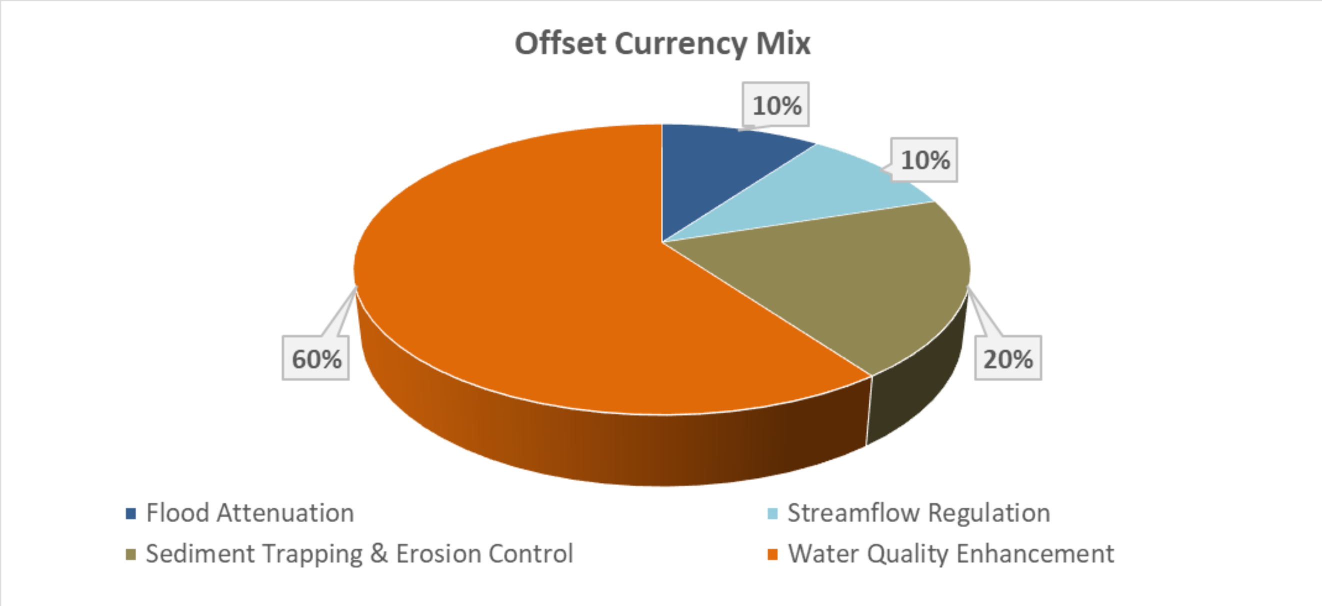


Figure 11.3: Illustration of the offset currency mix used to inform offset calculations in the eThekwini North Spatial Development Plan Area (Macfarlane, 2016).

Once a currency mix has been defined for the area in question, this is used to calculate a Functional Value Score that seeks to compare the functional value of the wetland with that of a "reference" wetland. This represents a wetland that would score optimally across the full suite of services being assessed. Based on experience, a wetland will rarely score >3.2 across the full set of services since some attributes that are good for one service, detract from the ability of the wetland to provide another service. As such, the Weighted Supply Score calculated based on the individual scores and weightings of individual Function / Service Groups should be divided by a "Realistic Reference Score" for the region. Such a wetland would be described as one which provides optimal services in the particular catchment context. A default score of 3.2 is recommended but may be refined based on local experience. This is demonstrated in the example below under both a "Present State" and "Future State" scenario (Table 11.2).

Table 11.2: Worked example illustrating how functional hectare equivalents are calculated.

Integrating scores to assess Functional Value & Hectare Equivalents			
Function / Service Groups	**Weighting (%)**	**Present State**	**Future State**
Flood Attenuation	10%	0.5	1.5
Streamflow Regulation	10%	1.0	2.0
Sediment Trapping & Erosion Control	20%	1.3	1.8
Water Quality Enhancement	60%	1.0	2.4
Weighted Supply Score		1.0	2.2
Realistic Reference score		3.2	
Functional Value (%)		31.6%	67.2%
Wetland Area (Ha)		10.0	10.0
Functional Hectare Equivalents (Unadjusted)		**3.16**	**6.72**

Functional Hectare Equivalents are then calculated by multiplying the Functional Value score by the wetland area. In the example above, the development impact would be 3.16 ha Equivalents, using “Present State” as a measure of residual impact which would be aligned with a no net loss approach. In the eThekwini context, however, where a “Net Gain” policy has been adopted, residual impacts are assessed based on the concept of “Opportunity Loss” which accounts for the loss of wetland function under a realistic rehabilitated state. In this example, where the target wetland is heavily degraded, and functional value can be dramatically improved through rehabilitation, the functional hectare equivalents under a realistic “Future State” are considerably higher than the baseline scenario.

11.4 Calculating a Functional Ratio

Wetlands in certain settings may be playing more valuable roles than those in other locations. The loss of these wetlands may thus have a greater relative impact on Water Resources and Ecosystem Services and would require an increased offset target to adequately compensate for the services to be lost. A functional offset ratio is therefore introduced in order to differentiate between systems based on local demand. Loss of wetlands located in critical catchment contexts (high local demand scores) are therefore regarded as more significant (with higher offset requirements) than those located in contexts with low local demand.

Functional importance ratios are calculated automatically in the spreadsheet tool based on the local demand scores for the wetland in question and weightings applied to the different Function / Service groups (Table 11.3). In most instances, the demand score is taken as the same for both the Present and Future State although there may be situations where a motivation for changing the demand to account for future conditions may be preferable. As with supply scores, the functional offset modifier is allocated with reference to a realistic "high demand" scenario. A final ratio is then allocated automatically based on the local demand score (Table 11.4). By applying this approach, higher offset targets are applied to wetlands that are playing a particularly important role in the landscape whereas wetlands located in contexts where demand for functions is low give rise to lower offset targets. Such an approach supports the notion of avoiding critical ecological infrastructure.

Table 11.3: Calculating the functional importance ratio based on the demand for key regulating and supporting services.

Integrating scores to calculate a Functional Importance Ratio for offset calculations			
Function / Service Groups	**Weighting%**	**Present State**	**Future State**
Flood Attenuation	10%	2.0	2.0
Streamflow Regulation	10%	1.5	1.5
Sediment Trapping & Erosion Control	20%	2.5	2.5
Water Quality Enhancement	60%	3.0	3.0
Weighted Demand Score		2.7	2.7
Functional Importance Ratio		**1.25**	**1.25**

Table 11.4: Allocation of functional importance ratios based on local demand scores for key ecosystem services.

Demand score	Ratio	Rationale
0-1.0	***0.75***	Wetlands located within a context where they provide very limited benefits to society
1.1-2.0	***1***	Wetlands quite poorly placed to address key water-resource challenges
2.1-3.0	***1.25***	Wetlands are well positioned to address key water-resource challenges
>3.0	***1.5***	Wetlands located in critical areas, where wetland functions are particularly important

So, in the case of the example provided in Table 11.2, an offset target based on Present State would be calculated as 3.16 x 1.25 = 3.95 functional hectare equivalents. If "Opportunity Loss" is also accounted for, the offset target would be considerably higher at 8.4 functional hectare equivalents (6.72 x 1.25).

In summary then, offset requirements for Water Resources and Ecosystem Services are calculated as follows:

1. Delineating the wetland that will be impacted by the proposed development.
2. Calculating the predicted wetland functionality (as a percent) based on either the Present State or a realistic rehabilitation Future State and the area of wetland over which this impact will apply.
3. Calculating the functional importance ratio based on the landscape context and local demand.
4. Multiplying the area of wetland, functionality (%) and functional importance ratio to calculate the number of functional hectare equivalents that will be required.

11.5 Assessing gains from offset activities

The assessment of functional gains for offset receiving areas follows the same approach applied to impacted sites with gains in functional value being calculated based on the expected improvement in ecosystem functioning relative to baseline conditions (Figure 11.4). The improvement in functioning is then simply calculated by subtracting the current functional value score from that expected following successful rehabilitation.

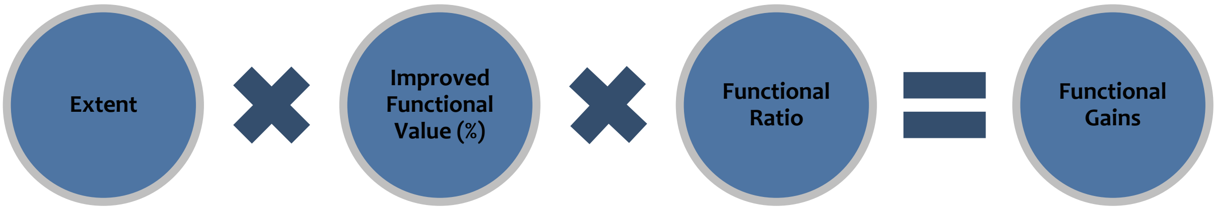


Figure 11.4: Outline of the approach used to assess functional gains from planned offset activities.

The preliminary offset gains are then adjusted based on the Functional Ratio of the targeted wetland (See Table 10.4). By following this approach, preference is given to wetlands located within scenarios with high demand for regulating and supporting services. This approach is in line with the national wetland offset guidelines which have specifically highlighted the importance of selecting offset sites that are well placed to improve key ecosystem services.

In summary then, the anticipated contributions to meeting functional targets are calculated by:

1. Delineating wetlands within the offset site.
2. Calculating the predicted improvement in wetland functionality (%) as a result of proposed offset activities and the area of wetland over which this change will apply.
3. Calculating the functional importance ratio based on the landscape context and local demand.
4. Multiplying the area of wetland, functionality change (%) and functional importance ratio together to calculate the number of functional hectare equivalents that will be gained.

PART 2: BACKGROUND TO THE TECHNIQUE AND ITS DEVELOPMENT

12. National and international imperatives to which ecosystem service provision may potentially contribute

Wetlands and riparian areas represent ecological infrastructure which can make potentially important ecosystem service contributions to several different broad-scale imperatives/objectives of government, both at national and international levels (Table 12.1). WET-EcoServices has potential relevance to all of the imperatives listed although the particular ecosystem services which have the most relevance vary according to the specific imperative/ objective. For example, for human safety and disaster resilience, the ecosystem service which is the most relevant is flood attenuation, with the other regulating ecosystem services also being potentially important (Table 12.1).

Table 12.1: Key broad-scale imperatives to which ecosystem service provision may potentially contribute.

Broad-scale imperatives	Relevant ecosystem services
Water resource management	Water quality-related regulating services (i.e. phosphate, nitrate and toxicant removal) are the most relevant given the considerable catchment water quality issues facing South Africa and the widely demonstrated contribution of wetlands and riparian areas to enhancing/buffering water quality. Streamflow regulation, sediment trapping and flood attenuation are also of direct high relevance.
Biodiversity conservation	Biodiversity maintenance is the most relevant. Regulation services are also relevant insofar as they support/protect downstream biodiversity values/assets from upstream impacts.
Human safety and disaster resilience	All regulating services are relevant, but with flood attenuation being particularly relevant.
Socio-economic development and poverty elimination	Provisioning services and cultural services are the most directly relevant to socio-economic development opportunities and livelihoods. Regulating services are also relevant insofar as they support/protect downstream provisioning and cultural services from upstream impacts.
Climate change mitigation and adaptation	The carbon storage service is the most relevant to mitigation. Regulating services are the most relevant to adaptation. Provisioning services are also relevant to adaptation, particularly with respect to poor rural communities.

Water resources management

The primary legislation governing the sustainable and equitable management of water resources in South Africa, is the National Water Act (NWA) (Act 36 of 1998) under which wetlands are included as a component of the water resource protected under the Act. Understanding the importance of ecosystem services provided by wetlands and riparian areas is central to decision-making and such an assessment is therefore integrated into most Water Use Licencing applications. The need to specifically consider the supply and demand of water-related ecosystem services when setting Resource Quality Objectives for wetlands at a catchment scale has also been emphasised (Bredin et al., 2019).

The National Water Resources Strategy (NWRS2) (DWS, 2013) provides a mechanism for operationalizing the National Water Act. The overarching goal of NWRS2 (DWS, 2013) is that water is efficiently and effectively managed for equitable and sustainable growth and development. It is interesting to note that DWS (2013) acknowledges the contribution that wetland ecosystem services (and wetland rehabilitation geared around these services) can play towards achievement of the strategy.

Biodiversity conservation

The National Biodiversity Act (Act 10 of 2004) provides for the management and conservation of South Africa's biodiversity within the framework of the National Environmental Management Act, 1998, and includes the protection of species and ecosystems that warrant protection. At an international level the key imperative for biodiversity conservation is the Convention on Biological Diversity (CBD). As South Africa's requirement as one of the contracting parties to the CBD, a National Biodiversity Strategy and Action Plan (NBSAP) (Government of South Africa 2015) has been developed to fulfil the objectives of the Convention. The current NBSAP document covers the period 2015-2025 and identifies the priorities for biodiversity management in South Africa for this period, aligning these with the priorities and targets in the global agenda, as well as national development imperatives (Government of South Africa 2015).

NBSAP recognizes that priority ecological infrastructure may vary according to the particular service/imperative that is of interest. For example, priority ecological infrastructure supporting water services may differ from that which is priority ecological infrastructure for disaster risk reduction. Prioritisation methods should include both ecological and socio-economic factors, considering the beneficiaries and the providers of the ecosystem services (Government of South Africa 2015).

Human safety and disaster resilience

A disaster is defined by the UN International Strategy for Disaster Risk Reduction (UNISDR) as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources".

"Ecosystem-based disaster risk reduction is the sustainable management, conservation and restoration of ecosystems to provide services that reduce disaster risk by mitigating hazards and by increasing livelihood resilience" (PEDRR, 2019). The policy framework linked to disaster management in South Africa, including the National Disaster Management Act and the Policy Framework for Disaster Risk Management in South Africa, provide numerous opportunities for the adoption of Ecosystem-based approaches as a response measure (DEA and SANBI, 2016).

Socio-economic development and poverty elimination

Prominent amongst the national imperatives existing around Socio-economic development and Poverty elimination is the National Development Plan (NDP) 2030, which sets out a thirty-year vision and road map to address South Africa's priorities. Its overarching aim is to eliminate poverty and reduce inequality by 2030 by ensuring, amongst other priorities, a transition to an environmentally sustainable, climate change resilient, low carbon economy and just society (DEA and SANBI, 2016). At an international level, Socio-economic development and Poverty elimination are captured in the 17 Sustainable Development Goals of the United Nations. Those goals most directly linked with ecosystem services from wetlands and riparian areas are Goal 1 of No poverty, Goal 2 of Zero hunger, Goal 6 of Clean water and sanitation, Goal 14 of Life below water and Goal 15 of life on land.

Climate change mitigation and adaptation

Climate change mitigation refers to "human intervention to reduce the sources or enhance the sinks of greenhouse gases" (Team et al., 2014). Interventions to mitigate climate change include technological and behavioural changes that reduce reliance on fossil fuels and the emission of carbon dioxide (CO2) as well as interventions to prevent changes to land cover, e.g. drainage of natural peatlands and conversion to agricultural lands, which are a significant contributor to climate change through direct greenhouse gas emissions and decreased carbon sinks (Team et al., 2014; DEA and SANBI, 2016).

Part of broad strategies to adapt to climate change is Ecosystem-based adaptation (EbA), which uses biodiversity and ecosystem services to help people adapt and build resilience and reduce the vulnerability to the adverse effects of climate change (CBD, 2009; DEA and SANBI, 2016). Rural and poor communities have the lowest access to modern technology and innovations that would help them adapt and therefore rely most directly on ecosystem services for water and food security and ultimately, as resources to use for adaptation (CBD, 2009).

13. Key concepts underpinning the technique

The purpose of this section is to outline some of the key concepts, as reflected in the literature, which underpin WET-EcoServices. For each of these concepts a brief description is also provided of how WET-EcoServices is "located" in relation to the concept.

13.1 Ecosystem services defined

The Millennium Ecosystem Assessment (2003) defines ecosystem services as the benefits people obtain from ecosystems. Closely aligned with this definition, The Economics of Ecosystems and Biodiversity (TEEB), an international initiative to draw attention to the benefits of biodiversity, defines ecosystem services as the benefits that people, society and the economy receive from nature (TEEB, 2010; Russi et al., 2013). However, Fisher et al. (2009) point out that services and benefits are not synonymous, illustrating this with the following example: "Nutrient cycling is a process in which one outcome is clean water. Nutrient cycling is a service that humans utilize, but indirectly. Clean water provision is also a service that humans utilize, but directly. Clean water, when consumed for drinking, is a benefit of ecosystem services. The benefit being the point at which human welfare is directly affected and the point where other forms of capital (built, human, social) are likely needed to realize the gain in welfare. Here, clean water provision is a service and clean water for consumption − requiring extraction tools or knowledge − is a benefit" Fisher et al. (2009: 645). To take another example, that of recreation, Fisher et al. (2009) note that while ecosystem services may contribute to recreation, e.g. by providing scenic locations for people to visit, recreation itself is not an ecosystem service.

Drawing on Boyd and Banzhaf (2007), Fisher et al. (2009: 645) propose that ecosystem services be defined as "the aspects of ecosystems utilized (actively or passively) to produce human well-being. Defined this way, ecosystem services include ecosystem organization or structure as well as process and/or functions if they are consumed or utilized by humanity either directly or indirectly." The importance of the human user in the definition is emphasized further by Olander et al. (2018: 1263): "Until there is some person somewhere who benefits from a given element or process of an ecosystem, that element or process is not a service." The definition of Fisher et al. (2009: 645) is used for WET-EcoServices. However, it should be added that WET-EcoServices also includes the assessment of biodiversity maintenance, which is framed in less anthropocentric terms than all of the other services in that it attempts to encompass the intrinsic value of a wetland/riparian area for maintaining biodiversity without the need to locate any human beneficiaries.

13.2 Categorization of ecosystem services

WET-EcoServices follows fairly closely the categorization of ecosystem services by MEA (2005), namely supporting services, regulating services, provisioning services and cultural services. Since the MEA (2005) was published, ecosystem services research has progressed through both theoretical conceptualization and practical applications arising out of several different initiatives (La Notte et al., 2019). However, a single standard approach and standards for ecosystem services measures are still lacking, and a plurality of ecosystem service conceptualizations and classification systems have emerged (La Notte et al., 2017; Olander et al., 2018). It is nevertheless considered important to note a few key changes/additions which have been recommended since the publication of the MEA (2005) framework. Probably the most important initiative through which such changes/additions to MEA (2005) have been recommended is the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. The IPBES (2017) categorization, while still being strongly rooted in the ecosystem services classification used by the Millennium Ecosystem Assessment (MEA), drew attention to the overlap that often exists between the main ecosystem services categories identified by MEA (2005) (notably, supporting and regulating services) and recommended some adjustments to the categorization, recognizing three main groups: regulating, material and non-material. In addition, a shift in terminology from "services" to "contributions" was recommended by IPBES (Diaz et al., 2015). This shift has yet to be widely taken up in the general literature and within government and practitioner circles in South Africa, and it was therefore decided that WET-EcoServices will continue using the terminology "services". A decision was also taken to retain the MEA (2005) terminology but not to separate out supporting and regulating services, and therefore to align more closely with the three categories recommended by Diaz et al. (2015).

The ordering and categorisation of ecosystem services in the MEA (2005) framework is informed primarily by knowledge from the natural sciences and economics and do not adequately recognise the importance of context and politics in the social construction and value of these assets (Sutherland et al., 2016; Arias-Arévalo et al., 2017). Himes and Muraca (2018) also draw attention to the need to recognize the different ways in which people articulate the importance of ecosystem services in their specific, socio-culturally embedded language of valuation. By its nature a prescriptive rapid assessment technique such as WET-EcoServices does not easily take into account value pluralism and culturally-specific means of expressing value. Thus, it is important to acknowledge that the technique remains limited in these respects. However, the need to contextualize a WET-EcoServices assessment is indicated upfront. It is also emphasized that WET-EcoServices should not be used as the sole means of assessing ecosystem services, but instead it needs to be nested within a broader process. This broader process should include the following elements (adapted from Kumar et al., 2017): (1) define the purpose for which the ecosystem services are being considered; (2) scope the process for how the ecosystem services are to be assessed, including stakeholder engagement and participation and how to account for different types of knowledge and information which may be appropriate for the assessment; and (3) select techniques for assessing ecosystem services which are appropriate and proportionate for the purpose of the assessment.

13.3 Ecosystem supply and demand

To understand the full potential which wetlands have for delivering ecosystem services, both supply (the capacity of an ecosystem to produce a service) and demand (the societal demand for a service) must be individually considered (Wei et al., 2017; Bengtsson et al., 2019). Demand for an ecosystem service can change independently of its supply, and supply can change without altering demand (Bengtsson et al., 2019). For example, the supply of water by a wetland can change irrespective of the demand for that water by users.

Provisioning services supply can be directly quantified by biophysical features (e.g. the volume of food supplied), cultural services supply depends on a mix of biophysical and social conditions (e.g. aesthetically pleasing views) and regulating services supply can be measured based on relevant ecosystem processes (e.g. carbon sequestration) (Wei et al., 2017).

The demand for commodity services (e.g. provisioning services and some cultural services) can be captured by the amount of consumption or the market price. The demand of non-commodity services (e.g. most regulating services and cultural services) can be captured by desires that include preferences and the need for risk prevention (Wei et al., 2017). Evaluating such desires involves different groups of stakeholders who benefit from these ecosystem services. Through participatory methods the level of ecosystem services desires can be quantified with respect to the importance, and the cultural and economic values, that different stakeholder groups place on the ES. (Wei et al., 2017). Participatory methods are time consuming by nature, and therefore in the absence of existing studies and information it can be appreciated how assessing demand with a rapid assessment technique is likely to be very challenging.

In the case of most regulating services, desires of downstream users are assumed to be risk avoidance and protecting existing use values. The demand for such users is therefore assessed initially be evaluating the risk posed to downstream users by assessing indicators for upstream catchment activities which elevate flood risks, increase sediment loads or pollution levels. This score is then refined by accounting for the number of beneficiaries in a defined downstream service area and their level of dependence on the service provided. Classes used to inform this assessment are very coarse but seek to reflect the range of variability that is generally encountered in South Africa and to separate demand scores out across the spectrum of situations typically encountered. Classes used to assess the number of users affected range from 1-10 people (Low) to >1000 people (High).

When assessing the current demand for provisioning and cultural services, due consideration also needs to be taken of the access constraints to the service, which may be both physical (e.g. distance of the wetland from the users) and institutional (e.g. in the form of regulations which may prevent access) (Olander et al., 2018). For the purposes of the WET-EcoServices assessment, current demand is therefore based on current access and use rather than on the desire of potential users. It may be, for example, that a wetland on private land has a fish resource which people from the neighbouring community have a desire to harvest but for which they not entitled. These people from the neighbouring community and the potential contribution that the fish resource might make to their welfare would not be considered as a factor that forms a part of the current demand, but may do so in the future, e.g. if access arrangements were made with the owner of the wetland.

Similarly, while ecosystem services supply is typically assessed for a wetland in its current state/situation, it can also be assessed for potential future states/situations. Comparing current and potential future states has useful applications in several decision contexts, including wetland rehabilitation planning and environmental impact assessment. Another valuable area of comparison within a variety of decision contexts is ecosystem services supply compared against demand. For example, Chen et al. (2019) undertook explicit spatial mapping of ecosystem services supply and demand associated with land use changes in order to provide relevant insights for enhancing land management in urban areas in an attempt to ensure that supply meets or exceeds demand.

13.4 Ecological infrastructure

Closely linked with the concept of ecosystem services is the concept of ecological infrastructure, which refers to naturally functioning ecosystems that deliver such services to people. "Naturally functioning ecosystems" are ecosystems that have at least some of their natural ecological processes intact, and could be in good or fair ecological condition, and in some cases even in poor ecological condition (SANBI, 2013; 2017). Ecological infrastructure is conceptualized as the nature-based equivalent of built infrastructure and is just as important for providing services and underpinning socio-economic development (SANBI, 2013). Strategic investment in ecological infrastructure can lengthen the life of existing built infrastructure and reduce the need for additional built infrastructure, thereby saving costs (SANBI, 2013). The example is given of Mount Fletcher Dam in the Eastern Cape, which had lost 70% of its water holding capacity within four years of completion as a result of sediment from the catchment, and it is contended that investment in wetland rehabilitation and improved management of grasslands in the dam's catchment will increase its lifespan (SANBI, 2013). WET-EcoServices applies specifically to wetland and riparian ecological infrastructure, across a range of ecological conditions from pristine to poor.

13.5 A rapid assessment technique defined

Fennessy et al. (2004) define a "rapid" field technique as taking no more than two people half a day in the field and requiring no more than half a day of office preparation and data analysis to carry out the full assessment. Fennessy et al. (2004) also consider the relative ease of collecting field data required by the technique, i.e. a rapid assessment should not require a very high level of expertise and/or specialized equipment. Rapid field techniques occupy the middle tier of both the "three-tier framework" of Fennessy et al. (2004) for wetland monitoring and assessment and the National Wetland Monitoring Programme (Wilkinson et al., 2016). WET-EcoServices is specifically identified as a rapid field technique, both in terms of its time and expertise requirements.

13.6 Assessment of ecosystem services using indicators

Most rapid assessment techniques require users to rate various indicators as a basis for assessing the value/importance of the specific ecosystem service being assessed. "Indicators are easily observable characteristics that are correlated with quantitative or qualitative observations of the performance of a function or service (Hruby, 1999, NRC, 2002). Most indicators represent relatively stable characteristics that describe the structure of the ecosystem or its physical or geologic properties (Smith et al., 1995). Indicators, unfortunately, cannot reflect actual rates at which functions are performed because rates can change in time. Our knowledge however, "is sufficiently well developed such that indicators can be used as shortcuts to judge whether functions are occurring at appropriate levels" (NRC, 2002: 120). So, in effect, developers of rapid assessment techniques select a sub-set of indicators based on best available science and use these as surrogates for estimating the capability and opportunity that a wetland has to perform a particular function. For a technique based on indicators to be scientifically defensible it is essential that the rationale behind each indicator is clearly documented, together with guidance as to how each indicator should be rated, which are both important aspects of the WET-EcoServices technique.

13.7 The role of WET-EcoServices within the broader economic valuation framework.

It is widely recognised that ecosystem services must first be described and measured before they can be valued, mapped or included in decision-making processes (Haines-Young and Potschin, 2013). Indeed, assessing ecosystem services can be viewed as a three-step approach including:

- ***Identification***: This includes identifying and defining ecosystem services relevant to the assessment;
- ***Quantification***: Quantification aims at determining the units of ecosystem services for reporting purposes; and
- ***Valuation***: Valuation of ecosystem services relates to the human use of the services and establishes ways to value the benefits that accrue or may accrue to society (TEEB, 2010; COWI, 2014).

Figure 13.1 provides a useful overview of the cascade of information required to inform economic valuation. Essentially, WET-EcoServices provides rapidly-assessed indicators to represent key biophysical attributes and functions affecting those ecosystem services which are most relevant to the South African context. The "Benefits" are semi-quantitatively assessed based on the abovementioned indicators, which reflect ecosystem supply, as well as on indicators reflecting ecosystem service demand. It is, however, critical to note that WET-EcoServices does not go so far as to quantify the Value of these ecosystem services, which requires the application of specific economic valuation techniques.

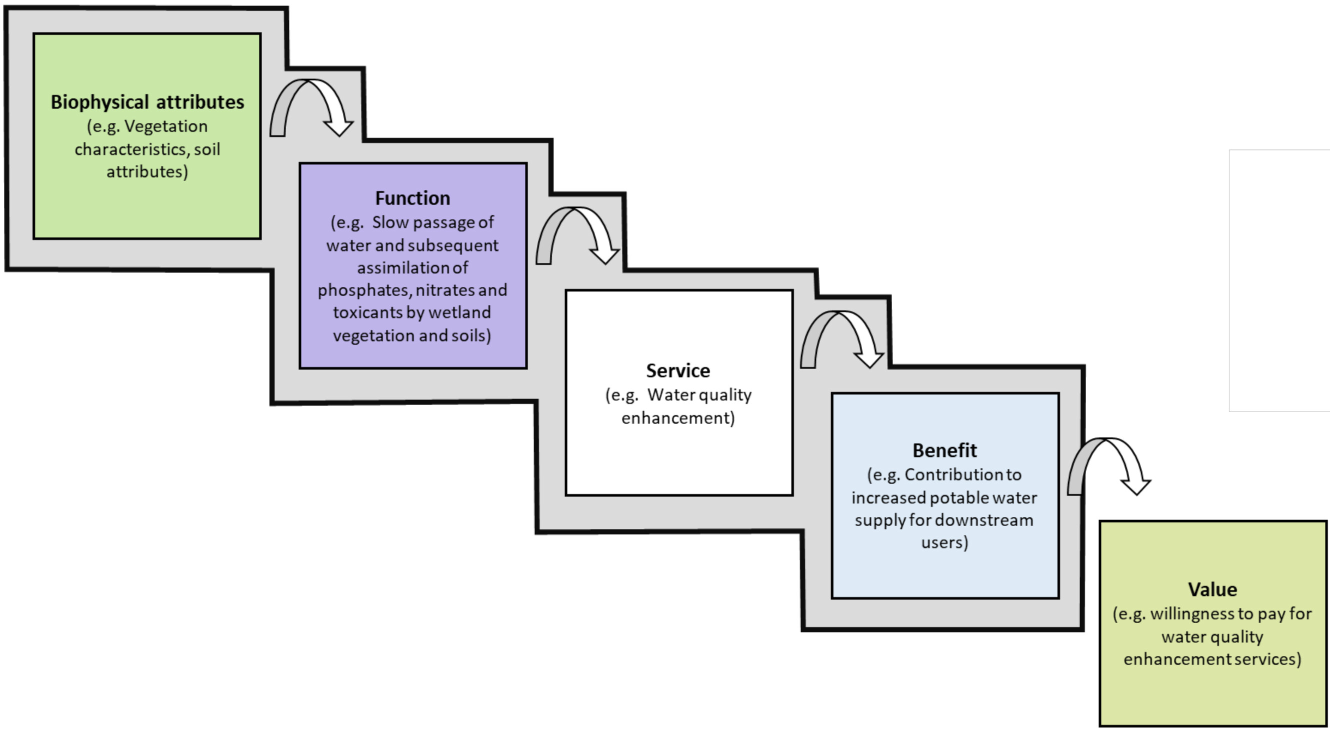


Figure 13.1: The ecosystem service cascade illustrating aspects covered as part of the WET-EcoServices framework (adapted from Haines-Young and Potschin, 2011)

Considerable work has been done to develop and refine approaches to economic valuation that can be used to assign monetary values to ecosystem services provided by water resources. Despite this work, there are still a myriad of different approaches used for valuing ecosystem goods and services which include market value approaches (which involve the quantification of production), surrogate market or revealed preference approaches (which involve observation of related behaviour), and simulated market or stated preference approaches (which involve direct questioning) (Turpie and Kleynhans, 2010). Consequently, most economic valuations seek to quantify the most important benefits rather than trying to quantify the economic values of the full suite of benefits provided since this can be cumbersome and costly to achieve in practice. In being designed to identify the most important ecosystem services, WET-EcoServices therefore has a potentially very useful role to play in directing valuation efforts to those services which are likely to have the highest values. Indicators assessed as part of the technique may also provide useful information to inform an economic assessment, although the level of detail provided, particularly with respect to demand, would generally be indicative and require further refinement.

Once sufficient economic valuations had been conducted across a range of different wetland/riparian types and contexts then WET-EcoServices might potentially be useful in assisting to generalize these results across other wetland/riparian areas of similar types and contexts. However, this remains an area for further research, which would need to address South Africa's great diversity of wetland/riparian types together with the paucity of valuation studies.

14. The process that was followed in revising the technique

14.1 Overview of the process

This section briefly describes the overall process which was followed to revise and refine WET-EcoServices Version 1 into Version 2. The process began with soliciting comment on Version 1 and reviewing international best practice, which informed the development of an initial draft, and this was applied and tested, which, in turn, informed the development of the updated version (Figure 14.1). Whilst the graphic suggests a straight-forward, linear process, the technique was developed through numerous iterations, with feedback from testing used to slowly improve and refine the technique.

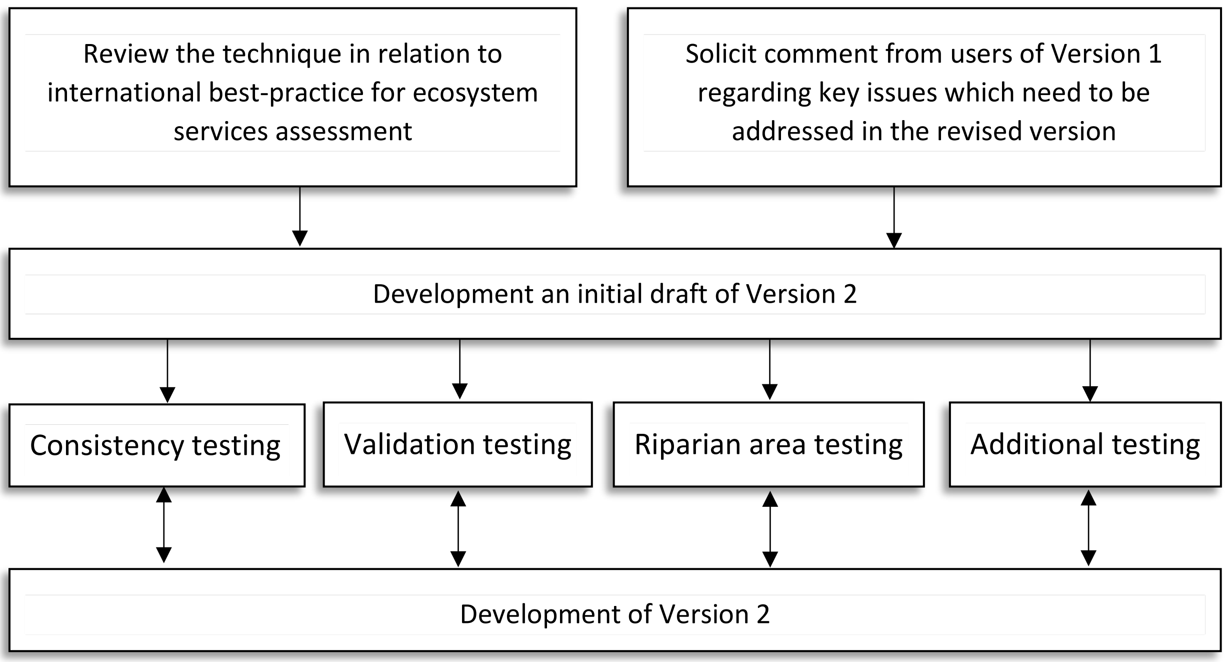


Figure 14.1: An overall summary of the process which was followed to revise WET-EcoServices.

14.2 A review of the technique in relation to international best-practice

The following key insights and recommendations emerged from the review against international best-practice for ecosystem services assessment, which were considered when revising WET-EcoServices.

- It is important that ecosystem services assessment be explicitly located within a decision-making process that specifies why the assessment is required and how the results will be used.
- A trade-off needs to be made between a detailed assessment of individual ecosystem services and a more rapid assessment of a wider range of services.
- A rapid assessment can also be used to flag services that are particularly important and are worth investing more time in assessing. Such thinking could be specifically highlighted in the technique, although detailed assessments are beyond the scope of this technique.
- Selection of indicators should focus on easily observable and relatively stable characteristics that describe the structure of the ecosystem, and from which functioning/processes can be inferred.
- Capturing the rationale for indicator selection and providing guidance on how the user is to rate each indicator are important elements to include in the technique.
- Using algorithms to integrate scores from individual indicators into overall scores for each ecosystem service is regarded as generally more desirable than leaving it up to the user to calculate a final score based on "gut feel" but does lack the flexibility of "gut feel" scoring methods.
- Transparency is an important aspect of the existing technique that should be retained. This can be done by clearly documenting the rationale for indicator selection and scoring which can then be interrogated and improved on as more information becomes available.
- It is important to be clear on the "benchmark" against which wetland functions are rated.
- Clarifying the spatial and temporal scale of benefits is important to ensure that users of the technique approach the assessment from the same perspective.
- The assessment should try to integrate the socio-economic context of beneficiaries into the assessment as far as possible.
- Rapid assessment techniques are not designed for monetary valuation but can be used to flag ecosystem services for subsequent monetary valuation.
- Refine the technique to be more explicit in terms of distinguishing ecosystem services supply and demand and the beneficiaries of the services.

In adding to/refining WET-EcoServices (e.g. as was required in order to better distinguish between supply and demand) it was, however, recognized that the time taken to carry out an assessment could not be unduly increased. This was in order to ensure that WET-EcoServices remained within the framework of what is considered a truly rapid technique, as elaborated upon in Section 12.5.

14.3 Comments solicited from users of the technique

The following is a summary of issues with WET-EcoServices Version 1 which were identified as needing to be addressed, based on feedback from users.

General issues relating to ease of use. A range of general issues relating to the ease of use of the WET-EcoServices technique were identified, e.g. some of the nuances (e.g. surface roughness changing over the season) could be elaborated upon a bit more in the manual, and the questions that relate back to the WET-Health assessment framework should be more explicitly highlighted in order to ensure that the answers are carried through the assessments.

The unit of assessment. Wet-Ecoservices was designed for assessments of entire HGM units. However, under certain circumstances it may be more appropriate to apply the assessment at a finer scale, particularly where there is a high variability in wetland attributes within a specific HGM unit. Care must however be taken not to apply the technique at too fine a scale. Thus, guidance is required to help users define appropriate units of assessment.

Indicators requiring refinement. Some indicators were identified as requiring refinement, e.g. consideration of organic-rich soils is limited to peats, but this should be extended beyond true peats to include all organic soils given the very limited occurrence of true peats in South Africa (Grundling and Grobler, 2005) and the fact that organic soils which fall short of being true peats may nonetheless still possess many of the hydrological and biogeochemical properties of true peats. Additionally, in terms of identifying wetland settings with strong groundwater-surface water links, underlying rock types such as dolomites are considered but primary aquifers also need to be considered given their potentially strong links.

Additional potentially important indicators which are missing. Some important indicators were identified as missing, e.g. anthropogenic reduction in low flows are not accounted for when assessing the streamflow regulation service of a wetland; and vulnerability of the wetland to erosion does not consider discharge, but this could potentially be achieved by using wetland size as a proxy for discharge, which could be combined with considering longitudinal slope, as described in the guideline of Macfarlane et al. (2009).

Provisioning services which are not considered individually. Several different natural resources are all considered together in the existing technique, and consideration should be given to splitting out the most important of these.

The relative importance of indicators (attributes) in determining the ecosystem services score. Some attributes (e.g. direct evidence of sediment deposition) appear to be afforded too much prominence in determining the score for the ecosystem service. In other cases, the effect of particularly important indicators is overly diluted when considered together with other less important indicators. There is therefore a need to review and refine the manner in which the scores for individual ecosystem services are calculated.

Issues relating to supply and demand. Equal weighting is given to supply (identified as effectiveness of the wetland in performing the service) and demand (identified as opportunity for the wetland to perform the service). Thus, in cases where demand is very high but supply very low, an intermediate importance score is given even though the wetland has very limited capability to supply the service. This appears counter-intuitive, and therefore a revised means of combining the supply and demand scores is required. In addition, for provisioning services, WET-EcoServices does not allow for calculating a separate score for supply (effectiveness) and demand (opportunity). This is a limitation for several applications of the tool, e.g. for exploring different development/land-use options.

Inclusion of an overall importance score. The tool does not generate an overall importance score by integrating the individual scores for all (or groups of) individual ecosystem services assessed. Guidance for generating such composite scores therefore needs to be provided for those applications where an overall score is required (as is the case for offset calculations).

Inclusion of size of the wetland's upslope/upstream catchment in the assessment of regulatory services. WET-EcoServices draws attention to the upstream/upslope catchment area of a wetland over which the wetland can potentially exert a regulatory influence on flood events and sources of pollution. However, it does not include any consideration of the absolute size of the upstream catchment. For any given wetland unit, the larger this upstream/upslope catchment area, the larger the area over which the wetland is able to exert a regulatory influence.

Consideration of wetland size in the assessment of ecosystem services provision. Although WET-EcoServices highlights size as an issue which the operator needs to consider along with the importance score, it does not integrate size into an overall importance score. Thus, the technique is not able to provide quantitative measures of ecosystem service provision, analogous to the approach of hectare equivalents derived from WET-Health scores which are used to evaluate rehabilitation outcomes and to inform offset accounting.

14.4 Consistency testing of the technique

A consistency test of the initial draft of WET-EcoServices Version 2 was conducted at the Mpophomeni wetland, KwaZulu-Natal in April 2018, preceded the day before by a half-day assessor-training training workshop. In the test, the participants (7 environmental consultants with experience in wetland assessment, 12 honours students from the University of KwaZulu-Natal Geography Department, and two municipal officials) independently carried out an assessment of the Mpophomeni wetland. The focus was on field indicators, including indicators such as pattern of low flows and hydrological zones represented in the wetland for which preliminary guidelines had been prepared by the project team. The exercise was used in particular to identify those indicators which gave the least consistent scores and which assessors found most difficult/ problematic to assess.

Once the assessors had completed their assessments, a report back session was conducted with all of the assessors, which proved very useful in identifying problem areas with WET-EcoServices. It also contributed to increasing the competency of the participants by requiring that they apply it on their own and then receive feedback on their results, thereby allowing them to see exactly where they were miss-scoring, and to better understand why this was the case.

Results of the assessment yielded several valuable insights (all documented in the Preliminary testing report) in terms of improvements to the WET-EcoServices indicators. For illustrative purposes, two examples are given below.

- Direct evidence of sediment deposition in the Assessment Unit. Inexperienced users found it difficult to specifically identify areas of sediment deposition, generally over-scoring this indicator. This assessment can be refined by focussing specifically on *recent* deposition that can be more easily identified and reflects current rather than historic processes and would also align with WET-Health.

- Number of users of water from Assessment Unit for agriculture or industrial use. Scoring was inconsistent, in particular because there was no guidance as to whether livestock watering was a form of agricultural use. Better clarity is required in terms of what constitutes agricultural use.

14.5 Validation testing

From an initial 10 potential candidate sites in South Africa with information relevant to ecosystem services supply, three sites were selected for formal validation testing (Table 14.1). The primary criterion used in the selection process was the availability of detailed information relating to regulating services, which tend to be the most difficult to assess.

Table 14.1: The three primary sites for the validation testing of WET-EcoServices.

Wetland site	HGM type	Land-use context	Ecosystem services to be covered in the case
Manalana (Craigieburn), Limpopo Province	Hillslope seep Unchannelled valley bottom	Communal agriculture	Streamflow regulation, flood attenuation, erosion control, sediment trapping
Kromme River, Eastern Cape	Unchannelled valley bottom Channelled valley bottom	Private agriculture	Water quality regulation, flood attenuation, erosion control, sediment trapping
Zaalklapspruit, Mpumalanga Province	Channelled valley bottom, pre-rehabilitation and post-rehabilitation	Mining; commercial agriculture	Water quality regulation, sediment trapping

Existing detailed information on the three wetlands was collected, consolidated and presented to a small panel of experts who then rated the supply of the selected ecosystem services based on this information and their professional understanding of wetland functioning. The same three sites were independently assessed with WET-EcoServices and the results were compared with those of the panel of experts to identify specific areas of agreement and disparity.

The correspondence between the expert panel scores and the independent WET-EcoServices assessments were generally reasonably close (within 20%). However, some important disparities were revealed:

- Toxicant removal had the greatest disparity between the experts' scores and the WET-EcoServices scores. One of the contributing factors is that WET-EcoServices includes a very broad spectrum within this category, including heavy metals, biocides and pathogenic bacteria. This leads to potential confusion, and therefore this category would be better named as "Toxicant and pathogen removal".

- In some cases, WET-EcoServices was over-scoring phosphate assimilation where sediment being trapped is very coarse, and likely to have a significantly lower phosphate adsorption capacity than where sediment is finer. Soil texture was included as an indicator for wetlands in order to address this issue.

14.6 Testing the technique on riparian areas

It was noted at the first reference group meeting that the project was ambitious to also include non-wetland riparian areas with the available resources, and therefore it is recognized that the extent of validation in non-wetland areas was to be limited so as not to compromise on testing in relation to wetlands. Nonetheless, the first draft of the WET-EcoServices tool that included the assessment of riparian areas was informally tested on the riparian zones in the offset sites for the Dube TradePort TradeZone 2 development and the Tongaat Hulett Inyaninga development located in the northern coastal regions of the eThekwini Municipality.

As part of the assessment of the gains to be achieved with the rehabilitation of the wetland and riparian areas within the offset areas as part of the offset planning process, the riparian areas had been divided into Assessment Units in terms of similar hydrological and geomorphic characteristics. These Assessment Units were thus assessed together with a broad suite of wetland systems using the revised WET-EcoServices tool. A summary of the riparian Assessment Units assessed is provided in Table 14.2 below.

Table14.2: List of the riparian zone Assessment Units considered in the tool testing with relevant descriptions.

Assessment Unit	Description
Moderately-steep active banks along perennial uMdloti River	• Morphological riparian feature is a steep bank that forms part of the macro channel of the Mdloti River. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Steep active banks along perennial uMdloti River	• Morphological riparian feature is a steep bank that forms part of the macro channel of the Mdloti River. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Moderately-sloping alluvial surface along perennial uMdloti River	• Morphological riparian feature is a moderately sloping alluvial surface that forms part of the macro channel of the Mdloti River. • Dense mix of herbaceous / grassland and woody vegetation dominated by alien invasive trees and shrubs.
Gently sloping flood bench along perennial uMdloti River (Herbaceous vegetation)	• Morphological riparian feature is a flood bench within the active channel[2]. • Dense herbaceous emergent wetland vegetation.
Gently sloping, low lying flood bench along perennial uMdloti River (Woody vegetation)	• Morphological riparian feature is a flood bench within the active channel. • Dense woody alien invasive and riparian vegetation.

[2] The portion of river that conveys flowing water at sufficiently regular intervals to maintain channel form (the presence of distinct bed and banks) and keep the channel free of established terrestrial vegetation.

Assessment Unit	Description
Incised seasonal stream (Middle / lower reaches of small tributary, catchment 100-1000 ha)	• Morphological riparian feature is a steep bank that forms part of the active channel. • Channel is 4-5 m wide x 2-3 m deep. • Bed appears to be alluvial. • Bank and instream vegetation comprise mixed herbaceous and woody patches (indigenous and alien).
Incised headwater stream (at head / upper reaches of small tributary, 1st & 2nd order streams, catchment 10-100 ha)	• Morphological riparian feature is a steep bank that forms part of the active channel. • Bank vegetation varies from herbaceous alien, weedy and/or pioneer communities to dense alien thicket.
Steep active banks along perennial uMdloti River	• Morphological riparian feature is a steep bank that forms part of the macro channel of the Mdloti River. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Moderately-steep active banks along perennial uMdloti River	• Morphological riparian feature is a steep bank that forms part of the macro channel of the Mdloti River. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Steep macro banks along perennial uMdloti River	• Morphological riparian feature is a steep bank that forms part of the macro channel of the Mdloti River. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Moderately-steep macro banks along perennial uMdloti River	• Morphological riparian feature is a steep bank that forms part of the macro channel of the Mdloti River. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Moderately-steep macro banks along abandoned channel depression	• Morphological riparian feature is a steep bank that forms part of the macro channel of an abandoned channel depression. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
Gently sloping flood bench within active channel along perennial uMdloti River (Mixed woody and herbaceous vegetation)	• Morphological riparian feature is a flood bench within the active channel[3]. • Dense mix of herbaceous and woody vegetation.
Gently sloping flood bench outside of active channel along perennial uMdloti River (Mixed woody and herbaceous vegetation)	• Morphological riparian feature is a flood bench within the active channel[4]. • Dense mix of herbaceous and woody vegetation.
High terrace (Under cultivation)	• Morphological riparian feature is an elevated sloping terrace like feature outside of the macro channel. • Under active cane cultivation with no indigenous vegetation.
Moderately-sloping macro banks	• Morphological riparian feature is moderately-sloping macro bank above an alluvial terrace. • Dense to moderately dense woody vegetation dominated by alien invasive trees and shrubs.
High terrace (Secondary vegetation, abandoned cultivation)	• Morphological riparian feature is an elevated sloping terrace like feature outside of the macro channel. • Mix of secondary herbaceous and woody vegetation.
Incised headwater stream (at head / upper reaches of small tributary, 1st & 2nd order streams, catchment 10-100 ha)	• Morphological riparian feature is a steep bank that forms part of the active channel. • Bank vegetation varies from herbaceous alien, weedy and/or pioneer communities to dense alien thicket.
Incised headwater stream (at head / upper reaches of small tributary, 1st order streams, catchment <10 ha)	• Morphological riparian feature is a steep bank that forms part of the active channel.

[3] The portion of river that conveys flowing water at sufficiently regular intervals to maintain channel form (the presence of distinct bed and banks) and keep the channel free of established terrestrial vegetation.

[4] The portion of river that conveys flowing water at sufficiently regular intervals to maintain channel form (the presence of distinct bed and banks) and keep the channel free of established terrestrial vegetation.

Assessment Unit	Description
	• Bank vegetation varies from herbaceous alien, weedy and/or pioneer communities to dense alien thicket.
Incised headwater stream (at head / upper reaches of small tributary, 1st & 2nd order streams, catchment 10-100 ha, downstream of road culvert)	• Morphological riparian feature is a steep bank that forms part of the active channel. • Bank vegetation varies from herbaceous alien, weedy and/or pioneer communities to dense alien thicket.
Elevated flood terrace (Under cultivation) within estuary FMZ	• Morphological riparian feature is an elevated sloping terrace like feature outside of the macro channel. • Under active cane cultivation with no indigenous vegetation. • Within estuary functional management zone.
Elevated flood bench (Woody vegetation)	• Morphological riparian feature is an elevated sloping terrace like feature outside of the macro channel. • Dense woody vegetation (Riparian and mangrove forest). • Within estuary functional management zone.

The results of the assessment were compared and contrasted with wetlands in the project area to check that results were comparable with the "gut feel" scores of the authors. For the most part, the supply and importance scores for the riparian zones assessed appeared to be satisfactory and in line with expectations except for flood attenuation and erosion control services. The major issue that arose during the application of the first draft of the tool to the riparian zones was how to score the criterion, "Size of the contributing upstream topographically defined catchment" considering the different lateral and longitudinal hydro-geomorphic processes present within riparian zones. For example, a riparian alluvial terrace typically intercepts runoff carrying sediment and pollutants from upslope / adjoining slopes, and it can intercept flood waters from the upstream catchment carrying sediment and pollutants during channel overtopping onto the terrace during infrequent flooding events. This applies to most riparian zones that are inundated during flood events. Deciding on which process pathway to assess has significant implications for how the "Size of the contributing upstream topographically defined catchment" criterion is assessed (hereafter referred to as the 'catchment size' criterion). This in turn has a significant influence on the overall supply score which is strongly influenced by the catchment size criterion, i.e. it sets the maximum supply score for regulating services like flood attenuation, sediment trapping and pollutant removal.

In the first version of the tool used in this case study, the catchment size criterion was interpreted to consider the entire catchment of the stream or river along which the riparian zones under assessment are located. This is how the criterion was initially envisaged by the developers. Based on this understanding, the catchment size for the riparian zones bordering the mainstem Mdloti River was assessed as large (score = 4). The assessments of the case study revealed that the supply scores for flood attenuation for the steep well-vegetated riparian zones along the Mdloti River that experiences annual flooding is moderately-high. Considering that the riparian zone was steep and unlikely to detain flood waters, this score was considered too high. Tweaking the catchment size score to reflect the lateral catchment water inputs with a catchment size score of 2 was found to reduce the score by a whole point, i.e. from 2.8 to 1.8, which seemed to be a more realistic score in relation to the characteristics of wetlands that score similar. Similarly, erosion control scores were found to be quite high also partly due to scoring the catchment size as large (score = 4). Reducing this score to 2 reduced the supply score for erosion control to moderate levels which is considered a more realistic outcome.

Despite scoring the catchment size as large (i.e. 4), the supply scores for sediment trapping and pollutant removal / trapping services provided by steep well vegetated riparian zones were still assessed as being moderately-low. This is because in this first draft of the tool, a maximum catchment size of 2 was programmed into catchment context calculation formula to down weight riparian zones in relation to wetlands. However, the application of this rule was considered random and subjective, and it is preferable that the scoring and integration of the supply criteria be integrated in a way that doesn't require such poorly justifiable tweaks.

The most elegant solution to the above issues that was agreed on between the project team was to restrict the assessment of riparian zones to only consider the interception of water, sediment and pollutants from lateral inputs. With this adjustment, most riparian zones within the study areas typically score 1-2 for catchment size which effectively down weights the regulating services scores relative to wetlands, which accounts for both lateral and upstream inputs. The tool was then revised to factor this in and the case study riparian zones re-assessed. In the end, steeper riparian zones along the Mdloti River were assessed as providing a moderately-low supply of all regulating functions except erosion control. This result appears to be a more appropriate representation of the ecosystem services provided by the riparian areas relative to wetlands. Nevertheless, although the authors are happier with the refinements, a clear limitation exists with the technique in that it does not specifically consider the water quality enhancement and sediment trapping benefits associated with the flows from the upstream catchment. This is likely to be particularly problematic for the assessment of riparian areas that are regularly inundated by flows from the stream channel or those in arid environments which, due to limited rainfall, ae rarely activated with flows from lateral sources.

14.7 Additional testing

WET-EcoServices was applied to a set of wetlands in Adam's Mission, South Coast, KwaZulu-Natal, with a particular emphasis on assessing supply and demand for provisioning services. These assessments took place within the context of a broader social study on wetland use and governance, and the case study was valuable in providing an opportunity to refine the social dimension of WET-EcoServices. Specifically, it helped to highlight some of the limitations of the technique which need to be made more explicit.

- The technique does not explicitly deal with trade-offs between different ecosystem services, for example where water quality enhancement impacts negatively on the supply of water for domestic use and cultural/spiritual practices.
- The technique does not explicitly deal with relational values, as elaborated further in Section 15.

An initial version of WET-EcoServices Version 2 was also applied at an additional two sites, the Broomvlei wetland in the Western Cape and the Karibu wetland in Limpopo province. The application was with assessors who were not part of the team refining the tool, thereby providing opportunity for further feedback from users of the technique. It also afforded the opportunity for the developers of the technique to compare the results of the assessment against their expert judgement. For Broomvlei, the focus was on demand assessment, with Myles Mander providing specialist feedback from a resource economics perspective. For the Karibu wetland in Limpopo province, the focus was on selected field indicators, with a group applying the technique including both experienced and inexperienced assessors.

This additional testing yielded valuable insights, including the following:

- An improved method of scoring demand, through revisions to the way in which scores for the number of users and their dependency are integrated.
- An improved means of diagrammatically representing supply and demand.
- Rewording of a key indicator, "Distribution of low flows", so as to improve consistency in its rating.

15. Key refinements and additions to Version 2

This section lists key refinements and additions to Version 2 compared with WET-EcoServices Version 1, also including the reasons for these changes (Table 15.1).

Table 15.1: A summary of the key refinements and additions made to Version 2.

Key refinements	Reason for the change/addition
Non-wetland riparian areas have been included	Extensive watercourses are non-wetland, supporting riparian habitat, which are nonetheless important for ecosystem services (NRC, 2002; Capon and Pettit, 2018).
For all of the services assessed, supply and demand are assessed separately and the beneficiaries of the services are noted, in particular the level of dependency of the beneficiaries on the services being assessed.	For consistency and for the most informed decision-making it is important that all regulating and provisioning services be represented in terms of both supply and demand. In many cases, supply of a particular service may be very high but demand may be very low, and vice versa. Where supply and demand lie relative to each other for each ecosystem service helps inform the identification of specific management threats and opportunities. An approximate estimate of number of users and their dependency has further relevance to management.
Modification or replacement of some existing indicators	To better account for new knowledge and the specific context in South Africa, some of the indicators were refined, e.g. presence of peat was changed to refer more broadly to organic soils (see Section 12.3 for the specific reasoning) and primary aquifers were added to settings considered to have potentially strong surface-groundwater links. A key indicator − that of representation of hydrological zones, was modified by adding a non-wetland class in order to accommodate non-wetland riparian areas. A few of the indicators have been replaced with indicators better related to the ecosystem service or for which information is more readily available at a national level than the previous indicator.
Deletion of 15 indicators (listed in Appendix C)	These indicators, included in Version 1, were deleted for a variety of reasons, which are all outlined in Appendix C.
Addition of new indicators	Two specific indicators to accommodate the specific circumstances of riparian areas were added, namely lateral cross-sectional slope of the unit and pattern of lateral flows. Four new indicators for biodiversity, to draw on readily available datasets, which were not available when Version 1 was developed. A suite of additional indicators to better account for demand for ecosystem services. This includes indicators for both human use and the environment.
Improvements to ease of use of the technique	Fuller explanations provided for tricky attributes, such as the surface roughness of the vegetation.
Refinements to the algorithms used to determine the scores for each ecosystem service based on the relevant indicator scores	In Version 1, the scores for each ecosystem service were generally based on an algorithm comprising a simple average of the scores for the relevant indicators. However, in Version 2, the algorithms have been refined in an attempt to reflect the relative importance and interactions of the attributes represented by the indicators through weighting and grouping of the indicators.
Inclusion of more explicit guidance in terms of how the results of the ecosystem services assessment will support decision-making	In order to best support decision-making, it is useful upfront to consider questions such as How will the importance scores be used? and What specific decisions are to be informed?
An integrated score with supply weighted higher than demand	In Version 1 inadequate account was taken of the relative contributions of supply- and demand-related indicators in calculating an overall importance score.
Using the size of the wetland/riparian area as a multiplier for determining functional hectare equivalents for offset calculations	For applications such as offset determinations it is necessary to use size of the wetland/riparian area in a semi-quantitative manner, but Version 1 lacked this capability.
The addition of a module to carry out offset calculations for water resources management	When WET-EcoServices is used in the context of offset determinations (usually taking place within the context of water resources management) explicit guidance was required to promote consistent application.
The addition of recommendations for scoring overall Ecological Importance and Sensitivity (EIS)	The existing guidance for wetland EIS determination was somewhat limited and specific guidance lacking in terms of how to integrate findings from a more detailed Wet-EcoServices assessment, if available.
Confidence scores no longer included for individual indicators	In Version 1, users were required to include confidence scores for each indicator assessed which was used to provide an overall confidence score for each ecosystem service. This was found to be overly onerous, and was therefore excluded from the assessment. Users are, however, encouraged to document any key limitations to their assessments when presenting and discussing results and to record their level of confidence in the overall assessment.

16. Limitations of the technique and recommendations for improving future assessments

This section provides an overview of some important limitations of the technique, including cross references to key concepts underpinning the technique. Particular attention is given in this section to: (1) limitations that deal specifically with the coarse resolution of the study (Table 16.1); and (2) limitations of the system relating to field testing across a range of types and contexts (Table 16.2). Based in particular on a reflection on these limitations, it then provides specific recommendations for improving the assessment if resources are available for a higher resolution assessment. Recommendations are also provided for further research and development to improve the assessment of wetland/riparian ecosystem services in South Africa.

Table 16.1: Key limitations of the technique in terms of resolution[1], and recommendations for addressing the limitations when undertaking an intermediate resolution assessment

Limitation	Recommendations
WET-EcoServices is specifically designed as a rapid field assessment technique, and whilst a range of initiatives have aimed to use the underlying principles to inform regional assessments, a desktop approach for regional / catchment assessment has still not been developed.	An increasing orientation towards desktop assessment is becoming more feasible as remote sensing technologies rapidly advance and regional and national data layers progressively improve. Focussed research should therefore be undertaken to identify and develop desktop indicators for reliably representing key functional attributes that are currently assessed based on field indicators. These can then be integrated with desktop indicators of demand to improve methods for rating EIS at a catchment scale.
Whilst WET-EcoServices can be used to quantify the relative importance of different wetlands in providing different ecosystem services, the derived scores have not been specifically benchmarked against real case studies where detailed information (e.g. on water quality) is available.	Ongoing research which aims to contrast the outcomes of the WET-EcoServices assessment relative to case studies that specifically quantify the levels to which different services are supplied should be actively encouraged. Such research can then be used to review and refine future versions of the technique.
WET-EcoServices cannot be used to quantity the values of ecosystem services provided by wetlands.	With a growing interest in the importance of natural capital, and economic valuation, potential exists to use WET-EcoServices assessments to inform regional and national valuation estimates. This could potentially be achieved by benchmarking WET-EcoServices scores with economic valuation case studies and then extrapolating such results across multiple wetlands.
Identifying, in the context of a rapid assessment, the number of users and their dependency on specific services may often be challenging, particularly where there is demand for many different provisioning services.	Greater use could be made of course-level proxies (e.g. land-tenure) from which demand for specific services could be inferred. Such proxies will need to be tested across a diversity of socio-economic and landscape contexts in order to determine their reliability.
Demand for the ecosystem services, while taking into account the number of users, does so at a very coarse scale, using only a few (five) classes to represent the number of users. For certain assessments it may be necessary to estimate number of users more accurately. Furthermore, the class intervals were chosen for the South African context, where the majority of wetland/riparian areas being assessed are relatively small (i.e. 1-50 ha) and may not be appropriate for the assessment of either much larger units of assessment or much smaller units of assessment, particularly for provisioning and cultural services.	Where a more accurate assessment is required, a greater number of classes should be used, e.g. 10 classes instead of 5, and for an intermediate resolution assessment, the approximate actual number of users would generally need to be estimated. Where a set of predominantly large wetlands are being assessed at a rapid level then the class intervals for the five classes could be extended or where a set of predominantly very small wetlands were being assessed then the class intervals could be contracted (with documented motivation) to better account for the range of users in the context being assessed.
Demand for regulating and supporting services only accounts for demand that can be clearly linked with land-uses upstream of the wetland that pose a risk to downstream users and applies to selected defined users in the river reach downstream of the Assessment Unit. Broader water resource management challenges (e.g. the	Consider integrating a measure of “regional catchment demand” into the assessment. This could potentially be achieved by using desktop PES / EIS datasets that reflects the impacts of flows and physico-chemical modifications at a quinery catchment for most of the country. An option here, would be to consider using this to assign a starting demand score (e.g. 2/4 if changes in flows / water quality are very high) and then to increase the demand score where local demand indicates that local users receive more direct benefits.

Limitation	Recommendations
need to reduce flood peaks in urban areas) is not accounted for.	
Assessing the dependency of users on specific services provided by the Assessment Unit is based on a simplistic assessment of the accessibility of alternative sites providing these services.	For intermediate resolution assessments, the alternative would be, through workshop/s and/or focus group discussion/s, to hear directly from users as to how dependent they are on the services provided by the Assessment Unit and why so. In this way, more explicit account would be taken of the socio-economic factors influencing dependency.
WET-EcoServices assigns a single dependence class to users of an ecosystem based on the predominant dependence. However, it is recognized that dependence is seldom uniform across the group of users, which needs to be accommodated if a higher resolution assessment is required.	For intermediate resolution assessments, the alternative would be to use the estimated number of users and approximate percentages across the dependence classes. For example, of the 150 users of a wetland, approximately 20% (i.e. 30 users) have a high dependence, 60% (i.e. 90 users) have a moderate dependence and the remaining 20% (i.e. 30 users) have a low dependence.
Although WET-EcoServices makes explicit reference to spiritual/religious contributions of ecosystems, this representation is limited in its depth and is largely with reference to spiritual/religious practices, which can be easily observed. However, spiritual contributions can be made by ecosystems without any spiritual/religious practices occurring, but instead may take place in more subtle and much less easily observed ways Thus, the technique is limited in its coverage of the diversity of ways in which people may potentially be affected spiritually/emotionally/religiously through interacting with a wetland/riparian area.	For an intermediate resolution assessment, include discussions with users about the variety of subtle ways in which an area might contribute to one's spiritual enrichment. For example, when standing next to a wetland and simply appreciating its beauty/aesthetics, one may spontaneously experience a feeling of transcendence or spiritual connection which would not be apparent to an anyone else and which even one may not consciously think of as a "spiritual experience" but which has affected one at an emotional level and which has contributed positively to one's well-being.
The technique is limited in terms of its representation of the overlap between different services, which may be great, as emphasized by IPBES (2017) and illustrated with the above example of the overlap between the aesthetic and spiritual.	For an intermediate resolution assessment, qualitative interviews with some individual users are likely to be required in order to better understand the overlaps and relationships between different services. Refer to IPBES (2017) for further discussion around the overlap between different services.
The technique does not deal explicitly with culturally specific ways of expressing value and with relational values.	As above, qualitative interviews with individual users are likely to be useful. Specific issues potentially needing to be addressed are described in more detail in Sections 12.2.
Although the technique assists in assessing individual wetlands for comparative purposes, it does not explicitly account for the cumulative contributions of group/s of wetlands at a landscape/catchment scale. It also is focussed only on wetland and riparian ecosystems and does not cover other ecosystem types.	For catchment- and landscape-scale assessments including a variety of different ecosystem service types, users are referred to the desktop ecosystem services mapping techniques such as InVest (Sharp et al., 2014) and ARIES (Bagstad et al., 2011) and the desktop mapping assessments employed by Quayle and Pringle (2013) and Pringle et al. (2017). In addition, an important area of future development of WET-EcoServices would be to enhance its capability for being used primarily at a desktop level.
The technique does not result in a detailed description of a wetland/riparian site, including the direct description of hydrogeomorphic processes, and therefore ecosystem services are assessed largely based on very coarse-scale proxies. Sites with complex/unusual hydrological inputs (e.g. where supplied by a regional aquifer that extends beyond the topographically defined catchment) are likely to be least well accounted for.	For an intermediate resolution assessment, it is recommended that the guidelines for applying hydropedology in support of wetland assessment by Job and Le Roux (2019) be used to characterize the wetland in the context of its surrounding hillslopes. The guidelines given in WET-Health Level 2 assessment for characterizing the reference state of a wetland in terms of hydrology, geomorphology, vegetation and water quality are also of relevance.
The technique very simplistically represents how different ecosystem services are generated at different scales	For an intermediate resolution assessment, it is recommended that the downstream service area distances be tailored for the different water-related regulating services rather than using a generic distance across all of these services.
Although the technique employs several indicators designed for desktop assessment, it does not provide a cost-effective means of assessing large	For very broad-scale assessments, desktop mapping methods such as ARIES (Bagstad et al., 2011) are recommended, and a review of the relevant nationally-available data layers be undertaken. One of the critical data layers

Limitation	Recommendations
numbers of wetlands at a landscape/catchment scale.	which likely will need to be included is that of Strategic Water Source Areas (SWSAs)[2]

[1]Where it is noted that WET-EcoServices is specifically designed for assessment at a rapid level.

[2]Strategic Water Source Areas (SWSAs) are areas that have a relatively high natural runoff in the region of interest, and which is made accessible for supporting the region's population or economy, contributing substantially to development needs, often far away from the source (Nel et al., 2017). Twenty-two SWSAs have been identified based on a joint consideration of high runoff areas and water demand by major urban development or economic nodes. While covering only 8% of the region, SWSAs contribute 50% of the water supply, and when linked to downstream urban centres, these areas support at least 51% of South Africa's population (Nel et al., 2017). Wetlands and riparian areas which are located within SWSAs could be viewed as having additional importance in terms of water-related regulating services, and thus SWASs are considered to be an important inclusion for broad-scale assessments of wetland/riparian areas. However, it was decided not to include SWASs in the WET-EcoServices Version 2 because of the scale of the assessment in this technique is at the level of individual wetlands, for which catchment runoff and downstream water users are considered, and therefore there may be a fairly high level of "double counting" if they were included as an additional criterion in the technique.

Table 16.2: Key limitations of the technique in terms of testing.

Limitations	Recommendations
Application and testing has been limited within the following biophysical types/contexts: (1) non-wetland riparian ecosystems; (2) non-vegetated wetlands; and (3) wetland/riparian areas in arid climates.	Further testing and development of WET-EcoServices should focus on the under-represented types/contexts listed in the limitations. In addition, a particular effort should be made to use sites where data and understanding levels are relatively high, and can therefore be used to help further validate the technique.
Certain services (notably streamflow regulation) are more difficult to validate than others, and these services have received less attention in the testing than those more easily validated and for which data are available.	It would be valuable to identify a few South African wetlands representing a diversity of wetland types and climatic contexts where the contribution (or otherwise) to streamflow regulation in particular as well as other ecosystem services has been directly quantified, based as far as possible on existing data. These sites will then provide a basis for further refinement and validation.
The technique is limited in the full extent to which it is able to account for how the social context influences the services ascribed to an ecosystem.	A specific investigation is recommended of how different wetland/riparian area attributes might be viewed under different social contexts[2].
There has been limited reflection on how the results of WET-EcoServices assessments have been used within a decision-making context.	Considerable attention has been given to better integrating WET-EcoServices within an overall assessment of wetland importance. This included the preparation of a report with recommendations for refining the assessment of EIS which is used to inform environmental authorization processes (Macfarlane et al., 2019). A systematic review of how the results are used in a broad suite of decision-making contexts would also be beneficial.

[2] For example, in an affluent suburb with low crime, a wetland/riparian area with dense, shrubby vegetation located within an urban landscape dominated by buildings and paved surfaces may be viewed very positively for its aesthetics and the attraction it has for charismatic wildlife, but in a poor suburb with a high crime rate, the same wetland/riparian area may be viewed very negatively, primarily being an area where criminals can hide.

PART 3: CASE STUDIES DEMONSTRATING DIFFERENT APPLICATIONS OF THE TECHNIQUE

17. The Manalana and Kromme case studies: comparing different wetland HGM types within a local catchment

The purpose of the Manalana and Kromme case studies is to illustrate the application of WET-EcoServices Version 2 applied in order to provide a broad comparison of ecosystem services provided by a diversity of wetlands. The results were used to inform general management planning. The first comparison is made between two different HGM units in the same local catchment in the Manalana (Craigieburn) area of Bushbuck Ridge, Limpopo Province, which is in a communal agriculture context.

The second overall comparison is between two different HGM units in the Kromme wetland, Eastern Cape, which is in a commercial agricultural context, following which a brief comparison is made between the Manalana and Kromme sites in order to better understand how land-use context might affect the supply and demand of ecosystem services.

Finally, a preliminary assessment of trade-offs between different ecosystem services is made in one of the HGM units where the likelihood for trade-offs appears to be potentially high between provisioning for cultivation and other provisioning services and regulating services.

17.1 Background information on the sites

Background information on the two Manalana sites

Manalana HGM 1 and 2 are located in the Manalana catchment, a tributary of the Sand River. Both HGM units lie immediately upstream of major erosion gullies (Figure 17.1) which were threatening to actively erode into the respective HGM units, but were halted by erosion control structures (weirs) put in place by Working for Wetlands.

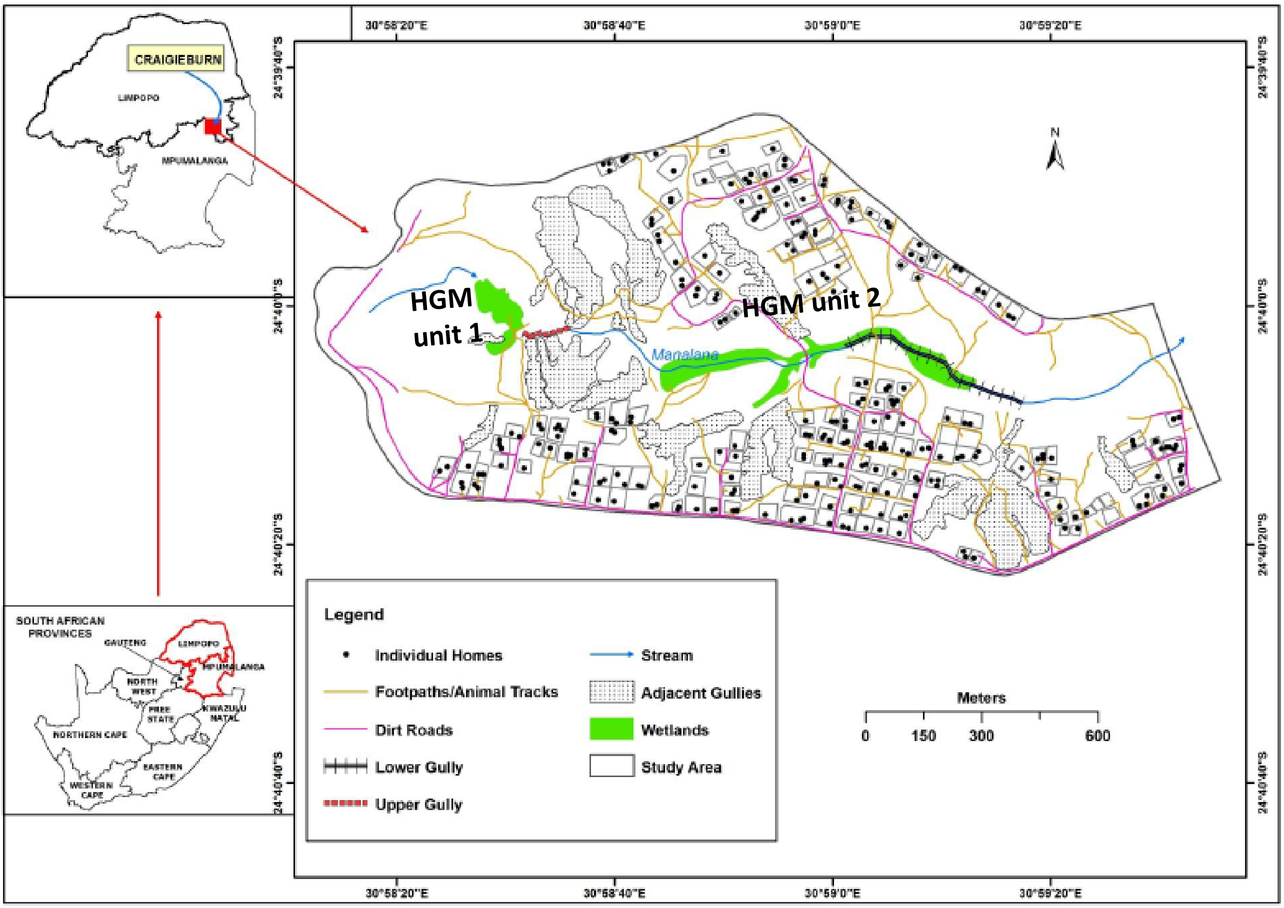


Figure 17.1: Occurrence of erosion gullies and homesteads within the upper Manalana catchment (from Ngetar, 2011).

HGM 1 is a hillslope seep feeding into a channelled valley bottom in its lowermost portions. It includes three prominent hillslopes, facing east, south and north respectively. Low flows would naturally have occurred mainly as sub-surface seepage through the three hillslopes in the interflow soils and with some diffuse surface flow in the responsive soils. However, the creation of extensive raised beds across most of the HGM unit has resulted in a network of minor channels in between the beds, which serve to collect and, to some extent, concentrate low flows. Approximately half of these beds have been abandoned, with the result that the beds and intervening channels have become less accentuated, but they are likely to still influence low flows. In Figure 17.2, the cultivated beds are clearly visible in the 2003 image, and in the 2016 image, where cultivation is less extensive, but the pattern of the beds are still visible in the abandoned areas.

Figure 17.2: HGM 1, shown in 2003 (second image) and 2016 (first image).

Figure 17.3: Raised beds in HGM 1, with those in the foreground in the process of being cleared for cultivation and those in the middle-ground abandoned and covered with *Phragmites mauritianus*.

HGM 2 is comprised predominantly of an unchannelled valley bottom, but with some lateral hillslope areas. As for HGM 1, much of the unit has been cultivated and converted to raised beds and the intervening channels between the beds to some extent concentrate low flows through the unit (Figure 17.4). However, as can be seen in Figure 17.5, these channels support dense growth of indigenous hydric species.

Figure 17.4: HGM 2, shown in 2016.

Figure17.5: HGM 2, showing varying levels of land-use transformation

Most (~80%) of HGM 1 is occupied by the temporarily saturated/flooded zone (Nkosi, 2005) and the remaining ~20% is occupied by the seasonal zone, which is located predominantly in the lowest-lying areas near the outlet of the unit. HGM unit 2 is subject to much more prolonged wetness than HGM 1, and the extent of the temporary, seasonal and permanent zones were estimated as 26%, 38% and 36% respectively (Nkosi, 2005).

In HGM 1, *Phragmites mauritianus* and *Imperata cylindrica* are the most frequently found species. According to DWAF (2003) these are classified as facultative wetland species respectively, which indicates their ability to inhabit both terrestrial and wetland environments. HGM 2 possesses considerably more obligate hydric species than HGM 1, reflective of the higher level of wetness. Dominant plants found in HGM 2 include *Schoenoplectus brachyceras* (Letshago), *Pycreus mundii*, *Thelypterus* sp. (a hydric fern), *Cyperus latifolius* and *Phragmites mauritianus* (Nkosi, 2005).

Background information on the two Kromme Wetland sites

There have been several geomorphological and ecological studies on the wetland areas along the Kromme River, which is an important source of water for the Nelson Mandela Bay Metropolitan area (Haigh et al., 2009). Of these wetland areas, which support extensive stands of palmiet (*Prionium serratum*), two sections (Figure 17.6) have received particular attention from a research perspective.

Figure 17.6: Overview of the Kromme River, showing the location of the selected upper and lower wetland sections.

The upper wetland section (often referred to as the Kompanjiesdrif basin) consists of two main portions (west and east) both dominated by intact vegetation of the tall (3 m) and robust palmiet (*Prionium serratum*). Although the western portion is 3.5 km in length and the eastern portion 2 km, they seem to be similar in terms of vegetation structure and hydro-geomorphology and are both underlain by organic sediment.

Headward erosion by a large gully at the foot of the eastern portion has been halted with a large erosion-control gabion weir (Figure 17.7). Several alluvial fans, predominantly stemming from the Suuranys mountain range to the north, impinge into the Upper Kromme section (Pulley et al., 2018).

The Lower wetland section is located 17.5 km downstream of the upper section and is preceded by a confined erosional channel, which loses confinement when it enters the Lower section, where sandy flood-deposited sediment covers the valley floor (Pulley et al., 2018). Vegetation of the lower portion comprises a mosaic of small palmiet patches, mixed sedges/grasses/shrubs and open sandy patches. Although Pulley et al. (2018) describes both the confined and unconfined areas, Rebelo (2017) focussed on the unconfined portion, which is taken as the focal area of assessment for the Lower section.

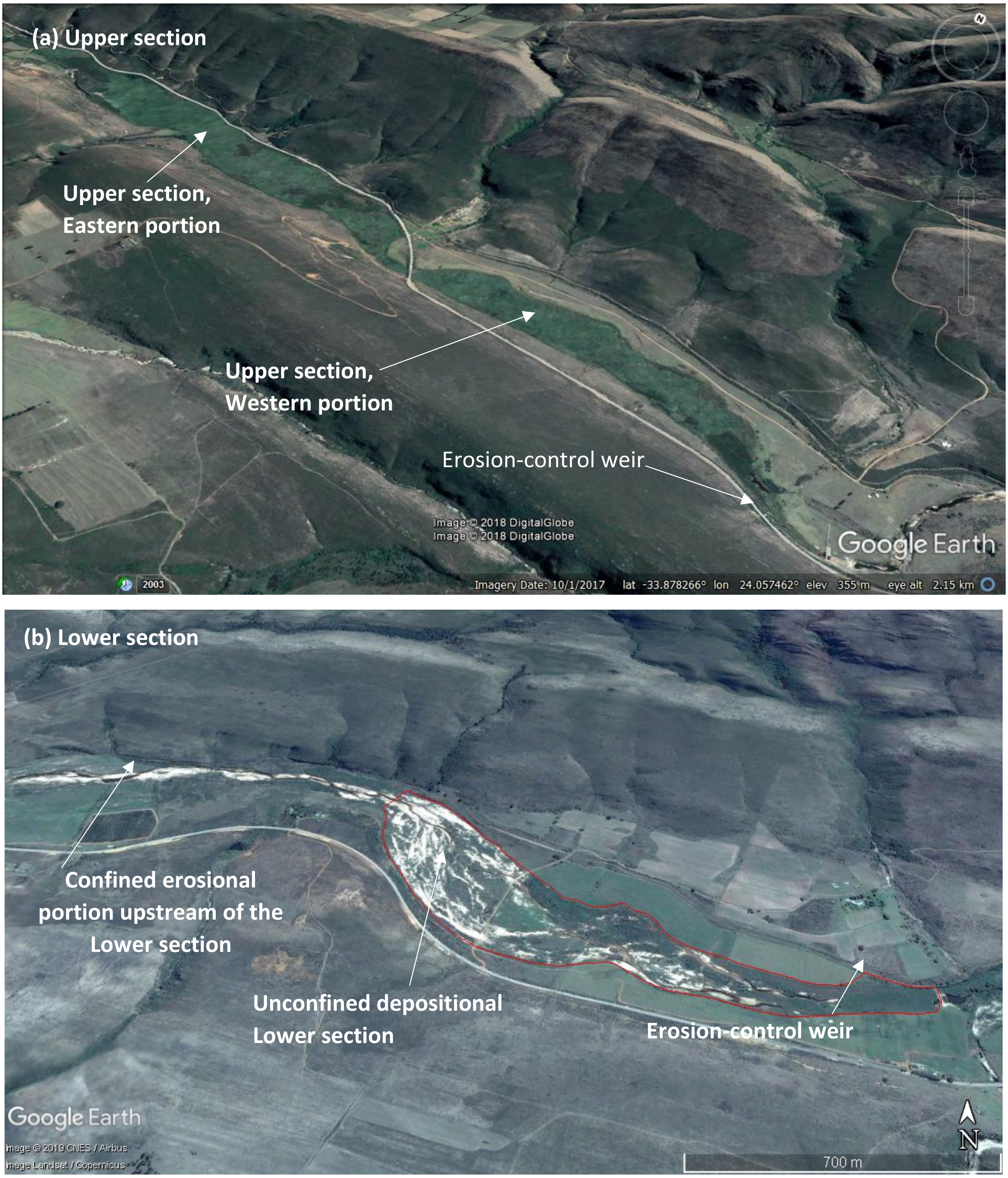


Figure 17.7: The Upper (a) and Lower (b) wetland sections of the Kromme River.

The Kromme Wetland is flanked by two mountain ranges (the Suuranys and Tsitsikamma) and is located in a shallow valley bottom location. The local climate in the K90A catchment is characterized by an annual precipitation of 716 mm and a mean annual potential evapotranspiration of about 1980 mm for the valley floor (Haigh et al., 2002). The geology of the wetland's catchment consists primarily of shales and Table Mountain Group quartzite with a cross section of the upper HGM unit's geology depicted below. Sediment is characterised as organic with fine clay interrupted by distinct sand layers in the upper HGM unit; while the lower HGM unit is dominated by sandy sediment. For both HGM units the catchment is predominantly natural but with some pasture for the dairy and meat industries and limited orchards. Other impacts are limited, with small areas affected by alien invasive species (principally black wattle) and limited road infrastructure/water supply dams.

Although the upper section is classified as an unchannelled valley bottom, low flows are not spread uniformly across the unit but occur predominantly towards the margins of the unit in what could be described as weakly channelled flow. The lower portion is classified as a channelled valley bottom. However, the unconfined Eastern portion is inherently depositional and comprises a large flood-out feature immediately downstream of the terminus of an erosion gully (McNamara, 2018) with a somewhat braided channel which is very dynamic.

From the sequence of satellite images of the lower section shown in Figure 17.8, it can be seen that shortly prior to a major storm event in 2012, bare sandy areas were very limited in extent. However, shortly after the storm, much of the area (except immediately upstream of the erosion control structure) is covered in bare sand, presumably as a result of extensive deposition of sand in the wetland. By the next image (2013) the extent of bare sandy areas have started to diminish, as a result of the increase in vegetation patches, and this increase continues progressively over time so that by 2017 vegetation cover is much increased but has not yet attained the level prior to the 2012 storm event. In contrast, the upper section shows complete vegetation cover throughout the same time period from 2012 to 2017.

Figure 17.8: A sequence of Google Earth images from February 2012 to March 2016 of the lower portion. The extensive sediment deposited during the 2012 flood was confirmed by McNamara (2018) by coring through the recent sedimentary deposits. The pre-2012 surface was easily identifiable due to the abrupt transition from off-white sand deposits to a black organic-rich topsoil at the contact between flood and former valley-fill deposits, respectively (Figure 17.9) (McNamara, 2018).

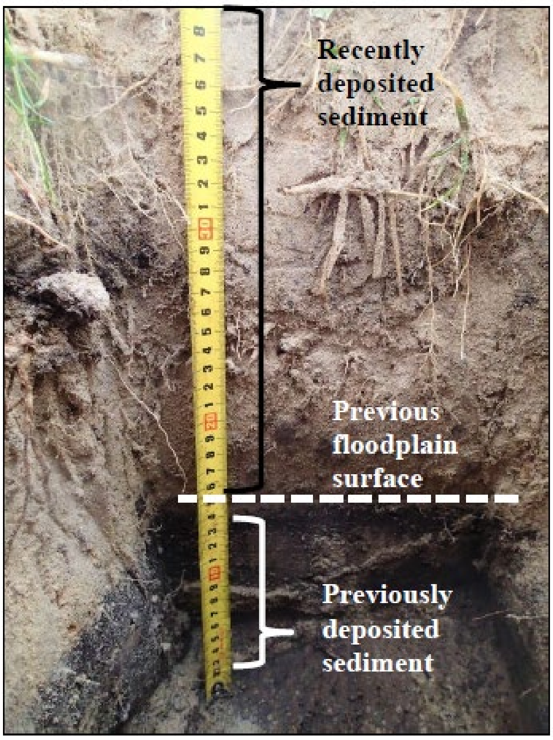


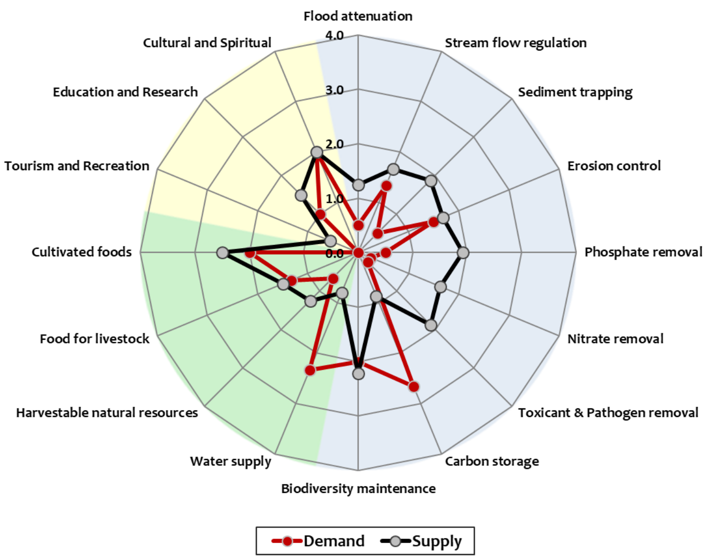
Figure 17.9: The distinction between recently and previously deposited sediment (from McNamara 2018)

17.2 Results of the WET-EcoServices assessment for the four sites

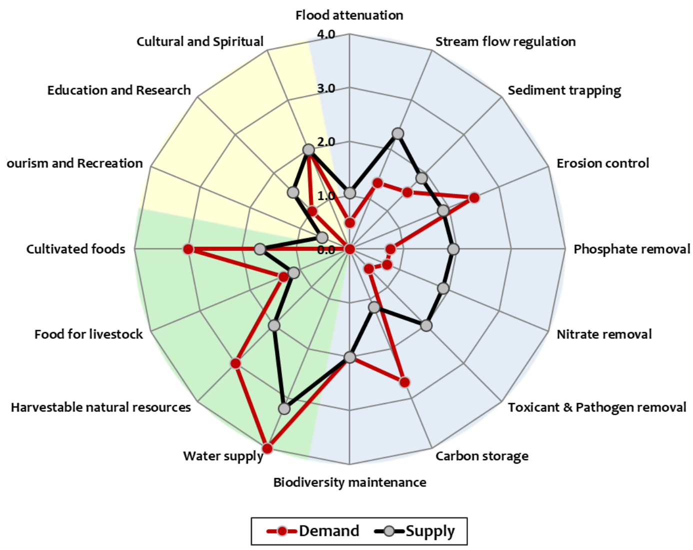
Graphical summary of the overall results

Figure 17.10 graphically represents a summary of ecosystem service supply and demand through the spider diagrams which are generated by the WET-EcoServices spreadsheet. Key trends revealed in these diagrams are discussed following the figures.

Manalana HGM 1



Manalana HGM 2



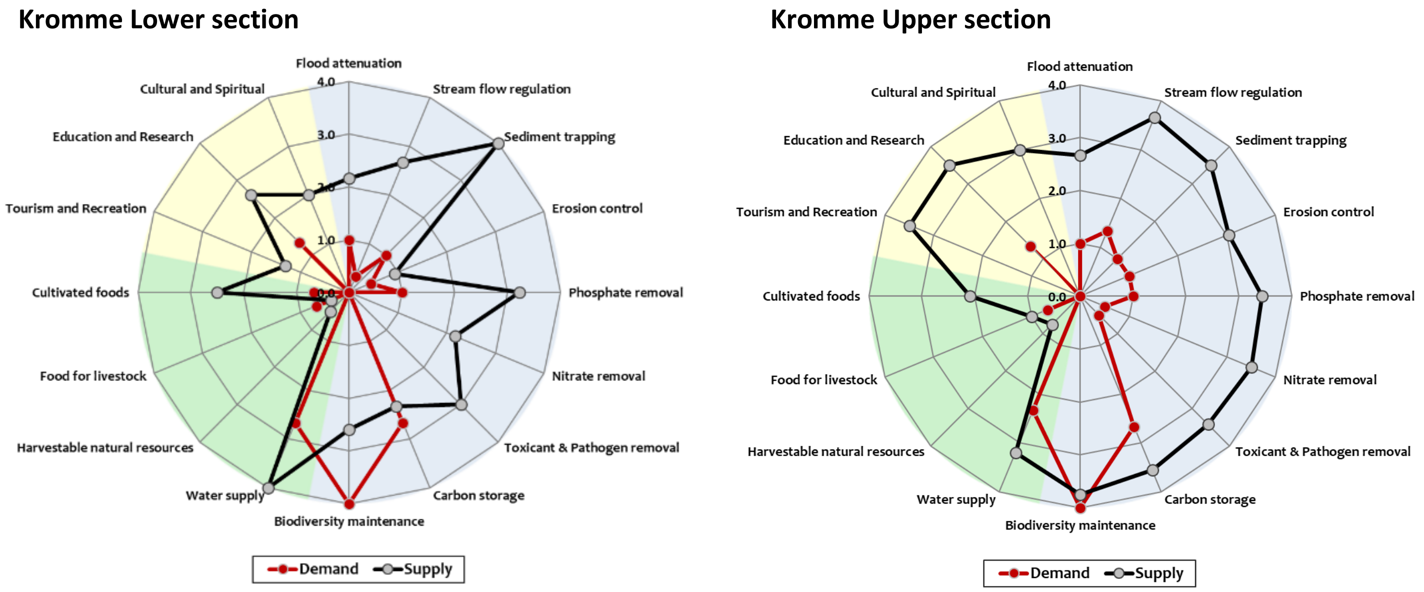


Figure 17.10: Summary of the supply and demand scores for the HGM units assessed from the Manalana and the Kromme.

A comparison of the two Manalana HGM units

A comparison of Manalana HGM 1 and 2, shows generally similar patterns in terms of supply and demand in both HGM units, but with four main differences:

There is a much higher supply and demand for harvestable natural resources and water supply in HGM 2 than in HGM 1. The higher level of wetness in HGM 2 supports extensive *Schoenoplectus brachyceras* sedges, which are sought after for craft production, and in addition HGM 2 has a much more sustained discharge of sub-surface water, which is used for domestic purposes.

Demand for sediment trapping and water quality enhancement services are somewhat higher in HGM 2 than HGM1. This is because sources of sediment, nutrients, toxicants and pathogens are somewhat greater in HGM 2 than HGM 1 given the greater extent of human settlements and erosion features in its catchments compared with HGM 1 (as can be seen from Figure 16.1). However, the supply of these services is fairly similar in both HGM units given their similar pattern of low flows, vegetation cover, etc. and the fact that both have been similarly somewhat compromised by cultivation within the unit, although supply of nitrate assimilation in HGM 2 is slightly higher given the somewhat more favourable level of wetness in this unit than in HGM 1.

The demand for cultivated foods relative to supply is higher in HGM 2 than in HGM 1. Here it should be noted that the relatively high level of wetness of HGM 2 is taken by the technique to indicate a somewhat lower suitability (and therefore supply) for cultivation generally than HGM 1. However, local farmers cultivate taro, which is unusually tolerant of waterlogging, and therefore is suitable for this specific crop.

Demand for erosion control is higher in HGM 2 than HGM 1 given the greater importance of the site for direct use, which would be compromised if major erosion were to take place.

Based on the four main differences described above, it can be appreciated that overall HGM 2 is more important than HGM 1 from an ecosystem services perspective, particularly in terms of provisioning services. Therefore, one can imagine that under limited resources, HGM 2 might be prioritized higher than HGM 1, especially if the management of wetlands for supporting local livelihoods was a high priority.

A comparison of the two Kromme units

A comparison of the Kromme lower and upper sections (units) shows reasonably similar patterns in terms of provisioning services, most of which are fairly low in terms of both supply and demand, except for water supply. Both units also show a generally low demand for cultural services, but the upper unit scores higher in terms of supply of these services.

The greatest contrasts between the Lower and Upper units lie with the supply of regulating/supporting services:

All regulating/supporting services, with the exception of sediment trapping, *scored higher for supply in the Upper than in the Lower unit*. This is primarily owing to the Upper unit comprising a well-vegetated, intact palmiet (*Prionium serratum*) bed with low flows reasonably widely distributed through the unit, compared with the Lower unit which lacked the organic soils, and had lower vegetation cover and somewhat more confined flows.

Biodiversity maintenance scored very high in terms of demand in both units, in particular given that both represent a threatened wetland type, but *in terms of supply, the Upper unit scored significantly higher*, owing mainly to its ecological condition being much better than the Lower unit, and therefore it representing the threatened type much better than the Lower unit.

Based on the main differences described above, it can be appreciated that overall the Upper unit is more important than the Lower unit from an ecosystem services perspective, particularly in terms of biodiversity maintenance and carbon storage. Therefore, one can imagine that under limited resources the Upper unit might be prioritized higher than Lower unit. However, it is important to note that, as can be appreciated from the time sequence in Figure 16.8, the Lower unit is very dynamic in terms of key parameters influencing ecosystem services supply, notably sediment deposition and vegetation cover, and its supply is likely to improve if vegetation cover continues to increase and fine sediments accumulate gradually over time.

A brief overview across all four sites

Simultaneously comparing all four sites in Figure 16.10, it can be seen how the Manalana units show somewhat higher importance for provisioning services relative to regulating services, which is typical of the communal rural context of these two units. In contrast, for the Kromme units, regulating services are generally more important than provisioning services, except for water supply. It should be noted that demand for water quality enhancement services was, however, fairly low, which is typical of a commercial agricultural context with limited intensive agriculture. Where intensive agriculture is more prevalent then demand for regulating services is likely to be much higher. A further key difference is the greater importance for biodiversity maintenance of the Kromme sites than the Manalana sites, especially Kromme Upper, which provides the only instance in the four sites of an ecosystem service being very close to its maximum score for both supply and demand.

A preliminary identification of potential trade-offs in Manalana HGM 2

Trade-offs between specific ecosystem services are typically associated with uses that involve high levels of alteration of the ecosystem, notably cultivation in the wetland/riparian area. Cultivation often impacts negatively on regulating services generally and on provisioning services which depend on maintenance of the ecological condition of the wetland/riparian area. Having identified Manalana HGM 2 as the priority site but with a high potential for trade-offs given the high extent of cultivation in the unit, the following specific question is now addressed: To what degree are trade-offs occurring amongst the different services which it supplies?

WET-EcoServices does not explicitly assess trade-offs amongst different uses, and trade-offs are not immediately apparent from the supply and demand scores. However, it is informative to return to the score sheet to examine the scores for key indicators to determine the extent to which the use has altered these key indicators negatively. Doing this for Manalana HGM 2 reveals that the pattern of low flows and vegetation cover have been moderately altered, with a corresponding moderate impact on regulating services.

There is limited fertilizer application and very limited application of biocides in the wetland and its catchment, and cultivation in the wetland does not appear to be unduly reducing the acceptability of the quality of the water which is being supplied directly from the wetland.

The greatest trade-off is probably in terms of loss off biodiversity maintenance, owing to the loss of natural vegetation to cultivation. However, the wetland is not of a threatened vegetation type, for which there would be high biodiversity maintenance demand. Therefore, this loss is significantly lower than would have been the case, for example, if a large proportion of the Kromme Upper HGM unit had been cultivated. Overall, therefore the trade-offs are surprisingly moderate with respect to the provisioning service for cultivation and the other ecosystem services for which there is a relatively high demand.

18. The Zaalklapspruit case study: comparing ecosystem services supply with- and without rehabilitation

18.1 Background information on the Zaalklapspruit wetland

The Zaalklapspruit wetland, in Mpumalanga province, is located shortly downstream of extensive coal mining operations which are feeding acid mine drainage into the wetland. In 2014, a 31 ha portion of the Zaalklapspruit wetland was rehabilitated specifically to improve the wetland's capability for toxicant removal, so as improve its contribution to mitigating acid mine drainage. A WET-EcoServices assessment was carried out shortly before rehabilitation in 2012 and again three years after rehabilitation in 2017. The purpose of this case is to use these two assessments to examine two questions:

- What contribution has the rehabilitation made in terms of ecosystem service supply generally?
- What specific contribution has the wetland rehabilitation made to the trapping of toxicants?

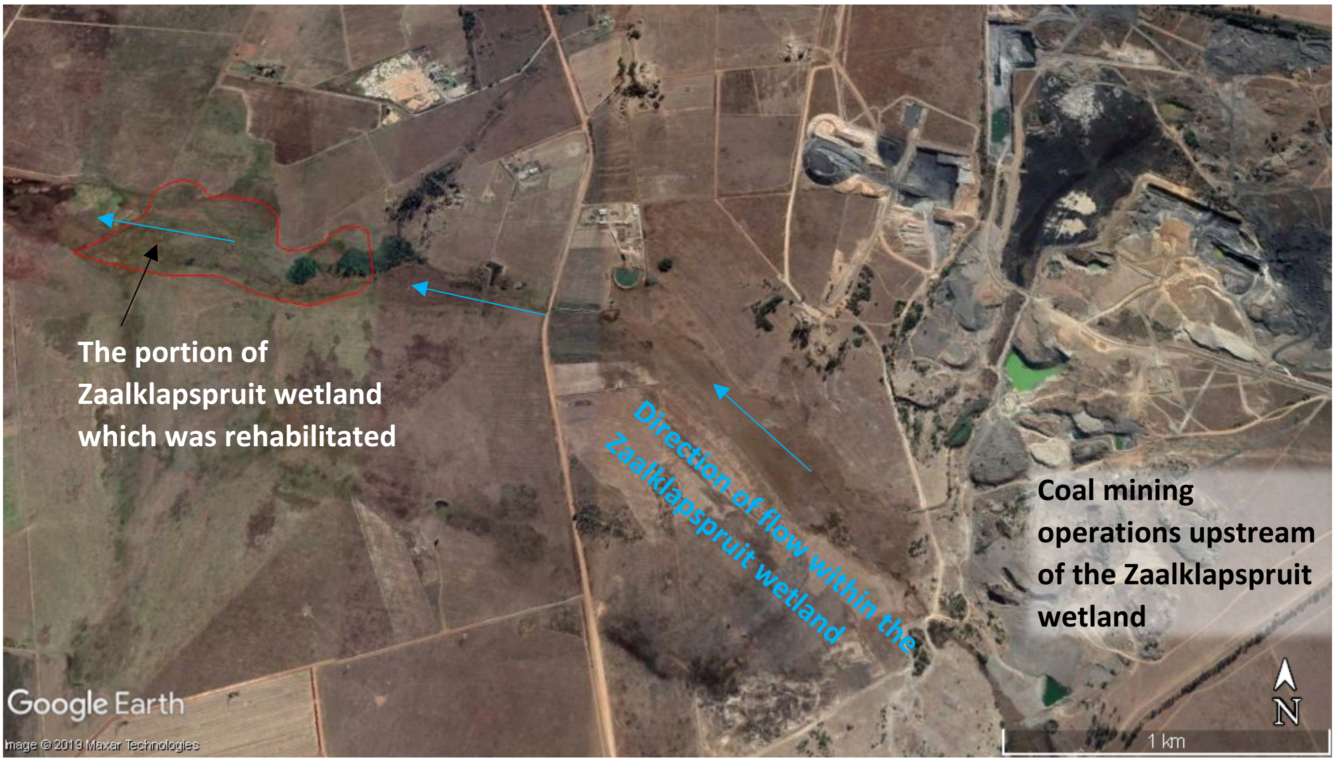


Figure 18.1: Location of the rehabilitated portion of Zaalklapspruit wetland in relation to mining.

The Zaalklapspruit Wetland is located in a shallow valley bottom along the Grootspruit River in a landscape of quite low topographic relief. The local climate is characterized by a low mean annual precipitation of 668.4 mm and a high mean annual potential evapotranspiration of 2104.6 mm. Rainfall intensity in the area is an average of 50,7 mm/24hr with the geology of the wetland's catchment consisting primarily of shales and sandstones with a few dolerite intrusions. Soils are characterised as clay loam/ sandy clay loam with a moderately high run-off potential.

The control on the formation and dynamics of the system is linked to the base level of the Zaalklapspruit stream into which this wetland system flows. This prevents down-cutting of the valley and encourages alluvial deposition in the valley upstream of this junction. Water inputs into the wetland are primarily from the upstream catchment although the presence of significant areas of seasonal and temporary seepage areas leading into the wetland suggests that lateral sub-surface seepage is also an important input.

Some transformation of wetland areas has taken place in response to historic agricultural activities which have included ridge and furrow cultivation, drainage and construction of small impoundments for livestock watering. Poplars (*Populus* spp.) have also impacted part of the wetland.

Rehabilitation interventions focused on a 31 ha portion of the wetland through which water flows were being confined by an incised channel (Figure 18.2) and ridges and furrows created for cultivation, subsequently abandoned. The installation of rehabilitation weirs in the channel has resulted in less confined flows across this impacted portion of the wetland (Figure 18.3).

Figure 18.2: The main incised channel through the Zaalklapspruit wetland pre-rehabilitation

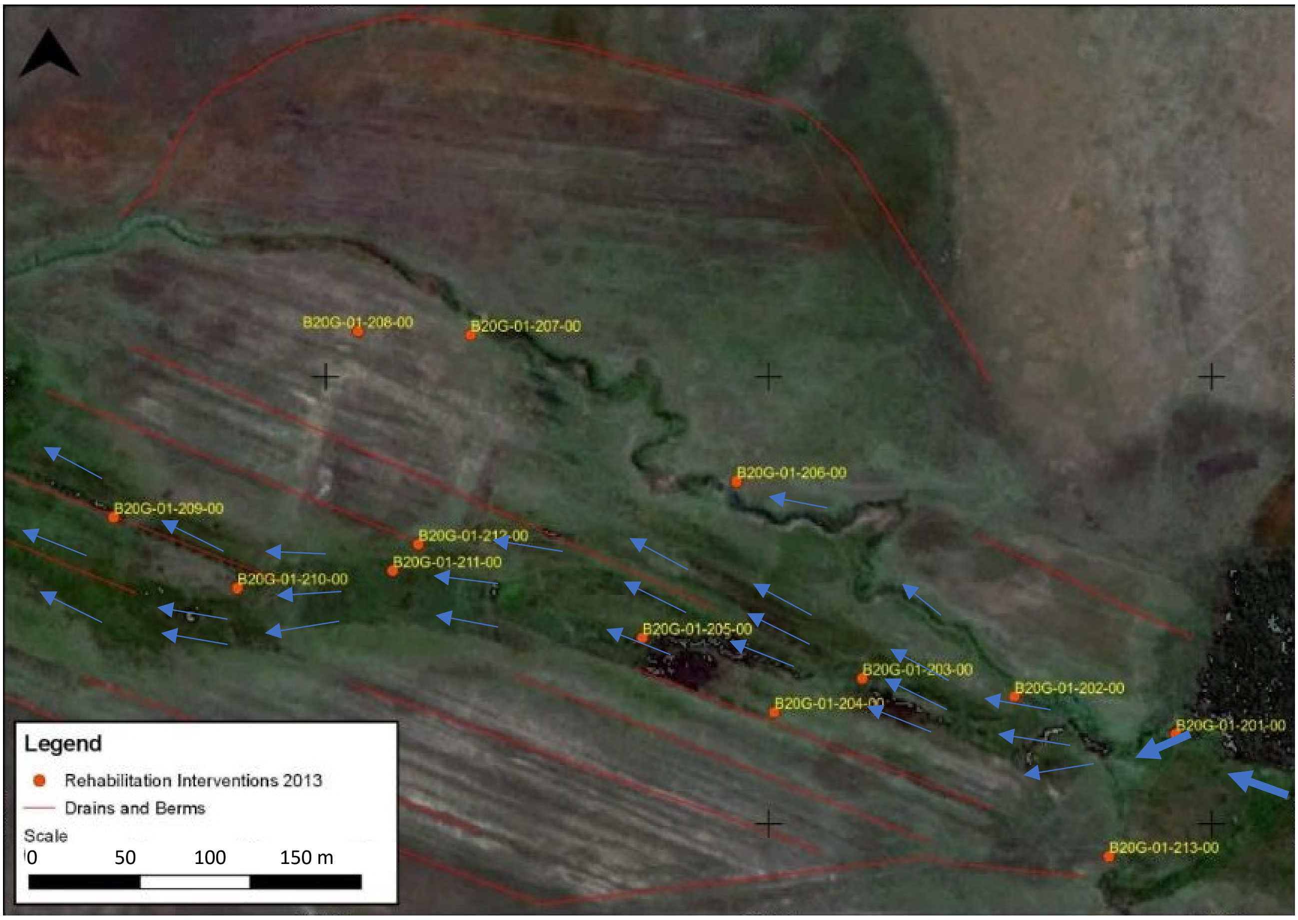


Figure 18.3: Distribution of low to intermediate flows through the HGM unit post-rehabilitation, indicated by arrows, with arrow size representing the proportional flows through the specific area (modified from Kotze et al., 2019).

The catchment land-use was historically characterized by livestock grazing and dryland cultivation. While large areas are still managed for these purposes, mining (primarily coal) has resulted in considerable changes to the landscape in the catchment. Other impacts are limited, with small areas affected by alien invasive species (principally wattle and gum) and limited road infrastructure. Natural vegetation encountered in the catchment can be considered in fair condition with minimal signs of degradation observed. Likewise, land under cultivation in the catchment is relatively well managed with reasonable conservation practices in place.

Both pre- and post-rehabilitation, the wetland HGM unit is a channelled valley bottom. In the pre-rehabilitation situation, the low flows remain within the stream channel. However, in the post-rehabilitation situation, although low flows are contained in the natural stream channel in the upper portion of the unit, they are soon deflected out of the channel by rehabilitation weirs so that in the mid and lower portions most of the low flows proceed as diffuse flow along the southern portion of the valley floor in the HGM unit (Figure 18.3). When visited in March 2017 for the Kotze et al. (2019) assessment, these diffuse flows were clearly visible and flows in the stream channel flowing through the centre of the HGM unit did not continue to the outlet of the unit but stopped in the lower portion of the HGM unit.

In the post-rehabilitation situation, given the deflection of flows out of the channel described for the "Pattern of low flows", stormflows are likely to be spread across at least the southern portion of the HGM unit in most years and in some years on several occasions in the year. In the pre-rehabilitation situation, flooding would be less frequent, but probably at least every 2-5 years.

In the post-rehabilitation situation, approximately 50% of the unit is occupied by the seasonally saturated/flooded zone and 25% by the permanent zone, which is confined mainly to the diffuse flow area along the south of the HGM unit, referred to in the pattern of low flows. The remaining 25% is occupied by the temporary zone, which is confined mainly to the margins of the HGM unit and levees and other higher-lying areas adjacent to the main stream channel. In the pre-rehabilitation situation, approximately 40% of the unit is occupied by the seasonally saturated/flooded zone and 20% by the permanent zone, and 40% is occupied by the temporary zone, i.e. somewhat drier than the post-rehabilitation situation.

Vegetation is predominantly of intermediate height (0.7-1.0 m) dominated by sedges and grasses (notably *Pycreus nittidus* and *Leersia hexandria*) with some patches of *Typha capensis* (1.0-2.0 m) in the permanent zone. Aerial cover is generally good (> 90%) and in the survey of March 2017 whereby vegetation was surveyed (Kotze et al., 2019) no obvious ill effects of the acid mine drainage on the wetland vegetation could be seen. In the pre-rehabilitation situation, the vegetation is similar in height, structure and cover, but the patches of taller vegetation (1.0-2.0 m) are more limited in extent.

18.2 Results of the WET-EcoServices assessment

Figure 18.4 graphically represents a summary of ecosystem service supply for the pre- and post-rehabilitation situations, which is of relevance to the first question addressed by the case, namely what contribution has the rehabilitation made in terms of ecosystem service supply generally? From Figure 18.4 it can be seen that cultural and provisioning services have largely been unaffected by the rehabilitation. However, the supply of several regulating services has generally been enhanced by rehabilitation, notably for streamflow regulation, phosphate removal, nitrate removal, toxicant removal and carbon storage.

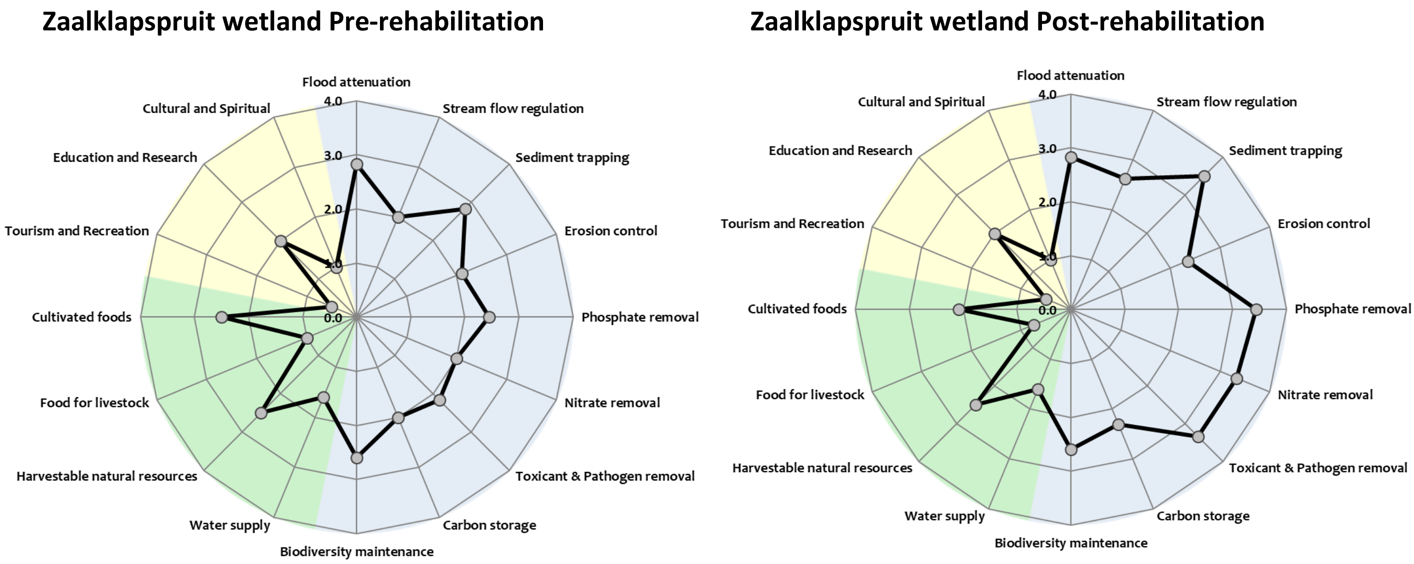
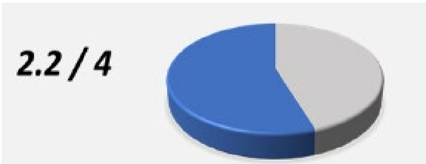


Figure 18.4: A summary of the ecosystem supply scores for the Zaalklapspruit wetland pre- and post-rehabilitation.

In relation to the second question addressed by the case, namely "What specific contribution has the wetland rehabilitation made to the trapping of toxicants?" it is noted that the supply score improved from 2.2 to 3.3, with 4 being the maximum score possible. Therefore, it could be stated that based on the WET-EcoServices assessment, the capability of the wetland for trapping toxicants has been increased from 55% of the maximum "ideal plausible" capability of a wetland to 83% of this maximum. This represents an overall improvement of 27%. However, it is important to note that this does not take into account the size of the affected area, and in order to do so, WET-EcoServices employs the concept of hectare equivalents of functionality (Table 18.1). From Table 16.1 it can be seen that the contribution of the rehabilitation to removing toxicants is 9 ha equivalents of functionality, i.e. equivalent to 9 ha of wetland with the maximum "ideal plausible" capability of removing toxicants.

Table 18.1: Calculating the contribution of the Zaalklapspruit rehabilitation to toxicant removal, as expressed in functional hectare equivalents.

	Pre-rehabilitation	Post-rehabilitation
Ecosystem service supply (functional capability)		
Size of the unit	31 ha	
Hectare equivalents of functionality	17 ha (31 ha x 2.2/4)	26 ha (31 ha x 3.3/4)
Contribution of the rehabilitation in terms of hectare equivalents	9 ha equivalents (26-17 ha)	

The functional hectare equivalent "currency" helps to make comparisons across different wetlands. For example, if rehabilitation of another wetland had an overall improvement of 54% but the wetland was only 6 ha in size then the contribution would be 3 hectare equivalents, which is a third of the contribution shown in Table 16.1 for the Zaalklapspruit wetland.

It is important to emphasize, however, that the functional hectare equivalent "currency" is an indirect semi-quantitative measure for comparative purposes. Where data are available directly quantifying a service, then these should be used for validating the assessment. In most cases, quantitative data would not be available. However, Zaalklapspruit is an unusual case in that direct evidence of the provision of water quality regulating services is available from the study of de Klerk et al. (2016) (also reported in Oberholster et al., 2016) which compared selected water quality parameters measured upstream and downstream of the rehabilitated Zaalklapspruit wetland, both before rehabilitation interventions and after rehabilitation interventions. The results of de Klerk et al. (2016) and Oberholster et al. (2016) confirm that while inflow concentrations of heavy metals such as Zinc remained similar pre- and post-rehabilitation, the outflow concentrations of these metals declined one to two orders of magnitude post-rehabilitation, confirming the substantial contribution of rehabilitation to trapping toxicants, at least in the short term.

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APPENDICES

Appendix A: An elaboration of the 36 ecosystem services included in the RAWES method of McInnes and Everard (2017)

Ecosystem service	Example	Examples of questions assessors can ask about this service
Provision of fresh water	Water used for domestic drinking supply, for irrigation, for livestock, etc.	• Does the wetland provide a source of fresh water? • Does the wetland store fresh water for human use? • Is the wetland a net source of pollution, degrading fresh water provision?
Provision of food	Crops, fruit, fish, etc.	• What is grown in the wetland, either formally or from informal harvesting? • Are animals are harvested from the wetland? • Are livestock using the wetland?
Provision of fibre	Timber for building, wool for clothing, etc.	• Are any natural materials such as wood, fibre, straw, animal fibre (wool/hide/sinew/antler/other) taken from the wetland?
Provision of fuel	Fuelwood, peat, etc.	• Is any material taken from the wetland and used as fuel for domestic or other uses?
Provision of genetic resources	Rare breeds used for crop/stock breeding, etc.	• Are any native or rare strains of plants and animals, wild and domesticated, which could contribute genetic diversity for human uses (for instance for drug manufacture, improving resilience of domestic animals and plants, horticultural trade, etc.)
Provision of natural medicines and pharmaceuticals	Plants used as traditional medicines, etc.	• Are there any plants, animals or their parts derived from the wetland which are harvested and used for their medicinal properties?
Provision of ornamental resources	Collection of shells, flowers, etc.	• Are there any plants, animals or their parts are derived from wetland that are collected and used/sold for their ornamental properties?
Clay, mineral, aggregate harvesting	Sand and gravel extracted for building use, clay extracted for brick-making, etc.	• What substances are extracted or dug up from the wetland for construction or other human uses?
Waste disposal	Dumping of solid waste, discharge of waste water, etc.	• Does the wetland provide a location for the disposal of liquid, solid or other waste materials?
Energy harvesting from natural air and water flows	Water wheels driven by flowing water, windmills driven by the wind, etc.	• Are any technologies (water wheels, wind turbines, etc.) used to capture natural flows of energy through or across the wetland?
Air quality regulation	Removal of airborne particles from the exhaust of cars, chimneys of industry, dust from agricultural land, etc.	• Is there a source for airborne pollutants? • Does the wetland habitat structure help to settle out airborne pollutants? • Does the state of the wetland make it a source of air pollutants (microbial, particulate or chemical)?
Local climate regulation	Regulation of the local microclimate, through shading, reducing air temperature, etc.	• Does the wetland habitat structure provide shade for humans? • Does the wetland have areas of standing water with or without vegetation that will be generating evapotranspiration and consequently reducing air temperatures?
Global climate regulation	Regulation of the global climate through control in greenhouse gas	• Does the wetland store and/or sequester carbon?

Ecosystem service	Example	Examples of questions assessors can ask about this service
	emissions, the sequestration of carbon, etc.	• Does this balance with generation of methane and other greenhouse gases?
Water regulation	Regulation of flows of surface water during high and low flows, regulation of recharge of groundwater, etc.	• Do the topography, permeability and roughness of the wetland enable it to store water during high rainfall/discharge and top slowly release it back to surface waters or to groundwater? • Does the wetland regulate discharges during dry periods to buffer low flows during dry weather?
Flood hazard regulation	Regulation and storage of flood water, regulation of intense rainfall events, etc.	• Does the wetland regulate, store and retain floodwaters? • Does the wetland store rainfall and surface water that might contribute to flooding and damage to property or ecosystems downstream?
Storm hazard regulation	Regulation of tidal or storm surges, regulation of extreme winds, etc.	• Does the complexity of habitat, particularly trees, tall reeds and other vegetation and surface topography, absorb energy from extreme events such as storms and waves that might otherwise damage property or adjacent ecosystems?
Pest regulation	Control of pest species such as mosquitoes, rats, flies, etc.	• Do natural predation and other ecological processes in the wetland regulate and control pest organisms? • Is the wetland a source of pests (for example rats thriving in dirty water systems)?
Regulation of human diseases	Presence of species that control the species (vectors) that transmit human diseases such as malaria, schistosomiasis, etc.	• Do natural predation and other ecological processes in the wetland regulate organisms that may cause human diseases? • Are faecal deposits, bacteria or other potentially pathogenic microbes immobilised by processes in the wetland? • Is the condition of the wetland contributing to the negative spread of populations of disease vectors (such as mosquitoes)?
Regulation of diseases affecting livestock	Presence of species that control the species (vectors) that transmit diseases to livestock, e.g. leptospirosis	• Do natural predation and other ecological processes in the wetland regulate organisms that may cause diseases in livestock? • Are faecal deposits, bacteria or other potentially pathogenic microbes immobilised by processes in the wetland? • Is the condition of the wetland contributing to the negative spread of populations of disease vectors (such as mosquitoes or snails)?
Erosion regulation	Regulation of energy environment to reduce risk of erosion, presence of dense vegetation protecting soils, etc.	• Does the wetland vegetation provide protection from erosion for the soils? • Are there any signs of erosion, such as bare earth, in the wetland?
Water purification	Cleaning of water, improvement of water quality, deposition of silts, trapping of contaminants and pollutants, etc.	• Do physico-chemical (sunlight exposure in shallow waters, detention of water in aerobic and anaerobic microhabitats) and biological processes in the wetland result in the breakdown of organic, microbial and other pollutants in the water passing though? • Are suspended solids deposited? • Is there a noticeable change in the quality, such as the turbidity, of water entering and leaving the wetland?
Pollination	Pollination of plants and crops by pollinators such as bees, butterflies, wasps, etc.	• Do populations of pollinating organisms (butterflies, wasps, bees, bats, etc.) in the wetland contribute to pollination within the wetland? • Do pollinators using the wetland also help to pollinate nearby crops, gardens, allotments, etc.?
Salinity regulation	Freshwater in the wetland provides a barrier to saline waters.	• Does the hydrology of the wetland help prevent saline water contaminating freshwaters? • Does the presence of freshwater in the wetland prevent the salinisation of soils?
Fire regulation	Providing physical barriers/wet conditions to the spread of fire, etc.	• Does the configuration of waterbodies (ditches, streams, etc.) help to prevent the spread of fires?

Ecosystem service	Example	Examples of questions assessors can ask about this service
		• Is there water at or near the soil surface that restricts the spread of fire? • Are organic rich or peat soils drained and susceptible to fire and burning?
Noise and visual buffering	Wetland trees or tall reeds absorbing and buffering the impact of noise.	• Is there a source (busy road, industry, construction, etc.) and receptor (houses, wildlife, etc.) for noise pollution? • Does wetland ecosystem structure, particularly tall trees and reeds, provide visual screening as well as suppress noise transmission?
Cultural heritage	Importance of the wetland for historical or archaeological value, as an example of traditional uses, etc.	• Does the wetland system have cultural importance, either due to its natural character or traditional uses or management practices, as a cultural landscape?
Recreation and tourism	Importance of the wetland for providing a location for recreation such as fishing, water sports or swimming, or as a tourism destination, etc.	• Is the wetland used for organised or informal recreational purposes? • Is there infrastructure provided for access and recreation? • Are their wider tourism/ecotourism benefits flowing from these uses?
Aesthetic value	The wetland is overlooked by properties, is part of an of known area of natural beauty, is used as a subject for painters and artists, etc.	• Does the wetland provide aesthetic benefits through the desirability of siting houses of commercial development adjacent to it? • Does the presence of a wetland have a significant impact on property prices? • Is the wetland depicted in many works of art?
Spiritual and religious value	The wetland holds plays a role in local religious festivals, the wetland is considered as a sacred site, the wetland forms part of a traditional belief system, etc.	• What spiritual and/or religious values do people derive from the wetland? • Does the wetland hold any important spiritual or cultural value to people? • Does the wetland play any part in traditional religious ceremonies? • Are there any traditional wetland management practices (such as the timing of planting and cropping of rice to Buddhist or other traditions
Inspirational value	Presence of local myths, stories, histories (oral or written) or art/design relating to the wetland	• Are there any particular myths or other folklore associated with the wetland? • Do any wetland animals appear or are featured in local stories and myths? • Does the wetland inspire people to create music or other forms of art? • Have particularly ways of designing and building developed which reflect the wetland?
Social relations	Presence of fishing, grazing or cropping communities which have developed within and around the wetland.	• Have communities formed around the wetland and its uses, including for example fishing (subsistence, commercial and recreational), cropping or stock management, walking and jogging, birdwatching and photography, etc.?
Educational and research	Use of the wetland for education and research.	• Is the wetland used for any educational purposes, organised or informal, ranging from school-level visits to university research and teaching? • Are there any public awareness or educational materials present?
Soil formation	Deposition of sediment, accumulation of organic matter, etc.	• Do accretion processes (both sedimentation of mineral material and the build-up of organic material) on the wetland result in the formation of soils?

Ecosystem service	Example	Examples of questions assessors can ask about this service
Primary production	Presence of primary producers such as plants, algae, etc.	• Do photosynthetic processes on the wetland produce organic matter and store energy in biochemical form?
Nutrient cycling	Source of nutrients present from inputs from agricultural land, internal cycling of plant material, inputs of nutrients from floodwaters, presence of fauna to recycling nutrients, etc.	• Do wetland processes biochemically transform nutrients (for example nitrification/denitrification)? • Are nutrients settled out in particulate forms, changing the characteristics of water passing through the system? • Are there abundant invertebrates and detritivores that are decomposing and cycling organic material?
Water recycling	Presence of wetland vegetation and open water result in evapotranspiration and local recycling of water, relatively closed canopies and low exposure to winds retains water in local cycles, sandy or coarse substrates allow exchange with groundwaters, etc.	• Does the structure of the wetland retain water in tight cycles (for example recapture of vapour produced by evapotranspiration)? • Does the wetland enable exchanges with groundwater (either discharge or recharge)?

Appendix B: A preliminary desktop guide for assessing wetland ecosystem services based on hydrogeomorphic type (adapted from Kotze 2019)

South Africa has a great diversity of wetland types and climatic contexts, and an attempt is made in Table B1 to represent how some of this diversity influences the supply of range of different ecosystem services.

Table B1: Preliminary rating[1] of the ecosystem services potentially supplied by a wetland based upon its hydrogeomorphic (HGM) wetland type, and climatic setting (**humid to sub-humid and semi-arid**)

Ecosystem services: / HGM types	Flood attenuation	Sediment trapping	Erosion control	Streamflow regulation	Water quality regulation	Carbon storage	Water provision	Grazing	Plants for crafts & construction	Medicinal plants	Indigenous/ wild foods	Cultivated foods	Tourism & recreation
Floodplain wetland[2]	3.5	3	3	1	3	2.5	3	4	3	3	3	4	4
	4	3.5	3	0.5	2.5	1.5	2	4	2	2.5	3	4	4
Valley-bottom wetland, channelled	2	3	3	2	3.5	2.5	3	3	3	4	2	3	3
	3	3	3	1.5	3	1.5	2	3	2.5	3	2	3	2.5
Valley-bottom wetland, unchannelled	2.5	4	4	1.5	4	4	3	3	4	3	2	3	3
	3.5	4	4	1	3.5	2	2	3.5	3.5	2.5	2	3	2.5
Seep with channelled outflow[3]	1.5	1	3	3	2	3	4	3	3	4	2	3	2
	2	1	3	3	1.5	2	3	3	2.5	3.5	2	3	2
Seep without channelled outflow	1.5	1	2	1	1.5	2.5	1.5	3	2	3	1	3	2
	2	1	2	0.5	1	1	0.5	2	1.5	2	1	2	1.5
Depression, exorheic[4]	2	1	1	1	2	3	3	3	2	1	3	2	3
	2.5	1	1	0.5	1.5	1.5	1	1.5	1.5	1	3	2	2
Depression, endorheic	2	1	1	0	1	2	1	2	1	1	3	1	3
	2.5	1	1	0	0.5	1	0	1	0.5	0.5	2	0	2
River channel	2	2	3	2	2.5	1	4	2	2	2	3	1	4
	2.5	2	3	2	2	0.5	2.5	2	2	2	3	1	3

[1]The same range in scores from 0 to 4 is used as is applied by WET-EcoServices (Kotze et al., 2008) with 0 indicating a likely absence of the service, 2 an intermediate importance and 4 a very high importance.

[2]A floodplain wetland is taken as typically comprising predominantly floodplain flat with floodplain depressions contained within the flat. If a particular floodplain unit is characterized by the very limited extent of depressions then this unit is probably best treated as a channelled valley bottom unless it is particularly wide (i.e. > 500 m).

[3]A seep with channelled outflow is assumed to be supplied with a sustained source of sub-surface water, including groundwater and deep interflow.

[4]Exorheic depressions generally experience flushing, which prevents the accumulation of solutes. However, under arid conditions this flushing will often be inadequate to prevent such accumulations, and therefore under arid conditions these depressions may need to be treated as endorheic in terms of water provision.

Rationale underlying Table B1 – Regulating services

The rationale for the influence of HGM wetland type over regulatory services is largely based on Kotze et al. (2008). However, some adjustments have been made, in particular taking into account the catchment interception potential (as elaborated upon by Hansen et al. [2018]) of the respective HGM units, which was not accounted for by Kotze et al. (2008). Further rationale, mainly concerning the influence of climatic context is given below.

Flood attenuation: If a wetland is already flooded on arrival of a flood event then its capability to attenuate floods is lower than if it was in a dry state on arrival of the flood, and areas which remain flooded for prolonged periods are generally most extensive in wetlands in humid climates and least extensive in wetlands in arid climates, which tend to be ephemerally flooded.

Sediment trapping: This is assumed to be less affected by the climatic context than the HGM type, but as described by Grenfell et al. (2014) climate may influence sediment trapping through its influence over how sustained/episodic streams in the wetland are likely to be.

Streamflow regulation: HGM wetland types scored highest in terms of streamflow regulation are those most likely to be sustained most by groundwater or deep interflow, i.e. with sustained water sources. As discussed earlier, a key factor limiting the extent to which a wetland sustains streamflow is evapo-transpirative loss, which is already potentially high in humid climates and increasing progressively with increasing aridity.

Water quality regulation: A variety of processes including chemical precipitation, adsorption and ion exchange contribute to the assimilative capacity of a wetland, and several of these required sustained reducing conditions, which are associated with prolonged saturation. Such conditions are most prevalent in humid climates, and progressively declining in extent and duration with increasing aridity. They are also more prevalent in certain HGM wetland types, notably unchannelled valley bottoms.

Carbon storage: Soil organic matter is promoted under sustained reducing conditions, which are associated with prolonged saturation, which, as indicated above, are most prevalent in humid climates and in certain HGM wetland types.

Rationale underlying Table B1 – Provisioning services

Water provision: A hillslope seepage feeding a stream channel is assumed to generally be maintained by a sustained supply of sub-surface water discharging to the ground surface. This type includes areas which would be referred to as springs, and it generally provides a reliable source of clean water, often even in semi-arid conditions. Springs remain a critical source of water for many rural communities without access to reliable piped water. In contrast, seeps without channelled outflow are generally maintained by a less sustained supply of water, rendering these areas less reliable sources of water. The inward-draining character of endorheic depressions generally results in a concentration of solutes through evaporation in the wetland, leading to water which is naturally poor for human consumption.

Besides the lower volumes of water generally stored in wetlands under semi-arid conditions than under humid conditions, the prevalence of salt accumulation is also much more likely under semi-arid conditions than under humid conditions, which impacts negatively on the value of this water for human use.

Grazing: Many floodplains are occupied by a large proportion of seasonally flooded or saturated grasslands of high grazing value, particularly in the flat and shallow depression areas of the floodplain. The other hydro-geomorphic types tend to have a lower proportion of these grasslands, but nonetheless generally provide valuable grazing. In terms of climatic context, under humid conditions, the prolonged flooding of extensive areas of the wetland limits access to some of the potentially grazable and harvestable resources. In semi-arid climates resources are more accessible but tend to be present even in the dry season.

Plants for crafts: Unchannelled valley-bottom wetlands are generally characterized by permanent saturation and deep sediments, and the most prolific growth of fibrous plants that are typically used for crafts. In contrast, endorheic depressions and seeps without channelled outflow generally have the least prolific growth of fibrous plants.

***Medicinal plants**:* Wentzel and Van Ginkel (2012) list hydric species used for medicinal purposes according to preferred HGM wetland type, which allows for HGM wetland types to be scored according to their potential supply of medicinal plants. Channelled valley-bottom wetlands are scored the highest given that the greatest number of medicinal hydric species is listed as occurring in this HGM wetland type. In contrast, depressions have the lowest number of listed medicinal hydric species.

Indigenous or wild foods: Rivers provide the most extensive habitat for a variety of indigenous and introduced fish species used for human consumption. In addition, key habitats for fish, floating aquatic plants, frogs and many birds are depressions, including isolated depressions, as well as depressions contained within floodplains which are most important for fish. Mammals and grasshoppers are generally most favoured where grazing is good.

Cultivated foods: In scoring the HGM wetland types according to their potential for the cultivation of food, the types are considered in terms of (a) supply of water and nutrients and (b) limitations in terms of salts or excess wetness. As explained for 'Water provision', endorheic depressions are often characterized by a high concentration of salts, resulting in their generally being unsuitable for cultivation. Exorheic depressions typically do not accumulate solutes to the same degree as endorheic depressions, but deep flooding limits cultivation, at least seasonally. Unchannelled valley-bottom and seeps with channelled outflow are generally characterized by excessive wetness, which can usually be practically overcome, primarily through artificial drainage. However, while this may be relatively easily achieved for seeps, which are generally small, for large un-channelled wetlands with gentle longitudinal slopes, artificial drainage may require a considerable investment and also have potentially considerable environmental impacts.

Tourism and recreation: Two key linked features considered in scoring importance for tourism is the presence of open water and wetland-dependent birds. Open water areas are generally very limited or absent in Hillslope seepages and most extensive in depressions and the depression component of floodplains.

'Education and Research' and 'Cultural experience', both of which are likely to be strongly related to the social context of the wetland, are not included in Table B1. It is considered inappropriate to single out specific HGM wetland types for research value given that research is required for all types. It is also difficult to single out specific HGM wetland types which are of particular cultural value. However, wetlands which store water, particularly those which occur in a relatively dry climate, where water is scarce, seem to feature most prominently amongst the wetlands with a high cultural significance. In addition, several of the crafts produced from wetland plants have cultural significance, for example traditional sleeping mats continue to play an important role in the exchange of gifts at many weddings in KwaZulu-Natal (Kotze and Traynor 2011). Thus, 'water provision' and 'plants for crafts' could potentially be used as surrogates for cultural heritage.

Appendix C: Indicators omitted from the technique

This section lists indicators omitted from the final draft of WET-EcoServices Version 2 which were originally included in WET-EcoServices Version 1. The omission of indicators is seen in the context of maintaining the technique as rapid. However, it is noted some of these indicators may be useful in more detailed assessments.

Omitted indicator	Reason/s behind the omission
Size of the HGM unit relative to the HGM unit's catchment	This indicator, which was only used for flood attenuation, was replaced by an indicator of the absolute size of the unit's catchment, which was also used for all water quality regulating services.
Sinuosity of the stream channel	This indicator, which was only used for flood attenuation, is one of several factors influencing the frequency with which storm flows spread across the Assessment Unit. Given this fact and the fact that the frequency with which storm flows spread across the Assessment Unit is an indicator, it was decided to omit this indicator.
Level of direct application of fertilizers/biocides to the wetland.	In WET-EcoServices Version 1, direct application is now combined with fertilizer/biocide sources in runoff from the wetland's catchment as both contribute to demand for water quality enhancement services
Contribution of sub-surface water inputs relative to surface water inputs.	In the absence of already available detailed information, this is a difficult indicator to assess at a rapid level. In addition, WET-EcoServices Version 1 only used this indicator for assessing a single service, namely nitrate assimilation.
Level of cumulative loss of wetlands in the catchment	Historical extent of wetlands lacking in most catchments, making this a very challenging indicator to assess at a rapid level.
Alteration of natural hydrological regime	Recognizing that the purpose of WET-EcoServices is not to cover ecological condition in any detail, these several indicators of ecological condition have been replaced by vegetation condition, which is taken as an overall integrating surrogate of ecological condition.
Alteration of sediment regime	
Alteration of water quality regime	
Removal of indigenous vegetation	
Invasive and pioneer species encroachment	
Presence of fences, roads, weirs, powerlines and other obstructive/hazardous barriers	This indicator has been included as a modifying factor when scoring the connectivity of the wetland/riparian area.
Total number of different natural resources used in the HGM unit.	In WET-EcoServices Version 2, several new indicators have been added dealing with specific natural resources, e.g. livestock grazing, sedges and grasses and medicinal plants, thereby replacing this indicator.
Level of poverty	This indicator has been included as a factor to consider when scoring the level of dependency on certain provisioning services in the absence of specific information about dependency.
The total number of different crops cultivated in the HGM unit	While it is still recognized that cropping with several crops contributes to increased resilience of a cropping system, this indicator was deemed not to be critical in terms of either supply or demand to the service that wetlands provide for crop production.
Registered SAHARA (South African Heritage Resources Agency) site	This indicator was omitted because a review of over 50 different wetland sites across a great variety of land-use contexts showed that none of these were SAHARA sites, suggesting that it is likely to be a very uncommon occurrence for wetland/riparian areas to be registered as SAHARA sites.