Supporting better decision-making around coal mining in the Mpumalanga Highveld through the development of mapping tools and refinement of spatial data on wetlands

Report to the

WATER RESEARCH COMMISSION

by

Namhla Mbona, Nancy Job, Janis Smith, Jeanne Nel, Stephen Holness, Siyabulela Memani and John Dini

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Obtainable from
Water Research Commission
Private Bag X03
GEZINA, 0031

orders@wrc.org.za or download from www.wrc.org.za

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The appendices listed on the last page of this report all appear on the enclosed CD.

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EXECUTIVE SUMMARY

BACKGROUND

The Mpumalanga Highveld region of South Africa contains one of the highest concentrations of Freshwater Ecosystem Priority Areas (FEPAs) in the country. The unique grassland and wetland association within the area is host to numerous threatened and conservation-worthy species and ecosystems. The area is also the source of several of the country's major rivers, which collectively contribute 26% of South Africa's natural mean annual runoff and 28% of its available water yield. Beneath the surface, the Mpumalanga Highveld straddles coalfields that are estimated to collectively contain 51% of national recoverable coal reserves.

Opencast mining methods used to extract this coal frequently have significant negative impacts on overlying water-related ecosystems and their constituent biodiversity, and thereby on the ability of these ecosystems to continue to provide water-related ecosystem services to adjacent and downstream users. This region is thus at the centre of a significant water-biodiversity-energy nexus in which the trade-offs are currently more visible and contested than anywhere else in the country.

RATIONALE

It is the intention that focussing the project within this area will help to mitigate the land-use conflicts and encourage integrated development that accounts for the significant role played by biodiversity and ecosystem services in supporting sustainable development. Regulatory decisions about land-use planning and development rely heavily on the availability and quality of data. The National Freshwater Ecosystem Priority Areas (NFEPA) project achieved a significant step in mapping and prioritising freshwater ecosystems within South Africa. However, the national scale of the project means that finer-scale applications are constrained by data accuracy issues. In an area such as the Mpumalanga Highveld, where highly accurate data is needed to support regulatory decision-making, further refinement of the wetland data is essential. Not only is such data important to regulatory decision-making, but it also forms the basis for a number of decision support tools and guidelines being developed for the mining sector.

OBJECTIVES AND AIMS

Designed within the above context, this project set out to achieve the following aims:

Aim 1

To ground-truth and refine the current data layers on the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt, in order to support informed and consistent decision-making by regulators in relation to the water-biodiversity-energy nexus.

Aim 2

To incorporate these revised data layers into the atlas of high-risk freshwater ecosystems and guidelines for wetland offsets, currently being developed by the South African National Biodiversity Institute (SANBI), in order to improve the scientific robustness of these tools.

Aim 3

To support the uptake, and development of the necessary capacity to apply the data, atlas and guidelines by regulators and the coal mining industry in their planning and decision-making processes.

METHODOLOGY

A total of 365 quinary catchments spread across four Water Management Areas (WMA) within the Mpumalanga Highveld were targeted by the project. This study area was chosen such that it encompasses the majority of the opencast coal mining activities taking place in Mpumalanga. A three-step approach was taken in the refinement of wetland data within these areas. The approach was developed with the intention of being applicable throughout the country, in order to support similar validation exercises of wetland spatial data in other areas. Firstly, desktop preparation was conducted with a thorough review of existing data. Wetland boundaries were delineated using aerial imagery and topographic data. Secondly, a subset of selected wetlands was visited in the field for further ground-truthing and validation of the digitised data. Finally, the field and desktop data were collated and reviewed by wetland and GIS specialists. At each of these steps, data on wetland boundaries, type and condition were collected.

Training on wetland identification and desktop delineation was conducted during the course of the project. The primary result was an updated spatial dataset for the wetlands of the Mpumalanga Highveld. Additional analysis was conducted on this dataset to determine changes to ecosystem threat status, protection level and Freshwater Ecosystem Priority

Areas (FEPAs) arising from refinement of the wetland data. The updated wetland data are now available for integration into a number of decision support tools and guidelines.

RESULTS AND DISCUSSION

Aim 1: To ground-truth and refine the current data layers on the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt.

An updated spatial dataset of wetlands in the Mpumalanga Highveld was developed (MHWet). Wetlands, amounting to a total area of 590 391 ha, have been mapped to date, representing 19.8% of the surface area in the study area. This contrasts strongly with the previous best state of knowledge, in the form of the National Wetland Map 4 (NWM4), which contained wetlands amounting to only 213 579 ha (or 7.2%) in the same area.

The final MHWet map identified 49 wetland ecosystem types in the study area, including one that has not been previously mapped in the country (Mesic Highveld Grassland Group 7_Floodplain), and two types that were not previously identified in the study area (Central Bushveld Group 1_Floodplain and Central Bushveld Group 2_Seep).

Approximately 30% of wetlands in the region are now mapped with a high degree of confidence. Comparisons between the datasets show that, for the study area, the national-scale NWM4 data had a wetland detection accuracy of 54% and a spatial extent accuracy of 25%. MHWet results indicate that 39% of the wetlands in the region are in good ecological condition and 18% are in moderate condition, while 43% are in poor condition. As a result of the improved data, the ecosystem threat status and protection level levels for the wetland types in the study area were updated from those originally calculated through the 2011 National Biodiversity Assessment. The threat status of 23 wetland ecosystem types was decreased, and no wetland types were upgraded to higher threat status. Improvements in ecosystem protection level are recommended for nine ecosystem types. The area of FEPAs in the study area increased from 27% of the wetland area in the Mpumalanga Highveld to 36%. This increase is a result of the increased extent of the newly mapped wetlands in MHWet, combined with the increased extent of good condition wetlands.

Aim 2: To incorporate these revised data layers into the atlas of high-risk freshwater ecosystems and guidelines for wetland offsets.

The updated wetland data have been, or will be, incorporated into the *Mining and Biodiversity Guideline*, *Wetland Offsets Guideline* and the *Decision support tool for high-risk wetlands*. In the *Mining and Biodiversity Guideline*, the revised wetland layer feeds into the category of areas of highest biodiversity importance, especially through the additional area of wetlands classified as FEPAs. The *Wetland Offsets Guideline* is based on a data driven assessment of the size and significance of residual impacts on wetlands. The accuracy of this assessment is enhanced through the improved robustness of the underlying primary data on the size, type and condition of the wetlands provided by MHWet. In addition, the offset ratios used in the *Wetland Offsets Guideline* draw heavily on secondary analyses such as assessments of the ecosystem threat status and protection levels for wetlands. The current project, which has significantly improved the quality and reliability of the wetland data in the area of concern, will result in a major improvement in the *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga*.

Aim 3: To support the uptake, and development of the necessary capacity to apply the data, atlas and guidelines by regulators and the coal mining industry in their planning and decision-making processes.

The updated Mpumalanga Wetland Map (MHWet) can be accessed on the SANBI Biodiversity GIS website at http://bgis.sanbi.org/MHwetlands/project.asp. Dissemination channels for the updated wetland data are strong, given that the data will feed into the decision support tools and guidelines mentioned above. These tools are all available and will be updated through a range of web-based GIS portals or will be distributed as stand-alone GIS viewers. Uptake of the tools and guidelines has been supported by almost two years of training and capacity building through the SANBI programme of work on mining, which is ongoing. Over 1000 participants have attended training workshops on the *Mining and Biodiversity Guideline* and *Wetland Offsets Guideline* thus far, from a range of stakeholder organisations including mining houses, non-governmental organisations, consultants and government. Most of the participants felt that the training was effective in improving understanding of the key content of the guidelines and that the *Mining and Biodiversity Guideline* had been helpful in integrating biodiversity issues into mining more effectively.

Although initially piloted for mining, ultimately these tools will be applicable to any activity that impacts on wetlands. The improved wetland data as a result of this project has thus strengthened existing tools and will enable mining houses and regulators to take full cognisance of wetland, water resource and biodiversity issues, in pursuit of a set of optimal development scenarios for the Mpumalanga Highveld.

In addition to the above, the project also produced a wetland inventory manual, still to be published by the Water Research Commission, which provides a standardised set of guidance to those interested in mapping wetlands at a systematic, landscape scale or to those involved in improving the National Wetland Map. These standardised methods are a key output of the project, are nationally applicable and should not be overlooked, even though the primary emphasis of the project was on improving the spatial data for Mpumalanga. Future initiatives to update inventory data at local scales will benefit by not having to invest in method development to anything like the extent that this project did. The use of these methods in other mapping projects should result in the generation of data that is compatible with the National Wetland Inventory, making it easier to incorporate the resulting data into the National Wetland Map.

CONCLUSIONS

This project has contributed to the refinement of data on the extent, distribution, condition and type of wetlands in the study area. Standardised methods for ground-truthing and refining the NFEPA data have been developed, providing a consistent methodological platform for improving the quality of spatial wetland data in other parts of the country. Additionally, accuracy and confidence of wetland data have been significantly improved.

Through this process, capacity in Mpumalanga was strengthened and uptake of tools was encouraged. The project created valuable opportunities to network and to identify areas of expertise and skills within the province and the stakeholder group. It also built on existing expertise and engaged with the Mpumalanga wetland community of practice to develop the capacity of people in relevant institutions, through learning-by-doing and onsite training.

The revised wetland data will be incorporated into the existing architecture of the National Wetland Inventory of which SANBI is the curator. The improvements to the data have implications for:

- Ecosystem threat status for wetland ecosystem types and wetland vegetation types, including the need to update the ecosystem threat status in the National Biodiversity Assessment (NBA) 2011 and contributing to setting the basis for potentially listing specific freshwater ecosystem types as “Threatened” under the provisions of the National Environmental Management: Biodiversity Act (No. 10 of 2004).
- Ecosystem protection levels for wetland ecosystem types, including the need to update the ecosystem protection levels for 9 of the wetland ecosystem types in the NBA 2011.
- Freshwater Ecosystem Priority Areas, in which the wetland area has increased by 9%.

The National Freshwater Ecosystem Priority Areas (NFEPA) project provides an extremely effective foundation for national, provincial and catchment-scale strategies for conserving freshwater biodiversity. NFEPA maps are widely used in a range of applications, including by DWS and other regulatory authorities for decision-making pertaining to mining, and by SANBI to underpin tools being developed through its mining work. The results of this project have quantitatively illustrated, in no uncertain terms, the extent of wetland area in the Mpumalanga Highveld that was not captured in NWM4, and hence in the NFEPA project. Similar mapping accuracies to those found in the Mpumalanga Highveld study area can be expected in the rest of the country, suggesting that the weaknesses in NWM4 are sufficiently severe and widespread to warrant investment in the improvement of the quality of the National Wetland Map as a matter of urgency.

RECOMMENDATIONS FOR FUTURE RESEARCH

Building on lessons learned during this project, a set of recommendations are presented, spanning the various elements of work covered by the project.

Recommendations for further improvement of the new dataset of Mpumalanga Highveld wetlands:

1. Ensure appropriate messaging accompanies the dissemination of the dataset.
2. Undertake further ground-truthing.
3. Refine wetland typing in the dataset.
4. Improve confidence in the assignment of HGM types.
5. Use quinary catchments as the units for reviewing wetland data.
6. Refine GIS techniques for capturing data.
7. Agree on the final set of attributes for the dataset.
8. Secure and incorporate other wetland datasets.

Recommendations for the development of a high confidence wetland inventory for the entire Mpumalanga Province

1. Establish the necessary partnerships and clarify roles and responsibilities of the partners.
2. Link provincial wetland mapping processes to the provincial aquatic conservation plan.

Recommendations for mapping wetlands at a systemic landscape scale

1. Develop a national strategy for updating the National Wetland Map.

2. Employ the wetland inventory manual compiled through this project as a standardised approach for wetland mapping and ground-truthing of NFEPA data in other catchments.
3. Adopt a catchment-based approach when selecting study areas for mapping initiatives, and ensure that these areas are small enough to be manageable.
4. Ensure the capacity of mapping project teams corresponds to study area size and contains both wetland and GIS technical expertise.
5. Invest in capacity building as a central and ongoing component of any wetland mapping project.

Recommendations for updating national products that rely on wetland maps

1. Standardise the approach used for updating other products that draw on spatial wetland data.
2. Update national products that draw on spatial wetland data at the appropriate frequencies.

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This project would not have been possible without the visionary approach adopted by the magistrate and prosecutor in the matter (case 462/07/2009, Ermelo Regional Court) between the State and a coal mining company charged with contravening the National Water Act and National Environmental Management Act after illegally mining within a wetland and diverting a river, among other activities. In return for agreeing to plead guilty to the charges, the mining company received a fine of R1 million, suspended for five years; agreed to rehabilitate the damage caused; and pay R1 million to each of the Water Research Commission, Mpumalanga Department of Economic Development, Environment and Tourism, and the Mpumalanga Tourism and Parks Agency. At the time, this was the largest penalty ever imposed on a mining company in a criminal prosecution for environmental violations. In addition, the restitutive elements of the plea agreement, in the form of the requirement for rehabilitation of the affected ecosystems and payments to government agencies supporting water resource and environmental management of water, enabled these agencies to strengthen their pursuit of their statutory mandates. It is the payment from the mining company to the Water Research Commission that enabled the Commission to procure the project described in this report, with the explicit aim of strengthening decision-making relating to mining and water resource management in the Mpumalanga coalfields.

This list would not be complete without acknowledging the Groen Sebenza programme for its role in bringing new talent into the biodiversity sector and enabling the programme "pioneers" to grow their careers while contributing to the successful completion of projects such as this one.

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LIST OF ABBREVIATIONS

CDSM	Chief Directorate of Surveys and Mapping
CMA	Catchment Management Agency
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DWA	Department of Water Affairs (now the Department of Water and Sanitation)
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EN	Endangered
FEPA	Freshwater Ecosystem Priority Areas
GIS	Geographic Information Systems
GPS	Global Positioning System
HGM	Hydro-geomorphic
LT	Least Threatened
MHWet	Mpumalanga Highlands Wetland Map
MTPA	Mpumalanga Tourism and Parks Agency
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act
NFEPA	National Freshwater Ecosystem Priority Areas
NGO	Non-governmental organisation
NWI	National Wetland Inventory
NWM4	National Wetland Map 4
SAEON	South African Environmental Observation Network
SAMBF	South African Mining and Biodiversity Forum
SANBI	South African National Biodiversity Institute
VU	Vulnerable
WMA	Water Management Area
WRC	Water Research Commission
WWF	World Wide Fund for Nature

1 INTRODUCTION AND OBJECTIVES

1.1 Context of the project

The National Freshwater Ecosystem Priority Areas (NFEPA) project identifies a set of priority areas which together meet national biodiversity goals for freshwater ecosystems. It also provides a single, nationally consistent information source for incorporating freshwater ecosystem and biodiversity goals into planning and decision-making processes. Multiple institutions have already invested significant funding and specialist time in the collaboration, which generated the *Atlas of Freshwater Ecosystem Priority Areas in South Africa: Maps to support sustainable development of water resources* (Nel *et al.*, 2011a) and its supporting technical and implementation manuals (Nel *et al.*, 2011b; Driver *et al.*, 2011). Based on the National Wetland Map 4 (NWM4), the NFEPA project was a tremendous step forward in consolidating existing information and generating new information on the distribution, type and condition of freshwater ecosystems. It represents the current best available national-scale spatial dataset on freshwater ecosystems. As a result, the NFEPA data is widely consulted, and the spatial data, in particular, is used in many other mapping exercises countrywide. However, experience in using the maps has shown that there is room to improve the underlying data (particularly the wetland layers) used to identify the Freshwater Ecosystem Priority Areas (FEPAs), and that this has implications for the confidence that can be attached to the information on ecosystem typing, condition and threat status generated by the NFEPA project.

The NFEPA project team acknowledged that, being national-scale, the datasets would not be completely accurate at fine scale and that there was an ongoing need to refine these datasets over time, using more localized approaches. The NFEPA dataset was developed as a guide to support decision-making, rather than being a decision-making tool in its own right. The importance of site level investigations and ground-truthing of the data wherever possible has been constantly emphasised, recognising that a national-scale dataset will always have limitations in terms of accuracy and level of detail.

The constant incremental refinement of the underlying datasets will ultimately permit the identification of FEPAs to be revisited at an appropriate time in the future. In the meantime, however, these datasets are also being used for a range of other applications, and for these it is important and urgent that the data is as accurate as possible, particularly in areas where decisions based on the data may be contested or result in significant impact. This is especially the case where the Department of Water and Sanitation (DWS, formerly the Department of Water Affairs) and other authorities are already using FEPA maps in regulatory decision-making, as applicants may challenge decisions if elements of the foundational data are perceived to be flawed.

Regulatory decision-making involving freshwater ecosystems is particularly relevant for the mining sector. In areas like Mpumalanga, with conflicting land uses and trade-offs between mining, food and water security, generating a clear and accurate picture of the extent, distribution, condition and type of freshwater ecosystems is an essential prerequisite to informed and consistent decision-making by regulators. This project thus presented a timely opportunity to develop standardised methods for ground-truthing and refining the NFEPA project data, and to apply these methods in an area where the trade-offs between mining and wetlands are highly contested.

The direct relevance of the project to mining does not only lie in the use of FEPA maps by DWS and other regulatory authorities for decision-making pertaining to mining. NFEPA project data already underpins tools being developed by the South African National Biodiversity Institute (SANBI) through its mining work, namely a *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* and *Wetland Offsets Guideline*, both of which are initially being directed primarily at the mining sector.

1.1.1 *Decision support tool for high-risk wetlands*

The *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* is being developed with co-funding from the CoalTech Research Association and has been tailored specifically for regulatory authorities and mining houses. It identifies those freshwater ecosystems that are of particular value for biodiversity targets and/or the provision of ecosystem services. This decision support tool allows both regulators and mining companies to identify the level of risk attached to mining in particular ecosystems. Risk in this context is a multi-dimensional concept that ranges from risk to environment and human well-being due to loss of ecological infrastructure and ecosystem services, to business and reputational risk to the mining company.

There is a bewildering range of biodiversity-related data available, which regulators and applicants alike are expected to take into account in planning and decision-making, including FEPA maps, threatened and protected ecosystems and species, protected areas and priorities identified under provincial systematic biodiversity conservation plans. Covering the coal mining areas of the Mpumalanga Highveld, *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* refines, collates and integrates these existing spatial data to provide a single, coherent product accessible to both specialist GIS users and general users. This is aimed at improving decision-making, providing clarity to mining houses and regulators, and ensuring everyone is using the same easily and freely available spatial data.

The *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* will thus allow the revised data generated by this project to be quickly disseminated as part of an existing process. Ground-truthing will dramatically improve the usefulness and robustness of the tool, which is likely to be used extensively across Mpumalanga by a sector that has a significant impact on freshwater resources.

1.1.2 *Wetland Offsets Guideline*

Associated with the task to identify high-risk wetlands, is a project to develop offset guidelines for wetlands (SANBI & DWS, 2014). Regulators, particularly the DWS, increasingly require that the permanent, residual impacts of mining on wetlands be compensated for by means of offsets. In response, there is a demand for consistent guidance on how wetland offsets should be implemented. This need is being met in the form of a set of best practice guidelines, currently at an advanced stage of development by SANBI with co-funding from CoalTech. The DWS has been instrumental in the process and has indicated its intention to adopt the guidelines formally, thereby giving them similar legal status to the wetland delineation guidelines (DWAF, 2005). Although initially being piloted for mining, energy and large scale infrastructure projects, ultimately these guidelines will be applicable to any activity that results in legally sanctioned loss of wetlands.

The *Wetland Offsets Guideline* also draws heavily on the ecosystem threat status and protection levels for wetland types, derived though the National Biodiversity Assessment (NBA, Driver *et al.*, 2012). The NBA was informed by the NFEPA project data. Multipliers used by the guidelines influence the size of the offset required, depending on the threat status of the ecosystem type that will be impacted upon by mining. The higher the threat status of the wetland type to be impacted upon, the greater the size of the wetland offset required. With large multipliers for Critically Endangered ecosystem types, the NBA threat status data probably has the most significant influence on the size of the offset required, and hence on the cost of the offset. Improved wetland data would contribute to the design of offsets that adequately compensate for lost wetland functioning in Mpumalanga.

Ground-truthing and refinement of the current data layers of the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt would also contribute to setting the basis for potentially listing specific freshwater ecosystem types as "Threatened" under the provisions of the National Environmental Management: Biodiversity Act (No. 10 of 2004). This listing is dependent on robust data on freshwater ecosystem type, condition of wetlands and threat status. Currently data are not of sufficient quality to allow this listing, and hence, unlike terrestrial habitat types, aquatic habitats in Mpumalanga are not effectively covered by this legislation.

1.2 Study area

The Mpumalanga Highveld comprises a wide, open area above the eastern escarpment (*Figure 1*). It is a temperate region, located almost entirely within the Grassland Biome, and is characterised by undulating hills dominated by grasslands and interspersed with wetlands and small areas of savanna. The unique grassland and wetland association within the area is also host to numerous threatened and conservation-worthy species and ecosystems. The Mesic Highveld Grassland Bioregion, which covers much of the study area, contains a number of ecosystems that are threatened and in need of protection, including the Eastern Highveld Grasslands (ecosystem threat status is Vulnerable) the Wakkerstroom / Luneberg Grasslands and Chrissiesmeer Panveld (both of which have an ecosystem threat status of Endangered (RSA, 2011). The grasslands are species rich, containing a number of endemic plants, such as the Barberton Daisy. Renowned for its exceptional birding opportunities, the Mpumalanga grassland and wetland ecosystems host a number of endemic bird species, with specials including Rudd's Lark, Botha's Lark and the Yellow-breasted Pipit. The area also has one of the highest concentrations of Freshwater Ecosystem Priority Areas (FEPAs) in the country.

Significantly, the Mpumalanga Highveld is a source of several of the country's major rivers. The Vaal component of the vast Vaal-Orange system originates in this area and flows westwards to the Atlantic. The Olifants River flows northwards from the region and the watersheds of the Komati River and the Great Usuthu River (a tributary to the Pongola River) drain eastwards. The Water Management Areas (WMAs) of which these rivers form part (i.e. Upper Vaal, Olifants, Inkomati and Usuthu-Mhlatuze) collectively contribute 26% of South Africa's natural mean annual runoff and 28% of its available water yield (DWAF, 2004). The rivers rising in the study area thus make an important contribution to South Africa's water security. Unfortunately, demand for water has already exceeded available supply in the Inkomati and Olifants WMAs (DWAF, 2004). The headwaters of these rivers are characterised by areas rich in wetlands that provide a range of ecosystem services, including regulating services (such as stream flow regulation, water purification and flood attenuation) that contribute to the sustainable functioning of the river basins, as well as provisioning (including grazing and water supply) and cultural services.

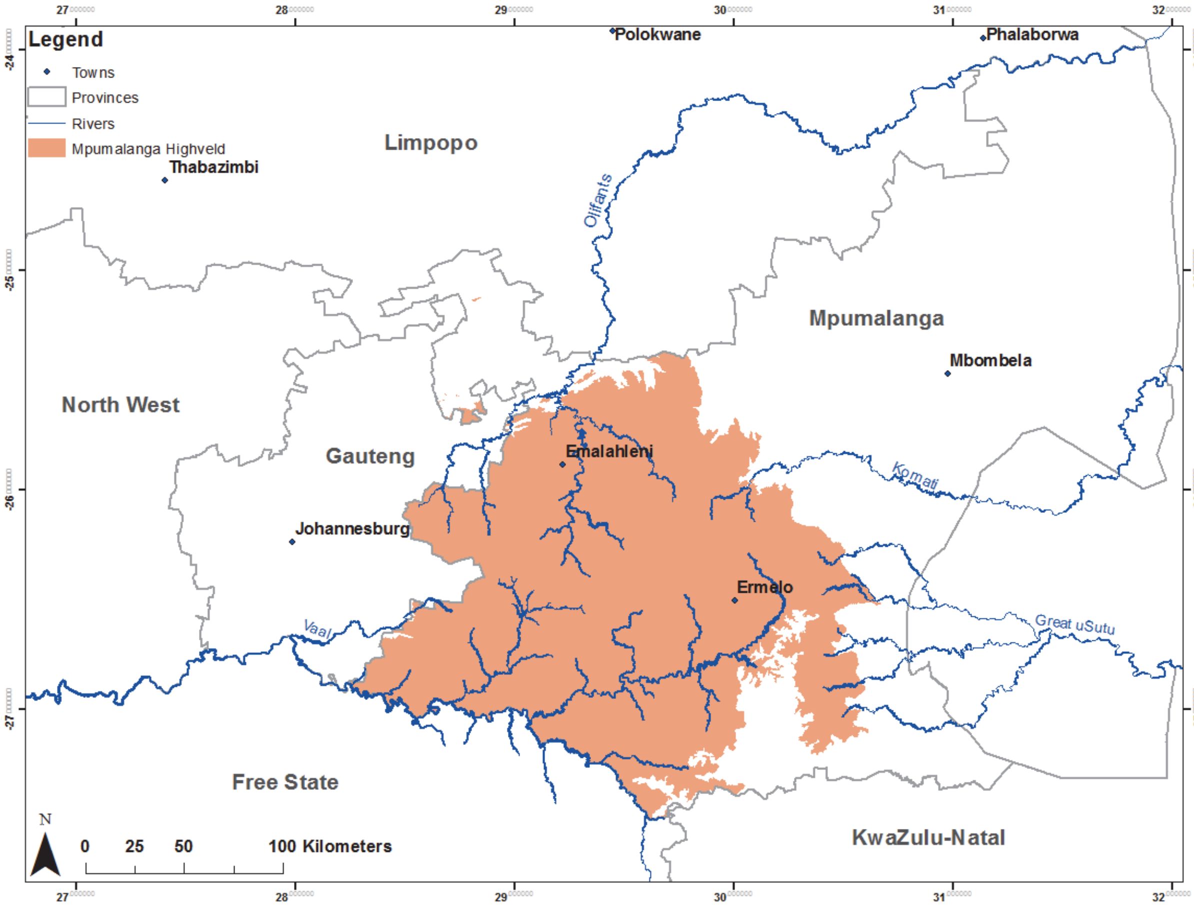


Figure 1: The Mpumalanga Highveld study area of the project.

The Mpumalanga Highveld is also a mineral rich area and central to large industry in South Africa. The Highveld, Ermelo and Witbank coalfields underlie the study area (Eberhard, 2011) and are estimated to collectively contain 51% of national recoverable coal reserves (WWF-SA, 2011). The size of these reserves, and the potential of their extraction to fundamentally transform the landscapes in which they are located, comes into clearer focus when it is taken into account that South Africa is the sixth largest coal producing country globally (Eberhard, 2011). Several large, international coal-mining companies and an increasing number of smaller independent mines operate extensively throughout the study area.

Coal accounts for 70% of primary energy consumption, 93% of electricity generation and 30% of petroleum liquid fuels in South Africa (Eberhard, 2011). The coal is primarily used within South Africa for power generation, but the Mpumalanga coalfields contribute extensively to exports from the coal terminal at Richards Bay (GCIS, 2013). Eleven operational coal-fired power stations are found in Mpumalanga, located in proximity not only to the coal reserves, but also to the enormous amounts of good quality water required throughout the year for power generation. Also located in the area are two coal liquefaction plants.

Aboveground, much of the Mpumalanga Highveld grasslands are used for agriculture, particularly rangeland for sheep (wool) and cattle (dairy). Large tracts of commercial forestry are also found, which provide timber for a number of large pulp mills.

The Mpumalanga Highveld is thus at the centre of a water-biodiversity-energy nexus within South Africa. Each of these competing land-uses is a necessary priority within the context of socio-economic development. The trade-offs required in this region, in relation to the water-biodiversity-energy nexus, are thus currently more visible and contested than anywhere else in the country. It is the intention that focussing the project within this area will help to mitigate the land-use conflicts and encourage integrated development that accounts for the significant role played by biodiversity and ecosystem services in supporting sustainable development.

1.3 Aims of the project

The project had the following aims:

1. To ground-truth and refine the current data layers of the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt, in order to support informed and consistent decision-making by regulators in relation to the water-biodiversity-energy nexus.
2. To incorporate these revised data layers into the atlas of high-risk freshwater ecosystems and guidelines for wetland offsets, currently being developed by SANBI, in order to improve the scientific robustness of these tools.
3. To support the uptake, and development of the necessary capacity to apply the data, atlas and guidelines by regulators and the coal mining industry in their planning and decision-making processes.

1.4 Approach of the project

The approach taken for the implementation of the project involved seven activities:

1. Develop a conceptual approach for aligning the ground-truthing with other relevant national and provincial processes.
2. Develop field-sampling procedures and standardised forms.
3. Train field workers.
4. Collate field data and populate in a GIS.
5. Compare field results with national and provincial broad-scale wetland assessments and examine the implications to mining planning, decision-making and management.
6. Revision of decision-support tools.
7. Capacity development with regulators, the mining industry and other stakeholders.

The approach for each of the activities is described below:

Activity 1. Develop a conceptual approach for aligning the ground-truthing with other relevant national and provincial processes.

A range of relevant initiatives and repositories for data on freshwater ecosystems in Mpumalanga are already in place. This project built on existing expertise and tools that exist, including other current Water Research Commission (WRC) funded projects relevant to the inventory, classification and assessment of freshwater ecosystems. By aligning with existing national programmes for wetland and river health, the investment made in this project complemented existing initiatives. The Mpumalanga Wetland Forum, which is an excellent mechanism for accessing the wetland community of practice in the province, was engaged at this stage and guided the development of the project.

Activity 2. Develop field-sampling procedures.

a. Identify priority catchments/sub-catchments for ground-truthing using stratified field sampling techniques.

Emphasis was placed on verifying the ecosystem threat status and protection levels of those wetland types that overlap with areas of exploitable coal resources. The project effort focussed on wetlands rather than rivers, recognizing that the wetland data in the NFEPA project are newer, patchier and of lower quality than the well-established data layers for rivers. Rivers that are associated with wetlands were considered where possible, but the rivers themselves were beyond the scope of this wetland project. Wetlands were classified into ecosystem types using the SANBI classification system (Ollis *et al.*, 2013) that underpins the NWM4 and the NFEPA wetland data. These types, and their threat status, are key inputs into a number of biodiversity and mining decision-making processes. Criteria for prioritization included mining potential, ecosystem threat status, land-cover pressures, wetland types impacted by mining, wetlands of known ecosystem service importance and wetland FEPAs.

b. Develop field sampling procedures and standardized forms.

Existing tools for field sampling were investigated and refined as needed. The future repositories of the data generated was a key determinant of procedures and instruments. This includes the SANBI National Wetland Inventory (generator of the National Wetland Map, which is the primary wetland input into the NFEPA project). The minimum attributes verified for each ecosystem that was ground-truthed included presence/absence (i.e. errors of omission and commission), type (classification using the SANBI hydro-geomorphic-based system, Ollis *et al.*, 2013), condition and delineation. The use of technology to facilitate data capture and transfer was explored, using platforms such as smartphones, tablets and custom-built applications using software like Android.

Activity 3. Train and deploy field workers.

Ground-truthing is people-intensive, and consequently provides excellent opportunities for developing capacity within relevant institutions. The work is ideal for students, interns and young professionals, with the necessary training and supervision. Training was done at a workshop that followed a learning-by-doing approach, through onsite training in the field. Institutions targeted included the DWS Mpumalanga regional office, relevant provincial departments and agencies (e.g. Mpumalanga Tourism and Parks Agency, MTPA), members of the Mpumalanga Wetland Forum and Groen Sebenza (Jobs Fund) placements in SANBI and other organisations.

Activity 4. Collate field data and populate in a GIS.

Using procedures and standards developed earlier in the project, data were collated and metadata created that will be incorporated into the existing architecture of the National Wetland Inventory. The advantage of this is that no new databases were created. Existing databases for the inventory were refined where necessary. The curation of the data will be undertaken by SANBI, and hence is secure for the long-term. Resources for this have already been earmarked by SANBI on its core budget.

Activity 5. Compare field results with national and provincial broad-scale wetland assessments and examine the implications to mining planning, decision-making and management.

Analysis included answering the following questions:

- How do the field results compare with the NWM4 in terms of the extent, distribution and condition of wetlands and ecosystem type classification?
- Does ecosystem threat status (Critically Endangered, Endangered, Vulnerable or Least Threatened) change for any of the wetland types?

- Does the protection level change for any of the wetland types?
- How does this affect the current *Mining and Biodiversity Guideline* and *Wetland Offsets Guideline*?
- Can the analysis support the identification of wetlands or sub-catchments that are good receiving areas for offsets arising from licence conditions attached to mining authorisations?
- Recommendations on an integrative monitoring framework that will encompass natural, physical and societal needs. The monitoring framework will be based on integrating existing processes (e.g. National Biodiversity Assessment and listing of ecosystems that are threatened and in need of protection under the Biodiversity Act) to ensure that environmental protection and sustained biodiversity from a landscape perspective are provided. It will also link with other projects underway to develop monitoring frameworks, such as the current WRC project on wetland monitoring.

Activity 6. Revision of decision-support tools.

The *Decision support tool for high-risk wetlands* and the *Wetland Offsets Guideline* were updated to incorporate the revised data sets, to ensure that decision-makers can effectively access this data. The spatial data for the *Mining and Biodiversity Guideline* was also updated to incorporate the revised Mpumalanga wetland data. The project engaged with appropriate regulators, the mining industry and other stakeholders to ensure that the content, format and documentation associated with the decision support tools met user requirements.

Activity 7. Capacity development with regulators, the mining industry and other stakeholders.

In parallel to all the above steps, key future users of raw data from the NFEPA project, the *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* and the *Wetland Offsets Guideline* were engaged to shape these tools into a form most suitable for their needs, and to support the creation of the capacity necessary to apply these tools. A number of initiatives are underway within the SANBI Freshwater and Grasslands Programmes to mainstream appropriate biodiversity information into both the mining industry and the regulators controlling it. Regulators include the Department of Mineral Resources (DMR), the DWS, the Department of Environmental Affairs (DEA) and provincial authorities. Initiatives underway include the *Mining and Biodiversity Guideline*, the *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the*

Highveld of Mpumalanga and *Wetland Offsets Guideline*. The project engaged with the appropriate regulators, the mining industry and other stakeholders as part of the broader project, in a way that would not have been possible in a separate stand-alone project.

1.4.1 Stakeholder involvement

As part of the detailed preparations and consultation for the project, a stakeholder workshop was convened by SANBI on 15 August 2013 at the Olifants River Lodge near Witbank. The workshop aimed specifically to:

1. Solicit feedback on the proposed approach to be followed by the project.
2. Explore opportunities for collaboration with other relevant initiatives.
3. Discuss how the project could best be used to build capacity within the province.

The stakeholder workshop was attended by 19 representatives from a range of relevant institutions, including provincial government, environmental consultants and environmental non-governmental organisations (NGOs). The full workshop report is included in the disc of electronic documents that accompany this report. Most of the stakeholders showed an interest in an improved wetland dataset. Stakeholders who have worked with the NFEPA data confirmed and stressed the need to improve the spatial accuracy of the data.

Stakeholders were invited to become partners of the project. The options for involvement included:

1. Sharing contact details of relevant GIS or environmental personnel that can share additional data for the area.
2. Sharing additional data that already exists.
3. Assisting in field visits, either in their capacity as wetland specialists, to increase their knowledge and/or to assist in accessing the properties of landowners with whom they have relationships.

1.5 Structure of the report

An introduction to the study area, the prominent issues and the reasons for the project is given in this introductory chapter (Chapter 1). Chapter 2 details the approach to data refinement that was taken by the project and covers the technical aspects of the methodology with regards to desktop GIS methods and field work. These methods accounted for the majority of the work and resulted in the project's primary output, an improved spatial layer of wetlands for the Mpumalanga Highveld (MHWet). During the implementation of the project, significant training and capacity building was provided to relevant stakeholders. Details of this training are given in Chapter 0. Once the refined wetland data had been collated it was compared to the existing NWM4 data to show how the current project has refined the wetland data for the study area. The ecosystem threat status, protection levels and FEPAs were updated, based on the improved dataset (Chapter 4). Chapter 5 reveals how the improved data has or will be integrated into a number of decision support tools and guidelines for dissemination. Finally, a summary of the relevant conclusions and recommendations are given in Chapter 6.

This is a technical report, intended to provide a scientific audience with details of the technical process and methodology for wetland mapping that was developed. Another output of this project, a wetland inventory manual (described in more detail in Section 3.5), will be published as a separate WRC report. This manual will provide a standardised set of guidelines to those interested in mapping wetlands at a systematic, landscape scale or to those involved in improving the National Wetland Map.

2 METHODS AND TOOLS FOR REFINING SPATIAL DATA ON WETLANDS

2.1 Catchment approach

The project followed an approach of reviewing wetland data one sub-WMA at a time. It further divided the wetland data, grouping it according to the set of quinary catchments (*Figure 2*) prepared by the NFEPA project ("River_FEPA" dataset, see Nel *et al.*, 2011b), reviewing all the wetlands within one quinary at a time. A quinary catchment is a hydrological unit, which represents a fifth order catchment, as part of a scaled hierarchy based on river catchment sizes (WRC, 2013). Quinaries provide a useful planning unit at a scale smaller than quaternary catchments. The study area included 365 quinary catchments from four WMAs (*Table 1*). The illegal coal mining activity that gave rise to this project (see Acknowledgements) is located within this study area.

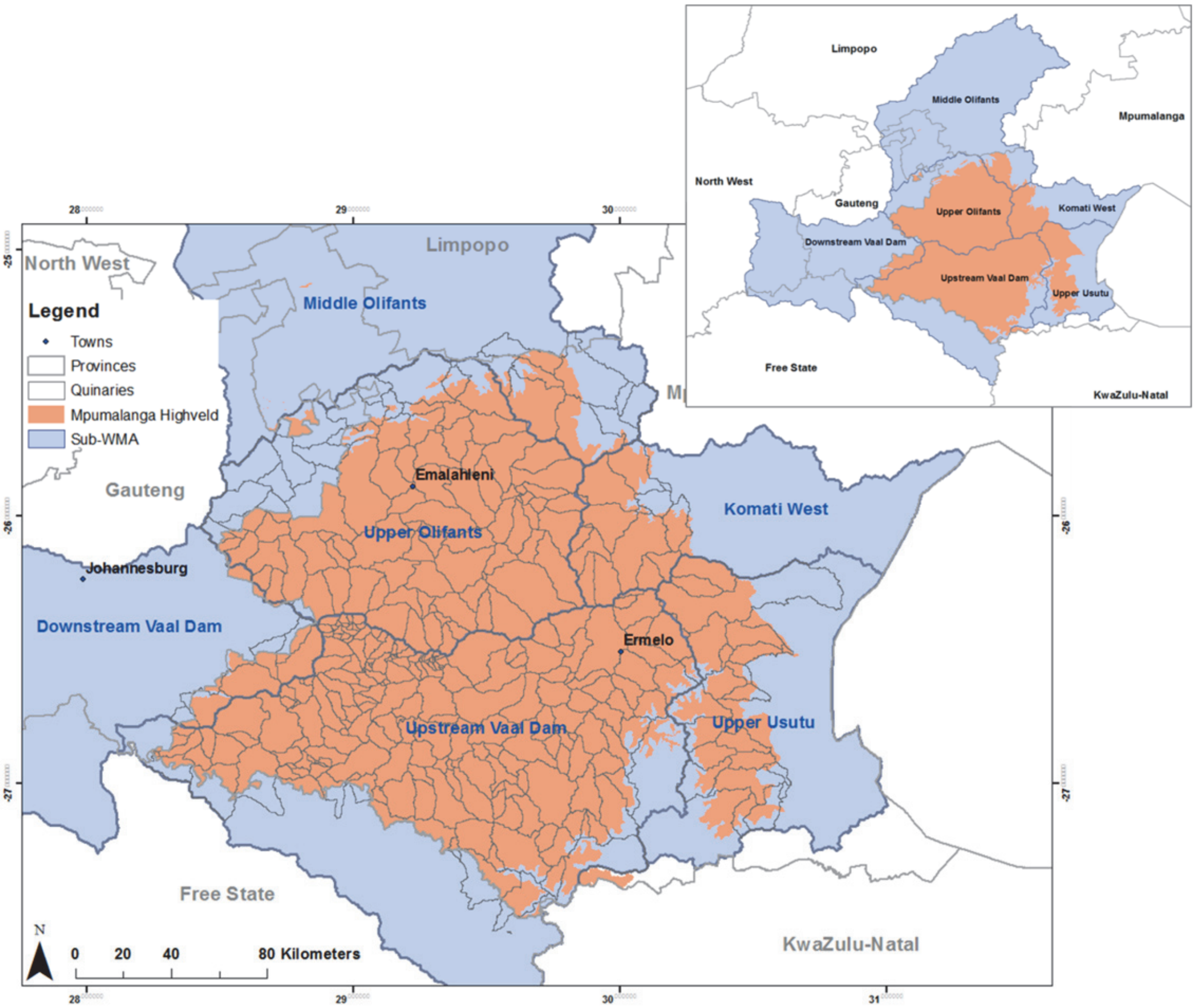


Figure 2: Final set of quinaries for the study area, showing sub-WMAs (blue) and the NFEPA quinary catchment boundaries (grey).

The benefit of working according to catchments is ease of data management, particularly more manageable-sized datasets for desktop and field review. At the scale of a sub-catchment, it is much easier to compare and contrast amongst the wetlands, which improves the review confidence and calibration of results.

For long-term strategic management and communication, it is also useful to report on the status of the catchment datasets, either per quinary or per sub-WMA, for example: "completed in 2014", "ground-truthing currently underway", "planned for 2015".

Table 1: The WMAs and sub-WMAs that made up the study area.

WMA	Sub-WMA	Number of quinaries included in the project	Percentage area of Sub-WMA
Usuthu to Mhlatuze	Upper Usuthu	22	44.2
Inkomati	Komati West	14	33.5
Olifants	Upper Olifants	94	100.0
	Middle Olifants	9	8.5
Upper Vaal	Upstream Vaal	220	70.5
	Downstream Vaal	6	5.4
TOTAL		**365**	

2.2 Methods

The over-riding priority of the project was to improve the accuracy and confidence in the spatial component of the wetland mapping. Secondary to this, was an attempt to verify and update hydro-geomorphic type for the mapped wetlands using the classification system developed by SANBI (Ollis *et al.*, 2013). Thirdly, an indication of wetland condition was considered a very desirable goal of this project.

The approach described in the following sections was tested as part of the refinement of the wetland data for the Mpumalanga Highveld. However, the protocols and tools described below are sufficiently robust and generic to be usable in all biomes and catchments across the country. The approach detailed here will also be presented in a more user-friendly stand-alone wetland inventory manual (still to be published), which explains how to undertake ground-truthing work on NFEPA data.

2.2.1 Three major steps in the approach to data refinement

The approach to data refinement followed three major steps, namely, 1) desktop preparation, 2) selected fieldwork, and 3) desktop follow-up and review by wetland specialists (*Figure 3*). At each stage, wetland boundaries, regional wetland type and wetland condition were assessed and updated. Once these steps were completed, the data was subjected to analysis as described in Chapter 4.

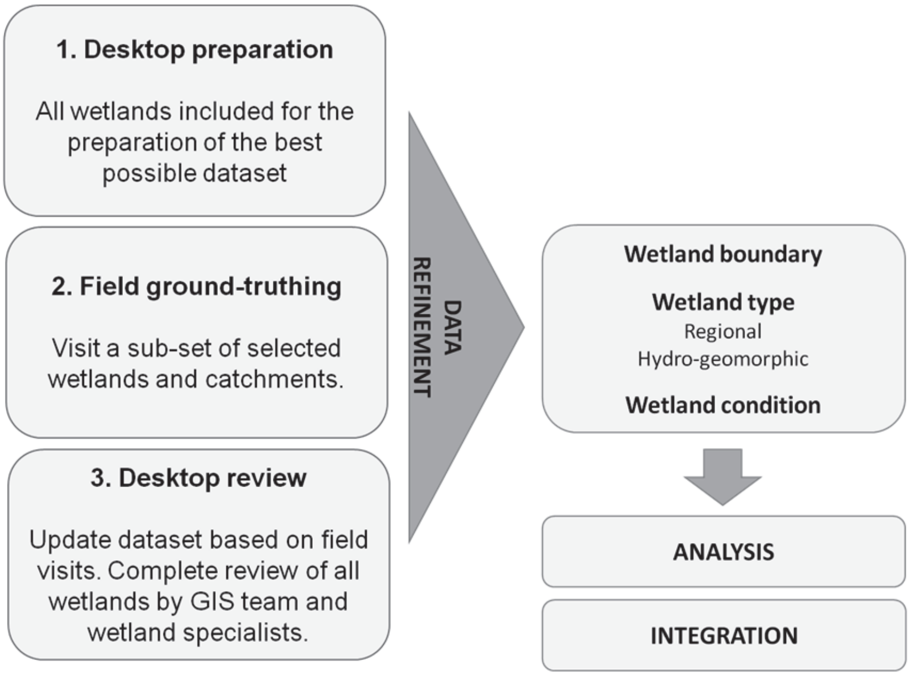


Figure 3: The general approach for the refinement of wetland spatial data and information. "Regional" wetland type in this figure corresponds with "WetVeg Group" in the current NFEPA dataset.

For any wetland mapping work, but particularly for large study areas, desktop preparation was found to be essential before going into the field. Desktop preparation is necessary to be properly prepared for the time spent in the field. It was simply not feasible to map more than a few entire wetlands on a tablet computer in the field per day; certainly not for the number of wetlands that needed to be visited in such a large study area. Drawing wetland boundaries onto hard copy map print-outs proved more feasible instead. However, investing in mapping that is as accurate as possible ahead of time is irreplaceable preparation, as a fraction of the time is then needed per wetland in the field to adjust wetland boundaries and collect other information.

Due to the significant size of the project area, the time available for the project was almost entirely used for desktop mapping. The desktop mapping also has a time consuming learning curve, with mapping and correcting taking much longer in the early stages of the project, then progressing more quickly over time as the personnel became more competent in recognising wetlands. Thus, only limited time for fieldwork and review steps was available for this study. However, the wetland inventory manual (still to be published) will provide more detail on how to assign adequate time to all three steps in future projects.

2.3 Wetland boundary delineation

Wetlands are areas where water is the primary factor controlling the environment and, therefore, wetlands develop in areas where soils are saturated or inundated with water, for varying lengths of time and at different frequencies. Wetlands are defined in the National Water Act (No. 36 of 1998) as land:

> "*...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 for life in saturated soil*."

The over-riding priority of the project was to improve the accuracy and confidence in the spatial component of the wetland mapping. This equates, primarily, to removing any erroneously mapped wetland polygons and confirming existing mapped wetlands in NWM4, and secondarily, to adding newly mapped wetlands.

2.3.1 Desktop boundary delineation

The majority of wetlands for this project were subjected to desktop “delineation” (desktop mapping of wetlands using appropriate remote sensing imagery). As mentioned above, desktop preparation was an essential investment prior to ground-truthing.

It is important to build on existing mapping and review new work against what has been done before so as not to go “backwards” or create data that is in conflict with existing datasets and stakeholder knowledge. First, the National Wetland Inventory spatial dataset, the NWM4 was reviewed. This had been used for the NFEPA and National Biodiversity Assessment projects. In the NFEPA project, wetlands larger than 100 ha were divided according to the landscape setting classes based on the rationale that larger wetlands can extend over more than one landscape setting class. The challenge of developing an accurate national-scale dataset resulted in an overly fragmented layer that did not correspond to HGM type or extent in many instances. Thus, the first step in preparing the NFEPA data was to dissolve the fragments.

In addition to NFEPA, certain existing datasets were reviewed, with a focus on gathering moderate to high confidence presence/absence information. It was easier to draw the polygons from scratch rather than building on existing datasets, to avoid GIS complications, data errors and topology errors. The NFEPA layer was therefore used as underlying data and extra surface area that was not mapped was added to this layer.

The following existing datasets were incorporated during desktop preparation:

- NFEPA.
- MTPA wetland point data.
- Working for Wetlands wetland polygons prepared by wetland ecologists.
- Chief Directorate of Surveys and Mapping (CDSM): inland waters layer.
- Upper Olifants sub-WMA wetland inventory data collated by Exigent Engineering Consultants for CoalTech (Exigent Engineering Consultants, 2006).

The Exigent data (Exigent Engineering Consultants, 2006) was used as an overlay with the digitised data. Some attribute columns were taken into the new layer, including type (which is similar to HGM unit) and dominant vegetation.

New wetlands were digitised using a combination of SPOT 5 imagery, Google Earth satellite imagery and 1:50 000 contour and river lines (*Figure 4*). Delineating wetland boundaries at the desktop level was achieved through heads-up digitizing over raster imagery within GIS software.

Figure 4: Example of desktop digitising (yellow) in addition to existing NFEPA mapping (blue).

Desktop determination of wetland extent was determined by:

- Visible patches of open water.
- Visible signs of the presence of vegetation clumps or patterns indicative of periodic soil saturation and indicator communities/species (i.e. vegetation colour, pattern and texture).
- Location within the landscape.
- Contour lines which indicate watersheds.
- River lines which indicate the direction of water flow.

On satellite imagery wetlands often appear different in colour and texture from the surrounding dryland areas. Wetlands are most often found in low-lying regions in the landscape as channelled or unchannelled valley bottoms or in seepage areas at higher elevations as hillslope seeps. There is often connectivity between hillslope seeps and valley bottom wetland areas. Wetlands are sometimes found at the tops of mountains, generally on plateaus, however this is less common. Wetlands appear slightly differently depending on the soil and vegetation. However, wetlands can often appear darker than the surrounding dryland and have a more mottled texture. This is very common in the summer rainfall regions of South Africa where soils tend to be darker in water-logged areas. Wetlands are often difficult to farm and will often appear as unfarmed areas in a highly transformed agricultural landscape. The presence of dams on a farm is also a good indicator of where wetlands may be or where they may have once been.

The approximate extent of the hydro-geomorphic units was mapped where these could be identified (see Section 2.4.2). Floodplain and valley bottom wetlands were frequently fringed with extensive seepage areas and, due to the extensive area being mapped, these were often simply mapped as floodplain or valley bottom in order to complete the task timeously. Where there was uncertainty regarding the presence and/or extent of a wetland, a precautionary approach was taken, such that the wetland layer presented is likely to over-estimate the extent of wetlands.

2.3.2 Field boundary delineation

Six sub-WMAs were selected in which to conduct field boundary delineation. These were Komati West, Middle Olifants, Upper Olifants, Upper Usuthu, Upper Vaal and Downstream Vaal. In these six areas, a sub-set of wetlands within several catchments were viewed by means of a rapid field approach described below, and within these areas the boundaries of a further subset of wetlands were examined in more detail according to wetland delineation field practice, outlined in multiple international protocols and in the DWS wetland delineation manual (DWAF, 2005). The DWS delineation manual describes a number of wetland attributes that can be used to identify wetlands and delineate their boundaries with the adjacent terrestrial areas. These attributes include the presence of plants adapted to, or tolerant of, saturated soils. Hydromorphic soils are another identifying attribute that display characteristics resulting from prolonged saturation: a high water table results in saturation at or near the surface, leading to anaerobic conditions developing in the top 50 cm of the soil. Observing evidence of the presence of each of these features, by means of indicators, is widely accepted as a valid way to identify wetlands.

A principle was decided of collecting less data on more wetlands, rather than more data on fewer wetlands. For the field work, this was achieved through applying three levels of detail:

1. Detailed site assessment (high confidence) for a select few wetlands during the field visit.
2. Rapid visual or “drive-through” survey (moderate to high confidence) for as many more wetlands as it was possible to view within a two or three-day field trip.
3. Desktop review following field visit, using the high confidence site assessments and understanding gained from the field trip to inform the extrapolation of information to the rest of the catchment.

Consideration was given to site accessibility. During the field visit, attempts were made to access and see as much of the wetland system as possible, allocating 1-2 hours per wetland for detailed assessment, and a maximum of 15-30 minutes for the rapid drive-through survey. Much time was taken in travelling between wetlands. No properties were entered where property owners were not able to be contacted. These made up the majority of properties and for these, off-site wetland determinations were made by observing site characteristics from adjacent vantage points. In some cases, this was done with the aid of binoculars. Field observations of hydrology and vegetation were assessed in combination with landscape setting and team experience. For wetlands that were not visible, determinations were made by desktop analysis of current imagery and other existing data, as well as the experience of the team.

GPS co-ordinates were recorded on the field datasheets (see Section 2.7) for every wetland observed, as well as notes about whether the wetland boundary was adjusted or a new wetland mapped.

Adjustments to existing mapped wetland boundaries or new mapping of wetland boundaries were recorded on a hard copy map or on a tablet. Various advantages and disadvantages were experienced for hard copies and tablet mapping. Using a hard copy map, it is difficult to find the correct orientation and direction, whereas tablets have active GPS and maps that assist in determining current location and position. Tablets also provide the advantage of being able to directly save data. However, tablets suffer from disadvantages of limited battery life, screen reflection when there is direct sunlight and are dependent on reasonable 3G data signal strength.

Due to challenges experienced during the field work, often only a GPS point was taken and datasheet entries made for a wetland, without adjusting the wetland boundary on tablet or hard copy map in the field. This required more extensive follow up to take place later on the desktop and was less than ideal, as the opportunity was lost for verifying the boundary in the field.

2.3.3 Desktop follow-up

Following field ground-truthing, field notes were entered into spreadsheets with the corresponding GPS co-ordinates. Spreadsheets were then joined to GIS shapefiles and the wetland boundaries of polygons were adjusted based on observations in the field. The final set of attributes and the SANBI mapping guidelines (GeoTerraImage and Wetlands Consulting Services, 2012) spreadsheet were joined to the polygon shapefile. The final set of attributes was assigned as part of a GIS exercise, to a sub-set consistent with the SANBI mapping guidelines (*Table 2*). Note that these mapping guidelines will be incorporated into the wetland inventory manual (still to be published) in order to provide a single source of standardised guidance on wetland mapping.

Table 2: The final set of attributes that was collected for the rapid field assessment.

Name	Explanation
WetID	The WetID is an identifier that can be used to tell which polygons belong to the same wetland system and point from the field survey notes.
HGM	Different hydro-geomorphic units from the national wetland classification system (Ollis *et al.*, 2013).
Hydrology	Scoring assigned to the hydrology condition ranging from 1 good -10 worst.
Vegetation	Scoring assigned to the vegetation condition ranging from 1 good -10 worst.
Dominant Plants	Plants or vegetation that were observed during the rapid assessment.

2.3.4 Review

The intention was to review datasets one quinary at a time. However, due to the large project area, the majority of the project time was involved in the actual desktop digitising, thus neither the Upper Olifants nor the Upstream Vaal datasets were subject to review according the methods documented in this section. Recommendations for addressing this are discussed in Chapter 6.

The review included checking that the digitising team had followed the following steps when mapping:

- Check for any NFEPA polygons that were missed by the new mapping, verify if they are wetlands and, if so, include into the new mapping.
- Use CDSM dataset, specifically the mapped artificial wetlands, a) to check if any new mapping inadvertently mapped a known dam as wetland and b) to verify mapped dams – allocate these as high confidence.
- Use CDSM dataset, specifically the perennial and non-perennial pans, a) to check if any known depressions were inadvertently missed in the new mapping and b) to verify any corresponding mapped polygons to be depression HGM type – allocate these as high confidence.
- Make use of the Working for Wetlands wetland polygons mapped by wetland specialists to a) align boundary of new mapping with Working for Wetlands mapping and b) adjust any corresponding mapped polygons to be the same HGM types as the Working for Wetlands mapping – allocate these as high confidence.

The datasets were reviewed over Google Earth and SPOT imagery in a systematic manner to confirm wetland boundary. HGM types were reviewed visually, making use of the steps described earlier. Unfortunately, time did not allow for the final step of local expert review.

2.3.5 Tools to support wetland boundary delineation

The following existing tools were used in the wetland mapping process:

- SANBI mapping guidelines (GeoTerraImage and Wetlands Consulting Services, 2012).
- DWS delineation manual (DWAF, 2005).
- ArcGIS mobile on tablet showing GPS location.

The following new tools were developed for the project:

- Published web map feature services of wetland data.
- Wetland plant species list.

2.4 Wetland classification

Secondary to establishing a high confidence presence/absence wetland layer, was an attempt to verify and update wetland type for the mapped wetlands. Wetlands for this project were classified according to the National Classification System for Wetlands and Other Aquatic Ecosystems (Ollis *et al.*, 2013).

2.4.1 Regional wetland ecosystem type

The identification of regional wetland ecosystem types is important, in that they help inform our understanding and accuracy with respect to ecosystem service importance and ecosystem threat status and protection levels, and thus prioritisation into wetland FEPAs. This is a key challenge of desktop digitising and of the outcomes of the NFEPA wetland component.

Due to the large study area, a focus on strengthening wetland ecosystem/regional type was considered to be secondary to the key aims of improving spatial accuracy and accurately assigning HGM type, as it was unfeasible to achieve in a systematic manner across the full study area and across the multiple scales of assessment (from desktop to field). For this reason, the current NFEPA wetland groups were retained for this project. The NFEPA attribute "WetVeg Group" (see Nel *et al.*, 2011b) is synonymous with the term regional wetland ecosystem types, as used in this project.

The *Vegetation types of South Africa, Swaziland and Lesotho* (Mucina and Rutherford, 2006), describes several "azonal" wetland types for the Mpumalanga Highveld, including Temperate Freshwater Wetlands (272 polygons or 98%), Subtropical Freshwater Wetlands (2 polygons or 0.72%) and Subtropical Salt Pans (2 polygons or 0.72%). These are supported by detailed descriptions and a plant species list. However, the vast majority of the wetlands fall within "Temperate Freshwater Wetlands" which is considered inadequate to describe the variation in wetlands present in the study area. For example, wetland ecologists familiar with the area know that the Mpumalanga Highveld Grasslands support extensive peatlands, as well as a high density and diversity of pans (from freshwater to saline, and perennial to temporary inundation). Although we acknowledge these different types of wetlands are present in the study area, at this point there is no way to accurately automate this on desktop.

The NFEPA project assigned a wetland regional type by drawing on the vegetation types within which the wetlands were embedded. For the NFEPA, these were called "wetland vegetation groups" or "WetVeg Group" (*Figure 6*). This was not a reference to plant species present, but rather that the *Vegetation types of South Africa, Swaziland and Lesotho* (Mucina and Rutherford, 2006) was considered to represent the current most accurate available spatial coverage of origins (paleoecological patterns), climate, geology and soils, all of which are potential spatial regional surrogates for endemic or biodiversity-rich wetland types. Guided by regional workshops with wetland ecologists, the 438 vegetation type classes of the South African vegetation map were grouped into 133 groups, theoretically anticipated to represent areas of similar regional turnover of wetland ecological characteristics and biodiversity support functions (Nel *et al.*, 2011b).

Table 3 illustrates how the groups are based on terrestrial vegetation types (that is, the environmental factors that each terrestrial vegetation type represents) where, for example, Frankfort Highveld Grassland is grouped with several other terrestrial vegetation types into Mesic Highveld Grassland Group 2. It follows that a wetland occurring within Frankfort Highveld Grassland is also assigned to Mesic Highveld Grassland Group 2. The 133 groups prepared for the NFEPA were called "wetland vegetation groups" or "WetVeg Group" in the NFEPA data attributes. *Table 3* lists only those WetVeg Groups and associated terrestrial vegetation types occurring within the study area boundary. The Mpumalanga Highveld Grasslands includes 12 out of the 133 regional wetland types (WetVeg Groups).

The study area falls mostly within the Mesic Highveld Grassland Bioregion (98.3%), with small sections of Central Bushveld (1.15%), Dry Highveld Grassland (0.047%) and Sub-escarpment Grassland (0.001%). These vegetation types collectively cover the majority of the study area (>99.5%), with a range of other types making up the remaining balance.

Table 3: The regional wetland types of the study area by biome and bioregion, according to the NFEPA.

Biome	Bioregion	% study area	Terrestrial vegetation type	Regional wetland type
Grassland	Mesic Highveld Grassland (MHG)	98.3	*Frankfort Highveld Grassland* *Tsakane Clay Grassland* *Northern Free State Shrubland*	MHG 2
			Soweto Highveld Grassland	MHG 3
			Rand Highveld Grassland *Eastern Highveld Grassland*	MHG 4
			KaNgwane Montane Grassland *Paulpietersburg Moist Grassland*	MHG 5
			Lydenburg Montane Grassland	MHG 6
			Sekhukhune Montane Grassland	MHG 7
			Amersfoort Highveld Clay Grassland *Wakkerstroom Montane Grassland*	MHG 8
	Sub-escarpment Grassland (SEG)	0.001	*Ithala Quartzite Sourveld*	SEG 2
			Low Escarpment Moist Grassland	SEG 3
	Dry Highveld Grassland (DHG)	0.047	*Bloemfontein Karroid Shrubland*	DHG 1
Savanna	Central Bushveld (CB)	1.14	*Loskop Mountain Bushveld* *Gold Reef Mountain Bushveld* *Andesite Mountain Bushveld*	CB 1
			Central Sandy Bushveld	CB 3

2.4.2 Hydro-geomorphic wetland type

Wetland systems can be grouped according to broadly similar hydrologic processes (the way in which water moves into, through and out of the wetland systems) and geomorphic factors (such as the position of the wetland in the landscape, landscape shape and processes active in this location) (*Figure 5*). This is named the hydro-geomorphic (HGM) approach to classifying wetlands (Brinson, 1993) and has been adapted for South Africa (Ollis *et al.*, 2013). A hydro-geomorphic approach to defining wetlands is valuable because of the important influences of hydrology and geomorphology on the location and nature of wetlands in the landscape, and the potential to infer functional information about wetlands from HGM types.

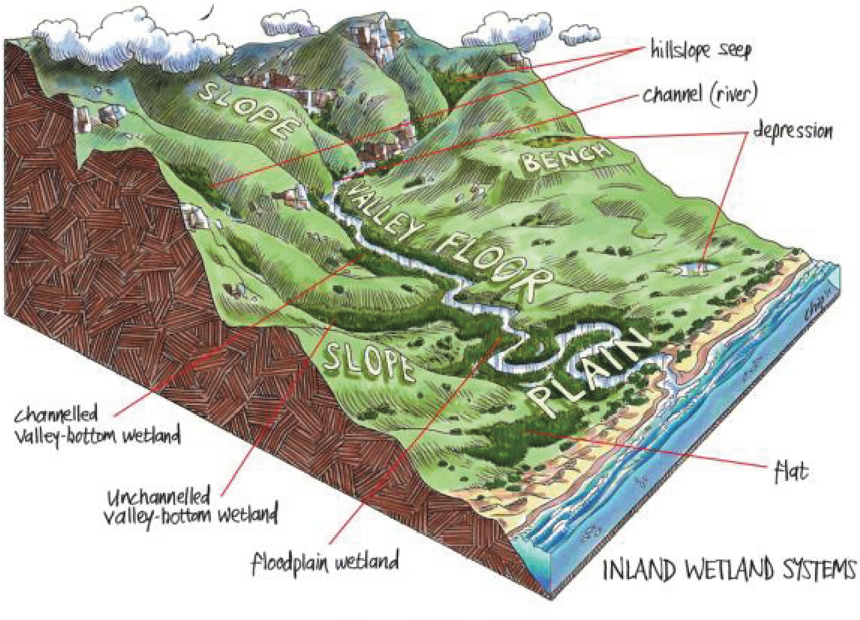


Figure 5: Graphic depiction of HGM units used in the national wetlands classification system (Ollis et al., 2013).

The *National Classification System for Wetlands and Other Aquatic Ecosystems* has a six-tiered structure (*Figure 6*). The hierarchical structure progresses from "Systems" (Marine vs. Estuarine vs. Inland) at the broadest spatial scale (Level 1), through to "Hydro-geomorphic (HGM) Units" at Level 4. The HGM Unit (Level 4) is the focal point of the classification system, with the lower levels (Level 5 and 6) providing a more detailed description of the characteristics of a particular HGM Unit. Wetlands for this study were classified to Level 4.

WETLAND / AQUATIC ECOSYSTEM CONTEXT		FUNCTIONAL UNIT		WETLAND/AQUATIC ECOSYSTEM CHARACTERISTICS
LEVEL 2: REGIONAL SETTING	LEVEL 3: LANDSCAPE UNIT	LEVEL 4: HYDRO-GEOMORPHIC UNIT	LEVEL 5: HYDROLOGICAL REGIME	LEVEL 6: DESCRIPTORS
		River	Perenniality	
DWA Level 1 Ecoregions OR NFEPA WetVeg Groups OR Other spatial framework	Valley floor	Floodplain wetland	Period and depth of inundation Period of saturation	Natural vs. artificial Salinity pH Substratum type Vegetation cover type Geology
	Slope	Channelled valley-bottom wetland		
	Plain	Unchannelled valley-bottom wetland		
	Bench (hilltop / saddle / shelf)	Depression		
		Seep		
		Wetland flat		

Figure 6: The basic structure of the Inland component of the national classification system, showing HGM units as a level 4 classification (Ollis et al., 2013).

HGM type was primarily assigned at a desktop scale, based on a visual interpretation of imagery, assisted by topography/contour and river lines. Hydro-geomorphic units can be recognised on GIS imagery as follows:

- **Channelled valley-bottom wetlands** are characterized by their location on valley floors, the absence of characteristic floodplain features and the presence of a river channel flowing through the wetland. Dominant water inputs to these wetlands are from the river channel flowing through the wetland, resulting from flooding, subsurface flow or overland flow.
- An **Unchannelled valley-bottom wetland** is similar to a channelled valley-bottom wetland, but without a river channel running through it. These wetlands are characterised by their location on valley floors, an absence of distinct channel banks, and the prevalence of diffuse flows. Water inputs are typically from an upstream channel and seepage from adjacent valley side-slopes. These are usually characterised by alluvial sediment deposition, generally leading to a net accumulation of sediment and the presence of vegetation. Minor channels are often present, particularly towards the lower end of the wetland where flow often begins to concentrate.
- A **Floodplain** is a wetland area on the mostly flat or gently sloping land adjacent to and formed by an alluvial river channel. Floodplain wetlands generally occur on a plain and are typically characterised by a suite of geomorphological features associated with river-derived depositional processes, including point bars, scroll bars, oxbow lakes and levees.
- **Seeps** are located on gently to steeply sloping land and are dominated by the colluvial (gravity-driven), unidirectional movement of water and material down-slope. Seeps are often located on the side-slopes of a valley but they do not typically extend onto a valley floor. Water inputs are primarily via subsurface flows from an up-slope direction. Seeps are often associated with diffuse overland flow during and after rainfall events. It is important to note that a seep can share a boundary with a distinct river channel and feed into the channel via diffuse surface flow or subsurface flow.
- A **Wetland flat** is a level or near-level wetland area that is not fed by water from a river channel, and which is typically situated on a plain or a bench. The primary source of water for a wetland flat is generally precipitation, with the exception of wetland flats situated on a coastal plain where groundwater may rise to or near the ground surface. Horizontal water movements within the wetland are typically weak and multi-directional. It is important not to confuse wetland flats with floodplain wetlands, which are connected to and fed by a river, while the wetland flats are fed

only by precipitation and or groundwater. Closed elevation contours are not evident around the edge of a wetland flat. Small ponded areas that form depressional micro features are considered part of a wetland flat.

- A **Depression** is an inland aquatic ecosystem with closed or near closed elevation contours, which increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates. Dominant water sources are precipitation, groundwater discharge, interflow and (diffuse or concentrated) overflow. Depressions may be flat-bottomed or round-bottomed, and may have any combination of inlets and outlets or lack them completely.
- **Dams** (in channel) are an artificial body of water formed by the unnatural accumulation of water behind an artificial barrier that has been constructed across a river channel or an unchannelled valley bottom wetland. Off-channel dams are artificial water bodies created specifically for the storage of water, which are not located along the course of a river channel or an unchannelled valley bottom wetland. Water accumulates within these dams through surface runoff, precipitation, and the diversion or pumping of water from other locations such as rivers via canals or pipelines, or from groundwater via wind pumps.

HGM type was assigned in the field for only a small sub-set of wetlands. The extended version datasheet prepared for this project made provision for observation of hydrological regime in those wetlands that were visited in the field. This information can be quick to gather where it is observed in the field and could be used to deepen understanding of the range of wetlands found in the study area. However, it was not possible to assign this attribute with confidence to every wetland in the study area as the large majority of wetlands were not visited in the field, and therefore this information does not appear in the final set of attributes for the project.

The extended version datasheet also included certain Level 5 wetland indicators, which could be used to help assign a wetland regional type. For the depressions (pans) of this study area, it is useful to know if they are perennial or non-perennial, and useful to know which vegetation communities are present e.g. *Phragmites* reeds, which at times indicate the presence of peat. However, as this information could not be systematically collected across the entire study area, it could not contribute to the overall purpose of the WRC project.

Similarly, Level 6 of the classification system characterises wetlands in terms of structural features, with criteria comprising geology, natural versus artificial, vegetation cover type, substratum and salinity. Certain of these were included in the datasheet as it does not take much more time to collect them when one is on site and can directly observe them. With the exception of the natural vs artificial distinction, which was assigned to every wetland in the study area, it was not possible to confidently assign any other Level 6 characteristics systematically to every wetland in the study area.

Dams were included as an HGM type for this project. This is a departure from the NFEPA project, which assigned a stand-alone attribute column for the distinction between natural and artificial wetlands. Essentially, dams are wetlands with a transformed HGM type (thus, it is incorrect to assign them an HGM type), and they have a transformed condition status (thus, it is misleading to assign them a further condition status). This does not preclude certain dams from playing an important role in the support of biodiversity.

2.4.3 Tools to support wetland classification

The following existing tools were used in the wetland classification process:

- SANBI mapping guidelines (GeoTerraImage and Wetlands Consulting Services, 2012).
- SANBI classification system (Ollis *et al.*, 2013).

The following new tools were developed for the project:

- Datasheets (see Section 2.7).

2.5 Condition assessment

An indication of wetland condition was considered a very desirable goal of this project.

2.5.1 Desktop assessment

The majority of wetlands were assessed via desktop and were assigned an updated wetland condition through modelling of condition, as described in Chapter 4.

2.5.2 Field assessment

The principles and methodology of WET-Health (MacFarlane *et al.*, 2008) informed the rapid assessment and the assignment of condition scores to the sub-set of wetlands visited in the field. A good understanding of the full WET-Health method is considered essential to being able to assign a very rapid condition score with confidence. The members of the field team familiar with the WET-Health methods were able to observe and assess the detailed criteria, and were capable of filling in the simplified scores required in the datasheet for this study. Only a small sub-set of wetlands were visited in the field.

There are many, complex factors which affect wetland condition, and not all of them are visible, even during a site visit, especially if it is a once-off visit and where only a part of the wetland is visited. For this reason, an attempt was made to identify a sub-set of specific issues that could be rapidly assessed, with a moderate to high level of confidence. These were incorporated into the datasheet (Section 2.7). The approach adopted was a rapid wetland health assessment (based on the WET-Health method), for each wetland visited in the field. WET-Health is designed to evaluate the environmental condition ("ecological health") of a wetland, by examining change from the historical natural condition of various parameters. Three components are typically considered, namely hydrology, geomorphology (factors influencing landform) and vegetation. For this study, only vegetation and hydrology were considered, with impacts to geomorphology being incorporated into the scores for these two. During visual assessments of wetlands, the team rated the estimated average wetland condition. WET-Health uses the concept of the reference state, and measures deviation from this reference state on a scale of 0 to 10.

WET-Health typically divides wetland areas into disturbance units, which reflect differing land uses (for example, natural, cultivated or dominated by invasive alien trees) within the wetland and different levels of disturbance. However, for this study, a score was assigned only to the wetland as a whole. Dams were not assigned a condition score. For vegetation, only within-wetland impact was assessed. For hydrological functioning, both within-wetland and impacts from the wetland catchment were considered. Water quality is a further issue of importance in assessing wetland health, however, it was not possible to assess in this study. A notes section on the datasheet did allow for any observations to be recorded.

2.5.3 Tools to support wetland condition

The following tools were used to assess wetland condition:

- WET-Health (MacFarlane *et al.*, 2008).
- WET-Index of Habitat Integrity (DWA, 2007).
- Datasheets (see Section 2.7).

2.6 Wetland delineation confidence levels

Wetlands were ranked according to High, Moderate and Low levels of confidence in wetland desktop delineation (*Table 4*). High confidence status was afforded to mapped wetlands that were ground-truthed and reviewed by a wetland specialist, or were verified using existing high confidence data, for example, CDSM data (dams or pans) or external wetland specialist datasets. Moderate confidence wetlands were reviewed by a wetland specialist, but not ground-truthed. Low confidence wetlands were mapped at a desktop level, but not reviewed by a wetland specialist.

Table 4: Confidence levels assigned to mapped wetland polygons depending on the ground verification and specialist review process.

Confidence level	Description
High	Wetland delineation reviewed by at least one wetland specialist and either ground-truthed or verified using existing high confidence datasets.
Moderate	Mapping outputs reviewed by at least one wetland specialist.
Low	Mapping outputs not reviewed by an expert.

2.7 Datasheets

The minimum attributes that were verified for each ground-truthed wetland included:

- Presence/absence and spatial boundary.
- Type (classification using the SANBI hydro-geomorphic-based system).
- Condition.

Two separate datasheets were prepared for the project, one for a more detailed assessment (*Figure 7*) and one for rapid assessment (*Figure 8*). The rapid assessment was the predominant datasheet used for the sub-set of wetlands visited in the field. The data collected on this datasheet corresponds with the final set of attributes joined to the wetland polygon shapefile. Filling out of the rapid assessment datasheet was accompanied by drawing any adjusted boundaries onto a hard copy printout or a tablet. Given the large project area and limited available time, very few detailed assessments could be undertaken. However, these were considered important preparation for undertaking rapid assessments, for example, calibrating understanding of the wetlands of the region, and informing the list of plant species likely to be commonly encountered. From this, an abbreviation for each plant name could be developed ahead of the rapid assessment work, based on the first two letters of the plant species and genus. These four letters could be rapidly input, saving time and space when visiting many wetlands in a short space of time.

Mpumalanga Wetland Ground-Truthing Field Form

Sub-WMA		**GPS co-ordinates***	
Quinary catchment #		**Date**	
Wetland name / id #		**Team**	
Photo numbers			
Confidence	☐ Assessment from a distance	☐ Walked part of the wetland	☐ Walked through entire wetland

**take gps where wet id unknown or where walking wetland boundary or adding new wetland or specific to notes*

1. Confirm existing wetland boundary Y / N **Adjusted** Y / N

2. HYDRO-GEOMORPHIC (HGM) TYPE(S*) **can be more than one*

☐ Dam ☐ Seep ☐ Depression/Pan: SALT OPEN SEDGE GRASS REED FRINGE UNVEGETATED
☐ Valley Bottom: CHANNELLED UNCHANNELLED UNSURE ☐ Floodplain wetland ☐ Flat

Position in landscape	☐ Slope	☐ Bench	☐ Plain	☐ Valley bottom

3. WETLAND HEALTH

Dominant water source (s). *(for health score, consider if impacted or natural)*	☐ River ☐ Overland flow ☐ Hillslope interflow / shallow groundwater ☐ Groundwater *(permanently wet?)* ☐ Rain ☐ Unsure

Observed land use and disturbances that may affect catchment and wetland vegetation and hydrological functioning:

Dam	Grazing	Cultivation	Brick making	Abstraction	Plantation
Old land	Drain/s	Dumping/infilling	Mining	Bridge	Road
Invasive plants	Cattle trampling	Erosion	Vegetation clearing	Other:	

Notes: to help with final wetland health score, consider the percent area affected by the above land use/disturbances on a scale of 1-5 where 1= **Less than 10%;** 2=**10% - 25%;** 3=**25%- 50%;** 4= **50%-75%;** 5=**75%-100%**

FINAL WETLAND HEALTH SCORE

Hydrology										PES	*Notes: one score for entire wetland; 0 is natural, 10 is heavily impacted*
1	2	3	4	5	6	7	8	9	10		*Hydrology score reflects impacts within wetland and its catchment –is quantity, timing or flow impacted into, through or out of wetland?*
Vegetation											*Vegetation score reflects impacts within wetland only*
1	2	3	4	5	6	7	8	9	10		*PES = average of hydrology/vegetation where A= 0-0.9 unmodified B=1-1.9; C=2-3.9 moderate; D=4-5.9 largely modified; E=6-7.9; F=8-10 critically modified*

4. REGIONAL WETLAND TYPE *(for depression/pans see also HGM above)*

Soil texture	☐ Peat	☐ Black/high organic	☐ Loam	☐ Clay	☐ Sand	☐ Silt/mud	☐ Bedrock

Observations: dense clay / bedrock / gley colours / mottles / oxidised roots Depth within soil pit__________cm

Hydroperiod ☐ Unsure *Note: soil/ plants help indicate hydroperiod; Intermittent =<3 months; Seasonal >3 months*

Inundation	Intermittent	Seasonal	Permanent	**Saturation**	Intermittent	Seasonal	Permanent

Dominant and Indicator wetland plants *OBL [obligate] = always found in wetland in the study area; FW = mostly in wetland*

ARNE Arundinella nepalensis **FW / G**	JULO Juncus lomatophyllus **OBL / S**	PYNI Pycreus nitidus **OBL / S**
APJU Aponogeton junceus **OBL / A**	JUOX Juncus oxycarpus **OBL / S**	Ranunculus sp. **OBL / Herb**
CAAU Carex austro-africana **OBL / S**	LEHE Leersia hexandra **OBL / G**	SCBR Schoenoplectus brachyceras **OBL / S**
CEAS Centella asiatica **OBL / Herb**	Limosella sp **OBL / Herb**	SCBR Schoenoplectus corymbosus **OBL / S**
CYMA Cyperus marginatus **OBL / S**	MEAQ Metha aquatic **OBL / Herb**	SCMU Schoenoplectus muriculatus **OBL / S**
IMCY Imperata cylindrica **FW / G**	MIJU Miscanthus junceus **FACW / G**	SCFI Scirpus ficiniodes **OBL / S**
FUPU Fuirena pubescens **FW / S**	NYTH Nymphoides thunbergii **OBL /A**	TYCA Typha capensis **OBL / R**
JUEF Juncus effusus **OBL / S**	Persicaria sp **OBL / Herb**	Xyris sp. **OBL / Herb**
JUEX Juncus exsertus **OBL / S**	PHAU Phragmites australis **OBL / R**	

Where plant species names are unknown: ☐Sedges[S] ☐Grasses[G] ☐Reeds[R] ☐Aquatic[A] ☐Other

Notes

Figure 7: Full ground-truthing datasheet.

Sub-WMA________ NFEPA quinary_________ Date _______________

WET ID/ gps	Boundary adjusted?	HGM	Veg	Hydro	Dominant plants*	Notes

*for abbreviations and other guidance for filling out these columns see detailed field datasheet

Figure 8: Rapid assessment datasheet

2.8 Software

The use of technology to facilitate data capture and transfer was explored, using platforms such as smartphones, tablets and custom-built applications using software like Android.

Several software options and mobile apps were tested, and the project eventually selected the ArcGIS mobile platform as the most appropriate for the purpose (https://play.google.com/store/apps/details?id=com.esri.android.client). The app uses the ArcGIS Runtime SDK engine to zoom to layers, query and edit. An advantage of the ArcGIS Runtime SDK is that it is available for all major phone operating systems, so the same app is available for Apple's iOS, Windows Mobile, etc. The runtime SDK can be adapted and be used by a developer. A developer sets it up (at a once-off cost) and anybody can download, install, and use it without having to download or import forms before it is operational. An off-the-shelf product like ArcGIS comes with the added advantage of not having to worry about continual maintenance and updating of the app, which would be the case if a custom-made app was built for the mapping. The ArcGIS mobile application has been developed by ESRI. The technical maintenance for it is done by ESRI and its usually quick response on bugs and queries.

The NFEPA data operational basemap with Google Earth imagery and topographical maps can be displayed, and users can select which layers they wish to view and edit. Users then have the option of creating new wetland polygons, or point records for wetlands or species of interest on the graphics layer. Forms have to be completed for each new wetland being mapped, which is easy to do. If many users are predicted through citizen science-like initiatives, then the ArcGIS Runtime SDK is a good option as there are few, if any, bugs in the software. Web feature services provide an interface allowing requests for spatial and supporting data on geographical features across the web. The service also allows the data to be edited and updated by a user across the web. A basic web feature service only allows querying and retrieval of features, while the more advanced transactional web feature service (which we used) allows creation, deletion, and updating of spatial data. The feature services can be created on ArcGIS desktop and published using an ArcGIS online account. The data should be clipped into smaller portions to help with data connection and saving. When a form has been filled in and a wetland polygon drawn, it will be saved on cloud server using internet connection. When in office the data can be downloaded as a shapefile and be used on ArcGIS desktop or any other GIS software.

3 TRAINING

Several types of training were conducted over the course of the project. For field-based training, a workshop was held that focussed on the collection of wetland inventory data in the field. This workshop also covered aspects of relevant GIS. Finally, once the refined dataset had been incorporated into wetland decision support tools, widespread and ongoing training was conducted on the use of these tools (see Chapter 5). This chapter focuses on the field-based and GIS training that was conducted during the course of the wetland data refinement. This training is relevant to the outcomes of this project and contributed to significant capacity building amongst the core project team and its supporting partners.

A field-based training workshop was held on the 7th and 8th of November 2013, at Ezemvelo Nature Reserve in Bronkhorstspruit. The purpose of the workshop was to:

- Share the tools under development and apply them together in the field.
- Build capacity for wetland inventory data collection within Mpumalanga.

Amongst the tools discussed at the workshop was the ESRI ArcGIS mobile application for cell phones and tablets, as well as the standardised datasheets for inventory data collection along with other supporting guidance. The full workshop report and other supporting documents relating to the training component of the project are included in the data disk that accompanies this report.

3.1 Approach

The workshop approach followed the "Active Learning Framework" for meaningful environmental learning (*Figure 9*), recommended by Michelle Heistermann (2011) of the Mondi Wetlands Programme. The framework outlines the key components to ensure a meaningful learning experience for any training exercise.

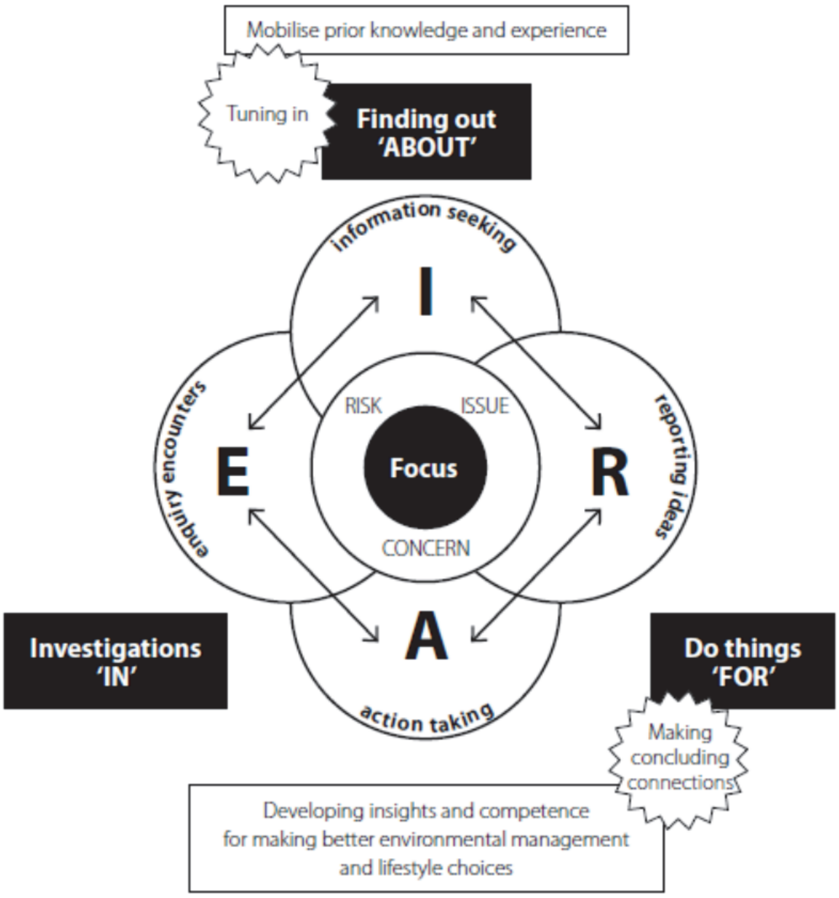


Figure 9: The Active Learning Framework (O'Donoghue, 2001)

The workshop combined classroom work as well as time spent out in the field. Topics covered included wetland delineation, identification of common wetland plants, classification of wetland types and rapid condition assessment, which collectively offered an overview of the basics needed to collect the inventory data efficiently, consistently and systematically. Much of the training was interactive or in groups.

3.2 Participants

The workshop was attended by a set of provincial stakeholders who could contribute to and/or benefit from the refinement of wetland data resulting from the project. These stakeholders are regularly involved in tasks such as reviewing wetland data, reviewing development applications or auditing mining disturbances on wetlands. Thus, they were interested in becoming more familiar with the status of wetlands in the province and in the standardised methodologies for improving the existing data.

Sixteen people attended the workshop, excluding the project team. The following organisations were represented at the workshop:

- Mpumalanga Department of Agriculture, Rural Development and Land Administration.
- Rand Water.
- Department of Water and Sanitation (DWS).
- South African Environmental Observation Network (SAEON).
- Department of Agriculture, Fisheries and Forestry (DAFF).
- Komatiland Forests.
- WWF-Mondi Wetlands Programme.

3.3 Presentations

The “Active Learning Framework” was used to structure the presentations made at the workshop. The framework stages (*Figure 9*), were customised for the workshop, beginning with presentations to aid “Tuning in”, through a learning process, resulting in “Networking and Long Term Outcomes”.

“Tuning in” provided participants with the necessary background to the project, its context and foundational concepts. An introduction was given to the previous NFEPA project and its outcomes. The necessity for improved data refinement in the Mpumalanga Highveld was explained. This was followed by specific presentations on the topics of wetland delineation, identification of common wetland plants, classification of wetland types and rapid condition assessment. The presentations aimed to be in-depth, but not too long, with lots of pictures and maps (especially local examples) to keep everyone engaged. There were questions and discussions over several of the slides.

The next stage of the workshop was a learning-and-sharing opportunity. All workshop participants introduced themselves, stating their affiliation and particular area of interest. Links were made as often as possible throughout the workshop to the participants’ individual work and experience, to keep the workshop relevant and to learn more about stakeholder needs.

Several sessions also gave the participants a chance to mobilize their prior knowledge by practicing their skills. For example, GIS skills were used when loading the necessary data, interpreting the NFEPA data and mapping new wetlands. Plant identification skills were assessed during the identification of the live plant samples. To make the best use of time and keep all participants engaged and learning during these activities, they worked together in groups. The more experienced members could help the less experienced members to do the work and more people could experience the activity. The diversity of the group in terms of skills, experience and work context was also productive for problem solving and deliberation. There was active and thorough participation in all of the tasks by the workshop participants.

In her work with the Western Cape wetland ground-truthing project, Michelle Heistermann (2011) emphasised that dissonance (the discomfort which comes from conflicting views) provides opportunities for discussion, debate and deliberation, which are crucial for learning. At the workshop, this was shown through, for example, a debate on whether to collect point data instead of investing in polygon data, or when the group struggled to understand the logic behind some of the mapping decisions. Michelle advised that these debates actually created opportunities for social learning.

Through the course of the workshop, connections were made that would enhance "Networking and long-term outcomes". The group work, in particular, increased the opportunity for discussion and for connections to be made. A useful outcome of the workshop was the sharing of information between participants who form part of the same community of practice in Mpumalanga, but who had not all met each other prior to the workshop. The workshop thus provided a valuable opportunity to network and to identify areas of expertise and skills within the province and the stakeholder group. This will support continued collaboration to update the wetland inventory for Mpumalanga into the future. Lessons learned here will also be tested for their applicability nationally by SANBI in its future wetland inventory and NFEPA ground-truthing work.

Workshop attendees were provided with a range of resources, including the official NFEPA GIS layers and technical reports.

3.4 Field visit

The learning process continued seamlessly from the classroom to the field, where the theory presented in the classroom was put into practice. The field visit presented opportunities to apply the mapping decisions from the morning's desktop exercise in a practical setting. This included becoming familiar with individual sites and their broader catchments, observing the soil and vegetation, and investigating wetland impacts and condition (*Figure 10*). Participants were able to draw on the expertise of the project team, who had been developing and testing the methodology in several Mpumalanga catchments. During their investigation in the field, the participants were exposed to the skills needed to review and ground-truth the NFEPA mapping. As much as possible, the participants were encouraged to carry out the tasks themselves e.g. taking soil samples by augering (*Figure 10*), identifying wetland plants and filling in the data sheets.

Figure 10: Workshop participants orientating themselves in the field and taking soil samples using a hand auger.

3.5 Wetland inventory manual

Participants of the workshops used a preliminary version of a wetland inventory manual developed through the WRC project, which provides a standardised set of processes and methods for inventorying wetlands. The manual describes a set of steps to verify and refine the current (NFEPA) data on the extent, distribution, condition and type of wetland ecosystems. It outlines the three-step process of desktop GIS preparation, field visits for ground-truthing and final review. The particular focus is to provide guidance on updating wetland spatial boundaries and the attributes associated with each wetland. The manual is intended to standardise methods for ground-truthing, which can be applied country-wide, at a range of scales, with the long term goal of strengthening of the National Wetland Inventory of South Africa. The complete manual will be published as a separate WRC report).

4 ASSESSMENT OF WETLANDS IN THE STUDY AREA

This chapter serves to document the methods and findings of the fifth activity towards achieving the project aims (described in Section 1.4). The purpose of Activity 5 was to assess the refined wetland data, and to compare it with the existing national and provincial broad scale wetland assessments. The results of this comparison will have implications for the incorporation of the refined wetland data into mining planning, decision-making and management (Chapter 5).

The assessment of wetlands was conducted by:

- Exploring the extent to which differences between datasets result from differences in confidence levels in wetland delineation within the Mpumalanga Highveld.
- Examining wetland detection and spatial overlap between the National Wetland Map 4 (NWM4) and the Mpumalanga Highveld Wetland map (MHWet).
- Examining the classification of hydro-geomorphic (HGM) types between NWM4 and MHWet.
- Examining the classification of wetland condition between NWM4 and MHWet.
- Exploring the implications for assessing the ecosystem threat status of wetlands.
- Exploring the implications for Freshwater Ecosystem Priority Areas (FEPAs) in the Mpumalanga Highveld.
- Exploring the implications for assessing the protection levels for wetlands.

4.1 Developing an improved Mpumalanga Highveld Wetlands (MHWet) layer

Wetlands were mapped using a combination of desktop digitising from Google imagery and field mapping. Wetlands were mapped for part of, or all of, the six sub-catchments of the study area, namely Komati West, Middle Olifants, Upper Olifants, Upper Usuthu, Upper Vaal and Downstream Vaal (see *Table 1*). Not all wetlands were visited and confidence levels were assigned to describe the level of confidence of the mapped data (see Section 2.6). Individual GIS layers for the six sub-catchments were combined to provide a single wetland GIS layer (*Figure 11*) that could be statistically compared to wetlands in NWM4 for the same study area (*Figure 12*). The improved GIS layer contained newly captured information on HGM type and wetland delineation confidence levels. Wetlands amounting to a total area of 590 391 ha were mapped, which represents 19.8% of the surface area of the study area. This is significantly more than the previous best source of information, in the form of the NWM4, which contained wetlands amounting to 213 579 ha (or 7.2%) in the same area.

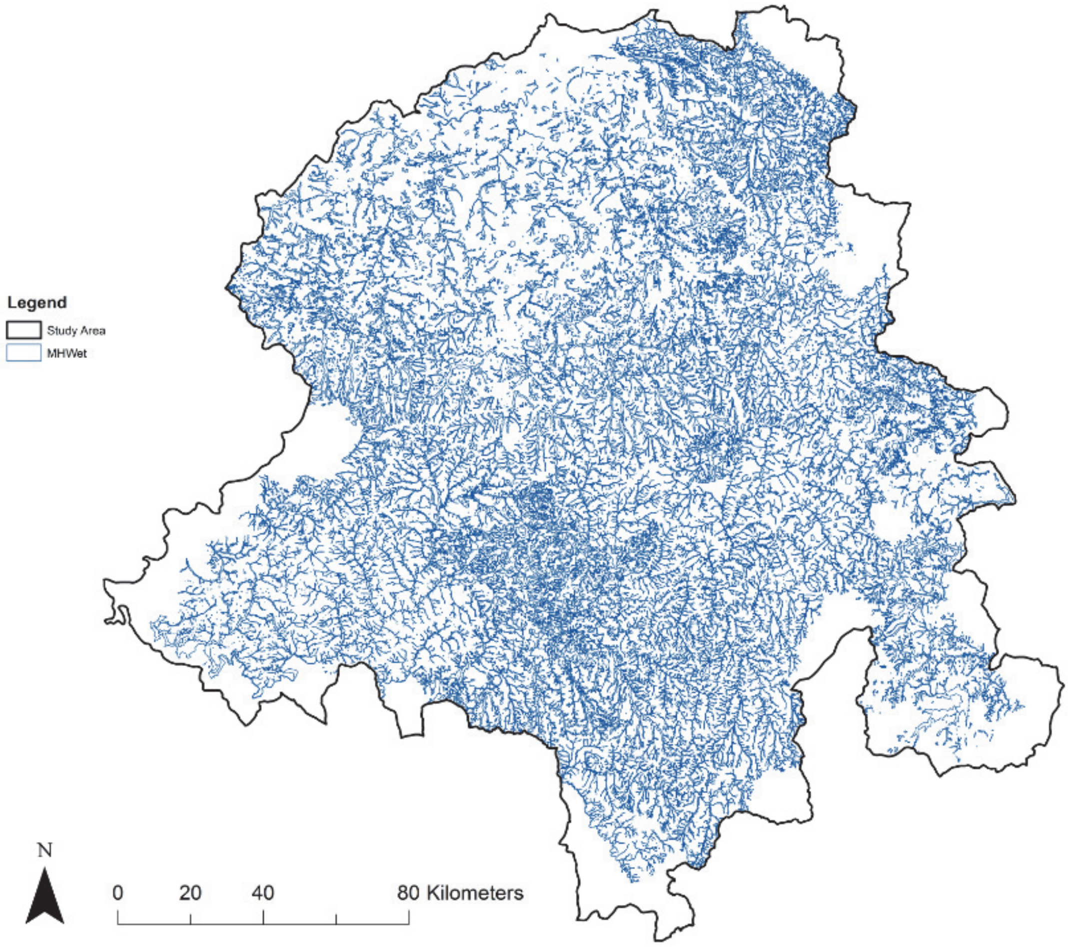


Figure 11: The revised Mpumalanga Highveld Wetlands (MHWet) map. It was preferred to map entire quinary catchments, and hence blank areas within the study area boundary form part of quinary catchments that extend beyond the study area.

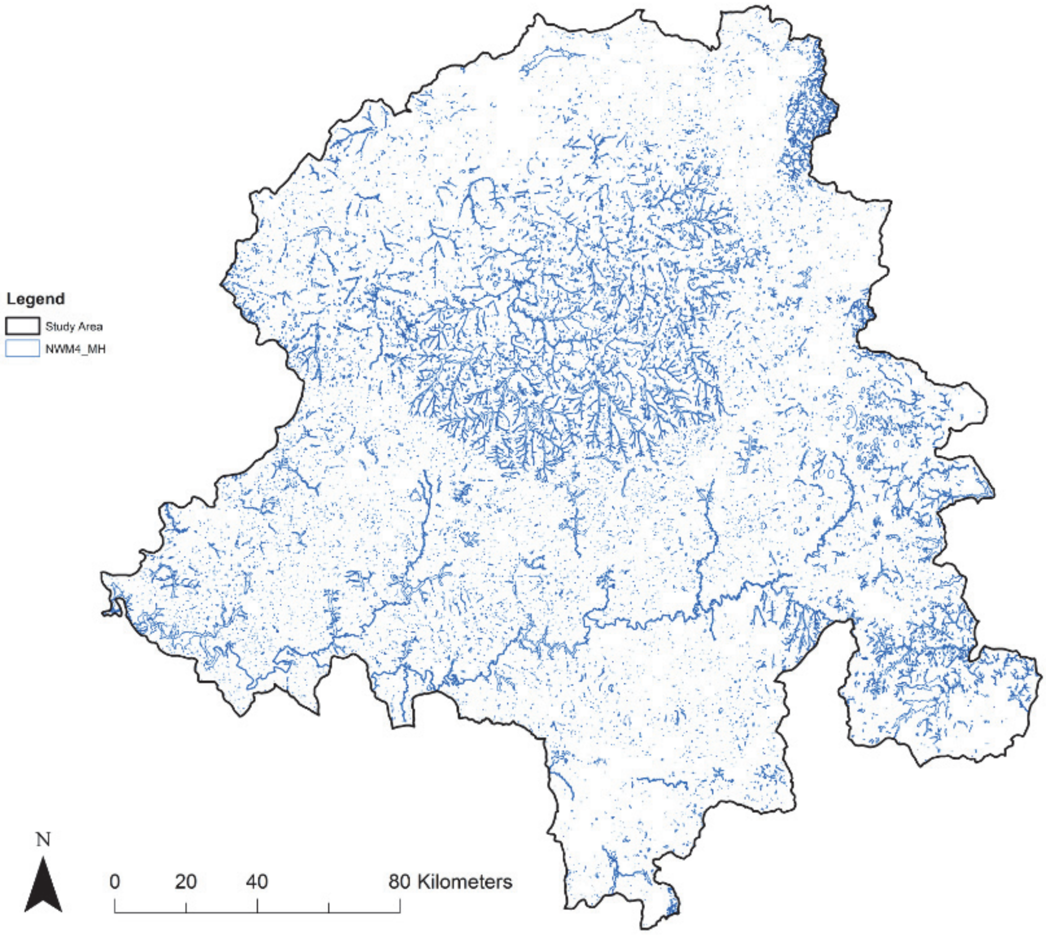


Figure 12: The National Wetland Map 4 for the study area

To derive wetland types according to NWM4, a wetland vegetation group was first assigned to each wetland functional unit (defined as a contiguous spatial unit, which may be made up of several polygons). The GIS layer of wetland vegetation groups (Nel *et al.*, 2011a), which characterises the regional context within which wetlands occur, was used to classify wetland vegetation groups. Each wetland functional unit was assigned the wetland vegetation group that occupied the majority of its area. Wetland types were then classified by combining the wetland vegetation group and HGM unit to identify 49 unique combinations, representing distinct wetland types in the Mpumalanga Highveld study area.

Wetland condition was not measured in the field as originally anticipated. In the absence of field survey data for wetland condition, an index of relative condition was derived using the same approach as NFEPA (Nel *et al.*, 2011b). This approach used the percentage of natural land cover (from the 30 m resolution 2009 SANBI 'Mosaic National Land Cover') in and around the wetland as a surrogate measure of wetland condition. Percentage natural land cover was calculated within four areas: the wetland itself, and the wetland surrounded by GIS buffers of 50, 100 and 500 m from the delineated wetland polygon. The minimum of these four percentages was used to guide the condition category of the wetland, using the following rules:

- Non-riverine wetlands were considered in good, moderately modified or heavily modified condition if the minimum percentage natural land cover was ≥ 75%, 25-75% or < 25% respectively. These wetlands were coded 'AB', 'C' and 'Z' respectively.
- Riverine wetlands associated with a heavily modified NFEPA river (i.e. in a D, E or F ecological category) were assigned the condition category of that river irrespective of the surrounding natural land cover.
- Wetlands associated with natural or only moderately modified NFEPA rivers (i.e. in an A, B, or C ecological category) were assigned a condition based on the minimum percentage natural land cover rule used for non-riverine wetlands because the surrounding land use is more likely to be a driver of ecosystem degradation than the moderate condition of the associated river.
- Several riverine wetlands are associated with rivers too small to be included in the NFEPA rivers network GIS layer – in these instances, the river condition was unknown and the wetland was assigned a condition based on the natural land cover rule alone.
- All dams identified by the digitizers were coded as 'Dam'.

Wetland FEPAs were identified by assigning FEPA status to all wetlands in the MHWet GIS layer that overlapped with a FEPA identified by NFEPA (Nel *et al.*, 2011a). The entire wetland functional unit within a sub-quaternary catchment was used.

The final MHWet layer (*Figure 11*) identified 49 wetland ecosystem types in the study area. One of these wetland types (Mesic Highveld Grassland Group 7_Floodplain wetland) is a completely new wetland ecosystem type to the country (was not previously mapped). It is evaluated here as having an ecosystem threat status of Least Threatened (LT) and a protection level of Not Protected. Two of these wetland types are newly mapped in the study area (Central Bushveld Group 1_Floodplain wetland, Central Bushveld Group 2_Seep) but not the country. Respectively, they were evaluated as Critically Endangered (CR) and Least Threatened (LT) in the 2011 National Biodiversity Assessment (NBA; Driver *et al.*, 2012) 2011, and the status of both did not change in this re-assessment.

An updated Mpumalanga Wetland Map, containing the MHWet, can be accessed on the SANBI Biodiversity GIS website at http://bgis.sanbi.org/MHwetlands/project.asp.

4.2 Wetland delineation confidence levels

Almost 30% of the wetland area mapped has been ground-truthed or reviewed by at least one wetland specialist (high category in *Figure 13*). The vast majority of mapped wetland area (58%) is of low confidence, having been captured through desktop digitising and interpretation using Google maps and ancillary GIS data (e.g. contour lines, rivers, geology and vegetation). Nevertheless, the mapping exercise constitutes significant improvements to the NWM4 GIS layer (*Figure 12*).

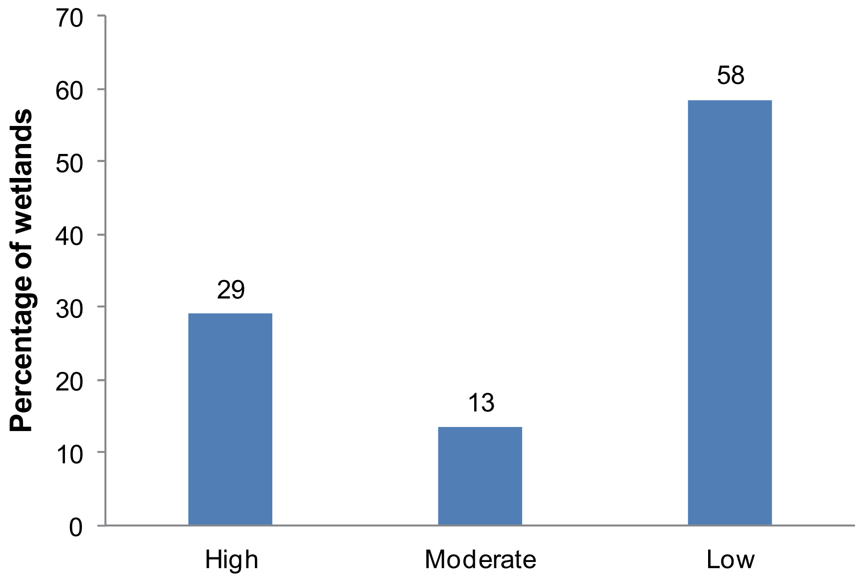
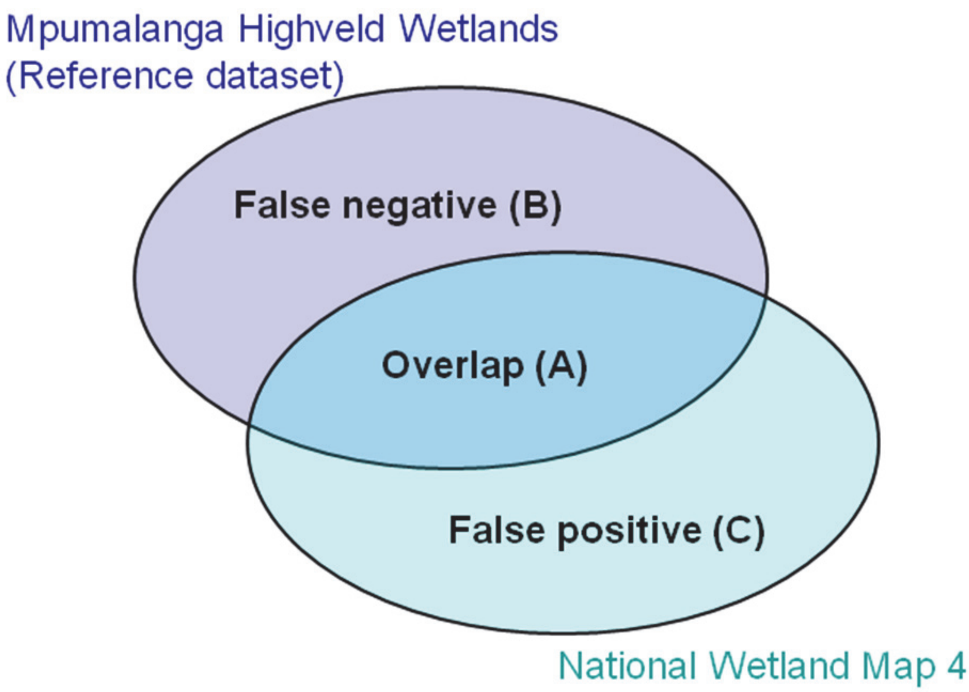


Figure 13: Proportion of wetlands mapped with high, moderate or low wetland confidence levels. See Table 4 for confidence level descriptions.

In the activities below, we use all mapped wetlands in MHWet to undertake the accuracy assessment of NWM4. This assumes that MHWet is a good reflection of reality for not only the high confidence wetlands, but also the remaining ones of moderate and low confidence.

4.3 Wetland detection and spatial overlap

The assessment of wetland mapping accuracy was calculated using a similar approach to that followed by GeoTerraImage (2008) in assessing the accuracy of previous versions of the National Wetland Map (*Figure 14*). Wetland detection and spatial overlap is explained as omission (false negatives) and commission (false positives). Section 4.3.1 and 4.3.2 respectively explain how accuracy of spatial detection and actual wetland delineation were calculated.



$$\% \text{ Accuracy} = A/(A+B) \times 100$$

$$\% \text{ Omission} = B/(A+B) \times 100$$

$$\% \text{ Commission} = C/(A+B) \times 100$$

Figure 14: Assessment of wetland mapping accuracy.

4.3.1 Accuracy in spatial detection

This task intended to test the detection accuracy within the NWM4, without stringent rules on spatial delineation accuracy. It was a basic assessment of the accuracy of the NWM4 in merely detecting wetlands, irrespective of the accuracy in mapping the spatial extent of the wetlands correctly. Assuming that MHWet is a good reflection of reality, and therefore acts as the reference dataset for purposes of this accuracy assessment, non-overlapping polygons can be described as either false negative or false positive polygons. False negative polygons, or errors of omission, are those polygons that are absent in NWM4, but are present in reality (i.e. in the improved MHWet layer). False positive polygons, or errors of commission) are those that are present in NWM4, but which are not a wetland in reality (i.e. do not appear in the MHWet layer) (*Table 5*).

Table 5: Wetland detection accuracy for NWM4 compared to MHWet.

Overlap	**Count of polygons**	**%**
Both (A)	29 040	54
False negative (B)	24 825	46
False positive (C)	18 316	34
Total	**72 181**	

Table 5 shows that, disregarding the accuracy of spatial delineation, detection accuracy of a wetland in NWM4 is approximately 54% (using the equations in *Figure 14*). The extent of false positive detection – where wetlands were detected where none exists in reality – was surprisingly high (34%). Approximately 46% of the time, NWM4 did not detect the presence of wetlands that exist in reality.

4.3.2 Accuracy in actual wetland delineation

This is a more stringent test of the accuracy of NWM4, assessing not just the detection accuracy, but also spatial delineation accuracy. The assessment considers total area of overlapping polygons.

Assuming that MHWet is a good reflection of reality, *Table 6* shows that NWM4 only detected 25% of the wetland area mapped by MHWet. Seventy-five percent of the wetland area captured in the MHWet was not detected by NWM4 (false negative area; *Table 6*), and non-wetland areas amounting to 12% of the total wetland area, mapped by MHWet were incorrectly classified by NWM4 as wetlands (false positive).

Table 6: Wetland spatial extent accuracy for NWM4 compared to MHWet.

Overlap	**Area (ha)**	**%**
Both (A)	144 866	25
False negative (B)	445 525	75
False positive (C)	68 713	12
Total	**659 105**	

4.4 Classification of hydro-geomorphic type

To test the accuracy of classification of HGM type in NWM4, we examined the HGM type classification in overlapping polygons of NWM4 and MHWet (*Table 7*).

Overall, *Table 7* shows high classification accuracy in NWM4 for depressions (81%) and dams (70%), which makes sense as the majority of these were classified using 1:50 000 topographic maps from the Chief Directorate of Surveys and Mapping rather than modelled landscape topography. Reasonable classification accuracy is also achieved for floodplain (65%) and channelled valley-bottom wetlands (52%), and when these HGM types are classified incorrectly, they are commonly classified as each other (i.e. floodplain wetlands are commonly classified as channelled valley-bottom wetlands and vice versa). Seeps, flats and unchannelled valley-bottom wetlands have very low classification accuracy in NWM4.

Table 7: Classification of HGM types of overlapping wetland polygons in NWM4 compared to MHWet based on percentage area of overlap. The shaded blocks represent the wetland polygons that were classified the same in NWM4 and MHWet. Valleyhead seeps were removed as a national HGM type between the classification carried out for NWM4 and MHWet.

		MHWet						
		Channelled valley-bottom wetland	**Dam**	**Depression**	**Flat**	**Floodplain wetland**	**Seep**	**Unchannelled valley-bottom wetland**
NWM4	**Channelled valley-bottom wetland**	52	4	1	0	29	13	0
	Dam	11	70	1	0	12	5	0
	Depression	4	8	81	0	1	7	0
	Flat	31	2	15	0	16	35	1
	Floodplain wetland	26	1	0	0	65	7	0
	Seep	48	2	2	0	22	20	5
	Unchannelled valley-bottom wetland	25	5	13	0	17	40	0
	Valleyhead seep	37	2	8	0	22	31	0

4.5 Classification of wetland condition

To compare the assessment of wetland condition between NWM4 and MHWet, the overlapping polygons in the two GIS layers were overlaid and statistics based on area and wetland condition of these overlapping polygons were extracted. This assessment showed a much higher proportion of wetlands in good ecological condition (AB) in the MHWet compared to NWM4 (*Figure 15*), while the proportion of wetlands in a moderate ecological condition (C) has not changed substantially. The proportion of wetlands in poor condition (D, E, F, Z or Dam) has decreased in MHWet compared to NWM4. These changes contribute to changes in ecosystem threat status (Section 4.6).

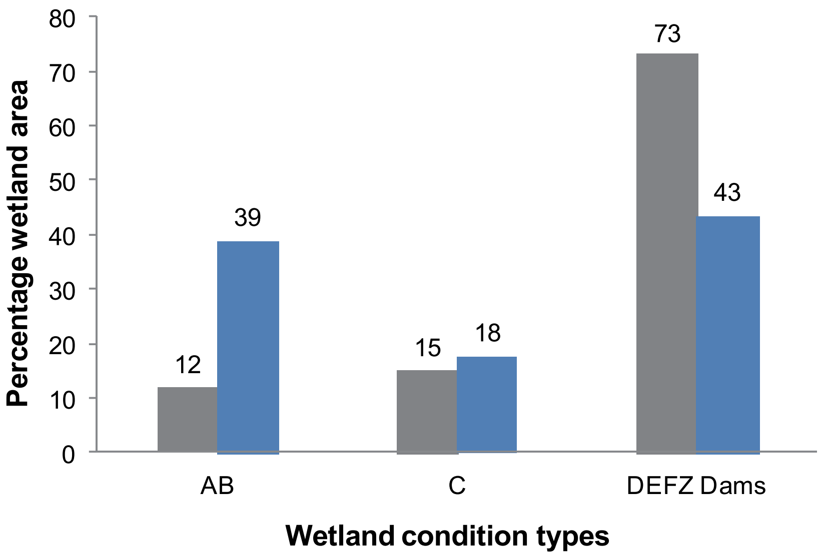


Figure 15: Percentage area of wetland in different wetland condition categories for the NWM4 (grey bars) and the MHWet (blue bars).

4.6 Implications for ecosystem threat status of wetlands

Ecosystem threat status is an indication of the degree to which an ecosystem is still intact or the degree to which it is losing its structure, composition and function. Ecosystem types can be categorized as follows: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Least Threatened (LT) (Driver *et al.*, 2012). Ecosystem threat status of the wetland types recorded in the study area was re-assessed based on the new extent of wetland at a national level resulting from the newly mapped wetlands in Mpumalanga Highveld. This was done using the same methods as in the NBA 2011 for wetlands (Nel *et al.*, 2011b). The percentage area of each wetland ecosystem type in good condition and moderate condition was calculated. An ecosystem threat status category was assigned to each wetland ecosystem type by comparing these percentages against the thresholds for each threat status class (*Table 8*).

Table 8: Thresholds used for defining threatened ecosystems. The GIS layers of river condition and wetland condition were used to identify ecosystem types in good or moderately modified condition. Ecological category refers to condition categories.

	Critically Endangered	Endangered	Vulnerable
NBA 2011 criterion for identifying threatened ecosystems across terrestrial, freshwater, estuarine and marine environments	Ecosystem type remaining in good condition ≤ biodiversity target	Ecosystem type remaining in good condition ≤ (biodiversity target + 15% of total extent of ecosystem type)	Ecosystem type remaining in good or moderately-modified condition ≤ 60% of total extent of ecosystem type
Thresholds applied to river ecosystems	Length of river ecosystem type in an A or B ecological category ≤ 20% of the total length for that ecosystem type	Length of river ecosystem type in an A or B ecological category ≤ 35% of the total length for that ecosystem type	Length of river ecosystem type in an A, B or C ecological category ≤ 60% of the total length for that ecosystem type
Thresholds applied to wetland ecosystems	Area of wetland ecosystem type modelled in good condition ≤ 20% of the total area for that ecosystem type	Area of wetland ecosystem type modelled in good condition ≤ 35% of the total area for that ecosystem type	Area of wetland ecosystem type modelled in good or moderately-modified condition ≤ 60% of the total area for that ecosystem type

This reassessment showed that of the 49 wetland ecosystem types in Mpumalanga Highveld, 23 changed their ecosystem threat status (46%) (*Figure 16a*). All became less threatened than previously evaluated; none became more threatened. A decision on whether to change the NBA 2011 ecosystem threat status at a national level was based on the ratio of *original* NWM4 area inside the study area to that outside the study area. Any wetland ecosystem type with more than 60% of its area inside the study area was changed; while those with less than this threshold were kept the same (*Table 9*).

On this basis, we recommend that the NBA 2011 ecosystem threat status be updated for ten of the 49 wetland ecosystem types re-assessed. The final re-assessed ecosystem threat status for all 793 wetland ecosystem types in South Africa (*Figure 16b*) is provided in Appendix A1.

Table 9: Recommended revisions to ecosystem threat status for wetland type. Extent of change reflects the number of classes between this assessment and the NBA 2011.

Wetland ecosystem type	NBA 2011 ecosystem threat status	New assessment of ecosystem threat status	Extent of change	% NWM4 inside study area	Decision	Recommended ecosystem threat status
Central Bushveld Group 1_Channelled valley-bottom wetland	CR	EN	1	17	Don't change	CR
Central Bushveld Group 1_Floodplain wetland	CR	EN	1	0	Don't change	CR
Central Bushveld Group 1_Seep	EN	LT	2	3	Don't change	EN
Central Bushveld Group 3_Channelled valley-bottom wetland	CR	EN	1	2	Don't change	CR
Central Bushveld Group 3_Seep	CR	EN	1	4	Don't change	CR
Mesic Highveld Grassland Group 2_Channelled valley-bottom wetland	CR	EN	1	21	Don't change	CR
Mesic Highveld Grassland Group 2_Floodplain wetland	CR	EN	1	38	Don't change	CR
Mesic Highveld Grassland Group 2_Seep	CR	VU	2	14	Don't change	CR
Mesic Highveld Grassland Group 3_Channelled valley-bottom wetland	CR	LT	3	70	Change	LT
Mesic Highveld Grassland Group 3_Floodplain wetland	CR	LT	3	73	Change	LT
Mesic Highveld Grassland Group 3_Seep	CR	LT	3	63	Change	LT
Mesic Highveld Grassland Group 3_Unchannelled valley-bottom wetland	CR	EN	1	49	Don't change	CR
Mesic Highveld Grassland Group 4_Channelled valley-bottom wetland	CR	LT	3	96	Change	LT
Mesic Highveld Grassland Group 4_Depression	CR	EN	1	85	Change	EN
Mesic Highveld Grassland Group 4_Flat	CR	EN	1	90	Change	EN
Mesic Highveld Grassland Group 4_Floodplain wetland	CR	EN	1	80	Change	EN
Mesic Highveld Grassland Group 4_Seep	EN	LT	2	91	Change	LT
Mesic Highveld Grassland Group 4_Unchannelled valley-bottom wetland	CR	LT	3	86	Change	LT
Mesic Highveld Grassland Group 5_Depression	CR	EN	1	90	Change	EN
Mesic Highveld Grassland Group 6_Unchannelled valley-bottom wetland	EN	LT	2	9	Don't change	EN
Mesic Highveld Grassland Group 7_Channelled valley-bottom wetland	CR	LT	3	6	Don't change	CR
Mesic Highveld Grassland Group 7_Floodplain wetland	N/A	LT	N/A	0	Add as new SA wetland type	LT
Mesic Highveld Grassland Group 7_Unchannelled valley-bottom wetland	CR	LT	3	23	Don't change	CR

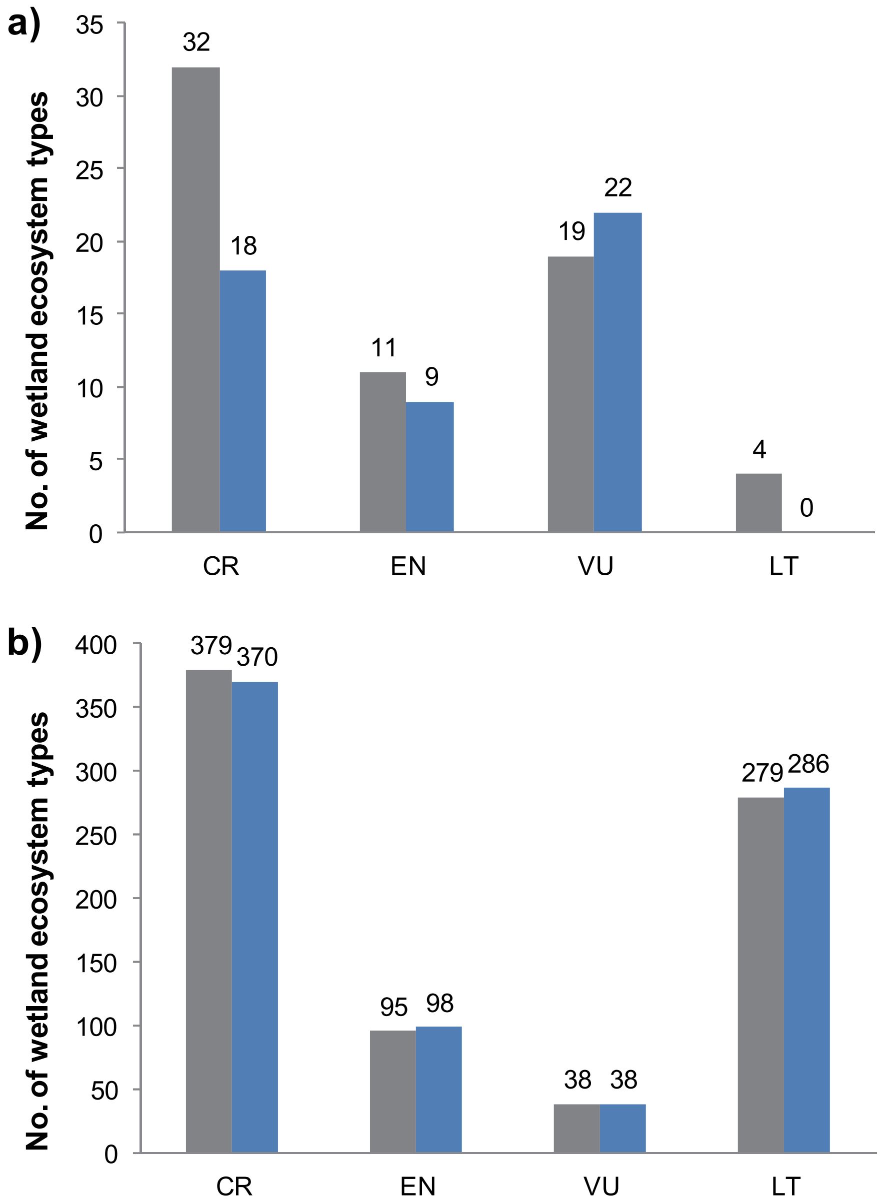


Figure 16: Summary of changes in ecosystem threat status for wetland ecosystem types for a) the study area only and b) all wetland ecosystem types in South Africa. Grey bars represent NMW4, blue bars represent the new ecosystem threat status from this assessment (MHWet).

Acknowledging the low confidence in the desktop classification of HGM types in NWM4, the NBA 2011 also assessed ecosystem threat status for wetland vegetation groups rather than the wetland ecosystem types. Wetland vegetation groups represent a coarser level of the classification hierarchy used to derive wetland ecosystem types. The percentage area of wetland in good and moderate condition was calculated for each wetland vegetation group, and an ecosystem threat status category was assigned to each wetland vegetation group by comparing these percentages with the thresholds for wetland ecosystems (*Table 8*).

In addition to the wetland ecosystem types, the ecosystem threat status of wetland vegetation groups was also re-assessed for this project. At the level of wetland vegetation groups, this re-assessment found that there are 11 wetland vegetation groups in the Mpumalanga Highveld study area. Of these, six changed their ecosystem threat status (54%). All became less threatened than previously evaluated; none became more threatened. A decision on whether to change the NBA 2011 ecosystem threat status at a national level was based on the ratio of *original* NWM4 area inside the study area to that outside the study area. Any wetland ecosystem type with more than 60% of its area inside the study area was changed, while those with less than this threshold were kept the same. On this basis, the ecosystem threat status of two wetland vegetation groups were recommended for updating (*Table 10*). The final re-assessed ecosystem threat status for all 133 wetland vegetation groups in South Africa is provided in Appendix A2.

Table 10: Recommended revisions to ecosystem threat status for wetland vegetation groups. Extent of change reflects the number of classes between this assessment and the NBA 2011.

Wetland Vegetation Group	NBA 2011 ecosystem threat status	New assessment of ecosystem threat status	Extent of change	% NWM4 inside study area	Decision	Recommended Ecosystem Threat Status
Central Bushveld Group 1	CR	EN	1	11	Don't change	CR
Central Bushveld Group 2	VU	LT	1	7	Don't change	VU
Central Bushveld Group 3	EN	EN	0	3	Don't change	EN
Mesic Highveld Grassland Group 2	CR	EN	1	31	Don't change	CR
Mesic Highveld Grassland Group 3	CR	LT	3	68	Change	LT
Mesic Highveld Grassland Group 4	CR	LT	3	89	Change	LT
Mesic Highveld Grassland Group 5	EN	EN	0	18	Don't change	EN
Mesic Highveld Grassland Group 6	LT	LT	0	38	Don't change	LT
Mesic Highveld Grassland Group 7	EN	LT	2	5	Don't change	EN
Mesic Highveld Grassland Group 8	LT	LT	0	29	Don't change	LT
Sub-Escarpment Grassland Group 3	CR	CR	0	0.1	Don't change	CR

4.7 Implications for protection levels for wetlands

Ecosystem protection level measures how well South Africa's formal protected areas are doing at meeting targets for conserving the full variety of ecosystem types across the country. This indicator measures how much of the biodiversity target for each ecosystem type has been included in protected areas, thus helping to focus protected area expansion on the least protected ecosystem types. The ecosystem protection levels of the wetland ecosystem types occurring in the study area were re-assessed based on the new extent of wetland at a national level resulting from the newly mapped wetlands in Mpumalanga Highveld.

The re-assessment was done using the same methods as in the NBA 2011 for wetlands (Nel *et al.*, 2011b). A 20% biodiversity target, as used by the NFEPA project (Nel *et al.*, 2011b), based on recommendations from a national cross-sector policy process (Roux *et al.*, 2006). This target was used for representing wetland ecosystems in protected areas. The 20% is a proportion of the total area of each wetland ecosystem type. The biodiversity target for the 49 wetland ecosystem types in the study area was based on 20% of the newly mapped area; the biodiversity target for the remaining wetland ecosystem types remained the same as it was for the NBA 2011. To be considered as protected in this assessment, wetland ecosystems had to be in formal protected areas AND be in a good condition (A or B ecological category). Thus, a wetland ecosystem with a total area of 100 ha in South Africa, would have a biodiversity target of 20 ha against which its area in good condition within formal protected areas was assessed. Based on this, an ecosystem protection level category was assigned, where well-protected wetland ecosystem types were defined as those with more than 100% of their biodiversity target in protected areas and in good condition. Similarly, moderately protected and poorly protected wetland ecosystem types have respectively at least 50% and 5% of their target in protected areas and in good condition; while not protected have less than 5%.

In re-assessing the 49 wetland ecosystem types in the study area, 18 changed their ecosystem protection levels (38%) (*Figure 17a*). The ecosystem protection levels improved for all wetland ecosystem types. A decision on whether to change the NBA 2011 ecosystem protection levels at a national level was based mainly on the extent to which the percentage biodiversity target met had changed (*Table 11*). The ecosystem protection level was only changed in instances where the threshold into the next category had been surpassed substantially. Substantial change was defined as having at least a further 15% added to the lower threshold of the respective protection level category. For example, to change from Not Protected to Poorly Protected (defined as having 5-50% of the biodiversity target protected), the change in protection level had to be at least 20% (5+15%). Similarly, to change from Poorly Protected to Moderately Protected (where 50-100% of the biodiversity target is protected), the change in protection level had to be at least 65%. On this basis, we recommend the change in ecosystem protection level for 9 of these 18 wetland types (*Table 11*). The final re-assessed ecosystem protection level categories for all 793 wetland ecosystem types in South Africa *(Figure 17b)* are provided in Appendix A3.

Table 11: Recommended revisions to protection levels for wetland types. Extent of change reflects the number of classes between this assessment and the NBA 2011.

Regional wetland type	New Ecosystem Protection calculations	NBA 2011 Ecosystem Protection Levels	Final Ecosystem Protection levels	% target met in AB	Extent of change	Decision
Central Bushveld Group 1_Channelled valley-bottom wetland	Poorly protected	Not protected	Not protected	12.72775	1	Don't change
Central Bushveld Group 1_Floodplain wetland	Poorly protected	Not protected	Poorly protected	42.01673	1	Change
Central Bushveld Group 1_Seep	Well protected	Poorly protected	Well protected	173.2945	2	Change
Central Bushveld Group 2_Channelled valley-bottom wetland	Poorly protected	Not protected	Poorly protected	44.22329	1	Change
Central Bushveld Group 2_Floodplain wetland	Poorly protected	Not protected	Not protected	6.528406	1	Don't change
Central Bushveld Group 2_Seep	Well protected	Poorly protected	Well protected	237.5004	2	Change
Central Bushveld Group 3_Channelled valley-bottom wetland	Moderately protected	Poorly protected	Poorly protected	54.15092	1	Don't change
Central Bushveld Group 3_Depression	Well protected	Poorly protected	Moderately protected	106.4422	2	Change
Central Bushveld Group 3_Seep	Poorly protected	Not protected	Not protected	18.88766	1	Don't change
Mesic Highveld Grassland Group 2_Channelled valley-bottom wetland	Poorly protected	Not protected	Not protected	17.79986	1	Don't change
Mesic Highveld Grassland Group 2_Flat	Poorly protected	Not protected	Not protected	6.492833	1	Don't change
Mesic Highveld Grassland Group 2_Floodplain wetland	Poorly protected	Not protected	Poorly protected	21.06494	1	Change
Mesic Highveld Grassland Group 4_Seep	Poorly protected	Not protected	Not protected	5.045616	1	Don't change
Mesic Highveld Grassland Group 4_Unchannelled valley-bottom wetland	Moderately protected	Not protected	Moderately protected	86.78591	2	Change
Mesic Highveld Grassland Group 5_Depression	Poorly protected	Not protected	Not protected	6.690559	1	Don't change
Mesic Highveld Grassland Group 6_Seep	Well protected	Poorly protected	Well protected	542.9055	2	Change
Mesic Highveld Grassland Group 7_Floodplain wetland	Not protected	N/A	Not protected	0	N/A	N/A
Sub-Escarpment Grassland Group 3_Channelled valley-bottom wetland	Poorly protected	Not protected	Poorly protected	20.75222	1	Change

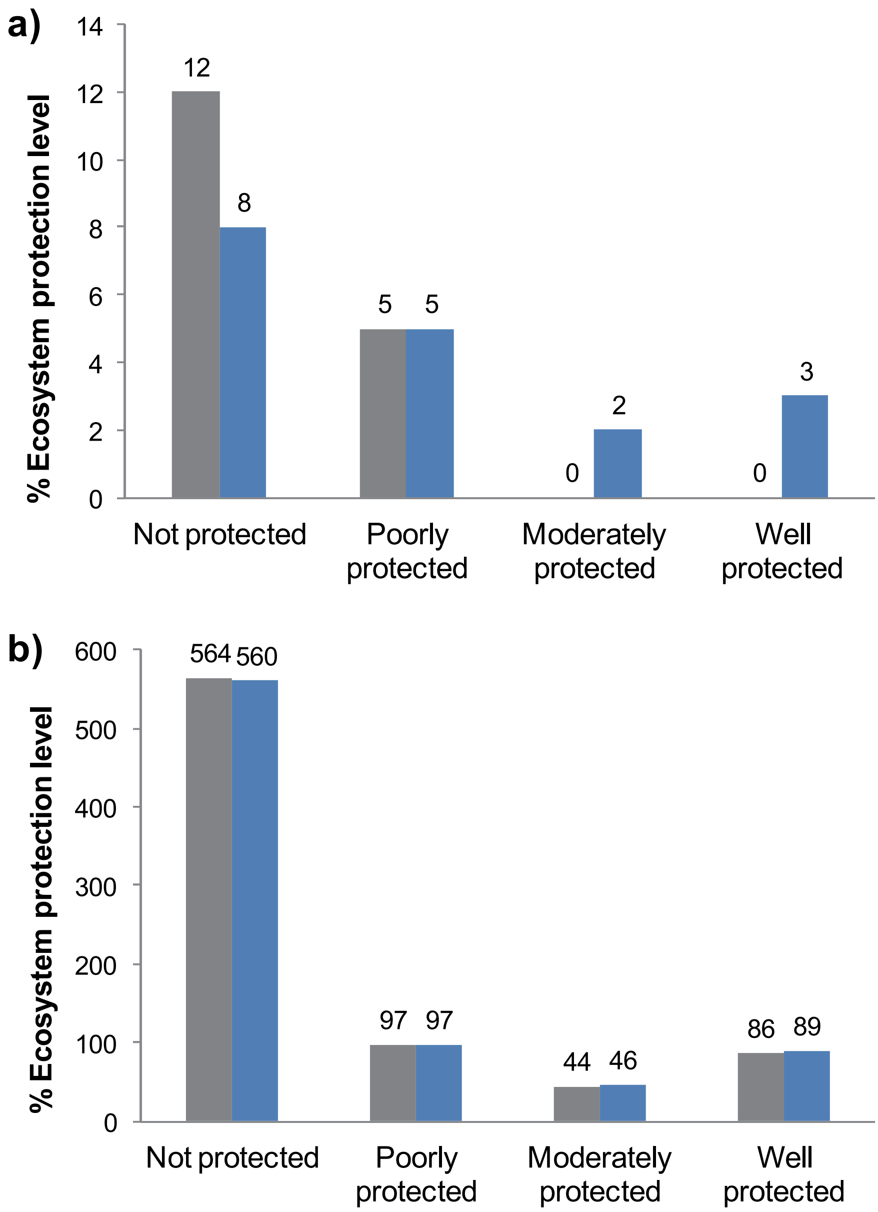


Figure 17: Summary of changes in ecosystem protection levels for wetland ecosystem types for a) the study area only and b) all wetland ecosystem types in South Africa. Grey bars represent NMW4, blue bars represent the new ecosystem threat status from this assessment (MHWet). Note that a) excludes Mesic Highveld Grassland Group 7_Floodplain which was not represented as a regional wetland type for NMW4.

The same method was used to assess ecosystem protection levels for wetland vegetation groups. In this case, the biodiversity target for wetland vegetation groups was calculated as 20% of the newly mapped area in the study area, and the area of the NWM4 in the remainder of the country. Ecosystem protection levels for wetland vegetation groups were not calculated for the NBA 2011, and therefore there is no change in status. The final assessment of ecosystem protection levels for all 133 wetland vegetation groups is provided in Appendix A4.

4.8 Implications for Freshwater Ecosystem Priority Areas (FEPAs)

Wetland FEPAs were identified by assigning FEPA status to all wetlands in the MHWet GIS layer that overlapped with a FEPA identified in NWM4 by the NFEPA project (Nel *et al.*, 2011a). Any wetland functional unit within a sub-quaternary catchment that overlapped with a previously identified wetland FEPA in NWM4 was classified as a FEPA. Overall, FEPAs have increased from 27% of the wetland area in Mpumalanga Highveld to 36% (*Table 12*). This 9% increase is expected given the increased extent of the newly mapped wetlands in MHWet (*Figure 12*), combined with the increased extent in good and moderate condition wetlands (*Figure 15*). Also expected, is that the biggest increases were from valley-bottom and floodplain wetlands, as the original satellite imagery used in NWM4 was unable to pick up contiguous linear units.

Table 12: Proportion of FEPAs in the study area expressed as a percentage of the respective total area.

	NWM4			MHWet		
HGM type	**Area FEPA (ha)**	**Total Area (ha)**	**% FEPA**	**Area FEPA (ha)**	**Total Area (ha)**	**% FEPA**
Channelled valley-bottom wetland	21 726	59 396	37	91 772	209 545	44
Depression	10 743	22 856	47	5 464	23 931	23
Flat	3 938	14 133	28	67	524	13
Floodplain wetland	6 493	45 791	14	28 860	104 074	28
Seep	7 243	22 022	33	85 702	210 595	41
Unchannelled valley-bottom wetland	960	2 998	32	3 419	6 250	55
Valleyhead seep	306	954	32	0	0	0
Dam	6 487	45 429	14	0	35 474	0
Total	**57 896**	**213 579**	**27**	**215 284**	**590 392**	**36**

5 INTEGRATION OF REFINED SPATIAL DATA INTO RELEVANT DECISION SUPPORT LAYERS AND MINING-RELATED TOOLS

The preceding chapters predominantly address the project's primary aim to ground-truth and refine the current data of the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld. The updated Mpumalanga Wetland Map, containing MHWet, can be accessed on the SANBI Biodiversity GIS website at http://bgis.sanbi.org/MHwetlands/project.asp.

In addition to this primary aim, the project had two secondary aims:

- To incorporate these revised data layers into the atlas of high risk freshwater ecosystems and guidelines for wetland offsets, currently being developed by SANBI, in order to improve the scientific robustness of these tools.
- To support the uptake, and development of the necessary capacity to apply the data, atlas and guidelines by regulators and the coal mining industry in their planning and decision-making processes.

Improved spatial data is only valuable if it is actually used in decision-making. There has already been significant investment in several key decision support tools and guidelines. The integration of the refined wetland data produced by this project into these tools and guidelines is thus highly important to ensure the best available data is being used in decision-making. The products that will benefit from the refined wetland spatial data include:

- **National Wetland Map 5**: The next update to the National Wetland Map will include the refined Mpumalanga data and any other improvements to data for other parts of the country.
- ***Atlas of Freshwater Ecosystem Protected Areas in South Africa***: The constant incremental refinement of the underlying datasets will ultimately permit the identification of FEPAs to be revisited. The implications for the NFEPA project outputs were detailed in Section 4.8 of the preceding Chapter 4 and are not repeated here.
- ***Mining and Biodiversity Guideline***: A key component of this guideline was the development of integrated spatial decision support tools at a national scale. These tools included key wetland information such as FEPAs, and therefore needed to be updated with the spatial information from the current project. The process of inclusion of the updated wetland data generated by the current project is described in Section 5.1.

- ***Wetland Offsets Guideline***: This guideline links directly to spatial biodiversity information and includes methodologies for wetland offset site selection, compensation ratios and hectare equivalents used to determine the size and functionality of wetland offsets. The process of inclusion of the updated wetland data generated by the current project is described in Section 5.2.
- ***Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga***: This decision support tool is aimed at providing best available information to support sensible decisions in an area where the trade-offs from the water-biodiversity-energy nexus are highly contested. The process of inclusion of the updated wetland data generated by the current project is described in Section 5.3.

Although the production of decision support tools and guidelines is a significant step towards ensuring that the improved wetland data is used to support decision-making, developing these products is only an initial step in mainstreaming their use. Therefore, Section 5.4 of this Chapter outlines the mainstreaming processes led by the SANBI Grasslands Programme to support the uptake, and develop the necessary capacity to apply the data, atlas and guidelines by regulators and the coal mining industry in their planning and decision-making processes.

5.1 Inclusion of revised wetland data into the *Mining and Biodiversity Guideline*

5.1.1 Background to the guideline

The mining industry plays a vital role in South Africa's growth and development. However, if mining is not strategically planned and carefully implemented, it has significant negative impacts on biodiversity and ecosystems, in particular the catchments, rivers and wetlands that produce and deliver water-related services. The *Mining and Biodiversity Guideline: Mainstreaming biodiversity into the mining sector* (*Figure 18*; DEA, DMR, CoM, SAMBF & SANBI, 2013) interprets the best available biodiversity knowledge and science in terms of the implications and risks for mining in a practical and user-friendly guideline for integrating relevant biodiversity information into decision-making.

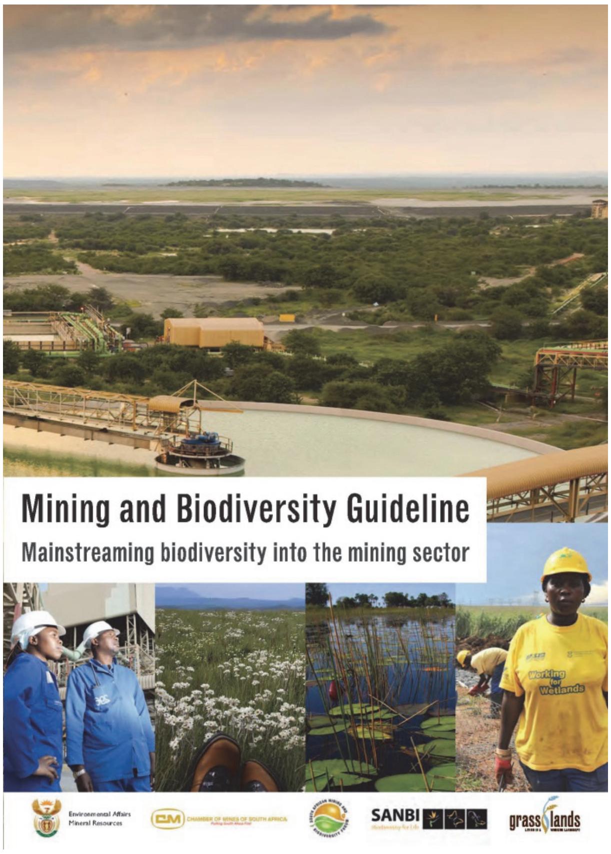


Figure 18: The* Mining and Biodiversity Guideline *interprets the best available biodiversity knowledge and science in terms of the implications and risks for mining.

The guideline is a product of the unique collaboration between the mining and biodiversity sectors. The Chamber of Mines and the South African Mining and Biodiversity Forum (SAMBF) initiated the development of this guideline, in partnership with the Department of Environmental Affairs (DEA) and the Department of Mineral Resources (DMR), and with technical input and co-ordination by the South African National Biodiversity Institute (SANBI) Grasslands Programme. Numerous other stakeholders including government, non-governmental organisations (NGOs), the scientific community and the private sector co-operated in its development. The guideline has the highest possible political support, being formally endorsed by the Ministers of both Environmental Affairs and Mineral Resources, as well as the Chief Executive Officer of the Chamber of Mines. The Chamber of Mines has committed its full membership – 69 major mining companies – to implementing the guideline.

The guideline provides a tool to facilitate the sustainable development of South Africa's mineral resources in a way that enables regulators, industry and practitioners to minimise the impact of mining on the country's biodiversity and ecosystem services. It provides the mining sector with a practical, user-friendly manual for integrating biodiversity considerations into planning processes and managing biodiversity during the operational phases of a mine, from exploration through to closure. From a business perspective, the guideline explains the value for mining companies of adopting a risk-based approach to managing biodiversity. The early identification and assessment of mining impacts on biodiversity provides an opportunity to put in place environmental management plans and actions that reduce risks to biodiversity, people and business. It gives direction on how to avoid, minimise or remedy mining impacts, as part of a thorough environmental impact assessment and robust environmental management programme.

The mitigation of negative impacts on biodiversity and ecosystem services is a legal requirement and should take on different forms depending on the significance of the impact and the area being affected. Mitigation requires proactive planning that is enabled by following the mitigation hierarchy. Its application is intended to avoid disturbance of ecosystems and loss of biodiversity, and where they cannot be avoided altogether, to minimise, rehabilitate or offset negative impacts on biodiversity. This approach lays the groundwork for integrating relevant biodiversity information into decision-making at every stage of the mining life cycle.

5.1.2 Integration of the revised wetland data

The *Mining and Biodiversity Guideline* provides explicit direction in terms of where mining-related impacts are legally prohibited, where biodiversity priority areas may present high risks for mining projects, and where biodiversity may limit the potential for mining. The guideline distinguishes between four categories of priority areas in relation to their importance from a biodiversity and ecosystem service point of view as well as the implications for mining. The spatial component is a key part of the guideline.

The guideline identifies a set of biodiversity priority areas that are sensitive to mining (*Figure 19*). For each category, the implications for mining are clearly set out, and a framework for appropriate decision-making in that area is described based on its biodiversity importance and sensitivity to mining (*Figure 20*). The biodiversity priority areas are divided into four categories based on the underlying biodiversity features (e.g. priority wetlands) and the sensitivity of these features to mining impacts. A number of these biodiversity features are wetland related (e.g. FEPA wetlands) and it is critical that they are appropriately identified.

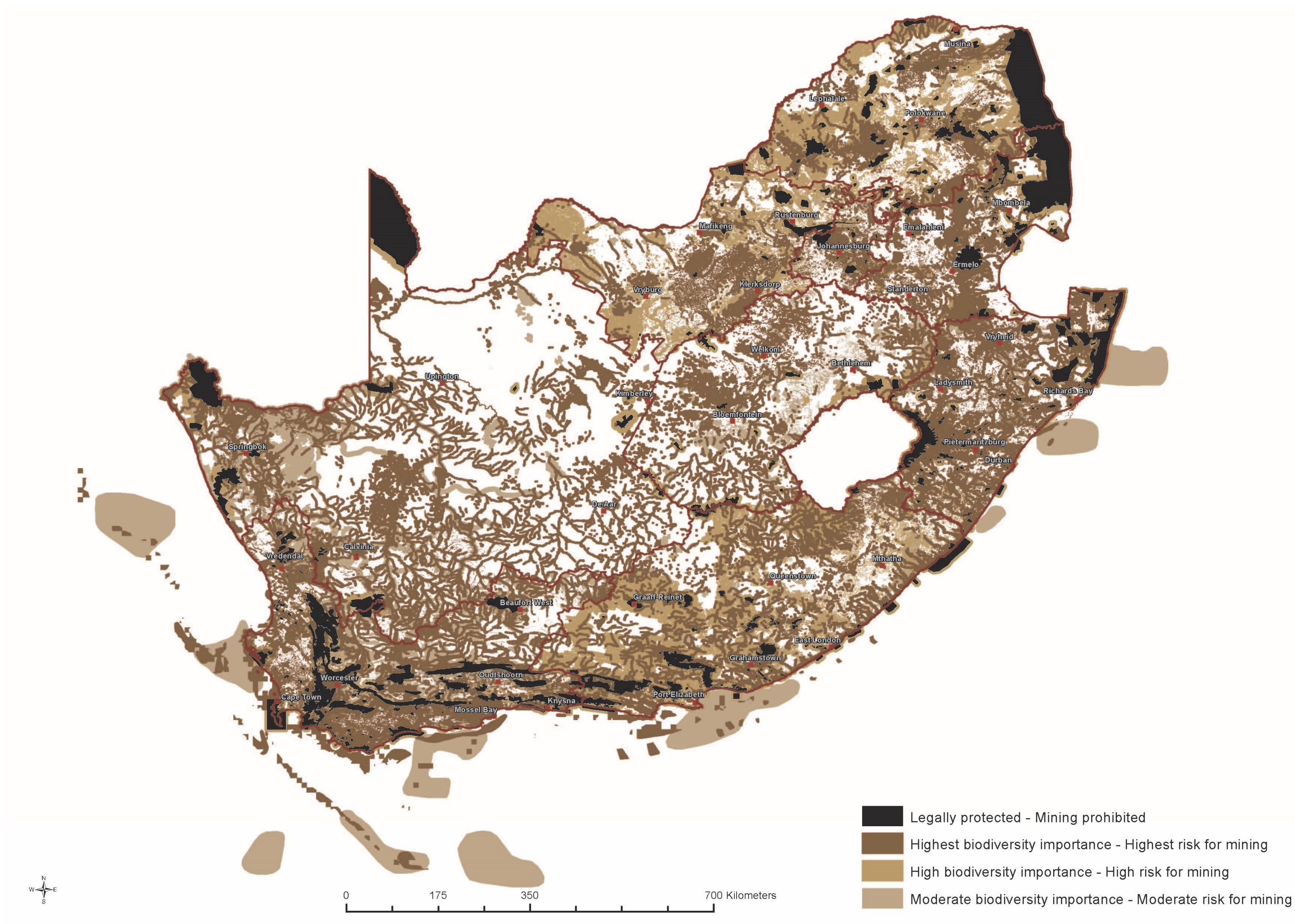


Figure 19:** A primary product of the* **Mining and Biodiversity Guideline** ***was a map of Biodiversity Priority Areas sensitive to the impacts of mining. Although this map is shown at a national level, it is supported by far more detailed GIS information, which is distributed electronically.

Category	Biodiversity priority areas	Risk for mining	Implications for mining
A. Legally protected	• Protected areas (including National Parks, Nature Reserves, World Heritage Sites, Protected Environments, Nature Reserves) Areas declared under Section 49 of the Mineral and Petroleum Resources Development Act (No. 28 of 2002)	**Mining prohibited**	Mining projects cannot commence as mining is legally prohibited. Although mining is prohibited in Protected Areas, it may be allowed in Protected Environments if both the Minister of Mineral Resources and Minister of Environmental Affairs approve it. In cases where mining activities were conducted lawfully in protected areas before Section 48 of the Protected Areas Act (No. 57 of 2003) came into effect, the Minister of Environmental Affairs may, after consulting with the Minister of Mineral Resources, allow such mining activities to continue, subject to prescribed conditions that reduce environmental impacts.
B. Highest biodiversity importance	• Critically endangered and endangered ecosystems • Critical Biodiversity Areas (or equivalent areas) from provincial spatial biodiversity plans • River and wetland Freshwater Ecosystem Priority Areas (FEPAs) and a 1km buffer around these FEPAs • Ramsar Sites	**Highest risk for mining**	Environmental screening, environmental impact assessment (EIA) and their associated specialist studies should focus on confirming the presence and significance of these biodiversity features, and to provide site-specific basis on which to apply the mitigation hierarchy to inform regulatory decision-making for mining, water use licences, and enviromental authorisations. If they are confirmed, the likelihood of a fatal flaw for new mining projects is very high because of the significance of the biodiversity features in these areas and the associated ecosystem services. These areas are viewed as necessary to ensure protection of biodiversity, environmental sustainability, and human well-being. An EIA should include the strategic assessment of optimum, sustainable land use for a particular area and will determine the significance of the impact on biodiversity. This assessment should fully take into account the environmental sensitivity of the area, the overall environmental and socio-economic costs and benefits of mining, as well as the potential strategic importance of the minerals to the country. Authorisations may well not be granted. If granted, the authorisation may set limits on allowed activities and impacts, and may specify biodiversity offsets that would be written into licence agreements and/or authorisations.
C. High biodiversity importance	• Protected area buffers (including buffers around National Parks, World Heritage Sites* and Nature Reserves) • Transfrontier Conservation Areas (remaining areas outside of formally proclaimed protected areas) • Other identified priorities from provincial spatial biodiversity plans • High water yield areas • Coastal Protection Zone • Estuarine functional zone *Note that the status of buffer areas of World Heritage Sites is subject to a current intra-governmental process.	**High risk for mining**	These areas are important for conserving biodiversity, for supporting or buffering other biodiversity priority areas, and for maintaining important ecosystem services for particular communities or the country as a whole. An EIA should include an assessment of optimum, sustainable land use for a particular area and will determine the significance of the impact on biodiversity. Mining options may be limited in these areas, and limitations for mining projects are possible. Authorisations may set limits and specify biodiversity offsets that would be written into licence agreements and/or authorisations.
D. Moderate biodiversity importance	• Ecological support areas • Vulnerable ecosystems • Focus areas for protected area expansion (land-based and offshore protection)	**Moderate risk for mining**	These areas are of moderate biodiversity value. EIAs and their associated specialist studies should focus on confirming the presence and significance of these biodiversity features, identifying features (e.g. threatened species) not included in the existing datasets, and on providing site-specific information to guide the application of the mitigation hierarchy. Authorisations may set limits and specify biodiversity offsets that would be written into licence agreements and/or authorisations.

***Figure 20: Categories of Biodiversity Priority Areas included in the* Mining and Biodiversity Guideline.**

The revised wetland layer developed for the current project feeds into the category of areas of highest biodiversity importance. Relevant aspects of this category include Critically Endangered (CR) and Endangered (EN) ecosystems and wetland FEPAs. The current project has influenced both the spatial accuracy of the biodiversity feature information (i.e. the extent, boundaries and type of wetlands are now far better defined) and the assessment of the features (i.e. certain wetland types have had their ecosystem threat status and/or inclusion or exclusion from the FEPA set adjusted). Both of these types of changes fundamentally impact on the identification and classification of biodiversity priority areas in the *Mining and Biodiversity Guideline*. The revised wetland data from the current project have hence significantly improved the quality of information underlying the guideline.

The data underlying the *Mining and Biodiversity Guideline* are housed by the SANBI BGIS website (http://bgis.sanbi.org/Mining/project.asp). Revised versions of the underlying data will only be released via the website, and hence users will have access to the latest version of the integrated spatial data. Although the *Mining and Biodiversity Guideline* makes it clear that users should access BGIS for the latest version of the data as a matter of course, SANBI will also notify users of major updates via appropriate list servers and industry bodies.

5.1.3 Dissemination of the *Mining and Biodiversity Guideline*

The revised data are available on the SANBI BGIS website, which provides free, easily useable and up to date access to the appropriate biodiversity information supporting the *Mining and Biodiversity Guideline*. The following products are available for download or interaction on the website:

- *Mining and Biodiversity Guideline* – this is the full guideline document that outlines the six principles for good decision-making and goes into detail on the implications for mining companies and regulators at every stage of the mining cycle. It provides detailed guidance on how best to utilize the underlying data, including the updated wetland layers created by the current project.
- Executive summary of the *Mining and Biodiversity Guideline* – this provides a shorter overview of the document for decision makers.
- Poster of the *Mining and Biodiversity Guideline* – this is a wall poster designed to communicate the main messages of the *Mining and Biodiversity Guideline* and serve as a summary of the different categories of biodiversity priority areas and the implications for mining.

- The up-to-date spatial data that underlie the map of biodiversity priority areas. This layer incorporates the revised wetland layer for Mpumalanga. It allows GIS users to easily download the data for use in their own systems.
- Mapping tool – this allows non-GIS users to interactively explore the spatial data and produce customized maps of biodiversity priority areas for their area of interest. It hence allows the user to produce a map, which includes the updated/revised Mpumalanga wetland layer, and thus include it in their decision-making processes.

5.2 Integration of revised wetland data into the *Wetland Offsets Guideline*

5.2.1 Background to the guideline

Although it is always better to first avoid impacts on wetlands, then minimize them through careful planning, and rehabilitate impacts on site as much as possible, in many cases there may still be residual impact on wetlands and their associated ecosystem services. A potential approach for dealing with unavoidable residual impacts is the use of wetland offsets. The Department of Water and Sanitation (DWS) Directorate: Water Abstraction and Instream Use collaborated with SANBI in order to develop a best practice guideline for wetland offsets for South Africa (SANBI & DWS, 2014). The guideline was developed with the financial support of CoalTech (a coal industry research body), the Water Research Commission (WRC) and the SANBI Grasslands Programme.

The *Wetland Offsets Guideline* (*Figure 21*) provides a comprehensive approach for compensating for residual impacts on wetlands. The guideline describes a process for evaluating required offsets in terms of the significance of residual impacts on water resources and ecosystem services, ecosystem conservation and species of special concern (*Figure 22*). The guideline includes methodologies for wetland offset site selection, compensation ratios and hectare equivalents used to determine the size and functionality of wetland offsets. This guideline incorporates water resource management principles and practices.

The intention is to adopt the guideline within the DWS to ensure that wetland offsets are applied in a consistent, predictable and acceptable manner. The guideline outlines standardised processes and principles/criteria to follow when there are residual impacts on wetlands and water resources after minimisation/mitigation of impacts and on site rehabilitation initiatives have been exhausted. Although the offset guidelines have been driven by the urgent need for consistent offset guidelines for the mining sector, the guidelines are applicable for all sectors and by all authorities involved in regulating impacts on wetlands.

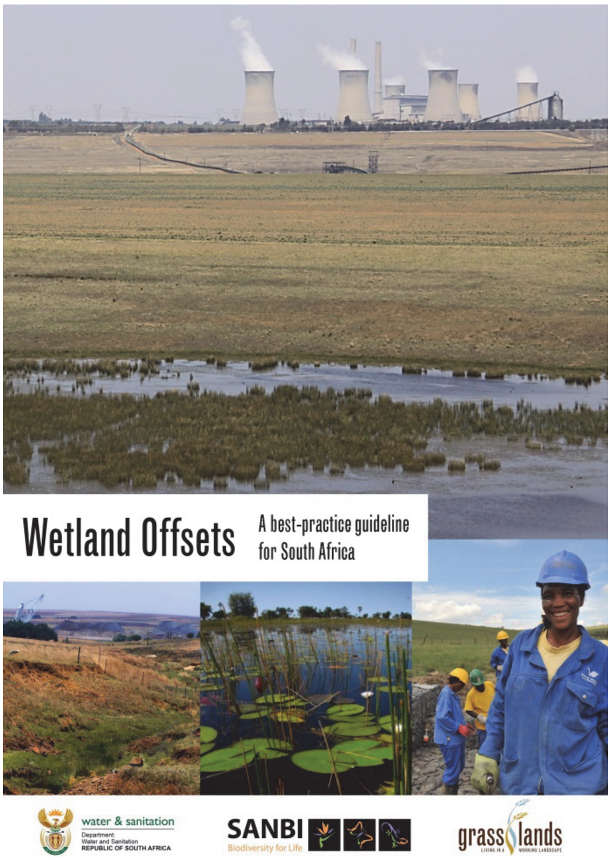


Figure 21: The* Wetland Offsets Guideline *is a practical guideline for wetland offsets for South Africa, which incorporates water resource management principles and practices as well as biodiversity requirements (SANBI & DWS, 2014).

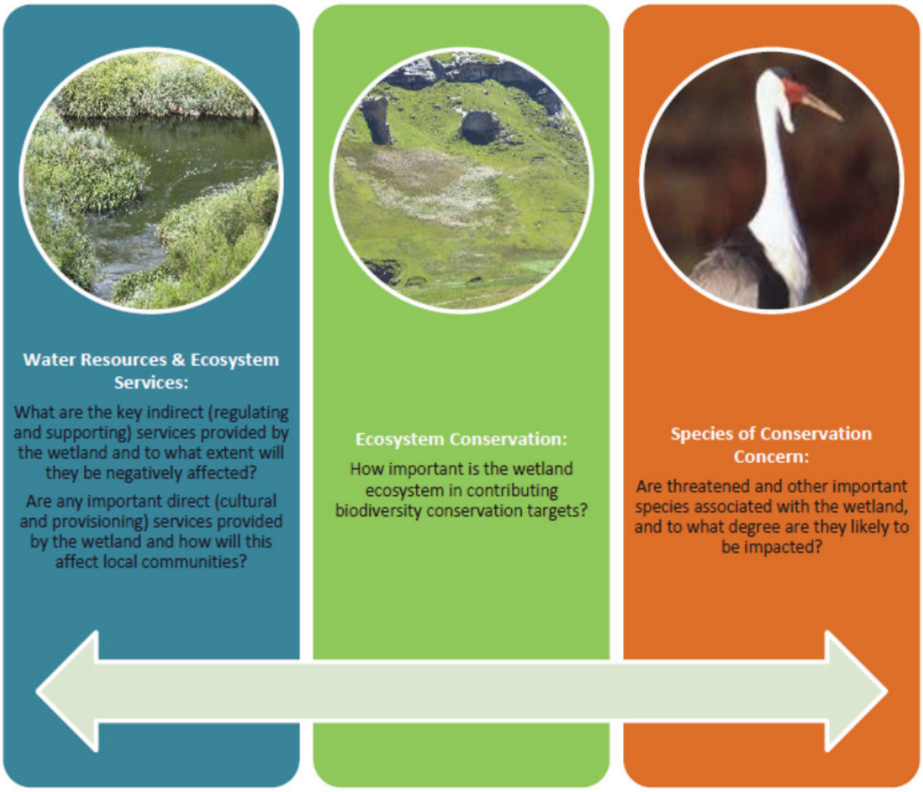


Figure 22: The* Wetland Offsets Guideline *describes a process for evaluating required offsets in terms of the significance of residual impacts on water resources and ecosystem services, ecosystem conservation and species of special concern (SANBI & DWS, 2014).

The *Wetland Offsets Guideline* includes:

- **The legal framework and policy principles:** describing national and international standards and guidelines on offsets, the South African legal context and existing policies, strategies and guidelines for offsets in South Africa, and other legislative issues including roles and responsibilities of the various parties.
- **Assessing impacts on wetlands in order to identify wetland offset requirements:** describing in detail how to calculate the size and value of the offset including assessing offset requirements for water resources and ecosystem services, ecosystem conservation and species of special concern as well as the complex system of calculating hectare equivalents.
- **Assessing offset receiving sites for water resources and ecosystem services:** describing the identification of the receiving site (where the offset is to happen), site assessment in terms of requirements for water resources and ecosystem services, ecosystem conservation and species of special concern, and adjustment of the offset contribution to account for increased offset security and implementation risk.

- **Implementing a wetland offset:** describing the planning and implementation requirements necessary for an offset in order to ensure that it meets specific offset requirements. It deals with standard requirements for any wetland offsets, how to compile a wetland offset report, how to develop a wetland offset management plan, how to develop a monitoring plan and its submission, review and approval, the implementation and monitoring of the plan and finally, verification and sign off procedures.

The guideline is accompanied by the *Wetland Offsets Calculator*, an Excel spreadsheet that helps the user to determine the wetland offset targets and assess potential gains for the receiving area in terms of contribution to wetland functionality targets, ecosystem conservation targets and species conservation targets. It is a tool that companies can use in the early planning stages of their mining or other operations to assess risks involved.

The guideline has gone through a process of intensive public and stakeholder consultation under the auspices of the DWS with the technical support of SANBI. This process will result in the formal adoption/endorsement of the guidelines, thereby giving them similar legal status to the wetland delineation guidelines (DWAF, 2005). This process will be completed during the 2014/15 financial year. Although initially being piloted for mining, ultimately these guidelines will be applicable to any activity that results in the legally sanctioned loss of wetlands.

5.2.2 Incorporation of the revised wetland data

The *Wetland Offsets Guideline* is based on a data driven assessment of the size and significance of residual impacts on wetlands (and hence the required offset) in terms of the significance of residual impacts on water resources and ecosystem services, ecosystem conservation and species of special concern (*Figure 23*). All of these components are dependent on robust underlying primary data on the size, type and condition of the wetland. In addition, the offset ratios used in the guideline draw heavily on secondary analyses such as assessments of the ecosystem threat status and protection levels for wetlands.

Although the primary data on wetlands (i.e. size, type and condition) can and should be validated at a site level when an offset is potentially required, should this data not be robust, then the use of the *Wetland Offsets Guideline* for strategic planning is severely undermined. More importantly, the secondary assessments on which the offset multipliers heavily depend cannot be validated at a site level as they are dependent on data for entire wetland vegetation groups. The offset ratios used by the guideline may have a significant influence on the size of the offset required, depending on the threat status and protection level of the wetland to be impacted. Although a lot of uncertainly in the data was eliminated by the use of the wetland assessments at a group rather than type level, it is nevertheless critical that the underlying data are robust.

The key factors are:

- The size/extent and distribution of wetlands at the wetland group level.
- The ecosystem threat status of wetlands at the wetland group level.
- The protection levels of wetlands at the wetland group level.
- Whether or not wetlands are identified as FEPAs.

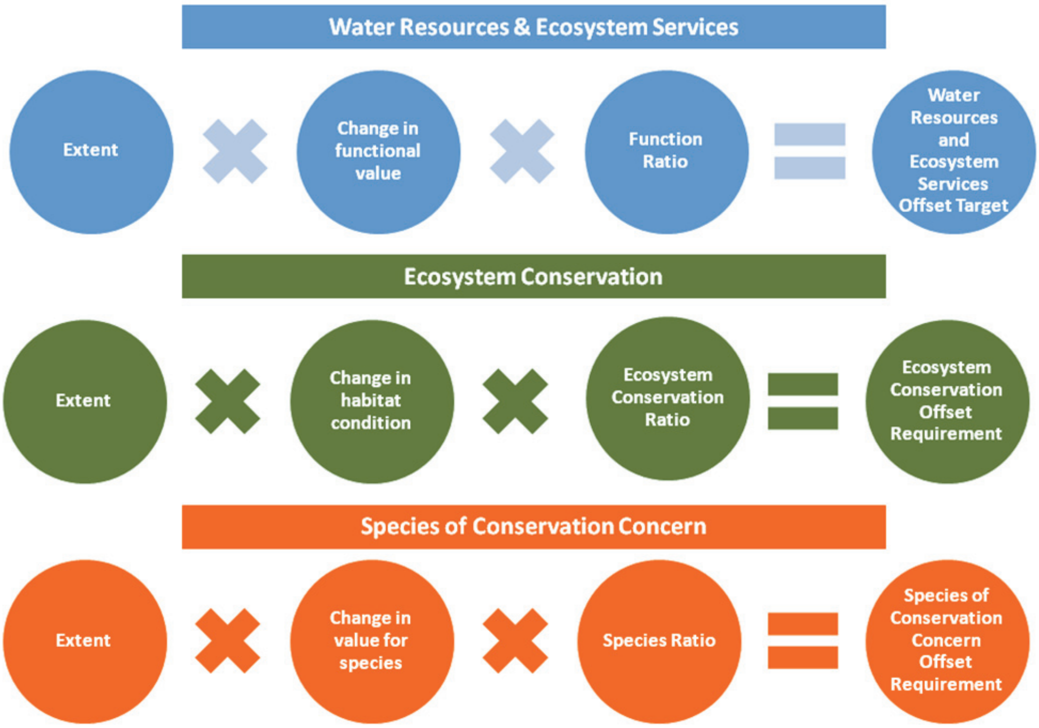


Figure 23: The centre of the* Wetland Offsets Guideline *is an approach to determine the size and nature of required wetland offsets, which is summarised in this diagram. The approach is heavily dependent on high quality wetland data (SANBI & DWS, 2014).

Many of these key information inputs into the *Wetland Offsets Guideline* were significantly updated by the current mapping revision for the Mpumalanga Highveld area. Updated tables of ecosystem threat status and protection level of wetlands at the wetland group level have been included in the appendix of the guideline, and were built into the *Wetland Offsets Calculator* accompanying the guideline. However, the most important contribution that the current project has made in terms of the application of wetland offsets in South Africa is that the guideline is now on a far more scientifically robust and defensible foundation in Mpumalanga. The revision of the wetland data for the study area has significantly improved the robustness of the key metrics underlying the *Wetland Offsets Guideline*. Far more confidence can now be placed in the application of the guideline. The improved data will contribute to the design of offsets that adequately compensate for lost wetland functions in Mpumalanga, which can then potentially result in the offsets process being taken up more rapidly elsewhere. Given the rate of coal mining expansion in Mpumalanga, it is likely that offsets will be triggered in this area more frequently than in other parts of the country for years to come.

5.2.3 Dissemination of the *Wetland Offsets Guideline*

The revised *Wetland Offsets Guideline* and supporting information are available on the SANBI BGIS website which provides free, easily useable and up to date information. The following products are available for download on the website:

- *Wetland Offsets Guideline* – the most up to date version of the guideline is available for download.
- *Wetland Offsets Calculator* – The guideline is accompanied by the *Wetlands Offsets Calculator*, an Excel spreadsheet that helps the user to determine the wetland offset targets.

5.3 Integration of revised wetland data into the *Decision support tool for high-risk wetlands*

5.3.1 Background to the decision support tool

The *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* is a collaborative initiative between SANBI, the CSIR and CoalTech, with co-funding from the WRC. It is aimed at integrating the best available information on wetlands and associated sensitive landscapes in the Mpumalanga Highveld at the finest possible desktop level. In areas like Mpumalanga, with conflicting land uses and trade-offs between mining, food and water security, investment in generating a clear and accurate picture of the extent, distribution, condition and type of freshwater ecosystems is an essential prerequisite to informed and consistent decision-making by regulators. This decision support tool is aimed at providing best available information to support sensible decision-making.

The decision support tool is tailored specifically for regulatory authorities and mining houses and identifies those freshwater ecosystems that are of particular value for biodiversity targets and/or the provision of ecosystem services. This decision support tool allows both regulators and mining companies to identify the level of risk attached to mining in particular ecosystems. Risk in this context is a multi-dimensional concept that ranges from risk to environment and human well-being due to loss of ecological infrastructure and ecosystem services, to business and reputational risk to the mining company. Covering the coal mining areas of the Mpumalanga Highveld, the atlas refines, collates and integrates existing spatial data to provide a single, coherent product accessible to both specialist GIS users and general users. This is aimed at improving decision-making, providing clarity to mining houses and regulators, and ensuring everyone is using the same easily and freely available spatial data.

The decision support tool is based on the same underlying concept as the *Mining and Biodiversity Guidelin*e i.e. that providing the best possible quality science based data will result in better decisions being made by mining houses and regulators on wetland, water resource and biodiversity issues. It is always in the interest of responsible and transparent decision-making that the best possible information is available to all involved. Further, if this information is available early in the decision-making process, the prospects for significant reduction in overall impact are increased. Once projects have made a significant investment in a site or project (including in environmental assessments), it becomes less likely that impacts will be avoided completely and more likely that the best possible outcome will be limited re-design of mine layouts and expensive rehabilitation and potentially offsets. This is clearly undesirable both from a mining point of view (as there are increased costs, risks, impacts to manage, and potentially residual impacts to offset) and from a biodiversity and water resource perspective (as the objective of the biodiversity and water resource sectors is to safeguard the resource and avoid impacts altogether).

However, it is often not possible for individual projects to do sufficiently detailed environmental planning to inform strategic decision-making on projects across broad planning areas. Therefore, the decision support tool is designed to make the sort of information that would often only be addressed later and at a site level, available earlier in the decision-making process. The same information is made available to industry, regulators and civil society, to ensure that each of these sectors can make informed decisions.

5.3.2 Incorporation of the revised wetland data

Poor quality wetland data would undermine the usefulness and credibility of the *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga*. Therefore, the current project, which has significantly improved the quality and reliability of the wetland data in the area of concern, has resulted in a major improvement in the tool.

Key outputs from the current project, which will be included in the final version of the decision support tool, are:

- The size/extent and distribution of wetlands at the wetland type level.
- The size/extent and distribution of wetlands at the wetland group level.
- The ecosystem threat status of wetlands at the wetland type level.
- The ecosystem threat status of wetlands at the wetland group level.
- The protection levels of wetlands at the wetland type level.
- The protection levels of wetlands at the wetland group level.
- Whether or not wetlands are identified as FEPAs.

In addition, as a consequence of the current project and the associated revision of the decision support tool, the following additional or revised inputs will be included:

- The updated Present Ecological State / Ecological Importance and Sensitivity scores for rivers in Mpumalanga (DWS, 2014).
- The updated Mpumalanga Biodiversity Sector Plan (MTPA, 2014).
- The updated spatial layers for the *Mining and Biodiversity Guideline* (SANBI, 2014).

5.3.3 Dissemination of the decision support tool

The *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga* will be made available both on the internet via the SANBI BGIS website as well as in a stand-alone GIS viewer (*Figure 24*). The final version has been completed and will be available on the SANBI BGIS website and as a stand-alone DVD. The publically available products will be:

- A web based GIS viewer/atlas that allows both GIS and non-GIS users to interactively explore the spatial data and produce customized maps of Biodiversity Priority Areas for their area of interest.
- A stand-alone GIS Viewer on DVD to provide easy offline access for viewing the maps. Users can zoom into specified areas of the country and query underlying data using the GIS viewer.
- The up-to-date spatial data for the features included in the decision support tool. All layers will be made freely available in standard GIS format so that users who have access to or operate GIS systems can fully utilize the data.

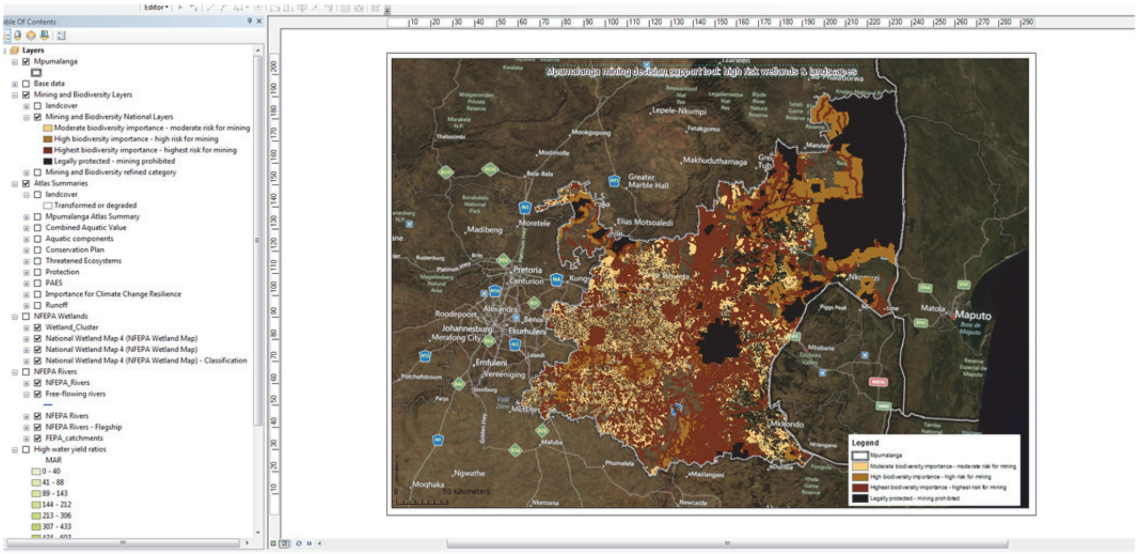


Figure 24: The* Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga *will be made available both on the internet via SANBI BGIS as well as in a stand-alone GIS viewer.

5.4 Capacity development with regulators, the mining industry and other stakeholders

The capacity development work undertaken for this project builds on SANBI's extensive programme of work on mining that started well before the current WRC project. The current project builds on existing initiatives within the SANBI Freshwater and Grasslands Programmes to mainstream appropriate biodiversity information into both the mining industry and the regulators controlling it (DMR, DWS, DEA and provincial authorities). These initiatives focussed on the *Mining and Biodiversity Guideline* and the *Wetland Offsets Guideline*, with additional smaller activities working on products such as the *Decision support tool for identifying high-risk wetlands and related landscape features for coal mining in the Highveld of Mpumalanga.* The pooling of these resources with the WRC funding resulted in outcomes that are beyond what SANBI originally planned, or what WRC could achieve by investing these resources separately in similar work. Furthermore, it ensured that the depth of engagement with appropriate regulators, the mining industry and other stakeholders, was done in a way and over a longer time period than would have been possible in a separate stand-alone project.

The mining interventions of the SANBI Freshwater and Grasslands Programmes were undertaken in partnership with the SAMBF. The Chamber of Mines runs this forum, in partnership with government (particularly the DEA and DMR) and the biodiversity sector. It was designed to serve as a platform for mining companies, NGOs and government to participate in discussions about biodiversity and mining. The SAMBF is also involved in developing and providing biodiversity-related resources and information in the form of user-guides, tools and processes targeted towards various stages of the mining life cycle. The partnership between SANBI and the SAMBF was an essential foundation for the mining and biodiversity mainstreaming programme.

5.4.1 Training and capacity building events

An extensive training programme has been undertaken focussing on the *Mining and Biodiversity Guideline* and the *Wetland Offsets Guideline*. This includes dissemination, workshops and its inclusion in training for mining engineering students and DMR officials. Rollout, capacity building and training on the various guidelines have been ongoing for almost two years. Training has been conducted at a number of sessions at different venues. Training events under the SAMBF, DEA and DWS banners have been supported by the mining industry. Participants in the training sessions have been from the private sector, academic institutions, NGOs and government. In total, 1090 people have attended various training and capacity building events on the *Mining and Biodiversity Guidelines* or *Wetland Offsets Guideline*. This number excludes attendees at a number of conferences and events where only a small part of the day was allocated to either of these issues. 889 people have attended major training events where either one or more full days was allocated to mining and biodiversity or offset issues, or where there was a dedicated event lasting at least half a day specifically organized by the mining component of the SANBI Grasslands Programme (*Figure 25*).

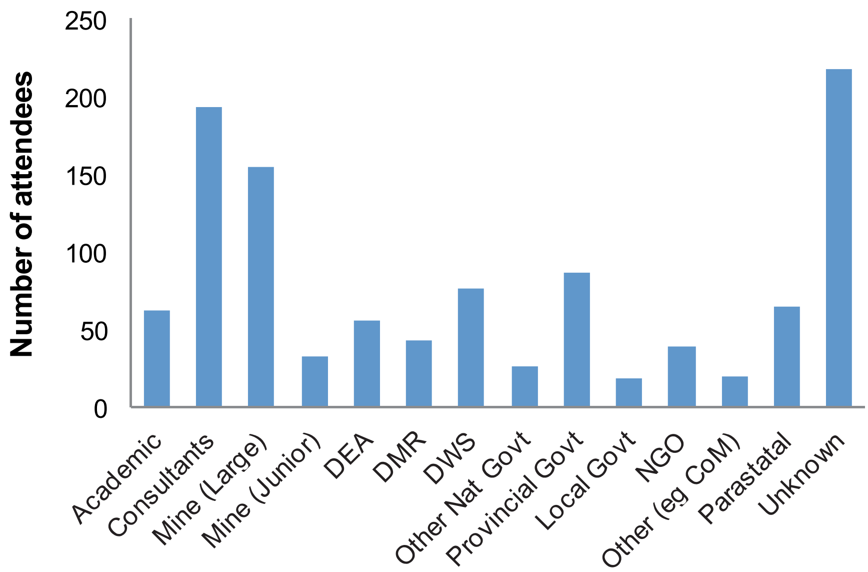


***Figure 25: Number of attendees of various major training and capacity building events on the* Mining and Biodiversity Guideline *or* Wetland Offsets Guideline.**

Most of the participants felt that the training was very effective in improving their understanding of the key content of the guidelines (Survey, 2014). Through training events, a large number of relevant people have been made aware of the guidelines and more importantly of its value for protecting biodiversity for sustainable development. There is strong support for continued training events, especially for detailed training on specific issues and for specific sectors.

5.4.2 Training and capacity building effectiveness

An informal survey by SANBI/SAMBF was conducted online in 2014 to assess the training and establish the degree to which the *Mining and Biodiversity Guideline* was being used to influence planning decisions. Of the 43 respondents, a notable 89% answered that the guideline had helped to integrate biodiversity issues into mining more effectively (Survey, 2014). In addition, most (97%) had used the guideline to varying extents in the process of their work. The majority felt that the guideline had been used to some extent to influence outcomes (56%), although a large proportion agreed that although it was generally useful, it did not influence outcomes (41%). Only a small proportion of respondents believed that the guideline did not help influence outcomes in any way (3%).

Although this survey was of limited extent, it gives some indication that the *Mining and Biodiversity Guideline* has been valuable in closing the research-implementation gap. However, methods still need to be developed to more accurately measure the uptake of the guideline, both nationally and internationally. This will be the most important test of its worth and utilisation. We have not yet gauged the effectiveness of training on the *Wetland Offsets Guideline* and other mainstreaming products.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The mining industry plays a vital role in South Africa's growth and development. However, extracting mineral resources from the earth also has significant potential to cause serious environmental degradation, some of which can be irreversible if mining is not planned, implemented and regulated with an understanding of the full range of its social, ecological, hydrological and economic costs and benefits. In the Mpumalanga Highveld, wetlands are particularly vulnerable to coal mining related impacts. It is generally most economical to mine shallow coal deposits in low-lying parts of the landscape, where erosion has stripped off some of the overlying layers of rock. These are also the parts of the landscape where water tends to concentrate, and are hence where wetlands are most likely to form. Where this is the case, it is usually not possible to mine the coal using opencast methods without destroying many hectares of wetlands and associated riverine ecosystems. Thus, opencast coal mining in Mpumalanga or elsewhere can and does have significant negative impacts on water-related ecosystems and their constituent biodiversity. This impacts on the ability of these ecosystems to continue to provide water-related ecosystem services to adjacent and downstream users.

In areas like Mpumalanga, with conflicting land uses and trade-offs between mining, food and water security, investment in generating a clear and accurate picture of the extent, distribution, condition and type of freshwater ecosystems is an essential prerequisite to informed and consistent decision-making by regulators.

The National Freshwater Ecosystem Priority Areas (NFEPA) project provides an extremely effective foundation for national, provincial and catchment-scale strategies for conserving freshwater biodiversity. NFEPA maps are widely used in a range of applications, including by Department of Water and Sanitation (DWS) and other regulatory authorities for decision-making pertaining to mining and by South African National Biodiversity Institute (SANBI) to underpin tools being developed through its mining work. The results of this project have quantitatively illustrated, in no uncertain terms, the extent of wetland area in the Mpumalanga Highveld that was not captured in NWM4, and hence in the NFEPA project. The magnitude of the disparity, with 75% of the wetland area mapped in MHWet going undetected by NWM4/NFEPA, reinforces the anecdotal reports from wetland experts in other parts of the country regarding weaknesses in the quality of the NWM4 data.

Similar mapping accuracies to those found in the Mpumalanga Highveld study area can therefore be expected in the rest of the country, although experience with previous versions of the National Wetland Map has shown that mapping accuracy does vary from one area to another (GeoTerraImage, 2008). Nonetheless, sufficient data has been collected to indicate that the weaknesses in NWM4 are sufficiently severe and widespread to warrant investment in the improvement of the quality of the National Wetland Map as a matter of urgency. Unfortunately, the products produced by the National Wetland Inventory to date have been seen as end or finished products, rather than as starting points for further local and site level refinement by custodians and users of the data.

This project supports better decision-making around coal mining in the Mpumalanga Highveld through the refinement of data on the extent, distribution, condition and type of wetlands, and incorporation of revised data layers into key tools that support several planning and decision-making processes. This project thus presented a timely opportunity to develop standardised methods for ground-truthing and refining the NFEPA data. Tools developed to support decision-making are only as robust as the data they use, which is why the primary focus of this project was on the refinement of spatial and attribute data on wetlands. Through this process, capacity in Mpumalanga was strengthened and uptake of tools was encouraged. The project created valuable opportunities to network and to identify areas of expertise and skills within the province and the stakeholder group. It also built on existing expertise and engaged with the Mpumalanga wetland community of practice to develop the capacity of people in relevant institutions, through learning-by-doing and onsite training.

6.1.1 Refinement of data on wetlands

The primary objective of this project was to undertake ground-truthing and refining of the current data layers of the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt. This focused primarily on improving the accuracy and confidence in the spatial component of the wetland mapping. Secondary to this, were efforts to verify and update hydro-geomorphic type for the mapped wetlands and update information on wetland condition.

Improving the accuracy and confidence in the spatial component of the wetland mapping equated, primarily, to removing any erroneously mapped wetland polygons and confirming existing mapped wetlands, and secondarily, to adding newly mapped wetlands. Several technical recommendations related to this process are presented in the section below.

Through these updates on extent, distribution, condition and type of wetlands, significant improvements to the NWM GIS layers were made. This included assigning confidence levels to wetland data and improvements in accuracy of spatial wetland detection and overlap, which have important implications in terms of the confidence with which users can apply the data. Additionally, a new wetland ecosystem type to the country was mapped: Mesic Highveld Grassland Group 7 Floodplain.

The data have been incorporated into the existing architecture of the National Wetland Inventory. The advantage of this is that no new databases were created. Existing databases for the inventory were refined where necessary and the long-term curation of the data is secured through SANBI.

These improvements have implications for:

- **Ecosystem threat status** for wetland ecosystem types and wetland vegetation groups: The re-assessment in this project resulted in the ecosystem threat status for 23 of the 49 (46%) wetland ecosystem types recorded in the Mpumalanga Highveld being changed. All became less threatened than previously evaluated. It is recommended that, for ten of these wetland ecosystem types, the ecosystem threat status in the NBA 2011 should be updated. At the level of wetland vegetation groups, this re-assessment found that the ecosystem threat status of six of the 11 (54%) wetland vegetation groups present in the study area changed. All became less threatened than previously evaluated. It is recommended that for two of these wetland vegetation groups, the ecosystem threat status in the NBA 2011 should be updated.
- **Ecosystem protection levels**: In re-assessing the 49 wetland ecosystem types in the study area, 18 changed their ecosystem protection levels (38%). The ecosystem protection levels improved for all wetland ecosystem types. It is recommended that the ecosystem protection levels for nine of these 18 wetland ecosystem types should be changed at a national level. Ecosystem protection levels for wetland vegetation groups were not calculated for the NBA 2011, and therefore there is no change in status.
- **Freshwater Ecosystem Priority Areas**: Overall, FEPAs have increased from 27% of the wetland area in the Mpumalanga Highveld to 36%. This 9% increase was expected given the increased extent of the newly mapped wetlands in MHWet, combined with the increased extent in good and moderate condition wetlands. The biggest increases were from valley-bottom and flood plain wetlands.

- **Listing of threatened or protected ecosystems:** The ground-truthing and refinement of the current data layers of the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt will also contribute to setting the basis for potentially listing specific freshwater ecosystem types as "Threatened" under the provisions of the National Environmental Management: Biodiversity Act (No. 10 of 2004). This listing is dependent on robust data on freshwater ecosystem type, condition of wetlands and threat status. Currently data are not of sufficient quality to allow this listing, and hence, unlike terrestrial habitat types, aquatic habitats in Mpumalanga are not effectively covered by this legislation.

6.1.2 Incorporation of revised data layers into key tools

The incorporation of the updated wetland data into key tools that support several planning and decision-making processes was a secondary aim of the project. This included supporting the uptake and development of the necessary capacity to apply the data and guidelines by regulators and the coal mining industry in their planning and decision-making processes.

The key tools into which the revised data layers are being incorporated are the *Decision support tool for identifying high-risk wetlands in Mpumalanga* and the *Wetland Offsets Guideline*. The revised wetland data make an important contribution to improving the scientific robustness of these tools. This provides a more defensible foundation, in Mpumalanga specifically, and far more confidence can now be placed in the application of the *Wetland Offsets Guideline*. The spatial data that supports another existing tool, the *Mining and Biodiversity Guideline*, is also being updated.

Although initially piloted for mining, ultimately these tools will be applicable to any activity that has the potential to impact upon wetlands. The improvement to wetland data through this project has thus strengthened existing tools and, it is hoped, will contribute to better decision-making by mining houses and regulators that takes full cognisance of wetland, water resource and biodiversity issues, in pursuit of a set of optimal development scenarios for the Mpumalanga Highveld. It is always in the interest of responsible and transparent decision-making that the best possible information is available to all involved.

The uptake of tools and development of the necessary capacity to apply the data and guidelines by regulators and the coal mining industry in their planning and decision-making processes has been supported through this project. The *Decision support tool for high-risk wetlands in Mpumalanga* will thus allow the revised data generated by this project to be quickly disseminated as part of an existing process. The improvements to the data have dramatically improved the usefulness and robustness of the wetland data in Mpumalanga. This has improved the likelihood that the data will be used more extensively across Mpumalanga by a sector that has a significant impact on freshwater resources.

6.2 Recommendations

Building on lessons learned during this project, a set of recommendations are presented below, spanning the various elements of work covered by the project. These recommendations are grouped into those specific to further improvement of the MHWet dataset, and those that support the improvement of wetland inventory information more generally in South Africa.

6.2.1 Recommendations for further improvement of the new dataset of Mpumalanga Highveld wetlands

Ensure appropriate messaging accompanies the dissemination of the dataset. The Mpumalanga Highveld wetlands map that was produced through this project presents a significant improvement in wetland spatial information for the region, and represents the best current state of knowledge. However, it still has some limitations in terms of accuracy and completeness. The messaging that should accompany the dissemination and use of the dataset is thus one that points out that this dataset is not perfect, but is the best current source of wetland spatial information and is a vast improvement on what was available for the area in the NWM4. Messaging should also invite users to provide feedback, based on their use of the dataset, which will assist in filling gaps and enhancing accuracy.

Undertake further ground-truthing. Due to time and personnel constraints, the majority of wetlands were only mapped at a low level of confidence (as defined in *Table 4*). This cannot replace the need for detailed ground-truthing. Aspects of wetland condition and regional wetland type can only be confidently assigned after a field visit. These wetland characteristics, while modeled during desktop preparation, still require verification through detailed ground-truthing. Field classification is essential to gather data for accurate regional typing and to explore the potential for setting future modelling rules according to environmental variables. Much more ground-truthing is necessary using the longer, detailed version of the datasheet. Updated plant lists are also required before further ground-truthing.

Refine wetland typing in the dataset. At this point, there is no way to automate accurately the allocation of regional wetland type at the desktop level. There is still much that is unknown about the full diversity of wetlands in South Africa and their constituent biodiversity. Wetland type is an important component of aquatic conservation planning, which sets targets to conserve a representative sample of biodiversity pattern. The accuracy of the wetland types used in the current conservation planning products remains to be tested through field verification and academic studies. This is challenging, as drivers of wetland diversity derive from, and are reflected at, multiple spatial levels, from broad-level regional patterns through to fine-scale habitat structure, chemistry and species assemblage differences. This shortcoming of the current datasets must be acknowledged, as the importance of fine-scale research cannot be replaced by the data that is currently available.

Improve confidence in the assignment of HGM types*.* For the most part, HGM type was assigned at a desktop level based on a visual interpretation of the imagery, assisted by topography/contour and river lines. Doing the typing in this way, with such a large project area, has resulted in low confidence in the assigned HGM types. This must be acknowledged so that the data can be used in an appropriate way and to gain the trust of the users.

Use quinary catchments as the units for reviewing wetland data. Once the detailed ground-truthing is complete for a sub-catchment, and the findings incorporated into an updated dataset, a review of the wetlands in every quinary catchment should be conducted in order to achieve a higher level of mapping confidence. In this way, knowledge gained in the field, and expert knowledge of the area, is incorporated into the dataset to improve accuracy. This important stage cannot be replaced as it contributes to increased confidence in the dataset. At the scale of a sub-catchment, it is much easier to compare and contrast amongst the wetlands, which improves the review confidence and calibration of results. This should be undertaken one final time to identify any remaining data errors.

Refine GIS techniques for capturing data. Recommendations for GIS mapping can be made based on issues identified during the project. These issues arise from primary data capture techniques and data collation. Problems caused are usually hidden until the layer is interrogated and used for further analysis. If there are various data capturers and digitizers, an individual with experience in GIS primary data capture should be in control of collating the various data layers to create the final GIS product. GIS capture techniques should be planned out carefully and primary capturing (digitizing) of GIS layers should be done by experienced practitioners according to a strict GIS protocol.

Some of the errors that arise from haphazard data capture include multipart polygons, which create difficulties when performing any spatial analysis in ArcGIS. There is a need to use single part polygons when digitizing wetlands. This is important especially when this data is to be used for any other GIS analysis. This issue is even apparent within the existing NFEPA dataset. In addition, overlapping polygons with different HGM types also created complications. Standardised data capture will assist with reducing overlapping of polygons in the GIS layer. Attribute data consistencies should be taken into account when creating data in a GIS as inconsistencies can influence any analysis intending to use the specific GIS layer. Correcting these issues will be particularly important if attempting a system of mapping updates based on citizen science or by incremental additions using the tablet-based applications.

Agree on the final set of attributes for the dataset. The final set of attributes for the MHWet dataset requires revisiting, based on experience during the mapping stage, and agreement with primary users of the data. Different data users have differing needs for data analysis and require information on data source and confidence as well as the basic identifying information such as the name of the wetland. Based on feedback from wetland specialists the requirement for source and confidence information is a recurring recommendation. These users would like to know which wetlands were mapped and reviewed by a specialist, which were modelled and which came from survey and mapping. Also, the current set of attributes for NFEPA are important informants for a conservation planning technical analysis but are not ideal for a public inventory layer. There is also a need to reconcile attributes between this project and the NFEPA project, particularly in the treatment of dams. In the NFEPA project, dams were identified through a stand-alone attribute column that distinguished between natural and artificial wetlands. In the MHWet dataset, dams were included as a category of HGM type.

Secure and incorporate other wetland datasets. Ongoing inventory work will benefit from gaining access to other existing wetland datasets covering the study area, which could not be secured for this project. Maintaining and strengthening relationships with wetland specialists in the region is one mechanism for facilitating access to supplementary data. Protocols need to be in place to accept this data and reconcile it with the new wetlands map created through this project. This requires both GIS expertise to incorporate additional data and align the attributes, and wetland expertise to make appropriate decisions on adjustments and further review. The accuracy of this protocol and its proper implementation must be evident to the wetland community to reassure users that the data has not lost value or been inadvertently altered during incorporation.

6.2.2 Recommendations for the development of a high confidence wetland inventory for the entire Mpumalanga Province

Establish the necessary partnerships and clarify roles and responsibilities of the partners. The current project has helped to make significant strides towards a wetland inventory of high confidence for the province. It must however be kept in mind that the project did not cover the entire province, and the areas that it did cover were not all mapped with high confidence. Achieving a highly accurate inventory for the entire province will ultimately involve multiple partnerships and a long-term commitment over several years. Such partnerships need to be formed between a dedicated core wetland inventory team, primary stakeholders and other users of wetland inventory information, such as the provincial departments of agriculture and environment, DWS regional office and CMAs, and municipalities, with a role for consultancy inputs. A key initial question is with which mandated department to base the core wetland inventory team, SANBI, DWS or the province. Irrespective, very clear communication and collaboration between these three would be important.

Link provincial wetland mapping processes to the provincial aquatic conservation plan. Updating the Mpumalanga provincial aquatic conservation plan is also a long-term goal. The task is large and will require multiple years of investment, collective thinking and focussed ground-truthing. The updating of the aquatic conservation plan will benefit from being part of a long-term programme of investment in the provincial wetland inventory, and will require clear communication and collaboration between national and provincial entities.

6.2.3 Recommendations for mapping wetlands at a systemic landscape scale

Develop a national strategy for updating the National Wetland Map. This project has shown that the base dataset (NWM4) upon which the analyses were carried out to produce the FEPA maps is in urgent need of further improvement, as elaborated earlier in this chapter. Ignoring the current flaws in these foundational data will have implications for the credibility of any products that build upon these foundations. Improving the quality of first order wetland inventory data for the country as a whole is a daunting task that is beyond the ability of any single organisation to address individually. Experience through this project, which covered a part of one province, showed that considerable time, financial and human resources are required to do the task justice.

Given the magnitude of the task, a carefully crafted strategy for updating the National Wetland Map will be required; one that takes account of current human and financial resource constraints. Such a strategy would guide both implementation and the ongoing improvement of the wetland inventory methods, while at the same time refining the existing data on the extent and types of wetlands. Organisations that would be considered primary generators, users and/or custodians of wetland inventory data would be the logical lead agents in realising such an approach. Such organisations might include (in no particular order) DWS, DEA, WRC, CSIR and SANBI at national scale, in collaboration with a range of relevant organisations with similar interests and mandates at provincial, local and catchment scales.

Taking into account the magnitude of the task and the resources available to tackle it, the strategy should ideally adopt a patchwork of approaches for updating inventory information in different areas. This implies carving the country up into logical units within which more localised initiatives to update inventory information can be pursed. These approaches should capitalise on local opportunities, capacity, funding and institutional champions (e.g. the existence of a willing Catchment Management Agency, municipality, provincial or national agency such as SANParks).

Where initiatives are already underway or planned in provinces, municipalities or other organisations, it makes sense to support these, not least to ensure there is no duplication of effort where resources are already scarce. A review of job tasks, competencies and priorities with respect to the mandate of wetland conservation and monitoring would help support provinces in their endeavours to motivate at managerial levels to improve the capacity of provincial conservation agencies and departments to carry out wetland mapping.

An enabling factor for the proposed patchwork approach to update the National Wetland Map is the existence of a proposed standardised methodology for wetland mapping that will serve as a common language cutting across the variety of localised initiatives (see the following recommendation).

Certain components of an update to NFEPA can be supported by scientific research, and in some instances can be undertaken by private specialist consultancies (for example, if commissioned to prepare a wetland map for an Environmental Management Framework or other strategic projects that cover a large area). However, the government custodians of wetland conservation should ideally take leadership in developing catchment/WMA, provincial and national strategies. In the interim, it makes sense to begin with necessary refinement of wetland data wherever possible.

Employ the wetland inventory manual compiled through this project as a standardised approach for wetland mapping and ground-truthing of NFEPA data in other catchments. This project has proposed a set of methods and tools that can be used to update wetland inventory data in any part of the country (see the wetland inventory manual, still to be published). These standardised methods are a key output of the project, are nationally applicable and should not be overlooked, even though the primary emphasis of the project was on improving the spatial data for Mpumalanga. Future initiatives to update inventory data at local scales will benefit by not having to invest in method development to anything like the extent that this project did. The use of these methods in other mapping projects should result in the generation of data that is compatible with the National Wetland Inventory, making it easier to incorporate the resulting data into the National Wetland Map.

Adopt a catchment-based approach when selecting study areas for mapping initiatives, and ensure that these areas are small enough to be manageable. The project described in this report took an approach that divided the study area into work packages using quinary catchments as the units for collecting, assessing and improving wetland information. This was effective in determining which catchments had been completed and scheduling those to undertake next. It is recommended that a single catchment should be selected at a time and systematically reviewed (e.g. from north to south) so that a catchment can be fully completed and not be left partially complete. The catchment approach also allows for comparisons within and between catchments, which greatly assists in decision-making. Comparisons can be used to determine the relative importance of wetlands and the range of wetland types and disturbances. Such comparisons are also effective learning mechanisms for those involved in wetland mapping.

The site-level refinement of wetland mapping is a slow and time-consuming process. Although the current project made significant progress in updating the mapping of Mpumalanga wetlands, in retrospect it was dealing with too large an area. We therefore recommend that a key part of the design of future landscape-level mapping projects is the careful scaling of study area size to match the resources available to the project.

Ensure the capacity of mapping project teams corresponds to study area size and contains both wetland and GIS technical expertise. Projects of this nature require careful coordination of the various tasks of field-based training, preparing maps and tools, inputting data into datasheets and updating GIS layers in a timeous manner that would ensure that multiple teams are able to work concurrently. A dedicated co-ordinator would be better able to co-manage the various tasks, while organising meetings, planning sessions and providing support for each of the project partners. The type of expertise required, which combines wetland technical knowledge with advanced GIS data capture and manipulation skills, necessitates a multi-disciplinary, team-based approach. The lack of such expertise constituted one of the largest hurdles to be overcome by the project, and necessitated subtle redesign of the approach in order to accommodate the lack of readily available expertise and the length of time it took to develop the competence of project team members to the necessary standard.

Invest in capacity building as a central and ongoing component of any wetland mapping project. "Output-based capacity building" is strongly recommended as an approach to any capacity building related to improving the wetland inventory into the future. The premise of this is that – as opposed to a single workshop – ongoing engagement over the course of mapping one complete catchment together would be more effective at developing the improved capacity needed to generate consistent, high quality spatial wetland data. Participants often require much longer than a once-off workshop to understand and become familiar with new ideas and methods. Comprehensive and ongoing training is also likely to be more effective than simply providing a manual or written guideline detailing how people should go about their work. The recommended approach is to invest in working with a core group over an extended period, to understand the challenges and develop feasible solutions together.

6.2.4 Recommendations for updating national products that rely on wetland maps

Standardise the approach used for updating other products that draw on spatial wetland data. There is similarly the need for a standardised process to update other maps, tools and guidelines that are dependent on underlying detailed wetland spatial and attribute data. It is important that large-scale projects aimed at updating wetland data also include clear processes (or at least specific recommendations) for updating key national datasets such as:

- The **National Wetland Inventory** (which generates the National Wetland Map) requires more frequent full and partial updates and a clear update protocol, recognising that the most feasible and appropriate way of doing this is through incremental updates that take place at more localised scales (e.g. municipal, sub-WMA, provincial or jurisdictional).
- **Ecosystem threat status and protection levels** require an appropriate update process and data repository to disseminate the most current status. As the base data can change rapidly, it is necessary for the responsible institutions to implement

systems to provide quicker update cycles than the current five to seven year cycle applied through the NBA.

- The identification of **FEPAs** needs to be formally revised and updated. This dataset cannot be seen as a once-off assessment. Systems need to be in place for an appropriate update process and data repository, together with agreement on the frequency of revising the FEPA dataset.
- The spatial data underlying the ***Mining and Biodiversity Guideline*** needs to be updated on a frequent basis to ensure the product remains valid. This dataset cannot be seen as a once-off assessment. Systems need to be in place for an appropriate update process and data repository to serve the spatial assessments of biodiversity priority area categories.

Update national products that draw on spatial wetland data at the appropriate frequencies. It will be important to keep key national spatial information datasets, and associated products, up to date. If this does not occur, these tools will suffer rapid loss of relevance. The key national datasets that would benefit from more robust update protocols and regular updates are listed in the recommendation above.

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APPENDIX A

Appendix A contains the following:

- Appendix A1 – The final re-assessed ecosystem threat status for all 793 wetland ecosystem types in South Africa
- Appendix A2 – The final re-assessed ecosystem threat status for all 133 wetland vegetation groups in South Africa
- Appendix A3 – The final re-assessed ecosystem protection level categories for all 793 wetland ecosystem types in South Africa
- Appendix A4 – The final assessment of ecosystem protection levels for all 133 wetland vegetation groups in South Africa

Owing to the length of these lists, they are not reproduced here, but are available on the accompanying data disc in the following supplementary file formats for ease of accessibility:

- Appendix A.docx (word document)
- Appendix A.xlsx (excel spreadsheet)

A Stakeholder Workshop Report on this project is also included on the CD.