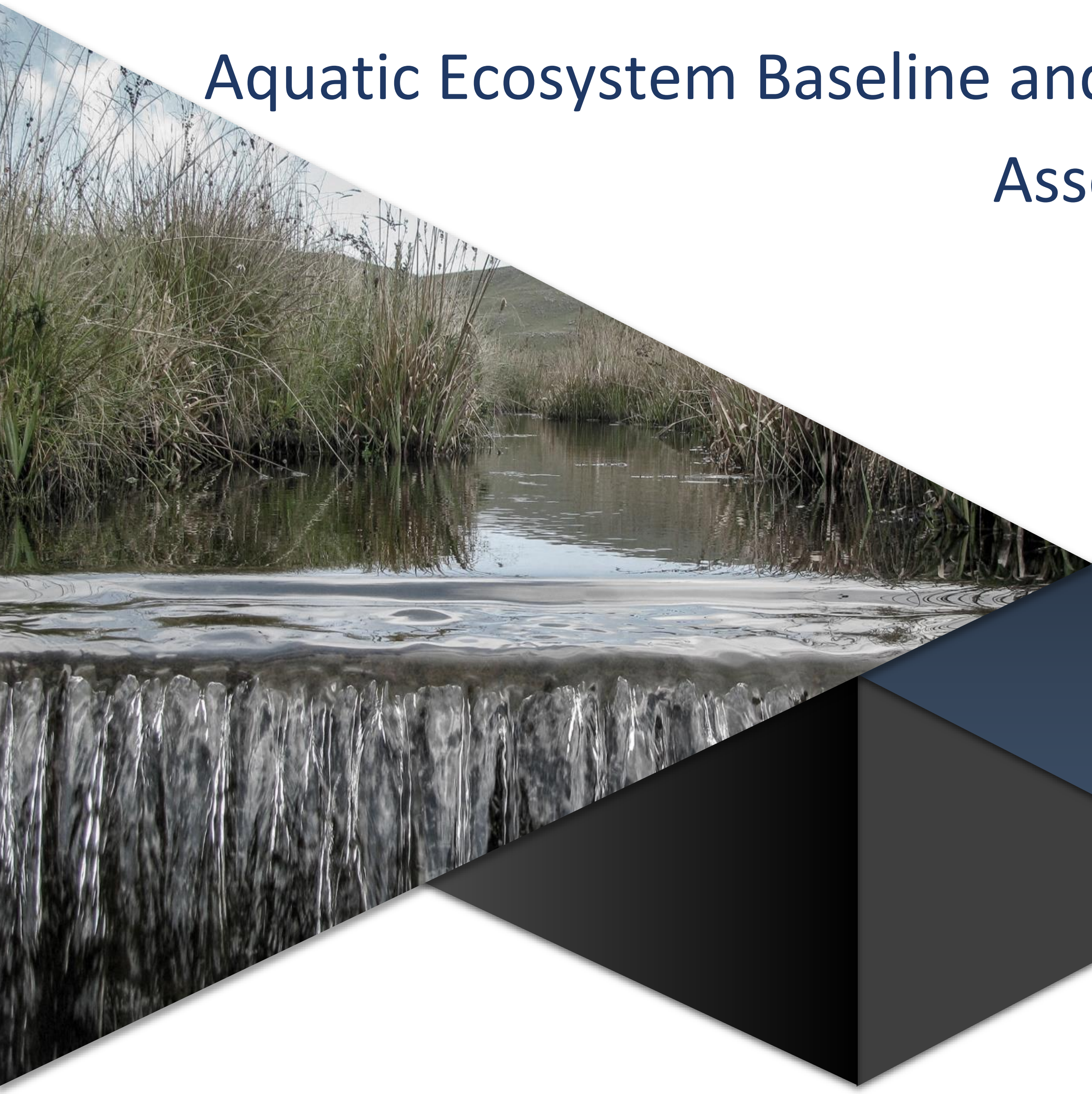
Appendix H.4

AQUATIC BIODIVERSITY ASSESSMENT

Dalmanutha Wind Energy Facility (Alternative 1 and 2), Belfast

Aquatic Ecosystem Baseline and Impact Assessment



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Specialist Report Requirement Checklist (as per gazetted procedures for the assessment and minimum criteria for reporting on identified environmental themes in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998.)

Requirement	Report Section
2.7. The findings of the specialist assessment must be written up in an Aquatic Biodiversity Specialist Assessment Report that contains, as a minimum, the following information:	
2.7.1. contact details of the specialist, their SACNASP registration number, their field of expertise and a curriculum vitae;	Appendix E Appendix F
2.7.2. a signed statement of independence by the specialist;	Page ii Page iii
2.7.3. a statement on the duration, date and season of the site inspection and the relevance of the season to the outcome of the assessment;	Section 1.2
2.7.4. the methodology used to undertake the site inspection and the specialist assessment, including equipment and modelling used, where relevant;	Appendix A
2.7.5. a description of the assumptions made, any uncertainties or gaps in knowledge or data;	Section 1.3
2.7.6. the location of areas not suitable for development, which are to be avoided during construction and operation, where relevant;	Section 4.10
2.7.7. additional environmental impacts expected from the proposed development;	Section 5.3
2.7.8. any direct, indirect and cumulative impacts of the proposed development on site;	Section 5
2.7.9. the degree to which impacts and risks can be mitigated;	Section 5.4
2.7.10. the degree to which the impacts and risks can be reversed;	Section 5.4
2.7.11. the degree to which the impacts and risks can cause loss of irreplaceable resources;	Section 5.4
2.7.12. a suitable construction and operational buffer for the aquatic ecosystem, using the accepted methodologies;	Section 4.10
2.7.13. proposed impact management actions and impact management outcomes for inclusion in the Environmental Management Programme (EMPr);	Section 5.6 Section 5.7
2.7.14. a motivation must be provided if there were development footprints identified as per paragraph 2.4 above that were identified as having a "low" aquatic biodiversity sensitivity and that were not considered appropriate;	Section 5.5 Section 6
2.7.15. a substantiated statement, based on the findings of the specialist assessment, regarding the acceptability or not of the proposed development and if the proposed development should receive approval or not; and	Section 6
2.7.16. any conditions to which this statement is subjected.	Section 6

Dalmanutha Wind Energy Facility (Alternative 1 and 2), Belfast, Mpumalanga

Aquatic Ecosystem Baseline Assessment

Project Ref. No: 220021

Prepared for:

WSP GOLDER

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May 2023

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(Aquatic Science, Ecological Science, Zoological Science)

DECLARATION OF INDEPENDENCE BY SPECIALIST

I, **KIEREN BREMNER DUNNE**, in my capacity as a specialist consultant, hereby declare that I -

- act as an independent consultant;
- will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- declare that there are no circumstances that may compromise my objectivity in performing such work;
- do not have any financial interest in the undertaking of the activity, other than remuneration for the work performed in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have expertise in conducting the specialist report relevant to this application, including knowledge of the National Environmental Management Act, 1998 (Act No. 107 of 1998), regulations and any guidelines that have relevance to the proposed activity;
- based on information provided to me by the project proponent and in addition to information obtained during the course of this study, have presented the results and conclusion within the associated document to the best of my professional ability;
- undertake to have my work peer reviewed on a regular basis by a competent specialist in the field of study for which I am registered; and
- as a registered member of the South African Council for Natural Scientific Professions, will undertake my profession in accordance with the Code of Conduct of the Council, as well as any other societies to which I am a member.

29 May 2023

Date

Kieren Bremner Dunne Pr.Sci.Nat.
Senior Specialist
Ecology International (Pty) Ltd
SACNASP Reg. No. 119341
(Aquatic Science)

DECLARATION OF INDEPENDENCE BY SPECIALIST

I, **BYRON GRANT**, in my capacity as a specialist consultant, hereby declare that I -

- act as an independent consultant;
- will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- declare that there are no circumstances that may compromise my objectivity in performing such work;
- do not have any financial interest in the undertaking of the activity, other than remuneration for the work performed in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
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____

Byron Grant Pr.Sci.Nat.
Director & Principal Specialist
SACNASP Reg. No. 400275/08
(Aquatic Science, Ecological Science & Zoological Science)

29 May 2023

____

Date

EXECUTIVE SUMMARY

Dalmanutha Wind (Pty) Ltd appointed WSP Group Africa (Pty) Ltd (WSP) as the lead Environmental Assessment Practitioner (EAP) to complete the Environmental Impact Assessment (EIA) process required to gain Environmental Authorisation for a proposed Dalmanutha Wind Energy Facility to be located near the town of Belfast in the Mpumalanga Province of South Africa. WSP, in turn, appointed Ecology International (Pty) Ltd as independent ecological specialists to conduct the required surface water and aquatic specialist assessment to inform the necessary environmental processes as well as the Water Use Licence Application (WULA) process.

Following a detailed desktop review, a site-based assessment of the associated watercourses (the Waarkraalloop and the Klein-Komati River) was undertaken from the 4th to the 10th of June 2022 and again from the 3rd to the 6th of October 2022. The Klein-Komati River Catchment is designated as a river Freshwater Ecological Priority Area (FEPA), which encompasses all of its associated sub-catchment areas, and approximately 24 FEPA-designated wetlands were identified within the study area. Through the aquatic baseline specialist assessment, the Integrated EcoStatus of Waarkraalloop and the Klein-Komati River, inclusive of their associated tributaries, were determined as largely natural (Ecological Category B) to moderately modified (Ecological Category C) from the perspective of both their riparian and instream elements and were regarded as of ‘High’ Ecological Importance with ‘Very High’ Ecological Sensitivity. The Integrated Present Ecological States of both the Waarkraalloop and the Klein-Komati River, thus meet the Target Ecological Category designated for the Komati Catchment by the Department of Water and Sanitation (Government Gazette No. 40531, 2016). In addition, based on their Ecological Importance and Sensitivity any further deterioration in either the instream ecological integrity or the riparian habitat integrity must be prevented as far as possible.

While the operational phase of any given wind energy or solar energy project is known for its low carbon footprint, with no to negligible generation of water or air pollution other than that potentially related to maintenance activities, it is important to note that without appropriate mitigation and management measures in place, particularly during the construction phase of the proposed project, the cumulative footprint and its associated impacts for both of the proposed project alternatives have the potential to be significant with impact ratings determined as largely ‘Moderate’ and ‘High’. However, with suitable mitigation measures in place, it is possible to reduce the impacts of either of the proposed project alternatives to the aquatic ecology of the area from all project related activities to ‘Low’ and ‘Very Low’ level impacts. It is thus critical that the mitigation measures as stipulated in Section 5.6 be strictly adhered to in order to limit impacts to the aquatic resources associated with the proposed project. Furthermore, the assessment of residual impacts is based on the assumption that the mitigation measures proposed are feasible and will be implemented. Where proposed mitigation measures are not deemed feasible, then re-assessment of impact significance would be required based on what would be feasible.

On consideration of the findings of the specialist aquatic baseline assessment and the project specific impacts associated with the proposed project, it is the reasoned opinion of the ecologist that with strict adherence to the recommendations and mitigation measures provided in this report, impacts to

the receiving aquatic environment as a result of either of the proposed project development alternatives have the potential to be kept to a minimum. A further cumulative benefit, is the potential sterilisation of this area from mining rights in support of renewable energy, thereby contributing to the long-term sustainable use and conservation of water resources and resulting in positive long-term benefits for this FEPA designated catchment.

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ACRONYMS

ASPT	Average Score Per Taxon
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs (now Department of Water and Sanitation)
DWS	Department of Water and Sanitation
EC	Ecological Category
FEPA	Freshwater Ecosystem Priority Area
FRAI	Fish Response Assessment Index
IHAS	Invertebrate Habitat Assessment System
IHI	Index for Habitat Integrity
MIRAI	Macro-Invertebrate Response Assessment Index
NBA	National Biodiversity Assessment
NFEPA	National Freshwater Ecosystem Priority Areas project
NWRS	National Water Resource Strategy
PES	Present Ecological State
REMP	River EcoStatus Monitoring Programme
RHP	River Health Programme
SAIAB	South African Institute for Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SASS5	South African Scoring System, Version 5
WMA	Water Management Areas
WRC	Water Research Commission
WWF	Worldwide Fund for Nature

1. INTRODUCTION

1.1 Project Description

Dalmanutha Wind (Pty) Ltd appointed WSP Group Africa (Pty) Ltd (WSP) as the lead Environmental Assessment Practitioner (EAP) to complete the Environmental Impact Assessment (EIA) process required to gain Environmental Authorisation for a proposed wind energy facility (WEF) to be located near the town of Belfast in the Mpumalanga Province of South Africa. WSP appointed Ecology International (Pty) Ltd as independent ecological specialists to conduct the required aquatic specialist assessment to inform the necessary environmental processes as well as the Water Use Licence Application (WULA) process.

1.2 Terms of Reference

Based on the proposed application, the Terms of Reference for the assessment of the associated aquatic ecosystems were based on the gazetted procedures for the assessment and minimum criteria for reporting on identified environmental themes in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. In this regard, the following stressor, habitat and response indicators were to be evaluated in order to enable an adequate description of the associated freshwater aquatic ecosystem and the determination of the Present Ecological State (PES):

- *In situ* water quality assessment;
- Habitat assessment, utilising the Index for Habitat Integrity (IHI), the Invertebrate Habitat Assessment Systems (IHAS version 2.2) and the Fish Habitat Cover Rating (HCR) tool;
- Macroinvertebrate assessment, including the generation of reference conditions and determination of PES utilising the South African Scoring System Version 5 (SASS5) and the Macro-Invertebrate Response Assessment Index (MIRAI) within lotic systems (rivers), where relevant;
- Ichthyofaunal assessment, including the evaluation of reference conditions and determination of PES utilising the Fish Response Assessment Index (FRAI) in the lotic systems (rivers), where relevant;
- Determination of any aquatic species of conservation concern (including Threatened species) that may be present within the study area;
- Determination of any alien/invasive aquatic species that may be present within the study area;
- Determination of the integrated PES through the latest EcoStatus approach;
- Assessment of Ecological Importance and Sensitivity (EIS) of the river reaches associated with the study area; and
- Determination of freshwater ecosystem functional buffer requirements.

A detailed description of the methodology used to address the above Terms of Reference is provided in Appendix A. The site-based assessment of the associated watercourses was undertaken from the 4th to the 10th of June 2022 and from the 3rd to the 6th of October 2022.

1.3 Assumptions and Limitations

In order to obtain a comprehensive understanding of the dynamics and diversity of the biota on a site, including species of conservation concern, studies should include investigations through the different seasons of the year, over a number of years, and extensive sampling of the area. This is particularly relevant where seasonal limitations to biodiversity assessments exist for the area of the proposed activity. Due to project time constraints inherent with Environmental Authorisation application processes, such long-term research is seldom feasible and the information contained within this report is based on two seasonal field surveys conducted during the high and low flow periods.

Predictions on future changes on ecosystems and populations once a development has happened are seldom straightforward, except in cases such as the total loss of a habitat to development. However, most development impacts are indirect, subtle, and cumulative or unfold over several years following construction or commencement of activities. Whilst a possible mechanism for an impact to occur can usually be identified, the actual likelihood of occurrence and its severity are much harder to describe (Hill & Arnold, 2012). Furthermore, a review to test the accuracy of the predictions of an ecologist following completion of the development is very rarely undertaken, which means the capacity to predict the future is not tested and therefore remains unknown (Hill & Arnold, 2012).

A closely related issue is that of the effectiveness of ecological mitigation which stems from ecological assessments (including freshwater ecological assessments), as well as in response to legal and planning policy requirements for development. Many recommendations may be incorporated into planning conditions or become conditions of licences, but these recommendations are implemented to varying degrees. What is often missing is the follow-up monitoring and assessment of the mitigation with sufficient scientific rigour or duration to determine whether the mitigation, compensation or enhancement measure has actually worked in the way intended (Hill & Arnold, 2012).

2. GENERAL CHARACTERISTICS

2.1 Location

The proposed Dalmanutha WEF (Alternative 1 and 2) is to be located approximately 7 km southeast of the Belfast town within Emakhazeni Local Municipality. Site access is via the N4, the R33, or the R36. The proposed Dalmanutha WEF (Alternative 1 and 2) is to be located on the following farm portions:

- Berg-en-Dal 378 JT (Portions 1 and 9);
- Vogelstruispoort 384 JT (Portion 5 and 7);
- Waaikraal 385 JT (Portions 6, 7, 8, 10, 12,13 and 24);
- Leeuwkloof 403 JT (Portions 3 and 4);
- Leeuwkloof 404 JT (Portions 1 and 2);
- Geluk 405 JT (Portion 3);
- Camelia 467 JT (Portion 0); and
- Welgevonden 412 JT (Portion 1).

The location of the proposed facility is indicated in Figure 2.

2.2 Biophysical Attributes

2.2.1 Climate

According to Kleynhans *et al.* (2007), the study area is located within the Highveld Ecoregion, with rainfall seasonality being early to mid-summer, and mean annual temperatures ranging from 12°C to 18°C (Figure 1). Mean annual precipitation of the quaternary catchment is approximately 714.7 mm/annum, with a potential evaporation of 1863.5 mm/annum (Macfarlane et al., 2008).

2.2.2 Geology

Geology underlying the study area is made up of elements from the Silverton and Magaliesberg Formations of the Pretoria Group (which form part of the Transvaal Supergroup) and are characterised by siliciclastic rocks, as well as elements from the Madzaringwe Formation of the Ecca Group (part of the Karoo Supergroup), which is also characterised by siliciclastic rocks (Kent, 1980).

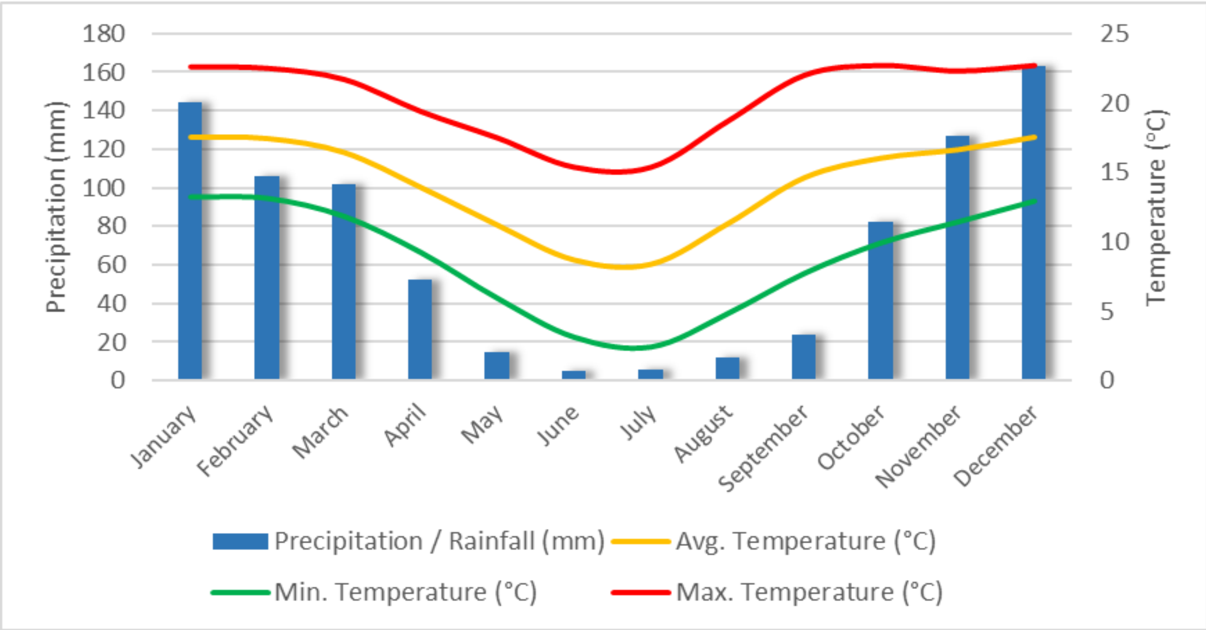


Figure 1: Monthly average rainfall and temperatures recorded for Belfast, South Africa (climate-data.org)

3. FRESHWATER ECOSYSTEM CHARACTERISTICS

3.1 Freshwater Ecoregion

The proposed Dalmanutha WEF (Alternative 1 and 2) is located within the Southern Temperate Highveld freshwater ecoregion, which is delimited by the South African interior plateau sub-region of the Highveld aquatic ecoregion, of which the main habitat type, in terms of watercourses, is regarded as Savannah-Dry Forest Rivers. Aquatic biotas within this bioregion have mixed tropical and temperate affinities, sharing species between the Limpopo and Zambezi systems. The Southern Temperate Highveld freshwater ecoregion is considered to be bio-regionally outstanding in its biological distinctiveness and its conservation status is regarded as Endangered. The ecoregion is defined by the temperate upland rivers and seasonal pans (Nel et al., 2004; Darwall et al., 2009; Scott, 2013).

3.2 National Ecoregional Typing

Ecoregional typing was completed at a national level is based on spatially variable combinations of causal factors including physiography, climate, geology, soils and potential natural vegetation. The proposed Dalmanutha WEF (Alternative 1 and 2) is located primarily within the Northern Escarpment Mountains Ecoregion (Level II Ecoregion 10.03), however, a portion of the wetern portion of the study area falls within the Highveld Freshwater Ecoregion (Level II Ecoregion 11.02).

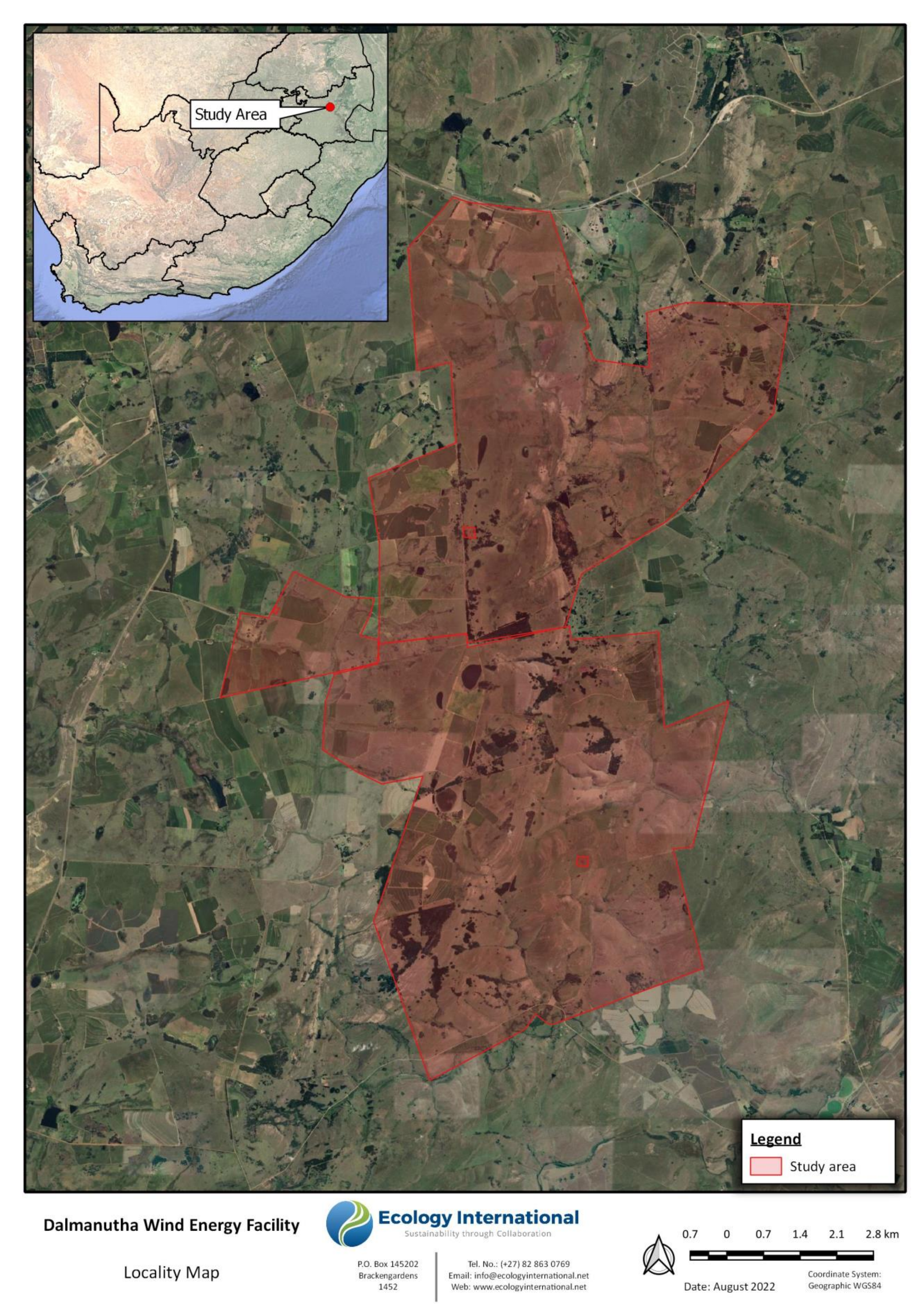


Figure 2: Location of the study area associated with the proposed Dalmanutha WEF (Alternative 1 and 2)

3.3 Associated Water Resources

The NWRS-1 (National Water Resource Strategy, Version 1) originally established nineteen (19) Water Management Areas (WMAs) within South Africa and proposed the establishment of the nineteen (19) Catchment Management Agencies to correspond to these areas. In rethinking the management model, and based on viability assessments with respect to water resources management, available funding, capacity, skills and expertise in regulation and oversight, as well as to improve integrated water systems management, the original nineteen (19) designated WMAs have been consolidated into nine (9) WMAs.

The entire study area is located within the revised Inkomati-Usuthu WMA, the major rivers of which include the Nwanedzi, Sabie, Crocodile (East), Komati and Usuthu rivers. More specifically, the proposed Dalmanutha WEF (Alternative 1 and 2) is located within the X11D quaternary catchment. The study area is located upstream of the Komati River and is associated with the Klein-Komati River south and south-west of the study area. The Waarkraalloop (a tributary of the Klein-Komati) flows through and to the east of the study area. Numerous wetlands and tributaries of these systems are also present (Figure 3).

3.4 Strategic Water Source Areas

Strategic Water Source Areas (SWSAs) are landscapes where a relatively large volume of runoff produces water for the majority of South Africa. Strategic water source areas can be regarded as natural 'water factories', supporting growth and development needs that are often a far distance away. Deterioration of water quality and quantity in these areas can have a disproportionately large negative effect on the functioning of downstream ecosystems and the overall sustainability of growth and development in the regions they support (Nel et al., 2013).

While the proposed study area is not located within any designated Strategic Water Source Areas (SWSA), it is located within the Komati River catchment approximately 18 km upstream of the Mpumalanga Drakensburg Surface Water SWSA. The Komati River is an important water source within the Mpumalanga Drakensburg Surface Water SWSA.

3.5 National Freshwater Ecosystem Priority Areas

The National Freshwater Ecosystem Priority Areas (NFEPA) project represents a multi-partner project between the Council for Scientific and Industrial Research (CSIR), South African National Biodiversity Institute (SANBI), Water Research Commission (WRC), Department of Water Affairs (DWA; now Department of Water and Sanitation, or DWS), Department of Environmental Affairs (DEA), Worldwide Fund for Nature (WWF), South African Institute of Aquatic Biodiversity (SAIAB) and South African National Parks (SANParks). More specifically, the NFEPA project aims to:

- Identify Freshwater Ecosystem Priority Areas (hereafter referred to as 'FEPAs') to meet national biodiversity goals for freshwater ecosystems; and
- Develop a basis for enabling effective implementation of measures to protect FEPAs, including free-flowing rivers.

The first aim uses systematic biodiversity planning to identify priorities for conserving South Africa's freshwater biodiversity, within the context of equitable social and economic development. The second aim comprises a national and sub-national component. The national component aims to align DWS and DEA policy mechanisms and tools for managing and conserving freshwater ecosystems. The sub-national component aims to use three case study areas to demonstrate how NFEPA products should be implemented to influence land and water resource decision-making processes at a sub-national level (Driver et al., 2011). The project further aims to maximize synergies and alignment with other national level initiatives such as the National Biodiversity Assessment (NBA) and the Cross-Sector Policy Objectives for Inland Water Conservation.

According to the current outputs of the NFEPA project (Nel et al., 2011; Figure 2), the study area falls within three wetland vegetation groups: Mesic Highveld Grassland Group 4, Mesic Highveld Grassland Group 5 and Mesic Highveld Grassland Group 6. The western portion of the study area falls within the Klein-Komati River catchment, which is designated as a River FEPA and encompasses all of its associated sub-catchment areas. Four (4) designated wetland cluster areas are also associated with this area (Figure 3). According to Driver et al. (2011), wetland clusters are groups of wetlands embedded in a relatively natural landscape. This allows for important ecological processes such as migration of frogs and insects between wetlands.

Further, SANBI recently undertook a wetland mapping exercise for the Mpumalanga Highveld region in order to expand on the detailed wetland delineations undertaken in adjacent catchments, for inclusion into the NFEPA project (Mbona et al., 2015). Mpumalanga Tourism and Parks Agency (MPTA) recognises that wetlands are specialised systems that perform various ecological functions and play an integral role in biodiversity conservation. The project sought to map the extent, distribution, condition and type of freshwater ecosystems in the Mpumalanga Highveld coal belt. The delineations were based on identifying wetlands on Spot 5 imagery within the Mpumalanga Highveld boundary and supported by Google Earth imagery, 1:50 000 contour lines, 1:50 000 river lines, data from previous studies in the area, and data from the original NFEPA wetlands layer. Hydrogeomorphic (HGM) units were identified at a desktop level and confirmed by means of ground-truthing. These refined layers will eventually be incorporated 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 (Mbona et al., 2015). According to Mbona et al. (2015), approximately twenty-four (24) FEPA-designated wetlands are associated with the proposed Dalmanutha WEF (Alternative 1 and 2) based on the revised wetland mapping inventory for the Mpumalanga Highveld region (Figure 3).

3.6 Mpumalanga Biodiversity Sector Plan

A Biodiversity Conservation Plan, also known as a Biodiversity Sector Plan, is a tool that guides and informs land use and resource-use planning and decision-making by a full range of sectors whose policies, programmes and decisions impact on biodiversity, in order to preserve long-term functioning and health of priority areas known as Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs). A Biodiversity Conservation Plan is based on a systematic biodiversity planning approach, which is clearly outlined in the guidelines for bioregional planning (NEMBA Guidelines No 291 of 2009) and the technical guidelines for CBA maps (SANBI, 2017; cited in Hawley et al., 2019).

The Mpumalanga Biodiversity Sector Plan (MBSP) is a comprehensive environmental inventory and spatial plan that is intended to guide conservation and land use decisions in support of sustainable development (Lötter & Ferrar, 2006; Lötter 2014; Mpumalanga Tourism and Parks Agency, 2014). The MBSP maps the distribution of the province's known biodiversity into several categories for both the terrestrial and freshwater realms. These are ranked according to ecological and biodiversity importance and their contribution to meeting the quantitative targets set for each biodiversity feature, with compatible land uses identified accordingly.

According to the latest revision of the freshwater component of the provincial biodiversity sector plan (Mpumalanga Tourism and Parks Agency, 2019), the wetlands associated with the western half of the study area may be regarded as ESAs as part of the identified FEPA wetlands and wetland clusters. These areas and their surrounds are considered important FEPA sub-catchments. The Klein-Komati River and its tributaries are further classified as CBAs as the Klein-Komati River is classified as a FEPA river. One CBA wetland was also identified in the north-western portion of the study area. The eastern portion of the study area is dominated by Other Natural Areas, however, this excludes the southern portion of the study area, which once again forms part of the Klein-Komati River sub-catchment areas and are classified as ESAs (Figure 4).

3.7 Resource Directed Measures

Within the Inkomati-Usutu Water Management Area (WMA), the classification and development of Resource Quality Objectives (RQOs) were determined by the Department of Water and Sanitation in 2016 for all or part of every significant water resource within the catchments of the Inkomati catchment, including the Komati River (drainage region X1), the Crocodile River (drainage region X2), the Sabie-Sand Rivers (drainage region X3), and the river systems falling within drainage region X4.

Water resources were classified within the catchment as Integrated Units of Analysis (IUAs) in terms of their extent of permissible utilisation and protection as either Class I: indicating high environmental protection and minimal utilisation; Class II indicating moderate protection and moderate utilisation; or Class III indicating sustainable minimal protection and high utilisation. A target Ecological Category for each IUA was provided. Further, RQOs were defined for each prioritised resource unit (RU) within each IUA in terms of water quantity and quality, habitat, and biota, and a Recommended Ecological Category (REC) was assigned.

The water resources within the study area fall within drainage region X1 (the Komati River) and IUA X1-3. They are classified as Class II systems, indicating a moderate level of protection and utilisation and a target Ecological Category C is applicable to all the systems observed.

Table 1 represents a summary of the attributes associated with the area under study.

Table 1: Summary of relevant site attributes

Political Region	Mpumalanga
Level 1 Ecoregion	Northern Escarpment Mountains (dominant) Highveld (small portion to the west)
Level 2 Ecoregion	10.03 and 11.02
Freshwater Ecoregion	Southern Temperate Highveld
Geomorphic Province	Mpumalanga Highlands Northeastern Highveld
Geology	Silverton Formation (Pretoria Group) Magaliesberg Formation (Pretoria Group) Madzaringwe Formation (Ecca Group)
Wetland Vegetation Classification	Mesic Highveld Grassland Group 4 Mesic Highveld Grassland Group 5 Mesic Highveld Grassland Group 6
Water Management Area	Inkomati-Usuthu
Secondary Catchment	X1
Quaternary Catchment	X11D
Watercourses	Valley Bottom Wetlands Depressional Wetlands (Pans) Klein-Komati River and its tributaries Waarkraalloop and its tributaries
Stream Order	1
Slope Class	Upper Foothills
NFEPA Status	FEPA Wetlands Wetland Clusters FEPA River and sub-catchments

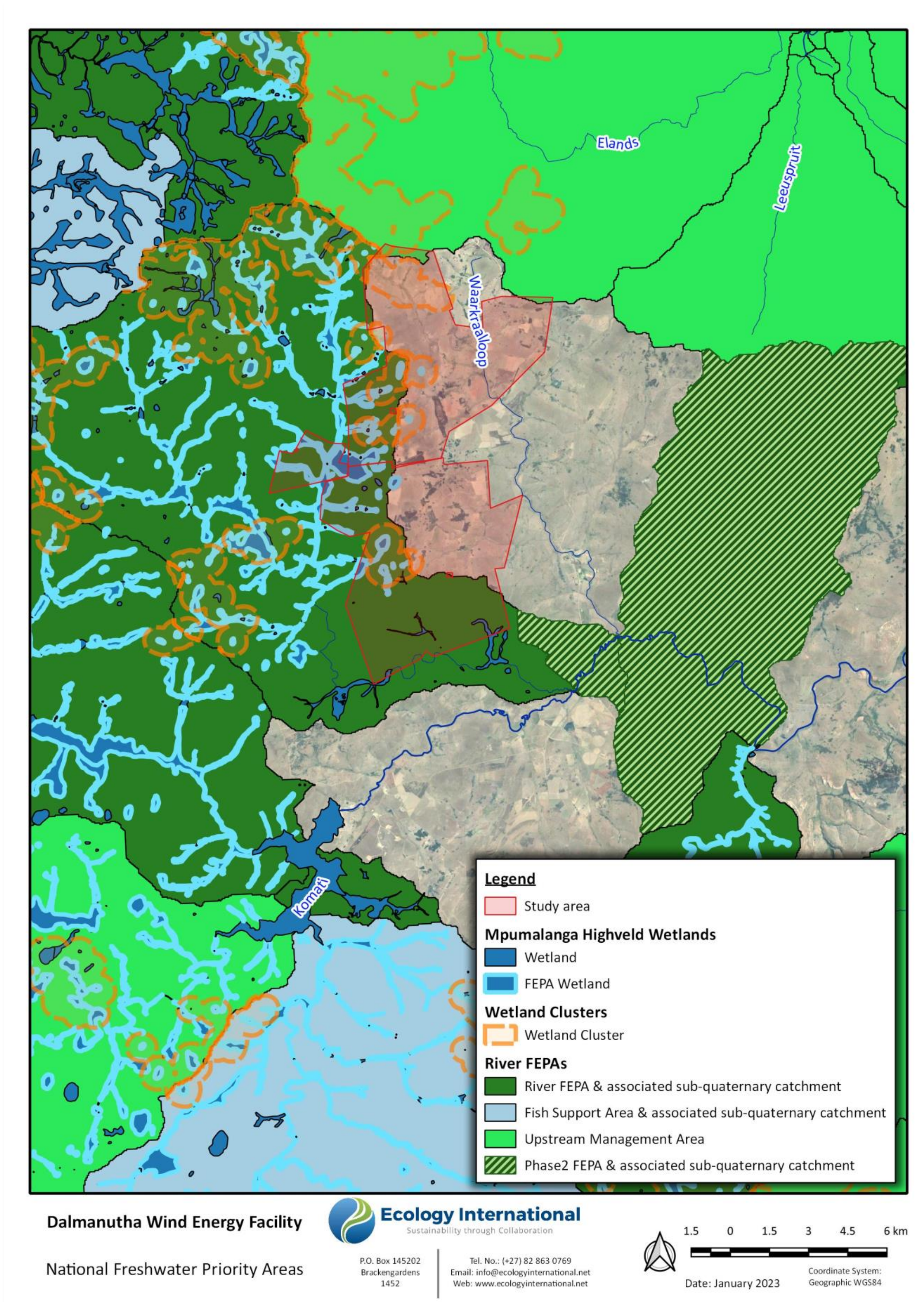


Figure 3: National Freshwater Ecosystem Priority Areas associated with the study area

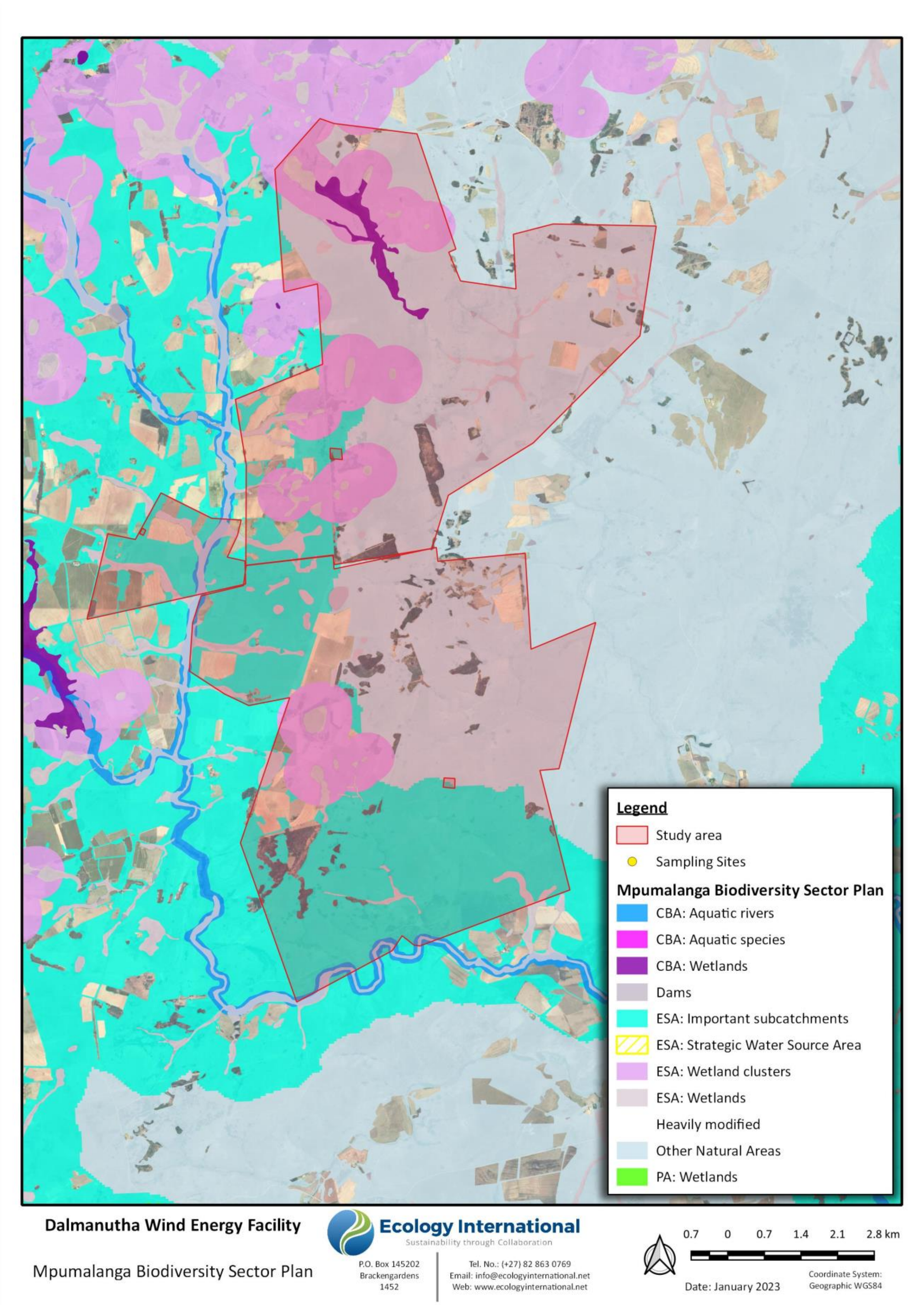


Figure 4: Mpumalanga Biodiversity Sector Plan classification of the study area

4. RESULTS

4.1 Selection of Sampling Sites

Sampling sites were selected based on the location of the proposed infrastructure in relation to the aquatic systems present and the impacts likely to be expressed on these systems as a result of the implementation of the proposed project. Co-ordinates of the various sampling sites were recorded and are listed in Table 2 and presented graphically in Figure 5. Photographs of the identified sampling sites are provided in Appendix B.

Table 2: Co-ordinates and descriptions of sites assessed during the aquatic specialist assessment

Catchment	River	Site	Coordinates	Elevation	Description
Waarkraalloop	Unnamed Tributary	**DWEF 1**	25°46'40.68"S 30°07'52.49"E	1,690m	Located in an open area on a tributary of the Waarkraalloop, which confluences with the Kwaaimanspruit, which in turn, confluences with the Komati River further downstream of the study area.
	Unnamed Tributary	**DWEF 5**	25°50'46.57"S 30°09'03.95"E	1,544m	Located on a tributary of the Waarkraalloop downstream of DWEF4.
	Waarkraalloop	**DWEF 2**	25°46'22.86"S 30°08'10.58"E	1,687m	Located on the Waarkraalloop, upstream of the confluence with the tributary on which DWEF1 is located.
		DWEF 3	25°47'27.90"S 30°08'35.77"E	1,647m	Located on the Waarkraalloop at a road crossing. The site is located downstream of the confluence with the tributary on which DWEF1 is located.
		DWEF 4	25°49'11.55"S 30°08'56.55"E	1,572m	Located in on the Waarkraalloop, which confluences with the Kwaaimanspruit, which in turn, confluences with the Komati River further downstream of the study area.
		DWEF 6	25°50'44.77"S 30°09'44.87"E	1,515m	Located on the Waarkraalloop downstream of the confluence with the tributary on which DWEF5 is located. **During the October 2022 assessment, the site was moved approximately 400 m downstream due to access restrictions whilst conducting the survey.**
Klein-Komati	Unnamed Tributary	**DWEF 7**	25°48'26.07"S 30°04'51.65"E	1,717m	Located on a tributary of the Klein-Komati River
		DWEF 8	25°51'06.89"S 30°04'16.17"E	1,679m	Located downstream of DWEF7 on an unnamed tributary, approximately 200 m upstream of its confluence with the Klein-Komati River.
	Unnamed Tributary	**DWEF 11**	25°53'05.12"S 30°07'08.77"E	1,528m	Located on an unnamed tributary of the Klein-Komati River downgradient of the Dalmanutha study area.
	Unnamed Tributary	**DWEF 12**	25°52'20.98"S 30°08'03.48"E	1,556m	Located on an unnamed tributary of the Klein-Komati River downgradient of the Dalmanutha study area.
	Klein-Komati	**DWEF 9**	25°51'09.19"S 30°04'11.09"E	1,679m	Located on the Klein-Komati River upstream of the confluence with the unnamed tributary on which sites DWEF7 and DWEF8 are located.
		DWEF 10	25°54'04.50"S 30°04'52.80"E	1,584m	DWEF10 is located on the Klein-Komati River downstream of the western portion of the study area.
		DWEF 13	25°53'33.57"S 30°08'57.69"E	1,489m	Located on the Klein-Komati River, downgradient of the Dalmanutha study area.

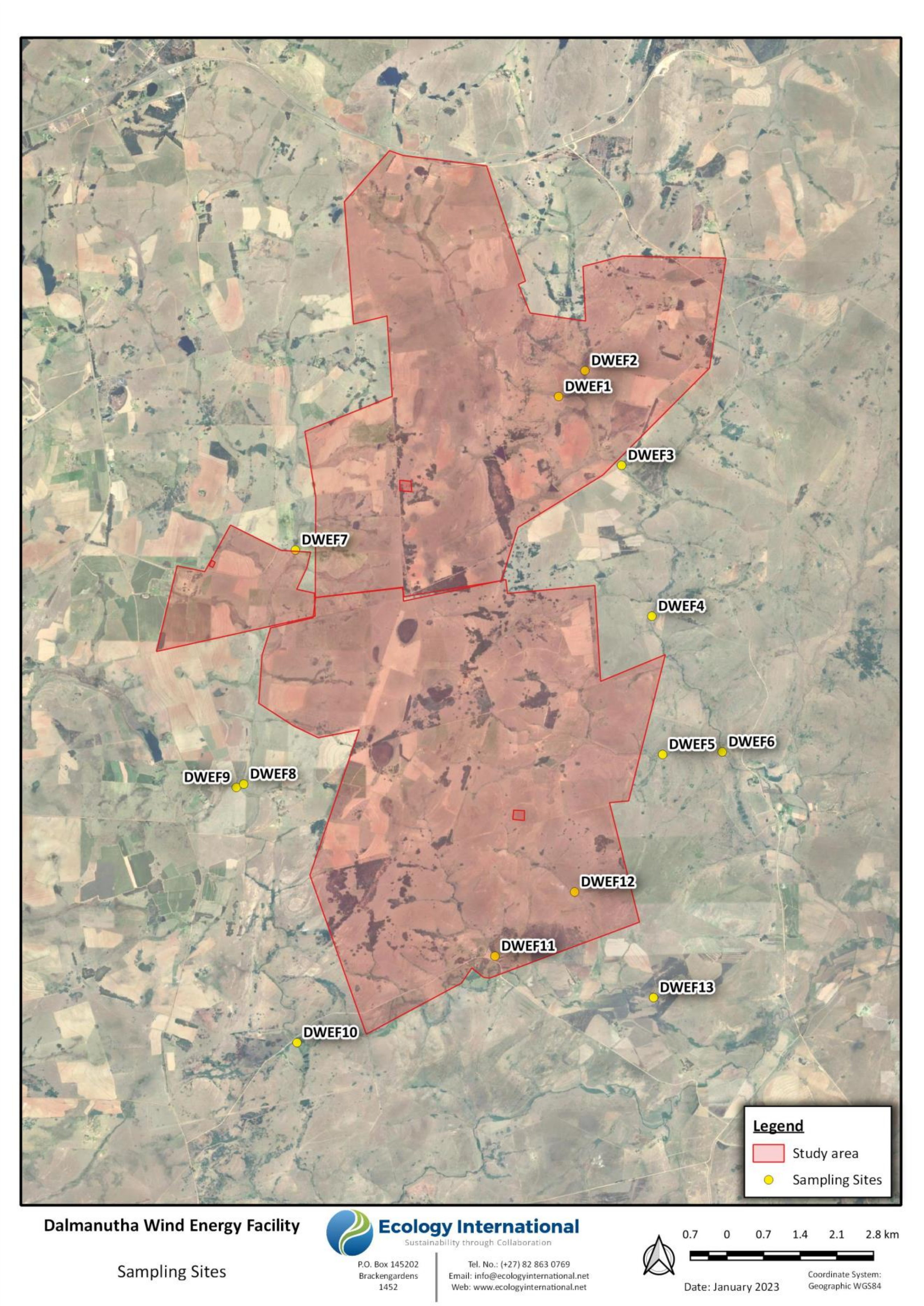


Figure 5: Aquatic sampling sites utilised during the aquatic specialist assessment

4.2 Water Quality

Aquatic communities are influenced by numerous natural and human-induced factors, including physical, chemical and biological factors. The assessment of water quality variables in conjunction with assessment of biological assemblages is therefore important for the interpretation of results obtained during biological investigations.
Table 3 provides the *in situ* water quality data obtained at each assessment site.

RQOs for water quality were not gazetted for the X1-3 IUA. As such, the generic Resource Water Quality Objectives (RWQOs) for the Inkomati catchment (as stipulated by the Department of Water and Sanitation, previously the Department of Water Affairs (2011)) were used for pH and Electrical Conductivity values. The guidelines provided in the Target Water Quality Range as stipulated by the Department of Water and Sanitation, previously the Department of Water Affairs and Forestry (1996) were used for Dissolved Oxygen. All water quality parameters observed fell within the stipulated objectives as indicated in Table 3.

pH values observed were regarded as marginally alkaline, with a slightly increased alkalinity observed at all sites during the October 2022 assessment in relation to the values observed during the June 2022 assessment. Nevertheless, all values fell within the prescribed range of 6.5-8.4. Elevated pH values are known to result from anthropogenic eutrophication when excessive primary production leads to the depletion of CO_2 from the water in the presence of sunlight. The seasonal increases in alkalinity may therefore be linked to the slight increases in electrical conductivity observed at each site during the October 2022 assessment. It is considered possible that agropastoral activities within the catchment may be acting as a source of potential nutrient input. However, the impact from such activities at present is regarded as minor and limited in extent.

In situ electrical conductivity values obtained throughout the 2022 aquatic baseline assessment were all below that of the prescribed upper limits and were not deemed of concern in respect of the biotic assemblages present. Very little information is available with regards to the salinity tolerances of freshwater organisms in South Africa, although some research is being done by various tertiary institutions in this regard. However, available research does indicate changes in the distribution patterns of individual species or communities can be attributed to changes in salinities. Nevertheless, a number of generalisations can be made based on current research results, including (Dallas & Day, 2004):

- It is often the rate of change rather than the final salinity that is most critical;
- Juvenile stages are often more sensitive to increased salinity concentrations;
- Salinity may act as an antagonist or a synergist in relation to a variety of toxicants; and
- The responses of freshwater organisms to alterations in salinity are likely to be related to the evolutionary origins on the taxon of which they are a part.

In situ dissolved oxygen values obtained for the study area during 2022, were not deemed to be of concern when taken in context of the characteristics of the associated watercourses and fell within the range of saturation (80%-120%) considered ideal for the survival of aquatic life. For most freshwater fish species, the minimum ideal dissolved oxygen concentration is 5 mg/ℓ, although some species will tolerate lower levels (Grant et al., 2014).

Table 3: *In situ* water quality variables determined during the 2022 aquatic specialist baseline assessment

Catchment	River	Site	Survey	Temp. (°C)	pH	Electrical conductivity µS/cm)	Total Dissolved Salts (mg/ℓ)	Dissolved oxygen (mg/ℓ)	Dissolved oxygen (% sat)
		RWQO* TWQR**	-	5-30**	≥6.5-≤8.4*	30mS/m (300 µS/cm)*	-	<5**	80% - 120% saturation**
Waarkraalloop	Unnamed Tributary	DWEF 1	Jun '22	10.40	7.78	46.60	32.62	11.92	106.40
			Oct '22	21.00	8.18	50.30	35.20	8.17	92.40
	Unnamed Tributary	DWEF 5	Jun '22	10.20	8.18	130.40	91.28	12.66	113.40
			Oct '22	23.10	8.37	163.40	114.20	7.53	87.49
	Waarkraalloop	DWEF 2	Jun '22	11.00	8.09	56.40	39.48	10.41	95.50
			Oct '22	16.80	8.45	84.10	58.40	7.83	83.60
		DWEF 3	Jun '22	11.80	7.93	52.90	37.03	11.72	109.80
			Oct '22	20.40	8.26	97.30	67.90	8.32	94.50
		DWEF 4	Jun '22	7.20	8.27	99.30	69.51	13.48	111.90
			Oct '22	22.80	8.45	160.30	112.40	8.22	95.50
		DWEF 6	Jun '22	9.60	8.61	121.20	84.84	12.53	112.70
			Oct '22	21.90	8.32	184.60	129.70	7.76	87.10
Klein-Komati	Unnamed Tributary	DWEF 7	Jun '22	8.70	7.87	98.80	69.16	12.85	111.20
			Oct '22	19.40	8.24	127.80	89.90	7.08	82.6
		DWEF 8	Jun '22	5.40	7.96	98.10	68.67	13.52	106.90
			Oct '22	22.4	8.36	136.4	95.50	8.03	91.20
	Unnamed Tributary	DWEF 11	Jun '22	10.70	8.36	72.40	50.68	12.38	106.80
			Oct '22	17.20	8.50	99.50	70.00	8.18	86.20
	Unnamed Tributary	DWEF 12	Jun '22	12.00	8.01	147.90	103.53	12.14	112.60
			Oct '22	20.80	8.07	172.40	119.90	7.94	86.30
	Klein-Komati	DWEF 9	Jun '22	7.70	7.92	152.40	106.68	13.59	114.70
			Oct '22	24.10	8.35	146.80	102.50	7.56	96.59
		DWEF 10	Jun '22	8.60	8.13	123.70	86.59	13.28	114.10
			Oct '22	22.10	8.96	123.80	85.6	7.50	86.70
		DWEF 13	Jun '22	7.00	8.22	118.60	83.02	13.89	114.50
			Oct '22	23.30	8.22	138.70	97.7	8.44	95.70

*Department of Water Affairs (2011)

**Department of Water Affairs and Forestry (1996)

4.3 Aquatic Habitat

4.3.1 Index for Habitat Integrity

The ecological condition of the instream and riparian habitat of the watercourses associated with the study area was determined through the application of the Index for Habitat Integrity, Version 2 (IHI-96-2; Kleynhans, *pers. comm.*, 2015), which was also used to provide a surrogate for the riparian vegetation component of the integrated EcoStatus model. While the recently upgraded IHI-96-2 replaces the relatively comprehensive and expensive IHI assessment model developed by Kleynhans (1996), it is important to note that the IHI-96-2 does not replace the IHI model developed by Kleynhans et al. (2008a), which should preferably be applied where sufficient data is available (i.e. intermediate and comprehensive Reserve Determinations). Consequently, the IHI-96-2 model is meant to be used in cases where a relatively large number of river reaches needs to be assessed, budget and time provisions are limited, and/or detailed available information is lacking (i.e. rapid Reserve Determinations and for RHP purposes). Since time on site was limited, the use of aerial photography and observations made at each of the assessed sampling points was used to inform the adapted IHI model, which allows for a rapid, field-based, visual assessment of modifications to a number of pre-selected biophysical drivers within a localised portion of the associated hydrogeomorphic unit (Kemper, 1999). Table 4 presents the results obtained following the application of the IHI approach within the watercourses associated with study area.

According to the IHI approach, the streams associated with the proposed project areas were determined to range from natural (Ecological category A) to moderately modified (Ecological category C; Table 4). The general riparian structure of the watercourses associated with the study area were expected to comprise the natural grassland features of the vegetation unit, while instream characteristics were expected to comprise largely of clear flowing water over a variety of cobble habitats with minimal gravel, sand and mud deposits. Modifications to the habitat integrity observed within the study area were related to impacts associated with the proliferation of woody alien invasive species such as black wattle (*Acacia mearnsii*), yellow firethorn (*Pyracantha angustifolia*), grey poplar (*Populus x canescens*) and various *Eucalyptus* sp. Additional impacts arising from stream crossings such as roads and weirs included moderate to severe impacts relating to erosion and incision of the banks, bed and flow modifications and inundation. Water abstraction was also observed at some points with the largest impact observed at DWEF 7. Trampling, erosion and loss of bankside cover as a result of cattle watering was also observed in some areas.

Table 4: Index for Habitat Integrity (IHI) values obtained for the instream and riparian components of the watercourses associated with the study area

Catchment	River	Site	Component	RQO*	IHI Value	Ecological Category
Waarkraalloop	Unnamed Tributary	DWEF 1	Instream	-	88	A/B
			Riparian	-	95	A
	Unnamed Tributary	DWEF 5	Instream	-	99	A
			Riparian	-	94	A
	Waarkraal loop	DWEF 2	Instream	C	87	B
			Riparian		78	B/C
		DWEF 3	Instream		81	B/C
			Riparian		72	C
		DWEF 4	Instream		84	B
			Riparian		90	A/B
		DWEF 6	Instream		88	A/B
			Riparian		78	B/C
Klein-Komati	Unnamed Tributary	DWEF 7	Instream	-	77	B/C
			Riparian	-	73	C
		DWEF 8	Instream	-	83	B
			Riparian	-	95	A
	Unnamed Tributary	DWEF 11	Instream	-	87	B
			Riparian	-	78	B/C
	Unnamed Tributary	DWEF 12	Instream	-	87	B
			Riparian	-	92	A/B
	Klein-Komati	DWEF 9	Instream	C	81	B/C
			Riparian		92	A
		DWEF 10	Instream		82	B
			Riparian		61	C
		DWEF 13	Instream		86	B
			Riparian		76	C

* (Department of Water and Sanitation, 2016)

4.3.2 Invertebrate Habitat Assessment System

The Invertebrate Habitat Assessment System (IHAS, Version 2.2), developed by McMillan (1998), has routinely been used in conjunction with the South African Scoring System, version 5 (SASS5) as a measure for the variability in the amount and quantity of aquatic macroinvertebrate biotopes available for sampling. However, according to a recent study conducted within the Mpumalanga and Western Cape regions, the IHAS method does not produce reliable scores with regard to the suitability of habitat at sampling sites for aquatic macroinvertebrates (Ollis et al., 2006). Furthermore, the performance of the IHAS seems to vary between geomorphologic zones and between biotope groups (Ollis et al., 2006). Therefore, more testing of the IHAS method is required before any final conclusion can be made regarding the accuracy of the index. An adaptation of the IHAS method was, however, retained for the purposes of this assessment, as the basic data remains of value and is suitable for the comparison of sampling effort across the various sites based on available invertebrate habitat. Results are thus presented relative to an "ideal" aquatic macroinvertebrate sampling habitat and need to be interpreted with caution taking into consideration the nature of the watercourse surveyed. Results obtained during the baseline assessment are presented in Figure 6.

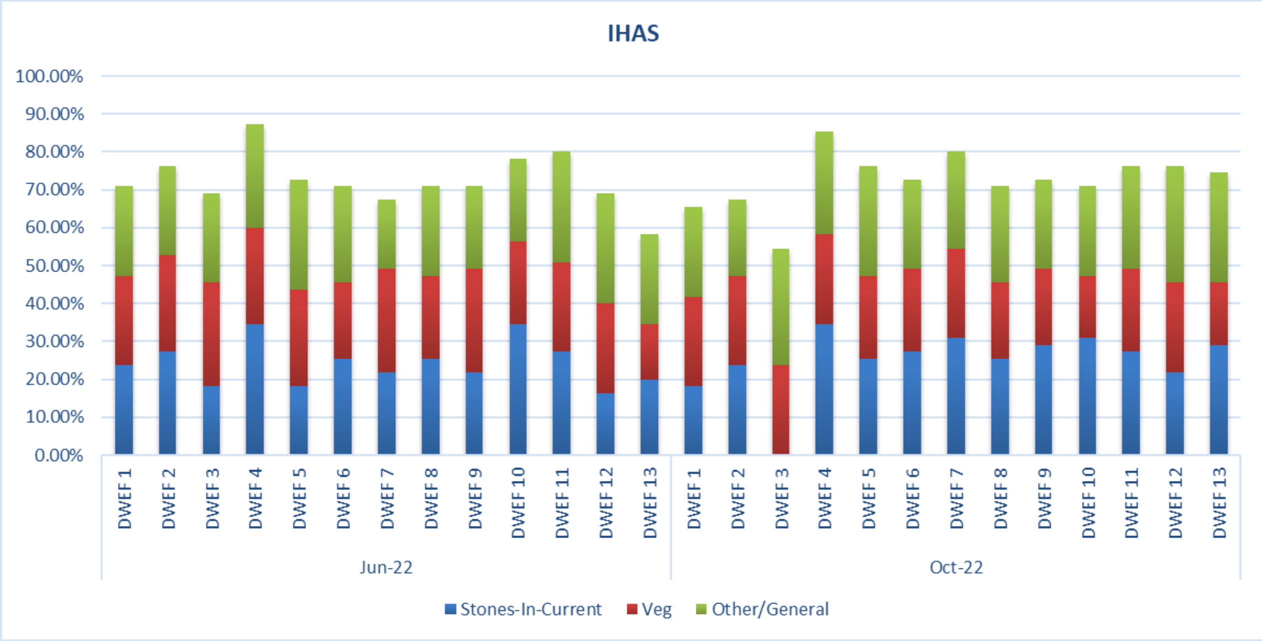
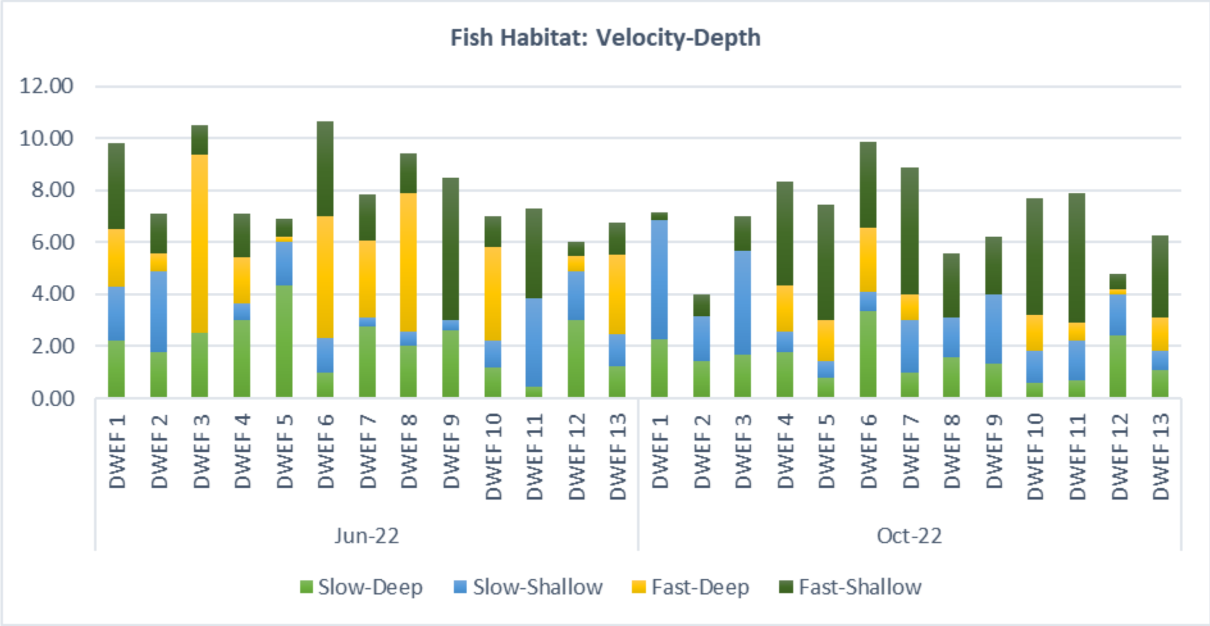


Figure 6: IHAS biotope values for sites assessed during the aquatic specialist baseline assessment

Aquatic macroinvertebrate habitat diversity was regarded as 'Good' to 'Excellent' at most sites, largely due to the availability of extensive cobble habitat and the high hydraulic flow diversity at the time of the assessment. As such, habitat was not expected to present a limiting factor to the presence of a diverse array of aquatic macroinvertebrates within the watercourses associated with the study area.

4.3.3 Fish Habitat Cover Rating

For the purpose of recording the general fish habitats available (i.e. slow-deep, slow-shallow, fast-deep and fast-shallow) that relate to the broad hydraulic conditions that may be available for different fish species, the Fish Habitat Cover Rating tool developed by (Kleynhans, 1999a) was utilised during the present study. In general, the tool takes into consideration the presence of features that provide cover for fish (i.e. refuge from high flow velocity, predators, high temperatures, etc.), estimating the relative abundance of both the velocity-depth classes and the cover classes according to a specified guideline. Results obtained following this approach are presented graphically in Figure 7.



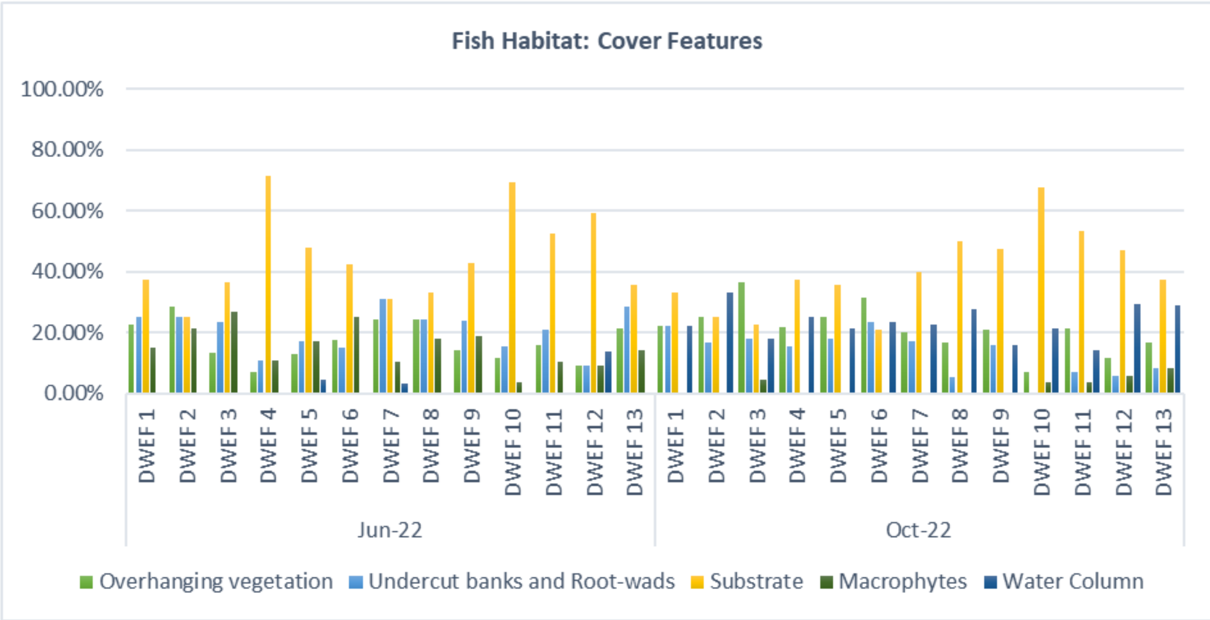


Figure 7: Fish Habitat Cover Rating velocity-depth (top) and cover feature (bottom) values for sites assessed during the aquatic specialist baseline assessment

During the baseline aquatic assessment conducted during June 2022 and October 2022, sites displayed a diverse range of fish habitat features, with varying degrees of dominance. This was largely attributed to the longitudinal zonation of the watercourses, being primarily upper foothill and transitional reaches, as well as the high baseflows as a result of the higher-than-average rainfall experienced during the preceding summer 2021/2022 rainfall season. By far the most dominant fish habitat cover feature within the study area was substrate, which again was expected given the zonation of the various reaches assessed. Some seasonal differences in velocity-depth classes and cover features were however noted, with a higher proportion of fast-deep classes being prominent during the June 2022 assessment relative to the October 2022 assessment.

4.4 Aquatic Macroinvertebrates

A total of 60 aquatic macroinvertebrate taxa were collected in the study area during the 2022 aquatic baseline assessment. Throughout the study area, the macroinvertebrate assemblage was dominated by taxa with a low requirement for unmodified water quality and with preference for moderately fast flowing water over cobble habitat (Figure 8), however, numerous moderately to highly sensitive taxa were also observed. In addition, the assemblage was dominated by aquatic breathers, with a maximum of 43% air-breathers at any given site. The number of taxa collected at each site during each of the seasonal surveys, along with their respective SASS5 and ASPT scores are indicated in Table 5.

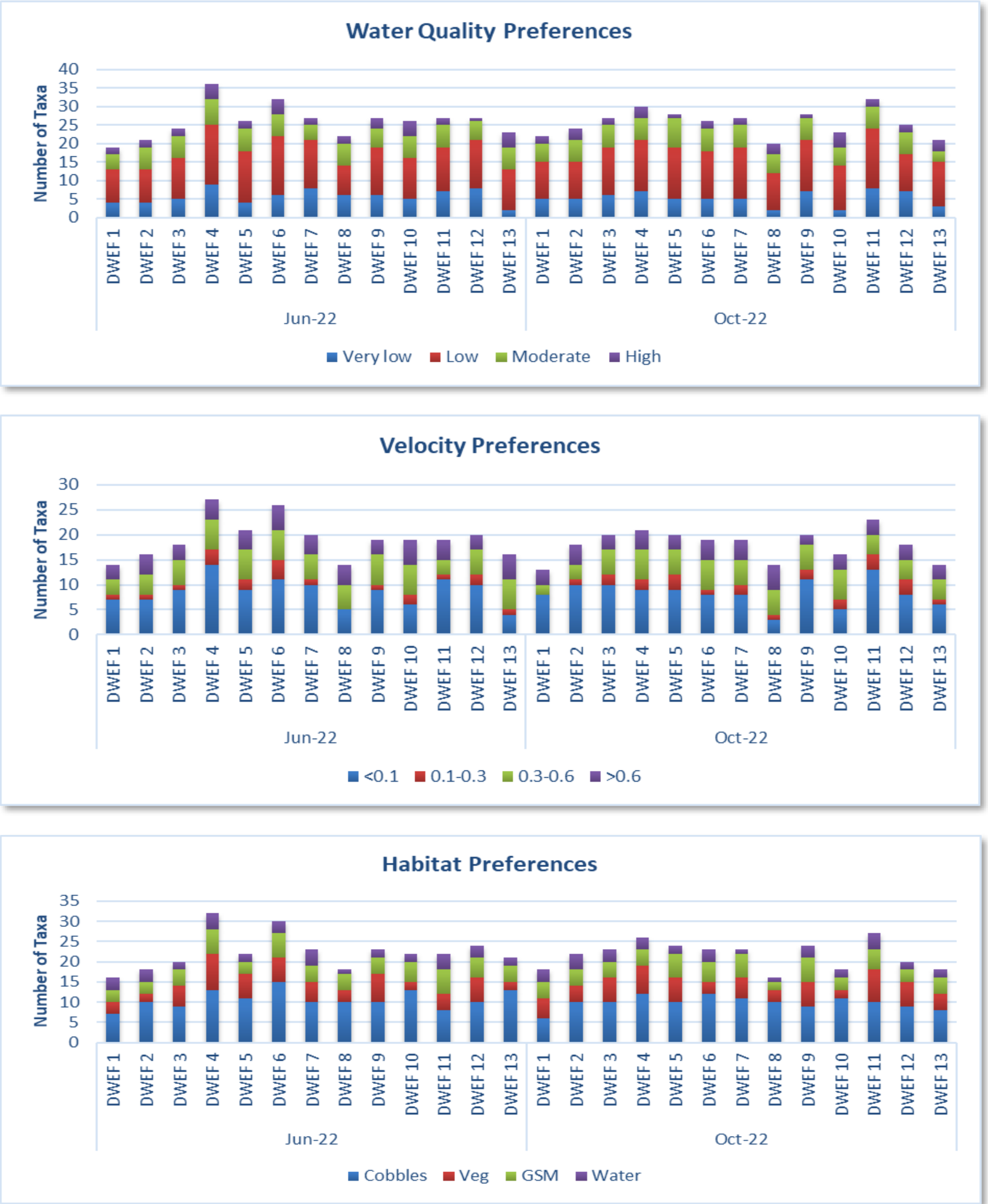


Figure 8: Aquatic macroinvertebrate assemblage preference profiles based on Thirion (2008; revised 2016) for taxa collected during the aquatic specialist baseline assessment

Table 5: Aquatic macroinvertebrate results obtained during the 2022 aquatic specialist baseline survey

Catchment	River	Site	Survey	SASS5 Score	No. of Taxa	ASPT*
Waarkraalloop	Unnamed Tributary	**DWEF 1**	Jun '22	122	20	6.10
			Oct '22	136	23	5.91
	Unnamed Tributary	**DWEF 5**	Jun '22	171	28	6.11
			Oct '22	174	29	6.00
	Waarkraalloop	**DWEF 2**	Jun '22	134	22	6.09
			Oct '22	160	26	6.15
		DWEF 3	Jun '22	156	25	6.24
			Oct '22	168	28	6.00
		DWEF 4	Jun '22	227	38	5.97
			Oct '22	193	32	6.03
		DWEF 6	Jun '22	216	34	6.35
			Oct '22	165	28	5.89
Klein-Komati	Unnamed Tributary	**DWEF 7**	Jun '22	149	28	5.32
			Oct '22	170	29	5.86
		DWEF 8	Jun '22	136	23	5.91
			Oct '22	143	21	6.81
	Unnamed Tributary	**DWEF 11**	Jun '22	163	28	5.82
			Oct '22	188	34	5.53
	Unnamed Tributary	**DWEF 12**	Jun '22	157	29	5.41
			Oct '22	153	27	5.67
	Klein-Komati	**DWEF 9**	Jun '22	168	28	6.00
			Oct '22	167	30	5.57
		DWEF 10	Jun '22	177	27	6.56
			Oct '22	164	24	6.83
		DWEF 13	Jun '22	170	24	7.08
			Oct '22	139	22	6.32

*Average Score Per Taxon

4.4.1 Present Ecological State

SASS5 data obtained during the present assessment was used in the Macro-Invertebrate Response Assessment Index (MIRAI; Thirion, 2008) to determine the PES according to the most acceptable method. Chutter (1998) developed the SASS protocol as an indicator of water quality. However, this method gives an indication of more than mere water quality, providing valuable information on the present state of the invertebrate assemblages present. Because SASS was developed for application in the broad synoptic assessment required for the River Health Programme (RHP; now the River EcoStatus Monitoring Programme (REMP)), it does not have a particularly strong cause-effect basis. The aim of the MIRAI, therefore, is to provide a habitat-based cause-and-effect foundation to interpret the deviation of the observed aquatic invertebrate assemblages from the reference condition (Thirion, 2008). This does not preclude the calculation of SASS scores should they be required. However, the use of the MIRAI is now the accepted approach for determining the PES of riverine watercourses.

Results obtained during the 2022 aquatic specialist baseline assessment indicated that the aquatic macroinvertebrate assemblages present within the watercourses associated the study area were in a largely natural to moderately modified state (Ecological Category B and Ecological Category C; Table 6), based on the perceived expected aquatic macroinvertebrate diversity. Accordingly, the ecological state of all the sites fell within the Resource Quality Objective (RQO) for Quaternary Catchment X11D within which the watercourses are located.

Table 6: MIRAI values obtained for each site within the watercourses assessed during the 2022 aquatic specialist baseline assessment, based on the MIRAI approach (Thirion, 2008)

<table>
<tr><th>Catchment</th><th>River</th><th>Site</th><th>Target Ecological Category*</th><th>MIRAI Score</th><th>Ecological Category</th></tr>
<tr><td rowspan="6">Waarkraalloop</td><td>Unnamed Tributary</td><td>DWEF 1</td><td>-</td><td>65.36</td><td>C</td></tr>
<tr><td>Unnamed Tributary</td><td>DWEF 5</td><td>-</td><td>77.42</td><td>C</td></tr>
<tr><td rowspan="4">Waarkraalloop</td><td>DWEF 2</td><td rowspan="4">C</td><td>69.02</td><td>C</td></tr>
<tr><td>DWEF 3</td><td>72.11</td><td>C</td></tr>
<tr><td>DWEF 4</td><td>83.04</td><td>B</td></tr>
<tr><td>DWEF 6</td><td>80.4</td><td>B/C</td></tr>
<tr><td rowspan="7">Klein-Komati</td><td rowspan="2">Unnamed Tributary</td><td>DWEF 7</td><td>-</td><td>75.01</td><td>C</td></tr>
<tr><td>DWEF 8</td><td>-</td><td>72.81</td><td>C</td></tr>
<tr><td>Unnamed Tributary</td><td>DWEF 11</td><td>-</td><td>81.65</td><td>B/C</td></tr>
<tr><td>Unnamed Tributary</td><td>DWEF 12</td><td>-</td><td>74.12</td><td>C</td></tr>
<tr><td rowspan="3">Klein-Komati</td><td>DWEF 9</td><td rowspan="3">C</td><td>62.01</td><td>C</td></tr>
<tr><td>DWEF 10</td><td>74.24</td><td>C</td></tr>
<tr><td>DWEF 13</td><td>71.94</td><td>C</td></tr>
</table>

* (Department of Water and Sanitation, 2016)

4.5 Ichthyofauna

Based on a review of historic collection records and information regarding habitat requirements of fish species, a total of 12 indigenous fish species have been recorded within the surrounding area and thus have the potential to be present within the watercourses under study (Table 7). During the June 2022 and October 2022 aquatic studies, a total of 863 specimens comprising nine species were collected within the assessed watercourses, including one alien fish species. Figure 9, Figure 10 and Figure 11 present graphical representations of the contribution of the various fish species to the total catch, the composition of the fish assemblage collected at each site, and the catch-per-unit-effort obtained at each site. In general, *Chiloglanis pretoriae* (Shortspine Suckermouth) and *Enteromius anoplus s.l.* (Chubbyhead Barb) were noted to dominate the fish assemblage collected during the June 2022 and October 2022 aquatic studies, collectively comprising over 60% of the total annual catch. However, given the high numbers of *Chiloglanis* spp. collected during the October 2022 assessment as well as the challenges in separating the two species observed (*C. pretoriae* and *C. emarginatus)* in the field (particularly smaller individuals), identification of individual species was done until two species were confirmed, after which the species was enumerated collectively. As such, it is likely that *C. pretoriae* may dominate the assemblage by as much as 50%.

Although not conclusive, species present at each site between seasons was similar from a composition perspective, with only sites DWEF3 and DWEF10 showing marked differences. Catch-per-unit-effort was also noted to be similar between surveys, with only sites DWEF6, DWEF8 and DWEF12 showing a marked difference in the relative abundances for fish between the June 2022 and the October 2022 field surveys. In general, higher densities and abundance of species were nevertheless noted at sites lower down in the catchment than those higher up.

Table 7: Fish species with a potential for occurrence within the associated watercourses

Scientific Name	Common Name	Conservation Status*	Expected	Collected
Indigenous Species				
Anguilla mossambica	Longfin Eel	NT	X	
Amphilius engelbrechti	Incomati Mountain Catfish	Not yet assessed	X	
Amphilius uranoscopus	Stargazer Mountain Catfish	LC	X	X
Chiloglanis emarginatus	Phongola Suckermouth	VU	X	X
Chiloglanis pretoriae	Shortspine Suckermouth	LC	X	X
Enteromius anoplus s.l.	Chubbyhead Barb	LC**	X	X
Enteromius paludinosus	Straightfin Barb	LC	X	X
Labeobarbus marequensis	Lowveld Largescale Yellowfish	LC	X	
Labeobarbus nelspruitensis	Incomati Chiselmouth	NT	X	
Labeobarbus polylepis	Bushveld Smallscale Yellowfish	LC	X	X
Pseudocrenilabrus philander	Southern Mouthbrooder	LC	X	X
Tilapia sparrmanii	Banded Tilapia	LC	X	X
Non-native Species				
Micropterus salmoides	Largemouth Bass	Alien		X

* LC = Least Concern; NT = Near Threatened; VU = Vulnerable

** Species complex – new descriptions of species from the complex indicate that current Red List assessment is obsolete

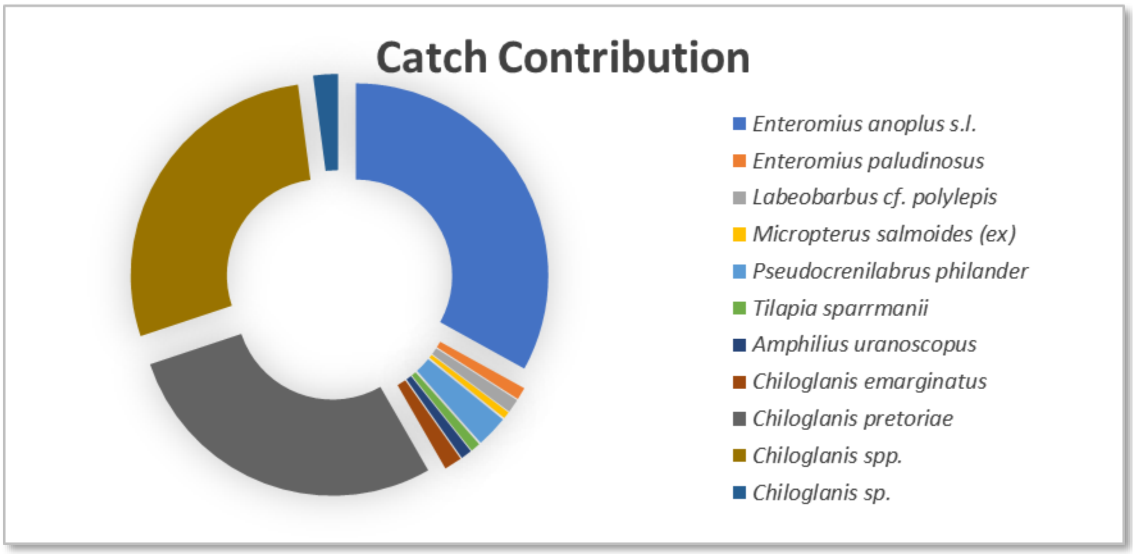


Figure 9: Contribution of each species to total catch within the associated watercourses based on as data collected during the June 2022 and October 2022 aquatic surveys

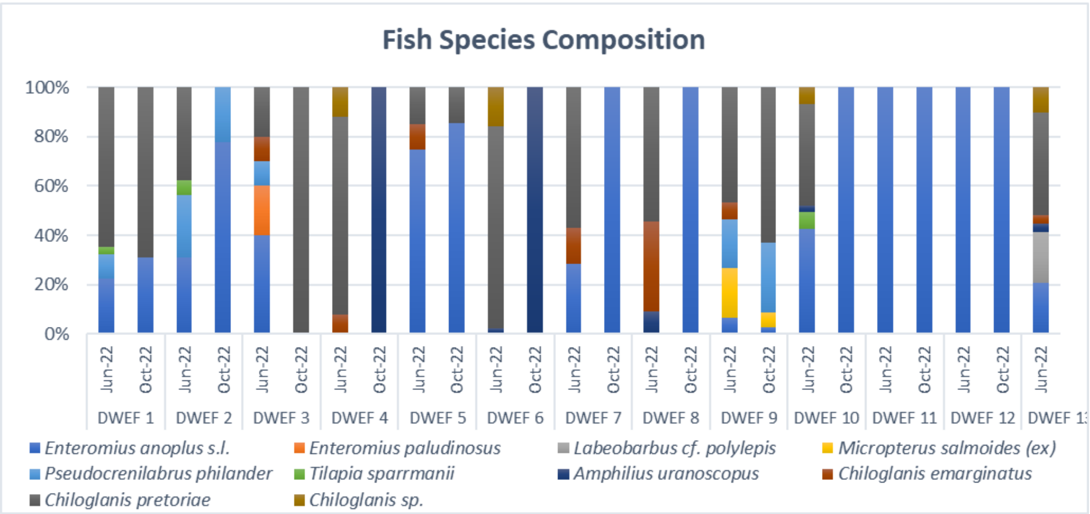


Figure 10: Fish species collection data obtained the during the June 2022 and October 2022 aquatic surveys

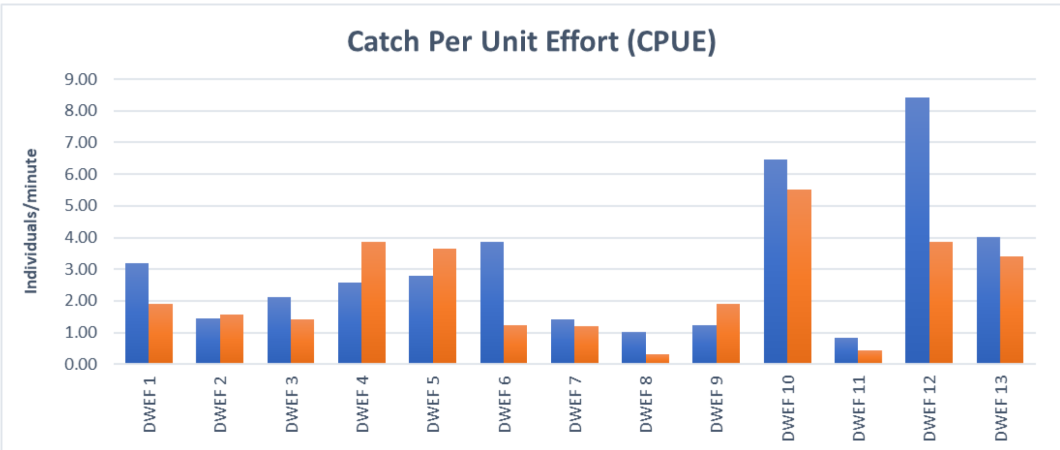


Figure 11: Catch-Per-Unit-Effort (CPUE) for sites assessed the during the June 2022 and October 2022 aquatic surveys

4.5.1 Present Ecological State

Assessment of the ecological state of the fish assemblage of the watercourses associated with the study area was primarily conducted by means of the Fish Response Assessment Index (or FRAI; Kleynhans, 2008), part of the larger suite of EcoStatus models. The procedure followed to determine the fish PES, or Ecological Category, in accordance with the FRAI methodology is an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions. In the case of the present assessment, the observed response was determined by means of fish sampling as well as a consideration of species requirements and driver changes (Kleynhans, 2008). For the purposes of the present study and due to the general mobility of fish along a specific riverine reach, sites located along the same riverine reach were assessed collectively. Results obtained during the 2022 annual assessment period for the watercourses associated with the proposed Dalmanutha WEF (Alternative 1 and 2) are provided in Table 8.

Table 8: Present Ecological State of the fish assemblage present within watercourses associated with the Dalmanutha WEF (Alternative 1 and 2), based on the FRAI approach (Kleynhans, 2008)

Catchment	River	Site	Target Ecological Category*	FRAI Score	Ecological Category
Waarkraalloop	Unnammed Tributary	DWEF1	-	86.20	B
	Unnammed Tributary	DWEF5	-	84.60	B
	Waarkraalloop	DWEF2	C	62.90	C
		DWEF3			
		DWEF4			
		DWEF6			
Klein-Komati	Unnammed Tributary	DWEF7	-	59.90	C/D
		DWEF8	-		
	Unnammed Tributary	DWEF11	-	64.20	C
	Unnammed Tributary	DWEF12	-	90.20	A/B
	Klein-Komati	DWEF9	C	65.40	C
		DWEF10			
		DWEF13			

* (Department of Water and Sanitation, 2016)

Based on the results obtained following the application of the FRAI on the assessed watercourses, it was determined that the mainstem Waarkraalloop was classified as moderately modified (Ecological Category C) from the perspective of the fish assemblage, whereas the tributaries of the Waarkraalloop are considered to be in a largely natural state (Ecological Category B; Table 8). Lower than expected Frequency-of-occurrence of *Enteromius anoplus s.l.* (Chubbyhead Barb), as well as the lack of *Labeobarbus* spp. Was observed, which may be related to the presence of weirs in the system preventing upstream migration of the species from the Komati River located downstream. Review of the FRAI score obtained further indicates that the present state of the mainstem Waarkraalloop only just meets the Target Ecological Category designated for the catchment by the Department of Water and Sanitation (Government Gazette No. 40531, 2016).

Within the Klein-Komati catchment, the mainstem Klein-Komati River was classified as moderately modified (Ecological Category C) from the perspective of the fish assemblage, whereas the tributaries ranged from being in a natural/near-natural state (Ecological Category A/B) to a moderately/largely modified state (Ecological Category C/D; Table 8). Further review of the drivers of the ecological state within the mainstem Klein-Komati River indicates that impacts contributing greatly to the ecological state include the impacts of alien fish species, notably the piscivorous *Micropterus salmoides* (Largemouth Bass), and upstream migration barriers in the form of large weirs and dams within the greater catchment. In contrast, results obtained within the tributary associated with sites DWEF7 and DWEF8 suggest that water quality is a significant contributor to the ecological state of the associated system, with the absence of several expected species noted.

4.6 Integrated EcoStatus

EcoStatus is defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna, as well as its capacity to provide a variety of goods and services (Iversen et al., 2000). In essence, the EcoStatus represents an ecologically integrated state of a system and represents both the drivers (hydrology, geomorphology and physic-chemical conditions) and the responses (aquatic invertebrates, fish and riparian vegetation) (Kleynhans & Louw, 2008). The integrated EcoStatus approach basically integrates several of approaches including aquatic macroinvertebrates, fish and riparian vegetation, with each component given a confidence score which is then taken into account in the development of the final integrated PES.

Based on the integration of results obtained during the 2022 baseline aquatic assessment for the watercourses associated with the proposed Dalmanutha WEF (Alternative 1 and 2) project (Table 9), it was determined that integrated instream component of both the Waarkraalloop and the Klein-Komati Rivers and their tributaries, were predominantly moderately modified (Ecological category C; Table 9). Further integration of the riparian element for each site (obtained through calculation of surrogate values from the IHI approach) suggests that, from the perspective of instream and riparian elements, these watercourses may be regarded as largely natural (Ecological Category B) to moderately modified (Ecological Category C). This is based on the largely intact structure of the riparian zones associated with each site where impacts were limited mostly to the encroachment of isolated stands of alien and invasive woody plant species, and in some places, impacts related to erosion and incision of the river banks. The Present Ecological States of both the Waarkraalloop and the Klein-Komati Rivers, thus meet the Target Ecological Category designated for the catchment by the Department of Water and Sanitation (Government Gazette No. 40531, 2016). However, any further deterioration in either the instream ecological integrity or the riparian habitat integrity, may result in a deviation from the designated Target Ecological Category for these watercourses.

Table 9: EcoStatus categories obtained during the 2022 aquatic specialist baseline assessment

Catchment	River	Site	Aquatic Macro-invertebrates	Fish	Integrated Instream Category	Riparian Vegetation	EcoStatus Category
Waarkraalloop	Unnamed Tributary	DWEF 1	C	B	C	A	B
	Unnamed Tributary	DWEF 5	C	B	B/C	A	B
	Waarkraalloop	DWEF 2	C	C	C	C	C
		DWEF 3	C	C	C	C	C
		DWEF 4	B	C	C	A/B	B
		DWEF 6	B/C	C	C	C	C
Klein_Komati	Unnamed Tributary	DWEF 7	C	C/D	C	C	C
		DWEF 8	C	C/D	C	A	B/C
	Unnamed Tributary	DWEF 11	B/C	C	C	C	C
	Unnamed Tributary	DWEF 12	C	A/B	B/C	A	B
	Klein-Komati	DWEF 9	C	C	C	A	C
		DWEF 10	C	C	C	C/D	C
		DWEF 13	C	C	C	C	C

4.7 Species of Conservation Importance

Species of conservation concern are those that are important for South Africa's conservation decision-making processes. For the purposes of this document, species of conservation concern are taken to include those listed as Threatened (Critically Endangered, Endangered or Vulnerable), Extinct in the Wild, Data Deficient, Near Threatened, Critically Rare, Rare and Declining (Raimondo et al., 2009). Aquatic taxa regarded as being of conservation concern were identified based on confirmed observations and/or on distribution records (known extant and probably extant), while their likelihood of occurrence within the study area was based on the representivity of habitat within the watercourses under study. It should, however, be noted that with the exception of Odonata, Mollusca and Crustacea which were assessed by Darwall et al. (2009) and Van Deventer et al. (2019), the aquatic macroinvertebrate taxa in South Africa have not had their conservation status adequately assessed in terms of the IUCN Red List assessment procedure (Barber-James, pers. Comm., 2017[1]).

Based on collection records for the study area, it was determined that several fish species of conservation concern were expected or confirmed to be present within the associated watercourses. These include the following species:

- *Chiloglanis emarginatus* (Phongola Suckermouth) – currently classified in terms of the IUCN Red List criteria at a global and regional (southern Africa) level as Vulnerable, and provincially as Near Threatened;
- *Labeobarbus nelspruitensis* (Incomati Chiselmouth) – currently classified in terms of the IUCN Red List criteria at a global and regional (southern Africa) level as well as at a provincial level as Near Threatened.

[1] 1 Dr. Helen M. Barber-James, Head: Department of Freshwater Invertebrates, Albany Museum. Personal electronic communication, 11 April 2017

While the conservation status of the *Enteromius anoplus* species complex itself has been determined to be of Least Concern (Woodford, 2017), the very recent studies of Kambikambi et al. (2021) have described several new species from the complex, with more new species descriptions expected. Consequently, the results obtained by Kambikambi et al. (2021) indicate that the current IUCN Red List assessment of *E. anoplus* is obsolete. It is, therefore, clear that further studies are required to understand the geographic ranges and thus conservation status of the populations of the members of the *Enteromius* group collected within the assessed study area to determine the significance of those specimens from a conservation perspective. Nevertheless, the provincial Mpumalanga Tourism and Parks Agency recognises three forms of this species complex as occurring in Mpumalanga, of which those occurring within the study area are likely to represent the Escarpment form which is considered to be Endangered at a provincial level. In addition, *Amphilius engelbrechti* (Incomati Mountain Catfish), which was recently described from the *A. natalensis* complex (Mazungula & Chakona, 2021), has not yet been assessed at a national or global level in terms of conservation status. However as with the *Enteromius anoplus* complex, the provincial Mpumalanga Tourism and Parks Agency recognises three forms of this species complex as occurring in Mpumalanga, of which those occurring within the study area are likely to represent the Mpumalanga form which is considered to be Vulnerable at a provincial level.

4.8 Non-native Species

For the purpose of the present study, alien species are defined as those that have been introduced from outside the political boundaries of South Africa, whereas extralimital species are species native to South Africa that have been translocated into areas where they do not naturally occur. Within the context of the present study, non-native species are therefore collectively taken to include both alien and extralimital species.

During the present study, only one (1) non-native aquatic macro-invertebrate species was identified within the study area, namely *Physa acuta* (Physa Snail). Accidentally introduced prior to 1956 (probably with aquatic plants imported through the aquarium trade), this highly invasive species is well distributed throughout most of South Africa, although their impact on indigenous species is unknown (De Moor & Bruton, 1988). According to the unified framework proposed by Blackburn et al. (2011), *P. acuta* can be classified as fully invasive species, with individuals dispersing, surviving and reproducing at multiple sites across a greater or lesser spectrum of habitats and extent of occurrence.

In addition, only one (1) non-native fish species was identified within the study area, namely *Micropterus salmoides* (Largemouth bass). The largemouth bass, native to North America, is a carnivorous fish species introduced in South Africa as a sports fish for angling purposes in 1928 and has subsequently spread throughout the country. It is currently listed as a NEMBA category 1B invasive species (invasives.org.za). The species is among the world's one hundred (100) worst invaders and negatively affects aquatic biodiversity in many regions worldwide. The species has been linked to the extirpation of native fishes, as well as changes to their abundance and behaviour in their natural habitats (Kimberg et al., 2014) and their presence is likely to have a significant impact on the natural assemblage and abundance of the expected fish populations for the watercourses associated with the study area.

4.9 Ecological Importance and Ecological Sensitivity

Ecological importance refers to biophysical aspects in the sub-quaternary reach that relates to its capacity to function sustainably. In contrast, ecological sensitivity considers the attributes of the sub-quaternary reach that relates to the sensitivity of biophysical components to general environmental changes such as flow, physico-chemical and geomorphic modifications. Essentially, the ecological importance and the ecological sensitivity of the relevant reaches are assessed to obtain an indication of its vulnerability to environmental modification within the context of the PES. This would relate to the ability of the sub-quaternary reach to endure, resist and able to recover from various forms of human use (Department of Water and Sanitation, 2014).

Both the mainstem Waarkraalloop and the mainstem Klein-Komati Rivers were assessed by the Department of Water and Sanitation (2014) in terms of Ecological Importance and Ecological Sensitivity from an aquatic perspective. Based on the condition of the various watercourses assessed and the results of the 2022 specialist aquatic baseline assessment, the values were adjusted where necessary to provide an updated assessment of the observed Ecological Importance and Sensitivity. According to the results of this assessment, the Waarkraalloop and its associated tributaries may be regarded as of 'High' Ecological Importance with a 'Very High' Ecological Sensitivity. Similarly, the Klein-Komati and its associated tributaries may also be regarded as of 'High' Ecological Importance with a 'Very High' Ecological Sensitivity (Table 10).

Table 10: Ecological Importance and Ecological Sensitivity for the reaches of the Waarkraalloop and the Klein-Komati associated with the proposed project, as determined from an aquatic perspective (Department of Water and Sanitation, 2014)

Ecological Importance	**Description**			
	Waarkraalloop		**Klein-Komati**	
	DWS (2014)	Adjusted	DWS (2014)	Adjusted
Fish representivity	High	High	Low	High
Fish rarity	High	High	High	High
Invertebrate representivity	High	Very high	Very High	Very high
Invertebrate rarity	Very High	Very high	Very High	Very high
Ecological Importance for riparian/wetland/instream (vertebrates excl. fish)	High	High	High	High
Riparian/Wetland natural vegetation importance	Low	Low	Low	Low
Habitat diversity class	Low	Moderate	Low	High
Instream migration link	High	High	Moderate	High
Riparian/Wetland zone migration link	High	High	High	High
Riparian/Wetland zone habitat integrity class	High	High	High	High
Instream habitat integrity class	High	High	High	High
Mean Ecological Importance Value	***High***	***High***	***High***	***High***
Ecological Sensitivity				
Fish physico-chem sensitivity	Very High	Very high	Very High	Very high
Fish flow sensitivity	Very High	Very high	Very High	Very high
Invertebrate physico-chem sensitivity	High	Very high	Very High	Very high

Invertebrate velocity preference	Very High	Very high	Very High	Very high
Riparian/Wetland/instream vertebrates sensitivity to water level/flow changes	High	High	High	High
Stream size sensitivity to modified flow/water level changes	High	High	High	High
Riparian/Wetland/instream vegetation intolerance to water level/flow changes	Low	Moderate	High	High
Mean Ecological Sensitivity Value	***Very High***	***Very High***	***Very High***	***Very High***

4.10 Freshwater Ecosystem Buffers

Buffer zones associated with water resources have been shown to perform a wide range of functions and have been proposed as a standard measure to protect water resources and associated biodiversity on this basis. These functions can include (Macfarlane & Bredin, 2016):

- Maintaining basic aquatic processes;
- Reducing impacts on water resources from upstream activities and adjoining land uses;
- Providing habitat for aquatic and semi-aquatic species;
- Providing habitat for terrestrial species; and
- A range of ancillary societal benefits.

However, despite the range of functions potentially provided by buffer zones, buffer zones are unable to address all water resource-related problems. For example, buffers can do little to address impacts such as hydrological changes caused by stream flow reduction activities or changes in flow brought about by abstractions or upstream impoundments. Buffer zones are also not the appropriate tool for mitigating against point-source discharges (e.g. sewage outflows), which can be more effectively managed by targeting these areas through specific source-directed controls (Macfarlane & Bredin, 2016).

In determining the functional buffer zones necessary for the Waarkraalloop and the Klein-Komati River as well as their tributaries, use was made of the buffer zone guideline; 'Buffer Zone Guidelines for Wetlands, Rivers and Estuaries', as described and developed by Macfarlane & Bredin (2016). While the tool requires the input of specific data pertaining to each resource, buffer determinations also rely heavily on the professional expertise of a qualified specialist and each buffer may be regarded as site specific.

For the application of the guideline, data is inserted into a series of excel-based Buffer Zone Tools, which then provide the buffer zone requirements for a particular activity at a particular site. The excel spreadsheets then inform a buffer model which is populated automatically for construction and operational phases (independently and collectively) from the data capture sheets provided. Further to this, the guideline provides a list of land-use sectors used to evaluate the threat of the proposed activities which informs the mitigation measures to be applied. The main sectors include agriculture, industry, mixed use/commercial/retail/business, civic and social, residential, open space, transportation, service infrastructure and mining.

As this project is related to the energy generation sector, the land use applied to the buffer is that of *Industry* with the sub-sector allocated as *Electricity Generation Works*. Consideration was given to site-based attributes such as topography, climatic variables, soils, etc. According to results obtained following this approach, *a functional buffer of at least 63m from the edge of the macro-channel of the watercourse* is proposed for protection of the riverine ecosystem and maintenance of a functional riverine buffer zone. Primary determinants in this regard pertain to the characteristics of the watercourse, the nature of the proposed activities, the slope of the buffer, the vegetation characteristics of the buffer, soil permeability and the micro-topography of the buffer zone. ***The final width of the integrated buffer zones will however need to also consider inputs from terrestrial specialist assessments as well as the relevant wetland specialist assessment, and may require further expansion.***

5. IMPACT ASSESSMENT

5.1 Proposed Project Activities

Two alternatives are included as part of the proposed Dalmanutha WEF (Alternative 1 and 2) project:

- Alternative 1: 70 turbines, the locations of which are spread across much of the proposed project area; and
- Alternative 2: 44 turbines and two solar fields, which eliminates much of the northern portion of the study area from the proposed development.

Both alternatives make use of 33kV cables (to be laid underground were possible), a 33/132kV on-site Independent Power Producer (IPP) substation and Battery Energy Storage System (BESS), as well as a 132kV over the fence cable to connect the on-site substation to the Common Collector Switching Station (CCSS).

Infrastructure associated with Alternative 1 includes the following:

- Up to 70 wind turbines with a foundation of approximately 25m^2 in diameter and approximately 3m depth;
- IPP portion onsite substation and BESS;
- Operation and maintenance building infrastructure;
- Temporary contractor laydown area and construction camp;
- Temporary batching plant, wind tower factory and yard;
- Access roads
  - Internal roads ±8 to 10m, which may be increased to approximately 12m on the bends. The roads will be positioned within a 20m wide corridor to accommodate cable trenches, stormwater channels, etc and the length of each will be approximately 60km.
- Other associated infrastructure includes:
  - A medium voltage collector system (33kV);
  - A 132kV over-the-fence cable to connect the on-site substation to the CCSS;
  - Fencing and lighting;
  - Lightning protection;
  - Telecommunication infrastructure;
  - Stormwater channels;
  - Water pipelines;

    - Offices;
    - Operational control centre;
    - Ablution facilities;
    - A gatehouse;
    - Control centre, offices, warehouses;
    - Security building; and
    - A visitor's centre.

The proposed development footprint (buildable area) is approximately 400ha (subject to finalisation based on technical and environmental requirements), and the extent of the project area is approximately 9197 ha. The development footprint includes the turbine positions and all associated infrastructure as outlined above

Infrastructure associated with Alternative 2 includes the following:

- Up to 44 wind turbines with a foundation of approximately 25m2 in diameter and approximately 3m depth;
- Solar PV array;
- IPP portion onsite substation and BESS;
- Operation and maintenance building infrastructure;
- Temporary contractor laydown area and construction camp;
- Temporary batching plant, wind tower factory and yard;
- Access roads
    - WEF internal roads ±8 to 10m, which may be increased to approximately 12m on the bends. The roads will be positioned within a 20m wide corridor to accommodate cable trenches, stormwater channels, etc and the length of each will be approximately 60km;
    - SEF internal roads may be up to 4m wide.
- Other associated infrastructure includes:
    - A medium voltage collector system for the WEF (33kV);
    - A low and medium voltage cabling system for the SEF (33kV);
    - A 132kV over-the-fence cable to connect the on-site substation to the CCSS;
    - Fencing and lighting;
    - Lightning protection;
    - Telecommunication infrastructure;
    - Stormwater channels;
    - Water pipelines;
    - Offices;
    - Operational control centre;
    - Ablution facilities;
    - A gatehouse;
    - Control centre, offices, warehouses;
    - Security building; and
    - A visitor's centre.

The proposed development footprint (buildable area) is approximately 400ha (subject to finalisation based on technical and environmental requirements), and the extent of the project area is approximately 9197 ha. The development footprint includes the turbine positions and all associated infrastructure as outlined above

The activities likely to be associated with the proposed development footprint includes the following**:**

- Constructions activities:
  - Clearing of vegetation and stripping of topsoils;
  - Earthworks for foundations. potential borrow pits, burying of cables, etc;
  - Materials management, inclusive of the transport, use, and storage of chemicals and other substances such as cement, oils and hydrocarbons;
  - Construction of the turbines (and solar fields [alternative 2]), road network and substations;
  - Movement of vehicles and machinery;
- Operational activities:
  - Physical presence of turbines (and solar fields [alternative 2]), road network and substations;
  - Materials management, inclusive of the transport, use, and storage of chemicals and other substances such as cement, oils and hydrocarbons;
  - Movement of vehicles and machinery for maintenance activities;
- Decommissioning activities:
  - Physical presence of former turbines (and solar fields [alternative 2]), road network and substations; and
  - Use of vehicles and heavy machinery to remove infrastructure.

5.2 Impact Assessment Approach

In order to ensure uniformity, a standard prescribed impact assessment methodology was utilised so that a wide range of impacts could be compared. The impact assessment methodology makes provision for the assessment of impacts against the following criteria:

- Magnitude;
- Extent;
- Duration;
- Probability of Occurrence; and
- Significance.

The assessment of impacts and mitigation evaluates the likely extent and significance of the potential impacts on identified receptors and resources against the defined assessment criteria, to develop and describe measures that must be taken to avoid, minimise or compensate for any adverse environmental impacts, to enhance positive impacts, and to report the significance of residual impacts that occur following mitigation.

The key objectives of the risk assessment methodology are to identify any additional potential environmental issues and associated impacts likely to arise from the proposed project, and to propose a significance ranking. Issues/aspects were reviewed and ranked against a series of significance criteria to identify and record interactions between activities and aspects, and resources and receptors to provide a detailed discussion of impacts. The assessment considers direct[2], indirect[3], secondary[4] as well as cumulative[5] impacts.

A standard risk assessment methodology is used for the ranking of the identified environmental impacts pre-and post-mitigation (i.e. residual impact). The significance of environmental aspects is determined and ranked by considering the criteria[6] presented in Table 11.

Table 11: Impact Assessment Criteria and Scoring System

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Magnitude (M) The degree of alteration of the affected environmental receptor	Very low: No impact on processes	Low: Slight impact on processes	Medium: Processes continue but in a modified way	High: Processes temporarily cease	Very High: Permanent cessation of processes
Impact Extent (E) The geographical extent of the impact on a given environmental receptor	Site: Site only	Local: Inside activity area	Regional: Outside activity area	National: National scope or level	International: Across borders or boundaries
Impact Reversibility (R) The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change	Reversible: Recovery without rehabilitation		Recoverable: Recovery with rehabilitation		Irreversible: Not possible despite action
Impact Duration (D) The length of permanence of the impact on the environmental receptor	Immediate: On impact	Short term: 0-5 years	Medium term: 5-15 years	Long term: Project life	Permanent: Indefinite
Probability of Occurrence (P) The likelihood of an impact occurring in the absence of pertinent environmental management measures or mitigation	Improbable	Low Probability	Probable	Highly Probability	Definite
Significance (S) is determined by combining the above criteria in the following formula:	$[S = (E + D + R + M) \times P]$ $Significance = (Extent + Duration + Reversibility + Magnitude) \times Probability$				
IMPACT SIGNIFICANCE RATING					
Total Score	**4 to 15**	**16 to 30**	**31 to 60**	**61 to 80**	**81 to 100**
Environmental Significance Rating (Negative (-))	**Very low**	**Low**	**Moderate**	**High**	**Very High**

[2] Impacts that arise directly from activities that form an integral part of the Project.
[3] Impacts that arise indirectly from activities not explicitly forming part of the Project.
[4] Secondary or induced impacts caused by a change in the Project environment.
[5] Impacts are those impacts arising from the combination of multiple impacts from existing projects, the Project and/or future projects.
[6] The definitions given are for guidance only, and not all the definitions will apply to all the environmental receptors and resources being assessed. Impact significance was assessed with and without mitigation measures in place.

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Environmental Significance Rating (Positive (+))	Very low	Low	Moderate	High	Very High

The impact significance without mitigation measures was assessed with the design controls in place. However, impacts without mitigation measures in place are not representative of the proposed development's actual extent of impact and were included to facilitate understanding of how and why mitigation measures were identified. The residual impact is what remains following the application of mitigation and management measures and is thus the final level of impact associated with the development. Residual impacts also serve as the focus of management and monitoring activities during project implementation to verify that actual impacts are the same as those predicted in this report.

The mitigation measures chosen were based on the mitigation sequence/hierarchy which allows for consideration of five (5) different levels, which include avoid/prevent, minimise, rehabilitate/restore, offset and no-go in that order. The idea is that when project impacts are considered, the first option should be to avoid or prevent the impacts from occurring in the first place if possible, however, this is not always feasible. If this is not attainable, the impacts can be allowed, however they must be minimised as far as possible by considering reducing the footprint of the development for example so that little damage is encountered. If impacts are unavoidable, the next goal is to rehabilitate or restore the areas impacted back to their original form after project completion. Offsets are then considered if all the other measures described above fail to remedy high/significant residual negative impacts. If no offsets can be achieved on a potential impact, which results in full destruction of any ecosystem for example, the no-go option is considered so that another activity or location is considered in place of the original plan.

The mitigation sequence/hierarchy is shown in Figure 12 below.

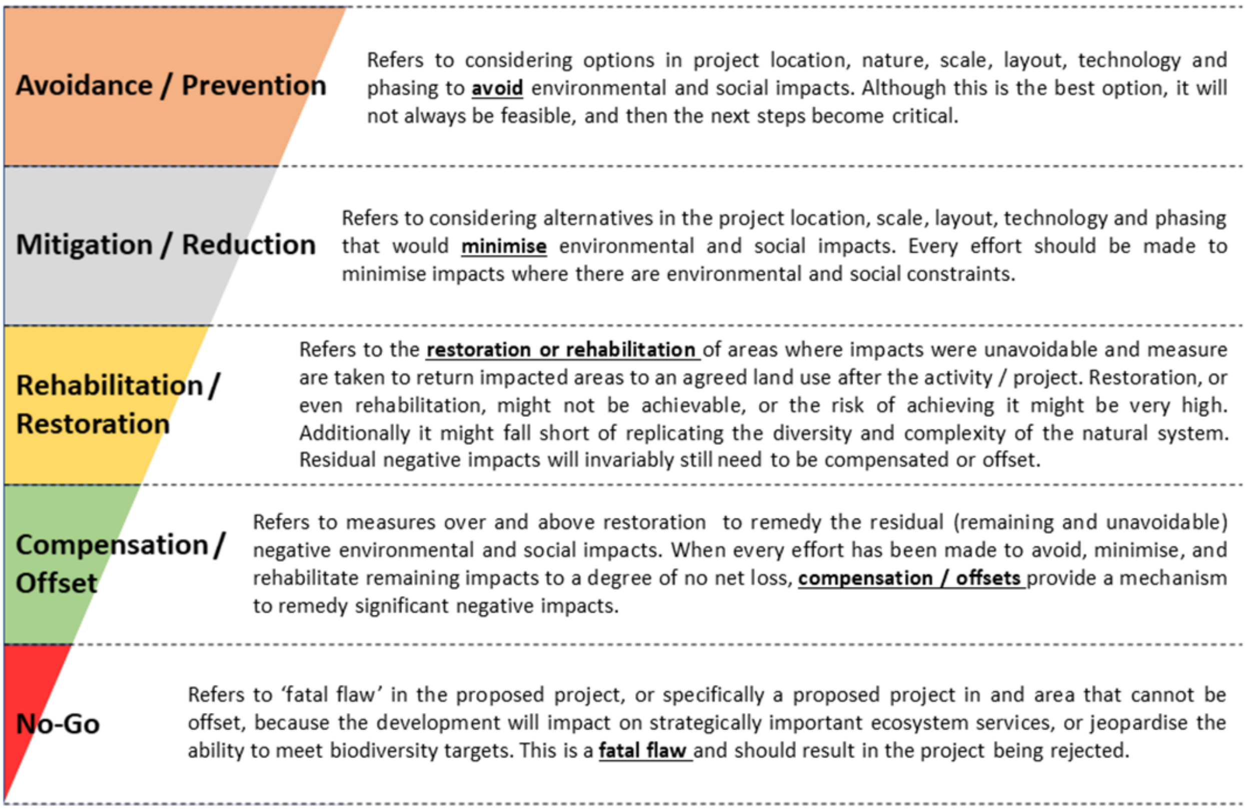


Figure 12: The mitigation hierarchy

5.3 Identification and Assessment of Potential Impacts

The range of potential impacts anticipated as a result of the proposed activities have been identified in line with the nature of the proposed activities, the proximity of these activities to the watercourses associated with the study area, as well as according to the baseline conditions and sensitivities identified in Sections 2, 3 and 4 of this report and are described in detail in the sections below. Due to the nature of the proposed project, the various potential impacts are likely to include the following:

- Erosion and sedimentation of aquatic habitats through clearing of vegetation and other earthworks activities;
- Water quality deterioration;
- Loss of unique biodiversity features and/or fragmentation of watercourses through the placement of new crossings or infrastructure;
- Loss of catchment yield and/or altered surface water runoff within the wind farm site; and
- Invasive alien plant species encroachment.

It is important to note that while the footprints of each turbine, the proposed solar fields for Alternative 2, the substations and the road networks may appear relatively small, the cumulative footprint and its associated impacts have the potential to be significant. It is thus critical that the mitigation measures as stipulated in Section 5.6 be strictly adhered to in order to limit impacts to the aquatic resources associated with the proposed project (Figure 13). The assessment of residual impacts is based on the assumption that the mitigation measures proposed are feasible and will be implemented. Where proposed mitigation measures are not deemed feasible, then re-assessment of impact significance would be required based on what would be feasible.

Figure 13: Example of the construction of the foundation of a single wind turbine (UK Department of the Environment and Northern Ireland Environment Agency, 2015)

5.3.1 Sedimentation of Aquatic Habitats

The clearing of vegetation and the stripping of topsoil for surface infrastructure such as the substations, etc. can result in the movement of sediment into downstream and adjacent aquatic systems, particularly during rainfall events. In addition, the use of heavy machinery within the construction footprint will lead to soil compaction, increasing the runoff potential over the topsoil and the reduction in stormwater infiltration into the soil profile, thereby increasing the likelihood of erosion gully formation and the deposition of sediment within the surrounding watercourses and wetland systems. Further, the construction of various roads across wetlands and drainage lines throughout the study area may increase the potential for fragmentation and/or result in the confinement of flow ultimately leading to erosional processes which will further add to the sediment input into the surrounding aquatic ecosystems.

Various impacts have been attributed to sedimentation of aquatic ecosystems, including reduction of light penetration (resulting in reduction in photosynthesis and subsequently, productivity), alteration of foraging dynamics of both carnivores and herbivores, impacting on predator and prey relationships, clogging of gills, rendering the watercourse unfit for various aquatic organisms, truncating and shifting the trophic pyramid, absorption of nutrients onto suspended particles, rendering them unavailable and thereby reducing the productivity of the watercourse, and filling of interstitial spaces, thereby destroying habitat for macro invertebrates and vertebrates owing to sedimentation, etc.

However, numerous variables (including sediment characteristics, sediment concentration, exposure time, temperature, natural ecosystem processes, etc.) dictate the vulnerability of aquatic assemblages and fish species specifically to elevated suspended sediment loads within a natural system. For example, warm water species differ in their response to elevated silt loads at different stages of their life histories (e.g. Smit et al., 1998) and at different water temperatures. In other studies, the response of species has also been shown to vary with duration of exposure, with short-term exposure reported to increase the frequency of gill flaring during periods of elevated turbidity in an attempt to facilitate clearing of suspended sediment on the gill surfaces (e.g. Berg & Northcote, 1985; Servizi & Martens, 1992), while long term exposure potentially causing thickening of the gill epithelium and loss of respiratory function (e.g. Bell, 1973). Still other research indicates the cardiovascular response of lacustrine fish is more extreme than that of riverine fish of the same species, suggesting that compensatory mechanisms that can minimise cardio-respiratory disruption caused by increased suspended silt concentrations are more prevalent in riverine species in relation to lacustrine species (Bunt et al., 2004). Sediment deposition within both the Waarkraalloop and the Komati River Catchments is further expected to smother available stones biotopes, leading to a reduction in abundance and diversity of flow-sensitive hydraulic habitat, ultimately resulting in a loss of sensitive aquatic biota noted to be present.

5.3.2 Water Quality Deterioration

During the construction phase, as activities are taking place within and adjacent to watercourses and wetlands, there is a possibility that water quality may be impaired. Typically, impairment will occur as a consequence of sediment disturbance resulting in an increase in turbidity. Water quality may also be impaired as a consequence of accidental spillages and the intentional washing and rinsing of equipment. The proposed cement batching plants, as well as the potential use and storage of hydrocarbons and other potential pollutants, have the potential to result in impaired water quality.

Changes in water quality have the potential to cause a shift in aquatic species composition, favouring only tolerant species, resulting in the localised exclusion of sensitive species. Sudden drastic changes in water quality can also have chronic effects on aquatic biota leading to localised extinction. Pollution could also result in negative impacts to people and livestock that are reliant on water resources for drinking purposes. Furthermore, the Klein-Komati River and its tributaries are classified as CBAs as the Klein-Komati River is classified as a FEPA river, which makes water quality considerations and the protection of biodiversity particularly relevant.

5.3.3 Loss of Unique Biodiversity Features

The loss of aquatic biodiversity within the associated watercourses as a result of proposed activities poses several concerns, and has particular relevance to several flow and water quality sensitive macroinvertebrate taxa observed to be present within the associated watercourses, as well as the confirmed presence of *Chiloglanis emarginatus*, which has a conservation status of 'Vulnerable'. The activities of the proposed project may impact on biodiversity through:

- Loss of habitat availability as a result of sedimentation impacts; and
- Impaired water quality as a result of chemical spills, cement, and other pollutants.

5.3.4 Altered Surface Water Runoff Patterns and Potential Loss of Catchment Yield

Earthworks and surface hardening as a result of the proposed project has the potential to result in changes to infiltration of water to underground aquifers, surface water runoff patterns, as well as the lateral flow of water through soils, thereby influencing the flow and distribution of water in the study area. Changes to surface water runoff patterns and the movement of water through the landscape, has the potential to result in an increased magnitude and periodicity of flooding, which may impact the natural flow regimes of the receiving watercourses.

5.3.5 Fragmentation of Watercourses

Physical structures such as road crossings have the potential to fragment river networks, impeding the free movement of water, sediment, organic matter, nutrients, energy, and has the potential to limit local movement and migration patterns of freshwater fish and other species. The disruption of these water-mediated connections has the potential to further influence crucial ecosystem processes and functions within river networks and alter habitats through inundation and/or loss of downstream flow, and even the confinement of flow as mentioned above. To further elaborate, any anthropogenic activities within either the riparian and/or instream zones of a watercourse, have the potential to influence stream hydrology, biophysical characteristics, and ecological and functional integrity at many scales. Together, these changes impact stream biophysical and chemical characteristics, which further influence aquatic and riparian habitat availability and quality, freshwater biodiversity, and associated ecosystem processes and functions such as nutrient cycling regimes, sediment redistribution, and ecosystem productivity (Jumani et al., 2020).

5.3.6 Invasive Alien Plant Species Encroachment

The proliferation of alien and/or invasive plants poses a risk to indigenous plant species and would be facilitated by disturbance of natural vegetation and surface soil layers during vegetation clearing and general construction, acting as seed areas that will ultimately facilitate the invasion of associated watercourses and riparian areas which will result in a decrease in the ecological state, ultimately impacting on the RQOs designated for the catchment. Alien and/or invasive plant species have the ability to out-compete and replace indigenous flora, which will in turn impact on natural biodiversity. Alien species generally out-compete indigenous species for water, light, space and nutrients as they are adaptable to changing conditions and are able to easily invade a wide range of ecological niches, posing an ecological threat as they alter habitat structure, lower biodiversity (both number and "quality" of species), change nutrient cycling and productivity, and modify food webs. Although the impact is initiated during the construction phase, it is really an operational issue as recovery of vegetation community types is a long-term process. The significance of this impact is regarded as high as the incidence of alien and/or invasive species observed in the study and investigation areas, increases the potential for the spread of these species and a result of the proposed activities.

5.4 Impact Assessment Ratings

The impact assessment tables present a breakdown of the perceived impacts and the associated ratings for each potential impact prior to mitigation as well as following the application of mitigation measures. Table 12 presents the results for Alternative 1, while Table 2 presents the results for

Alternative 2.

5.5 Cumulative and Latent Impacts

The proposed Dalmanutha Wind Energy Facility is located in a fairly remote part of the Komati River catchment where current impacts to the aquatic resources are largely related to agropastoral activities, isolated small rural residential dwellings and growing informal rural settlements. Conversion of isolated grasslands and croplands to forestry was also observed. The Mpumalanga Highveld region contains one of the highest concentrations of FEPAs in the country (Sections 3.4 and 3.5). Therefore, although the study area is not situated in a SWSA, it is situated in a region that is considered the source of several of the country's major rivers, which collectively contribute 28% of South Africa's available water yield (biodiversityadvisor.sanbi.org, accessed December 2022). Beneath the surface, however, the Mpumalanga Highveld straddles coalfields that are estimated to collectively contain 51% of national recoverable coal reserves and the water resources associated with the study area are continually under threat from ever encroaching coal mining activities in the greater catchment.

Furthermore, the impacts of coal mining and the associated use for energy production has the potential to result in significant carbon emissions, which in turn, contributes to climate change. The effects of climate change are far reaching and have been proven to result in disruptions to weather patterns, with increasing impacts to water availability (Kusangaya et al., 2013). The extraction and use of coal-fired energy can contribute to greenhouse gas (GHG) emissions by as much as 67.5 to 1,689.0 grams of CO2-equivalents per kilowatt-hour, depending on the technologies being used. In contrast, while wind energy facilities have been shown to result in carbon emissions over the course of their life cycles (construction phase, operational phase and decommissioning phase), these fall within a range of about five to 26.0 grams of CO2-equivalents per kilowatt hour, with the largest emissions associated with the construction phase which largely involves the materials used in construction and the associated transport (yaleclimateconnections.org; Mello et al., 2020). During the operational phase, however, wind energy is known for its low carbon footprint, with no to negligible generation of water or air pollution other than that potentially related to maintenance activities. Wind energy facilities also generally do not require water for cooling purposes, which is an extremely important consideration given South Africa's scarcity of water. Unlike fossil fuels and nuclear power plants, wind energy has one of the lowest water-consumption footprints, which makes it key for conserving hydrological resources.

The sterilisation of this area from mining rights in support of renewable energy therefore has significant potential to contribute to the long term conservation of water resources and result in positive long-term benefits for the catchment.

Table 12: Assessment of potential impacts associated with the proposed Dalmanutha Wind Energy Facility (Alternative 1)

CONSTRUCTION																				
Impact number	Aspect/Receptor	Description	Stage	Character	Ease of Mitigation	Pre-Mitigation							Post-Mitigation							
						(M+	E+	R+	D)x	P=	S	Rating	(M+	E+	R+	D)x	P=	S	Rating
Impact 1:	Clearing of vegetation and stripping of topsoils	Onset of erosion and sedimentation Altered surface water runoff patterns Loss of biodiversity Proliferation of alien and invasive species	Construction	Negative	Moderate	4	3	3	4	4	**56**	**N3**	2	1	3	4	2	**20**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 2:	Earthworks	Onset of erosion and sedimentation Altered surface water runoff patterns Loss of biodiversity Potential fragmentation of watercourses Proliferation of alien and invasive species	Construction	Negative	Moderate	4	3	3	4	4	**56**	**N3**	3	1	3	4	2	**22**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 3:	Materials management	Water and soil pollution Loss of biodiversity	Construction	Negative	High	3	3	3	5	3	**42**	**N3**	1	1	3	1	2	**12**	**N1**
					Significance	**N3 - Moderate**							**N1 - Very Low**						
Impact 4:	Construction of turbines, road network and substations	Altered surface water runoff patterns Loss of biodiversity Potential fragmentation of watercourses	Construction	Negative	Moderate	4	2	5	4	4	**60**	**N3**	3	1	5	4	2	**26**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 5:	Movement of vehicles and machinery	Water and soil pollution Prolirefation of alien and invasive species	Construction	Negative	Moderate	3	2	5	4	4	**56**	**N3**	2	1	2	4	2	**18**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						

OPERATIONAL																			
Impact number	**Aspect/Receptor**	**Description**	**Stage**	**Character**	**Ease of Mitigation**	**Pre-Mitigation**							**Post-Mitigation**						
						(M+	**E+**	**R+**	**D)x**	**P=**	**S**		**(M+**	**E+**	**R+**	**D)x**	**P=**	**S**	
Impact 1:	Physical presence of turbines, road network and substations	Altered surface water runoff patterns Loss of biodiversity Potential fragmentation of watercourses	Operational	Negative	Low	4	2	5	5	4	**64**	**N4**	3	1	5	5	2	**28**	**N2**
					Significance	**N4 - High**							**N2 - Low**						
Impact 2:	Materials management	Water and soil pollution Loss of biodiversity	Operational	Negative	High	3	3	3	5	3	**42**	**N3**	1	1	3	1	2	**12**	**N1**
					Significance	**N3 - Moderate**							**N1 - Very Low**						
Impact 3:	Movement of vehicles and machinery for maintenance activities	Water and soil pollution	Operational	Negative	Moderate	2	2	3	4	4	**44**	**N3**	1	1	2	4	1	**8**	**N1**
					Significance	**N3 - Moderate**							**N1 - Very Low**						
DECOMISSIONING																			
Impact number	**Aspect/Receptor**	**Description**	**Stage**	**Character**	**Ease of Mitigation**	**Pre-Mitigation**							**Post-Mitigation**						
						(M+	**E+**	**R+**	**D)x**	**P=**	**S**		**(M+**	**E+**	**R+**	**D)x**	**P=**	**S**	
Impact 1:	Physical presence of former turbines, road network and substations	Altered surface water runoff patterns Loss of biodiversity Potential fragmentation of watercourses	Decommissioning	Negative	Low	4	2	5	5	4	**64**	**N4**	3	1	5	5	2	**28**	**N2**
					Significance	**N4 - High**							**N2 - Low**						
Impact 2:	Use of vehicles and heavy machinery to remove infrastructure	Water and soil pollution Loss of biodiversity Proliferation of alien and invasive species	Decommissioning	Negative	Moderate	3	2	3	4	4	**48**	**N3**	2	1	2	4	2	**18**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 1:	Electricity generation	Sterilisation from mining rights Maintenance of biodiversity	Cumulative	Positive	High	3	3	3	4	5	**65**	**P4**	3	3	3	4	5	**65**	**P4**
					Significance	**P4 - High**							**P4 - High**						

Table 13: Assessment of potential impacts associated with the proposed Dalmanutha Wind Energy Facility (Alternative 2)

CONSTRUCTION																			
Impact number	**Aspect**	**Description**	**Stage**	**Character**	**Ease of Mitigation**	**Pre-Mitigation**							**Post-Mitigation**						
						(M+	**E+**	**R+**	**D)x**	**P=**	**S**	**Rating**	**(M+**	**E+**	**R+**	**D)x**	**P=**	**S**	**Rating**
Impact 1:	Clearing of vegetation and stripping of topsoils	Onset of erosion and sedimentation Altered surface water runoff patterns Loss of biodiversity Proliferation of alien and invasive species	Construction	Negative	Moderate	4	3	3	4	4	**56**	**N3**	2	1	3	4	2	**20**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 2:	Earthworks	Onset of erosion and sedimentation Altered surface water runoff patterns Loss of biodiversity Loss of catchment yield Potential fragmentation of watercourses Proliferation of alien and invasive species	Construction	Negative	Moderate	4	3	3	4	4	**56**	**N3**	2	1	3	4	2	**20**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 3:	Materials management	Water and soil pollution Loss of biodiversity	Construction	Negative	High	3	3	3	5	3	**42**	**N3**	1	1	3	1	2	**12**	**N1**
					Significance	**N3 - Moderate**							**N1 - Very Low**						
Impact 4:	Construction of turbines, solar fields, road network and substations	Altered surface water runoff patterns Loss of biodiversity Loss of catchment yield through surface hardening Potential fragmentation of watercourses	Construction	Negative	Moderate	4	2	5	4	4	**60**	**N3**	3	1	5	4	2	**26**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						
Impact 5:	Movement of vehicles and machinery	Water and soil pollution Loss of catchment yield and altered surface water runoff patterns due to surface hardening Prolirefation of alien and invasive species	Construction	Negative	Moderate	3	2	5	4	4	**56**	**N3**	2	1	2	4	2	**18**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						

OPERATIONAL																			
Impact number	**Receptor**	**Description**	**Stage**	**Character**	**Ease of Mitigation**	**Pre-Mitigation**							**Post-Mitigation**						
						(M+	**E+**	**R+**	**D)x**	**P=**	**S**		**(M+**	**E+**	**R+**	**D)x**	**P=**	**S**	
Impact 1:	Physical presence of turbines, solar fields, road network and substations	Altered surface water runoff patterns Loss of biodiversity Loss of catchment yield through surface hardening Potential fragmentation of watercourses	Operational	Negative	Low	4	2	5	5	4	**64**	**N4**	2	1	5	5	2	**26**	**N2**
					Significance	**N4 - High**							**N2 - Low**						
Impact 2:	Materials management	Water and soil pollution Loss of biodiversity	Operational	Negative	High	3	3	3	5	3	**42**	**N3**	1	1	3	1	2	**12**	**N1**
					Significance	**N3 - Moderate**							**N1 - Very Low**						
Impact 3:	Movement of vehicles and machinery for maintenance activities	Water and soil pollution Loss of catchment yield and altered surface water runoff patterns due to surface hardening	Operational	Negative	Moderate	2	2	3	4	4	**44**	**N3**	1	1	2	4	1	**8**	**N1**
					Significance	**N3 - Moderate**							**N1 - Very Low**						
DECOMISSIONING																			
Impact number	**Receptor**	**Description**	**Stage**	**Character**	**Ease of Mitigation**	**Pre-Mitigation**							**Post-Mitigation**						
						(M+	**E+**	**R+**	**D)x**	**P=**	**S**		**(M+**	**E+**	**R+**	**D)x**	**P=**	**S**	
Impact 1:	Physical presence of former turbines, former solar fields, road network and substations	Altered surface water runoff patterns Loss of biodiversity Loss of catchment yield through surface hardening Potential fragmentation of watercourses	Decommissioning	Negative	Low	4	2	5	5	4	**64**	**N4**	2	1	5	5	2	**26**	**N2**
					Significance	**N4 - High**							**N2 - Low**						
Impact 2:	Use of vehicles and heavy machinery to remove infrastructure	Water and soil pollution Loss of biodiversity Proliferation of alien and invative species	Decommissioning	Negative	Moderate	3	2	3	4	4	**48**	**N3**	2	1	2	4	2	**18**	**N2**
					Significance	**N3 - Moderate**							**N2 - Low**						

CUMULATIVE																				
Impact number	**Receptor**	**Description**	**Stage**	**Character**	**Ease of Mitigation**	**Pre-Mitigation**							**Post-Mitigation**							
						(M+	**E+**	**R+**	**D)x**	**P=**	**S**		**(M+**	**E+**	**R+**	**D)x**	**P=**	**S**		
Impact 1:	Electricity generation	Sterilisation from mining rights Maintenance of biodiversity	Cumulative	Positive	High	3	3	3	4	5	**65**	**P4**	3	3	3	4	5	**65**	**P4**	
					Significance	**P4 - High**							**P4 - High**							

5.6 Mitigation Measures

Throughout the life of the proposed project and during all phases, it must be ensured that sound environmental management is in place. During final micro-siting, efforts should be made to place the turbines, solar PV array, on-site substation, roads, and other infrastructure associated with the facility as far as possible outside any functional buffers for the freshwater resources on site, inclusive of wetlands, drainage lines and rivers. It will be necessary to refer to the wetland study for this project in this regard.

The following additional mitigation measures pertain to the designated buffer zone:

- No activities, roads or infrastructure (other than the absolute minimum necessary and approved road-crossings) are to be located within the final designated buffer zone area (of either rivers or the wetlands as indicated in the associated relevant wetland report);
- Indigenous vegetation cover within the designated buffer zone is to be maintained at a minimum of 80% to ensure that the buffer remains functional, and must be assessed annually;
- Alien vegetation establishment within these buffer zone areas is to be strictly controlled through the development and implementation of a detailed alien management plan developed in accordance with legislative requirements.

The following management and mitigation measures are prescribed for the design of any approved road-crossings:

- Design of infrastructure should be environmentally and structurally sound and should take into consideration any required restoration of the affected watercourses as well as the reach-scale movement needs of the expected fish assemblages and other migratory fauna;
- Culvert designs should be such that no fragmentation of the affected systems occurs;
- Where the gradient allows, culvert design must ensure that the base of the culverts are countersunk in line with the baseflows of the watercourse;
- Should any sloped culverts be necessary, these should include the use of baffles or a roughened channel to ensure complex flow throughout culvert length (as opposed to laminar flow). Various options for inclusion of baffles are available, and final design selection would require engineering input and consideration of hydraulic roughness through the culvert;
- The number of culverts installed should be suitable for the gradient, width and flow profiles of the watercourses being crossed so as to avoid upstream inundation, erosion and incision, and alterations to the natural channel;
- Pipe culverts are to be avoided at all watercourse crossings to limit opportunities of flow confinement and channel incision of the wetland units, drainage lines and rivers. Piped culverts have the additional impact of limiting fish movement between reaches;
- Designs should account for high flow velocities, which may result in further scouring of the watercourse downgradient of the structure and as such, bed and bank protection downgradient of structures should be considered.

During the construction phase, the following mitigation measures are prescribed:

- Ensure that site offices, ablutions, contractor laydown areas, construction materials and stockpiles, where relevant, are placed outside and above the 1:100 year flood line;
- Limit the footprint area of the construction activities to what is absolutely essential in order to minimise impacts as a result of vegetation clearing and compaction of soils;
- As far as possible, site clearing activities should take place at the end of the wet season to minimise the risk of erosion, incision and sedimentation of the associated watercourses, and as far as possible, all remaining construction activities should take place during the dry winter months to minimise impacts as a result of high flows and runoff from exposed soils and materials;
- Ensure a soil management programme is implemented and maintained to minimise the potential for erosion and sedimentation;
- All/any topsoil or building material stockpiles must be protected from erosion, stored on flat areas where runoff will be minimised, and be surrounded by bunds. Stockpiles must also only be stored for the minimum amount of time necessary;
- Erosion berms or suitable water attenuation measures should be installed on roadways and downstream of construction and infrastructure areas to prevent gully formation and siltation of the associated watercourses.
- Active rehabilitation, re-sloping, and re-vegetation of disturbed areas immediately after construction must take place;
- All erosion noted within the construction footprint should be remedied immediately and included as part of an ongoing rehabilitation plan;
- Implement and maintain an alien vegetation management programme;
- No unnecessary crossing of the watercourses should take place;
- Only authorised personnel should be allowed within the construction area;
- Watercourses should be designated as “No-Go” areas and be off limits to all unauthorised vehicles and personnel;
- No material may be dumped or stockpiled within or adjacent to the watercourses;
- No mixing of construction materials such as cement should be permitted within or adjacent to watercourses and no such mixing may occur on bare soils in the surrounding areas;
- Movement of heavy machinery should be minimised to what is essential for the completion of the necessary project activities and should not be allowed to drive indiscriminately through the surrounding areas or within the associated watercourses;
- Any movement of machinery should make use of existing roads or servitudes and no new access roads should be cut unless absolutely necessary;
- All vehicles must be regularly inspected for leaks;
- Re-fuelling must take place on a sealed surface area away from the watercourses to prevent ingress of hydrocarbons into topsoil;
- Storage of potentially hazardous materials (including but not limited to fuel, oil, cement, etc.) must be above any 100-year flood line or outside the designated watercourse buffer, whichever is greater;

- A walled concrete platform, dedicated store with adequate flooring or bermed area must be used to accommodate chemicals such as fuel, oil, paint, herbicide and insecticides, as appropriate, in well-ventilated areas;
- All spills should be immediately cleaned up and treated accordingly; and
- Appropriate sanitary facilities must be provided for the duration of the construction activities and all waste must be removed to an appropriate waste facility.

During the operational phase, the following mitigation measures are prescribed:

- Ensure a soil management programme is implemented and maintained to minimise the potential for erosion and sedimentation;
- Erosion berms or suitable water attenuation measures should be installed on roadways and downstream of infrastructure areas to prevent gully formation and siltation of the associated watercourses.
- All erosion noted within the operational footprint should be remedied immediately and included as part of an ongoing rehabilitation plan;
- Implement and maintain an alien vegetation management programme;
- Movement of maintenance vehicles should be minimised to what is essential for the completion of the necessary maintenance activities and should not be allowed to drive indiscriminately through the surrounding areas or within the associated watercourses;
- All vehicles must be regularly inspected for leaks;
- Re-fuelling must take place on a sealed surface area away from the watercourses to prevent ingress of hydrocarbons into topsoil;
- Storage of potentially hazardous materials (including but not limited to fuel, oil, etc.) must be above any 100-year flood line or outside the designated watercourse buffer, whichever is greater;
- A walled concrete platform, dedicated store with adequate flooring or bermed area must be used to accommodate chemicals such as fuel, oil, paint, herbicide and insecticides, as appropriate, in well-ventilated areas;
- All spills should be immediately cleaned up and treated accordingly; and
- Appropriate sanitary facilities must be provided for the duration of the operational activities and all waste must be removed to an appropriate waste facility.

The following mitigation measures are regarded as suitable for the decommissioning phase of the project:

- Ensure that as far as possible all decommissioning activities take place outside of the delineated watercourses;
- Limit the footprint area of the decommissioning activities to what is absolutely essential in order to minimise impacts;
- All erosion noted within the decommissioning footprint should be remedied immediately and included as part of the ongoing rehabilitation plan;
- A suitable alien and/or invasive plant species control programme must be put in place so as to prevent further encroachment as a result of disturbance to the surrounding terrestrial zones;

- Watercourses should be designated as “No-Go” areas and be off limits to all unauthorised vehicles and personnel;
- No material may be dumped or stockpiled within any watercourses in the vicinity of the proposed decommissioning footprint;
- No vehicles or heavy machinery may be allowed to drive indiscriminately within any delineated watercourses. All vehicles must remain on demarcated roads and within the decommissioning area footprint;
- All vehicles must be regularly inspected for leaks;
- Re-fuelling must take place on a sealed surface area away from any associated watercourses to prevent ingress of hydrocarbons into topsoil;
- All spills should be immediately cleaned up and treated accordingly;
- Appropriate sanitary facilities must be provided for the duration of the decommissioning activities and all waste must be removed to an appropriate waste facility.

5.7 Monitoring Programme

An adaptive management monitoring programme of the aquatic resources associated with the proposed project must be implemented during both the construction and decommissioning phases of the proposed project by a suitably qualified aquatic ecologist registered as a Professional Natural Scientist in the field of Aquatic Science with the South African Council for Natural Scientific Professions. This monitoring programme should commence prior to the start of the construction and decommissioning activities and should continue for the duration of these phases and until such a time as the appropriate remedial actions post construction and/or decommissioning have been implemented and the natural ecological processes have stabilised. This is regarded as necessary to ensure the integrity of all water resources in the area specifically during and as a result of the construction activities. Furthermore, the monitoring programme must ensure that there is no decrease in the health and functional integrity of the affected freshwater ecosystems. The following approach is proposed:

- Monitoring sites should align with the existing site localities (Section 4.1) selected to establish the baseline ecological state of the associated watercourses;
- Detailed monitoring protocols should include assessment of water quality, habitat integrity, aquatic macroinvertebrate assemblages and fish assemblages following the latest EcoStatus approach;
- Monitoring activities should take place quarterly during the construction phase of the proposed project and biannually for a period of three years following the completion of the construction activities, or until such a time as the ecological processes have stabilised and the aquatic specialist confirms no risk to the receiving watercourses as a result of any latent construction related disturbances. A similar approach should be followed during the decommissioning phase of the proposed project;
- Due to the Ecological Importance and Sensitivity of the associated watercourses, these assessments should be carried out for the life of the proposed project on a biannual basis; and
- During the construction phase, additional visual assessments should be carried out on a monthly basis to monitor any emerging impacts that may affect the receiving aquatic

environment and to allow for corrective measures to be immediately implemented by the relevant Environmental Control Officer.

6. CONCLUSION AND RECOMMENDATIONS

The field surveys included the selection of 13 assessment sites (DWEF1-13) located in and around the study area and which were selected based on the location of the proposed infrastructure in relation to the aquatic systems present and the impacts likely to be expressed on these systems as a result of the implementation of the proposed project activities.

Water quality

In general, the water quality of the watercourses assessed was regarded as 'Good' and fell within the parameters stipulated for the greater Inkomati Catchment (as stipulated by the Department of Water and Sanitation, previously the Department of Water Affairs (2011)) and the Target Water Quality Range as stipulated by the Department of Water and Sanitation, previously the Department of Water Affairs and Forestry (1996).

Habitat

The riparian structure of the watercourses associated with the study area was expected to comprise the natural grassland features of the vegetation unit, while instream characteristics were expected to comprise largely of clear flowing water over a variety of cobble habitats with minimal gravel, sand and mud deposits. According to the IHI approach, the streams associated with the proposed project areas may be regarded as natural (Ecological category A) to moderately modified (Ecological category C). Modifications to the habitat integrity observed within the study area were related to impacts associated with the proliferation of woody alien invasive species such as black wattle (*Acacia mearnsii*), yellow firethorn (*Pyracantha angustifolia*), grey poplar (*Populus x canescens*) and various *Eucalyptus* sp. Additional impacts arising from stream crossings such as roads and weirs included moderate to severe impacts relating to erosion and incision of the banks, bed and flow modifications and inundation. Water abstraction was also observed at some points with the largest impact observed at DWEF 7. Trampling, erosion and loss of bankside cover as a result of cattle watering was also observed in some areas.

Aquatic macroinvertebrate habitat diversity was regarded as 'Good' to 'Excellent' at most sites, largely due to the availability of extensive cobble habitat and the high hydraulic flow diversity at the time of the assessment. As such, habitat was not expected to present a limiting factor to the presence of a diverse array of aquatic macroinvertebrates within the watercourses associated with the study area. In terms of habitat availability for fish, sites displayed a diverse range of fish habitat features, with varying degrees of dominance. However, by far the most dominant fish habitat cover feature within the study area was substrate, which was expected given the upper foothill and transitional zonation of the various reaches assessed.

Macroinvertebrates

The macroinvertebrate assemblages observed (comprising more than 60 taxa throughout the study area) were dominated by taxa with a low requirement for unmodified water quality and with preference for moderately fast flowing water over cobble habitat, however, numerous moderately to highly sensitive taxa were also observed. In addition, the assemblages were dominated by aquatic breathers, with a maximum of 43% air-breathers at any given site. The results of the MIRAI indicated that the aquatic macroinvertebrate assemblages present within the watercourses associated the study area were in a largely natural to moderately modified state (Ecological Category B and Ecological Category C).

Ichthyofauna

A total of 12 indigenous fish species have been recorded within the surrounding area and thus have the potential to be present within the watercourses assessed. During the June 2022 and October 2022 aquatic studies, a total of 863 specimens comprising nine species were collected within the assessed watercourses, including one alien fish species. In general, *Chiloglanis pretoriae* (Shortspine Suckermouth) and *Enteromius anoplus s.l.* (Chubbyhead Barb) were noted to dominate the fish assemblage observed, collectively comprising over 60% of the total annual catch. Of significance was the confirmed presence of *Chiloglanis emarginatus* (Phongola Suckermouth), currently classified in terms of the IUCN Red List criteria at a global and regional (southern Africa) level as Vulnerable, and provincially as Near Threatened. Based on the results obtained following the application of the FRAI on the assessed watercourses, it was determined that the mainstem Waarkraalloop was classified as moderately modified (Ecological Category C), whereas the tributaries of the Waarkraalloop are considered to be in a largely natural state (Ecological Category B). Within the Klein-Komati catchment, the mainstem Klein-Komati River was classified as moderately modified (Ecological Category C), whereas the tributaries ranged from being in a natural/near-natural state (Ecological Category A/B) to a moderately/largely modified state (Ecological Category C/D). Review of the drivers of the ecological states observed indicates that impacts contributing greatly to the deviations from reference conditions include the impacts of alien fish species, notably the piscivorous *Micropterus salmoides* (Largemouth Bass), and upstream migration barriers in the form of large weirs and dams within the greater catchment.

Integrated EcoStatus and Ecological Importance and Sensitivity

The Klein-Komati River Catchment is designated as a river FEPA, which encompasses all of its associated sub-catchment areas, and approximately 24 FEPA-designated wetlands were identified within the study area. Through the aquatic baseline specialist assessment, the Integrated EcoStatus of the Waarkraalloop and the Klein-Komati River, inclusive of their associated tributaries, were determined as largely natural (Ecological Category B) to moderately modified (Ecological Category C) from the perspective of both their riparian and instream elements and were regarded as of ‘High’ Ecological Importance with ‘Very High’ Ecological Sensitivity. The Integrated Present Ecological States of both the Waarkraalloop and the Klein-Komati River, thus meet the Target Ecological Category designated for the Komati Catchment by the Department of Water and Sanitation (Government Gazette No. 40531, 2016). In addition, based on their Ecological Importance and Sensitivity any further deterioration in either the instream ecological integrity or the riparian habitat integrity must be prevented as far as possible.

Impact Assessment

While the operational phase of any given wind energy or solar project is known for its low carbon footprint, with no to negligible generation of water or air pollution other than that potentially related to maintenance activities, it is important to note that without appropriate mitigation and management measures in place, particularly during the construction phase of both of the proposed project alternatives for the proposed project, the cumulative footprint and its associated impacts have the potential to be significant with impact ratings determined as largely 'Moderate' and 'High'. However, with suitable mitigation measures in place, it is possible to reduce the impacts of both project alternatives to the aquatic ecology of the area from all project related activities to 'Low' and 'Very Low' level impacts. It is thus critical that the mitigation measures as stipulated in Section 5.6 be strictly adhered to in order to limit impacts to the aquatic resources associated with the proposed project. Furthermore, the assessment of residual impacts is based on the assumption that the mitigation measures proposed are feasible and will be implemented. Where proposed mitigation measures are not deemed feasible, then re-assessment of impact significance would be required based on what would be feasible.

Conclusion

On consideration of the findings of the specialist aquatic baseline assessment and the project specific impacts associated with the proposed project, it is the reasoned opinion of the ecologist that with strict adherence to the recommendations and mitigation measures provided in this report, impacts to the receiving aquatic environment as a result of either alternative related to the proposed development have the potential to be kept to a minimum. A further cumulative benefit, is the potential sterilisation of this area from mining rights in support of renewable energy, thereby contributing to the long-term sustainable use and conservation of water resources and resulting in positive long-term benefits for this FEPA designated catchment.

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APPENDIX A: METHODOLOGY

***In situ* water quality**

During the various field surveys, *in situ* water quality variables were measured at each site using an ExTech EC500 combination meter for measurement of temperature, pH, electrical conductivity, and Total Dissolved Solids, as well as an ExTech DO600 Portable Dissolved Oxygen Meter.

Index of Habitat Integrity, Version 2 (IHI-96-2)

The Index of Habitat Integrity (IHI, Version 2; Kleynhans, *pers. comm.*, 2015) aims to assess the number and severity of anthropogenic perturbations along a river/stream/wetland and the potential inflictions of damage toward the habitat integrity of the system (Dallas, 2005). Various abiotic (e.g. water abstraction, weirs, dams, pollution, dumping of rubble, etc.) and biotic (e.g. presence of alien plants and aquatic animals, etc.) factors are assessed, which represent some of the most important and easily quantifiable, anthropogenic impacts upon the system (Table 14).

In accordance with the original IHI approach (Kleynhans, 1996), the instream and riparian components were each analysed separately to yield two separate ecological conditions (i.e. Instream and Riparian components). However, it should be noted that the data for the riparian area is primarily interpreted in terms of the potential impact upon the instream component and as a result, may be skewed by a potentially deteriorated instream condition.

Table 14: Descriptions of criteria used in the assessment of habitat integrity (Kleynhans, 1996; cited from Dallas, 2005)

Criterion	Relevance
Water abstraction	Direct impact upon habitat type, abundance and size. Also impacted in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in the temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment. Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included
Water quality modification	Originates from point and diffuse sources. Measured directly, or agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments.
Alien/Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependent upon the species involved and scale of infestation.

Alien/Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river. Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

In accordance with the level of the impact created by the abovementioned criterion, the assessment of the severity of impact of the modifications is based on six descriptive categories with ratings ranging from 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact; 9). It should be noted that a confidence level (high, medium, low) was also assigned to each of the scored metrics, based on available knowledge of the site and/or adjacent catchment.

Table 15: Description of scoring guidelines for the assessment of modifications to habitat integrity (Kleynhans 1996; cited from Dallas, 2005)

Impact Category	Description	Score
None	No discernible impact or the factor is located in such a way that it has no impact on habitat quality diversity, size and variability.	0
Small	The modification is limited to a very few localities and the impact on habitat quality, diversity, size and variability is also very small.	1 - 5
Moderate	The modification is present at a small number of localities and the impact on habitat quality, diversity, size and variability is also limited.	6 - 10
Large	The modification is generally present with a clearly detrimental impact on quality habitat quality, diversity, size and variability. Large areas are, however, not influenced	11 - 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability almost the whole of the defined section are affected. Only small areas are not influenced.	16 - 20
Critical	The modification is present overall with a high intensity; the habitat quality, diversity, size and variability in almost the whole of the defined section are detrimentally influenced.	21 - 25

Each of the allocated scores are then moderated by a weighting system (Table 16), which is based on the relative threat of the impact to the habitat integrity of the riverine system. The total score for each impact is equal to the assigned score multiplied by the weight of that impact. The estimated impacts (assigned score / maximum score [25] X allocated weighting) of all criteria are then summed together, expressed as a percentage and then subtracted from 100 to determine the Present Ecological State score (or Ecological Category) for the instream and riparian components, respectively.

Table 16: Criteria and weights used for the assessment of habitat integrity (Kleynhans, 1996; cited from Dallas, 2005)

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality modification	14	Water abstraction	13
Inundation	10	Inundation	11
Alien/Exotic macrophytes	9	Flow modification	12
Alien/Exotic aquatic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	**100**	**TOTAL**	**100**

However, in cases where selected instream component criteria (i.e. water abstraction, flow, bed and channel modification, water quality and inundation) and/or any of the riparian component criteria exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper, 1999). The following rules were applied in this respect:

- Impact = Large, lower the integrity status by 33% of the weight for each criterion with such a rating.
- Impact = Serious, lower the integrity status by 67% of the weight for each criterion with such a rating.
- Impact = Critical, lower the integrity status by 100% of the weight for each criterion with such a rating.

Subsequently, the negative weights were added for both the instream and riparian facets of the assessment and the total additional negative weight subtracted from the provisionally determined integrity to arrive at a final habitat integrity estimate (Kemper, 1999). The eventual total scores for the instream and riparian zone components are then used to place the habitat integrity in a specific habitat integrity ecological category (Table 15).

Invertebrate Habitat Assessment System (IHAS), Version 2.2

Assessment of the available habitat for aquatic macroinvertebrate colonization at each of the sampling sites during rapid biomonitoring practices are vital to the correct interpretation of results obtained following biological assessments. It should be noted that the available methods for determining habitat quality are not specific to rapid biomonitoring assessments and are inherently too variable in their approach to achieve consistency amongst users.

Nevertheless, the Invertebrate Habitat Assessment System (IHAS) has routinely been used in conjunction with the South African Scoring System (SASS) as a measure of the variability of aquatic macroinvertebrate biotopes available during sampling (McMillan, 1998). The scoring system was traditionally split into two sections, namely the sampling habitat (comprising 55% of the total score) and the general stream characteristics (comprising 45% of the total score), which were summed together to provide a percentage and then categorized according to the values in Table 18.

Table 17: Ecological Categories for the habitat integrity scores (Kleynhans, 1999; cited from Dallas, 2005)

Score (% of Total)	Category	Description
90 - 100	A	Unmodified, natural.
80 - 89	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
60-79	C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
40-59	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
20-39	E	The loss of natural habitat, biota and basic ecosystem functions is extensive.
0 - 19	F	Modifications have reached a critical level and there has been an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Table 18: Adapted IHAS Scores and associated description of available macroinvertebrate habitat (Dr. P. McMillan, pers. comm., 2006)

IHAS Score (%)	Description
>75	Excellent
65-74	Good
55-64	Adequate / Fair
<55	Poor

However, the lack of reliability and evidence of notable variability within the application of the IHAS method has prompted further field validation and testing, which implies a cautious interpretation of results obtained until these studies have been conducted (Ollis et al., 2006). In the interim and for the purpose of this assessment, the IHAS method was adapted by excluding the assessment of the general stream characteristics, which resulted in the calculation of a percentage score out of 55 that was then categorised by the aforementioned Table 20. Consequently, the assessment index describes the quantity, quality and diversity of available macroinvertebrate habitat relative to an "ideal" diversity of available habitat.

Fish Habitat Cover Rating

Th Fish Habitat Cover Rating approach (Kleynhans, 1999a) was developed to assess habitats according to different attributes that are surmised to satisfy the habitat requirements of various fish species. At each site, the following depth-flow (df) classes are identified, namely:

- Slow (<0.3m/s), shallow (<0.5m) - Shallow pools and backwaters.
- Slow, deep (>0.5m) - Deep pools and backwaters.
- Fast (>0.3m/s), shallow - Riffles, rapids and runs.
- Fast, deep - Usually rapids and runs.

The relative contribution of each of the above-mentioned classes at a site was estimated and indicated as:

0 = Absent
1 = Rare (<5%)
2 = Sparse (5-25%)
3 = Moderate (25-75%)
4 = Extensive (>75%)

For each depth-flow class, the following cover features (cf) -considered to provide fish with the necessary cover to utilise a particular flow and depth class- were investigated:

- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes

The amount of cover present at each of these cover features (cf) was noted as:

0 = absent
1 = Rare/very poor (<5%)
2 = Sparse/poor (5-25%)
3 = Moderate/good (25-75%)
4 = Extensive/excellent (>75%)

The fish habitat cover rating (HCR) was calculated as follows:

- The contribution of each depth-flow class at the site was calculated (df/∑df).
- For each depth-flow class, the fish cover features (cf) were summed (∑cf).
- HCR = df/∑df x ∑cf.

The amount and diversity of cover available for the fish community at the selected sites was graphically expressed as habitat cover ratings (HCR) for different flow-depth classes as a stacked bar chart.

Aquatic Macroinvertebrates

Rapid biological monitoring (or biomonitoring) protocols have become important tools in the investigation of water quality and the determination of the overall ecosystem health (or integrity). This has largely been evident in the ability of standardized bio-assessment methods being able to assess the cumulative effect of water quality on biological systems over a period of time rather than only a snap-shot at the precise time of collection, as previously provided through routine chemical analysis of water.

While there are a number of indicator organisms that are used within these assessment indices, there is a general consensus that benthic macroinvertebrates are amongst the most sensitive components of the aquatic ecosystem. This was further supported by their largely non-mobile (or limited mobility) within reaches of associated watercourses, which also allows for the spatial analysis of disturbances potentially present within the adjacent catchment area. However, it should also be noted that their heterogeneous distribution within the water resource is a major limitation, as this results in both spatial and temporal variability within the collected macroinvertebrate assemblages (Dallas & Day, 2004).

The South African Scoring System, Version 5 (SASS5) is essentially a biological assessment index which determines the health of a river based on the aquatic macroinvertebrates collected on-site, whereby each taxon is allocated a score based on its perceived sensitivity/tolerance to environmental perturbations (Dallas, 1997). However, the method relies on a standardised sampling technique using a handheld net (300mm x 300mm, 1000µm mesh size) within each of the various habitats available for standardised sampling times and/or areas. Niche habitats (or biotopes) sampled during SASS5 application include:

- Stones (both in-current and out-of-current);
- Vegetation (both aquatic and marginal); and
- Gravel, sand and mud.

Once collection is complete, aquatic macroinvertebrates are identified to family level and a number of assemblage-specific parameters are calculated including the total SASS5 score, the number of taxa collected, and the Average Score per Taxa, which is the SASS score divided by the total number of taxa identified (Thirion et al., 1995; Davies & Day, 1998; Dickens & Graham, 2002; Gerber & Gabriel, 2002). The SASS bio-assessment index has been proven to be an effective and efficient means to assess water quality impairment and general river health (Dallas, 1997; Chutter, 1998).

To determine the Present Ecological State (PES; or Ecological Category) of the aquatic macroinvertebrates collected within the study area, the Macroinvertebrate Response Assessment Index (MIRAI) was applied. This biological index integrates the ecological requirements of the macroinvertebrate taxa in a community (or assemblage) and their response to flow modification, habitat change, water quality impairment and/or seasonality (Thirion, 2008). The presence and abundance of the aquatic macroinvertebrates collected are compared to a derived list of families/taxa expected to be present under natural, un-impacted (or reference) conditions. Consequently, the three (or four) metric groups utilised during the application of the MIRAI were combined within the model to derive the ecological condition of the site in terms of aquatic macroinvertebrates (Table 19).

Table 19: Allocation protocol for the determination of the PES (or Ecological Category) for aquatic macroinvertebrates following the MIRAI application

MIRAI Percentage	Category	Description
>89	A	Excellent Unimpaired; community structures and functions comparable to the best situation to be expected. Optimum community structure for stream size and habitat quality.
80-89	B	Very Good – Minimally impaired; largely natural with few modifications. A small change in community structure may have taken place but ecosystem functions are essentially unchanged.
60-79	C	Good – Moderately impaired; community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive forms. Basic ecosystem functions are still predominantly unchanged.
40-59	D	Fair – Largely impaired; fewer families present than expected, due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
20-39	E	Poor – Seriously impaired; few aquatic families present, due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
<20	F	Very poor – Critically impaired; few aquatic families present. If high densities of organisms, then dominated by a few taxa. Only tolerant organisms present.

Ichthyofauna

Fish were collected by means of electro-narcosis, whereby an anode and a cathode are immersed in the water to temporarily stun fish in the near vicinity. Thereafter, the fish are easily scooped out by means of a hand net. A photographic record of fish collected was taken. All fish were identified in the field and released back into the river where possible.

Assessment of the PES of the fish assemblage of the watercourses downstream of the present study was conducted by means of the Fish Response Assessment Index (FRAI; Kleynhans 2008). The procedure followed to determine the fish Present Ecological State, or Ecological Category, is an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions. In the case of the present assessment, the observed response was determined by means of fish sampling as well as a consideration of species requirements and driver changes (Kleynhans 2008). The expected fish species assemblage within the study area was derived from Kleynhans et al. (2008) and aquatic habitat sampled.

It should be emphasised that although the FRAI uses essentially the same information as the Fish Assemblage Integrity Index (FAII), it does not follow the same procedure. The FAII was developed for application in the broad synoptic assessment required for the River Health Programme, and subsequently does not offer a particularly strong cause-and-effect basis. The purpose of the FRAI, on the other hand, is to provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the perceived reference condition (Kleynhans, 2008).

The FRAI is based on the assessment of metrics within metric groups. These metrics are assessed in terms of:

- Habitat changes that are observed or derived;
- The impact of such habitat changes on species with particular preferences and tolerances; and
- The relationship between the drivers used in the FRAI and the various fish response metric groups are indicated in Figure 14. Table 20 provides the steps and procedures required for the calculation of the FRAI.

Interpretation of the FRAI score follows a descriptive procedure in which the FRAI score is classified into a particular PES Class or Ecological Category based on the integrity classes of (Kleynhans, 1999b). Each class gives a description of generally expected conditions for a specific range of FRAI scores (Table 21).

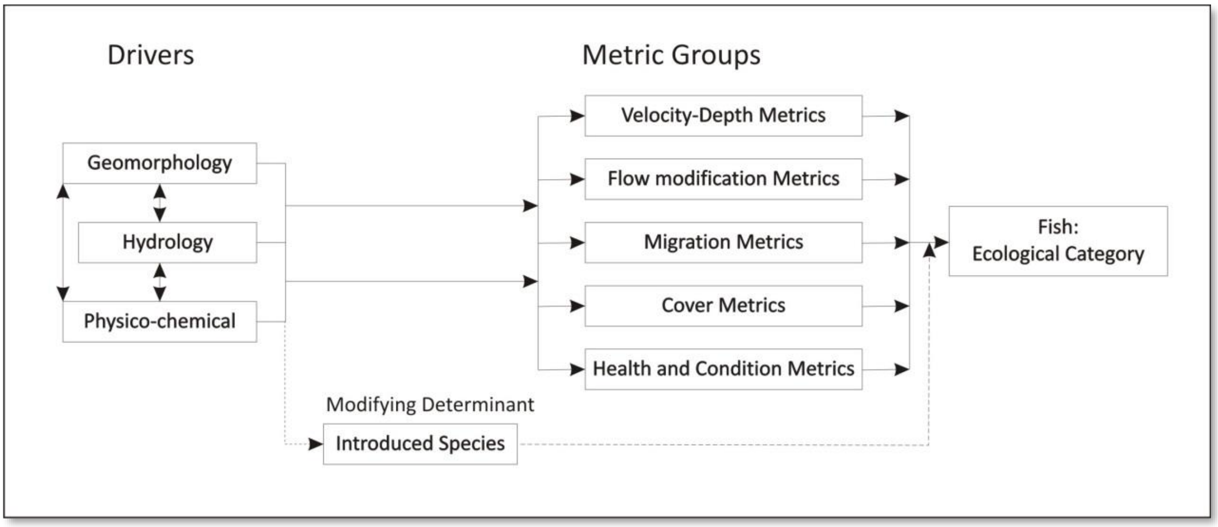

Figure 14: Relationship between drivers and fish metric groups

Table 20: Main steps and procedures in calculating the Fish Response Assessment Index

Step	Procedure
River section earmarked for assessment	As for study requirements and design
Determine reference fish assemblage: species and frequency of occurrence	• Use historical data & expert knowledge • Model: use ecoregional and other environmental information • Use expert fish reference frequency of occurrence database if available
Determine present state for drivers	• Hydrology • Physico-chemical • Geomorphology; or • Index of habitat integrity
Select representative sampling sites	Field survey in combination with other survey activities
Determine fish habitat condition at site	• Assess fish habitat potential Assess fish habitat condition
Representative fish sampling at site or in river section	• Sample all velocity depth classes per site if feasible • Sample at least three stream sections per site

Collate and analyse fish sampling data per site	Transform fish sampling data to frequency of occurrence ratings
Execute FRAI model	• Rate the FRAI metrics in each metric group • Enter species reference frequency of occurrence data • Enter species observed frequency of occurrence data • Determine weights for the metric groups • Obtain FRAI value and category • Present both modelled FRAI & adjusted FRAI.

Table 21: Allocation protocol for the determination of the PES/Ecological Category for fish following application of the FRAI

FRAI Percentage	Category	Description
90-100	**A**	Unmodified and natural. Community structures and functions comparable to the best situation to be expected. Optimum community structure for stream size and habitat quality.
80-89	**B**	Largely natural with few modifications. A small change in community structure may have taken place but ecosystem functions are essentially unchanged.
60-79	**C**	Moderately modified. Community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive forms. Basic ecosystem functions are still predominantly unchanged.
40-59	**D**	Largely modified. Fewer species present then expected due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
20-39	**E**	Seriously modified. Few species present due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
0-19	**F**	Critically modified. Few species present. Only tolerant species present, if any.

EcoStatus Determination

The EcoStatus is defined as: *The totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services.* In essence, the EcoStatus represents an ecologically integrated state representing the drivers (hydrology, geomorphology, physico-chemical) and responses (fish, aquatic invertebrates and riparian vegetation) (Kleynhans & Louw, 2008).

For the purpose of the present assessment, the latest ECOSTATUS4 1.01 model was used, which is an upgraded and refined version of the original ECOSTATUS4 model of Kleynhans & Louw (2008). The results obtained from the fish and aquatic macroinvertebrate response indices (i.e. FRAI and MIRAI) are to be integrated within the model to determine an Instream Ecological Category, whereas the riparian elements from the IHI-96-2 model can be used as a surrogate for the Riparian Ecological Category in the following manner (Dr. C.J. Kleynhans, *pers. comm.*, 2015):

*Riparian Vegetation EC = 100-((IHI 'Vegetation removal')+(IHI 'Exotic vegetation encroachment'))/50*100)*

APPENDIX B: SITE PHOTOGRAPHS

DWEF 1 – Jun 2022

DWEF 1 – Oct 2022

DWEF 2 – Jun 2022

DWEF 2 – Oct 2022

DWEF 3 – Jun 2022

DWEF 3 – Oct 2022

DWEF 4 – Jun 2022

DWEF 4 – Oct 2022

DWEF 5 – Jun 2022

DWEF 5 – Oct 2022

DWEF 6 – Jun 2022

DWEF 6 – Oct 2022

DWEF 7 – Jun 2022

DWEF 7 – Oct 2022

DWEF 8 – Jun 2022

DWEF 8 – Oct 2022

DWEF 9 – Jun 2022

DWEF 9 – Oct 2022

DWEF 10 – Jun 2022

DWEF 10 – Oct 2022

DWEF 11 – Jun 2022

DWEF 11 – Oct 2022

DWEF 12 – Jun 2022

DWEF 12 – Oct 2022

DWEF 13 – Jun 2022

DWEF 13 – Oct 2022

Appendix C: Aquatic Macroinvertebrates

Relative abundances (Dickens & Graham, 2002):

1 = 1 individual

A = 2 – 10 individuals

B = 11 – 100 individuals

C = 101 – 1000 individuals

D = >1000 individuals

Aquatic macroinvertebrate collection records for the study area during the June 2022 assessment.

Taxon	DWEF 1	DWEF 2	DWEF 3	DWEF 4	DWEF 5	DWEF 6	DWEF 7	DWEF 8	DWEF 9	DWEF 10	DWEF 11	DWEF 12	DWEF 13
Porifera				A	A	A						A	
Turbellaria	A	B	A	A	A	A	A	1	B	B	B	A	B
Oligochaeta		A		A		A	A	1		A	A	1	
Potamonautidae	A	A	1	1		A	A	A	A	A	A	1	A
Hydracarina				1	1			A			A		
Perlidae										1			1
Baetidae >2spp	B	A	B	B	B	B	B	B	B	B	B	B	B
Caenidae	B	A	B	B	B	A	B	B	B	B	B	B	B
Heptageniidae			1	B	1	B	A			A			B
Leptophlebiidae	B	B	B	B	B	B	A	B	B	B	B	B	B
Trichorythidae	C	C	B	B	B	B	B	B	B	B	B	1	B
Coenagrionidae	B	B	B	B	B	A	B	A	B	A	B	B	
Aeshnidae	A	1	A	A	A	B		A	A	A	A	A	A
Corduliidae			1										
Gomphidae	A		1	B	A	B			B	A	A		A
Libellulidae		1							1				
Pyralidae									1				
Corixidae	B	A	B	B	B	B	B	A	B	A	B	B	
Gerridae				1		A	1		1		1		

Naucoridae	1	1	1	B	1	A	B			A	A	B	
Nepidae				1									
Notonectidae			1	1	1	A		1			1	A	
Pleidae				1	1	1			B				
Veliidae	1	A		1	A	1	1			A	A	A	1
Ecnomidae		A											
Hydropsychidae 1sp							A						
Hydropsychidae 2spp			A		A							A	
Hydropsychidae >2spp	B	B		B		B		B	B	B	B		B
Philopotamidae				A		A				A	1		A
Leptoceridae			A	B	A	A	A	1	A	A	B	A	A
Pisuliidae									1				
Dytiscidae		A	1	A	A	A	A		B		B	A	A
Elmidae					A		A	A		1			1
Gyrinidae	B	B	B	A	A	A	B	A	A	B	B	A	B
Helodidae				1									
Hydraenidae		1											
Hydrophilidae	1		B	B	B	B	B	B	B	A		A	1
Psephenidae			A	A	A	A	A	A	A	A		A	
Athericidae						1							1
Blepharoceridae						A							
Ceratopogonidae				A		B	A		A		A	A	1
Chironomidae	B	B	B	B	B		B	B	B	B	B	B	B
Culicidae				1			1						
Dixidae	1	1	1	1							A	1	
Muscidae							1						
Simuliidae	B	B	B	B	A	B	B	A	B	B	B	B	B
Tabanidae				A		1				1			
Tipulidae	1	1	1	A	1	A		A		A	A	A	A
Ancylidae				A	B	A	A	B	B			A	A
Lymnaeidae									1			A	

Planorbinae	1		A	B	A	A	1		A		A	A	
Sphaeridae				A		A	A	1	A	1	A	A	
SASS Score	**122**	**134**	**156**	**227**	**171**	**216**	**149**	**136**	**168**	**177**	**163**	**157**	**170**
No. of Taxa	**20**	**22**	**25**	**38**	**28**	**34**	**28**	**23**	**28**	**27**	**28**	**29**	**24**
ASPT	**6.10**	**6.09**	**6.24**	**5.97**	**6.11**	**6.35**	**5.32**	**5.91**	**6.00**	**6.56**	**5.82**	**5.41**	**7.08**

Aquatic macroinvertebrate collection records for the study area during the October 2022 assessment.

Taxon	DWEF 1	DWEF 2	DWEF 3	DWEF 4	DWEF 5	DWEF 6	DWEF 7	DWEF 8	DWEF 9	DWEF 10	DWEF 11	DWEF 12	DWEF 13
Porifera		A		A		1	B		A		A	A	
Turbellaria	B	A	A	1	1	A	B	B	A	B	B	A	A
Oligochaeta		1			1		A		A			A	
Potamonautidae	B	A	A	B		A	A		1		A	1	1
Hydracarina	1			A	A	B	1	A	A	B	1	A	
Perlidae								A		1			A
Baetidae 1sp										A			
Baetidae >2spp	B	B	B	B	B	B	B	B	B	B	B	B	B
Caenidae	B	B	B	B	B	B	B	B	B	B	B	B	B
Heptageniidae			A	A		B	B	1		B	A		A
Leptophlebiidae	B	B	A	B	B	B	A	A	A	B	B	B	B
Trichorythidae	B	B	A	B	B	B	B	B	C	B	B		A
Chlorocyphidae			1		1								
Chlorolestidae	A										B		
Coenagrionidae	A	B	B	A	B	A	B		B	A	B	A	B
Lestidae					B	1	1				A		A
Aeshnidae		1		A					A	A		A	
Gomphidae	B	A	A		A	B	A		A	A	A		A
Libellulidae					1	B					1	1	
Pyralidae		1											
Belostomatidae									B		1		
Corixidae	B	A	B	B		B	A		B	A	1	B	
Gerridae			A			A					A		
Hydrometridae		1		1									
Naucoridae			A	A	A		B	B	A		1	B	A
Nepidae		1											
Notonectidae	A			A	A				A			1	
Pleidae			A				A		B				

Veliidae	A	A		A		A			A	A	A		A
Ecnomidae		1											
Hydropsychidae 1sp	A				A	1	A						
Hydropsychidae 2spp				B				A	A	B	A		A
Hydropsychidae >2spp		A											
Philopotamidae				1								1	
Leptoceridae	A		A	B	A	A	B	1	B	A	B	A	A
Dytiscidae	A	A	A	A	A		B	A	A		B	A	B
Elmidae		1				A	A	1					
Gyrinidae	B	B	B	B	B	B	B	B	B	A	A	B	B
Haliplidae											1		
Helodidae	1			1						A		1	
Hydraenidae			A					A				1	
Hydrophilidae		A	A	A	A		B	A	B		B	A	B
Psephenidae			1	1	1	1	1		A				
Athericidae					1					1			
Ceratopogonidae	A			1	1	1	A	1	A		1	B	A
Chironomidae	B	A	B	B	B	B	A	B	B	B	B	B	B
Culicidae			1	A							1		
Dixidae	A	1	A		1				1		A	1	
Simuliidae	B	B	1	A	A	B	A	B		B	B	B	B
Tabanidae										A			
Tipulidae		1	1	1	A	A	1		1	A	A		
Ancylidae			A	A	A	A	1	B	B	A			
Planorbinae			B	B	A	1		1			B	A	
Sphaeridae	1		B	A	1	1	A		B		1		1
SASS Score	**136**	**160**	**168**	**193**	**174**	**165**	**170**	**143**	**167**	**164**	**188**	**153**	**139**
No. of Taxa	**23**	**26**	**28**	**32**	**29**	**28**	**29**	**21**	**30**	**24**	**34**	**27**	**22**
ASPT	**5.91**	**6.15**	**6.00**	**6.03**	**6.00**	**5.89**	**5.86**	**6.81**	**5.57**	**6.83**	**5.53**	**5.67**	**6.32**

Appendix D: Ichthyofauna

Fish collection records for the study area as collected during the June 2022 and October 2022 assessments.

Species	**DWEF 1**		**DWEF 2**		**DWEF 3**		**DWEF 4**		**DWEF 5**		**DWEF 6**		**DWEF 7**		**DWEF 8**		**DWEF 9**		**DWEF 10**		**DWEF 11**		**DWEF 12**		**DWEF 13**		**Total**
	Jun-22	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	**Jun-22**	**Oct-22**	
Amphilius uranoscopus								1			1	1			1				2						1	1	**8**
Chiloglanis emarginatus					1		2		2				2		4		1								1		**13**
Chiloglanis pretoriae	20	20	6		2	16	20		3	6	36		8		6		7	22	30						12	29	**243**
Chiloglanis sp.							3				7								5						3		**18**
Chiloglanis spp.				18				80				18		11		1				114							**242**
Enteromius anoplus s.l.	7	9	5	7	4				15	36			4	14		4	1	1	31	7	5	7	67	52	6	3	**285**
Enteromius paludinosus					2																					7	**9**
Labeobarbus polylepis																									6	4	**10**
Micropterus salmoides (ex)																	3	2									**5**
Pseudocrenilabrus philander	3		4	2	1												3	10									**23**
Tilapia sparrmanii	1		1																5								**7**
Total	**31**	**29**	**16**	**27**	**10**	**16**	**25**	**81**	**20**	**42**	**44**	**19**	**14**	**25**	**11**	**5**	**15**	**35**	**73**	**121**	**5**	**7**	**67**	**52**	**29**	**44**	**863**
No. Species	**4**	**2**	**4**	**3**	**5**	**1**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**5**	**4**	**5**	**2**	**1**	**1**	**1**	**1**	**6**	**5**	**11**

Appendix E: Curriculum Vitae of Authors

Name:	**Byron Grant** Pr.Sci.Nat.
Company:	Ecology International (Pty) Ltd
Years of Experience:	18 years
Nationality:	South African
Languages:	English (mother tongue), Afrikaans
SACNASP Status:	Professional Natural Scientist (Reg. No. 400275/08)
Email address:	byron@ecologyinternational.net
Contact Number:	(+27) 82 863 0769

EDUCATIONAL QUALIFICATIONS

- B. Sc. (Botany & Zoology), Rand Afrikaans University (1997 - 1999);
- B. Sc. (Honours) Zoology, Rand Afrikaans University (2000);
- M. Sc. (Aquatic Health) *cum laude,* Rand Afrikaans University (2001 – 2004);
- Introduction to quantitative research using sample surveys, Rand Afrikaans University (2004);
- SASS5 Field Assessment Accreditation in terms of the River Health Programme, Department of Water Affairs (2005 – present);
- Monitoring Contaminant Levels: Freshwater Fish (*awarded Best Practice*), University of Johannesburg (2005);
- EcoStatus Determination training workshop, Department of Water Affairs and Forestry (2006);
- Multi-disciplinary roles in defining EcoStatus and setting flow requirements during an ecological reserve study, Department of Water Affairs (2008);
- Water Use Licence Applications: Section 21 (c) and (i) training workshop, Department of Water Affairs (2009);
- Advanced Wetland Course, University of Pretoria (2010) (*awarded with Distinction*);
- Determination of the Present Ecological State within the EcoClassification process, University of the Free State (2011);
- River Health Programme Training Workshop, Department of Water and Sanitation – Resource Quality Information Services (2014);
- Tools for Wetland Assessments, Rhodes University (2015);
- RHAM (Rapid Habitat Assessment Model) Training Workshop, Department of Water and Sanitation – Resource Quality Information Services (2015);
- Wetland, River and Estuary Buffer Determination Training Workshop, Institute for Natural Resources (2015);
- Fish Invertebrate Flow Habitat Assessment Model (FIFHA), Department of Water and Sanitation – Resource Quality Information Services (2015);
- Wetland Plant Taxonomy, Water Research Commission (2017);

- Vegetation Response Assessment Index (VEGRAI), Mr. James MacKenzie (co-developer of index) (2018);
- Wetland Soils, Agricultural Research Council in association with the University of the Free State (2018);
- Hydropedology and Wetland Functioning (Short course), Terrasoil Science in association with the Water Business Academy (2018);
- HCV (High Conservation Value) Assessor Training Course, Astra-Academy (2019).

KEY QUALIFICATIONS

- **Project Management:**

  Project management and co-ordination of specialist-related projects, including:
  - Aquatic assessments (see below);
  - Floral and Faunal assessments:
    - Design and implementation of monitoring programmes;
    - Baseline ecological assessments
    - Ecological impact and mitigation assessments;
    - Rescue and relocation assessments;
    - Alien and invasive vegetation management plans;
  - Wetland assessments:
    - Design and implementation of wetland monitoring programmes;
    - Wetland delineation studies;
    - Wetland Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) determination assessments;
    - Wetland management plans;
    - Wetland impact and mitigation assessments;
    - Wetland offset strategies and assessments;
    - Wetland Reserve Determinations;
  - Water quality studies;
  - Dust monitoring studies;
  - Ecological Risk Assessments;
  - Biodiversity Action Plans (BAP);
  - Biodiversity Management Strategies;
  - Water Research Commission projects.

- **Specialist Assessments:**

  Extensive experience in conducting specialist aquatic assessments and providing specialist ecological input, including:
  - Baseline aquatic biodiversity assessments, including the determination of the Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) according to latest methodology;
  - Aquatic impact and mitigation assessments;

- Design, management and implementation of biological monitoring programmes for the aquatic environment;
- Protocol development;
- Fish kill investigations;
- Ecological Flow Requirements;
- Reserve Determinations;
- Aquatic toxicity assessments;
- Bioaccumulation studies;
- Human health risk assessments for the consumption of freshwater fish;
- Surface water quality studies;
- Application of various monitoring indices, including the South African Scoring System version 5 (SASS5), the Macro-Invertebrate Response Assessment Index (MIRAI), the Invertebrate Habitat Assessment System (IHAS), the Index for Habitat Integrity (IHI), the Rapid Habitat Assessment Model (RHAM), the Fish Assemblage Integrity Index (FAII), the Fish Response Assessment Index (FRAI), the Physico-chemical Assessment Index (PAI), Riparian Vegetation Response Index (VEGRAI), Fish Invertebrate Flow Habitat Assessment Model (FIFHA), determination of EcoStatus, etc.;
- Eco-Conditional Requirement (Eco-0) assessments for Green Star Accreditation;
- Watercourse Protection Plans relating to Eco-Conditional Requirement (Eco-0) for Green Star Accreditation.

- **Specialist Review:**
  Specialist and independent review of impact assessment and management reports for all sectors of government, civil society and the scientific and legal fraternity:
  - Member of Technical Advisory Group for the Green Building Council of South Africa;
  - Member of Reference Groups for Water Research Commission;
  - Peer review of specialist biodiversity reports;
  - Peer reviewer for African Journal of Aquatic Science.

PROFESSIONAL REGISTRATIONS

- South African Council for Natural Scientific Professions (SACNASP) – Professional Natural Scientist (Aquatic Science, Ecological Science, Zoological Science), Reg. No. 400275/08

Other Society Memberships

- South African Society of Aquatic Scientists
- South African Wetland Society (Founding Member)
- Zoological Society of Southern Africa

Other Memberships

- Aquatox Forum
- Gauteng Wetland Forum
- Klipriviersberg Sustainability Association – Development Integration Team
- Yellowfish Working Group

COUNTRIES OF EXPERIENCE

- South Africa
- Lesotho
- Swaziland
- Mozambique
- Ghana
- Namibia
- Cameroon

SPECIALIST WORKSHOP PARTICIPATION

- Wetland and Watercourse Buffers Determination workshop. Project for the Department of Water Affairs, Sub-directorate: Water Abstraction and Instream Use;
- NEMBA category 2 alien fish species mapping for Gauteng, Limpopo and Northwest Provinces and a national review workshop, South African Institute for Aquatic Biodiversity (SAIAB);
- National Freshwater Ecosystem Priority Areas project – Specialist Input Workshop, South African National Biodiversity Institute (SANBI);
- Biodiversity Offsets Strategy workshop, Gauteng Department of Agriculture, Conservation and Environment (GDACE);
- Minimum Requirements for Biodiversity Assessments (Version 2) workshop, Gauteng Department of Agriculture, Conservation and Environment (GDACE);
- Gauteng Nature Conservation Bill, Gauteng Department of Agriculture and Rural Development (GDARD);
- Mainstreaming Biodiversity in Mining Training Workshop, SANBI's Grasslands Programme (in partnership with the South African Mining and Biodiversity Forum and the Departments of Environmental Affairs and Mineral Resources);
- National Biodiversity Offset Workshop, Department of Environmental Affairs (DEA), Endangered Wildlife Trust (EWT);
- Accreditation/certification of Wetland Practitioners Workshop, South African Wetland Society.

PRESENTATIONS AND PUBLICATIONS

Brink, K., Gough, P., Royte, J.J., Schollema, P.P. & Wanningen, H. (eds). (2018). From Sea to Source 2.0. Protection and restoration of fish migration in rivers worldwide. World Fish Migration Foundation. *Contributing author.*

Grant, B., Huchzermeyer, D. & Hohls, B. (2014). *A Manual for Fish Kill Investigations in South Africa.* WRC Report No. TT 589/14. Water Research Commission, Pretoria.

Grant, B., Hohls, B. & Huchzermeyer, D. (2013). Development of a Fish Kill Protocol for South Africa. South African Society for Aquatic Scientists - 2013 Conference, Arniston. Oral presentation.

Mlambo, S.S., van Vuren, J.H.J., Basson, R. & Grant, B. (2010). Accumulation of hepatic HSP70 and plasma cortisol in *Oreochromis mossambicus* following sub-lethal metal and DDT exposure. *African Journal of Aquatic Science* 35(1): 47-53.

Grant, B., van Vuren, J.H.J. & Cronjé, M.J. (2004). HSP 70 response of *Oreochromis mossambicus* to Cu^{2+} exposure in two different types of exposure media. South African Society for Aquatic Scientists – 2004 Conference, Cape Town. Poster presentation.

EMPLOYMENT EXPERIENCE

- **Ecology International:** Date: June 2017 - Present
  Role: Director & Principal Biodiversity Specialist
  - Management and co-ordination of staff members and specialists
  - Project management on various scales for environmental and biodiversity specialist-related services;
  - Co-ordinating, implementing and conducting specialist studies for various types of projects, including:
    - Protocol development;
    - Monitoring programmes;
    - Environmental Impact Assessments;
    - Strategic-level assessments (e.g. Strategic Environmental Assessments, Environmental Management Frameworks, State of the Environment Reports, etc.);
    - Biodiversity Management Plans, Biodiversity Action Plans, etc.;
  - Acting as an information source concerning environmental legislation;
  - Development of terms of reference and project proposals;
  - Quality control of specialist reports; and
  - Interfacing with clients in the consulting, mining, and government industries.

- **Independent Specialist:** Date: February 2017 – May 2017

Role: Principal Biodiversity Specialist

- Project management on various scales for biodiversity specialist-related services;
- Co-ordinating, implementing and conducting specialist studies for various types of projects, including:
    - Protocol development;
    - Monitoring programmes;
    - Environmental Impact Assessments;
    - Strategic-level assessments (e.g. Strategic Environmental Assessments, Environmental Management Frameworks, State of the Environment Reports, etc.);
    - Biodiversity Management Plans, Biodiversity Action Plans, etc.;
- Acting as an information source concerning environmental legislation;
- Development of terms of reference and project proposals;
- Quality control of specialist reports; and
- Interfacing with clients in the consulting, mining, and government industries.

- **GIBB** (June 2015 – January 2017)

Role: Principal Specialist

- Project management on various scales for specialist-related services;
- Co-ordinating, implementing and conducting studies for various types of projects, including:
    - Monitoring programmes;
    - Environmental Impact Assessments;
    - Strategic-level assessments (e.g. Strategic Environmental Assessments, Environmental Management Frameworks, State of the Environment Reports, etc.);
    - Biodiversity Management Plans, Biodiversity Action Plans, etc.;
- Acting as an information source concerning environmental legislation;
- Development of terms of reference and project proposals;
- Quality control of specialist reports; and
- Interfacing with clients in the consulting, mining, and government industries.

- **Strategic Environmental Focus** (August 2009 – June 2015)

Role: Principal: Specialist Services

- Management and co-ordination of staff members and specialists;
- Project management on various scales for specialist-related services;
- Co-ordinating, implementing and conducting studies for various types of projects, including:
    - Monitoring programmes;
    - Environmental Impact Assessments;
    - Strategic-level assessments (e.g. Strategic Environmental Assessments, Environmental Management Frameworks, State of the Environment Reports, etc.);

    - Biodiversity Management Plans, Biodiversity Action Plans, etc.;
- Acting as an information source concerning environmental legislation;
- Development of terms of reference and project proposals;
- Quality control of specialist reports; and
- Interfacing with clients in the consulting, mining, and government industries.

- **Strategic Environmental Focus** (March 2009 – July 2009)

  Role: Senior Natural Scientist
  - Project management for water, aquatic and monitoring-related projects;
  - Management and co-ordination of specialists;
  - Co-ordinating, implementing and conducting studies for various water and monitoring-related projects;
  - Acting as an information source concerning environmental legislation;
  - Development of terms of reference and project proposals;
  - Quality control of specialist reports; and
  - Interfacing with clients in the consulting, mining, and government industries.

- **Strategic Environmental Focus** (July 2006 – February 2009)

  Role: Aquatic Specialist
  - Conducting specialist assessments in the field of aquatic ecology and water science.
  - Acting as an information source concerning environmental legislation.

- **ECOSUN cc.** (January 2005 – June 2006)

  Role: Aquatic Scientist
  - Conducting specialist assessments in the field of aquatic ecology and water science.
  - Acting as an information source concerning environmental legislation.

- **Rand Afrikaans University** (January 2003 – December 2004).

  Role: Student Mentor / Post-Graduate Research Assistant
  - Validation of Antibodies for HSP70 Detection in the Freshwater Snail *Melanoides tuberculata* - B.Sc. (Honours) Student (January 2003 – December 2003);
  - The use of genotoxic and stress proteins in the active biomonitoring of the Rietvlei system, South Africa – M.Sc. Student (January 2003 – December 2003);
  - A comparison between Whole Effluent Toxicity (WET) testing and Active Biomonitoring (ABM) as indicators of in stream aquatic health – M.Sc. Student (January 2003 – December 2003);
  - The use of HSP70 and cortisol as biomarkers for heavy metal exposure - M.Sc. Student (January 2004 – December 2005).

- **Rand Afrikaans University** (January 2000 – December 2004)

  Role: Practical Demonstrator
  - Field supervisor for B.Sc. Honours (Zoology);
  - Aquatic Ecology (3rd year);

- Human Physiology (2nd year); and
- Ecology and Conservation (for Vista University)

Name:	**Kieren Jayne Bremner Pr.Sci.Nat.**
Company:	Ecology International (Pty) Ltd
Years of Experience:	14 years
Nationality:	South African
Languages:	English (fluent), Afrikaans (Fluent), French (Basic)
SACNASP Status:	Professional Natural Scientist (Reg. No. 119341 [Active])
Email address:	kieren@ecologyinternational.net
Contact Number:	(+27) 72 262 4325

EDUCATIONAL QUALIFICATIONS AND TRAINING

-
- B.Sc. (Zoology and Biochemistry), Rand Afrikaans University (2004);
- B.Sc. Honours (Natural and Environmental Science), Rand Afrikaans University (2005);
- M.Sc. (Aquatic Health), University of Johannesburg (2011);
- Advanced 4x4 driving, Colt Driving School (2005);
- Environmental Auditing Workshop, University of Johannesburg (2006);
- First Aid Certificate (Level 1), Sharpminds (2008);
- Public Participation, Golder Associates (2008);
- SASS5 Field Assessment Accreditation in terms of the River Health Programme, Department of Water Affairs (2009 – present);
- RHAM (Rapid Habitat Assessment Model) Training Workshop, Department of Water and Sanitation – Resource Quality Information Services (2015);
- Wetland Plant Taxonomy, Water Research Commission (2017);
- Vegetation Response Assessment Index (VEGRAI), Mr. James MacKenzie (co-developer of index) (2018);
- Tools for Wetland Assessment – Rhodes University (2018);
- Fish Identification – South African Institute of Aquatic Biodiversity (2018);
- Wetland Soils, Agricultural Research Council in association with the University of the Free State (2018);
- Water Use Licence Applications: Section 21 (c) and (i) training workshop, Department of Water Affairs (2019);
- Grammar for Writers – South African Writers College (2019);
- Wetland Rehabilitation – presented by Piet-Loius Grundling (DEA) and Cilliers Blaauw (Aurecon) (2019)
- Editing and Copywriting – South African Writers College (2020).

KEY QUALIFICATIONS

- **Project Management:**

  Project management and co-ordination of specialist-related projects, including:

  - Aquatic assessments:
    - Design and implementation of monitoring programmes;
    - Baseline ecological assessments
    - Ecological impact and mitigation assessments;
  - Wetland assessments:
    - Design and implementation of wetland monitoring programmes;
    - Wetland delineation studies;
    - Wetland Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) determination assessments;
    - Wetland management plans;
    - Wetland impact and mitigation assessments;
    - Wetland offset strategies and assessments;
  - Water quality studies;
  - Ecological Risk Assessments.

- **Specialist Assessments:**

  Extensive experience in conducting specialist aquatic assessments and providing specialist ecological input, including:

  - Baseline aquatic biodiversity assessments, including the determination of the Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) according to latest methodology;
  - Aquatic impact and mitigation assessments;
  - Design, management and implementation of biological monitoring programmes for the aquatic environment;
  - Protocol development;
  - Aquatic toxicity assessments;
  - Bioaccumulation studies;
  - Surface water quality studies;
  - Application of various monitoring indices, including the South African Scoring System version 5 (SASS5), the Macro-Invertebrate Response Assessment Index (MIRAI), the Invertebrate Habitat Assessment System (IHAS), the Index for Habitat Integrity (IHI), the Rapid Habitat Assessment Model (RHAM), the Fish Assemblage Integrity Index (FAII), the Fish Response Assessment Index (FRAI), Riparian Vegetation Response Index (VEGRAI), determination of EcoStatus, etc.

- **Specialist Review:**

  Specialist and independent review of impact assessment and management reports for all sectors of government, civil society and the scientific and legal fraternity:

- Peer review of specialist reports.

PROFESSIONAL REGISTRATIONS

- South African Council for Natural Scientific Professions (SACNASP) – Professional Natural Scientist (Aquatic Science), Reg. No. 119341

Other Society Memberships

- South African Society of Aquatic Scientists
- South African Wetland Society

Other Memberships

- Gauteng Wetland Forum

COUNTRIES OF EXPERIENCE

- South Africa
- Botswana
- Mali
- Senegal
- Ghana
- Malawi
- Tanzania
- Democratic Republic of Congo

EMPLOYMENT EXPERIENCE

Ecology International September 2020 - Present

Role: Senior aquatic and wetland specialist

- Project management on various scales for environmental and biodiversity specialist-related services;
- Co-ordinating, implementing and conducting specialist studies for various aquatic and wetland projects, including:
  - Protocol development;

  - Monitoring programmes;
  - Baseline impact assessments;
  - Strategic-level assessments (e.g. Strategic Environmental Assessments, Environmental Management Frameworks, State of the Environment Reports, etc.);
- Acting as an information source concerning environmental legislation;
- Interfacing with clients in the consulting, mining, and government industries.

Scientific Aquatic Services, Johannesburg, Gauteng January 2020 – August 2020

Role: SAS Divisional Manager, Senior Aquatic and Wetland Ecologist

- Co-ordinating and managing the wetland and aquatic specialist teams;
- Mentoring and training junior staff. In eight months, three of five members of my team submitted their SACNASP applications and were awaiting confirmation;
- Principle specialist on various aquatic and wetland baseline and ongoing biomonitoring assessments;
- Client liaison and project management. In eight months, I was actively involved in more than 20 projects and reviewed more than 90 reports.

Digby Wells Environmental, Johannesburg, Gauteng September 2017 – January 2020

Role: Unit Manager – Wetlands, Senior Aquatic and Wetland Ecologist

- Co-ordinating and managing the wetland specialist team;
- Principle specialist on various aquatic and wetland related assessments throughout South Africa, DRC, Mali, Senegal, Tanzania, Malawi and Botswana.

Scientific Aquatic Services, Johannesburg, Gauteng August 2015 – August 2017

Role: Senior Aquatic and Wetland Ecologist

- Initiated and/or actively involved in more than 24 ongoing seasonal biomonitoring and toxicological testing programmes employing monitoring indices such as IHAS. IHI, SASS5/MIRAI, FAII/FRAI, VEGRAI, RHAM, WET-Health and WET-Ecoservices
- Principle specialist and/or team member on more than 15 aquatic and wetland baseline assessments.

Estuary Care, Kenton-on-sea, Eastern Cape 2014 - 2015

Role: Ecologist

- Water quality monitoring
- Trend analysis
- Reporting

Sustainable Seas Trust, Kenton-on-sea, Eastern Cape 2014

Role: Team Member

- Education and awareness: Mini-SASS days and clean up initiatives;
- Assisted with the compilation of the book: South African Coasts: A celebration of our seas and shores

Scientific Aquatic Services, Johannesburg, Gauteng April 2009 – April 2013

Role: Aquatic Ecologist

- Initiated and/or actively involved in more than 35 ongoing seasonal biomonitoring and toxicological testing programmes employing monitoring indices such as IHAS. IHI, SASS5/MIRAI, FAII/FRAI and VEGRAI
- Team member various aquatic and wetland baseline assessments throughout South Africa, the Democratic Republic of Congo and Ghana.

TWP Engineering, Johannesburg, Gauteng November 2007 – March 2009

Role: Junior Environmental Scientist

- Editing of documents
- Assist in compilation of documents
- Assist in public participation processes
- As a junior, took initiative and spear-headed the first two aquatic biomonitoring specialist assessments (specialist studies) at the company and sourced external resources to assist with expertise.

Rand Afrikaans University, Johannesburg, Gauteng 2006 - 2007

Role: Practical Demonstrator and Laboratory Assistant

- Assist in setting up practical sessions
- Provide assistance to students throughout practical sessions
- Assess students' preparation and progress
- Marking of papers and reports
- Assist in general laboratory maintenance and functioning

Rand Afrikaans University, Johannesburg, Gauteng 2005

Role: Research Assistant

- Doc.I. Pieterse in general research and laboratory tasks

Appendix F: Proof of SACNASP Registration of Author

SACNASP

South African Council for Natural Scientific Professions

herewith certifies that

Byron Grant

Registration Number: 400275/08

is a registered scientist

in terms of section 20(3) of the Natural Scientific Professions Act, 2003
(Act 27 of 2003)
in the following fields(s) of practice (Schedule 1 of the Act)

Ecological Science (Professional Natural Scientist)
Zoological Science (Professional Natural Scientist)
Aquatic Science (Professional Natural Scientist)

Effective **29 January 2014** Expires **31 March 2023**

Chairperson

Chief Executive Officer

To verify this certificate scan this code

SACNASP

South African Council for Natural Scientific Professions

herewith certifies that

Kieren Jayne Bremner

Registration Number: 119341

is a registered scientist

in terms of section 20(3) of the Natural Scientific Professions Act, 2003
(Act 27 of 2003)
in the following fields(s) of practice (Schedule 1 of the Act)

Aquatic Science (Professional Natural Scientist)

Effective **1 August 2018** Expires **31 March 2023**

Botha
Chairperson

Chief Executive Officer

To verify this certificate scan this code

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