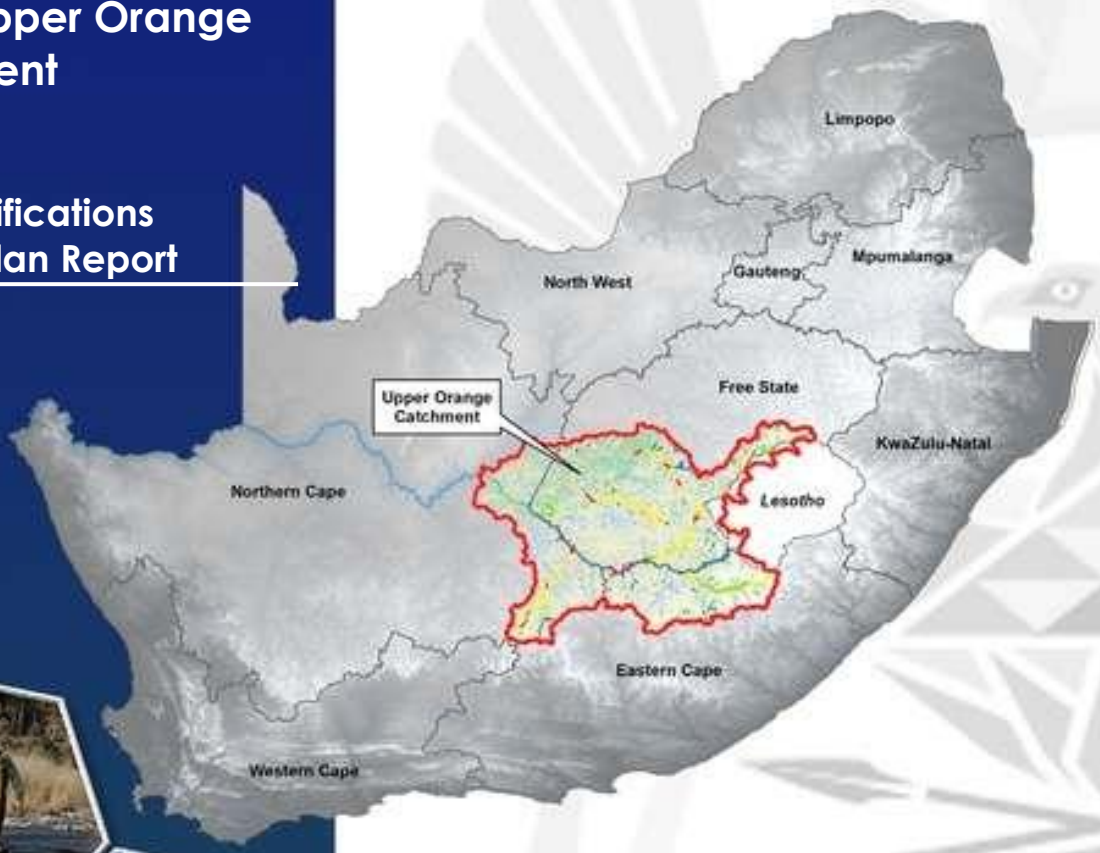
DEPARTMENT OF WATER AND SANITATION

A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment

WP11343

Ecological Specifications and Monitoring Plan Report



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Bold type indicates this report

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LIST OF ACRONYMS

BHN	Basic Human Needs
CD: WEM	Chief Directorate: Water Ecosystems Management
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
Eco-specs	Ecological Specifications
EIS	Ecological Importance and Sensitivity
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FCS	Fast Course Substrate
FS	Fine Substrate
GSM	Gravel, Sand, Mud
MIRAI	Macroinvertebrate Response Assessment Index
MV	Marginal Vegetation
NWA	National Water Act
NWM	National Wetland Map
PES	Present Ecological State
REC	Recommended Ecological Category
REMP	River Eco-Status Monitoring Programme
SPI	Specific Pollution Index
TPC	Thresholds of Potential Concern
VEGRAI	Vegetation Response Assessment Index
VFCS	Very Fast Course Substrate
WMA	Water Management Area
WRC	Water Research Commission

EXECUTIVE SUMMARY

This phase forms part of the following study: A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange. The purpose of this study is to determine the Reserve (quantity and quality of the EWR and BHN) for priority rivers, wetlands and groundwater areas at a high level of confidence in the Upper Orange Catchment. The results from the study will guide the Department of Water and Sanitation (DWS) to meet the objectives of maintaining, and if attainable, improving the ecological state of the water resources. The primary deliverable will be the preparation of the Reserve templates for the Upper Orange River Catchment, specifying the Ecological Water Requirements (EWR) for rivers and Ecological Specifications (EcoSpecs) for the management of the priority rivers, wetlands and groundwater areas.

To date, the EWRs were determined for the rivers in the Upper Orange Catchment area. The groundwater Reserve has also been determined. In terms of the wetlands, all twelve Wetland Resource Units (WRUs) that were identified and assessed as part of this study had some level of Reserve set for them. Based on the outcomes of the decision support system, none of the WRUs require EWR quantification. As such, EcoSpecs were set for all WRUs. These EcoSpecs can be incorporated into Water Use License conditions to allow for monitoring and auditing of the condition of the wetland resources.

Based on these results and the review of the eco-categorisation, the objectives for the protection of the ecosystem have now been defined through EcoSpecs and monitoring requirements for the maintenance at each EWR site, as well as for selected field verification sites. The EcoSpecs are intended to provide the quantifiable and enforceable descriptors of the quantity, quality habitat and biotic integrity as they pertain to the ecological objectives for a particular water resource. These are the values of parameters (usually maximum concentrations) that should not be exceeded to meet the Recommended Ecological Category (REC) specified for the water resource. The EcoSpecs (ecological information only) will relate to and expand on the Resource Quality Objectives (RQOs) that will be set for the Upper Orange catchment area (study recently initiated in 2023).

Therefore, this report describes the EcoSpecs and monitoring requirements for maintenance of the Reserve in the water resources of the Upper Orange catchment area as they relate to hydrology, water quality, geomorphology, riparian vegetation, habitat and biota of rivers, and groundwater and wetlands. Overall, these EcoSpecs will support the attainment of the Reserve going forward.

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1. INTRODUCTION

1.1 Background

The National Water Act (No. 36 of 1998) (NWA) is founded on the principle that the National Government has overall responsibility for and authority over water resource management for beneficial public use without seriously affecting the functioning and sustainability of water resources. Chapter 3 of the NWA enables the protection of water resources by the implementation of Resource Directed Measures (RDM). As part of the RDM process, an Ecological Reserve must be determined for a significant water resource to ensure a desired level of protection.

The Reserve (water quantity and quality) is defined in terms of (i) Ecological Water Requirements (EWR) based on, the quantity and quality of water needed to protect aquatic ecosystems; water quantity, quality, habitat and biota in the desired state and (ii) Basic Human Needs (BHN), ensuring that the essential needs of individuals dependant on the water resource is provided for. These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources while allowing economic development.

The Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS) is responsible for coordinating all Reserve Determination studies in terms of the Water Resource Classification System (WRCS). These studies include the surface water (rivers, wetlands and estuaries) and groundwater components of water resources.

The Reserve has priority over other water uses in terms of the NWA and should be determined before license applications are processed, particularly in stressed and over utilised catchments. Accordingly, the CD: WEM identified the need to determine the Reserve for the ecosystems (rivers, wetlands and groundwater) of the Upper Orange River catchment in the Orange Water Management Area (WMA 6). The aim is to provide adequate protection for (i) possible hydraulic fracturing (HF) activities, (ii) assessment of various water use license applications, and (iii) evaluation of impacts of current and proposed developments on the availability of water.

1.2 Purpose of this Study

It is important to note the following:

- Priority rivers are selected by assessing water use impacts (quantity and quality) to determine the integrated water use index (IWUI) or water stress and (ii) integrated ecological index (IEI) that considers the PES and the ecological importance (EI) and ecological sensitivity (ES) of each sub-quaternary reach. This results in the identification of priority resource units where the EWRs need to be quantified.
- A “high confidence study” refers to a combination of different river level assessments, from desktop extrapolation to Intermediate assessments. Furthermore, a wider coverage of the catchment has been undertaken, not only the main stem Orange River

and major tributaries, but inclusive of the smaller tributaries within the catchment. Groundwater and wetland priority resources and their interactions will also be assessed.

Therefore, the purpose of this study is to determine the Reserve (quantity and quality of the EWR and BHN) for priority rivers, wetlands and groundwater areas at a high level of confidence in the Upper Orange Catchment. The results from the study will guide the Department to meet the objectives of maintaining, and if attainable, improving the ecological state of the water resources. The primary deliverable will be the preparation of the Reserve templates for the Upper Orange Catchment, specifying the ecological water requirements and ecological specifications/ conditions for the management of the priority rivers, wetlands and groundwater areas.

1.3 Purpose of this Report

The purpose of this Ecological Specifications (EcoSpecs) and Monitoring Report is to provide the processes, approaches and results of step 7 in accordance with the 8-step process as outlined in Regulation 810 (Government Gazette 33541) dated 17 September 2010 (**Figure 1-1**), as well as The Reserve determination process as outlined in the recently completed study, 'Development of Procedures to operationalise Resource Directed Measures (DWS, 2017).

Thus, the purpose of this report is to provide ecological specifications for the protection of the water resources as determined and general guidelines for the development of monitoring programmes for the water resources of the Upper Orange catchment area, namely rivers, wetlands and groundwater. The level of monitoring is different for rivers, as compared to wetlands and groundwater. Therefore, the following information is provided:

- Rivers: EcoSpecs and Thresholds of Potential Concern (TPCs) for geomorphology, riparian vegetation, habitat and biota, quantity and quality and associated monitoring programme.
- Wetlands: EcoSpecs are provided for identified priority wetlands with monitoring guidelines;
- Groundwater: Evaluation of the current monitoring network, identification of gaps, and suggested improvements and/or new monitoring borehole sites were deemed necessary.

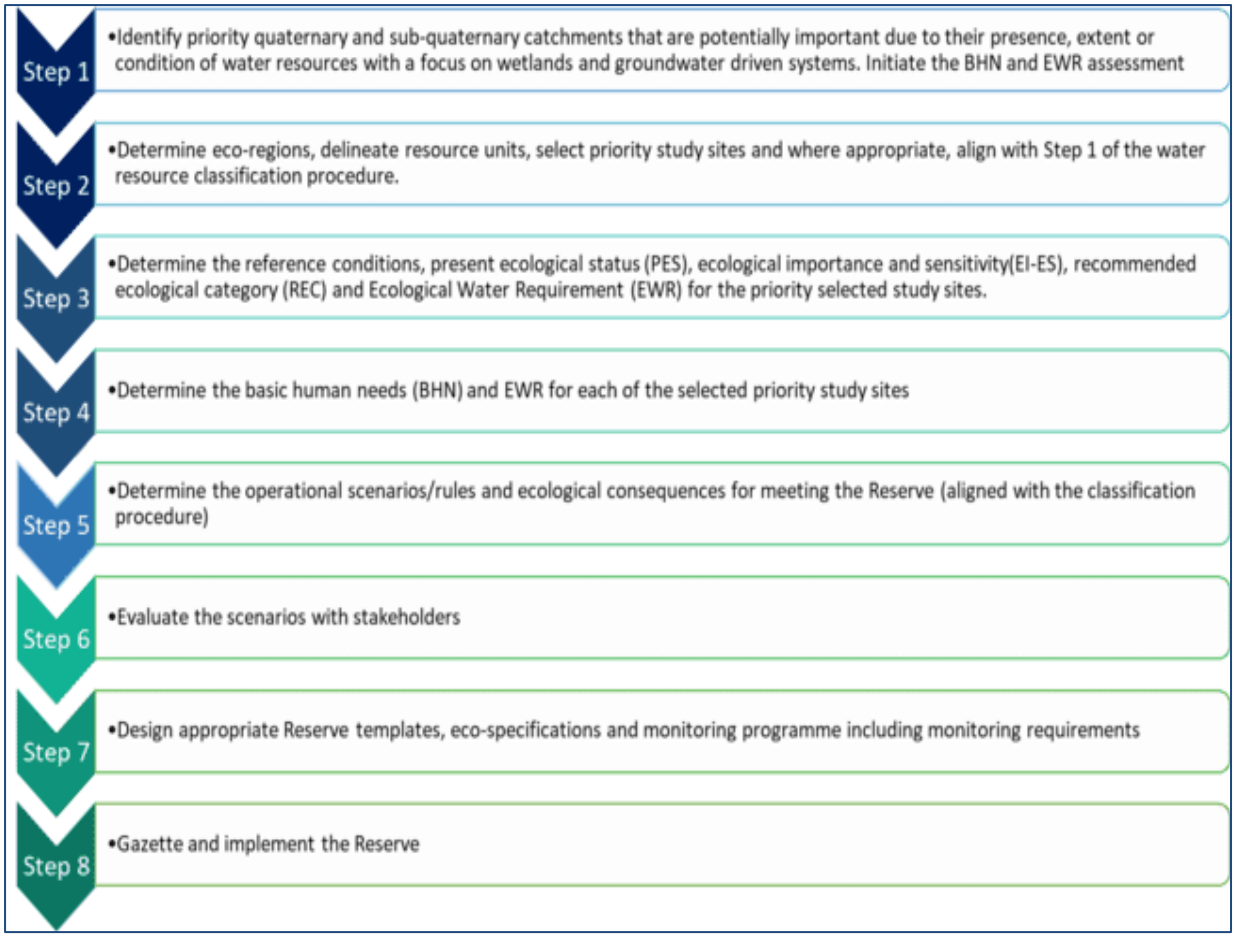


Figure 1-1: Integrated steps for the determination of the Reserve (DWS, 2017)

This report draws on the results from the following reports:

- The Rivers Eco-categorisation report (Report No. RDM/WMA13/00/CON/COMP/1223 Volume 1 and Volume 2 (a, b respectively);
- The Rivers EWR Quantification Report (Report No. RDM/WMA13/00/CON/COMP/1323);
- The Wetland Report (Report No. RDM/WMA13/00/CON/COMP/0922); and
- The Groundwater Report (Report No. RDM/WMA13/00/CON/COMP/1022.

2. OVERVIEW OF THE STUDY AREA

The study area of the Upper Orange Catchment forms part of the Orange WMA6 (**Figure 2-1**) and includes the main stem Orange River from the Lesotho border to the confluence with the Vaal River at Douglas. The major tributaries of the Orange River include the Kraai, Caledon and Seekoei Rivers. Although the Modder-Riet River drains into the Vaal River, due to their interconnectivity (i.e., water transfers) with the Upper Orange River, are included in this study. The study area consists of 129 quaternary catchments, covering an approximate area of 106 000 km^2. This includes secondary catchments D1, D2, D3 and C5 namely:

i. The Orange River from the Lesotho Border to the Gariep Dam, including the main tributaries: Kornetspruit, Sterkspruit, Stormbergspruit and Brandwaterspruit (catchments D12, D14 and the SA part of D15 and D18);
ii. The Caledon River from its headwaters and its tributaries to the Gariep Dam (catchments D21, D22, D23, D24);
iii. The Kraai River catchment (catchment D13); and
iv. The Orange River from the Gariep Dam to Marksdrift weir (catchments D31, D33, D34 and D35), just upstream from the confluence with the Vaal River. This includes the Seekoei River (catchment D32) in the south and the Modder-Riet River (catchments C51 and C52) in the north.

The Gariep and Vanderkloof Dams on the main stem Orange River are two of the country's largest reservoirs with main uses for the generation of hydropower, transfers of water and releases for irrigation and other demands, including estuarine requirements, before reaching its confluence with the Vaal River.

The current infrastructure for water use is mainly for irrigation, transfer of water within the study area (Caledon River to Modder River, Vanderkloof Dam to the Riet River, Marksdrift on Orange River to Modder-Riet Rivers) and to other WMAs (e.g., transfer to Great Fish River in the Eastern Cape), domestic use, stock watering and power generation at the Gariep and Vanderkloof Dams. The Bloemfontein metropolitan area is the largest in the study area with smaller towns scattered throughout the catchment. Larger towns include Herscell/ Sterkspruit, Aliwal North, Burgersdorp, Ficksburg, Ladybrand, Botshabelo, Kimberley and Colesberg.

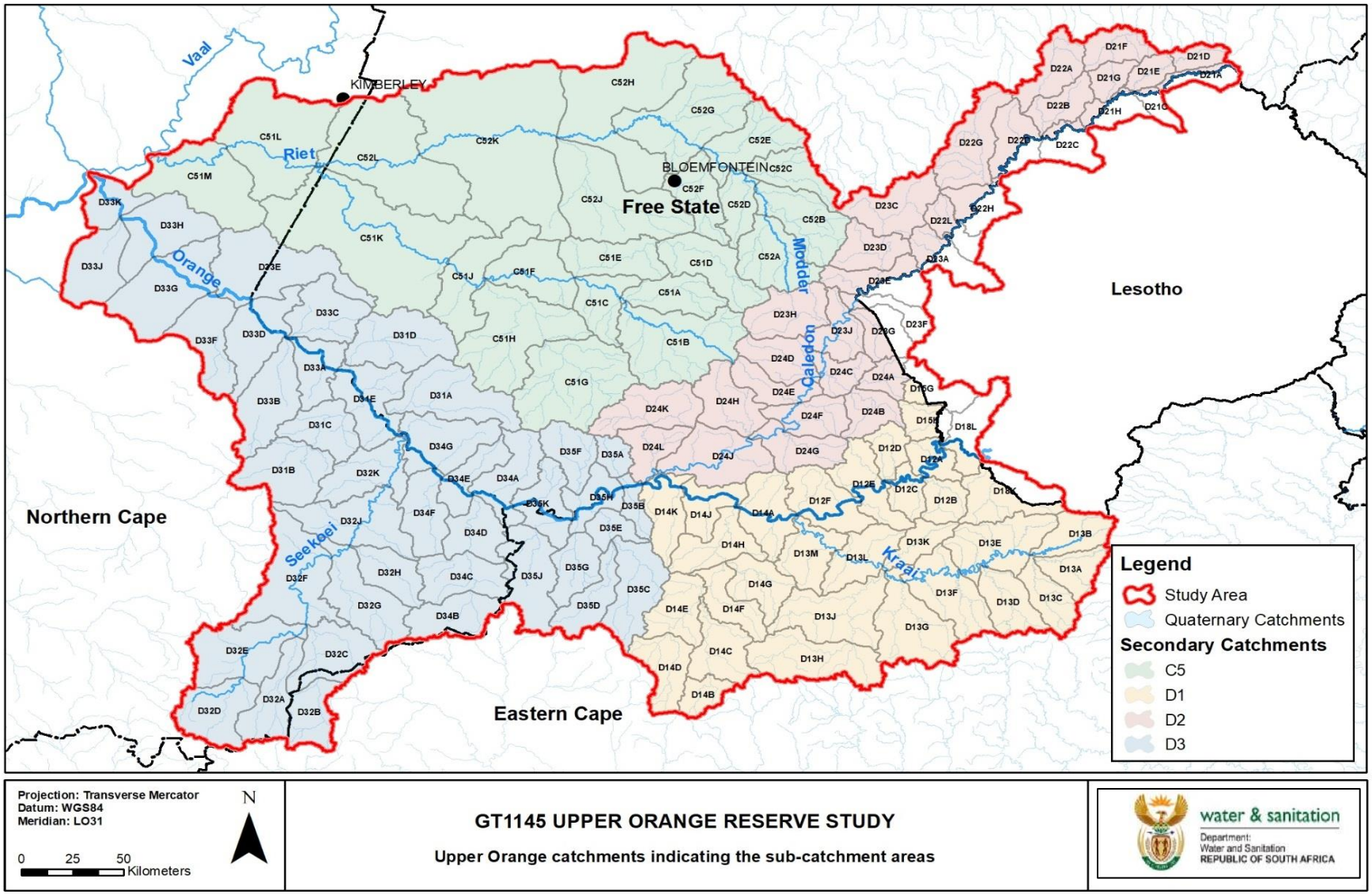


Figure 2-1: Upper Orange Catchment

2.1 Rivers

Ten (10) Intermediate and six (6) Rapid 3 Ecological Water Requirements (EWR) sites were selected within the priority Resource Units (RU) in the study area respectively. A further 25 field verification sites were assessed from a water quality perspective. These EWR sites are listed in **Table 2-1** and further information of these sites can be sourced from The Rivers Eco-categorisation Report (Report No. RDM/WMA13/00/CON/COMP/1223 Volume 1 and Volume 2 (a, b respectively).

Table 2-1: Summary of the selected EWR sites and field verification sites in the study area

	RU	EWR site code	River	Quat	Co-ordinates	
INTERMEDIATE	R_RU04	UO_EWR01_I	Middle Caledon	D22D	-28.9091020	27.7849240
	R_RU01	UO_EWR02_I	Sterkspruit	D12B	-30.5178445	27.3690799
	R_RU02a	UO_EWR03_I	Upper Orange	D12F	-30.6528889	26.8230496
	R_RU05	UO_EWR04_I	Lower Caledon	D24J	-30.2801149	26.6530603
	R_RU06	UO_EWR05_I	Seekoei	D32J	-30.5339007	24.9625368
	R_RU08	UO_EWR06_I	Upper Riet	C51F	-29.5347873	25.5244957
	R_RU09a	UO_EWR07_I	Upper Modder (Sannaspos)	C52G	-29.1600170	26.5724920
	R_RU03	UO_EWR08_I	Lower Kraai	D13M	-30.6900700	26.7415700
	R_RU10	UO_EWR09_I	Lower Riet	C51L	-29.0269630	24.5129190
	R_RU07	UO_EWR10_I	Lower Orange	D33K	-29.1448547	23.6914039
RAPID 3	R_RU13	UO_EWR01_R	Little Caledon	D21D	-28.5577960	28.4057090
	R_RU14	UO_EWR02_R	Brandwater (Groot)	D21G	-28.6803400	28.1399260
	R_RU16	UO_EWR03_R	Mopeli	D22G	-29.1012050	27.5707510
	R_RU11a	UO_EWR04_R	Upper Kraai	D13E	-30.8517900	27.7768900
	R_RU12	UO_EWR05_R	Wonderboomspruit	D14E	-31.0052620	26.3419380
	R_RU09b	UO_EWR06_R	Middle Modder (Soetdoring)	C52H	-28.8071910	26.1096950
FIELD VERIFICATION	R_RU04	UO_EWR01_FV	Middle Caledon	D23A	-29.3689250	27.4051890
	R_RU30	UO_EWR02_FV	Meulspruit	D22B	-28.8857310	27.8349440
	R_RU31	UO_EWR03_FV	Witspruit	D24C	-30.0082600	26.9283150
	R_RU22	UO_EWR04_FV	Gryskopspruit	D12D	-30.3396290	27.1768780
	R_RU26	UO_EWR05_FV	Karringmelkspruit	D13K	-30.8117650	27.2649730
	R_RU23	UO_EWR06_FV	Bokspruit	D13A	-30.8846900	27.8845570
	R_RU27	UO_EWR07_FV	Holspruit	D13J	-30.9953160	27.0566390
	R_RU11b	UO_EWR08_FV	Sterkspruit (trib. of Bell/Kraai)	D13C	-30.9176210	27.8007530
	R_RU11c	UO_EWR09_FV	Bell	D13B	-30.8526010	27.7865570

	RU	EWR site code	River	Quat	Co-ordinates	
	R_RU32a	UO_EWR10_FV	Groenspruit	D24H	-30.2411900	26.5613000
	R_RU32b	UO_EWR11_FV	Skulpspruit	D24H	-30.2344400	26.5113400
	R_RU18	UO_EWR12_FV	Fouriespruit	C51A	-29.6712110	26.0743930
	R_RU37	UO_EWR13_FV	Renoster	C52F	-29.1163200	26.3287010
	R_RU21	UO_EWR14_FV	Os-spruit	C52E	-28.9391700	26.5114110
	R_RU33	UO_EWR15_FV	Hondeblaf	C31C	-30.2051380	24.7180300
	R_RU40	UO_EWR16_FV	Trib. van Zyl	C51G	-30.0312030	25.7864630
	R_RU04	UO_EWR17_FV	Slykspruit	D24L	-30.3930030	26.1209250
	R_RU11d	UO_EWR18_FV	Langkloofspruit	D13D	-30.9541260	27.6061290
	R_RU25	UO_EWR19_FV	Wasbankspruit	D13G	-31.1555400	27.2844420
	R_RU39	UO_EWR20_FV	Lower Modder	C52K	-28.8916600	25.6564450
	R_RU19a	UO_EWR21_FV	Upper Kromellenboog	C51G	-30.0662820	25.6810560
	R_RU19b	UO_EWR22_FV	Lower Kromellenboog	C51H	-29.6536000	25.4350700
	R_RU41	UO_EWR23_FV	Tele	D18K	-30.4485880	27.5823370
	R_RU02b	UO_EWR24_FV	Orange	D12A	-30.3987570	27.3429870
	R_RU42	UP_EWR25_FV	Maghaleng	D15H	-30.1641200	27.3982510

2.2 Wetlands

Twelve wetland resource units (WRU) were selected for the Upper Orange Catchment (**Table 2-2**). These systems varied drastically in terms of their type, integrity, functionality and size, but were all regarded as important.

Table 2-2: Summary of the WRU selected for the Upper Orange Reserve study

WRU Number	Latitude	Longitude	Quaternary Catchment	Associated River/Groundwater Area
WRU 02	-28.73001	28.11370	D21G	Brandwater River
WRU 03	-28.73884	26.06407	C52H	Not associated
WRU 04	-30.48439	24.61705	D31B	Hondeblaf River
WRU 05	-31.34201	27.19072	D13G	Wolwespruit
WRU 06	-30.82522	27.46506	D13E	Klein-Wildebeesspruit
WRU 10	-29.63414	24.65006	D33C	Lemoenspruit
WRU 11	-28.99778	25.83439	C52G	Kaalspruit

WRU Number	Latitude	Longitude	Quaternary Catchment	Associated River/Groundwater Area
WRU 12	-28.71019	26.29506	C52G	Rietspruit
WRU 13	-28.93325	27.72073	D22G	Rantsho River
WRU 15	-29.81707	25.47559	C51H	Prosesspruit
WRU 16	-31.21736	27.66851	D13D	Rytjiesvlaktespruit
WRU 17	-30.67606	27.95689	D13B	Kraai River

2.3 Groundwater

Based on a variety of geohydrological, management and geo-political criteria, the catchment was subdivided into fourteen (14) Groundwater Resource Units (GRUs). The GRUs and quaternary catchments within the Upper Orange Catchment are listed in **Table 2-3**.

Table 2-3: Upper Orange Catchment GRU's and Quaternary Catchments

GRU	Quaternary Catchments
GRU1	D21F, D22A, D21D, D21E, D21G, D21A, D22B, D22G, D21H, D21C, D22D, D22C, C52C, D22F, D23C, D22H, C52B, D22L, C52A, D23D, D23A, D23E, D23H, D23J, D23F, D23G
GRU2	C52A, C51D, C51A, D23H, D23J, D23F, C51B, D23G, D24D, C51G, D24C, D31A, D24C, D31A, D24E, D24A, D15G, D24H, D18L, D24K, D24B, D24F, D15H, D34G, D24G, D35F, D24J, D12D, D24L, D34A, D34E, D35A, D12A, D12E, D35K, D12C, D35H, D12F, D34F, D14A, D35B, D14K, D14J, D12B, D34D, D35E, D35J, D35G, D34C
GRU3	C52H, C52G, C52K, C52E, C52J, C52C, C52F, C51K, C52D, C52B, C52A, C51J, C51D, C51E, C51F, D23E, C51A, C51C, C51H, D23H, D23J, D23F, C51B, C51G, D24K
GRU4	C52H, C52G, C52E, C52F
GRU5	C52K, C52L, C51J
GRU6	C51K, C51J, C51F, C51H, D31D, D31A
GRU7	D18L, D15H, D12D, D12A, D12E, D18K, D12C, D18G, D12B, D13B, D13E, D13K, D13L, D13F, D13A, D13C, D13G, D13D, D13J
GRU8	D12E, D12C, D12F, D12B, D13M, D13K, D13L, D13F, D14G, D14F, D13G, D13J, D14C, D13H
GRU9	D24J, D35K, D35H, D12F, D14A, D35B, D14K, D14J, D34D, D14H, D35E, D13M, D35J, D35G, D35C, D32G, D35D, D32H, D34C, D14G, D14F, D14E, D34B, D14C, D32C, D14D, D14B, D23B
GRU10	D32F, D32G, D32E, D32C, D32A, D32D, D32B
GRU11	D34G, D34A, D34E, D32K, D34F, D32J, D34D, D32F, D35J, D32G, D32H, D34C, D34B
GRU12	D31D, D33A, D33B, D31A, D31E, D31C, D34G, D32K, D31B, D34F, D32J, D32F, D32G, D32H
GRU13	C92C, C92B, C51L, C52L, C51M, C51K, D33K, D33H, D33J, D33E, D33G, D33C, D33D, D33F, D33A, D33B, D31E, D31C, D31B
GRU14	C52H, C52G, C52K, C52L, C52J, C51K, C51J, D33E, C51E, C51F, D33C, C51H, D33D, D31D, C51G, D33A, D33B, D31A, D31E, D34G

3. RIVERS: CONTEXTUAL

3.1 What are Ecological Specifications

EcoSpecs must possess qualities that render them quantifiable, measurable, verifiable, and enforceable, ensuring comprehensive protection for all facets of the resource and upholding ecological integrity. Key elements within the EcoSpecs encompass:

- Requirements for water quantity, encompassing flow requirements for river reaches, and/or water level prerequisites for both standing water and groundwater. This extends to groundwater level mandates aimed at sustaining spring and baseflow in rivers and other ecological features; and

- Clearly defined and measurable biological criteria and habitat criteria, originating from EcoSpecs, serve as explicit specifications for ecological attributes. These attributes include flow, physical-chemical characteristics, and biological integrity, all of which mirror the health, community structure, and distribution of aquatic biota.

Overall, EcoSpecs are associated with the Ecological Reserve process and are provided at EWR sites. For this study, the EWR sites are situated in the identified and prioritised Resource Units (RUs) and thus the detailed EcoSpecs will provide the output of this Reserve determination. The EcoSpecs will be presented in a numerical quantitative format and will be used for monitoring and compliance purposes.

3.2 What are Thresholds of Potential Concern

The TPCs represent upper and lower benchmarks along a continuum of change in selected environmental indicators. They are utilised and interpreted based on the guidelines established by Rogers and Bestbier (1997). The following principles guide the utilisation of TPCs:

- Upon reaching a TPC level (or when modelling predicts its attainment), an assessment is triggered to determine the causes and extent of the observed change. This assessment serves as the foundation for deciding whether management actions are necessary or if recalibrating the TPC is warranted. TPCs furnish management with strategic goals or endpoints for system management.

- TPCs serve as the foundation for an inductive approach to adaptive management, essentially functioning as hypotheses regarding the limits of acceptable change in ecosystem structure, function, and composition. The validity and appropriateness of TPCs are subject to ongoing scrutiny, and they must be adaptively modified as understanding and experience with the managed system evolve.

- Consequently, the confidence in the validity of a TPC can be enhanced through more detailed monitoring surveys, effectively reducing uncertainty.

3.3 What is ecological monitoring based on in the monitoring programme

The ecological monitoring process, aligned with this program, entails the collection and analysis of data from routine monitoring events/ surveys to assess changes in water resource conditions. The primary goal is to measure the EcoSpecs, ultimately determining whether the Ecological Category (EC) is achieved (Kleynhans *et al.,* 2009).

The monitoring principles in this report focuses on measuring the EC. EcoSpecs and TPCs, therefore describe the PES and/or REC for each of the components. The key principles and concepts include:

- Data obtained from the field surveys for rivers, wetlands and groundwater forms the baseline;
- Future monitoring must compare conditions to this baseline;
- For rivers, EcoSpecs and TPCs describe the baseline, allowing monitoring to assess if the system is maintaining the PES, degrading, or achieving the REC if different from the PES;
- Monitoring should commence soon after baseline data is collected to ensure that this data represents the recent baseline;
- Important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined;
- Monitoring must be applied within an Adaptive Management Framework:
    - It will be important to conduct **implementation monitoring**. This monitoring will assess whether the activities are carried out as designed. It will further identify which variables are most likely to be causing a change in the resource and help eliminate from consideration some potential causes of change (Kershner 1997; Elzinga *et al.,* 1998). In terms of the Ecological Reserve this would, *inter alia*, refer to whether flows are released as was specified for the attainment of a particular EC. Subsequently, **effectiveness monitoring** measures whether the EcoSpecs proposed are attained by following the particular management scenario (Kershner 1997);
- Thus, when/if TPCs are exceeded, more intensive monitoring or research may be needed to determine the cause of the decrease. If a cause for decrease is suspected, the proposed management interventions (in addition to others (Elzinga *et al*., 1998) will need to be actioned.

Ultimately, this monitoring programme will provide information on the health of the aquatic ecosystems associated with the Upper Orange catchment area. This will relate to the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP), and in particularly situations, to the DWS River Eco-status Monitoring Programme (REMP) (evolved from the River Health Programme (RHP) in 2016), and which is a component of the NAEHMP. The REMP is primarily aimed at providing information on the health or integrity of rivers for national state of the rivers reporting and as input to resource management at a large number of sites based on biological responses. Thus, data obtained from this monitoring programme within this study area will contribute, where applicable to the REMP.

Management actions for rivers aim to maintain or attain (if different from the PES) the REC. These actions relate to management objectives specified in terms of flow and water quality EcoSpecs. In addition, land use objectives may be included within the management actions, should impacts be non-flow related aspects contributing to the PES of the system (i.e.

upstream dysfunctional wastewater treatment works (WWTW), alien invasive plants in riparian zones, etc.). It is crucial to distinguish between setting management objectives in terms of habitat to achieve or maintain certain ECs, and defining EcoSpecs for the biophysical responses that describe the ECs.

Therefore, and importantly, monitoring the ecological responses will test the predictions made during an EWR study. It furthermore will assess whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the PES or REC is being achieved. It is therefore crucial that monitoring be driven by objectives, as it forms the foundation of a monitoring programme (Elzinga *et al.,* 1998).

Refer to **Figure 3-1** for the links between the Reserve steps and monitoring as per DWA (2009).

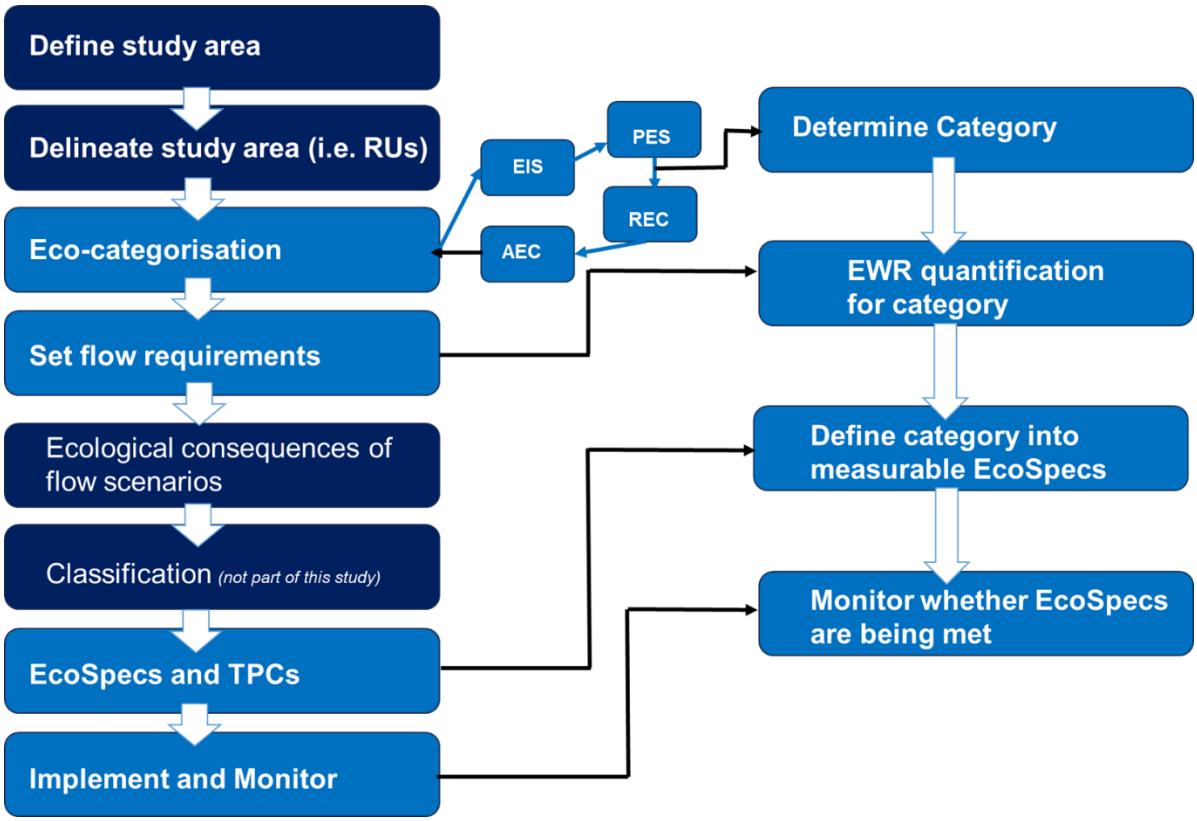


Figure 3-1: Eight steps of the Ecological Reserve process with links to those pertaining to Eco-categorisation and monitoring

3.3.1 The Adaptive Management Approach

It is important that the design of this monitoring program for this study adheres to the principles of adaptive management, whereby monitoring provides the critical link between meeting the objective (i.e. the EcoSpecs) and adaptive management (Elzinga *et al.,* 1998). This approach further provides guidance in addressing concerns should the specified EcoSpecs and TPCs (Rogers & Bestbier, 1997) be exceeded. Overall, this provides the evidence for management change or continuation of current practices (Elzinga *et al.,* 1998).

An adaptive management approach to water resources management implies:

- A systematic trial and error approach that uses feedback loops to allow a learning – from-experience-system and which permits adjustment of water management practices to address evolving issues and conditions;
- A focus on developing an understanding of the baseline biophysical aspects of a catchment;
- Quantification of management and scientific uncertainties and sensitivities, predicting ranges of potential changes, and developing testable management options/hypotheses and scenarios; and
- Planning for and managing those changes to reduce management risks.

Therefore, it is crucial that monitoring be driven by objectives as it forms the foundation of a monitoring programme (cf. Elzinga *et al.,* 1998):

- The REC represents the overall management objective for this study;
- The design features specifying what is measured (biological and habitat criteria), the effectiveness of measurement, and the frequency of measurement are determined by the expression of an objective; and
- Management is structured to achieve the objective, while monitoring is crafted to assess whether the objective has been achieved.

When monitoring is done within the adaptive management framework it will:

- Indicate whether the REC specifications and objectives are met;
    - For example, the Eco Status process (Kleynhans & Louw 2007 and as described in Report No. RDM/WMA13/00/CON/COMP/1223), instream biota, which are the indicators used during monitoring to detect problems and attainment of the REC based on any significant driver (water quality, flow, geomorphology) changes and/or the EcoSpecs and TPCs assigned for the biota are exceeded.
- Give new insights into ecosystem function and structure;
- Assist in the re-examination of understanding of aquatic and riparian ecosystems, thereby providing information needed to adapt the goals for managing these systems (Kershner, 1997).

Ultimately, this is the fundamentals of a Decision Support System (DSS) that operationalises the adaptive management approach (Elzinga *et al.,* 1998). The DSS will be assessed and outlined in more detail during the WRCS currently being undertaken, and which will further include management options for implementation.

4. APPROACH

When establishing EcoSpecs, this process fully relied on all available data (i.e. JBS3, DWS River Eco-status Monitoring Programme (REMP), and the two (2) river field surveys undertaken). Thus, baseline conditions are available for the monitoring to be implemented, which must ensure that either the PES is maintained and/or the REC is achieved.

The river's condition is described in terms of biophysical components during the Eco-categorisation process. The drivers of the system include physical-chemical (water quality), hydrological and geomorphological components and the responses include fish, macroinvertebrates and the riparian vegetation components. Overall, it is these biophysical components which describe the state of the EWR site and forms the basis for indicator groups to be assessed during the ecological monitoring.

The EcoSpecs (and monitoring programme) is based on the level of detail available and confidence in the results from the surveys and the assessments per EWR site. Thus, more detailed EcoSpecs will be provided for the Intermediate EWR sites with less but focussed EcoSpecs for the Rapid level 3 EWR sites. The main impacts at the Rapid level 3 sites will be used to guide the selection of EcoSpecs and to inform the monitoring programme. The field verification sites were selected to provide an overview of the smaller tributaries in the study area. As such, only some of these sites have been selected (especially where water quality was impaired) and EcoSpecs developed.

4.1 Hydrology

The hydrological EcoSpecs for the EWR sites are included in the water quantity aspects of the Ecological Reserve as provided in the Rivers EWR Quantification Report (Report No. RDM/WMA13/00/CON/COMP/1323). These EcoSpecs are in the format of summary tables with the requirements specified for the various flow components and assurance tables or EWR rule curves. The curves specify the frequency of occurrence relationships of the defined maintenance and drought flow requirements for each month of the year. The tables thus specify the % of time that defined flows should equal or exceed the flow regime required to satisfy the ecological Reserve.

The following descriptors of the hydrological characteristics should be used:

- Total Mean Annual Maintenance Low flow volume
- Total Mean Annual Drought flow volume
- Monthly mean Maintenance Low and Drought flows
- Monthly exceedance curves for the complete flow regime

It is further important to include the specific duration, magnitude (daily averages), volume and timing of freshets and floods as specified in the EWR report.

A summary of the hydrological descriptors and detailed flood requirements are provided in this report with the monthly summary and rule tables available as electronic files. It is important to note that the floods as specified per EWR site should be used as the EcoSpec and not the

average monthly high flow values (maintenance high) in the summary tables as these floods were specified to provide specific functions to maintain the riverbed and channels to provide adequate habitats for the biota.

4.2 Water quality

During the initial desktop assessment of water quality data, significant gaps were identified in both reference and recent conditions at each EWR site. The analysis involved the use of various data sources to compile information on the current and historical physical-chemical state of the evaluated river systems and their associated catchments. The primary source was the DWS Resource Quality Information Services (RQIS) website, which is linked to the nationwide DWS monitoring network. However, data obtained from RQIS lacked reference or baseline conditions, mainly being collected after major impacts had occurred in the catchments. Furthermore, inconsistent monitoring practices resulted in substantial gaps spanning several years in the data. To address this, additional recent information was acquired from the DWS Free State Regional Office. Complementary data sources, including local conservation bodies, literature, and input from area experts, were also explored to enhance the overall understanding of water quality conditions in the studied areas.

Noting the above, and the aim to obtain some level of water quality baseline conditions, this study made use of valuable diatom data which was collected during both river surveys. It was the diatoms, and macroinvertebrate data, that was used to infer the reference conditions and the current status of the river systems from a water quality perspective. Diatoms are valuable indices of water quality owing to the following reasons:

- Long environmental memory: Analyses of diatom fossil records allow for the reconstruction of the history of water quality in an area. This is useful in assessing the changes in water over time and possibly infer the reference/natural state of the system in question (Harding and Taylor, 2014);
- Diverse species composition: Diatom communities exhibit extensive species diversity. Each species has unique preferences and tolerances to specific physical-chemical changes in their environment. By analysing diatom communities, it is possible to identify which physical-chemical properties have deviated from natural and are driving the physical-chemical status currently observed in the system in question;
- Indicators of nutrient enrichment: Nutrient enrichment is one of the leading contributors to impaired water quality in the catchment. This is largely due to the mismanaged wastewater treatment works, which discharge poorly and, in some cases, untreated wastewater into watercourses. Certain diatom species are known to be good indicators of eutrophic water bodies. Therefore, these species can be used for identifying river systems with elevated nutrient concentrations (Harding *et al.,* 2005; Kelly & Whitton, 1995);
- Sensitivity to pollutants: Diatoms are good indicators of inorganic pollution in river systems such as heavy metal pollution (Harding *et al.,* 2005); and
- Rapid assessment and monitoring: Diatom sampling is relatively easy, quick and ultimately cost effective (based on the integrated water quality picture that can be achieved with the results), and often in the absence of other water quality information. This allows for an effective and holistic assessment of water quality. It is acknowledged though that the analytical/ID skills are limited (Taylor *et al.,* 2005; Taylor *et al.,* 2007).

The establishment of water quality EcoSpecs primarily relies on diatom baseline data, acknowledging the absence of specific methods developed for deriving EcoSpecs and TPCs for diatoms, although some prior studies have experimented with this approach (DWS, 2015). The outlined approach is based on the Diatom Assessment Protocol, a Water Research Commission (WRC) initiative in South Africa by Taylor *et al*. (2007). Utilizing the OMNIDIA software (Version 5.3), developed for calculating diatom indices in water quality studies, the diatom community composition, temporal and spatial changes, and key indicator species/genera were assessed. These indicators, reflecting physical-chemical metrics such as pH, salinity, nutrients, oxygen, and organics, were identified based on their relevance to South African rivers (Dallas and Day, 2004). General guidelines per site were provided, specifying species influencing the Specific Pollution Index (SPI) score and pollution-related events leading to an increase in these species. Notably, the guidelines focus on species frequently observed during river surveys, serving as reliable indicators of deteriorated water quality conditions or changes in community composition at the EWR sites.

Furthermore, the water quality EcoSpecs and TPCs were also determined using the *in situ* water quality data measured during both river surveys. These parameters included pH, electrical conductivity, dissolved oxygen, salinity, temperature and clarity. However, owing to only two (2) measurements per site, the confidence is low. The same confidence applied to the diatoms.

4.3 **Geomorphology**

The geomorphological eco-categorisation process combined the system drivers (flow and sediment changes) and site character and pressures to produce an overall score. The assessment was based on historic aerial images, satellite images and a single site survey to capture some basic parameters. The eco-specifications and TPCs are based on the observed data that was part of the eco-categorisation process. The main indicators for the EcoSpecs are:

- Channel pattern – is there a shift in the channel pattern indicating changes to the drivers, such as a shift from single channel to braided channel due to increased sediment input or reductions in flow?
- Channel width – is there a change in channel width due to contraction or bank erosion?
- Channel depth – is there a shift in the bed level relative to the flood features due to sediment deposition, bed erosion and channel incision?
- Dominant mobile sediment type of riffles/rapids – is there a shift in the sediment composition of the riffle/rapid type habitat? Sedimentation will show a fining of the observed sediment size; and
- Extent of bank erosion – is there a large change in bank erosion indicating ongoing disturbance at the site or changes to the system drivers (flow and sediment supply)?

Due to natural variability, the EcoSpec measurements will vary over time, but the direction of change should not be uniform over time, i.e. channel incision increasing with every monitoring event.

4.4 Riparian vegetation

Riparian vegetation is best described by making comparisons against the natural / reference state (or condition) for the different zones (i.e. marginal, lower, upper zones) with specific assessments made using vegetation components. During the eco-categorisation phase, the following vegetation components were assessed using the Vegetation Response Assessment Index (VEGRAI) of Kleynhans *et al.* (2007) performed at each Intermediate EWR site to characterise the overall state of the riparian zone:

- Level of exotic vegetation / invasive alien plant species (both perennial and annual) that had infested the riparian zones:
    - The aerial cover of invasive alien plant species was estimated using aerial images supported by on-the-ground observations, the results of which indicate an important impact on riparian vegetation that affects the overall EC of the site (important to the note: the overall EC is a function of multiple deviations from the reference condition, and not merely the abundance of alien species).
- Terrestrialisation (terrestrial plant species encroaching within the riparian zone:
    - Under reference conditions, woody terrestrial species are not expected to occur within the marginal zone of the riparian zone. However, these species are expected to be present in the upper zone in quantities aligned with the natural flooding frequency, magnitude, and duration of the reach, as well as the adjacent terrestrial vegetation community.
- General vegetation structure and composition which includes:
    - Indigenous riparian woody species cover (this is more for those EWR sites where the macro-channel bank and alluvial bars is dominated by woody riparian species);
    - Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs; and
    - Reed cover as a separate non-woody component that typically assesses cover and abundance of *Phragmites sp*.

Thus, the EcoSpecs and TPCs were determined for these different components for riparian vegetation. It should be noted that the riparian vegetation at a number of the Intermediate EWR sites had been severely affected by recent flooding, which was more pronounced within the marginal zone, and to some degree the lower zone. This made it more challenging when determining EcoSpecs and TPCs that otherwise would have been more easily defined in time allowing for the plant communities to recover and stabilise.

4.5 Fish

The following data were used for determining EcoSpecs and TPSs for the fish community in the Upper Orange catchment area:

- Data collected during the two (2) river field surveys; and
- Relevant historic data and observations from previous surveys in the catchment.

EcoSpecs were subsequently delineated for various metrics, including:

- The PES of the fish assemblage;
- The Frequency of Occurrence (FROC) (Kleynhans and Louw, 2007) i.e.:
    - 0=absent;
    - 1=present at very few sites (<10%);

  - 2=present at few sites (>10 - 25%);
  - 3=present at about >25 - 50% of sites;
  - 4=present at most sites (>50 - 75%); and
  - 5=present at almost all sites (>75%).
- Indicator species: primary species or variable used as indicator for relevant metric. These indicator species were identified for each of these diverse metrics, with a focus on highlighting primary indicator species that would most effectively signal potential concerns, particularly in terms of flow and flow-related water quality;
- Species richness;
- Migratory requirements;
- Alien species; and
- Specific habitat features like fast shallow habitats and rocky substrates.

4.6 Macroinvertebrates

The following data were used for determining EcoSpecs and TPSs for the macroinvertebrate community in the Upper Orange catchment area:

- Data collected during the two (2) river field surveys; and
- Relevant historic data and observations from previous surveys in the catchment.

For each site, appropriate indicator taxa were chosen by utilising the macroinvertebrate preference data found in Thirion's (2007) Macroinvertebrate Response Assessment Index (MIRAI) spreadsheets, supplemented by specialist expertise. The MIRAI data delineate, for each taxon, preferences for various variables such as flow velocity, habitat types, and water quality, rated on a scale from 0 to 5. The preference is defined by the following ratings:

- 0 - No preference (does not occur);
- 1 - Very low preference (coincidental);
- 2 - Low preference;
- 3 - Moderate preference;
- 4 - High preference; and
- 5 - Very high preference.

Consequently, the indicator taxa were specifically chosen based on their preferences aligned with the community's key driver at the designated site and their sensitivities. Additionally, consideration was given to whether the taxon had been recorded during the site surveys conducted for this study or in prior REMP surveys, and/or whether they were expected, with a high FROC (4 or 5).

EcoSpecs are provided for several parameters, with the intention of supporting the monitoring process:

- MIRAI score;
- South African Scoring System version 5 (SASS5) and Average Score Per Taxon (ASPT);
- Diversity of invertebrate community;
- Physical habitat quality;
- Physical habitat diversity;
- Response to water quality;
- Indicator Taxon; and

- Alien invasive macroinvertebrates and/or outbreak/pest abundances

The establishment of EcoSpecs and TPCs is driven by a comprehensive understanding of the site, encompassing its hydrology, habitat characteristics, SASS5 and MIRAI scores, and macroinvertebrate preferences. Whenever feasible, the "presence/absence" and "abundance" of indicator taxa were provided to define the EcoSpec and TPC.

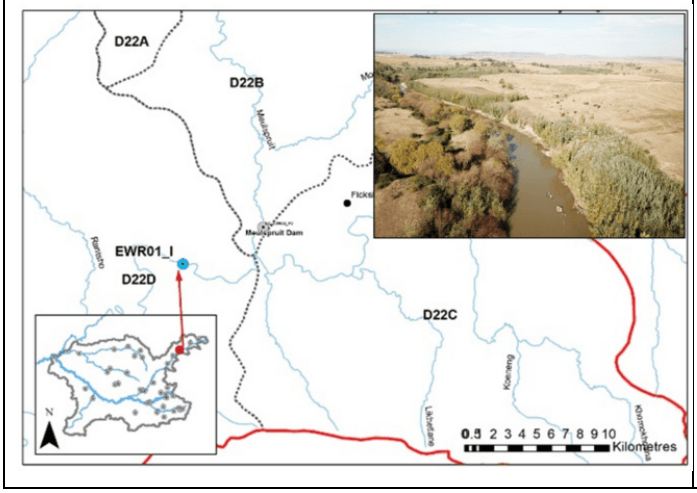
5. RIVERS: ECOLOGICAL SPECIFICATIONS AND TPCs

INTERMEDIATE EWR SITES

5.1 UO_EWR01_I: Middle Caledon

This EWR site is situated upstream and downstream of the confluence with the Rantsho and Meulspruit rivers near Ficksburg. The channel is partly confined with a deeply incised channel, approximately 50m wide, homogenous with some inundated sandbars. The riverbed is muddy, and both banks are sandy, steep, and highly erodible, with poor habitat availability and very turbid water. The surroundings consist of settlements, grazing areas, and small-scale croplands. The Lesotho side is heavily overgrazed and eroded, contributing to a high fine sediment load. The riparian zone has steep banks infested with invasive alien trees like Black Locust, Poplar, and Wattle, along with Weeping Willow. The marginal zone faces high baseflows, and lower banks lack vegetation, impacted by bank erosion, footpaths, and livestock trampling. Solid waste issues upstream contribute to a degraded overall EcoStatus categorized as E, indicating a seriously modified condition with severe stress on the system. Catchment degradation increases sediment loads and reduces habitat diversity. Alien infestations and bank erosion degrade the habitat, affecting fish and macroinvertebrates. Impoundments downstream act as barriers for fish migrations. Invasive alien trees demand significant investment for effective management, while solid waste and failing sewer systems pose growing threats to water quality.

Figure 5-1 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Middle Caledon
EWR Site Code	**UO_EWR01_I**
Driver component	**PES**
HAI	C
Diatoms	D
GAI	D
Response component	**PES**
FRAI	D
MIRAI	C
VEGRAI	E
Ecostatus	**E**
REC	**D**

Figure 5-1: UO_EWR01_I: Middle Caledon and associated PES/EcoStatus/REC

5.1.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-1** with the detailed flood requirements in **Table 5-3**. Monitoring of compliance to be undertaken at gauge D2H035.

Table 5-1: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
D	674.0	545.8	25.394	3.77	79.548	11.80	156.076	23.16

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-2: Final flood requirements for the Middle Caledon (UO_EWR01_I)

Floods	Criteria	FINAL
Class 1	m^3/s	20
	# days	4
	Months	Oct-Jan, Mar, Apr
	Type	Average
Class 2	m^3/s	35
	# days	5
	Months	Nov-Mar
	Type	Average
Class 3	m^3/s	60
	# days	3
	Months	Jan, Feb
	Type	Peak

5.1.2 Water quality: EcoSpecs and TPCs

Due to the limited baseline physical-chemical water quality data, the South African Water Quality Guidelines for aquatic ecosystems (DWAF, 1996) were used. The Target Water Quality Requirements (TWQR), Chronic Effect Value (CEV), and Acute Effect Value (AEV) for each water quality parameter are shown in **Table 5-3**. These can be viewed as the EcoSpecs and are not to be exceeded for all parameters for all EWR sites and field verification sites. Furthermore, refer to **Table 5-4** for the EcoSpecs and TPCs for the Diatoms, indicative of the ecological water quality.

Table 5-3: Water quality EcoSpecs based on TWQR (DWAF, 1996)

Parameter	Unit	TWQR	CEV	AEV	Notes
Aluminium* (pH<6.5)	µg/L	5.00	10.00	100.00	†
Aluminium (pH>6.5)	µg/L	10.00	20.00	150.00	†

Parameter	Unit	TWQR	CEV	AEV	Notes
Ammonia (un-ionised)	µg N/L	7.00	15.00	100.00	†§
Arsenic	µg/L	10.00	20.00	130.00	†
Atrazine	µg/L	10.00	19.00	100.00	†
Cadmium* ($CaCO_3$/L = <60mg)	µg/L	0.15	0.30	3.00	†
Cadmium ($CaCO_3$/L = 60-119mg)	µg/L	0.25	0.50	6.00	†
Cadmium ($CaCO_3$/L = 120-180mg)	µg/L	0.35	0.70	10.00	†
Cadmium ($CaCO_3$/L = >180mg)	µg/L	0.40	0.80	13.00	†
Cadmium criteria for cold water adapted fish species					†
Cadmium ($CaCO_3$/L = <60mg)	µg/L	0.07	0.15	1.80	†
Cadmium ($CaCO_3$/L = 60-119mg)	µg/L	0.10	0.19	2.80	†
Cadmium ($CaCO_3$/L = 120-180mg)	µg/L	0.15	0.29	5.10	†
Cadmium ($CaCO_3$/L = >180mg)	µg/L	0.17	0.34	6.20	†
Chlorine	µg/L	0.20	0.35	5.00	†
Chromium (VI)	µg/L	7.00	14.00	200.00	†
Chromium (III)	µg/L	12.00	24.00	340.00	†
Copper* ($CaCO_3$/L = <60mg)	µg/L	0.30	0.53	1.60	†
Copper ($CaCO_3$/L = 60-119mg)	µg/L	0.80	1.50	4.60	†
Copper ($CaCO_3$/L = 120 -180mg)	µg/L	1.20	2.40	7.50	†
Copper ($CaCO_3$/L = >180mg)	µg/L	1.40	2.80	12.00	†
Cyanide	µg/L	1.00	4.00	110.00	†
Dissolved Oxygen	%	80-120	60.00	40.00	φ
Endosulfan	µg/L	0.01	0.02	0.20	†
Fluoride	µg/L	750.00	1500.00	2540.00	†
Iron		10%**	10%**	10%**	†
Lead* ($CaCO_3$/L = <60mg)	µg/L	0.20	0.50	4.00	†
Lead ($CaCO_3$/L = 60-119mg)	µg/L	0.50	1.00	7.00	†

Parameter	Unit	TWQR	CEV	AEV	Notes
Lead ($CaCO_3$/L = 120 -180mg)	µg/L	1.00	2.00	13.00	†
Lead ($CaCO_3$/L = >180mg)	µg/L	1.20	2.40	16.00	†
Manganese	µg/L	180.00	370.00	1300.00	†
Mercury	µg/L	0.04	0.08	1.70	†
Nitrogen	mg/L	0.50	2.50	10.00	††
pH		5%**	5%**	5%**	§§
Phenol	µg/L	30.00	60.00	500.00	†
Phosphorus (inorganic)	µg/L	5.00	25.00	250.00	††
Selenium	µg/L	2.00	5.00	30.00	†
Total Dissolved Solids (TDS)	mg/L	15%**	15%**	15%**	φφ
Suspended solids	mg/L	10%**	10%**	10%**	†††
Zinc	µg/L	2.00	3.60	36.00	†

** Target Water Quality Requirements (TWQR), Chronic Effect Value (CEV), and Acute Effect Value (AEV) depend on the pH and / or water hardness ($CaCO_3$/L).*

*** Concentrations should be within specified percentage of background values.*

† 90% of all measurements should be within the TWQR. All measurements must be below the CEV to ensure protection of aquatic ecosystems. Where only sparse or sporadic data are available, interpretation should take into account the fact that the data may not be representative. In the case of accidental spills, chronic and acute toxicity effects will occur if measurements exceed the AEV.

§ Single measurements of ammonia are of limited use. Preferably, weekly ammonia concentrations, averaged over a period of at least 4 weeks, with the minimum and maximum values should be reported and compared to the TWQR.

φ Single values are not of use. The arithmetic mean of the daily (24-hour) minimum instantaneous concentrations measured at hourly intervals over seven consecutive days or 1-day minimum concentration should be compared to the TWQR.

†† Single measurements are a poor basis for assessment. Occasional increases concentration above the TWQR are less important than continuously high concentrations. Average summer concentrations provide the best basis from which to estimate the likely biological consequences. Weekly concentrations, averaged over a period of at least 4 weeks, should be compared with the TWQR.

§§ Background pH values, in addition to diel and seasonal variability, need to be established if deviations from natural pH values are to be assessed. The significance of pH changes to aquatic biota depends on the extent, duration and timing of the changes. Small changes in pH often cause large changes in the concentration of available metallic complexes and can lead to significant increases in the availability and toxicity of most metals. All pH measurements for the site in question should be within the TWQR.

φφ Changes in electrical conductivity (EC) provide useful and rapid estimates of changes in the TDS concentration, once the relationship between EC and TDS has been established for a particular water body. However, changes in EC values provide no information on the changes in the proportional

concentrations of the major ions. Similarly, the relationship between TDS and EC will not reflect changes in the concentration of minor ions and nutrients such as phosphate and nitrate. Changes in the long-term shifts in the TDS concentration are more important than single values. Therefore, mean or seasonal mean values for the concentrations in a dataset should be compared with the TWQR.

††† All TSS measurements should be within the TWQR. Changes in TSS concentration that are unrelated to natural variation (e.g., diel and seasonal patterns) may have effects on biodiversity. Background TSS levels need to be established if deviations from such "natural" levels for a particular water body at a particular time are assessed. The significance of changes in TSS depends on the extent, duration, frequency and timing of the changes. Elevated levels of TSS will have a greater effect in areas which have lower background TSS levels.

Table 5-4: Diatom EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Diatoms		
Diatoms	SPI Score: 8.6 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality

**Specific Pollution sensitivity Index (>17: A-high water quality; 13-17: B-good water quality; 9-13: C-moderate water quality; 5-9: poor water quality; and <5: E seriously modified water quality) (adapted from Eloranta & Soininen, 2002)*

5.1.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-5**.

Table 5-5: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	D	E or lower
Channel pattern	Single wandering channel, possibly braided during very low baseflows	Braided channel except for the lowest baseflows where a braided channel might be observed
Channel width	~ 50 m wide macro channel	Macro channel narrows to <40m or widens to >60m
Median particle size of riffle/rapid	Medium gravel (13 mm)	No gravels along faster flow paths
Extent of bank erosion	~ 50%	>70%

5.1.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-6**.

Table 5-6: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 40% for entire riparian zone.	Alien species cover increases above 40% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 5 - 20%. Indigenous non-woody vegetation cover maintained between 10 – 50%.	Indigenous woody vegetation cover decreases below 5% or increases above 20%. Indigenous non-woody vegetation cover decreases below 10% or increases above 50%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by non-woody species.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 30%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 30%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the lower zone, dominated by non-woody species.	Diversity of indigenous species within the lower zone decreases below 5 species.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 -	Indigenous woody vegetation cover decreases below 10% or

Metric	EcoSpec	TPC
	40%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 30 – 60%.	increases above 40%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 30% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the upper zone, dominated by non-woody species.	Diversity of indigenous species within the upper zone decreases below 5 species.

5.1.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-7.**

Table 5-7: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at about 25% to 50% of sites during summer (FROC = 3)	Absent from all sites during summer
	Labeo capensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Absent from all sites during summer
Fish habitats and cover features	Fast-deep Slow-deep Undercut Banks	Maintenance of fast-deep and slow-deep habitats with undercut banks	Loss of undercut banks as a cover feature

5.1.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality**.

The indicator taxa selected for this site are listed in **Table 5.8**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007).

To reiterate and applies for all sites, the indicator macroinvertebrate taxa were specifically chosen based on their preferences aligned with the community's key driver at the designated site and their sensitivities. Additionally, consideration was given to whether the taxon had been recorded during the site surveys conducted for this study or in prior DWS REMP monitoring events, and/or whether they were expected, with a high FROC (4 or 5). In addition, indicator taxa marked with an *asterisk* signify families that haven't been recorded but are expected for the reach, with a high FROC. Therefore, documenting these indicator taxa could potentially enhance the macroinvertebrate PES at the site, thereby potentially contributing to achieving the sites identified REC. Grey cells indicate the preferences of the macroinvertebrates to the velocity and substrate classes. This applies for all the matching tables throughout the report.

Table 5-8: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
* Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Caenidae	6	4.5	3.5	3	3	3	3	4.5	0	LOW
Gomphidae	6	4.5	4	3	2.5	2.5	1	4.5	0	LOW
Hydropsychidae 1sp	4	1	2.5	4	4.5	4.5	1	1.5	0	LOW

[1] SQ: sensitivity score of the indicator macroinvertebrate [2]Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired water quality. Grey cells indicate the preferences of the macroinvertebrates to the velocity and substrate classes. This applies for all the matching tables throughout the report.

Please refer to **Table 5-9** for the proposed EcoSpecs and TPCs.

Table 5-9: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 62.0% (Category C). The MIRAI score to be maintained as a mid-C in the range >62 – 70%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤ 61%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 69 with an ASPT of 4.9. Total SASS5 score should remain >75, with ASPT value >5.2.	PES: SASS5 scores <45 and ASPT <4.0.
Diversity of invertebrate community	-	PES: 10 families were collected during the field survey (14 families in total taking into account a survey conducted at the same site in 2021). Of these, one scored ≥ 10 sensitivity. More than 14 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present (although should Leptophlebiidae be recorded, this may improve the ASPT of the community).	PES: Less than 10 taxa collected. Less than 2 taxa with a sensitivity scoring of ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual - Moderate turbidity, although when water levels are lower, the clarity should increase. Moderate levels of silt.	Increase in sediment deposition, highly turbid conditions within the water column.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat diversity	Biotopes and diversity	GSM (including pockets of gravel) and marginal vegetation should be available to sample.	A reduction in pockets of gravel and lack of inundated marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Gomphidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.

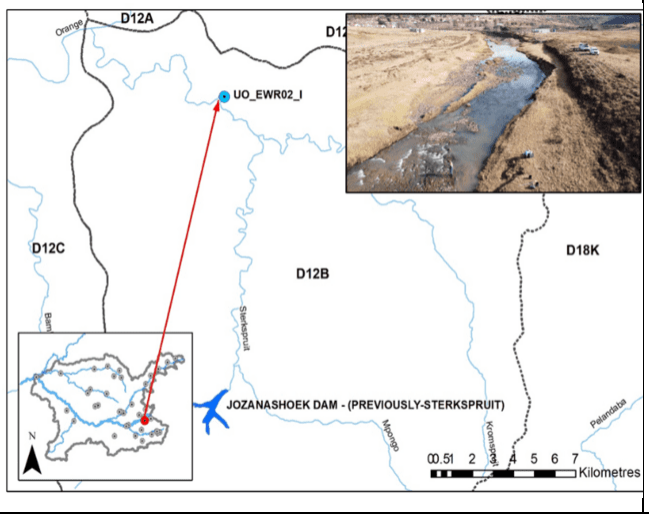
Parameter	Indictor[1]	EcoSpec	TPCs
	Hydropsychidae 1sp	Hydropsychidae 1 spp present in ≥A abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Absence of Hydropsychidae 1 spp in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.

*[1]The habitat preferences of indicator genera are listed in the Macroinvertebrate Response Assessment Index (MIRAI) worksheets, which are provided electronically. *The indicator taxa signify families that haven't been recorded but are expected for the reach, with a high FROC. Therefore, documenting these indicator taxa could potentially enhance the macroinvertebrate PES at the site, thereby potentially contributing to achieving the sites identified REC – should the REC be better than the identified PES of the macroinvertebrates assemblage. This note applies to all macroinvertebrate EcoSpecs and TPC tables throughout the report.*

5.2 UO_EWR02_I: Sterkspruit

The site, situated downstream from Sterkspruit and Hershell towns, but upstream of the Sterkspruit sewage maturation pond, exhibits a confined valley setting with cobbles, boulders, and bedrock forming riffles and pools. The river, approximately 5m to 10m wide (macro channel 30m wide), shows signs of modifications with erosion on both banks, cattle trampling, and grazing. The overall EcoStatus for this EWR site is categorised as D, indicating serious modification, with a notable loss of natural habitat and ecosystem functions. The catchment degradation contributes to elevated suspended sediment loads, channel sedimentation, and reduced habitat diversity. Marginal disturbance degrades habitat along the inset benches and banks. Water quality is severely compromised due to dysfunctional and unmaintained WWTW facilities, including the adjacent maturation pond discharging directly into the river downstream of the site. This compromises the health and integrity of the biotic community. Macroinvertebrates show a response to poor water quality, despite available habitat. From a fish perspective, although the reach isn't expected to support a diverse fish assemblage under reference conditions, current catchment practices and failing sewage infrastructure result in lower frequencies of occurrence of expected species and the loss of several species from the reach. The riparian vegetation has suffered from years of livestock and town development impacts, including overgrazing, trampling, and bank erosion/collapse. Recent illegal sand mining activities have further degraded riparian habitats.

Figure 5-2 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Sterkspruit
EWR Site Code	UO_EWR02_I
Driver component	PES
HAI	C
Diatoms	C
GAI	D
Response component	PES
FRAI	D/E
MIRAI	D
VEGRAI	D
Ecostatus	D
REC	C/D

Figure 5-2: UO_EWR02_I: Sterkspruit and associated PES/EcoStatus/REC

5.2.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-10** with the detailed flood requirements in **Table 5-11**. As no gauge situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-10: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C/D	30.7	25.2	0.016	0.05	4.712	15.33	11.814	38.43

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-11: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	4
	# days	4
	Months	Average
	Type	Nov, Dec, Feb, Apr
Class 2	m^3/s	10
	# days	**3**
	Months	Average
	Type	Jan, Feb
Class 3	m^3/s	15
	# days	2
	Months	Peak
	Type	Mar

5.2.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-12**.

Table 5-12: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 12.1 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

5.2.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-13**.

Table 5-13: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	D or higher	E or lower
Channel pattern	Single wandering channel	Braided or incised straight channel
Channel width	Macro channel of ~30 m wide	Macro channel width of <20 m or >40 m
Median particle size of riffle/rapid	Coarse gravels (29 mm)	Loss of gravels with cobble becoming dominant, or sand dominating the riffle habitat
Extent of bank erosion	20%	>50%

5.2.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-14**.

Table 5-14: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 5%. Indigenous non-woody vegetation cover maintained between 20 – 60%.	Indigenous woody vegetation cover increases above 5%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the marginal zone, dominated by *Cyperus marginatus* and a scattered	Diversity of indigenous species within the marginal zone decreases below 10 species, with *Cyperus marginatus* not dominant and *Gomphostigma virgatum* absent.

Metric	EcoSpec	TPC
	presence of *Gomphostigma virgatum*.	
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained between 40 – 80%.	Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, dominated by *Cynodon dactylon*.	Diversity of indigenous species within the lower zone decreases below 10 species,
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained between 40 – 80%.	Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.2.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-15.**

Table 5-15: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites (FROC = 4)	Present at <50% of sites (FROC ≤3)

Metric	Indicator	EcoSpec	TPC (biotic)
Fish habitats and cover features		Fast-shallow velocity-depth class present in moderate abundance (3)	Fast-shallow class sparse or rare (≤2)
Substrate	Substrate within reach	Maintenance of riffle/rapid substate	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.2.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'D' (largely modified) using the MIRAI methodology, was found to be **water quality**.

The indicator taxa selected for this site are listed in **Table 5-16**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007). The EcoSpecs and TPCs in **Table 5-17**.

Table 5-16: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Perlidae	12	0.5	3	4	3.5	4	0.5	1.5	0	HIGH
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE
* Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Aeshnidae	8	2.5	3.5	4	2.5	4	3	3	0	MODERATE

Table 5-17: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 49.4% (Category D).	PES: MIRAI ≤41% REC: MIRAI ≤57%

Parameter	Indictor[1]	EcoSpec	TPCs
		The MIRAI score to be maintained as a mid-D in the range >42 – 52%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	
SASS5 and ASPT Score	-	PES: The SASS5 score was 109 with an ASPT of 5.7. Total SASS5 score should remain >115, with ASPT value >5.8. REC: SASS5 score ≥130, with ASPT value > 6.0.	PES: SASS5 scores <100 and ASPT <5.5. REC: SASS5 scores < 140, ASPT < 6.5.
Diversity of invertebrate community	-	PES: 19 families were collected during both surveys. Of these, 3 scored ≥ 10 sensitivity. More than 19 different families (taxa) should be present, with at least 4 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 25 families should occur at an abundance of A to B, which should include expected taxa with a high FROC, which were not recorded namely Leptophlebiidae and Hydropsychidae >2spp in ≥A abundances.	PES: Less than 15 taxa collected. Less than 2 taxa with a sensitivity scoring of ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 23 families, with less than two taxa scoring ≥ 10. Taxon namely Leptophlebiidae and Hydropsychidae >2spp not recorded. Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat quality	Biotopes and quality	Visual: The small cobbles area downstream, upstream and along the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Perlidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances	Baetidae 2 spp or less in two consecutive samples.

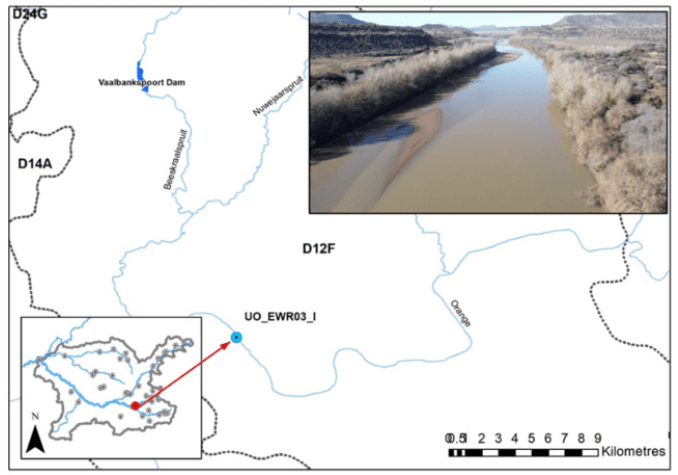
Parameter	Indictor[1]	EcoSpec	TPCs
		Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s – 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependent taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.

5.3 UO_EWR03_I: Upper Orange

The site, situated in a partially confined valley with terraces and narrow flood benches, features a ~120m wide river with a homogenous sand bed channel and limited habitat diversity. Located approximately 8 km upstream from the Kraai River confluence, the area is predominantly agricultural with small-scale croplands and grazing areas. The EcoStatus for this EWR site is categorized as D, largely modified, attributed to in-stream sand mining, elevated sediment loads, channel sedimentation, and reduced habitat diversity. Disturbance along the margins degrades habitat associated with inset benches and banks, impacting the biota, including fish and macroinvertebrates. Large impoundments in the upper catchment (Lesotho) alter hydrology and substrate diversity in the reach. Impoundments and weirs below the reach act as migratory barriers, particularly for fish species moving upstream from the Orange River system during seasonal migrations. The presence of the Gariep Dam artificially elevates source populations for several fish species, including alien species. The riparian vegetation faces challenges from alien tree invasions, leading to the loss of functions provided by native species, particularly in protecting and stabilizing banks against floods and erosion.

Figure 5-3 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Upper Orange
EWR Site Code	UO_EWR03_I
Driver component	PES
HAI	D
Diatoms	C
GAI	C
Response component	PES
FRAI	D
MIRAI	C/D
VEGRAI	D
Ecostatus	D
REC	D

Figure 5-3: UO_EWR03_I: Upper Orange and associated PES/EcoStatus/REC

5.3.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-18** with the detailed flood requirements in **Table 5-19**. Although no gauge in close vicinity of this site, gauge D1H009 can be used for flood monitoring. For baseflows, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-18: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
D	4 259.5	3 456.3	206.669	4.85	554.061	13.01	1 067.45	25.06

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-19: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	200
	# days	5
	Months	Oct-Dec, Mar, Apr
	Type	Average
Class 2	m^3/s	400
	# days	3
	Months	Jan, Mar
	Type	Average
Class 3	m^3/s	800
	# days	6
	Months	Feb
	Type	Peak

5.3.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-20**.

Table 5-20: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 9.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

5.3.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-21.**

Table 5-21: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C or higher	D or lower
Channel pattern	Single wandering channel, possibly braided during very low baseflows	Braided channel except for the lowest baseflows where a braided channel might be observed
Channel width	~ 120 m wide macro channel	Macro channel >140 m or <100 m
Median particle size of riffle/rapid	Sand	If the bed is dominated by silt or gravel/cobble
Extent of bank erosion	40%	>60%

5.3.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-22.**

Table 5-22: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 40% for entire riparian zone.	Alien species cover increases above 40% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 5 - 20%. Indigenous non-woody vegetation cover maintained between 10 – 50%.	Indigenous woody vegetation cover decreases below 5% or increases above 20%. Indigenous non-woody vegetation cover decreases below 10% or increases above 50%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal	Diversity of indigenous species within the marginal zone decreases below 5 species.

Metric	EcoSpec	TPC
	zone, dominated by *Phragmites australis*.	
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 30%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 30%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the lower zone, with a mix of woody and non-woody species (including a small proportion of terrestrial species).	Diversity of indigenous species within the lower zone decreases below 5 species and dominated by either woody or non-woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 50 - 80%, with terrestrial species making up to 60% of the cover. Indigenous non-woody vegetation cover maintained between 10 – 30%.	Indigenous woody vegetation cover decreases below 50% or increases above 80%, with terrestrial species cover increasing above 60%. Indigenous non-woody vegetation cover decreases below 10% or increases above 30%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 20 indigenous species within the upper zone, dominated by terrestrial woody species.	Diversity of indigenous species within the upper zone decreases below 5 species.

5.3.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-23.**

Table 5-23: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Absent from all sites during summer
	Labeo capensis	Present at most sites during summer (FROC = 4)	Absent from all sites during summer
Fish habitats and cover features	Fast-deep Slow-deep Undercut Banks	Maintenance of fast-deep and slow-deep habitats with undercut banks	Loss of undercut banks as a cover feature

5.3.6 Macroinvertebrates: EcoSpecs and TPCs

Habitat availability is constrained at this location, characterised by a broad and uniform alluvial system that exclusively offers the GSM biotope and sparse marginal vegetation for the macroinvertebrate community. Consequently, the macroinvertebrate community exhibited a sensitivity to physical-chemical conditions ranging from low to very low, and a corresponding sensitivity to limited habitat availability. Consequently, the leading factor influencing the macroinvertebrate PES, rated with an ecological category of a 'C/D' (moderately to largely modified) by the MIRAI methodology, was **water quality,** followed closely by the deficiency in **habitat availability**.

The macroinvertebrate indicator taxa are listed in **Table 5-24**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007). The EcoSpecs and TPCs in **Table 5-25.**

Table 5-24: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
*Aeshnidae	8	2.5	3.5	4	2.5	4	3	3	0	MODERATE
*Elmidae	8	1.5	3	4	4.5	4	1	3.5	0	MODERATE
*Baetidae 2spp	6	3	3.5	4	4	4	4	4	0	LOW
Caenidae	6	4.5	3.5	3	3	3	3	4.5	0	LOW
*Gomphidae	6	4.5	4	3	2.5	2.5	1	4.5	0	LOW

Table 5-25: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 60.5% (Category C/D).	PES: MIRAI ≤57%.

Parameter	Indictor[1]	EcoSpec	TPCs
		The MIRAI score to be maintained between >58 - ≤62%, using the reference data used in this study, or recording alterations to these.	
SASS5 and ASPT Score	-	PES: The SASS5 score was 46 with an ASPT of 4.6. Total SASS5 score should remain >60, with ASPT value >5.0.	PES: SASS5 scores <40 and ASPT <4.0.
Diversity of invertebrate community	-	PES: 10 families were collected during the field survey. Of these, no taxa scored ≥ 10 sensitivity. More than 10 different families (taxa) should be present, with at least 2 of these scoring ≥ 7, and at an abundance of A to B. Most indicators selected were not recorded but expected with high FROCs. Thus at least 2 of those expected should be recorded.	PES: Less than 10 taxa collected. Less than 2 taxa scoring ≥ 7. None of the indicator taxon recorded, especially Caenidae. Any taxon (adults) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: Moderate turbidity, although when water levels are lower, the clarity should increase. Moderate levels of silt.	Increase in sediment deposition, highly turbid conditions within the water column.
Physical habitat diversity	Biotopes and diversity	GSM (including pockets of gravel) and marginal vegetation should be available to sample.	A reduction in pockets of gravel and lack of inundated marginal vegetation.

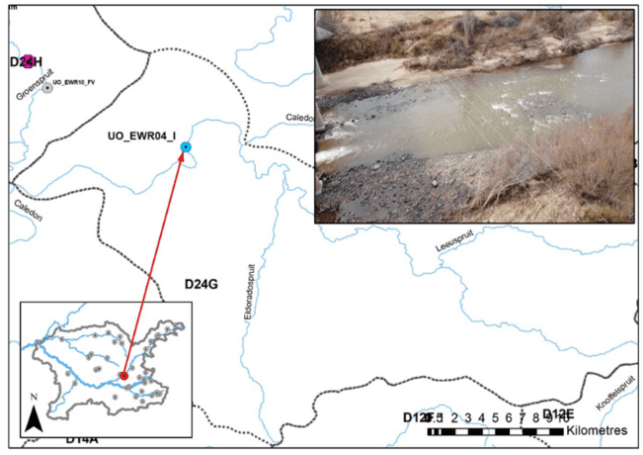
Parameter	Indictor[1]	EcoSpec	TPCs
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	*Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	*Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
	*Baetidae 2spp	Baetidae >2 spp present in ≥A abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
		- 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	*Gomphidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.4 UO_EWR04_I: Lower Caledon

Located just downstream of the N6 road bridge between Rouxville and Smithfield, the with transfers of water from the Caledon River to the Knellpoort Dam and Welbedacht Dam approximately 100 km upstream. The area is predominantly used for extensive sheep farming, featuring localized irrigation of lucerne from the Caledon River. The overall EcoStatus for this EWR site is classified as largely modified (Category D). Catchment degradation is fuelled by elevated suspended sediment loads, leading to channel sedimentation and reduced habitat diversity. The site experiences high disturbance along the margins, resulting in the degradation of habitats associated with inset benches and banks. The altered system dynamics at the catchment scale compromise the integrity of the biota. The presence of Welbedacht Dam and catchment activities, including high erosion rates due to the loss of basal cover, intensive cultivation, and increased catchment development, contribute to modifications in hydrology and water quality. In terms of the fish, migratory barriers are present both downstream (Gariep Dam, Van Der Kloof Dam) and upstream (Welbedacht Dam). Riparian vegetation has been directly impacted by the bridge construction, with localized stormwater runoff and erosion. The area has also witnessed a moderate infestation of alien invasive plants and the encroachment of woody shrubs. Recent flooding has removed most non-woody vegetation, including trees and shrubs established along the margins and lower banks.

Figure 5-4 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Lower Caledon
EWR Site Code	UO_EWR04_I
Driver component	PES
HAI	C
Diatoms	D
GAI	C
Response component	PES
FRAI	D
MIRAI	D
VEGRAI	D
Ecostatus	D
REC	C/D

Figure 5-4: UO_EWR04_I: Lower Caledon and associated PES/EcoStatus/REC

5.4.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-26** with the detailed flood requirements in **Table 5-27**. Although no gauge in close vicinity of this site, gauge D2H033 downstream of Welbedacht Dam can be used for flood monitoring. For baseflows, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-26: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C/D	1 353.6	1 109.8	36.860	2.72	203.857	15.06	398.387	29.43

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-27: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	40
	# days	5
	Months	Oct-Dec, Mar, Apr
	Type	Average
Class 2	m^3/s	65
	# days	5
	Months	Nov, Dec, Jan, Mar
	Type	Average
Class 3	m^3/s	110
	# days	4
	Months	Jan, Feb, Mar
	Type	Average
Class 4	m^3/s	160
	# days	7
	Months	Feb
	Type	Peak

5.4.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-28**.

Table 5-28: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 9.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

5.4.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-29**.

Table 5-29: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C or higher	D or lower
Channel pattern	Single wandering channel, possibly braided during very low baseflows	Braided channel except for the lowest baseflows where a braided channel might be observed
Channel width	Macro channel of ~70 m	Macro channel of <50 m or >90 m
Median particle size of riffle/rapid	Very coarse gravels (42 mm)	If the mobile sediment at the riffle changes to sand/silt or only cobble and boulder
Extent of bank erosion	~ 30%	>50%

5.4.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-30**.

Table 5-30: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.

Metric	EcoSpec	TPC
Exotic vegetation	Alien species cover maintained below 20% for entire riparian zone.	Alien species cover increases above 20% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%. Indigenous non-woody vegetation cover maintained between 10 – 40%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%. Indigenous non-woody vegetation cover decreases below 10% or increases above 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 15 - 30%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 10 – 60%.	Indigenous woody vegetation cover decreases below 15% or increases above 30%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 10% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody and non-woody species (including a small proportion of terrestrial species).	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 20 - 50%, with terrestrial species making up to 30% of the cover.	Indigenous woody vegetation cover decreases below 20% or increases above 50%, with terrestrial species cover increasing above 30%.

Metric	EcoSpec	TPC
	Indigenous non-woody vegetation cover maintained between 30 – 60%.	Indigenous non-woody vegetation cover decreases below 30% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, dominated by grasses and terrestrial woody species.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.4.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-31**.

Table 5-31: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤3)
	Labeo capensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites (FROC ≤2)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.4.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as an ecological category 'D' (largely modified) using the MIRAI methodology, was found to be **water quality**.

The indicator taxa selected for this site are listed in **Table 5-32**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007). It is further worth noting that one of the selected indicator families being Hydropschyidae, are not highly responsive to declines in water quality. Therefore, if there are future alterations in flow conditions that fail to meet the requirements of the EWR, this family may no longer persist at the site due to flow alternation, despite the quality of the water. The EcoSpecs and TPCs in **Table 5-33**.

Table 5-32: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE
*Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
*Aeshnidae	8	2.5	3.5	4	2.5	4	3	3	0	MODERATE
*Baetidae 2spp	6	3	3.5	4	4	4	4	4	0	LOW
*Caenidae	6	4.5	3.5	3	3	3	3	4.5	0	LOW
Gomphidae	6	4.5	4	3	2.5	2.5	1	4.5	0	LOW

Table 5-33: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 46.0% (Category D). The MIRAI score to be maintained as a mid-D in the range >42 – 52%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 43 with an ASPT of 4.8. Total SASS5 score should remain >60, with ASPT value >5.2. REC: SASS5 score ≥100, with ASPT value > 5.8.	PES: SASS5 scores <40 and ASPT <4.2. REC: SASS5 scores < 120, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 9 families were collected during both surveys. Of these, 1 scored ≥ 9 sensitivity. More than 9 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 14 families should occur at an abundance of A to B, which should include 2 or more expected indicator taxa in ≥A abundances.	PES: Less than 8 taxa collected. No taxa scoring ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 14 families, with less than 2 taxa scoring ≥ 10. None of the expected indicator taxon recorded. Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat quality	Biotopes and quality	Visual: The small artificial cobble area located just downstream of the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys.

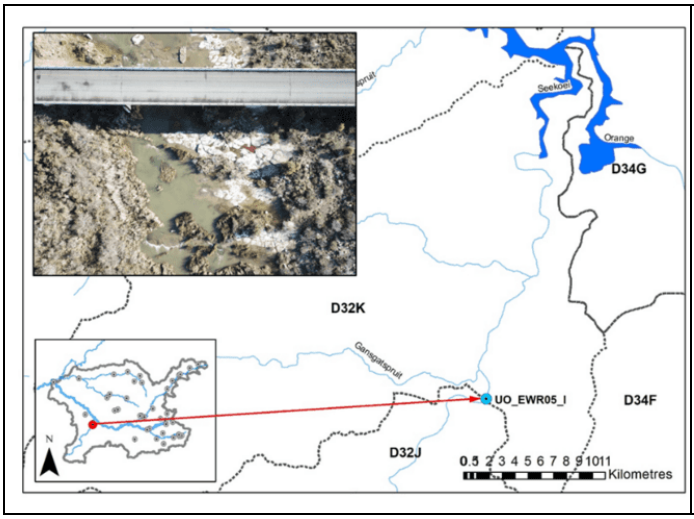
Parameter	Indictor[1]	EcoSpec	TPCs
		dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	*Baetidae 2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Caenidae	Caenidae present in ≥B abundances.	Caenidae absent (or individuals only) on two or more consecutive surveys

Parameter	Indictor[1]	EcoSpec	TPCs
		These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Biotopes are exposed.
	Gomphidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.5 UO_EWR05_I: Seekoei

The reach, located off a district road R369, is relatively unconfined with a river incised into the valley floor. Flood features are narrow, and the river pattern is straight to sinuous with various habitats available, including bedrock, boulder, cobble, and gravel. Positioned approximately 40 km northwest from Colesberg and 60 km downstream of the Karoo Gariep Nature Reserve, the overall EcoStatus for this EWR site is categorised as moderately modified (Category C). There has been a loss and change of natural habitat and biota frequencies and abundances. Upstream catchment degradation resulted in increased suspended sediment loads. However, multiple weirs trap most of the sediment. Margin disturbance at the site is relatively low, with degradation of habitat associated with inset benches and banks. All expected fish species, including non-native ones, are present. However, the system's fragmentation due to various weirs likely impacts species, decreasing recruitment from limited access to suitable spawning areas. The macroinvertebrate community, though not diverse, responds to water quality modifications. Riparian vegetation is relatively good, with impacts mainly attributed to weir and bridge activities, resulting in vegetation removal. The site has a low infestation of alien plants.

Figure 5-5 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Seekoei
EWR Site Code	UO_EWR05_I
Driver component	PES
HAI	B/C
Diatoms	C
GAI	C
Response component	PES
FRAI	C
MIRAI	C
VEGRAI	B/C
Ecostatus	C
REC	C

Figure 5-5: UO_EWR05_I: Seekoei and associated PES/EcoStatus/REC

5.5.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-34** with the detailed flood requirements in **Table 5-35**. Monitoring of compliance to be undertaken at gauge D3H015.

Table 5-34: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)

C	24.279	18.397	0	0	1.043	4.30	8.301	34.19

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-35: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	5
	# days	2
	Months	Oct-Jan, Apr, May
	Type	Average
Class 2	m^3/s	10
	# days	2
	Months	Feb
	Type	Average
Class 3	m^3/s	20
	# days	2
	Months	Mar
	Type	Peak

5.5.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-36**.

Table 5-36: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 12.4 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

5.5.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-37**.

Table 5-37: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C or higher	D or lower
Channel pattern	Straight to wandering channel	Braided channel
Channel width	Macro channel of ~50 m	<40 m or >65 m
Median particle size of riffle/rapid	Coarse gravels (20 mm)	If the riffle habitat has no gravels and cobbles (bedrock only), or when the riffle habitat is largely sand and silt
Extent of bank erosion	15%	>40%

5.5.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-38**.

Table 5-38: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained between 40 – 70%.	Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 40% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.

Metric	EcoSpec	TPC
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 20 - 40%, with terrestrial species making up less than 20% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 40%.	Indigenous woody vegetation cover decreases below 20% or increases above 40%, with terrestrial species cover increasing above 20%. Indigenous non-woody vegetation cover decreases below 20% or increases above 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with *Phragmites australis* dominating.	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 30 - 60%, with terrestrial species making up to 50% of the cover. Indigenous non-woody vegetation cover maintained between 20 – 40%.	Indigenous woody vegetation cover decreases below 30% or increases above 60%, with terrestrial species cover increasing above 50%. Indigenous non-woody vegetation cover decreases below 20% or increases above 40%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, dominated by terrestrial woody species and low shrubs.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.5.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-39**.

Table 5-39: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)

Metric	Indicator	EcoSpec	TPC (biotic)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Present at <50% of sites during the summer (FROC ≤3)
	Labeo capensis	Present at most sites during summer (FROC = 4)	Present at <50% of sites during the summer (FROC ≤3)
Velocity-depth class	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class

5.5.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality**. It further must be noted that this sites biotope was dominated by bedrock, which is not a preferrable biotope for most macroinvertebrates. This was taken cognisance of when selected the indicator taxon. Thus, should the listed indicator taxa in **Table 5-40** be recorded, the site will be maintained at the identified baseline of a C Category.

The indicator taxa selected for this site are listed in **Table 5-40**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007).

The EcoSpecs and TPCs in **Table 5-41**.

Table 5-40: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
*Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
*Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE
*Atyidae	8	4	3.5	0.5	0	1	4.5	0.5	0	MODERATE
Hydraenidae	8	1	1.5	3	4	4	3	1.5	3	MODERATE

Table 5-41: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 67.2% (Category C). The MIRAI score to be maintained between >65 - ≤78%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤61%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 138 with an ASPT of 4.6. Total SASS5 score should remain >138, with ASPT value >4.8.	PES: SASS5 scores ≤61 and ASPT <4.0.
Diversity of invertebrate community	-	PES: 30 families were collected during the field survey. Of these, 1 taxon scored ≥ 10 sensitivity. More than 30 families (taxa) should be present, with at least 2 of these scoring ≥ 10, and at an abundance of A to B. Some of the indicators selected were not recorded but expected with high FROCs. Thus at least 2 of those expected should be recorded.	PES: Less than 25 taxa collected. Less than 2 taxa scoring ≥ 9. None of the indicator taxon recorded, especially Baetidae >2spp and Hydraenidae. Any taxon (adults) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: Inundated marginal vegetation and bedrock should be available to sample.	Bedrock with extensive algae cover. Lack of inundated marginal vegetation.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat diversity	Biotopes and diversity	Bedrock is the dominating SASS5 biotope, with good marginal and instream aquatic vegetation which should remain.	Marginal vegetation is exposed (no wetted stems). Limited to no aquatic vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The surface of the bedrock should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae 2spp	Baetidae >2 spp present in ≥A abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥A abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

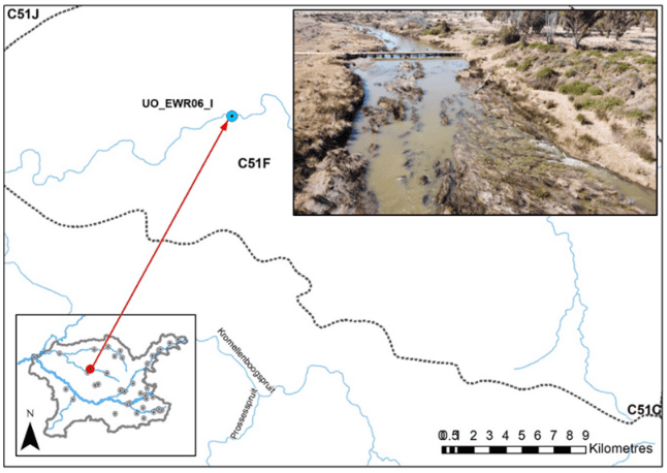
Parameter	Indictor[1]	EcoSpec	TPCs
		the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	
	*Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s, water quality deterioration and SIC become exposed.
	*Atyidae	Atyidae present in ≥B abundances. Maintain moderate water quality and ensure the marginal vegetation is inundated.	Atyidae absent (or individuals only) on two or more consecutive surveys Water quality deterioration and marginal vegetation and stems become exposed.
	Hydraenidae	Hydraenidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain moderate water quality and ensure the SIC and marginal vegetation are covered.	Hydraenidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s, water quality deterioration and SIC, vegetation/stems become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.6 UO_EWR01_6: Upper Riet

The reach, situated in the upper to middle reaches of the Riet River, is largely unconfined, with a macro channel incised into gently sloping hillslopes. The river displays a straight to sinuous macro channel pattern, featuring a braided low-flow channel pattern with bedrock, boulder, gravel, and silt sediment types. Positioned upstream of the Kalkfontein Dam Nature Reserve and approximately 20 km from the confluence of the Kromellenboog, the overall EcoStatus for this EWR site is categorised as moderately modified (Category C). There has been a loss and change of natural habitat and biota in terms of frequencies of occurrence and abundances. Catchment degradation increases suspended sediment loads, leading to higher turbidity and silt deposits over coarser habitats. Margin disturbance at the site is relatively low but shows degradation of habitat associated with inset benches and banks. The fish assemblage is moderately modified, with Kalkfontein Dam and several weirs impacting the assemblage due to movement limitations. Flow modifications and the presence of non-native species also impacted the fish species. The macroinvertebrate community primarily responded to poor water quality overall.

Figure 5-6 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Upper Riet
EWR Site Code	UO_EWR06_I
Driver component	PES
HAI	C
Diatoms	D
GAI	C
Response component	PES
FRAI	C
MIRAI	C
VEGRAI	C
Ecostatus	C
REC	C

Figure 5-6: UO_EWR06_I: Upper Riet and associated PES/EcoStatus/REC

5.6.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-42** with the detailed flood requirements in **Table 5-43**. As no gauge situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-42: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C	105.2	76.2	0.078	0.07	8.721	8.29	32.671	31.05

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-43: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	15
	# days	5
	Months	Nov, Dec, Jan, Apr
	Type	Average
Class 2	m^3/s	25
	# days	3
	Months	Feb
	Type	Average
Class 3	m^3/s	50
	# days	3
	Months	Mar
	Type	Peak

5.6.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-44**.

Table 5-44: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 19.3 Category (A): High water quality	SPI Score: <16.7 Category B: Good water quality

5.6.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-45**.

Table 5-45: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C or higher	D or lower
Channel pattern	Wandering high flow and braided at low flows	Braided at high flows or wandering at low flows
Channel width	Macro channel of ~40 m	<30 m or >50 m
Median particle size of riffle/rapid	Coarse gravels (28 mm)	Loss of gravels with the riffle being dominated by sand or by cobble and boulders only
Extent of bank erosion	~ 15%	Bank erosion along 40% of the bank length

5.6.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-46**.

Table 5-46: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 10%. Indigenous non-woody vegetation cover maintained above 70%.	Indigenous woody vegetation cover increases above 10%. Indigenous non-woody vegetation cover decreases below 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Schoenoplectus brachyceras* and *Miscanthus junceus*.	Diversity of indigenous species within the marginal zone decreases below 5 species.

Metric	EcoSpec	TPC
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 15%. Indigenous non-woody vegetation cover maintained above 70%.	Indigenous woody vegetation cover increases above 15%. Indigenous non-woody vegetation cover decreases below 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with *Cynodon dactylon* dominating.	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 25%. Indigenous non-woody vegetation cover maintained above 60%.	Indigenous woody vegetation cover increases above 25%. Indigenous non-woody vegetation cover decreases below 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of grasses and terrestrial woody species.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.6.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-47**.

Table 5-47: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Present at <50% of sites during summer (FROC ≤3)
	Labeo capensis	Present at most sites during summer (FROC = 4)	Present at <50% of sites during summer (FROC ≤3)

Metric	Indicator	EcoSpec	TPC (biotic)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate within reach	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.6.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality**.

The indicator taxa selected for this site are listed in **Table 5-48**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007).

The EcoSpecs and TPCs in **Table 5-49**.

Table 5-48: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
*Atyidae	8	4	3.5	0.5	0	1	4.5	0.5	0	MODERATE
*Aeshnidae	8	2.5	3.5	4	2.5	4	3	3	0	MODERATE
Hydraenidae	8	1	1.5	3	4	4	3	1.5	3	MODERATE
Gomphidae	6	4.5	4	3	2.5	2.5	1	4.5	0	LOW
Caenidae	6	4.5	3.5	3	3	3	3	4.5	0	LOW

Table 5-49: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 62.0% (Category C). The MIRAI score to be maintained between >63 - ≤78%, using the reference data used in this study, or recording alterations to these.	PES: MIRAI ≤61%.
SASS5 and ASPT Score	-	PES: The SASS5 score was 125 with an ASPT of 5.0. Total SASS5 score should remain >130, with ASPT value >5.2.	PES: SASS5 scores ≤90 and ASPT <4.5.
Diversity of invertebrate community	-	PES: 25 families were collected during the field survey. Of these, 1 taxa scored ≥ 10 sensitivity. More than 25 different families (taxa) should be present, with at least 2 of these scoring ≥ 10, and at an abundance of A to B. Some of the indicators selected were not recorded but expected with high FROCs. Thus atleast 1 of those expected should be recorded.	PES: Less than 20 taxa collected. Less than 2 taxa scoring ≥ 9. None of the indicator taxon recorded (barring Atyidae and Aeshnidae). Any taxon (adults) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The small to large cobble area located downstream of the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation. Loss of pockets of gravel along the cross-section.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp. present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

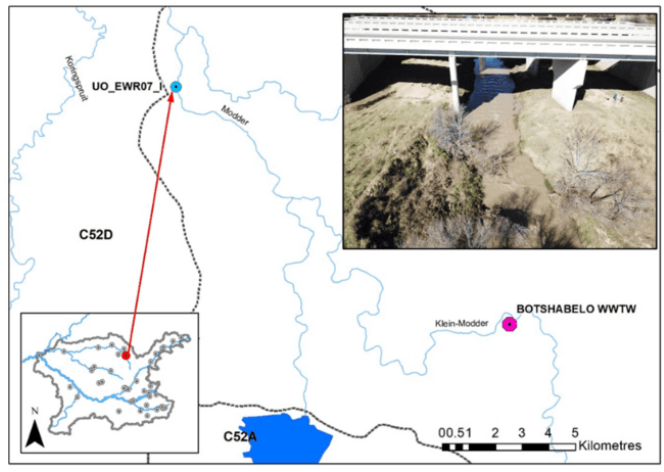
Parameter	Indictor[1]	EcoSpec	TPCs
		the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	
	*Atyidae	Atyidae present in ≥B abundances. Maintain moderate water quality and ensure the marginal vegetation is inundated.	Atyidae absent (or individuals only) on two or more consecutive surveys Water quality deterioration and marginal vegetation and stems become exposed.
	*Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
	Hydraenidae	Hydraenidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain moderate water quality and ensure the SIC and marginal vegetation are covered.	Hydraenidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC, vegetation/stems become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Gomphidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Caenidae	Gomphidae present in ≥A abundances. These indictor taxa have a wide range of flow preferences over the GSM biotope.	Gomphidae absent (or individuals only) on two or more consecutive surveys GSM becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.7 UO_EWR07_I: Upper Modder

The stretch along the upper reaches of the Modder River, approximately 30 km east of Bloemfontein off the N8, features largely unconfined terrain with gently sloping hillslopes and an incised channel displaying narrow flood features. Positioned about 13 km downstream of Rustfontein Dam, the overall EcoStatus for this EWR site is categorised as largely modified (Category D). Catchment degradation is causing an increase in suspended sediment loads, resulting in higher turbidity and silt deposits over coarser habitats. Margins at the site experience widespread disturbance, leading to the degradation of habitat associated with inset benches and banks. Water quality is severely compromised, with diatoms reflecting impacts downstream of Botshabelo and the dysfunctional WWTW. This significantly affects the biota, particularly fish and macroinvertebrates, responding to very poor water quality, suggesting potential fish kill events due to raw sewage input from Botshabelo and smaller upstream tributaries. This reach serves as the primary movement corridor for fish moving upstream from Mocke's Dam. The marginal and lower zones exhibit a poor to severely modified state, primarily due to bank erosion, livestock grazing/trampling, stormwater runoff impacts, and altered habitat structure from the weir and bridges.

Figure 5-7 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Upper Modder
EWR Site Code	UO_EWR07_I
Driver component	PES
HAI	C/D
Diatoms	D
GAI	D
Response component	PES
FRAI	C
MIRAI	D
VEGRAI	D
Ecostatus	D
REC	C

Figure 5-7: UO_EWR07_I: Upper Modder and associated PES/EcoStatus/REC

5.7.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-50** with the detailed flood requirements in **Table 5-51**. Monitoring of compliance to be undertaken at gauge C5H003.

Table 5-50: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C	61.0	40.0	2.313	3.79	9.156	15.02	21.909	35.94

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-51: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	4
	# days	3
	Months	Nov, Dec, Jan, Mar, Apr
	Type	Average
Class 2	m^3/s	16
	# days	3
	Months	Jan, Mar
	Type	Average
Class 3	m^3/s	30
	# days	3
	Months	Feb
	Type	Peak

5.7.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-52**.

Table 5-52: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 5.6 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality

5.7.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-53**.

Table 5-53: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	D or higher	E or lower
Channel pattern	Straight to wandering	Braided channel pattern
Channel width	~ 20 m wide macro channel away from the engineered sections	Macro channel width of < 15m or > 30m
Median particle size of riffle/rapid	Medium gravels (12 mm)	If there is a loss of gravels, with the riffle consisting of cobble and boulder, or sand and silt only
Extent of bank erosion	~ 30%	> 50%

5.7.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-54**.

Table 5-54: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.
Exotic vegetation	Alien species cover maintained below 30% for entire riparian zone.	Alien species cover increases above 30% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 30%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal	Diversity of indigenous species within the marginal zone decreases below 5 species.

Metric	EcoSpec	TPC
	zone, which comprises a mix of grasses and sedges.	
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 40%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 40%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with *Cynodon dactylon* dominating.	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 30%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with grasses dominating.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.7.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-55**.

Table 5-55: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at most sites during summer (FROC = 4)	Present at <50% of sites (FROC ≤3)

Metric	Indicator	EcoSpec	TPC (biotic)
	Labeo capensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites (FROC ≤2)

5.7.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as an ecological category 'D' (largely modified) using the MIRAI methodology, was found to be **water quality**.

The indicator taxa selected for this site are listed in **Table 5.56**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007).

If some of these indicator taxa chosen for monitoring are absent from the site, it indicates a persistence or worsening of water quality deterioration during the monitoring program. The EcoSpecs and TPCs in **Table 5-57**.

Table 5-56: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
*Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
*Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE
Ecnomidae	8	2	3.5	3.5	1.5	4	1	1.5	0	MODERATE
*Caenidae	6	4.5	3.5	3	3	3	3	4.5	0	LOW

Table 5-57: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 50.0% (Category D). The MIRAI score to be maintained as a mid-D in the range >42 – 52%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥63%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 63 with an ASPT of 4.5. Total SASS5 score should remain >80, with ASPT value >5.0. REC: SASS5 score ≥130, with ASPT value > 6.0.	PES: SASS5 scores <60 and ASPT <4.0. REC: SASS5 scores < 140, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 14 families were collected during both surveys. Of these, 1 scored ≥ 10 sensitivity. More than 14 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 20 families should occur at an abundance of A to B, which should include expected taxa with a high FROC, which were not recorded namely	PES: Less than 10 taxa collected. Less than 1 taxa scoring ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 18 families, with less than 2 taxa scoring ≥ 10. No recordings of the expected indicator taxon. Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
		Hydropsychidae >2spp, Trichorythidae and Caenidae in ≥A abundances.	
Physical habitat quality	Biotopes and quality	Visual: The small to large cobble area located along the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample. Bedrock habitat available downstream of the cross-section.	Immobile cobbles with extensive algae cover. Lack of inundated marginal vegetation. Loss of pockets of gravel along the cross-section.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, odour, solid waste).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

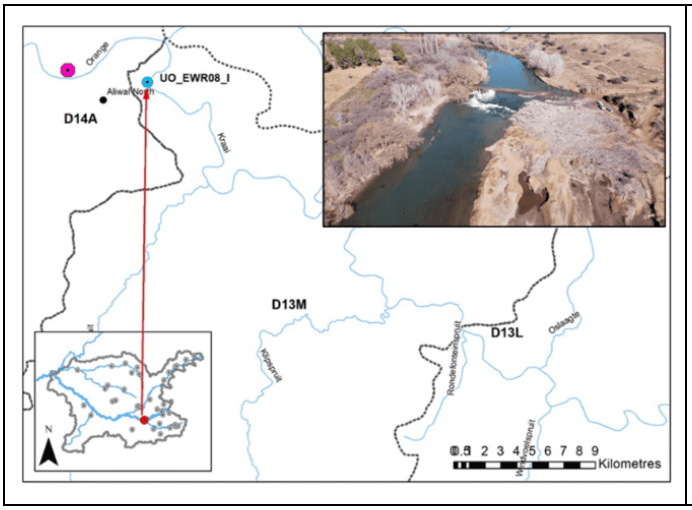
Parameter	Indictor[1]	EcoSpec	TPCs
		of 15cm and covered and/or GSM and marginal vegetation.	
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	Ecnomidae	Ecnomidae present in A abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate	Ecnomidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
		water quality and ensure the SIC are at a depth of 15cm and covered.	
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Chironomidae	Chironomidae present in ≤ B abundances. Chironomidae have a wide range of preferences and thrive in very low water quality. They can further be an indication of extensive nutrient inputs (i.e. sewage),	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.8 UO_EWR08_I: Lower Kraai

This free-flowing river, approximately 30 meters wide and just upstream from the confluence of the Orange River, presents a variety of biotopes. The overall EcoStatus for this EWR site is moderately modified (Category C), indicating a degree of loss and change in natural habitat and biota frequencies and abundances. Catchment degradation contributes to elevated suspended sediment loads, causing higher turbidity during increased flows and silt deposits over coarser habitats. Marginal disturbance at the site is moderate, resulting in some degradation of habitat associated with inset benches and banks. Although all expected fish are still present, their frequency of occurrence is marginally reduced due to flow modifications, water quality alterations, instream barriers, and cover elements. The aquatic macroinvertebrate community remains stable, indicative of moderately modified conditions. While some sensitive macroinvertebrates prefer good water quality and fast to very fast flow conditions, the majority respond to water quality modifications. The marginal vegetation is severely modified, experiencing extensive scour erosion and removal, extending into the lower zone. Habitat structure in the marginal and lower zones upstream of the weir has been altered by the weir, and the right bank is compromised by alien plants.

Figure 5-8 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Lower Kraai
EWR Site Code	UO_EWR08_I
Driver component	PES
HAI	B
Diatoms	C
GAI	C
Response component	PES
FRAI	C
MIRAI	C
VEGRAI	D/E
Ecostatus	C
REC	B/C

Figure 5-8: UO_EWR08_I: Lower Kraai and associated PES/EcoStatus/REC

5.8.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-58** with the detailed flood requirements in **Table 5-59**. Although no gauge in close vicinity of this site, gauge D1H011 can be used for flood monitoring. For baseflows, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-58: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
B/C	719.0	675.3	40.997	5.70	200.869	27.94	334.513	46.52

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff

Table 5-59: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	30
	# days	4
	Months	Oct, Nov, Dec, Jan, Apr
	Type	Average
Class 2	m^3/s	75
	# days	4
	Months	Jan, Feb, Apr
	Type	Average
Class 3	m^3/s	100
	# days	4
	Months	Feb
	Type	Average
Class 4	m^3/s	250
	# days	5
	Months	Mar
	Type	Peak

5.8.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-60**.

Table 5-60: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 13.8 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality

5.8.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in **Table 5-61**.

Table 5-61: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C or higher	D or lower
Channel pattern	Wandering channel (alternating bars)	Braided (overwhelmed with sediment) or straight channel (loss of mobile sediment)
Channel width	100 m wide macro channel (away from engineered works)	Macro channel < 80 m or more than 120 m
Median particle size of riffle/rapid	Coarse gravels (30 mm)	Loss of gravels, with sand or cobble dominating the riffle habitat
Extent of bank erosion	~ 25%	More than 40% of banks eroding

5.8.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-62**.

Table 5-62: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a D category.	VEGRAI score in a E (or worse) category.

Metric	EcoSpec	TPC
Exotic vegetation	Alien species cover maintained below 30% for entire riparian zone.	Alien species cover increases above 30% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained below 20%. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover increases above 30%. Indigenous non-woody vegetation cover decreases below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Cyperus marginatus*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 10% of the cover. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 10%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody and non-woody (*Cynodon dactylon* dominating) vegetation.	Diversity of indigenous species within the lower zone decreases below 10 species and dominated by terrestrial woody vegetation.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%, with terrestrial species making up less than 20% of the cover. Indigenous non-woody vegetation cover maintained between 30 - 70%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%, with terrestrial species cover increasing above 20%. Indigenous non-woody vegetation cover decreases

Metric	EcoSpec	TPC
		below 30% or increases above 70%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of grasses and woody vegetation.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.8.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-63**.

Table 5-63: Fish EcoSpecs and TPCs see previous

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤4)
	Labeobarbus kimberleyensis	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites during summer (FROC ≤2)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.8.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as an ecological category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality**. Although habitat availability at this site was good, the stones-in-current were smothered by algae, converting a good biotope into a poor biotope. Consequently, the macroinvertebrate indicator taxa listed in **Table 5-64**, were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007). The selected indicator taxa were observed during either both or at least one of the site surveys conducted for this site (as well as during the REMP monitoring). Therefore, their absence from the site during the monitoring program would suggest either a persistence or exacerbation of water quality deterioration, and/or with some indicator taxon, it may also indicate that their specific flow requirements are not being met. The EcoSpecs and TPCs in **Table 5-65**.

Table 5-64: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Perlidae	12	0.5	3	4	3.5	4	0.5	1.5	0	HIGH
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE

Table 5-65: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 65.3% (Category C). The MIRAI score to be maintained as a mid-C in the range >65 – 72%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	PES: MIRAI ≤61% REC: MIRAI ≤78%
SASS5 and ASPT Score	-	PES: The SASS5 score was 157 with an ASPT of 6.3. Total SASS5 score should remain >160, with ASPT value >6.5. REC: SASS5 score ≥180, with ASPT value > 6.8.	PES: SASS5 scores <120 and ASPT <6.0. REC: SASS5 scores < 180, ASPT < 6.8.
Diversity of invertebrate community	-	PES: 25 families were collected during both surveys. Of these, 3 scored ≥ 10 sensitivity. More than 25 different families (taxa) should be present, with at least 4 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, with all indicator taxa recorded in ≥A abundances.	PES: Less than 20 taxa collected. Less than 1 taxa scoring ≥ 10. Some of the indicator taxon are not recorded. Any taxon (adults) with an abundance of D. REC: Less than 25 families, with less than 4 taxa scoring ≥ 10. Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat quality	Biotopes and quality	Visual: The cobbles area upstream, from the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Perlidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s, for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances	Baetidae 2 spp or less in two consecutive samples.

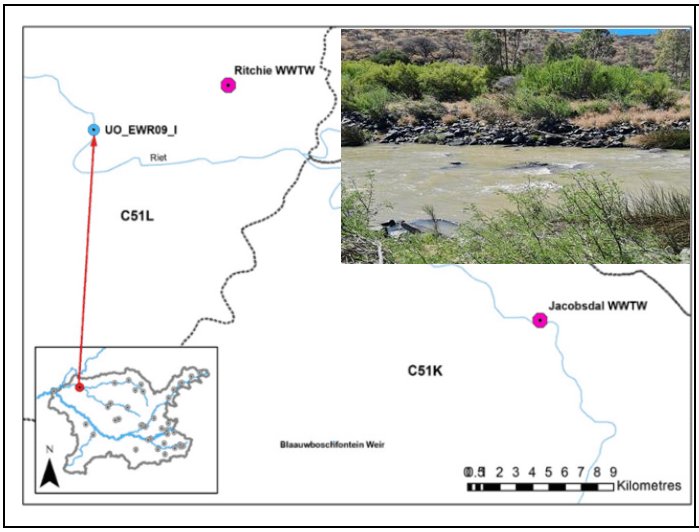
Parameter	Indictor[1]	EcoSpec	TPCs
		Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Velocities decrease below 0.3m/s for longer than a week,and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All taxa with a preference for very low water quality are within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.9 UO_EWR09_I: Lower Riet

Situated downstream of the Modder River confluence and the farming town of Modder River, this site falls within the Mokala National Park and is impacted by two upstream dams: the Krugersdrift Dam on the Modder River (approximately 140 km upstream, north of Bloemfontein) and the Kalkfontein Dam (approximately 80 km upstream) on the Riet River SSE of Koffiefontein. The area experiences intensive irrigation of crops along the banks of both the Modder and Riet Rivers. The overall EcoStatus for this EWR site is classified as moderately modified (Category C), signifying a system in a moderately altered condition. Catchment degradation stems from grazing, changes in hillslope-channel connectivity, and cropping, leading to elevated fine sediment loadings and siltation of coarser habitats. Dams and weirs along the Modder and Riet Rivers trap bedload sediment, reducing the extent of coarser habitats in the reach. Disturbance along banks and channel margins is localized due to the protected area. Biologically, both the fish and macroinvertebrate communities represent moderately modified conditions (Category C), while the riparian vegetation component remains largely natural with few modifications, primarily related to water quality and vegetation removal caused by cattle trampling.

Figure 5-9 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Lower Riet
EWR Site Code	UO_EWR09_I
Driver component	PES
HAI	C
Diatoms	C
GAI	C
Response component	PES
FRAI	C
MIRAI	C
VEGRAI	B
Ecostatus	C
REC	B/C

Figure 5-9: UO_EWR09_I: Lower Riet and associated PES/EcoStatus/REC

5.9.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-66** with the detailed flood requirements in **Table 5-67**. Monitoring of compliance to be undertaken at gauge C5H014.

Table 5-66: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
B/C[4]	373.8	214.4	0.544	0.15	54.274	14.52	89.974	24.07

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff | [4] Requirements as specified from Vaal comprehensive Reserve for a REC=D

Table 5-67: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	4
	# days	4
	Months	Nov, Dec, Jan, Feb, Mar, Apr
	Type	Average
Class 2	m^3/s	25
	# days	7
	Months	Nov, Dec, Jan, Feb, Mar
	Type	Average

5.9.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-68**.

Table 5-68: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	No information	No information

5.9.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in Table 5-69.

Table 5-69: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C or higher	D or lower
Channel pattern	Wandering to anastomosing	Braided channel (overwhelmed with bed sediment)
Channel width	Macro channel width of ~100 m	Macro channel width of <80 m or more than 120 m
Median particle size of riffle/rapid	Not measured, but likely to be gravel	If gravels are no longer present at the riffles, with sand or only cobble/boulder/bedrock dominating the faster flow areas
Extent of bank erosion	~10% (low due to bedrock nature of reach)	Bank erosion of > 30%

5.9.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-70**.

Table 5-70: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 13% for entire riparian zone.
Marginal zone		
Vegetation cover	Maintain marginal vegetation component that is dominated by reeds covering less than 60%.	Reed vegetation increases above 60%. Woody vegetation cover increases above 20%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.

Metric	EcoSpec	TPC
Lower riparian zone		
Vegetation cover	Maintain mix of woody and non-woody riparian species with small (<10%) cover of terrestrial woody species.	Woody vegetation cover increases above 40% with terrestrial species increasing above 10%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of indigenous grasses, shrubs and trees.	Diversity of indigenous species within the lower zone decreases below 10 species.
Upper riparian zone		
Vegetation cover	Maintain mix of riparian and terrestrial species.	Proportion of terrestrial woody species increases above 50%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, with a mix of indigenous grasses, shrubs and trees.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.9.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in Table 5-71.

Table 5-71: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >62% (Ecological Category C).	FRAI Score: <62% (Ecological Category C/D)
Indicator fish species and presence	*Labeobarbus kimberleyensis*	Present at about 50% of sites assessed during summer (FROC = 3)	Present at <50% of sites during summer
	Labeobarbus aeneus	Present at most sites during summer (FROC = 4)	Present at <50% of sites during summer (FROC ≤3)

Metric	Indicator	EcoSpec	TPC (biotic)
	Austroglanis sclateri	Present at about 50% of sites assessed during summer (FROC = 3)	Present at <50% of sites during summer
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
	Slow-deep velocity-depth class within reach	Maintenance of slow-deep velocity-depth class within reach during winter low-flow period	Reduced suitability and./or abundance of slow-deep velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate within reach	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.9.6 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality**.

The indicator taxa selected for this site are listed in **Table 5.72**, and which were selected as monitoring indicators for this site. The indicators' velocity and biotope preferences are rated on a scale of 0 (low) to 5 (very high) according to Thirion (2007).

The EcoSpecs and TPCs in **Table 5-73**.

Table 5-72: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Heptageniidae	13	1	4	4.5	3	4.5	0.5	1.5	0	HIGH
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE

Table 5-73: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: >62 - ≤78 (Category C)	PES: MIRAI ≤61%

Parameter	Indictor[1]	EcoSpec	TPCs
		The MIRAI score to be maintained as a C in the range >62 - ≤78%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	 REC: MIRAI ≤78%
SASS5 and ASPT Score	-	PES: The SASS5 score should remain >150, with ASPT value >6.2. REC: SASS5 score ≥180, with ASPT value > 6.8.	PES: SASS5 scores <120 and ASPT <6.0. REC: SASS5 scores < 180, ASPT < 6.8.
Diversity of invertebrate community	-	PES: More than 25 different families (taxa) should be present, with at least 3 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, with all indicator taxa recorded in ≥A abundances.	PES: Less than 20 taxa collected. Less than 1 taxa scoring ≥ 10. Some of the indicator taxon are not recorded. Any taxon (adults) with an abundance of D. REC: Less than 25 families, with less than 3 taxa scoring ≥ 10. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.

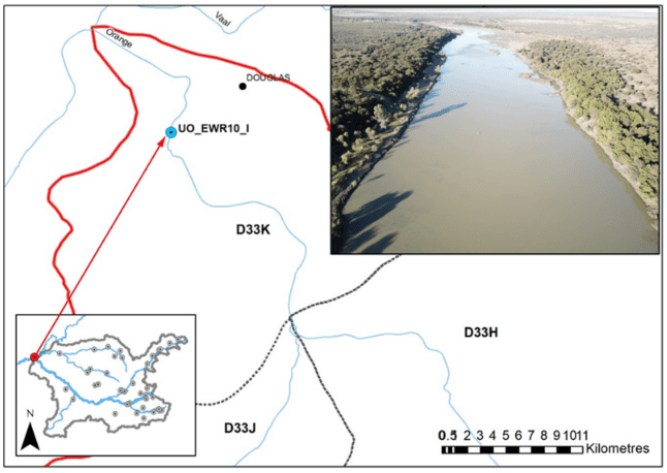
Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation)	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Heptageniidae	Heptageniidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Heptageniidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s, for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.10 UO_EWR10_I: Lower Orange

Located approximately 13 km southwest of the town of Douglas, 12 km upstream of the Vaal River confluence, and 2.5 km downstream of Marksdrift weir, this EWR site is characterised by an incised macro-channel around 160 m wide. The channel displays a straight to sinuous planform with pool-riffle and pool-rapid reach types. The overall EcoStatus for this site is categorized as moderately modified (Category C), indicating a system in a moderately altered condition with a loss and change in natural habitat and biota frequencies and abundances. Catchment degradation has led to increased suspended sediment loads, causing sedimentation of coarser habitats. Localised weirs and dams upstream trap bedload, further reducing the extent of coarse sediment habitats. Trampling and vegetation changes at the reach scale are relatively minor, with recent scouring and deposition evident from the last floods. Fish species expected under reference conditions are confirmed, but some occur at a lower frequency than expected. The presence of two large impoundments upstream and hydropower discharges are considered the primary drivers of deviation from reference conditions. From a riparian vegetation perspective, the marginal vegetation zone has degraded, mainly from flooding and scouring of banks, while the lower and upper zones remain in a relatively moderate state. Overall, riparian vegetation at the site is moderately modified, with flow alterations unlikely to significantly change to assist in managing vegetation condition.

Figure 5-10 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Lower Orange
EWR Site Code	**UO_EWR010_I**
Driver component	**PES**
HAI	C/D
Diatoms	D
GAI	C/D
Response component	**PES**
FRAI	B/C
MIRAI	D
VEGRAI	C
Ecostatus	C
REC	C

Figure 5-10: UO_EWR10_I: Lower Orange and associated PES/EcoStatus/REC

5.10.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-74** with the detailed flood requirements in **Table 5-75**. Monitoring of compliance to be undertaken at gauge D3H008.

Table 5-74: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C	6 674.2	3 283.8	366.113	5.49	1 047.52	15.69	1 427.81	21.39

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres | [3] Present Day Mean Annual Runoff | [4] Percentiles of the EWR rule (flow duration table) – applicable to all EWR sites.

Table 5-75: Final flood requirements

Floods	Criteria	FINAL
Class 1	m^3/s	65
	# days	3
	Months	Oct-Jan, Apr
	Type	Average
Class 2	m^3/s	100
	# days	3
	Months	Mar, Apr, May
	Type	Average
Class 3	m^3/s	155
	# days	3
	Months	Nov, Dec, Jan
	Type	Average
Class 4	m^3/s	229
	# days	3
	Months	Feb, Mar
	Type	Average
Class 5	m^3/s	550
	# days	7
	Months	Feb
	Type	Peak

5.10.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-76**.

Table 5-76: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 7.8 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality

5.10.3 Geomorphology: EcoSpecs and TPCs

EcoSpecs and TPCs for geomorphology are shown in Table 5-77.

Table 5-77: Geomorphology EcoSpecs and TPCs

Metric	EcoSpec	TPC
GAI level IV	C/D or higher	D or lower
Channel pattern	Wandering (higher flows) to braided (during low baseflow)	Braided channel during higher flows
Channel width	Macro channel of ~ 180 m wide	Macro channel of <150 m or >220 m wide
Median particle size of riffle/rapid	Not measured, but likely to be gravel	Loss of gravels, with riffle habitat being dominated by sand or large immobile coble and boulders
Extent of bank erosion	~ 25%	> 50%

5.10.4 Riparian vegetation: EcoSpecs and TPCs

EcoSpecs and TPCs for riparian vegetation are shown in **Table 5-78**.

Table 5-78: Riparian vegetation EcoSpecs and TPCs

Metric	EcoSpec	TPC
VEGRAI score and category	VEGRAI score maintained in at least a C category.	VEGRAI score in a D (or worse) category.

Metric	EcoSpec	TPC
Exotic vegetation	Alien species cover maintained below 10% for entire riparian zone.	Alien species cover increases above 10% for entire riparian zone.
Marginal zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 5 – 10 indigenous species within the marginal zone, dominated by *Phragmites australis*.	Diversity of indigenous species within the marginal zone decreases below 5 species.
Lower riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 10 - 40%. Indigenous non-woody vegetation cover maintained between 20 - 60%.	Indigenous woody vegetation cover decreases below 10% or increases above 40%. Indigenous non-woody vegetation cover decreases below 20% or increases above 60%.
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the lower zone, with a mix of woody (dominated by *Salix mucronata*) and non-woody (dominated by *Cynodon dactylon* and *Phragmites australis*).	Diversity of indigenous species within the lower zone decreases below 10 species.
Upper riparian zone		
Vegetation cover	Indigenous woody vegetation cover maintained between 60 - 80%.	Indigenous woody vegetation cover decreases below 60% or increases above 80%.

Metric	EcoSpec	TPC
Species richness and composition.	Aim to maintain a reasonable diversity of 10 – 20 indigenous species within the upper zone, dominated by woody vegetation.	Diversity of indigenous species within the upper zone decreases below 10 species.

5.10.5 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-79**.

Table 5-79: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >78% (Ecological Category B/C).	FRAI Score: <78% (Ecological Category C)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at all sites during summer (FROC = 5)	Present at <50% of sites (FROC ≤3)
	Labeobarbus kimberleyensis	Present at about 50% of sites during summer (FROC = 3)	Present at <25% of sites (FROC ≤2)
	Labeo capensis	Present at <75% of sites (FROC ≤4)	Present at <75% of sites (FROC ≤4)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Slow-deep velocity-depth class within reach	Maintenance of slow-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of slow-deep velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate during lower flow periods	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.10.6 Macroinvertebrates: EcoSpecs and TPCs

At this site, changes in water quality did not impact the macroinvertebrate community. Rather, the community exhibited a discernible response to variations in flow. Consequently, the dominant factor influencing the macroinvertebrate PES, evaluated as an ecological category 'D' (largely modified) through the MIRAI methodology, was determined to be **flow.** Although, habitat availability at this site was also poor, this too was a driver of the PES for the macroinvertebrates. The site has experienced numerous flooding events in the last two years, resulting in the removal of marginal vegetation, due to scouring and significant sediment deposition along the banks. Consequently, the macroinvertebrate indicator taxa listed in **Table 5-80**, were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007). The selected indicator taxa were observed during the site survey, including during the previous Joint Basin Survey 3 (JBS) in 2021, prior to the floods. Hence, if these taxa are not present at the site during the monitoring program, it indicates that the flow preferences of the taxon are not being fulfilled and/or the habitat is not undergoing recovery.

The EcoSpecs and TPCs in **Table 5-81**.

Table 5-80: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Heptageniidae	13	1	4	4.5	3	4.5	0.5	1.5	0	HIGH
*Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Caenidae	6	4.5	3.5	3	3	3	3	4.5	0	LOW
Simuliidae	5	1.5	2	3.5	4.5	4.5	1.5	0.5	0	LOW

Table 5-81: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 50.0% (Category D). The MIRAI score to be maintained as a mid-D in the range >50 – 55%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥63%	PES: MIRAI ≤41% REC: MIRAI ≤61%
SASS5 and ASPT Score	-	PES: The SASS5 score was 51 with an ASPT of 6.4. Total SASS5 score should remain >65, with ASPT value >6.5. REC: SASS5 score ≥120, with ASPT value > 6.8.	PES: SASS5 scores <50 and ASPT <5.0. REC: SASS5 scores < 140, ASPT < 6.5.
Diversity of invertebrate community	-	PES: 8 families were collected during both surveys. Of these, 1 scored ≥ 9 sensitivity. More than 10 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 18 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which	PES: Less than 8 taxa collected. No recorded taxa scoring ≥ 9 sensitivity. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D (i.e. Simuliidae). REC: Less than 18 families, with less than 3 taxa scoring ≥ 10. No recordings of the expected indicator taxon. Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
		were not recorded namely Baetidae >2spp in ≥A abundances.	
Physical habitat quality	Biotopes and quality	Visual: The cobbles area far downstream from the cross-section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Increased sediment deposition along banks, lack of marginal vegetation regrowth and/or lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation)	Marginal vegetation is exposed (no wetted stems) and/or no marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Heptageniidae	Heptageniidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Heptageniidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week and biotopes become exposed.
	Caenidae	Caenidae present in ≥B abundances. These indictor taxa have a wide range of flow preferences and biotopes, as long as covered.	Caenidae absent (or individuals only) on two or more consecutive surveys Biotopes are exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

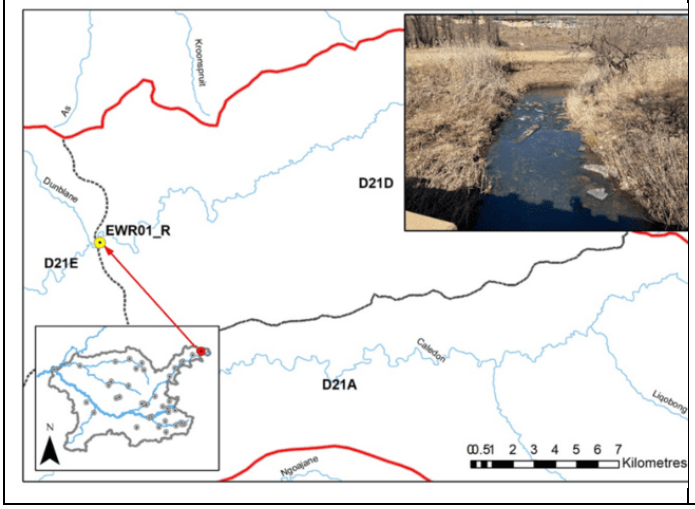
RAPID 3 EWR SITES

It is crucial to emphasise that EcoSpecs were established only for the key components of the Rapid 3 EWR sites. This selection focused on components that played a pivotal role in the system and which significantly influence the overall EcoStatus of the site.

5.11 UO_EWR01_R: Little Caledon

Situated downstream from the town of Clarens along an incised floodplain reach, the overall EcoStatus of the site has been categorized as moderately modified (Category C). This classification is largely attributed to the fish component, where alien species dominate, spawning substrate and cover features have decreased, and downstream dams impede the seasonal migration of *Labeobarbus aeneus* from the Caledon River. The macroinvertebrates, on the other hand, are primarily influenced by water quality.

Figure 5-11 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Little Caledon
EWR Site Code	**UO_EWR01_R**
Driver component	**PES**
Diatoms	C
IHI (instream)	B
IHI (riparian)	B
Response component	**PES**
FRAI	D
MIRAI	D
Ecostatus	C
REC	B/C

Figure 5-11: UO_EWR01_R: Little Caledon and associated PES/EcoStatus/REC

5.11.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-82** with the freshet requirements in **Table 5-83**. It should be noted that the high flow requirements are based on fish and macroinvertebrate requirements only, thus only freshets were specified at all the rapid 3 EWR sites. As no gauge situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-82: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
B/C	25.9	1.919	7.41	5.981	23.09	10.154	39.20

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres

Table 5-83: Final freshet requirements

Months	Freshets*			
	m^3/s	days	m^3/s	days
October	6	2		
November	5	2	10	3
December	14	3		
January	34	3		
February	45	4		
March	34	4	14	3
April	5	2		

** Based on fish and macroinvertebrates only*

5.11.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-84**.

Table 5-84: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 7.8 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality

5.11.3 Habitat Integrity: Instream and Riparian EcoSpecs and TPCs

EcoSpecs and TPCs for riparian and instream habitat integrity are shown in **Table 5-85**.

Table 5-85: Habitat Integrity for instream and riparian: EcoSpecs and TPCs

Metric	EcoSpec	TPC
Habitat integrity: Instream score and category	IHI: Instream score: 85% (B)	IHI: Instream score: ≤81% Further increase in algae growth
Habitat integrity: riparian score and category	IHI: Riparian score: 85% (B)	IHI: Riparian score: ≤81% Increase in bank erosion

5.11.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-86**.

Table 5-86: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Enteromius oraniensis*	Present at about 25% to 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
	Labeobarbus aeneus	Present at less than 10% of sites during summer (FROC = 1)	Absent at all sites
Velocity-depth class	Slow-deep velocity-depth class within reach	Maintenance of slow-deep velocity-depth class within reach throughout the year	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates
Non-native fish species	Any non-native fish species	No non-native fish species present	Any non-native fish species

5.11.5 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality**.

Consequently, the macroinvertebrate indicator taxa listed in **Table 5-87**, were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007).

The EcoSpecs and TPCs in **Table 5-88**.

Table 5-87: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
*Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Aeshnidae	8	2.5	3.5	4	2.5	4	3	3	0	MODERATE
Elmidae	8	1.5	3	4	4.5	4	1	3.5	0	MODERATE

Table 5-88: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 57.7% (Category D).	PES: MIRAI ≤41%

Parameter	Indictor[1]	EcoSpec	TPCs
		The MIRAI score to be maintained at the top end of a D in the range >56 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	REC: MIRAI ≤77%
SASS5 and ASPT Score	-	PES: The SASS5 score was 130 with an ASPT of 5.4. Total SASS5 score should remain >130, with ASPT value >5.5. REC: SASS5 score ≥140, with ASPT value > 6.8.	PES: SASS5 scores <100 and ASPT <4.8. REC: SASS5 scores < 170, ASPT < 6.7.
Diversity of invertebrate community	-	PES: 24 families were collected during both surveys. Of these, 3 scored ≥ 9 sensitivity. More than 24 different families (taxa) should be present, with at least 3 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which were not recorded namely Hydropsychidae >2spp in ≥A abundances.	PES: Less than 20 taxa collected. Only 1 or less taxa scoring ≥ 9 sensitivity. Some of the indicator taxon recorded (barring Hydropsychidae>2spp). Any taxon (adults) with an abundance of D (i.e. Simuliidae). REC: Less than 28 families, with less than 3 taxa scoring ≥ 10. No recordings of the expected indicator taxon (Hydropsychidae >2spp). Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
Physical habitat quality	Biotopes and quality	Visual: The cobbles area along the cross section should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Water levels lowered over the causeway resulting in pooling upstream, and thus impacted flow moving downstream.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation)	Marginal vegetation is exposed (no wetted stems) and/or no marginal vegetation.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances.	Hydropsychidae 2 spp or less in two consecutive samples.

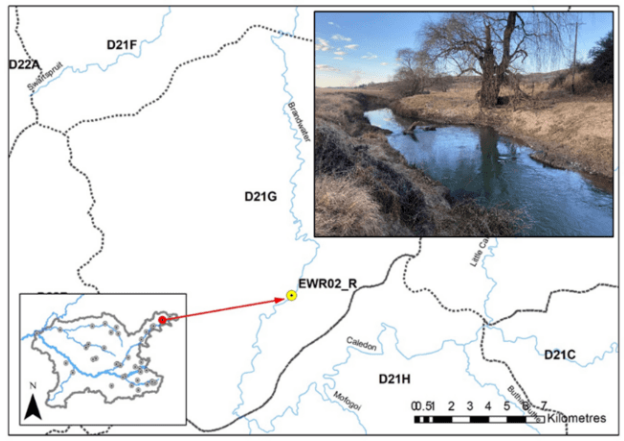
Parameter	Indictor[1]	EcoSpec	TPCs
		Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s, water quality deterioration and SIC become exposed.
	Aeshnidae	Aeshnidae present in ≥A abundances. Habitat and water quality should be adequate to ensure suitable habitats for	Aeshnidae absent in one of two consecutive samples.

Parameter	Indictor[1]	EcoSpec	TPCs
		this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Velocities decrease below 0.3m/s, water quality deterioration and marginal vegetation become exposed.
	Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Chironomidae	Chironomidae present in ≤ B abundances. Chironomidae have a wide range of preferences and thrive in very low water quality. They can further be an indication of extensive nutrient inputs (i.e. sewage),	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.12 UO_EWR02_R: Brandwater (Groot)

Situated approximately 10 km from the town of Fouriesburg, accessible from a road bridge on the R26, this reach features a partly confined valley setting with an incised channel. The river, about 5 meters wide, displays modifications to its bed and channel due to bridge construction, as well as cattle trampling and grazing. The overall EcoStatus has been classified as moderately modified (Category C), primarily influenced by biotic components. The macroinvertebrate assemblages are notably affected by water quality as the main driver. Within the fish assemblage, water quality also plays a significant role in contributing to the ecological state, although cover and velocity-depth metrics are still identified as primary contributors.

Figure 5-12 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Brandwater
EWR Site Code	UO_EWR02_R
Driver component	PES
Diatoms	C
IHI (instream)	C
IHI (riparian)	B/C
Response component	PES
FRAI	D
MIRAI	D
Ecostatus	C
REC	B/C

Figure 5-12: UO_ EWR02_R: Brandwater (Groot) and associated PES/EcoStatus/REC

5.12.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-89** with the freshet requirements in **Table 5-90**. As no gauge situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-89: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
B/C	56.0	2.001	3.57	11.846	21.16	17.325	30.95

[1] *Natural Mean Annual Runoff* | [2] *Million Cubic Metres*

Table 5-90: Final freshet requirements

Months	Freshets*			
	m^3/s	days	m^3/s	days
October	1.3	2		
November	1.5	5		
December	1.5	5		
January	1.5	5	10	2
February	1.5	5	10	2
March	1.5	5	10	2
April	1.3	2		

** Based on fish and macroinvertebrates only*

5.12.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-91**.

Table 5-91: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 9.0 Category (C/D): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

5.12.3 Habitat Integrity: Instream and Riparian EcoSpecs and TPCs

EcoSpecs and TPCs for riparian and instream habitat integrity are shown in **Table 5-92**.

Table 5-92: Habitat Integrity for instream and riparian: EcoSpecs and TPCs

Metric	EcoSpec	TPC
Habitat integrity: Instream score and category	IHI: Instream score: 75% (C)	IHI: Instream score: ≤61% Further increase in algae growth
Habitat integrity: riparian score and category	IHI: Riparian score: 80% (B/C)	IHI: Riparian score: ≤77%

5.12.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-93**.

Table 5-93: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)

5.12.5 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as an ecological category 'D' (largely modified) using the MIRAI methodology, was found to be **water quality**.

Consequently, the macroinvertebrate indicator taxa listed in **Table 5-94**, were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007). Some of the selected indicator taxa were observed during the single site survey (as well as during the REMP monitoring). Therefore, their absence from the site during the monitoring program would suggest either a persistence or exacerbation of water quality deterioration, and/or with some indicator taxon, it may also indicate that their specific flow requirements are not being met.

The EcoSpecs and TPCs in **Table 5-95**.

Table 5-94: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE

Table 5-95: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 57.1% (Category D). The MIRAI score to be maintained at the top end of a D in the range >56 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥79%	PES: MIRAI ≤41% REC: MIRAI ≤77%
SASS5 and ASPT Score	-	PES: The SASS5 score was 34 with an ASPT of 4.3 from the survey. Total SASS5 score should remain >50, with ASPT value >4.8. REC: SASS5 score ≥120, with ASPT value > 6.0.	PES: SASS5 scores <30 and ASPT <3.8. REC: SASS5 scores < 120, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 8 families were collected during both surveys. Of these, 3 scored ≥ 9 sensitivity. More than 8 different families (taxa) should be present, with at least 3 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 28 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the	PES: Less than 20 taxa collected. Only 1 or less taxa scoring ≥ 9 sensitivity. Some of the indicator taxon recorded (barring Hydropsychidae>2spp). Any taxon (adults) with an abundance of D (i.e. Simuliidae). REC: Less than 28 families, with less than 3 taxa scoring ≥ 10. No recordings of the expected indicator taxon (Hydropsychidae

Parameter	Indictor[1]	EcoSpec	TPCs
		expected taxa with a high FROC, which were not recorded namely Hydropsychidae >2spp in ≥A abundances.	>2spp). Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The cobbles area along the cross section should comprise movable cobbles. GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Increase in steep bank erosion along both left and right banks.
Physical habitat diversity	Biotopes and diversity	The only SASS5 biotopes available to sample are (i.e. SIC, SOOC and GSM)	The loss of the small pocket of SIC and SOOC owing to increase sediment inputs from bank erosion covering the biotopes.
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

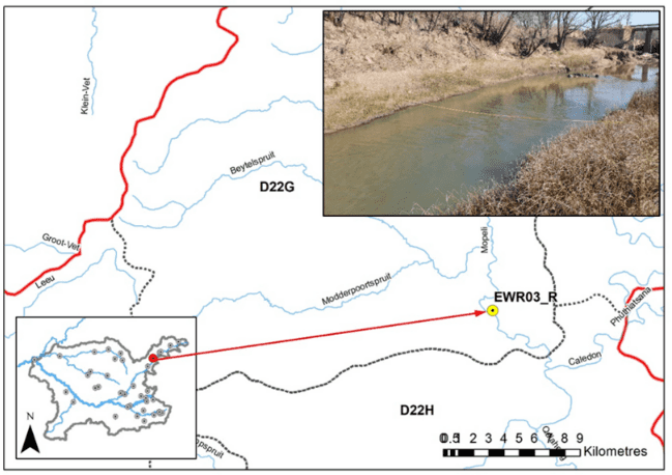
Parameter	Indictor[1]	EcoSpec	TPCs
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All those taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.13 UO_EWR03_R: Mopeli

The site, situated along the S872 district road within a confined valley setting, faces significant modifications. Upstream of the site, a derelict weir, a cross-over bridge, and a broken-up causeway bridge contribute to impediments in river hydraulics, with bridge rubble and log jams affecting the left bank. The Mopeli site exhibits considerable modifications in the channel, banks, and high flow conditions. The overall EcoStatus is categorized as C/D (moderately to largely modified), primarily due to biotic components. The aquatic macroinvertebrate category is influenced by poor habitat availability, dominated by bedrock, and flow conditions. For the fish community, the ecological category is driven by the fragmentation of the reach caused by various weirs limiting connectivity to the Caledon River, variable seasonal flows, and physical-chemical modifications.

Figure 5-13 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Mopeli
EWR Site Code	UO_EWR03_R
Driver component	PES
Diatoms	C
IHI (instream)	C
IHI (riparian)	C
Response component	PES
FRAI	D
MIRAI	D
Ecostatus	C/D
REC	C/D

Figure 5-13: UO_ EWR03_R: Mopeli and associated PES/EcoStatus/REC

5.13.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-96** with the freshet requirements in **Table 5-97**. As no gauge situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-96: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C/D	49.35	0.945	1.91	8.962	18.16	14.483	29.34

[1] *Natural Mean Annual Runoff* | [2] *Million Cubic Metres*

Table 5-97: Final freshet requirements

Months	Freshets*			
	m^3/s	days	m^3/s	days
October	1.5	2		
November	3.0	2		
December	3.0	2		
January	3.0	2	10	3
February	3.0	2	10	3
March	3.0	2	10	3
April	1.5	2		

** Based on fish and macroinvertebrates only*

5.13.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-98**.

Table 5-98: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 10.7 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality

5.13.3 Habitat Integrity: Instream and Riparian EcoSpecs and TPCs

EcoSpecs and TPCs for riparian and instream habitat integrity are shown in Table 5-99.

Table 5-99: Habitat Integrity for instream and riparian: EcoSpecs and TPCs

Metric	EcoSpec	TPC
Habitat integrity: Instream score and category	IHI: Instream score: 71% (C)	IHI: Instream score: ≤61% Further increase in algae growth Log jam at the bridge not removed which is impeding on

Metric	EcoSpec	TPC
		hydraulics and scouring of the river.
Habitat integrity: riparian score and category	IHI: Riparian score: 72% (C)	IHI: Riparian score: ≤61% Further increase in bank erosion and new growth of alien invasive plants.

5.13.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-100**.

Table 5-100: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)

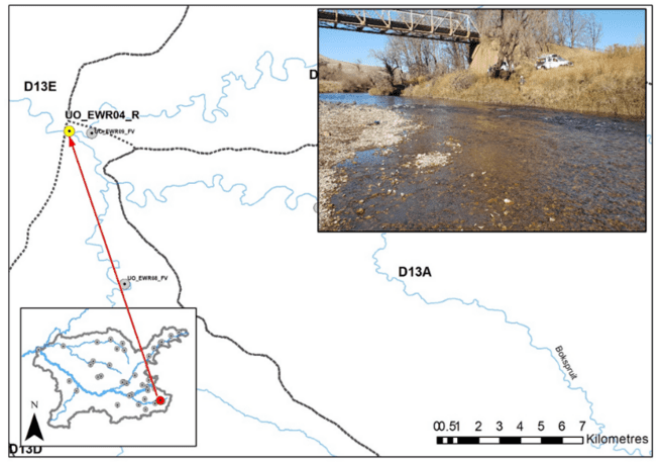
5.13.5 Macroinvertebrates: EcoSpecs and TPCs

Macroinvertebrates were not assigned EcoSpecs and TPCs at this location due to its unsuitability for such organisms. The site is characterised by bedrock dominance, significant steep banks with erosion on the right bank, and substantial sediment deposition on the left bank. Consequently, there is a lack of marginal vegetation and suitable habitat for macroinvertebrates. The macroinvertebrate PES was influenced by water quality, but the site may prove more useful for ecological assessment from a diatom and IHI perspective.

5.14 UO_EWR04_R: Upper Kraai

Situated in a partly confined valley, the upper Kraai site features a channel approximately 40m wide, following a pool-riffle longitudinal pattern. It is positioned just downstream of the Bell/Kraai River, around 200m from the confluence with the Sterkspruit. The overall EcoStatus has been determined as a C category, indicating a moderately modified state. The significant modification primarily stems from the seriously altered condition of the fish community, characterized by a high diversity and abundance of non-native fish species.

Figure 5-14 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Upper Kraai
EWR Site Code	**UO_EWR04_R**
Driver component	**PES**
Diatoms	B
IHI (instream)	A/B
IHI (riparian)	A/B
Response component	**PES**
FRAI	D
MIRAI	C
Ecostatus	C
REC	B

Figure 5-14: UO_ EWR04_R: Upper Kraai and associated PES/EcoStatus/REC

5.14.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-101** with the freshet requirements in **Table 5-102**. As no gauge is situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-101: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
B	200.93	9.082	4.52	64.438	32.07	80.456	40.04

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres

Table 5-102: Final freshet requirements

Months	Freshets*			
	m^3/s	days	m^3/s	days
October	7.0	2		
November	7.0	2		
December	10.0	3		
January	10.0	3	20	2
February	10.0	3	20	2
March	10.0	3	20	2
April	7.0	2		

** Based on fish and macroinvertebrates only*

5.14.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-103**.

Table 5-103: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 16.2 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality

5.14.3 Habitat Integrity: Instream and Riparian EcoSpecs and TPCs

EcoSpecs and TPCs for riparian and instream habitat integrity are shown in **Table 5-104**.

Table 5-104: Habitat Integrity for instream and riparian EcoSpecs and TPCs

Metric	EcoSpec	TPC
Habitat integrity: Instream score and category	IHI: Instream score: 90% (A/B)	IHI: Instream score: ≤87%
Habitat integrity: riparian score and category	IHI: Riparian score: 90% (A/B)	IHI: Riparian score: ≤87%

5.14.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-105**.

Table 5-105: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at about 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
	Enteromius oraniensis	Present at about 25% to 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class within reach	Maintenance of fast-shallow velocity-depth class within reach throughout the year	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate during lower flow periods	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.14.5 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'C' (moderately modified) using the MIRAI methodology, was found to be **water quality** (likely due to return flows from irrigation).

Consequently, the macroinvertebrate indicator taxa listed in **Table 5-106**, were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007).

The EcoSpecs and TPCs in **Table 5-107**.

Table 5-106: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Perlidae	12	0.5	3	4	3.5	4	0.5	1.5	0	HIGH
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
*Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Trichorythidae	9	0.5	2	3.5	4.5	4.5	1	0.5	0	MODERATE
*Elmidae	8	1.5	3	4	4.5	4	1	3.5	0	MODERATE
Simuliidae	5	1.5	2	3.5	4.5	4.5	1.5	0.5	0	LOW

Table 5-107: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 71.6% (Category C). The MIRAI score to be maintained as a mid-C in the range >72 – ≤78%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥83%	PES: MIRAI ≤61% REC: MIRAI ≤81%
SASS5 and ASPT Score	-	PES: The SASS5 score was 94 with an ASPT of 5.5. Total SASS5 score should remain >100, with ASPT value >5.6. REC: SASS5 score ≥130, with ASPT value > 6.2.	PES: SASS5 scores <90 and ASPT <5.0. REC: SASS5 scores < 130, ASPT < 6.2.
Diversity of invertebrate community	-	PES: 17 families were collected during the single survey. Of these, 4 scored ≥ 9 sensitivity. More than 17 different families (taxa) should be present, with at least 5 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present. REC: More than 22 families should occur at an abundance of A to B, which should include all indicator taxon, as well as the expected taxa with a high FROC, which were not recorded namely	PES: Less than 15 taxa collected. No recorded taxa scoring ≥ 9 sensitivity. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D (i.e. Simuliidae). REC: Less than 22 families, with less than 4 taxa scoring ≥ 9. No recordings of the expected indicator taxon. Any taxon (adult) with an abundance of D.

Parameter	Indictor[1]	EcoSpec	TPCs
		Hydropschyidae >2spp in ≥A and Elmidae in A abundances.	
Physical habitat quality	Biotopes and quality	Visual: The wide range of cobble selection along this reach should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, and odour).
Indicator Taxon	Perlidae	Perlidae present in ≥A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Perlidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	*Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

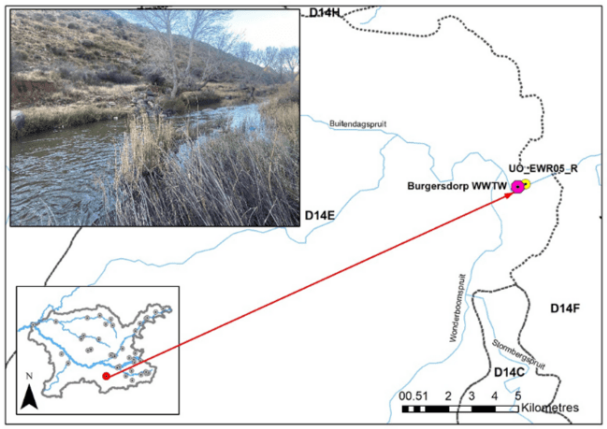
Parameter	Indictor[1]	EcoSpec	TPCs
		the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	
	Trichorythidae	Tricorythidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. High velocities are present and of > 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Tricorythidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC become exposed.
	*Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC biotope is at 15cm and covered.	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Simuliidae	Simuliidae present in ≤ B abundances.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.

Parameter	Indictor[1]	EcoSpec	TPCs
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.15 UO_EWR05_R: Wonderboomspruit

Positioned downstream from the town of Burgersdorp along the R391 road, the site has an overall EcoStatus of a D category. The impairment in all components is primarily driven by physical-chemical modification, attributed to the upstream town of Burgersdorp and its associated unmaintained and failing municipal infrastructure, particularly the WWTW. Evidence of instream and riparian sewage pollution is notable. Additionally, the presence of weirs within the reach is further limiting upstream migration and recruitment of key fish species from lower reaches.

Figure 5-15 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Wonderboomspruit
EWR Site Code	**UO_EWR05_R**
Driver component	**PES**
Diatoms	E
IHI (instream)	C
IHI (riparian)	C/D
Response component	**PES**
FRAI	D
MIRAI	D
Ecostatus	D
REC	C/D

Figure 5-15: UO_ EWR05_R: Wonderboomspruit and associated PES/EcoStatus/REC

5.15.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-108** with the freshet requirements in **Table 5-109**. Monitoring of compliance to be undertaken at gauge D1H001.

Table 5-108: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C/D	25.93	0.365	1.41	4.884	18.84	8.396	32.38

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres

Table 5-109: Final freshet requirements

Months	Freshets*			
	m^3/s	days	m^3/s	days
October			6	2
November	2.5	2		
December	2.5	2		
January	2.5	2		
February	2.5	2		
March	2.5	2	20	3
April			6	2

** Based on fish and macroinvertebrates only*

5.15.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-110**.

Table 5-110: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 4.6 Category (E): Seriously modified water quality	Already at lowest EC and high cause for concern.

5.15.3 Habitat Integrity: Instream and Riparian EcoSpecs and TPCs

EcoSpecs and TPCs for riparian and instream habitat integrity are shown in **Table 5-111**.

Table 5-111: Habitat Integrity for instream and riparian EcoSpecs and TPCs

Metric	EcoSpec	TPC
Habitat integrity: Instream score and category	IHI: Instream score: 70% (C)	IHI: Instream score: ≤61%

Metric	EcoSpec	TPC
		Further increase in algae growth Log jam at the bridge not removed which is impeding on hydraulics and scouring of the river.
Habitat integrity: riparian score and category	IHI: Riparian score: 61% (C/D)	IHI: Riparian score: ≤57% Physical-chemical modifications due to failing WWTW infrastructure and increased macroplastics.

5.15.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-112**.

Table 5-112: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus umbratus*	Present at about 50% of sites (FROC = 3)	Present at <25% of sites (FROC <3)
	Enteromius oraniensis	Present at 50% to 75% of sites (FROC = 4)	Present at <50% of sites (FROC <4)
Velocity-depth class	Slow-shallow velocity-depth class within reach	Maintenance of Slow-shallow velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class within reach	Maintenance of fast-shallow velocity-depth class within reach throughout the year	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Cover	Substrate at EFR Site	Maintenance of riffle/rapid substate during lower flow periods	Increased sedimentation of riffle/rapid substrates, excessive algal

Metric	Indicator	EcoSpec	TPC (biotic)
			growth on substrates

5.15.5 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'D' (largely modified) using the MIRAI methodology, was found to be **water quality**.

Consequently, the macroinvertebrate indicator taxa listed in **Table 5-113**, were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007). If some of these indicator taxa chosen for monitoring are absent from the site, it indicates a persistence or worsening of water quality deterioration during the monitoring program.

The EcoSpecs and TPCs in **Table 5-114**.

Table 5-113: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
*Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Elmidae	8	1.5	3	4	4.5	4	1	3.5	0	MODERATE
Hydraenidae	8	1	1.5	3	4	4	3	1.5	3	MODERATE
*Aeshnidae	8	2.5	3.5	4	2.5	4	3	3	0	MODERATE

Table 5-114: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 56.9% (Category D). The MIRAI score to be maintained at the top end of a D in the range >57 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 102 with an ASPT of 5.1. Total SASS5 score should remain >110, with ASPT value >5.2. REC: SASS5 score ≥130, with ASPT value > 5.8.	PES: SASS5 scores <90 and ASPT <4.8. REC: SASS5 scores < 140, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 20 families were collected during both surveys. Of these, 1 scored ≥ 10 sensitivity. More than 20 different families (taxa) should be present, with at least 2 of these scoring ≥ 10, and at an abundance of A to B. All indicators should be present (barring the expected but not recorded indicator taxa). REC: More than 23 families should occur at an abundance of A to B, which should include both expected indicator taxa	PES: Less than 18 taxa collected. No taxa scoring ≥ 10. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 23 families, with less than 3 taxa scoring ≥ 10. None of the expected

Parameter	Indictor[1]	EcoSpec	TPCs
		namely Hydropsychidae >2spp and Aeshnidae in ≥A and A abundances respectively.	indicator taxon recorded. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The range of cobble selection along this reach should comprise movable cobbles. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, odour and solid waste).
Indicator Taxon	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Hydropsychidae >2spp	Hydropsychidae >2 spp. present in ≥A abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and SIC become exposed.
	Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
	Elmidae	Elmidae present in A abundances. Habitat and medium flows should be adequate to ensure suitable habitats for this sensitive taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate	Elmidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and/or when the SIC becomes exposed.

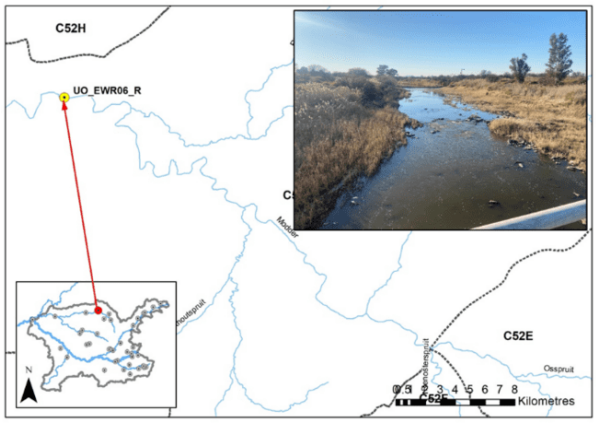
Parameter	Indictor[1]	EcoSpec	TPCs
		water quality and ensure the SIC biotope is at 15cm and covered.	
	Hydraenidae	Hydraenidae present in A abundances, in at least one of two consecutive survey samples. Flows and water quality should be adequate to ensure suitable habitats for this flow and water quality dependant taxon. High velocities are present and of > 0.6 m/s, maintain moderate water quality and ensure the SIC and marginal vegetation are covered.	Hydraenidae absent in one of two consecutive samples. Velocities decrease below 0.6m/s for longer than a week, water quality deterioration and SIC, vegetation/stems become exposed.
	*Aeshnidae	Aeshnidae present in A abundances. Habitat and water quality should be adequate to ensure suitable habitats for this taxon. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the GSM and vegetation biotope are present.	Aeshnidae absent in one of two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and marginal vegetation become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Chironomidae Turbellaria	Chironomidae and/or Turbellaria present in ≤ B abundances. Chironomidae have a wide range of preferences.	Ensure that this group does not dominate the macroinvertebrate assemblage, defined as D (>1000) abundance for more than two consecutive surveys.

Parameter	Indictor[1]	EcoSpec	TPCs
		Indicator taxon thrive in very low water quality. They can further be an indication of extensive nutrient inputs (i.e. sewage),	
	Macroinvertebrates	All other taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.16 UO_EWR06_R: Middle Modder

Situated off the R700 road, approximately 30 km north of Bloemfontein, and roughly 4 km downstream of the Doringspruit confluence within the Soetdoring Nature Reserve, this site exhibits the impact of from both a water quantity and quality perspective. Downstream, the Krugersdrift Dam has led to extensive inundation of the system beyond the EWR site. The overall EcoStatus is largely modified (Category D), with all components contributing to this primarily driven by impaired water quality. Upstream urban areas, coupled with unmaintained and failing municipal infrastructure, especially WWTWs, collectively contribute to the compromised water quality. Additionally, from a fish perspective, the fragmentation of longitudinal connectivity is noted as a significant driver of the ecological state of the fish assemblage, limiting their movement.

Figure 5-16 provides a map and photographs of the EWR site, coupled with a summary of the ECs, representative of broad qualitative EcoSpecs, and determined for the PES. The PES is representative of the baseline.



River	Middle Modder
EWR Site Code	UO_EWR06_R
Driver component	**PES**
Diatoms	D
IHI (instream)	D
IHI (riparian)	D
Response component	**PES**
FRAI	D
MIRAI	D
Ecostatus	D
REC	C/D

Figure 5-16: UO_ EWR06_R: Middle Modder and associated PES/EcoStatus/REC

5.16.1 Hydrology: EcoSpecs

A summary of the EcoSpecs for hydrology is shown in **Table 5-115** with the detailed freshet requirements in **Table 5-116**. As no gauge situated close to the site, discharge to be measured during biological and other surveys as specified in Section 6 of the report.

Table 5-115: Hydrology EcoSpecs

REC	nMAR[1] (MCM[2])	Drought flows (MCM)	Drought (%nMAR)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)
C/D	113.68	1.798	1.58	23.746	20.89	38.603	33.96

[1] Natural Mean Annual Runoff | [2] Million Cubic Metres

Table 5-116: Final freshet requirements

Months	Freshets*			
	m^3/s	days	m^3/s	days
October	9.0	3		
November	7.0	5		
December	7.0	5		
January	7.0	5		
February	7.0	5	20	3
March	7.0	5	20	3
April	9.0	3		

** Based on fish and macroinvertebrates only*

5.16.2 Water quality: EcoSpecs and TPCs

EcoSpecs and TPCs for water quality are shown in **Table 5-117**.

Table 5-117: Water quality EcoSpecs and TPCs

Metric	EcoSpecs	TPCs
Physical variables/parameters		
Please refer to table 5-3 for EcoSpecs (TWQR)		
Diatoms		
Diatoms	SPI Score: 6.8 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality

5.16.3 Habitat Integrity: Instream and Riparian EcoSpecs and TPCs

EcoSpecs and TPCs for riparian and instream habitat integrity are shown in **Table 5-118**.

Table 5-118: Habitat Integrity for instream and riparian EcoSpecs and TPCs

Metric	EcoSpec	TPC
Habitat integrity: Instream score and category	IHI: Instream score: 54% (D)	IHI: Instream score: ≤41% Further abstraction and irrigation.

Metric	EcoSpec	TPC
Habitat integrity: riparian score and category	IHI: Riparian score: 58% (D)	IHI: Riparian score: ≤41% New growth of alien invasive plants.

5.16.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs for fish are shown in **Table 5-119**.

Table 5-119: Fish EcoSpecs and TPCs

Metric	Indicator	EcoSpec	TPC (biotic)
Metric	**Indicator**	**EcoSpec**	**TPC (biotic)**
FRAI score and category	PES	FRAI Score: >42% (Ecological Category D).	FRAI Score: <42% (Ecological Category D/E)
Indicator fish species and presence	*Labeobarbus aeneus*	Present at about 25% to 50% of sites during summer (FROC = 3)	Present at <25% of sites (FROC ≤2)
	Labeo capensis	Present at about 50% to 75% of sites during summer (FROC = 4)	Present at <50% of sites (FROC ≤3)
Velocity-depth class	Fast-deep velocity-depth class within reach	Maintenance of fast-deep velocity-depth class within reach during summer high-flow period	Reduced suitability and./or abundance of fast-deep velocity-depth class
	Fast-shallow velocity-depth class at EFR site	Maintenance of fast-shallow velocity-depth class at EFR Site during summer high-flow period	Reduced suitability and./or abundance of fast-shallow velocity-depth class
Substrate	Substrate at EFR Site	Maintenance of riffle/rapid substate at EFR site	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates

5.16.5 Macroinvertebrates: EcoSpecs and TPCs

Alterations in flow at this site did not significantly affect the macroinvertebrate community. Instead, the community demonstrated notable responses linked to low to very low requirements for unaltered physical-chemical conditions. Consequently, the primary factor influencing the macroinvertebrate PES, evaluated as a category 'D' (largely modified) using the MIRAI methodology, was found to be **water quality**.

Consequently, the macroinvertebrate indicator taxa listed in **Table 5-120,** were selected as monitoring indicators for this site. Their velocity and biotope preferences are rated at a preliminary level on a scale of 0 (low) to 5 (very high) (Thirion, 2007). If some of these indicator taxa chosen for monitoring are absent from the site, it indicates a persistence or worsening of water quality deterioration during the monitoring program.

The EcoSpecs and TPCs in **Table 5-121**.

Table 5-120: Macroinvertebrate indicator taxa

Indicator Family	Velocity preference					Substrate preference				WQ Preference[2]
	SQ[1]	<0.1	0.1-0.3	0.3-0.6	>0.6	Cobbles	Veg	GSM	Water	
*Heptageniidae	13	1	4	4.5	3	4.5	0.5	1.5	0	HIGH
Baetidae >2spp	12	3	3.5	4	4	4	4	4	0	HIGH
Hydropsychidae >2spp	12	1	2.5	4	4.5	4.5	1	1.5	0	HIGH
*Leptophlebiidae	9	2	3.5	4.5	3.5	4	1	3.5	0	MODERATE
Ecnomidae	8	2	3.5	3.5	1.5	4	1	1.5	0	MODERATE

Table 5-121: Macroinvertebrate EcoSpecs and TPCs

Parameter	Indictor[1]	EcoSpec	TPCs
MIRAI Score and category	-	MIRAI score: 55.9% (Category D). The MIRAI score to be maintained in the mid-D range of >55 – ≤58%, using the reference data used in this study, or recording alterations to these. REC: MIRAI ≥59%	PES: MIRAI ≤41% REC: MIRAI ≤57%
SASS5 and ASPT Score	-	PES: The SASS5 score was 56 with an ASPT of 5.1. Total SASS5 score should remain >70, with ASPT value >5.2. REC: SASS5 score ≥100, with ASPT value > 5.8.	PES: SASS5 scores <55 and ASPT <4.8. REC: SASS5 scores < 120, ASPT < 6.0.
Diversity of invertebrate community	-	PES: 11 families were collected during the single survey. Of these, 1 scored ≥ 9 sensitivity. More than 11 different families (taxa) should be present, with at least 2 of these scoring ≥ 9, and at an abundance of A to B. All indicators should be present (barring the expected but not recorded indicator taxa). REC: More than 18 families should occur at an abundance of A to B, which should include both expected indicator taxa	PES: Less than 10 taxa collected. No taxa recorded with a sensitivity scoring of ≥ 9. None of the indicator taxon recorded. Any taxon (adults) with an abundance of D. REC: Less than 20 families, with less than 3 taxa scoring ≥ 10. None of the expected

Parameter	Indictor[1]	EcoSpec	TPCs
		namely Hydropsychidae >2spp and Leptophlebiidae in ≥A abundances.	indicator taxon recorded. Any taxon (adult) with an abundance of D.
Physical habitat quality	Biotopes and quality	Visual: The range of cobble selection along this reach should comprise movable cobbles and boulders. Inundated marginal vegetation and GSM should be available to sample.	Immobile cobbles with extensive algae and fine silt cover. Lack of inundated marginal vegetation. Limited pockets of gravel.
Physical habitat diversity	Biotopes and diversity	All SASS5 biotopes should be available (i.e. SIC, SOOC, GSM and inundated marginal vegetation, excluding aquatic vegetation).	Marginal vegetation is exposed (no wetted stems).
Response to water quality	Water quality	During flow periods, water should be clear, non-odorous, and low in suspended solids. The SIC and SOOC surfaces should neither be slippery nor covered with silt.	Observed deterioration (turbidity, silt, odour and solid waste).
Indicator Taxon	*Heptageniidae	Heptageniidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure the SIC are at a depth of 15cm and covered.	Heptageniidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
	Baetidae >2spp	Baetidae >2 spp present in ≥B abundances Flows should be adequate to ensure suitable habitats for these moderate to fast flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered and/or GSM and marginal vegetation.	Baetidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week, and biotopes become exposed.
	Hydropsychidae >2spp	Hydropsychidae >2 spp present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these moderate flow dependant taxa. Moderate to high velocities are present and of 0.3m/s - 0.6 m/s, ensure the SIC are at a depth of 15cm and covered.	Hydropsychidae 2 spp or less in two consecutive samples. Velocities decrease below 0.3m/s for longer than a week and SIC become exposed.
	*Leptophlebiidae	Leptophlebiidae present in ≥B abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain good water quality and ensure	Leptophlebiidae absent (or individuals only) on two or more consecutive surveys. Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.

Parameter	Indictor[1]	EcoSpec	TPCs
		the SIC are at a depth of 15cm and covered, and ensuring GSM is present.	
	Ecnomidae	Ecnomidae present in A abundances. Flows should be adequate to ensure suitable habitats for these flow dependant taxa. Moderate velocities are present and between 0.3 - 0.6 m/s, maintain moderate water quality and ensure the SIC are at a depth of 15cm and covered.	Ecnomidae absent (or individuals only) on two or more consecutive surveys Velocities decrease below 0.3m/s for longer than a week, water quality deterioration and SIC become exposed.
Alien invasive macroinvertebrates and/or outbreak abundances	Macroinvertebrates	All taxa with a preference for very low water quality within the sensitivity score range of 1 – 5.	Should there be an outbreak (i.e. tolerant taxa dominating the macroinvertebrate assemblage, defined as D (>1000) abundance, for more than two consecutive surveys, must be raised immediate with DWS.

5.17 Field Verification Sites: EcoSpecs

5.17.1 Hydrology: EcoSpecs

The hydrology EcoSpecs for selected field verification sites (where flows have been impacted by upstream use or dams) are based on the output from the DRM for low as well as high flows (see **Table 5-122**). No additional freshets or floods were specified and the DRM proposed freshets were accepted. Discharge at these sites to be measured during biological and other surveys as specified in Section 6 of the report.

5.17.2 Water quality: EcoSpecs

Please refer to **Table 5-123** for the selected field verification sites whereby diatoms and habitat integrity EcoSpecs have been determined.

Table 5-122: Summary of hydrology EcoSpecs for field verification sites

EWR site	River	Quat[1]	REC	nMAR[2] (MCM[3])	Low flows (%nMAR)	Drought (%nMAR)	High flows (%nMAR)	Total EWR as %nMAR for REC
UO_EWR01_FV	Meulspruit	D22B	D	63.6	3.13	0.41	0	3.13
UO_EWR02_FV	Witspruit	D24C	C	21.7	7.78	1.33	11.40	19.18
UO_EWR05_FV	Bokspruit	D13A	B	60.4	32.01	2.95	12.98	44.99
UO_EWR06_FV	Holspruit	D13J	C	36.9	5.96	0.71	12.08	18.05
UO_EWR07_FV	Sterkspruit, tributary of Kraai	D13C	B/C	47.6	25.64	2.71	11.59	37.24
UO_EWR17_FV	Langkloofspruit	D13D	B	43.8	32.09	4.68	12.36	44.45
UO_EWR19_FV	Lower Modder	C52K	C	156.8	5.60	0.21	12.22	17.82

[1] Quaternary catchment / [2] Natural Mean Annual Runoff | [3] Million Cubic Metres

5.17.3 Diatom and habitat integrity: EcoSpecs

Table 5-123: Field verification site EcoSpecs for diatoms and habitat integrity

Metric	EcoSpecs	TPC
UO_EWR01_FV: Meulspruit (PES: D; REC: D)		
Diatoms	SPI Score: 9.3 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 71% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 61% (C/D)	IHI: Riparian score: ≤57%
UO_EWR02_FV: Witspruit (PES: C/D; REC: C)		
Diatoms	SPI Score: 6.7 Category (D): Poor water quality	SPI Score: <4.8 Category E: Seriously modified water quality
Habitat Integrity: Instream	IHI: Instream score: 74% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 86% (B)	IHI: Riparian score: ≤81%
UO_EWR03_FV: Gryskopspruit (PES: C; REC: C)		
Diatoms	SPI Score: 2.5 Category (E): Seriously modified water quality	Already at lowest EC and high cause for concern.
UO_EWR04_FV: Karringmelkspruit (PES: B; REC: B)		
Diatoms	SPI Score: 15.2	SPI Score: <12.8

Metric	EcoSpecs	TPC
	Category (B): Good water quality	Category C: Moderate water quality
Habitat Integrity: Instream	IHI: Instream score: 95% (A)	IHI: Riparian score: ≤91%
Habitat Integrity: Riparian	IHI: Riparian score: 92% (A)	IHI: Riparian score: ≤91%
UO_EWR05_FV: Bokspruit (PES: B/C; REC: B)		
Diatoms	SPI Score: 10.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 86% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 88% (B)	IHI: Riparian score: ≤81%
UO_EWR06_FV: Holspruit (PES: C; REC: C)		
Diatoms	SPI Score: 9.7 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 70% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 72% (C)	IHI: Instream score: ≤61%
UO_EWR07_FV: Sterkspruit (tributary of Bell/Kraai) (PES: C; REC: B/C)		
Diatoms	SPI Score: 12 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 82% (B)	IHI: Riparian score: ≤81%

Metric	EcoSpecs	TPC
Habitat Integrity: Riparian	IHI: Riparian score: 82% (B)	IHI: Riparian score: ≤81%
UO_EWR08_FV: Bell (PES: B/C; REC: B)		
Diatoms	SPI Score: 17.3 Category (A): High water quality	SPI Score: <16.7 Category B: Good water quality
Habitat Integrity: Instream	IHI: Instream score: 81% (B/C)	IHI: Riparian score: ≤77%
Habitat Integrity: Riparian	IHI: Riparian score: 84% (B)	IHI: Riparian score: ≤81%
UO_EWR09_FV: Groenspruit (PES: C/D; REC: C)		
Diatoms	SPI Score: 7.3 Category (D): Poor water quality	SPI Score: <4.8 Category D: Seriously modified water quality
UO_EWR11_FV: Fouriespruit (PES: C; REC: C)		
Diatoms	SPI Score: 11.2 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
UO_EWR13_FV: Os-spruit (PES: B/C; REC: B/C)		
Diatoms	SPI Score: 12.8 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
UO_EWR17_FV: Langkloofspruit (PES: B/C; REC: B)		
Diatoms	SPI Score: 14.1 Category (B): Good water quality	SPI Score: <12.8 Category C: Moderate water quality

Metric	EcoSpecs	TPC
Habitat Integrity: Instream	IHI: Instream score: 87% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 80% (B/C)	IHI: Riparian score: ≤77%
UO_EWR18_FV: Wasbankspruit (PES: C; REC: B/C)		
Diatoms	SPI Score: 12.4 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 84% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 69% (C)	IHI: Instream score: ≤61%
UO_EWR19_FV: Lower Modder (PES: C/D; REC: C)		
Diatoms	SPI Score: 12.0 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 56% (D)	IHI: Riparian score: ≤41%
Habitat Integrity: Riparian	IHI: Riparian score: 75% (C)	IHI: Instream score: ≤61%
UO_EWR21_FV: Lower Kromellenboog (PES: C; REC: B/C)		
Diatoms	SPI Score: 8.0 Category (D): Poor water quality	SPI Score: <4.8 Category D: Seriously modified water quality
Habitat Integrity: Instream	IHI: Instream score: 84% (B)	IHI: Riparian score: ≤81%
Habitat Integrity: Riparian	IHI: Riparian score: 88% (B)	IHI: Riparian score: ≤81%

Metric	EcoSpecs	TPC
UO_EWR23_FV: Orange (PES: C/D; REC: C)		
Diatoms	High load of fine sediment, very few diatom cells present	
Habitat Integrity: Instream	IHI: Instream score: 63% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 54% (D)	IHI: Riparian score: ≤41%
UO_EWR24_FV: Maghaleng (PES: C/D; REC: C/D)		
Diatoms	High load of fine sediment, very few diatom cells present	
UO_EWR25_FV: Middle Caledon (PES: D; REC: C/D)		
Diatoms	SPI Score: 10.3 Category (C): Moderate water quality	SPI Score: <8.8 Category D: Poor water quality
Habitat Integrity: Instream	IHI: Instream score: 71% (C)	IHI: Instream score: ≤61%
Habitat Integrity: Riparian	IHI: Riparian score: 61% (C/D)	IHI: Riparian score: ≤57%

6. MONITORING AND MANAGEMENT PROGRAMME FOR ALL COMPONENTS

The following should be read for the rivers (this section), wetlands (Section 10) and groundwater (Section 14) proposed monitoring programme.

Due to practical constraints, implementing a comprehensive monitoring program within the scope of this project is not viable. The monitoring program outlined in this report is designed to be more realistic, focusing on developing the fundamental concepts that should guide future monitoring efforts for rivers. Furthermore, a pragmatic management programme has been provided that identifies those indicators that will provide the most information on the state of the water resources if monitored.

Adaptive management is an iterative process encompassing the following five key steps, as outlined by Williams (2011):

(1) making decisions under uncertainty;
(2) monitoring environmental outcomes;
(3) evaluating the impact of decisions on outcomes using monitoring data;
(4) enhancing our understanding of the system; and
(5) utilising updated knowledge to enhance future management practices.

For further information on the adaptive management approach, refer to **Section 3.3.1.** Unfortunately, a notable gap exists in many monitoring programs, as they are not explicitly designed to establish a clear link between decisions and environmental outcomes, thereby disrupting the continuity of the adaptive management cycle from Step 1 onward (Conroy and Peterson, 2013; Westgate *et al.,* 2013). Furthermore, this is reiterated from a South African perspective in accordance with Rogers & Bestbier (1997). Instead, most monitoring programs have been designed with the aim of documenting trends in metrics that are supposedly indicative of ecosystem health. Although these monitoring programmes play a crucial role in reporting progress toward overarching policy goals, they are recognised as ineffective for adaptive management purposes (Rogers & Bestbier, 1997). Thus, the clear vision outlined in the National Water Acts policy, a robust, flexible, and long-term plan is essential, backed by all stakeholders in water resource management: Government, water services authorities, providers, catchment management agencies, user associations, research organisations, and the private sector. Therefore, it is imperative that the adaptive management approach be employed, i.e "uses feedback loops to allow a learning–from-experience-system and which permits adjustment of water management practices to address evolving issues and conditions.

Thus, it is essential to recognise that the concepts presented in **Table 6.1, Table 10-1 and Table 14-1,** for all components underlying the monitoring program, should be regarded as testable hypotheses. These hypotheses must be confirmed, adjusted, or rejected through ongoing monitoring efforts. This approach is particularly crucial within the framework of an adaptable management and monitoring strategy, if we intend to ensure the achievement of EcoSpecs. In addition, a brief management plan for rivers has been included within **Table 6-2.** These have been set, based on the proposed monitoring programme, and for where adaptive management can be implemented, for the achievement of the proposed EcoSpecs to be met.

6.1 Rivers Monitoring and Management Programme

The ecological integrity of the aquatic ecosystem (fish, macroinvertebrates and habitats) will be affected in several ways by flow regulation and water quality (drivers). These include both beneficial and adverse effects. Some species may increase in abundance in the rivers whereas others may be lost from a specific reach. Water quality, as a driver, would impact on the health of the ecosystem, influencing the habitat and causing changes to both the macroinvertebrate and the fish communities.

Please refer to **Table 6-1** which provides the primary concepts guiding the monitoring to measure whether the EcoSpecs are being achieved for each EWR site.

Table 6-1: Monitoring programme for rivers

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
Flow/Quantity	Changes in flow have a severe impact on habitats, dilution, and biota. Flows should be gauged at existing gauges as specified for the various sites, on a continuous time step. Where there is no gauge, the discharge should be monitored during surveys.	Continuously at existing flow gauges close to biomonitoring site, else discharge during other surveys.	All Intermediate and Rapid 3 EWR sites
Water quality	*In situ* water quality: Parameters that must be assessed at each of the sampling site must include: pH, salinity, Dissolved Oxygen (DO), EC, Total Dissolved Solids (TDS), water temperature (which further forms part of the water quality management actions); water clarity using clarity tubes to monitor the sediment loads within the systems, Escherichia coli (e-coli) test kits would be advantageous to use during *in-situ* monitoring.	Monthly	All EWR sites, including Field Verification sites
	Other water quality parameters to be tested in laboratories: pH, DO, EC, TDS and water temperature; E coli (although needs to be tested within 24 hours of sample retrieval), Cyanobacteria, Phosphates (PO_4^{-3}), Nitrate plus nitrite nitrogen (NO_3+NO_2-N).	Monthly	All Intermediate EWR sites
	Diatoms should be analysed at every EWR site with results interpreted according to the Species-specific Pollution Index (SPI). Inferences must be made from the percentage of Pollution Tolerant Valves (%PTV), percentage of deformed cells and dominant indicator species. Diatoms samples can be sent through to the North-West University, who had the baseline results of the diatoms from this study for comparison purposes.	Biennial	All EWR sites, including Field Verification sites

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	Important *compliance monitoring* for water quality. The DWS to ensure enforcement and accountability within the municipalities that are responsible for all WWTWs located upstream of the identified EWR sites. Green drop scores were provided within the Scenario and Consequence Report (Report No. RDM/WMA13/00/CON/COMP/1423) and thus should be taken cognisant of during DWS audits. The above compliance monitoring should be linked with the monitoring programme to meet the specified EcoSpecs for water quality.	Annually	UO_EWR01_I UO_EWR02_I UO_EWR04_I UO_EWR06_I UO_EWR07_I UO_EWR09_I
General habitat and site characteristics	General description of the aquatic sampling sites must be compiled. Fixed upstream and downstream photo point monitoring (at the cross-section point) to capture at least: • Channel and Bank condition; • Instream and marginal vegetation state and extent of inundation; • Water clarity; • Algal cover; • Depth of flow over coarse substrates (cobbles/ bedrock); • Turbulence and extent of white water in rapids; and • Morphological conditions. Furthermore, watershed features (i.e., surrounding land use, sources of pollution, erosion, new development etc.).	Bi-annually during the SASS5 surveys	All Intermediate and Rapid 3 EWR sites
	The Rapid Habitat Assessment Method (RHAM) should be undertaken. This is a rapid approach and cost-effective to assess instream habitat conditions in wade-able, and to	Bi-annually during the SASS5 surveys	All Rapid 3 EWR sites

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	a more limited degree, non-wade able streams. The RHAM data is used to assess habitat suitability for indicator instream biota (fish and macroinvertebrates). The premise of the RHAM is that suitable habitat conditions will indicate the likely presence, abundance and frequency of occurrence of particular biota. Baseline conditions are used to indicate the change in habitat conditions and the derived impact on the indicator biota.		
Riparian vegetation	Riparian vegetation should be assessed using the Riparian Vegetation Response Assessment Index (VEGRAI level 4) method to monitor the changes in vegetation, particularly in terms of woody and non-woody cover/abundance/composition, alien invasive plants (AIP), riparian drivers and impacts, etc.	Every 5 years preferably during early autumn	All Intermediate EWR sites
	Conduct the IHI – it will be important especially for the riparian component of this model to be used as a surrogate to the VEGRAI score in order to run the Eco-status Model for all Rapid 3 EWR sites.	Annually	All Rapid 3 EWR sites
	Desktop vegetation assessment (woody to non-woody to open area comparisons using Google Earth and/or other satellite imagery for interrogation and to compare to previous years of possible regrowth etc. Land cover information and the PESEIS 2023 should be used.	Every 5 years	All Intermediate and Rapid 3 EWR sites
Macroinvertebrates	Ensure the data and results from other monitoring programmes namely DWS quarterly REMP monitoring, monitoring conducted by SANParks, and the five yearly Joint Basin Survey (JBS) monitoring, through ORASECOM, are included with the data collected and running of the MIRAI, from this studies EWR sites and monitoring programme. These are as follows:	Annually	UO_EWR04_I UO_EWR07_I UO_EWR08_ UO_EWR09_I UO_EWR10_I UO_EWR01_R UO_EWR02_R

<table>
<tr><th>Component</th><th>Monitoring programme to meet the specified EcoSpecs</th><th>Frequency</th><th>EWR site application</th></tr>
<tr><td rowspan="2"></td><td>
<table>
<tr><th>UO_EWR site</th><th>DWS REMP Site</th><th>JBS</th><th>SanParks</th></tr>
<tr><td>UO_EWR04_I</td><td>-</td><td>OSAEH_26_8</td><td>-</td></tr>
<tr><td>UO_EWR07_I</td><td>C5MODD-SANNA</td><td>OSAEH_11_18</td><td>-</td></tr>
<tr><td>UO_EWR08_</td><td>D2KRAA-ALIWA</td><td>OSAEH_26_11</td><td>-</td></tr>
<tr><th>UO_EWR site</th><th>DWS REMP Site</th><th>JBS</th><th>SanParks</th></tr>
<tr><td>UO_EWR09_I</td><td>C5RIET-DEKRA</td><td>OSAEH_29_5</td><td>Monitoring site</td></tr>
<tr><td>UO_EWR10_I</td><td>-</td><td>OSAEH_26_3</td><td>-</td></tr>
<tr><td>UO_EWR01_R</td><td>D2CAL-EWR01</td><td>-</td><td>-</td></tr>
<tr><td>UO_EWR02_R</td><td>D2GROOT-FARM1</td><td>-</td><td>-</td></tr>
<tr><td>UO_EWR06_R</td><td>C5MODD-SANNA</td><td>OSAEH_11_19</td><td>-</td></tr>
</table>
</td><td></td><td>UO_EWR06_R</td></tr>
<tr><td>In addition to the routine quarterly REMP that DWS conduct, additional aquatic macroinvertebrates monitoring using the South African Scoring System 5 (SASS5) should be conducted at all other EWR sites, which are not aligned to the existing REMP sites. This will provide an indication of the state of the aquatic environment, detect trends and to ensure that the EcoSpecs are being met.</td><td>Bi-annually (wet and dry season)</td><td>All Intermediate and Rapid 3 EWR sites</td></tr>
</table>

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	The Macroinvertebrate Response Assessment Index (MIRAI) must be conducted to identify the ecological category of the aquatic macroinvertebrates and to continually track the trends.	Annual basis for the last hydrological year	All Intermediate and Rapid 3 EWR sites
	The Integrated Habitat Assessment System (IHAS - version 2) was developed specifically for use with rapid biological assessment protocols in South Africa (McMillan, 1998), and reflects the suitability of habitat as a percentage, where 100% represents "ideal" habitat availability. IHAS is conducted in conjunction with the South African Scoring System Version 5 (SASS5).	Bi-annually with the SASS5 monitoring	All Intermediate and Rapid 3 EWR sites
Fish	If possible, and if equipment is available (electro-shocker), ichthyofauna (fish) surveys should be undertaken. Electrofishing should be conducted for at least 60 minutes and/or when all habitat-velocity-depth classes have been shocked and/or no additional fish species are being recorded. Fish species diversity and abundances should be recorded, fish health assessment and the presence of Red Data species. Whereas aquatic macroinvertebrate communities are good indicators of short-term localised conditions in a river, fish being relatively long-lived and mobile are: • Good indicators of long-term influences; • Good indicators of general habitat conditions; • Integrate effects of diverse trophic levels; and • Consumed by humans. Indigenous species should be returned to the water as soon as possible whereas introduced species should be euthanised. All results and samples should be lodged with the appropriate national databases. Any observations of *L. kimberleyensis* should be considered significant due to the widespread decline in the abundance of this species.	Annually (wet season)	All Intermediate and Rapid 3 EWR sites

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	The Fish Response Assessment Index (FRAI) must be conducted to identify the ecological Category of the fish and to continually track the trends.	Annual basis for the last hydrological year	All Intermediate and Rapid 3 EWR sites
EcoStatus	The EcoStatus model should be run for all EWR sites. The riparian vegetation ecological category to be used to complete the EcoStatus for all Intermediate EWR sites, and the riparian IHI Category to be used as a surrogate to the riparian vegetation to complete the EcoStatus for all Rapid3 EWR sites.	Annually following the completion of running the MIRAI, FRAI, VEGRAI and IHI	All Intermediate and Rapid 3 EWR sites
	Following the completion of the current update to the 2011 PES and EIS database for primary, secondary catchments on a sub-quaternary reach scale for the Upper Orange, the EcoStatus results from the EWR sites should be compared to the updated PES and EIS database.	Annually	All Intermediate and Rapid 3 EWR sites
Geomorphology	Conduct GAI level IV during low flow conditions. A cross sectional survey should be included to enable the channel shape, width and depth to be compared over time.	Every 5 years	All Intermediate EWR sites
	Channel pattern during low flow – this can be done based on freely available satellite images, such as through Google Earth. It is important to do the assessment for low flow periods when most of the river morphology is exposed.	Every 2 years	All Intermediate EWR sites
	Channel width – the measurement can be done across the riffle/rapid with a long tape measure or as part of a cross-sectional survey.		
	Median particle size for mobile bed sediment along riffle/rapid. A random selection of 100 mobile/loose clasts are collected and the b-axis measured. The median (D50), D16 and D84 must be calculated for monitoring purposes.		

Component	Monitoring programme to meet the specified EcoSpecs	Frequency	EWR site application
	Extent of bank erosion – this is a visual assessment of the length of bank showing erosion compared to the length of the stable section.		
Analysis and Interpretation	The data collected from the rivers EWR sites monitoring programme should be analysed and interpreted on a bi-annual basis, with a trends report published on an annual basis. This report should be externally reviewed.	Annually	All EWR sites

Table 6-2: Management programme for rivers

Component	Management programme as a result of the monitoring programme
Flow/Quantity	• Manage and maintain all active gauging weirs and stations throughout the study area. • Investigate possible new gauging weirs close to EWR sites where no continuous flow data is available.
Quality	• With water quality being the primary driver throughout the Upper Orange catchment area, it is vital and important that the management of compliance monitoring for water quality be undertaken. DWS must ensure that water quality monitoring is being undertaken and is being managed; • All DWS laboratories are encouraged to undertake assessments and implement interventions to improve analytical performance and ensure credible and reliable analytical data; • Laboratories must aim to become accredited, if not already; • The DWS to ensure enforcement and accountability within the municipalities that are responsible for all WWTWs located upstream of the identified EWR sites; • Allocation plans, water use licensees, directives must be reviewed and managed; and • Compliance audits must be undertaken and managed.

Component	Management programme as a result of the monitoring programme
Riparian vegetation	• Compile an alien plant control programme for riparian zones and adjacent buffers (up to 20m). The programme should seek support from landowners and should include financial incentives for landowners that can support implementation of the alien plant control programme. • Eradication and control of exotic vegetation within riverine areas should be implemented to enhance riparian functioning, increase bank stability, reduce erosion, and improve the general buffering capacity of rivers, while sustaining instream habitats for aquatic biota. • Highest priority should be given to riparian areas with sparse/scattered alien trees to limit further spread (e.g. UO_EWR01_I, UO_EWR03_I and UO_EWR07_I). Highly infested areas will require intensive and on-going management to effectively eradicate problem species, together with revegetation and ongoing maintenance. Livestock pressures (i.e. grazing and trampling) will require special consideration, especially given that rivers are freely accessed by communities and their livestock, but livestock can also be an asset for rebuilding soils and restoring vegetation cover.
Overall	• Catchment management strategies must be developed to assist with the management of overgrazing and trampling.
	• Riverine buffers must be implemented for all new applications, and grazing management within these buffer zones strictly controlled.

7. WETLANDS: CONTEXTUAL

Ecological specifications and the quantification of EWRs for wetlands were part of this Upper Orange Reserve study. Ecological specifications (as defined in Section 3.1) are presented for all WRUs in Section 9 below. However, no EWRs have been quantified for any of the WRUs because of several factors (see below). Upon the assessment of the various WRUs, each of the systems were reviewed in terms of the necessity and relevance of quantifying the EWRs.

The considerations listed below have been incorporated into a decision support system which systematically guides an assessor through the process of deciding whether a WRU should receive an EWR quantification or not (Figure 7-1). This process was applied to the twelve WRUs assessed in this study – the results being that none of the WRUs were considered suitable candidates for EWR quantifications to be undertaken. This decision support system should be read in conjunction with the numbered items below which unpack the motivation for the quantification of EWRs for selected WRUs. These numbers correspond with the numbers in Figure 7-1.

1. As highlighted in the Wetland Field Survey Report (Report No RDM/WMA13/00/CON/COMP/0522) the various WRUs were subjected to a tiered assessment approach, which was adopted by the team to prioritise the wetlands that could be visited during the fieldwork and to define the level of assessment and engagement that was going to be undertaken at each visited wetland. Three tiers were identified in which site visits and assessments for Tier 3 were of moderate intensity whilst Tier 1 and 2 were of lower intensity. Therefore, any of the systems which fell within the Tier 1 and 2 level of intensity were excluded from EWR quantification, as insufficient information/data would be available to allow for the development of EWRs at an accepted confidence level;
2. The hydrogeomorphic (HGM) unit type was a significant contributing factor in terms of prioritising systems for the derivation of EWRs, as only those systems supported by a stream/river could be considered, i.e., channelled valley-bottom and floodplain wetlands. Furthermore, WRUs that met the HGM unit type criteria but water and sediment inputs into the system were mostly sustained by lateral inputs (with limited inputs from the catchment upstream) were excluded. Generally, this was considered appropriate where the upstream inputs were only considered to contribute approximately 30% of the hydrological, geomorphic and water quality inputs and functioning of the system. There are some cases where unchannelled valley-bottom wetlands are supported by river related flows. In cases where an unchannelled valley-bottom or seep wetlands received greater than 70% of their hydrological inputs from river related flows, these systems were included for consideration for EWR quantification;
3. The integrity assessments also took into account expected drivers of change in the catchments of the WRUs. This involved thorough reviews and observations of current land use practices within the catchments, including the desktop mapping of these land uses. Where applicable, the historical imagery for the WRUs and their associated catchments was also reviewed to develop an understanding of the level of modification that has occurred within these systems in recent times. For the systems located in more rural areas, and in which the catchment land use practices have not significantly

changed over time, developing EWR's was not considered as it unlikely that significant modifications to the systems will occur within the short- to medium-term;

4. Significant biodiversity (e.g. cranes or endangered species) and ecosystem assets (e.g. peat wetlands or significant areas of permanently saturated wetland) likely to be influenced by changes in stream flows were considered for these systems too, and any significant features that would be detrimentally influenced by reduced flows were considered in prioritising WRUs for the development of EWRs;
5. Location of the WRU in relation to its catchment, i.e., whether the system is located near the headwaters or further downstream was also considered, with systems located in the catchment's headwaters being considered less likely to be influenced by major flow altering activities e.g. a large water storage dam;
6. The number of landholdings/owners in relation to the upstream catchment and wetland was considered in prioritising WRUs for the development of EWRs. For instance, if the upstream catchment is mainly plantation forestry owned by a single entity committed to environmental stewardship, there's a lower likelihood of water access challenges compared to a scenario with multiple farms and irrigated croplands near or upstream of the wetland;
7. The level of overall degradation of the WRU, especially relating to in-system impacts on water distribution and retention was considered. Although some of the wetlands are largely degraded, the impacts contributing to the level of degradation can be partially mitigated through the adoption of some of the prescribed management and maintenance activities. However, other priority systems which are largely degraded might be locked in these altered states and EWR quantification would not serve to influence the long-term integrity or trajectory of change for the ecosystem. These latter systems, where no rehabilitation options are available, were excluded from development and quantification of the EWRs; and
8. Finally, the availability of any river related flow data from a nearby weir and/or previous studies also influenced the prioritisation process, as without such data, any quantities set for the system would be based on a number of assumptions and thereby, be considered of low confidence.

All twelve WRUs that were identified and assessed as part of this study had some level of Reserve set for them. Based on the outcomes of the decision support system in **Figure 7-1**, none of the WRUs require EWR quantification. As such, ecological specifications have been set for all WRUs. These EcoSpecs can be incorporated into Water Use License conditions to allow for monitoring and auditing of the condition of the resources.

It is important to add that the DSS will be assessed and outlined in more detail during the WRCS currently being undertaken, and which will further include management options for implementation.

Monitoring and EcoSpecs, as outlined in Sections 3.1 and Section 3.2 of this report applies to wetlands except that TPCs are not applicable at present for wetlands. This is mainly due to depauperate data availability which in turn does not allow for defining wetland specific TPCs.

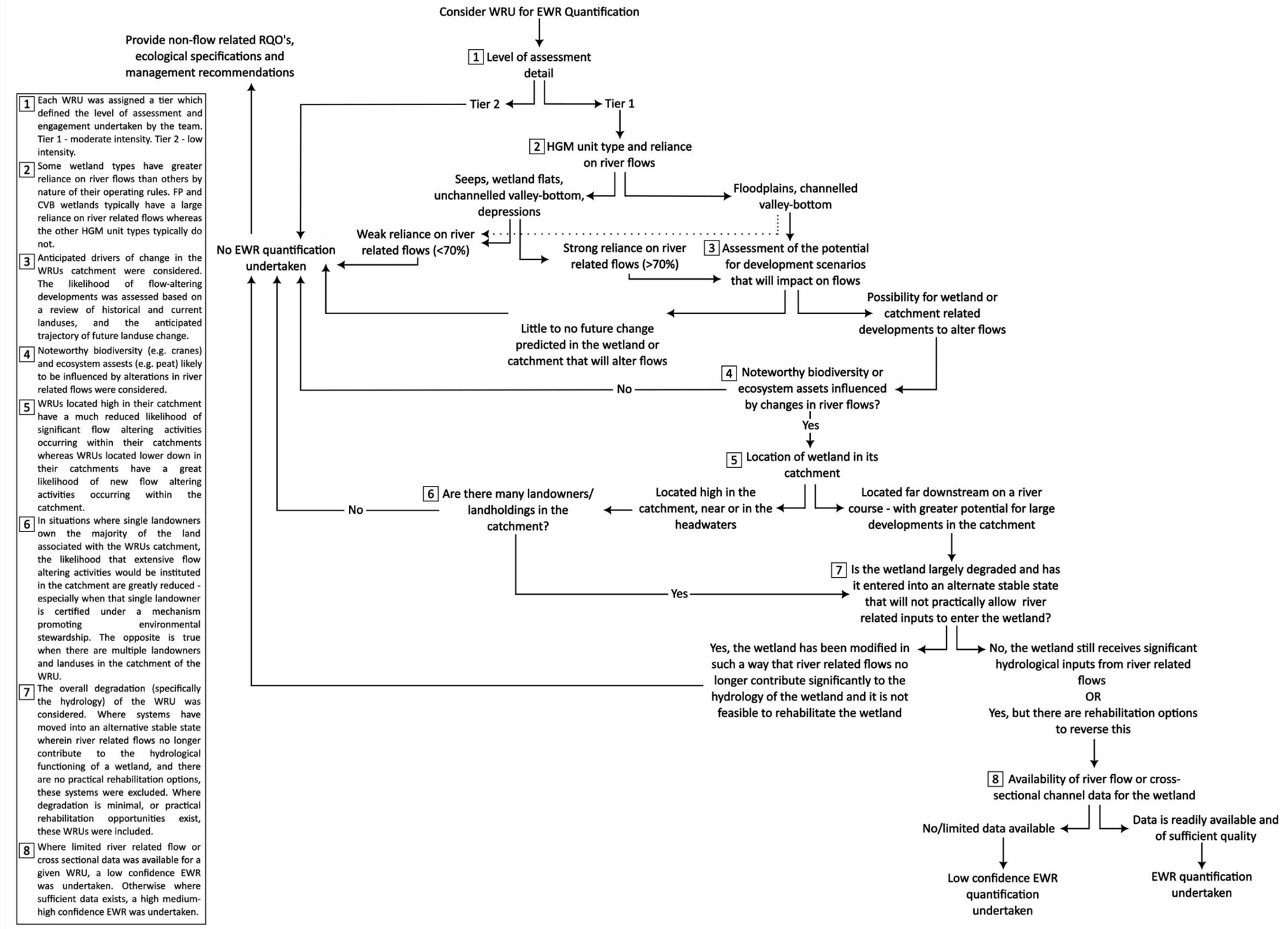


Figure 7-1: Decision support system used to determine which WRUs would receive an EWR quantification and which systems would receive detailed ecological specifications and non-flow related RQOs

8. WETLANDS: APPROACH

When establishing EcoSpecs, this process relied on all available previously field-based and desktop derived data (i.e. JBS3, ORASECOM studies, National Wetland Map 5 and any available specialist studies in the study area), and the wetland field survey undertaken. Thus, baseline conditions are available for the monitoring of wetlands to be implemented, which must ensure that either the PES is maintained and/or the REC is achieved.

The wetland's condition is described in terms of biophysical components during the Eco-categorisation process. The drivers of the system include hydrological, geomorphological, and water quality components. While the responses predominantly include vegetation components, additional hydrological responses can sometimes be observed and can be useful. Overall, it is the integration of these biophysical components into the WET-Health framework which describes the state of the WRU and forms the basis for understanding the indicator groups to be assessed during the ecological monitoring.

The EcoSpecs (and monitoring programme) is based on the level of detail available and confidence in the results from the surveys and the assessments per wetland. The WRUs were split into three tiers of assessment detail with Tier 1 being rapid and low detail sites and Tier 3 being Intermediate detail of assessment and engagement. Thus, more detailed EcoSpecs were provided for the Tier 3 WRUs, and less rigorous and focussed EcoSpecs for the rapid Tier 1 sites.

A total of 12 WRUs were selected for the Upper Orange Catchment for assessment. The primary objectives of these assessments were to validate desktop data, determine the EcoStatus (PES, EIS, and REC) of the priority wetlands, identify threats and propose feasible management actions to counter or reverse degradation. Given that the scope of this project for the wetland component was brief, the majority of the EcoSpecs are based on a low-cost desktop assessment of the WRUs every 3-5 years. Given the recent advancements in the accuracy of land-cover desktop wetland assessments, a periodic desktop assessment of each WRU has been prescribed as a minimum EcoSpec. Using the best available wetlands maps in conjunction with resources like Google Earth, assessors can evaluate the condition of invasive alien vegetation, erosion, and land-use encroachment within wetland areas. A comparative analysis should be conducted between baseline records (using field verified data from this study) and the most recent available imagery. At present the SANBI National Wetland Map (NWM5) is the most up to date national wetland map available and is periodically updated. The DWS should regularly consult with local municipalities, Provinces and the National DEA, to ensure that any updated wetland maps of the study area are obtained to be consulted during the monitoring phases. This will ensure that the most up to date information on known wetland extent is used for the monitoring procedures.

Thereafter, specific EcoSpecs have been set for the WRUs based on the site-specific needs and include monitoring of AIP encroachment, monitoring sediment and pollutant discharge into the WRUs among other indicators. Some of these indicators can be observed through a desktop assessment of the WRU, but some of them will require infield verification.

9. WETLANDS: ECOLOGICAL SPECIFICATIONS

9.1 WRU 02 – Brandwater Floodplain

Refer to **Table 9-1** for the wetland PES summary and **Table 9-2** for the REC and EcoSpecs for this wetland system.

Table 9-1: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 02 - Brandwater Floodplain			
Assessment Unit	Brandwater Floodplain 1			
HGM type	Floodplain wetland			
Wetland area (ha)	258.6 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.6	2.8	1.5	5.6
PES Score (%)	64%	72%	85%	44%
Ecological Category	**C**	**C**	**B**	**D**
Combined Impact Score	3.4			
Combined PES Score (%)	66%			
Combined Ecological Category	**C**			

Table 9-2: Wetland REC and EcoSpec

REC	EcoSpec
C	A desktop-based landcover assessment must be undertaken every 3-5 years to monitor the integrity of the flood-out zones adjacent to the channel within the floodplain. The density of drains within these flood-out zones must be monitored, and a qualitative assessment of the level of desiccation of these flood-outs should simultaneously be conducted using historical aerial/satellite imagery.

9.2 WRU 03 - Soutpan Depression Wetland Complex

Refer to **Table 9-3** for the wetland PES summary and **Table 9-4** for the REC and EcoSpecs for this wetland system.

Table 9-3: Wetland PES summaries

Wetland PES Summary				
Wetland name	WRU 03 – Soutpan Wetland Complex			
Assessment Unit	WRU 03a Soutpan			
HGM type	Depression without flushing			
Wetland area (ha)	1860.7 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.7	2.3	3.6	4.8
PES Score (%)	63%	77%	64%	52%
Ecological Category	C	C	C	D
Combined Impact Score	3.6			
Combined PES Score (%)	64%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	WRU 03b - Soutpan Wetland Complex			
Assessment Unit	WRU 03b Remaining Depression Wetlands			
HGM type	Depression without flushing			
Wetland area (ha)	698.0 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	1.2	1.7	0.8	1.0
PES Score (%)	88%	83%	92%	90%
Ecological Category	B	B	A	B
Combined Impact Score	1.2			
Combined PES Score (%)	88%			
Combined Ecological Category	B			

Table 9-4: Wetland REC and EcoSpec

REC	EcoSpec
WRU03a: C	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the depression wetlands are under increasing pressure from the surrounding land uses. A detailed landcover-based assessment of the depression wetlands must be undertaken to assess the extent of sediment deposition and nutrient flushes from the surrounding landscape.
WRU03b: B	

9.3 WRU 04 – Philipstown Unchannelled Valley-Bottom Wetland Complex

Refer to **Table 9-5** for the wetland PES summary and **Table 9-6** for the REC and EcoSpecs for this wetland system.

Table 9-5: Wetland PES summaries

Wetland PES Summary				
Wetland name	WRU 04a			
Assessment Unit	Phillips Town Depression Wetland			
HGM type	Depression without flushing			
Wetland area (ha)	1148.8 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	0.0	0.3	0.5	1.0
PES Score (%)	100%	97%	95%	90%
Ecological Category	A	A	A	B
Combined Impact Score	0.4			
Combined PES Score (%)	96%			
Combined Ecological Category	A			

Wetland PES Summary				
Wetland name	WRU 04b			
Assessment Unit	Phillips Town UCVB Wetland			
HGM type	Unchannelled VB wetland			
Wetland area (ha)	192.6 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	2.9	1.8	0.6	4.1
PES Score (%)	71%	82%	94%	59%
Ecological Category	C	B	A	D
Combined Impact Score	2.4			
Combined PES Score (%)	76%			
Combined Ecological Category	C			

Table 9-6: Wetland REC and EcoSpec

REC	EcoSpec
WRU04a: A	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the wetlands are under increasing pressure from the surrounding land uses. A further detailed landcover-based assessment of the depression wetland must be undertaken to assess the extent of sediment deposits and or nutrient flushes from the surrounding landscape.
WRU04b: C	

9.4 WRU 05 – Wolwespruit Headwaters Wetland Complex

Refer to **Table 9-7** for the wetland PES summary and **Table 9-8** for the REC and EcoSpecs for this wetland system.

Table 9-7: Wetland PES summaries

Wetland PES Summary				
Wetland name	WRU 05a			
Assessment Unit	Wolwespruit UCVB Wetlands			
HGM type	Unchannelled VB wetland			
Wetland area (ha)	340.0 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	2.4	2.2	1.7	4.8
PES Score (%)	76%	78%	83%	52%
Ecological Category	C	C	B	D
Combined Impact Score	2.8			
Combined PES Score (%)	72%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	WRU 05b			
Assessment Unit	Wolwespruit Seep Wetlands			
HGM type	Seep			
Wetland area (ha)	80.5 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	2.1	2.1	1.5	4.2
PES Score (%)	79%	79%	85%	58%
Ecological Category	C	C	B	D
Combined Impact Score	2.4			
Combined PES Score (%)	76%			
Combined Ecological Category	C			

Table 9-8: Wetland REC and EcoSpec

REC	EcoSpec
WRU05a: C	Landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor if the wetlands are under increasing pressure from the surrounding land uses.
WRU05b: C	

9.5 WRU 06 – Klein- Wildebeesspruit Wetland Complex

Refer to **Table 9-9** for the wetland PES summary and **Table 9-10** for the REC and EcoSpecs for this wetland system.

Table 9-9: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 06a			
Assessment Unit	Klein-Wildebeesspruit CVB Wetlands			
HGM type	Channelled VB wetland laterally maintained (i.e. with substantial lateral inputs)			
Wetland area (ha)	949.8 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	4.4	3.0	3.0	6.8
PES Score (%)	56%	70%	70%	32%
Ecological Category	D	C	C	E
Combined Impact Score	4.3			
Combined PES Score (%)	57%			
Combined Ecological Category	D			

Wetland PES Summary				
Wetland name	WRU 06b			
Assessment Unit	Klein-Wildebeesspruit Seep Wetlands			
HGM type	Seep			
Wetland area (ha)	456.9 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	4.7	3.3	3.3	7.1
PES Score (%)	53%	67%	67%	29%
Ecological Category	D	C	C	E
Combined Impact Score	4.6			
Combined PES Score (%)	54%			
Combined Ecological Category	D			

Table 9-10: Wetland REC and EcoSpec

REC	EcoSpec
WRU06a: D	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the wetlands are under increasing pressure from the surrounding land uses.
WRU06b: C	

9.6 WRU 10 – Luckhof Depression Wetland Complex

Refer to **Table 9-11** for the wetland PES summary and **Table 9-12** for the REC and EcoSpecs for this wetland system.

Table 9-11: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 10			
Assessment Unit	Luckhof Depression Wetland Complex			
HGM type	Depression with flushing			
Wetland area (ha)	1841.8 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	0.4	1.1	4.3	1.1
PES Score (%)	96%	89%	57%	89%
Ecological Category	A	B	D	B
Combined Impact Score	1.6			
Combined PES Score (%)	84%			
Combined Ecological Category	B			

Table 9-12: Wetland REC and EcoSpec

REC	EcoSpec
B	A landcover-based assessment of the catchments of this RU must be undertaken every 3-5 years to monitor whether the depression wetlands are under increasing pressure from the surrounding land uses. A further detailed landcover-based assessment of the depression wetlands themselves must be undertaken to assess the extent of sediment deposits and or nutrient flushes from the surrounding landscape, especially as these may be concentrated by the hydraulic linkages across the irrigation canal. All discharge points which are currently routed into the WRU must be investigated every 3-5 years for adverse impacts on the wetlands.

9.7 WRU 11 – Kaalspruit Wetland Complex

Refer to **Table 9-13** for the wetland PES summary and Table 9-14 for the REC and EcoSpecs for this wetland system.

Table 9-13: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 11a			
Assessment Unit	Kaalspruit Valley Bottom Wetlands			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	2839.3 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	1.9	2.2	1.9	4.1
PES Score (%)	81%	78%	81%	59%
Ecological Category	B	C	B	D
Combined Impact Score	2.5			
Combined PES Score (%)	75%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	WRU 11b			
Assessment Unit	Kaalspruit Depression Wetlands			
HGM type	Depression without flushing			
Wetland area (ha)	1050.6 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	2.3	2.6	2.7	4.2
PES Score (%)	77%	74%	73%	58%
Ecological Category	C	C	C	D
Combined Impact Score	2.9			
Combined PES Score (%)	71%			
Combined Ecological Category	C			

Table 9-14: Wetland REC and EcoSpec

REC	EcoSpec
WRU11a: C	No further cultivation must be permitted within any of the remaining intact wetland areas, and no additional dams must be allowed within the remaining intact portions of the wetland.
WRU11b: C	

9.8 WRU 12 – Aardoringspruit Wetland Complex

Refer to **Table 9-15** for the wetland PES summary and **Table 9-16** for the REC and EcoSpecs for this wetland system.

Table 9-15: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 12a			
Assessment Unit	Aardoringspruit Valley Bottom Wetland			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	665.9 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.3	1.4	1.0	4.2
PES Score (%)	67%	86%	90%	58%
Ecological Category	C	B	B	D
Combined Impact Score	2.6			
Combined PES Score (%)	74%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	WRU 12b			
Assessment Unit	Aardoringspruit Wetland Flat			
HGM type	Flat			
Wetland area (ha)	1075.4 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	3.4	2.2	1.9	5.4
PES Score (%)	66%	78%	81%	46%
Ecological Category	C	C	B	D
Combined Impact Score	3.3			
Combined PES Score (%)	67%			
Combined Ecological Category	C			

Table 9-16: Wetland REC and EcoSpec

REC	EcoSpec
WRU12a: C WRU12b: C	To maintain the REC, it is necessary to maintain the hydrological functioning of the HGM units in such a way that the patterns of water retention and distribution are not altered further than what they are currently. This requires that additional dams must not be constructed within the wetland and no additional roads must be constructed within the wetland either. While no cultivation has yet taken place in the wetland, no intensive cultivation must be permitted in the remaining intact portions of the wetland. The wetland is widely used for grazing, but the grazing pressure must be kept at an

	appropriate level to prevent further erosion in the discontinuously channelled portion of the HGM unit.

9.9 WRU 13 – Rantsho Wetland Complex

Refer to **Table 9-17** for the wetland PES summary and **Table 9-18** for the REC and EcoSpecs for this wetland system.

Table 9-17: Wetland PES summaries

Wetland PES Summary				
Wetland name	WRU 13a			
Assessment Unit	Rantsho Floodplain Wetland			
HGM type	Floodplain wetland			
Wetland area (ha)	95.0 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	4.9	3.1	2.8	7.0
PES Score (%)	51%	69%	72%	30%
Ecological Category	D	C	C	E
Combined Impact Score	4.5			
Combined PES Score (%)	55%			
Combined Ecological Category	D			

Wetland PES Summary				
Wetland name	WRU 13b			
Assessment Unit	Rantsho CVB Wetland			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	71.4 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	2.8	1.6	1.6	4.9
PES Score (%)	72%	84%	84%	51%
Ecological Category	C	B	B	D
Combined Impact Score	2.7			
Combined PES Score (%)	73%			
Combined Ecological Category	C			

Wetland PES Summary				
Wetland name	WRU 13b			
Assessment Unit	Rantsho UCVB Wetland			
HGM type	Unchannelled VB wetland			
Wetland area (ha)	108.1 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	4.7	2.8	3.4	7.0
PES Score (%)	53%	72%	66%	30%
Ecological Category	D	C	C	E
Combined Impact Score	4.5			
Combined PES Score (%)	55%			
Combined Ecological Category	D			

Table 9-18: Wetland REC and EcoSpec

REC	EcoSpec
C	To maintain the current state of the Rantsho Wetland Complex, no further cultivation or other intensive land uses must be permitted to expand into the remaining intact portions of the wetlands. Furthermore, no further infrastructure such as dams or roads must be permitted within the remaining intact portions of the wetland. Additionally, there must be no further degradation of the water quality such that it impacts the downstream freshwater ecosystems. Agricultural and livestock operations must periodically be monitored for discharge into WRU 13. There must be no further encroachment of woody alien invasive vegetation into any of the wetland areas, and efforts should be made to remove the current population of Salix babylonica individuals that line sections of the channel in the FP and CVB wetlands. In addition, AIPs must be managed within a 200 m radius of the wetland to avoid additional AIP propagules entering the HGM unit.

9.10 WRU 15 – Jagersfontein Discontinuously Channelled Valley-Bottom Wetland

Refer to **Table 9-19** for the wetland PES summary and **Table 9-20** for the REC and EcoSpecs for this wetland system.

Table 9-19: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 15			
Assessment Unit	Jagersfontein Valley Bottom Wetland			
HGM type	Channelled VB wetland not laterally maintained			
Wetland area (ha)	1907.3 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	1.5	1.5	6.7	4.1
PES Score (%)	85%	85%	33%	59%
Ecological Category	B	B	E	D
Combined Impact Score	3.2			
Combined PES Score (%)	68%			
Combined Ecological Category	C			

Table 9-20: Wetland REC and EcoSpec

REC	EcoSpec
C	To maintain the REC, it is necessary to maintain the hydrological functioning of the HGM units in such a way that the patterns of water retention and distribution are not altered further than they are.

9.11 WRU 16 – Barkley Pass Wetland Complex

Refer to **Table 9-21** for the wetland PES summary and **Table 9-22** for the REC and EcoSpecs for this wetland system.

Table 9-21: Wetland PES summaries

Wetland PES Summary				
Wetland name	WRU 16a			
Assessment Unit	Barkley Pass Valley Bottom Wetlands			
HGM type	Channelled VB wetland laterally maintained (i.e., with substantial lateral inputs)			
Wetland area (ha)	189.5 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	0.0	0.3	0.4	1.0
PES Score (%)	100%	97%	96%	90%
Ecological Category	A	A	A	B
Combined Impact Score	0.4			
Combined PES Score (%)	96%			
Combined Ecological Category	A			

Wetland PES Summary				
Wetland name	WRU 16b			
Assessment Unit	Barkley Pass Seep Wetlands			
HGM type	Seep			
Wetland area (ha)	47.4 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	0.0	0.3	0.4	1.0
PES Score (%)	100%	97%	96%	90%
Ecological Category	A	A	A	B
Combined Impact Score	0.4			
Combined PES Score (%)	96%			
Combined Ecological Category	A			

Table 9-22: Wetland REC and EcoSpec

REC	EcoSpec
WRU16a: A	To maintain the current integrity of these wetlands and the REC, no land use changes should be permitted within the wetlands themselves.
WRU16b: A	

9.12 WRU 17 – Tiffindell Seep Wetland Complex

Refer to **Table 9-23** for the wetland PES summary and **Table 9-24** for the REC and EcoSpecs for this wetland system.

Table 9-23: Wetland PES summary

Wetland PES Summary				
Wetland name	WRU 17			
Assessment Unit	Tiffindell Seep Wetlands			
HGM type	Seep			
Wetland area (ha)	196.0 ha			
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	0.3	0.4	0.4	1.4
PES Score (%)	97%	96%	96%	86%
Ecological Category	A	A	A	B
Combined Impact Score	0.6			
Combined PES Score (%)	94%			
Combined Ecological Category	A			

Table 9-24: Wetland REC and EcoSpec

REC	EcoSpec
A	To maintain the current integrity of these wetlands and the REC, no land use changes must be permitted within the wetlands themselves, and only very specific, low-impact land uses should be allowed in these catchments. No infrastructure such as roads or dams must be allowed within the wetlands, and the encroachment of AIP species should be managed in the wetlands and their catchments.

10. WETLANDS: MONITORING AND MANAGEMENT PROGRAMME

The integrity and functioning of wetlands may be affected by changes in land use practices within the wetland systems and their associated catchment areas. The main drivers of the systems include hydrology, geomorphology, water quality and vegetation. Generally, changes in the hydrology have knock-on effects on the other drivers e.g. the reduction in flows may result in the desiccation of the system, soils becoming more susceptible to erosion and the vegetation characteristics changing to more terrestrial species. Water quality, as a driver, would impact on the health of the ecosystem, influencing the habitat and species composition.

Similar to the rivers, please refer to **Table 10-1** for the primary concepts guiding a proposed monitoring programme for the various wetland resource units. Based on these, some management measures have further been provided in **Table 10-2**, which should be addressed for adaptive management. To reiterate, DSS will be assessed and outlined in more detail during the WRCS currently being undertaken, and which will further include management options for implementation.

Table 10-1: Wetland monitoring programme

Component	Monitoring programme	Frequency	EWR site application
Water quality	*In situ* water quality: Parameters that should be assessed at each of the prioritised wetland RUs must include: pH, DO, EC, TDS and water temperature (which further forms part of the water quality management actions).	Bi-annually (wet and dry season)	All prioritised wetland RUs
	Water clarity monitoring using clarity tubes to monitor the sediment loads within the systems. These water clarity measurements can only effectively be undertaken in wetlands that have channelled flows and should be undertaken towards the bottom end of the wetland, from within the channel.		WRU 02 WRU 06 WRU 11 WRU 12 WRU 13 WRU 15 WRU 16
General Habitat Assessment	General description of the wetland sites and broader wetland habitat (as documented in the final wetland report). Parameters to be capture include; site photographs (for further identification of major changes and documentation of habitat conditions); catchment features (i.e., surrounding land use, sources of pollution, erosion, etc.).	Bi-annually (wet and dry season),	All prioritised wetland RUs
Wetland integrity assessment	An integrity assessment, using the WET-Health assessment technique (Macfarlane et al. 2020), of the WRU's should be undertaken to establish if there are any significant changes to the integrity of the system. The assessment should include a visit to the WRU's (where possible) and not be solely reliant on aerial imagery.	Every 3 – 5 years	All prioritised wetland RUs
Agriculture and/or agriculture run-off	Assessment of the wetlands to ensure no further agriculture develops within or around the wetland. Furthermore, no further agricultural runoff to be discharged into the wetlands. Assessment to be conducted during the wetland integrity assessment	Annual	All prioritised wetland RUs

Component	Monitoring programme	Frequency	EWR site application
Dams/impoundments or roads	Assessment of the wetlands to ensure no further dams/impoundments or roads are developed within or through the wetland. Additionally, the construction of significant dams in the catchment of these wetlands should also be subject to an EWR quantification for the wetland downstream of the proposed dam site.	Annual	WRU 05 WRU 06 WRU 11 WRU 13 WRU 15 WRU 17
Geomorphology and Erosion	Control measures should be implemented, particularly for sites where severe erosion is taking place either directly within the wetland and/or buffer zone. In many instances severe erosion within a wetland would be subject to engineered designs to halt the erosional features. However, in areas where wind erosion may be more prevalent, 'softer' rehabilitation methods may be suitable e.g. brush-packing and/or potholes or ecologs (interventions). Erosion control measures would also need to be adopted in those areas that are heavily infested with alien vegetation, following the clearing of alien vegetation. Sites will need to be assessed and implementation plans developed to properly manage erosion.	Annually. Although any rehabilitation work would be subject to a detailed rehabilitation plan.	WRU 03 WRU 10 WRU 11 WRU 15
	Sediment sources into depression wetlands must be rehabilitated.	Annually	WRU 03 WRU 10 WRU 11
Buffers	Buffer zones around depression wetlands must be maintained.	Annually	WRU11
Analysis and Interpretation	The data collected from this wetland monitoring programme should be analysed and interpreted on a bi-annual basis, with a trends report published on an annual basis. This report should be externally reviewed.	Annually	All WRUs

Table 10-2: Management programme per wetland resource unit

WRU	Management programme per wetland resource unit
WRU02	No additional cultivation should be allowed to take place within the wetland, especially not within an intact portion or flood-out zone. There should be no further encroachment of AIP species within the wetland. Additional recommendations include the removal of *Salix babylonica* trees from the channel of the wetland and ensuring the control of alien invasive plants takes place within the wetland – provided that their removal can be undertaken safely and in such a way that it is beneficial both to the wetland and the landowners (i.e., their removal does not result in unnecessary and excessive ecological damage to the wetland and provided that these trees are not currently used by farmers to provide livestock with shaded areas).
WRU04a, b	There must be no expansion of agricultural activities or other land uses into the remaining intact UCVB wetland areas.
WRU05a, b	No further dams must be permitted within any of the wetland areas, and an appropriate groundwater study must be undertaken before any further boreholes/wind pumps are constructed within the wetland and its catchment. No further cultivation must be permitted within the remaining intact portions of the wetland and there must be no further changes to the natural hydrology of the wetland – e.g., from perennial to seasonal wetness zones. No further drains must be permitted within the remaining intact portions of the wetlands and no new roads should be constructed through intact wetland areas. A WET-Health assessment of the complex must be undertaken every 2-3 years1 with a specific focus on the Hydrology module and the 'Change in water distribution and retention' score – specifically for the UCVB wetlands. Where possible, existing roads must be upgraded to incorporate sufficient through flow capacity in the form of culverts or permeable road bedding to encourage natural water distribution and retention across the width of the wetland up and downstream of the roads. In addition, rotational burning (2-3 years) of the wetland should be encouraged where possible to promote vegetation vigour although this should be sensitive to the requirements of the crane species utilising the system
WRU06a, b	No further cultivation must be permitted within the remaining intact portions of the wetland and there must be no further changes to the natural hydrology of the wetland – e.g., from perennial to seasonal wetness zones. No further drains must be permitted within the remaining intact portions of the wetlands and no new roads should be constructed through intact wetland areas. There should be no further encroachment of AIP species within the wetland. Additional recommendations include the removal of AIP trees from the channel of the

[1] The frequency of these assessments is high because of the threat status of the wetland and its importance as a headwater wetland.

WRU	Management programme per wetland resource unit
	wetland valley-bottom wetlands and ensuring the control of alien invasive plants takes place within the wetland – provided that their removal can be undertaken safely and in such a way that it is beneficial both to the wetland and the landowners (i.e., their removal does not result in unnecessary and excessive ecological damage to the wetland and provided that these trees are not currently used by farmers to provide livestock with shaded areas).
WRU10	No further agricultural runoff must be discharged into the WRU without appropriate mitigation measures being implemented. No further cultivation should be permitted within the remaining intact portions of the WRU either.
WRU11a, b	Formal buffer areas between the cultivated areas and the depression wetlands must be established and maintained with the adoption of appropriate mitigation measures. AIP species must also be managed at the current levels, and further encroachment of AIP species must be avoided. No new road must be approved through any of the remaining intact wetland areas. A large sediment deposit was observed in one of the depression wetlands. The erosion source resulting in the deposition of this sediment must be rehabilitated immediately to prevent the further loss of wetland functioning and integrity in subsequent rainfall seasons.
WRU12a, b	To maintain the REC, it is necessary to maintain the hydrological functioning of the HGM units in such a way that the patterns of water retention and distribution are not altered further than what they are currently. This requires that additional dams must not be constructed within the wetland and no additional roads must be constructed within the wetland either. While no cultivation has yet taken place in the wetland, no intensive cultivation must be permitted in the remaining intact portions of the wetland. The wetland is widely used for grazing, but the grazing pressure must be kept at an appropriate level to prevent further erosion in the discontinuously channelled portion of the HGM unit.
WRU13a, b	To maintain the current state of the Rantsho Wetland Complex, no further cultivation or other intensive land uses must be permitted to expand into the remaining intact portions of the wetlands. Furthermore, no further infrastructure such as dams or roads must be permitted within the remaining intact portions of the wetland. Additionally, there must be no further degradation of the water quality such that it impacts the downstream freshwater ecosystems. Agricultural and livestock operations must periodically be monitored for discharge into WRU 13. There must be no further encroachment of woody alien invasive vegetation into any of the wetland areas, and efforts should be made to remove the current population of Salix babylonica individuals that line sections of the channel in the FP and CVB wetlands. In addition, AIPs must be managed within a 200 m radius of the wetland to avoid additional AIP propagules entering the HGM unit.

WRU	Management programme per wetland resource unit
WRU15	No additional dams must not be constructed within the wetland and no additional roads must be constructed within the wetland either. Furthermore, while no cultivation has yet taken place in the wetland, no intensive cultivation should be permitted in the remaining intact portions of the wetland and an appropriate buffer zone. The wetland is widely utilised for grazing, but the grazing numbers must be kept at an acceptable level to prevent further erosion in the discontinuously channelled portion of the HGM unit. Also, annual monitoring of water quality in the HGM unit downstream of Jagersfontein town must be undertaken to ensure that the WWTW, the diamond mine and the town of Jagersfontein are not contributing to a significant decline in the water quality and the biota in the wetland. Water quality parameters that should be monitored include diatoms, E. coli, temperature, turbidity and electrical conductivity at a minimum.
WRU16a, b	Only very specific, low-impact land uses must be permitted in the catchments of these wetlands unless appropriate studies and mitigation measures are implemented. No infrastructure such as roads or dams must be allowed within the wetlands, and the encroachment of AIP species must be managed in the wetlands and their catchments.
WRU17	To maintain the current integrity of these wetlands and the REC, no land use changes must be permitted within the wetlands themselves, and only very specific, low-impact land uses should be allowed in these catchments. No infrastructure such as roads or dams must be allowed within the wetlands, and the encroachment of AIP species should be managed in the wetlands and their catchments.
Catchment management: Boreholes	Visual assessment of the wetlands and their immediate catchments to ensure no additional boreholes or windmills to be drilled in the catchment without groundwater studies. Additional authorisation of boreholes and windmills should be accompanied by groundwater studies.
Catchment management: Alien vegetation	Compile an alien weed infestation eradication implementation programme. Eradication and control of exotic vegetation within the wetland habitat should be implemented to enhance wetland integrity and functioning, increase bank stability, reduce erosion, and improve the general buffering capacity of systems. The portions of the wetland and/or buffer area with sparse/scattered alien vegetation should be prioritised to limit further spread. Highly infested areas will require intensive and on-going management to effectively eradicate problem species, together with revegetation and ongoing maintenance. Livestock pressures (i.e. grazing and trampling) will require special consideration, especially given that wetlands are freely accessed by communities and their livestock, but livestock can also be an asset for rebuilding soils and restoring vegetation cover. An Alien Plant Control Plan will need to be developed with realistic and attainable targets set;

11. GROUNDWATER: CONTEXTUAL

Active groundwater monitoring networks have been established by DWS and SANParks (Mokala National Park). The data comprises of water levels and several water quality parameters (i.e. EC, major cations and anions). The spatial distribution of the monitoring boreholes is provided in **Figure 11-1**. The DWS monitoring comprises of manual and logger water levels as per Hydstra database, as well as bi-annual water quality monitoring and analysis as per the WMS database.

Groundwater level data indicates relatively stable trends with seasonal variations. Groundwater quality trends, using EC as overall water quality indicator, indicate mainly stable trends in GRU1, GRU2, GRU7, GRU10 and GRU14. A decreasing trend in EC is observed in GRU3, whilst increasing trends in EC are observed in GRU8, GRU9, GRU12. A more erratic trend in EC is observed in GRU4 and GRU13.

In addition, groundwater use is available for the entire Upper Orange Catchment. This data is managed in DWS's WARMS database.

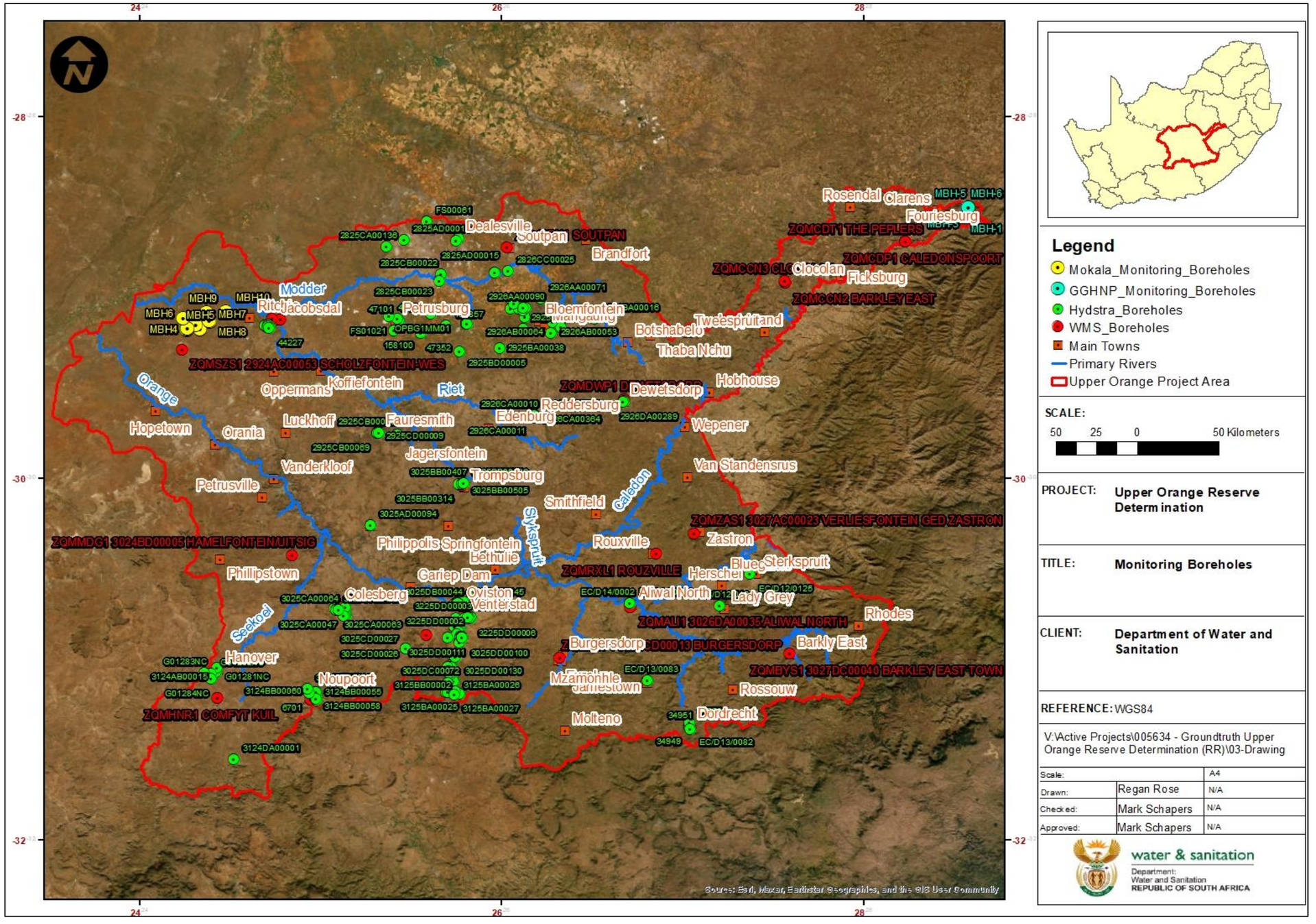


Figure 11-1: Existing monitoring boreholes

12. GROUNDWATER: APPROACH

To date the Groundwater Reserve has been assessed in terms of groundwater quantity and quality (for mor information, please refer to Report No. RDM/WMA13/00/CON/COMP/1022). The Groundwater Reserve data was further assessed to describe 1) Groundwater quantity in terms of a Stress Index (SI) and 2) Groundwater Quality in term of statistical water quality parameters. In accordance with WRC (2012) the Stress Index is defined as follows:

Stress Index (SI) = GW_{use}/Recharge

Where:
Re = Recharge
GW_{use} = Groundwater Use

The SI results were then divided into categories from “A” (Natural) to “F” (Critically Modified) for each quaternary catchment (**Table 12-1**). A maximum of SI value of 0.4 or 40% (i.e. C category) is provided as a guideline. This implies that all SI values > 0.4 or 40% need water balance assessments and categorised hydrogeological investigations for new water use applications. This is then provided as a Quantity Directive.

Table 12-1: SI Categories

Category	Value	Value (%)	Description
A	0.05	5	Natural
A/B	0.1	10	Natural to good
B	0.2	20	Good
B/C	0.3	30	Good to Fair
C	0.4	40	Fair
C/D	0.5	50	Fair to Poor
D	0.6	60	Poor
D/E	0.7	70	Poor to Seriously Modified
E	0.8	80	Seriously Modified
E/F	0.9	90	Seriously Modified to Critically Modified
F	1	100	Critically modified

A statistical analysis of the available groundwater quality parameters was used to provide a groundwater quality index for each quaternary catchment and GRU where possible. In quaternary catchment where data is not available, the groundwater quality index for the GRU was used to fill the gaps. In accordance with the DWA (1998) Assessment Guide, the groundwater quality index was categorized as follows:

- Class 0 – Ideal
- Class 1 – Good
- Class 2 – Marginal

The groundwater quality index was then used to provide the Groundwater Quality status for each quaternary catchment.

13. GROUNDWATER: ECOLOGICAL SPECIFICATIONS

Based on outcomes of the Groundwater Reserve, groundwater quantity and quality indices were derived for the study area on a quaternary catchment scale. **Table 13-1** contains the basic dataset for the DWS GRDM and is extended to include groundwater quantity and quality indices and directives.

The groundwater quantity directive identified three levels of potential stresses on the groundwater component in the quaternary catchments, each with a specific guideline to address further groundwater allocations as follows:

- Minimum Stress Index Level:
  - Groundwater investigation limited to local water balance estimation and hydrocensus.
- Moderate Stress Index Level:
  - Groundwater investigation more detail in terms of hydrogeological conditions, hydrocensus, limited monitoring requirements, mapping of other abstractions and water balance.
- High Stress Index Level:
  - High-level groundwater investigation, monitoring boreholes, specific license conditions, aquifer characterisation, recharge estimates, regional potential impacts and piezometric mapping.

Ecological specifications of the groundwater resources are directly linked to these indexes, namely in the case of the groundwater component status of the reserve in a high stress index level, the water use may be already impacting on the total reserve of the quaternary catchment and further allocations should be carefully considered.

The groundwater quality Index has been derived from an assessment of the quaternary groundwater quality WMS database, which in certain instances are either absent or old (when the climate and current land use may have been different). In such cases the groundwater quality index has been aggregated to a GRU level. It is therefore considered to be slightly more conservative (i.e. showing a fresher quality signature).

The groundwater quality directive describes the time series component of the quaternary catchment's groundwater quality. Of particular importance in this assessment is the long-term rising trends in salinity, i.e. EC/TDS, chloride, sodium, nitrate and nitrite, TALK and fluoride. In this case the groundwater quality reserve should specify at least a marginal water quality in terms of the DWA (1998) Assessment Guide and further deterioration should not be allowed without very strict mitigation measures. It must further be noted that increases in salinity do not always imply an impacted source but it could also imply less favourable recharge conditions coupled with increased residence time of groundwater in the aquifer (i.e. older groundwater).

Table 13-1: Groundwater quantity and quality indices per quaternary catchment

Quaternary Catchment	Recharge (Mm3/a)	BHN Gw Reserve (Mm3/a)	Gw Baseflow (Mm3/a)	Gw Reserve (Mm3/a)	Gw Use (Mm3/a)	Stress Index	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Allocable Gw (Mm3/a)	Gw Reserve (as % Recharge)
C51A	11.21	0.004	1.92	1.924	1.821	0.163	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	7.460	17.17
C51B	24.55	0.007	3.00	3.007	1.221	0.050	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	20.320	12.25
C51C	10.51	0.003	0.96	0.963	0.983	0.094	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	8.562	9.16
C51D	15.80	0.017	1.92	1.937	0.574	0.036	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	13.285	12.26
C51E	13.68	0.010	2.04	2.05	1.247	0.091	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	10.384	14.98
C51F	13.88	0.005	1.08	1.085	0.869	0.063	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	11.926	7.82
C51G	27.11	0.007	4.68	4.687	1.992	0.073	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	20.433	17.29
C51H	27.67	0.010	3.48	3.49	3.602	0.130	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	20.576	12.61
C51J	17.59	0.005	1.20	1.205	2.870	0.163	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	13.517	6.85
C51K	50.30	0.017	0.72	0.737	8.117	0.161	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	41.447	1.47
C51L	20.91	0.009	0.48	0.489	0.362	0.02	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	20.055	2.34
C51M	10.36	0.007	0.36	0.367	0.030	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	9.967	3.54
C52A	24.85	0.008	3.96	3.968	2.981	0.120	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	17.905	15.97
C52B	25.98	0.013	2.76	2.773	0.016	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	23.189	10.67
C52C	15.87	0.005	1.44	1.445	0.836	0.053	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	13.587	9.11
C52D	11.44	0.005	0.96	0.965	0.777	0.068	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	9.698	8.44
C52E	16.47	0.007	1.32	1.327	0.819	0.050	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	14.320	8.06
C52F	12.99	0.046	1.20	1.246	1.786	0.138	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	9.956	9.59
C52G	28.52	0.015	1.68	1.695	10.347	0.363	Moderately Modified	Marginal, Class 2	Moderate Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	16.474	5.94
C52H	29.80	0.029	0.12	0.149	17.939	0.602	Seriously Modified	Marginal, Class 2	High Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	11.707	0.50
C52J	34.51	0.068	0.36	0.428	23.919	0.693	Seriously Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	10.161	1.24
C52K	56.60	0.024	0.24	0.264	27.484	0.486	Largely Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	28.855	0.47
C52L	39.18	0.015	0.24	0.255	4.934	0.126	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	33.990	0.65
D12A	15.38	0.039	13.20	13.239	0.129	0.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	2.008	86.10
D12B	16.80	0.058	18.60	18.658	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	-1.856	111.05
D12C	14.96	0.013	2.52	2.533	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	12.422	16.94
D12D	13.52	0.002	1.80	1.802	0.006	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	11.715	13.33
D12E	26.82	0.007	3.48	3.487	1.057	0.039	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	22.280	13.00
D12F	24.99	0.005	3.12	3.125	0.287	0.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	21.580	12.50
D13A	18.60	0.003	33.24	33.243	0.135	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-14.778	178.73
D13B	20.21	0.003	35.52	35.523	0.006	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-15.320	175.78
D13C	20.38	0.003	28.80	28.803	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-8.427	141.36
D13D	28.93	0.004	32.04	32.044	0.761	0.026	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-3.877	110.77
D13E	28.90	0.008	64.68	64.688	0.113	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-35.897	223.80
D13F	33.00	0.008	48.12	48.128	0.046	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	-15.175	145.85
D13G	34.57	0.008	9.84	9.848	0.069	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	24.651	28.49
D13H	14.89	0.008	6.60	6.608	0.146	0.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	8.139	44.37

Quaternary Catchment	Recharge (Mm3/a)	BHN Gw Reserve (Mm3/a)	Gw Baseflow (Mm3/a)	Gw Reserve (Mm3/a)	Gw Use (Mm3/a)	Stress Index	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Allocable Gw (Mm3/a)	Gw Reserve (as % Recharge)
D13J	34.98	0.007	7.08	7.087	0.498	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	27.395	20.26
D13K	11.81	0.003	23.52	23.523	0.161	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	-11.875	199.20
D13L	20.70	0.004	6.12	6.124	0.106	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	14.474	29.58
D13M	10.25	0.005	3.96	3.965	0.325	0.032	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	5.956	38.70
D14A	7.83	0.007	4.08	4.087	0.278	0.035	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	3.469	52.17
D14B	4.74	0.002	1.32	1.322	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	3.419	27.88
D14C	8.96	0.004	3.36	3.364	0.290	0.032	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	5.310	37.53
D14D	8.14	0.003	2.04	2.043	0.459	0.056	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	5.639	25.10
D14E	7.24	0.004	1.80	1.804	0.360	0.050	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, nitrate and fluoride	5.075	24.92
D14F	6.73	0.003	2.88	2.883	0.104	0.02	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	3.738	42.87
D14G	27.94	0.003	3.12	3.123	0.047	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	24.774	11.18
D14H	8.41	0.004	2.16	2.164	0.539	0.064	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	5.707	25.73
D14J	6.22	0.003	1.56	1.563	0.286	0.046	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	4.368	25.14
D14K	7.60	0.003	1.80	1.803	0.281	0.037	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	5.515	23.73
D15G	12.83	0.001	18.60	18.601	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	-5.769	144.96
D15H	8.46	0.002	12.12	12.122	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	-3.659	143.24
D18K	31.88	0.039	48.00	48.039	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	-16.160	150.69
D18L	19.65	0.049	25.20	25.249	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	-5.600	128.50
D21A	22.65	0.003	0.00	0.003	0.006	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	22.638	0.01
D21C	12.73	0.001	0.00	0.001	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	12.728	0.01
D21D	13.42	0.007	6.84	6.847	0.004	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	6.564	51.04
D21E	16.70	0.008	7.32	7.328	0.370	0.022	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	9.003	43.88
D21F	25.00	0.015	4.56	4.575	0.350	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	20.075	18.30
D21G	11.57	0.007	2.64	2.647	0.021	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	8.898	22.89
D21H	20.45	0.003	13.20	13.203	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	7.247	64.56
D22A	27.63	0.011	4.44	4.451	0.092	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	23.082	16.11
D22B	25.54	0.009	3.84	3.849	0.005	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	21.687	15.07
D22C	21.40	0.002	16.20	16.202	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	5.196	75.72
D22D	22.65	0.009	4.44	4.449	0.229	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	17.971	19.64
D22G	38.05	0.015	6.12	6.135	0.197	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	31.713	16.13
D22H	20.06	0.006	4.32	4.326	0.172	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	15.559	21.57
D22L	11.79	0.005	2.40	2.405	0.070	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	9.319	20.39
D23A	24.25	0.006	3.24	3.246	0.058	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	20.943	13.39
D23C	26.46	0.013	3.72	3.733	0.044	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	22.678	14.11
D23D	16.38	0.011	2.52	2.531	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	13.846	15.45
D23E	20.35	0.006	3.12	3.126	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	17.224	15.36
D23F	6.48	0.001	2.16	2.161	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	4.314	33.37
D23G	14.80	0.002	2.88	2.882	0.002	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride	11.920	19.47
D23H	20.48	0.005	2.76	2.765	0.413	0.020	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	17.299	13.50

Quaternary Catchment	Recharge (Mm3/a)	BHN Gw Reserve (Mm3/a)	Gw Baseflow (Mm3/a)	Gw Reserve (Mm3/a)	Gw Use (Mm3/a)	Stress Index	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Allocable Gw (Mm3/a)	Gw Reserve (as % Recharge)
D23J	14.40	0.004	2.28	2.284	0.307	0.021	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	11.807	15.86
D24A	5.97	0.002	1.92	1.922	0.033	0.01	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	4.018	32.18
D24B	9.05	0.002	2.04	2.042	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	7.008	22.56
D24C	6.90	0.003	1.20	1.203	0.283	0.041	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	5.416	17.43
D24D	10.14	0.002	1.44	1.442	0.035	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	8.663	14.22
D24E	8.38	0.001	1.08	1.081	0.262	0.031	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	7.040	12.90
D24F	10.52	0.002	1.56	1.562	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	8.953	14.85
D24G	13.51	0.003	2.52	2.523	0.000	0.00	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	10.991	18.67
D24H	12.52	0.003	2.04	2.043	0.345	0.028	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	10.129	16.32
D24J	17.25	0.005	2.16	2.165	0.780	0.045	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	14.307	12.55
D24K	8.22	0.003	1.92	1.923	0.425	0.052	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	5.875	23.39
D24L	7.39	0.002	1.08	1.082	0.467	0.063	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	5.843	14.64
D31A	13.71	0.004	2.16	2.164	1.257	0.092	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	10.292	15.78
D31B	10.08	0.002	0.60	0.602	0.294	0.029	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	9.180	5.97
D31C	6.96	0.001	0.60	0.601	0.065	0.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	6.293	8.64
D31D	15.04	0.003	1.20	1.203	1.224	0.081	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; Elevated TALK, nitrate and nitrite	12.609	8.00
D31E	10.25	0.003	1.20	1.203	0.115	0.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	8.933	11.74
D32A	7.78	0.001	0.60	0.601	0.401	0.052	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	6.781	7.72
D32B	6.48	0.003	0.72	0.723	1.104	0.170	Largely Natural	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	4.652	11.16
D32C	10.06	0.003	0.60	0.603	0.255	0.025	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, nitrate and nitrite	9.202	5.99
D32D	9.24	0.001	0.60	0.601	0.000	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	8.635	6.51
D32E	9.28	0.002	0.60	0.602	0.269	0.029	Unmodified	Good, Class 1	Minimum Stress Index Level	Slight elevated salinity; High nitrate and nitrite	8.411	6.49
D32F	15.57	0.003	0.84	0.843	0.412	0.026	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	14.315	5.41
D32G	10.83	0.003	0.84	0.843	2.186	0.202	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	7.800	7.78
D32H	5.97	0.002	0.48	0.482	0.385	0.064	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	5.107	8.07
D32J	14.64	0.003	0.84	0.843	0.295	0.02	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	13.497	5.76
D32K	7.80	0.002	0.60	0.602	0.118	0.02	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	7.075	7.72
D33A	9.02	0.002	0.36	0.362	0.120	0.01	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	8.542	4.01
D33B	10.31	0.002	0.24	0.242	0.024	0.00	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	10.041	2.35
D33C	10.02	0.002	0.36	0.362	0.229	0.023	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	9.424	3.61
D33D	11.25	0.002	0.24	0.242	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	11.007	2.15
D33E	18.60	0.006	0.12	0.126	0.344	0.02	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	18.127	0.68
D33F	11.69	0.003	0.12	0.123	0.018	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	11.545	1.05
D33G	16.26	0.005	0.24	0.245	0.023	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	15.995	1.51
D33H	9.30	0.004	0.24	0.244	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	9.052	2.62
D33J	7.33	0.004	0.12	0.124	0.069	0.01	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	7.138	1.69
D33K	4.65	0.002	0.24	0.242	0.000	0.00	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	4.407	5.21
D34A	9.07	0.003	0.36	0.363	1.712	0.189	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	6.996	4.00
D34B	8.00	0.003	0.12	0.123	0.781	0.098	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	7.100	1.54

Quaternary Catchment	Recharge (Mm3/a)	BHN Gw Reserve (Mm3/a)	Gw Baseflow (Mm3/a)	Gw Reserve (Mm3/a)	Gw Use (Mm3/a)	Stress Index	Gw Quantity Description	Gw Quality Index	Gw Quantity Directive i.t.o new allocations	Gw Quality Status	Allocable Gw (Mm3/a)	Gw Reserve (as % Recharge)
D34C	8.49	0.003	0.12	0.123	0.846	0.100	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	7.522	1.45
D34D	6.73	0.002	0.12	0.122	0.235	0.035	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	6.369	1.81
D34E	5.90	0.002	0.12	0.122	0.478	0.081	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	5.302	2.07
D34F	7.69	0.004	0.12	0.124	0.305	0.040	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	7.261	1.61
D34G	10.96	0.003	0.36	0.363	1.407	0.128	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	9.192	3.31
D35A	3.07	0.001	0.84	0.841	0.522	0.170	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	1.709	27.38
D35B	3.11	0.001	0.72	0.721	0.218	0.070	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	2.169	23.20
D35C	11.06	0.004	2.28	2.284	0.709	0.064	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	8.065	20.65
D35D	6.82	0.002	1.20	1.202	0.127	0.02	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	5.487	17.63
D35E	3.67	0.001	0.72	0.721	0.423	0.115	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	2.523	19.66
D35F	6.62	0.002	1.56	1.562	0.446	0.067	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	4.616	23.58
D35G	6.40	0.002	0.84	0.842	2.194	0.343	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity, chloride, fluoride	3.363	13.16
D35H	6.07	0.002	1.08	1.082	0.298	0.049	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	4.690	17.83
D35J	19.14	0.003	1.80	1.803	1.261	0.066	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	16.074	9.42
D35K	8.19	0.002	1.08	1.082	0.911	0.111	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	6.201	13.20

Please note:

- **GW Quantity Directive** description based on the estimation of the so-called aquifer Stress Index (i.e. Use/Recharge, groundwater use divided by the local recharge), A (<0.1), B (0.10-0.20), C (0.20-0.40), D (0.40-0.60), E (0.60-0.80) and F (0.80-1.00). MAX stress should be a C. All SI's >C needs water balance assessments and categorised hydrogeological investigations for new water use applications (viz. Quantity Directive as a guideline).
- **Quality Index** description based on the DWAF *et al,* 1998 Domestic water quality classification and the available water quality data – which unfortunately is based on a quaternary level and outdated as well. This is just a narrative of the water quality status.
- **GW Quantity Directive** describes the actual activity required to allow additional water allocations and is based on the *Quantity Index*, *Allocable Groundwater and Recharge (% of Recharge).* The following criteria has been adopted as a guideline for future groundwater investigations to support water use license conditions:
    - Minimum Stress Index Level (Groundwater investigation limited to local water balance estimation and hydrocensus)
    - Medium Stress Index Level (Groundwater investigation more detail in terms of hydrogeological conditions, hydrocensus, limited monitoring requirements, mapping of other abstractions and water balance);
    - High Stress Index Level (High-level groundwater investigation, monitoring boreholes, specific license conditions, aquifer characterisation, recharge estimates, regional potential impacts and piezometric mapping)
    - Quaternary Catchment water balance assessment required (Current water balances for quaternary catchment does not match and Allocable groundwater is < 1 Mm^3/a)); and
    - Groundwater allocation (or use) significantly over-allocated, means that use is potentially impacting on the Groundwater Component of the Reserve.
- **GW Quality Status** describes specific groundwater quality signatures and should help as an indicator of management measure to address these water quality trends. Some of the trends are regional impacts, i.e. the EC, nitrate and nitrite, chloride, sodium, TALK and fluoride.

14. GROUNDWATER: MONITORING PROGRAMME

*B*ased on the groundwater quantity and quality directives, the following primary concepts guiding a groundwater monitoring programme is recommended for each quaternary catchment as follows:

a. Groundwater Quantity:

- Minimum Stress Index Level
  - Monthly water levels and meter readings
- Moderate Stress Index Level
  - Continuous water levels (loggers) and weekly meter readings
- High Stress Index Level
  - Continuous water levels (loggers) and weekly meter readings

b. Groundwater Quality

- Ideal
  - Bi-annual monitoring for major cations and anions
- Class 1
  - Bi-annual monitoring for major cations and anions
- Class 2
  - Quarterly monitoring for major cations and anions

The recommended groundwater monitoring programme for each quaternary catchment is presented in **Table 14-1** overleaf.

Additionally, it is essential to expand the groundwater monitoring program into the quaternary catchments identified in **Table 14-2**. These catchments lack sufficient data on groundwater quality and levels. Once monitoring networks are in place, the following parameters are recommended for ongoing monitoring:

- Monthly water levels. Alternatively continuous monitoring with the use of data loggers to be downloaded on a quarterly basis; and
- Bi-annual sampling and laboratory analysis for major cations, anions and selected metals (SANS 241: 2015 short analysis).

Table 14-1: Recommended Groundwater Monitoring Programme

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
13, 14	D33C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13, 14	D33D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13, 14	D33E	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	C51M	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D14A	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D14B	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D14D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9, 11	D34B	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D35C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9	D35D	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
3, 4	C52E	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
3, 4	C52F	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
3, 4, 14	C52G	Moderately Modified	Marginal, Class 2	Moderate Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
3, 4, 14	C52H	Seriously Modified	Marginal, Class 2	High Stress Index Level	Elevated salinity, sodium, chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
1	D21A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D21H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D22L	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D23A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D23C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1	D23D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; headwater catchment; favourable recharge	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3	C51C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3	C52D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D13D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
7	D13E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7	D18K	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2	D23G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	C52A	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	D23F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	D23H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 2, 3	D23J	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 3	C52B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 3	C52C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
1, 3	D23E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinities; slightly elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 14	C51E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 6, 14	C51F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 6, 14	C51H	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 5, 6, 14	C51J	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 6, 13, 14	C51K	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
3, 14	C52J	Seriously Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
3, 5, 14	C52K	Largely Modified	Ideal, Class 0	High Stress Index Level	Low salinity, elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
2	D15G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24A	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24B	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24C	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24E	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24H	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D24L	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11	D34A	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11	D34E	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D35A	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2	D35F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	C51A	Largely Natural	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	C51B	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	C51D	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3, 14	C51G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D12A	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7, 8	D12B	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7, 8	D12C	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
2, 7	D12D	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7, 8	D12E	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D15H	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 7	D18L	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 3	D24K	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 6, 12, 14	D31A	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11, 12	D34F	Unmodified	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 11, 12, 14	D34G	Largely Natural	Good, Class 1	Minimum Stress Index Level	Low salinity; slightly elevated fluoride, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32A	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32B	Largely Natural	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32D	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity, but elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13, 14	D31E	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13, 14	D33A	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13, 14	D33B	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13F	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13G	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13J	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13K	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
7, 8	D13L	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Relatively low salinity; Elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10, 11, 12	D32F	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13	D31B	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
12, 13	D31C	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
11, 12	D32J	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
11, 12	D32K	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; elevated nitrate and nitrite, TALK	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
6, 12, 14	D31D	Unmodified	Good, Class 1	Minimum Stress Index Level	Relatively low salinity; Elevated TALK, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
10	D32E	Unmodified	Good, Class 1	Minimum Stress Index Level	Slight elevated salinity; High nitrate and nitrite	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
13	C51L	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8	D13H	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D12F	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D14J	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D14K	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D24J	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9, 11	D34C	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9, 11	D34D	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 8, 9	D35B	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D35E	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D35G	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
2, 9	D35H	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings

GRU	Quaternary Catchment	GW Quantity Description	GW Quality Index	GW Quantity Directive i.t.o new allocations	GW Quality Status	Recommended Groundwater Monitoring Programme
2, 9, 11	D35J	Unmodified	Ideal, Class 0	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
2, 9	D35K	Largely Natural	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, chloride, fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
9	D14E	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity, nitrate and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D13M	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14C	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14F	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14G	Unmodified	Good, Class 1	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Bi-annual monitoring for major cations and anions; Monthly water levels and meter readings
8, 9	D14H	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride and fluoride	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9, 10	D32C	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
9, 10, 11, 12	D32G	Moderately Modified	Good, Class 1	Moderate Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	Bi-annual monitoring for major cations and anions; Continuous water level monitoring; Weekly meter readings
9, 11, 12	D32H	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, fluoride, TALK, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
5, 13, 14	C52L	Largely Natural	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33F	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33G	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33H	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33J	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings
13	D33K	Unmodified	Marginal, Class 2	Minimum Stress Index Level	Slightly elevated salinity; Elevated chloride, nitrate and nitrite	Quarterly monitoring for major cations and anions; Monthly water levels and meter readings

Table 14-2: Quaternary catchments with no groundwater quality data

GRU	Quaternary Catchments
GRU1	C52B, C52C, D21A, D21C, D21D, D21F, D21G, D21H, D22A, D22B, D22C, D22D, D22H, D22L, D23A, D23C, D23D, D23E, D23F, D23G, D23H, D23J
GRU2	C51D, C51G, D12A, D12B, D12C, D12E, D12F, D14J, D14K, D15G, D15H, D18L, D23F, D23G, D23H, D23J, D24A, D24B, D24C, D24E, D24F, D24H, D24J, D24K, D24L, D31A, D34A, D34C, D34D, D34E, D34F, D34G, D35A, D35B, D35E, D35F, D35G, D35H, D35K
GRU3	C51B, C51C, C51D, C51E, C51F, C51G, C51H, C51J, C52B, C52C, C52D, C52E, C52F, C52G, C52J, C52K, D23E, D23F, D23H, D23J, D24K
GRU4	C52E, C52F, C52G
GRU5	C51J, C52K, C52L
GRU6	C51F, C51H, C51J, D31A, D31D
GRU7	D12A, D12B, D12C, D12E, D13A, D13B, D13C, D13E, D13F, D13G, D13J, D13K, D13L, D15H, D18K, D18L
GRU8	D12B, D12C, D12E, D12F, D13F, D13G, D13J, D13K, D13L, D13M, D14C, D14F, D14G
GRU9	D12F, D13M, D14B, D14C, D14D, D14F, D14G, D14H, D14J, D14K, D24J, D32C, D32H, D34B, D34C, D34D, D35B, D35C, D35D, D35E, D35G, D35H, D35K
GRU10	D32A, D32B, D32C, D32D, D32F
GRU11	D32F, D32H, D32J, D34A, D34B, D34C, D34D, D34E, D34F, D34G
GRU12	D31A, D31B, D31C, D31D, D31E, D32F, D32H, D32J, D33A, D33B, D34F, D34G
GRU13	C51L, C52L, D31B, D31C, D31E, D33A, D33B, D33C, D33D, D33E, D33F, D33G, D33H, D33J, D33K
GRU14	C51E, C51F, C51G, C51H, C51J, C52G, C52J, C52K, C52L, D31A, D31D, D31E, D33A, D33B, D33C, D33D, D33E, D34G

15. CONCLUSION

Based on the findings and the eco-categorisation review, the goals for safeguarding the ecosystem have been established using EcoSpecs. These specifications outline the monitoring criteria necessary to maintain the integrity of each EWR site and selected field verification sites. EcoSpecs serve as quantifiable and enforceable benchmarks for the quantity, quality, habitat, and biotic components aligned with specific ecological objectives for a given water resource.

EcoSpecs primarily define parameter values, typically maximum concentrations that should not be surpassed to achieve the Recommended Ecological Category (REC) designated for the water resource. The EcoSpecs, focusing solely on ecological information, will be complemented and elaborated with the setting of Resource Quality Objectives (RQOs) for the Upper Orange catchment area during the study initiated by DWS in 2023.

This report details the EcoSpecs and monitoring requisites essential for maintaining the ecological Reserve in the water resources of the Upper Orange catchment area. These specifications encompass hydrology, water quality, geomorphology, riparian vegetation, habitats and biota of rivers, groundwater, and wetlands. In essence, these EcoSpecs play a crucial role in advancing the realisation of the Reserve's objectives moving forward.

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