water and sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments

RIVER SPECIALIST MEETING REPORT

September 2022

FC/02825.cdr
Last updated: 2022/09/25

Department of Water and Sanitation

Chief Directorate: Water Ecosystems Management

PROJECT NUMBER**:** WP 11387

River Specialist Meeting Report

CLASSIFICATION OF SIGNIFICANT WATER RESOURCES AND DETERMINATION OF RESOURCE QUALITY OBJECTIVES FOR WATER RESOURCES IN THE USUTU TO MHLATHUZE CATCHMENTS

SEPTEMBER 2022

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa, September 2022. Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: River Specialist Meeting Report. DWS Report. Prepared by: WRP Consulting Engineers (Pty) Ltd. DWS Report: WEM/WMA3/4/00/CON/CLA/0922.

REPORT SCHEDULE

Index Number	DWS Report Number	Report Title
1	WEM/WMA3/4/00/CON/CLA/0122	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Inception Report including Gap Analysis chapter**
2	WEM/WMA3/4/00/CON/CLA/0222	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Status Quo and Delineation of Integrated Units of Analysis and Resource Unit Report**
3	WEM/WMA3/4/00/CON/CLA/0322	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Units Delineation and Prioritisation Report**
4	WEM/WMA3/4/00/CON/CLA/0422	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Hydrology Systems Analysis Report**
5	WEM/WMA3/4/00/CON/CLA/0522	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River EWR estimates for Desktop Biophysical Nodes Report**
6	WEM/WMA3/4/00/CON/CLA/0622	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River Survey Report**
7	WEM/WMA3/4/00/CON/CLA/0722	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Basic Human Needs Report**
8	WEM/WMA3/4/00/CON/CLA/0822	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Groundwater Report**
9	WEM/WMA3/4/00/CON/CLA/0922	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River specialist meeting Report**
10	WEM/WMA3/4/00/CON/CLA/1022	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Estuary Survey Report**
11	WEM/WMA3/4/00/CON/CLA/1122	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Wetland Report**
12	WEM/WMA3/4/00/CON/CLA/1222	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecological Water Requirements Report**
13	WEM/WMA3/4/00/CON/CLA/1322	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Scenario Description Report**
14	WEM/WMA3/4/00/CON/CLA/0123,	Classification of Significant Water Resources and

Index Number	DWS Report Number	Report Title
	volume 1	Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecological Consequences Report, Volume 1: Rivers**
	WEM/WMA3/4/00/CON/CLA/0123, volume 2	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecological Consequences Report, Volume 2: Estuaries**
15	WEM/WMA3/4/00/CON/CLA/0323	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecosystem Services Consequences Report**
16	WEM/WMA3/4/00/CON/CLA/0423	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Economic & User water quality Consequences Report**
17	WEM/WMA3/4/00/CON/CLA/0523	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Water Resource Classes Report**
18	WEM/WMA3/4/00/CON/CLA/0623, volume 1	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Quality Objectives Report, Volume 1: Rivers**
	WEM/WMA3/4/00/CON/CLA/0623, volume 2	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Quality Objectives Report, Volume 2: Estuaries**
	WEM/WMA3/4/00/CON/CLA/0623, volume 3	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Quality Objectives Report, Volume 3: Wetlands and Groundwater**
19	WEM/WMA3/4/00/CON/CLA/0723	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Monitoring and Implementation Report**
20	WEM/WMA3/4/00/CON/CLA/0124	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Main Report**
21	WEM/WMA3/4/00/CON/CLA/0224	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Issues and Responses Report**
22	WEM/WMA3/4/00/CON/CLA/0324	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Close out Report**

Shaded Grey indicates this report.

APPROVAL

Project Name:	*Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments*
Report Title:	***River Specialist Meeting Report***
Author(s):	*D Louw (compiler)*
Editor:	*S Koekemoer*
Client Report No.:	*WEM/WMA3/4/00/CON/CLA/0922*
Contract Number:	*WP11387*
Lead Consultant:	*WRP Consulting Engineers, supported by Scherman Environmental*
Status of Report:	*FINAL*
First Issue:	*September 2022*
Final Issue:	*September 2022*

Approved for the PSP by:

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ACKNOWLEDGEMENTS

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TERMINOLOGY AND ACRONYMS

AEV	Acute Effect Value
ANZG	Australia and New Zealand Guidelines
BDI	Biological Diatom Index
BHN	Basic Human Needs
CPUE	Catch Per Unit Effort
CD: WEM	Chief Directorate: Water Ecosystems Management
DEM	Digital Elevation Model
DGV	Default Guideline Value
d/s	downstream
DRIFT	Downstream Response to Imposed Flow Transformations
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
EC	electrical conductivity
FD	Fish Habitat - Fast Deep
FS	Fish Habitat - Fast Shallow
SD	Fish Habitat - Slow Deep
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphology Driver Assessment Index
GSM	Gravel, sand and mud
IHI	Index of Habitat Integrity
IHI	Index of Habitat Integrity
IUCMA	Inkomati Usuthu Catchment Management Agency
IUCN	International Union for Conservation of Nature
LB	Left bank
MCB	Macro Channel Bank
MIRAI	Macroinvertebrate Response Assessment Index
MCM	Million Cubic Meters
NEMP	National Eutrophication Monitoring Programme
NMMP	National Microbial Monitoring Programme
NWA	National Water Act
nMAR	Natural Mean Annual Runoff
PC	Physico-Chemical
PAI	Physico-chemical driver Assessment Index
PTV	Pollution Tolerant diatom Valves
PD	Present Day
PES	Present Ecological State
PES	Present Ecological State
REC	Recommended Ecological Category
RC	Reference Condition

RQO	Resource Quality Objectives
RDRMv2	Revised Desktop Reserve Model version 2
RB	Right bank
SRTM	Shuttle Remote Topography Mission
SADI	South African Diatom Index
SPI	Specific Pollution sensitivity Index
SQR	sub-quaternary reach
TDI	Trophic Diatom Index
TWQR	Target Water Quality Range
u/s	upstream
WWTW	Waste Water Treatment Works
WWTW	Waste Water Treatment Works
WMS	Water Monitoring System
wq	water quality
WQSU	Water Quality Sub-Unit
WRCS	Water Resource Classification System

SPELLING

There are multiple references to the spelling of various Rivers, Lakes, Dams and Estuaries, depending on the source of information. For the purposes of this report, the following Table presents the selected spelling of indicated water resources and places.

Selected Spelling for this Study	Alternate spellings
Usutu River	Usuthu River
Mhlathuze River	Mhlatuze, uMhlatuze River
Pongola (river, Town & Pongolapoort Dam)	Phongola, Phongolo
Lake Sibaya	Lake Sibiya, Lake Sibhayi, Lake Sibhaya
Eswatini	eSwatini
Umfolozi River	Mfolozi River
Amatigulu River	Amatikulu, Matigulu River
Goedertrouw Dam	Lake Phobane
Mfuli River	Mefule River
aMatigulu/iNyoni Estuary	
Sibiya Estuary	
Mlalazi Estuary	
uMhlathuze /Richards Bay Estuary	
iNhlabane Estuary	
uMfolozi/uMsunduze Estuary	
St Lucia Estuary	
uMgobezeleni Estuary	
Kosi Estuary	
Hluhluwe Game Reserve	
iMfolozi Game Reserve	
Ithala Game Reserve	
Ndumo Game Reserve	

Tembe Elephant Reserve	
iSimangaliso Wetland Park	
Kosi Bay and Coastal Forest Area	
uMkhuze Game Reserve	

GLOSSARY

Basic Human Needs	Water needs to be set aside for basic human needs such as drinking, food preparation, and health and hygiene purposes. This is referred to as the Basic Human Needs Reserve (BHNR).
Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
Ecosystem services	The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.
EcoClassification	The term used for the Ecological Classification process - refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers relative the natural or close to the natural reference condition. The purpose of the EcoClassification process is to gain insights and understanding into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river.
Integrated Unit of Analysis (IUAs)	An IUA is a homogeneous area that can be managed as an entity. It is the basic unit of assessment for the Classification of water resources, and is defined by areas that can be managed together in terms of water resource operations, quality, socio-economics and ecosystem services.
Resource Quality Objectives (RQOs)	RQOs are numeric or descriptive goals or objectives that can be monitored for compliance to the Water Resource Classification, for each part of each water resource. “The purpose of setting RQOs is to establish clear goals relating to the quality of the relevant water resources” (NWA, 1998).
Sub-quaternary reaches (SQR)	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments), to a sub-quaternary reach or quinary level.
Target Ecological Category (TEC)	This is the ecological category toward which a water resource will be managed once the Classification process has been completed and the Reserve has been finalised. The draft TECs are therefore related to the draft Classes and selected scenario.
Water Resource Class	The Water Resource Class (hereafter referred to as Class) defines three management classes, Class I, II, and III, based on extent of use and alteration of ecological condition from the predevelopment condition.

1 INTRODUCTION

1.1 BACKGROUND

Chapter 3 of the National Water Act, 1998 (NWA) (Act 36 of 1998), deals with the protection of water resources. Section 12 of the NWA requires the Minister to develop a system to classify water resources. In response to this, the Water Resource Classification System (WRCS) was gazetted on 17 September 2010 and published in Government Gazette 33541 as Regulation 810. The WRCS is a stepwise process whereby water resources are categorised according to specific classes that represent a management vision of a particular catchment. This vision takes into account the current state of the water resource, the ecological, social and economic aspects that are dependent on the resource. Once significant water resources have been classified following the WRCS, Resource Quality Objectives (RQOs) must be determined to give effect to the class. The implementation of the WRCS therefore assesses the costs and benefits associated with utilisation versus protection of a water resource. Section 13 of the NWA requires that Water Resource Classes and RQOs be determined for all significant water resources.

Thus, the Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS) initiated a study for determining the Water Resource Classes and RQOs for all significant water resources in the Usutu to Mhlathuze Catchment. The Usutu to Mhlathuze Catchments are amongst many water-stressed catchments in South Africa. These catchment areas are important for conservation and contain a number of protected areas, natural heritage sites, cultural and historic sites as well as other conservation areas that need protection. There are five RAMSAR[1] sites within the catchment, which includes the world heritage site and St Lucia. The others are Sibaya, Kosi Bay, Ndumo Game Reserve and Turtle Beaches.

1.2 STUDY AREA

The study area is the Usutu to Mhlathuze Catchment that has been divided into six drainage areas and secondary catchment areas as follows (refer to the locality map provided as **Figure 1.1**):

- W1 catchment (main river: Mhlathuze).
- W2 catchment (main river: Umfolozi).
- W3 catchment (main river: Mkuze).
- W4 catchment (main river: Pongola) - part of this catchment area falls within Eswatini.
- W5 catchment (main river: Usutu) - much of this catchment falls within Eswatini.
- W7 catchment (Kosi Bay estuary and Lake Sibaya).

Note that all assessments within Eswatini are excluded apart from the hydrological modelling required to assess any downstream rivers in South Africa that either run through Eswatini or originate (source) in Eswatini.

[1] A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention, also known as "The Convention on Wetlands", an intergovernmental environmental treaty established in 1971 by UNESCO in the Iranian city of Ramsar, which came into force in 1975.

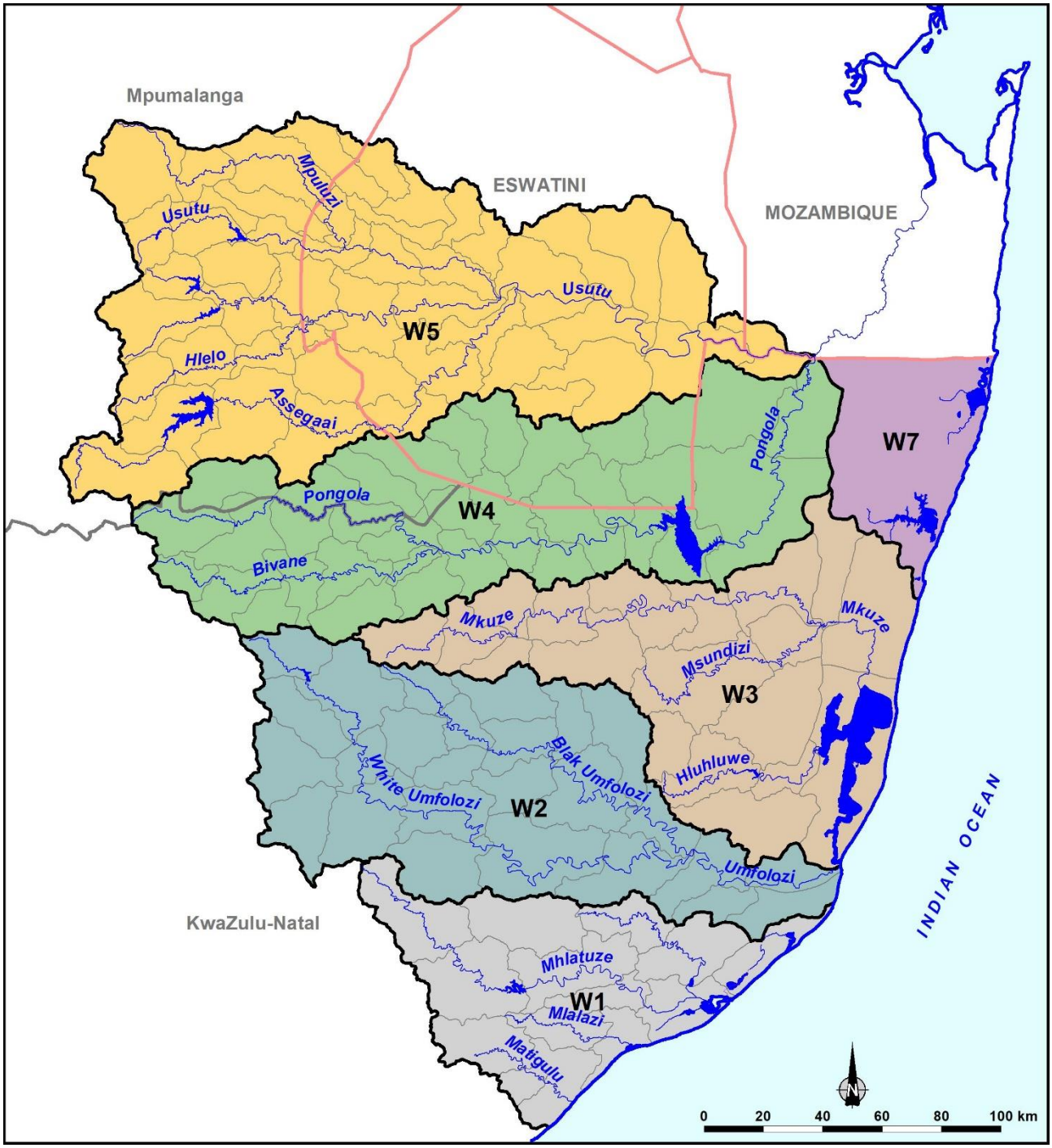

Figure 1 Locality Map of the Study Area

1.3 PURPOSE OF THIS REPORT

The purpose of this report is to document the results of the specialist preparatory work that has been undertaken and the outcomes of the workshop (12 – 16 September 2022).. The EWR specialist meeting forms part of Task 3: Quantify BHN and EWR (Figure 1.2). The detailed results will be provided in Report 12: Ecological Water Requirements Report.

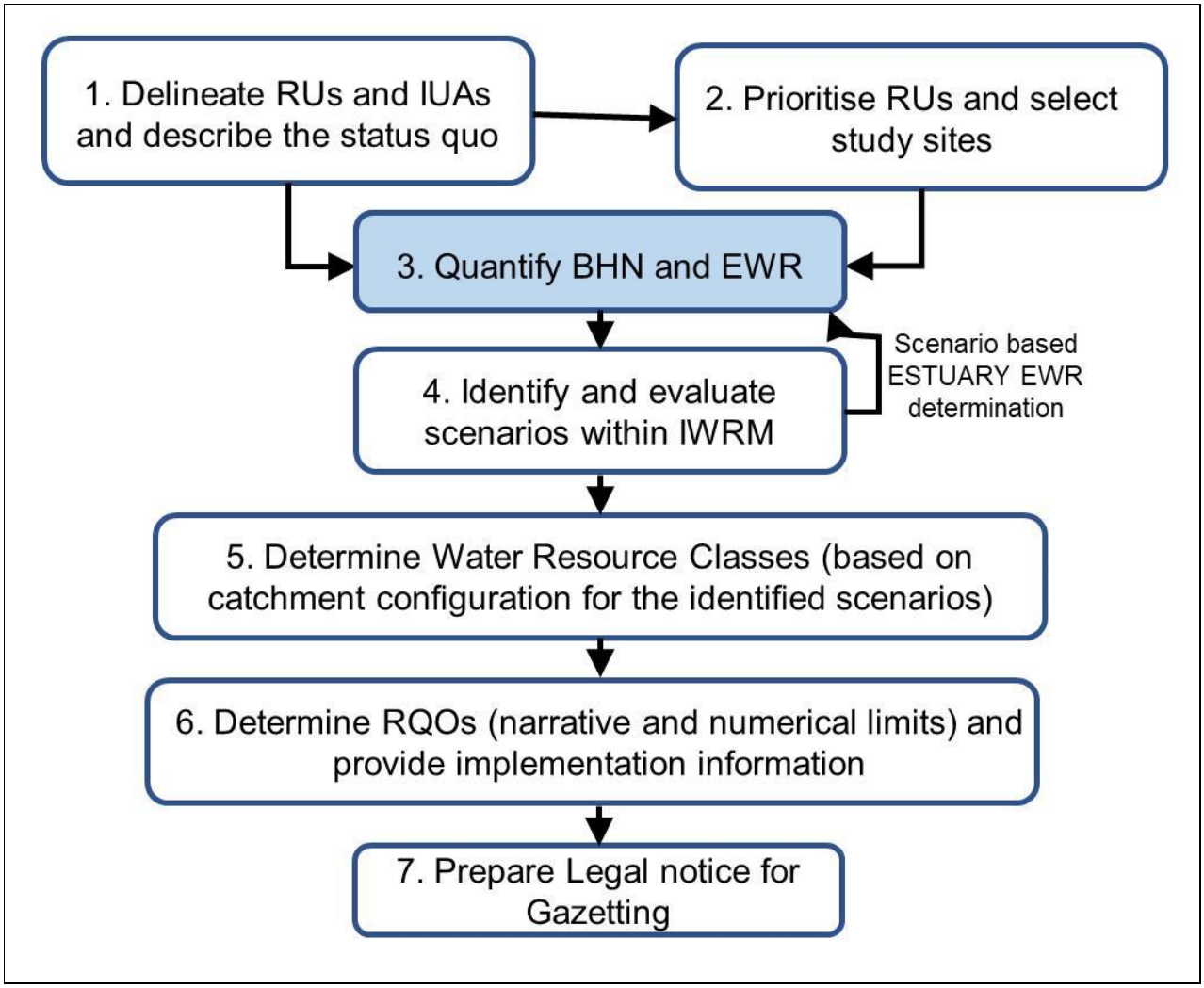

Figure 2 Project Plan for the Usutu-Mhlathuze Classification study

1.4 EWR SITES

A field survey was undertaken during July 2022 to assess the EWR sites. No new EWR sites were selected for this study (DWS, 2022) except for EWR NG1 (Ngwempisi River). Site details of the eight EWR sites are provided in Table 1.1.

Table 1.1 EWR sites of the Usutu-Mhlathuze Classification study

EWR MA1: Matigulu River		
	Co-ordinates	S29.02010 E31.47040
	SQ code	W11A-03612
	RU	RU W11-2
	IUA	IUA W11
	Level 2 EcoRegion	17.01
	Geomorph Zone	Upper foothills
EWR NS1: Nseleni River		
	Co-ordinates	S28.63410 E31.92517
	SQ code	W12G-03229
	RU	RU W12-8
	IUA	IUA W12-b
	Level 2 EcoRegion	13.03
	Geomorph Zone	Lower foothills
EWR WM1: White Mfolozi River		
	Co-ordinates	S28.23146 E31.18666
	SQ code	W21H-02897
	RU	RU W21-5
	IUA	IUA W21
	Level 2 EcoRegion	14.05
	Geomorph Zone	Lower foothills
EWR BM1: Black Mfolozi River		
	Co-ordinates	S27.93890 E31.21030
	SQ code	W22A-02610
	RU	RU W22-1
	IUA	IUA W22
	Level 2 EcoRegion	3.1
	Geomorph Zone	Upper foothills
EWR MK1: Mkuze River		
	Coordinates	S27.59210 E32.21800
	SQ code	W31J-02480
	RU	RU W31-5
	IUA	IUA W31-b
	Level 2 EcoRegion	3.08
	Geomorph Zone	Lowland

EWR UP1: Pongola River		
	Coordinates	S27.36413 E30.96962
	SQ code	W42E-02221
	RU	RU W42-2
	IUA	IUA W42-b
	Level 2 EcoRegion	3.1
	Geomorph Zone	lower/upper foothills
EWR AS1: Assegaai River		
	Coordinates	S27.06230 E30.98880
	SQ code	W51E-02049
	RU	RU W51-3
	IUA	IUA W52
	Level 2 EcoRegion	4.06
	Geomorph Zone	lower/upper foothills
EWR NG1: Ngwempisi River		
	Coordinates	S26.679448 E30.70213
	SQ code	W53E-01790

1.5 REPORT OUTLINE

The report outline is as follows:

- **Chapter 1** provides general background information on the study area and the Project Plan. This chapter also provides a general overview of the EWR sites that were assessed as part of Task 3.
- **Chapter 2 – 3** provide the outcomes of the specialist meeting and presents the EcoClassification results as well as the EWR of the respective sites.
- **Chapter 4 lists the references used in the report.**
- **The appendices** are the specialist reports that were generated during the workshop.

2 ECOCLASSIFICATION RESULTS

The EcoClassification results for the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) is provided in **Table 2.1 – 2.8** for each EWR site.

2.1 PRESENT ECOLOGICAL STATE

2.1.1 EWR MA1: Matigulu River

Table 2.1 Present Ecological State

Component	PES	Causes	Sources
Instream IHI[1]	**B/C (80%)**	The dominant impacts are on bed modification based on increase sedimentation (catchment use) and benthic growth.	
Riparian IHI	**B/C (78%)**	The key impacts are non-flow related and are based on bank structure changes in the non-marginal zone as well as longitudinal and lateral connectivity issues based on presence of alien vegetation.	
Water quality	**B (84.5%)**	Elevated turbidity and salts; small increase in nutrient levels.	Sedimentation from overgrazing and erosion. Elevated salts from cultivation activities and presence of rural settlements.
Geomorphology	**B (87%)**	Increased sand deposits.	Catchment erosion.
Riparian vegetation	**B/C (79.4%)**	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, Chromolaena,* and *Ageratum*).
Fish	**B (86.4%)**	Decreased habitat availability due to lower flows, deteriorated water quality, and sedimentation.	Water abstraction, settlements and catchment erosion.
Macro-invertebrates	**B/C (80.9%)**	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients and salinity), as well as increased sedimentation.	Catchment erosion and donga formation. Trampling and grazing result in erosion.
EcoStatus	**B/C (81.3%)**	Derived using the EcoStatus model.	

1 Index of Habitat Integrity

2.1.2 EWR NS1: Nseleni River

Table 2.2 Present Ecological State

Component	PES	Causes	Sources
Instream IHI	**B/C (81%)**	The major impacts are bed and bank modification. These impacts are non-flow related due to alien vegetation, and the direct impact of riparian landowners.	
Riparian IHI	**C (70.3%)**	Impacts on the riparian zone are linked largely to invasive alien vegetation, which is the dominant cause of the status.	
Water quality	**B (82.7%)**	Elevated turbidity and salts; small increase in nutrient levels.	Sedimentation from extensive settlements and related activities. Elevated salts from cultivation activities (and marine influence).
Geomorphology	**B (85%)**	Limited increased fine sediment deposits	Catchment erosion.
Riparian vegetation	**C (64.4%)**	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, Chromolaena,* and *Ageratum*).
Fish	**C (67.9%)**	Reduced vegetation cover along flood features.	Vegetation clearing for fences and security.

Component	PES	Causes	Sources
Macro-invertebrates	**B/C 79.4%)**	Altered habitats and flows, sedimentation and altered marginal vegetation as cover.	Water transfer (Mhlathuze River), agriculture (especially sugar cane), catchment erosion, and alien vegetation encroachment.
EcoStatus	**C (68.4%)**	Derived using the EcoStatus model.	

2.1.3 EWR WM1: White Mfolozi River

Table 2.3 Present Ecological State

Component	PES	Causes	Sources
Instream IHI	**B/C (79.3%)**	The dominant impacts are on bed modification based on increase sedimentation (catchment use) and benthic growth.	
Riparian IHI	**B/C (77.4%)**	The key impacts are bank structure changes in the non-marginal zone as well as longitudinal and lateral connectivity issues based on the presence of alien vegetation.	
Water quality	**B (84.5%)**	Elevated turbidity; small increase in nutrient levels.	Sedimentation (and a small nutrient elevation) from extensive settlements and related activities.
Geomorphology	**B/C (78.8%)**	Increased sand deposits.	Catchment erosion.
Riparian vegetation	**B/C (81.3)**	Altered species composition.	Alien plant species (perennial and invasive), including *Sesbanea,* although density was low.
Fish	**C (73%)**	Reduced habitat/flows, sedimentation of bottom substrates and water quality deterioration (nutrients, turbidity).	Water abstraction, dams, irrigation, catchment erosion, subsistence farming.
Macro-invertebrates	**B/C (81.1%)**	Sensitive taxa impacted by reduced water availability, deteriorating water quality parameters (increased nutrients and salinity), as well as siltation.	Irrigation agriculture, mines, afforestation, settlements and towns use water. Trampling and grazing result in erosion.
EcoStatus	**B/C (79.2%)**	Derived using the EcoStatus model.	

2.1.4 EWR MB1: Black Mfolozi River

Table 2.4 Present Ecological State

Component	PES	Causes	Sources
Instream IHI	**B/C (77.7%)**	The major impact is on bank modification and connectivity issues which are non-flow related.	
Riparian IHI	**C (74.4%)**	Impacts are related to non-marginal substrate exposure and invasive alien vegetation.	
Water quality	**B/C (81.8%)**	Elevated intermittent sulphates and salts.	Intermittent elevated sulphates from upstream mining activities.
Geomorphology	**A (93%)**	Possible increase in height of right flood bench.	Catchment erosion and/or increased magnitude of flood peaks.
Riparian vegetation	**B/C (74.9%)**	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea,* and *Lantana*).
		Vegetation removal.	Overgrazing by livestock and wood removal and collection.
Fish	**C (75.9%)**	Reduced water quality, slightly reduced bottom substrates.	Mining and catchment erosion.
Macro-invertebrates	**B/C (81.2%)**	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients, sulphides and salinity). Siltation.	Mining in catchment. Catchment erosion due to vegetation removal for sugarcane, roads and rural homesteads.
EcoStatus	**C (76.9%)**	Derived using the EcoStatus model.	

2.1.5 EWR MK1: Mkuze River

Table 2.5 Present Ecological State

Component	PES	Causes	Sources
Instream IHI[1]	C (66.3%)	Flow and non-flow related impacts include flow abstraction, nutrient , salts and toxic issues and sedimentation.	
Riparian IHI	C (72.1%)	Decreased flows, substrate exposure and alien vegetation impact the site and are flow and non-flow related.	
Water quality	C/D (58.3%)	Elevated intermittent sulphates and salts, presumably from upstream coal-mining. Toxics and elevated nutrients and turbidity.	Elevated salts, particularly sodium and sulphates from upstream mining activities. Nutrient and turbidity increases, and expected toxics due to upstream activities such as coal-mining, settlements, irrigated crops and High Risk Mkuze Waste Water Treatment Works (WWTW).
Geomorphology	B (82.26%)	Increased sediment load, bank destabilisation	Catchment erosion, livestock grazing and trampling.
Riparian vegetation	C (73.0 %)	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, lantana* and *Mellia*).
		Reduced woody cover.	Targeted wood removal.
Fish	C (75.4%)	Water quality deterioration and altered beds due to siltation.	Catchment erosion, mining, WWTW, over grazing, subsistence farming.
Macro-invertebrates	C (77.7%)	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients, sulphates and salinity), as well as siltation.	Catchment erosion from rural settlements and agricultural. Upstream WWTW, mining and sewage.
EcoStatus	C (74.8%)	Derived using the EcoStatus model.	

2.1.6 EWR UP1: Upper Pongolo River

Table 2.6 Present Ecological State

Component	PES	Causes	Sources
Instream IHI	B/C (80.5%)	Impacts are small, largely non-flow related with catchment changes being the most dominant.	
Riparian IHI	B/C (77.8%)	Dominant impacts are related to bank structure modification (substrate exposure and invasive alien vegetation), which are non-flow related.	
Water quality	A/B (88.3%)	Elevated turbidity.	Upstream cultivation and urban and rural settlements.
Geomorphology	A/B (89.8%)	Small increase in channel sediments.	Local catchment erosion.
Riparian vegetation	C (70%)	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, lantana* and *Mellia*).
		Reduced woody cover.	Targeted wood removal.
Fish	C (73.9%)	Water quality deterioration and altered rocky substrate condition (sedimentation).	Rural settlements, forestry, catchment erosion.
Macro-invertebrates	B/C (79.5%)	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients and salinity), as well as increased sedimentation.	Local sand mining. Numerous forestry roads, heavy grazing pressure and dense rural settlements - increased sediment yield and load.
EcoStatus	C (73.5%)	Derived using the EcoStatus model.	

2.1.7 EWR AS1: Assegaai River

Table 2.7 Present Ecological State

Component	PES	Causes	Sources
Instream IHI	**C/D (59.1%)**	Impacts are small, largely non-flow related with catchment changes being the most dominant.	
Riparian IHI	**C/D (58.7%)**	Dominant impacts are related to bank structure modification (substrate exposure and invasive alien vegetation), which are non-flow related.	
Water quality	**B/C (80.6%)**	Elevated nutrient levels, with some evidence of toxics.	Upstream agricultural activities.
Geomorphology	**C (70.84%)**	Reduced coarse sediment Reduced flood magnitude	Heyshope Dam.
Riparian vegetation	**C (69.9)%**	Altered species composition.	Perennial alien species had invaded the banks with up to 50% cover in places. Dominant species were *A. mearnsii, A. melanoxylon,* and *Lantana camara.* Others included *Sesbanea punicea.*
		Increased woody vegetation and to some extent non-woody vegetation cover.	Flow regulation and reduced flooding disturbance.
Fish	**C (69.2%)**	Altered water quality, habitat deterioration (sedimentation), flow modification and over-exploitation.	Towns/settlements, WWTW, forestry, dams (such as Heyshope), catchment erosion, poaching.
Macro-invertebrates	**B/C (78.6%)**	Flow modifications and nutrient enrichments.	Nutrient enrichments from the upstream settlements and towns. Reduced floods due to the Heyshope Dam.
EcoStatus	**C (74.16%)**	Derived using the EcoStatus model.	

2.1.8 EWR NG1: Ngwempisi River

Table 2.8 Present Ecological State

Component	PES	Causes	Sources
Instream IHI	**C (64.3%)**	Flow changes due to upstream Morgenstond and Westoe dams. Non-flow related impacts due to sedimentation and marginal and non-marginal bank modification as well as connectivity issues.	
Riparian IHI	**C/D (61.8%)**	Flow changes due to upstream dams and non-flow related impacts due to invasive alien vegetation.	
Water quality	**B (85.5%)**	Elevated turbidity and small toxics input expected.	Upstream forestry and roads network.
Geomorphology	**B (83.3%)**	Reduction is bedload sediment (sands and gravels) and reduced floods.	Upstream dams and weir.
Riparian vegetation	**B/C (77.4%)**	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea,* and *Solanum mauritianun*).
Fish	**C (72.8%)**	Altered water quality, bed modification, reduced habitat suitability and abundance.	Amsterdam, agriculture, livestock farming, WWTW, informal settlement, catchment erosion, agriculture, dams and weirs, as well as water abstraction.
Macro-invertebrates	**B (87.3%)**	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients and salinity), as well as siltation.	Trampling and grazing result in localised erosion.
EcoStatus	**B/C (79.8%)**	Derived using the EcoStatus model.	

2.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

A summary of the Ecological Importance and Sensitivity (EIS) results are provided in Table 2.9.

Table 2.9 EIS Results

EWR site	EIS
EWR MA1	Moderate
EWR NS1	Moderate
EWR WM1	Moderate
EWR BM1	Moderate
EWR MK1	High
EWR UP1	Moderate
EWR AS1	Moderate
EWR NG1	Moderate

2.3 RECOMMENDED ECOLOGICAL CATEGORY

A summary of the EcoClassification results are provided in Table 2.10 and recommendations for the Recommended Ecological Category (REC) is also provided.

Table 2.10 EcoClassification results and REC recommendations

EWR site	PES	EIS	REC	COMMENT
EWR MA1	**B/C**	Moderate	**B/C**	Due to the **MODERATE** importance, the REC is set to maintain the PES of a **B/C** EC.
EWR NS1	**C**	Moderate	**C**	Due to the moderate importance, the REC is set to maintain the PES of a C EC.
EWR WM1	**B/C**	Moderate	**B/C**	Due to the MODERATE importance, the REC is set to maintain the PES, i.e. a **B/C EC**.
EWR BM1	**C**	Moderate	**C**	Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.
EWR MK1	**C**	High	**C**	Due to the HIGH importance, the REC is set to improve the PES of a C to a **B EC**. Flows will only be set for a C however, as this improvement must be achieved by addressing catchment issues rather than increased flows.
EWR UP1	**C**	Moderate	**C**	Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.
EWR AS1	**C**	Moderate	**C**	Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.
EWR NG1	**B/C**	Moderate	**B/C**	Due to the moderate importance, the REC is set to maintain the PES of a **B/C EC**.

3 ECOLOGICAL WATER REQUIREMENTS

Ecological Water Requirements are provided per EWR site in this section.

3.1 MATIGULU RIVER: EWR MA1 - RECOMMENDATIONS FOR A B/C EC

The flow requirements are summarised in **Table 3.1** and **3.2**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 12.63 Million Cubic Meters (MCM) and equates to 17.4% of the natural mean annual runoff (nMAR). Total flow EWR is 19.14 MCM which equates to 26.3% of the nMAR. The text in red on the flow duration tables refers to the wettest and driest months.

Table 3.1 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	1.968	33	4	0.096
2	Annual	6.164	37	3	0.339
3	Annual	16.109	37	1	0.886
4	1:2 year	56.257	41	1	3.436
5	1:5 year	182.173	49	1	13.341

Table 3.2 Low flow Flow Duration Table (EWR rule table)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.65	0.65	0.65	0.60	0.48	0.39	0.32	0.26	0.20	0.19
Nov	0.66	0.66	0.66	0.62	0.48	0.37	0.32	0.24	0.20	0.20
Dec	0.63	0.63	0.63	0.56	0.46	0.36	0.30	0.23	0.19	0.19
Jan	0.55	0.55	0.55	0.52	0.42	0.34	0.29	0.22	0.18	0.18
Feb	0.52	0.51	0.51	0.48	0.42	0.35	0.29	0.20	0.15	0.10
Mar[1]	0.65	0.58	0.52	0.49	0.44	0.38	0.29	0.21	0.14	0.08
Apr	0.54	0.54	0.53	0.50	0.43	0.36	0.30	0.22	0.15	0.12
May	0.56	0.56	0.56	0.51	0.43	0.36	0.31	0.24	0.15	0.13
Jun	0.53	0.53	0.53	0.50	0.44	0.37	0.31	0.24	0.16	0.14
Jul	0.54	0.54	0.54	0.52	0.44	0.36	0.31	0.25	0.17	0.15
Aug[1]	0.36	0.35	0.35	0.34	0.32	0.27	0.20	0.17	0.14	0.07
Sep	0.58	0.58	0.57	0.54	0.45	0.37	0.31	0.24	0.18	0.18

1 The low flows for the 60th and 90th percentiles for the wettest (March) and driest (August) month.

3.2 NSELENI RIVER: EWR NS1 - RECOMMENDATIONS FOR A C EC

The flow requirements are summarised in **Table 3.3** and **3.4**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 4.755 MCM and equates to 15.2% of the nMAR. The total flow is 6.85 MCM which equates to 21.9% of the nMAR.

Table 3.3 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	2.006	33	4	0.098
2	Annual	5.007	33	3	0.245
3	Annual	8.031	37	1	0.442

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
4	1:2 year	29.115	45	1	1.955
5	1:5 year	83.297	57	1	7.113

Table 3.4 Low flow Flow Duration Table (EWR rule table)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.24	0.24	0.19	0.17	0.14	0.13	0.12	0.09	0.07	0.05
Nov	0.24	0.24	0.19	0.18	0.15	0.14	0.12	0.09	0.07	0.06
Dec	0.24	0.24	0.19	0.17	0.15	0.14	0.12	0.09	0.06	0.06
Jan	0.24	0.23	0.19	0.16	0.14	0.14	0.13	0.09	0.07	0.06
Feb	0.23	0.23	0.17	0.15	0.15	0.14	0.12	0.09	0.07	0.06
Mar	0.24	0.23	0.19	0.18	0.15	0.15	0.13	0.10	0.08	0.07
Apr[1]	0.25	0.23	0.22	0.20	0.18	0.16	0.14	0.12	0.10	0.08
May	0.23	0.23	0.19	0.17	0.15	0.15	0.12	0.09	0.07	0.06
Jun	0.23	0.23	0.19	0.16	0.16	0.14	0.12	0.10	0.08	0.06
Jul	0.24	0.23	0.19	0.15	0.15	0.14	0.12	0.10	0.07	0.06
Aug[1]	0.14	0.13	0.13	0.12	0.11	0.10	0.08	0.06	0.04	0.03
Sep	0.24	0.23	0.18	0.14	0.14	0.12	0.12	0.09	0.06	0.06

1 The low flows for the 60th and 90th percentiles for the wettest (April) and driest (August) month.

3.3 WHITE MFOLOZI RIVER: EWR WM1 - RECOMMENDATIONS FOR A B/C EC

The flow requirements are summarised in **Tables 3.5** and **3.6**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 54.741 MCM and equates to 24.6% of the nMAR. The total flow EWR is 89.314 MCM equating to 40.1% of the nMAR.

Table 3.5 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	10.063	65	4	0.982
2	Annual	24.437	68	3	2.525
3	Annual	60.377	72	1	6.604
4	1:2 year	242.909	84	1	31
5	1:5 year	582.74	92	1	81.451

Table 3.6 Low flow Flow Duration Table (EWR rule table)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.919	1.595	1.542	1.407	1.292	1.101	0.974	0.903	0.833	0.721
Nov	2.826	2.098	1.838	1.690	1.551	1.396	1.178	1.032	0.938	0.706
Dec	3.106	2.849	2.267	1.915	1.794	1.569	1.365	1.206	1.063	0.902
Jan	3.074	2.947	2.599	2.264	2.070	1.879	1.552	1.324	1.167	0.918
Feb[1]	3.247	3.073	2.825	2.539	2.257	1.979	1.699	1.439	1.262	0.942
Mar	3.106	3.094	2.816	2.531	2.433	2.091	1.804	1.576	1.446	0.933
Apr	2.805	2.801	2.631	2.324	2.263	2.029	1.743	1.464	1.385	1.181
May	2.626	2.491	2.288	2.101	2.056	1.813	1.561	1.324	1.140	0.941
Jun	2.312	1.967	1.855	1.721	1.677	1.523	1.270	1.098	1.011	0.833
Jul	1.962	1.759	1.673	1.510	1.378	1.262	1.132	1.001	0.952	0.758
Aug	1.671	1.505	1.415	1.258	1.165	1.090	1.016	0.938	0.844	0.724
Sep[1]	1.591	1.453	1.324	1.212	1.105	1.001	0.916	0.839	0.773	0.640

1 The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

3.4 BLACK MFOLOZI RIVER: EWR BM1 RECOMMENDATIONS FOR A C EC

The flow requirements are summarised in the **Tables 3.7** and **3.8**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 18.38 MCM and equates to 11% of the nMAR while the total flow EWR is 43.58 MCM and equates to 26.1% of the nMAR.

Table 3.7 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	11.172	61	4	1.022
2	Annual	22.108	65	3	2.156
3	Annual	42.351	72	1	4.633
4	1:2 year	68.275	76	1	7.883
5	1:5 year	251.252	104	1	39.699

Table 3.8 Low flow Flow Duration Table (EWR rule table)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.62	0.44	0.40	0.39	0.37	0.31	0.24	0.19	0.19	0.17
Nov	1.11	0.78	0.67	0.61	0.52	0.42	0.31	0.24	0.19	0.14
Dec	1.26	0.99	0.89	0.79	0.68	0.55	0.41	0.31	0.22	0.19
Jan	1.46	1.43	1.09	0.87	0.79	0.65	0.49	0.37	0.32	0.25
Feb[1]	1.34	1.23	1.10	0.95	0.82	0.70	0.58	0.48	0.40	0.35
Mar	1.25	1.20	1.05	1.02	0.92	0.78	0.59	0.46	0.36	0.31
Apr	1.05	0.99	0.93	0.87	0.82	0.70	0.58	0.45	0.37	0.32
May	0.81	0.77	0.77	0.73	0.67	0.58	0.47	0.38	0.33	0.29
Jun	0.67	0.64	0.63	0.60	0.53	0.46	0.37	0.30	0.26	0.24
Jul[1]	0.60	0.58	0.56	0.52	0.46	0.39	0.31	0.24	0.20	0.17
Aug	0.40	0.40	0.39	0.37	0.35	0.31	0.26	0.22	0.20	0.20
Sep	0.41	0.37	0.35	0.34	0.32	0.28	0.21	0.18	0.18	0.15

1 The low flows for the 60th and 90th percentiles for the wettest (February) and driest (July) month.

3.5 MKUZE RIVER: EWR MK1 RECOMMENDATIONS FOR A C EC

The flow requirements are summarised in **Tables 3.9** and **3.10**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 34.74 MCM and equates to 21.9% of the nMAR. The total flow EWR is 58.87 MCM which equates to 37.1% of the nMAR.

Table 3.9 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	12.325	72	4	1.348
2	Annual	25.011	76	3	2.888
3	Annual	40.539	84	1	5.174
4	1:2 year	90.433	92	1	12.64
5	1:5 year	181.323	108	1	29.752

Table 3.10 Low flow Flow Duration Table (EWR rule table)

m³/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.47	1.20	1.01	0.88	0.79	0.67	0.57	0.48	0.35	0.34
Nov	2.40	1.83	1.33	1.10	0.93	0.77	0.65	0.54	0.45	0.38
Dec	2.44	2.16	1.74	1.41	1.08	0.86	0.69	0.57	0.47	0.43
Jan	2.49	2.15	2.01	1.49	1.18	0.91	0.73	0.59	0.50	0.44
Feb[1]	2.53	2.23	1.86	1.52	1.19	0.90	0.72	0.58	0.48	0.39
Mar	2.57	2.25	2.25	1.98	1.54	1.12	0.80	0.74	0.59	0.45
Apr	2.35	2.03	1.76	1.50	1.16	0.91	0.72	0.59	0.48	0.47
May	1.86	1.67	1.47	1.27	1.07	0.84	0.69	0.58	0.45	0.42
Jun	1.60	1.43	1.21	1.05	0.89	0.73	0.60	0.51	0.43	0.40
Jul	1.39	1.31	1.06	0.90	0.80	0.68	0.58	0.50	0.42	0.40
Aug[1]	1.23	1.06	0.93	0.83	0.73	0.64	0.55	0.47	0.40	0.35
Sep	1.08	0.97	0.77	0.69	0.63	0.51	0.42	0.36	0.32	0.32

1 The low flows for the 60th and 90th percentiles for the wettest (February) and driest (August) month.

3.6 UPPER PONGOLA RIVER: EWR UP1 RECOMMENDATIONS FOR A C EC

The flow requirements are summarised in **Tables 3.11** and **3.12**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 54.84 MCM and equates to 15.4% of the nMAR while the total flow EWR is 97.314 MCM and equates to 27.3% of the nMAR.

Table 3.11 High flow requirements

Flood Class	Frequency	Peak (m³/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	8.237	84	4	1.051
2	Annual	23.241	88	3	3.107
3	Annual	56.52	96	1	8.243
4	1:2 year	70.101	100	1	10.65
5	1:5 year	222.272	120	1	40.523

Table 3.12 Low flow Flow Duration Table (EWR rule table)

m³/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.27	2.11	1.63	1.23	0.95	0.69	0.50	0.41	0.35	0.10
Nov	3.04	2.97	2.46	1.88	1.46	1.09	0.81	0.63	0.55	0.45
Dec	3.34	3.05	2.72	2.36	1.94	1.55	1.22	0.94	0.79	0.64
Jan	3.18	2.89	2.60	2.42	2.16	2.03	1.64	1.25	0.99	0.83
Feb[1]	2.58	2.50	2.42	2.30	2.16	1.98	1.76	1.49	1.19	0.92
Mar	5.04	5.04	3.37	3.14	3.08	2.53	2.01	1.72	1.57	1.21
Apr	3.12	2.94	2.57	2.57	2.56	2.27	1.85	1.65	1.47	1.22
May	3.33	3.15	2.72	2.39	2.03	1.74	1.45	1.22	0.96	0.70
Jun	2.99	2.89	2.40	1.97	1.54	1.17	0.84	0.70	0.60	0.38
Jul	2.38	2.26	1.75	1.22	0.96	0.70	0.52	0.43	0.31	0.11
Aug	1.60	1.51	1.21	0.98	0.64	0.48	0.35	0.25	0.14	0.05
Sep[1]	1.90	1.58	1.25	0.96	0.70	0.50	0.34	0.21	0.12	0.03

1 The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

3.7 ASSEGAAI RIVER: EWR AS1 RECOMMENDATIONS FOR A C EC

The flow requirements are summarised in **Tables 3.13** and **3.14**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR** is 40.06 MCM and equates to 12.2% of the nMAR. The total flow EWR is 70.850 MCM which equates to 21.6% of the nMAR.

Table 3.13 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	12.226	68	4	1.263
2	Annual	34.201	80	3	4.157
3	Annual	47.269	84	1	6.032
4	1:2 year	75.305	92	1	10.526
5	1:5 year	0:23	96	1	14.587

Table 3.14 Low flow Flow Duration Table (EWR rule table)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.81	1.60	0.92	0.57	0.42	0.35	0.31	0.27	0.23	0.20
Nov	3.58	2.22	1.40	0.84	0.58	0.48	0.41	0.36	0.32	0.24
Dec	3.58	3.31	1.82	1.31	0.92	0.69	0.62	0.54	0.45	0.30
Jan	4.16	2.70	2.30	1.59	1.25	1.04	0.92	0.76	0.61	0.51
Feb[1]	2.92	2.34	1.91	1.54	1.29	1.10	0.95	0.82	0.69	0.61
Mar	3.40	2.98	1.86	1.44	1.23	1.08	0.92	0.79	0.69	0.57
Apr	3.62	2.42	1.74	1.29	1.08	0.96	0.89	0.80	0.67	0.59
May	3.39	2.27	1.54	1.05	0.82	0.74	0.67	0.57	0.53	0.49
Jun	2.92	1.96	1.21	0.79	0.60	0.52	0.45	0.40	0.38	0.38
Jul	2.30	1.66	1.00	0.64	0.45	0.39	0.34	0.31	0.29	0.28
Aug	1.95	1.40	0.83	0.52	0.38	0.34	0.29	0.26	0.24	0.24
Sep[1]	1.99	1.24	0.76	0.48	0.36	0.30	0.26	0.23	0.20	0.18

1 The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

3.8 NGWEMPISI RIVER: EWR NG1 RECOMMENDATIONS FOR A B/C EC

The flow requirements are summarised in **Tables 3.15** and **3.16**. The detailed report will be made available on the raw data flash drive provided at the end of the study. **The low flow EWR is** 30.46 MCM and equates to 19.5% of the nMAR while the total flow EWR is 50.82 MCM and equates to 32.5% of the nMAR.

Table 3.15 High flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	5.172	53	4	0.41
2	Annual	20.122	61	3	1.84
3	Annual	40.757	65	1	3.975
4	1:2 year	80.639	76	1	9.311
5	1:5 year	162.551	88	1	21.732

Table 3.16 Low flow Flow Duration Table (EWR rule table)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.27	1.06	0.65	0.52	0.37	0.28	0.22	0.17	0.12	0.09
Nov	2.10	1.59	1.27	0.85	0.60	0.43	0.30	0.23	0.19	0.14
Dec	2.81	2.45	1.84	1.32	0.97	0.71	0.55	0.38	0.29	0.21
Jan	3.49	2.89	2.47	1.56	1.19	0.97	0.80	0.64	0.51	0.50
Feb[1]	3.49	2.97	2.37	1.78	1.30	1.00	0.82	0.69	0.60	0.43
Mar	3.42	2.89	2.44	1.75	1.26	0.98	0.75	0.65	0.49	0.38
Apr	3.01	2.61	2.13	1.55	1.14	0.87	0.73	0.59	0.43	0.19
May	2.40	1.21	0.96	0.82	0.66	0.56	0.43	0.35	0.21	0.10
Jun	1.12	0.72	0.57	0.46	0.39	0.34	0.29	0.23	0.16	0.11
Jul	0.64	0.49	0.35	0.30	0.25	0.21	0.18	0.15	0.12	0.08
Aug	0.49	0.33	0.28	0.25	0.20	0.17	0.14	0.12	0.10	0.07
Sep[1]	0.50	0.37	0.30	0.24	0.22	0.19	0.15	0.13	0.09	0.06

1 The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

4 REFERENCES

Department of Water and Sanitation, South Africa, June 2022. Classification of Significant Water Resources and Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: Resource Units Delineation and Prioritisation Report. Prepared by: WRP Consulting Engineers (Pty) Ltd. DWS Report: WEM/WMA3/4/00/CON/CLA/0322.

5 APPENDIX A: FLUVIAL GEOMORPHOLOGY

A1 APPROACH AND METHODOLOGY

The Geomorphology Driver Assessment Index (GAI) was assessed according to an updated version of Rowntree (2013). Google Earth was used as the primary source for assessing upstream impacts including: presence of dams, catchment land use and erosion potential, visible erosion features such as gullies, degradation of wetlands, sand mining activities. Local terrain (channel confinement) was assessed from Google Earth and the site visit.

Channel gradient at the site was estimated according to the water surface slope measured at the highest available discharge in the 2013 - 2014 surveys. As the discharge increase local irregularities in the profile are drowned out and the gradient approaches the regional slope. The channel gradient at EWR NG1 was estimated from Google Earth as no survey was available.

At the site, morphological features were plotted on to previously surveyed transects where available and on to site images downloaded from Google Earth. Notes were taken of material comprising the channel bed, flood benches and banks and presence of flood debris. The condition of the channel bed was assessed in terms of bed material size classes, embeddedness and mobility. A quantitative assessment of bed material would have increased the confidence of the EWR assessment but there was insufficient time at the sites to achieve a full assessment. Photographs are used to capture the diversity of physical habitat at the site. These were compared to photographs from earlier site visits in 2013 and 2014.

Access to the instream channel and the opposite bank was restricted at some sites due to strong flows and slippery rocks. This was the case at the Assegai and Pongola Rivers. The EWR site at the Nseleni River was not accessed. A site upstream was visited but the time available was restricted.

A2 EWR MA1: MATIGULU RIVER

A2.1.1 Site Description

General setting

With a catchment of 446 km^2, EWR MA1 has a relatively small catchment area. The valley side slopes were relatively well vegetated with woody vegetation and did not appear to present an elevated erosion risk; there is a high settlement density of the ridges. There is localised erosion on hillslopes. Tributaries and wetlands appear intact with no evidence of gully erosion.

Site geomorphology

The Matigulu River at EWR MA1 is a bedrock controlled channel with a local site gradient of 0.0077, placing it in the Upper Foothills category. The channel is confined within a V-shaped valley; a narrow flood bench has developed on the right bank and locally on the left bank.

The channel type is pool-rapid, dominated by bedrock and boulder. The mobile bedload is dominated by sand and fine gravel. There was a general lack of medium to coarse gravels and no evidence of silt on the channel bed. A flood channel exists on the left bank, separated from the main channel by a high terrace or levee comprised of sand. This channel does not appear to have a clear exit to the main channel downstream.

Macro-channel banks on the right bank are comprised of boulder, on the left bank are in places formed in bedrock. The flood bench is composed of coarse boulder overlain by sand, which is most extensive on the right bank. Flood debris indicated recent inundation of the flood bench to a depth of ~1.5 m.

Instream habitat (low flow as observed during site visit)
The rapid section comprises a series of boulder rapids and runs, providing a variety of fast flowing habitats. At the time of the visit the water depth was generally shallow. The bed of the runs was mostly composed of large cobble with shallow sand sheets evident. Boulder clusters form stable sites colonised by reeds.

The downstream pool provides a low energy habitat (at low flows) with a mobile bed of clean sand and fine gravel. There was no evidence of silt deposits within the gravels. Water depths in the pool at the site were shallow.

Small pools on exposed bedrock provides additional low energy habitat with sand or fine gravel deposits.

A2.1.2 Results and Interpretation of the GAI

Based on the GAI (Rowntree, 2013), the PES for EWR MA1 was estimated to be 87.4% or B category. This was very similar to the estimate from 2013 (B = 86%). The main impact at this site is likely to be a moderately increased sediment supply due to disturbances around settlements and cultivated fields, though vegetation on the adjacent hillslopes is largely intact. The relatively steep site gradient and valley confinement limits the sediment deposition potential so any increase in supply has a smaller impact. None the less, there is evidence of sand deposits in the fast flow environments as well as in the pool.

Table A1 EWR MA1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	0.45	0.45	0.20	0.00	2.83
Sediment balance	2.00	80.00	1.18	0.36	0.43	0.00	3.41
Bed & bank stability	3.00	40.00	0.00	0.18	0.00	0.00	4.00
TOTALS		220.00		1.00	0.63		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					87.4		
HABITAT DRIVER CATEGORY					B	0.00	3.25
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					0.53	0.00	4.00
HABITAT CHANGE STATUS					89.4		
HABITAT CHANGE CATEGORY					B		

A3 EWR NS1: NSELENI RIVER

A3.1.1 Site Description

General setting

The Nseleni River has a catchment area of 363 km^2. There is widespread high density rural settlement with much disturbed ground giving a high erosion risk, often next to small streams feeding into main river. There are many tracks and pathways. The urban settlement of Ntambanana is located in the middle catchment, providing potential for increased storm runoff and erosion. Non-settled areas are mostly bush with some grassland. The Fundimvelo nature reserve occupies a significant area in the lower catchment; one small dam and water holes were observed on Google Earth.

Site geomorphology

The EWR site on the Nseleni River was not visited. Observations were limited to a brief visit to an upstream site.

The river is strongly confined, flowing in a V-shaped incision into the adjacent terraces. The steep banks are densely wooded. A narrow flood bench at a height of approximately 1 m was observed on the left bank; the right bank was steep done to the water's edge. High flows will therefore be confined to a narrow channel width, generating higher velocities.

The local site gradient of 0.00233 places it in the Lower Foothills category. The 2014 report describes the EWR NS1 site as being a pool-riffle channel type with the bed dominated by coarse substrate of boulder and cobble, as was confirmed by the 2022 field visit. The riffle was not seen to be impacted by significant silt or sand deposits. Fine material in pools included organic particulate matter. Banks were generally cohesive, being composed of fine silt, clay and sand with some cobble and gravel. Bedrock was exposed at the base of the right bank at the upstream site.

Instream habitat (low flow as observed during site visit)

The instream habitat at this site comprises pool and riffle. The pool at the visited site was relatively shallow (~ 50 cm) with deposits of fine organic particulate matter on the bed. The riffle was dominated by boulder and cobble with mixed gravels. The bed material in the riffle had an open structure with no evidence of infilling by fines. The large bed material in the riffle would be stable over a wide flow range. At the low flow conditions observed in July 2022 the flow types were dominated by shallow runs with chutes over boulder. At the higher flows in December 2013 there were more standing waves typical of riffle flow.

A3.1.2 Results and Interpretation of the GAI

The GAI was assessed according to Rowntree (2013). The PES for EWR NS1 was estimated to be 85% or a B category. This was higher than the estimate reported in 2014 (B/C = 81.7%). There is widespread erosion in the middle to upper catchment due to rural settlement; bank stability reported as good (2014 report). There was limited deposition of fines observed on the bed of the upstream site visited in 2022. The confined nature of the channel would increase the relative stream power and the flushing action for fine silts.

Table A2 EWR NS1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	0.71	0.40	0.29	5.71	3.00
Sediment balance	2.00	90.00	1.43	0.36	0.51	0.00	2.81
Bed & bank stability	3.00	60.00	0.00	0.24	0.00	0.00	2.25
TOTALS		250.00		1.00	0.80		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					84.00		
HABITAT DRIVER CATEGORY					B	2.29	2.75
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					Not assessed		
HABITAT CHANGE STATUS							
HABITAT CHANGE CATEGORY							

A4 EWR WM1: WHITE MFOLOZI RIVER

A4.1.1 Site Description

General setting

The White Mfolozi EWR site has a large catchment area of 3,140m km^2. Approximately half the catchment area shows evidence of erosion in association with dense rural settlement and associated cultivation. There is serious gully erosion in the western headwaters of the catchment, including incision of wetlands, increasing connectivity and sediment supply. Local slopes are steep and in places lack ground cover that will increase surface wash erosion. Forestry and irrigated agriculture cover a further third of the catchment. Steep slopes closer to the site are not obviously impacted and have good cover.

The Klipfontein Dam near Vryheid, completed in 1983, with a full supply capacity of 18 Mm^3, controls approximately 10% of the catchment above the EWR site. There are also a number of small dams on tributaries. Overall these will have a small impact on flood flows and sediment retention.

Site geomorphology

The White Mfolozi River at EWR WM1 is a bedrock controlled channel with a local site gradient of 0.00426 placing it in the Lower Foothills category. The channel is confined in a gorge with a narrow flood bench alongside the main channel. The main low-flow channel is ~30 m wide within a macro-channel width of ~90 m. This gives space for some dissipation of flow energy at high flows.

The channel type is pool-rapid, dominated by bedrock, boulder and cobble. Bedrock outcrops on the left bank. Boulders dominate the rapid downstream of the transect. At the transect the channel bed consisted of boulder and cobble, with lee bars of sand and loose mixed gravels behind the boulders. Silt deposition in the low flow channel was not evident. According to the 2014 report sand deposits were more extensive at the time of the site visit, but less extensive than earlier that year. This indicates a dynamic situation where the extent of sand is related to the most recent flood events.

A cobble and boulder bar flanks the right side of the channel, sloping gently up to a flood bench at around 1.4 m. There are extensive sand and gravel patches on the bar, especially at its upstream end closer to the causeway. The causeway may be acting to reduce lateral velocities, increasing the potential for deposition. The flood bench is composed of sand, with some bedrock or boulder intrusions. There is a variable cover of grass.

The left side of the channel is flanked by bedrock with a convoluted surface that contains isolated pools. Sand deposits were seen at low points in the bedrock. The flood bench is composed of sand with a dense grass cover and scattered trees. The flood bench is separated from the vertical bank of the macrochannel by a grass covered rocky slope. Flood debris indicated recent inundation of the flood bench to a depth of ~2 m.

Instream habitat (low flow as observed during site visit)
Instream habitat was dominated by a shallow run across the hydraulic transect, with a bedrock and boulder rapid downstream. At higher flows a flood channel is activated behind a boulder bar on the left bank. Bedrock on the left channel edge contained detached or isolated pools containing deposits of sand.

A4.1.2 Results and Interpretation of the GAI

Driver status indicates a high C (78.8%) due to upstream impacts, specifically increased hillslope connectivity and sediment supply due to erosion in subsistence farming areas on highly erodible soils. Geological reports indicate Ecca Shales in the local area. Additional impacts include forestry, commercial farming, urban development and a dam in the upper catchment. Increased hillslope connectivity may have increased the magnitude of floods, which would have been coupled with high sediment loads.

At the time of the 2022 site visit there was little evidence of habitat degradation but in 2014 more extensive sand deposits were observed, resulting in a C category of 77%. It was noted in the 2014 report that these were more extensive in July 2014 than in December 2013. Sand deposition thus appears to be a dynamic process that does not exhibit a trend towards increased deposition. This is confirmed by historic Google Earth imagery that shows significant shifts from one image to the next.

This is a relatively high gradient site within a confined setting so floods will have a high stream power and sediment transport capacity. In lower gradient/less confined settings sediment deposition may become a problem.

Table A3 EWR WM1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	1.42	0.45	0.65	19.23	3.42
Sediment balance	2.00	70.00	1.30	0.32	0.42	0.00	4.00
Bed & bank stability	3.00	50.00	0.00	0.23	0.00	0.00	4.00
TOTALS		220.00		1.00	0.63		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					86.7		
HABITAT DRIVER CATEGORY					C	8.74	3.74
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					0.90	20	3.00
HABITAT CHANGE STATUS					81.94		
HABITAT CHANGE CATEGORY					B		

A5 EWR BM1: BLACK MFOLOZI RIVER

A5.1.1 Site Description

General setting

The catchment area at the site EWR BM1 is 243 km^2 which is the smallest area of all the eight sites. Forestry in the upper catchment accounts for 70% of the catchment land cover. Forestry roads will have a small impact on sediment supply. There is evidence of gully erosion in lower catchment upstream of the site and there is local slope erosion in the upper catchment but overall risk to increased sediment supply was considered to be low. No dams were observed.

Site geomorphology

The Black Mfolozi River at EWR BM1 is a bedrock controlled channel with a local site gradient of 0.0062 placing it in the Upper Foothills category. The channel is confined within a V-shaped valley with a narrow flood bench alongside the main channel.

The channel type is bedrock cascade, dominated by bedrock. Weathered bedrock outcrops form the macrochannel slope on the left bank. Downstream of the main survey site the channel forms a long narrow pool flanked by dense reeds. Coarse to medium gravel is the dominant loose bed material, with very fine gravel deposits and limited silt at the head of the downstream pool. The survey transect was located over raised bedrock with a deep channel with gravels on the right side and a shallow bedrock shelf on the left side. A lee bar supporting marginal zone grass species had developed over the bed rock since the 2013 survey.

A flood bench is well developed on the right bank, with a good grass cover. This measured ~10 m in the vicinity of the transect but broadened downstream alongside the pool to between 20 – 30 m. Comparing photographs between November 2013 and July 2022 there is possible evidence of erosion along the right bank. There was limited marginal zone habitat.

The flood bench on the left bank is less well developed and in several places the bedrock slope comes to the edge of the channel. Deposits of sand and very fine gravel were observed in the marginal zone.

Habitat (low flow as observed during site visit)

The instream habitat in the upstream section consisted of bedrock run and bedrock rapid with pockets of mixed gravel. Exposed bedrock in the rapids provided substrate for grasses. A small flood channel on the right bank flood bench provided backwater habitat at the observed flow. The downstream pool was narrow (4 – 6 m) so flow depth was 'deep' and velocity would have been relatively high as indicated by glide/run flow types.

A5.1.2 Results and Interpretation of the GAI

The PES for the site EWR BM1 was estimated as A (93%). The 2014 report gives a PES of A/B (89%). The catchment is generally in good condition though there is moderate gully erosion in the catchment immediately upstream of the site. Forestry and other land uses do not appear to be impacting significantly on the channel network. There are no clear indicators of habitat degradation at the site, with the possible exception of stripping to bedrock on the left bank and some incursion of silt into fine gravels at the head of the downstream pool. Otherwise gravels and cobbles retain and open structure. This would indicate increased high flows, for which there is no obvious cause. The habitat condition was estimated to be A (94%).

Table A4 EWR BM1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	0.27	0.45	0.12	0.00	3.27
Sediment balance	2.00	70.00	0.65	0.32	0.21	0.00	3.00
Bed & bank stability	3.00	50.00	0.00	0.23	0.00	0.00	3.00
TOTALS		220.00		1.00	0.33		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					93.40		
HABITAT DRIVER CATEGORY					A	0.00	3.12
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					0.28	0.00	3.00
HABITAT CHANGE STATUS					94.44		
HABITAT CHANGE CATEGORY					A		

A6 EWR MK1: MKUZE RIVER

A6.1.1 Site Description

General setting

The Mkuze River at site EWR MK1 has the largest catchment of the eight sites (3180 km^2). The upper catchment has indications of significant degradation due to land use associated with dense rural settlements as well as irrigated agriculture on floodplains. Approximately 58% of the catchment is moderately to severely impacted by erosion. The site is located at the edge of the Mkuze Game Reserve in relatively level terrain. There is dense rural settlement to the north of the river but given the gentle slopes the erosion risk is considered low.

Site geomorphology

The Mkuze River at EWR MK1 is a low gradient river crossing an undulating plain. A site gradient of 0.00097 puts it in a lowland river category which has the expected condition of a mobile sand bed river.

The river at the survey site has a semi-confined meandering channel. As predicted the channel bed consists of mobile sand with a braided character with exposed mid-channel bars at low flow. There was evidence of silt deposition over these bars. Alternating point bars on the right and left banks were elevated above the bed of the river. Recent sand deposits were observed on these bars. The point bars are subject to periodic sediment deposition and revegetation as observed from historic Google Earth imagery.

Marginal zone features were poorly developed, with steep banks on either side of the low-flow channel. The bank on the right bank was composed of sand but that on the left bank had a higher silt content. A narrow flood bench was observed on either side of the channel, backed by a higher terrace. Trampling by cattle constituted a significant disturbance. The 'terrace' on the right bank was more probably a levee, separating the main channel from the flood plain. A number of flood channels were observed crossing this floodplain but they did not appear to have been active recently. This may be due to sediment deposition at the upstream inflow points (not investigated). The terrace on the left bank was better developed and extended for several hundred meters away from the river to a higher terrace and inactive flood channel behind it.

Habitat (low flow as observed during site visit)

Instream habitat at the time of the site visit consisted of shallow glide and run over a mobile sand bed. Deeper run habitat was observed at the right edge of the hydraulic transect. Higher flows would cover the exposed sand bars and would increase the elevation of dunes on the bed. These would flatten out at very high flows.

A6.1.2 Results and Interpretation of the GAI

The PES for the site EWR MK1 was estimated as a low B (82.3%). The 2014 report gives a PES of A/B (89%). There is widespread erosion in upper and middle catchment associated with rural settlements and extensive livestock grazing on the right bank. Where there is flow in the channel the bed is composed of mobile sand but there is more silt on exposed channel bars. A possible loss of active floodplain channels was noted. The estimated PES is considerably lower than from 2014 due to increased rating of catchment erosion and livestock disturbance.

Table A5 EWR MK1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	0.58	0.36	0.21	31.25	2.91
Sediment balance	2.00	90.00	1.16	0.32	0.37	0.00	2.16
Bed & bank stability	3.00	90.00	0.96	0.32	0.31	0.00	3.00
TOTALS		220.00		1.00	0.63		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					82.26		
HABITAT DRIVER CATEGORY					B	11.16	2.70
					WEIGHED SCORE	FLOW RELATED	CONFIDENCE
Morphological change					0.80	0.00	3.00

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
HABITAT CHANGE STATUS					83.94		
HABITAT CHANGE CATEGORY					B		

A7 EWR UP1: PONGOLA RIVER

A7.1.1 Site Description

General setting

The EWR UP1 site on the Pongola River has a catchment area of 1787 km^2. The condition of the upper catchment is considered to be good with a low erosion risk. Land cover comprised upland grassland, forest patches and wooded waterways. Valley bottom wetlands in forestry were intact. Some burning was evident. The middle catchment was characterised by dense rural settlement close to the river, presenting a moderate to high erosion risk. Further down the catchment there was extensive forestry with some cultivation and urban development; again wetlands appeared to be in good condition. Erosion risk was considered to be low. The lower catchment was characterised by forestry and cultivation with urban development at Frischgewaagd. Degraded stream courses join main river 3 km upstream of site. Sand mining was evident at the site and probably elsewhere along the river.

Site geomorphology

The site on the Upper Pogola (EWR UP1) is situated in moderately sloping V-shaped valley; the channel is confined with a narrow flood bench on either side. A site gradient of 0.005 puts it at the transition between a lower and upper foothills category.

The site was described as an alluvial channel with fixed boulders with a pool-rapid channel morphology. The channel bed was dominated by boulder with loose cobble and mixed gravel deposits in the lee of boulders and in runs. The marginal zone, where present on the right bank, consisted of sands and very fine gravel. The flood bench was comprised of sand and very fine gravel over boulder. It was much disturbed by sand mining so that the morphology was indistinct. The bench sloped up to a narrow terrace at the foot of the hillslope. Upstream a narrow secondary channel with two branches crossed the flood bench/marginal zone.

The left bank was not visited due to high flow and slippery substrate.

Habitat (low flow as observed during site visit)

Habitat comprised broken water in the rapid and fast run in the main channel between. Edge habitat included shallow pool. The bed material in runs and pools consisted of loose mixed gravels and some cobble. No embeddedness was observed. Bed material in the rapid was not assessed. The dominant habitat in the secondary channel was riffle and shallow run. The bed material showed some evidence of embeddedness. The secondary channel joined the main channel through a pool within the right bank.

A7.1.2 Results and Interpretation of the GAI

The PES for the site EWR UP1 was estimated as A/B (89.8%). The 2014 report gives a PES of B (87%). The upper catchment is in good condition. There is extensive forestry throughout catchment but valley bottom wetlands appear to be intact. Dense rural settlement with local gully erosion and moderate erosion potential on hillslopes occurs in the middle catchment. At the site

there is significant local disturbance of right bank by sand mining. Despite these disturbances the instream and marginal riparian habitat appears close to natural.

Table A6 EWR UP1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	0.37	0.40	0.15	0.00	2.83
Sediment balance	2.00	80.00	0.57	0.32	0.18	0.00	3.41
Bed & bank stability	3.00	70.00	0.65	0.28	0.18	0.00	4.00
TOTALS		220.00		1.00	0.51		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					89.76		
HABITAT DRIVER CATEGORY					A/B	9.03	2.90
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					0.31	0.00	4.00
HABITAT CHANGE STATUS					93.85		
HABITAT CHANGE CATEGORY					A		

A7 EWR AS1: ASSEGAI RIVER

A7.1.1 Site Description

General setting

The EWR AS1 site on the Assegai River has a catchment area of 2330 km^2. Land use is dominated by grassland with extensive forestry on moderate slopes, cultivation, much of it under irrigation, and urban settlement (Piet Retief). The erosion risk is considered to be low.

A major impact is the Heyshope Dam which has a catchment area of 1123 km^2, controlling 48% of the catchment. There is evidence of channel incision below the dam in locations where the topography has enabled a floodplain to develop. This incision is accompanied by meander cutoffs and incision of wetland tributaries. Channel incision is a common response to sediment retention by a dam. Incision is prevented where the channel is bedrock controlled, as is the case at the EWR site.

Site geomorphology

The site on the Assegai River (EWR AS1) is situated in moderately sloping V-shaped valley; the channel is confined with a narrow flood bench on either side. A site gradient of 0.00476 puts it at the transition between a lower and upper foothills category.

The site was described as an alluvial channel with a pool-rapid channel morphology. The channel bed was dominated by boulder with fine gravels and sand. At the upstream end of the site, either bedrock or large boulder form islands within the channel that provided substrate for *Phragmites* reeds. A backwater channel was present on the right bank. High flows would overtop the flood bench and return to the main channel.

There is a clear marginal zone with boulders on the right bank evident from the hydraulic transect. The marginal zone, where present on the right bank, consisted of sands and very fine gravel. There was no clear flood bench on either bank that would equate to an annual flood. The flood

bench on the right bank was estimated to be inundated by floods with a frequency of 1 in 5 years. This bench was comprised of boulder with a sand covering.

The left bank was not visited due to high flow and slippery substrate.

Habitat (low flow as observed during site visit)
Habitat comprised broken water in the rapid and fast run in the main channel between rapids. Edge habitat included shallow pool. The bed material in runs and pools consisted of imbricated cobble with some loose mixed gravels. Bed material in the rapid was not assessed. The dominant habitat in the backwater channel was pool. A large pool with deep water occurred below the surveyed site.

A7.1.2 Results and Interpretation of the GAI

The PES for the site EWR AS1 was estimated as C (70.8%). The 2014 report gives a PES of C (65%). A major impact is the Heyshope Dam, completed in 1983, that controls 48% of the catchment area and has reduced flood flows as well as the MAR; it will also have trapped potential bed sediment. As noted above, channel incision is evident in lower gradient reaches below the dam but not at the site due to the bedrock control. Sediment retention may have resulted in the lack of fine sediment on the flood benches that are dominated by boulders.

There is extensive forestry in catchment below the dam but erosion risk low due to relatively flat terrain. Lateral silt deposits noted in 2014 were not evident in 2022.

Table A7 EWR AS1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	2.29	0.42	0.95	57.14	3.57
Sediment balance	2.00	80.00	1.22	0.33	0.41	0.00	2.65
Bed & bank stability	3.00	60.00	0.40	0.25	0.10	0.00	.96
TOTALS		220.00		1.00	1.46		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					70.84		
HABITAT DRIVER CATEGORY					C	23.81	2.61
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					0.65	80	3.00
HABITAT CHANGE STATUS					85.20		
HABITAT CHANGE CATEGORY					B		

A8 EWR NG1: NGEMPISI RIVER

A8.1.1 Site Description

General setting

With a catchment area of 1398 km^2, EWR NG1 has one of the largest catchments of those visited. Land use forestry and commercial cultivation are more or less equal, mostly located on gentle to moderate slopes. The valley side slopes in the local area are relatively well vegetated with woody vegetation and grassland; the grassland is subject to frequent burning as indicated by sequential Google Earth images.

The site lies 40 km downstream from the Morgenstond Dam built in 1978, which has a full supply capacity of 101 Mm^3 and a catchment area of 448 km^2. A second dam, the Jerico Dam, is located on the Mpama River. The Jericho Dam, built in 1966, has a full supply capacity of 59 Mm^3 and a catchment area of 218 km^2. The two dams thus control a catchment area of 666 km^2, or 48% of the catchment area at the site. Upstream of the site there is extensive cultivation on commercial farms with local centre pivot irrigation adjacent to the river. Water is likely to be abstracted from pools in the river but there is no sign of abstraction weirs. A gauging weir is located immediately upstream of the site.

Site geomorphology

The Ngwempisi River at EWR NG1 is a bedrock controlled channel with a local site gradient of 0.0097 placing it in the Upper Foothills/Transition category. The channel is confined within a V-shaped valley; a narrow flood bench has developed on the right bank and locally on the left bank.

The channel type is pool-rapid, dominated by bedrock and boulder. The site investigated spanned a complex rapid between pools. The mobile bedload is dominated by cobble and gravels as evident from lateral deposits. There was no evidence of silt deposits within the channel. A dominant feature of the site is an island complex composed of large boulder. Multiple channels cut across the island.

There is no clear macro-channel bank on the left bank, the marginal zone and flood bench are comprised of boulder, gravels and sand, with bedrock outcropping at the bridge. The left bank comprises more sand and fine gravel, with some bedrock outcrops. Flood debris indicated recent inundation of the flood bench to a depth of ~1.5 - 2 m.

Habitat (low flow as observed during site visit)

The rapid section comprises a series of boulder rapids and runs, providing a variety of fast flowing habitats. At the time of the visit the water depth was generally shallow, increasing in the downstream pool. The bed of the runs was mostly composed of large cobble. Boulder clusters in the rapids form stable sites colonised by reeds.

The islands were well vegetated with fringing reeds (*Phragmites*) and willow.

Small isolated pools occurred in the left bank marginal zone.

A8.1.2 Results and Interpretation of the GAI

The PES for EWR NG1 was estimated to be 83.3% or B category, though the habitat change category was estimated to be an A (94.4%) as there was little evidence of change at the site. The

main impacts at this site are the upstream dams (Morgenstond & Jerico) plus the weir immediately above site which will retain sediment and reduce the frequency and magnitude of floods; there may be a small increase is sediment supply from cultivated lands and forestry but slopes are mostly gentle to moderate. The vegetation on the adjacent hillslopes is largely intact. The relatively steep site gradient and valley confinement limit the sediment deposition potential so any change in supply has a smaller impact. There is possible evidence of scour of the marginal zone as a result of sediment depletion, though this could also be the natural result of large floods.

Table A8 EWR NG1: Summary of the GAI assessment

COMPONENT	RANK	RELATIVE WEIGHTING (%)	RATING	WEIGHT	WEIGHED SCORE	FLOW RELATED	CONFIDENCE
System Connectivity	1.00	100.00	0.9	0.5	0.45	62.7	2.86
Sediment balance	3.00	40.00	0.67	0.2	0.13	0.00	3.00
Bed & bank stability	2.00	60.00	0.27	0.3	0.08	0.00	4.00
TOTALS		200.00		1.00	0.66		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					86.7		
HABITAT DRIVER CATEGORY					B	31.03	3.23
					WEIGHED SCORE	**FLOW RELATED**	**CONFIDENCE**
Morphological change					0.28	50.00	3.00
HABITAT CHANGE STATUS					94.4		
HABITAT CHANGE CATEGORY					A		

A9 REFERENCES

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6 APPENDIX B: DIATOMS

B1 APPROACH AND METHODOLOGY

B1.1.1 Background

The periphyton assemblage (primarily algae) represent the primary producer trophic level, exhibit a different range of sensitivities, and will often indicate effects only indirectly observed in the benthic and fish communities. As in the benthic macroinvertebrate and fish assemblages, integration of structural/compositional and functional characteristics provides the best means of assessing impairment. Algae generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. As primary producers, algae are most directly affected by physical and chemical factors. Algal assemblages are sensitive to some pollutants which may not visibly affect other aquatic assemblages, or may only affect other organisms at higher concentrations (i.e., herbicides) (USEPA, 1999).

B1.1.2 Aims and Objectives

The aim of the diatom sampling and analysis is to provide biological water quality information for conditions on the day of biological component sampling regarding the aquatic health and functioning of the aquatic system, and providing additional input to the physico-chemical component of the study as a response variable. The overall objective of this report is to assess the impacts of anthropogenic activities on the Present Ecological State of the receiving aquatic ecosystem.

B1.1.3 Methodology

Sampling and Analysis: Samples at the EWR site were collected and analysed according to the prescribed protocol in Taylor *et al*. (2007a;b).

Diatom based water quality score: Results were interpreted according to the Specific Pollution sensitivity Index (SPI – CEMAGREF, 1982) or South African Diatom Index (SADI, Harding and Taylor, 2011) to assess the “health status” of each river. Furthermore, Harding and Taylor’s (2011) adjusted current SPI and SADI class limit boundaries for Reserve studies (see **Table B3**) were used to determine the ecological category for the site.

Other indices housed within the OMNIDIA programme (Lecointe. and Prygiel, 1993) used to infer integrated water quality included:

- Biological Diatom Index (BDI, Prygiel and Coste, 2000): Primarily a practical index, as it treats morphologically related taxa as one group and composes so-called associated taxa eliminating species that are difficult to identify.
- The ecological characterisation of diatom species based on Van Dam *et al.* (1994): Includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state.
- Trophic Diatom Index (TDI) (Kelly and Whitton, 1995): This index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.
- Valve deformities were also noted as it is an indication of possible metal toxicity that may be present within the system. According to Luís *et al*. (2008) several studies on metal polluted

rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, *pers. comm*.).

Table B1 Class limit boundaries for the SPI index applied in this study (Harding and Taylor, 2011)

Interpretation of index scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	18 - 20
A/B		17 - 18
B	Good quality	15 - 17
B/C		14 - 15
C	Moderate quality	12 - 14
C/D		10 - 12
D	Poor quality	8 - 10
D/E		6 - 8
E	Bad quality	5 - 6
E/F		4 - 5
F		<4

B1.3.4 Terminology

Several key ecological terms used in South African diatomology are summarised in **Table B2** for the meaningful reading and understanding of the diatom results.

Table B2 Diatoms: Key ecological terms Taylor *et al*. (2007a)

Trophy	
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.
Mineral content	
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm
Brackish (very high electrolyte content)	> 1000 µS/cm
Saline	6000 µS/cm
Pollution (Saprobity)	
Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)
Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)
Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-ά-mesosaprobic)
Strongly polluted	BOD <13, O_2 deficit <75% (ά-mesosaprobic)
Very heavily polluted	BOD <22, O_2 deficit <90% (ά-meso-polysaprobic)
Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)

B2 RESULTS

Table B3 provides a summary of the results obtained following a detailed assessment of the diatom assemblage at each of the selected EWR sites during the July 2022 EWR site visit.

Table B3 Diatom results obtained for EWR sites assessed during the July 2022 EWR site visit

Site	No species	SPI score	Water Quality Class	Category	PTV (%)	Valve deformities (%)
EWR WM1	18	15.4	Good quality	B	1.8	0
EWR MA1	28	16.5	Good quality	B	5.3	0
EWR BM1	21	17	Good quality	A/B	0	0
EWR AS	26	15.3	Good quality	B	12	0
EWR NP	16	16.3	Good quality	B	0.5	0
EWR MK	27	8.7	Poor quality	D	67	0
EWR UP	20	17.5	Good quality	A/B	1	0

B2.1.1 EWR MA1: Matigulu River

Site EWR MA1 obtained a SPI score of 16.5, reflecting good biological water quality (Ecological Category B; **Table B3**). Nutrient levels and salinity concentrations were regarded as moderate based on the diatom assemblage collected, while organic load were considered low. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were moderate (**Table B2**).

The diatom community was dominated by *Achnanthidium crassum*, a species with a wide ecological amplitude usually found in alkaline streams and slow flowing waters (Taylor *et al*., 2007b), as well as species from the genus *Nupela,* suggesting that the water was acidic with low conductivity (Taylor and Cocquyt, 2016). Sub-dominant species, *Achnanthidium minutissima* and *Gomphonema venusta* further suggested that the water was of good quality. *Cocconeis placentula* was also dominant and suggested that inorganic nutrient levels were elevated (Taylor *et al*., 2007b; Kelly *et al*, 2001 and 2005; Teply and Bahls, 2006). Sub-dominant species, also suggested that elevated nutrient levels did impact the site to some extent. The sub-dominant *Navicula gregaria* is very common in eutrophic to hypereutrophic fresh waters with moderate to high electrolyte content, also extending to brackish waters and is tolerant of strongly polluted conditions and a good indicator species for these conditions (Taylor *et al*., 2007b). According to Congresti *et al*. (2005) this species is resistant to chlorination (2005) and is pollution tolerant with an optimum filterable P between 0.35 and 1 mg/L (Davey *et al.,* 2008*).*

B2.1.2 EWR WM1: White Mfolozi River

Site EWR WM1 obtained a Specific Pollution sensitivity Index (SPI) score of 15.4, reflecting good biological water quality (Ecological Category B; **Table B3**). Nutrient levels and salinity concentrations were regarded as moderate based on the diatom assemblage collected, while organic load was considered low. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were moderate (**Table B2**).

Dominant species with a preference for good clean water included *Achnanthidium minutissimum*, *Achnanthidium latecephalum* and species from the genus *Nupela*. The dominance of these species suggested that flow was elevated at the time of sampling, as *Achnanthidium* species are indicators of flushing events while the dominance of *Nupela* species suggested that the water was acidic with low conductivity (Taylor and Cocquyt, 2016). However, *Cocconeis placentula* and *Reimeria uniseriata* were also dominant. It is suspected that elevated flow resulted in the influx of

elevated nutrient and organic load which the diatoms were still adapting to. *Cocconeis placentula* is a fast-growing, pioneer species that is able to colonise bare substrates quickly; tolerant of moderate, but not severe, organic load, extending into brackish biotopes, but is however an indicator of inorganic nutrients (Taylor *et al*., 2007b; Kelly *et al*, 2001 and 2005; Teply and Bahls, 2006). *Reimeria uniseriata* is found in alkaline, meso- to eutrophic waters with moderate electrolyte content and seems to be able to grow in conditions of reduced light penetration (i.e. high turbidity) (Taylor *et al*., 2007b).

B2.1.3 EWR BM1: Black Mfolozi River

Site EWR BM1 obtained a SPI score of 17, reflecting high biological water quality (Ecological Category A/B; **Table B3**). Nutrient levels were regarded as moderate based on the diatom assemblage collected, while organic load and salinity concentrations were considered low. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were slight to moderate (**Table B2**).

More than 50% of the community was dominated by sensitive species which included *Achnanthidium minutissimum*, *Achnanthidium latecephalum* and species from the genus *Nupela*. *Cocconeis placentula* was also dominant and suggested that inorganic nutrient levels were elevated (Taylor *et al*., 2007b; Kelly *et al*, 2001 and 2005; Teply and Bahls, 2006). While *Encyonopsis leei* var. *sinensis* was dominant and prefers moderate water quality with moderate electrolyte content (Taylor *et al*., 2007b), most species at moderate and low abundance consisted of sensitive species.

B2.1.4 EWR MK1: Mkuze River

Site EWR MK1 obtained a SPI score of 8.7, reflecting poor biological water quality (Ecological Category D; **Table B3**). Nutrient levels, salinity concentrations and organic load were regarded as high to very high based on the diatom assemblage collected. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were very heavy (**Table B2**).

While *Achnanthidium* species were prolific, suggesting that flow was elevated, species with a preference for deteriorated water quality dominated the diatom community and included *Nitzschia frustulum*, *Tryblionella apiculata*, and *Cocconeis placentula* with *Mayamaea atomus* var. *permitis* occurring at sub-dominant level. According to Cholnoky (1968), *Nitzschia frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that it is extremely tolerant of salinity and high alkalinity, becoming abundant in brackish waters because competition from other diatom species is reduced. It is tolerant of critical levels of pollution (Taylor *et al*., 2007b) with a salinity optima of 16.52 g/L (Wilson *et al*., 2011). Stenger-Kovács *et al*. (2014), states that this species has a preference for waters with elevated SO_4 concentration. *Tryblionella apiculata* is found in electrolyte-rich waters and tolerant of strongly polluted conditions (Taylor *et al.*, 2007b). *Mayamaea atomus* var. *permitis* is a key indicator of sewage effluent and one of the most pollution resistant diatoms (Taylor *et al.*, 2007b). It is aerophilous species and found in alkaline, heavily polluted waters with a high electrolyte content (Taylor *et al.*, 2007b).

B2.1.5 EWR UP1: Pongola River

Site EWR UP1 obtained a SPI score of 17.5, reflecting high biological water quality (Ecological Category A/B; **Table B3**). Nutrient levels, salinity concentrations and organic load were regarded as slight based on the diatom assemblage collected. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were slight (**Table B2**).

Sensitive species dominated the diatom community and dominant species included *Achnanthidium rivulare*, *Gomphonema venusta*, and *Navicula heimansioides*. The sub-dominance of *Cocconeis placentula* and *Melosira varians* suggested that nutrients and salinity concentration impacted the site to some extent but was not deemed a concern.

B2.1.6 EWR AS1: Assegaai River

Site EWR AS1 obtained a Specific Pollution sensitivity Index (SPI) score of 15.3, reflecting good biological water quality (Ecological Category B; **Table B3**). Nutrient levels, organic load and salinity concentrations were regarded as low based on the diatom assemblage collected. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were moderate (**Table B2**).

Sensitive species dominated the diatom community and dominant species included *Achnanthidium rivulare*, *Gomphonema venusta*, and *Navicula heimansioides*. *Achnanthidium rivulare* prefers well oxygenated waters and tolerates moderate nutrient and salinity levels (Taylor *pers. comm*., 2010), while *Gomphonema venusta* is found in circumneutral to weakly alkaline, oligo- to mesotrophic waters with a low to moderate electrolyte content (Taylor *et al*., 2007b). *Navicula heimansioides* occurs in weakly acidic to circumneutral, oligotrophic, electrolyte-poor waters (Taylor *et al*., 2007b). The presence of *Navicula schroeteri* var. *symmetrica* and *Nitzschia perspicua* at sub-dominant level suggests that some form of salinity input is present within the reach (Taylor *et al.*, 2007b).

B2.1.7 EWR NG1: Ngwempisi River

Site EWR NP obtained a SPI score of 16.3, reflecting good biological water quality (Ecological Category B; **Table B3**). Nutrient levels and salinity concentrations were regarded as moderate based on the diatom assemblage collected, while organic load were considered low. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various indices within OMNIDIA suggested pollution levels were moderate (**Table B2**).

Sensitive species were dominant and included *Achnanthidium rivulare*, *Gomphonema venusta* and *Navicula notha*. *Navicula notha* has a preference for acidic or circumneutral, oligotrophic, electrolyte-poor waters (Taylor *et al.*, 2007b). The dominance of *Cocconeis placentula* and *Melosira varians* suggested that nutrients and salinity concentration impacted the site to some extent. *Cocconeis placentula* suggested that inorganic nutrient levels were elevated (Taylor *et al*., 2007b; Kelly *et al*, 2001 and 2005; Teply and Bahls, 2006) while *Melosira varians* becomes particularly abundant in eutrophic, occasionally slightly brackish, waters (Taylor *et al.*, 2007b) with a preference for magnesium sulphate bicarbonate waters (Bahls, 1984). Informal housing and Amsterdam WWTW may be the source of elevated nutrients and salinity concentration.

B3 CONCLUSION

A summary of the diatom results obtained at the various EWR sites during the June 2022 EWR site visit is provided in **Figure B1**.

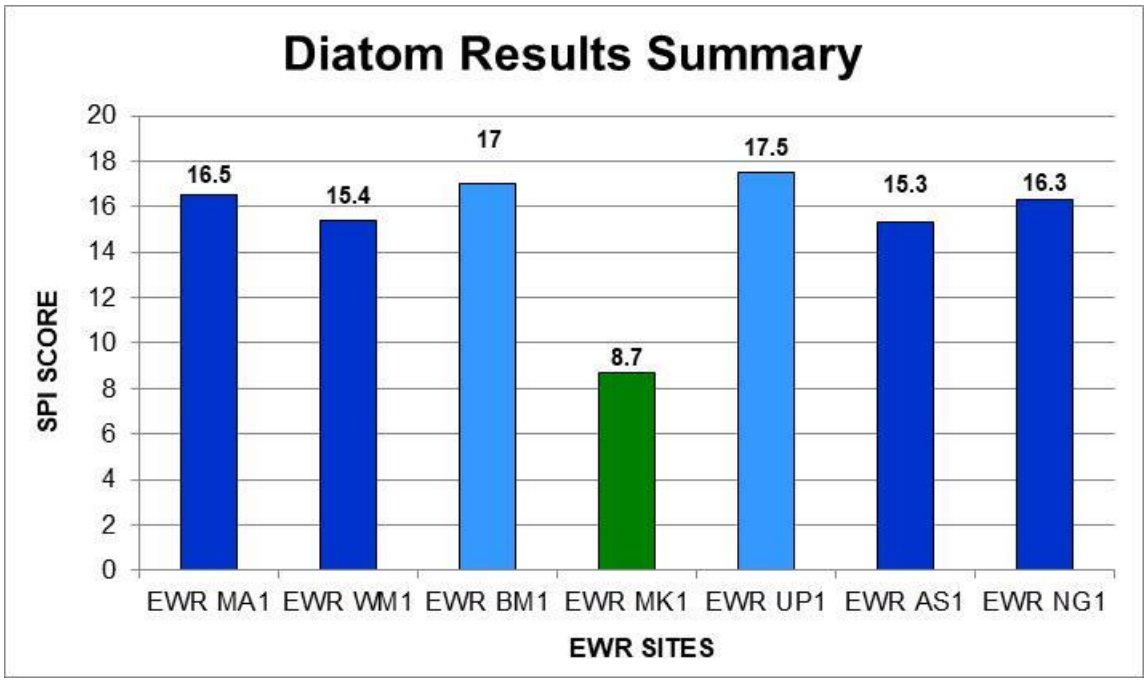

Figure B1 Diatom results obtained at the various EWR sites in June 2022

EWR MA1 was characterised by good water quality (B Ecological Category). Diatom data suggested inorganic nutrients impacted the site to some extent.

EWR WM1 was characterised by good water quality (B Ecological Category). Diatom data suggested that flow was recently elevated resulting in an influx of nutrient and organic load. Turbidity was elevated which would impact the life-cycles of instream biota.

EWR BM1 was characterised by high water quality (A/B Ecological Category). Diatom data suggested that inorganic nutrients impacted the site to some extent.

EWR MK1 was characterised by poor water quality (D Ecological Category). Diatom data suggested that the site was impacted mainly by sewage effluent containing high organic load, nutrient levels and salinity concentration especially SO_4-based salinity. Elevated flow may have ameliorated some of the impact on the site.

EWR UP1 was characterised by high water quality (A/B Ecological Category). Diatom data suggested that nutrients and salinity concentration had a slight impact on the site.

EWR AS1 was characterised by good water quality (B Ecological Category). Diatom data suggested that salinity impacted the site to some extent.

EWR NG1 was characterised by good water quality (B Ecological Category). Diatom data suggested that nutrients and salinity concentration impacted the site to some extent.

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7 APPENDIX C: WATER QUALITY

C1 APPROACH AND METHODOLOGY

The standard approach, as outlined in DWAF (1998) for determining the water quality present state for rivers, was followed in this assessment. Note that the results outlined in this Appendix are built on the results of the EWR determination study conducted by Southern Waters in 2014 (DWS, 2014), other than EWR NG1 (Ngwempisi River), which is highlighted in **Table C.1** and is an additional site selected during the field survey of July 2022.

Other important information sources are the Status Quo report prepared for this study (DWS, 2022), and an EcoStatus report prepared for the Inkomati Usuthu Catchment Management Agency (IUCMA) in January 2020, which contained a water quality component (Roux et al., 2020). The diatom results for this study (Appendix B; Koekemoer) were utilized for the nutrient state assessment in the PAI tables, and the geomorphology appendix (Appendix A; Rowntree) for input on turbidity and sedimentation aspects of water quality.

The first step is to select the data to be used for determining present state through the application of the Physico-chemical driver Assessment Index (PAI) spreadsheet model. **Table C.1** shows the details of the EWR sites, including physico-chemical data available and considered for use. Note that this list is not exhaustive and focusses on data from DWS's Water Monitoring System (WMS) most suitable for use. **The data are generally only available until 2018, significantly impacting on the confidence of the assessment.** Data were extracted from WMS by Marica Erasmus of DWS's Resource Quality Information Services directorate.

Results of the 2020 EcoStatus study (Roux *et al*., 2020) for the Assegaai and Ngwempisi rivers were updated with data sourced from the IUCMA database for 2020 and 2021. Data were extracted by Caroline Tlowana.

Data utilized for the assessment is shown per EWR site.

Table C1 EWR sites and associated detail. Shaded site EWR NG1 is an additional site selected during July 2022

EWR SITE	RIVER	COORDINATES	SQR	DATA CONSIDERED FOR ASSESSMENT
EWR MA1	Matigulu	S29.02010 E31.47040	W11A-03612	W1H010 (WMS W11_102810); n=656, 1965-1992. WMS W11_192167 u/s Amatikulu Sugar Mill; n=31, 2014-2018.
EWR NS1	Nseleni	S28.63410 E31.92517	W12G-03229	WMS W12_188841 u/s Lake Nsezi; n=152, 2005-2017 (NEMP, NMMP). WMS W12_187078 between N2 bridge + Mposa confluence; n=792, 2003-2017 (NEMP, NMMP).
EWR WM1	White Mfolozi	S28.23146 E31.18666	W21H-02897	W2H022 (WMS W21_102851); n=15, 1983-1997. W2H005 (WMS W21_102834) @ Overvloed/Ulundi d/s EWR site; n=1254, 1971-2018. WMS W21_192483 u/s James Nxumalo Ponds at Ulundi; n=16, 2011-2017. WMS W21_188976 @ Onrust d/s of D38 road bridge; n=81, 2006-2017. Far u/s of EWR WM1.
EWR BM1	Black Mfolozi	S27.93890 E31.21030	W22F-02748	W2H028 (WMS W22_102857); n=253, 1988-2018 (NMMP). W2H008 (WMS W22_102837); n=147, 1971-1996.
EWR MK1	Mkuze	S27.59210 E32.21800	W31J-02480	W3H032 (WMS W31_102886); n=274, 1995-2018. Far u/s of EWR MK1. W3H008 (WMS W31_102866); n=868, 1969-2001. Further u/s of EWR MK1 than W3H023.
EWR UP1	Upper Pongola	S27.36413 E30.96962	W42E-02221	WMS W42_189409; n=11, 2008-2014. Upstream EWR UP1. WMS W42_1000011663; n=68, 2002-2009. D/s of the confluence with the Wit River. W4H044 (WMS W41_102897): Bivane River @ Welgelegen; n=36, 2009-2014.
EWR AS1	Assegaai	S27.06230 E30.98880	W51E-02049	W5H022 (WMS W51_102914); n=479, 1977-2020. WMS W51_189548 before confluence with the Klipmisselspruit; n=129, 2006-2019. (IUCMA code U-30). WMS W51_189547 after confluence with the Klipmisselspruit; n=128, 2006-2019. (IUCMA code U-32). IUCMA code U-23. Assegaai u/s Heyshope Dam. IUCMA code U-26. Assegaai on road bridge to Mahamba Border Gate.
EWR NG1	Ngwempisi	S26.679448 30.70213	W53E-01790	W5H026 (WMS W53_102918); n=796, 1977-2020. IUCMA code U-41. Ngwempisi on N2 road bridge to Ermelo. IUCMA code U-44. Ngwempisi on R33 road bridge to Amsterdam.

SQR: sub-quaternary reach
NEMP: National Eutrophication Monitoring Programme
NMMP: National Microbial Monitoring Programme
u/s: upstream
d/s: downstream

C1 EWR MA1: MATIGULU RIVER

C1.1.1 Site Description

The Matigulu River is predominantly rural along its length with subsistence agriculture interspersed with commercial farming being the major activities. There is natural vegetation around the EWR site, with subsistence farming downstream. The valley side slopes at the EWR site are relatively well vegetated with woody vegetation and do not appear to present an elevated erosion risk, despite the high settlement density of the ridges. However, there is evidence of sand deposits in the fast flow environments.

The Amaticulu Sugar Mill is in the lower reaches. Note that the lower reaches of the SQR was identified as a water quality priority area (DWS, 2022a) due to effluents from the Amaticulu Sugar Mill, cultivation and sand-mining.

C1.1.2 Results and Interpretation of the PAI

The following data sources were used for Reference Condition (RC) and PES respectively:

RC: Benchmark conditions for an A category river in DWAF (2008).
PES: Refer to **Table C.1**. Both sets of data were used. Although the gauging weir is close to the site, data is only available until 1992. More recent data is from a point downstream of the site and upstream of the Amaticulu Sugar Mill, but for a limited number of variables. The 2014 assessment data was also evaluated.

The water quality table for the assessment is shown below.

River	Matigulu	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	MA1	**PES**	W11_192167, downstream of site and upstream Amaticulu Sugar Mill, 2014-2018; n=8-15. *2014 assessment:* W1H009Q01 (W12_102809) Mhlatuze R @ Riverview. 2009/02/03 – 2014/02/04; n=40 (EC only).
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	-	No data
	Sodium as Na	-	
	Magnesium as Mg	-	
	Calcium as Ca	-	
	Chloride as Cl	-	
	Potassium as K	-	
Electrical conductivity	mS/m	49.49: downstream of the site	2
Nutrients (mg/L)	SRP-P	0.006 (2014) 0.2 (downstream)	2
	TIN-N	0.222 (2014) 0.1 (downstream)	0
Physical variables	pH (5 th and 95th % tiles)	7.3 + 8.4 (2014) 7.2 + 7.9 (downstream)	0.5

	Temperature (º C)	-	0.5. Largely natural temperature range expected.
	Dissolved oxygen (mg/L)	-	0.5. Largely natural oxygen range expected.
	Turbidity (NTU)	-	2. Moderate impact expected due to land–use and sediment deposits at the site.
Response variable	Chl-*a*: phytoplankton (ug/L)	-	
	Macroinvertebrate score (MIRAI) SASS score ASPT score	81.0% 204 6	B/C
	Diatoms	SPI=16.5 (n=1)	Indicates Good water quality
	Fish score (FRAI)	86.4%	B
Toxics (mg/L)	Ammonia (as N)	0.11 (n=8)	Limited toxics expected at the site, although ammonia levels are elevated.
Overall site classification (from PAI table)			**B (84.5%)**

-: no data

The integrated physico-chemical category is a **B category** (**Table C2**). The assessment is of low confidence due to the poor dataset available for analysis. Diatom results indicate Good water quality (category B for diatoms). Elevated salts are seen downstream of the site.

Table C2 PAI table for EWR MA1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**FOOTHILL**
WIDTH (m)	**2-15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.50	N	4.00	50.00		40.00
Salts	2.00	NONE SPECIFIED	4.00	50.00		40.00
Nutrients	1.00	NONE SPECIFIED	4.00	65.00		90.00
Water Temperature	0.50	N	2.50	55.00		60.00
Water clarity	2.00	NONE SPECIFIED	2.50	55.00		50.00
Oxygen	0.50	N	2.50	75.00		60.00
Toxics	0.50	N	3.00	100.00		80.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	0.92	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	0.92					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	0.93					
FINAL PC MODIFICATION RATING	0.92					
P-C CATEGORY %	P-C CATEGORY					
84.5	B	REVISED % & CATEGORY (2014)				

C2 EWR NS1: NSELENI RIVER

C2.1.1 Site Description

The EWR site is located in an area of extensive subsistence farming. Widespread erosion is evident in the upper to middle catchments due to rural settlements and related activities. The stream is shallow and well-shaded at the EWR site (July 2022).

C2.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: Benchmark conditions for an A category river in DWAF (2008).
PES: WMS W12_188841 upstream of Lake Nsezi.

The water quality table for the assessment is shown below.

River	Nseleni	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	NS1	**PES**	WMS W12_188841, n=33, 2012-2017.
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	29.4	No method available for categorizing inorganic salt ions. Electrical conductivity used as surrogate.
	Sodium as Na	85.6	
	Magnesium as Mg	18.77	
	Calcium as Ca	19.8	
	Chloride as Cl	142.4	
	Potassium as K	4.68	
Electrical conductivity	mS/m	76	Elevated EC due to marine influence at monitoring point.
Nutrients (mg/L)	SRP-P	0.015	1
	TIN-N	0.025	0
Physical variables	pH (5 th and 95th % tiles)	6.8 + 8.5	0.5
	Temperature (^{o} C)	-	0.5. Largely natural temperature range expected.
	Dissolved oxygen (mg/L)	-	0.5. Largely natural oxygen range expected.
	Turbidity (NTU)	-	2. Moderate impact expected due to land–use and expected turbidity at the site.
Response variable	Chl-*a*: phytoplankton (ug/L)	9.74 (n=22)	0
	Macroinvertebrate score (MIRAI) SASS score ASPT score	79.4% 132 5.0	B/C
	Diatoms	-	
	Fish score (FRAI)	67.9	C
Toxics (mg/L)	Ammonia (as N)	0.4	Limited toxics expected at the site, although ammonia levels are elevated.
	Fluoride (F)	0.608	
Overall site classification (from PAI table)			**B (82.7%)**

-: no data

The integrated physico-chemical category is a **B category** (**Table C3**). The assessment is of low confidence due to the dataset available for analysis.

Table C3 PAI table for EWR NS1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**FOOTHILL**
WIDTH (m)	**2-15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.50	N	4.00	50.00		40.00
Salts	2.00	NONE SPECIFIED	4.00	50.00		40.00
Nutrients	1.00	NONE SPECIFIED	4.00	65.00		90.00
Water Temperature	1.00	N	2.50	55.00		60.00
Water clarity	2.00	NONE SPECIFIED	2.50	55.00		50.00
Oxygen	0.50	N	2.50	75.00		60.00
Toxics	1.00	N	3.00	100.00		80.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	1.09	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	1.09					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	1.10					
FINAL PC MODIFICATION RATING	1.10					
P-C CATEGORY %	P-C CATEGORY					
82.7	B	REVISED % & CATEGORY (2014)				

C3 EWR WM1: WHITE MFOLOZI RIVER

C3.1.1 Site Description

This EWR site is situated in an area of largely natural vegetation. Extensive subsistence farming is evident upstream of the site, which may result in turbidity impacts due to highly erodible soils. The river is wide and unshaded.

C3.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: benchmark conditions for an A category river in DWAF (2008).
PES: W2H005 (WMS W21_102834) @ Overvloed/Ulundi downstream of the EWR site.

The water quality table for the assessment is shown below.

River	White Mfolozi	Water Quality Monitoring Points	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	WM1	PES	W2H005 (WMS W21_102834, n=38, 2014-2018.
	Parameter / units	PES value	Rating for PAI / Comment
Inorganic salt ions (mg/L)	Sulphate as SO_4	24.77	No method available for categorizing inorganic salt ions. Electrical conductivity used as surrogate.
	Sodium as Na	32.28	
	Magnesium as Mg	20.43	
	Calcium as Ca	25.92	
	Chloride as Cl	29.51	
	Potassium as K	3.45	
Electrical conductivity	mS/m	41.5	
Nutrients (mg/L)	SRP-P	0.01	1
	TIN-N	0.26	0
Physical variables	pH (5 th and 95th % tiles)	8.05 + 8.6	1
	Temperature (º C)	-	1. Largely natural temperature range expected.
	Dissolved oxygen (mg/L)	-	0.5. Largely natural oxygen range expected.
	Turbidity (NTU)	-	2. Moderate impact expected due to land–use, highly erodible soils and expected turbidity at the site.
Response variable	Chl-*a*: phytoplankton (ug/L)	9.74 (n=22)	0
	Macroinvertebrate score (MIRAI) SASS score ASPT score	81/1% 163 6	B/C
	Diatoms	SPI=15.4 (n=1)	Indicates Good water quality
	Fish score (FRAI)	73%	C
Toxics (mg/L)	Ammonia (as N)	0.0126	B
	Fluoride (F)	0.77	A
Overall site classification (from PAI table)			**B (84.5%)**

-: no data

The integrated physico-chemical category is a **B category** (**Table C4**). The assessment is of moderate confidence as recent data (post-2018) could not be sourced, although the gauging weir is in the same Water Quality Sub-Unit (WQSU) as the EWR site (DWS, 2014).

Diatom results indicate Good water quality (category B for diatoms), although a small deterioration in water quality state is evident since 2014.

Table C4 PAI table for EWR WM1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**FOOTHILL**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	1.00	N	4.00	50.00		40.00
Salts	1.00	NONE SPECIFIED	4.00	50.00		40.00
Nutrients	1.00	NONE SPECIFIED	4.00	65.00		90.00
Water Temperature	1.00	N	2.50	60.00		60.00
Water clarity	2.00	NONE SPECIFIED	2.50	50.00		50.00
Oxygen	0.50	N	2.50	75.00		60.00
Toxics	0.50	N	3.00	100.00		80.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	0.92	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	0.92					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	0.95					
FINAL PC MODIFICATION RATING	0.92					
P-C CATEGORY %	P-C CATEGORY					
84.5	B	REVISED % & CATEGORY (2014)				

C4 EWR BM1: BLACK MFOLOZI RIVER

C4.1.1 Site Description

This site is in the upper, hilly part of the Black Umfolozi River catchment. Upstream activities include forestry, conservation and some coal mining. There is some localised erosion close to the site, but generally low impacts in the surrounding area.

C4.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: benchmark conditions for an A category river in DWAF (2008).
PES: W2H028Q01 (WMS W22_102857).

The water quality table for the assessment is shown below.

River	Black Mfolozi	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	BM1	**PES**	W2H028 (WMS W22_102857, n=29, 2014-2018.
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	234.8: 95th percentile 70.4: median	Intermittent elevated sulphates
	Sodium as Na	35.13	
	Magnesium as Mg	22.7	
	Calcium as Ca	65.34	
	Chloride as Cl	26.25	
	Potassium as K	5.48	
Electrical conductivity	mS/m	58.18	Due to elevated sulphate levels
Nutrients (mg/L)	SRP-P	0.01	1
	TIN-N	0.1	0

Physical variables	pH (5 th and 95th % tiles)	7.5 + 8.3	1
	Temperature (º C)	-	1. Largely natural temperature range expected.
	Dissolved oxygen (mg/L)	-	0.5. Largely natural oxygen range expected.
	Turbidity (NTU)	-	1. Some localized erosion at the site due to land–use.
Response variable	Chl-*a*: phytoplankton (ug/L)	-	
	Macroinvertebrate score (MIRAI) SASS score ASPT score	81.2% 185 6.3	B/C
	Diatoms	SPI=17 (n=1)	Indicates Very Good water quality
	Fish score (FRAI)	75.9%	C
Toxics (mg/L)	Ammonia (as N)	0.005	A
	Fluoride (F)	0.58	A
Overall site classification (from PAI table)			**B/C (81.8%)**

-: no data

The integrated physico-chemical category is a **B/C category** (**Table C5**). The assessment is of moderate confidence as recent data could not be sourced. Diatom results indicate Good water quality (category A/B for diatoms). Despite the good water quality state, intermittent high sulphate levels moved the assessment from a B to B/C category. It is assumed upstream mining is responsible for intermittent increases.

Table C5 PAI table for EWR BM1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**FOOTHILL**
WIDTH (m)	**2-15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	1.00	N	4.00	50.00		40.00
Salts	2.00	NONE SPECIFIED	4.00	50.00		40.00
Nutrients	1.00	NONE SPECIFIED	4.00	65.00		90.00
Water Temperature	1.00	N	2.50	55.00		60.00
Water clarity	1.00	NONE SPECIFIED	2.50	55.00		50.00
Oxygen	0.00	N	2.50	75.00		60.00
Toxics	1.50	N	3.00	100.00		80.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	1.06	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	1.06					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	1.05					
FINAL PC MODIFICATION RATING	1.20					
P-C CATEGORY %	P-C CATEGORY					
81.8	B/C	REVISED % & CATEGORY (2014)				

C5 EWR MK1: MKUZE RIVER

C5.1.1 Site Description

Impacts in the Mkuze River include forestry, coal mining in the upper catchment, dams (including an Inter Basin Transfer (IBT) from Pongolapoort Dam), rural areas, irrigated crops, alien vegetation, instream dams, erosion and sedimentation. The EWR site is downstream of the IBT, with extensive commercial agriculture and subsistence farming upstream of the site.

Note that a water quality priority area was delineated in the SQR directly upstream of the reach containing the EWR site, i.e. SQR W31J-02469, with impacts being from the High Risk Mkuze Waste Water Treatment Works (WWTW). It is anticipated that these impacts will extend into W31J-02480.

Drivers are elevated turbidity, toxics, nutrients and salts, particularly sulphates.

C5.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: benchmark conditions for an A category river in DWAF (2008).
PES: W3H032Q01 (WMS W31_102886).

The water quality table for the assessment is shown below.

River	Mkuze	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	MK1	**PES**	W3H032 (WMS W31_102886, n=44, 2005-2018 (two records after 2009, i.e. one record for 2010 and one for 2018).
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	208.3: 95th percentile 164.7: median	Consistently elevated sulphate and sodium levels
	Sodium as Na	432.43	
	Magnesium as Mg	78.7	
	Calcium as Ca	78.81	
	Chloride as Cl	538	
	Potassium as K	5.00	
Electrical conductivity	mS/m	275: 95th percentile 235: median	4
Nutrients (mg/L)	SRP-P	0.018	1
	TIN-N	0.282	0
Physical variables	pH (5 th and 95th % tiles)	7.9 + 8.6	1
	Temperature (º C)	-	1. Largely natural temperature range expected.
	Dissolved oxygen (mg/L)	-	1. Largely natural oxygen range expected.
	Turbidity (NTU)	-	2.5. Widespread erosion in upper and middle catchment; moderate-large changes expected at the site.
Response	Chl-*a*: phytoplankton	-	

variable	(ug/L)		
	Macroinvertebrate score (MIRAI) SASS score ASPT score	77.7% 124 5.0	C
	Diatoms	SPI=8.7 (n=1)	Indicates Poor water quality
	Fish score (FRAI)	75.4%	C
Toxics (mg/L)*	Ammonia (as N)	0.029	1
	Fluoride (F)	0.42	0
	Manganese (Mn)	0.005	0
	Iron (Fe)	0.102	4
	Aluminium (Al)	0.07	Exceeds the Target Water Quality Range (TWQR) (DWAF, 1996)
	Boron (B)	0.5	within the 95% species protection Default Guideline Value (DGV) (ANZG, 2021a)
	Chromium (Cr)	0.008	0
	Lead (Pb)	0.054	Exceeds the TWQR but within the Acute Effect Value (AEV), DWAF (1996)
	Nickel (Ni)	0.006	Within the 95% species protection Default Guideline Value (DGV) (ANZG, 2021b)
	Zinc (Zn)	0.154	Exceeds all aquatic ecosystem guidelines
Overall site classification (from PAI table)			**C/D (58.3%)**

-: no data

*: average hardness is 336.4 mg/L$CaCO_3$, so hard water

The integrated physico-chemical category is a **C/D category** (**Table C6**). The assessment is of low confidence due to the poor dataset available for analysis. The monitoring site is upstream of the EWR site. Although data, particularly high sulphates and electrical conductivity levels, may better reflect conditions upstream of the EWR site, poor water quality would extend down to the EWR site.

Diatom results indicate Poor water quality (category D for diatoms). Nutrient levels, salinity concentrations and organic load were regarded as high to very high based on the diatom assemblage collected. No valve deformities were noted within the assemblage during June 2022, suggesting that metal toxicity was below detection limits, with limited bio-availability. Further analysis of the various diatom indices suggests high pollution levels.

Table C6 PAI table for EWR MK1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**LOWLAND**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	1.00	N	4.00	60.00		40.00
Salts	4.00	NONE SPECIFIED	4.00	50.00		40.00
Nutrients	2.00	NONE SPECIFIED	4.00	70.00		90.00
Water Temperature	1.00	N	2.50	60.00		60.00
Water clarity	2.50	NONE SPECIFIED	2.50	50.00		50.00
Oxygen	1.00	N	2.50	65.00		60.00
Toxics	3.50	N	3.00	100.00		80.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	2.20	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	2.20					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	2.15					
FINAL PC MODIFICATION RATING	2.50					
P-C CATEGORY %	P-C CATEGORY					
58.3	C/D	REVISED % & CATEGORY (2014)				

C6 EWR UP1: UPPER PONGOLA RIVER

C6.1.1 Site Description

Impacts in the upper Pongola catchment are extensive forestry, agriculture, dams, urban areas, alien vegetation, overgrazing, erosion and sand mining. The EWR site is located in the upper portion of the Pongolo River close to the town of Frischgewaagd. The major land-use in the upper part of the catchment is forestry with commercial agriculture. There is also mining upstream of the EWR site, with sand-mining evident at the site.

C6.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: benchmark conditions for an A category river in DWAF (2008).
PES: 2014 assessment: W4H044 (WMS W41_102897): Bivane River @ Welgelegen.
WMS W42_189409. Upstream EWR UP1. This monitoring point was considered, but data insufficient for an assessment.

The water quality table for the assessment is shown below.

River	Upper Pongola	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	UP1	**PES**	*2014 assessment:* W4H004Q01 (W41 102897) Bivane River @ Welgelegen 2009/02/11 to 2014/02/25 n = 36 (for EC)
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	4-13	No impacts expected.
	Sodium as Na	-	
	Magnesium as Mg	-	
	Calcium as Ca	-	
	Chloride as Cl	-	

	Potassium as K	-	
Electrical conductivity	mS/m	11	0
Nutrients (mg/L)	SRP-P	0.005	0.5
	TIN-N	0.167	0
Physical variables	pH (5 th and 95th % tiles)	7.1 + 8.2	1
	Temperature (º C)	-	0.5. Largely natural temperature range expected.
	Dissolved oxygen (mg/L)	-	0.5. Largely natural oxygen range expected.
	Turbidity (NTU)	-	1. Upper catchment in good condition; some gully erosion in the area. Small changes expected.
Response variable	Chl-*a*: phytoplankton (ug/L)	-	
	Macroinvertebrate score (MIRAI) SASS score ASPT score	79.5% 210 6.7	C
	Diatoms	SPI=17.5 (n=1)	Indicates Very Good water quality
	Fish score (FRAI)	73.9%	B/C
Toxics (mg/L)*	Ammonia (as N)	-	
	Fluoride (F)	-	
Overall site classification (from PAI table)			**A/B (88.3%)**

-: no data

The integrated physico-chemical category is an **A/B category** (**Table C7**). The assessment is of low confidence due to the poor dataset available for analysis. Diatom results indicate Good water quality (category A/B for diatoms).

Table C7 PAI table for EWR UP1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**FOOTHILL**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	1.00	N	4.00	50.00		40.00
Salts	0.00	NONE SPECIFIED	4.00	50.00		40.00
Nutrients	0.50	NONE SPECIFIED	4.00	65.00		90.00
Water Temperature	0.50	N	2.50	60.00		60.00
Water clarity	1.00	NONE SPECIFIED	2.50	50.00		50.00
Oxygen	0.50	N	2.50	75.00		60.00
Toxics	0.50	N	3.00	100.00		80.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	0.56	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	0.56					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	0.56					
FINAL PC MODIFICATION RATING	0.56					
P-C CATEGORY %	P-C CATEGORY					
88.3	A/B	REVISED % & CATEGORY (2014)				

C7 EWR AS1: ASSEGAAI RIVER

C7.1.1 Site Description

Upstream influences are Heyshope Dam, irrigation, afforestation and domestic water use. Commercial and subsistence agriculture takes place in the catchment around the Heyshope Dam with limited coal mining (DWAF, 2004). The town of Piet Retief is located well upstream of the site, with an outlet from the Piet Retief and Uthiza WWTWs into the Ndhlozane tributary (in W51F) of the Assegaai River. Main water quality impactors are therefore in the lower reaches and the road network. Approximately 50% of the reach is in Eswatini and not assessed. Note that sediments are trapped in Heyshope Dam, resulting in the lack of fines at the boulder-dominated site.

C7.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: benchmark boundary tables for an A category river in DWAF (2008).
PES: IUCMA U-26 and W5H022Q01 (WMS W51_102914).

The water quality table for the assessment is shown below.

River	Assegaai	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008). W5H006Q01, Swartwater River at Zwartwater: 1977-1981; n=145.
EWR Site	AS1	**PES**	IUCMA data, U-26: July 2016-Feb 2022; n=57-64. W5H022Q01: 2015-2019; n=49.
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	-	No impacts expected. No method available. Electrical conductivity used as surrogate.
	Sodium as Na	-	
	Magnesium as Mg	-	
	Calcium as Ca	-	
	Chloride as Cl	-	
	Potassium as K	-	
Electrical conductivity	mS/m	21.63: IUCMA * 24.74: DWS	0
Nutrients (mg/L)	SRP-P	0.03: IUCMA 0.05: DWS	2.5
	TIN-N	0.6: IUCMA 0.3: DWS	1
Physical variables	pH (5 th and 95th % tiles)	7.4 + 8.17: IUCMA 6.9 + 8.2: DWS	1
	Temperature (º C)	-	Although Heyshope Dam is upstream of the EWR site, little impact is expected due to the distance from the dam to the site. Impact is on trapped sediments in the dam. Ratings: 1
	Dissolved oxygen (mg/L)	-	
	Turbidity (NTU)	13.9: IUCMA (n=14; 2021-Feb 2022)	
Response variable	Chl-*a*: phytoplankton (ug/L)	-	
	Macroinvertebrate score (MIRAI) SASS score	78.6%: 2020 IUCMA	B/C (2020 IUCMA report)

	ASPT score		
	Diatoms	SPI=15.3 (n=1)	B
	Fish score (FRAI)	69.2%	C
Toxics (mg/L)*	Ammonia (as N)	0.20: IUCMA * 0.22: DWS	4
	Fluoride (F)	-	
Overall site classification (from PAI table)			**B/C (80.6%)**

* Data of July 2016-Feb 2017 seems problematic and inconsistent with other and historical data sources. Data from March 2017 to February 2022 used for the PES.
-: no data

The integrated physico-chemical category is a **B/C category** (**Table C8**). IUCMA data records are up to February 2022, with the assessments therefore being of moderate confidence. Data indicates water quality of Good – Moderate state. Diatom results also indicate Good water quality (category B for diatoms).

Table C8 PAI table for EWR AS1

PERENNIAL (Y/N)	**Y**
GEOMORPH ZONE	**FOOTHILL**
WIDTH (m)	**>15**

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	1.00	N	4.00	60.00		50.00
Salts	0.00	NONE SPECIFIED	4.00	50.00		50.00
Nutrients	2.50	NONE SPECIFIED	4.00	75.00		65.00
Water Temperature	1.00	N	2.50	55.00		70.00
Water clarity	1.00	NONE SPECIFIED	2.50	50.00		60.00
Oxygen	1.00	N	2.50	65.00		70.00
Toxics	2.00	N	3.00	100.00		100.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	1.36	MEAN CONF →	3.21			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	1.36					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	1.32					
FINAL PC MODIFICATION RATING	1.36					
P-C CATEGORY %	P-C CATEGORY					
80.6	B/C	REVISED % & CATEGORY (2014)				

C8 EWR NG1: NGWEMPISI RIVER

C8.1.1 Site Description

Main water quality impactors are extensive forestry, roads and erosion along the river. The lower reach is in Eswatini, as such it is not assessed. Note that the 2006 Maputo Basin assessment determined that water quality was a C category for the Lower Ngwempisi based on data from Eswatini's site at Nkonyeni. The driving issue was eutrophication. The following was also noted: *As the river is wide and shallow at this point, impacts may be expected on temperature and oxygen levels. Although sedimentation was evident at the site, it is assumed that alluvial lowland rivers would naturally have high sedimentation levels (Scherman, 2007).*

C8.1.2 Results and Interpretation of the PAI

The following data sources were used for RC and PES respectively:

RC: benchmark boundary tables for an A category river in DWAF (2008).
PES: IUCMA U-44 and W5H026Q01 (WMS W53_102918). Both monitoring points are in close proximity to the EWR site.

The water quality table for the assessment is shown below.

River	Ngwempisi	**Water Quality Monitoring Points**	
		RC	Benchmark tables (DWAF, 2008)
EWR Site	NG1	**PES**	IUCMA data, U-44: July 2016- July 2016-Feb 2022; n=57-64. W5H026Q01: 2015-2019; n=44.
	Parameter / units	**PES value**	**Rating for PAI / Comment**
Inorganic salt ions (mg/L)	Sulphate as SO_4	-	No impacts expected. No method available. Electrical conductivity used as surrogate.
	Sodium as Na	-	
	Magnesium as Mg	-	
	Calcium as Ca	-	
	Chloride as Cl	-	
	Potassium as K	-	
Electrical conductivity	mS/m	12.08: IUCMA 19.15: DWS (n=44)	0
Nutrients (mg/L)	SRP-P	0.01: IUCMA 0.05: DWS (n=44)	2.5
	TIN-N	0.27: IUCMA 0.2: DWS (n=10, 2015-2016 only).	1
Physical variables	pH (5 th and 95th % tiles)	7.17 + 8.15: IUCMA 6.8 + 8.1: DWS (n=44)	1
	Temperature (^{o} C)	-	Although both Jerico and Morgenstond dams are upstream of the SQR, little impact is expected due to the distance from the dams to the site. Rating: 0.5
	Dissolved oxygen (mg/L)		
	Turbidity (NTU)	13.9: IUCMA (n=14; 2021-Feb 2022)	Some impact expected from forestry activities and cultivated lands. Rating: 1.
Response variable	Chl-*a*: phytoplankton (ug/L)	-	
	Macroinvertebrate score (MIRAI) SASS score ASPT score	87.3% 140 6.6	B
	Diatoms	SPI=16.3 (n=1)	Indicate Good water quality
	Fish score (FRAI)	72.8%	C
Toxics (mg/L)*	Ammonia (as N)	0.1: IUCMA 0.2: DWS (n=34)	D
Overall site classification (from PAI table)			**B (85.5%)**

-: no data

The integrated physico-chemical category is a **B category** (**Table C.9**). IUCMA data records are up to February 2022, with the assessment therefore being of moderate confidence. Data indicates water quality of a Good state for this reach. Diatom results also indicate Good water quality (category B for diatoms).

Table C9 PAI table for EWR NG1

PERENNIAL (Y/N)	Y
GEOMORPH ZONE	LOWLAND
WIDTH (m)	>15

METRIC	RATING	THRESHOLD EXCEEDED?	CONF	DEFAULT WEIGHTS	ADJUSTED RANKS	ADJUSTED WEIGHTS
pH	0.50	N	4.00	60.00		50.00
Salts	0.00	NONE SPECIFIED	4.00	50.00		50.00
Nutrients	2.00	NONE SPECIFIED	4.00	70.00		65.00
Water Temperature	0.50	N	2.50	60.00		70.00
Water clarity	1.00	NONE SPECIFIED	2.50	50.00		60.00
Oxygen	0.50	N	2.50	65.00		70.00
Toxics	1.00	N	2.00	100.00		100.00
PC MODIFICATION RATING WITH THRESHOLD APPLIED (MAX)	0.84	MEAN CONF →	3.07			
CALCULATED PC MODIFICATION RATING WITHOUT THRESHOLD AND WITH DEFAULT WEIGHTS	0.84					
CALCULATED P-C RATING WITHOUT THRESHOLD AND BASED ON ADJUSTED WEIGHTS	0.83					
FINAL PC MODIFICATION RATING	0.84					
P-C CATEGORY %	P-C CATEGORY					
85.5	B	REVISED % & CATEGORY (2014)				

C9 REFERENCES

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8 APPENDIX D: INDEX OF HABITAT INTEGRITY

D1 APPROACH AND METHODOLOGY

The Index of Habitat Integrity (IHI) is described in a manual and summarised below (Kleynhans *et al*. 2009).

The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans 1996).

Habitat integrity assessment is approached from an instream and riparian zone perspective. Both of these are formulated according to metric groups, each with a number of metrics that enable the assessment of habitat integrity. The model functions in an integrated way, using the results from the assessment of metric groups, or metrics within a metric group, for the assessment of other metric groups where appropriate.

Assessment of habitat integrity is based on an interpretation of the deviation from the reference condition. Specification of the reference condition follows an impact-based approach where the intensity and extent of anthropogenic changes are used to interpret the impact on the habitat integrity of the system. To accomplish this, information on abiotic changes that can potentially influence river habitat integrity are obtained from surveys or available data sources. These changes are all related and interpreted in terms of modification of the drivers of the system, namely hydrology, geomorphology and physico-chemical conditions and how these changes would impact on the natural riverine habitats.

Interpretation of the severity of impacts is based on the natural characteristics of the river. The premise is that the severity of impacts on the habitat integrity of a river will vary according to the natural characteristics of the river, i.e. particular river types will be more sensitive to certain impacts than other types.

D2 EWR MA1: MATIGULU RIVER

The results are summarised in **Table D1**. Note that all parameters are scored from 0 to 5.

Table D10 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	2.0
Zero Flows	0.5
Floods	1.0
HYDROLOGY RATING	**1.0**
pH	0.5
Salts	1.0
Nutrients	1.0
Water Temperature	0.5
Water clarity	2.0
Oxygen	1.0
Toxics	0.0
PC RATING	**1.0**

Sediment	1.5
Benthic Growth	1.0
BED RATING	**1.3**
Marginal	1.0
Non-marginal	1.0
BANK RATING	**1.0**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**
INSTREAM IHI %	**80.0**
INSTREAM IHI EC	**B/C**
INSTREAM CONFIDENCE	**3.3**
RIPARIAN IHI	
Base Flows	1.0
Zero Flows	0.0
Moderate Floods	1.0
Large Floods	0.0
HYDROLOGY RATING	**0.4**
Substrate Exposure (marginal)	1.0
Substrate Exposure (non-marginal)	1.5
Invasive Alien Vegetation (marginal)	1.0
Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	0.0
Erosion (non-marginal)	0.5
Physico-Chemical (marginal)	0.0
Physico-Chemical (non-marginal)	0.0
Marginal	1.0
Non-marginal	2.0
BANK STRUCTURE RATING	**1.4**
Longitudinal Connectivity	1.5
Lateral Connectivity	1.5
CONNECTIVITY RATING	**1.5**
RIPARIAN IHI %	**78.0**
RIPARIAN IHI EC	**B/C**
RIPARIAN CONFIDENCE	**3.0**

D3 EWR NS1: NSELENI RIVER

The results are summarised in **Table D2**.

Table D11 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	2.0
Zero Flows	0.5
Floods	0.5
HYDROLOGY RATING	**0.9**
pH	1.0
Salts	2.0

Nutrients	1.0
Water Temperature	0.5
Water clarity	2.0
Oxygen	1.0
Toxics	0.0
PC RATING	**1.0**
Sediment	1.0
Benthic Growth	1.5
BED RATING	**1.2**
Marginal	1.0
Non-marginal	1.5
BANK RATING	**1.2**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**
INSTREAM IHI %	**81.0**
INSTREAM IHI EC	**B/C**
INSTREAM CONFIDENCE	**3.1**
RIPARIAN IHI	
Base Flows	1.0
Zero Flows	0.0
Moderate Floods	1.0
Large Floods	0.0
HYDROLOGY RATING	**0.4**
Substrate Exposure (marginal)	1.0
Substrate Exposure (non-marginal)	1.5
Invasive Alien Vegetation (marginal)	2.5
Invasive Alien Vegetation (non-marginal)	2.5
Erosion (marginal)	0.5
Erosion (non-marginal)	1.0
Physico-Chemical (marginal)	0.0
Physico-Chemical (non-marginal)	0.0
Marginal	2.5
Non-marginal	2.5
BANK STRUCTURE RATING	**2.5**
Longitudinal Connectivity	1.0
Lateral Connectivity	1.0
CONNECTIVITY RATING	**1.0**
RIPARIAN IHI %	**70.3**
RIPARIAN IHI EC	**C**
RIPARIAN CONFIDENCE	**3.0**

D4 EWR WM1: WHITE MFOLOZI RIVER

The results are summarised in **Table D3**.

Table D12 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	-2.0
Zero Flows	0.0
Floods	1.0
HYDROLOGY RATING	**0.8**
pH	1.0
Salts	1.5
Nutrients	1.0
Water Temperature	0.5
Water clarity	2.0
Oxygen	0.5
Toxics	0.0
PC RATING	**0.8**
Sediment	2.0
Benthic Growth	2.0
BED RATING	**2.0**
Marginal	1.0
Non-marginal	1.0
BANK RATING	**1.0**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**
INSTREAM IHI %	**79.3**
INSTREAM IHI EC	**B/C**
INSTREAM CONFIDENCE	**3.3**
RIPARIAN IHI	
Base Flows	1.0
Zero Flows	0.0
Moderate Floods	1.5
Large Floods	0.5
HYDROLOGY RATING	**0.7**
Substrate Exposure (marginal)	1.0
Substrate Exposure (non-marginal)	1.5
Invasive Alien Vegetation (marginal)	1.5
Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	0.5
Erosion (non-marginal)	1.0
Physico-Chemical (marginal)	0.0
Physico-Chemical (non-marginal)	0.0
Marginal	1.5
Non-marginal	2.0
BANK STRUCTURE RATING	**1.8**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**

RIPARIAN IHI %	**77.4**
RIPARIAN IHI EC	**B/C**
RIPARIAN CONFIDENCE	**3.0**

D4 EWR BM1: BLACK MFOLOZI RIVER

The results are summarised in **Table D4**.

Table D13 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	-2.0
Zero Flows	1.0
Floods	1.0
HYDROLOGY RATING	**1.3**
pH	1.0
Salts	2.0
Nutrients	1.0
Water Temperature	0.5
Water clarity	1.0
Oxygen	0.5
Toxics	1.5
PC RATING	**1.0**
Sediment	1.0
Benthic Growth	0.5
BED RATING	**0.8**
Marginal	1.5
Non-marginal	1.0
BANK RATING	**1.3**
Longitudinal Connectivity	1.5
Lateral Connectivity	0.0
CONNECTIVITY RATING	**1.2**
INSTREAM IHI %	**77.7**
INSTREAM IHI EC	**B/C**
INSTREAM CONFIDENCE	**3.5**
RIPARIAN IHI	
Base Flows	1.0
Zero Flows	0.5
Moderate Floods	1.5
Large Floods	0.5
HYDROLOGY RATING	**0.8**
Substrate Exposure (marginal)	1.5
Substrate Exposure (non-marginal)	2.0
Invasive Alien Vegetation (marginal)	2.0
Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	1.0
Erosion (non-marginal)	1.0
Physico-Chemical (marginal)	0.0
Physico-Chemical (non-marginal)	0.0
Marginal	2.0

Non-marginal	2.0
BANK STRUCTURE RATING	**2.0**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**
RIPARIAN IHI %	**74.4**
RIPARIAN IHI EC	**C**
RIPARIAN CONFIDENCE	**3.0**

D5 EWR MK1: MKUZE RIVER

The results are summarised in **Table D5**.

Table D14 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	-2.5
Zero Flows	2.0
Floods	1.0
HYDROLOGY RATING	**1.8**
pH	1.0
Salts	4.0
Nutrients	3.0
Water Temperature	1.0
Water clarity	2.0
Oxygen	1.0
Toxics	3.0
PC RATING	**2.5**
Sediment	2.0
Benthic Growth	1.0
BED RATING	**1.3**
Marginal	1.5
Non-marginal	2.0
BANK RATING	**1.7**
Longitudinal Connectivity	1.5
Lateral Connectivity	0.0
CONNECTIVITY RATING	**0.9**
INSTREAM IHI %	**66.3**
INSTREAM IHI EC	**C**
INSTREAM CONFIDENCE	**3.5**
RIPARIAN IHI	
Base Flows	1.5
Zero Flows	1.5
Moderate Floods	1.5
Large Floods	0.5
HYDROLOGY RATING	**1.2**
Substrate Exposure (marginal)	2.0
Substrate Exposure (non-marginal)	2.0
Invasive Alien Vegetation (marginal)	1.5

Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	1.0
Erosion (non-marginal)	1.0
Physico-Chemical (marginal)	1.0
Physico-Chemical (non-marginal)	0.0
Marginal	2.0
Non-marginal	2.0
BANK STRUCTURE RATING	**2.0**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**
RIPARIAN IHI %	**72.1**
RIPARIAN IHI EC	**C**
RIPARIAN CONFIDENCE	**3.0**

D6 EWR UP1: UPPER PONGOLA RIVER

The results are summarised in **Table D6**.

Table D15 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	-1.5
Zero Flows	0.0
Floods	0.5
HYDROLOGY RATING	**0.5**
pH	1.0
Salts	1.0
Nutrients	1.0
Water Temperature	0.5
Water clarity	1.0
Oxygen	0.5
Toxics	0.0
PC RATING	**0.6**
Sediment	1.0
Benthic Growth	0.5
BED RATING	**0.8**
Marginal	1.0
Non-marginal	1.5
BANK RATING	**1.2**
Longitudinal Connectivity	1.0
Lateral Connectivity	0.0
CONNECTIVITY RATING	**0.7**
INSTREAM IHI %	**85.7**
INSTREAM IHI EC	**B**
INSTREAM CONFIDENCE	**3.5**
RIPARIAN IHI	
Base Flows	1.0
Zero Flows	0.0

Moderate Floods	0.5
Large Floods	0.0
HYDROLOGY RATING	**0.3**
Substrate Exposure (marginal)	2.0
Substrate Exposure (non-marginal)	2.0
Invasive Alien Vegetation (marginal)	1.5
Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	1.0
Erosion (non-marginal)	1.0
Physico-Chemical (marginal)	1.5
Physico-Chemical (non-marginal)	0.0
Marginal	2.0
Non-marginal	2.0
BANK STRUCTURE RATING	**2.0**
Longitudinal Connectivity	0.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.5**
RIPARIAN IHI %	**77.8**
RIPARIAN IHI EC	**B/C**
RIPARIAN CONFIDENCE	**3.0**

D7 EWR AS1: ASSEGAAI RIVER

The results are summarised in **Table D7**.

Table D16 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	-3.0
Zero Flows	1.5
Floods	3.5
HYDROLOGY RATING	**2.5**
pH	1.0
Salts	1.0
Nutrients	3.0
Water Temperature	1.0
Water clarity	1.0
Oxygen	0.5
Toxics	2.0
PC RATING	**2.0**
Sediment	1.5
Benthic Growth	1.5
BED RATING	**1.5**
Marginal	2.0
Non-marginal	2.5
BANK RATING	**2.2**
Longitudinal Connectivity	2.5
Lateral Connectivity	1.0
CONNECTIVITY RATING	**2.0**

INSTREAM IHI %	**59.1**
INSTREAM IHI EC	**C/D**
INSTREAM CONFIDENCE	**3.5**
RIPARIAN IHI	
Base Flows	1.5
Zero Flows	1.0
Moderate Floods	3.0
Large Floods	3.5
HYDROLOGY RATING	**2.3**
Substrate Exposure (marginal)	2.0
Substrate Exposure (non-marginal)	3.0
Invasive Alien Vegetation (marginal)	1.5
Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	1.5
Erosion (non-marginal)	2.0
Physico-Chemical (marginal)	1.5
Physico-Chemical (non-marginal)	0.0
Marginal	2.0
Non-marginal	3.0
BANK STRUCTURE RATING	**2.5**
Longitudinal Connectivity	1.0
Lateral Connectivity	0.5
CONNECTIVITY RATING	**0.8**
RIPARIAN IHI %	**58.7**
RIPARIAN IHI EC	**C/D**
RIPARIAN CONFIDENCE	**3.0**

D8 EWR NG1: NGWEMPISI RIVER

The results are summarised in **Table D8**.

Table D17 Summary of Instream and Riparian Habitat Integrity results

INSTREAM HABITAT INTEGRITY	
Base Flows	-3.0
Zero Flows	1.0
Floods	3.0
HYDROLOGY RATING	**2.1**
pH	1.0
Salts	0.0
Nutrients	2.0
Water Temperature	1.0
Water clarity	1.0
Oxygen	0.5
Toxics	1.0
PC RATING	**1.0**
Sediment	2.0
Benthic Growth	1.5
BED RATING	**1.8**
Marginal	2.0

Non-marginal	2.5
BANK RATING	**2.2**
Longitudinal Connectivity	2.5
Lateral Connectivity	1.0
CONNECTIVITY RATING	**2.0**
INSTREAM IHI %	**64.3**
INSTREAM IHI EC	**C**
INSTREAM CONFIDENCE	**3.5**
RIPARIAN IHI	
Base Flows	1.5
Zero Flows	1.0
Moderate Floods	3.0
Large Floods	3.5
HYDROLOGY RATING	**2.3**
Substrate Exposure (marginal)	1.5
Substrate Exposure (non-marginal)	1.0
Invasive Alien Vegetation (marginal)	2.0
Invasive Alien Vegetation (non-marginal)	2.0
Erosion (marginal)	1.0
Erosion (non-marginal)	1.5
Physico-Chemical (marginal)	1.0
Physico-Chemical (non-marginal)	0.0
Marginal	2.0
Non-marginal	2.0
BANK STRUCTURE RATING	**2.0**
Longitudinal Connectivity	1.5
Lateral Connectivity	0.5
CONNECTIVITY RATING	**1.1**
RIPARIAN IHI %	**61.8**
RIPARIAN IHI EC	**C/D**
RIPARIAN CONFIDENCE	**3.0**

D9 REFERENCES

Kleynhans, C.J. 1996.A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo System, South Africa). *Journal of Aquatic Ecosystem Health*. **5**: 41-54.

Kleynhans, C.J., Louw, M.D., and Graham, M. (2009) Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

9 APPENDIX E: FISH AND THE FRAI

E1 BACKGROUND

A comprehensive reserve determination (Report no: RDM/WMA6/CON/COMP/0813) was conducted on the Usutu/Mhlatuze Water Management Areas by Tlou Consulting in 2013/2014 (DWS, 2014). The fish specialist component as part of this study was performed by Dr. B. Paxton. The Reserve determination was done using the Downstream Response to Imposed Flow Transformations (DRIFT) method and the Fish Response Assessment Index (FRAI – Kleynhans, 2007)) was applied at low confidence as part of the EcoClassification process. The results generated during the initial EWR study (2013/14) will be used primarily as the basis for the current classification study with some refinement required to ensure applicability and more recent status reflected by the relevant models (such as FRAI). A rapid field survey was therefore undertaken during July 2022 by relevant specialists to familiarise themselves with the EWR sites and limited additional fish sampling was also performed where applicable. The original fish results together with the July 2022 rapid survey results as well as other readily available information was used to refine and update the FRAI for the purpose of the current study.

E2 REFINEMENT OF FRAI RESULTS

Results from the 2014 FRAI assessment were used as the basis for the 2022 study, and inconsistencies adjusted as required. Evidence of deterioration (or improvement) since the 2014 study was noted, and accounts for changes from the 2014 adjusted FRAI scores and category.

The reference species list for each site was refined based on all available information (PESEIS data, 2014 EWR study, 2022 rapid survey, other available information). As a general rule species with a low probability of occurring at the site (PESEIS rating 1), euryhaline and estuarine species were omitted (some exceptions were made).

As a general rule the 2014 FRAI used the same “reference” Frequency of Occurrence (FROC) rating for all species, and the “present/observed” FROC was only based on the fish sampled during the 2014 survey. The automated FRAI used as a first step in 2014 under-estimated fish PES and was adjusted by the fish specialist. The various metrics in the FRAI was then adjusted (no adjustments to the FROC made) to get to a specific ecological category, assuming to be a true reflection of the status of the fish at the time of the 2014 EWR. As part of the current (2022) refinement of the FRAI’s the expected FROC had to be amended and the observed/present FROC had to be derived, aiming to get to a FRAI score and category as close to the initial (2014) calculation. The PES (category) was only amended/updated if information (drivers and fish) was available to indicate notable change (improvement or deterioration) at the site between 2014 and 2022.

Fish species list (Abbreviations, Scientific names, Conservation status)

Abbreviations	Scientific Names	Conservation status (IUCN, 2022)
AAEN	*AWAOUS AENEOFUSCUS*	
ABER	*ACANTHOPAGRUS BERDA*	
AKAT	*MICROPANCHAX (APLOCHEILICHTHYS) KATANGAE*	
ALAB	*ANGUILLA BENGALENSIS LABIATA*	
AMAR	*ANGUILLA MARMORATA*	
AMOS	*ANGUILLA MOSSAMBICA*	Near-threatened (NT)
AMYA	*MICROPANCHAX (APLOCHEILICHTHYS) MYAPOSAE*	Near-threatened (NT)
AURA	*AMPHILIUS URANOSCOPUS*	
BGUR	*BARBUS GURNEYI*	Vulnerable (VU)
BANN	*ENTEROMIUS ANNECTENS*	
BANO	*ENTEROMIUS ANOPLUS*	
BARG	*ENTEROMIUS CROCODILENSIS (ARGENTEUS)*	
BEUT	*BARBUS EUTAENIA*	
BLAT	*BRYCINUS LATERALIS*	
BNAT	*LABEOBARBUS NATALENSIS*	
BTOP	*ENTEROMIUS TOPPINI*	
BTRI	*ENTEROMIUS TRIMACULATUS*	
BUNI	*ENTEROMIUS UNITAENIATUS*	
BPAU	*ENTEROMIUS PALUDINOSUS*	
BVIV	*ENTEROMIUS VIVIPARUS*	
CGAR	*CLARIAS GARIEPINUS*	
CTHE	*CLARIAS THEODORAE*	
GCAL	*GLOSSOGOBIUS CALLIDUS*	
GGIU	*GLOSSOGOBIUS GIURIS*	
LCYL	*LABEO CYLINDRICUS*	
LMOL	*LABEO MOLYBDINUS*	
LROS	*LABEO ROSAE*	
MACU	*MICRALESTES ACUTIDENS*	
MBRE	*MESOBOLA BREVIANALIS*	
MMAC	*MARCUSENIUS MACROLEPIDOTUS/PONGOLENSIS*	
MFAL	*MONODACTYLUS FALCIFORMIS*	
OMOS	*OREOCHROMIS MOSSAMBICUS*	Vulnerable (VU)
PPHI	*PSEUDOCRENILABRUS PHILANDER*	
RDEW	*REDIGOBIUS DEWAALI*	
SINT	*SCHILBE INTERMEDIUS*	
SZAM	*SYNODONTIS ZAMBEZENSIS*	
TREN	*COPTODON RENDALLI*	
TSPA	*TILAPIA SPARRMANII*	
VNEL	*LABEOBARBUS (VARICORHINUS) NELSPRUITENSIS*	Near-threatened (NT)

E3 EWR SITES

Refer to **Table E1** for list of relevant EWR sites used as part of the current study. These sites were also visited during the July 2022 field trip. An additional site was selected and sampled in the Ngwempisi River during July 2022.

Table E1 EWR sites used as part of the current study (visited during July 2022)

EWR Site	River	Co-ordinates	SQ code	Flow during July 2022 site visit[1]
EWR MA1	Matigulu	S29.02010 E31.47040	W11A-3612	-
EWR NS1	Nseleni	S28.63410 E31.92517	W12G-3229	-
EWR WM1	White Mfolozi	S28.23146 E31.18666	W21H-2897	-
EWR BM1	Black Mfolozi	S27.93890 E31.21030	W22F-2748	0.50 m^3/s
EWR MK1	Mkuze	S27.59210 E32.21800	W31J-2480	-
EWR UP1	Upper Pongola	S27.36413 E30.96962	W42E-2221	-
EWR AS1	Assegaai	S27.06230 E30.98880	W51E-2049	2.67 m^3/s
EWR NG1	Ngwempisi	S26.679448 E30.70213	W53E-1790	1.69 m^3/s

1 Only three EWR sites had gauges and flows were sourced from these local gauges. None of the other sites had local gauges and there was insufficient time to permit taking manual discharge measurements during the site visit.

E4 EWR MA1 (MATIGULU RIVER)

E4.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR MA1 is situated in the Matigulu River (sometimes referred to as Matikulu River) (S29.0201 E31.4704) in RU W11-2 and IUA W11 (Matigulu). The Matigulu River at this site is a bedrock river with a pool-rapid morphology. The channel bed in the rapid is dominated by bedrock and boulder, sand bars have formed in shallow pools.

Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E1**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E2** and **Figure E1**).

Figure E1 EWR MA1: Upstream and across

Table E2 Habitat Cover Ratings for fish at site EWR MA1 during July 2022

Velocity-depth class	Sites	Matigulu
SLOW-DEEP (>0.5m; <0.3m/s)	Abundance	2
	Overhanging vegetation	2
	Undercut banks and Root-wads	1
	Substrate	2
	Macrophytes	1
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	2
	Overhanging vegetation	2
	Undercut banks and Root-wads	0
	Substrate	3
	Macrophytes	1
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	2
	Overhanging vegetation	1
	Undercut banks and Root-wads	0
	Substrate	4
	Macrophytes	1
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	1
	Undercut banks and Root-wads	0
	Substrate	4
	Macrophytes	1

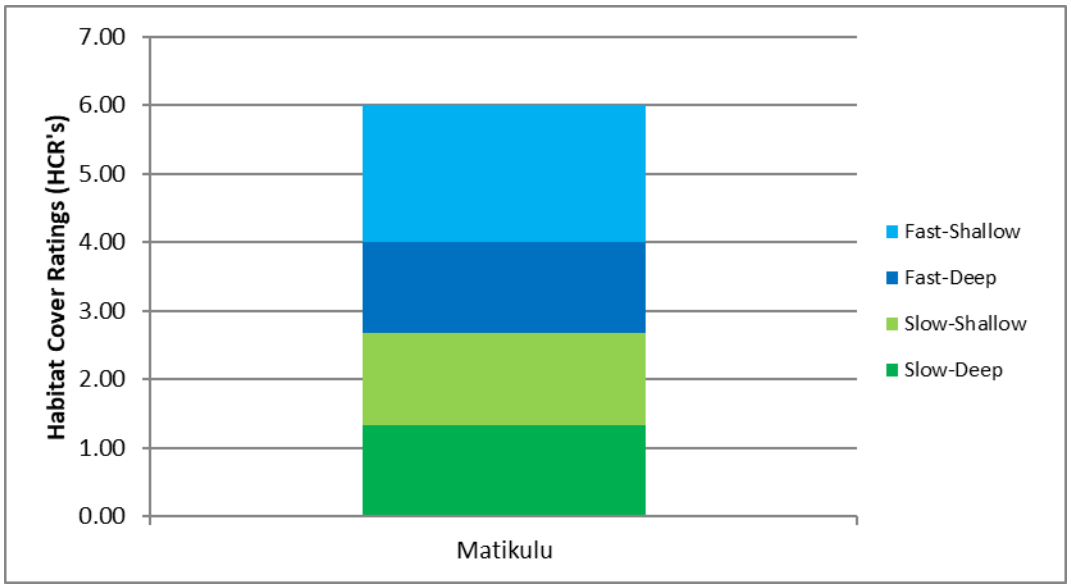

Figure E2 Fish Habitat Cover Ratings calculated for each velocity-depth category at site MA1 (July 2022 survey)

E4.1.2 FISH

EWR study (B. Paxton, July 2014 survey): Of the 23 fish species expected at the EWR Site MA1 on the Matigulu River under reference conditions (Kleynhans *et al*., 2007; Department of Water

Affairs 2013, National database records SAIAB and KZN Wildlife), five species were collected during the course of the survey (**Table E3**). The fish species compliment at the site was found to have a strongly euryhaline component with a lower proportion of freshwater species being present. Three species at the site are considered to have a preference of Fast Shallow (FS) and Fast Deep (FD) habitat classes, one of which (*L. natalensis*) was found to be present at the site.

July 2022 rapid site visit (P. Kotze): Three indigenous fish species were sampled (**Table E3**) with *M. falciformis* being the most abundant (sampled in FS and FD with rocks/substrate as cover). *Labeobarbus natalensis* was also relatively abundant, also indicating a preference for FS and FD with substrate as cover.

Table E3 Fish species sampled (abundance and CPUE) at site EWR MA1 during July 2014 (Paxton) and July 2022 (Kotze).

		2014/07		2022/07	
Scientific Name	**English Common Name**	**Abundance (N)**	**CPUE[1] (ind/hr)**	**Abundance**	**CPUE (ind/hr)**
Anguilla mossambica	Longfin eel	1	1.7		
Awaous aeneofuscus	Freshwater Goby	8	6.86	4	8
Glossogobius giuris	Tank goby	2	1.71		
Labeobarbus natalensis	Kwazulu-Natal yellowfish/Scaly	5	4.29	8	16
Monodactylus falciformis	Cape Moony	13	11.14	12	24
Micropterus salmoides (alien)	Largemouth bass	1	0.86		
Oreochromis mossambicus	Mozambique tilapia	2	1.71		

1 Catch Per Unit Effort

FRAI: Various refinements were made to the 2014 FRAI model (see introduction section for a description of the approach followed and **Table E4** for further comments). A FRAI score of 87.6% falling in a category B (Slightly modified from natural conditions) was calculated in the 2014 EWR study. The FRAI was amended for the purpose of the 2022 study to a score of 86.4% (Category B) (**Table E4**).

Table E4 Fish species expected to occur site EWR MA1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, amended 2022 FROC reference and PES ratings and comparison of 2014 and 2022 FRAI scores and categories

Abbreviations	**Scientific Names: Reference species**	**Probability of occurrence in reach or at site***	**2014 EWR study (Paxton): Reference FROC**	**Refined: Reference FROC (2022)**	**Refined: Present FROC (observed and habitat derived)**	**Comments**
OMOS	*OREOCHROMIS MOSSAMBICUS*	High/definite	1.00	3	3	
TREN	*COPTODON RENDALLI*	High/definite		1	0.5	
BNAT	*LABEOBARBUS NATALENSIS*	High/definite	1.00	5	4.5	
AAEN	*AWAOUS AENEOFUSCUS*	High/definite	1.00	5	5	
GGIU	*GLOSSOGOBIUS GIURIS*	*Moderate*	1.00	3	3	
AMAR	*ANGUILLA MARMORATA*	High/definite	1.00	1	1	

Abbreviations	Scientific Names: Reference species	Probability of occurrence in reach or at site*	2014 EWR study (Paxton): Reference FROC	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)	Comments
AMOS	*ANGUILLA MOSSAMBICA*	High/definite	1.00	1	1	
BGUR	*ENTEROMIUS GURNEYI*	High/definite	1.00	3	2	
BPAU	*ENTEROMIUS PALUDINOSUS*	High/definite	1.00	3	2	
BTRI	*ENTEROMIUS TRIMACULATUS*	High/definite	1.00	3	2	
BVIV	*ENTEROMIUS VIVIPARUS*	High/definite	1.00	3	2	
CGAR	*CLARIAS GARIEPINUS*	High/definite	1.00	3	3	
CTHE	*CLARIAS THEODORAE*	High/definite	1.00	1	1	
GCAL	*GLOSSOGOBIUS CALLIDUS*	High/definite	1.00	3	2	
LMOL	*LABEO MOLYBDINUS*	High/definite	1.00	3	2	
MBRE	*MESOBOLA BREVIANALIS*	*Moderate*	1.00	1	0.5	
MMAC	*MARCUSENIUS MACROLEPIDOTUS*	*Moderate*	1.00	1	0.5	
PPHI	*PSEUDOCRENILABRUS PHILANDER*	High/definite	1.00	3	2	
TSPA	*TILAPIA SPARRMANII*	High/definite	1.00	5	3	
MFAL	*MONODACTYLUS FALCIFORMIS*	Not expected	Not included	3	3	Although estuarine/euryhaline species, sampled during both surveys at site and therefore included.
MSAL	*MICROPTERUS SALMOIDES*	Alien species (not expected)	1.00			Alien/Intruded species cannot be expected under reference conditions and was erroneously included in 2014 EWR study. Excluded in updated FRAI.
AKAT	*APLOCHEILICHTHYS KATANGAE*	Not expected	1.00			Not expected in PESEIS, therefore excluded.
ALAB	*ANGUILLA BENGALENSIS LABIATA*	Not expected	1.00			Not expected in PESEIS, therefore excluded.
GAES	*GILCHRISTELLA AESTUARIA*	Not expected	1.00			estuarine/euryhaline species, excluded
AMYA	*APLOCHEILICHTHYS MYAPOSAE*	Moderate	1.00			Coastal lakes and rivers, excluded from EWR site.
FRAI (%)			**87.6**		**86.4**	
FRAI (EC)			**B**		**B**	

*Based on PESEIS (2014) and other available information (survey data).

FREQUENCY OF OCCURRENCE (FROC) RATINGS:

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%)

5=PRESENT AT ALMOST ALL SITES (>75%)

E5 EWR NS1 (NSELENI RIVER)

E5.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR NS1 is situated in the Nseleni River (S28.6341 E31.92517) in RU W12-8 and IUA W12-b (Mfule, Mhlatuzane, Nseleni). Access to the site was a problem during July 2022 as an electrified fence with no gates prevented access. Furthermore, the vegetation has become so encroached that movement within the riparian from far downstream access was impossible. Upstream the channel had steep banks with a pool riffle/rapid morphology. Small boulders dominated the riffle/rapid and were also found on the bed of the pool. Banks were comprised of sand with superficial silt deposits

Photographs of the EWR site and river directly upstream of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E3** and **Figure E4**.

Figure E3 Photographs of the Nseleni River upstream of the EWR site

Figure E4 Photographs of the Nseleni River at the EWR site

E5.1.2 Fish

EWR study (B. Paxton, July 2014 survey): Based on Kleynhans *et al.* (2007), National database records (SAIAB and KZN Wildlife) and the Department of Water Affairs (2013), 20 fish species were expected at EWR Site NS1 on the Nseleni River under reference conditions. Of these, only two (*P. philander* and *G. callidus*) were collected during the course of the July 2014 survey.

A FRAI score of 68.1%, falling in a category C was calculated during the 2014 EWR study. Conditions observed at the site at the time of the survey were considered inadequate to support fish species with a preference for FS and FD habitat classes. However, these conditions are not expected to be substantially different from reference. Three fish species which would be expected at the site under reference conditions are considered moderately intolerant of modified physico-chemical conditions and none of these were found to be present during surveys. Fish cover in the form of overhanging vegetation, woody debris, as well as undercut banks and root wads were abundant and one species with a preference for cover was found to be present (*P. philander*). No species with a strong requirement for migration were present. The trend at this site was considered to be stable.

July 2022 rapid site visit (P. Kotze): No additional sampling could be performed. The FRAI model was updated resulting in a score of 67.9% (Category C) (**Table E5**).

Table E5 Fish species expected to occur site EWR NS1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, amended 2022 FROC reference and PES ratings and comparison of 2014 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	PESEIS rating (for SQ)	2014 EWR study (Paxton): Reference FROC[1]	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
PPHI	*PSEUDOCRENILABRUS PHILANDER*	High/definite	3.00	5	4
GCAL	*GLOSSOGOBIUS CALLIDUS*	High/definite	3.00	3	3
OMOS	*OREOCHROMIS*	High/definite	3.00	3	2
BNAT	*LABEOBARBUS NATALENSIS*	High/definite	3.00	3	1.5
GGIU	*GLOSSOGOBIUS GIURIS*	Moderate	3.00	1	0.5
AAEN	*AWAOUS AENEOFUSCUS*	Low	3.00	1	0.5
AKAT	*APLOCHEILICHTHYS KATANGAE*	Low	3.00	1	0.5
ALAB	*ANGUILLA BENGALENSIS LABIATA*	Moderate	3.00	1	0.5
AMAR	*ANGUILLA MARMORATA*	Moderate	3.00	1	0.5
AMOS	*ANGUILLA MOSSAMBICA*	High/definite	3.00	2	1
AMYA	*APLOCHEILICHTHYS MYAPOSAE*	Moderate	3.00	1	0.5
BGUR	*ENTEROMIUS GURNEYI*	Moderate	Not included	1	0.5
BPAU	*ENTEROMIUS PALUDINOSUS*	High/definite	Not included	3	2
BTRI	*ENTEROMIUS TRIMACULATUS*	High/definite	Not included	3	2
BVIV	*ENTRIMIUS VIVIPARUS*	High/definite	3.00	3	2
CGAR	*CLARIAS GARIEPINUS*	High/definite	3.00	3	2.5
CTHE	*CLARIAS THEODORAE*	Moderate	3.00	1	0.5
GAES	*GILCHRISTELLA AESTUARIA*	Moderate	3.00		
LMOL	*LABEO MOLYBDINUS*	High/definite	3.00	3	2
MBRE	*MESOBOLA BREVIANALIS*	Moderate	3.00	1	0.5
MMAC	*MARCUSENIUS MACROLEPIDOTUS (CAUDISQUAMATUS SP. NOV)*	High/definite	3.00	2	1
TSPA	*TILAPIA SPARRMANII*	Moderate	3.00	2	1
FRAI (%)			**68.1%**		**67.8%**
FRAI (EC)			**C**		**C**

1 Refer to **Table E4** for FROC ratings.

E6 EWR WM1 (WHITE UMFOLOZI RIVER)

E6.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR WM1 is situated in the White Umfolozi River (S28.23146 E31.18666) in RU W21-5 and IUA W21 (Upper and Middle White Umfolozi). The White Umfolozi River at this site has a pool-rapid morphology dominated by boulder. An extensive point bar on the right bank is comprised of sand, cobble and boulder. Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E5**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E6** and **Figure E5**).

Figure E5 EWR WM1 (July 2022)

Table E6 Habitat Cover Ratings for fish at site EWR WM1 during July 2022

Velocity-depth class	Sites	White Umfolozi
SLOW-DEEP (>0.5m; <0.3m/s)	Abundance	0
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	0
	Macrophytes	0
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	1
	Overhanging vegetation	0
	Undercut banks and Root-wads	1
	Substrate	4
	Macrophytes	0
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	4
	Macrophytes	0
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	4
	Macrophytes	0

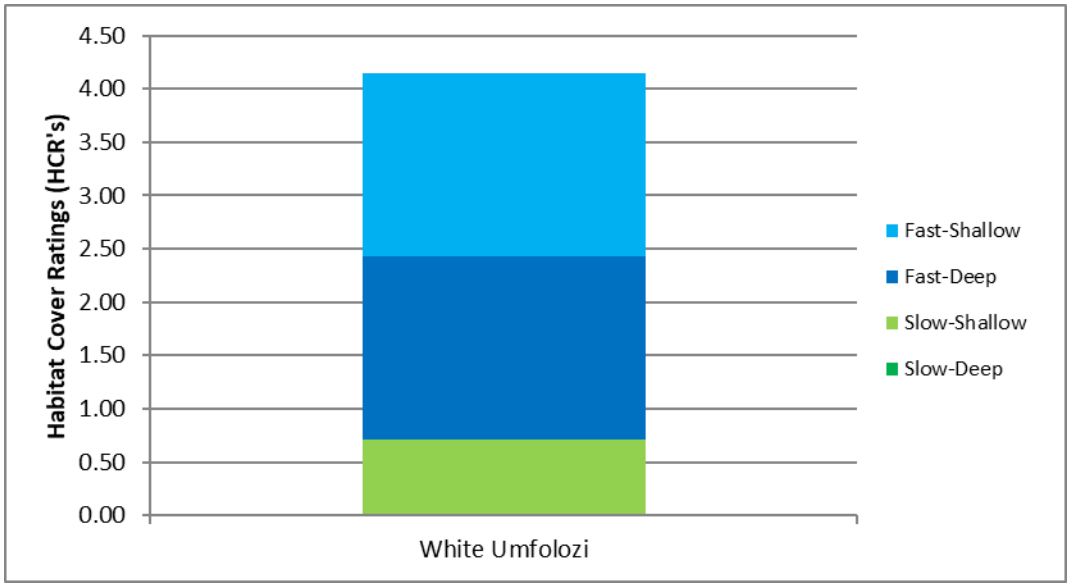

Figure E6 Fish Habitat Cover Ratings calculated for each velocity-depth category at site WM1 (July 2022 survey)

E6.1.2 Fish

EWR study (B. Paxton, July 2014 survey): Of the 19 fish species expected under reference conditions at the EWR Site WM1 on the White Mflolozi River (Kleynhans et al. 2007; Department of Water Affairs 2013, National database records SAIAB and KZN Wildlife), four species were collected during the course of the July 2014 survey (**Table E7**). Habitat conditions observed at the site were considered adequate to support fish species with a preference for FS and FD habitat classes and the conditions are not expected to be substantially different from reference. A FRAI score of 72.6% (category C) was calculated for the site.

July 2022 rapid site visit (P. Kotze): Four indigenous fish species were sampled (**Table E7**) with *Labeo molybdinus* being the most abundant (sampled in FS and FD with rocks/substrate as cover). *Labeobarbus natalensis* abundance was notably lower than during the 2014 survey and only adults were sampled directly downstream of the bridge (none sampled in rapids downstream of bridge). *Amphilius uranoscopus* was also relatively abundant during 2022, notably more abundant than during July 2014. Various refinements were made to the 2014 FRAI model (see introduction section for a description of the approach followed and **Table E8**). A FRAI sore of 72.6% falling in a category C (Moderately modified from natural conditions) was calculated in the 2014 EWR study. The FRAI was amended to a score of 73.1% (Category C) (**Table E8**).

Table E7 Fish species sampled (abundance and CPUE) at site EWR WM1 during July 2014 (Paxton) and July 2022 (Kotze)

Scientific Name	English Common Name	2014/07		2022/07	
Amphilius uranoscopus	Stargazer (Mountain-Catfish)	1	1.2	5	7.1
Labeobarbus natalensis	Kwazulu-Natal yellowfish/Scaly	23	27.6	4	5.7
Clarias gariepinus	Sharptooth Catfish	1	1.2	2	2.9
Labeo molybdinus	Leaden Labeo	18	21.6	8	11.4

Table E8 Fish species expected to occur at site EWR WM1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, amended 2022 FROC reference and PES ratings and comparison of 2014 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Probability of occurrence in reach or at site*	2014 EWR study (Paxton): Reference FROC	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
AURA	*AMPHILIUS URANOSCOPUS*	High/definite	2.00	3	2.5
CGAR	*CLARIAS GARIEPINUS*	High/definite	2.00	3	3
BNAT	*BARBUS NATALENSIS*	High/definite	4.00	4	3.5
ALAB	*ANGUILLA BENGALENSIS*	Moderate	2.00	2	1
AMAR	*ANGUILLA MARMORATA*	Moderate	2.00	2	1
AMOS	*ANGUILLA MOSSAMBICA*	High/definite	2.00	2	1
BANO	*ENTEROMIUS ANOPLUS*	Moderate	2.00	2	1
BARG	*ENTEROMIUS CROCODILENSIS*	Moderate	Not included	2	1
BPAU	*ENTEROMIUS PALUDINOSUS*	High/definite	2.00	2	1
BTRI	*ENTEROMIUS TRIMACULATUS*	High/definite	2.00	2	1
BUNI	*ENTEROMIUS UNITAENIATUS*	High/definite	2.00	2	1
BVIV	*ENTEROMIUS VIVIPARUS*	High/definite	2.00	2	1
LCYL	*LABEO CYLINDRICUS*	Low	2.00	1	0.5
LMOL	*LABEO MOLYBDINUS*	Moderate	4.00	4	3.5
MACU	*MICRALESTES ACUTIDENS*	Moderate	2.00	2	1
MMAC	*MARCUSENIUS MACROLEPIDOTUS*	Moderate	2.00	2	1
OMOS	*OREOCHROMIS MOSSAMBICUS*	Moderate	2.00	2	1
TSPA	*TILAPIA SPARRMANII*	High/definite	4.00	3	2
FRAI (%)			**72.6**		**73.1**
FRAI (EC)			**C**		**C**

Refer to **Table E4** for FROC ratings.

E7 EWR BM1 (BLACK UMFOLOZI RIVER)

E7.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR BM1 is situated in the Black Umfolozi River (S27.93890 E31.21030) in RU W22-1 and IUA W22 (Upper Black Umfolozi). The Black Umfolozi at this site has a bedrock cascade morphology with flat bedrock and bedrock steps. A long pool confined by reeds occurs downstream of the site. The dominant bed material is bedrock; sand dominates the flood benches. Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E7**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E9** and **Figure E8**).

Figure E7 EWR BM1 (July 2022)

Table E9 Habitat Cover Ratings for fish at site EWR BM1 during July 2022

Velocity-depth class	Sites	Black Umfolozi
SLOW-DEEP (>0.5m; <0.3m/s)	Abundance	2
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	3
	Macrophytes	3
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	3
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	3
	Macrophytes	3
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	1
	Overhanging vegetation	1
	Undercut banks and Root-wads	0
	Substrate	3
	Macrophytes	0
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	3
	Macrophytes	1

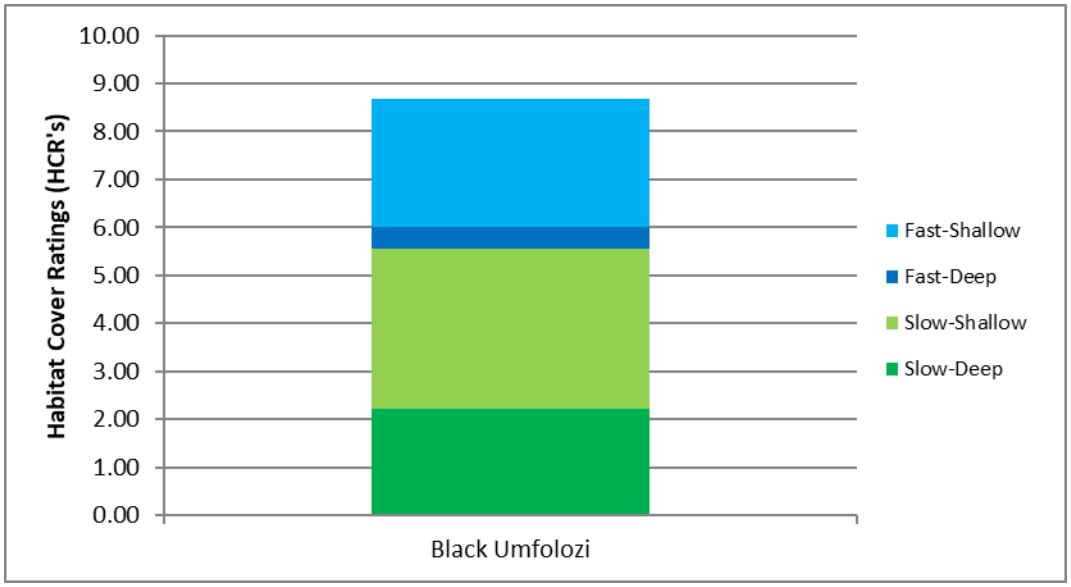

Figure E8 Fish Habitat Cover Ratings calculated for each velocity-depth category at site BM1 (July 2022 survey)

E7.1.2 Fish

EWR study (B. Paxton, July 2014 survey): Two fish species with strong preferences for faster flow-depth classes (FS and FD) and intolerant to moderately-intolerant of no-flow conditions were found at this site (*L. natalensis* and *A. uranoscopus*). One of these species (*A. uranoscopus*) is considered intolerant of modified physico-chemical conditions, suggesting that water quality conditions at the site were relatively good. One species with a requirement for overhanging marginal vegetation (*B. trimaculatus*) and one species with a strong requirement for migration between reaches were present (*L. natalensis*). The trend at this site is considered to be stable. Of the 15 fish species expected under reference conditions at the EWR Site BM1 on the Black Mflolozi River (Kleynhans *et al.,* 2007; Department of Water Affairs 2013, National database records SAIAB and KZN Wildlife), five species were collected during the course of the 2014 survey (**Table E10**).

The adjusted FRAI scores were based on an assessment of habitat available at the site, i.e. the frequency and diversity of flow habitat classes. Habitat conditions observed at the site were considered adequate to support fish species with a preference for FS and FD, as well as Slow Deep (SD) habitat classes and the conditions are not expected to be substantially different from reference. A FRAI score of 75.9% (category C) was calculated during the 2014 study.

July 2022 rapid site visit (P. Kotze): Six indigenous fish species were sampled at the site (**Table E10**) with the intolerant species *Enteromius eutenia* being the most abundant species sampled (**Table E10)**. This was primarily as a result of the abundant overhanging vegetation as cover, which also resulted in high abundance of other species such as *T. sparrmanii.* Although flow was good at the time of the survey and preferred habitats were available, no *A. uranoscopus* and *L. natalensis* were sampled. The reasons for their absence at the time of the survey is unsure but may be attributed to natural seasonal variation and these species are thought to still be present in this reach. Various refinements were made to the 2014 FRAI model (see introduction section for a description of the approach followed and **Table E11** for further comments). The FRAI model was amended to a score of 75.9% calculated (Category C) (**Table E11**).

Table E10 Fish species sampled (abundance and CPUE) at site EWR BM1 during July 2014 (Paxton) and July 2022 (Kotze)

Scientific Name	English Common Name	2014/07		2022/07	
		Abundance (N)	CPUE (ind/hr)	Abundance (N)	CPUE (ind/hr)
Amphilius uranoscopus	Stargazer (Mountain-Catfish)	6	8.0		
Enteromius eutenia	Orangefin Barb	32	42.6	20	33.3
Enteromius paludinosus	Straightfin Barb			5	8.3
Enteromius trimaculatus	Threespot Barb	1	1.3	5	8.3
Labeobarbus natalensis	Kwazulu-Natal yellowfish/Scaly	13	27.6		
Labeo molybdinus	Leaden Labeo			3	5.0
Oreochromis mossambicus	Mozambique Tilapia			2	3.3
Tilapia sparrmanii	Banded Tilapia	3	4.0	15	25.0

Table E11 Fish species expected to occur at Site EWR BM1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, amended 2022 FROC reference and PES ratings and comparison of 2014 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Probability of occurrence in reach or at site	2014 EWR study (Paxton): Reference FROC	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
AAEN	*AWAOUS AENEOFUSCUS*	Moderate	Not included	1	0.5
AURA	*AMPHILIUS URANOSCOPUS*	High/Definite	2.00	3	2.5
BEUT	*BARBUS EUTAENIA*	Not listed	2.00	3	2.5
BNAT	*BARBUS NATALENSIS*	High/Definite	2.00	2	1.5
ALAB	*ANGUILLA BENGALENSIS*	Moderate	2.00	1	0.5
AMOS	*ANGUILLA MOSSAMBICA*	Moderate	2.00	1	0.5
BANO	*ENTEROMIUS ANOPLUS*	Moderate	3.00	2	1
BARG	*ENTEROMIUS CROCODILENSIS*	Moderate	Not included	1	0.5
BPAU	*ENTEROMIUS PALUDINOSUS*	Not listed	Not included	2	1
BTRI	*ENTEROMIUS TRIMACULATUS*	High/Definite	3.00	3	2.5
BUNI	*ENTEROMIUS UNITAENIATUS*	Moderate	3.00	3	2
BVIV	*ENTEROMIUS VIVIPARUS*	Moderate	3.00	3	2
CGAR	*CLARIAS GARIEPINUS*	Moderate	3.00	3	2
CTHE	*CLARIAS THEODORAE*	Not listed	2.00	1	0.5
LMOL	*LABEO MOLYBDINUS*	Moderate	4.00	3	2
OMOS	*OREOCHROMIS MOSSAMBICUS*	Moderate	4.00	3	2
PPHI	*PSEUDOCRENILABRUS PHILANDER*	Moderate	4.00	3	2
TSPA	*TILAPIA SPARRMANII*	Moderate	4.00	4	3.5
LCYL	*LABEO CYLINDRICUS*	Low	Not included	Not included	Not included
ANAT	*AMPHILIUS NATALENSIS*	Moderate	Not included	Not included	Not included
FRAI (%)			**75.9**		**75.9**
FRAI (EC)			**C**		**C**

Refer to **Table E4** for FROC ratings.

E8 EWR MK1 (MKUZE RIVER)

E8.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR MK1 is situated in the Mkuze River (S27.59210 E32.21800) in RU W31-4 and IUA W31-b (Lower Mkuze). The Mkuze River at this site is a sand-bed river with sand banks. Flood channels are characteristic of the floodplain but these are choked with shrubs and woody debris. The recently erected fence has probably resulted in an increase in forest floor and bank vegetation since 2014 due to absence of animals such as elephant and grazers. Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E9**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E12** and **Figure E10**).

Figure E9 EWR MK1 (July 2022)

Table E12 Habitat Cover Ratings for fish at site EWR MK1 during July 2022

Velocity-depth class	Sites	Mkuze
SLOW-DEEP (>0.5m; <0.3m/s)	Abundance	1
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	0
	Macrophytes	1
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	3
	Overhanging vegetation	3
	Undercut banks and Root-wads	2
	Substrate	0
	Macrophytes	1
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	0
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	0
	Macrophytes	0
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	2
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	0
	Macrophytes	1

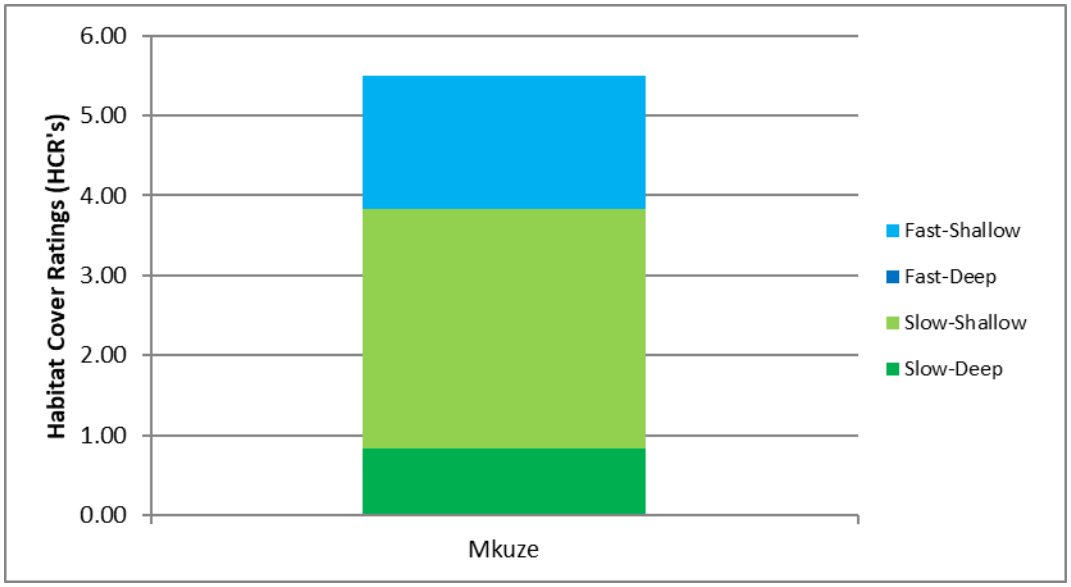

Figure E10 Fish Habitat Cover Ratings calculated for each velocity-depth category at site MK1 (July 2022 survey)

E8.1.2 Fish

EWR study (B. Paxton, July 2014 survey): Of the 31 fish species expected at the EWR Site MK1 on the Mkuze River under reference conditions (Kleynhans *et al*. 2007; Department of Water Affairs 2013, National database records SAIAB and KZN Wildlife), four species were collected during the course of the 2014 survey at FROCs higher than expected (**Table E13**). Although the diversity of habitats at the site were low (primarily FS and SS) with no exposed cobble, the site is located in a sand-bed reach and this condition is not expected to be different from reference. A FRAI score of 78.5% (category C) was calculated for the site in 2014.

July 2022 rapid site visit (P. Kotze): Five indigenous fish species were sampled (**Table E13**) with most species being very abundant. As mentioned during the 2014 study the river again consisted of a sand bed with no rocks as cover, most fish utilizing the undercut bank, rootwads and overhanging vegetation as cover. Some refinements were made to the 2014 FRAI model (see introduction section for a description of the approach followed and **Table E14**). The updated FRAI model resulted in a score of 75.4% (Category C) (**Table E14**).

Table E13 Fish species sampled (abundance and CPUE) at site EWR MK1 during July 2014 (Paxton) and July 2022 (Kotze)

Scientific Name	English Common Name	2014/07		2022/07	
		Abundance (N)	CPUE (ind/hr)	Abundance	CPUE (ind/hr)
Enteromius trimaculatus	Threespot Barb			30	51.4
Enteromius paludinosus	Straightfin Barb	14	14.0		
Enteromius viviparus	Bowstripe Barb	31	31.0	100	171.4
Clarias gariepinus	Sharptooth Catfish	5	5.0	20	34.3
Labeo molybdinus	Leaden Labeo			3	5.1
Oreochromis mossambicus	Mozambique Tilapia	16	16.0	15	25.7

Table E14 Fish species expected to occur site EWR MK1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, amended 2022 FROC reference and PES ratings and comparison of 2014 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Probability of occurrence in reach or at site*	2014 EWR study (Paxton): Reference FROC:	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
AAEN	*AWAOUS AENEOFUSCUS*	High/Definite	1.00	2	1.5
ABER	*ACANTHOPAGRUS BERDA*	Moderate	1.00	1	0.5
AKAT	*APLOCHEILICHTHYS KATANGAE*	Low	1.00	1	0.5
ALAB	*ANGUILLA BENGALENSIS LABIATA*	Low	1.00	1	0.5
AMAR	*ANGUILLA MARMORATA*	High/Definite	1.00	1	0.5
AMOS	*ANGUILLA MOSSAMBICA*	High/Definite	1.00	1	1
BANN	*ENTEROMIUS ANNECTENS*	Moderate	1.00	1	0.5
BANO	*ENTEROMIUS ANOPLUS*	Moderate	Not included	1	0.5
BARG	*ENTEROMIUS ARGENTEUS*	Not listed	1.00	1	0.5
BLAT	*BRYCINUS LATERALIS*	Moderate	1.00	1	0.5
BNAT	*LABEOBARBUS NATALENSIS*	High/Definite	1.00	1	0.5
BTOP	*ENTEROMIUS TOPPINI*	High/Definite	1.00	1	0.5
BTRI	*ENTEROMIUS TRIMACULATUS*	High/Definite	Not included	5	4.5
BUNI	*ENTEROMIUS UNITAENIATUS*	Moderate	1.00	1	0.5
BPAU	*ENTEROMIUS PALUDINOSUS*	High/Definite	1.00	4	3.5
BVIV	*ENTEROMIUS VIVIPARUS*	High/Definite	1.00	5	4.5
CGAR	*CLARIAS GARIEPINUS*	High/Definite	1.00	3	3
CTHE	*CLARIAS THEODORAE*	Moderate	1.00	1	0.5
GCAL	*GLOSSOGOBIUS CALLIDUS*	High/Definite	1.00	1	0.5
GGIU	*GLOSSOGOBIUS GIURIS*	Moderate	1.00	1	0.5
LCYL	*LABEO CYLINDRICUS*	Moderate	1.00	1	0.5
LMOL	*LABEO MOLYBDINUS*	High/Definite	1.00	2	1.5
LROS	*LABEO ROSAE (LABEO ALTEVILIS)*	Moderate	1.00	1	0.5
MACU	*MICRALESTES ACUTIDENS*	Moderate	1.00	1	0.5
MBRE	*MESOBOLA BREVIANALIS*	High/Definite	1.00	1	0.5
MMAC	*MARCUSENIUS MACROLEPIDOTUS*	Moderate	1.00	1	0.5
OMOS	*OREOCHROMIS MOSSAMBICUS*	High/Definite	1.00	5	4.5
PPHI	*PSEUDECRENILABRUS PHILANDER*	High/Definite	Not included	2	1
RDEW	*REDIGOBIUS DEWAALI*	Moderate	1.00	1	0.5
SINT	*SCHILBE INTERMEDIUS*	Moderate	1.00	1	0.5
SZAM	*SYNODONTIS ZAMBEZENSIS*	Moderate	1.00	1	0.5
TREN	*TILAPIA RENDALLI*	High/Definite	1.00	1	0.5
TSPA	*TILAPIA SPARRMANII*	Moderate	1.00	1	0.5
NORT	*NOTHOBRANCHIUS ORTHONOTUS*	Moderate	1.00	Excluded	Excluded
FRAI (%)			**78.5**		**75.3**
FRAI (EC)			**C**		**C**

Refer to **Table E4** for FROC ratings.

E9 EWR UP1 (PONGOLA RIVER)

E9.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR UP1 is situated in the Pongola River (S27.36413 E30.96962) in RU W42-4 and IUA W42-a (Upper Pongola). The Pongola River at this site has a pool-rapid morphology with the rapids dominated by large boulder; the flood bench comprises medium to large boulder within a sand -fine gravel matrix. Sand mining was a local disturbance on the flood bench. A secondary channel

parallel to the right-hand bank provides significant low flow habitat comprised of riffle and run. Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E11**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E15** and **Figure E12**).

Figure E11 EWR UP1 (July 2022)

Table E15 Habitat Cover Ratings for fish at site EWR UP1 during July 2022

Velocity-depth class	Sites	Pongola
SLOW-DEEP (>0.5m; 0.3m/s)	Abundance	0
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	0
	Macrophytes	0
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	1
	Overhanging vegetation	1
	Undercut banks and Root-wads	1
	Substrate	4
	Macrophytes	0
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	1
	Undercut banks and Root-wads	2
	Substrate	4
	Macrophytes	0
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	1
	Undercut banks and Root-wads	2
	Substrate	4
	Macrophytes	0

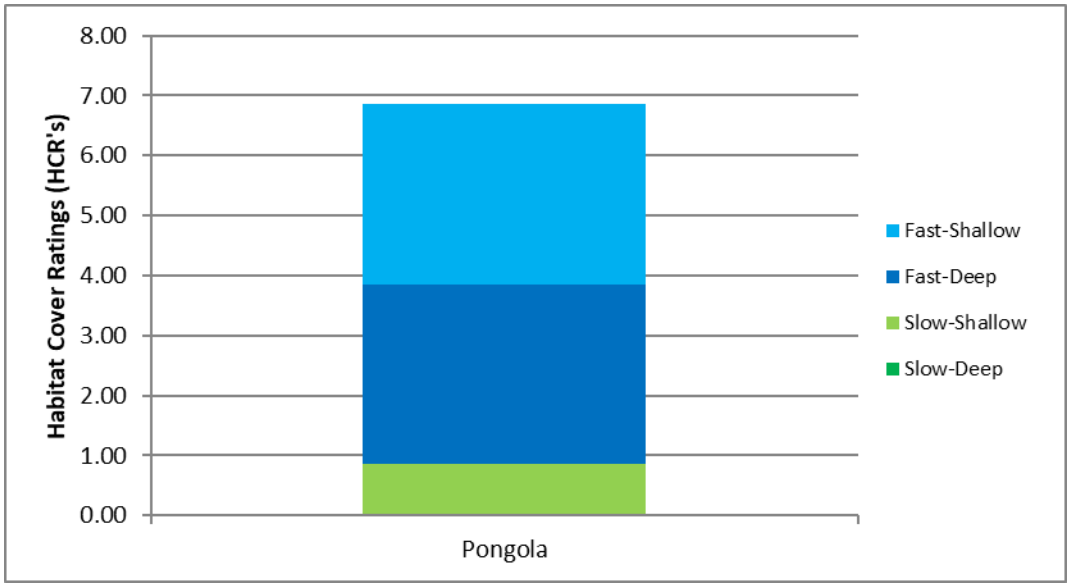

Figure E12 Fish Habitat Cover Ratings calculated for each velocity-depth category at site UP1 (July 2022 survey)

E9.1.2 Fish

EWR study (B. Paxton, July 2014 survey): Of the 29 fish species expected at the EWR Site UP1 on the Pongola River under reference conditions (Kleynhans et al. 2007; Department of Water Affairs 2013, National database records SAIAB and KZN Wildlife), four species were collected during the course of the 2014 survey at FROCs equal to or lower than expected **(Table E16**). EWR Site UP1 exhibited a wide diversity of habitat types including FD, FS and SD as well as a diversity of cover types including large bed structure (boulders), and marginal vegetation. It is presumed therefore that the site is capable of supporting all the species expected to be present under reference conditions. A FRAI sore of 70.1% falling in a category C (moderately modified from natural conditions) was calculated in the 2014 EWR study

July 2022 rapid site visit (P. Kotze): Six indigenous fish species were sampled (**Table E16**) during the July 2022 survey with various intolerant and moderately intolerant species being present. *Chiloglanis anoterus* was the most abundant species present at the site. Various rheophilic species was also sampled. Habitat diversity and abundance for fish was high at the site with fast-shallow and fast-deep being especially well represented. Various refinements were made to the 2014 FRAI model (see introduction section for a description of the approach followed and **Table E17**) with an amended 2022 FRAI score of 73.9 calculated (Category C) (**Table E17**).

Table E16 Fish species sampled (abundance and CPUE) at site EWR UP1 during July 2014 (Paxton) and July 2022 (Kotze).

Scientific Name	English Common Name	2014/07		2022/07	
		Abundance (N)	CPUE (ind/hr)	Abundance	CPUE (ind/hr)
Chiloglanis anoterus	Pennant Tail Suckermouth (Or Rock Catlet)	4	4.8	30	51.4
Chiloglanis swierstrai	Lowveld Suckermouth (Or Rock Catlet)			10	17.1
Labeobarbus marequensis	Largescale Yellowfish			2	3.4
Labeobarbus polylepis	Smallscale Yellowfish	2	2.4		
Labeo cylindricus	Redeye Labeo			1	1.7

Scientific Name	English Common Name	2014/07		2022/07	
		Abundance (N)	CPUE (ind/hr)	Abundance	CPUE (ind/hr)
Labeo molybdinus	Leaden Labeo	1	1.2		
Marcusenius pongolensis	Bulldog			3	5.1
Opsaridium peringueyi	Southern Barred Minnow			2	3.4
Tilapia sparrmanii	Banded Tilapia	1	1.2		

Table E17 Fish species expected to occur at site EWR UP1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, amended 2022 FROC reference and PES ratings and comparison of 2014 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Probability of occurrence in reach or at site*	2014 EWR study (Paxton): Reference FROC	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
AMAR	*ANGUILLA MARMORATA*	Low	3.00	1	0.5
AMOS	*ANGUILLA MOSSAMBICA*	High/definite	3.00	1	0.5
AURA	*AMPHILIUS URANOSCOPUS*	High/definite	3.00	3	2
BANO	*ENTEROMIUS ANOPLUS*	High/definite	3.00	1	0.5
BARG	*BARBUS ARGENTEUS*	High/definite	3.00	1	0.5
BMAR	*LABEOBARBUS MAREQUENSIS*	High/definite	3.00	3	2
BPAU	*BARBUS PALUDINOSUS*	Low	3.00	1	0.5
BPOL	*LABEOBARBUS POLYLEPIS*	High/definite	3.00	3	2
BTRI	*BARBUS TRIMACULATUS*	Moderate	3.00	2	1
BUNI	*BARBUS UNITAENIATUS*	High/definite	3.00	2	1
CANO	*CHILOGLANIS ANOTERUS*	High/definite	3.00	5	4.5
CEMA	*CHILOGLANIS EMARGINATUS*	High/definite	3.00	1	0.5
CSWI	*CHILOGLANIS SWIERSTRAE*	High/definite	Not included	2	1.5
CGAR	*CLARIAS GARIEPINUS*	High/definite	3.00	3	3
LCYL	*LABEO CYLINDRICUS*	Low	3.00	3	2
LMOL	*LABEO MOLYBDINUS*	Moderate	3.00	3	2
LROS	*LABEO ROSAE*	Low	3.00	1	0.5
MBRE	*MESOBOLA BREVIANALIS*	Moderate	3.00	1	0.5
MMAC	*MARCUSENIUS PONGOLENSIS (MACROLEPIDOTUS)*	High/definite	3.00	2	1.5
OMOS	*OREOCHROMIS MOSSAMBICUS*	High/definite	3.00	2	1
OPER	*OPSARIDIUM PERINGUYI*	Not included	Not included	2	1.5
PCAT	*PETROCEPHALUS WESSELSI*	Low	3.00	1	0.5
PPHI	*PSEUDOCRENILABRUS PHILANDER*	Low	3.00	1	0.5
TREN	*TILAPIA RENDALLI*	Low	3.00	1	0.5
TSPA	*TILAPIA SPARRMANII*	High/definite	3.00	3	2
VNEL	*VARICORHINUS NELSPRUITENSIS*	High/definite	3.00	2	1
FRAI (%)			**70.1**		**73.9**
FRAI (EC)			**C**		**C**

*Based on PESEIS (2014) and other available information (survey data).
Refer to **Table E4** for FROC ratings.

E10 EWR AS1 (ASSEGAAI RIVER)

E10.1.1 Site description and fish habitat assessment (July 2022 survey)

EWR AS1 is situated in the Assegaai River (S27.06230 E30.98880) in RU W51-3 and IUA W52 (W5 Downstream major dams and Hlelo). The Assegai River has a pool-rapid morphology with the rapids dominated by boulder; silt and fine gravel deposits with limited cobble characterize the

pools. The flood bench comprises medium to large boulder within a sand matrix. BIsland with reeds commonly develop on rapids. A truncated flood channel lies along the edge of the right bank flood bench, against the hillslope.

Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E13**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E18** and **Figure E14**).

Figure E13 EWR AS1 (July 2022)

Table E18 Habitat Cover Ratings for fish at site EWR AS1 during July 2022.

Velocity-depth class	Sites	Assegaai
SLOW-DEEP (>0.5m; <0.3m/s)	Abundance	0
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	0
	Macrophytes	0
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	2
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	3
	Macrophytes	2
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	4
	Macrophytes	1
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	2
	Undercut banks and Root-wads	1

Velocity-depth class	Sites	Assegaai
	Substrate	4
	Macrophytes	1

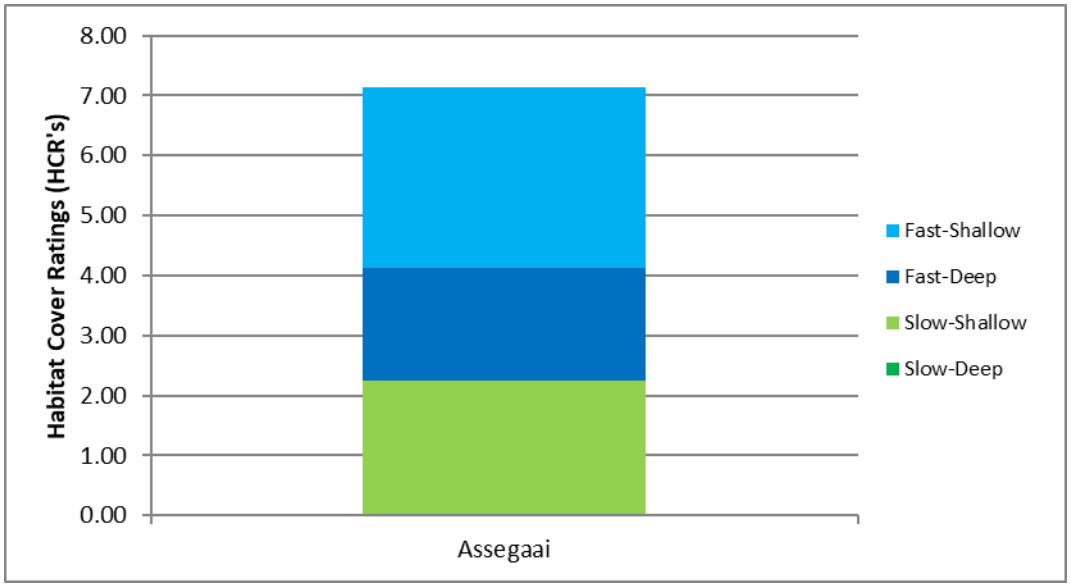

Figure E14 Fish Habitat Cover Ratings calculated for each velocity-depth category at site AS1 (July 2022 survey).

E10.1.2 Fish

EWR study (B. Paxton, July 2014 survey): Based on Kleynhans *et al*. (2007), National database records (SAIAB and KZN Wildlife) and the Department of Water Affairs (2013), 18 fish species were expected at EWR Site AS1 on the Assegai River under reference conditions. Of these, four were collected during the course of the 2014 survey **(Table E18**). The flow habitat conditions observed at the site were considered adequate to support fish species with a preference for FS, FD habitat classes and the conditions are not expected to be substantially different from reference, although some impacts are expected from the Heyshope Dam upstream.

Five fish species which are expected at the site under reference conditions are considered intolerant of modified physico-chemical conditions and two of these were found to be present during survey (*C. anoterus* and *C. emarginatus*). Water quality at the site is not therefore expected to be significantly impaired. Fish cover in the form of overhanging vegetation woody debris, as well as undercut banks and root wads were abundant and one species with a preference for cover was found to be present (*B. trimaculatus*). One species with a strong requirement for migration (*L. marequensis*) were present and two with an intolerance for no-flow as well as FD and FS flow conditions were also found to be present (*C. anoterus* and *C. emarginatus*). The trend at this site is considered to be stable.

IUCMA monitoring (2010-2019): IUCMA 2019: The fish assemblage recorded at site EWR AS1 (IUCMA site W5ASSE-ZANDB) for the 2019 survey consisted of only four species of an expected 19 species of indigenous fish for this reach, one species more than found during the 2015 survey, but three species less for the 2010 survey (**Table E19**). The most abundant fish species collected was *Labeobarbus marequensis*, a hardy rheophilic species (moderately tolerant to modified water quality – 2.9 on Fish sensitivity Scales) which was also the most abundant species during the 2010 and 2015 surveys. The riffle dwelling fish species, *Chiloglanis anoterus,* was the second most

abundant species for this site since 2010, collected in the fast-shallow habitat available. This species is intolerant to modified water quality (4.5 Fish sensitivity Scales) and may be an indication why it was not collected in high abundance. The alien and invasive species, *Micropterus salmoides,* was as with the 2015 survey, present at this site. The CPUE for the 2019 survey was calculated at 2.88 (141 individuals; 49 minutes) indicating a decline in abundance from the 2010 and 2015 surveys when a CPUE of 11.21 and 4.93 respectively was calculated. A possible reason for the lower abundance of fish and species collected, could be related to reduced water quality. A Fish EcoStatus rating for 2019 of W5ASSE-ZANDB was calculated at 66.3% based on all available information, placing this reach in an Ecological Category C (moderately impaired with low diversity of species and abundance) consistent with the 2015 survey results (Category C – 62%).

July 2022 rapid site visit (P. Kotze): Four indigenous fish species were sampled during 2022 (Table 7-2) with the intolerant *C. anoterus* being the most abundant species at the site. Another intolerant and also rheophilic species (*A. uranoscopus*) as well as *L. nelspruitensis* was also sampled. The refined FRAI model resulted in a score of 69.2% (category C), being slightly better than the 2019 score by IUCMA (69.2%). The abundance of C. anoterus at the time of the 2022 survey may be an indication of improved conditions (potentially flow and water quality) after a good rainy season. The 2022 FRAI score was lower than the 2014 EWR score (81.8%) and also resulted in a decrease from a category B/C to a C (more comparable with recent IUCMA assessment) (**Table E20**).

Table E19 Fish species sampled (abundance and CPUE) at site EWR AS1 during July 2014 (Paxton), between 2010 1nd 2016 (IUCMA) and July 2022 (Kotze).

Scientific Name	English Common Name	2014/07[A]		2010-2019[C]	2022/07[B]	
		Abundance	CPUE*	Presence (X)	Abundance	CPUE*
Amphilius uranoscopus	Stargazer (Mountain-Catfish)	5	5.0	X	1	2.4
Enteromius trimaculatus	Threespot Barb	1	1.0			
Labeobarbus marequensis	Largescale Yellowfish	9	9.0	X		
Chiloglanis anoterus	Pennant Tail Suckermouth (Or Rock Catlet)			X	30	72.0
Chiloglanis emarginatus	Phongola suckermouth	5	5.0	X		
Pseudocrenilabrus philander	Southern mouthbrooder			X		
Tilapia sparrmanii	Banded Tilapia			X	1	2.4
Labeobarbus nelspruitensis (Varicorhinus nelspruitensis)	Incomati Chiselmouth			X	3	7.2
Micropterus salmoides (alien)	Largemouth bass (alien)			X		

*CPUE in individuals/hr.
A: 2014 EWR study (B. Paxton)
B: 2022/07 Rapid site visit (P. Kotze)
C: IUCMA monitoring (201/2015/2019) (MTPA, F. Roux, A. Hoffman).

Table E20 Fish species expected to occur site EWR AS1 (or SQ reach) under reference conditions, 2014 FROC reference ratings, IUCMA expected species, amended 2022 FROC reference and PES ratings and comparison of 2014, 2019 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Probability of occurrence in reach or at site*	2014 EWR study (Paxton): Reference FROC	IUCMA expected spp (2019_	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
AMOS	*ANGUILLA MOSSAMBICA*	High/definite	2.00	X	1	0.5
AURA	*AMPHILIUS URANOSCOPUS*	High/definite	2.00	X	2	1.5
BANO	*BARBUS ANOPLUS*	Moderate	3.00	X	3	2
BARG	*BARBUS ARGENTEUS*	High/definite	3.00	X	3	2
BMAR	*LABEOBARBUS MAREQUENSIS*	High/definite	4.00	X	4	3
BPOL	*LABEOBARBUS POLYLEPIS*	High/definite	4.00	X	4	2
BTRI	*BARBUS TRIMACULATUS*	Low	4.00	X	2	1
BUNI	*BARBUS UNITAENIATUS*	Low	3.00	X	2	1
BVIV	*BARBUS VIVIPARUS*	Low	3.00	X	2	1
CANO	*CHILOGLANIS ANOTERUS*	High/definite	High/definite	X	5	4
CEMA	*CHILOGLANIS EMARGINATUS*	Low	2.00	X	2	1
CSWI	*CHILOGLANIS SWIERSTRAI*	Moderate	2.00	X	2	1
CGAR		Not listed		X	2	2
LCYL	*LABEO CYLINDRICUS*	Low	2.00	X	1	0.5
LMOL	*LABEO MOLYBDINUS*	Moderate	4.00	X	2	1
OPER	*OPSARIDIUM PERINGUEYI*	Moderate	2.00	X	1	0.5
PPHI	*PSEUDOCRENILABRUS PHILANDER*	High/definite	4.00	X	4	3
TSPA	*TILAPIA SPARRMANII*	High/definite	4.00	X	4	3
VNEL	*VARICORHINUS NELSPRUITENSIS*	High/definite	2.00	X	2	1
FRAI (%)			**81.8**	**66.3**		**69.2**
FRAI (EC)			**B/C**	**C**		**C**

E11 EWR NG1 (NGWEMPISI RIVER)

E11.1.1 Site description and and fish habitat assessment (July 2022 Survey)

EWR NG1 was selected as an additional and new EWR site. EWR NG1 is situated in the Ngwempisi River (S26.679448 E30.70213) in RU W53-3 and IUA W52 (W5 Downstream major dams and Hlelo). The site is downstream of a gauging weir and Jericho and Morgenstond Dams. The site has a strong bedrock control and is dominated by bedrock and boulder. Channel morphology at the site is dominated by a complex island with multiple channels and downstream there is a pool-rapid sequence upstream of the gorge. The transect is located in a run across the downstream end of the island complex, crossing two main channels and a third minor channel running along the right bank (not visible on the photographs).

Photographs of the EWR site reflecting fish habitats (July 2022) are illustrated in **Figure E15**. The habitats available for fish at the time of the July 2022 survey is reflected as habitat cover ratings (**Table E21** and **Figure E16**).

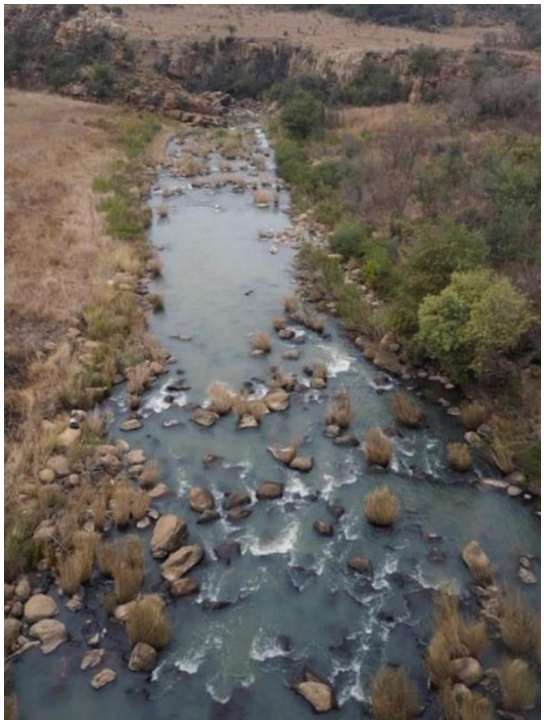

Figure E15 EWR NG1 Ngwempisi River (July 2022)

Table E21 Habitat Cover Ratings for fish at site EWR NG1 during July 2022

Velocity-depth class	Sites	Ngwempisi
SLOW-DEEP (>0.5m; <0.3m/s)	Abundance	1
	Overhanging vegetation	2
	Undercut banks and Root-wads	2
	Substrate	3
	Macrophytes	0
SLOW-SHALLOW (<0.5m; <0.3m/s)	Abundance	2
	Overhanging vegetation	2
	Undercut banks and Root-wads	1
	Substrate	3
	Macrophytes	1
FAST-DEEP (>0.3m; >0.3m/s)	Abundance	2
	Overhanging vegetation	0
	Undercut banks and Root-wads	0
	Substrate	4
	Macrophytes	0
FAST-SHALLOW (<0.3m; >0.3m/s)	Abundance	3
	Overhanging vegetation	1
	Undercut banks and Root-wads	1
	Substrate	4
	Macrophytes	0

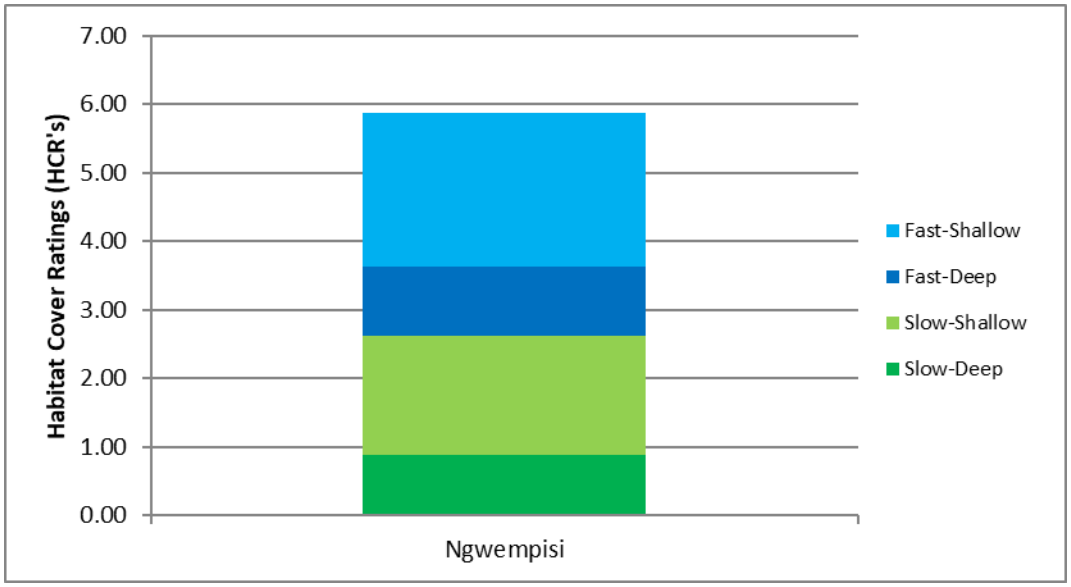

Figure E16 Fish Habitat Cover Ratings calculated for each velocity-depth category at site NG1 (July 2022 survey)

E11.1.2 Fish

This site was a new inclusion and hence no data is available as part of the 2014 EWR study. This site form part of the IUCMA (MTPA) monitoring programme and therefore some valuable biological information was available.

IUCMA (2019) (site W5NGWE-SKURWE): The fish assemblage recorded for the 2019 survey consisted of only five species of an expected 14 species of indigenous fish for this reach, two species less than recorded during the 2015 survey, but only one species less for the 2010 survey. One exotic species, *Micropterus salmoides*, not expected and previously recorded, was collected for the first time (**Table E22**). The most abundant fish species collected was the riffle dwelling fish species, *Chiloglanis anoterus* comprising of 69.16% (74 individuals) of the fish assemblage. *Labeobarbus polylepis* was not collected during the present survey, but their absence can be attributed to their migratory behaviour. No Cichlids were collected during the present survey. In general, FROC of the recorded species is low and could have been altered as a result of flow regulation and loss of instream habitat due to sedimentation. The CPUE for the present survey was calculated at 2.38 (107 individuals; 45 minutes) indicating a sharp decline in abundance from the 2010 and 2015 surveys when a CPUE of 10.10 and 10.62 respectively was calculated. A possible reason for the lower abundance of fish and species collected, could be related to reduced water quality. A Fish EcoStatus rating of 73% was calculated for this reach based on all available information, placing this reach in an Ecological Category C (moderately impaired with low diversity of species and abundance), indicating a decline in the Fish EcoStatus from the Category B (83.1%) –largely natural with few modifications during the 2015 survey.

July 2022 rapid site visit (P. Kotze): Eight indigenous fish species were sampled (**Table E22**) during the rapid 2022 survey comparing well with the species composition noted by IUCMA monitoring between the period 2010 and 2019. As described by the IUCMA report, *C. anoterus* was again found to be the most abundant species at the site (**Table E22**). Overall, there are no indication (based on the comparison of the 2019 and 2022) fish survey results to indicate any notable recent improvement or deterioration, and a 2022 FRAI score of 72.9% (category C) was calculated (**Table E23**).

Table E22 Fish species sampled (abundance and CPUE) at site EWR NG1 during 2010-2019 (IUCMA/MTPA) and July 2022 (Kotze)

Scientific Name	English Common Name	2010-2019[A]	2022/07[B]	
		Presence (X)	Abundance	CPUE*
Amphilius uranoscopus	Stargazer (Mountain-Catfish)	X	2	3.3
Enteromius crocodilensis	Rosefin Barb	X	1	1.7
Labeobarbus marequensis	Largescale Yellowfish	X	8	13.3
Labeobarbus polylepis	Smallscale Yellowfish	X	1	1.7
Chiloglanis anoterus	Pennant Tail Suckermouth (Or Rock Catlet)	X	30	50.0
Clarias gariepinus	Sharptooth Catfish		1	1.7
Marcusenius pongolensis (macrolepidotus)	Bulldog	X	1	1.7
Tilapia sparrmanii	Banded Tilapia	X	1	1.7
Micropterus salmoides (alien)	Largemouth bass	X		

A: IUCMA monitoring (2010/2015/2019) (MTPA, F. Roux, A. Hoffman).
B: 2022/07 Rapid site visit (P. Kotze).

Table E23 Fish species expected to occur site at EWR AS1 (or SQ reach) under reference conditions, IUCMA expected species, 2022 FROC reference and PES ratings and comparison of 2019 and 2022 FRAI scores and categories

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Probability of occurrence in reach or at site*	IUCMA (2019)	Refined: Reference FROC (2022)	Refined: Present FROC (observed and habitat derived)
MMAC	*MARCUSENIUS MACROLEPIDOTUS*	High/Definite	X	2	1.5
AMOS	*ANGUILLA MOSSAMBICA*	High/Definite	X	1	0.5
BANO	*BARBUS ANOPLUS*	Low	X	2	0.5
BARG	*BARBUS ARGENTEUS*	High/Definite	X	3	2.5
LCYL	*LABEO CYLINDRICUS*	Moderate	X	2	0.5
LMOL	*LABEO MOLYBDINUS*	Moderate	X	2	0.5
BMAR	*LABEOBARBUS MAREQUENSIS*	Moderate	X	4	3
BPOL	*LABEOBARBUS POLYLEPIS*	High/Definite	X	4	2
AURA	*AMPHILIUS URANOSCOPUS*	High/Definite	X	4	3
CGAR	*CLARIAS GARIEPINUS*	Not listed	X	5	4
CANO	*CHILOGLANIS ANOTERUS*	High/Definite	X	5	4
CEMA	*CHILOGLANIS EMARGINATUS*	Low	X	1	0.5
PPHI	*PSEUDOCRENILABRUS PHILANDER*	Moderate	X	2	1
TSPA	*TILAPIA SPARRMANII*	Moderate	X	3	2
FRAI (%)			**73**		**73%**
FRAI EC			**C**		**C**

E12 REFERENCES

Department of Water & Sanitation (DWS). 2014. Chief Directorate – Water Ecosystems: Reserve determination study of selected surface water and groundwater resources in the Usutu/Mhlathuze Water Management Area. River Intermediate EWR – Volume 3: Specialist Reports. Prepared by Tlou Consulting (Pty) Ltd and Southern Waters Ecological Research and Consulting. Report no: RDM/WMA6/CON/COMP/0813.

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Kleynhans CJ, Louw MD, Moolman J. 2007. River Ecoclassification: manual for Ecostatus Determination (Version 2). Module D: Volume 2 Reference Frequency of Occurrence of fish species inn South Africa. *WRC Report TT 331/08*. Water Research Commission, Pretoria.

E13 ADDENDUM: SELECTED FISH PHOTOS (JULY 2022 SURVEY)

Plate 1: *Awaous aenofuscus* (Matigulu, July 2022).

Plate 2: *Labeobarbus natalensis* (Matigulu, July 2022).

Plate 3: *Monodactylus falciformis* (Matigulu, July 2022).

Plate 4: *Marcusenius pongolensis* (Pongola River, July 2022)

Plate 5: *Opsaridium peringueyi* (Pongola River, July 2022)

Plate 6: *Amphilius uranoscopus* (Ngwempisi River, July 2022).

10 APPENDIX F: MACRO-INVERTEBRATES AND THE MIRAI

F1 BACKGROUND

A comprehensive Reserve determination (Report no: RDM/WMA6/CON/COMP/0813) was conducted on the Usutu/Mhlatuze Water Management Areas by Tlou Consulting in 2013/2014 (DWS, 2014). The main objective of the 2014 macroinvertebrate study was to identify the relationship between macroinvertebrates and flow level changes, and to predict what impacts, if any, will occur with changes to the present-day flow regime. The original macro-invertebrate results together with the July 2022 reconnaissance results as well as other readily available information was used to refine and update the MIRAI for the purpose of the current study.

F2 EWR SITES

The Usutu to Mhlatuze catchment comprises the study area, with major rivers including the Usutu, Pongola, Mhlatuze, Mfolozi and Mkuze. Eight sites were selected within the study area, including the new Ngwempisi River site. These sites were visited during the July 2022 field trip.

Table F1 EWR sites used as part of the current study (visited during July 2022)

EWR site	River	Co-ordinates
EWR MA1	Matigulu River	S29.02010 E31.47040
EWR NS1	Nseleni River	S28.63410 E31.92517
EWR WM1	White Mfolozi River	S28.23146 E31.18666
EWR BM1	Black Mfolozi River	S27.93890 E31.21030
EWR MK1	Mkuze River	S27.59210 E32.21800
EWR UP1	Upper Pongola River	S27.36413 E30.96962
EWR AS1	Assegaai River	S27.06230 E30.98880
EWR NG1	Ngwempisi River	S26.679448 E30.70213

The Macro-invertebrate specialist component as part of this study was performed by Miss C. Todd. The results generated during the initial EWR study (2013/14) will primarily be used by the current project to compare historical invertebrate distribution data, status of the EWR sites during that period and asses the application of appropriate indicator taxa. These search criteria provide information considered relevant and necessary in order to fulfil the requirements of predicting responses of selected indicator taxa to changes in different flow regimes.

A rapid field survey was undertaken by the current EWR specialist team during July 2022, in order to familiarise themselves with the EWR sites and add an additional site in the Ngwempisi River.

F3 INITIAL SASS SCORES AND INFORMATION REGARDING THE RESULTANT ECOCLASSIFICATION

Site		SASS	% Invertebrate EC	EC
Site AS1_W51E-2049	MIRAI[1] Assegaai River, North Eastern Highlands, 4.06E	6.68	78.6	B/C
Site BM1_W22A-2610	MIRAI Black Mfolozi BM1 Upper Site 3 1 Lowveld V2	6.51	81.2	B/C

Site		SASS	% Invertebrate EC	EC
Site BM2_W22C-2688	MIRAI Black Mfolozi, BM2, Downstream Site, North Eastern Uplands 14.04	6.14	79.8	B/C
Site MA1_W11A-3612	MIRAI Matigulu River, North Eastern Coastal Belt 17.01D	6.0	80.9	B/C
Site MK1_W31J-2480	MIRAI Mkuze River, Lowveld 3.08E	5.0	77.7	C
Site NS1_W12G-3229	MIRAI Nseleni, NE Uplands E, 14.05	5.08	79.4	B/C
Site UP1_W42E-2221	MIRAI Pongola, Upper Site, 3.1 Lowveld	6.7	79.5	B/C
Site WM1_W21H-2897	MIRAI White Mfolozi, NE Uplands D 14.05	6.0	81.1	B/C
	MIRAI Ngwempisi	6.6	87.3	B

1 Macroinvertebrate Response Assessment Index.

F4 EVALUATION OF THE 2014 MIRAI RESULTS

The 2014 report made use of the following macroinvertebrate indicator groups and taxa:

- **Macro-invertebrate indicator groups**

Group and preferences	Taxon and sensitivities
Vegetation dwellers with slow flowing water. Slow (0.1 - 0.3 m/s) with vegetation.	Atyidae (Freshwater Shrimps) - Sensitive
	Coenagrionidae (Sprites & Blues) – Low sensitivity
Cobble dwellers with fast flow. Very fast (>0.6 m/s) with cobbles.	Palaemonidae (Freshwater Prawns) - Sensitive
	Perlidae (Stoneflies) - Highly Sensitive
	Philopotamidae - Sensitive
	Psephenidae (Water pennies) - Sensitive
	Hydropsychidae (Caddisflies) - Low to highly sensitive
Cobble dwellers with moderate flow. Moderate (0.3 - 0.6 m/s) with cobbles.	Heptageniidae (Flatheaded mayfly) - Highly Sensitive
	Elmidae (Riffle Beetles) - Sensitive
Gravel, sand, mud dwellers. Slow (0.1 - 0.3 m/s)	Gomphidae (Clubtails) - Low
Gravel, sand, mud dwellers. Moderate (0.3 - 0.6 m/s)	Polymitarcyidae (Pale Burrowers) - Sensitive
Standing water over cobbles. Standing water (<0.1 m/s) with cobbles.	Leptophlebiidae (Prongills) - Moderate

- **Presence of macro-invertebrate indicators used by the 2014 surveys**

Macroinvertebrate distribution records were obtained from Resource Quality Services, DWS, with data obtained mainly from the Rivers Database for the purpose of compiling macroinvertebrate reference conditions for the various regions. Thirion (2014) contains distribution maps per family-level macroinvertebrate taxon with associated detail and is useful as a graphic means of interpreting macroinvertebrate distributions.

- **The macro-invertebrate indicators used by the 2014 reports**

Indicators	EWR sites						
	AS1	UP1	NS1	MK1	BM1	WM1	MA1
Atyidae (Freshwater Shrimps)	X				X		
Palaemonidae (Freshwater Prawns)					X	X	X
Perlidae (Stoneflies)	X	X			X		X
Hydropsychidae (Caddisflies)	X	X	X		X	X	X
Heptagenaidae (Flatheaded mayflies)	X	X			X	X	
Elmidae (Riffle beetles)			X			X	X

Indicators	EWR sites						
	AS1	UP1	NS1	MK1	BM1	WM1	MA1
Gomphidae (Clubtails)	X	X		X	X	X	X
Leptophlebidae (Pronggills)	X	X	X		X	X	X
Baetidae (Minnow mayflies)	X	X	X	X	X	X	X
Chironomidae (Midges)	X	X	X	X	X	X	X
Simulidae (Blackflies)	X	X	X	X	X	X	X
Coenagrionidae (Sprites and Blues)		X	X	X		X	X

F5 EWR MA 1 (MATIGULU RIVER)

F5.1.1 Site description (July 2022 survey)

Site MA1 on the Matigulu River occurs within the North Eastern Coastal Belt 17.01 Ecoregion, in the Upper Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F1** shows the EWR MA1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Rapids at controls over boulders and bedrock. Some riffles in side channels with rocks and cobble.
- Vegetation: Extensive marginal reed beds along the stream edges and islands.
- Gravel, sand and mud (GSM): Course sediment in most areas where the flow does not create too much turbulence.

Figure F1 Riverine biotopes at EWR MA1 (July 2022)

F5.1.2 Macro-invertebrates

Reference condition - There would be approximately 65 taxa present with an associated SASS total score of 220 and an ASPT of 7. Key indicator species at the site during the current assessment:

- Palaemonidae, Perlidae, Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s).
- Coenagrionidae - inundated marginal vegetation.

F6 EWR NS1 (NSELENI RIVER)

F6.1.1 Site description (July 2022 survey)

Site NS1 on the Nseleni River occurs within the North Eastern Uplands 14.05 Ecoregion, in the Lower Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F2** shows the EWR NS1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Abundant shallow slow flow through rocks and fixed boulders. Some cobble riffles at stream controls.
- Vegetation: Abundant overhanging shrubs and woody vegetation. Most of the stream in a shady environment.
- Gravel, sand and mud: Coarse sand and gravel throughout the reach. Mud and fines in quiet backwaters

Figure F2 Riverine biotopes at EWR NS1 (July 2022)

F6.1.2 Macro-invertebrates

Reference condition - There would be approximately 70 taxa present with an associated SASS total score of 220 and an ASPT of 7. Key indicator species at the site during the current assessment:

- Hydropsychidae (>0.6 m/s) and Elmidae (0.3 – 0.6 m/s).
- Coenagrionidae - inundated marginal vegetation.

F7 EWR WM1 (WHITE UMFOLOZI RIVER)

F7.1.1 Site description (July 2022 survey)

Site WM1 on the White Mfolozi River occurs within the North Eastern Uplands 14.05 Ecoregion, in the Upper Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F3** shows the EWR WM1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Abundant deep, fast flowing rapids over bedrock and boulders between sandy runs. Some riffles in side channels with cobble.
- Vegetation: Restricted marginal reed patches along the edges and islands.
- Gravel, sand and mud: Abundant sediment in the pools and runs, however scoured in the rocky rapids.

Figure F3 Riverine biotopes at EWR WM1 (July 2022)

F7.1.2 Macro-invertebrates

Reference condition - There would be approximately 69 taxa present with an associated SASS total score of 220 and an ASPT of 7. Key indicator species at the site during the current assessment:

- Palaemonidae, Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s).

F8 EWR BM1 (BLACK UMFOLOZI RIVER)

F8.1.1 Site description (July 2022 survey)

Site BM1 on the Black Mfolozi River occurs within the Lowveld 3.1 Ecoregion, in the Upper Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F4** shows the EWR BM1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Abundant deep, fast flowing rapids over bedrock and boulders. Some riffles in side channels and controls with cobble.
- Vegetation: Marginal reed beds along the channels and islands.
- Gravel, sand and mud: Some fines in the pools, but the area is well-scoured due to the bedrock rapids.

Figure F4 Riverine biotopes at EWR BM1 (July 2022)

F8.1.2 Macro-invertebrates

Reference condition - There would be approximately 68 taxa present with an associated SASS total score of 220 and an ASPT of 7. Key indicator species at the site during the current assessment:

- Palaemonidae, Perlidae, Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s).

- Atyidae - inundated marginal vegetation.

F9 EWR MK1 (MKUZE RIVER)

F9.1.1 Site description (July 2022 survey)

Site MK1 on the Mkuze River occurs within the Lowveld 3.08 Ecoregion, in the Lower Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F5** shows the EWR MK1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: No Stones-in-current present in this reach; some faster channels with some gravel.
- Vegetation: Overhanging woody vegetation from the river banks (poor habitat), shrubs and grass overhanging undercut banks are favourable marginal habitat.
- Gravel, sand and mud: Most of the river bed is covered evenly with a combination of coarse or finer alluvial sediment.


Figure F5 Riverine biotopes at EWR MK1 (July 2022)

F9.1.2 Macro-invertebrates

Reference condition - There would be approximately 60 taxa present with an associated SASS total score of 150 and an ASPT of 7. Key indicator species at the site during the current assessment:

- Hydropsychidae (>0.6 m/s).
- Gomphidae - shallow-slow, sandy habitats.

F10 EWR UP1 (PONGOLA RIVER)

F10.1.1 Site description (July 2022 survey)

Site UP1 on the Pongola River occurs within the Lowveld 3.1 Ecoregion, in the Upper Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F6** shows the EWR UP1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Extensive deep, fast flowing rapids over boulders and bedrock. Some riffles in side channels with rocks and cobble.
- Vegetation: Extensive marginal reed beds and good overhanging vegetation along the river edges.
- Gravel, sand and mud: Mostly course sediment in backwaters and side channels.

Figure F6 Riverine biotopes at EWR UP1 (July 2022)

F10.1.2 Macro-invertebrates

Reference condition - There would be approximately 68 taxa present with an associated SASS total score of 220 and an ASPT of 7. Key indicator species at the site during the current assessment:

- Perlidae, Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s).
- Atyidae - inundated marginal vegetation.

F11 EWR AS1 (ASSEGAAI RIVER)

F11.1.1 Site description (July 2022 survey)

Site AS1 on the Assegaai River occurs within the North Eastern Highlands Ecoregion 4.06, within the Lower Foothills geomorphological zone (Kleynhans *et al*., 2007). **Figure F7** shows the EWR AS1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Abundant deep, fast flowing rapids over fixed boulders. Some riffles in side channels with rocks and cobble.
- Vegetation: Marginal reed beds along the pool and overhanging vegetation in side channels and along river run.
- Gravel, sand and mud: Some fines in the upstream pool, but most of the finer sediments scoured from the fast-flowing rapid.

Figure F7 Riverine biotopes at EWR AS1 (July 2022)

F11.1.2 Macro-invertebrates

Reference condition - There would be approximately 67 taxa present with an associated SASS total score of 250 and an ASPT of 7. The favourable MIRAI score of 86.4% (B) during the 2015 EWR studies, has declined to a B/C (78.6%) during the latest macro-invertebrate studies (2019).

Several taxa recorded up- and downstream from the site during previous surveys, were absent during both the 2015 and 2019 surveys. Key indicator species at the site during the current assessment:

- Perlidae, Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s).
- Atyidae - inundated marginal vegetation.

F12 EWR NG1 (NGWEMPISI RIVER)

F12.1.1 Site description (July 2022 survey)

Figure F8 shows the EWR NG1 site during July 2022, and the evaluation of riverine environment identified the following biotopes:

- Stones-in-current: Extensive deep, fast flowing rapids over boulders and bedrock. Some riffles in side channels with rocks and cobble.
- Vegetation: Extensive marginal reed beds and good overhanging vegetation along the river edges.
- Gravel, sand and mud: Mostly course sediment in backwaters and side channels.

Figure F8 Riverine biotopes at EWR NG1 (July 2022)

F12.1.2 Macro-invertebrates

Table F2 Summarised SASS5 form for NG1

Taxon	Stones	Vegetation	GSM	Total
Turbellaria 3	A	1	A	B
Perlidae 12	1			1
Baetidae >2 spp 12	B	B		B
Caenidae 6		A		A
Heptageniidae 10	A	1		A
Leptophlebiidae 13	B			B
Tricorythidae 9	B			B
Pyralidae 13	1			1
Coenagrionidae 4		A		A
Libellulidae 4	A			A
Corixidae 3	1	B		B
Naucoridae 7		A		A
Veliidae 5		A		A
Hydropsychidae 2spp = 6	B		1	B
Philopotamidae 10	A			A
Leptoceridae 6		A		A

Taxon	Stones	Vegetation	GSM	Total
Dytiscidae 5		1		1
Gyrinidae 5		A		A
Psephenidae 10	A			A
Culicidae 1			1	1
Chironomidae 2	A	A	B	B
SASS Score	107	68	12	140
No of families	13	12	4	21
ASPT	8.2	5.6	3.0	6.6

Estimated abundance: 1 = 1; A = 2 - 10; B = 11 - 100; C = 101 - 1000; D = >1000.

Key indicator species at the site during the current assessment:

- Perlidae, Philopotamidae, Psephenidae and Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s).
- Coenagrionidae - inundated marginal vegetation.

F13 REFERENCES

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Kleynhans, C.J., Louw, M.D. and Moolman J. 2007. River EcoClassification: manual for EcoStatus Determination (Version 2). Module D: Volume 2 Reference Frequency of Occurrence of fish species in South Africa. WRC Report TT 331/08. Water Research Commission, Pretoria.

11 APPENDIX G: RIPARIAN VEGETATION

G1 APPROACH AND METHODOLOGY

The Present Ecological State (PES) of the riparian zone for each of the sites was assessed using the Riparian Vegetation Response Assessment Index (VEGRAI) level 4 (Kleynhans *et al*., 2007; with modifications). The data and outcomes from the study done in 2013 have been used to support the current study with updates from additional components such as geomorphology and botanical name changes. Site descriptions and VEGRAI results have been replicated or summarised from the 2013 study hereinunder. For more site-specific detail please also refer to the EcoStatus and specialist DWS reports (DWS, 2014a; 2014b).

G2 EWR AS1: ASSEGAI RIVER

G2.1.1 Site Description

The extent of the assessment area for VEGRAI at the Assegaai River is shown in **Figure G1** and a photograph showing typical riparian vegetation in **Figure G2**.

Figure G1 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Assegaai River (upstream and downstream limits of site indicated by red lines)

Figure G2 Typical riparian vegetation at the Assegaai River, dominated by marginal and lower zone grasses and sedges, Cape Willow and alien Australian Wattle species.

G2.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: C (69.9%), Confidence: 3.2
General Vegetation Overview: The site occurs within Ithala Quartzite Sourveld which refers to a terrestrial vegetation type within the Grassland Biome (Mucina & Rutherford, 2006) and as such has much grassland influence. **Reference State:** Aerial photographs from 1961 to 2013 show a slight increase in woody cover in places, while Google Earth images © show no noticeable change since 2009. The expected reference condition is likely to have been dominated by non-woody riparian vegetation such as grasses, sedges and reeds with scattered clumps of woody, trees and shrubs, particularly along banks and upper zone alluvial features. **Present State:** A summary of the VEGRAI score is shown **in Table G1**. Sub-zones are described below: The marginal zone was dominated by a mixture of woody and non-woody vegetation, mostly dense; a likely response to flow regulation and reduced flooding disturbance (with Heyshope Dam upstream). Woody vegetation was dominated by *Salix mucronata* while non-woody vegetation was dominated by reeds, sedges and grasses. *Salix mucronata* provides good overhanging cover for instream fauna, as does *Ishaemum fasiculatum* which grows into the water. *Gomphostigma virgatum* was absent at the site, possibly due to competition (shading) from *S. mucronata*, again a likely response to flow regulation. The lower zone consisted mostly of dense non-woody vegetation but with a dense band of *S. mucronata* along the stream side. Species were similar to the marginal zone with the addition of *Cynodon dactylon*. *Syzygium* species were absent in the zone.

Riparian vegetation: PES: C (69.9%), Confidence: 3.2
The upper zone consisted of a floodplain area with several high flow channels and backwater areas. Vegetation comprised a mix of woody and non-woody vegetation but dominated by woody vegetation with different species from the marginal and lower zones: Dominant woody species were *Searsia gerarrdii* and *Combretum erythrophyllum*. Perennial alien species such as *Sesbanea punicea* and *Acacia mearnsii* were present but with low cover (5%) of the zone. The density of woody cover suggests the reduction of flooding disturbance in the flow regime. *Ziziphus mucronata* and *Syzygium* species were absent. The bank was dominated by woody vegetation, mostly thicket, with some open grassland in places. Perennial alien species had invaded the banks with up to 50% cover in places. Dominant species were *A. mearnsii, A. melanoxylon, A. caffra, Lantana camara* and *Diospyros lyceoides*. *Ziziphus mucronata* was absent. Some wood harvesting was prevalent.

Table G1 Summary detail of level 4 VEGRAI for the Assegaai River

LEVEL 4 ASSESSMENT	Assegaai River			26 November 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	76.9	6.2	3.2	1.0	8.0
Lower Zone	78.5	9.4	3.0	2.0	12.0
Upper Zone	70.5	42.3	3.4	3.0	60.0
MCB	60.2	12.0	3.4	4.0	20.0
LEVEL 4 VEGRAI (%)				69.9	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				3.2	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	76.9	78.5	70.5	60.2	
EC (Zone)	**C**	**B/C**	**C**	**C/D**	
Confidence (Zone)	3.2	3.0	3.4	3.4	

G3 EWR BM1: BLACK MFOLOZI RIVER

G3.1.1 Site Description

The extent of the assessment area for VEGRAI at the Black Mfolozi River (site BM1) is shown in **Figure G3** and a photograph showing typical riparian vegetation in **Figure G4**.

Figure G3 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Black Mfolozi (BM1) River (upstream and downstream limits of site indicated by red lines)

Figure G4 Typical riparian vegetation at the Black Mfolozi River (site BM1), dominated by grass, reeds and sedges along the valley floor and a woody upper zone

G3.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: C (74.9%), Confidence: 3.2

General Vegetation Overview:
The site occurs within Northern Zululand Sourveld which refers to a terrestrial vegetation type within the Savanna Biome (Mucina & Rutherford, 2006) and as such terrestrial tree components are expected to occur naturally within the riparian zone.

Reference State:
Aerial photographs from 1943 to 2014 show no noticeable change in woody cover. The expected reference condition is likely to have been dominated by a mix of woody and non-woody riparian vegetation.

Present State:
A summary of the VEGRAI score is shown in **Table G2**. Sub-zones are described below:

The marginal zone was dominated by non-woody vegetation, but *Salix mucronata* was expected and appeared missing. Recent large flood disturbance was evident at the time of assessment. Reeds dominated pools and quiet areas, while sedges and grasses dominated elsewhere. Sedge and grass clumps also occurred instream and were associated with cobble outcrops. *Breonadia salicina* was also absent.

The lower zone was dominated by non-woody vegetation, mainly grasses and sedges with some reeds near pools areas. All woody individuals were small, damaged or stunted and mostly alien. *Sesbanea* and *Lantana* cover was up to 20% in places and many weed species were present. *Syzygium guineense* and *Combretum erythrophyllum* were absent, although the latter was present in the upper zone. Grazing pressure and plant harvesting was high.

The upper zone was dominated by non-woody vegetation, but wood remnants were visible. The prevalence of terrestrial woody (such as *D. cinerea* and *Vachellia sieberiana*) and alien (*Sesbanea*, *Lantana* and *Melia azedrach*) species was high. Harvesting and overgrazing occurred. Bedrock features were mostly clear of vegetation. Few individuals of *F. sycomorus, S. cordatum* and *C. erythrophyllum* existed and *S. guineense* was absent.

The MCB was dominated by thick and encroached woody vegetation, mainly terrestrial species. Dominant species were *C. erythrophyllum* and V*. sieberiana* and *S. africana* was absent. The right bank (RB) comprised alluvium while the left bank (LB) consisted predominantly of bedrock.

Table G2 Summary detail of level 4 VEGRAI for the Black Mfolozi River

LEVEL 4 ASSESSMENT	Black Mfolozi River			28 November 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	80.1	5.0	3.2	1.0	6.3
Lower Zone	76.8	7.2	3.0	2.0	9.4
Upper Zone	74.9	44.5	3.4	3.0	59.4
MCB	72.9	18.2	3.4	4.0	25.0
LEVEL 4 VEGRAI (%)				74.9	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				3.2	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	80.1	76.8	74.9	72.9	
EC (Zone)	**B/C**	**C**	**C**	**C**	
Confidence (Zone)	3.2	3.0	3.4	3.4	

G4 EWR BM2: BLACK MFOLOZI RIVER

G4.1.1 Site Description

The extent of the assessment area for VEGRAI at the Black Mfolozi River (Site BM2) is shown in **Figure G5** and a photograph showing typical riparian vegetation in **Figure G6**.

Figure G5 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Black Mfolozi (BM2) River (upstream and downstream limits of site indicated by red lines)

Figure G6 Typical riparian vegetation at the Black Mfolozi (Site BM2) dominated by open bedrock with patches of hydrophilic[2] grasses and sedges

G4.1.2 Results and Interpretation of the VEGRAI

The second site on the Black Mfolozi was similar to the first in terms of vegetation, just with more influence by bedrock. Summary VEGRAI scores are shown in **Table G3**.

Table G3 Summary detail of level 4 VEGRAI for the Black Mfolozi River

LEVEL 4 ASSESSMENT	Black Mfolozi River			28 November 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	84.5	5.3	3.2	1.0	6.3
Lower Zone	76.8	7.2	3.0	2.0	9.4
Upper Zone	74.9	44.5	3.4	3.0	59.4
MCB	78.8	19.7	3.4	4.0	25.0
LEVEL 4 VEGRAI (%)				76.7	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				3.2	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	84.5	76.8	74.9	78.8	
EC (Zone)	**B**	**C**	**C**	**B/C**	
Confidence (Zone)	3.2	3.0	3.4	3.4	

G5 EWR MA1: MATIGULU RIVER

G5.1.1 Site Description

The extent of the assessment area for VEGRAI at the Matigulu River is shown in **Table G7** and a photograph showing typical riparian vegetation in **Table G8**.

[2] Hydrophilic vegetation grows in water or on substrates that are at least periodically inundated (i.e., plants typically found in wet habitats).

Figure G7 **Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Matigulu River (upstream and downstream limits of site indicated by red lines)**

Figure G8 **Typical riparian vegetation at the Matigulu River included grasses, sedges and reeds with scattered trees within the macro channel floor and more dense trees along the banks (background)**

G5.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: B/C (79.4%), Confidence: 3.0

General Vegetation Overview:
The site occurs within KwaZulu-Natal Coastal Belt which refers to a terrestrial vegetation type within the Indian Ocean Coastal Belt Biome (Mucina & Rutherford, 2006).

Reference State:
Aerial photographs from 1937 to 2013 show no noticeable trending change in woody cover other than localized oscillatory dynamics probably associated with large flooding events. Google Earth Imagery © since 2009 also show no evidence of trending changes to vegetation. The expected reference condition is likely to have been dominated by a mix of woody and non-woody riparian vegetation.

Present State:
A summary of the VEGRAI score is shown in **Table G4**. Sub-zones are described below:

The marginal zone was dominated by non-woody vegetation, mostly reeds, sedges and grasses, with high vegetative cover. The sub-zone was mostly cobble and boulder with some alluvial deposits. Dominant habitats included grass in the water (*Ishaemum faciculatum*), sedge and grass banks and reed clumps in the water. Impacts were low, with cattle at the site (no overgrazing prevalent), low prevalence of aliens and no large dams upstream. Water abstraction and farm dams would have reduced flow however and resulted in some regulation.

The lower zone was dominated by non-woody vegetation but with scattered prevalence of *Syzygium gerrardii, S. cordatum* and *Ficus sycomorus*. Grasses dominated but common habitats included reed beds (patches) and cobble sedge / grass bars. *S. guieneense, B. salicina* and *C. erythrophyllum* were absent.

The upper zone consisted of mixed woody and non-woody vegetation with a distinct absence of tall trees. This may be due to recent large floods or wood harvesting. *C. erythrophyllum*, large *Ficus* and *T. emetica* were absent.

The macro channel bank (MCB) was mostly steep, dominated by woody vegetation and the prevalence of terrestrial species was high. This suggests reduced flooding disturbance. Woody vegetation was dominated by *Vachellia* species, while *S. africana* was absent.

Table G4 Summary detail of level 4 VEGRAI for the Matigulu River

LEVEL 4 ASSESSMENT	Matigulu River			02 December 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	85.4	6.1	3.1	1.0	7.1
Lower Zone	79.8	8.6	2.8	2.0	10.7
Upper Zone	69.3	7.4	2.8	3.0	10.7
MCB	80.3	57.4	3.3	4.0	71.4
LEVEL 4 VEGRAI (%)				79.4	
VEGRAI EC				**B/C**	
AVERAGE CONFIDENCE				3.0	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	85.4	79.8	69.3	80.3	
EC (Zone)	**B**	**B/C**	**C**	**B/C**	
Confidence (Zone)	3.1	2.8	2.8	3.3	

G6 EWR MK1: MKUZE RIVER

G6.1.1 Site Description

The extent of the assessment area for VEGRAI at the Mkuze River is shown in **Figure G9** and a photograph showing typical riparian vegetation in **Figure G10**.

Figure G9 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Mkuze River (upstream and downstream limits of site indicated by red lines)

Figure G10 Typical riparian vegetation at the Mkuze River, dominated by marginal zone reeds and grasses, and tall woody species forming riparian forest, dominated by Sweet Thorn and Wild Fig amongst others, with overhanging habitats for instream fauna

G6.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: C (73.0%), Confidence: 3.2
General Vegetation Overview: The site occurs within Lowveld Riverine Forest, a critically endangered but well protected Vegetation Type specifically riparian in nature. Lowveld Riverine Forest consists of tall dense forests fringing larger rivers where it forms gallery forest, frequently dominated by *Ficus sycomorus* and *Diospyros mespiliformis* (Mucina & Rutherford, 2006). **Reference State:** Aerial photographs from 1942 to 2013 show an increase in woody vegetation in places but reductions in others. Large events such as Demoina have had severe impacts and resulted in interesting vegetation (and channel) shifts. Google Earth images © since 2003 show a marked increase in woody cover in areas that were denuded but no change in areas that were already dense with woody vegetation. The expected reference condition is in keeping with the Vegetation Type: tall, dense gallery forest. **Present State:** A summary of the VEGRAI score is shown in **Table G5**. Sub-zones are described below: The marginal zone was dominated by sandy features with two dominant vegetation types: dense woody, tall vegetation which overhangs into the water; and non-woody grass / sedge bars. Woody vegetation was mainly *Ficus sycomorus, F. caprefolia* and *Senegalia sweinfurthii*. Non-woody vegetation was dominated by *Phragmites mauritianus, Arundinella napalensis* and *Ishaemum fasiculatum* which grew into the water. *Syzygium* was absent. The lower zone consisted of densely vegetated unconsolidated alluvial deposits. Dominated by woody vegetation similar to the marginal zone, reed clumps and grass / sedge bars. *Syzygium* and *C. erythrophyllum* were absent. The upper zone was similar to the lower zone but with less reeds and non-woody vegetation and taller more dense woody vegetation. Wood harvesting was prevalent. The MCB consisted mostly of unconsolidated alluvium with 40-50% woody cover and 30 - 40% reeds

Riparian vegetation: PES: C (73.0%), Confidence: 3.2
and grass. Species and habitats were similar to the upper zone. The floodplain was extensive and consisted of a mixture of tall trees with closed canopy and tall tree and shrub more open and scattered. *Ficus sycomorus* and *Vachellia xanthophloea* dominated and *S. aficanus, F. albida* and *D. mespiliformis* were absent. Alien invasion was high (20 - 40% in places) and patchy i.e. related to disturbance. The floodplain was extensively disturbed, cleared and cultivated. Wood harvesting was intense as was grazing and browsing.

Table G5 Summary detail of level 4 VEGRAI for the Mkuze River

LEVEL 4 ASSESSMENT	Mkuze River			30 November 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	84.5	16.9	3.2	1.0	100.0
Lower Zone	81.4	16.3	3.0	2.0	100.0
Upper Zone	80.2	16.0	3.0	3.0	100.0
MCB	80.0	16.0	3.3	4.0	100.0
Floodplain	38.9	7.8	3.4	5.0	100.0
LEVEL 4 VEGRAI (%)				73.0	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				3.2	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	**Floodplain**
VEGRAI % (Zone)	84.5	81.4	80.2	80.0	38.9
EC (Zone)	**B**	**B/C**	**B/C**	**B/C**	**D/E**
Confidence (Zone)	3.2	3.0	3.0	3.3	3.4

G7 EWR NS1: NSELENI RIVER

G7.1.1 Site Description

The extent of the assessment area for VEGRAI at the Nseleni River is shown in **Figure G11** and a photograph showing typical riparian vegetation in **Figure G12**.

Figure G11 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Nseleni River (upstream and downstream limits of site indicated by red lines)

Figure G12 Typical riparian vegetation at the Nseleni River comprised dense woody mostly closed canopy forest and riparian trees (such as Wild Fig) with the channel well shaded

G7.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: C (64.4%), Confidence: 3.2

General Vegetation Overview:
The site occurs within Zululand Coastal Thornveld which refers to a terrestrial vegetation type within the Savanna Biome (Mucina & Rutherford, 2006).

Reference State:
Aerial photographs from 1957 to 2014 show an increase in woody cover, especially where agriculture has pulled back off the river environment, a trend also apparent from Google Earth © imagery since 2004. The expected reference condition is likely to have been dominated by dense woody vegetation with the addition of kloof species.

Present State:
A summary of the VEGRAI score is shown in **Table G6**. Sub-zones are described below:

The marginal zone was mostly well shaded with steep banks where pools exist or else cobble areas with undercut roots. Instream root habitat and overhanging vegetation were dominant. The sub-zone was dominated by woody vegetation but where sunny more open areas exist, grasses and sedges occurred. A small amount of clearing existed for the crossing, otherwise impacts were low. Dominant species *included F. sycomorus, P. reclinata, C. sexangularis, I. fasiculatum* and *Stenotaphrum. Syzygium* and *G. virgatum* were absent.

The lower zone consisted mostly of mud banks that are well shaded and exposed roots were common. Some areas of cobble bed that are more open existed and were covered by grasses and sedges. Woody vegetation, frequently tall, with a closed canopy dominated and vegetation characteristics were similar to the marginal zone. *Nuxia oppositifolia* was also a lower zone dominant, in addition to the species found on the marginal zone. *Syzygium* was absent.

The upper zone consisted of steep alluvial banks with dense woody cover. The tree and shrub layer was closed canopy and shaded out the understorey. Where areas have been cleared for access alien species have heavily invaded (mostly *Chromolaena odorata* and *Lipia*). *Syzygium* and *Combretum* were absent.

The banks were steep, dominated by woody vegetation and merge with terrestrial forest (kloof vegetation). Overall, an effective riparian corridor existed (dense woody belt dominated by indigenous vegetation), but alien species invasion was high in cleared areas. The banks had been extensively cleared along security fences of property and for limited access to the river. *Ilex mitis* was not observed at the site.

Table G6 Summary detail of level 4 VEGRAI for the Nseleni River

LEVEL 4 ASSESSMENT	Nseleni River			01 December 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	85.0	6.1	3.1	1.0	7.1
Lower Zone	78.1	8.4	3.3	2.0	10.7
Upper Zone	61.8	6.6	3.1	3.0	10.7
MCB	60.6	43.3	3.4	4.0	71.4
LEVEL 4 VEGRAI (%)				64.4	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				3.2	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	85.0	78.1	61.8	60.6	
EC (Zone)	**B**	**B/C**	**C/D**	**C/D**	
Confidence (Zone)	3.1	3.3	3.1	3.4	

G8 EWR UP1: PONGOLA RIVER

G8.1.1 Site Description

The extent of the assessment area for VEGRAI at the Upper Pongola River is shown in **Figure G13** and a photograph showing typical riparian vegetation in **Figure G14**.

Figure G13 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the Upper Pongola River (upstream and downstream limits of site indicated by red lines)

Figure G14 Typical riparian vegetation at the Upper Pongola River, dominated by marginal and lower zone grasses and reeds, Cape Willow, Wattle, Sweet Thorn and upper zone grasses and shrubs

G8.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: C (70.0%), Confidence: 3.2
General Vegetation Overview: The site occurs within Swaziland Sour Bushveld which refers to a terrestrial vegetation type within the Savanna Biome (Mucina & Rutherford, 2006). **Reference State:** Aerial photographs from 1961 to 2013 show no noticeable change in woody cover. Similarly, Google Earth images © show no noticeable change since 2006. The expected reference condition is likely to have been dominated by a mix of woody and non-woody riparian vegetation. **Present State:** A summary of the VEGRAI score is shown in **Table G7**. Sub-zones are described below: The marginal zone was dominated by non-woody vegetation but with the presence of *Salix mucronata*. *Gomphostigma virgatum* was absent. It consisted of a narrow band of vegetation with both alluvium and cobble. Dominant species were *P. australis, I. fasiculatum, C. longus, P. senegalensis* and *S. mucronata*. *Cyperus marginatus* and *Breonadia salicina* were absent from the site. Some weed species occurred but in low abundance. The lower zone was similar to the marginal zone with the addition of a few species, notably *Cynodon dactylon* and *Cyperus dives*. Perennial alien cover was between 10 - 20%, mainly *Sesbanea punicea*. *Syzygium* and *B. salicina* were absent from the site. The upper zone consisted of mixed alluvium and cobble bars with mostly small woody vegetation displaying flood damage from recent floods. Alien invasion was high with up to 10% cover by *Sesbanea punicea* and *Lantana camara*. Non-woody ground cover was good. Some grazing occurred and some wood harvesting was evident. *Ziziphus mucronata* and *Vachellia karoo* were absent (may be an indication of harvesting).

Riparian vegetation: PES: C (70.0%), Confidence: 3.2
The bank was dominated by woody vegetation, mostly S*. ataxycantha* and *Faurea saligna*. Cover of perennial aliens was around 20% with *M. azedarach, A. mearnsii* and *Eucalyptus* all present. Expect to find more V*. karoo* and *Spirostachys africana* was absent. Some erosion was evident and wood harvesting occurred.

Table G7 Summary detail of level 4 VEGRAI for the Pongola River

LEVEL 4 ASSESSMENT	Upper Pongola River			27 November 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	79.0	5.6	3.1	1.0	7.1
Lower Zone	77.0	8.3	3.0	2.0	10.7
Upper Zone	67.0	7.2	3.3	3.0	10.7
MCB	68.5	49.0	3.4	4.0	71.4
LEVEL 4 VEGRAI (%)				70.0	
VEGRAI EC				**C**	
AVERAGE CONFIDENCE				3.2	
	Su-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	79.0	77.0	67.0	68.5	
EC (Zone)	**B/C**	**C**	**C**	**C**	
Confidence (Zone)	3.1	3.0	3.3	3.4	

G9 EWR WM1: WHITE MFOLOZI RIVER

G9.1.1 Site Description

The extent of the assessment area for VEGRAI at the White Mfolozi River is shown in **Figure G15** and a photograph showing typical riparian vegetation in **Figure G16**.

Figure G15 Satellite image from Google Earth © showing the placement and extent of the VEGRAI assessment area for the White Mfolozi River (upstream and downstream limits of site indicated by red lines)

Figure G16 Typically, riparian vegetation was sparse at the White Mfolozi River with scattered grasses, sedges and a few riparian trees, mostly in shrub form

G9.1.2 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: B/C (81.3%), Confidence: 3.2
General Vegetation Overview: The site occurs within Northern Zululand Sourveld which refers to a terrestrial vegetation type within the Savanna Biome (Mucina & Rutherford, 2006). **Reference State:** Aerial photographs from 1937 to 2011 show no noticeable change in woody cover. The expected reference condition is likely to have been dominated by a mix of woody and non-woody riparian vegetation with the addition of kloof species as the reach passes through the gorge. **Present State:** A summary of the VEGRAI score is shown in **Table G8**. Sub-zones are described below: The marginal zone was scoured from recent floods at the time of the assessment. The zone was dominated by non-woody species, mostly sedges and grasses, but was mostly open cobble. Cattle on site indicate that grazing takes place but the site is remote within a gorge. The lower zone was dominated by non-woody vegetation with scattered woody individuals and alien cover low (<10%). Vegetation had been recently scoured from floods. Dominant species similar to the marginal zone (grasses and sedges) but with *Nuxia oppositifolia, S. cordatum, S. gueneense, F. sur* and *P. reclinata*. *B. salicina* was absent. The upper zone was similar to the lower zone. The MCB was dominated by woody vegetation or open bedrock and is within a gorge environment with a cliff and bedrock. *Spirostachys africana* is absent.

Table G8 Summary detail of level 4 VEGRAI for the White Mfolozi River

LEVEL 4 ASSESSMENT	White Mfolozi River			29 November 2013	
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**	**WEIGHT**
Marginal Zone	84.1	21.0	3.1	1.0	25.0
Lower Zone	84.8	12.7	3.0	2.0	15.0
Upper Zone	80.1	40.0	3.3	3.0	50.0
MCB	75.6	7.6	3.3	4.0	10.0
LEVEL 4 VEGRAI (%)				81.3	
VEGRAI EC				**B/C**	
AVERAGE CONFIDENCE				3.2	
	Sub-zone				
	Marginal Zone	**Lower Zone**	**Upper Zone**	**MCB**	
VEGRAI % (Zone)	84.1	84.8	80.1	75.6	
EC (Zone)	**B**	**B**	**B/C**	**C**	
Confidence (Zone)	3.1	3.0	3.3	3.3	

G10 EWR NG1: NGEMPISI RIVER

G10.1.1 Site Description

A photograph showing typical riparian vegetation is shown in **Figure G18**.

Figure G17 Typically, riparian vegetation was a good mix of woody and non-woody vegetation at the Ngwempisi River with tufted grasses, sedges and marginal zone trees and shrubs, and woody and non-woody prevalence in the non-marginal zone

G10.1.1 Results and Interpretation of the VEGRAI

Riparian vegetation: PES: B/C (77.4%), Confidence: 1.4
Present State: A summary of the VEGRAI score is shown in **Table G9**. Sub-zones are described below: The marginal zone was well vegetated with tufted grasses and reeds and overhanging vegetation and in-channel growth. Some woody vegetation was also prevalent and common, the shrub *Cliffortia* mainly (with overhang) but also *Salix mucronate.* The right bank of the non-marginal zone was dominated by woody vegetation while the left bank was dominated by non-woody vegetation (burnt grass mainly). Aliens included *Sesbanea*, Wattle and *Solanum mauritianum.*

Table G9 Summary detail of level 4 VEGRAI for the Ngwempisi River.

LEVEL 4 ASSESSMENT	Ngwempisi			09 September 2022
RIPARIAN VEGETATION EC METRIC GROUP	**CALCULATED RATING**	**WEIGHTED RATING**	**CONFIDENCE**	**RANK**
Marginal zone	78.8	35.0	1.4	1.0
Non-marginal	76.3	42.4	1.5	2.0
LEVEL 4 VEGRAI (%)				77.4
VEGRAI Ecological Category				**B/C**
AVERAGE CONFIDENCE				1.4
	Sub-zone			
	Marginal zone	**Non-marginal**	**0.0**	**0.0**
VEGRAI % (Zone)	78.8	76.3	not assessed	not assessed
EC (Zone)	**B/C**	**C**		

G11 REFERENCES

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12 APPENDIX H: ECOHYDRAULICS AND EWR DETERMINATION

H1 ECOHYDRAULICS

H1.1.1 Methodology

The ecohydraulic information used in this study is largely from the "*Reserve Determination Study for selected water, groundwater, estuaries and wetlands in the Usutu/Mhlatuze Water Management Area"* study (DWS 2014). This 2014 study provided ecohydraulic information for eight EWR sites, of which two were on the Black Mfolozi River, and the remaining six comprised the Assegaai, Upper Pongola, Mkuze, White Mfolozi, Nseleni and Matigulu Rivers; the study team re-visited these sites in June 2022, for this project. The current study used the same sites, excluding one of the Black Mfolozi sites, but including an additional site on the Ngwempisi River. For two of the existing sites, namely BM1 and MK1 on the Black Mfolozi and Mkuze River, respectively, the rating relationships were revised, which affected the medium-to-high flow range (refer to **Section H1.1.2**). The ecohydraulic information for EWR Site NG1 on the Ngwempisi River is based a single low flow rating measurement and a modelled high flow (refer to **Section H1.1.3**).

The methodology used to generate ecohydraulic information for use in EWR assessments is well documented in the literature, including in Rowlston *et al*. (2000), DWS (undated), Jordanova *et al.* (2004), Hirschowitz et al. (2007), and Birkhead (2010), and can be consulted for further details.

H1.1.2 Revised hydraulic analyses

EWR BM1: Black Mfolozi River

The DWS (2014) hydraulic analysis for the EWR site on the Black Mfolozi noted that the surveyed strand lines did not correlate with gauged discharges from the upstream station, and they were consequently ignored. The modelled high flow rating was based on a resistance value (Manning's *n* = 0.045) calculated from a slope-area survey after Cyclone Domoina (1984) and an energy gradient (*S*) of 0.0063. The revised rating, however, uses a lower energy gradient (0.0011) which appears reasonable given the downstream morphology (predominantly runs/pools); this is also supported by the valley slope derived from the Shuttle Remote Topography Mission (SRTM) Digital Elevation Model (DEM); the high flow resistance was also reduced (*n* = 0.035). The revised rating (**Figure H1**) plots closer to the lower of the two surveyed strand lines (73 m^3/s; 26/122013)

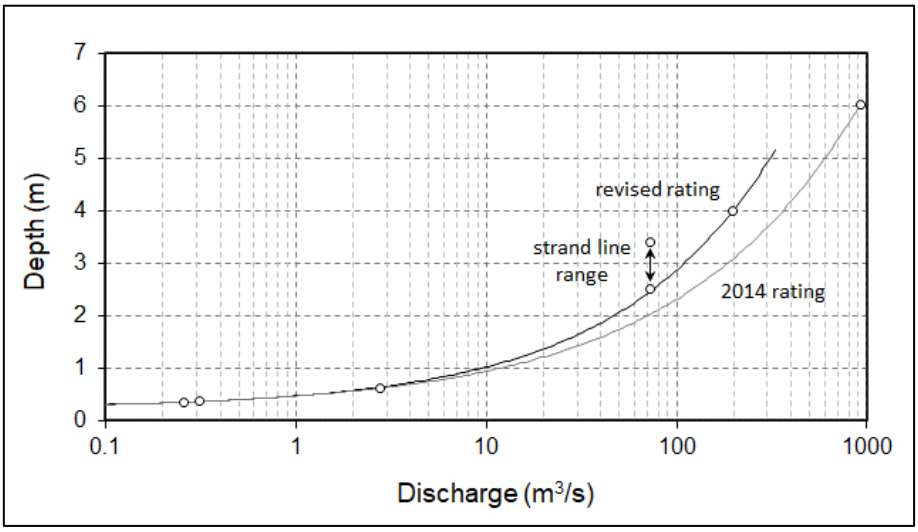

Figure H1 Revised rating relationship for EWR Site BM1 on the Black Mfolozi River

EWR MK1: Mkuze River

The DWS (2014) hydraulic analysis for the EWR site on the Mkuze River modelled a high flow rating point (maximum depth *y* = 4.7 m) using an area-weighted average flow resistance (*n* = 0.07) based on the sand bed active channel (*n* = 0.025) and extensive floodplains on both banks (*n* = 0.06 and 0.20 for the left and floodplains, respectively). The active channel overtops at a maximum depth of approximately 3.1 m, and a revised rating relationship incorporates a medium-to-high rating point (prior to overtopping: *y* = 2.5; *n* = 0.035); the recommended 1:5 flood event for the site is 2.5 m.

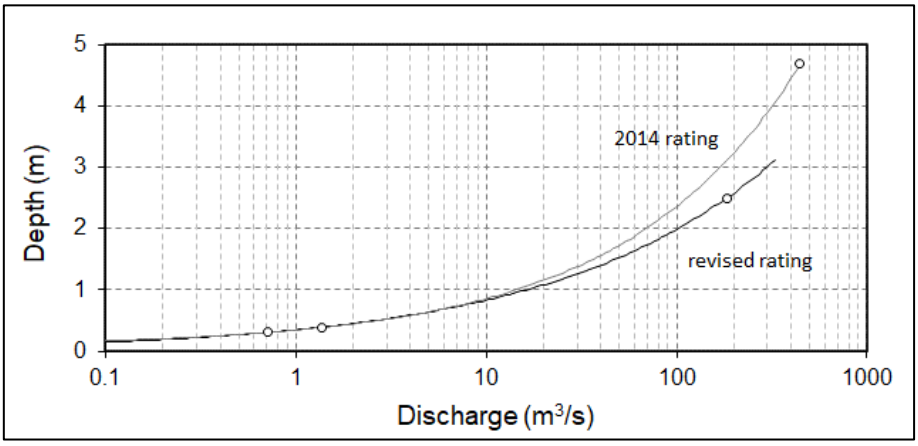

Figure H2 Revised rating relationship for EWR Sites MK1 on the Mkuze River

H1.1.3 EWR NG1: Ngwempisi River

Three bench marks/fixed stations were installed at EWR Site NG1 on the Ngwempisi River, with the relative orientation of the surveyed cross-section provided in Table H1, and illustrated in **Figure H2** to **Figure H4**. The surveyed cross-section is plotted in **Figure H5** and the rating data/relationship in **Figure H6**.

Table H1 Orientation of the cross-section surveyed at EWR Site NG1 relative to bench marks/fixed stations

Bench Mark		Orientation (degrees)	Horizontal distance (m)	Elevation (m)
At	BM1	0.00	-	100.00
To	BM2	104.614	2.46	100.19
	BM3	300.356	22.54	100.31

Figure H3 **Location of the surveyed cross-section at the downstream end of a boulder rapid; approximate positions of bench marks/fixed stations are indicated with circular markers; flow direction is top-to-bottom**

Figure H4 **Position of the surveyed cross-section; flow direction is right to left; discharge of 1.69 m^3/s (22/07/2022)**

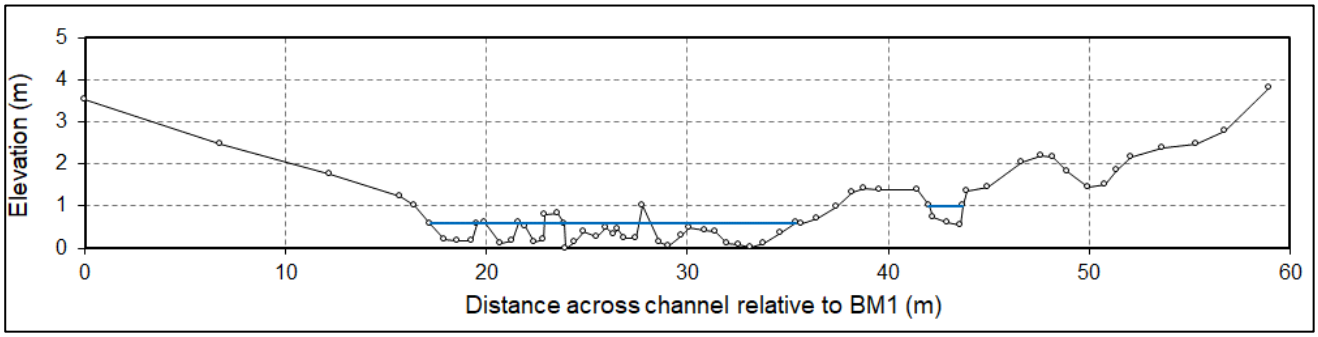

Figure H5 **Surveyed cross-sectional profile across the Ngwempisi River (EWR Site NG1) relative to the position of BM1 (refer to** Error! Reference source not found.**); maximum depth of 0.58 m is indicated, corresponding to a discharge of 1.69 m³/s**

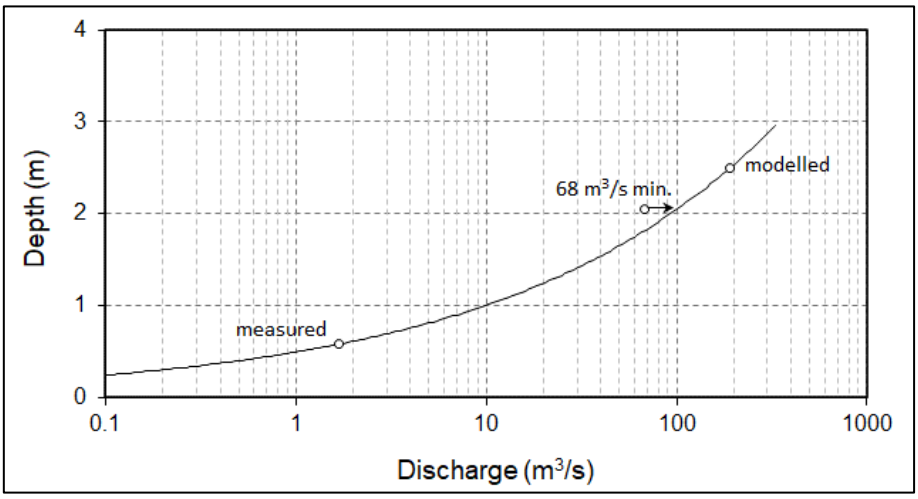

Figure H6 **Measured (*y* = 0.58; *S* = 0.015; *n* = 0.16) and modelled (*y* = 2.5; *S* = 0.01; *n* = 0.040) rating points and modelled relationship for EWR Site NG1 on the Ngwempisi River; the surveyed strand line corresponds to a discharge > 68 m³/s (maximum rating of DWS Gauge W5H026)**

H1.1.4 Rating relationships

Rating relationship coefficients for the EWR Sites on the Black Mfolozi and Mkuze Rivers (revised) and Ngwempisi Rivers are provided in **Table H2**.

Table H2 **Rating relationship coefficients of the form $Q = ay^b + c$, where Q is discharge (m³/s) and y is maximum depth (m) for EWR Sites on the Black Mfolozi, Mkuze and Ngwempisi Rivers**

EWR Site	*a*	*b*	*c*
BM1	0.235	0.525	0.231
MK1	0.350	0.378	0.000
NG1	0.493	0.309	0.000

H1.1.5 Confidences

An indication of the confidence in the hydraulic modelling at the EWR sites is provided in **Table H3**; these are as provided by DWS (2014) that also gives additional explanations for the ratings, including advantages and disadvantages of the site character and further details. Although the

medium-to-high flow rating relationships were modified for use in this study, the high flow ratings are unchanged. Explanations for the confidence ratings EWR Site NG1 are given, which was not part of the DWS (2014) Reserve determination.

Table H3 Confidences (0=none, 1=low, 3=medium, 5=high)

EWR	Site character	Data	Confidence	
			Low flows	High flows
MA1	2	2	2	2
NS1	2	2	2	1
WM1	2	2	2	3
BM1	3	2	2	2
MK1	3	2	3	2
UP1	2	2	3	2
AS1	3	3	3	2
NG1	2	1	2	2
	Site character: advantages - gauging station located upstream; disadvantages - located at the downstream end of a steep boulder rapid (refer to **Figure H1**); two-channels at low flows with a third high flow channel. Data rating: one observed low-flow rating point; a high flow strand line from the recent (2021/22) wet season that was linked to a minimum discharge estimate (gauge exceeded its maximum rating). Low flow: depth at which flow ceases is unclear; large scale roughness elements increase uncertainty at discharges lower than measured. High flow: some uncertainty in the high flow energy gradient - cross-section located between a rapid and run.			

H2 EWR DETERMINATION

The determination of EWRs in this study applied Version 2 of the Revised Desktop Reserve Model (RDRMv2). The RDRM may be used for higher-order (non-desktop) applications of the Habitat-Flow Stressor-Response Ecological Water Requirement (EWR) Methodology (referred to internationally Environmental Flow Assessments), when additional site-specific hydraulic and ecological information is available. The RDRM explicitly includes the links and relationships between hydrology, hydraulics and hydraulic-habitat, and ecological response compared to the original Desktop Reserve Model (refer to Hughes and Hannart 2003). Version 2 of the original RDRM (refer to Hughes *et al*. 2014) was refined under the auspices of a Water Research Commission (WRC) project (WRC 2018).

For this project, the data requirements and EWR assessment at the desktop level for biophysical nodes is described in an earlier report (DWS, 2022), and is therefore not repeated here. Additional (i.e., non-desktop) data inputs applied in this higher-confidence EWR assessment included:

- Surveyed cross-sectional profiles;
- Modelled rating relationships;
- Adjustment of default shifts at low and high ends to obtain recommended (low flow) discharges at the 60th (maintenance) and 90th (drought) percentiles on the wet and dry season flow duration curves; recommended discharges were assessed for the Present Ecological State (PES) for fish and macroinvertebrates; and
- High flow requirements comprising three intra-annual, 1:2 and 1:5-year return period event peaks (vegetation and fluvial morphology).

Generally, for all sites, EWR requirements were constrained to Present Day (PD) flows. Exceptions were, however, for the Matigulu and Mkuze EWR sites where the modelled PD hydrology is substantially less than naturalised and somewhat uncertain.

The EWR results are provided in the following formats as text files:

- RDRMv2 generated reports;
- Assurance rules for EWR low flows and total flows (in 10^6 m^3); and
- Time-series of monthly EWR low and total flows (in 10^6 m^3)[3].

H3 REFERENCES

Birkhead, A.L. 2010. The role of Ecohydraulics in the South African Ecological Reserve. In: Ecohydraulics for South African Rivers, James, C.S. and King, J.M. (eds), Water Research Commission (WRC) report no. TT K5/1767/1. WRC, Pretoria, South Africa. Available at http://www.wrc.org.za

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Hughes, D.A. and Hannart, P. 2003. A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. *Journal of Hydrology* 270(3-4), 167–181.

[3] Note, total flow time-series are not constrained to PD, whereas the assurance rules are.

[4] https://www.dws.gov.za/Documents/Policies/WRPP/River%20Ecosystems.htm; it, however, appears that this DWS link to the extensive series of reports is no longer active.

Rowlston, B., Jordanova A.A. and Birkhead A.L. 2000. Hydraulics In: Environmental flow assessment for rivers: Manual for the Building Block Methodology, King, JM, Tharme, RE and de Villiers, MS, (eds), Water Research Commission (WRC) report no.TT 131/00, 340 pp. WRC, Pretoria, South Africa.

Water Research Commission (WRC). 2018. Refinement of the Revised Desktop Reserve Model Project K5/2539/2. Final Report Volume 1: RDRM Refinement – background and description. 53 pp. Available at http://www.wrc.org.za.

13 APPENDIX I: COMMENTS AND RESPONSE REGISTER

No.	Section	Comment	From	Addressed?
1	Whole Report	Editorial comments.	M Sekoele	All edits addressed and corrected.
2	Glossary	I suggest we add EcoClassification.	M Sekoele	Addressed.
3		Can we stick to the term as defined in the WRCS.	M Sekoele	Addressed.
4	Sec 2. Table 2.1 – 2.8	Why are we not saying PES here given that this section is looking into the PES? Moreover Table 2.10 it is reflected as PES. For consistency purposes let's use PES.	M Sekoele	Addressed.
5	Table 2.10 Pg. 2-5	Based on the comments, is this not supposed to be B?	M Sekoele	The C REC relates to flow requirements that are realistic. The B REC can only be achieved by addressing catchment issues and therefore setting flows for this EC would be unrealistic.
6	Chapter 3 Table 3.1-3.16	Under glossary of terms there is an explanation of what a class is. The use of this here could create confusion with the class as explained under glossary. Maybe be specific here what class this is	M Sekoele	Addressed.
7		Why is there a difference between how the high flow and low flow are reflected? High flows are annually whilst low flows are monthly with specific %.	M Sekoele	Floods are report as annual or less often. Peaks, number of events and duration are reported, which cannot be shown in a monthly flow duration table. The purpose of the report is only to supply EWR results. These results are the standard output required by DWS. Low flows are provided as a flow duration table (as are total flows in the complete EWR reports provided as raw data). The reason the low flows are provided is that that is used to set monthly operating rules in the system. The floods are provided separately (they are not annual) but specific events for different class floods. The model decides in which month the flood will 'be placed' based on a trigger provided by the natural flow duration tables. Specific class floods are provided in the table given as they are required by dam engineers for deciding on outlet sizes and how to operate for floods. Annual within the flood table refers to floods that generally should occur every year (high assurance) except of course in drought years.
8		Can these reds be explained for the reader's ease?	M Sekoele	Addressed.
9	Sec. A1	Was it necessary to carry out the quantitative assessment?	M Sekoele	Addressed.

No.	Section	Comment	From	Addressed?
	Pg. A1			
10	Sec. A4.1.2 Pg. A5	Ecca Shales? Why a question mark here?	M Sekoele	Addressed.
11	Sec. C1.1.1	What is RC? There is a need within the report for a table for acronyms.	M Sekoele	Addressed. Note that all acronyms used in the main report and appendices are listed at the beginning of the report.
12	Sec. C2.1.2 Pg. C5	Water quality table: Any rating for PAI/Comment for Inorganic salt ions?	M Sekoele	Addressed.
13	Sec. C5.1.2 Pg. C10	Water quality table: Why are other cells not populated?	M Sekoele	Addressed.
	Sec. E2 Pg.E1	Whilst it is important to note or bring forward what might be deemed as errors, it is not necessary to capture such in a report. I therefore request that such statements be removed from the report and focus be on the information regarding refinement/update of the FRAI.	M Sekoele	Addressed.
	Sec. E2 Pg.E1	This aim of this report is not to evaluate and provide opinion on the outcome of the previous study, please remove such statements.	M Sekoele	Addressed.
	Table E1 Pg. E3	Why other EWRs have no flow information? Can that be highlighted please for the reader's understanding.	M Sekoele	Addressed.
	Sec. E11.1.1 Pg E25	Is this not Morgenson?	M Sekoele	Spelling is correct in the report.