DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems

DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE THUKELA CATCHMENT

QUANTIFICATION OF ECOLOGICAL WATER REQUIREMENTS REPORT WP 11255

Study Report No.

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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

REPORT INDEX	REPORT NUMBER	REPORT TITLE
1.0	RDM/WMA04/00/CON/CLA/0119	Inception Report
2.0	RDM/WMA04/00/CON/CLA/0120	Water Resources Information and Gap Analysis Report
3.0	RDM/WMA04/00/CON/CLA/0220	Specialist Workshops Report
4.0	RDM/WMA04/00/CON/CLA/0320	Status Quo and Integrated Unit of Analysis and Resource Units Report
5.0	RDM/WMA04/00/CON/CLA/0420	Linking the Socio-Economic and Ecological Value and Condition of the Water Resources
6.0	RDM/WMA04/00/CON/CLA/0520	Preliminary Resource Units Selection and Prioritisation Report
7.0	RDM/WMA04/00/CON/CLA/0620	Quantification of Ecological Water Requirements Report

TERMINOLOGY AND ABBREVIATIONS

Acronym	Description
ASPT	Average Score Per Taxon
CD: WE	Chief Directorate: Water Ecosystems
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Area
GRU	Groundwater Resources Unit
GSM	Gravel, Sand, Mud
IHAS	Integrated Habitat Assessment System (Version 7)
IUA	Integrated Unit of Analysis
KZN	KwaZulu-Natal
MPA	Marine Protected Area
NFEPA	National Freshwater Ecosystem Priority Areas
NMAR	Natural Mean Annual Runoff
NWA	National Water Act
PES	Present Ecological Sate
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
RDM	Resource Directed Measures
RUs	Resource Units
SIC	Stones-in-current

Acronym	Description
SOOC	Stones-out-of-current
TEC	Target Ecological Category
WMA	Water Management Area
WRCS	Water Resource Classification System
VEG	Vegetation
QV	Quality/Sensitivity Value (aquatic macroinvertebrates)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The Chief Directorate: Water Ecosystems has initiated a study for the determination of Water Resource Classes and associated Resource Quality Objectives in the Thukela Catchment.

Water Resource Classification, the Reserve and Resource Quality Objectives (RQOs) are protection-based measures that make up Resource Directed Measures (RDM), the protection principles contained in Chapter 3 of the National Water Act (Act No. 36 of 1998). Classification of priority water resources and determination of the Reserve are intended to ensure comprehensive protection of all water resources. An important consideration in the determination of RDM is that they should be technically sound, scientifically credible, practical, and affordable. Once the water resources class and the Reserve have been established, RQOs are established to give effect to determined water resources classes and the Reserve.

The ecological Reserve is not intended to protect the aquatic ecosystem *per se*, but to maintain aquatic ecosystems in such a way that they can continue to provide the goods and services to society and is specified for groundwater, wetlands, rivers and estuaries.

1.1. Study Objective

The main objective of the study is to determine water resource classes and RQOs for all significant water resources in the Thukela River catchment area that would facilitate sustainable use of the water resources while maintaining ecological integrity, specifically maintain or improving the present ecological state of the water resources.

The key aims of this study are therefore to co-ordinate the implementation of the Water Resource Classification System (WRCS) published as Regulation 810 in September 2010 for determination of water resource classes and associated RQOs in the Thukela catchment. The study is linked to the preliminary Reserve determination studies and other water resource management initiatives. Where the preliminary Reserve is available and relevant, the information has been adopted and where needed, within the ambit of this study, gaps have been filled.

The water resource classes and associated RQOs will assist the Department in ensuring that water resources within Thukela catchment are protected to achieve equitable share in a sustainable manner. In determining classes and associated RQOs, socio-economic factors and ecological goals will be considered by evaluating the magnitude of impacts in the present as well as proposed future developments. The water resource classes and associated RQOs will also assist the Department in the authorisation of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments, as well as ensure the economic, social and ecological goals are attained.

It is recognised that the successful determination of the water resource classes and RQOs will depend on the integration of a number of disciplines in respect of water resources with the water uses and the needs of the water users present in the catchment, through consultative processes. Specialist technical assessment and stakeholder engagement are key components to the process.

1.2. Purpose of this Report

This quantification of Ecological Water Requirements (EWR) Report describes the approaches, methods and models used to determine the EWR for priority rivers in the Thukela catchment at selected sites. These determinations are on the various levels of detail as described in volume 3 of the RDM methodology of 1999 (DWAF, 1999). Where available and applicable, information from previous Reserve studies were utilised and updated with new information from field surveys undertaken during September 2020.

2 STUDY AREA AND EWR SITES

The study area is the catchment of the Thukela River, predominantly in the KwaZulu-Natal Province, except for a narrow strip in the extreme north which falls in Mpumalanga Province. It is the largest river system within the Pongola to Mtamvuma Water Management Area (WMA 4). To enable improved representation of the water resources situation in the catchment and to facilitate the applicability and better use of information for strategic management and planning purposes, the catchment was divided into four sub-areas, based on practical considerations such as size and location of sub-catchments, homogeneity of natural characteristics, location of pertinent water infrastructure such as dams, and economic development (Table 1 and Figure 1).

Table 1: Sub-catchment areas of the Thukela catchment (DWS, 2004)

Sub-catchment	Description	Tertiary drainage regions	Catchment area [(1)] (km^2)
Upper Thukela	The catchment of the Thukela River to just upstream of the confluence of the Bushmans River	V11, V12, V13 and V14	7 645
Mooi/Sundays	The catchment of the Mooi, Bushmans and Sundays River as well as of smaller tributaries, down to the confluence of the Buffalo River with the Thukela River.	V20, V60, V70	8 496
Buffalo	The catchment of the Buffalo River	V31, V32 and V33	9 803
Lower Thukela	The catchment of the Thukela River between the confluence of the Buffalo River and the Indian ocean	V40 and V50	3 102

[1]WR2012 data

The Thukela catchment drains an area of 29 040km^2, rising on the escarpment of the Drakensberg and flowing approximately 512 km through the eastern slopes, the midlands, and discharging to the Indian Ocean. The two main drainage systems are the Upper Thukela and Buffalo rivers. This is attributed to the great Thukela Fault which runs in an east-west direction through the catchment as far as Colenso. The topography of the Thukela River Catchment varies dramatically, ranging from steep areas to gentle slopes.

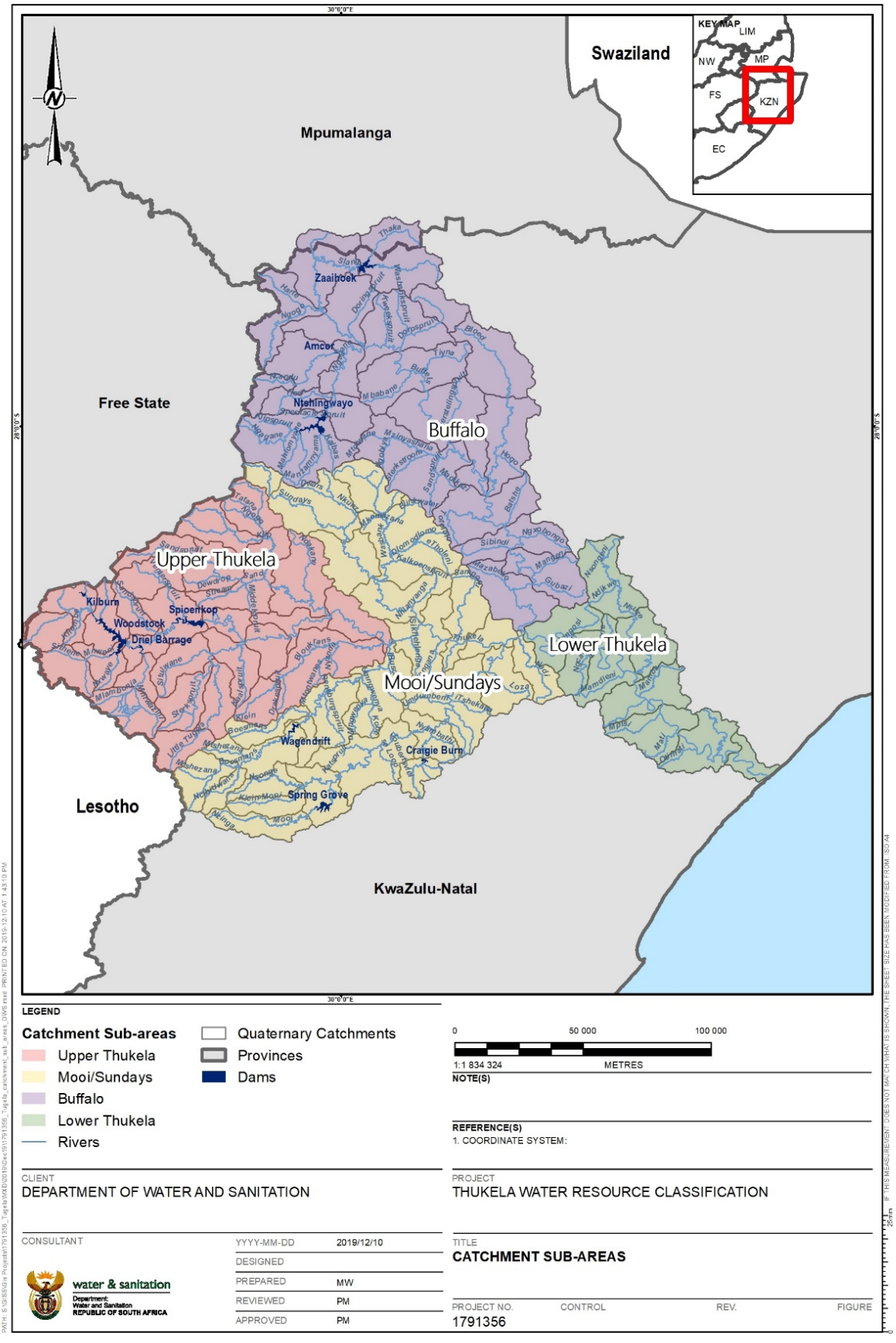

Figure 1: Thukela catchment sub-areas

The main topographic feature in the catchment is the Drakensberg Mountain Range in the west, which also demarcates the continental divide between the rivers flowing eastward to the Indian Ocean, notably the Thukela River, and the Orange/ Vaal River basin with its outflow to the Atlantic Ocean. The climate is strongly influenced by the topography and ranges from cool in the mountains to subtropical at the coast. Mean annual rainfall is in the range of 600 mm to approximately 1 500 mm, with most of the runoff originating in the vicinity of the escarpment and in the upper reaches of tributaries, where waterfalls are a significant feature.

The main river rises above Bergville. Major tributaries flowing into the Thukela River from the north include:

- The Klip River, which passes through Ladysmith,
- The Sundays River, and
- The Buffalo River, which rises above Newcastle.

Major tributaries into the Thukela River from the south include:

- The Little Thukela River,
- The Bloukrans River,
- The Bushmans River, passing through Estcourt, and
- The Mooi River.

The Thukela preliminary Reserve study concluded in 2003, included 17 Ecological Water Requirement (EWR) sites, nine in the upper Thukela Catchment and tributaries and eight sites in the Lower Thukela Catchment. A number of rapid Reserve determinations were undertaken between 2002 and 2005. However, no reports were available for these studies. Rapid assessments were undertaken for the Ngagane (upper and lower), Horn and Ncone Rivers in 2013 and for the Mooi River just upstream of the existing comprehensive site Thukela_10 in V20E during 2019. An intermediate assessment was undertaken during 2017 for the lower Thukela River at Thukela_16 and two additional sites just downstream of the new abstraction weir in quaternary catchment V50D. The results from these sites, together with the additional surveys undertaken in September 2020 will be used to define the EWRs per priority river and at the outlet of each Integrated Unit of Analysis (IUA).

The surveys included for the various levels of assessment are defined in Table 2.

The final EWR sites and level of assessments per IUA are listed in Table 3 and shown in Figure 2.

Table 2: EWR surveys per level of assessment

Comprehensive/ Intermediate	Rapid III	Rapid II	Rapid I	Desktop
Dry and post-wet season surveys Hydraulics Fish Macroinvertebrates Riparian vegetation Geomorphology Hydrology Water quality	Dry season survey Hydraulics Fish Macroinvertebrates Rapid Habitat Integrity Assessment Hydrology Water quality	Dry season survey Discharge only Fish Macroinvertebrates Rapid Habitat Integrity Assessment Hydrology Water quality	Dry season survey Fish Macroinvertebrates Rapid Habitat Integrity Assessment	No surveys Desktop PES/EI/ES results Hydrology

Table 3: Final EWR sites per IUA in the Thukela Catchment

IUA	Existing/ new	River	Quaternary	Level	Latitude	Longitude
1	THU_EWR23	Upper Buffalo	V31D	Rapid III	-27.6221	29.9617
2	May13_EWR2	Horn	V31F	Rapid III	-27.888	29.921
	THU_EWR19	Ncandu	V31J	Rapid III	-27.8017	29.8840
	May13_EWR3	Ngagane	V31K	Rapid III	-27.819	29.987
	Ngagane_dsk	Lower Ngagane	V31K	Desktop	Outlet V31K	
3	THU_EWR13A	Middle Buffalo	V32F	Rapid II	-28.0107	30.3931
	Thukela_EWR13	Middle Buffalo	V32H	Comprehensive	-28.153	30.476
4	Thukela_EWR14	Lower Buffalo	V33B	Comprehensive	-28.437	30.595
5	Blood_dsk	Blood	V32H	Desktop	Outlet of V32H	
6	THU_EWR7A	Upper Sundays	V60B	Rapid II	-28.3479	29.9682
	Thukela_EWR7	Upper Sundays	V60C	Comprehensive	-28.458	30.053
	Thukela_EWR8	Lower Sundays	V60F	Comprehensive	-28.636	30.204
7	THU_EWR20	Nsonge/ Hlatikulu	V20C	Rapid III	-29.2377	29.7853
	EWR_Mooi_N3	Mooi	V20E	Rapid III	-29.210	30.002
	Thukela_EWR11	Mooi	V20G	Comprehensive	-29.116	30.135
8	THU_EWR21	Mnyamvubu	V20G	Rapid II	-29.1610	30.2884
	THU_EWR12A	Mooi	V20H	Rapid III	-28.9191	30.4192
	Thukela_EWR12	Mooi	V20H	Comprehensive	-28.9039	30.4221
	Mooi_dsk	Mooi	V20J	Desktop	Outlet of V20J	

IUA	Existing/ new	River	Quaternary	Level	Latitude	Longitude
9	Thukela_EWR5	Middle Bushmans	V70F	Comprehensive	-28.897	30.035
	THU_EWR6A	Lower Bushmans	V70G	Rapid III	-28.8483	30.1496
	Thukela_EWR6	Lower Bushmans	V70G	Comprehensive	-28.801	30.167
10	Thukela_EWR1	Upper Thukela	V11J	Comprehensive	-28.722	29.378
	Thukela_EWR2	Upper Thukela	V11M	Comprehensive	-28.717	29.621
	Thukela_EWR3	Little Thukela	V13E	Comprehensive	-28.778	29.628
	Thukela1_dsk	Thukela	V14B	Desktop	Outlet of V14B	
11	THU_EWR22	Klip	V12A	Rapid III	-28.3952	29.7197
	Klip_dsk	Klip	V12G	Desktop	Outlet of V12G	
12	Thukela_EWR4A	Middle Thukela	V14E	Comprehensive	-28.705	30.059
	Thukela_EWR4B	Middle Thukela	V14E	Comprehensive	-28.747	30.145
	THU_EWR4C	Middle Thukela	V14E	Rapid I	-28.7564	30.1504
	Thukela_EWR9	Middle Thukela	V60J	Comprehensive	-28.769	30.515
	Thukela2_dsk	Middle Thukela	V60K	Desktop	Outlet of V60K	
13	Thukela_EWR15	Lower Thukela	V40B	Comprehensive	-28.785	30.911
	THU_EWR16	Lower Thukela	V50C	Intermediate	-29.1603	31.3373
14	V11A_dsk	Thukela	V11A	Desktop	66% V11A	
	V11B_dsk	Mnweni	V11B	Desktop	100% V11B	
	V11G_dsk	Mlambonja	V11G	Desktop	100% V11G	
	V13A_dsk	Little Thukela	V13A	Desktop	77% V13A	
	V70A_dsk	Bushmans	V70A	Desktop	87% V70A	
	V70B_dsk	Nsibidwana	V70B	Desktop	100% V70B	
	V20A_dsk	Mooi	V20A	Desktop	21% V20A	
	V20B_dsk	Little Mooi	V20B	Desktop	42% V20B	
15	THU_EWR17	Lower Thukela	V50D	Intermediate	-29.1677	31.4037

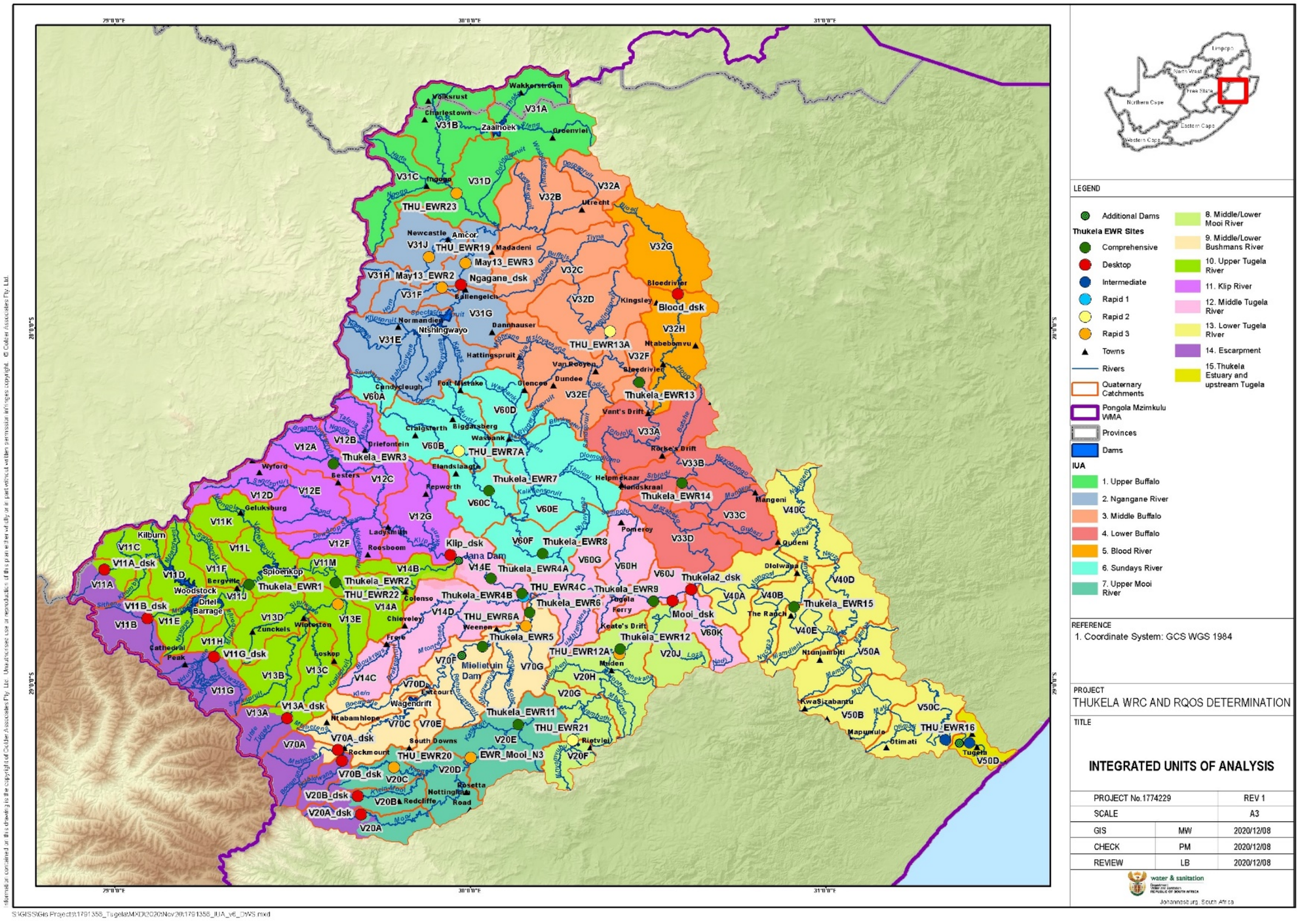

Figure 2: Thukela catchment showing IUAs with EWR sites

2.1. Approach

A number of approaches were followed for the quantification of the ecological water requirements. These are as follows:

(i) New Rapid I, 2 and 3 assessments (surveys in September 2020) and included the following:
- Information collected during the field surveys,
- Results from the Eco-classification process (Present Ecological State (PES), Ecological Importance (EI), Ecological Sensitivity (ES) and Recommended Ecological Category (REC),
- Desktop Reserve Model (DRM) within SPATSIM for the integration of data produced from the surveys and Eco-classification to quantify the EWRs,
- Results from the hydraulic modelling (cross-sectional profile and discharge) to evaluate the DRM requirements, and
- Evaluation of the water quality at specific selected sites where quality was identified as an issue.

(ii) Revisit of existing EWR sites from previous studies (mainly 2003 comprehensive sites). The surveys at these sites were undertaken to assess the PES due to increased or proposed new water uses in the upper catchments, e.g. Mooi River with the Spring Grove Dam that was constructed after the 2003 study.

(iii) River reaches where no existing EWR sites are present (e.g. Upper Thukela after Thukela and Little Thukela confluence, Blood River IUA). These have been undertaken on a desktop level, using the Desktop PES/EI/ES results as no additional information was available.

(iv) IUA14 has been defined as the Escarpment IUA with most of the river reaches in protected areas. The EWR for these have been undertaken on a desktop level, using the Desktop PES/EI/ES results as no additional information was available.

(v) Extrapolation to the outlets of IUAs where the existing EWR sites are not at the outlet. The information from the lowest EWR site in the IUA has been used for the extrapolation.

(vi) The results from all the other existing EWR sites where no additional information was obtained have been accepted as is and the adjustments were made where the hydrology used in this study differed significantly.

Proposed Target Ecological Categories (TEC) at each site were defined for the scenario analysis and determination of ecological consequences, taking into account the system requirements (dam release capacities, user requirements and yields of dams) at each of the EWR sites. It should be noted that the TECs used in this report are proposed categories. As the ecological consequences of these categories still need to be evaluated, the final TECs might differ.

Table 4 provides a summary of the information for all the EWR sites where the EWRs were quantified or re-assessed.

Table 4: Summary of EWR sites in the Thukela catchments

EWR site	Quaternary catchment/ Sub-reach	River	Coordinates	PES	EI/ES	REC	TEC	Level and comments
IUA 1: Upper Buffalo								
THU_EWR23	V31D-02370	Upper Buffalo	-27.6221; 29.9617	C	High	C	C	New Rapid III sites close to outlet of IUA
IUA 2: Ngagane River								
May13_EWR2	V31F-02600	Horn	-27.888; 29.921	C	Low	C	C	Existing Rapid III site
THU_EWR19	V31J-02487	Ncandu	-27.8017; 29.8840	C	Very high	B	B/C	New Rapid III site
May13_EWR3	V31G-02618	Ngagane	-27.819; 29.987	C	Low	C	C	Existing Rapid III site
Ngagane_dsk	V31K-02516	Ngagane	Outlet of V31K	C	Moderate / High	C	C	Outlet of IUA 2. Use desktop PES/EI/ES with May13_EWR3 and THU_EWR2 to extrapolate
IUA 3: Middle Buffalo								
THU_EWR13A	V32D-02699	Buffalo	-28.0107; 30.3931	D	Moderate / High	C/D	C/D	New Rapid II to update PES of existing 2003 Thukela_EWR13
Thukela_EWR13	V32F-02707	Buffalo	-28.153; 30.476	D	Moderate	D	C/D	Existing comprehensive site; use THU_EWR13A to update EWR. Use for outlet of IUA
IUA 4: Lower Buffalo								
Thukela_EWR14	V33B-03090	Buffalo	-28.437; 30.595	B/C	High	B	B/C	Existing comprehensive EWR site. Use for outlet of IUA
IUA 5: Blood River								
Blood_dsk	V32H-02834	Blood	Outlet of V32H	C	High	B/C	B/C	Outlet of IUA 5. Use Blood River Wetland and Desktop PES/EI/ES information to determine category and DRM to determine EWR
IUA 6: Sundays								

EWR site	Quaternary catchment/ Sub-reach	River	Coordinates	PES	EI/ES	REC	TEC	Level and comments
THU_EWR7A	V60B-02826	Sundays	-28.3479; 29.968	C/D	High	C	C	New Rapid II to update PES of existing 2003 Thukela_EWR7
Thukela_EWR7	V60C-03031	Sundays	-28.458; 30.053	B/C	Moderate	B/C	C	Existing comprehensive EWR site
Thukela_EWR8	V60F-03210	Sundays	-28.636; 30.204	D	Moderate	D	D	Existing comprehensive EWR site. Use for outlet of IUA
IUA 7: Upper Mooi								
THU_EWR20	V20C-03919	Nsonge	-29.2377; 29.7853	C	Very high / High	B/C	B/C	New Rapid III site. Use to extrapolate to Little Mooi/ Mooi upstream Spring Grove Dam
EWR_Mooi_N3	V20E-03884	Mooi	-29.210; 30.002	E	Moderate	D	D	Existing Rapid III site
Thukela_EWR11	V20E-03742	Mooi	-29.116; 30.135	B/C	Moderate	B/C	B/C	Existing comprehensive site. Use for outlet of IUA
IUA 8: Lower Mooi								
THU_EWR21	V20G-03853	Mnyamvubu	-29.1610; 30.2884	C	High	B/C	B/C	New Rapid II site
THU_EWR12A	V20H-03500	Mooi	-28.9193; 30.4189	C/D	High	C	C	New Rapid III site close to EWR12. Replace comprehensive site Thukela_EWR12 due to impacts of Spring Grove Dam. Use floods from comprehensive study
Mooi_dsk	V20J-03467	Mooi	Outlet of V20J	C	High	C	C	Outlet of IUA 8. Use desktop PES/EI/ES with THU_EWR12A to extrapolate
IUA 9: Middle/ Lower Bushmans								
Thukela_EWR5	V70F-03548	Bushmans	-28.897; 30.035	B/C	Moderate	B/C	C/D	Existing comprehensive site
THU_EWR6A	V70G-03515	Bushmans	-28.8483; 30.1496	D	High	C	C/D	New Rapid III site. Use floods from comprehensive site Thukela_EWR6

EWR site	Quaternary catchment/ Sub-reach	River	Coordinates	PES	EI/ES	REC	TEC	Level and comments
Thukela_EWR6	V70G-03440	Bushmans	-28.801; 30.167	B/C	High	B/C	C/D	Existing comprehensive site. Water quality deteriorated due to increased water use and discharges in upper catchment. Use for outlet of IUA
IUA 10: Upper Thukela								
Thukela_EWR1	V11L-03301	Thukela	-28.722; 29.378	D	Moderate	D	D	Existing comprehensive site.
Thukela_EWR2	V11M-03280	Thukela	-28.717; 29.621	C	Moderate	C	C	Existing comprehensive site.
Thukela_EWR3	V13E-03362	Little Thukela	-28.778; 29.628	C/D	Moderate	C/D	C/D	Existing comprehensive site.
Thukela1_dsk	V14B-03296	Thukela	Outlet of V14B	B	High	B	C	Outlet of IUA 10. Use Desktop PES/EI/ES with Thukela_EWR2 and Thukela_EWR3 to extrapolate EWR. Existing transfers to Vaal and increased water use from new transfer
IUA 11: Klip								
THU_EWR22	V12A-03003	Klip	-28.3952; 29.7197	C	High / Very high	B/C	C	New Rapid III site. Downstream of Ingula Hydro Pump station
Klip_dsk	V12G-03256	Klip	Outlet of V12G	C	High	B/C	C	Outlet of IUA 11. Use THU_EWR22 to extrapolate
IUA 12: Middle Thukela								
Thukela_EWR4A Thukela_EWR4B THU_EWR4C	V14E-03233	Thukela	-28.705; 30.059 -28.747; 30.145 -28.7564; 30.1504	C	High	B/C	B/C	Existing comprehensive sites New Rapid I site to update Thukela_EWR4 PES.
Thukela_EWR9	V60J-03395	Thukela	-28.769; 30.515	D	Moderate	D	D	Existing comprehensive site
Thukela2_dsk	V60K-03419	Thukela	Outlet of V60K	C	High	B/C	C	Outlet of IUA 12. Use Desktop PES/EI/ES with Thukela_EWR15 to extrapolate EWR
IUA 13: Lower Thukela								

EWR site	Quaternary catchment/ Sub-reach	River	Coordinates	PES	EI/ES	REC	TEC	Level and comments
Thukela_EWR15	V40B-03429	Thukela	-28.785; 30.911	C	High	C	C	Existing comprehensive site
THU_EWR16	V50D-03903	Thukela	-29.1603; 31.3373	C	High / Moderate	C	C	Existing intermediate site. Use for outlet of IUA at V50C
IUA 14: Escarpment								
V11A_dsk	V11A-03277	Thukela	66% V11A	B	High / Very high	B	B	Use Desktop PES/EI/ES to determine EWR
V11B_dsk	V11B—3410 V11B-03470	Sithene Thonyelana	100% V11B	B	Moderate / High	B	B	Use Desktop PES/EI/ES to determine EWR
V11G_dsk	V11G-03572 V11G-03582	Mlambonja Mhlwazini	100% V11G	B	Moderate / High	B	B	Use Desktop PES/EI/ES to determine EWR
V13A_dsk	V13C-03495	Little Thukela	77% V13A	C	High/ Very high	B	B	Use Desktop PES/EI/ES to determine EWR
V70A_dsk	V70A-03876	Bushmans	87% V70A	B	High	B	B	Use Desktop PES/EI/ES to determine EWR
V70B_dsk	V70B-03927	Nsibidwana	100% V70B	B	High	B	B	Use Desktop PES/EI/ES to determine EWR
V20A_dsk	V20A-04023	Mooi	21% V20A	C	High	B	B	Use Desktop PES/EI/ES to determine EWR
V20B_dsk	V20B-04034	Little Mooi	42% V20B	C	High	B/C	B/C	Use Desktop PES/EI/ES to determine EWR
IUA 15: Estuary and upper Thukela reach								
THU_EWR17	V50D-03903	Thukela	-29.1677; 31.4037	C	High	C	C	Existing intermediate site. Use for outlet of IUA at V50D (upper reaches of Estuary)

3 DATA COLLECTION AND MODELLING

Surveys were undertaken at each of the selected EWR sites, namely six Rapid III sites, three Rapid II sites and one Rapid I site. The chosen sites were evaluated by the various specialists in terms of advantages and disadvantages, as well as given a confidence score to provide evidence for undertaking field surveys. The scores allocated were from 0 to 5, with 0 = no confidence and 5 = high confidence that the EWR site provides sufficient indicators. The results of this evaluation are given in the table below.

Table 5: Thukela River catchment EWR site evaluation

Component	Confidence Score*	Advantages	Disadvantages
THU_EWR23: Upper Buffalo in V31D (Rapid III)			
Hydraulics	2	Easily accessible, section is fairly straight.	Weir structure upstream of section. Higher flows experienced.
Fish	3	Possible biotope representivity under normal low flow conditions	Poor biotope presence lower diversity – only 3 of 8 expected species, tolerant spp. present.
Macroinvertebrates	3	All three biotopes present (SIC/SOOC, marginal VEG and GSM) Two sensitive taxa recorded during present conditions for aquatic macroinvertebrates included *Baetidae* > 2 sp (QV:12) and *Heptageniidae* (Flatheaded mayflies) (QV:13). Overall IHAS score (70%) representing Good habitat availability for aquatic macroinvertebrates. Number of taxa: 22 Total SASS5 Score: 120	The flow conditions and water levels were not representative for the dry season owing to potential discharges upstream. High algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. ASPT score of 5.5 overall representing a community of tolerant taxa.
THU_EWR19: Ncandu River in V31J (Rapid III)			
Hydraulics	2.5	Easily accessible. Well defined banks.	Bridge culverts upstream of section. Collection of boulders upstream of section.
Fish	3	Under low seasonal flows, good biotope diversity – need good flow for system connectivity	Poor water quality, low flows, low biotope diversity 3 of 10 expected spp. present – some sensitive spp. present, lack of biotope diversity a concern under very low flow conditions present – concern of re-canalisation from refuge areas. Poor connectivity over extended periods may be result of loss of e.g. *AMOS* and *LRUB*

Component	Confidence Score*	Advantages	Disadvantages
Macroinvertebrates	3	All three biotopes present for aquatic macroinvertebrates (SIC/SOOC, marginal and instream VEG and GSM). Some sensitive taxa recorded during present conditions namely *Perlidae* (QV:12), *Heptageniidae* (Flatheaded mayflies) (QV:13), *Leptophlebiidae* (*Prongills*) (QV:9), *Tricorythidae* (Stout Crawlers) (QV:9) and *Psephenidae* (Water Pennies) (QV:10). Overall IHAS score (69%) representing *Good* habitat availability for aquatic macroinvertebrates. Number of taxa: 32 Total SASS5 Score: 190	High algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. ASPT score of 5.9 overall representing a community of tolerant taxa.
THU_EWR20: Nsonge River in V20C (Rapid III)			
Hydraulics	2	Easily accessible. Well-defined banks. Low flow experienced.	River meanders upstream section. Boulders on the sides of the channel causing flow in non-uniform direction. large pools form downstream of section.
Fish	3	WQ good, under good flow, good biotope diversity possible. Important upper reach refuge area, yet *AMOS* absent	Only 2 of 5 expected spp. – intolerant spp. absent due to habitat loss related to low flows. Indications of loss of connectivity (*AMOS*). Example of loss of overhanging vegetation and root wads result in loss of small cyprinids (e.g. *BVIV)*.
Macroinvertebrates	3	All three biotopes present for aquatic macroinvertebrates (SIC/SOOC, marginal VEG and GSM). Some sensitive taxa recorded during present conditions namely *Baetidae* > 2 sp (QV:12), *Leptophlebiidae* (Prongills) (QV:9), *Tricorythidae* (Stout Crawlers) (QV:9), *Hydropsychid*ae > 2 sp (QV:12) and Athericidae (Snipe flies) (QV:10).	Sampling effort was limited at this site due to partial marginal vegetation owing to undercut banks and vegetation die back/burnt, as well as low water levels over the SIC /SOOC biotopes. Very high silt loads present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota.

Component	Confidence Score*	Advantages	Disadvantages
			Overall IHAS score (62%) representing Adequate habitat availability for aquatic macroinvertebrates. Number of taxa: 14 Total SASS5 Score: 90 ASPT score of 6.4 overall representing a community of tolerant taxa.
THU_EWR22: Klip River in V12A (Rapid III)			
Hydraulics	2	Easily accessible. Low flow experienced.	Bridge culvert upstream of section. water users upstream of section. informal water abstraction 20m away from section during monitoring. Large distance between sampling for fish and macroinvertebrates and chosen hydraulic section.
Fish	3	Important migration for e.g. *AMOS*, low flows negative impact on corridor – connectivity important.	Very poor water quality – although 6 out of 8 spp. present, low numbers, indicating stress on system. Poor habitat diversity with low flows. Further limited survey data, mostly pre 2005. *LRUB* not collected (habitat not surveyed – deep pools).
Macroinvertebrates	3	All three biotopes present for aquatic macroinvertebrates (SIC/SOOC, marginal VEG and GSM), including good flow velocities considering being in the dry season. Some sensitive taxa recorded during present conditions namely *Perlidae* (QV:12) *Baetidae* > 2 sp (QV:12), *Heptageniidae* (Flatheaded mayflies) (QV:13), *Leptophlebiida*e (Prongills) (QV:9), *Crambidae* (Pyralidae) (QV:12) and *Psephenidae* (Water Pennies) (QV:10). Overall IHAS score (68%) representing *Good* habitat availability for aquatic macroinvertebrates. Number of taxa: 36	High algae and silt load present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. Cattle grazing and trampling resulting in bank erosion, contributing to sediment coverage over biotopes. ASPT score of 5.9 overall representing a community of tolerant taxa.

Component	Confidence Score*	Advantages	Disadvantages
		Total SASS5 Score: 213	
THU_EWR12A: Mooi River in V20H (Rapid III)			
Hydraulics	2	Flow direction is fairly uniform.	Difficult to access. Large pool downstream of section.
Fish	3	WQ in good condition (parameters tested). Connectivity important.	Low flows, lack of sensitive species – possibly linked to connectivity within the system. Only 6 of 14 spp. collected. Loss of overhanging vegetation result is loss of small Cyprinidae that prefer this habitat type. Also, loss of flow sensitive spp. One eel spp. (*AMAR*) absent and this can be related to habitat preference - prefer deeper water, low presence of habitat type due to flow conditions. Data set poor – mostly pre-1991, with one record of 2007.
Macroinvertebrates	3	All three biotopes present for aquatic macroinvertebrates (SIC/SOOC, marginal VEG and GSM. Limited sensitive taxa recorded during present conditions namely *Baetidae* > 2 sp (QV:12), *Leptophlebiidae* (Prongills) (QV:9) and *Hydropsychidae* > 2 sp (QV:12) Number of taxa: 23 Total SASS5 Score: 123	System deprived of flow. High fibrous algae and high silt loads present smothering habitats and transforming a potential good SIC biotope into a homogenous habitat that supports far less biota. Sampling effort limited for the VEG biotope owing to undercut banks. Overall IHAS score (55%) representing *Adequate* habitat availability for aquatic macroinvertebrates. ASPT score of 5.4 overall representing a community of tolerant taxa.
THU_EWR6A: Lower Bushmans River in V70G (Rapid III)			
Hydraulics	1	Section is straight. variety of vegetation sand riffles environment.	Large section, with island immediately downstream of section. A tributary occurs downstream of cross section. Large pool upstream of section. Sediment deposits on the right bank. Difficult to access.

Component	Confidence Score*	Advantages	Disadvantages
Fish	3	WQ fair	Only 6 out of 15 spp. expected. Flows and loss of connectivity and habitat diversity – poor data and mostly old surveys. Data show high presence of spp. that migrate over longer distances – e.g. for spawning. Loss of suitable spawning habitat, cover (vegetation) and siltation can be result of loss of effective recruitment.
Macroinvertebrates	3	Two biotopes present for aquatic macroinvertebrates (SIC/SOOC and GSM). Limited sensitive taxa recorded during present conditions namely Baetidae > 2 sp (QV:12), Heptageniidae (Flatheaded mayflies) (QV:13), Leptophlebiidae (Prongills) (QV:9) and Hydropsychidae > 2 sp (QV:12).	Poor water quality High fibrous algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. No sampling of the VEG biotope owing to undercut banks and bank erosion due to cattle grazing and trampling. High abundance of Simuliidae (Blackflies) (QV:5) and Chironomidae (Midges) (QV:2) sampled from both biotopes (QV:5) representative of poor water quality. Overall IHAS score (57%) representing *Adequate* habitat availability for aquatic macroinvertebrates. Number of taxa: 14 Total SASS5 Score: 80 ASPT score of 5.7 overall representing a community of tolerant taxa.
THU_EWR21: Mnyamvubu River in V20G (Rapid II)			
Fish	3	WQ fair, yet close proximity to impoundment not good.	No fish collected. Poor water quality lower down in Mooi River can act as “pollution plug”. In addition, no flow (no releases) could result in loss of fish and it takes time for recolonisation (not sure if this is the case in this situation). There is numerous

Component	Confidence Score*	Advantages	Disadvantages
			records of alien invasive predators in the impoundment (Lake Craigieburn) that can further contribute to loss of indigenous spp. Lower temperature and poor habitat diversity and flows, no connectivity (number of spp. migrate over longer distances to spawn as an example) and no recruitment from lower in the system due to poor quality in the main stem system. Data set for area below the dam wall all pre-1990.
Macroinvertebrates	3	Two biotopes present for aquatic macroinvertebrates (SIC/SOOC and GSM). Limited sensitive taxa recorded during present conditions namely *Baetidae* > 2 sp (QV:12), *Heptageniidae* (Flatheaded mayflies) (QV:13), *Leptophlebiidae* (Prongills) (QV:9) and *Hydropsychidae* > 2 sp (QV:12).	Poor water quality High fibrous algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. No sampling of the VEG biotope owing to undercut banks and bank erosion due to cattle grazing and trampling. High abundance of *Simuliidae* (Blackflies) (QV:5) and *Chironomidae* (Midges) (QV:2) sampled from both biotopes (QV:5) representative of poor water quality. Overall IHAS score (57%) representing *Adequate* habitat availability for aquatic macroinvertebrates. Number of taxa: 14 Total SASS5 Score: 80 ASPT score of 5.7 overall representing a community of tolerant taxa.
THU_EWR13A: Middle Buffalo River in V32D (Rapid II)			
Fish	3		WQ poor, exclude sensitive/intolerant spp., low flows

Component	Confidence Score*	Advantages	Disadvantages
			and poor habitat diversity. Limited riffle/pools that are accessible for surveying. Lack of migration and connectivity. Low biotope diversity. Only 1 of 9 spp. collected. Two of the spp. are alien invasive, 1 is a predator, the other a habitat modifier. In addition, very old records pre-1990.
Macroinvertebrates	5	All biotopes present for aquatic macroinvertebrates (SIC/SOOC, VEG and GSM). Limited sensitive taxa recorded during present conditions namely *Baetidae* > 2 sp (QV:12) and *Hydropsychidae* > 2 sp (QV:12).	Poor water quality - visual evidence of sewage. High fibrous algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. High abundance of *Simuliidae* (Blackflies) (QV:5) and *Chironomidae* (Midges) (QV:2) sampled from both biotopes (QV:5) representative of poor water quality. Overall IHAS score (56%) representing *Adequate* habitat availability for aquatic macroinvertebrates. Number of taxa: 14 Total SASS5 Score: 77 ASPT score of 5.5 overall representing a community of tolerant taxa.
THU_EWR7A: Upper Sundays River in V60B (Rapid II)			
Fish	3	WQ fair	Low spp. diversity – 2 from 8. Poor habitat and connectivity related to low flows and lack of habitat diversity. In addition, records very old – pre 1990.

Component	Confidence Score*	Advantages	Disadvantages
Macroinvertebrates	3	All biotopes present for aquatic macroinvertebrates (although limited SIC/SOOC, VEG and GSM). Some sensitive taxa recorded during present conditions namely *Baetidae* > 2 sp (QV:12), *Heptageniidae* (Flatheaded mayflies) (QV:13) and *Leptophlebiidae* (Prongills) (QV: 9). Number of taxa: 21 Total SASS5 Score: 117	High abundance of bedrock – which in essence is not a good biotope for aquatic macroinvertebrates. Overall IHAS score (63%) representing *Adequate* habitat availability for aquatic macroinvertebrates. ASPT score of 5.6 overall representing a community of tolerant taxa.
THU_EWR4C: Middle Thukela in V14E (Rapid I)			
Fish	3	WQ fair – yet metals noted One individual of *Labeo rubromaculatus* (Tugela Labeo) recorded with a status of *Vulnerable* in accordance to IUCN (2020-2).	5 out of 13 spp. collected. Low flows and limited habitat diversity result in low numbers of specimens. Many spp. migrate over longer distances to spawn. Flow fluctuations can impact on breeding and successful growth.
Macroinvertebrates	5	All biotopes present for aquatic macroinvertebrates (SIC/SOOC, VEG and GSM). A number of sensitive taxa recorded during present conditions namely *Baetidae* > 2 sp (QV:12), *Heptageniidae* (Flatheaded mayflies) (QV:13) and *Leptophlebiidae* (Prongills) (QV: 9), *Chlorocyphidae* (Jewels) (QV:10), *Crambidae* (Pyralidae) (QV:12) and *Psephenidae* (Water Pennies) (QV:10). Overall IHAS score (72%) representing *Good* habitat availability for aquatic macroinvertebrates. Number of taxa: 24 Total SASS5 Score: 145	Poor water quality High fibrous algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. ASPT score of 6.0 overall representing a community of tolerant taxa.

3.1. Hydraulics

During the site visit, the following activities were undertaken:

- EWR cross section was selected,
- A survey of the cross-sectional profile of the EWR site was carried out,
- Longitudinal water slope was surveyed,
- Discharge was measured,
- GPS co-ordinates of the site were captured, and
- EWR site photographs were taken.

The hydraulic data collected during the site visit is listed in Table 6.

Table 6: Hydraulics data measured for the Thukela River catchment EWR sites

EWR site	Survey date	River	Discharge Q (m^3/s)	Maximum flow depth (m)
THU_EWR23	11/09/2020	Upper Buffalo	1.240	0.580
THU_EWR19	07/09/2020	Ncandu	0.083	0.175
THU_EWR20	08/09/2020	Nsonge	0.085	0.120
THU_EWR22	10/09/2020	Klip	0.089	0.245
THU_EWR12A	08/09/2020	Lower Mooi	0.189	0.190
THU_EWR6A	09/09/2020	Bushmans	0.189	0.385
THU_EWR21*	07/09/2020	Mnyamvubu	0.972	0.89
THU_EWR13A*	10/09/2020	Middle Buffalo	0.026	0.105
THU_EWR7A*	11/09/2020	Sundays	1.240	0.580

* No cross-sectional profile was surveyed

Modelling was carried out using the measured data, as well as two modelled points to develop stage discharge curves. The following data was required in the use of the modelling: y (maximum flow depth), n (resistance coefficient), S (slope), Q (discharge), A (area) and WP (wetted perimeter). The measured and modelled data are shown in Table 7.

Table 7: Hydraulic data used to extend observed rating data at the EWR sites

EWR site	River	Discharge Q (m^3/s)	Maximum flow depth (m)	Manning's resistance, *n*	Surface Slope, S m/m)	Ave. Velocity, V (m/s)
THU_EWR23	Upper Buffalo	1.240	0.580	0.324	0.045	0.272
THU_EWR19	Ncandu	0.083	0.175	0.243	0.028	0.134
THU_EWR20	Nsonge	0.085	0.120	0.227	0.007	0.090
THU_EWR22	Klip	0.089	0.245	0.297	0.011	0.073
THU_EWR12A	Mooi	0.189	0.190	0.409	0.023	0.108
THU_EWR6A	Bushmans	0.189	0.385	0.262	0.004	0.057

The depth/discharge relationship (Hirschowitz PM, Birkhead AL, James CS) was determined using the following equation:

$$y = aQ^b + c$$

Y is the maximum depth, Q is the discharge (m3/s) and a, b and c coefficients. The coefficients used in the equation are shown in Table 8 below.

Table 8: Regression coefficients used in equation

EWR site	River	Regression coefficients		
		a	b	c
THU_EWR23	Upper Buffalo	0.5369	0.3360	0
THU_EWR19	Ncandu	0.3447	0.2758	0
THU_EWR20	Nsonge	0.6467	0.6559	0
THU_EWR22	Klip	0.4127	0.1763	0
THU_EWR12A	Mooi	0.3369	0.3446	0
THU_EWR6A	Bushmans	0.6041	0.2905	0

The cross-sectional views of the EWR sites per river, stage discharge relationships developed from the modelling and the detailed output tables are available electronically.

The confidence rating in the hydraulic modelling results for the EWR sites ranges from 0 = none to 5 = high and is indicated in Table 9.

Table 9: Confidence in the hydraulic modelled results

EWR site	River	Limits of measured discharge range (m^3/s)	Confidence rating for discharge range		Comments
		Q measured	Q< Q measured	Q> Q measured	
THU_EWR23	Upper Buffalo	1.240	**1** 0.130 m^3/s	**2** 7.630 m^3/s	Below 0.13 m^3/s, the riverbed is partially dry with a large roughness. Above 7.63 m^3/s the boulders are completely submerged altering the hydraulic conditions of the river.
THU_EWR19	Ncandu	0.083	**2** 0.011 m^3/s	**1** 7.461 m^3/s	Below 0.011 m^3/s, water depth is substantially low. Expected larger roughness. Above 7.461 m^3/s, the banks are flooded become inundated.
THU_EWR20	Nsonge	0.085	**1** 0.050	**2** 1.000	Below 0.05 m^3/s, cobbles are not submerged. Above 1.0

EWR site	River	Limits of measured discharge range (m^3/s)	Confidence rating for discharge range		Comments
		Q measured	Q< Q measured	Q> Q measured	
			m^3/s	m^3/s	m^3/s cobbles and boulders are entirely submerged.
THU_EWR22	Klip	0.089	**1** 0.015 m^3/s	**1** 20.0 m^3/s	Below 0.015 m^3/s, water trickles between cobbles. Above 20 m^3/s, the banks become inundated.
THU_EWR12A	Mooi	0.189	**1** 0.189 m^3/s	**1** 25 m^3/s	Below 0.189 m^3/s, the sides of the river of the river are dry and the cobbles are exposed. Above 25 m^3/s, the side banks are inundated.
THU_EWR6A	Bushmans	0.972	**1** 0.086 m^3/s	**1** 10.262 m^3/s	Below 0.086, the left bank of the river becomes dry and flow is only expected over the sediment build up to the right. Above 10.62 m^3/s, the island in the middle of the river is partially submerged influencing the hydraulic conditions.

3.2. Fish

Fish have widely been used as ecological indicators in the assessment of the integrity of riverine ecosystems (Kleynhans, 1999; Kotze, 2002; Karr, 1981; Belpaire *et al*., 2000 and Kleynhans, 2007). Some of the benefits of using fish as ecological indicators include:

- fish are well known and easily related to by people,
- the requirements and responses of fishes to changes in the state of environmental variables is also well documented, and used in a range of measures or indices that can be applied to manage the ecosystems in which they live,
- fish are relatively easy to sample and identify in the field; and
- sampling for fish is relatively inexpensive and can be undertaken fairly rapidly.

Fish surveys were undertaken at selected EWR sites. Electro-narcosis (conducting an electric current into the water, which immobilises the fish momentarily) was applied using an electro-fishing apparatus to sample all the available fish biotopes (i.e. the combinations of velocity-depth classes and available cover types). Although sampling protocols were adhered to, which includes sampling effort required for fish surveys, the site assessments were carried out

rapidly and without duplications due to time constraints of the study. Fish specimens were identified in-field using Freshwater Fishes of Southern Africa (Skelton, 2001), and returned alive. Any additional information pertaining to fish ecology and habitat drivers were also noted.

The ecological categories were determined using historical fish data from the broader study area, from comparable sites within the specific catchment and tributaries, and from the surveys at the EWR sites. Fish data were analysed by implementing the Fish Response Assessment Index (FRAI) (Kleynhans, 2007). FRAI assesses the attributes of fish assemblages in terms of the occurrence of a species expected to be present in segments of the river containing relatively homogenous habitats.

Fish species are categorised in the FRAI model according to an intolerance rating that take trophic preferences and specialisation into account, as well as all the flow, habitat, and water quality requirements. The ratings are then formulated into a relative FRAI index value, which is grouped into one of six descriptive fish assemblage integrity index classes.

The expected and observed Frequency of Occurrence (FROC) of fish species were compiled using the reference frequency of occurrence for fish species in South Africa (Kleynhans et al., 2007a). Data from the 2014 Present Ecological State, Ecological Importance and Ecological Sensitivity (PES/EI/ES) dataset (DWS, 2014) was also consulted with the derivation of FROC. These FROC values were used to interrogate the FRAI model to evaluate changes from reference conditions. FRAI is a rule-based model developed by DWA (Kleynhans, 2007) that assesses environmental intolerances and preferences of the reference fish assemblage, as well as the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers. These intolerance and preference attributes are categorised into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species.

Assessment of the response of the species metrics to changing environmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually the FRAI is based on a combination of fish sample data and available habitat for fish. Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation and to determine the Present Ecological Category of the fish assemblage.

The available fish information for the EWR sites is summarized in the table below using a score from 0 (no information) to 4 (large amount of data available).

Table 10: Information available for fish

COMPONENT	INFORMATION AVAILABILITY					DESCRIPTION OF INFORMATION
	0	1	2	3	4	
THU_EWR23				X		Lack of recent surveys
THU_EWR19			X			Limited for the site and reach
THU_EWR20			X			Low historic reference information – no recent surveys
THU_EWR22			X			Poor reach and system survey data
THU_EWR12A			X			Limited reach information – no recent data on system
THU_EWR6A			X			Fragmented data for the system – need more surveys
THU_EWR21			X			Old survey data in upper system
THU_EWR13A			X			Limited surveys from the reach
THU_EWR7A				X		Fragmented data from system, especially the reach
THU_EWR4C				X		More recent data available, yet fragmented data, need continuous surveys

3.3. Macroinvertebrates

Macroinvertebrate diversity and abundances were measured by a Department of Water and Sanitation SASS5 accredited practitioner at the EWR sites using the South African Scoring System Version 5 (SASS5; Dickens and Graham, 2002). Historical data (from the River Health Sites and PES/EI/ES databases and other data sources) and specialist knowledge were used to determine reference conditions. The following assessment methods were used to collect and/or analyse the data:

- The South African Scoring System Version 5 (SASS5). This index measures aquatic macroinvertebrate presence data at a family taxon level. Each taxon is allocated a sensitivity value between 1 and 15 according to its perceived sensitivity to water quality changes (with 1 being the least sensitive and 15 the most sensitive). Results are expressed as index scores: the SASS Score and the Average Score per Taxon (ASPT). The SASS scores obtained from the study sites can be interpreted to scores derived spatially for the ecoregion using biological bands (Dallas, 2007). The bands, which are calculated from a number of reference sites in the ecoregion, account for natural variability of scores (ASPT and SASS scores) which may be expected over the geographical area.
- The prescribed DWS Macroinvertebrate Response Assessment Index (MIRAI; Thirion, 2008) uses SASS5 and pre-determined reference condition data to determine the macroinvertebrate Ecological Condition of a site. The model considers three main drivers influencing macroinvertebrate community composition, namely: i) flow, ii) habitat and iii) water quality. These drivers create the instream habitats that affect instream biotic

communities. Therefore, the Ecological Category generated by the MIRAI reflects the influence of each drivers on the site and the macroinvertebrate community.

The available macroinvertebrate information for the EWR sites is summarized in the table below using a score from 0 (no information) to 4 (large amount of data available).

Table 11: Information available for macroinvertebrates

COMPONENT	INFORMATION AVAILABILITY					DESCRIPTION OF INFORMATION
	0	1	2	3	4	
THU_EWR23				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR19				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR20				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR22				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR12A				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR6A				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR21				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).
THU_EWR13A					X	Current data along with data collected seasonally during continuous surveys at this monitoring site between 2013 and 2015.
THU_EWR7A				X		Limited to the site and reach (historical reference aquatic macroinvertebrate data related to the water management area, Ecoregion 2, longitudinal zone and altitude similar to the monitoring site was provided by DWS).

COMPONENT	INFORMATION AVAILABILITY					DESCRIPTION OF INFORMATION
	0	1	2	3	4	
THU_EWR4C					X	Current data along with data collected by DWS and Gordon O'Brien at this monitoring site in 2011, 2012, 2015 and 2019.

3.4. Integrated Habitat Integrity assessment (IHI)

A rapid habitat integrity assessment was undertaken at each of the selected EWR sites. The rapid IHI is used as a surrogate during a rapid study when a riparian vegetation assessment is not undertaken. The habitat integrity assessments were conducted using the procedure described by Kleynhans, 1996 and the latest IHI DWS model. The habitat integrity was evaluated taking flow related impacts of the upstream catchment into account.

3.5. Hydrological data

The natural hydrology at all the EWR sites were obtained from the WRPM model and is based on a number of studies undertaken for the major tributaries of the Thukela River. The detailed sources and results of the hydrology is available in the Water Resources Information and Gap Analysis Report (RDM/WMA04/00/CON/CLA/0120).

The natural flow time series obtained from these studies for the period 1925 to 1994 were used and adjusted by catchment area to obtain the natural flows at the EWR sites. The natural Mean Annual Runoff (nMAR) per EWR site is shown in Table 12. The final natural time series per EWR site is provided electronically. Note that the table includes all the EWR sites, not only the new Rapid III sites.

Table 12: Natural MAR per EWR site in the Thukela River catchment

IUA	EWR site name	River	Quaternary catchment	Natural MAR ($10^6 m^3$)
1	THU_EWR23*	Upper Buffalo	V31D	221.96
2	May13_EWR2	Horn	V31F	21.61
	THU_EWR19*	Ncandu	V31J	50.83
	May13_EWR3	Ngagane	V31K	160.12
	Ngagane_dsk	Lower Ngagane	V31K	240.84
3	THU_EWR13A	Middle Buffalo	V32F	626.68
	Thukela_EWR13	Middle Buffalo	V32H	695.05
4	Thukela_EWR14	Lower Buffalo	V33B	831.09
5	Blood_dsk	Blood	V32H	94.71
6	THU_EWR7A	Upper Sundays	V60B	50.69
	Thukela_EWR7	Upper Sundays	V60C	90.28
	Thukela_EWR8	Lower Sundays	V60F	197.03
7	THU_EWR20*	Nsonge/ Hlatikulu	V20C	27.13
	EWR_Mooi_N3	Mooi	V20E	265.81

IUA	EWR site name	River	Quaternary catchment	Natural MAR (10^6m^3)
	Thukela_EWR11	Mooi	V20G	301.14
8	THU_EWR21	Mnyamvubu	V20G	31.71
	THU_EWR12A*	Mooi	V20H	361.85
	Mooi_dsk	Mooi	V20J	388.66
9	Thukela_EWR5	Middle Bushmans	V70F	281.45
	THU_EWR6A*	Lower Bushmans	V70G	298.37
	Thukela_EWR6	Lower Bushmans	V70G	303.14
10	Thukela_EWR1	Upper Thukela	V11J	705.42
	Thukela_EWR2	Upper Thukela	V11M	798.40
	Thukela_EWR3	Little Thukela	V13E	285.20
	Thukela1_dsk	Thukela	V14B	1145.20
11	THU_EWR22*	Klip	V12A	52.44
	Klip_dsk	Klip	V12G	253.09
12	Thukela_EWR4A, B, C	Middle Thukela	V14E	1423.83
	Thukela_EWR9	Middle Thukela	V60J	2050.76
	Thukela2_dsk	Middle Thukela	V60K	2461.22
13	Thukela_EWR15	Lower Thukela	V40B	3424.00
	THU_EWR16	Lower Thukela	V50C	3679.97
14	V11A_dsk	Thukela	V11A	66.90
	V11B_dsk	Sithene, Thonyelana	V11B	142.69
	V11G_dsk	Mlambonja, Mhlwazini	V11G	191.99
	V13A_dsk	Little Thukela	V13A	82.32
	V70A_dsk	Bushmans	V70A	113.46
	V70B_dsk	Nsibidwana	V70B	44.16
	V20A_dsk	Mooi	V20A	42.90
	V20B_dsk	Little Mooi	V20B	10.32
15	THU_EWR17	Lower Thukela	V50D	3690.53

* New Rapid III sites

3.6. Quantification of EWRs

The results of the field assessments of the various habitat and biotic components are used in the Ecoclassification of each site. This process includes the following:

(i) Definition of the reference conditions,
(ii) Determination of the present ecological state (Ecostatus model for each component and integrated),
(iii) Verification of the desktop Ecological Sensitivity and Ecological Integrity with actual surveyed data,

(iv) Determination of the trends, and
(v) Integration of all of the above to determine the REC and TEC.

The quantification of the EWRs used the Desktop Reserve Model (DRM) (SPATSIM, version 2.12) to calculate the Ecological Water Requirements (quantity) for the PES and TEC at the EWR sites. These EWR flow data were converted to hydraulic conditions at the Rapid III EWR sites (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model and evaluated by the ecologists. Where the modelled requirements were not adequate to provide the envisaged protection, the DRM was adjusted accordingly.

The following approaches were used for the new Rapid III sites:

- Verification of the drought and base flows (maintenance flows) using the DRM and hydraulic cross-sections,

- Specification of freshets and annual floods at the new rapid sites. Where an existing EWR site (intermediate or comprehensive) was in close proximity of the new site, the flood requirements from the previous studies were used as these were also based on riparian vegetation and geomorphology, and

- The release capacities of dams were taken into consideration, especially where the dams are close to the sites. These freshets were adjusted where required to be in line with the release capacities of the dams.

Drought flows are defined as the minimum flow required (flows occurring 90%-99.9% of the time) to ensure the survival of the aquatic ecosystem in a specific condition/ state for short, infrequent periods, when users are subject to water restrictions. Maintenance flows (flows occurring approximately 60%-70% of the time) are specified to meet the requirements of the aquatic ecosystem to maintain the ecosystem in a particular condition/ state during "normal" climatic years. Freshets are typically the small increases in base flows over a few days during the first spring and/or summer rains and towards the end of the summer season and have a specific ecological function (cues for spawning, cleaning of habitats).

These EWR results were then used to produce the final Ecological Reserve quantity results in the form of an assurance table or EWR rule curves. These curves specify the frequency of occurrence relationships of the defined maintenance and drought flow requirements for each month of the year. The tables thus specify the % of time that defined flows should equal or exceed the flow regime required to satisfy the ecological Reserve. The impacts of the specified EWR flows on the yields from dams and user demands were considered and a Target Ecological Category was specified for each of the EWR sites. This TEC will still provide adequate flows to maintain the aquatic ecosystem, and can be equal to the PES or REC. In cases where the TEC was lower than the REC, the ecological consequences will be determined.

The final total EWR results (summary tables, rule tables and long-term requirements) per EWR site is provided electronically**.**

4 EWR RESULTS

The results of the ecological Reserve determination of the various rivers in the Thukela catchments at the selected EWR sites are presented in this section. These include the new rapid sites, re-surveying of existing EWR sites and the re-assessment of the EWRs using existing hydraulics and biological data.

4.1. New Rapid III EWR sites

The new Rapid III EWR sites that were selected are:

i. THU_EWR23 in the Upper Buffalo River (UIA1)
ii. THU_EWR19 in the Ncandu River (IUA2)
iii. THU_EWR20 in the Nsonge (Hlatikulu) River (IUA7)
iv. THU_EWR22 in the Klip River (IUA11)

The following sections provide the summary results of the Ecoclassification process and the quantification of the EWRs at the EWR sites. The detailed model outputs (Ecostatus, FRAI, MIRAI, IHI, verification of EI and ES and the final EWR rule and summary tables) are available as electronic appendices.

4.1.1. THU_EWR23: Upper Buffalo River in V31D

The selected EWR site is situated upstream of a low water bridge and downstream of a small weir. However, due to the slope and the high flows during the surveys, the site was not inundated. The higher flows were a result of releases from Zaaihoek Dam in the Slang River, a tributary of the Buffalo River for irrigation purposes along the Slang and Buffalo Rivers.

Figure 3: View of the EWR site on the Upper Buffalo River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in the table below.

Table 13: THU_EWR23 reference conditions and present ecological state per component

COMPONENT	DESCRIPTION
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Upper Buffalo River at the EWR site would have supported a moderate diversity of fish, with up to eight indigenous fish species expected to have occurred – AMOS, BANO, BNAT, BPAL, BPAU, BVIV, CGAR and LRUB.
Present state	Only three out of the expected eight species of fish were collected from the Upper Buffalo River at the THU_EWR23 namely BNAT, BPAL and CGAR. *Anguilla mossambica* and *Labeo rubromaculatus* (absent from the survey (can be that they are present in deep pools not sampled) and *Labeobarbus natalensis* (sampled in very small numbers) are the rheophilic (i.e. flow-dependent) species that prefer the fast deep (FD), fast shallow (FS) and shallow deep (SD) habitats that was not present in sufficient areas or depth of the water column. The smaller barbs all require overhanging vegetation as cover, and this was very poorly represented at the site (low flow and drought conditions). In addition, the trampling and loss of the basal layer contribute to this component. Despite the time constraint for conducting the rapid survey, fish catches resulted in very low numbers of species being sampled. This can be related to the poor water quality, low flows (resulting in not enough depth in the water column) and poor habitat diversity (e.g. lack of vegetation). The loss of in-stream habitat (siltation and algae) contributes to loss of habitat for small fish to forage and use a cover against predators. The FRAI results indicate that the fish assemblage is currently in a “C” (65%) Ecological Category indicating that the fish community is modified (poor diversity). The present fish assemblage is determined by the available biotopes at the site, i.e. velocity-depth (fast-shallow mainly) and cover (substrate and water column). The lack of marginal and instream vegetation linked to the low flow and possible poor connectivity (lowering the options for migration) are the main negative impacts at the site. Water quality impacts would have significantly lower impact on the fish diversity and numbers and the altered hydrological signature of the system (i.e. the timing, magnitude, duration, and frequency of flows) would negatively impact the rheophilic species.
Macroinvertebrates	
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >200 and the Average Score Per Taxon (ASPT) should be >6.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Notonemouridae, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Coenagrionidae, Lestidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Corydalidae, Ecnomidae, Hydropsychidae 1sp, Hydropsychidae >2spp, Philopotamidae, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae,Athericidae,

COMPONENT	DESCRIPTION
	Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Physidae, Planorbinae, Corbiculidae, Sphaeridae, and Unionidae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a C (66.15%). This means the macroinvertebrate community is in a moderately modified state with moderate diversity of taxa. The most impacted driver metric is that of flow modification (59.0%); followed by water quality (65.6%) and habitat modification (73.5%) respectively. The table below provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Heptageniidae, Baetidae >2spp. According to the flow modification metric group, taxa with a preference for moderately fast flowing water were the most important groups of invertebrates, whereas taxa with a preference for standing water were the least important group of invertebrates in the system. Taxa with a preference for slow and very fast flowing water were the most impacted group of invertebrates. No invertebrates were recorded with a preference for slow flowing water, while only Hydropsychidae & Simuliidae were present in the very fast flowing water, with Elmidae (FROC 3) and the rest of the expected macroinvertebrates with a FROC<3 were not recorded as per the reference data respectively. According to the habitat modification metric group, taxa with a preference for vegetation were the most important group of macroinvertebrates, whereas taxa with a preference for the water column or surface were the least important group of invertebrates in the system. Taxa with a preference for cobbles/bedrock/boulders (5 recorded from an expected 27 taxa) and vegetation (7 recorded from an expected 16) were the most impacted group of invertebrates. Those taxa with a preference for gravel, sand and mud as well as the water column/water surface were the least impacted groups of invertebrates relative to the reference condition. According to the water quality metric group, taxa with a low requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition (12 taxa recorded out of an expected 24 taxa). Taxa with high, moderate and very low requirements for unmodified physico-chemical modification were the most impacted metric (2, 3 and 5 taxa were recorded from an expected 9, 18 and 17 taxa respectively), while the SASS score and ASPT were the least impacted metrics with regard to water quality modification. Overall, the present SASS5 and ASPT scores of 120 and 5.5 respectively did not exceed or match the reference data of 200 and 6.5 respectively. The present SASS5 and ASPT scores differed by 60% and more than 80% from the expected, respectively.

The PES per component as derived from the various models as well as the EcoStatus are provided in Table 14. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether it is flow or non-flow related impacts are also determined.

Table 14: PES per component and integrated PES for THU_EWR23

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C	F and NF	The fish assemblage is modified, and it is linked to a combination of non-flow related and flow related impacts. This includes a significant loss of habitat and protective cover (including increased sedimentation) within the broader system resulting in substrates becoming smothered. Nevertheless, altered flows (changed hydrological cycle – i.e. loss of floods and freshets) in the catchment due to transformed land cover and land use activities has exacerbated drivers of velocity-depth/cover.
Macroinvertebrates	C	F and NF	The main driver in the system affecting the macroinvertebrate community was modified flows as a result of changes in hydrology from the impoundment upstream leading to higher than normal flows, combined with water quality impacts/pollution. The high algae present was smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. Porifera were not identified owing to the siltation/high algae on the rocks.
HI: Instream	D	F and NF	Water abstraction for irrigation and increased flows during low flow months from Zaaihoek Dam. Bed and channel modified by low water bridge and weir
HI: Riparian	B	NF	Overgrazing, trampling and vegetation removal are primarily responsible for erosion along both the marginal and non-marginal zones.
ECOSTATUS	**C**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR23 are presented in the table below.

Table 15: Ecological trends for THU_EWR23

Component	Trend	Reason	Confidence (0-5)*
Fish	Negative	There have been some changes to the upstream catchment in recent year with flow regime changes (lower rainfall, lower runoff and increased abstraction), poor land-use practices and erosion, increased pollution from the catchment.	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses), water quality modification (from upstream impoundments, erosion, grazing cattle and human settlements) and good habitat availability were	4

		the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from low intensity agriculture and cattle grazing as well as low density rural human settlements. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time as a result of the proposed weir as only a reduction in base flows would occur.	
HI: Instream	Stable	Water releases and abstraction ongoing for many years	3
HI: Riparian	Stable	Grazing and cattle trampling ongoing	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve or even degrade if the river is a hard-working river. Table 16 provides the final results for the Buffalo River at THU_EWR23.

Table 16: Final ecological categories for THU_EWR23

Component	PES	Importance	REC	Trend	TEC
Fish	C	EI = High ES = High		Negative	Rationale: Releases are governed by operating rule for Zaaihoek Dam. Reach has constant unnatural high flow. Present status to be maintained.
Macroinvertebrates	C			Stable	
HI: Instream	D			Stable	
HI: Riparian	B			Stable	
ECOSTATUS	**C**	**High**	**C**		**C**

The final step is the quantification of the EWR and include the conversion of the EWR flow data for a TEC of a C category to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model. The maintenance and drought flows were examined for August and February. August is the month with the lowest maintenance flow (i.e. base-flow) and February is the month with the highest maintenance flow conditions.

The requirements of the DRM for September were also assessed as the surveys were undertaken on 11 September 2020. The discharge at the EWR site during the site visit was 1.240 m^3/s and was used as reference to adjust the recommended EWRs. It was taken into consideration that the flows were artificially high for September due to the releases from Zaaihoek Dam.

Together with site photographs and rating relationships (flow depth versus discharge) from the hydraulic model, water levels proposed by the DRM for drought and maintenance low flows were assessed in terms of the habitat and biotic requirements. The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates and depths for fish. The consensus reached by the aquatic ecologists was that the velocities at the critical habitat, recommended by the DRM model during September, was not adequate to provide the necessary velocities for the flow sensitive macroinvertebrates and depths for fishes. Also, the drought flows for September were not adequate to sustain the biota, even for a short period. Thus, the following changes were made to the desktop flow requirements:

Maintenance low flows:

- September – change from 0.223 m^3/s to 0.386 m^3/s
- February – change from 1.394 m^3/s to 2.412 m^3/s

Drought flows:

- September – change from 0.098 m^3/s to 0.143 m^3/s
- February – change from 0.559 m^3/s to 0.648 m^3/s

The final EWRs for specific months are given in Table 17 and shown on the graph in Figure 4.

Table 17: EWR results for specific months for Upper Buffalo River in V31E (TEC = C)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Maintenance low flows					
	September	0.386	0.40	0.20	0.19
	February	2.412	0.72	0.36	0.36
Drought flows					
	September	0.143	0.30	0.14	0.14
	February	0.648	0.48	0.24	0.23
Measured discharge at site visit (11/09/2020)		1.240	0.58	0.29	0.29

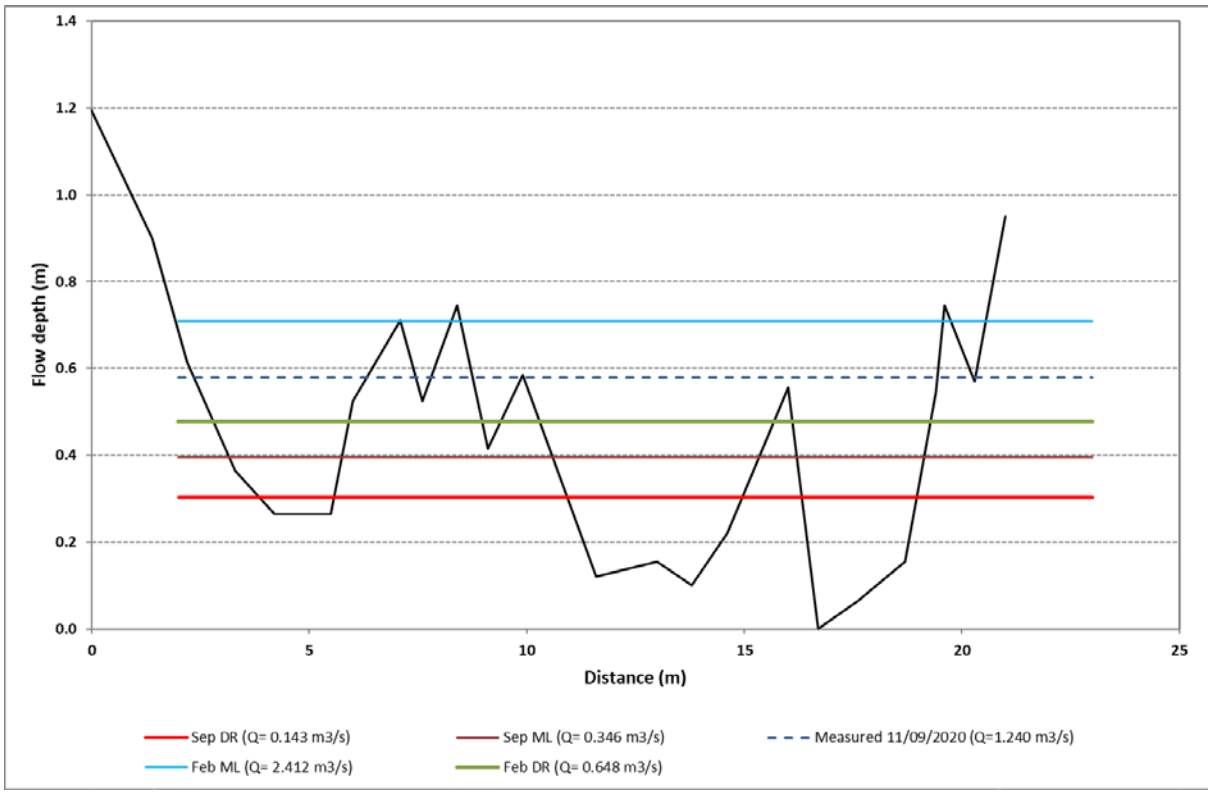

Figure 4: Water levels on cross-section for the Upper Buffalo River (THU_EWR23)

Additionally, the following freshets/ floods were specified (Table 18) for the Buffalo River. This will provide the necessary cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats.

Table 18: Freshets and annual flood requirements at THU_EWR23

Months	Flow (m^3/s)	Duration (days)	Flow (m^3/s)	Duration (days)
	Freshets		Floods	
September	2.8	2		
October	4.5	2		
November	4.5	2		
December	2.5	2	8	3
January	2.5	3	20	4
February	10	3	30	6
March	2.5	2	15	4
April	2.5	3		

The final EWR for the Upper Buffalo River at THU_EWR23 is summarised in Table 19.

Table 19: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V31D
River	Upper Buffalo
EWR Site Co-ordinates	-27.6221; 29.9617
Present Ecological State	C
Target Ecological Category	C
NMAR at EWR site	221.96
Total EWR	52.033 (23.44 %MAR)
Maintenance Low flows	33.134 (14.93 %MAR)
Drought Low flows	8.559 (3.86 %MAR)
Maintenance High flows	18.900 (8.51 %MAR)
Overall confidence	Low to medium

4.1.2. THU_EWR19: Ncandu River in V31J

The selected EWR site is situated downstream of a low water bridge. The flows were very low during the site surveys and limited habitats available for sampling.

Figure 5: View of the EWR site on the Ncandu River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in the table below.

Table 20: THU_EWR19 reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014: EKZN, 2020), the reach of the Ncandu River at the EWR site would have supported a moderate diversity of fish, with up to nine indigenous fish species expected (BANO, LRUB, BNAT, BPAL, ANAT, BVIV, AMOS, BPAU and CGAR.
Present state	Only three of the expected nine species of fish were collected from the Ncandu River at the THU_EWR19, namely BVIV, ANAT and BNAT. As the hydraulic habitats sampled favour rheophilic (i.e. flow-dependent) species, species such as LRUB and AMOS would more likely have been observed in slow-deep/pool habitats (absent during the survey). Despite the time constraint for conducting the rapid survey, fish catches resulted in a poor number of specimens collected. The FRAI results indicate that the fish assemblage is currently in a "C/D" (60%) Ecological Category indicating that the fish community is highly modified. The present fish assemblage is largely determined by the available biotopes at the EWR site, i.e. velocity-depth (fast-shallow mainly) and cover (mainly substrate, water column and limited vegetation). Flow alterations (largely through reduced base flows) would impact BANO, LRUB, BNAT, ANAT and AMOS. The lack of cover (mostly vegetation) excludes the small barbs and lack of deeper water the CGAR and OMOS. Water quality impacts would have lower impact on the fish ecology of the system (mainly the siltation) but is not as significant as the changes in hydraulic habitats (i.e. velocity-depth and changes in cover). The siltation and presence of the algae patches is a concern – i.e. lower habitat for small fish and its food sources (macro-invertebrates).
Macroinvertebrates	
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >200 and the Average Score Per Taxon (ASPT) should be >6.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Coenagrionidae, Lestidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae, and Unionidae.

COMPONENT	DESCRIPTIONS
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a B/C (79.04%). This means the macroinvertebrate community is in a slight to moderately modified state with high diversity of taxa but with fewer sensitive taxa. The most impacted driver metric is that of flow modification (77.1%); followed by habitat (79.8%) and water quality modification (80.1%) respectively. The table below provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Perlidae, Heptageniidae (Flatheaded mayflies), Leptophlebiidae (Prongills), Tricorythidae (Stout Crawlers) and Psephenidae (Water Pennies). According to the flow modification metric group, taxa with a preference for standing flowing water (10 taxa recorded from an expected 24 taxa) and moderately fast flowing water (7 recorded from an expected 9 taxa) were the most important groups of invertebrates. Taxa with a preference for slow and very fast flowing water were the least important group of invertebrates in the system as the present conditions recorded 2 and 3 taxa out of 7 expected taxa respectively. According to the habitat modification metric group, taxa with a preference for vegetation and cobbles/boulders/bedrock were the most important group of macroinvertebrates (6 and 12 taxa recorded from an expected 16 and 23 taxa respectively). Taxa with a preference for the water column or surface ad GSM were the least important group of invertebrates in the system, recording 2 and 5 taxa from an expected 5 and 11 taxa respectively. Taxa with a preference for vegetation and cobbles/boulders/bedrock were the most impacted group of invertebrates in accordance to the reference conditions. Those taxa with a preference for GSM as well as the water column/water surface were the least impacted groups of invertebrates relative to the reference condition. According to the water quality metric group, taxa with a low requirement for unmodified physico-chemical conditions were the most important indicators of the system's ecological condition (14 taxa recorded from an expected 23). Taxa with a very high requirement for unmodified physico-chemical conditions are the least important group of macroinvertebrates (3 taxa recorded from an expected 7 taxa). Taxa with moderate and very low requirements for unmodified physico-chemical modification were the most impacted metric (7 and 8 taxa recorded from an expected 17 and 16 taxa respectively). Overall, the present SASS5 of 190 was similar to the reference SASS5 score of 200 (95% of the reference conditions), while the ASPT scores of 5.9 did not exceed or match the reference data of 6.5.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication if it is flow or non-flow related impacts are also determined.

Table 21: PES per component and integrated PES for THU_EWR19

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C/D	F and NF	The fish assemblage is largely modified with affects from the non-flow related impacts (poor land-use and erosion) that resulted in the significant loss of habitat and protective cover. The altered flows in the catchment are then related to the inability to scour the system (silt and pollutants) and a further loss of velocity-depth/cover.
Macroinvertebrates	B/C	F and NF	The main driver in the system affecting the macroinvertebrate community was water quality and high algae present smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota, combined with erosion of banks resulting in sedimentation in important instream habitats.
HI: Instream	B	F and NF	Limited impacts at the site. Some abstraction for irrigation upstream. Channel incised with algae and silt.
HI: Riparian	B	NF	Cattle grazing and trampling with some undercut banks, possibly due to low water bridge upstream.
ECOSTATUS	**C**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR19 are presented in Table 22.

Table 22: Ecological trends for THU_EWR19

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable, but a concern is the sustained habitat modification – will have a negative impact in this small system.	There have been no major changes to the upstream catchment but increased small scale agriculture (cultivation and grazing) and the expansion in the population and settlements, will have an increased impact on this small channelled system.	3

Macroinvertebrates	Stable	Water quality modification (from erosion, grazing cattle, and adjacent human settlements), although good habitat availability were the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from low intensity agriculture and cattle grazing as well as low density rural human settlements. Some upstream irrigation activities as well. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	3
HI: Instream	Stable	No major increases in irrigation and other abstractions expected	3
HI: Riparian	Stable	Grazing and cattle trampling ongoing	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve or even degrade if the river is a hard-working river. Table 23 provides the final results for the Ncandu River at THU_EWR19.

Table 23: Final ecological categories for THU_EWR19

Component	PES	Importance	REC	Trend	TEC
Fish	C/D	EI = ES = Very High		Stable	Rationale: Improvement in PES can be achieved by management of upstream land use practices. Impacts are non-flow are water driven.
Macroinvertebrates	B/C			Stable	
HI: Instream	B			Stable	
HI: Riparian	B			Stable	
ECOSTATUS	**C**	**Very High**	**B**		**B/C**

The final step is the quantification of the EWR and include the conversion of the EWR flow data for a TEC of a B/C category to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model. The maintenance and drought flows were examined for July and February. July is the month with the lowest maintenance flow (i.e. base-flow) and February is the month with the highest maintenance flow conditions.

The requirements of the DRM for September were also assessed as the surveys were undertaken on 7 September 2020. The discharge at the EWR site during the site visit was 0.082 m^3/s and was used as reference to adjust the recommended EWRs.

Together with site photographs and rating relationships (flow depth versus discharge) from the hydraulic model, water levels proposed by the DRM for drought and maintenance low flows were assessed in terms of the habitat and biotic requirements. The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates and depths for fish. The consensus reached by the aquatic ecologists was that the velocities at the critical habitat, recommended by the DRM model during September, was not adequate to provide the necessary velocities for the flow sensitive macroinvertebrates and depths for fishes. Also, the drought flows for September were not adequate to sustain the biota, even for a short period. Thus, the following changes were made to the desktop flow requirements:

Maintenance low flows:

- September – change from 0.080 m^3/s to 0.105 m^3/s
- February – change from 0.492 m^3/s to 0.651 m^3/s

Drought flows:

- September – change from 0.027 m^3/s to 0.029 m^3/s
- February – change from 0.148 m^3/s to 0.170 m^3/s

The final EWRs for specific months are given in Table 24 and shown in the graph in Figure 6.

Table 24: EWR results for specific months for the Ncandu River in V31J (TEC = B/C)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Maintenance low flows					
	September	0.105	0.19	0,12	0.16
	February	0.651	0.31	0.21	0.43
Drought flows					
	September	0.029	0.13	0.08	0.07
	February	0.170	0.21	0.14	0.20
Measured discharge at site visit (07/09/2020)		0.082	0.18	0.11	0.14

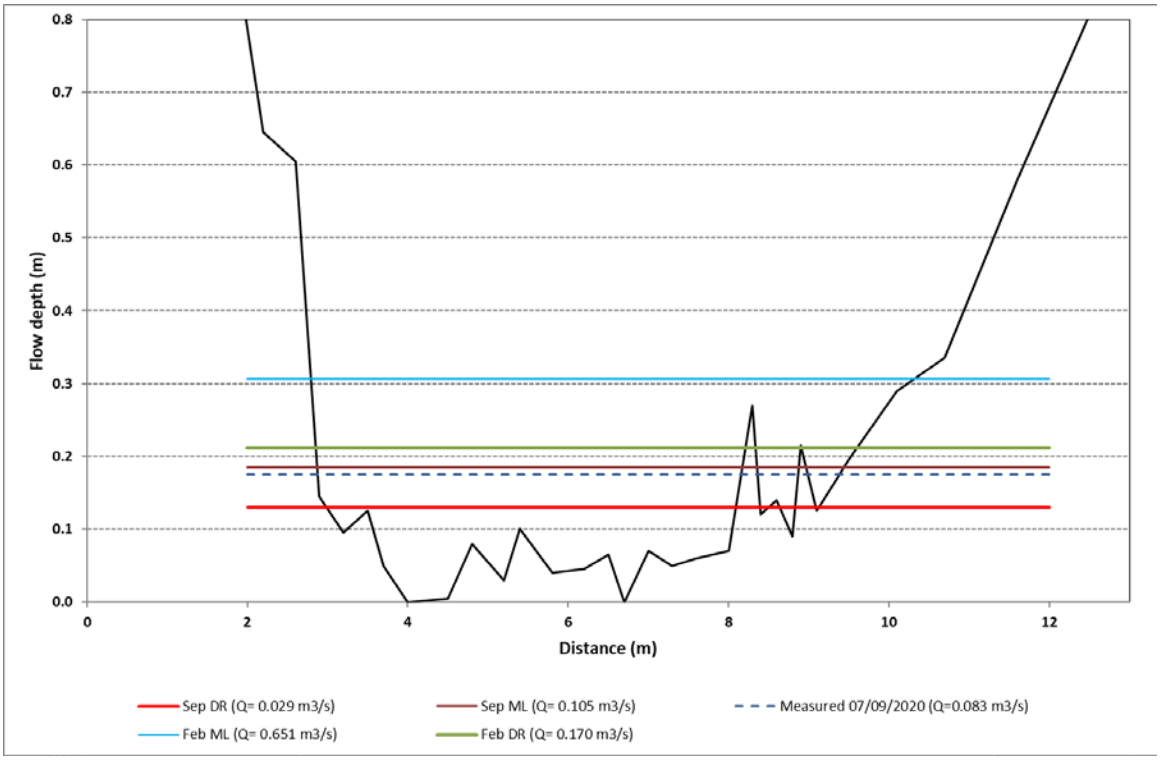

Figure 6: Water levels on cross-section for the Ncandu River (THU_EWR19)

As the PES of the Ncandu River at THU_EWR19 was determined as a C category, the requirements were also determined for the PES. The same aspects were considered as for the B/C category, namely velocities for flow sensitive macroinvertebrates and depths for fish.

Additionally, the following freshets/ floods were specified (Table 25) for the Ncandu River. This will provide the necessary cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats. As there are no dams upstream to release larger freshets or floods, those specified by the DRM for both the PES and TEC were accepted.

Table 25: Freshets and annual flood requirements at THU_EWR19 for TEC=B/C

Months	Flow (m^3/s)	Duration (days)	Months	Flow (m^3/s)	Duration (days)
September	0.957	2	January	4.278	2
October	2.844	2	February	20.973	2
November	5.188	2	March	6.461	2
December	8.556	2	April	1.534	2

The final EWR for the Ncandu River at THU_EWR19 is summarised in Table 26.

Table 26: Summary of the final EWR results (flows in million m3 per annum)

Quaternary Catchment	**V31J**	
River	Ncandu	
EWR Site Co-ordinates	-27.8017; 29.8840	
NMAR at EWR site	50.83	
Ecological Category	PES=C	TEC=B/C
Total EWR	11.820 (23.25 %MAR)	14.926 (29.36 %MAR)
Maintenance Low flows	6.326 (12.45 %MAR)	8.782 (17.28 %MAR)
Drought Low flows	2.007 (3.95 %MAR)	2.007 (3.95 %MAR)
Maintenance High flows	5.494 (10.81 %MAR)	6.144 (12.09 %MAR)
Overall confidence	Low to medium	

4.1.3. THU_EWR20: Nsonge (Hlatikulu) River in V20C

The selected EWR site is situated downstream of a bridge and intensive agricultural activities. Some farm dams and irrigation of pastures occur in the upstream catchment. A DWS gauging weir is situated approximately 100m downstream of the selected EWR site. The flows were very low during the site surveys and limited habitats available for sampling.

Figure 7: View of the EWR site on the Nsonge River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in Table 27.

Table 27: THU_EWR20 reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Nsonge (Hlatikulu) River at the EWR site would have supported a small diversity of fish, with up to five indigenous fish species expected – AMOS, BANO, BNAT, BPAL and BVIV.
Present state	Only two (BNAT and BVIV) out of the expected five species of fish were collected from the Nsonge (Hlatikulu) River at the EWR site THU_EWR20. A combination of the absent species relate to flow modifications (AMOS) and cover (small barbs) where the absence of especially vegetation limit the distribution of the diversity at the site. The water quality (higher nutrient content) will contribute to changes and linked to the siltation will limited the habitat, as the spawning areas and food sources are impacted negatively. The FRAI results indicate that the fish assemblage is currently in a "C" (66.7%) Ecological Category indicating that the fish community is modified. The present fish assemblage is largely determined by the available biotopes at the EWR site, i.e. velocity-depth (fast-shallow mainly and some slow shallow area). Cover is poor and is due to the lack of vegetation, shallow water column and the siltation. A concern in the long run is siltation of pools as this will lower refuge habitat during low flow condition, but also for the larger specimens (AMOS, BNAT) in summer flows.
Macroinvertebrates	
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >220 and the Average Score Per Taxon (ASPT) should be >7.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Notonemouridae, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Lestidae, Platycnemidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Corydalidae, Dipseudopsidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, olycentropodidae, Psychomyiidae, Hydroptilidae, Lepidostomatidae, Leptoceridae, Pisuliidae, Sericostomatidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Blepharoceridae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site.

COMPONENT	DESCRIPTIONS
	The macroinvertebrate Ecological Category is a C/D (61.47%). This means the macroinvertebrate community is in a moderately to considerably modified state, with a moderately diversity of taxa, although mostly tolerant. The most impacted driver metric is that of habitat (49.6%); followed by water quality (64.0%) and Flow modification (70.5%) respectively. The table below which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae > 2 spp., Leptophlebiidae (Prongills), Tricorythidae (Stout Crawlers), Hydropsychidae > 2 spp. and Athericidae (Snipe flies). According to the flow modification metric group, taxa with a preference for standing flowing water are the most important groups of invertebrates, although only 1 taxon was recorded from an expected 26 taxa. Those taxa with a preference for slow, moderately fast and very fast flowing waters were also impacted as only 1, 2 and 4 taxa were recorded from the expected 18, 12 and 10 taxa respectively. Overall, taxa with a preference for all flow modifications were impacted. According to the habitat modification metric group, taxa with a preference for cobbles/boulders/bedrock and vegetation were the most important group of macroinvertebrates, whereas taxa with a preference for the water column or surface are the least important group of invertebrates in the system. Taxa with a preference for cobbles/boulders/bedrock were the most impacted group of invertebrates, recording 8 from the expected 30 taxa, followed by vegetation, whereby no taxa were recorded from the expected 20 taxa. Those taxa with a preference for GSM, as well as the water column/water surface, were the least impacted groups of invertebrates relative to the reference condition (0 and 3 recorded from the expected 6 and 11 taxa respectively). According to the water quality metric group, taxa with a low and moderate requirement for unmodified physico-chemical conditions were the most important indicators of the system's ecological condition. Taxa with a very high requirement for unmodified physico-chemical conditions are the least important group of macroinvertebrates. Taxa with moderate and low requirements for unmodified physico-chemical modification were the most impacted metric with only recording 4 taxa from an expected 24 and 23 taxa respectively. Overall, the present SASS5 and ASPT scores were 90 and 6.4, which did not exceed or match the reference data of >220 and 7.5 respectively. The present SASS5 and ASPT scores were 40% and 85% of the reference conditions, respectively.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether it is flow or non-flow related impacts are also determined.

Table 28: PES per component and integrated PES for THU_EWR20

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C	F and NF	The fish assemblage is modified and is a result of modified flows, siltation, and signs of nutrient enrichment. One must remember that these streams are important refuge areas for smaller fish and critical spawning habitat for all species (except AMOS) in this system).
Macroinvertebrates	C/D	F	The main driver in the system affecting the macroinvertebrate community was modified flows as a result of changes in hydrology from impoundments upstream leading to reduced flows. As a result, velocity sensitive aquatic macroinvertebrates were absent. Furthermore, bank erosion and combined with poor water quality and high silt loads present smothering habitats and transforming a potential good SIC/ SOOC biotope into a homogenous habitat that supports far less biota. Porifera were not identified owing to the siltation on the rocks.
HI: Instream	C	F and NF	Extensive irrigation and numerous dams upstream. Widening of channel due to bridge upstream
HI: Riparian	B	NF	Trampling by cattle with some erosion.
ECOSTATUS	**C**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR20 are presented in the table below.

Table 29: Ecological trends for THU_EWR20

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable, but changing	Increased development (settlements and agriculture) will have an increase in impacts on the system. Impacts considered to be small, will have a large consequence on the small tributaries of the system.	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses) combined with water quality modification (silt, erosion, grazing cattle and human settlements) are the main drivers influencing macroinvertebrate community health. Overall the surrounding catchment area is impacted from high	3

Component	Trend	Reason	Confidence (0-5)*
		intensity agriculture and cattle grazing. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	
HI: Instream	Stable	No planned increased irrigation and dams	3
HI: Riparian	Stable	Limited impacts on riparian.	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. Table 30 provides the final results for the Nsonge River at THU_EWR20.

Table 30: Final ecological categories for THU_EWR20

Component	PES	Importance	REC	Trend	TEC
Fish	C	EI = Very High ES = High		Stable but changing	Rationale: Management of upstream activities and limitation on abstraction required to achieve ecological category.
Macroinvertebrates	D			Stable	
HI: Instream	C			Stable	
HI: Riparian	B			Stable	
ECOSTATUS	**C**	**High**	**B/C**		**B/C**

The final step is the quantification of the EWR and include the conversion of the EWR flow data for a TEC of a B/C category to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model. The maintenance and drought flows were examined for July and February. July is the month with the lowest maintenance flow (i.e. base-flow) and February is the month with the highest maintenance flow conditions.

The requirements of the DRM for September were also assessed as the surveys were undertaken on 8 September 2020. The discharge at the EWR site during the site visit was 0.085 m3/s and was used as reference to adjust the recommended EWRs.

Together with site photographs and rating relationships (flow depth versus discharge) from the hydraulic model, water levels proposed by the DRM for drought and maintenance low flows were assessed in terms of the habitat and biotic requirements. The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates and depths for fish. The consensus reached by the aquatic

ecologists was that the drought flows for September were not adequate to sustain the biota, even for a short period. Thus, the following changes were made to the desktop flow requirements:

Drought flows:

- September – change from 0.041 m^3/s to 0.060 m^3/s
- February – change from 0.109 m^3/s to 0.159 m^3/s

The final EWRs for specific months are given in Table 31 and shown on the graph in Figure 8.

Table 31: EWR results for specific months for the Nsonge River in V20C (TEC = B/C)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Maintenance low flows					
	September	0.101	0.14	0.07	0.18
	February	0.302	0.30	0.21	0.17
Drought flows					
	September	0.060	0.13	0.06	0.12
	February	0.159	0.20	0.12	0.17
Measured discharge at site visit (08/09/2020)		0.085	0.14	0.07	0.18

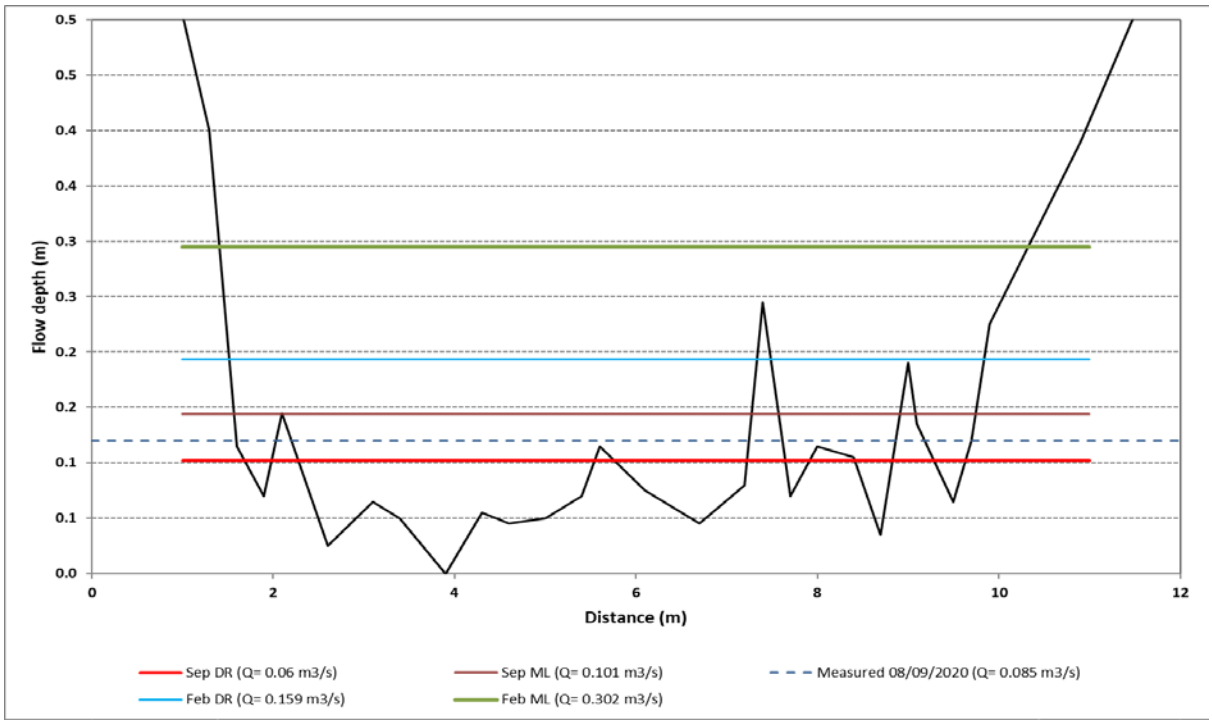

Figure 8: Water levels on cross-section for the Nsonge River (THU_EWR20)

As the PES of the Ncandu River at THU_EWR19 was determined as a C category, the requirements were also determined for the PES. The same aspects were considered as for the B/C category, namely velocities for flow sensitive macroinvertebrates and depths for fish.

As there are no dams with outlet capacities situated in the upper catchment, the freshets/ floods specified by the DRM for both the PES and TEC were accepted (Table 32) for the Nsonge River. This will provide the necessary cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats.

Table 32: Freshets and annual flood requirements at THU_EWR20 for TEC=B/C

Months	Flow (m^3/s)	Duration (days)	Months	Flow (m^3/s)	Duration (days)
September	0.485	2	January	9.525	2
October	0.894	2	February	1.807	2
November	2.096	2	March	3.615	2
December	1.807	2	April	0.545	2

The final EWR for the Nsonge River at THU_EWR20 is summarised in Table 33.

Table 33: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V20C	
River	Nsonge (Hlatikulu)	
EWR Site Co-ordinates	-29.2377; 29.7853	
NMAR at EWR site	27.13	
Ecological Category	PES=C	TEC=B/C
Total EWR	6.195 (22.84 %MAR)	7.864 (28.99 %MAR)
Maintenance Low flows	3.884 (14.32 %MAR)	5.351 (19.73 %MAR)
Drought Low flows	2.941 (10.84 %MAR)	2.941 (10.84 %MAR)
Maintenance High flows	2.310 (8.52 %MAR)	2.513 (9.26 %MAR)
Overall confidence	Low to medium	

4.1.4. THU_EWR22: Klip River in V12A

The selected EWR site is situated downstream of a low water bridge next to a rural village. Cattle watering, washing and abstraction of water (filling of water barrels) for the community are impacting on the site.

Figure 9: View of the EWR site on the Klip River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in the table below.

Table 34: THU_EWR22 reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Klip River at the EWR site support a moderate diversity (BANO, BNAT, CGAR, LRUB, AMOS, BVIV, TSPA and CCAR).
Present state	During the recent survey, six (AMOS, BNAT, BVIV, CGAR, TSPA and BANO) of the expected eight species of fish were collected from the Klip River at the EWR site THU_EWR22. The absence of LRUB can be ascribed to the lack of sufficient deep pools and the fact that no netting was conducted in the deeper pools present. The lack of vegetation and marginal shallow habitat is the preferred habitat for TSPA. The FRAI results indicate that the fish assemblage is currently in a "C" (64.3%) Ecological Category indicating that the fish community is modified (low numbers of all species collected).

COMPONENT	DESCRIPTIONS
	Water quality would have significantly impact on the fish ecology of the system and linked to the changes in hydraulic habitats (i.e. velocity-depth and cover), give the overall poor score and numbers of the species present.
	Macroinvertebrates
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >220 and the Average Score Per Taxon (ASPT) should be >7.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Notonemouridae, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Coenagrionidae, Lestidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Corydalidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Physidae, Planorbinae, Corbiculidae, Sphaeridae, Unionidae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a C (77.78%). This means the macroinvertebrate community is in a moderately modified state with moderate diversity of taxa. The most impacted driver metric is that of water quality (70.4%); followed by habitat (80.0%) and Flow modification (82.1%). See table below which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Perlidae, Baetidae > 2 spp., Heptageniidae (Flatheaded mayflies), Leptophlebiidae (Prongills), Crambidae (Pyralidae) and Psephenidae (Water Pennies). According to the flow modification metric group, taxa with a preference for standing flowing water are the most important groups of invertebrates, whereas taxa with a preference for slow flowing and very fast flowing water are the least important group of invertebrates in the system. Taxa with a preference for standing water were the most impacted group of invertebrates, recording 10 taxa from an expected 25 taxa, while those with a preference for slow, moderately fast, and very fast flowing water were equally the least impacted group of invertebrates, recording 3, 8 and 3 taxa from an expected 7, 11 and 8 taxa respectively. According to the habitat modification metric group, taxa with a preference for cobbles/boulders/bedrock are the most important group of macroinvertebrates, whereas taxa with a preference for the water column or surface are the least important group of invertebrates in the system. Taxa with a preference for cobbles/boulders/bedrock were the most impacted group of invertebrates, recording 15 taxa from an expected 26 taxa, followed by the occurrence of taxa with a preference for vegetation whereby only 6 taxa were recorded from an expected 16 taxa. Those taxa with a preference for GSM as well as the water column/water surface were the least impacted groups of invertebrates relative to the reference condition and which recorded 6 and 2 taxa from an expected 11 and 6 taxa respectively.

COMPONENT	DESCRIPTIONS
	According to the water quality metric group, taxa with a low requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition (17 taxa recorded from an expected 25 taxa). Taxa with a very high requirement for unmodified physico-chemical conditions are the least important group of macroinvertebrates (4 taxa recorded from an expected 8 taxa). Taxa with moderate and very low requirements for unmodified physico-chemical modification were the most impacted metric, recording 6 ad 9 taxa from an expected 18 and 16 taxa respectively. Overall, the present SASS5 of 213 was similar to the reference SASS5 score of 220 (95% of the reference conditions), while the ASPT scores of 5.9 did not exceed or match the reference data of 7.5 (approximately 75% of the reference data).

The PES per component as derived from the various models as well as the EcoStatus are provided in Table 35. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether it is flow, or non-flow related impacts are also determined.

Table 35: PES per component and integrated PES for THU_EWR22

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C	F and NF	The fish assemblage is largely modified, and the driver include siltation, high algae presence, poor water quality and the modified water flows - i.e. not sufficient depth/flow habitat present.
Macroinvertebrates	C	F and NF	The main driver in the system affecting the macroinvertebrate community is poor water quality resulting in high algae content, coupled with high silt loads smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. Furthermore, erosion of banks owing to cattle trampling and grazing contributing to the sedimentation.
HI: Instream	C	F and NF	Irrigation in the upper catchment with washing, cattle drinking and taking water in vicinity of the site. Algae and silt present.
HI: Riparian	C/D	NF	Vegetation removal, cattle grazing and trampling and unstable left bank due to brick-making activities.
ECOSTATUS	**C**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the

biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR22 are presented in Table 36.

Table 36: Ecological trends for THU_EWR22

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable	Although the fish community is stable (number of species) the low numbers is a concern. This is due to siltation (spawning habitat loss and food source scarcity), poor water quality (physiological stress- e.g. spawning potential) and limited habitat (flows and depth of the habitat).	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses) combined with water quality modification (upstream washing facility and detergent discharges, erosion, grazing cattle, and human settlements) are the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from low intensity agriculture and cattle grazing as well as low density rural human settlements. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	3
HI: Instream	Stable	No major changes expected upstream	3
HI: Riparian	Negative	Destabilisation of bank due to activities will lead to bank collapse, channel widening and silting up of habitats.	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. Table 37 provides the final results for the Klip River at THU_EWR22.

Table 37: Final ecological categories for THU_EWR22

Component	PES	Importance	REC	Trend	TEC
Fish	C	EI = High ES = Very High		Stable	Rationale: Ecological condition driven by anthropogenic activities. Predominantly non-flow and water impacts that require management of upstream activities.
Macroinvertebrates	C			Stable	
HI: Instream	C			Stable	
HI: Riparian	C/D			Negative	

Component	PES	Importance	REC	Trend	TEC
ECOSTATUS	**C**	**High**	**B/C**		**C**

The final step is the quantification of the EWR and include the conversion of the EWR flow data for a TEC of a C category to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model. The maintenance and drought flows were examined for July and February. August is the month with the lowest maintenance flow (i.e. base-flow) and February is the month with the highest maintenance flow conditions.

The requirements of the DRM for September were also assessed as the surveys were undertaken on 10 September 2020. The discharge at the EWR site during the site visit was 0.089 m^3/s and was used as reference to adjust the recommended EWRs. The flows were very low during the site visit.

Together with site photographs and rating relationships (flow depth versus discharge) from the hydraulic model, water levels proposed by the DRM for drought and maintenance low flows were assessed in terms of the habitat and biotic requirements. The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates and depths for fish. The consensus reached by the aquatic ecologists was that the velocities at the critical habitat, recommended by the DRM model during September, was not adequate to provide the necessary velocities for the flow sensitive macroinvertebrates and depths for fishes. Also, the drought flows for February were not adequate to sustain the biota, even for a short period. Thus, the following changes were made to the desktop flow requirements:

Maintenance low flows:

- September – change from 0.091 m^3/s to 0.113 m^3/s
- February – change from 0.427 m^3/s to 0.529 m^3/s

Drought flows:

- February – change from 0.196 m^3/s to 0.298 m^3/s

The final EWRs for specific months are given in Table 38 and illustrated in the graph in Figure 10.

Table 38: EWR results for specific months for the Klip River in V12A (TEC = C)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Maintenance low flows					
	September	0.113	0.28	0.16	0.05
	February	0.529	0.37	0.24	0.16
Drought flows					

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
	September	0.043	0.24	0.13	0.03
	February	0.298	0.33	0.20	0.10
Measured discharge at site visit (10/09/2020)		0.089	0.27	0.15	0.05

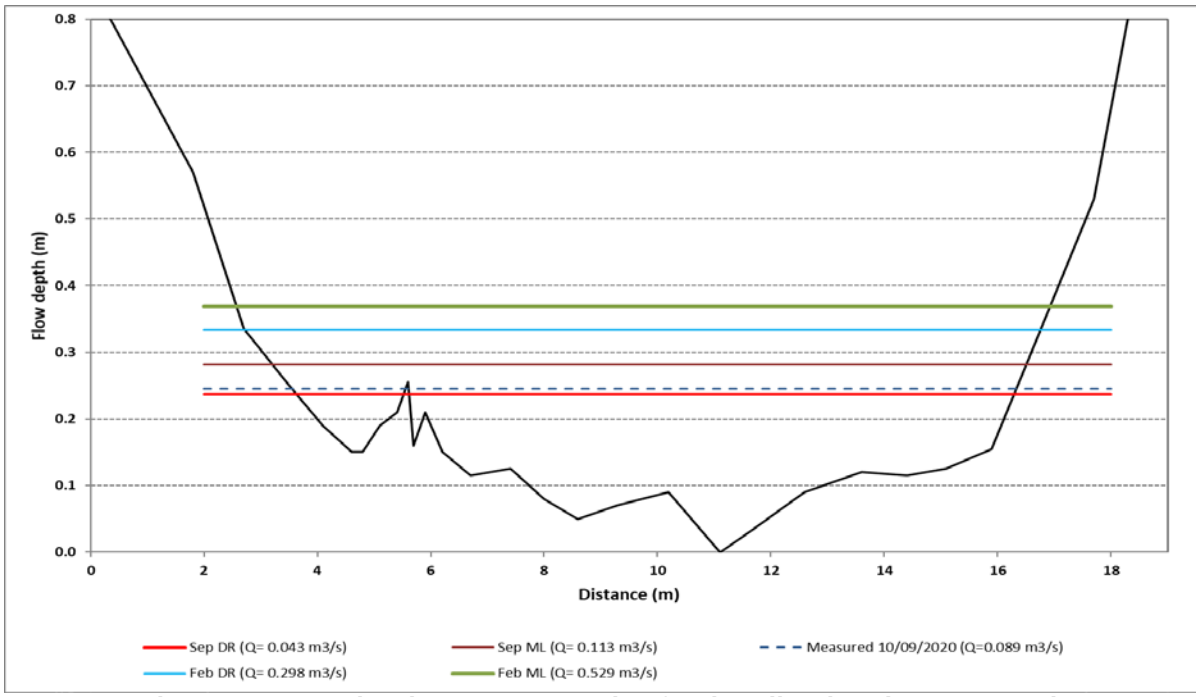

Figure 10: Water levels on cross-section for the Klip River (THU_EWR22)

Additionally, the following freshets/ floods were specified (Table 39) for the Klip River to provide the necessary cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats. As there are no large dams upstream of the EWR site, the freshets/ floods specified by the DRM were accepted, except for January that was too low. Thus, the flood was changed from 3.383 m^3/s to 10.858 m^3/s over two days.

Table 39: Freshets and annual flood requirements at THU_EWR22

Months	Flow (m^3/s)	Duration (days)	Months	Flow (m^3/s)	Duration (days)
September	1.233	2	January	10.858	2
October	2.009	2	February	21.474	2
November	3.570	2	March	3.583	2
December	7.167	2	April	1.250	2

The final EWR for the Klip River at THU_EWR22 is summarised in Table 40.

Table 40: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V12A
River	Klip
EWR Site Co-ordinates	-28.3952; 29.7197
Present Ecological State	C
Target Ecological Category	C
NMAR at EWR site	52.44
Total EWR	13.271 (25.31 %MAR)
Maintenance Low flows	7.085 (13.51 %MAR)
Drought Low flows	2.988 (5.70 %MAR)
Maintenance High flows	6.186 (11.80 %MAR)
Overall confidence	Low to medium

4.2. New Rapid II site

4.2.1. THU_EWR21: Mnyamvubu River in V20G

This site was assessed on a Rapid II level as no hydraulic cross-section was available. The site is situated just downstream of the Craigie Burn Dam and is dependent on releases from the dam.

Figure 11: View of the EWR site on the Mnyamvubu River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in the table below.

Table 41: THU_EWR21 reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Mnyamvubu River at the EWR site would have supported a moderate diversity of fish including AMOS, ANAT, BANO, BGUR, BNAT, LRUB, OMOS and TSPA and two exotic invasives, LMAC and MSAL.
Present state	No fish were collected during the survey. This is a concern and can be related to a number of reasons – possible no flow events (no releases from the impoundment), subsequent low flows not conducive to migrations from refuge areas, poor water quality acting as a chemical barrier in the main channel of the Mooi River and possible loss of diversity related to the alien invasive species, both which are predatory species The FRAI results indicate that the fish assemblage is currently in an “F” (10.8%) with an adjusted score of C/D (58.4) Ecological Category indicating that the fish community is largely modified. Under natural flow conditions, suitable flow and depth classes will be present. The water quality impacts would have significantly lower impacts on the fish ecology and include poor water quality (bottom releases) from the impoundment, siltation lower temperature (cold, bottom water) and loss of spawning area, habitat for habitation and loss of food resources (macro-invertebrates).
Macroinvertebrates	
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >200 and the Average Score Per Taxon (ASPT) should be >7.0. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Paleomonidae, Hydracarina, Notonemouridae, Perlidae, Baetidae, 2spp,Caenidae, Ephemeridae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Lestidae, Platycnemidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Corydalidae, Sialidae, Dipseudopsidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Polycentropodidae, Psychomyiidae, ydroptilidae, Lepidostomatidae, Leptoceridae, Pisuliidae, Sericostomatidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site.

COMPONENT	DESCRIPTIONS
	The macroinvertebrate Ecological Category is a C (70.46%). This means the macroinvertebrate community is in a moderately modified state, with moderate diversity of taxa. The most impacted driver metric is that of water quality (66.5%); followed by habitat (71.7%) and Flow modification (72.5%). See below table which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae > 2 spp., Tricorythidae (Stout Crawlers), Leptophlebiidae (Prongills) and Hydropsychidae > 2 spp. According to the flow modification metric group, taxa with a preference for standing flowing water are the most important groups of invertebrates although only 9 out of the expected 28 taxa were recorded, whereas taxa with a preference for slow, moderately fast and very fast flowing waters are the least important groups of invertebrates in the system. Three (3), 4 and 3 taxa were recorded from an expected 10, 12 and 9 taxa for these preferences respectively and thus were equally the least impacted group of invertebrates. According to the habitat modification metric group, taxa with a preference for cobbles/boulders/bedrock are the most important group of macroinvertebrates, whereas taxa with a preference for the water column or surface are the least important group of invertebrates in the system. Taxa with a preference for cobbles/boulders/bedrock were the most impacted group of invertebrates, recording 8 taxa from an expected 29 taxa, followed by the occurrence of taxa with a preference for vegetation whereby only 7 taxa were recorded from an expected 20 taxa. Those taxa with a preference for GSM as well as the water column/water surface were the least impacted groups of invertebrates relative to the reference condition and which recorded 3 and 1 taxa from an expected 13 and 6 taxa respectively. According to the water quality metric group, taxa with low and moderate requirements for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition, and which recorded 12 and 5 taxa of the expected 24 and 25 taxa in these preference groups respectively. Only 2 of the expected 12 taxa with a very high requirement for unmodified physico-chemical conditions was recorded and 7 of an expected 16 taxa with very low requirements were recorded and thus these 2 latter metrics were the least impacted. Overall, the present SASS5 of 147 and ASPT score of 5.7 did not exceed or match the reference data. The SASS5 score was approximately 70% and the ASPT score 80% of the reference data.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether flow or non-flow related impacts, are also determined.

Table 42: PES per component and integrated PES for THU_EWR21

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C/D	F and NF	The fish assemblage is largely modified due to impacts related to flow regime modifications, loss of habitat (flows and depth classes), water quality (bottom releases, temperature, and siltation) and the impact of the alien invasive predatory fish species present in the system.
Macroinvertebrates	C	F	The main driver in the system affecting the macroinvertebrate community is water quality coupled with modified flows as a result of the direct upstream Craigieburn Dam and thus changes in hydrology leading to reduced flows. As a result, velocity sensitive aquatic macroinvertebrates were absent. Furthermore, erosion of banks and high silt loads smothering habitats and transforming a potential good SIC/ SOOC biotope into a homogenous habitat that supports far less biota. Porifera were not identified owing to the siltation on the rocks.
HI: Instream	D	F and NF	Craigie Burn Dam just upstream site, thus river dependant on releases from the dam. Loss of GSM and some widening of the river
HI: Riparian	B	NF	Alien vegetation colonising on banks of river with some historic channel modification during dam construction.
ECOSTATUS	**C**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR21 are presented in the table below.

Table 43: Ecological trends for THU_EWR21

Component	Trend	Reason	Confidence (0-5)*
Fish	Negative	There have been major changes to the flow modifications and bottom releases will have an impact of the small tributary. Poor water quality in the Mooi River can act as a "barrier" for migratory species and the alien invasive will decimate populations in refuge areas.	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses and upstream Craigieburn Dam) combined with water quality modification (sediment loads, erosion) are	3

Component	Trend	Reason	Confidence (0-5)*
		the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from high intensity agriculture and cattle grazing as well as low density rural human settlements. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	
HI: Instream	Stable	River stabilised after construction of dam	3
HI: Riparian	Negative	Ongoing scouring due to releases from dam and alien vegetation increases	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. The table below provides the final results for the Mnyamvubu River at THU_EWR21.

Table 44: Final ecological categories for THU_EWR23

Component	PES	Importance	REC	Trend	TEC
Fish	C/D			Negative	Rationale:
Macroinvertebrates	C	EI = High		Stable	Freshets and pools needed to support habitat. Additional flow releases need from dam.
HI: Instream	D	ES = High		Stable	
HI: Riparian	B			Negative	
ECOSTATUS	**C**	**High**	**B/C**		**B/C**

As no hydraulic cross-sectional survey was done, the DRM results for maintenance and drought flows for a TEC of B/C and a PES of C were accepted.

Additionally, the freshets/ floods as specified by the DRM for the Mnyamvubu River have been checked against the release capacities of Craigie Burn Dam and adjusted, where too high. Table 45 shows the final freshets/ floods for the Mnyamvubu River.

Table 45: Freshets and annual flood requirements at THU_EWR21

Months	Flow (m^3/s)	Duration (days)	Months	Flow (m^3/s)	Duration (days)
September	1.123	2	January	6.301	2
October	2.083	2	February	6.055	2

Months	Flow (m^3/s)	Duration (days)	Months	Flow (m^3/s)	Duration (days)
November	2.819	2	March	4.204	2
December	2.102	2	April	0.925	2

The final EWR for the Mnyamvubu River at THU_EWR21 is summarised in Table 46.

Table 46: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V20G	
River	Mnyamvubu	
EWR Site Co-ordinates	-29.1610; 30.2884	
NMAR at EWR site	31.71	
Ecological Category	TEC=B/C	PES=C
Total EWR	8.869 (27.97 %MAR)	7.007 (22.10 %MAR)
Maintenance Low flows	5.771 (18.20 %MAR)	4.184 (13.20 %MAR)
Drought Low flows	2.125 (6.70 %MAR)	2.125 (6.70 %MAR)
Maintenance High flows	3.098 (9.77 %MAR)	2.824 (8.91 %MAR)
Overall confidence	Low	

4.3. Re-visit of 2003 Comprehensive sites

4.3.1. THU_EWR12A and 2003 Thukela_EWR12: Mooi River in V20H

The EWR for this site was determined on a Rapid III level. The new EWR site was selected just upstream of the 2003 EWR site. Both the sites fall within extensive irrigation areas with few stretches with no irrigation. The flows were very low during the site visit due to abstractions for irrigation and limited releases from both Spring Grove and Craigie Burn Dams in the upper catchment.

Figure 12: View of the EWR site on the Mooi River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in the table below.

Table 47: THU_EWR12A reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Mooi River at the EWR site would support a moderately large diversity of fish (AAEN, AMAR, AMOS, ANAT, BANO, BNAT, BPAL, BTRI, BVIV, CGAR, LMOL, LRUB, OMOS and TSPA).
Present state	Only six (AMOS, BNAT, BTRI, BVIV, CGAR and LMOL) of the expected species of fish were collected from the Mooi River at the EWR site THU_EWR12A and represent the more tolerant species (with reference to water quality). The species that are reliant on cover (vegetation and water depth) and migration are absent. When reviewing the FRAI results, it is clear that the fish assemblage is currently in a "C/D" (61.1%) adjusted Ecological Category (class "D" at 54% - not adjusted) indicating that the fish community is highly modified with few species and very low numbers of specimen's present. Water quality impacts have significantly lower impact on the fish ecology of the system, as did in the hydraulic habitats (i.e. velocity-depth and changes in cover).
Macroinvertebrates	

COMPONENT	DESCRIPTIONS
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >200 and the Average Score Per Taxon (ASPT) should be >7.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Paleomonidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Calopterygidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Lestidae, Platycnemidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Polycentropodidae, Hydroptilidae, Leptoceridae, Pisuliidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, hironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Physidae, Planorbinae, Thiaridae, Corbiculidae, Sphaeridae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat, and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a C (65.03%). This means the macroinvertebrate community is in a moderately modified state, with moderate diversity of taxa. The most impacted driver metric is that of water quality (60.2%); followed by habitat (66.2%) and Flow modification (67.9%). See table below which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae > 2 spp., Leptophlebiidae (Prongills) and Hydropsychidae > 2 spp. According to the flow modification metric group, 25 taxa with a preference for standing flowing water are expected, although only 10 were recorded and thus the most important groups of invertebrates. Taxa with a preference for slow, moderately fast and very fast flowing water recorded 1, 4 and 2 taxa from an expected 10, 10 and 8 taxa respectively in the system. Overall, all flow modification groups were thus impacted. According to the habitat modification metric group, taxa with a preference for cobbles/boulders/bedrock were the most important group of macroinvertebrates, although only recording 6 of the expected 26 taxa and thus the community was highly impacted. Those 18 taxa with a preference for vegetation, only 5 were recorded, while taxa with a preference for the water column or surface are the least important group of invertebrates in the system, expecting only 6 taxa, of which 3 were recorded. Those taxa with a preference for GSM were also the least impacted groups of invertebrates relative to the reference condition, recording 5 of the 11 expected taxa. According to the water quality metric group, taxa with a low and moderate requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition, although the latter community were highly impacted as only 3 of the expected 21 taxa were recorded. Nine (9) taxa with a very high requirement for unmodified physico-chemical conditions were expected, where only 2 were recorded. Taxa with very low requirements for unmodified physico-chemical modification were not as impacted, as 6 of the expected 18 taxa were recorded.

COMPONENT	DESCRIPTIONS
	Overall, the present SASS5 of 124 and ASPT score of 5.4 did not exceed or match the reference data. The SASS5 score was approximately 60% and the ASPT score 70% of the reference data.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether flow or non-flow related impacts, are also determined.

Table 48: PES per component and integrated PES for THU_EWR12A

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C/D	F and NF	The fish assemblage is largely modified due to poor water quality, siltation, loss of spawning and feeding habitat and cover (vegetation and flow/depth classes).
Macroinvertebrates	C	F and NF	The main driver in the system affecting the macroinvertebrate community was primarily due to adequate habitat availability, owing to limited vegetation due to undercut banks, and poor water quality whereby algae build-up was considerable, smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. Porifera were not identified owing to the siltation on the rocks. Furthermore, some velocity sensitive aquatic macroinvertebrates were absent
HI: Instream	D	F and NF	Intensive irrigation in upper catchments with transfer schemes to Mngeni catchment impacting on water availability. Bed modification due to siltation and algae as a result of upstream agricultural activities.
HI: Riparian	C/D	NF	Encroachment of cultivated lands and erosion of side channels entering the river
ECOSTATUS	**C/D**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the

biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR12A are presented in Table 49.

Table 49: Ecological trends for THU_EWR12A

Component	Trend	Reason	Confidence (0-5)*
Fish	Declining	There have been changes to the upstream catchment related to land-use practices resulting in erosion and that caused the siltation of the system. A loss of riffles and deep pools will continuously reduce refuge areas for small and large fish and the water quality deterioration will act as a "chemical barrier" for the numerous long distance migratory species.	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses) combined with water quality modification (upstream dams, erosion, grazing cattle and human settlements) are the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from low intensity agriculture and cattle grazing as well as low density rural human settlements. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	3
HI: Instream	Negative	Prolonged low flows and limited floods will increase siltation and poor water quality leading to algal growth	3
HI: Riparian	Stable	Impacts of upstream dams and transfers schemes ongoing and changes due to Spring Grove Dam already stabilised system	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. The table below provides the final results for the Mooi River at THU_EWR12A.

Table 50: Final ecological categories for THU_EWR12A

Component	PES	Importance	REC	Trend	TEC
Fish	C/D	EI = High ES = High		Declining	Rationale: Impacts are water quality related. Improved management of upstream sewage works, cattle feedlots and dairy farms required.
Macroinvertebrates	C			Stable	
HI: Instream	D			Negative	
HI: Riparian	C/D			Stable	

Component	PES	Importance	REC	Trend	TEC
ECOSTATUS	**C/D**	**High**	**C**		**C**

The final step is the quantification of the EWR and include the conversion of the EWR flow data for a TEC of a C category to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model. The maintenance and drought flows were examined for July and February. July is the month with the lowest maintenance flow (i.e. base-flow) and February is the month with the highest maintenance flow conditions.

The requirements of the DRM for September were also assessed as the surveys were undertaken on 8 September 2020. The discharge at the EWR site during the site visit was 0.189 m^3/s and was used as reference to adjust the recommended EWRs. The flow during the survey was very low.

Together with site photographs and rating relationships (flow depth versus discharge) from the hydraulic model, water levels proposed by the DRM for drought and maintenance low flows were assessed in terms of the habitat and biotic requirements. The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates and depths for fish. The consensus reached by the aquatic ecologists was that the velocities at the critical habitat, recommended by the DRM model during September, was not adequate to provide the necessary velocities for the flow sensitive macroinvertebrates and depths for fishes. Also, the drought flows for September were not adequate to sustain the biota, even for a short period. Thus, the following changes were made to the desktop flow requirements:

Maintenance low flows:

- September – change from 0.988 m^3/s to 1.503 m^3/s
- February – change from 2.759 m^3/s to 4.196 m^3/s

Drought flows:

- September – change from 0.531 m^3/s to 0.784 m^3/s
- February – change from 1.385 m^3/s to 2.046 m^3/s

The final EWRs for specific months are given in the table below and shown on the graph in Figure 13.

Table 51: EWR results for specific months for the Mooi River in V20H (TEC = C)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Maintenance low flows					
	September	1.503	0.39	0.23	0.56
	February	4.196	0.55	0.36	0.86

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Drought flows					
	September	0.784	0.31	0.16	0.43
	February	2.046	0.44	0.27	0.64
Measured discharge at site visit (08/09/2020)		0.189	0.16	0.06	0.10

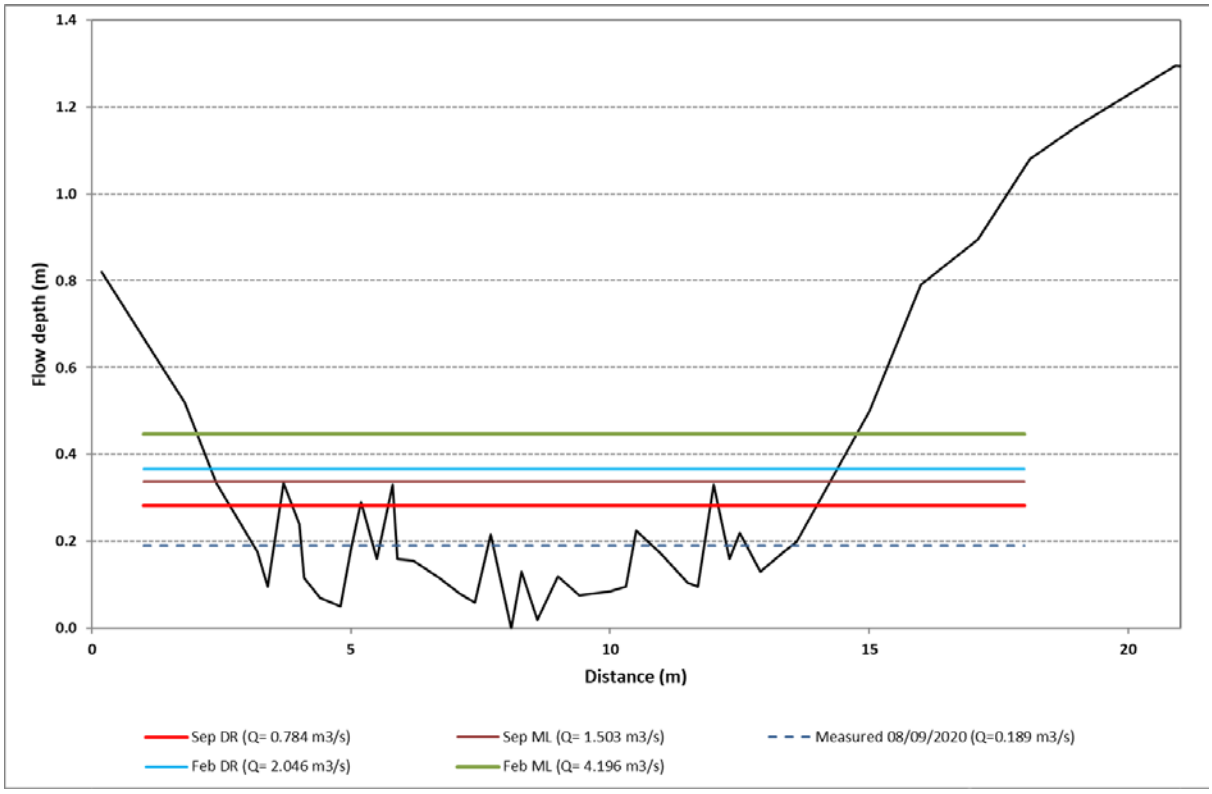

Figure 13: Water levels on cross-section for the Mooi River (THU_EWR12A)

As the PES of the Mooi River at THU_EWR12A was determined as a C/D category, the requirements were also determined for the PES. The same aspects were considered as for the C category, namely velocities for flow sensitive macroinvertebrates and depths for fish.

No freshets/ floods were specified for the EWR site (Thukela_EWR12) in the 2003 study. However, the freshets/ floods as specified for the Mooi River at Thukela_EWR11 upstream of this site in quaternary catchment V20G during the 2003 study were used as these were done on a high level of confidence compared to the once-off survey that was undertaken for this study (see table below). These 2003 floods not only considered cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats, it also included specific requirements for riparian vegetation and geomorphology.

Table 52: Freshets and annual flood requirements at THU_EWR12A (adjusted from 2003 study)

Months	Flow (m^3/s)	Duration (days)	Flow (m^3/s)	Duration (days)
	Freshets		Floods	
September	6	2		
October	8	2		
November	8	2		
December	8	2	33	3
January	15	3	33	3
February	15	2	50	6
March	15	3	33	3
April	8	2		

The final EWR for the Mooi River at THU_EWR12A is summarised in Table 53.

Table 53: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V20H	
River	Mooi	
EWR Site Co-ordinates	-28.9193; 30.4189	
NMAR at EWR site	361.85	
Ecological Category	TEC=C	PES=C/D
Total EWR	114.228 (31.57 %MAR)	96.373 (26.63 %MAR)
Maintenance Low flows	76.070 (21.02 %MAR)	58.214 (16.09 %MAR)
Drought Low flows	37.691 (10.42 %MAR)	37.691 (10.42 %MAR)
Maintenance High flows	38.159 (10.55 %MAR)	38.159 (10.55 %MAR)
Overall confidence	Medium	

4.3.2. THU_EWR6A - 2003 Thukela_EWR6: Lower Bushmans River in V70G

The EWR for this site was determined on a Rapid III level. The selected EWR site is situated downstream of intensive irrigation areas with a small community on the right bank. Some small-scale brick making activities are present just downstream of the selected site. The flows were very low at this site during sampling.

Figure 14: View of the EWR site on the Lower Bushmans River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in Table 56.

Table 54: THU_EWR6A reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Lower Bushmans River at the EWR site support a moderate diversity of fish (AAEN, ALAB, AMOS, BANO, BNAT, BTRI, BVIV, CGAR, LRUB, OMOS and TSPA with the alien invasive, CCAR present).
Present state	Only two of the expected five species of fish were collected (CGAR and BNAT) from the Lower Bushmans River at the EWR site THU_EWR6A. The FRAI results (adjusted percentage) indicate that the fish assemblage is currently in a "D" (56.2%) Ecological Category with the unadjusted class at "E" (34.8%) indicating that the fish community is severely modified. The modified water quality impacts (resulting in algal growth) the diversity and linked to the poor land-use practices (erosion and siltation) significantly lower the fish ecology of the system. The modified hydrological signature of the system (i.e. the timing, magnitude, duration and frequency of flows) further negatively impact the rheophilic and migrating species.

COMPONENT	DESCRIPTIONS
	Macroinvertebrates
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >180 and the Average Score Per Taxon (ASPT) should be >7.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Paleomonidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Calopterygidae, Chlorocyphidae, Chlorolestidae, Coenagrionidae, Platycnemidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae,Veliidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Polycentropodidae, Hydroptilidae, Leptoceridae, Pisuliidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Thiaridae, Corbiculidae, Sphaeridae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a C/D (58.89%). This means the macroinvertebrate community is in a moderately to considerably modified state, with moderate diversity of taxa which are predominantly tolerant. The most impacted driver metric is that of water quality (51.0%); followed by habitat (59.4%) and flow modification (65.0%). See below table which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae > 2 spp., Heptageniidae (Flatheaded mayflies), Leptophlebiidae (Prongills), and Hydropsychidae > 2 sp. According to the flow modification metric group, 25 taxa with a preference for standing flowing water are expected, although only 5 were recorded and thus the most important groups of invertebrates. Taxa with a preference for slow, moderately fast and very fast flowing water recorded at low diversities, being 1, 3 and 2 taxa from an expected 10, 10 and 8 taxa respectively in the system. Overall, all flow modification groups were thus impacted. According to the habitat modification metric group, taxa with a preference for cobbles/boulders/bedrock were the most important and dominant reference group of macroinvertebrates, although only recording 5 of the expected 27 taxa and thus the community was highly impacted. The expected 18 taxa with a preference for vegetation, only 1 was recorded, while taxa with a preference for the water column or surface are the least important group of invertebrates in the system, expecting only 6 taxa, of which 2 were recorded. Those taxa with a preference for GSM were also the least impacted groups of invertebrates relative to the reference condition, recording 3 of the 11 expected taxa. According to the water quality metric group, taxa with a low and moderate requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition, although both communities recorded low diversity compared to the expected diversity (7 and 1 taxa were recorded from the expected 24 and 20 taxa with a preference to low and moderate requirements for unmodified physico-chemical conditions respectively). Nine (9) taxa were expected with a preference for high requirements,

COMPONENT	DESCRIPTIONS
	although only 2 were recorded, while 17 taxa which have a preference for very low requirements were expected, but only 4 were recorded. Overall, the present SASS5 of 80 and ASPT score of 5.7 did not exceed or match the reference data of the SASS5 and ASPT scores of 180 and 7.5 respectively. The SASS5 score was approximately 44% and the ASPT score 76% of the reference data.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether flow or non-flow related impacts, are also determined.

Table 55: PES per component and integrated PES for THU_EWR6A

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	D	F and NF	The fish assemblage is severely modified and poor habitat diversity, cover, substrate and flows link to the modified flow regime contribute to the siltation and algal growth. The poor water quality impact negatively of the physiological processes e.g. breeding and growth and this is indicated in the lower diversity and small number of specimens collected.
Macroinvertebrates	C/D	F and NF	The main driver in the system affecting the macroinvertebrate community was primarily poor water quality owing to high nutrients, resulting in considerable algae blooms, smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. This therefore contributed to velocity sensitive aquatic macroinvertebrates being absent. Porifera were also not identified owing to the amount of algae coverage on the rocks. Furthermore, habitat availability was adequate owing to no vegetation being sampled due to erosion and undercut banks.
HI: Instream	D	F and NF	Extensive irrigation upstream with releases from Wagendrift Dam. High concentrations of algae and silt with bank erosion due to activities on the banks
HI: Riparian	D	NF	Extensive vegetation removal for agriculture, overgrazing, trampling and alien vegetation infestation on banks.
ECOSTATUS	**D**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the

PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR6A are presented in the table below.

Table 56: Ecological trends for THU_EWR6A

Component	Trend	Reason	Confidence (0-5)*
Fish	Negative	A decline in water quality (negative physiological responses by the fish), siltation and the modified flow regime lower migration potential, lead to a build-up in sediments and nutrients and this result in increased algal growth. The loss of spawning habitat and food resources (macro-invertebrates) is all negative factors lowering the current species diversity and contribute to the low numbers of specimens at the site.	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses) combined with water quality modification (upstream industrial complexes, high nutrient discharges, erosion, grazing cattle and human settlements) are the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from low intensity agriculture, cattle grazing as well as low density rural human settlements, but high industrial intensity upstream from the town Escort and beyond. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	4
HI: Instream	Negative	Irrigation and bank activities ongoing that will increase algae and siltation	3
HI: Riparian	Negative	Bank activities will de-stabilise banks further that will lead to bank collapse and increased sedimentation	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. The table below provides the final results for the Bushmans River at THU_EWR6A.

Table 57: Final ecological categories for THU_EWR6A

Component	PES	Importance	REC	Trend	TEC
Fish	D	EI = High ES = High		Negative	Rationale: Flow and water quality impacts are present. Upstream improvements in sources of water pollution are required.
Macroinvertebrates	C/D			Stable	
HI: Instream	D			Negative	
HI: Riparian	D			Negative	
ECOSTATUS	**D**	**High**	**C**		**C/D**

The final step is the quantification of the EWR and include the conversion of the EWR flow data for a TEC of a C/D category to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model. The maintenance and drought flows were examined for July and February. July is the month with the lowest maintenance flow (i.e. base-flow) and February is the month with the highest maintenance flow conditions.

The requirements of the DRM for September were also assessed as the surveys were undertaken on 9 September 2020. The discharge at the EWR site during the site visit was 0.189 m^3/s and was used as reference to adjust the recommended EWRs.

Together with site photographs and rating relationships (flow depth versus discharge) from the hydraulic model, water levels proposed by the DRM for drought and maintenance low flows were assessed in terms of the habitat and biotic requirements. The site-specific flow requirements were based mainly on the velocity and habitat requirements of flow-sensitive aquatic macroinvertebrates and depths for fish. The consensus reached by the aquatic ecologists was that the velocities at the critical habitat, recommended by the DRM model during September, was not adequate to provide the necessary velocities for the flow sensitive macroinvertebrates and depths for fishes. Thus, the following changes were made to the desktop flow requirements:

Maintenance low flows:

- September – change from 0.635 m^3/s to 1.625 m^3/s
- February – change from 1.658 m^3/s to 4.238 m^3/s

The final EWRs for specific months are given in the table below and shown on the graph in Figure 15.

Table 58: EWR results for specific months for Lower Bushmans River in V70G (TEC = C/D)

	Month	Discharge (m^3/s)	Depth (m)		Velocity (m/s) (average)
			Maximum	Average	
Maintenance low flows					
	September	1.625	0.70	0.42	0.12
	February	4.238	0.92	0.56	0.20
Drought flows					
	September	0.440	0.48	0.25	0.07
	February	1.108	0.62	0.35	0.10
Measured discharge at site visit (09/09/2020)		0.189	0.36	0.20	0.045

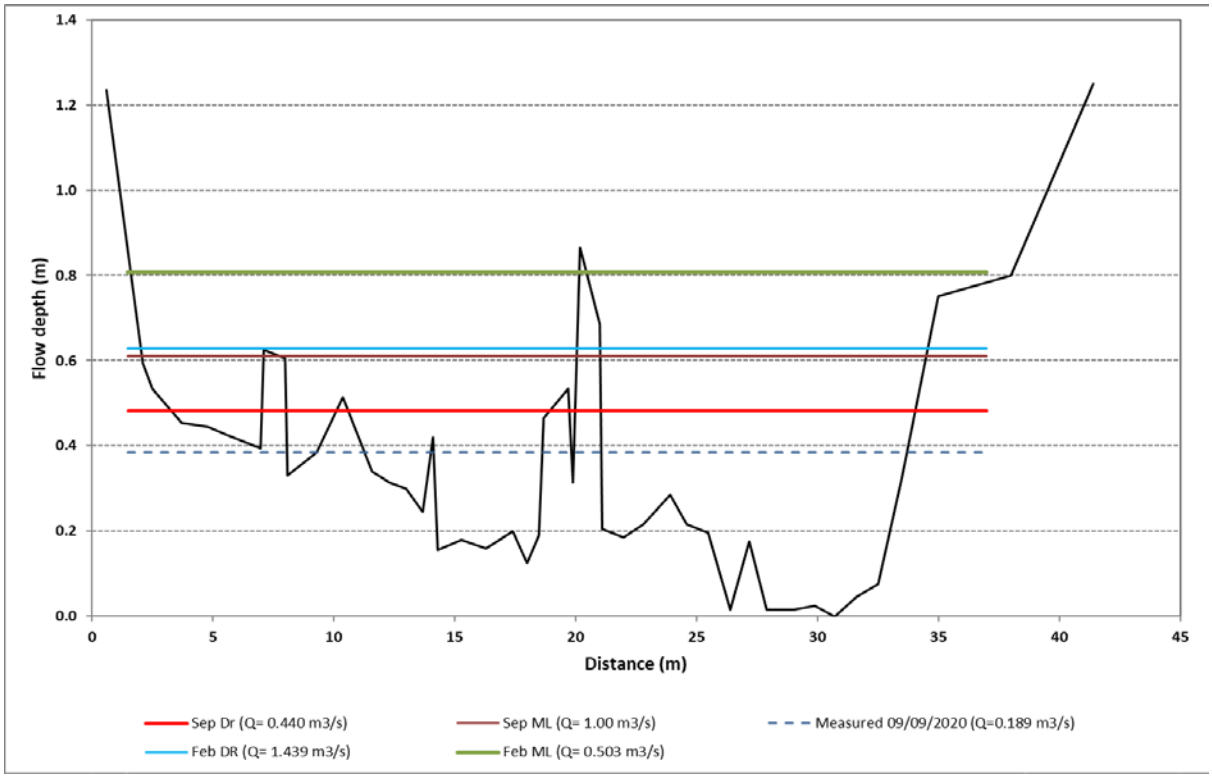

Figure 15: Water levels on cross-section for the Lower Bushmans River (THU_EWR6A)

As the PES of the Lower Bushmans River at THU_EWR6A was determined as a D category, the requirements were also determined for the PES. The same aspects were considered as for the C/D category, namely velocities for flow sensitive macroinvertebrates and depths for fish.

As the original EWR site on the lower Bushmans River (Thukela_EWR6) is situated in the same quaternary and only a small tributary enters the river between the two sites, the following changes were made to the 2003 study results:

- PES = B/C, as the river has deteriorated over the 20-year period since the original study from the results of the field surveys at THU_EWR6A. As no surveys were done at this site, the PES was kept a B/C.
- Only a REC was specified in 2003 (REC = B/C). However, due to the extensive use in the upper catchment, this is not feasible to obtain, and a TEC of a C/D category was specified for this site.

Specific conditions to improve the impacts (low flows, bad water quality and alien vegetation removal) will be specified to ensure the TEC of a C/D can be met at both the EWR sites.

The following tables provide the freshets/ floods used for both sites and a summary of the final EWR for the various categories. The freshets/ floods specified for site Thukela_EWR6 were used as these were done on a high level of confidence compared to the once-off survey that was undertaken for this study (see table below). The 2003 floods not only considered cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats, it also included specific requirements for riparian vegetation and geomorphology.

Table 59: Freshets and annual flood requirements at THU_EWR6A and Thukela_EWR6 for TEC=C/D

Months	**Flow (m^3/s)**	**Duration (days)**	**Flow (m^3/s)**	**Duration (days)**
	Freshets		**Floods**	
September	4	2		
October	6	3		
November	10	3		
December	10	3	20	4
January	30	3	35	4
February	20	3	40	6
March	10	3	25	5
April	6	2		

The final EWR for the Lower Bushmans River at THU_EWR6A is summarised in Table 60.

Table 60: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	**V70G**	
River	Lower Bushmans	
	THU_EWR6A	Thukela_EWR6

Quaternary Catchment	**V70G**			
EWR Site Co-ordinates	-28.8483; 30.1496		-28.801; 30.167	
NMAR at EWR site	298.37		303.14	
Target Ecological Category	TEC=C/D	PES=D	TEC=C/D	PES=B/C
Total EWR	121.190 (40.62 %MAR)	87.972 (29.48 %MAR)	89.089 (29.39 %MAR)	110.516 (36.46 %MAR)
Maintenance Low flows	83.299 (27.92 %MAR)	50.082 (16.79 %MAR)	51.285 (16.92 %MAR)	67.338 (22.21 %MAR)
Drought Low flows	21.952 (7.36 %MAR)	21.952 (7.36 %MAR)	22.120 (7.30 %MAR)	21.135 (6.97 %MAR)
Maintenance High flows	37.891 (12.70 %MAR)	37.891 (12.70 %MAR)	37.804 (12.47 %MAR)	43.178 (14.24 %MAR)
Overall confidence	Low-Medium		Medium	

4.3.3. THU_EWR13A (Rapid II) and 2003 Thukela_EWR13: Middle Buffalo River in V32F

The EWR for this site was determined on a Rapid II level, thus no hydraulic cross-section was surveyed. The purpose of the survey was to re-assess the present state of the Middle Buffalo River and to revise the results from the 2003 site Thukela_EWR13, if necessary. Although the new site is higher in the catchment than the 2003 site, it is still in the same ecoregion level 2 and only a small tributary enters the Buffalo River between the two EWR sites.

Figure 16: View of the EWR site on the Middle Buffalo River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in Table 61.

Table 61: THU_EWR13A reference conditions and present ecological state per component

COMPONENT	DESCRIPTIONS
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), the reach of the Middle Buffalo River at the EWR site support a moderate diversity of fish (AMOS, BANO, BNAT, PAL, BPAU, BVIV, CGAR, LRUB, OMOS and TSPA) with two alien invasive expected (CCAR and MSAL).
Present state	Only one (BNAT) was collected during the survey (6 specimens only). This was expected as the hydraulic habitats sampled would have favoured rheophilic (i.e. flow-dependent) and deep water species. The river consists of a deep channel for extended stretches with very little shallow areas or riffles and rapids. The FRAI results indicate that the fish assemblage is currently in a "E" (32.2% - unadjusted score with the adjusted value of C/D at 59.2%) Ecological Category indicating that the fish community is largely modified. Poor water quality and a lack of biotope diversity at this site contribute to the poor diversity and numbers. In addition, as no netting was done during sampling, the diversity and numbers was affected.
Macroinvertebrates	
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >180 and the Average Score Per Taxon (ASPT) should be >7.0 Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Coenagrionidae, Lestidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae, Unionidae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a D (56.82%). This means the macroinvertebrate community is in a considerably modified state, with mostly tolerant taxa present. The most impacted driver metric is that of flow modification (50.7%); followed by water quality (56.1%) and habitat (63.3%). See table below which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae >2spp, and Hydropsychidae >2spp.

COMPONENT	DESCRIPTIONS
	According to the flow modification metric group, most expected taxa had a preference for standing flowing water, although only 5 were recorded and thus the most important groups of invertebrates. Taxa with a preference for slow, moderately fast and very fast flowing water recorded at low diversities, being 1, 0 and 2 taxa from an expected 7, 10 and 8 taxa respectively in the system. Overall, all flow modification groups were thus impacted. According to the habitat modification metric group, taxa with a preference for cobbles/boulders/bedrock were the most important and dominant reference group of macroinvertebrates, although only 2 taxa were recorded from an expected 24 taxa and thus the community was highly impacted. The expected 16 taxa with a preference for vegetation, 3 were recorded, while taxa with a preference for the water column or surface are the least important group of invertebrates in the system, expecting only 6 taxa, of which 1 was recorded. Those taxa with a preference for GSM were also the least impacted groups of invertebrates relative to the reference condition, recording 3 of the 11 expected taxa. According to the water quality metric group, taxa with a low, moderate, and very low requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition, although all three communities recorded low diversity (7, 1 and 4 taxa) in comparison to their expected diversities being 24, 17 and 16 respectively. Eight (8) taxa were expected with a preference for high requirements, although only 2 were recorded. Overall, the present SASS5 of 77 and ASPT score of 5.5 did not exceed or match the reference data of the SASS5 and ASPT scores of 180 and 7.0 respectively. The SASS5 score was approximately 42% and the ASPT score 78% of the reference data.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether flow or non-flow related impacts, are also determined.

Table 62: PES per component and integrated PES for THU_EWR13A

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C/D	F and NF	The fish assemblage is largely modified due to poor water quality (impacting on the physiology of the fish), lack of biotope diversity, and poor cover for the smaller specimens of the migrating species and the barbs that prefer vegetation for cover.
Macroinvertebrates	D	F	The main driver in the system affecting the macroinvertebrate community was primarily poor water quality owing to high nutrients and visual observations of sewage. Many of the velocity sensitive aquatic macroinvertebrates were absent. Furthermore, habitat availability was adequate owing to limited vegetation being sampled due to erosion and undercut banks.

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
HI: Instream	D	F and NF	Irrigation abstractions in upper catchments, with algae, silt and organic matter present in the river. Bank collapse has resulted in deep, incised channel.
HI: Riparian	E	NF	Historic removal of riparian vegetation has resulted in alien vegetation infestation on the banks and the depositing of sand and silt due to collapsing banks.
ECOSTATUS	**D**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR13A are presented in Table 63.

Table 63: Ecological trends for THU_EWR13A

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable	There have been some changes in the upstream catchment related to land-use practices, erosion and siltation and an increased inflow of pollutants that contribute to the poor fish diversity. One can assume that the ecological trends are declining, and regular monitoring will be needed to monitor this river system.	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses) combined with water quality modification (upstream industrial complexes, high nutrient discharges, erosion, grazing cattle, and human settlements) are the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from high intensity agriculture, cattle grazing as well as low density rural human settlements, but high industrial intensity upstream from the town Newcastle and beyond. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	5
HI: Instream	Stable	Upstream catchment use includes irrigation abstractions and return flows from WWTW and other industrial activities in Newcastle	3

Component	Trend	Reason	Confidence (0-5)*
HI: Riparian	Negative	Ongoing bank collapse resulting in the depositing of silt and sand	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve or even degrade if the river is a hard-working river. Table 64 provides the final results for the Middle Buffalo River at THU_EWR13A.

Table 64: Final ecological categories for THU_EWR13A

Component	PES	Importance	REC	Trend	TEC
Fish	C/D	EI = Moderate ES = High		Stable	Rationale: Water quality impacts are influencing habitat heath. Management of the upstream water quality impacts will drive an improvement in ecological condition.
Macroinvertebrates	D			Stable	
HI: Instream	D			Stable	
HI: Riparian	E			Negative	
ECOSTATUS	**D**		**C/D**		**C/D**

Thus, the PES for the Middle Buffalo River remains a D category with a negative trend. It was recommended that the TEC be set for a C/D category with specific conditions to improve the non-flow impacts (stabilisation of banks, alien vegetation removal and ensure WWTWs are functioning to remove the organic matter from the river).

The characteristics used to determine the EWR in 2003 for Thukela_EWR13 (maintenance low flows, drought flows and floods/ freshets) were used to determine the EWR at this site for a PEC of a D category and a TEC of a C/D category.

The following tables provide the freshets/ floods used for both sites (Table 65) and a summary of the final EWR for the various categories (Table 66).

Table 65: Freshets and annual flood requirements at THU_EWR13A and Thukela_EWR13

Months	Flow (m^3/s)	Duration (days)	Flow (m^3/s)	Duration (days)
	Freshets		Floods	
September	2.5	2		
October	8	2		

November	8	2		
December	8	2	25	3
January	27.5	3	60	4
February	25	3	150	6
March	25	3	60	4
April	2.5	2		

Table 66: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	**V32D**		**V32F**	
River	Middle Buffalo			
EWR site name	THU_EWR13A		Thukela_EWR13	
EWR Site Co-ordinates	-28.0107; 30.3931		-28.153; 30.476	
NMAR at EWR site	626.68		695.05	
Ecological Category	TEC=C/D	PES=D	TEC=C/D	PES=D
Total EWR	100.616 (16.06 %MAR)	118.311 (18.88 %MAR)	132.098 (19.01 %MAR)	111.762 (16.08 %MAR)
Maintenance Low flows	24.759 (3.95 %MAR)	42.454 (6.77 %MAR)	47.082 (6.77 %MAR)	27.340 (3.93 %MAR)
Drought Low flows	22.432 (3.58 %MAR)	22.432 (3.58 %MAR)	25.309 (3.64 %MAR)	24.766 (3.56 %MAR)
Maintenance High flows	75.857 (12.10 %MAR)	75.857 (12.10 %MAR)	85.015 (12.23 %MAR)	84.421 (12.15 %MAR)
Overall confidence	Low		Medium-high	

4.3.4. THU_EWR7A (Rapid II) and 2003 Thukela_EWR7: Upper Sundays River in V60B

This site was assessed on a Rapid II level as no hydraulic cross-sectional survey was undertaken. The purpose of the surveys was to re-assess the present state of the Upper Sundays River and to revise the results from the 2003 site Thukela_EWR7, if necessary. Although the new site is higher in the catchment than the 2003 site, it is still in the same ecoregion level 2. However, a large tributary enters the Sundays River just downstream of the new EWR site. Thus, the results from the re-assessment can't be directly used for the original 2003 EWR site and the PES, REC and flow requirements from the 2003 study were not changed. The characteristics from the 2003 study were however used to determine the EWR for the new EWR site.

Figure 17: View of the EWR site on the Upper Sundays River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided in the table below.

Table 67: THU_EWR7A reference conditions and present ecological state per component

COMPONENT	DESCRIPTION
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EKZN, 2020), this reach of the Upper Sundays River has an expected list of eight indigenous fish species (AMOS, ANAT, BANO, BNAT, CGAR, LRUB, OMOS and TSPA.
Present state	Only two of the expected species of fish were collected from the Upper Sundays River at the EWR site THU_EWR7A – ANAT and BNAT. Again, low flows contribute to the poor habitat diversity and lack of deeper water for the larger species (e.g. LRUB and OMOS).

COMPONENT	DESCRIPTION
	The reference and observed frequency of occurrence of fish for the river was used and the FRAI results indicate that the fish assemblage is currently in a "C" (65.4%) Ecological Category, indicating a fish community that is largely modified. The present fish assemblage is largely determined by the lack of good biotopes and the large percentage of bedrock lower the suitable habitat (lack of riffles and rapids and vegetation). The relatively poor water quality contributes to the low diversity and numbers of fish collected (impact on the physiology of fish, e.g. breeding and general stress). The modified flow regime lowers the diverse depth classes and flow velocities expected to ensure the higher species diversity will be present.
Macroinvertebrates	
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >180 and the Average Score Per Taxon (ASPT) should be >6.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Oligochaeta, Hirudinea, Potamonautidae, Atyidae, Hydracarina, Perlidae, Baetidae >2spp, Caenidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Polymitarcyidae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Coenagrionidae, Lestidae, Protoneuridae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Hydroptilidae, Leptoceridae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helodidae, Hydraenidae, Hydrophilidae, Psephenidae, Athericidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Empididae, Ephydridae, Muscidae, Simuliidae, Tabanidae, Tipulidae, Ancylidae, Bulinae, Lymnaeidae, Planorbinae, Corbiculidae, Sphaeridae, Unionidae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a C (71.86%). This means the macroinvertebrate community is in a moderately modified state, with a moderate diversity of taxa present. The most impacted driver metric is that of water quality (68.4%); followed equally by both flow modification and habitat (73.3%). See table below which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae > 2 spp., Heptageniidae (Flatheaded mayflies) and Leptophlebiidae (Prongills). According to the flow modification metric group, most expected taxa had a preference for standing flowing water, whereby 9 taxa were recorded out of an expected 25 and thus the most important group of invertebrates. Taxa with a preference for slow, moderately fast and very fast flowing water recorded at low diversities, being 1, 4 and 2 2 taxa from an expected 7, 10 and 8 taxa respectively in the system. Overall, all flow modification groups were thus impacted. According to the habitat modification metric group, reference taxa with a preference for cobbles/boulders/bedrock were the most important and dominant reference group of macroinvertebrates, although only 7 taxa were recorded from an expected 25 taxa and thus the community was highly impacted. From the expected 16 taxa with a preference for vegetation, only 5 were recorded, while taxa with a preference for the water column or surface are the least important group of invertebrates in the system, expecting only 6

COMPONENT	DESCRIPTION
	taxa, of which 2 were recorded. Those taxa with a preference for GSM were also the least impacted groups of invertebrates relative to the reference condition, recording 3 of the 11 expected taxa. According to the water quality metric group, taxa with a low, moderate and very low requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition, although all three communities recorded low diversity (10, 3 and 6 taxa) in comparison to their expected reference diversities being 25, 17 and 16 respectively. Eight (8) taxa were expected with a preference for high requirements, although only 2 were recorded. Overall, the present SASS5 of 117 and ASPT score of 5.6 did not exceed or match the reference data of the SASS5 and ASPT scores of 180 and 6.5 respectively. The SASS5 score was approximately 65% and the ASPT score 86% of the reference data.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication if it is flow or non-flow related impacts are also determined.

Table 68: PES per component and integrated PES for THU_EWR7A

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C	F and NF	The fish assemblage is severely modified due to the poor water quality and lack of habitat diversity (flow depth classes, cover, and vegetation).
Macroinvertebrates	C	F	The main driver in the system affecting the macroinvertebrate community was habitat availability (calculated to be adequate) although an abundance of bedrock instream, which in essence is not a good biotope for aquatic macroinvertebrates and limited SIC biotopes. However, owing to limited silt and algae deposits on the rocks, Porifera were observed on some rocks. Furthermore, modified flows as a result of changes in hydrology from upstream impoundments altering flows, erosion of banks resulting in sedimentation in important instream habitats.
HI: Instream	C	F and NF	Extensive irrigation and large dam in upper reaches of the Sundays River. River incised onto bedrock and possible widening of river channel
HI: Riparian	D	NF	Natural vegetation removal into riparian zone replaced by alien invasive plants. Together with cattle paths and trampling causing bank collapse
ECOSTATUS	**C/D**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR7A are presented in Table 69.

Table 69: Ecological trends for THU_EWR7A

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable/decreasing	There have been changes to the upstream catchment related to the changes (degradation) of water quality and the flow regime (loss of floods and freshets).	3
Macroinvertebrates	Stable	Habitat and flow regimes in the catchment (from catchment-scale land uses) combined with water quality modification (from erosion, grazing cattle and human settlements) are the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from low intensity agriculture and cattle grazing. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	3
HI: Instream	Stable	River incised onto bedrock	3
HI: Riparian	Negative	Bank collapse causing channel widening ongoing	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. Table 70 provides the final results for the Upper Sundays River at THU_EWR7A.

Table 70: Final ecological categories for THU_EWR7A

Component	PES	Importance	REC	Trend	TEC
Fish	C	EI = High ES = High		Stable/ negative	Rationale: Ecological condition is driven by land use activities and poor water quality. Improvement is required.
Macroinvertebrates	C			Stable	
HI: Instream	C			Stable	
HI: Riparian	D			Negative	
ECOSTATUS	**C/D**		**C**		**C**

As no hydraulic cross-sectional survey was done, the DRM results for maintenance and drought flows for a TEC of C were compared to those specified for the 2003 EWR site (Thukela_EWR7). This EWR site is situated lower down on the Sundays River with a large tributary (Nkunzi River) entering the Sundays River between the two EWR sites. Thus, the characteristics used to determine the EWR in 2003 for Thukela_EWR7 (maintenance low flows, drought flows and floods/ freshets) were used to determine the EWR at this site for a PEC of a C/D category and a TEC of a C.

The freshets/ floods as specified for the Sundays River at Thukela_EWR7 during the 2003 study were used as these were done on a high level of confidence compared to the once-off survey that was undertaken for this study (see table below). The 2003 floods not only considered cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats, it also included specific requirements for riparian vegetation and geomorphology. The freshets/ floods were adjusted for the difference in MAR between the two sites.

The following tables provide the freshets/ floods used for THU_EWR7A and a summary of the final EWR for the various categories for both sites.

Table 71: Freshets and annual flood requirements at THU_EWR7A (adjusted from 2003 study)

Months	Flow (m^3/s)	Duration (days)	Flow (m^3/s)	Duration (days)
	Freshets		**Floods**	
September	0.8	2		
October	0.8	2		
November	1.95	2		
December	1.95	2	7.8	3
January	0.8	2	7.8	3
February	2.8	2	22.5	4
March	2.8	2	7.8	3

The final EWR for the Upper Sundays River at THU_EWR7A is summarised in Table 72.

Table 72: Summary of the final EWR results (flows in million m³ per annum)

Quaternary Catchment	V60B		V60C	
River	Upper Sundays			
EWR site name	THU_EWR7A		Thukela_EWR7	
EWR Site Co-ordinates	-28.3479; 29.9682		-28.458; 30.053	
NMAR at EWR site	50.69		90.28	
Ecological Category	PES=C/D	TEC=C	PES=B/C	TEC=C
Total EWR	14.646 (28.90 %MAR)	15.958 (31.48 %MAR)	33.173 (36.74 %MAR)	28.531 (31.60 %MAR)
Maintenance Low flows	5.485 (10.82 %MAR)	6.797 (13.41 %MAR)	16.783 (18.59 %MAR)	12.141 (13.45 %MAR)
Drought Low flows	2.869 (5.66 %MAR)	2.869 (5.66 %MAR)	5.139 (5.69 %MAR)	5.085 (5.63 %MAR)
Maintenance High flows	9.161 (18.07 %MAR)	9.161 (18.07 %MAR)	16.390 (18.15 %MAR)	16.390 (18.15 %MAR)
Overall confidence	Low		Medium-high	

4.3.5. THU_EWR 4C (Rapid I) and 2003 Thukela 4A & B: Middle Thukela River in V14E

This site was assessed on a rapid level 1. The selected EWR site is situated just downstream of the existing Thukela_EWR4B site and upstream of the confluence with the Bloukrans River. The purpose of the surveys was to re-assess the present state of the Middle Thukela River and to revise the results from the 2003 site Thukela_EWR4A and B, if necessary.

Figure 18: View of the EWR site on the Middle Thukela River

A description of the reference conditions and present ecological state for the fish and macroinvertebrates are provided Table 73.

Table 73: THU_EWR4C reference conditions and present ecological state per component

COMPONENT	DESCRIPTION
Fish	
Reference	Based on available information (Skelton, 2001; Kleynhans et al., 2007; DWS, 2014; EEKZN, 2020), the reach of the Middle Thukela River at the EWR site support a small diversity of fish (BVIV, CGAR, LMOL, LRUB, OMOS, TREN and PPHI) with one alien invasive reported (CCAR).
Present state	AMOS, CGAR, LMOL, LRUB and PPHI were sampled, although in small numbers. The lower flow can contribute to the lack of diversity, especially the lack of vegetation. The high algae and silt in areas, lower the habitat for the fish (small species for habitation, spawning and macro-invertebrates). A positive aspect was the presence of larger deep water species and those that migrate over longer distances. FRAI results indicate that the fish assemblage is currently in a class “C” (67.9%) Ecological Category, an indication that the fish community is largely modified. The present fish assemblage is an indication of the lack of sufficient flow/depth classes (habitat diversity), poor vegetation as cover, the high algal presence (poor water quality and restricting habitat) and strong flows (floods and freshets) to flush the system.
Macroinvertebrates	

COMPONENT	DESCRIPTION
Reference	SASS5 scores: Based on the derivation of the reference condition, the total SASS5 score should be >200 and the Average Score Per Taxon (ASPT) should be >7.5. Reference taxa based on assessments of rivers in the EcoRegion include: Porifera, Turbellaria, Potamonautidae, Perlidae, Heptageniidae, Leptophlebiidae, Oligoneuridae, Prosopistomatidae, Trichorythidae, Chlorocyphidae, Platycnemidae, eshnidae, Libellulidae, Ecnomidae, Hydropsychidae >2spp, Philopotamidae, Polycentropodidae, Elmidae, Haliplidae, Hydraenidae, Psephenidae, Athericidae, Empididae, Simuliidae, Tabanidae, Ancylidae, Oligochaeta, Hirudinea, Atyidae, Paleomonidae, Hydracarina, Baetidae >2spp, Caenidae, Polymitarcyidae, Calopterygidae, Chlorolestidae, Coenagrionidae, Corduliidae, Gomphidae, Pyralidae, Belostomatidae, Corixidae, Gerridae, Hydrometridae, Naucoridae, Nepidae, Notonectidae, Pleidae, Veliidae, Hydroptilidae, Leptoceridae, Pisuliidae, Dytiscidae, Gyrinidae, Helodidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Ephydridae, Muscidae, Tipulidae, Bulinae, Lymnaeidae, Planorbinae, Thiaridae, Corbiculidae, Sphaeridae, Unionidae.
Present state	The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to change from the reference condition. The model then derived the Ecological Category for the site. The macroinvertebrate Ecological Category is a C (75.08%). This means the macroinvertebrate community is in a moderately modified state, with a moderate diversity of taxa present. The most impacted driver metric is that of water quality (70.8%); followed by habitat (75.4%) and flow modifications (79.1). See table below which provides the summary of the data interpretation and the EC for the macroinvertebrates. Taxa characterising this site in terms of abundance and sensitivity include: Baetidae > 2 spp., Heptageniidae (Flatheaded mayflies) and Leptophlebiidae (Prongills), Chlorocyphidae (Jewels), Crambidae (Pyralidae) and Psephenidae (Water Pennies). According to the flow modification metric group, 18 of the expected 25 reference taxa with a preference for standing flowing water was recorded and thus the most important group of macroinvertebrates. Taxa with a preference for slow, moderately fast and very fast flowing water recorded at least 50% of the expected reference taxa and thus all flow modification groups were not highly impacted, as they were mostly present. According to the habitat modification metric group, reference taxa with a preference for cobbles/boulders/bedrock were the most important and dominant reference group of macroinvertebrates, and where 15 of the expected 28 taxa were recorded and thus the community not highly impacted. The taxa communities with a preference for vegetation (9 recorded out of the expected 17 taxa), GSM (7 recorded out of the expected 12 taxa) and water column or surface (5 recorded out of the expected 6 taxa), were also not highly impacted as at least 50% of the expected reference taxa were recorded and thus these communities were not highly impacted, as they were mostly present. According to the water quality metric group, taxa with a low requirement for unmodified physico-chemical conditions are the most important indicators of the system's ecological condition and which were not affected as 20 taxa were recorded out of the expected 24 taxa. Taxa with moderate and very low requirement for unmodified physico-chemical conditions were also not highly impacted as 10 and 11 taxa were recorded out of the expected 20 and 17 reference taxa respectively. Nine (9) taxa were expected with a preference for high requirements, and 4 were recorded. Overall, communities with the above water quality preferences were not highly impacted, as they were mostly present.

COMPONENT	DESCRIPTION
	Overall, the present SASS5 of 145 and ASPT score of 6.0 did not exceed or match the reference data of the SASS5 and ASPT scores of 200 and 7.5 respectively. The SASS5 score was approximately 85% and the ASPT score 76% of the reference data.

The PES per component as derived from the various models as well as the EcoStatus are provided in the table below. To determine the Ecostatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Riparian Habitat Integrity PES is then included in the assessment index and the integrated EcoStatus is calculated. The rationale and an indication of whether flow or non-flow related impacts, are also determined.

Table 74: PES per component and integrated PES for THU_EWR4C

COMPONENT	PES	Flow/ Non-flow	EXPLANATION
Fish	C	F and NF	The fish assemblage is largely modified and affected by non-flow related impacts that have resulted in a of habitat and protective cover, in particular increased algal growth and some siltation within the broader system resulting in substrates becoming smothered. In addition, the altered flows in the catchment due to transformed land cover and land use activities has exacerbated drivers of velocity-depth/cover.
Macroinvertebrates	C	F and NF	The main driver in the system affecting the macroinvertebrate community is poor water quality and high alga smothering habitats and transforming a potential good SIC/SOOC biotope into a homogenous habitat that supports far less biota. Porifera were not identified owing to the high number of algae on the rocks. Some velocity sensitive aquatic macroinvertebrates were absent.
HI: Instream	D	F and NF	Unseasonal releases for irrigation from upstream dams, transfers to Vaal catchment and urban use. High levels of silt and algae due to upstream and riparian zone activities causing erosion.
HI: Riparian	C	NF	Removal of riparian vegetation for use and cultivation which causes alien invasive plant infestation. Widening of banks due to downstream bridge
ECOSTATUS	**C**		

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state. Thus, the definition of the trend is "…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the

biota have adapted to the current habitat template or are still in a state of flux", Kleynhans and Louw (2008). The ecological trends for THU_EWR4C are presented in Table 75.

Table 75: Ecological trends for THU_EWR4C

Component	Trend	Reason	Confidence (0-5)*
Fish	Stable	There have been changes to the catchment related to land-use practices that resulted in erosion and siltation and water pollution. All contribute to habitat modification and physiological stress of the fish in the system (particularly the intolerant spp.).	3
Macroinvertebrates	Stable	Flow modification in the catchment (from catchment-scale land uses) combined with water quality modification (from erosion, grazing cattle and human settlements) are the main drivers influencing macroinvertebrate community health. Overall, the surrounding catchment area is impacted from high intensity agriculture and cattle grazing as well as low density rural human settlements. Assuming these catchment impacts remain unchanged the macroinvertebrate community health is therefore unlikely to deteriorate over time.	5
HI: Instream	Stable	Ongoing flow changes due to transfers, dams and irrigation water use	3
HI: Riparian	Negative	Alien invasive plants and clearing of banks	3

* 0 – no confidence to 5 – high confidence

The EcoStatus score (PES) can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC. If the resource is degraded (i.e. has a low PES) but has a high ecological importance and/ or ecological sensitivity, the REC can be upgraded if it is potentially feasible to do so. The final step is then to determine the TEC, based on the actual catchment developments, trends and feasibility to maintain, improve o even degrade if the river is a hard-working river. The table below provides the final results for the Middle Thukela River at THU_EWR4C.

Table 76: Final ecological categories for THU_EWR4C

Component	PES	Importance	REC	Trend	TEC
Fish	C	EI = High ES = High		Stable	Rationale: Flow and non-flow impacts present. Improved flow and water quality required to improve ecological condition.
Macroinvertebrates	C			Stable	
HI: Instream	D			Stable	
HI: Riparian	C			Negative	
ECOSTATUS	**C**		**B/C**		**B/C**

The PES as determined using the results from the re-surveying is a C category compared to the 2003 PES of a B/C. As the REC of the 2003 was a B/C, it was recommended that the Middle Thukela River be managed for a TEC of a B/C category.

As no hydraulic cross-sectional survey was done, the results from the 2003 EWR site (Thukela_EWR4B) for maintenance and drought flows for a B/C were used for this site. The freshets/ floods as specified for the Middle Thukela at Thukela_EWR4B during the 2003 study were used as these were done on a high level of confidence compared to the once-off survey that was undertaken for this study (see table below). The 2003 floods not only considered cues for fish movement and spawning and cleaning of macroinvertebrates habitats as well as ensuring that sediment build-up is a minimum to provide aquatic habitats, but it also included specific requirements for riparian vegetation and geomorphology. Table 77 provides the freshets/ floods used, and Table 78 a summary of the final EWR for this site for a PES of C and a TEC of B/C.

Table 77: Freshets and annual flood requirements at Thukela_EWR4B (THU_EWR4C)

Months	Flow (m^3/s)	Duration (days)	Flow (m^3/s)	Duration (days)
	Freshets		Floods	
September	15	4		
October	15	4		
November	55	4	90	6
December	55	4	90	6
January	90	6	120	7
February	55	4	250	8
March	55	4	90	6

The final EWR for the Upper Sundays River at THU_EWR7A is summarised in Table 78.

Table 78: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V14E	
River	Middle Thukela	
EWR site name	Thukela_EWR4B (THU_EWR4C)	
EWR Site Co-ordinates	-28.747; 30.145	
NMAR at EWR site	1423.83	
Ecological Category	PES=C	TEC=B/C
Total EWR	357.201 (25.09 %MAR)	404.231 (28.39 %MAR)
Maintenance Low flows	129.373 (9.09 %MAR)	176.403 (12.39 %MAR)
Drought Low flows	97.099 (6.82 %MAR)	97.584 (6.85 %MAR)
Maintenance High flows	227.828 (16.00 %MAR)	227.828 (16.00 %MAR)
Overall confidence	Medium to high	

4.4. IUAs with no EWR sites

4.4.1. Blood River in V32H (Blood_dsk)

No EWR site was selected on the Blood River as this is mainly a flood plain system, especially in the upper reaches of the system. Thus, the present state and recommended/ target ecological categories have been specified by the wetland component of this study. These categories, together with the Desktop PES/EI/ES results for the lower reaches of the Blood River (just before the confluence with the Buffalo River were used to determine the EWR on a desktop level).

The following table shows the PES, REC and TEC for the wetland and river, with the final selected category.

Table 79: Final ecological categories for the Blood River

Component	PES	Importance	REC	TEC Rationale
Wetland*	D	EI = High ES = High	D/C	86.5% of wetlands within IUA 5 are considered to be Largely to Critically Modified (wetland condition D/E/F), with only 3.7% of wetlands in a Natural to Largely Natural condition (wetland condition A/B). Wetlands within the northern and central portions of this IUA have been significantly impacted by commercial agriculture which includes extensive cultivation and construction of numerous farm dams, including large farm dams within the main body of the Blood River Vlei Priority Wetland. Southern reaches of the IUA are characterised by urban villages and subsistence agriculture that result in heavy direct utilisation of wetland resources, most notably through heavy livestock grazing. Erosion is a significant problem affecting wetlands within the IUA, as reflected by the high levels of degradation within Valley Bottom wetlands. The wetlands should not be allowed to deteriorate further. A category D/C would mean that improved land management must be put in place to ensure the sustainability of the system.
Desktop (V32H-02834)	C	EI = High	B/C	B/C – The impacts are mostly from abstraction of water and

		ES = High		small dams for irrigation in the upper reaches, with community water use in the middle to lower reaches. The instream habitats and continuity have been modified due to a large weir in the lower reaches for water provision to the communities. With both the EI and ES being high, the PES of a C would not provide adequate flows to contribute to the lower Buffalo River in IUA5 with a TEC of a B/C.
ECOSTATUS	**C**	**High**	**B/C**	**B/C**

* Detailed information is available in the wetlands report

The DRM model was used to determine the final EWR for the Blood River at the outlet of quaternary catchment V32H. The maintenance low flow and drought flows were adjusted upwards as these were very low for both the B/C and C categories. The following changes were made:

Maintenance flows:

- B/C – 23.23% nMAR to 17.43% nMAR
- C –8.69% nMAR to 12.49% nMAR

Drought flows:

- B/C – 3.32% nMAR to 6.35% nMAR
- C – 3.32% nMAR to 6.35% nMAR

and is summarised in the table below.

Table 80: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	**V32H**	
River	Blood	
EWR Site Co-ordinates	Outlet of V32H	
NMAR at EWR site	94.714	
Ecological Category	PES=C	TEC=B/C
Total EWR	20.232 (21.36 %MAR)	26.473 (27.95 %MAR)
Maintenance Low flows	11.829 (12.49 %MAR)	16.502 (17.42 %MAR)
Drought Low flows	6.014 (6.35 %MAR)	6.017 (6.35 %MAR)
Maintenance High flows	8.403 (8.87 %MAR)	9.971 (10.53 %MAR)
Overall confidence	Low	

4.4.2. Upper Thukela River in V14B (Thukela1_dsk)

No EWR site was selected for this reach of the Thukela River, although a number of access points to the river were visited. This was due to the free-flowing nature of the Thukela River in this reach before it enters the gorge area. The back water caused by the uThukela transfer weir also limited finding a suitable EWR site. Thus, the desktop PES/EI/ES information for this reach (V14B-03296) was used and changes made to the DRM requirements using the information from the following table shows the PES, REC and TEC for the Thukela River in V14B.

Table 81: Final ecological categories for the Upper Thukela

Component	PES	Importance	REC	TEC Rationale
Desktop (V14B-03296)	B	EI = High ES = High	B	C Quantity: The impacts are mostly from abstraction of water for irrigation in the upper reaches, with the uThukela Transfer Weir toward the lower end of the reach. The instream habitats and continuity have been modified due to this large weir for water transfer. Quality: The impacts are associated with agricultural activities and intensive irrigation in the catchment. In addition, the discharge of poorly treated domestic wastewater from the town of Colenso and localised settlements does contribute to organic load. Highly salinity is observed. Although both the EI and ES are high, the PES of a B would not be attainable due to the pressure of water use and impacts on the water quality on this reach. Thus, a TEC of a C was accepted.
ECOSTATUS	**B**	**High**	**B**	**C**

The DRM model was used to determine the final EWR for the Thukela River in this reach, using the information from the upstream and downstream EWRs to refine the requirements and specify floods and freshets. The final results are summarised in Table 82.

Table 82: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	V14B
River	Thukela
EWR Site Co-ordinates	Outlet of V14B

NMAR at EWR site	1145.20	
Ecological Category	PES=B	TEC=C
Total EWR	450.844 (39.37 %MAR)	357.329 (31.20 %MAR)
Maintenance Low flows	220.294 (19.24 %MAR)	126.780 (11.07 %MAR)
Drought Low flows	48.097 (4.20 %MAR)	48.097 (4.20 %MAR)
Maintenance High flows	230.550 (20.13 %MAR)	230.550 (20.13 %MAR)
Overall confidence	Low	

4.5. IUA14: Escarpment Areas

The DRM was used, with the final selected TEC, to determine the EWR at all the outlet sites for the rivers as in the table below. No adjustments were made to the EWRs as only desktop information was available. The following tables summarises the final TEC and rationale as well as the requirements per river.

Table 83: Summary of ecological categories for rivers in IUA14

Site name	River	PES	Importance	REC	TEC
V11A_dsk	Thukela	B	High / Very high	B	B
V11B_dsk	Sithene/ Thonyelana	B	Moderate/ High	B	B
V11G_dsk	Mlambonja/ Mhlwazini	B	Moderate / High	B	B
V13A_dsk	Little Thukela	C	High/ Very high	B	B
V70A_dsk	Bushmans	B	High	B	B
V70B_dsk	Ncibidwana	B	High	B	B
V20A_dsk	Mooi	C	High	B	B
V20B_dsk	Little Mooi	C	High	B/C	B/C

Table 84: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	River	Present Ecological State	Target Ecological Category	NMAR	Total EWR	Maintenance Low flows	Drought Low flows	Maintenance High flows	Overall confidence
V11A	Thukela	B	B	66.90	25.637 (38.32 %MAR)	19.698 (29.45 %MAR)	6.078 (9.09 %MAR)	5.939 (8.88 %MAR)	Low
V11B	Sithene/ Thonyelana	B	B	142.69	54.686 (38.32 %MAR)	42.017 (29.45 %MAR)	12.965 (9.09 %MAR)	12.669 (8.88 %MAR)	Low
V11G	Mlambonja/ Mhlwazini	B	B	191.99	72.971 (38.01 %MAR)	55.748 (29.04 %MAR)	16.575 (8.63 %MAR)	17.223 (8.97 %MAR)	Low
V13A	Little Thukela	C		82.32	19.038 (23.13 %MAR)	12.224 (14.85 %MAR)	7.098 (8.62 %MAR)	6.814 (8.28 %MAR)	Low
			B		29.172 (35.44 %MAR)	21.002 (25.51 %MAR)	7.098 (8.62 %MAR)	8.170 (9.92 %MAR)	Low
V70A	Bushmans	B	B	113.46	40.524 (35.72 %MAR)	29.404 (25.92 %MAR)	9.844 (8.68 %MAR)	11.120 (9.80 %MAR)	Low
V70B	Ncibidwana	B	B	44.16	15.773 (35.72 %MAR)	11.445 (25.92 %MAR)	3.831 (8.68 %MAR)	4.328 (9.80 %MAR)	Low
V20A	Mooi	C		42.90	9.736 (22.69 %MAR)	6.029 (14.05 %MAR)	3.716 (8.66 %MAR)	3.707 (8.52 %MAR)	Low
			B		14.806 (34.51 %MAR)	10.352 (24.13 %MAR)	3.716 (8.66 %MAR)	4.454 (10.38 %MAR)	Low
V20B	Little Mooi	C		10.32	2.358 (22.84 %MAR)	1.478 (14.32 %MAR)	0.893 (8.65 %MAR)	0.879 (8.52 %MAR)	Low
			B/C		2.993 (28.99 %MAR)	2.037 (19.73 %MAR)	0.893 (8.65 %MAR)	0.956 (9.26 %MAR)	Low

4.6. Extrapolation to outlets of IUAs

Extrapolation was undertaken for those IUAs where the existing or new EWR sites are not close to the outlet. The characteristics and results from the lowest EWR site in the IUA were used to determine the EWR with the DRM. The Desktop PES/EI/ES results were used to determine the final TEC. The following tables summarises the final TEC and rationale as well as the requirements per site.

Table 85: Summary of ecological categories for extrapolation to IUA outlets

Site name	River/ Reach	PES	EI / ES	REC	TEC	Comments
Ngagane_dsk	Ngagane V31K-02516	C	Moderate / High	C	C	Use Ngagane (May13_EWR3) to extrapolate. No adjustments made to DRM output
Mooi_dsk	Mooi V20J-03467	C	High / High	C	C	Use THU_EWR12A to extrapolate for ML, Drought, and freshets/ floods. No MAR adjustments made as only a small seasonal tributary (Loza River) enters between two sites
Klip_dsk	Klip V12G-03256	C	High / High	B/C	C	Use THU_EWR22 (Upper Klip) to extrapolate for ML and drought flows. Accept DRM freshets
Thukela2_dsk	Thukela V60K-03419	C	High/ High	B/C	C	Use Thukela_EWR15 to extrapolate EWR, check floods against Thukela_EWR9 and THU_EWR12A

Table 86: Summary of the final EWR results (flows in million m^3 per annum)

Quaternary Catchment	River	Present Ecological State	Target Ecological Category	NMAR	Total EWR	Maintenance Low flows	Drought Low flows	Maintenance High flows	Overall confidence
V31K	Ngagane	C	C	240.84	49.018 (20.35 %MAR)	23.328 (9.69 %MAR)	8.943 (3.71 %MAR)	25.689 (10.67 %MAR)	Low
V20J	Mooi	C	C	388.66	119.860 (30.84 %MAR)	81.939 (21.08 %MAR)	40.676 (10.47 %MAR)	37.921 (9.76 %MAR)	Low to medium
V12G	Klip	C	C	253.09	64.352 (25.43 %MAR)	34.292 (13.55 %MAR)	14.429 (5.70 %MAR)	30.060 (11.88 %MAR)	Low
V60K	Thukela	C	C	2461.22	660.126 (26.82 %MAR)	313.781 (12.75 %MAR)	128.076 (5.20 %MAR)	346.345 (14.07 %MAR)	Low

4.7. Existing EWR Sites

The results from existing EWR sites from previous studies were used without any changes. Where the nMAR that was used during the previous studies changed substantially with the accepted natural hydrology for this study, adjustments were made accordingly. If the nMAR accepted for this study is lower than the original study nMAR, it will result in higher percentages of EWR required. However, the actual flows required will be the same as for the initial study. Also, if the PES or TEC have changed due to additional information available from RHP or other surveying, the requirements were adjusted. The following tables summarises the final categories and the requirements per site.

Table 87: Summary of ecological categories from existing EWR sites

Site name	River/ Reach	PES	Importance	REC	TEC
May13_EWR2	Horn	C	Low	C	C
May13_EWR3	Ngagane	C	Low	C	C
Thukela_EWR14	Lower Buffalo	B/C	High	B	B/C
Thukela_EWR8	Lower Sundays	D	Moderate	D	D
EWR_Mooi_N3	Mooi	E	Moderate	D	D
Thukela_EWR11	Mooi	B/C	Moderate	B/C	B/C
Thukela_EWR5	Middle Bushmans	B/C	Moderate	B/C	C/D
Thukela_EWR1	Upper Thukela	D	Moderate	D	D
Thukela_EWR2	Upper Thukela	C	Moderate	C	C
Thukela_EWR3	Little Thukela	C/D	Moderate	C/D	C/D
Thukela_EWR9	Middle Thukela	D	Moderate	D	D
Thukela_EWR15	Lower Thukela	C	High	C	C
THU_EWR16	Lower Thukela	C	High/ Moderate	C	C
THU_EWR17	Lower Thukela	C	High	C	C

Table 88: Summary of the final EWR results (flows in million m^3 per annum)

Site Name	River	NMAR	Present Ecological State	Target Ecological Category	Total EWR	Maintenance Low flows	Drought Low flows	Maintenance High flows
May13_EWR2	Horn	21.61	C	C	7.272 (33.65 %MAR)	4.936 (22.84 %MAR)	0.756 (3.50 %MAR)	2.336 (10.81 %MAR)
May13_EWR3	Ngagane	160.12*	C	C	38.315 (23.93 %MAR)	21.325 (13.32 %MAR)	8.149 (5.09 %MAR)	16.990 (10.61 %MAR)
Thukela_EWR14	Lower Buffalo	831.09	B/C	B/C	193.144 (23.24 %MAR)	84.272 (10.14 %MAR)	19.413 (2.34 %MAR)	108.873 (13.10 %MAR)
Thukela_EWR8	Lower Sundays	197.03	D	D	38.522 (19.55 %MAR)	13.302 (6.75 %MAR)	8.963 (4.55 %MAR)	25.220 (12.80 %MAR)
EWR_Mooi_N3	Mooi	265.81*	E	D	53.863 (20.26 %MAR)	32.847 (12.36 %MAR)	19.747 (7.43 %MAR)	21.016 (7.91 %MAR)
Thukela_EWR11	Mooi	301.14*	B/C	B/C	120.638 (40.06 %MAR)	74.526 (24.75 %MAR)	18.267 (6.07 %MAR)	46.112 (15.31 %MAR)
Thukela_EWR5	Middle Bushmans	281.45	B/C		127.643 (45.35 %MAR)	62.934 (22.36 %MAR)	19.751 (7.02 %MAR)	64.709 (22.99 %MAR)
				C/D	92.046 (32.70 %MAR)	37.454 (13.31 %MAR)	19.509 (6.93 %MAR)	54.592 (19.40 %MAR)
Thukela_EWR1	Upper Thukela	705.42	D	D	122.076 (17.31 %MAR)	49.671 (7.04 %MAR)	44.729 (6.34 %MAR)	72.405 (10.26 %MAR)
Thukela_EWR2	Upper Thukela	798.40	C	C	218.492 (27.37 %MAR)	88.819 (11.12 %MAR)	33.815 (4.24 %MAR)	129.673 (16.24 %MAR)
Thukela_EWR3	Little Thukela	285.20	C/D	C/D	70.474	31.698	18.223	38.776

Site Name	River	NMAR	Present Ecological State	Target Ecological Category	Total EWR	Maintenance Low flows	Drought Low flows	Maintenance High flows
					(24.71 %MAR)	(11.11 %MAR)	(6.39 %MAR)	(13.60 %MAR)
Thukela_EWR9	Middle Thukela	2050.76	D	D	415.403 (20.26 %MAR)	125.168 (6.10 %MAR)	69.552 (3.39 %MAR)	290.235 (14.15 %MAR)
Thukela_EWR15	Lower Thukela	3424.0*	C	C	773.383 (22.59 %MAR)	436.933 (12.76 %MAR)	177.716 5.19 %MAR)	336.449 9.83 %MAR)
THU_EWR16	Lower Thukela	3679.97*	C	C	1391.959 (37.83 %MAR)	685.337 (18.62 %MAR)	351.013 (9.54 %MAR)	706.622 (19.20 %MAR)
THU_EWR17	Lower Thukela	3690.53*	C	C	1394.652 (37.79 %MAR)	688.029 (18.64 %MAR)	352.547 (9.55 %MAR)	706.622 (19.15 %MAR)

* New nMAR lower/ higher than original study nMAR, thus different percentages but volumes the same

5 THUKELA ESTUARY

Based on the preliminary Reserve assessment conducted during a low flow period in August 2001, the overall Estuarine Health Index (EHI) score was 70 (Table 89), which translates into a Present Ecological State (PES) of C (moderately modified) (DWAF 2004). The EHI takes into consideration the abiotic drivers (hydrology, hydrodynamics and mouth condition, water quality, and physical habitat alteration) and biotic responses (microalgae, macrophytes, invertebrates, fish, and birds). More recently, the Thukela Estuary was assigned a PES of D in the latest National Biodiversity Assessment (NBA), indicating that the estuary is heavily modified as a result of significant loss of Process and Pattern (van Niekerk et al. 2019). The Thukela Estuary was allocated an Estuary Importance Score (EIS) of 76, which falls within the 60 – 80 range, indicating that the estuary is important (DWAF 2004); this EIS was reaffirmed in the NBA (van Niekerk et al. 2019). Of the five criteria contributing to the importance rating, functional importance was allocated a score of 100 because of the movement corridor provided by the estuary for river invertebrates that breed in the marine environment and the roosting area provided for marine or coastal birds. At the time of the Estuarine Freshwater Requirements study, the Ecological Reserve Category (ERC), based on the estuary's PES, was determined to be a PES + 1; i.e. a Category B. If it was not possible to achieve this state, then a best attainable state of a Category C would be the minimum requirement.

Table 89: Estuary Health Index scores allocated to the Thukela Estuary (present state) based on the 2001-2004 Estuarine Flow Requirements study (DWAF, 2004) and latest National Biodiversity Assessment (van Niekerk *et al*. 2019)

Variable	Score (DWAF 2004)	Score (van Niekerk *et al*. 2019)
Hydrology	87	70
Hydrodynamics and mouth condition	80	75
Water quality	54	54
Physical habitat alteration	80	70
Habitat health score	**75**	**67**
Microalgae	65	60
Macrophytes	60	60
Invertebrates	60	40
Fish	70	45
Birds	70	45
Biotic Health Score	**65**	**48**
Estuarine Health Index scores	**70 (C)**	**58 (D)**

6 WATER QUALITY

This report is focused on the quantification of the EWRs per EWR site, hydronode or IUA outlet as applicable. EWR flows have been specified as inputs to the ecological consequences' assessment during the evaluation of scenarios as the next step.

For the purposes of this undertaking water quality was only assessed at a baseline level in order to provide an interpretation of biological responses at an EWR site to determine whether water quality as a driver is a problem. A brief overview of the water quality condition of the EWR sites based on *in situ* readings, visual observation and once-off grab samples taken, is provided below.

6.1. *In situ* Water Quality and Site Observation

The descriptions and co-ordinates for the EWR sites in the Thukela River catchment are listed in Table 2 and the locations are shown on Figure 2 in Section 2. *In-situ* field water quality measurements were taken, and once-off grab samples collected for analysis at an accredited laboratory.

During the site visit undertaken during September 2020, field measurements were taken for the following parameters:

- pH,
- Electrical Conductivity (EC), and
- Temperature.

The field measurements recorded during the site visit is listed in Table 90 and visual observations noted at the site are described in Table 91. The *in-situ* pH, EC and temperature measurements represent good to fair ecological condition at the EWR sites.

Table 90: Water Quality measured for the Thukela River catchment EWR sites

EWR site	Survey date	River	Temp (ºC)	EC (mS/m)	pH
THU_EWR23	11/09/2020	Upper Buffalo	14.8	14.2	7.6
THU_EWR19	07/09/2020	Ncandu	17.3	14.92	7.82
THU_EWR20	08/09/2020	Nsonge	19.7	15.2	7.2
THU_EWR22	10/09/2020	Klip	16.9	23.1	7.82
THU_EWR12A	08/09/2020	Lower Mooi	22.2	47.6	8.3
THU_EWR6A	09/09/2020	Bushmans	20.3	40.4	7.9
THU_EWR21	07/09/2020	Mnyamvubu	17.3	17.2	7.5
THU_EWR13A	10/09/2020	Middle Buffalo	19.5	31.6	7.61
THU_EWR7A	11/09/2020	Sundays	20.5	30.8	8.2
THU_EWR4C	10/09/2020	Middle Thukela	24.9	21.5	8.32

Table 91: Visual Observations for the Thukela River catchment EWR sites

EWR site	River	Observation
THU_EWR23	Upper Buffalo	High algae present. Nutrient and organic load impacts are noticeable. High Silt load in system.
THU_EWR19	Ncandu	High siltation, erosion and high algae observed.
THU_EWR20	Nsonge	Pollution by cattle and localised erosion. High silt observed.
THU_EWR22	Klip	Lots of string algae on rocks. High siltation. Organic pollution.
THU_EWR12A	Lower Mooi	High algae (fibrous) and siltation.
THU_EWR6A	Bushmans	High organic load impact. Local users describe discolouration of water. Water had an acidic odour. High algae and siltation.
THU_EWR21	Mnyamvubu	High algae
THU_EWR13A	Middle Buffalo	High reed growth, siltation, nutrient impacts.
THU_EWR7A	Sundays	Erosion, significant impacts by cattle grazing. High nutrients.
THU_EWR4C	Middle Thukela	High algae

6.2. Water Quality Analysis

The grab samples were analysed for physico-chemical, macro-ions, inorganics and trace metals. Table 92 shows the results of the analysis. The analysis reflects that overall the quality of water at the EWR sites is in a good to fair condition, with only a few constituents reflecting concentrations that exceed the water quality specifications of a D/E condition at some sites (indicated by red font) (DWS, 2008). However, water quality improvement is required in terms of driving the ecological health of the biota. Based on the analysis of the water chemistry and comparison to the ecological specifications, a qualitative indication of water quality PES and issues of concern are indicated in Table 93. At most sites, nutrients are a problem and resulting in eutrophic systems. This was is aligned to high algal growth noted at most sites.

An analysis of diatom samples collected that sites were also undertaken. Diatoms are the unicellular algal group widely used as indicators of river and wetland health. They provide a rapid response to specific physico-chemical conditions in water and are an indication of change. Their presence or absence (indicator taxa) can be used to detect conditions such as eutrophication, organic enrichment, salinization, and changes in pH. The results of the analysis are indicated in Table 93. The ecological water quality for all sites reflect moderate to good condition, except for the Buffalo River EWR. The levels of organic pollution were found to be relatively low at the EWR sites. For almost all sites, except the Mooi River the diatom index scores, were representative of the water chemistry.

Table 92: Water quality results of the once off sampling undertaken

Water quality constituent	Units	Buffalo EWR 13a	Mooi EWR 12a	Mnyamvubu EWR21	Nsonge EWR20	Bushmans EWR6a	Klip EWR22	Tugela EWR4C	Sundays EWR7a	Buffalo EWR 23	Ncandu EWR19
pH (Lab)	pH units	7.60	7.70	7.80	7.78	7.93	7.69	7.97	7.84	7.85	7.84
pH (Field)		7.61	8.3	7.5	7.2	7.9	7.82	8.32	8.2	7.6	7.82
Electrical Conductivity @ 25°C (Lab)	mS/m	28.5	48	6.8	5.52	31.5	12.6	12.74	10.6	14.5	9
Electrical Conductivity (Field)		31.6	47.6	17.2	15.2	40.4	23.1	21.5	30.8	14.2	14.92
Total Dissolved Solids	mg/l	204.7	309	48.9	39.8	227	91.2	91.9	76.50	104.60	61.80
Calcium as Ca	mg/l	21.1	42.7	5.2	4.60	25.4	12.80	12.50	9.80	12.80	9.30
Potassium as K	mg/l	4.58	3.57	1.11	1.77	2.32	1.92	1.53	1.91	2.13	1.24
Magnesium as Mg	mg/l	11.50	26.20	3.74	2.63	13.70	5.22	5.37	5.59	7.89	3.92
Sodium as Na	mg/l	24.30	31.60	5.11	3.37	32.30	9.97	9.63	5.84	8.20	5.19
Silicon as Si	mg/l	2.98	6.50	2.43	4.56	5.71	3.35	4.14	4.91	3.39	6.14
Fluoride as F	mg/l	0.177	0.290	0.077	0.056	0.197	0.130	0.120	0.126	0.147	0.081
Chloride as Cl	mg/l	18	20.6	5.39	6.61	14.20	3.16	6.89	3.60	8.26	3.15
NH_4^+*	mg/l	0.057	0.236	0.009	0.01	0.103	0.016	0.01	0.01	0.01	0.01
Ammonia (Free and Saline)	mg/l	16.9	0.559	0.343	0.13	5.79	0.13	1.92	0.130	2.19	0.147
Nitrate as N	mg/l	3.82	0.130	0.130	0.130	1.31	0.130	0.434	0.130	0.494	0.130
Nitrite	mg/l	0.461	0.035	0.012	0.009	0.220	0.011	0.038	0.009	0.057	0.013
TIN - estimated	mg/l	4.338	0.401	0.151	0.148	1.633	0.157	0.481	0.148	0.560	0.152
Ortho Phosphate as P	mg/l	0.073	<0.002	<0.002	<0.002	0.013	0.002	<0.002	<0.002	0.006	<0.002
PO_4 *	mg/l	0.224	0.002	<0.002	0.003	0.039	0.006	0.003	0.002	0.019	0.002
NO_2 as N*	mg/l	0.14	0.011	0.004	0.003	0.067	0.003	0.012	0.003	0.017	0.004
Sulphate as SO_4	mg/l	31.6	14.7	2.2	0.759	16.20	6.26	5.93	4.80	15.30	3.390

Water quality constituent	Units	Buffalo EWR 13a	Mooi EWR 12a	Mnyamvubu EWR21	Nsonge EWR20	Bushmans EWR6a	Klip EWR22	Tugela EWR4C	Sundays EWR7a	Buffalo EWR 23	Ncandu EWR19
Aluminium as Al	mg/l	0.027	0.013	0.034	0.053	0.004	0.038	0.075	0.109	0.115	0.010
Arsenic as As	mg/l	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	<0.001
Copper as Cu	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium as Cd	mg/l	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.001
Chromium Cr	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.003	0.001
Lead as Pb	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 93: Overall Water quality condition and diatom results

Sample site	Water quality condition and driver (Water chemistry)		Diatoms (Specific Pollution Index)	
Buffalo River EWR13a	E	Nutrients	D	Poor
Mooi EWR12a	B	Nutrients	C/D	Moderate
Mnyamvubu EWR21	B	Nutrients	B	Good
Nsonge EWR20	B	Nutrients	B	Good
Bushmans EWR6a	C	Nutrients	C	Moderate
Klip Upstream EWR22	C	Nutrients	C/D	Moderate
Tugela EWR4C	C	Toxics - Aluminium	C/D	Moderate
Sundays EWR7a	C/D	Toxics - Aluminium	C	Moderate
Buffalo River EWR23	D	Nutrients, Toxics - Aluminium	C	Moderate
Ncandu EWR19	B	Nutrients	Not sampled	

The water quality at many of the sites are the driver of the ecostatus of the biota (fish and macroinvertebrates). While the water quality on its own may not reflect a poor condition, the present state requires improvement to support the ecological health of the fish and biota that live within these systems.

8 CONCLUSION

Based on the preliminary Thukela Reserve studies, the update with new information and additional assessment undertaken as part of this study, the EWRs rivers in the Thukela catchment have been quantified. Table 94 summarises the EWR sites per IUA indicating the level of assessment and a confidence level of the data/ information used for the assessment, where:

0: no confidence,

1: low confidence,

2: low to medium confidence,

3: medium confidence,

4: medium to high confidence, and

5: high confidence.

Table 94: Confidence level of data/ information used

IUA	EWR site name	River	Level and comment	Confidence Level of data/ information used (0-5)*
1	THU_EWR23	Upper Buffalo	New Rapid III sites close to outlet of IUA	2
2	May13_EWR2	Horn	Existing Rapid III site	2
	THU_EWR19	Ncandu	New Rapid III site	2
	May13_EWR3	Ngagane	Existing Rapid III site	2
	Ngagane_dsk	Lower Ngagane	Outlet of IUA 2. Use desktop PES/EI/ES with May13_EWR3 and THU_EWR2 to extrapolate	1
3	THU_EWR13A	Middle Buffalo	New Rapid II to update PES of existing 2003 Thukela_EWR13	1
	Thukela_EWR13	Middle Buffalo	Existing comprehensive site	4
4	Thukela_EWR14	Lower Buffalo	Existing comprehensive EWR site	3
5	Blood_dsk	Blood	Blood River Wetland and Desktop PES/EI/ES information	1
6	THU_EWR7A	Upper Sundays	New Rapid II to update PES of existing 2003 Thukela_EWR7	1
	Thukela_EWR7	Upper Sundays	Existing comprehensive EWR site	4
	Thukela_EWR8	Lower Sundays	Existing comprehensive EWR site	3
7	THU_EWR20	Nsonge/ Hlatikulu	New Rapid III site	2
	EWR_Mooi_N3	Mooi	Existing Rapid III site	2
	Thukela_EWR11	Mooi	Existing comprehensive site	3
8	THU_EWR21	Mnyamvubu	New Rapid II site	1
	THU_EWR12A	Mooi	New Rapid III site close to EWR12. Replace comprehensive site	3
	Mooi_dsk	Mooi	Desktop PES/EI/ES with THU_EWR12A to extrapolate	2
9	Thukela_EWR5	Middle Bushmans	Existing comprehensive site	2
	THU_EWR6A	Lower Bushmans	New Rapid III site	2
	Thukela_EWR6	Lower Bushmans	Existing comprehensive site	3

IUA	EWR site name	River	Level and comment	Confidence Level of data/ information used (0-5)*
10	Thukela_EWR1	Upper Thukela	Existing comprehensive site	3
	Thukela_EWR2	Upper Thukela	Existing comprehensive site	3
	Thukela_EWR3	Little Thukela	Existing comprehensive site	3
	Thukela1_dsk	Thukela	Desktop PES/EI/ES with Thukela_EWR2 and Thukela_EWR3	1
11	THU_EWR22	Klip	New Rapid III site	2
	Klip_dsk	Klip	Desktop	1
12	Thukela_EWR4A, B, C	Middle Thukela	Existing comprehensive sites; New Rapid I site to update Thukela_EWR4	4
	Thukela_EWR9	Middle Thukela	Existing comprehensive site	3
	Thukela2_dsk	Middle Thukela	Desktop PES/EI/ES with Thukela_EWR15 to extrapolate EWR	1
13	Thukela_EWR15	Lower Thukela	Existing comprehensive site	3
	THU_EWR16	Lower Thukela	Existing intermediate site	4
14	V11A_dsk	Thukela	Desktop PES/EI/ES	1
	V11B_dsk	Sithene, Thonyelana	Desktop PES/EI/ES	1
	V11G_dsk	Mlambonja, Mhlwazini	Desktop PES/EI/ES	1
	V13A_dsk	Little Thukela	Desktop PES/EI/ES	1
	V70A_dsk	Bushmans	Desktop PES/EI/ES	1
	V70B_dsk	Nsibidwana	Desktop PES/EI/ES	1
	V20A_dsk	Mooi	Desktop PES/EI/ES	1
	V20B_dsk	Little Mooi	Desktop PES/EI/ES	1
15	THU_EWR17	Lower Thukela	Existing intermediate site	3

Proposed Target Ecological Categories (TEC) at each site have been defined for the scenario analysis and determination of ecological consequences, taking into account the system requirements (dam release capacities, user requirements and yields of dams) at each of the

EWR sites, and the requirements at the Thukela Estuary to maintain a category C. It should be noted that the TECs are proposed categories. As the ecological consequences of these categories still need to be evaluated at the scenario evaluation step, the final TECs might differ.

The PES at each EWR site and the proposed TEC is summarised in Table 94.

Table 95: Summary of the PES and TEC at EWR sites in the Thukela

IUA	EWR site name	River	Natural MAR (10^6m^3)	PES	TEC
1	THU_EWR23	Upper Buffalo	221.96	C	C
2	May13_EWR2	Horn	21.61	C	C
	THU_EWR19	Ncandu	50.83	C	B/C
	May13_EWR3	Ngagane	160.12	C	C
	Ngagane_dsk	Lower Ngagane	240.84	C	C
3	THU_EWR13A	Middle Buffalo	626.68	D	C/D
	Thukela_EWR13	Middle Buffalo	695.05	D	C/D
4	Thukela_EWR14	Lower Buffalo	831.09	B/C	B/C
5	Blood_dsk	Blood	94.71	C	B/C
6	THU_EWR7A	Upper Sundays	50.69	C/D	C
	Thukela_EWR7	Upper Sundays	90.28	B/C	C
	Thukela_EWR8	Lower Sundays	197.03	D	D
7	THU_EWR20	Nsonge/ Hlatikulu	27.13	C	B/C
	EWR_Mooi_N3	Mooi	265.81	E*	D
	Thukela_EWR11	Mooi	301.14	B/C	B/C
8	THU_EWR21	Mnyamvubu	31.71	C	B/C
	THU_EWR12A	Mooi	361.85	C/D	C
	Mooi_dsk	Mooi	388.66	C	C
9	Thukela_EWR5	Middle Bushmans	281.45	B/C	C/D
	THU_EWR6A	Lower Bushmans	298.37	D	C/D
	Thukela_EWR6	Lower Bushmans	303.14	B/C	C/D
10	Thukela_EWR1	Upper Thukela	705.42	D	D
	Thukela_EWR2	Upper Thukela	798.40	C	C

IUA	EWR site name	River	Natural MAR (10^6m^3)	PES	TEC
	Thukela_EWR3	Little Thukela	285.20	C/D	C/D
	Thukela1_dsk	Thukela	1145.20	B	C
11	THU_EWR22*	Klip	52.44	C	C
	Klip_dsk	Klip	253.09	C	C
12	Thukela_EWR4A, B, C	Middle Thukela	1423.83	C	B/C
	Thukela_EWR9	Middle Thukela	2050.76	D	D
	Thukela2_dsk	Middle Thukela	2461.22	C	C
13	Thukela_EWR15	Lower Thukela	3424.00	C	C
	THU_EWR16	Lower Thukela	3679.97	C	C
14	V11A_dsk	Thukela	66.90	B	B
	V11B_dsk	Sithene, Thonyelana	142.69	B	B
	V11G_dsk	Mlambonja, Mhlwazini	191.99	B	B
	V13A_dsk	Little Thukela	82.32	C	B
	V70A_dsk	Bushmans	113.46	B	B
	V70B_dsk	Nsibidwana	44.16	B	B
	V20A_dsk	Mooi	42.90	C	B
	V20B_dsk	Little Mooi	10.32	C	B/C
15	THU_EWR17	Lower Thukela	3690.53	C	C

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APPENDIX A

Electronic data