Report no. RDM/WMA04/00/CLA/0121

DEPARTMENT: WATER AND SANITATION
CHIEF DIRECTORATE: WATER ECOSYSTEMS MANAGEMENT
DIRECTORATE: WATER RESOURCE CLASSIFICATION

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

REPORT TITLE: SCENARIOS EVALUATION AND PROPOSED WATER RESOURCE CLASSES REPORT

FINAL

March 2021

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Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems

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SCENARIOS EVALUATION AND PROPOSED WATER RESOURCE CLASSES REPORT
WP 11255

Study Report No.

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Reports as part of this project:

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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
8.0	RDM/WMA04/00/CON/CLA/0121	Scenarios Evaluation and Proposed Water Resource Classes Report

TERMINOLOGY AND ABBREVIATIONS

Acronym	Description
CD: WE	Chief Directorate: Water Ecosystems
CRA	Comparative Risk Assessment
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EI	Ecological Infrastructure
ES	Ecosystem Services
ESBC	Ecologically Sustainable Base Configuration
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Area
GRU	Groundwater Resources Unit
IPCC	Intergovernmental Panel on Climate Change
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

Acronym	Description
TEC	Target Ecological Category
WMA	Water Management Area
WRCS	Water Resource Classification System
WWTW	Wastewater Treatment Works

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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 determined to give effect to the 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 appropriate water resource classes (Management Classes) and Resource Quality Objectives (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 with three water resource Management Classes (MC) defined as:

- Class I - minimally used and configuration of ecological categories of that water resource minimally altered from its pre-development condition,
- Class II - moderately used and configuration of ecological categories of that water resource moderately altered from its pre-development condition, and
- Class III - heavily used and configuration of ecological categories of that water resource significantly altered from its pre-development condition.

This study is linked to the previous 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 area, through consultative processes. Specialist technical assessment and stakeholder engagement are key components to the process.

1.2. Spatial Extent of the Study

The Thukela River is the only river system making up the V hydrological drainage region comprising secondary drainage regions V1 to V7 (Figure 1), four sub-areas based on watershed boundaries (Table 1) covering 12 tertiary drainage areas and 88 quaternary catchments.

Table 1: Sub-catchment areas of the Thukela catchment

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 with the Bushmans River.	V11, V12, V13 and V14	7645
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	8496
Buffalo	The catchment of the Buffalo River.	V31, V32 and V33	9803
Lower Thukela	The catchment of the Thukela River between the confluence of the Buffalo River and the Indian ocean.	V40 and V50	3102

[1]WR2012 data

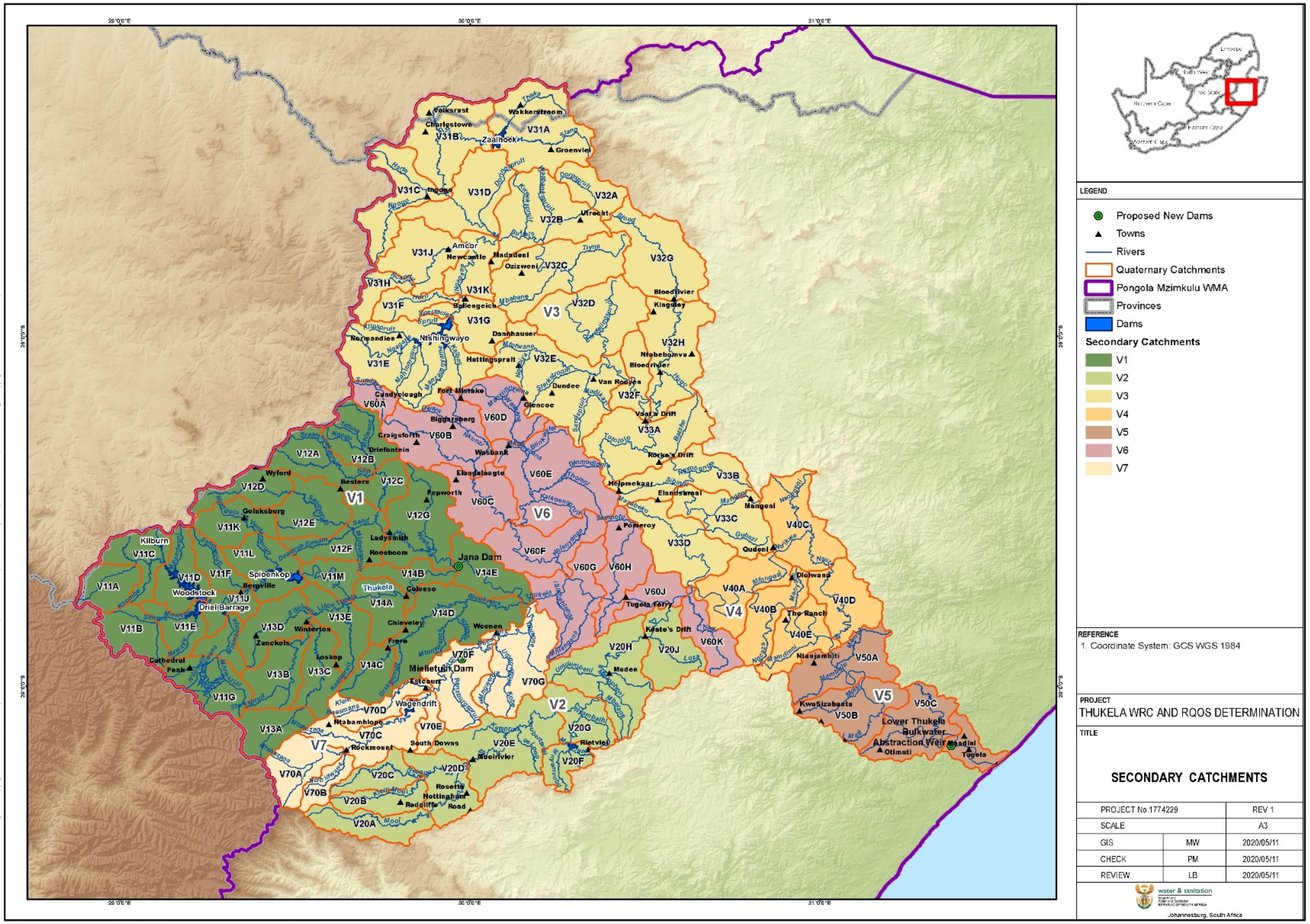


Figure 1: Secondary catchment area boundaries within the Thukela (V1 to V7)

1.3. Purpose of this Report

The purpose of this report is to provide the processes, approaches and results of steps 3 and 4 of the integrated process in adherence to Regulation 810 of Government Gazette 33541 for the classification of water resources (Figure 2), including:

i. A description of the process to define the operational scenarios,

ii. The approaches and results of the assessments to determine the ecological consequences of these scenarios for the rivers and the estuary,

iii. The approach and results of the socio-economic consequences of the defined scenarios, and

iv. Proposed water resource classes (WRC) to be presented and discussed during the stakeholder meetings to take place in the first quarter of 2021.

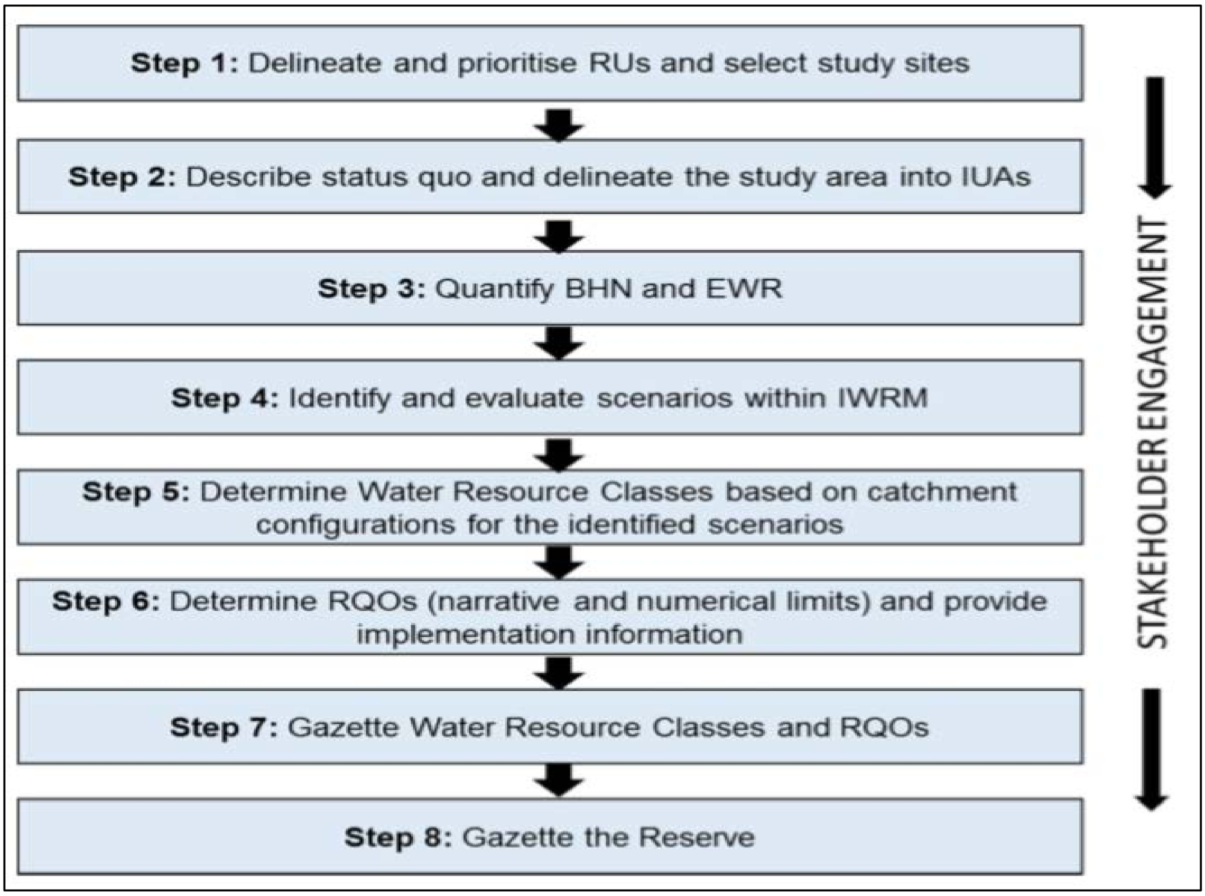


Figure 2: Water resource classes and RQOs determination in the Thukela catchment (integrated process in adherence to Regulation 810 of Government Gazette 33541)

2 THE EVALUATION OF SCENARIOS WITHIN THE INTEGRATED WATER RESOURCE MANAGEMENT PROCESS

An integral component of the water resource classification process is the scenario configuration and evaluation, which is an iterative process that assesses the resulting yields of alternate ecological protection categories; conservation targets and future use and development to determine what is most feasible for the Thukela catchment being classified, to support the recommended water resource management class options.

This task has been undertaken in compliance with the requirements of the study terms of reference that specifies that the classification process is required to build from existing and current initiatives within the framework of the integrated water resource management processes in the Thukela catchment and is illustrated in Figure 3. The study process is now in the final stages of the water resources classification process that will inform the setting of Resource Quality Objectives.

The scenario evaluation has been finalised and recommended scenarios are proposed.

2.1. Objectives of the scenarios' evaluation step

The objective of this step is to evaluate scenarios configured. Scenario evaluation has been incorporated into the integrated water resource management process so that a subset of catchment scenarios can be recommended towards proposed management classes.

The following activities have been undertaken as part of the water resource classification process:

- Inclusion of the following proposed scenarios:
  - Current scenario (2025) including the key current infrastructure developments in the Thukela catchment
  - Future development scenarios
    - A medium-term scenario (2030), and
    - A long term scenario (2040 - 2045).
- Water Resources Planning and Water Resource Yield Model analysis and adjustment,
- Reporting of ecological consequences and IUA- level ecological condition,
- Assessment of water quality implications,
- Description of the macro-economic implications,
- Evaluation of the overall scenario implications for the Thukela catchment, and
- Selection of a subset of recommended scenarios.

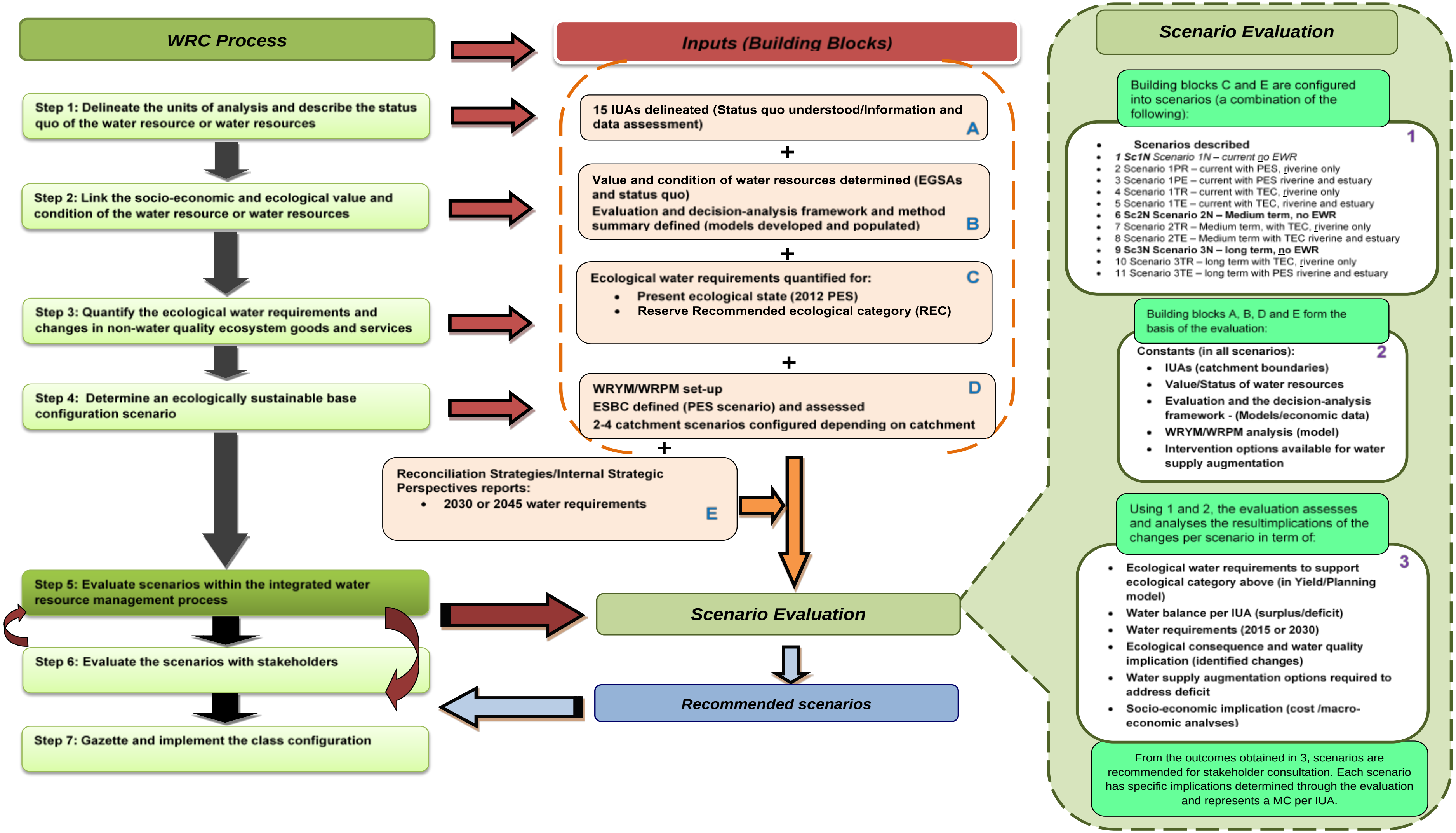


Figure 3: Scenarios evaluation within the integrated water resource management systems

2.2. Integrated Units of Analysis

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, and is the largest river system within the Pongola to Mtamvuma Water Management Area (WMA 4).

To enable improved representation of the water resources and socio-economic situation in the catchment, and to facilitate the determination of water resource classes, Integrated Units of Analysis (IUA) have been defined and are listed below. The detailed descriptions and rationale for these IUAs are provided in RDM/WMA04/00/CON/CLA/0320, 'Status Quo and Integrated Unit of Analysis and Resource Units Report'.

Table 2: IUAs delineated in the Thukela catchment

IUA	Delineation	Quaternary Catchment
1	Upper Buffalo	V31A; V31B; V31C; V31D
2	Ngagane River	V31E; V31F; V31G; V31H; V31J; V31K
3	Middle Buffalo	V32A; V32B; V32C; V32D; V32E; V32F
4	Lower Buffalo	V33A; V33B; V33C; V33D
5	Blood River	V32G; V32H
6	Sundays River	V60A; V60B; V60C; V60D; V60E; V60F
7	Upper Mooi River	V20A (lower portion); V20B (lower portion); V20C; V20D; V20E
8	Middle/ Lower Mooi River	V20F; V20G; V20H; V20J
9	Middle/Lower Bushmans River	V70A (lower portion); V70C; V70D; V70E; V70F; V70G
10	Upper Thukela River	V11A (lower portion); V11C; V11D; V11E; V11F; V11H; V11J; V11K; V11L; V11M; V13A (lower reaches); V13B; V13C; V13D; V13E; V14A; V14B
11	Klip River	V12A; V12B; V12C; V12D; V12E; V12F; V12G
12	Middle Thukela River	V14C; V14D; V14E; V60G; V60H; V60J; V60K
13	Lower Thukela River	V40A; V40B; V40C; V40D; V40E; V50A; V50B; V50C; V50D (upper portion)
14	Escarpment	V20A (upper reaches); V20B (upper reaches); V70A (upper reaches); V70B; V13A (upper reaches); V11G; V11B; V11A (upper reaches)
15	Thukela Estuary	V50D

2.3. Assessment of Biophysical Nodes

Biophysical nodes represent flow requirements and ecological state relevant for the IUA and are established to account for interactions between ecosystems. Allocation nodes are established to account for specific catchment issues or socio-economic aspects and to serve as modelling points for the scenario evaluation process in a catchment. The nodes are used to assess the response of upstream water resources to changes in water quality, quantity, and timing (DWA, 2007). Biophysical nodes should be located at interactions between ecosystems and at the end points of eco-system reaches to account for interactions. Allocation nodes should be located at the downstream edge of a reach of interest, as required for modelling and to allow for meaningful trade-offs.

Biophysical nodes have been selected within the study components (river, wetland, groundwater, and estuary) for analysis. These nodes represent the significant water resources that have a high ecological importance and/ or sensitivity that could be under threat due to its importance for water resource use and/ or where water use is high and/ or where water quality is impacted. The selected nodes are presented per water resource component.

Biophysical nodes have been selected for the significant water resources per IUA to quantify the Ecological Water Requirements (EWR) to inform the scenario analysis, the evaluation of ecological consequences and the determination of the water resource classes. These nodes are mostly existing EWR sites (key biophysical nodes) where a comprehensive Reserve assessment was undertaken.

Where limited information and gaps were identified for the scenario analysis, additional EWR sites were selected for Rapid Reserve assessments or extrapolation, including nodes at the outlet of each IUA (hypothetical modelling nodes). The biophysical hydronodes per IUA used for the scenario evaluation and their level of assessment are listed in Table 3 and shown in Figure 2. These sites were modelled and used to evaluate the ecological consequences and macroeconomic implications for the defined development scenarios. Key hydronodes (in bold in table below) where hydraulics information and biological survey data were available have been selected per IUA to evaluate the ecological consequences in detail.

Table 3: Biophysical nodes per IUA in the Thukela Catchment

IUA	Name	River	Quaternary	Level	Lat	Long
1	**THU_EWR23**	**Upper Buffalo**	**V31D**	**Rapid 3**	**-27.6221**	**29.9617**
2	May13_EWR2	Horn	V31F	Rapid 3	-27.888	29.921
	THU_EWR19	Ncandu	V31J	Rapid 3	-27.8017	29.8840
	May13_EWR3	**Ngagane**	**V31K**	**Rapid 3**	**-27.819**	**29.987**
	Ngagane_dsk	Lower Ngagane	V31K	Desktop	Outlet V31K	
3	THU_EWR13A	Middle Buffalo	V32F	Rapid 2	-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 (1)	Blood	V32H	Desktop	Outlet of V32H	
6	THU_EWR7A	Upper Sundays	V60B	Rapid 2	-28.3479	29.9682
	Thukela_EWR7	**Upper Sundays**	**V60C**	**Comprehensive**	**-28.458**	**30.053**
	Thukela_EWR8	Lower Sundays	V60F	Comprehensive	-28.636	30.204

IUA	Name	River	Quaternary	Level	Lat	Long
7	THU_EWR20	Nsonge/ Hlatikulu	V20C	Rapid 3	-29.2377	29.7853
	EWR_Mooi_N3	Mooi	V20E	Rapid 3	-29.210	30.002
	Thukela_EWR11	**Mooi**	**V20G**	**Comprehensive**	**-29.116**	**30.135**
8	THU_EWR21	Mnyamvubu	V20G	Rapid 2	-29.1610	30.2884
	THU_EWR12A (2)	**Mooi**	**V20H**	**Rapid 3**	**-28.9191**	**30.4192**
	Mooi_dsk	Mooi	V20J	Desktop	Outlet of V20J	
9	Thukela_EWR5	Middle Bushmans	V70F	Comprehensive	-28.897	30.035
	THU_EWR6A	**Lower Bushmans**	**V70G**	**Rapid 3**	**-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	-28.383	29.616
	Thukela1_dsk	Thukela	V14B	Desktop	Outlet of V14B	
11	**THU_EWR22**	**Klip**	**V12A**	**Rapid 3**	**-28.3952**	**29.7197**
	Klip_dsk	Klip	V12G	Desktop	Outlet of V12G	
12	**Thukela_EWR4B**	**Middle Thukela**	**V14E**	**Comprehensive**	**-28.747**	**30.145**
	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 (3)	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	

IUA	Name	River	Quaternary	Level	Lat	Long
15	THU_EWR17 (4)	Lower Thukela	V50D	Intermediate	-29.1677	31.4037

(1) No EWR site selected, thus no hydraulics or biological data available for scenario evaluation

(2) Replaces Thukela_12 (comprehensive site of 2003 study) just downstream of new site

(3) No EWR sites selected as in protected area and no upstream water use or scenarios defined

(4) Estuary was used for assessment

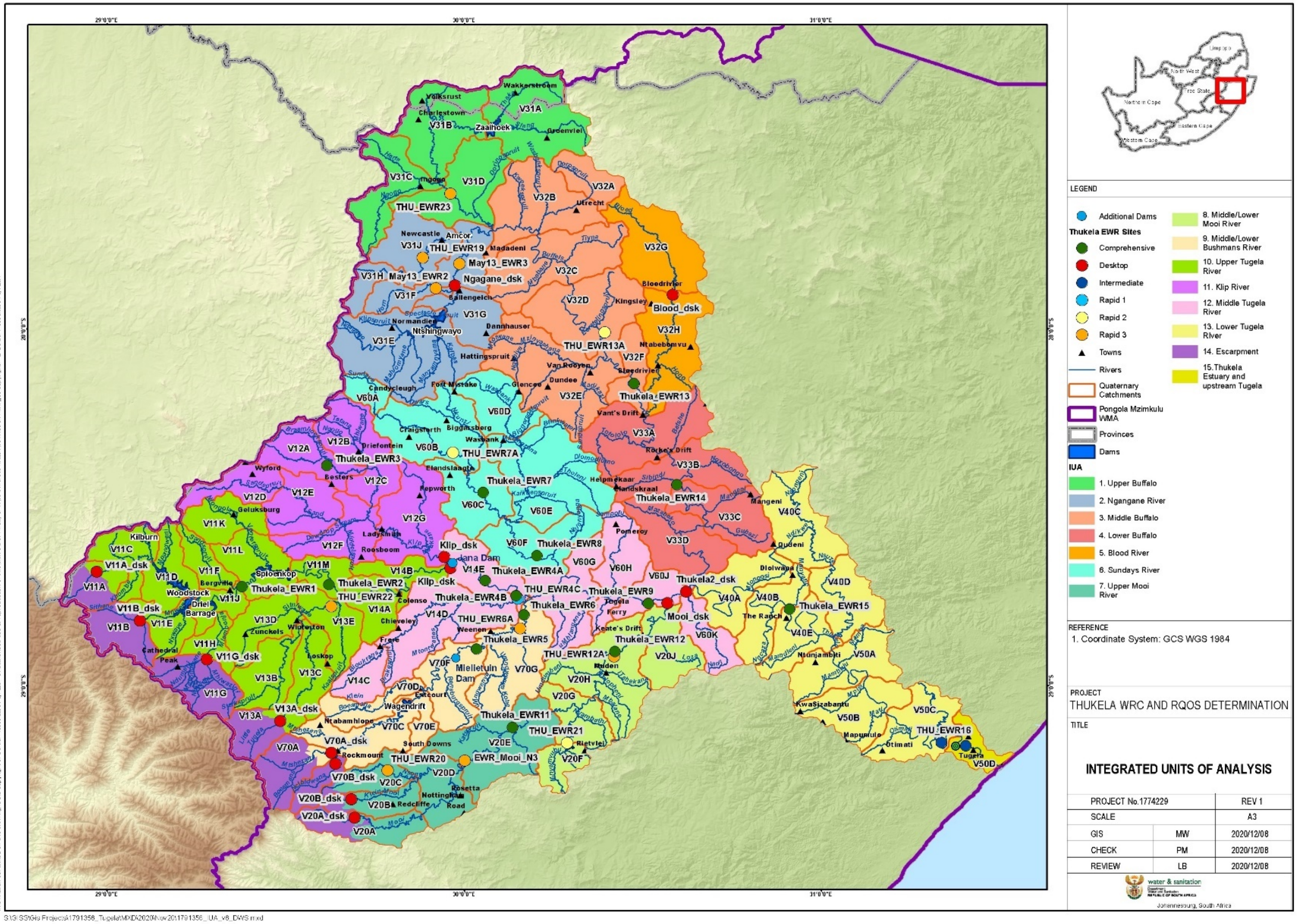


Figure 4: Thukela IUAs with EWR sites and hydronodes

3 WATER RESOURCE PLANNING ANALYSIS

The various planning scenarios that may be used to assess current and future development in the Thukela River Catchment need to cover a suitable range of likely futures and consider the plans of the Department of Water and Sanitation (DWS), as well as other government water services authorities, water service providers and the general public.

The Thukela River Catchment is a strategically important catchment with a number of existing large water resources developments and plans for future developments. As such, the Thukela River Catchment features in the long-term plans of multiple neighbouring catchments. This includes the Integrated Vaal, the Richards Bay (Mhlathuze), and KZN Coastal Metropolitan Areas Reconciliation Strategies. However, the Thukela River Catchment does not have a single consolidated Reconciliation Strategy. While the DWS has attempted to steer these various strategies and associated studies in a co-ordinated way, with consideration of the various plans by the other catchment stakeholders, there is no consolidated document that captures all the proposed interventions. The DWS, and the Study Team thus thought it prudent that a planning scenario definition document be prepared early in the Classification process, to consolidate the various plans and information into a single source that can guide the development of, and thereafter assessment of, selected scenarios required to inform the classification process and setting of Resource Quality Objectives (RQO).

3.1 Current Scenario

The key current infrastructure developments in the Thukela River Catchment are highlighted in Table 4 and include the main dams that have been developed in the catchment, together with large water conveyance infrastructure. This list excludes the various local water supply schemes for potable water, industry and irrigation within the catchment developed by the municipalities and farmers.

Table 4: Main dams in the catchment

Name	Sub - catchment	Purpose
Dams		
Woodstock/ Driel Barrage	Upper Thukela	Water transfer
Spioenkop	Upper Thukela	Water transfer (but now used for water supply and irrigation)
Zaaihoek	Buffalo	Water transfer
Ntshingwayo	Buffalo (Ngagane River)	Water supply and irrigation
Spring Grove	Mooi	Water Transfer and Irrigation
Mearns Weir	Mooi	Water Transfer and Irrigation
Craigieburn	Mooi (Mnyamvubu River)	Water supply and irrigation

Name	Sub - catchment	Purpose
Wagendrift	Boesmans	Water supply and irrigation
Qedusizi	Upper Thukela (Klip River)	Flood Control
Abstractions and Water conveyance infrastructure		
Thukela Vaal Scheme	Upper Thukela	Water transfer and hydropower
Buffalo Vaal Scheme	Buffalo	Water transfer
Mooi Mgeni Transfer Scheme (phase 1 and 2)	Mooi	Water transfer
Thukela to Mhlathuze scheme (also known as the Middledrift transfer)	Lower Thukela	Water Transfer
Lower Thukela Bulk Water Supply Scheme (phase 1)	Lower Thukela	Bulk Water supply

Additional to these large developments are numerous irrigation schemes, industrial supply, as well as domestic and rural water supply schemes. The information on these is captured in a range of reports and previous studies, as well as embedded in water resource models for the catchment.

The proposed best sources of information on these additional developments, to be used in defining the current scenario, are included in Table 5.

Table 5: Sources of information for current water requirements and developments

Source Name		Areas	Data comment
No.	Name		
All Water users			
<u>Water Resources Model</u>*			
1	Water Resources Models* (Integrated Vaal System AOA: July 2013)	Whole catchment	Utilised information from TWP Feasibility. Limited detail on Mooi.
2	Water Resources Models* (Umgeni Water Hydrology Update Study: 2019)	Upper Thukela	Includes the Mooi River in detail, with the Mgeni connected.
3	Water Resources Models* (Buffalo AOA: 2017)	Buffalo	Used system for Upper Buffalo built for Drought Operating Rules Study
<u>Studies</u>			

Source Name		Areas	Data comment
No.	Name		
4	Internal Strategic Perspective (ISP)	Whole catchment	All users included, but typically lumped and summarised at high level - difficult to use in models
5	WR2012 Study	Whole catchment	Water demands determined for national study – may lack benefit of detailed catchment focus.
5	Compulsory Licencing Process	Whole Catchment	Study and process not completed for Thukela
Municipal Water Requirements			
6	Universal Access Plans (for various District Municipalities by Umgeni Water)	Whole catchment	Built on master plans by Municipalities
7	All Towns Reconciliation Strategies (conducted by the DWS)	Large towns and bulk water schemes	These were conducted in detail a few years ago. Have not been updated for a while. Compare with UAPs (item 6 above)

** The term water resources models refers to either the WRYM or WRPM, which are very similar on how water use information is included in the models.*

Based on the review of the various sources of data and information, it was recommended that the proposed current scenario is modelled in a two-step process, namely:

Step 1: A first estimate of the catchment status quo. This would be based on the merging of the Thukela Water Resources Model (source 1 from Table 5), with the latest model available for the Mooi (source 2 from Table 5). While it is recognised that the data in the greater Thukela River Catchment in source 1 is somewhat dated, the process of verifying this data and updating it with that available in sources 3 to 6 will take time and care to build into the model. This will be conducted in *Step 2*.

Step 2: A follow-up and more detailed development of the modelled scenarios by investigating the latest information available, and updating the models and associated scenarios, as developed in *Step 1*, with the sources of information 3 to 6 from Table 5.

The purpose of the two steps was to:

- Establish a first order system balance with the inclusion of the preliminary Ecological Water Requirements (EWRs). Due to the lack of a consolidated catchment wide Reconciliation Strategy, the current status of the catchment needs to be confirmed, so that the Study Team can gauge the likelihood of balancing of water supply and development, and ecological protection. The information gathered from Step 1, will allow this in a timely manner, and will also help understand “hot-spots” and areas that need to be given more focus.

- Use the information gathered from Step 2 to generate the flows and information that was utilised by the specialist to assess the various development scenarios (and target ecological protection levels) and their associated impacts in more detail.

3.2 Future Development Scenarios

The same sources of information set out in Table 5, together with information gathered from two previous planning meetings, will be used to guide the inputs to the future development scenarios, and the associated population of the water resource models. Both sources 1 and 2 from Table 5, include a WRPM which models water developments and water requirements dynamically, and thus contain changes anticipated in the future. These can be extracted and updated as required for the purposes of this study.

The main future developments anticipated for the Thukela River Catchment are summarised in Table 6. This is based on the Study Team's experience and knowledge of the catchment, as well as through the engagements with the DWS, and Umgeni Water in the two planning meetings held.

Table 6: Anticipated and proposed major developments in the Thukela Catchment

No.	Development	Timing (driver)	Timing (date)	Area of Supply	Status
1	Thukela – Jana and Mielietuin dams	Once yield of LHWP-2 has been used	2040 - 2050	Vaal	Pre-feasibility
2	Thukela – Mhlathuze phase 2	Already commenced	2020/2021	Richards Bay and Mhlathuze	Under construction
3	LTBWSS – Phase 2	North Coast Water Requirements	2024/2025	North coast	Feasibility and partial design
4	uMWP-1 (affects MMTS)	Completion date of uMWP1	2026 – 2030	Coastal Metro areas	Feasibility
5	Little Mooi dams (Dartington & Hlatikhulu)	Irrigators' plans & EWR gazetting	Unknown	Irrigators	Design
6	Greytown Water Supply Scheme (from Craigieburn Dam)	Construction already started but currently on hold	Short term	Greytown and surrounding area	Under construction
7	Ladysmith Supply augmentation – bulk scheme	Ladysmith urgently needs around 50ML/d, new supply	Umgeni Water	Ladysmith and Surrounds	First 50ML/d needs urgent planning. Long term 150 to 200 ML/d needs study

No.	Development	Timing (driver)	Timing (date)	Area of Supply	Status
8	Newcastle Supply Augmentation – Water resource development	A new long-term resource is anticipated for Newcastle	Unknown - Long Term need	Newcastle, Dundee, and Glencoe	Feasibility Study needed

As indicated in Table 6, the timing of these various proposed developments varies and there is also some uncertainty on the possible implementation dates, and even sizes of development. In most instances, feasibility study or design work has been conducted to guide the inclusion of a suitable option. Options that may require further clarity are numbers 7 and 8 – the long-term supply augmentation for Ladysmith and Newcastle, respectively. For Option 7, the raising of Spioenkop Dam, or the use of Mielietuin Dam have been identified and could constitute scenario options.

For number 8 – the Newcastle intervention, a new dam on the Buffalo has been mentioned by the DWS. The location and size of such a dam still needs to be confirmed, together with the possible timing. This will depend on the date at which Ntshingwayo Dam becomes over-utilised. The inclusion of such an intervention can be considered a scenario but will have to be confirmed through an engagement with the Regional DWS.

The inclusion of additional developments in the Mooi for irrigation purposes has also been investigated by the farmers. There are two dam options, and the likelihood of these needs to be confirmed with the stakeholders. It is recommended that the inclusion or exclusion of the preferred option is covered by a scenario.

As the water use in the system associated with existing or proposed developments are not anticipated to diminish, the possibility of increased water resources pressure appears likely. While the future water requirements in neighbouring catchments are projected to increase (according to the plans and strategies of those catchments), the augmentation of those catchments may reduce the need for transfers from the Thukela, at least for a temporary period. This was discussed with the DWS and Umgeni Water at planning meetings held during the study. In summary the following was concluded:

- Thukela Vaal Transfer: The inclusion of the LHWP-2 will bring some temporary relief for the Vaal; however, the system is projected to be in a deficit again and the Thukela River and transfers to Sterkfontein Dam remain the main source of water security for the Vaal River System. Thus, the reduction in transfer is not anticipated to warrant investigation and the full transfer should be considered both for before the LHWP-2 and for the long term "ultimate" case.
- Buffalo Vaal Transfer: Any reduction or changes in water requirements for the Majuba Power Station, which will be required in the Vaal or for other purposes, has already been included in the long-term plans for addressing deficits (and in the Classification process for the Vaal). Thus, the full transfer should be catered for.
- Mooi – Mgeni Transfer: The situation in the Mooi is very similar to the Thukela - Vaal. The planned augmentation of the Mgeni by the uMWP-1 will bring some relief, but the

full transfer is anticipated to be needed in the long term, particularly for the Upper Mgeni that relies only on Midmar Dam and the Mooi Transfer. Additionally, the Lower Thukela BWSS assumes some releases from the Spring Grove Dam for support.

- The Mhlathuze Transfer: The transfer from the Thukela to the Mhlathuze at Middledrift, was built as an emergency scheme. It has however become an additional resource for the Mhlathuze region, *i.e.,* a long-term water balancing intervention. The 2nd phase will double the capacity to close to 2 m^3/s. The transfer is expected to continue to be needed to meet long-term growth in the Richards Bay area. The rule is to pump until the Goedertrouw Dam is above 60%, so it is in effect continuous pumping during drought years. A 3rd phase of upgrade to around 3 m^3/s has been proposed as an ultimate scenario.
- The Lower Thukela Bulk Water supply Scheme (LTBWSS): Umgeni Water is already busy with the design work for this upgrade and the civil infrastructure for phase 1 is already built to accommodate the upgrade. It was taken that it will happen soon and is of all future scenarios. Umgeni Water noted the possibility that some of this water may be supplied to the North into the King Chetiswayo District Municipality.

Based on the above, both current and long-term future scenarios should therefore consider the full transfer requirements of these transfers as the point of departure.

Considering the above realities, as well as the proposed developments described in Table 6, the following scenarios are proposed as options to accompany the current day scenario:

The medium-term scenario: This scenario caters for the committed infrastructure that is already in advanced stages of planning or construction. This specifically includes:

1. Phase 2 of the Mhlathuze Transfer.
2. Phase 2 of the Lower Thukela BWSS.
3. Growing water supply to the Ladysmith/ Ezakheni area. This could be achieved by either:
   a. Supply from the Thukela at the proposed Mielietuin Dam (a new WTP in the order of 50 ML/d is being considered by Umgeni Water), but without Mielietuin Dam itself), or
   b. Supply from the Spioenkop Dam, with the possibility of the dam being raised but the timing before 2030 is uncertain. The choice of these two options is still being investigated in a feasibility study to select the best option.
4. The support to the Mgeni River from Smithfield Dam (uMWP-1) not yet effective (so as to impose the full transfer requirement from the Mooi River).
5. The LHWP-2 completed, but the full Thukela - Vaal transfer still required to address growing needs in the Greater Vaal River System.
6. Water requirements at around a 2028 development level (for period just before 2030).

A long term "ultimate" scenario: This scenario encompasses all the planned long-term developments and likely depicts the catchment in its most stressed state. This would include:

1. The options from the medium-term scenario, but with a greater volume (anticipated to be in the order of 150 ML/d by Umgeni Water) abstracted for Ladysmith / Ezakheni at the proposed Mielietuin Dam, or at the raised Spioenkop Dam.

2. The Jana and Mielietuin Dams completed for the next phase of transfer to the Vaal.
3. The uMWP-1 completed and support to the Mooi according to long term needs in the upper Mgeni and the rest of the system.
4. The inclusion of:
    a. A new dam on the Little Mooi River for irrigation.
    b. A new dam on the Buffalo River (if Newcastle/Dundee requirements cannot be met), or
    c. An increase of up to 3 m^3/s for the transfer to the Mhlathuze River Catchment.
    d. These iterations may be conducted simultaneously or in combination, depending on water supply realities to be confirmed at the time.
5. Water requirements at the 2045 development level as a practical planning horizon.

The above scenarios were simulated using the Water Resources Model, with the operating rules associated with those developments currently followed or planned for.

3.3 Summary of the Planning Scenarios

For the initial assessments, the option of additional supply to Ladysmith and Ezakheni was provided from Spioenkop Dam, and then a raised Spioenkop Dam for the medium and long term scenarios respectively (i.e., scenarios 2 and 3). The size of the raising can reportedly be very large. For the preliminary assessment, a raising of around 50 million m^3/a (about 20% increase was considered). The full potential raising and how this compares against the long term option of water from Mielietuin Dam will been to be discussed.

Additionally, no new dams on the Mooi or Buffalo were considered. Based on the initial supply results for the scenarios these additional developments may be added if the supply to users in those respective areas is believed to be insufficient.

These development scenarios will be considered in combination with a suitable selection of target flows for ecological protection.

EWR Scenario Definitions

Linked to the above development level scenarios, there are also scenarios of various ecological water requirements associated with different environmental protection targets.

Table 7 summarises the scenarios. These are included in combination with the various development levels as a matrix of scenarios in Table 7. Additional to the scenario of no EWR's, there were three initial EWR scenarios considered:

- The PES (present ecological state)
- The TEC (target ecological category), and
- The TEC with the estuarine requirements added

The estuarine requirements were only added to the TEC at this stage as these two are more aligned. The need for the estuarine requirements to be linked to another EWR scenario will be assessed after the initial results are assessed.

Table 7: Summary of EWR scenarios linked to different development levels

Development level		EWR inclusions				
		None	**PES**	**PES with Estuary***	**TEC**	**TEC with Estuary**
Present	Scenario Report on what interventions are included	X	X		X	X
Medium term (2030)		X			X	X
Long term - Ultimate (2040-2045)		X			X	X

** Estuary requirements only linked to TEC for initial assessment.*

Table 8: Scenarios summary description

Scenarios			ID	
1	Current day with all existing major transfers operating based on current rules	• Scenario 1N – current no EWR	Sc1N	Sc1
		• Scenario 1PR – current with PES, riverine only	Sc1PR	Sc2
		• Scenario 1PE – current with PES riverine and estuary	Sc1PE	Sc3
		• Scenario 1TR – current with TEC, riverine only	Sc1TR	Sc4
		• Scenario 1TE – current with TEC, riverine and estuary	Sc1TE	Sc5
2	Medium-term with all major planned infrastructure (that is in the construction phase, or well progressed planning stages) before 2030 included	• Scenario 2N – Medium term, no EWR	Sc2N	Sc6
		• Scenario 2TR – Medium term, with TEC, riverine only	Sc2TR	Sc7
		• Scenario 2TE – Medium term with TEC riverine and estuary	Sc2TE	Sc8
3	Long-term “ultimate” scenario with all major infrastructure implemented and projected water requirements around 2045. Some iterations of this scenario may be required that relate to an irrigation dam on the Mooi River, a new development on the Buffalo River for Newcastle, another phase of the transfer to the Mhlathuze, or the raising of Spioenkop Dam	• Scenario 3N – long term, no EWR	Sc3N	Sc9
		• Scenario 3TR – long term with TEC, riverine only	Sc3TR	Sc10
		• Scenario 3TE – long term with TEC riverine and estuary	Sc3TE	Sc11

These initial EWR scenarios reportedly include the flood flows for the EWRs. The ability for these to be released will need to be reviewed against both the outlet capacities of the dams where releases are required, and the ability for the system to provide these and achieve a balance between environmental protection and socio-economic support and development. This has been conducted as a form of trade-off scenarios.

4 ECOLOGICALLY SUSTAINABLE BASE CASE CONFIGURATION (ESBC)

The process followed in terms of the establishment of the Ecologically Sustainable Base Configuration (ESBC) is described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWAF, February 2007a and 2007b).

The ESBC scenario, which could permit the maximum water use scenario, requires that the base condition for each water resource is at minimum established as either a D category or as whichever higher category is required to maintain all downstream nodes in at least a D category. However, where the ecological condition requires it, a higher ecological category needs to be set.

The ESBC scenario is established once this base condition is hydrologically and ecologically tested to ensure that it is feasible and can be achieved. In other words, the results will reflect whether the catchment water balance would be in surplus or deficit by implementing a D category EWR.

In terms of the Thukela catchment, the D ecological category was not selected as the default ESBC. Rather the selected ecological category per IUA is the Present Ecological State (PES). The ESBCs for the Thukela IUAs used for the scenario evaluation are listed in Table 9: ESBC (PES) and TEC for the Thukela catchment.

Additional to the establishment of the ESBC, the Target Ecological Category (TEC) was also determined as an alternate scenario at the nodes. The TEC is based on the ultimate target to achieve a sustainable system both ecologically and economically, considering the PES and Recommended Ecological Category (REC). Thus, the TEC can be the same as the PES or the REC. However, it may also be worse than the PES if a system is targeted for development that will impact the present state, or better where a higher level of protection is needed. Table 9 also indicates the TEC per node.

The quantified EWRs and rationale for the TEC per EWR site is provided in report RDM/WMA04/00/CON/CLA/0620, ‘Quantification of Ecological Water Requirements’. The revised PES and TEC after the initial assessment of the ecological consequences and system constraints are shown in the table below.

Table 9: ESBC (PES) and TEC for the Thukela catchment

IUA	EWR site	Sub-reach	River	PES	EI/ES	TEC
IUA1	THU_EWR23	V31D-02370	Upper Buffalo	C	High	C
IUA2	May13_EWR2	V31F-02600	Horn	C	Low	C
	THU_EWR19	V31J-02487	Ncandu	C	Very high	B/C

IUA	EWR site	Sub-reach	River	PES	EI/ES	TEC
	May13_EWR3	V31G-02618	Ngagane	C	Low	C/D
	Ngagane_dsk	V31K-02516	Ngagane	C	Moderate/ High	C/D
IUA3	THU_EWR13A	V32D-02699	Buffalo	D	Moderate/ High	C/D
	Thukela_EWR13	V32F-02707	Buffalo	D	Moderate	C/D
IUA4	Thukela_EWR14	V33B-03090	Buffalo	B/C	High	C
IUA5	Blood_dsk	V32H-02834	Blood	C	High	C
IUA6	THU_EWR7A	V60B-02826	Sundays	C/D	High	C
	Thukela_EWR7	V60C-03031	Sundays	C/D	Moderate	C/D
	Thukela_EWR8	V60F-03210	Sundays	D	Moderate	D
IUA7	THU_EWR20	V20C-03919	Nsonge	C	Very high / High	B/C
	EWR_Mooi_N3	V20E-03884	Mooi	E	Moderate	D
	Thukela_EWR11	V20E-03742	Mooi	C/D	Moderate	C/D
IUA8	THU_EWR21	V20G-03853	Mnyamvubu	C	High	C
	THU_EWR12A	V20H-03500	Mooi	C/D	High	C
	Mooi_dsk	V20J-03467	Mooi	C	High	C
IUA9	Thukela_EWR5	V70F-03548	Bushmans	B/C	Moderate	C
	THU_EWR6A	V70G-03515	Bushmans	D	High	C/D
	Thukela_EWR6	V70G-03440	Bushmans	B/C	High	C
IUA10	Thukela_EWR1	V11L-03301	Thukela	D	Moderate	D
	Thukela_EWR2	V11M-03280	Thukela	C	Moderate	C/D
	Thukela_EWR3	V13E-03362	Little Thukela	C/D	Moderate	C/D
	Thukela1_dsk	V14B-03296	Thukela	C	High	C/D
IUA11	THU_EWR22	V12A-03003	Klip	C	High / Very high	C
	Klip_dsk	V12G-03256	Klip	C	High	C
IUA12	Thukela_EWR4B	V14E-03233	Thukela	C	High	C
	Thukela_EWR9	V60J-03395	Thukela	D	Moderate	D
	Thukela2_dsk	V60K-03419	Thukela	C	High	C
IUA13	Thukela_EWR15	V40B-03429	Thukela	C	High	C

IUA	EWR site	Sub-reach	River	PES	EI/ES	TEC
	THU_EWR16	V50D-03903	Thukela	C	High / Moderate	C
IUA14	V11A_dsk	V11A-03277	Thukela	B	High / Very high	B
	V11B_dsk	V11B—3410 V11B-03470	Sithene Thonyelana	B	Moderate/ High	B
	V11G_dsk	V11G-03572 V11G-03582	Mlambonja Mhlwazini	B	Moderate / High	B
	V13A_dsk	V13C-03495	Little Thukela	C	High/ Very high	B
	V70A_dsk	V70A-03876	Bushmans	B	High	B
	V70B_dsk	V70B-03927	Nsibidwana	B	High	B
	V20A_dsk	V20A-04023	Mooi	B	High	B
	V20B_dsk	V20B-04034	Little Mooi	B/C	High	B/C
IUA15	THU_EWR17	V50D-03903	Thukela	C	High	C

5 WATER RESOURCES MODEL AND ANALYSIS OF MANAGEMENT SCENARIOS

The scenarios were analysed for the maximum hydrological record length available for the total Thukela catchment. This amounted to a record period of 69 years of continuous hydrological analyses and 828 monthly supply time-steps.

The WRPM model was updated with the latest available information from the Integrated Vaal River Reconciliation Strategy (IVRRS) and models, the KZN Reconciliation Strategy and associated linkage with the Lower Thukela Bulk Water Supply Scheme (LTBWSS), and the Umgeni Water Universal Access Plans for supply in the various Water services Authorities (typically district Municipalities).

The addition of the EWRs also required some refinement in resolution for the WRPM where modelling catchments needed to be subdivided to account for an EWR site located within a modelling sub-catchment. These changes are highlighted in the network diagram provided in Appendix B.

5.2 Results of Analyses

The first round analyses results are presented in Appendix C. A final round of revised scenarios including trade-offs and region specific interventions my still be needed to bring the system more into balance.

The results show that some areas of the Thukela are projected to be in a deficit. An important note is that the penalties in the model (which represent the operations of the system) were set-up to prioritise the EWRs and thus the impacts of water shortages in the system are realised as supply shortages on other users. This provides a mechanism to test the balance and see what the impacts on the socio-economics of the system are if the EWR's are satisfied.

The preliminary results show that some IUA's will be impacted, and some are even projected to have shortages even without EWRs implemented in the future. These will require a combination of review and trade-offs between the EWRs and the projected water requirements, and some additional water resources developments in strategic locations or a reduction in current water use. The preliminary perspective is the following users (or some users within these sectors) are projected to experience water supply challenges:

- **IUA 1 –** some irrigation and the Zaaihoek transfer to the Vaal
- **IUA 6 –** Irrigation and some domestic supply
- **IUA 7 –** Irrigation
- **IUA 8 –** Irrigation near the lower reaches
- **IUA 10 –** Irrigation and some domestic supply
- **IUA 11 –** Irrigation and some domestic supply
- **IUA 13 –** Irrigation and LTBWSS phase 2

As part of the scenario refinements, the outlet capacities (Table 10) for the various dams in the Thukela River Catchment were incorporated into the hydrological model to assess the capability of each dam to release the required freshets or floods for each of the EWR scenarios, specifically for the dams located in close proximity upstream of an EWR site. The EWR freshet/ flood requirements were adjusted where the dam outlet capacities were lower than the requirement.

The data in Table 10 were obtained from the DWS for the dams in the Thukela River Catchment.

Table 10: Dam outlet capacities

<table>
<tr><th>Dam name</th><th>Sub - catchment</th><th>Purpose</th><th>Capacity (million m^3)</th><th colspan="2">Spillway capacity (m^3/s)</th><th>Outlet capacity (m^3/s)</th></tr>
<tr><td rowspan="3">Woodstock</td><td rowspan="3">Upper Thukela</td><td rowspan="3">Water transfer</td><td rowspan="3">373.25</td><td>Ogee spillway</td><td>818</td><td rowspan="3">585</td></tr>
<tr><td>Auxiliary spillway</td><td>2 055</td></tr>
<tr><td>Ogee and Auxiliary combined</td><td>2 873</td></tr>
<tr><td>Spioenkop</td><td>Upper Thukela</td><td>water supply and irrigation</td><td>270.64</td><td colspan="2">5 227</td><td>35</td></tr>
<tr><td>Zaaihoek</td><td>Buffalo</td><td>Water transfer</td><td>184.63</td><td colspan="2">2 261</td><td>53</td></tr>
<tr><td>Ntshingwayo</td><td>Buffalo</td><td>Water supply and irrigation</td><td>194.56</td><td colspan="2">2 850</td><td>8.6</td></tr>
</table>

Dam name	Sub - catchment	Purpose	Capacity (million m^3)	Spillway capacity (m^3/s)	Outlet capacity (m^3/s)
Spring Grove	Mooi	Water Transfer and Irrigation	139.46	TBC	29.5
Craigieburn	Mooi	Water supply and irrigation	22.47	1 745	3.9
Wagendrift	Boesmans	Water supply and irrigation	55.90	2 420	135

The outlet capacities, specifically for the outlet infrastructure and excluding the spillway capacity, was confirmed where the capacity seemed too high.

6 ECOLOGICAL CONSEQUENCES

The scenario analysis described formed the basis for the assessment of the ecological consequences detailed in the sections to follow, and socio-economic consequences detailed in Section 7. The purpose of this is to assess the implications of the selected flow scenarios on the ecological categories by predicting the biotic responses to each scenario. The outcomes are then used to inform the final target ecological category of the recommended water resources class per IUA.

6.1. Ecological consequences

Ecological consequences were initially assessed for scenarios Sc1 to Sc5 (all the present day demands) with and without EWR with either the PES or TEC and including the rivers only or both the rivers and estuary, to establish the ESBC, namely:

Sc1 – present day demands without EWR

Sc2 – present day demands with PES EWR for the rivers

Sc3 – present day demands with PES EWR for the rivers and Estuary

Sc4 – present day demands with TEC EWR for the rivers

Sc5 – present day demands with TEC EWR for the rivers and Estuary

As the results for scenarios Sc2 and Sc3 (PES) and scenarios Sc4 and Sc5 (TEC) were almost the same due to the lower Thukela River having similar requirements as the Estuary, Sc2 and Sc4 were not further investigated.

The PES and TEC requirements were adjusted (mainly the freshets and floods) taking into consideration the outlet capacities of dams, especially where the EWR sites are in close vicinity downstream of the dam (e.g. Spioenkop, Chelmsford, Craigieburn and Spring Grove).

The TEC requirements were then further adjusted during the trade-off workshop where the socio-economic impacts were high (e.g., Thukela_EWR1 downstream Woodstock Dam where all floods were removed to ensure adequate water to be transferred to Gauteng).

These requirements were included in the WRPM and assessed by the ecologists. In cases where the EWRs were not fully met for the scenarios (Sc3, Sc5), the ecological consequences were also assessed, and changes made to the PES (Sc3) and TEC (Sc5).

The medium term (Sc6) and long term (Sc9) scenarios without EWR, were also assessed to evaluate the water available for the EWR after all demands have been met. As these demands have increased substantially due to increased transfers and other users, even with additional storage dams (raising of Spioenkop Dam, Mielietuin and Jana) and the uMWP-1 transfer scheme to the Mooi/ Mngeni systems. The results of Sc6 and Sc9 will be used to set specific conditions and requirements for compliance with the EWR in the implementation plan.

The Fish Invertebrate Flow Habitat Assessment Model (FIFHA) developed by Dr N Kleynhans and Dr C Thirion of the Department of Water and Sanitation' Resource Quality Information Services (RQIS) in 2016, was used to assess the impact of the resulting flows of the scenarios at key EWR sites (Table 12). The method is aligned to EcoClassification – EcoStatus assessment, the formulation of the Ecological Category (EC) (Kleynhans and Louw, 2007) and the specification of Ecological Water Requirements, specifically instream flows. The FIFHA model considers:

- Discharge,
- Average width and depth,
- Different flow-depth velocity classes for fish and inverts,
- Different biotope / substrate,
- Hydrology (Natural, Present day, and Baseflows)
- Various scenarios,
- Present Ecological Categories,
- Fish (flow dependent species), and
- Macroinvertebrates (sensitive and flow dependent/ habitat dependent species).

The biotas are those which show a response to change in flow/ habitat. The FIFHA model does not take water quality into account. In this respect water quality changes expected due to the various scenario's implementation, were assessed considering the present impacts and the potential trends and direction of change for each of the IUAs. Water quality implications are presented in Section 6.2. Further, the model also doesn't consider low or zero flows over the long term (consecutive months), thus expert opinion based on the understanding of the biota in the system was used to interpret these flows in terms of ecological consequences.

Table 11: Key EWR sites per IUA for scenario evaluation in the Thukela catchment

IUA	EWR site name	River	MAR ($10^6 m^3$)			
			Natural	Sc1	Sc3	Sc5
1	THU_EWR23	Upper Buffalo	221.96	153.48	157.66	158.06
2	May13_EWR3	Ngagane	160.12	80.03	113.72	114.99
3	Thukela_EWR13	Middle Buffalo	695.05	528.50	545.27	547.70
4	Thukela_EWR14	Lower Buffalo	831.09	648.21	670.34	672.34
5	Blood_dsk (1)	Blood	94.71	78.10	83.46	83.46
6	Thukela_EWR7	Upper Sundays	90.28	55.31	55.08	54.39
7	THU_EWR20	Nsonge/ Hlatikulu	27.13	24.92	25.32	25.51
	Thukela_EWR11	Mooi	301.14	117.34	168.02	172.30
8	THU_EWR12A	Mooi	361.85	159.85	213.64	217.93
9	THU_EWR6A	Lower Bushmans	298.37	242.36	247.06	248.90
10	Thukela_EWR2	Upper Thukela	798.40	111.59	267.97	222.84
11	THU_EWR22	Klip	52.44	49.73	49.74	49.74
12	Thukela_EWR4B	Middle Thukela	1,423.83	641.99	832.19	787.99
13	THU_EWR16	Lower Thukela	3,679.97	2,275.19	2598.30	2564.53
14	No scenarios assessed as no developments foreseen in this IUA					
15	Estuary (Described in Section 6.2)					

(1) No EWR site, used flow duration curve (FDC) for assessment

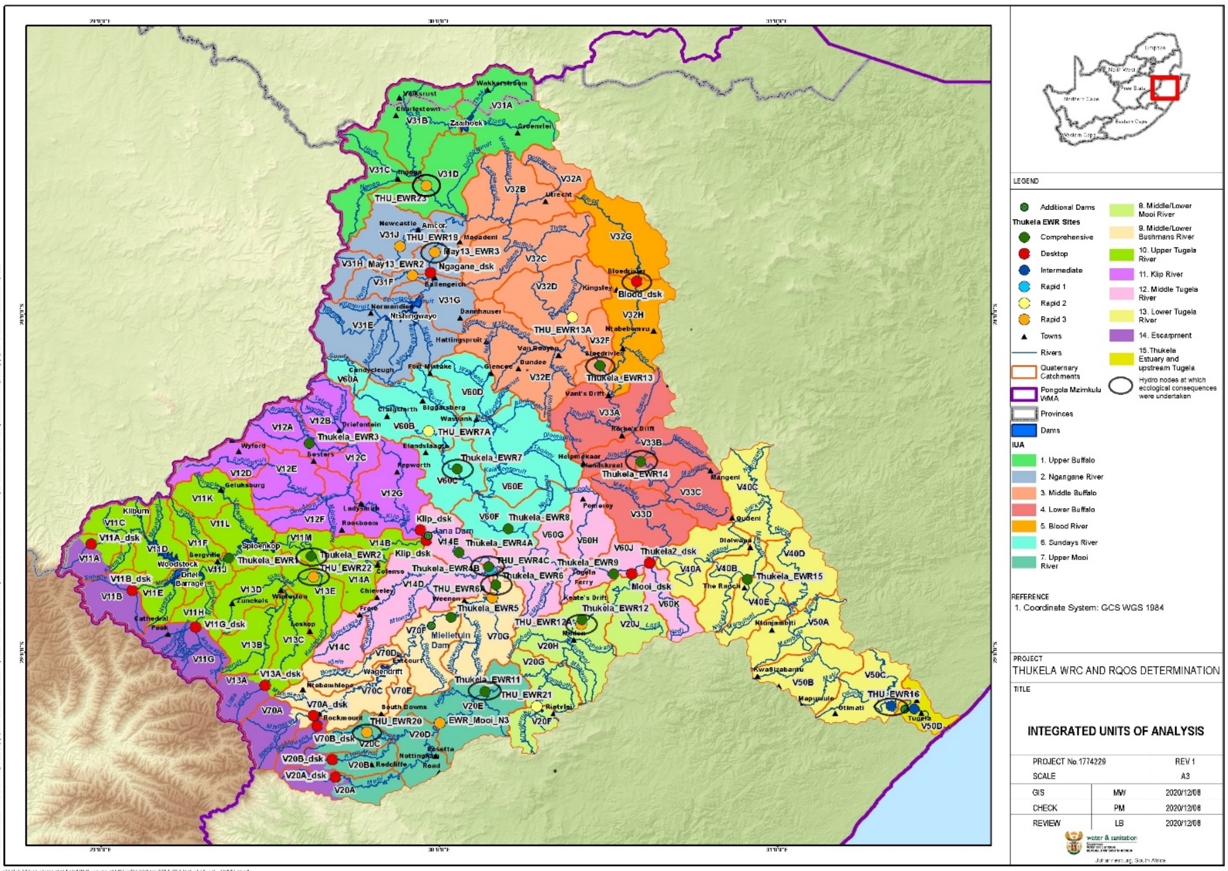


Figure 5: Hydro node sites at which ecological consequences were assessed

The hydrological changes associated with each of the selected scenarios as modelled with the WRPM were used as the primary driver of change. The flows for the selected key EWR sites per IUA were assessed in terms of how the changes in hydrology for the various scenarios will impact on the level of stress being experienced in the system and the state of the response variables. The seasonal distribution plots were prepared using the flows provided for the operational scenarios (Appendix A) and the ecological consequences of these scenarios are described in Table 11, where:

Ecological Category	≥TEC	<TEC-1 EC	<TEC-2 EC	E/F
Colour key	Green	Yellow	Orange	Red

Table 12: Ecological consequences at key EWR sites per IUA

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
1	Upper Buffalo	EWR23	V31D	C	C	C	C	Fish wet	B/C	B/C	B/C	The ecological flow requirements are met for scenario 1, 3 and 5 from the aquatic biota perspective. The ecological flows will maintain the various aquatic velocity-depth classes and aquatic biotopes, and thus these habitats will subsequently maintain the expected fish species and macroinvertebrates families. **Overall, the integrated ecological category for the scenarios meets both the revised PES and TEC.**
								Inverts wet	B/C	B/C	B/C	
								Fish dry	B/C	B/C	B/C	
								Inverts dry	B/C	B/C	B/C	
								Integrated	**B/C**	**B/C**	**B/C**	
2	Ngagane	May13_EWR3	V31K	C	C	C	C/D	Fish wet	C	A/B	A/B	The ecological flow requirements are met during the wet season for scenario 1, 3 and 5. The ecological flows will maintain the various aquatic velocity-depth classes and aquatic biotopes, and thus these habitats will subsequently maintain the expected fish species and macroinvertebrates families. The current flows meet the C in the high flows; however, concerns are increased abstraction, increased development (erosion, siltation, organics) and changes in rainfall patterns, then it will drop below C. During the dry season, the habitat
								Inverts wet	C	A	A	
								Fish dry	D	A	A	

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
								Inverts dry	D	A	A	deteriorates, and the scenarios do not meet the TEC of a C. Furthermore, owing to the zero flows extending into the wet season during present flows (which is detrimental to rheophilic fish species – species which are dependent on flow), it is our professional opinion that the overal integrated ecological category be adjusted to an E for scenario 1. To improve this category and owing to the fact that this river reach is a biodiversity refugia for aquatic biota, and thus adequate flows are required within this reach for fish spawning and further migration, effort is required in facilitating adequate releases from the upstream dams. This will improve the flows, especially during the wet season months where there are zero flows (i.e. present flows in January). **Overall, the integrated ecological category for scenario 1 does not meet either the revised PES and TEC. Scenario 3 and 5 meets both the PES and TEC.** It must be noted that the FIFHA does not take into account water quality and thus the A/B and A/B category for scenarios 3 and 5 respectively are not taking cognisance of the poor water quality at this site. Therefore, caution was taken when interpreting the FIFHA results. Furthermore, there must be a reduction in long-term freshets and floods as this is putting a constraint on the upstream dam.
								Integrated	**E**	**A/B**	**A/B**	

<table>
<tr><th rowspan="3">IUA</th><th rowspan="3">River</th><th rowspan="3">EWR sites</th><th rowspan="3">Quaternary Catchment</th><th rowspan="3">2020 PES</th><th rowspan="3">2020 TEC</th><th rowspan="3">Revised PES</th><th rowspan="3">Revised TEC</th><th rowspan="3"></th><th colspan="3">IUA</th><th rowspan="3">River</th></tr>
<tr><th>Sc1</th><th>Sc3</th><th>Sc5</th></tr>
<tr><th colspan="3">Ecological Category</th></tr>
<tr><td rowspan="5">3</td><td rowspan="5">Middle Buffalo</td><td rowspan="5">EWR13</td><td rowspan="5">V32H</td><td rowspan="5">D</td><td rowspan="5">C/D</td><td rowspan="5">D</td><td rowspan="5">C/D</td><td>Fish wet</td><td>B</td><td>A</td><td>A</td><td rowspan="5">The ecological flow requirements are met for scenario 1, 3 and 5 from the aquatic biota perspective. The ecological flows will maintain the various aquatic velocity-depth classes and aquatic biotopes, and thus these habitats will subsequently maintain the expected fish species and macroinvertebrates families. It is important to note that small increases in the impacts, can cause rapid change in the system – from C/D to D particularly during scenario 1 in the dry season. Scenario 3 identifies an improvement whereby both fish and macroinvertebrates during the wet and dry season, including the integrated category met the TEC.

However, the FIFHA does not take into account water quality and thus the A/B and A category for scenarios 3 and 5 respectively are not taking cognisance of the poor water quality at this site. Therefore, caution was taken when interpreting the FIFHA results.

Overall, the integrated ecological category for the scenarios meets both the revised PES and TEC.</td></tr>
<tr><td>Inverts wet</td><td>B</td><td>A/B</td><td>A</td></tr>
<tr><td>Fish dry</td><td>C/D</td><td>A/B</td><td>A</td></tr>
<tr><td>Inverts dry</td><td>C/D</td><td>A/B</td><td>A</td></tr>
<tr><td>Integrated</td><td>C</td><td>A/B</td><td>A</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Lower Buffalo</td><td rowspan="2">EWR14</td><td rowspan="2">V33B</td><td rowspan="2">B/C</td><td rowspan="2">B/C</td><td rowspan="2">B/C</td><td rowspan="2">C</td><td>Fish wet</td><td>C</td><td>D</td><td>D</td><td rowspan="2">The ecological flow requirements are met for macroinvertebrates for both wet and dry seasons. Owing to highly modified flows, the habitat is not adequate enough to support the expected fish species in this</td></tr>
<tr><td>Inverts wet</td><td>A/B</td><td>A</td><td>A</td></tr>
</table>

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
								Fish dry	D	A	A	IUA for scenario 3 and 5 during the wet season and for scenario 1 during the dry season. A concern is the changes in the cumulative impacts from the catchments feeding water to this site.
								Inverts dry	B/C	B/C	B/C	
								Integrated	**C**	**C**	**C**	**Overall, the integrated ecological category for scenarios 1, 3 and 5 will achieve the TEC, but not the PES.**
6	Upper Sundays	EWR7	V60C	B/C	C	C/D	C/D	Fish wet	C	D	D	The ecological flow requirements are met for macroinvertebrates for both the wet and dry seasons, where an EC higher than the TEC is expected. The highly modified flows, which has resulted in habitat alteration, results in an unacceptable EC for both scenarios for fish during the dry season, and during scenario 3 for the fish during wet season (D). Impacts for fish further related to migration loss due to low flows (loss of breeding and recruitment).
								Inverts wet	A/B	A/B	A/B	
								Fish dry	E	E/F	E/F	
								Inverts dry	A	A	A	
								Integrated	**C**	**C/D**	**C/D**	**Overall, the integrated ecological category for scenario 1 meets both the PES and TEC. Scenario 3 and 5 only will meet the TEC and not the PES.**
7	Middle Mooi	EWR11	V20G	B/C	B/C	C/D	C/D	Fish wet	D/E	A/B	A/B	The ecological flow requirements in scenario 1 are not met for the aquatic macroinvertebrates' community or the fish community for both the wet and dry seasons. However, the ecological flow requirements in scenarios 3 and 5 are met for the biota during both the wet and dry seasons.
								Inverts wet	D/E	A	A	
								Fish dry	F	B	B	
								Inverts dry	F	B	B	

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
								Integrated	**E**	**A/B**	**A/B**	It must be noted that the FIFHA does not take into account water quality and thus the A/B and A/B category for scenario 3 and 5 respectively are not taking cognisance of the poor water quality at this site. Therefore, caution was taken when interpreting the FIFHA results **Overall, the integrated ecological category for scenario 3 and 5 meets both the PES and TEC. Scenario 1 has an unacceptable category of an E and thus does not meet either the TEC or the PES.**
	Nsonge	EWR20	V20C	C	B/C	C	B/C	Fish wet	A	A	A	The ecological flow requirements are met during the wet season for the scenarios analysed. The habitat will maintain the expected species for both fish and macroinvertebrates during the wet season and achieve an EC better than the PES and TEC. However, during the dry season, the habitat deteriorates dramatically, and the scenarios do not meet the TEC of a B/C (with the exception of scenario 3 and 5 for the macroinvertebrates during the dry season). During scenario 1, the ecological flow requirements results in an E/F category in the fish community during the dry season which will be unacceptable as this will result in breeding habitat loss, recruitment, and loss of migration potential. **Overall, the integrated ecological category for scenario 3 and 5 meets both the PES and TEC. Scenario 1 will not meet either the TEC or the PES.**
								Inverts wet	A	A	A	
								Fish dry	E/F	C/D	C/D	
								Inverts dry	C/D	B	B	
								Integrated	**D**	**B/C**	**B/C**	

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
8	Lower Mooi	EWR12a	V20H	C/D	C	C/D	C	Fish wet	C/D	C	C/D	The ecological flow requirements are met for the wet and dry seasons for both fish and macroinvertebrates for both scenarios, with the exception of scenario 1 for the fish during the dry season which results in an unacceptable category of an F. **Overall, the integrated ecological category for scenarios 1, 3 and 5 meet the PES and TEC.**
								Inverts wet	C	A	A	
								Fish dry	F	A	A	
								Inverts dry	B/C	A	A	
								Integrated	**C**	**B/C**	**C**	
9	Bushmans	EWR6a	V70G	D	C/D	D	C/D	Fish wet	A	A	A	The ecological flow requirements are met during the wet season for scenarios 1, 3 and 5. The habitat will maintain the expected species for both fish and invertebrates during the wet season and achieve an ecological category better than the TEC. However, the ecological flow requirements expected for Sc1 during the dry season will not meet the TEC of a C/D. It must be noted that the FIFHA does not take into account water quality and thus the A/B and A/B category for scenarios 3 and 5 respectively are not taking cognisance of the poor water quality at this site. Therefore, caution was taken when interpreting the FIFHA results. Furthermore, poor habitat also does not get taken into account. The SIC at this site are covered in silt, there are undercut banks and high algae content smothering the habitats.
								Inverts wet	A/B	B	A/B	
								Fish dry	F	A/B	A/B	
								Inverts dry	E/F	A	A	
								Integrated	**D**	**A/B**	**A/B**	

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
												Overall, the integrated ecological category for scenario 3 and 5 meets both the PES and TEC. Scenario 1 will meet the PES, but not the TEC.
10	Upper Thukela	EWR2	V11M	C	C	C	C/D	Fish wet	B	A/B	A/B	The ecological flow requirements will be met for all components for scenario 1, 3 and 5, with the exception of scenario 3 and 5 for the fish during the dry season. This may be as a result of the impacts (flows and poor WQ) associated with the upstream Spioenkop Dam. Owing to reduced floods, the habitat will become embedded and smothered with silt, providing limited habitats to the aquatic biota. **Nonetheless, overall, the integrated ecological category for scenarios 1, 3 and 5 meet the PES and TEC.**
								Inverts wet	B/C	A	A/B	
								Fish dry	D	D/E	D/E	
								Inverts dry	A	C/D	C/D	
								Integrated	**C**	**C**	**C**	
11	Klip	EWR22	V12A	C	C	C	C	Fish wet	D	C/D	C/D	The ecological flow requirements are not met during the wet season for the fish community. This was owing to highly modified flows; the habitat is not adequate enough to support the expected fish species. This river reach is a biodiversity refugia for aquatic biota, and thus adequate flows are required within this reach for fish spawning, coupled with this reach being a migratory corridor. However, the requirements are met for the rest of the components whereby they have achieved an EC better than the TEC for both the fish and macroinvertebrates. However, the
								Inverts wet	A	A	A	
								Fish dry	B/C	A/B	A/B	
								Inverts dry	A/B	A	A	
								Integrated	**B/C**	**B/C**	**B/C**	

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA			River
									Sc1	Sc3	Sc5	
									Ecological Category			
												ecological flow requirements for fish for all the scenarios during **Nonetheless, overall, the integrated ecological category for scenario 1, 3 and 5 meet the PES and TEC.**
12	Middle Thukela	EWR4b	V14E	C	B/C	C	C	Fish wet	A	A	A	The ecological flow requirements are met during the wet season for scenarios 1, 3 and 5 and the habitat will maintain the expected fish species and macroinvertebrates and achieve an EC better than the TEC. However, the ecological flow requirements will not be met during the dry season for scenario 3 and 5 as both the fish and macroinvertebrates will only achieve an EC of a C/D compared to the TEC of a B/C. The minimum of 2qumec was not met for the dry season. **Nonetheless, overall, the integrated ecological category for scenarios 1, 3 and 5 meet the PES and TEC.**
								Inverts wet	B	A	A	
								Fish dry	C	C/D	C/D	
								Inverts dry	C	C/D	C/D	
								Integrated	**C**	**C**	**C**	
		EWR9	V60J	D	D	D	D	Fish wet	A/B			Inclusively the ecological flow requirements are met for all components for scenario 1. **Overall, the integrated ecological category for scenario 1 meet the PES and TEC.**
								Inverts wet	A			
								Fish dry	D			
								Inverts dry	C			

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
								Integrated	**B/C**			
13	Lower Thukela	EWR16	V50C	C	C	C	C	Fish wet	A	A	A	The ecological flow requirements are met during the wet season for scenario 1, 3 and 5 analysed and thus the habitat will maintain the expected fish species and macroinvertebrates during this season. However, during the dry season for scenario 1 only, owing to highly modified flows, the habitat is not adequate enough to support the expected fish species or macroinvertebrate community in this IUA and has thus resulted in an unacceptable EC for fish (category F) and macroinvertebrates (category D). It must be noted that the FIFHA does not take into account water quality and thus the A/B and A/B category for scenarios 3 and 5 respectively are not taking cognisance of the poor water quality at this site. Therefore, caution was taken when interpreting the FIFHA results. **Overall, the integrated ecological category for scenario 3 and 5 meets both the PES and TEC, of which it is better. Scenario 1 will not meet either the PES or TEC.**
								Inverts wet	A	A	A	
								Fish dry	F	B	B	
								Inverts dry	D	A	A	
								Integrated	**C/D**	**A/B**	**A/B**	
14	Thukela	-	V11A	-	-	-	-	-	-	-		• Although no formal biological/rapid 3 surveys were conducted within this IUA. A limited survey was undertaken which included: • *In situ* water quality
	Mnweni		V11B									
	Mlambonja		V11G									
	Bushmans		V13A									

IUA	River	EWR sites	Quaternary Catchment	2020 PES	2020 TEC	Revised PES	Revised TEC		IUA Sc1	IUA Sc3	IUA Sc5	River
									Ecological Category			
			V70A V70B V20A V20B									• Rapid cross section, discharge and flow velocities; and • Index of Habitat Integrity (IHI) . • The following impacts were identified during the survey: • Organic pollution (low impact): informal settlements, high density cattle farming and irrigation • Erosion (medium impact): cattle trampling, grazing and rural encroachment • Riparian alien invasive (low impact); and • In-stream alien invasive (bass and trout fish species) (medium-high impact). The presence of these alien invasive fish species in these upper river reaches is resulting in a lower fish diversity and abundance of the indigenous fish species whose occurrence should be expected.

It is important to note that improved flows through the scenarios must be maintained long-term, as this will enable achieving the objective of ensuring migratory fish species return, in-stream and riparian habitat improves and very importantly that the system is flushed in order to remove underlying silt and sediments which further improves water quality and habitat for the aquatic biota. It is vital that this is sustained overtime, as only then will the PES be improved to the recommended TEC.

IUA5 (Blood River) is the only IUA with no EWR site and hydraulic cross-section. The Blood River is mainly a wetland system and is covered in detail as part of the wetland assessment. However, the lower reaches form a defined river channel and thus a desktop EWR was determined for this system at the outlet of the IUA.

As no hydraulic cross-section or biological data were available to assess the ecological consequences, compliance with the EWR for PES and TEC were done using percentiles and flow duration curves. The table below indicate where the ecological category of a PES = C = TEC could not be met compared with Sc1 (present day demands). Scenarios 1, 3 and 5 are the same for the Blood River as no additional water resources developments are foreseen for this river.

Table 13: Estimated present day non-compliances with EWR for PES=TEC=C for Blood River

% tiles	All Months: PRS-EWR											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.1	22.85	19.49	24.18	63.08	42.91	19.38	6.47	4.94	3.32	14.92	13.47	29.91
1	20.67	19.22	24.09	40.69	37.45	18.05	6.30	4.30	3.09	6.74	10.97	21.69
5	8.80	11.81	15.55	20.33	26.20	10.03	4.34	0.98	0.85	1.02	0.60	0.81
10	3.04	7.12	10.67	11.62	15.59	8.56	2.47	0.80	0.37	0.38	0.40	0.41
15	1.23	6.20	7.73	9.00	11.98	6.73	1.78	0.65	0.23	0.21	0.17	0.25
20	0.57	3.91	5.98	7.25	9.00	5.78	1.55	0.57	0.15	0.15	0.13	-0.08
30	0.16	1.62	2.75	4.44	4.46	2.61	0.88	0.25	0.11	0.03	0.06	-0.18
40	0.00	0.42	1.28	3.67	2.36	1.21	0.54	0.20	0.08	0.00	-0.08	-0.23
50	-0.03	0.19	0.68	2.28	1.17	0.49	0.38	0.10	0.04	-0.08	-0.12	-0.26
60	-0.15	0.14	0.36	0.42	0.60	0.03	0.30	0.05	-0.02	-0.08	-0.13	-0.22
70	-0.18	0.06	0.34	0.09	-0.01	-0.18	0.29	0.03	-0.02	-0.07	-0.13	-0.19
80	-0.22	-0.05	0.39	0.00	-0.23	-0.15	0.07	-0.04	-0.04	-0.07	-0.12	-0.17
85	-0.19	-0.11	0.31	-0.03	-0.28	-0.16	0.04	-0.04	-0.06	-0.08	-0.11	-0.15
90	-0.14	-0.08	0.38	-0.05	-0.30	-0.14	-0.01	-0.06	-0.05	-0.09	-0.09	-0.12
95	-0.12	-0.13	0.30	-0.13	-0.33	-0.23	-0.07	-0.09	-0.07	-0.09	-0.09	-0.10
99	-0.10	-0.10	0.01	-0.26	-0.35	-0.22	-0.11	-0.11	-0.09	-0.08	-0.08	-0.09
99.9	-0.08	-0.08	-0.04	-0.33	-0.44	-0.25	-0.14	-0.13	-0.09	-0.08	-0.08	-0.09

It can be seen from the above table that there is currently non-compliance to both the PES and TEC for most of the months, even during the wet months. This will seriously impact on the biota in the system.

Ecological consequences results summary

In summary, the radar diagram (Figure 5) illustrates that Scenario 6 (medium-term with all major planned infrastructure before 2030 included) is the best fit for the fish and invertebrates for the wet season. For invertebrates in the dry season, Sc6 and Sc 9 are similar, however for fish Sc6 is the best option.

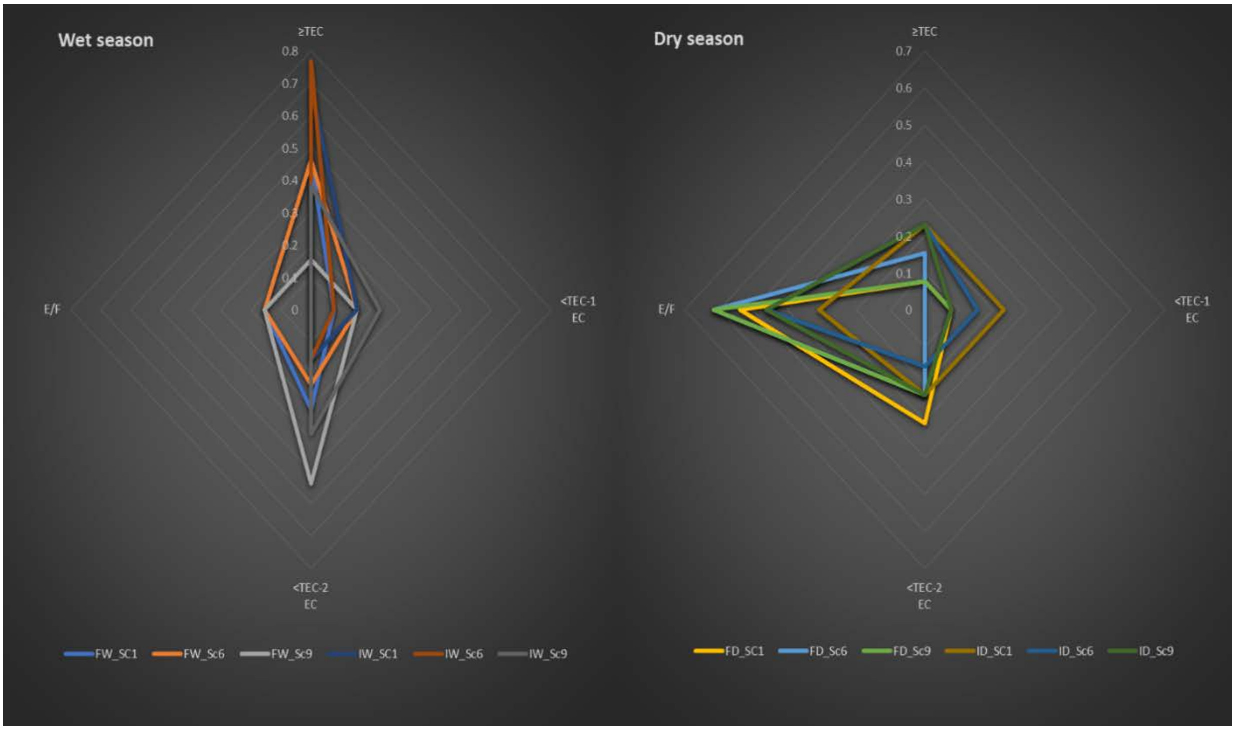


Figure 6: Radar diagram of the ecological consequences outcomes

6.2 Water Quality Consequences

Historical and baseline water quality at the priority sites is detailed in the Status Quo and Integrated Unit of Analysis and Resource Units Report, Report Number: RDM/WMA04/00/CON/CLA/0320, and also in the Quantification of Ecological Water Requirements Report, Report Number: RDM/WMA04/00/CON/CLA/0620.

The analysis reflected 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. 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 in the abovementioned reports, a qualitative indication of water quality present state and comment on whether deterioration is expected, considering the current drivers of pollution, are indicated in Table 15.

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.

Table 14: Overall water quality changes expected

IUA	River	Key EWR sites	QC	PES	TEC	Water Quality changes expected	
						Present State	Comments
1	Upper Buffalo	EWR23	V31D	C	C	D	Sc6: no change expected Sc9: no change expected
2	Ngagane	May13_ EWR3	V31K	C	C/D	D	Sc6: Deterioration if sanitation infrastructure not maintained Sc9: Deterioration if sanitation infrastructure not maintained
3	Middle Buffalo	EWR13	V32H	D	C/D	C	Sc6: no change expected Sc9: no change expected
4	Lower Buffalo	EWR14	V33B	B/C	C	C	Sc6: Deterioration if mine impacts increase Sc9: Deterioration if mine impacts increase
5	Blood River	-	V32H	C	C	C	Sc6: Deterioration if wetland habitat is further destroyed Sc9: Deterioration if wetland habitat is further destroyed
6	Upper Sundays	EWR7	V60C	C/D	C/D	D	Sc6: no change expected Sc9: no change expected
7	Middle Mooi*	EWR11	V20G	C/D	C/D B/C	B	Sc6: Deterioration if sanitation infrastructure not maintained Sc9: Deterioration if sanitation infrastructure not maintained
	Nsonge	EWR20	V20C	C	B/C	B	
8	Lower Mooi	EWR12a	V20H	C/D	C	B	Sc6: Deterioration if sanitation infrastructure not maintained Sc9: Deterioration if sanitation infrastructure not maintained
9	Bushmans	EWR6a	V70G	D	C/D	C	Sc6: Deterioration if sanitation infrastructure and industrial sector not maintained Sc9: Deterioration if sanitation infrastructure and industrial sector not maintained
10	Upper Thukela	EWR2	V11M	C	C/D	B	Sc6: no change expected Sc9: no change expected
11	Klip	EWR22	V12A	C	C	C	Sc6: Deterioration if sanitation infrastructure and industrial sector not maintained Sc9: Deterioration if sanitation infrastructure and industrial sector not maintained
12	Middle Thukela	EWR4b	V14E	C	C	C	Sc6: no change expected Sc9: no change expected
13	Lower Thukela	EWR16	V50C	C	C	C	Sc6: no change expected Sc9: no change expected
15	Estuary	EWR17	V50D	C	C	D	Sc6: Deterioration if sanitation infrastructure and industrial sector not maintained Sc9: Deterioration if sanitation infrastructure and industrial sector not maintained

* TEC=C/D for short term until uMWP-1 transfer in place, then TEC=B/C

7. ESTUARY ASSESSMENT

7.1 Approach to the estuary assessment

As the Thukela Estuary is a perched system (i.e., the water level in the estuary is higher than mean sea level) and largely river-dominated (minimal sea water intrusion), a one directional 1D hydraulic model was used to:

- assess the flow depth and velocities for a range of discharges (link between discharge and habitat availability); and
- model at what discharge sediment transport stops at the various transects. Daily satellite images and data from a tidal gauge within the estuary were used with daily discharge data to verify the discharge leading to mouth closure. A basic geomorphological description of the estuary was given that includes changes to the sediment input from the catchment.

Details of the methodology are included in the full report included as Appendix D, however included:

- Satellite image analysis,
- Hydraulic modelling, and
- Sediment analysis.

7.2 Background to the estuary assessment

7.2.1 The bigger catchment contributing to the estuary

In assessing the estuary, it is important to understand the bigger catchment. The Thukela River is the largest river system in KwaZulu-Natal (basin area of 29 100 km^2) and drains diverse topographical areas, ranging from the steep Drakensburg Escarpment (over 3,000 mamsl) to the coastal platform (Partridge et al., 2010)(Figure 7). The Escarpment comprises relatively erosion resistant basalt, whereas the Ladysmith Basin is located on erodible Karoo sediments with more resistant dolerite intrusions forming localised base level controls (Partridge et al., 2010).

The lower reaches of the Thukela River cross the south-eastern coastal hinterland and south-eastern coastal platform, that is mainly underlain by Karoo and Natal group rocks. The south-eastern coastal platform represents a narrow coastal platform that extends up to 62 km inland and falls between 6 and 65mamsl (Partridge et al., 2010)(Figure 8). The rivers assume straight courses with very little lateral widening of the valley as a result of tectonic activity that caused rapid uplift. River juvination occurred as a result of an ~800m uplift during the Plio-Pliestocene period (Rowntree and Wadeson, 1998). This led to incision from sea level upriver, creating various deep gorges and confined valleys along the lower reaches. This is contrary to most rivers where extensive floodplains, fine bed material and a meandering river channels are the norm along the lower reaches.

The Thukela River course has a gentle to moderate gradient and narrow valley forms with limited sediment storage space. This steep gradient and confined lower reaches support significant sediment throughput to the coast. The Thukela follows a logarithmic long profile from source to sea, despite several 'nick points' along its course (Figure 7).

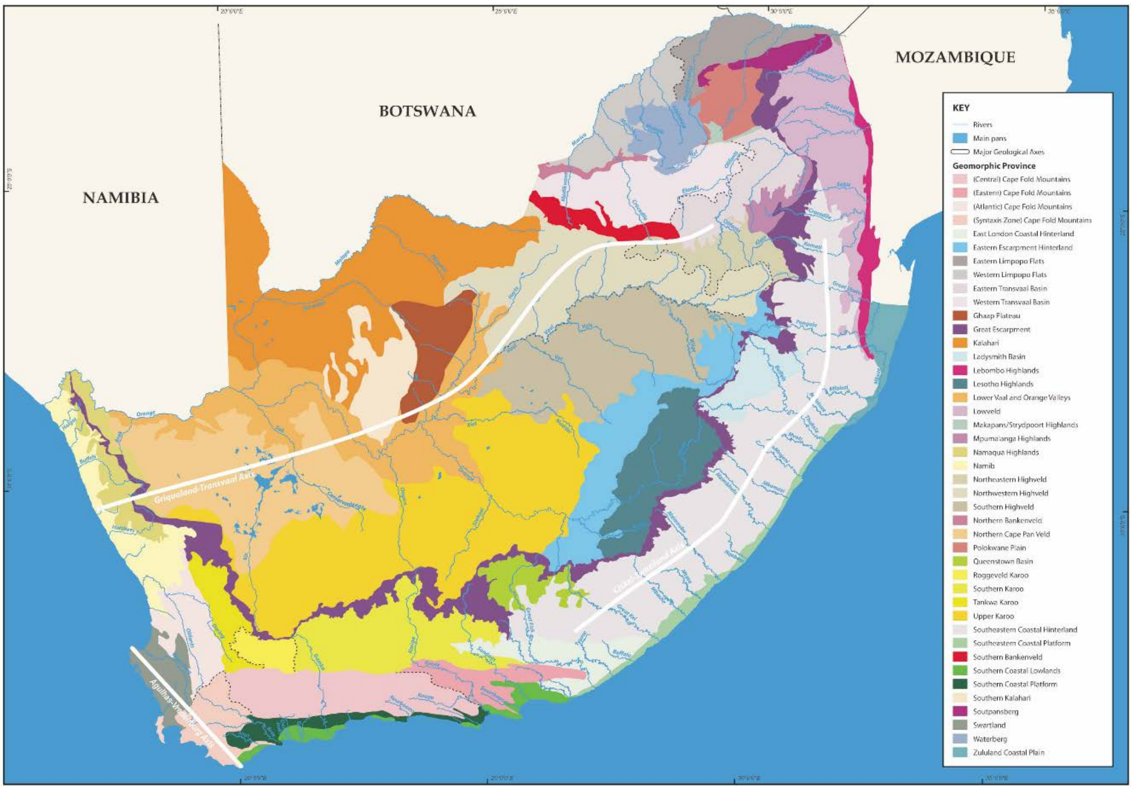


Figure 7: Geomorphic provinces of South Africa (image from Partridge et al., 2010)

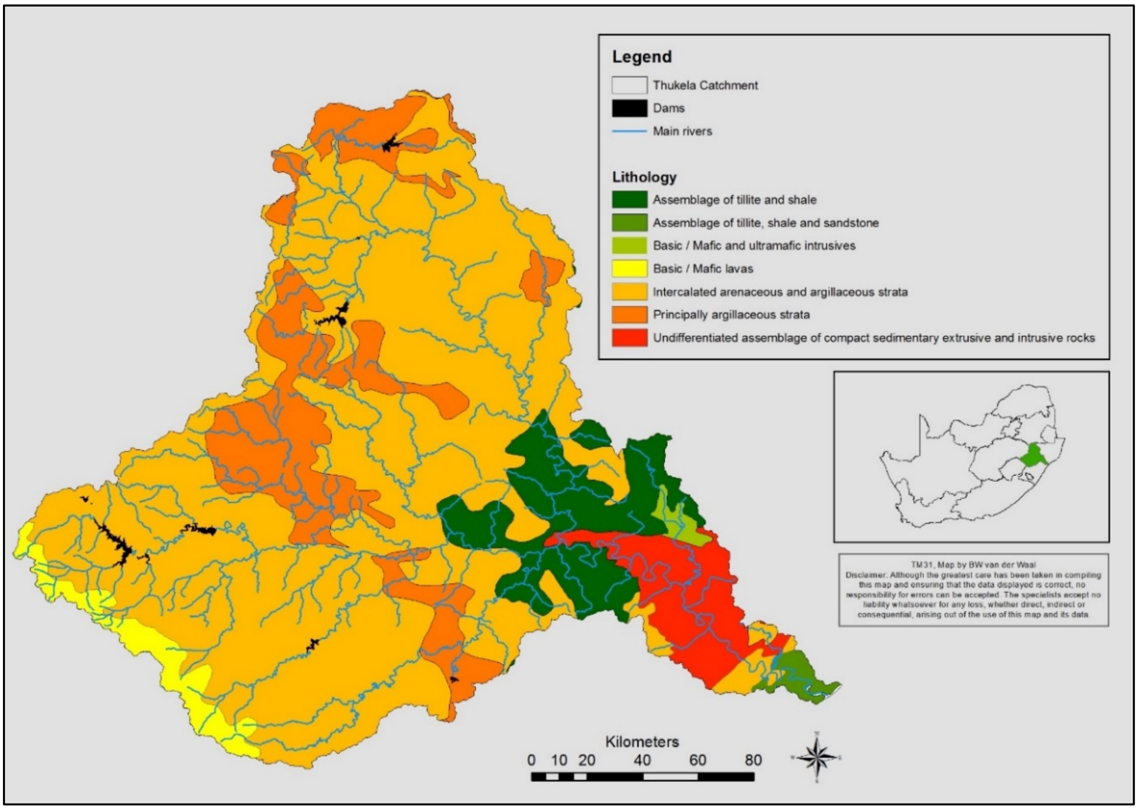


Figure 8: Lithology of the Thukela River basin (Data source: WR90)

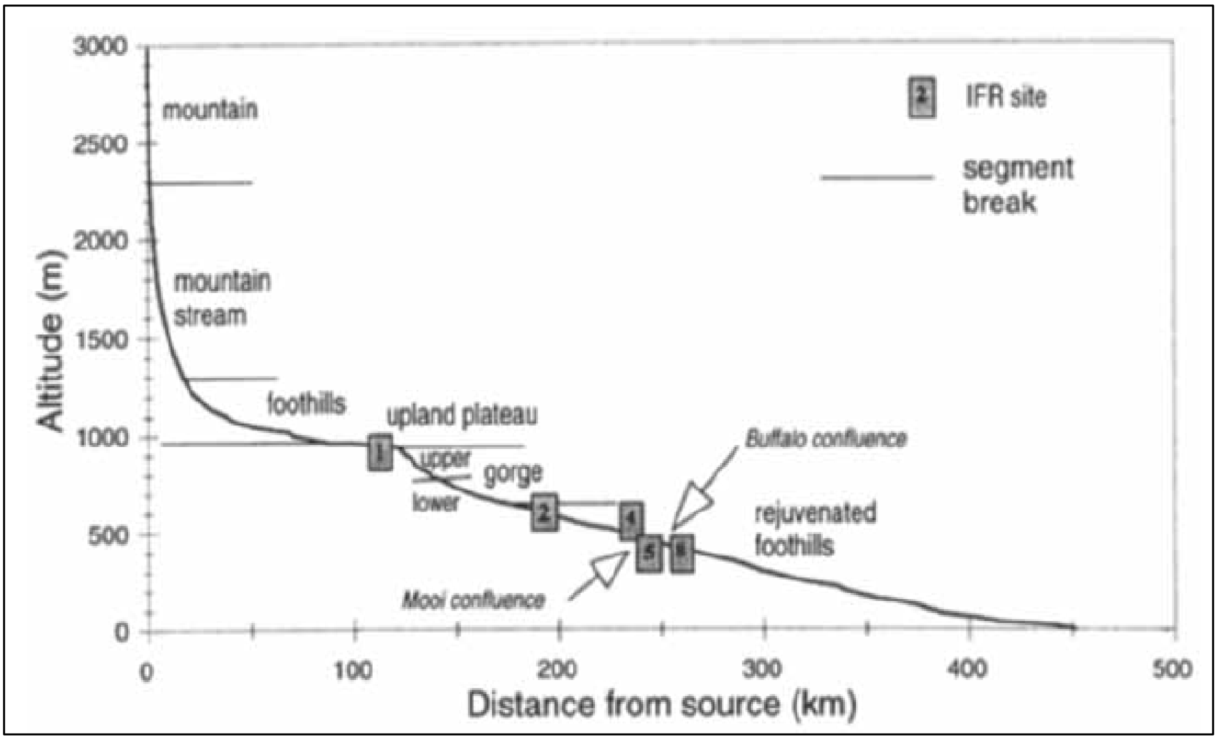


Figure 9: Longitudinal profile of the Thukela River (after Rowntree and Wadeson, 1998)

Hydrological assessments of available flow data for the lowest gauging weir suggest that flows are still largely natural, with relatively small changes to timing, magnitude, frequency, duration and rate of change in flows (Rivers-Moore, 2011).

Baseflows and freshets are reduced due to river regulation and water abstraction directly form the river. Large events are less impacted by flow regulation (compared to low flows), and large floods, such as the floods in 1987 where up to 11 300 m^3/s at Mandeni have been recorded since the large upstream dams have been present (Dollar, 2004).

The lower Thukela receives and transports large volumes of sand, silt, and clay. The water erosion prediction within the catchment is highest in the middle and upper reaches of the catchment, with low levels predicted for the lower catchment (Le Roux et al., 2008). Rowntree and Wadeson (1998) ascribe the high soil erosion rates of the middle catchment to erodible soils, steep valley slopes (a result of river rejuvenation over geological time), sparse vegetation cover and a high density rural population. It is argued that erosion is enhanced by poor grazing and tillage practices (Felhaber, 1984).

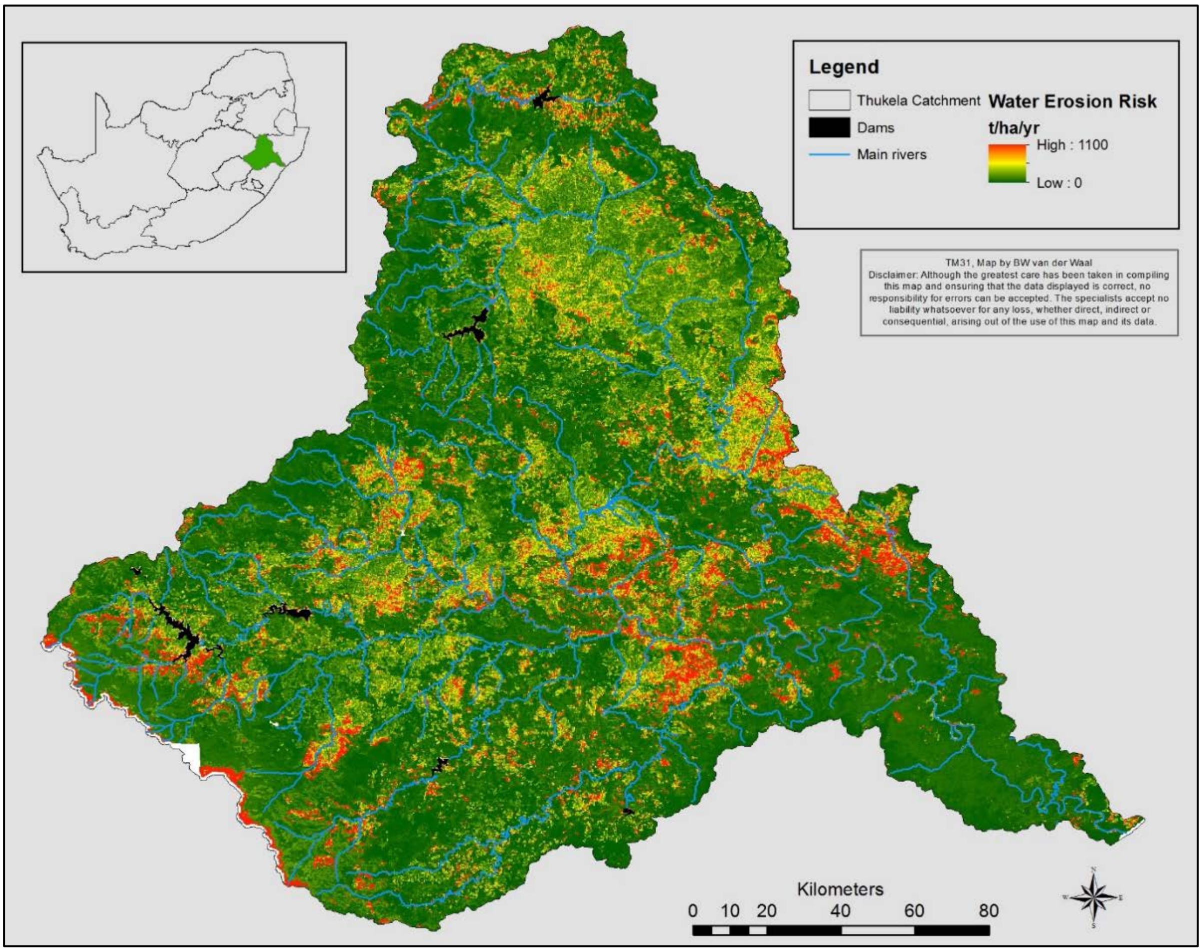


Figure 10: Water erosion potential for the Thukela River catchment (Le Roux et al., 2008)

Due to the sediment trapping of dams in the upper catchment and the perceived increase in erosion over the past 50 years, it is unknown whether the sediment yield for the lower Thukela has increased or decreased. Several studies on sediment yield were reviewed by Dollar (2004) and arguments exist for both scenarios. No evidence is available for sediment yield and shifts in sediment particle size.

Declines in fresh water and terrigenous sediment is often blamed for the decline in productivity of the Thukela banks (Lamberth et al., 2009; De Lecea and Cooper, 2016; De Lecea et al., 2016). There is a lack of measured sediment yield data, thus evidence from elsewhere in South Africa was used in this study to infer regional trends.

A study on the sediment yield of the Orange River alludes to a recent (hundreds of years) ten-fold increase in sediment yield compared to the longer term average since the Holocene (Compton et al., 2010). Authors attribute the increase in sediment yield to the start of cultivation and agriculture. This increase in yield does not include the storage function of the numerous dams in the catchment, thus the actual sediment yield should be greater than that measured out at sea. Similar increases in sediment yield due to over-grazing and cultivation for the Karoo uplands were observed since European settlement (Foster et al., 2012). The peak sediment yield occurred around the 1950s, with changes in landscape vegetation cover and connectivity playing a significant role in sediment delivery. Decreased stocking rates since the 1950 resulted in reductions in sediment yield since the 1970s (Foster et al., 2012). Observations in the Thukela basin from aerial images suggest that the area affected by sheet and gully erosion has decreased over the period 1944 to 1981 (Garland and Broderick, 1992). Although the authors acknowledge that this is not a surrogate for sediment yield, it should be an indication of reduced surface erosion and possibly reduced sediment yield.

Water and sediment connectivity has been altered by human activities. In the upper Thina River catchment, van der Waal and Rowntree (2017) found that landscape connectivity has increased through gully formation, livestock tracks and roads since the early 1920s, increasing sediment transport efficiency from the hillslopes to the river channel. Although large gullies are still expanding, areas of sheet erosion showed signs of stabilization. This change in landscape connectivity increases water and sediment delivery to the river channel.

Based on the above literature, it is likely that anthropogenic influence has increased the sediment yield of the Thukela basin through changes to land cover, land use and landscape connectivity. It is likely that erosion peaked in the early to mid-20th century, followed by reductions in erosion as soil conservation methods were adopted. Although hillslope-channel connectivity has increased due to land degradation, longitudinal connectivity has decreased in many areas due to dam developments.

There are more than 672 dams (large and small) in the Thukela River catchment (Rivers-Moore et al., 2007). According to the DWS hydrographic survey for the large dams in the Thukela catchment, a total of 2 Mm^3 of sediment is trapped on average per year (Table 1). Sediment yield estimations vary between 227-434 $t/km^2/a$ for the Thukela basin (see summary by Dollar, 2004). The majority of the large dams are situated in the upper catchment, thus having very little impact on sediment generated in the middle and lower catchment. Basson and Beck (2004) calculated a 20% reduction in effective sediment catchment area and an 8% reduction in peak flows for the estuary due to the existing dams.

Table 15: Dam volume, catchment area and sediment yield from DWS hydrographic survey (2016)

Dam	River system	Catchment km^2	Nested catchment km^2	Volume 1000 m^3	Sediment yield $m^3/km^2/a$	Sediment trapped m^3/a
Wagendrift	Bushmans	744	744	60 001	153	113 925
Hattingspruit	Hattingspruit	56	56	1 885	*250*	14 000
Amcor	Incandu	488	488	726	*250*	122 000
Ntshingwayo	Ngagane	830	830	78 407	244	202 695
Khombe weir /stuwal	Khombe	52	52	0	*250*	13 000
Windsor (abandoned)	Klip	764	764	4 618	140	106 833
Kilburn	Mnjaneni	30		35 966	*250*	7 500

Dam	River system	Catchment km^2	Nested catchment km^2	Volume 1000 m^3	Sediment yield m^3/km^2/a	Sediment trapped m^3/a
Craigie burn	Mnyamvubu	152	152	25 918	468	71 190
Putterill weir/stuwal	Putterillspruit	68	68	0	205	13 940
Clifford Chambers weir	Thukela	186		0	*250*	46 500
Driel barrage	Thukela	1 656		15 331	182	301 686
Spioenkop	Thukela	2 400	2 400	285 995	197	473 414
Woodstock	Thukela	1 149		381 306	412	473 312
Total			**5 554**		***250***	**1 959 995**

It was concluded that the current sediment yield is higher than natural due to anthropogenic influence on land cover and land use. It is likely that the sediment yield has decreased since the early 20th century, due to improved farming practices and numerous dams that trap water and sediment. Sediment deposition along the river channel is greater than under natural conditions and is a combined result of increased erosion and reduced flow competence to entrain sediment to the coast.

7.2.2 The Thukela River Estuary

The Thukela estuary is classified as a large, fluvially dominated estuary and as a large, shallow, sediment rich system (van Niekerk et al., 2020). Fluvial processes dominate these systems, with ebb-tidal deltas likely to form during high flows and mouth closure during low flows (van Niekerk et al., 2020). The estuary experiences minimal tidal influence and is a river-dominated estuarine system (Harrison et al., 2000). Due to limited sediment accommodation space in the catchment, the majority of the sediment is transported to the coast.

The Thukela River is estimated to contribute 10^7 tonnes of sediment per year to the coast (Flemming and Hay, 1984). Sediment deposition is mainly along the in continental shelf off the Thukela Mouth where extensive mud belts have formed (Felhaber, 1984)(Figure 11). This depositional area is called the Thukela banks and is about 50km wide at the Thukela River mouth and forms an important crustacean and linefish fishery (Turpie and Lamberth, 2010). Large volumes (~90%) of sediment dumped on the shelf is transported away by the high energy current on the continental shelf (Felhaber, 1984). The historically large sediment contribution of the Thukela system has been captured in a series of deltas that have formed over the past 18 000 years as sea level rose from – 50 m to the present sea level (0 m)(Figure 12; Engelbrecht et al., 2020).

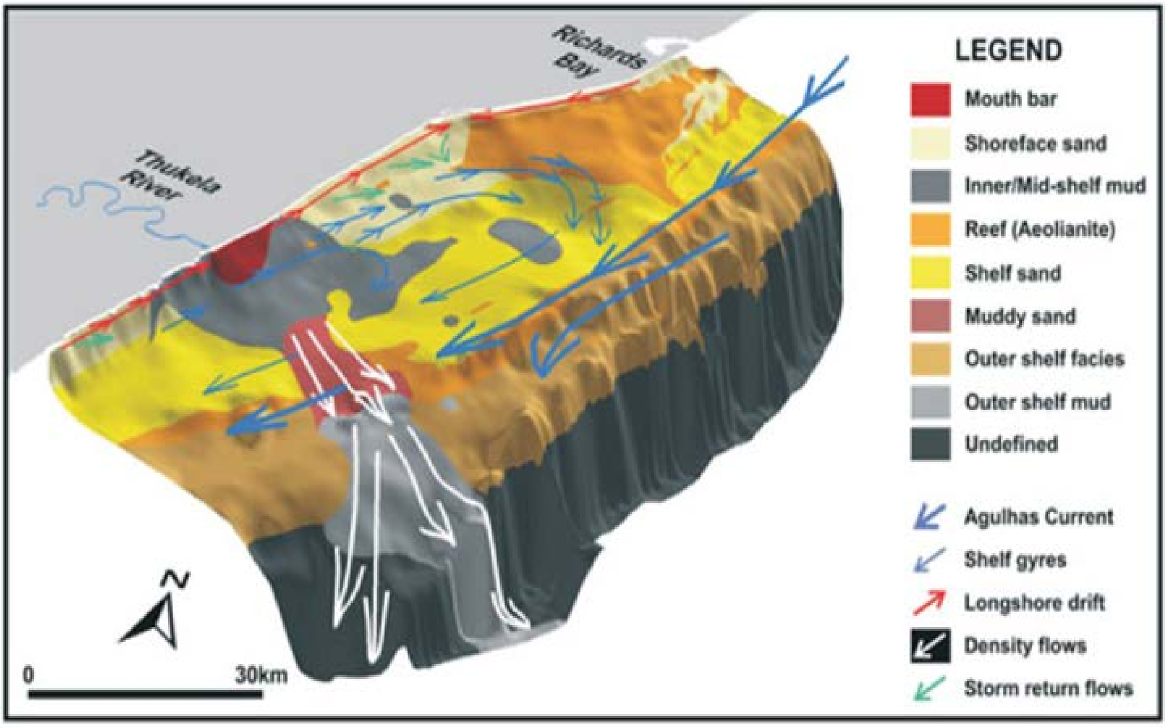


Figure 11: Representation of the Thukela banks (Image by Bosman et al., 2007)

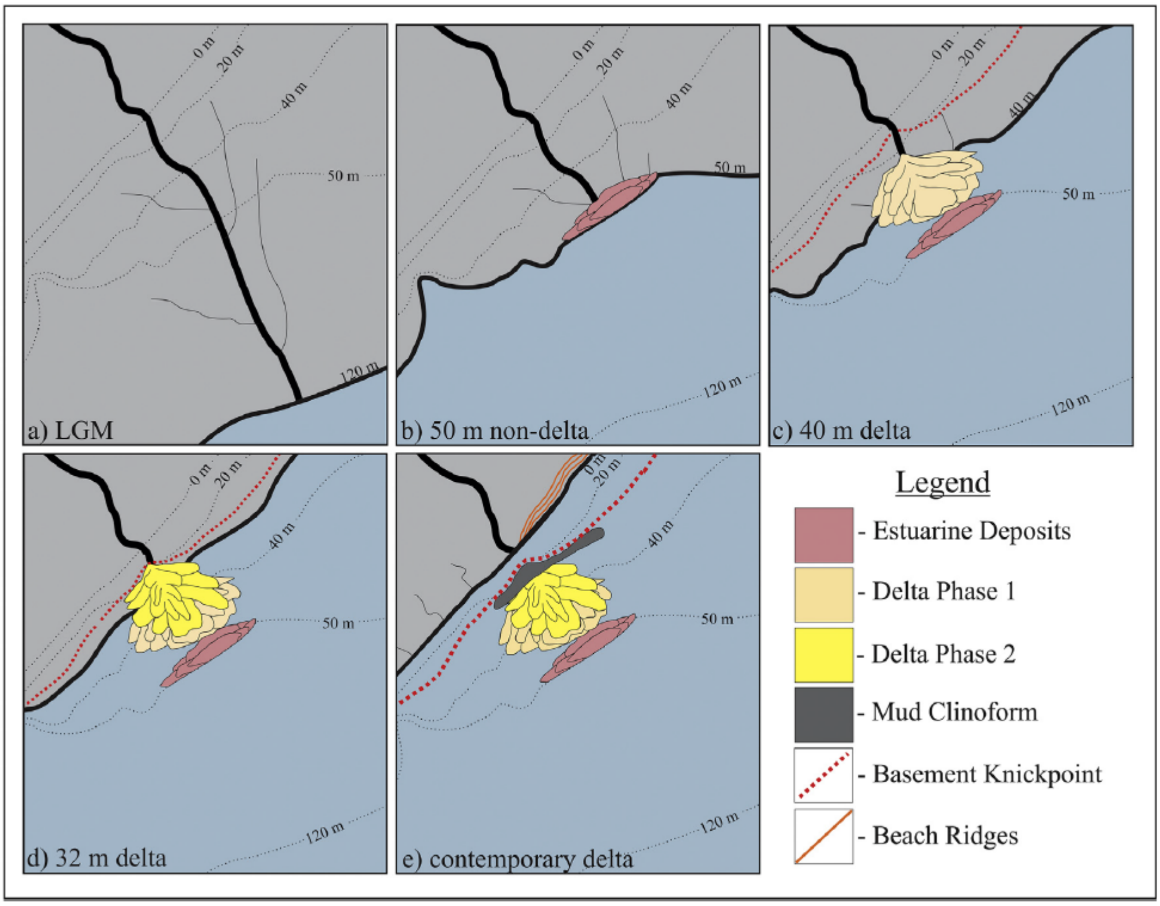


Figure 12: Delta evolution of the Thukela shelf delta over the past 18 000 years (Engelbrecht et al., 2020)

The Thukela River system remains an important source of sediment, organic matter and fresh water for the KwaZulu-Natal Bight (Lamberth et al., 2009; De Lecea and Cooper, 2016; De Lecea et al., 2016; Uken and Mkize, nd) and supports a wide variety of fish species in the bight that are dependent on soft sediment (Fennessy, 2016). The Thukela banks section of the Bight that is associated with inputs from the Thukela River has markedly finer sand (0.25-0.5 mm) and mud composition with greater organic content compared to the other regions of the Bight (Uken and Mkize, nd).

7.2.3 Sediment movement along the estuary and mouth closure

Large volumes of sand and silt are transported through the estuary during the highflow summer season (Nov-March). This sediment is deposited as a fan in the nearshore environment and reworked and distributed by wave action and south to north long-shore currents (Basson and Beck, 2004). Some of this coastal sediment is transported back into the mouth during the incoming flood tide (Taljaard et al., 2004). The tidal influence on mouth hydraulics and dynamics can be observed up to flows of 300$m^3.s^{-1}$, whereafter river flow out to sea dominates the hydraulics (Basson and Beck, 2004).

Riverbed and estuary sediment is dominated by coarse and medium sand (Table 16). Cohesive sediment is deposited along the banks or on sandbars along the wider parts of the estuary during low flow conditions, forming mud flats (Basson and Beck, 2004). Large floods (>1 in 10 year frequency) scour the bed and cohesive deposits from the estuary (Basson and Beck, 2004).

1D morphodynamic modelling was done by Basson and Beck (2004). The model showed that the estuary will become *longer and deeper* under natural conditions (with lower river sediment input of about 200$t.km^{-2}$) and for additional dam development in the middle catchment (which would mean reduced sediment input of about 200$t.km^{-2}$ and reduced flood flows), when compared to present conditions of high sediment input of about 400 $t.km^{-2}$ and partly reduced flood flows. For an increased sediment input scenario (600$t.km^{-2}$) the estuary will become shorter due to aggradation along the river section, with negligible changes to the estuary depth. The model also showed that fine sediment only builds up in the estuary (lower 2-3km) where velocities are low due to increased channel volume. This fine sediment is only flushed out during large flood events. Frequent large floods are essential to maintain the scouring to avoid fine sediment consolidation (Basson and Beck, 2004). Consolidated sediment is more persistent in a system.

Beck (2005) used detailed sediment transport modelling to calculate sediment transport in and out of a hypothetical river mouth. Sediment transport (size ranging from 0.035 to 0.2mm) took place once velocities were above 0.36m/s (Beck, 2005). Flood tide velocities were greater than ebb flows, but duration was shorter, resulting in nett sediment export from the mouth under low flow conditions. These parameters are likely to apply to the Thukela mouth as the sediment particle size is similar.

Table 16: Sediment character of the lower Thukela sub-catchment

Site	Median particle size (µm)	Size description	Author
Thukela at N2 bridge	220	Medium sand	Basson and Rooseboom, 1990
Thukela Estuary	300-600	Medium to coarse sand	DWAF 2004
Thukela Estuary 0.5 to 3.5 km from mouth	250-500	Medium sand	(Basson and Beck, 2004)
Thukela Estuary 0.5 to 3.5 km from mouth banks	<63	Silt and clay	(Basson and Beck, 2004)
Thugela below eMandeni confluence	212-2000	Medium to coarse sand	(Venter, 2013)
Thugela below eMandeni confluence	220-4000	Medium sand to fine gravel	(O'Brien et al., 2017)
Thukela Estuary high flow		Coarse and medium sand	Gongo, 2020
Thukela Estuary low flow		Medium sand	Gongo, 2020

Mouth closure takes place during low flow conditions when the lateral sediment input from long-shore drift and wave action overwhelm the transport rate of the ebb flow rate (Lara van Niekerk pers. Com.). Mouth closure is difficult to predict as it is influenced by river discharge, tidal fluctuations, wave size and lateral sediment transport by longshore currents. The influx of sediment into the mouth can take place under river flow conditions as high as 10 m^3/s as was observed for the Mgeni Estuary (CSIR 1990 referenced by Taljaard et al., 2004).

For the Thukela Estuary, mouth closures have been recorded for river flows of 7.7 m^3/s and lower, but the relationship is very dynamic due to high sediment influx into the estuary during coastal storm events (Taljaard et al., 2004). Observations also indicate that the mouth remained open for flows as low as 1 m^3/s, showing the complexity of river flow-mouth closure relationships. Mouth closure and the formation of a berm leads to the damming of the estuary. Breaching will occur when the estuary fills to a level that overtops the berm. This will lead to sediment mobilisation and incision of the berm, effectively draining the estuary to re-establish tidal flow and sediment dynamics. The period of mouth closure is dependent on the river discharge and berm height as this determines the time to fill the estuary to spill capacity.

Previous studies on estuaries approximate the berm height to reach elevations of 2.5masl (Taljaard et al., 2004). The water volume required to fill the estuary to a level of 2.5masl is estimated to be 4.6 million m^3 (Taljaard et al., 2004). At a flow rate of 1 m^3/s it can take 30-40 days for the estuary to breach and at river flows of 10 m^3/s it can take 2- 4 days to breach (Taljaard et al., 2004). Observations showed that the mouth remained closed for only 2-4 days for flows of 2 m^3/s, suggesting that processes other than only overtopping are contributing to berm breaching.

Based on the observed data, the likely mouth dynamics in relation to river discharge are presented in Table 18.

Table 17: Likely mouth state for various river discharge ranges for the Thukela River (Taljaard et al., 2004)

Flow rate (m^3/s)	Consequence
> 10	The mouth will stay open
5 - 10	The mouth closes occasionally. Water levels build up quickly and breaching occurs probably naturally within 1 to 2 days.
2 - 5	Mouth closure occurs more frequently than at flows higher than 5 m^3/s, but the mouth breaches normally again within 4 days. This is probably because the water level in the estuary is increased faster than the level of the berm.
1- 2	Mouth closure will occur. Available data indicates that closures often will be for short periods, but the mouth could stay closed for 15 to 40 days if the berm builds up faster than the water level in the estuary. Mechanical breaching may be required to prevent flooding.
< 1	The mouth will normally be closed, with a slow increase in water levels. A higher berm will build up and the mouth is likely to remain closed for period of up to a few months. Mechanical breaching may be required to prevent flooding.

7.3 Results and discussion of the estuary assessment

Four cross sections were surveyed during low tide. The location of the cross sections is indicated on a satellite image for the same day (Figure 13).

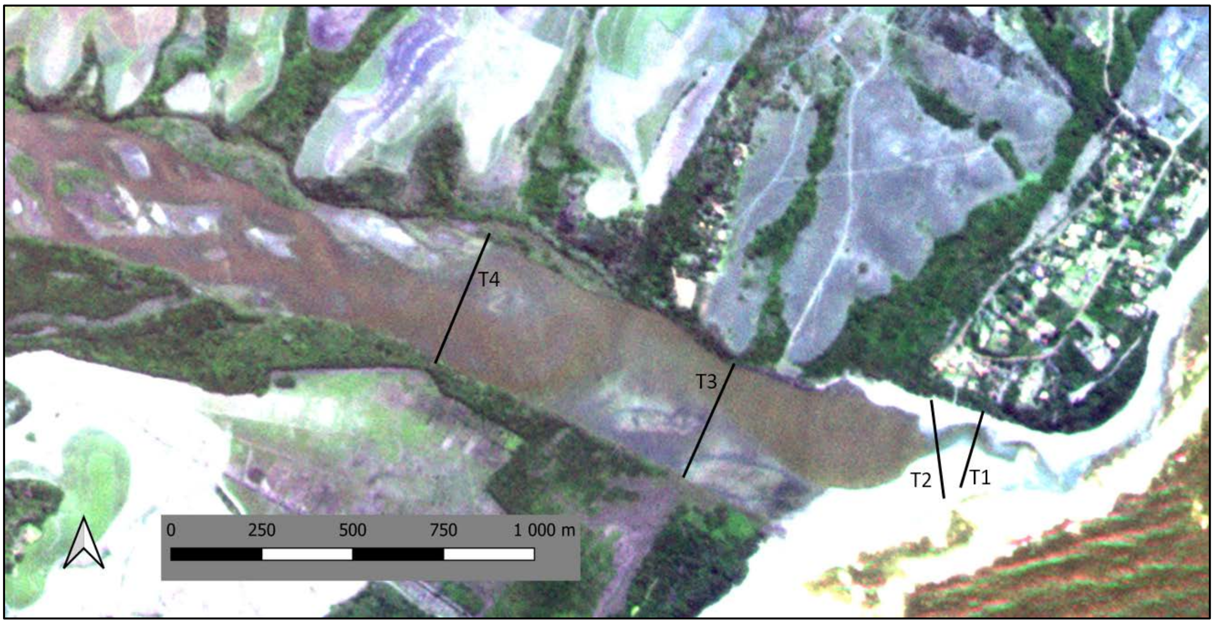


Figure 13: Location of the transects 1 to 4. Satellite image captured at 9am, 17 September 2020 at low tide and coincides with the cross-section survey date

7.3.1 Changes to the Thukela Estuary bathymetry

Based on the mapping presented in Figure 14, it is evident that there are more sandbars in the Thukela Estuary in 2020 compared to 2001. The location of the sandbars is closer to the mouth, suggesting sediment build-up in the lower parts of the estuary. The width of the estuary is narrower along the upper reaches in 2020, possibly a result of vegetation encroachment due to the recent drought and relatively small floods (no large scale scour took place recently). The mouth bar is narrower for 2020 compared to 2001, suggesting recent coastal erosion.

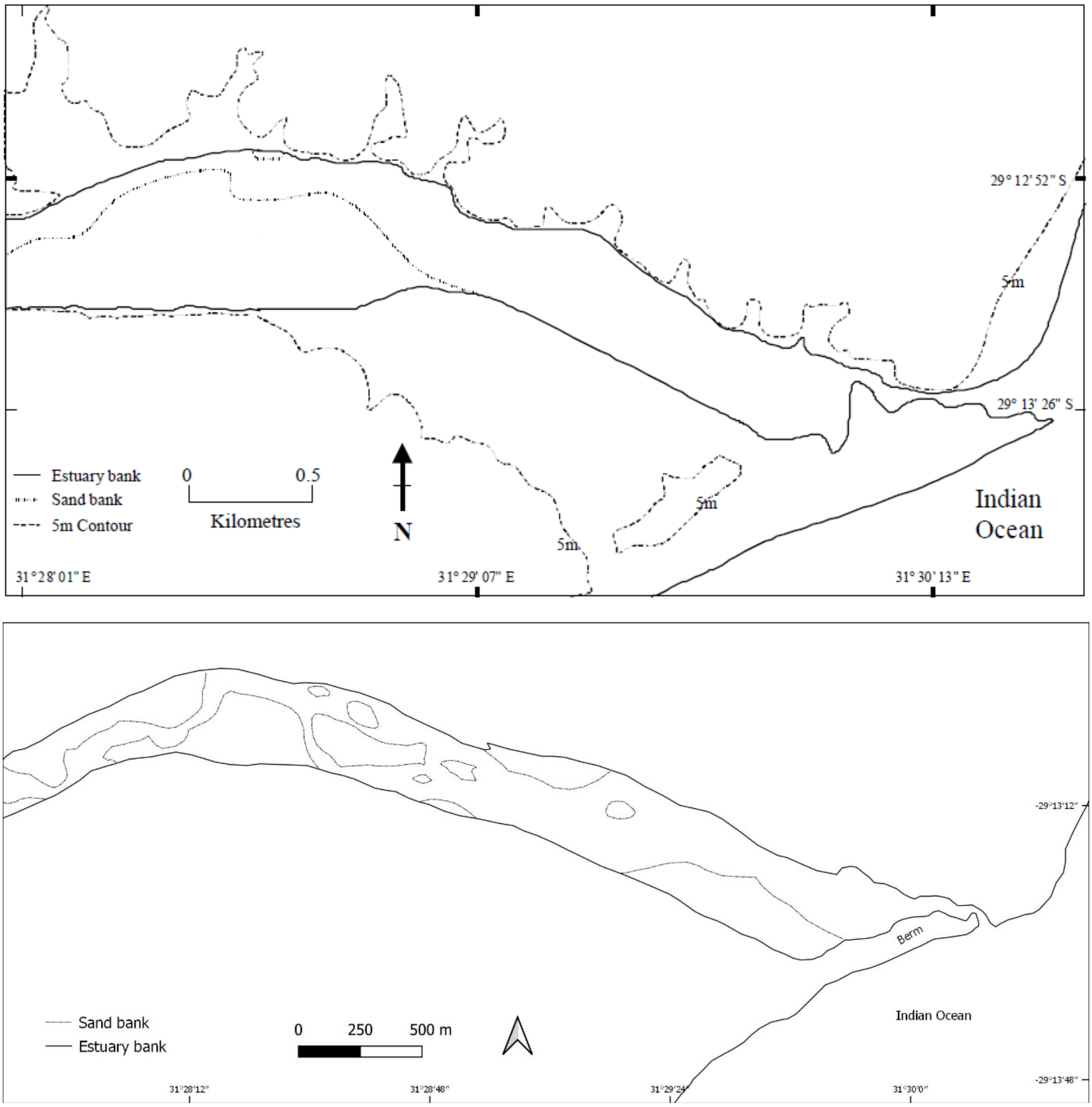


Figure 14: Maps for the Thukela Estuary from: a) 2001 (Taljaard et al., 2004) and b)17 September 2020 showing the banks of the estuary and the extent of the sand banks

The bathymetric survey (Figure 15) supports the current shallow conditions which results, along with data presented in Table 18 showing that the depth of the estuary decreased by up to 1.6m (at 750m from the mouth). The berm height ranged from 3.1 to 3.6masl, with the higher elevation being on the south bank. This is higher than the 2.5masl that is the average value observed for many South African estuaries.

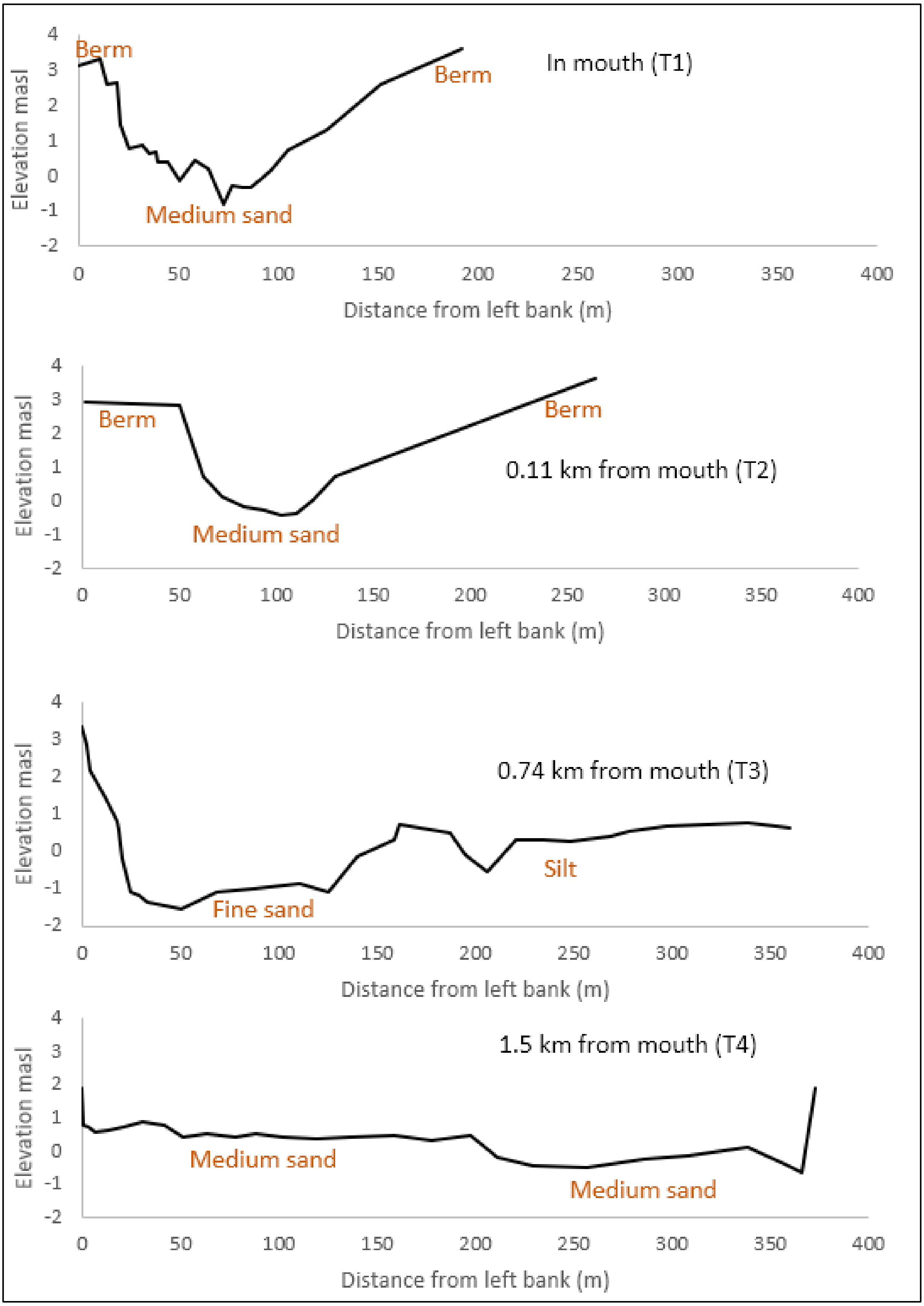


Figure 15: Cross sectional surveys of the Thukela Estuary

Table 18: Distances and thalweg elevations for the Thukela estuary in 1996 and September 2020

Distance from mouth	Distance from John Ross Bridge	Max depth m (DWAF 1996)	Max depth m (September 2020)
1.50	11.655	-1.7	-0.683
1.03	11.907	-1.7	
0.84	12.159	-2.9	
0.74	12.441	-3.3	-1.55
0.35	12.663	-1.1	
0.15	12.852	-1.3	
0.11			-0.44
0			-0.8

Figure 16 illustrates the longitudinal profile of the lower 2km of the Thukela Estuary showing bed elevation in 1996 and 2020.

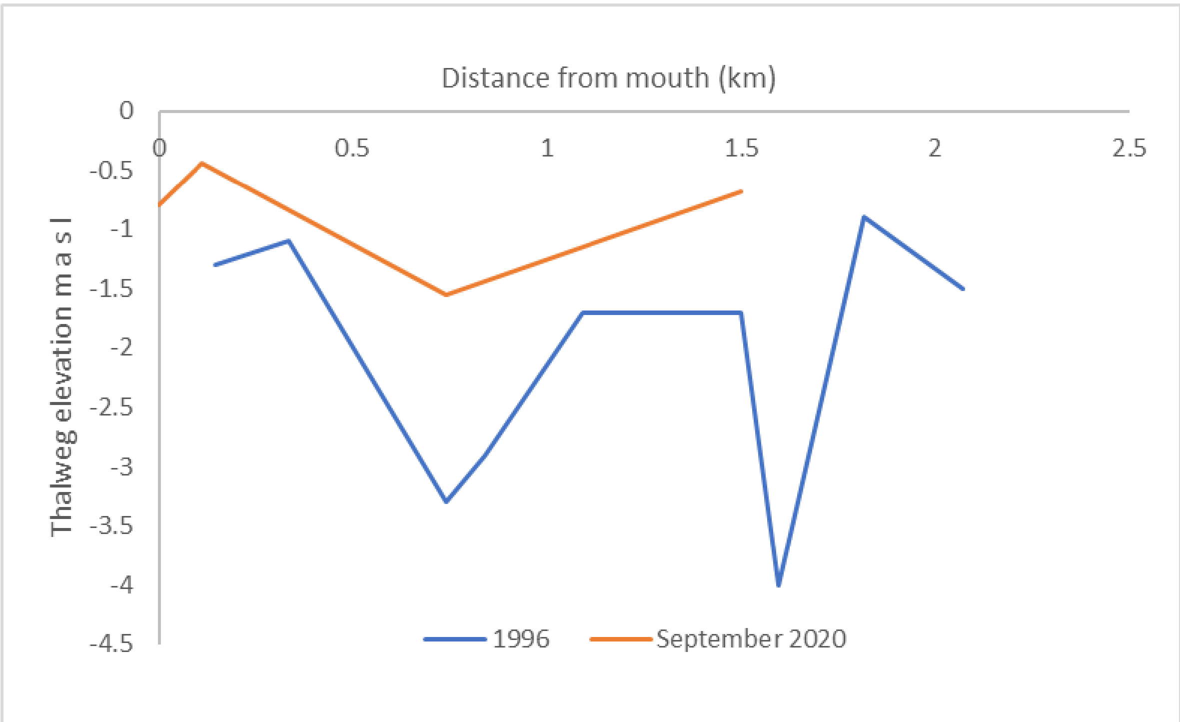


Figure 16: Longitudinal profile of the lower 2 km of the Thukela Estuary showing bed elevation in 1996 and 2020

Cross sections from DWAF 1996 are presented in Figure 17 that are close to the transects surveyed for this study in September 2020.

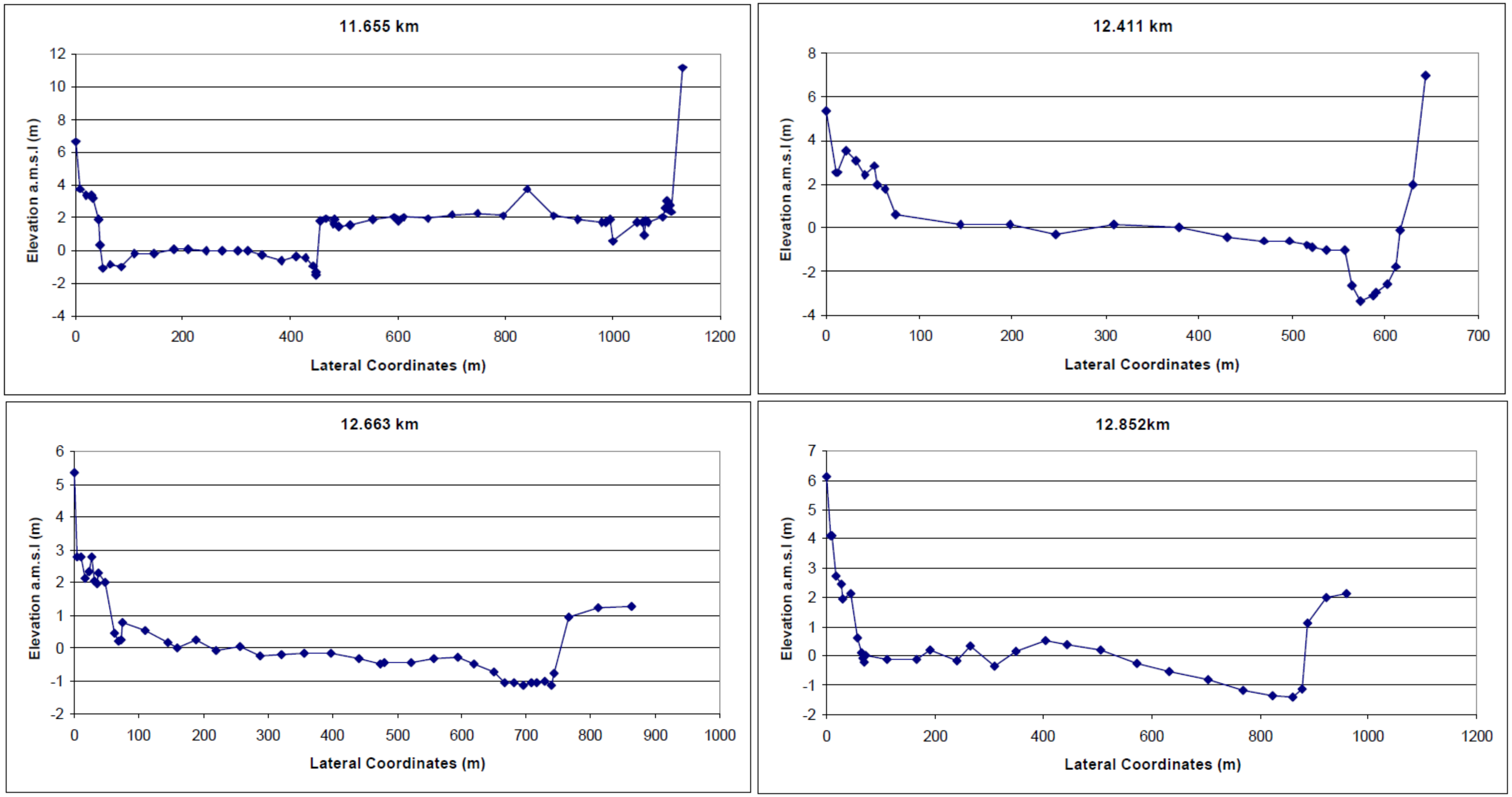


Figure 17: A selection of cross sections from the 1996 survey

7.3.1 Sediment character and transport

The sediment in the mouth is characterised by medium sand with no silt and clay (Table 19; Figure 18). This changes dramatically as you move away from the mouth with silt deposits in the shallow water and fine sand in the deeper water 740m upstream from the mouth. Further up the estuary, approximately 1,5km upstream of the mouth, the sediment becomes coarser with medium sand in both the deeper and shallower water. The sediment in shallower water has a larger silt component as velocities are generally lower away from the deeper channel. These sediment observations agree broadly with that observed previously, except for the fine sediment observed around Transect 3 (740m upstream of the mouth, see Table 19).

Table 19: Sediment particle size results for the Thukela Estuary

Location	Particle size description	D16 (mm)	D50 (mm)	D84 (mm)
T1 Mouth	Medium sand	0.27	0.38	0.77
T2 Mouth	Medium sand	0.30	0.43	1.30
T3 deep channel	Fine sand	0.035	0.125	0.22
T3 Shallow water over sand bank	Silt	0.015	0.037	0.17
T4 Deep channel	Medium sand	0.25	0.42	1.22
T4 Shallow water	Medium sand	0.03	0.42	1.47

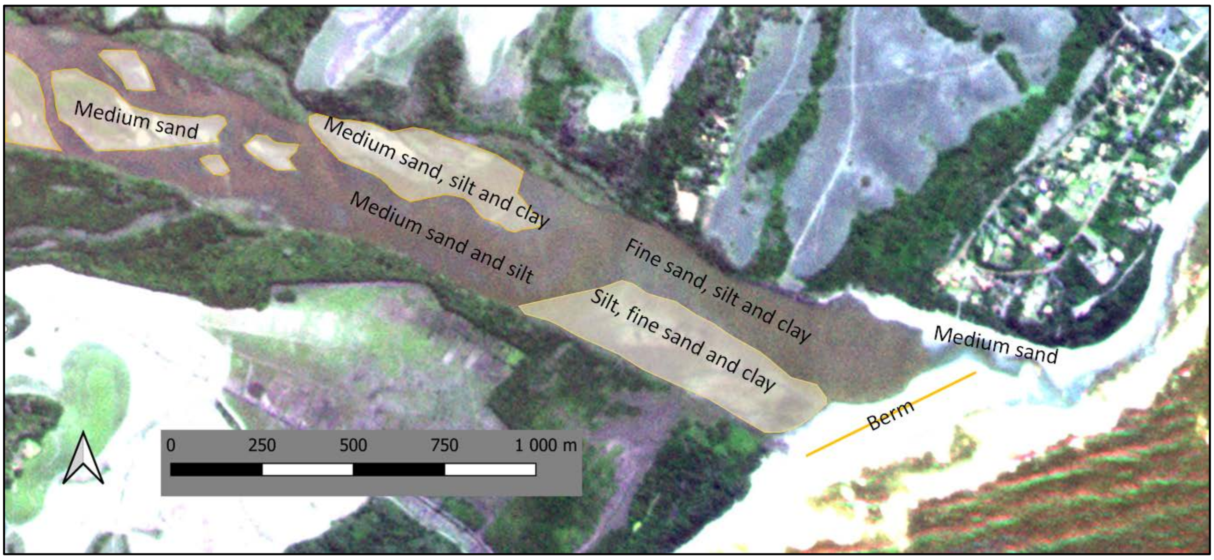


Figure 18: A map of the main sediment types in the Thukela Estuary in September 2020

The bed sediment during the observed flow conditions in September 2020 (river inflow of $4.2m^3/s$ and low tide mouth outflow of $18.8m^3/s$) reflect the energy available for sediment scour, transport, and deposition. Rapid sand transport took place at the mouth compared to the mostly static bed of the Thukela River at the John Ross Bridge at the observed discharges. The difference in average flow velocity and shear stress in relation to discharge for the various cross sections is shown in Figure 19. The mouth experiences high velocities and shear stress at low discharges. This results in mobile coarser sediment deposits with no fine sediment.

At Transect 3, the velocities and shear stress remain low due to the large cross sectional area and low slope, allowing fine material to settle out. Velocities and shear stress are higher at Transect 4 which explains the coarser nature of the sediment at Transect 4 compared to Transect 3. During the low flow conditions, river velocities and shear stress are not capable of transporting medium sand, observed in the river, through to the mouth. This is due to insufficient flow energy around Transect 3. Velocities in excess of 100 m^3/s are needed to transport medium sand from the river to the mouth. Discharges below 100 m^3/s can effectively transport sand and finer sediment to the estuary, but will not allow for transport to the mouth, resulting in sediment build up in the estuary as was observed.

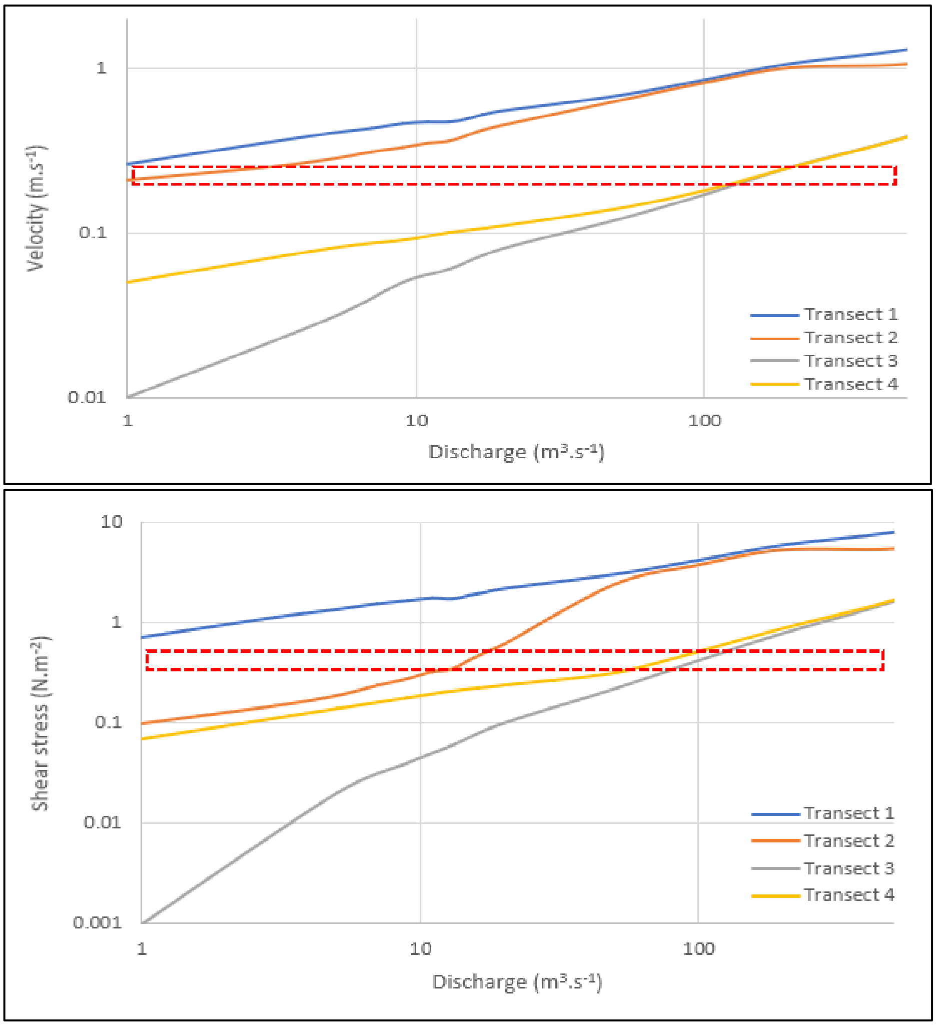


Figure 19: Discharge-velocity and discharge-shear stress curves for Transect 1 to 4 of the Thukela Estuary (The red dashed box indicates the threshold for medium sand entrainment)

7.3.2 Discharge and mouth closure

From the review of literature on the Thukela River mouth it is evident that mouth conditions are dynamic and not easily predicted. The observations made during this study show the tidal influence and resultant difference in river inflow (4.2m^3/s) and mouth outflow (18.8 m^3/s). These discharges observed in the mouth are capable of entraining the sand observed in the mouth (Figure 18). The sediment transport rate at the observed discharges is relatively low for these river discharge values (4.2 m^3/s) and is likely to be incompetent to entrain lateral inputs from long-shore drift and wave action during storm events with, leading to mouth closure.

As lateral sediment input is uncertain, it is not possible at this stage to model river discharge-mouth closure thresholds with moderate or high certainty. It is recommended to extend the database of observed river discharge and mouth closure. This approach is shown in Table 20, which contributes to this database. The two observed closure events for 2020 occurred at flow rates of 6.3m^3/s (closed for 1 day) and 7.6 m^3/s to 8.9 m^3/s (closed for at least 8 days; breached artificially) respectively. There are water abstractions downstream of the gauging weir V5T002, such as the Umgeni Water abstraction weir with an abstraction rate of 0.6 m^3/s reducing the flow rates into the estuary. Based on these observations, the results are in line with the 'occasional closing of the Thukela River Mouth' for discharges ranging from 5 to 10 m^3/s (Table 17).

The number of days of mouth closure shows a complex relationship where the higher discharge had a longer mouth closure period, contrary to what would be expected.

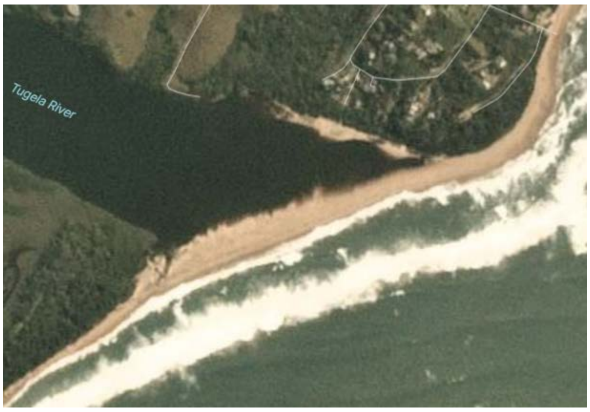
In this case the mouth was closed for more than 8 days for flows ranging from 7.6 m^3/s to 8.9 m^3/s. According to Table 17 the mouth is expected to breach after 1 to 2 days at this discharge as was seen for the closure event on 7 August 2020. Following this study, there is no evidence to disprove the river discharge–mouth condition table that was presented by Taljaard et al. (2004), with some uncertainty around the period (number of days) for which the mouth is closed.

Table 21 includes satellite images of mouth closure and Thukela River discharge at V5T002. Discharge data was extrapolated form weekly Sappi monitoring at V5H002. No mouth closures were detected for 2018 and 2019.

Table 20: Satellite images of mouth closure and Thukela River discharge at V5T002)

Date and image source	Image	Mouth condition	Discharge (m^3/s)
6 Aug 2020 PlanetScope		**Open**	**~6.3**
7 Aug 2020 PlanetScope		**Closed**	**~6.3**
8 Aug 2020 PlanetScope		**Open**	**~6.3**

Date and image source	Image	Mouth condition	Discharge (m^3/s)
11 Aug 2020 PlanetScope		**Open**	**~6.6**
14 Aug 2020 PlanetScope		**Closed**	**~7.6**
15 Aug 2020 PlanetScope		**Closed**	**~7.9**
18 Aug 2020 PlanetScope		**Closed**	**8.9**

Date and image source	Image	Mouth condition	Discharge (m^3/s)
19 Aug 2020 PlanetScope		**Closed**	**~8.3**
20 Aug 2020 PlanetScope		**Closed**	**~7.7**
21 Aug 2020 PlanetScope Breached on 22 Aug 2020		**Closed**	**~7.2**
25 Aug 2020 PlanetScope		**Open**	**~5.5**

7.3.3 Conclusions

The updates to the mouth state in relation to river discharge confirmed the mouth state for various river discharge ranges for the Thukela River presented by Taljaard et al. (2004). The 2020 mouth closure observations show that the period for which the mouth could be closed at a given discharge is variable and uncertain.

It is evident that siltation has occurred in the Thukela Estuary over the last 19 to 24 years. This is likely due to no recent large floods scouring the Thukela Estuary, increased fine sediment input from the catchment and reductions in low flows that can transport the fine sediment through the estuary to the coast. Management of the Thukela River system needs to be improved to prevent the siltation of the estuary. This includes changes to reduce soil erosion in the catchment, allow for higher base flow releases from dams and limit abstraction from the river channel or weirs for the middle and lower catchment.

Ongoing monitoring of the mouth, estuary bathymetry, sediment composition and river discharge for the lower Thukela River and coastal storm intensity will improve our understanding of the system and allow for adaptive management.

8. SOCIO-ECONOMIC CONSEQUENCES

The scenario evaluation step is represented by Task 5 in the Socio-Economic Guidelines for WRCS (Naidoo et al. 2007). This report represents the progress made towards completing Task 5. The results presented are the outputs of the field specific work sessions conducted with subject specialists. The draft outputs presented here will be assessed in a verification and refinement step with the relevant subject specialists. Refined outputs will be taken forward into the valuation phase where trade-offs in scenario will be quantified and assessed.

The overall objective of Task 5 is to evaluate the selected scenarios within the socio-economic framework towards identifying key ecosystem services at risk.

8.1 Methodology

The methodology, as per Task 5 in the Socio-Economic Guidelines for WRCS (Naidoo *et al.* 2017), was utilised to define linkages between the impacts of changing scenarios and socio-economic and ecological conditions within the Thukela catchment. By identifying these linkages, ecosystem services at risk are identified then used to measure, or quantify, the socio-economic impacts of varying scenarios.

The process involves conducting a Comparative Risk Assessment (CRA) which is an econometric method for defining linkages and identifying ecosystem services (ES) at risk.

The CRA allows for the definition of cause-effect relationship between environmental drivers (as introduced through scenarios), their environmental effects (impacts on ecological infrastructure (EI)), and ultimately the rating of risks to beneficiaries through their relationships with ecosystem services. This process ultimately defines numerous scenario-EI-ES chains of causality and rate the risks faced.

The process involved defining the following linkages in the chain of causality:

1) **Environmental hazard:** The environmental hazard is the environmental stressor which drives change. The hazard is identified as the input which initiates the chain of causality and is determined through the changes initiated through varying scenarios. Examples in this case include decreased surface water flow through over abstraction from rivers. Note the environmental hazard would vary between ecological infrastructure and across scenarios.
2) **Environmental effect statement:** The environmental effect statement describes the physical impacts that the environmental hazard has on specific ecological infrastructure. In line with the example above, this would describe that decreased surface water flow would modify natural flows processes and restrict primary productivity within the channel and riparian areas.
3) **Risk rating of ecosystem services.** The risk to the flow of ecosystem services is assessed in terms of the likelihood and consequences of impact by the identified environmental effect on the specific ecological infrastructure providing the service. The process is further detailed below:

Ecosystem risk is the function of the likelihood and consequence of a scenario to which EI is exposed.

Thus: ***Risk = f (likelihood, consequence)*** *of environmental effect on EI.*

For each scenario-EI-ES combination, two questions are asked:

Firstly, 'What is the likelihood that this ecosystem service, provided by the specific ecological infrastructure, will be affected under this scenario? This speaks to impacts that the scenario would have on the ability to provide the ecosystem service.

Secondly, 'What would be the consequences of this scenario in this ecological infrastructure to the delivery of this ecosystem service?' This speaks to the socio-economic consequences and therefore links directly to the relevant beneficiaries within the IUA.

The likelihood of an impact is the change in possibility that a specific scenario will have an impact on the EI and therefore the benefits received. The likelihood rating framework can be seen in Table 22. The consequence of the scenario is the change in the service from the environmental effect of the scenario on the exposed EI. A consequence rating framework can be seen in Table 23. Likelihood and consequence categories are chosen for each ES. It is important that the certainty is recorded to ensure transparency of the level of confidence in categories chosen. Risks are then automatically ranked according to risk levels (Table 24). A description of each risk is given (Risk Statement) which includes the underlying chain of causality between environmental effect and its consequence to ensure transparency of the ranking process. All of the below tables are adapted from the classification adopted by the IPCC (2007).

Table 21: Qualitative and quantitative classes of likelihood of impacts (environmental effect, or resultant change in the flow of an ecosystem service) of a scenario having an ecological consequence to a service from EI (IPCC, 2007)

Likelihood rating	Assessed probability of occurrence	Description
Almost certain	> 90%	Extremely or very likely, or virtually certain. Is expected to occur.
Likely	> 66%	Will probably occur
Possible	> 50%	Might occur; more likely than not
Unlikely	< 50%	May occur
Very unlikely	< 10%	Could occur
Extremely unlikely	< 5%	May occur only in exceptional circumstances

Table 22: Qualitative measures of consequence to ecosystem services arising from impacts linked to scenarios (IPCC, 2007)

Consequence rating	Level of consequence	Environmental effect
Severe	1	Substantial permanent loss of environmental service, requiring mitigation or offset.
Major	2	Major effect on the EI or service, that will require several years to recover, and substantial mitigation.
Moderate	3	Serious effect on the EI or service, that will take a few years to recover, but with no or little mitigation.
Minor	4	Discernable effect on the EI or service, but with rapid recovery, not requiring mitigation.
Insignificant	5	A negligible effect on the EI or service.

Table 23: Levels of risk, assessed as the product of likelihood and consequence in the event of an environmental effect on EI (IPCC, 2007)

Likelihood Rating	Consequence Rating				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	High	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Very unlikely	Low	Low	Low	High	Extreme
Extremely unlikely	Low	Low	Low	Medium	High

The output of the CRA process is an aggregated risk assessment for each of the scenario-EI-ES combinations for each IUA. Not all of these combinations are valuable, and the results are used to prioritise the key ecosystem services at risk per scenario across all IUAs.

The output is thus a prioritised list of risks, with diagnostic and causal descriptions for each priority risk. High and extreme risks are classed as priority risks. These risks and their relative weight (High risk=3, Extreme risk=4) are summed for each scenario to allow for a comparison of cumulative risks between scenarios. The beneficiaries of the identified ES will be at the greatest risk due to a specific scenario.

The CRA was conducted from November to January 2021 during numerous work sessions together with the various subject specialists on the project team. The inputs into the process are informed by the data gathered and specialist studies conducted to date. The field specific CRA work sessions conducted to date during the period 30/12/2020 to 14/01/2020 include the fields of: Hydrology, River Health, Wetlands, Groundwater and Estuaries[1].

8.2 Results

Results of the draft CRA can be found in electronic format in Appendix D. The results presented are the outputs of the field specific work sessions conducted with subject specialists and will be assessed in a verification step with all the specialists. The sections to follow summarise key outputs from the process.

8.2.1 Environmental Hazards

The environmental hazards identified for the varying scenarios are provided here. Please note, each hazard is ecological infrastructure specific, however, to prevent repetition, where suitable, hazards that share impacts have been aggregated below.

8.2.1.1 Impacts on water flow

Alterations of water flow, both rate and volume, in the Thukela catchment are driven by a variety of land-use and management activities including the following:

- Abstraction of surface water by transfers out of the catchment, agriculture, industrial processes, and domestic use,
- Abstraction of ground water for domestic use and agriculture,
- Storage of water in dams and impoundments (impact both waterways and wetlands);
- Timed releases by dams and impoundments, and
- Reduced base flow into estuary resulting in altered hydrological processes due to over abstraction upstream.

8.2.1.2 Impacts on water quality

Alterations of water quality in the Thukela catchment are driven by both point source and diffuse sources of inputs and contaminants from a variety of land-use and management activities including the following:

- Point and diffuse source nutrient contaminants from WWTW, sewerage effluent, commercial and livestock agricultural run-off,
- Historical mining activities resulting in spikes of salinity and metals,

[1] *Interpretation of the risk ratings cautionary note:* The risk assessment undertaken was for the purpose of prioritising ecosystem services that need to be evaluated in the next phase of the project. The risk assessment undertaken here was based on expert analysis and desktop data available and therefore the scale of impact has not yet been assessed. Out of this assessment only ecosystem services that have been comparatively rated as high or extreme are taken further to the next quantification step.

- Sedimentation and turbidity resulting from improper land use management predominantly from subsistence and livestock agriculture,
- Increased runoff from formal irrigation schemes introducing contaminants,
- Introduction of pathogens associated with waste effluent associated with improper management of sewerage works and livestock agriculture associated with waterways,
- Introduction of industrial effluent associated with manufacturing and industrial centres,
- Introduction of water contaminants into groundwater resources within alluvial regions associated with large cities and towns (>10 000 population) and mining.

8.2.1.3 Non-flow impacts

Non-flow hazards identified during the CRA process are provided in Table 25.

Table 24: Hazards identified through the CRA process which are not linked to scenarios

<table>
<tr><th colspan="2">Hazard</th><th>Ecological Infrastructure</th><th>Description</th></tr>
<tr><td colspan="2">Climate Change</td><td>Wetlands (Specifically at higher altitudes)</td><td>Reduced saturation within wetlands due to increased evapotranspiration as a result of climate change</td></tr>
<tr><td rowspan="3">Non-Flow related Impacts</td><td>Land Transformation leading to erosion and sedimentation</td><td>Rivers, Wetlands</td><td>Unsustainable land uses including physical land transformation, overgrazing, vegetation removal, increased runoff from irrigation</td></tr>
<tr><td>Land Transformation</td><td rowspan="2">Estuary</td><td>Alien invasive species along the Estuarine functional zone (in water and in flood zone). These include both plants and other species (e.g., large-mouth bass, other fish species, snail and invertebrate species).
Sugar cane farming within the estuarine functional zone. Note, now that the mouth closes, the sugar cane is periodically flooded. This causes conflict with farmers.</td></tr>
<tr><td>Illegal Activities</td><td>Fishing pressure is directly linked to illegal fishing due to the use of Gill nets. Recreational fishing also has some impact especially when removing larger individuals (e.g., Square Tail Cob and Slinger species)
Sand Mining on banks upstream of the estuary.</td></tr>
</table>

8.2.2 Scenarios and Impact Analysis

The scenarios developed for the Thukela Catchment are described in Table 26 focus on alterations in water retention (dam infrastructure), water transfers, release management and water supply to beneficiaries.

Table 25: Descriptions of scenarios in line with changing supply, demand and associated infrastructure

Scenario		Supply	Demand
1N	Current no EWR	Current (2020) - Water infrastructure	Current Socio-Economic (2020) - Transfers - Irrigation, industrial, domestic and rural supply EWR - **No allocation to EWR**
1PR	Current with PES, riverine only	Current (2020) - Water infrastructure	Current Socio-Economic (2020) - Transfers - Irrigation, industrial, domestic and rural supply EWR - **Specific allocation to river PES**
1PE	Current with PES riverine and estuary	Current (2020) - Water infrastructure	Current Socio-Economic (2020) - Transfers - Irrigation, industrial, domestic and rural supply EWR - **Specific allocation to river and estuary TEC**
1TR	Current with TEC, riverine only	Current (2020) - Water infrastructure	Current Socio-Economic (2020) - Transfers - Irrigation, industrial, domestic and rural supply EWR - **Specific allocation to river TEC**
1TE	Current with TEC, riverine and estuary	Current (2020) - Water infrastructure	Current Socio-Economic (2020) - Transfers - Irrigation, industrial, domestic and rural supply EWR - **Specific allocation to river and estuary TEC**
2N	Medium term, no EWR	Medium term (2030) - No increased water storage infrastructure	Medium term Socio-Economic (2030) - Increased Transfers o Mhlatuze Transfer (double the transfer to 2m/s o Lower Thukela BWS increase - Extract 50ML/d at Mielietuin Site (no dam) - No increase in irrigation, - Increased industrial, domestic and rural supply (2028) EWR - **No allocation to EWR**
2TR	Medium term, with TEC, riverine only	Medium term (2030) - No increased water storage infrastructure	Medium term Socio-Economic (2030) - Increased Transfers o Mhlatuze Transfer (double the transfer to 2m/s o Lower Thukela BWS increase o Extract 50ML/d at Mielietuin Site (no dam) - No increase in irrigation, - Increased industrial, domestic and rural supply (2028) EWR - **Specific allocation to river TEC**
2TE	Medium term with TEC riverine and estuary	Medium term (2030) - No increased water storage infrastructure	Medium term Socio-Economic (2030) - Increased Transfers o Mhlatuze Transfer (double the transfer to 2m/s o Lower Thukela BWS increase o Extract 50ML/d at Mielietuin Site (no dam) - No increase in irrigation, - Increased industrial, domestic and rural supply (2028) EWR - **Specific allocation to river and estuary TEC**
3N	Long term, no EWR	Long-term (2045) - Increased water storage infrastructure, o Mielietuin Dam o Jana Dam o Little Mooi Irrigation Dam	Long-term Socio-Economic (2045) - Increased demand as per Sc 2 - Increased Transfers o Full transfer Mooi-Mgeni o Mhlatuze Transfer (increase by 1m/s) o Extract 100ML/d from Mielietuin Dam - No increase in irrigation, - Increased industrial, domestic and rural supply (2045)

Scenario		Supply	Demand
		o Buffalo water supply dam (for Newcastle) o Raise Spioenkop Dam (additional capacity)	**EWR** - **No allocation to EWR**
3TR	Long term with TEC, riverine only	Long-term (2045) - Increased water storage infrastructure, o Mielietuin Dam o Jana Dam o Little Mooi Irrigation Dam o Buffalo water supply dam (for Newcastle) o Raise Spioenkop Dam (additional capacity)	Long-term Socio-Economic (2045) - Increased demand as per Sc 2 - Increased Transfers o Full transfer Mooi-Mgeni o Mhlatuze Transfer (increase by 1m/s) o Extract 100ML/d from Mielietuin Dam - No increase in irrigation, - Increased industrial, domestic and rural supply (2045) **EWR** - **Specific allocation to river TEC**
3TE	Long term with PES riverine and estuary	Long-term (2045) - Increased water storage infrastructure, o Mielietuin Dam o Jana Dam o Little Mooi Irrigation Dam o Buffalo water supply dam (for Newcastle) o Raise Spioenkop Dam (additional capacity)	Long-term Socio-Economic (2045) - Increased demand as per Sc 2 - Increased Transfers o Full transfer Mooi-Mgeni o Mhlatuze Transfer (increase by 1m/s) o Extract 100ML/d from Mielietuin Dam - No increase in irrigation, - Increased industrial, domestic and rural supply (2045) **EWR** - **Specific allocation to river and estuary TEC**

Scenarios were analysed in line with the hazards identified above. The focus was to determine the cause-and-effect linkages between changing scenarios and catchment specific hazards. If varying scenario did not influence a specific hazard, then the hazard did not form part of the CRA process.

Table 26: Assessment of causal linkage between scenario implementation and the influence on identified hazards

IUA	Name	Ecological Infrastructure	Identified Hazard	Scenario to exacerbate hazard										
				1N 1	1PR 2	1PE 3	1TR 4	1TE 5	2N 6	2TR 7	2TE 8	3N 9	3TR 10	3TE 11
1	Upper Buffalo	Rivers/Streams/Riparian	High Flows- EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Extractions for urban and irrigation demand	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Reduced Volume – Climate Change	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	Over abstraction	No	No	No	No	No	No	No	No	No	No	No
2	Ngagane	Rivers/Streams/Riparian	Low flows – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Non flow related impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	Over-abstraction	No	No	No	No	No	No	No	No	No	No	No
3	Middle Buffalo	Rivers/Streams/Riparian	High Flows- EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Water Quality	No	No	No	No	No	No	No	No	No	No	No
		Wetlands	Land Transformation	No	No	No	No	No	No	No	No	No	No	No
		Alluvial Aquifers	None- Alluvial System	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	Lower Buffalo	Rivers/Streams/Riparian	WQ – sediment, nutrient, pathogens	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	Non-Flow Impacts	No	No	No	No	No	No	No	No	No	No	No
		Wetlands	None – few wetlands	No	No	No	No	No	No	No	No	No	No	No
		Alluvial Aquifers	None- Alluvial System	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	Blood	Rivers/Streams/Riparian	High Flows- EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	Water Quality - Pathogens	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Reduced Volumes - Dams	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
6	Sunday	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ - Sediments	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifer	Over abstraction	No	No	No	No	No	No	No	No	No	No	No
7	Upper Mooi	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ – Pathogens, nutrients- sewerage, factory effluent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Reduced flow – dams	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	No current impacts	No	No	No	No	No	No	No	No	No	No	No
8	Lower Mooi	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ – Pathogens, nutrients-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Reduced volume - Plantations	No	No	No	No	No	No	No	No	No	No	No
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	None	No	No	No	No	No	No	No	No	No	No	No
9	Middle/ Lower Bushmans	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ – Effluent, pathogens, nutrients	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	None	No	No	No	No	No	No	No	No	No	No	No

IUA	Name	Ecological Infrastructure	Identified Hazard	Scenario to exacerbate hazard										
				1N 1	1PR 2	1PE 3	1TR 4	1TE 5	2N 6	2TR 7	2TE 8	3N 9	3TR 10	3TE 11
10	Upper Tugela	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	Over abstraction	No	No	No	No	No	No	No	No	No	No	No
11	Klip River	Rivers/Streams/Riparian	WQ - Nutrients	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	Over abstraction	No	No	No	No	No	No	No	No	No	No	No
		Alluvial Aquifers	None- Alluvial System	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12	Middle Tugela	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Wetlands	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Alluvial Aquifers	None- Alluvial System	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13	Lower Tugela	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ – Pathogens, nutrients,	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	Land use impacts	No	No	No	No	No	No	No	No	No	No	No
		Wetland	None – few wetlands	No	No	No	No	No	No	No	No	No	No	No
		Aquifer	None	No	No	No	No	No	No	No	No	No	No	No
14	Escarpment	Rivers/Streams/Riparian	Non-Flow	No	No	No	No	No	No	No	No	No	No	No
		Wetlands	Climate Change – Reduced Volumes	No	No	No	No	No	No	No	No	No	No	No
		Aquifers	None	No	No	No	No	No	No	No	No	No	No	No
15	Tugela Mouth	Rivers/Streams/Riparian	Low Flow – EWR not met	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Rivers/Streams/Riparian	WQ – Pathogens, nutrients, effluents from land use	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Estuary	Reduced Base Flow	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Estuary	Water Quality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Tugela Banks	Reduced inputs from estuary	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

8.3 Comparative Risk Assessment

The results of the Comparative Risk Assessment (CRA)[2] are discussed in the sections to follow. The raw results for the CRA are included in Appendix D.

8.3.1 IUA 1

IUA 1, the Upper Buffalo IUA, straddles the border of Mpumalaga (Dr Pixley Ka Isaka Seme Local Municipality) and Kwa-Zulu Natal (Newcastle and Emadlangeni Local Municipalities) provinces. The IUA principally includes the towns of Volksrust, Wakkerstroom, Charlestown and Groenvlei as well as the Mabola Protected Environment and Tafelkop Nature Reserve to the north-east. Key water transfers are from the Zaaihoek Transfer Scheme transferring water to the Gootdraai Dam and eventually to the Vaal system. The population of IUA 1 is approximately 46 051 with approximately 10 509 households. Mixed commercial dryland and irrigated agriculture dominate the land use within the IUA which are supported by local economies around the key towns. The town of Volksrus represents the commercial centre of the IUA, accounting for most of the region's manufacturing and commercial activities. Irrigation for agriculture is distributed along the Buffels and Ngogo Rivers.

Key water demands in IUA 1 are summarised in Table 28.

Table 27: Key water demand categories, locations and source of water in IUA 1

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 19: Wakkerstroom, Esizamelani DEM 20: Volksrust, Charlestown, Vukhuzakhe	DEM 19: Thaka River DEM 10: Buffalo River Zaaihoek Dam
- **Irrigation demand**	South and south western regions with lower demand in the upper catchment (TM31 and TM26)	TM31-Lower Buffalo River Ngogo River Slangrivier TM26-Upstream Zaaihoek (Thaka and Slang)
- **Transfers**	Vaal Catchment (TM26)	Zaaihoek Dam

Key ecological infrastructure in IUA 1 is summarised in Table 29.

Table 28: Key aquatic ecological infrastructure identified in IUA 1

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Buffalo River and its tributaries
Wetlands	Wakkerstroom and Groenvlei priority wetlands
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Much of the IUA along the escarpment

[2] Interpretation of the risk ratings cautionary note: The risk assessment undertaken was for the purpose of prioritising ecosystem services that need to be evaluated in the next phase of the project. The risk assessment undertaken here was based on expert analysis and desktop data available and therefore the scale of impact has not yet been assessed. Out of this assessment only ecosystem services that have been comparatively rated as high or extreme are taken further to the next quantification step.

The general location of the demands and ecological infrastructure are indicated in Figure 20. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

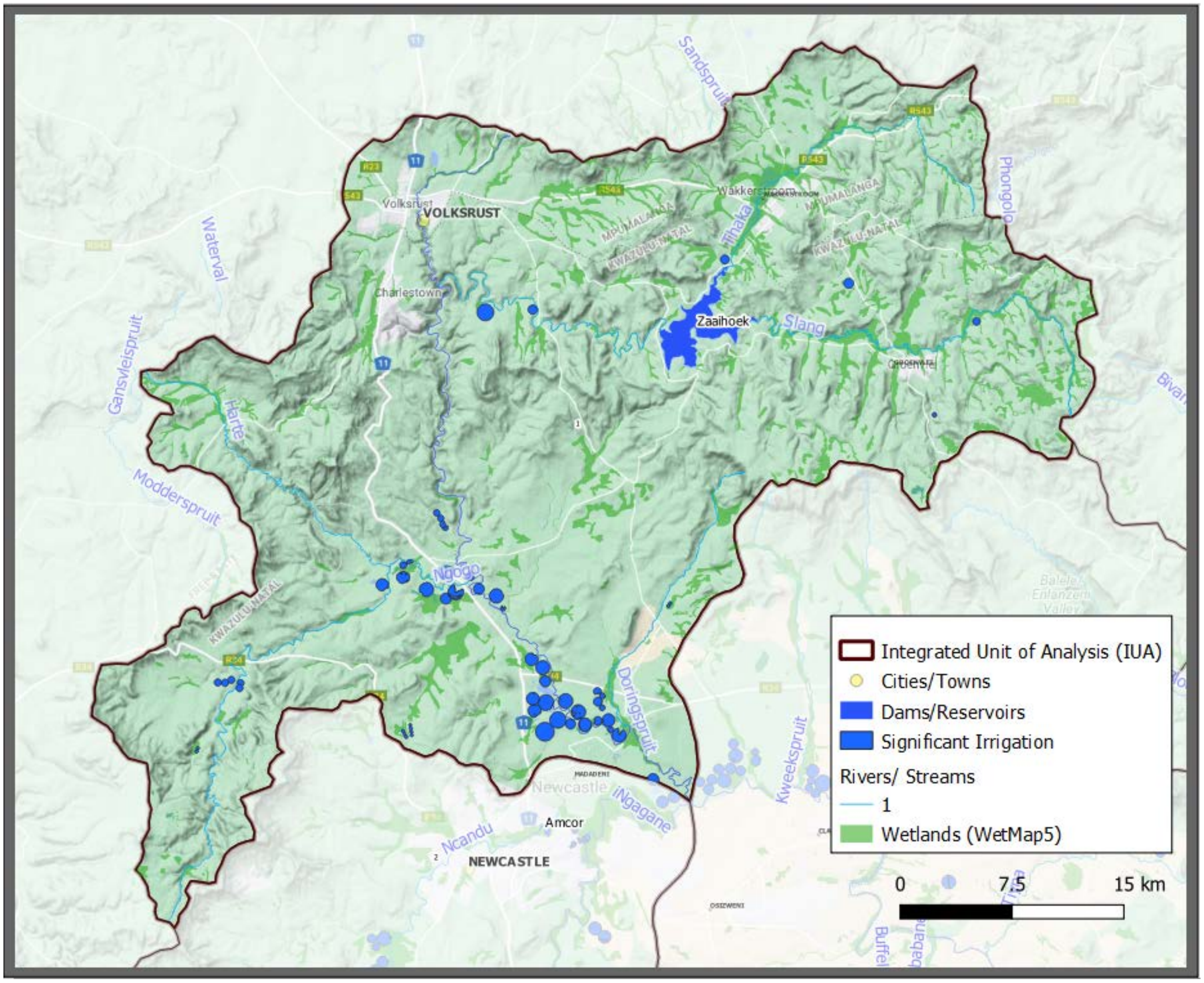


Figure 20: Locality of the demands, and ecological infrastructure are indicated for IUA 1

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource.

8.3.1.1 Environmental Effect Statement

There is currently not sufficient water available in IUA1 to effectively supply the current demands (93% in scenario 1). As the urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 1 is provided in Table 30.

Table 29: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 1

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
1	EWR	0.00	0.00	0.00	0.00	53.83	53.83	53.83	53.80	0.00	53.86	53.86	0.00	53.90	53.86
1	Irrigation Demand	13.22	13.22	13.22	10.60	6.56	6.56	6.53	5.96	10.75	6.43	5.87	10.69	7.98	6.72
1	Transfers	68.12	68.12	68.12	65.66	54.81	54.81	55.03	53.42	47.68	41.88	40.56	39.83	37.59	33.90
1	Urban Demands	3.32	4.22	5.18	2.87	2.37	2.37	2.37	2.27	3.60	3.06	2.90	4.35	4.01	3.72
1	**TOTAL (Formal Economy Only)**	**84.66**	**85.56**	**86.52**	**79.12**	**63.73**	**63.73**	**63.92**	**61.65**	**62.03**	**51.37**	**49.32**	**54.87**	**49.57**	**44.34**
1	**TOTAL ALLOCATION (incl EWR)**				**79.12**	**117.57**	**117.57**	**117.76**	**115.45**	**62.03**	**105.24**	**103.19**	**54.87**	**103.47**	**98.20**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 31 describes the environmental effects as aggregated for various scenarios.

Table 30: Environmental effect statement aggregated by scenario for IUA 1

Scenario	Description	Environmental Effect in IUA 1
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** Extractions for irrigation and urban demand upstream and downstream of Zaaihoek Dam. The waterways are utilised to distribute water for downstream use through releases from Zaaihoek Dam. These activities result in both high and low stream flows that do not align with natural flow cycles.

Scenario	Description	Environmental Effect in IUA 1
		Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly cycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Temporal impacts to habitats are driven by alterations of the following: - Flow Volume (impacts depth of microhabitats and other various biotopes, or ability for species to migrate, flood events); - Flow Rate (impacts rifles, flushes, dynamics between shallows and river banks) ; - Water temperature (this trigger may impact fish species spawning and productivity-e.g. high release in winter triggers fish spawning but unnaturally cold water impacts spawning success. Furthermore, fluctuations in temperature will result in fluctuations in electrical conductivity which may affect aquatic biota). - Water quality (eutrophication, microhabitats naturally vary over the year e.g. Flush events cause changes in water quality and stimulate spawning) These conditions vary naturally over time to maintain species diversity. Impacts on any trophic level could drive a cascade effect. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering of habitats (algae, silt, sediments) resulting in poor habitat availability and loss of aquatic biota. Low flows and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats and aquatic biota dependent on vegetation or using this habitat for cover/protection/refugia. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. Increased flows would likely have a positive effect on non-water provisioning services and cultural services are closely associated with wetland systems as opposed to waterways. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Habitats for species	The IUA represents areas where biotic species are highly flow dependent and there is a high heterogeneity of habitats.	Almost certain	Moderate	High	Highly heterogeneity of habitats re an almost certain impact from al flows. The consequence of this i would be moderate due to this di

Scenario	Description	Environmental Effect in IUA 1

Wetlands

Urban demands for Wakkerstroom, Esizamelani as well as irrigation demands are supplied from upstream of the Zaaihoek dam. The close association that the Wakkerstroom wetland has with these demands results in likely impact from increasing urban demand but more importantly no allocation of water to maintain the EWR. The impacts will result in reduced saturation of which are exacerbated by impacts of climate change. The Wakkerstroom wetland is a peatland of which if exposed to reduced flows, risks a loss of perennially causing a loss of peat. The peat is fundamental to habitats and flow of ecosystem services. In the worst case scenario a loss of perennially could result in peat fires and burning. Furthermore, impacts on the functioning of the wetland would result to reduced regulation of water and ultimately water to Zaaihoek Dam.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Habitats for species	See environmental effect statement. The cascade effect- habitat response.	Likely	Moderate	High	Note number of red data species (CR white winged f etc). Nationally significant Consequence of this loss w moderate. The likelihood o however is likely as the pe are very rare.
Landscape & amenity values	There are holiday homes and farms in the region that are valuable due to their placement. (similar to Dullstroom area)	Likely	Moderate	High	The presence of high ecoto the region results in high la amenity value.
Ecotourism & recreation	Important birding site. Both wetland and grassland. The impact on habitats would impact the tourism industry.	Likely	Moderate	High	"Lifers"- birders who specif to a region for key bird sp The presence of the speci draw card here in Wakkers The impacts are likely v moderate consequence ecotourism.
Educational values	Wakkerstroom is educationally significant. Note evidence of stored knowledge that is currently	Likely	Moderate	High	There is investment link training here directly or

<table>
<tr><th>Scenario</th><th>Description</th><th>Environmental Effect in IUA 1</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td>being researched. Birdlife SÁ-Have training centre there</td><td></td><td></td><td></td><td>wetland. Likely impacts with moderate consequences.</td></tr>
<tr><td>Inspirational Value</td><td>Linked to high ecotourism value of the region.,</td><td>Likely</td><td>Moderate</td><td>High</td><td>The linkage to ecotourism results in a likely impact which will have moderate consequences</td></tr>
</table>
The Groenvlei priority wetland will likely not be impacted due to its placement in the landscape.
Aquifers
Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region.
SWSA
The flow related nature of the impacts of these scenarios result in an unlikely impact to SWSA.
Socio-Economic Effect
Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 93%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.</td></tr>
<tr><td>2 (1PR)</td><td>Allocate to maintain current state (PES of C) in rivers. Allocate where possible to demand</td><td>Maintenance of current state of which experiences both high and low flows as a result of released flow from Zaaihoek Dam, for demands downstream. This results in increased flows from August-September. The increased flows are not more than natural flows. During dry periods however velocities may be higher than natural. The EWR is not met in dry periods.
This represents modified flows and therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as in dry seasons water will be allocated to maintaining the PES. The requirement of 53.86 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.</td></tr>
<tr><td>3 (1PE)</td><td>Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand</td><td>There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.</td></tr>
<tr><td>4 (1TR), 7 (2TR) and 10 (3TR)</td><td>Allocate to achieve TEC of C (Rivers only). Allocate where possible to demand</td><td>The allocation of 53,86 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 1 is equivalent to the PES for IUA 1 and therefore the environmental effects are the same as that of scenario 2.</td></tr>
</table>

Scenario	Description	Environmental Effect in IUA 1
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 53,86 million m3/a will ensure the EWR for both estuaries and rivers are met. The TEC for IUA 1 is equivalent to the PES for IUA 1 and therefore the environmental effects are the same as that of scenario 2.

8.3.2 IUA 2

IUA 2, the Ngagane River IUA, includes the Newcastle and Dannhauser local municipalities. The IUA includes the towns of Newcastle, Dannhauser and iNgagane as well as the Ncandu Nature reserve and Chelmsford Nature Reserve. Water resources in the IUA include the Ngagane River and tributaries as well as the Ntshingwayo and Amcor dams. The population of IUA 2 is approximately 173 661 with approximately 42 634 households. Mixed commercial dryland and irrigated agriculture dominate the land use within the IUA which are supported by local economies around the key town of Newcastle, where there is also significant manufacturing activity. IUA 2 has a large area devoted to annual crop cultivation and miscellaneous agriculture.

Key water demands in IUA 2 are summarised in Table 32.

Table 31: Key water demand categories, locations and source of water in IUA 2

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 10: Newcastle, Madedini & Oszweni, Rural DEM 21: Durnacol/Dannhauser, Eskom, Siltec DEM 22: Iscor Newcastle	DEM 10: Ntshingwayo Dam DEM 21: Ntshingwayo Dam DEM 22: Ntshingwayo Dam
- **Irrigation demand**	Throughout the catchment, upstream and downstream of Ntshingwayo dam (TM24 and TM25)	TM24.IRD: Upstream Ntshingwayo Dam TM 25: Downstream of dam - Ngagane, Horn, Ncandu, Rivers

Key ecological infrastructure in IUA 2 is summarised in Table 33.

Table 32: Key aquatic ecological infrastructure identified in IUA 2

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Ngagane river and its tributaries
Wetlands	No priority wetlands
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Along the western escarpment of the IUA

The general location of the demands and ecological infrastructure are indicated in Figure 21. Extraction points on water resources are key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

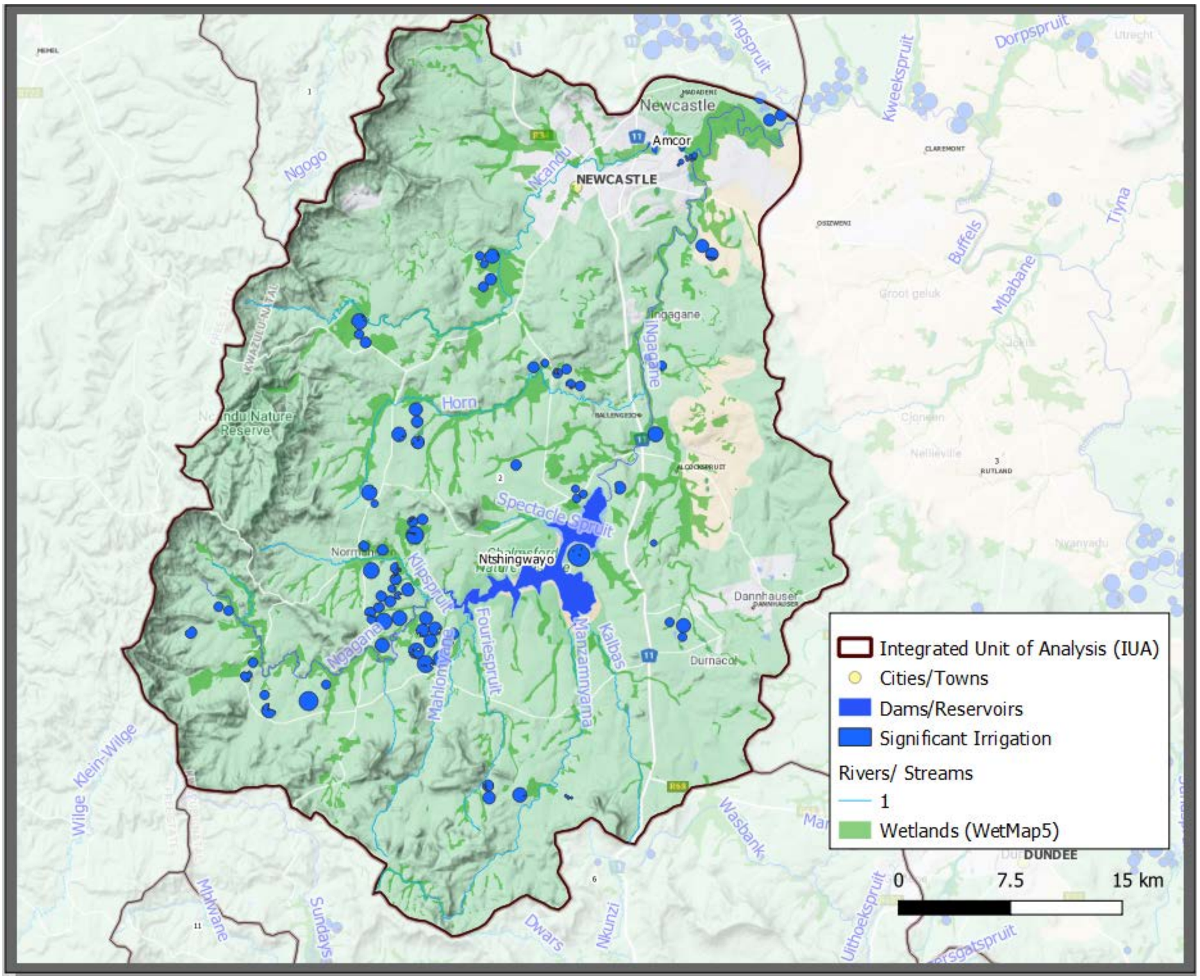


Figure 21: Locality of the demands, and ecological infrastructure are indicated for IUA 2

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.1.2 Environmental Effect Statement

There is currently not sufficient water available in IUA2 to effectively supply the current demands (97% in scenario 1). As urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 2 is provided in Table 34.

Table 33: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 2

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
2	EWR	0.00	0.00	0.00	0.00	111.07	111.07	113.09	113.09	0.00	113.03	113.03	0.00	113.21	113.09
2	Irrigation Demand	11.21	11.21	11.21	9.56	8.01	8.01	8.07	7.76	9.56	8.07	7.79	9.52	8.70	8.01
2	Urban Demands	53.27	57.52	62.22	53.26	35.54	35.54	35.64	33.27	57.52	37.53	35.04	61.59	47.24	40.78
2	**TOTAL (Formal Economy Only)**	**64.48**	**68.74**	**73.43**	**62.82**	**43.55**	**43.55**	**43.71**	**41.03**	**67.08**	**45.60**	**42.83**	**71.11**	**55.94**	**48.79**
2	**TOTAL ALLOCATION (incl EWR)**				**62.82**	**154.62**	**154.62**	**156.80**	**154.12**	**67.08**	**158.63**	**155.85**	**71.11**	**169.16**	**161.87**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 35 describes the environmental effects as aggregated for various scenarios.

Table 34: Environmental effect statement aggregated by scenario for IUA 2

Scenario	Description	Environmental Effect in IUA 2
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** Although the waterways are utilised to distribute water for downstream use through releases from Ntshingwayo Dam, most of the water in Ntshingwayo Dam is used for urban demands in IUA 2. These activities result in much lower stream flows that do not align with natural flow cycles. These low flows exacerbate existing water quality impacts which are evident in the catchment. Water

Scenario	Description	Environmental Effect in IUA 2
		quality issues are present due to historical mines in the region (high salinity, some spikes in metals, some turbidity) and sewerage effluent downstream of Newcastle. Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows, lowers habitat diversity across a yearly cycle and therefore influences species diversity and physiological rhythms and processes. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Increased concentration of metals, salts and turbidity will impact fish and macroinvertebrates (physiological stress) however no major impacts on habitats. Eutrophication will be caused by sewerage effluent, more in dry months, especially with low flows Increased nutrients would likely drive primary production. Temporal impacts to habitats are driven by alterations of the following: - Flow Volume (Impacts depth of microhabitats or ability for species to migrate, flood events); - Flow Rate (Impacts rifles, flushes, dynamics between shallows and riverbanks) - Water temperature (Impacts spawning and productivity-e.g., high release in winter triggers fish spawning but unnaturally cold water impacts spawning success) - Water quality (eutrophication, microhabitats naturally vary over the year e.g., Flush events cause changes in water quality and stimulate spawning) These conditions vary naturally over time to maintain species diversity. Impacts on any trophic level could drive a cascade effect. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. Impacts of modified flow are almost certain however with minor consequences on habitats for species in IUA 2 because of low diversity of habitats. Impacts on non-water provisioning services are relatively low due to the impact the scenario would have on primary productivity and the lack of cultural beneficiaries and subsequent impacts results in a low risk to cultural services. Results of the CRA process indicated only low and medium risks to ecosystem services as a result of these scenarios.

Scenario	Description	Environmental Effect in IUA 2
		Wetlands: No priority wetlands were identified in this IUA. **Aquifers** Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region. **SWSA** The flow related nature of the impacts of these scenarios results in an unlikely impact to the SWSA. **Socio-Economic Effect** Even though the EWR is not considered in these scenarios, the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 97%). As a result, water is allocated based on assurance of supply (penalties of no supply) and urban beneficiaries receive full demand and irrigation only receives 85%.
2 (1PR)	Allocate to maintain current state (PES C) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences low flows above and below Ntshingwayo Dam due to the position of the Dam and irrigation demands upstream. This represents modified flows and water quality impacts associated with the land use and therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as in dry seasons water will be allocated to maintaining the PES. The impacts on the non-priority wetlands upstream of Ntshingwayo Dam are not identified as significant. The requirement of 111 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of C and B/C (Rivers only). Allocate where possible to demand	The allocation of 113 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 2 is higher than the PES for IUA 2 and therefore the environmental effects would be similar in nature however reduced to that of scenario 2.

Scenario	Description	Environmental Effect in IUA 2
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (rivers and estuary). Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the same as scenario 4, 7 and 10.

8.3.3 IUA 3

IUA 3, the Middle Buffalo IUA, includes the Emadlangeni, Endumeni and Dannhauser local municipalities. The IUA includes the towns of Dundee, Utrecht, Claremont, Osizweni and Rutland as well as the Balele/Enlanzeni and Utrecht Town Park Nature Reserve. Water resources in the IUA include the Middle Buffalo River and tributaries. The population of IUA 3 is approximately 342 959, with approximately 75 312 households. Mixed commercial dryland and irrigated agriculture dominate the land use within the IUA which are supported by local economies around the key town of Utrecht. Some mining and quarrying activity can also be found in this IUA. Miscellaneous agriculture appears to be the most significant land cover in IUA 3, while pivot irrigation and residential usage appear to account for the bulk of water demand. Very little commercial or industrial activity is present in this IUA, however there are significant mining operations in the northern and southwestern areas.

Key water demands in IUA 3 are summarised in Table 36.

Table 35: Key water demand categories, locations and source of water in IUA 3

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 11A: Utrecht DEM 11B: Dundee/Glencoe	DEM 11A: Buffalo River DEM 11B: Dam 626 and Buffalo River
- **Irrigation demand**	Northern and southern regions (TM27 and TM28A)	TM 27: Buffalo River TM28A: Dam 626

Key ecological infrastructure in IUA 3 is summarised in Table 37.

Table 36: Key aquatic ecological infrastructure identified in IUA 3

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Buffalo river and its tributaries
Wetlands	Boschoffsvlei priority wetlands- Utrecht
Aquifers	Alluvial aquifers with high surface to groundwater interaction. Moderate to low shale siltstone aquifer resources.

The general location of the demands and ecological infrastructure are indicated in Figure 22. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

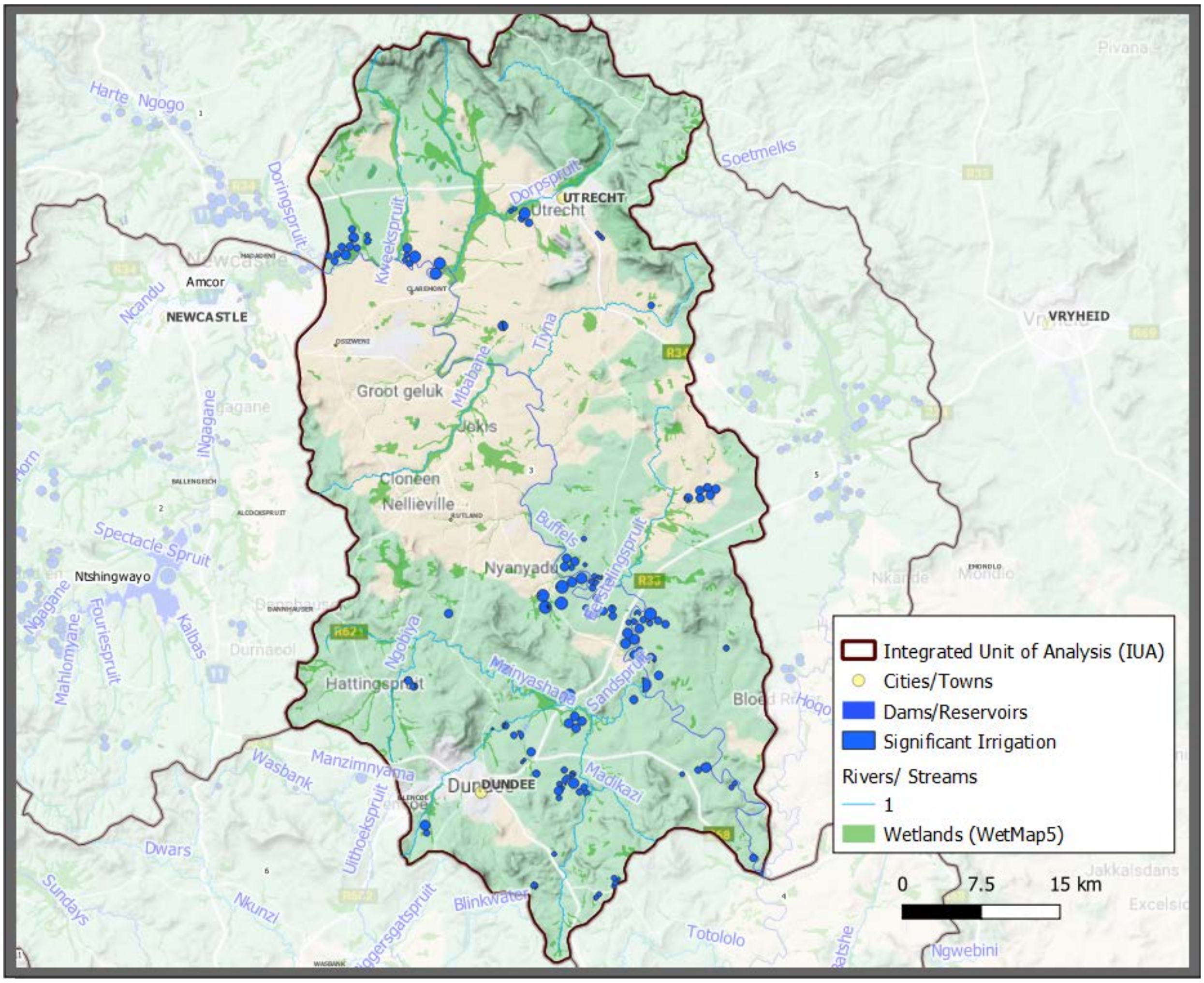


Figure 22: Locality of the demands, and ecological infrastructure are indicated for IUA 3

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.3.1 Environmental Effect Statement

There is currently not sufficient water available in IUA3 to effectively supply the current demands (99% in scenario 1). As urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 3 is provided in Table 38.

Table 37: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 3

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
3	EWR	0.00	0.00	0.00	0.00	257.05	257.05	284.20	284.20	0.00	284.20	284.20	0.00	284.20	284.20
3	Irrigation Demand	26.88	26.88	26.88	26.49	24.09	24.09	24.03	23.43	26.49	24.50	23.94	26.49	25.61	23.53
3	Urban Demands	11.44	13.02	18.29	11.45	10.69	10.69	10.66	10.56	13.02	12.30	12.11	18.29	17.88	16.93
3	**TOTAL (Formal Economy Only)**	**38.32**	**39.91**	**45.17**	**37.94**	**34.78**	**34.78**	**34.69**	**34.00**	**39.51**	**36.80**	**36.05**	**44.78**	**43.49**	**40.46**
3	**TOTAL ALLOCATION (incl EWR)**				**37.94**	**291.83**	**291.83**	**318.89**	**318.20**	**39.51**	**321.00**	**320.25**	**44.78**	**327.69**	**324.66**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Figure 4-12 describes the environmental effects as aggregated for various scenarios.

Table 38: Environmental effect statement aggregated by scenario for IUA 3

Scenario	Description	Environmental Effect in IUA 3
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** IUA 3 is currently impacted by increased flows from Zaaihoek Dam (IUA 1). This change occurs in the Buffalo River. This results in high flows (higher than natural?) in release months but a low flow in months of no release (when not considering the EWR). This, similarly to IUA 1, does not align with natural flow cycles. Furthermore, there are increased concentrations of nutrients from upstream waste water treatment plants (sewerage) and upstream and adjacent irrigation due to land uses.

Scenario	Description	Environmental Effect in IUA 3
		Sedimentation is also a risk, arising from subsistence and livestock (grazing and trampling) agriculture throughout the catchment. Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly cycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Increased concentration of nutrients together with high flows will likely drive primary production. Sedimentation would impact on carrying capacities of dams and influence irrigation operations. Temporal impacts to habitats are driven by alterations of the following: - Flow Volume (Impacts depth of microhabitats or ability for species to migrate, flood events); - Flow Rate (Impacts rifles, flushes, dynamics between shallows and river banks) ; - Water temperature (Impacts spawning and productivity-e.g. high release in winter triggers fish spawning but unnaturally cold water impacts spawning success) - Water quality (eutrophication, microhabitats naturally vary over the year e.g. Flush events cause changes in water quality and stimulate spawning) These conditions vary naturally over time to maintain species diversity. Impacts on any trophic level could drive a cascade effect. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. Impacts of modified flow are almost certain however with minor consequences on habitats for species in IUA 3 because of the presence of a low diversity of habitats. Impacts on non-water provisioning services are relatively low due to the impact the scenario would have on primary productivity and the lack of cultural beneficiaries and subsequent impacts results in a low risk to cultural services. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

<table>
<tr><th>Scenario</th><th>Description</th><th>Environmental Effect in IUA 3</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>Ecosystem Service</th><th>Description</th><th>Likelihood of Impact</th><th>Consequence of Impact</th><th>Risk Rating</th><th>Risk Description</th></tr>
<tr><td>Fresh Water (Natural Sources)</td><td>Communities that have no formal water sources/ Livestock grazers and subsistence irrigators</td><td>Almost certain</td><td>Moderate</td><td>High</td><td>The presence of zero flows in a highly rural landscape results in moderate consequences to rural communities. The likelihood of impact is almost certain.</td></tr>
<tr><td>Fresh Water (Natural Sources)</td><td>Communities that have no formal water sources/ Livestock grazers and subsistence irrigators</td><td>Almost certain</td><td>Moderate</td><td>High</td><td>The extent of water quality issues results in a moderate consequence with an almost certain likelihood of impact</td></tr>
</table>
Wetlands
The Boschoffsvlei priority wetland is situated in the upper catchment along the Dorpspruit at Utrecht. Irrigation and urban demands in this region are sourced from the Buffalo river downstream of the wetland. As a result, the wetland is not at risk.
Aquifers
Impacts on aquifers are likely in this IUA due to the alluvial nature of aquifers and the surface to groundwater interaction. No EWR allocation would therefore have an impact on groundwater recharge and quality of groundwater resources. The likelihood is possible that low flows would reduce recharge and consequence would be minor as there are no significant beneficiaries of groundwater resources in the IUA.
Socio-Economic Effect
Even though the EWR is not considered in these scenarios, the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 99%). As a result, water is allocated based on assurance of supply (penalties of no supply) and urban beneficiaries receive full demand and irrigation only receives 99%.
</td></tr>
<tr><td>2 (1PR)</td><td>Allocate to maintain current state (PES- D) in rivers. Allocate where possible to demand</td><td>Maintenance of current state of which experiences high and modified flows. Increased flows as per hazard from IUA 1 (not necessarily activities from this IUA). There are some zero flows August to October. The EWR is not met in dry periods. This represents modified flows and given the existing land uses and associated water quality impacts, represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons).</td></tr>
</table>

Scenario	Description	Environmental Effect in IUA 3
		The requirement of 257 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of C/D (Rivers only). Allocate where possible to demand	The allocation of 284 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 3 is higher than the PES for IUA 3 and therefore the environmental effects would be similar in nature however reduced in magnitude compared to that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the same as scenario 4, 7 and 10.

8.3.4 IUA 4

IUA 4, the Lower Buffalo IUA, includes the Msinga, Nqutu and Endumeni local municipalities. The IUA does not have large settlements with the largest being the village of Nqutu. There are no protected areas or expansive ecological features. Water resources in the IUA include the Lower Buffalo River and tributaries. The population of IUA 4 is approximately 100 993 with approximately 19608 households. Activities in this IUA consists mainly of subsistence agriculture. Although no particularly high-water consumption activities are based in this IUA, the rural communities rely heavily on the ecosystem services of the region. IUA 4 exhibits some of the lowest intensity agricultural and industrial use of the whole region under study. The high proportion of subsistence agriculture, however, points to the vital importance of ecosystem services in this area.

Key water demands in IUA 4 are summarised in Table 40.

Table 39: Key water demand categories, locations, and source of water in IUA 4

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 12: Umzinyathi DC	DEM 12: Buffalo River

Key ecological infrastructure in IUA 4 are summarised in Table 41.

Table 40: Key aquatic ecological infrastructure identified in IUA 4

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Middle Buffalo river and its tributaries
Wetlands	No Priority wetlands-very few wetlands overall.
Aquifers	Alluvial aquifers with high surface to groundwater interaction. Moderate to low shale siltstone aquifer resources.

The general location of the demands and ecological infrastructure are indicated in Figure 4-4. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

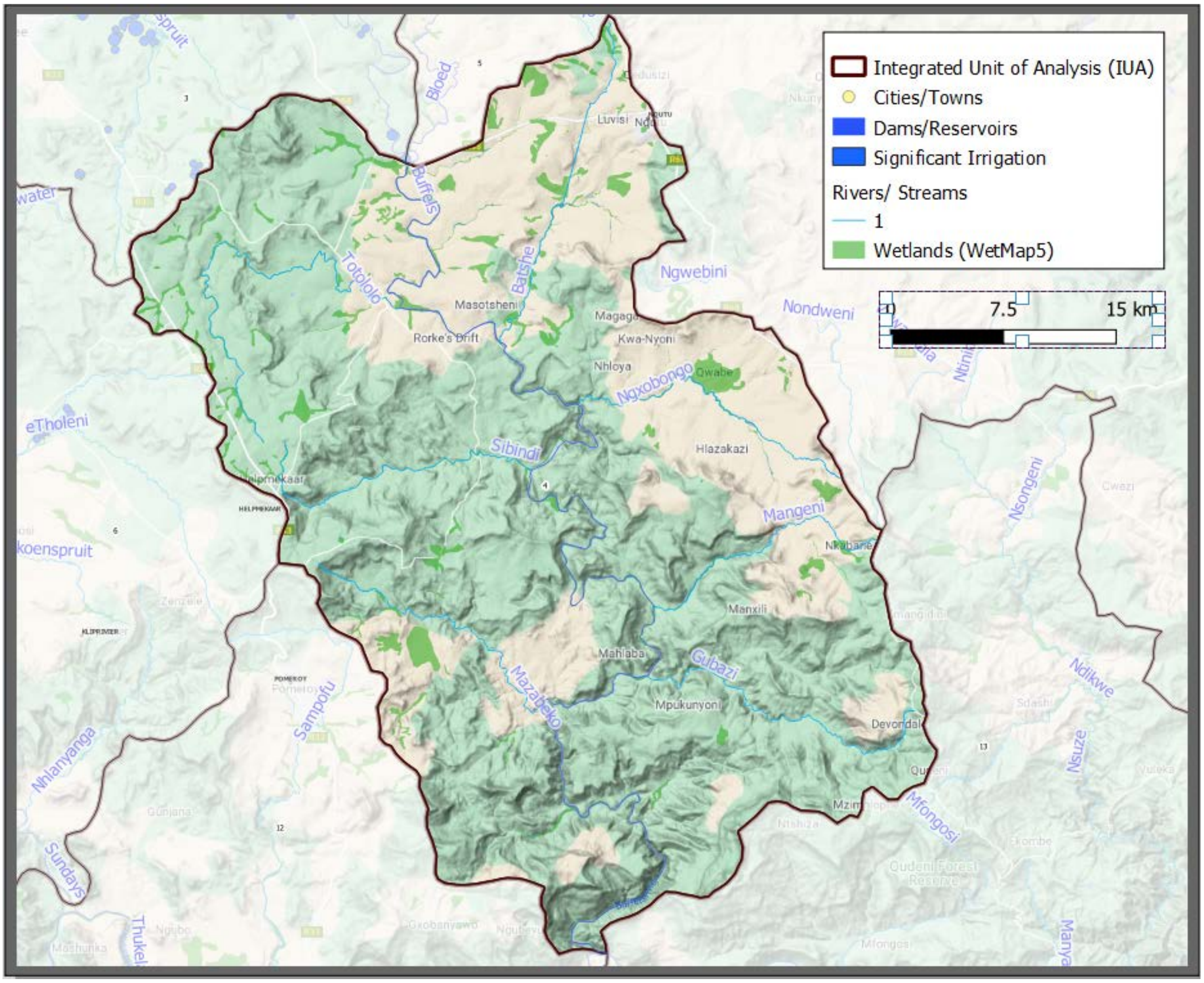


Figure 23: Locality of the demands, and ecological infrastructure are indicated for IUA 4

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.4.1 Environmental Effect Statement

There is currently sufficient water available in IUA4 to effectively supply the current demands (excludes EWR). As urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 4 is provided in Table 42.

Table 41: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 4

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
4	EWR	0.00	0.00	0.00	0.00	190.73	190.73	190.73	190.73	0.00	190.73	190.73	0.00	190.73	190.73
4	Urban Demands	3.39	6.18	12.05	3.41	3.15	3.15	3.15	3.12	6.18	5.80	5.71	12.05	11.73	10.94
4	**TOTAL (Formal Economy Only)**	**3.39**	**6.18**	**12.05**	**3.41**	**3.15**	**3.15**	**3.15**	**3.12**	**6.18**	**5.80**	**5.71**	**12.05**	**11.73**	**10.94**
4	**TOTAL ALLOCATION (incl EWR)**				**3.41**	**193.88**	**193.88**	**193.88**	**193.85**	**6.18**	**196.53**	**196.44**	**12.05**	**202.46**	**201.67**

There is currently sufficient water available to allocate to the very low demand in the catchment (augment system lower down). The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 43 describes the environmental effects as aggregated for various scenarios.

Table 42: Environmental effect statement aggregated by scenario for IUA 4

Scenario	Description	Environmental Effect in IUA 4
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** Although the IUA receives modified flows from upstream activities, water quality issues are the key environmental impact in this IUA due to the highly rural nature of beneficiaries within the catchment and cumulative impacts from upstream. More specifically issues include increased sediments, nutrient impacts and pathogens.

Scenario	Description	Environmental Effect in IUA 4
		Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly cycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Pathogens have no major impact on productivity however more on direct consumption of water (freshwater and recreation). Increased nutrients cause eutrophication in drier months which has negative impacts on ecosystem functionality and therefore drives increased primary productivity. Suspended sediments impact microhabitats by preventing light penetration and siltation which reduces heterogeneity of waterways (loss of interstitial habitat in riffles and siltation of pools). It is unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive due to nutrients), however high nutrients, can lead to algae blooms which can impact other aspects, such as irrigation equipment, and even lead to toxicity to animals should the lagal blooms be severe. It is however likely it would have an effect on the aquatic biota (fish and macroinvertebrates) within the streams, ultimately impacting on food provision. The presence of livestock grazers in the region, but no obvious fishing subsistence means the consequences would be minor. Similarly, the presence of traditional dwellings in the IUA and the use of raw materials for construction means consequences would likely be positive. It is unlikely that the water quality issues would impact the cultural services (water to livestock and households will be negatively impacted – health concern) of these traditional areas. The consequence of impact to the traditional communities are moderate. Likely major consequences to habitats for species due to existing poor conditions and existing homogenous habitats. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Subsistence agriculture and 35% of households rely on rivers/streams for primary water source	Possible	Severe	Extreme	The nature of contaminants results in a possible impact. The impacts on an IUA which is characteristic of high dependency (35% of households) of households on rivers and streams for their primary water source is severe.

<table>
<tr><th>Scenario</th><th>Description</th><th>Environmental Effect in IUA 4</th></tr>
<tr><td></td><td></td><td>Wetlands
The scenarios do not have significant impacts on wetlands in the IUA.
Aquifers
No EWR and low flows in Alluvial systems means the recharge rate will be reduced and the low flows would impact on water availability within the groundwater resources. Reduced recharge will reduce water for wetlands and baseflow for rivers which further impact EWR. Springs would have reduced flows.
<table>
<tr><th>Ecosystem Service</th><th>Description</th><th>Likelihood of Impact</th><th>Consequence of Impact</th><th>Risk Rating</th><th>Risk Description</th></tr>
<tr><td>Fresh Water (Natural Sources)</td><td>Subsistence agriculture and 35% of households rely on rivers/streams for primary water source.</td><td>Possible</td><td>Major</td><td>High</td><td>No EWR allocation would possibly impact the water provisioning as the systems are already lower yield resources. Consequence would be major as there are numerous community beneficiaries who rely directly on availability of water from natural sources (this case baseflow and springs).</td></tr>
</table></td></tr>
<tr><td>2 (1PR)</td><td>Allocate to maintain current state (PES- B/C) in rivers. Allocate where possible to demand</td><td>Maintenance of current state of which experiences modified flows and water quality impacts from upstream. This represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as the PES (which in this case is equal to the TEC) will be maintained. This is especially significant in dry seasons.
The requirement of 191 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.</td></tr>
<tr><td>3 (1PE)</td><td>Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand</td><td>There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.</td></tr>
<tr><td>4 (1TR), 7 (2TR) and 10 (3TR)</td><td>Allocate to achieve TEC of B/C (Rivers only). Allocate where possible to demand</td><td>The allocation of 191 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 4 is equivalent to the PES for IUA 4 and therefore the environmental effects are the same as that of scenario 2.</td></tr>
</table>

Scenario	Description	Environmental Effect in IUA 4
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 191 million m3/a will ensure the EWR for both estuaries and rivers are met. The TEC for IUA 4 is equivalent to the PES for IUA 4 and therefore the environmental effects are the same as that of scenario 2.

8.3.5 IUA 5

IUA 5, the Blood River IUA, includes the Emadlangeni, Abaqulusi, Nqutu and Endumeni local municipalities. Water resources in the IUA include the Blood River and its tributary the Hogo River. Key ecological features in the catchment are the extensive wetland systems midway down the Blood River. The population of IUA 5 is approximately 41 759 with approximately 8 305 households. Mixed commercial dryland and irrigated agriculture dominate the land use within the IUA, with subsistence agriculture also being a major feature. Commercial and subsistence agriculture dominate the landscape in IUA 5, pointing to the balancing between the economic roles of the commercial farming sector, as well as the informal sector in this area.

Key water demands in IUA 5 are summarised in Table 44.

Table 43: Key water demand categories, locations and source of water in IUA 5

Demand Category	Demand Location	Source of Water
- **Irrigation demand**	Central to upper regions with lower demand in the lower catchment (TM28B)	TM28B: Dummy Dam (combination of many small dams) and Blood River

Key ecological infrastructure in IUA 5 are summarised in Table 45.

Table 44: Key aquatic ecological infrastructure identified in IUA 5

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Blood river and its tributaries
Wetlands	Blood River Vlei and Upper Blood priority wetland
Aquifers	Moderate to low shale siltstone aquifer resources.

The general location of the demands and ecological infrastructure are indicated in Figure 4-5. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

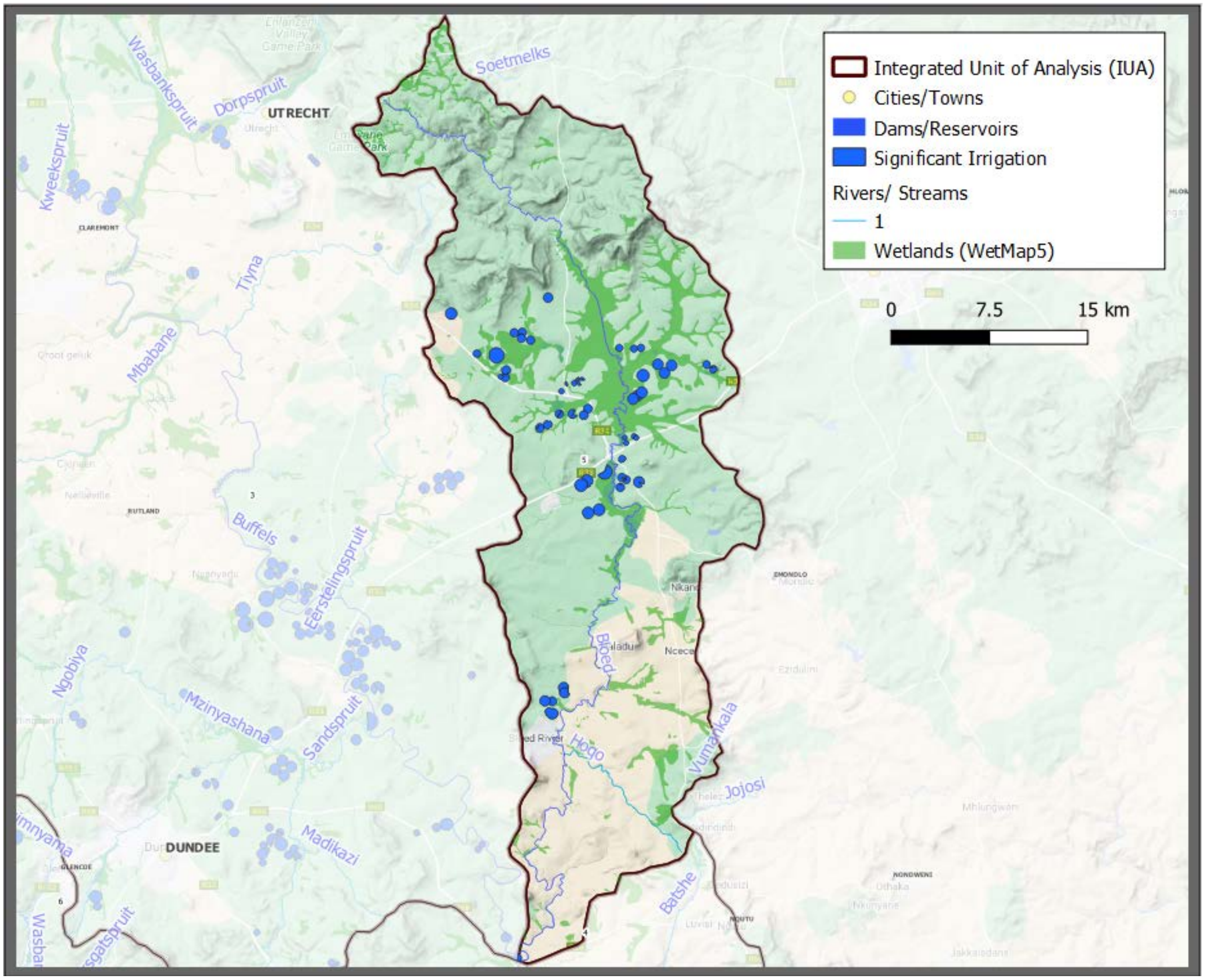


Figure 24: Locality of the demands, and ecological infrastructure are indicated for IUA 5

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.5.1 Environmental Effect Statement

There is currently not sufficient water available in IUA5 to effectively supply the current demands (98% in scenario 1). The demands do not however increase into the future. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 5 is provided in Table 46.

Table 45: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 5

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
5	EWR	0.00	0.00	0.00	0.00	18.16	18.16	21.32	21.54	0.00	21.13	21.32	0.00	20.94	21.44
5	Irrigation Demand	15.52	15.52	15.52	15.20	14.85	14.85	14.79	14.70	15.20	14.88	14.76	15.20	15.04	14.63
5	**TOTAL (Formal Economy Only)**	**15.52**	**15.52**	**15.52**	**15.20**	**14.85**	**14.85**	**14.79**	**14.70**	**15.20**	**14.88**	**14.76**	**15.20**	**15.04**	**14.63**
5	**TOTAL ALLOCATION (incl EWR)**				**15.20**	**33.02**	**33.02**	**36.11**	**36.23**	**15.20**	**36.01**	**36.08**	**15.20**	**35.98**	**36.08**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 47 describes the environmental effects as aggregated for various scenarios.

Table 46: Environmental effect statement aggregated by scenario for IUA 5

Scenario	Description	Environmental Effect in IUA 5
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** High levels of irrigation in the upper catchment results in higher flows downstream and lower flows in the dry season (modified flows). Furthermore, the presence of communities in the lower catchment results in increased observed pathogens (faecal pollution) in the water resources. Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity during the yearly hydrocycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability and functionality of the system.

Scenario	Description	Environmental Effect in IUA 5
		Temporal impacts to habitats are driven by alterations of the following: - Flow Volume (Impacts depth of microhabitats or ability for species to migrate, flood events); - Flow Rate (Impacts rifles, flushes, dynamics between shallows and river banks) ; - Water temperature (Impacts spawning and productivity-e.g. high release in winter triggers fish spawning but unnaturally cold water impacts spawning success) - Water quality (eutrophication, microhabitats naturally vary over the year e.g. Flush events cause changes in water quality and stimulate spawning) These conditions vary naturally over time to maintain species diversity. Impacts on any trophic level could drive a cascade effect. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impacts the riparian zone through a loss of overhanging vegetation and therefore loss of habitats. Constant high flows (releases from impoundments) may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. High flows would unlikely negatively impact primary productivity and may in fact promote primary growth. The presence of cattle grazers means the consequences could in fact be positive on food provisioning services (not really on the water resources). The EWR is not met and therefore there may be some minor impacts in the dry season. Consequences on fish provisioning is unclear due to unclear knowledge of fish collections. The presence of traditional dwellings in this region indicates the use of raw materials and similarly the impacts would likely be positive on this service. Impacts of pathogens on food i.e. fish or other collected organisms is possible- however no clear data is available on the collection of fish for subsistence and as such the consequence is minor. The likely stimulation of primary productivity would similarly have positive impacts on cultural services with minor consequences due to the lack of cultural economy. Pathogens would possibly reduce aquatic based recreational activities however the region is relatively isolated and no major industry exists. The consequences of an impact would be minor. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description

Scenario	Description	Environmental Effect in IUA 5

Fresh Water (Natural Sources)	Use of natural water sources by rural communities and livestock watering	Possible	Moderate	High	There are no zero flows however high densities of rural communities in the lower catchment. The likelihood of impact is therefore possible but with moderate consequences.
Habitats for species	Similar to IUA 1- Flow much higher than it should be however diversity of habitats are lower than IUA 1.	Likely	Moderate	High	Likelihood of impact is likely due to the nature of the hazard however habitats are not as diverse as IUA 1 and are slightly limited in IUA 5. Therefore, moderate consequence of an impact.
Fresh Water (Natural Sources)	Use of natural water sources by rural communities and livestock watering	Likely	Major	Extreme	Pathogens will directly impact the ability to use surface water for drinking and domestic purposes. The likelihood of an impact is therefore likely with major consequences.

Wetlands

The Upper Blood wetland is in the extreme northern regions of the IUA and is not impacted by the zero EWR scenarios. The Blood River Vlei falls within the agricultural land use within the catchment. Dams and pumphouses are observed within the wetland system and therefore a historical impact exists. Reduced volumes through over abstractions reduces natural processes such as flooding and overtopping (flooding of the wetland channel spreading out across wetland habitats). Despite impacts of zero EWR allocation the system is relatively resilient. Dams have become almost naturalised and operate as key points that keeps the system healthy.
The area is well established and therefore unlikely impacts but if there were more dams this would likely impact.

Results of the CRA process indicated the following high and extreme risks to associated ecosystem services

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Certainty	Ecosystem Service
Wetland	Habitats for species	The system is unique in terms of perennial to temporary habitats/channelled/unchanneled (highly diverse). Broader range of wildlife and bird species.	Likely	Moderate	High	Presence of key species (red data cranes) means moderate consequences of impacts on this system. Upper reaches are stable-some deforestation and climate change but not related to scenarios.

Aquifers

Scenario	Description	Environmental Effect in IUA 5
		Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 98%).
2 (1PR)	Allocate to maintain current state (PES-C) in rivers. Allocate where possible to demand	Maintenance of current state which represents modified flows and increased pathogen concentrations and therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 18 million m3/a allocation to maintain the PES will slightly reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is an additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore similar in nature but slightly lower in magnitude compared to scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of B/C (Rivers only). Allocate where possible to demand	The allocation of 21 million m3/a will ensure the TEC for rivers are met. The environmental effects will likely be similar to that of scenario 2 however to a lesser magnitude.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 22 million m3/a will ensure the EWR for both estuaries and rivers are met. There is an additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore similar in nature but slightly lower in magnitude compared to scenario 4, 7 and 10.

8.3.6 IUA 6

IUA 6, the Sundays River IUA, includes the local municipalities of Alfred Duma, Endumeni and Msinga. The IUA includes the smaller towns and communities of Kliprivier, Elandslagte, Wasbank and Etholeni. The population of IUA 6 is approximately 131 642 with approximately 26 492 households. This IUA places relatively low demand on water resources, being characterised by scattered dryland agriculture, rural settlements, and subsistence agriculture. Miscellaneous agriculture, mostly in the form of rangelands dominates the landscape of IUA 6, followed by subsistence agriculture, with a small amount of commercial agriculture.

Key water demands in IUA 6 are summarised in Table 48.

Table 47: Key water demand categories, locations and source of water in IUA 6

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 14: Klipriver, Mining, Rural	DEM 14: Sundays River
- **Irrigation demand**	Scattered throughout catchment ((NON2.IRD, MUNGUB2.IRD, TM14_M2.IRD, TM14B2.IRD)	NON2.IRD: Sundays MUNGUB2.IRD: Sundays TM14_M2.IRD: Dummy Dam (upper catchment Sundays River) TM14B2.IRD: Dummy Dam (Upper Wasbank River)

Key ecological infrastructure in IUA 6 are summarised in Table 49.

Table 48: Key aquatic ecological infrastructure identified in IUA 6

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Sundays and Wasbank rivers and their tributaries
Wetlands	Paddavlei and Boshberg priority wetlands
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Small portion of the IUA along the escarpment

The general location of the demands and ecological infrastructure are indicated in Figure 25. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

Figure 25: Locality of the demands, and ecological infrastructure are indicated for IUA 6

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.6.1 Environmental Effect Statement

There is currently not sufficient water available in IUA6 to effectively supply the current demands (only 56% of demands in scenario 1). As the urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 6 is provided in Table 50.

Table 49: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 6

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
6	EWR	0.00	0.00	0.00	0.00	87.10	87.10	85.68	85.68	0.00	85.59	85.59	0.00	85.49	85.49
6	Irrigation Demand	32.95	32.95	32.95	15.86	13.94	13.94	13.94	13.94	15.80	13.88	13.88	15.74	13.84	13.81
6	Urban Demands	11.01	12.16	13.43	8.70	6.56	6.56	6.56	6.56	9.33	7.06	7.06	9.97	7.63	7.63
6	**TOTAL (Formal Economy Only)**	**43.95**	**45.11**	**46.38**	**24.57**	**20.50**	**20.50**	**20.50**	**20.50**	**25.13**	**20.94**	**20.94**	**25.70**	**21.48**	**21.44**
6	**TOTAL ALLOCATION (incl EWR)**				**24.57**	**107.60**	**107.60**	**106.18**	**106.18**	**25.13**	**106.53**	**106.53**	**25.70**	**106.97**	**106.94**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 51 describes the environmental effects as aggregated for various scenarios.

Table 50: Environmental effect statement aggregated by scenario for IUA 6

Scenario	Description	Environmental Effect in IUA 6
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)**

Scenario	Description	Environmental Effect in IUA 6
		High levels of irrigation in the upper catchment results in low flows which increase gradually downstream. Land use activities have resulted in increased sedimentation instream. Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lowers habitat diversity across a yearly hydrocycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Low flows do not flush rivers which combined with higher temperatures result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact the riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased nutrients will stimulate primary productivity. It is possible that low flows would impact cultural services but with limited industry or beneficiaries' consequences would be insignificant. Furthermore, is unlikely that sediments would impact on these services but with the presence of traditional communities an impact would have moderate consequences. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Lower end are Communities. High informal livestock agriculture. 32% of households rely on rivers/streams for primary water source	Likely	Severe	Extreme	Low flow would likely impact the highly dependent communities in the catchment (32% source water from rivers and streams). the consequences of impact would therefore be severe.
Food Provisioning	The livestock grazers and the rural subsistence settlements	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
Fresh Water (Natural Sources)	Livestock irrigation and some subsistence- 32% of households rely on	Possible	Severe	Extreme	Sedimentation could possibly impact the use of water by communities, but consequences

<table>
<tr><th>Scenario</th><th>Description</th><th>Environmental Effect in IUA 6</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td>rivers/streams for primary water source</td><td></td><td></td><td></td><td>would be severe due to their high dependence on these systems.</td></tr>
<tr><td>Habitats for species</td><td>High diversity of habitats.</td><td>Likely</td><td>Moderate</td><td>High</td><td>Low flows result in likely impacts. Moderate consequence due to diversity of habitats.</td></tr>
</table>
Wetlands
The Paddavlei (Wasbank) and Boshberg (Sundays river) are both high up in the catchment and both fall on private commercial farming land. The key impacts here are from land transformation and are at high risk from erosional point of view. Varying scenarios are not expected to drive impacts.
Aquifers
Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region.
SWSA
The flow related nature of the impacts of these scenarios result in an unlikely impact to SWSA.
Socio-Economic Effect
Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 56%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.</td></tr>
<tr><td>2 (1PR)</td><td>Allocate to maintain current state (PES from D to B/C) in rivers. Allocate where possible to demand</td><td>Maintenance of current state of which experiences low flows which increase gradually downstream and increased sediments in waterways therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons).
The requirement of 87 million m3/a allocation to maintain the PES will slightly reduce the allowances to the demands of catchment beneficiaries compared to the previous scenarios.</td></tr>
<tr><td>3 (1PE)</td><td>Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand</td><td>There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.</td></tr>
</table>

Scenario	Description	Environmental Effect in IUA 6
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC from D to C (Rivers only). Allocate where possible to demand	The allocation of a reduced 86 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 6 is slightly lower than the PES for IUA 6 and therefore the environmental effects would be slightly higher than that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the same as scenario 4, 7 and 10.

8.3.7 IUA 7

IUA 7, the Upper Mooi IUA, includes the local municipalities of Mpofana and Umngeni and includes the towns of Mooi River and Bruntville. Water resources in the IUA include the Upper Mooi River and tributaries. The IUA incudes Spring Grove Dam from where the Mooi to Mgeni Transfer Scheme operates to provide water to Midmar Dam. The region falls into the Agricultural Socio-Economic Zone. The population of IUA 7 is approximately 31 715 with approximately 8 913 households. There are 44% of economically active residents that are employed with 63% being employed in the formal sector. The economy of IUA 7 exhibits a high level of reliance on high intensity commercial agriculture, including irrigated agriculture.

Key water demands in IUA 7 are summarised in Table 52.

Table 51: Key water demand categories, locations and source of water in IUA 7

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 8: Mooi Town and Textiles Mearns Rural Requirement	DEM 8: Mooi River-Upstream of Mearns Weir and Mearns weir
- **Irrigation demand**	Multiple irrigation demands throughout the catchment ('SPR_DIR','SPR_MIR', 'SPR_DIRECT', 'MRIB LITTLE MOOI_DIR', 'MRIB LITTLE MOOI_MIR', 'MRIB LM DIRECT_MIR', 'MRIB HLATIKULU_DIR', 'MRIB HLATIKULU_MIR','DAR_DIR', 'DAR_MIR', 'BIG MOOI REM_MIR', 'BIG MOOI REM_DIR', 'LITTLE MOOI REM_DIR', 'LITTLE MOOI REM_MIR', 'MEA_DIRECT', 'SUT UPPER_MIR', 'SUT UPPER_DIR', 'SUT LOWER_DIR', 'SUT LOWER_MIR', 'MIDD_DIR', 'MIDD_MIR'	Throughout the catchment, rivers and dams.
- **Transfers**	Umgeni Transfer (MMTS Total)	Mearns Weir

Key ecological infrastructure in IUA 7 is summarised in Table 53.

Table 52: Key aquatic ecological infrastructure identified in IUA 7

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Mooi river and its tributaries
Wetlands	Hlatikulu and lower portions of Stillerust priority wetlands
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Almost half of the IUA extending from the escarpment

The general location of the demands and ecological infrastructure are indicated in Figure 24. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

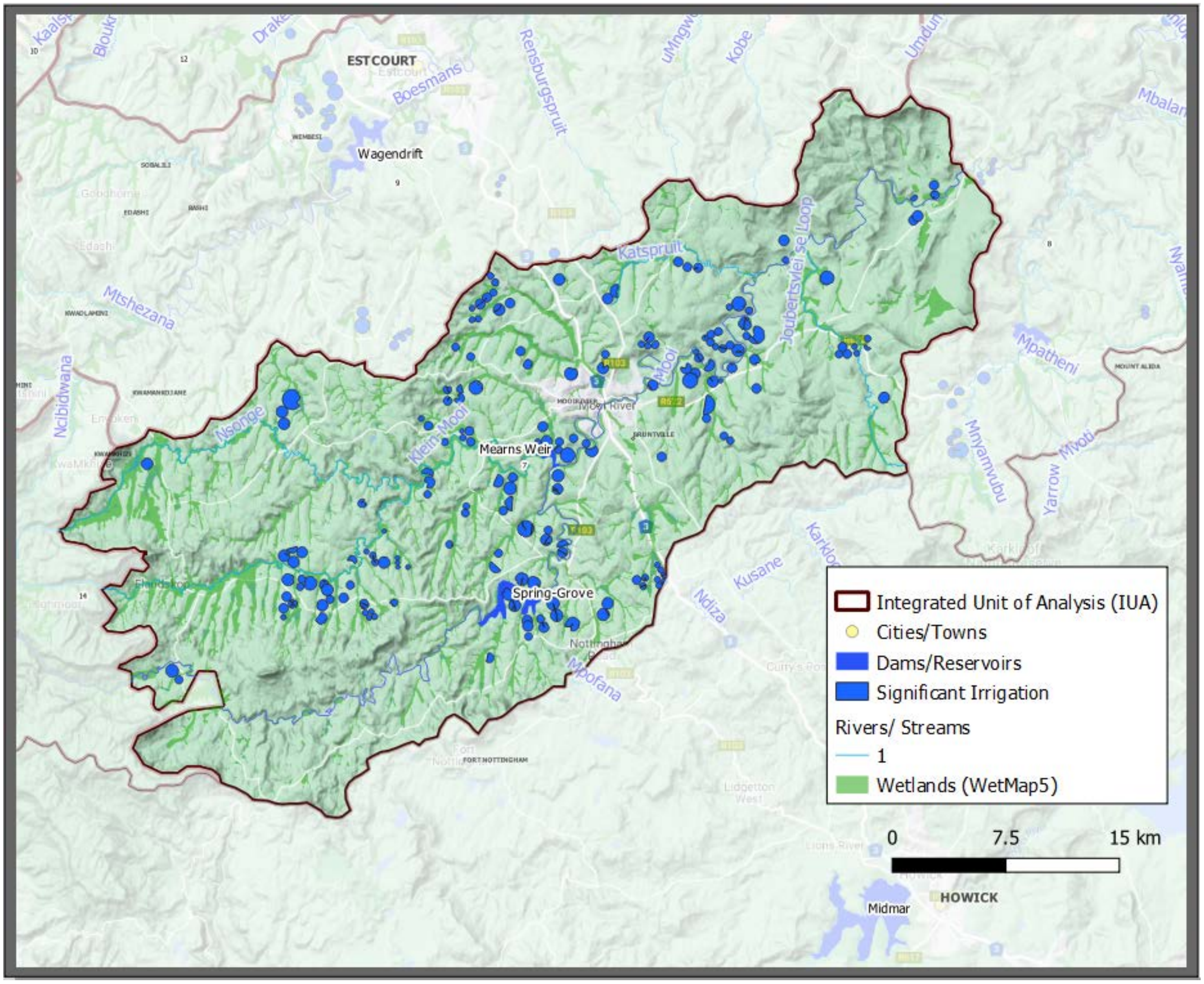


Figure 26: Locality of the demands, and ecological infrastructure are indicated for IUA 7

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.7.1 Environmental Effect Statement

There is currently not sufficient water available in IUA 7 to effectively supply the current demands (88% in scenario 1, 6 and 9). The demands do not increase into the future. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 7 is provided in Table 54.

Table 53: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 7

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)									
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
7	EWR	0.00	0.00	0.00	0.00	84.04	84.04	85.18	85.15	0.00	85.12	85.12	0.00	85.27	85.37
7	Irrigation Demand	46.57	46.57	46.57	31.79	22.17	22.17	21.73	21.44	31.76	21.48	21.22	31.85	23.49	22.08
7	Transfers	141.91	141.91	141.91	134.22	78.93	78.93	80.89	77.80	136.36	83.26	80.16	128.73	77.55	66.48
7	Urban Demands	2.46	2.46	2.46	2.40	1.36	1.36	1.42	1.36	2.40	1.36	1.29	2.43	1.64	1.45
7	**TOTAL (Formal Economy Only)**	**190.94**	**190.94**	**190.94**	**168.40**	**102.46**	**102.46**	**104.04**	**100.60**	**170.52**	**106.09**	**102.68**	**163.01**	**102.68**	**90.00**
7	**TOTAL ALLOCATION (incl EWR)**				**168.40**	**186.50**	**186.50**	**189.22**	**185.75**	**170.52**	**191.20**	**187.80**	**163.01**	**187.95**	**175.37**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 55 describes the environmental effects as aggregated for various scenarios.

Table 54: Environmental effect statement aggregated by scenario for IUA 7

Scenario	Description	Environmental Effect in IUA 7
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** High demands for irrigation activities results in low flows and the inability to meet EWR requirements. Floods and seasonality are maintained during the wet season but is mostly not achieved during the low flow period (April-Nov). There are also some zero flows, particularly during the wet seasons. Water

Scenario	Description	Environmental Effect in IUA 7
		Quality issues include pathogens and nutrients from irrigation and urban activities. Sewerage works are overloaded at Mooi River and factory (Old Mooi river textiles) discharges effluent into Mearns Weir. Alterations of the natural rhythm of flows directly impacts the various biotopes (riparian and instream) and therefore the functionality of the aquatic ecosystem. Unnatural or modified flows lower habitat diversity across a yearly hydrocycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact the riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. The flow and water quality hazards will have a low risk to non-water provisioning and educational cultural services. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Communities who use water for household of cattle watering purposes	Possible	Moderate	High	The zero flows result in a moderate consequence for communities with possible likelihood of impact
Habitats for species	Veg is hard hit here- this has continued for a long time. Zero flows have been recorded.	Almost certain	Moderate	High	Continued impacts are almost certain- due to the existing condition the consequences oof an impact on existing habitats is moderate.
Ecotourism & recreation	Trout fishing, Midmar mile and associated activities. Smaller localised beneficiaries i.e., guest houses and fishing. Swimming in rivers (however a bit cold).	Likely	Moderate	High	It is very likely that reduced flow will impact aquatic related recreational activities. Of which consequences in this developed tourism industry would be moderate.

Scenario	Description	Environmental Effect in IUA 7					
		Inspirational Value	Tourism to Midmar mile and midlands	Possible	Moderate	High	It is possible low flows could impact the inspirational value of Midmar. The consequences of which are moderate as the greater Midlands meander as an inspiration. Think on how this impacts tourism routes. (Note compare Rosetta (thriving) and Mooi river and then Winterton (thriving) and Bergville)
		Fresh Water (Natural Sources)	Communities who use water for household of cattle watering purposes	Possible	Moderate	High	Poor water quality would possibly impact water available to beneficiaries and due to the nature of water use in the catchment focussing on cattle watering this would have moderate consequences
		Habitats for species	High-Water quality issue- high algae- Highly diverse habitats and depth classes- however habitats not major issue. WQ major issue- Algae smothering habitats.	Almost certain	Moderate	High	Almost certain impacts with moderate consequences as flushing (which does occur) supports habitats.
		Landscape & amenity values	Real estate value	Possible	Moderate	High	Impacts on real estate values linked to aquatic resources is possible and the consequences as per linked to a large ecotourism industry would be moderate.
		Ecotourism & recreation	Fishermen/Midlands meander	Likely	Moderate	High	It is likely that the WQ hazard would impact the fishing stocks in the region. The consequences would be moderate due to the size of the industry
		Inspirational Value	Linked to tourism in the region	Possible	Moderate	High	WQ issues could possibly impact inspirational services through introduced odours and unnatural colours. This would have a moderate consequence on the regional tourism economy.
		Wetlands					

Scenario	Description	Environmental Effect in IUA 7
		The Hlatikulu and downstream portions of Stillerust are the priority wetlands of which are in the upper catchment and not significantly impacted by scenarios. The key impacts are from land use and non-flow impacts. Extensive wetlands in this IUA that are not priority wetlands. Decreased flow would impact some wetlands. Due to the nature of these wetland systems and the greater wetland complex it is unlikely to have overall blanket impacts on the entire system. Impacts of flow will likely be localised and only on main channels where impacts are experienced. This introduces resilience to the maintenance of ecosystem services. The dynamics of the wetland cluster means resilience of habitats would be high. Low flow impacts would likely impact specific wetlands but not all, resulting in an unlikely impact on habitats. The consequences similarly would be minor. **Aquifers** Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region. **SWSA** The flow related nature of the impacts of these scenarios result in an unlikely impact to SWSA. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 88%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.
2 (1PR)	Allocate to maintain current state (PES-E to B/C) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences low flows (some zero flows) and water quality impacts from associated land uses therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons).. The requirement of 84 million m3/a allocation to maintain the PES will slightly reduce the allowances to the demands of catchment beneficiaries compared to the previous scenarios.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.

Scenario	Description	Environmental Effect in IUA 7
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of D to B/C (Rivers only). Allocate where possible to demand	The allocation of 85 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 7 is greater than the PES for IUA 7 and therefore the environmental effects are smaller in magnitude as that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the same as scenario 2.

8.3.8 IUA 8

IUA 8, the Middle/ Lower Mooi IUA, includes portions of the Umvoti, Mpofana and Msinga local municipalities. The IUA includes the towns of Muden and Keates Drift. Protected areas include Mt Gilboa Nature Reserve and Craigie Burn Nature Reserve. Water resources in the IUA include the Mooi River and tributaries as well as the Craigie Burn Dam. The population of IUA 8 is approximately 56 074 with approximately 12 841 households. This IUA consists mainly of rangeland, with some irrigation agriculture present. Demand on water resources is relatively low. The mountainous terrain of this IUA does not lend itself to agricultural development, as such commercial agriculture accounts for a relatively low proportion of land cover, while the local economy appears to rely on subsistence agriculture.

Key water demands in IUA 8 are summarised in Table 56.

Table 55: Key water demand categories, locations and source of water in IUA 8

Demand Category	Demand Location	Source of Water
- **Irrigation demand**	Upper catchment	Craigie Burn Dam and Upper reaches of Mooi River

Key ecological infrastructure in IUA 8 are summarised in Table 57.

Table 56: Key aquatic ecological infrastructure identified in IUA 8

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Mooi River and its tributaries
Wetlands	Melmoth, Dartmoor and Scawby priority wetlands
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Upper catchment only

The general location of the demands and ecological infrastructure are indicated in Figure 27. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

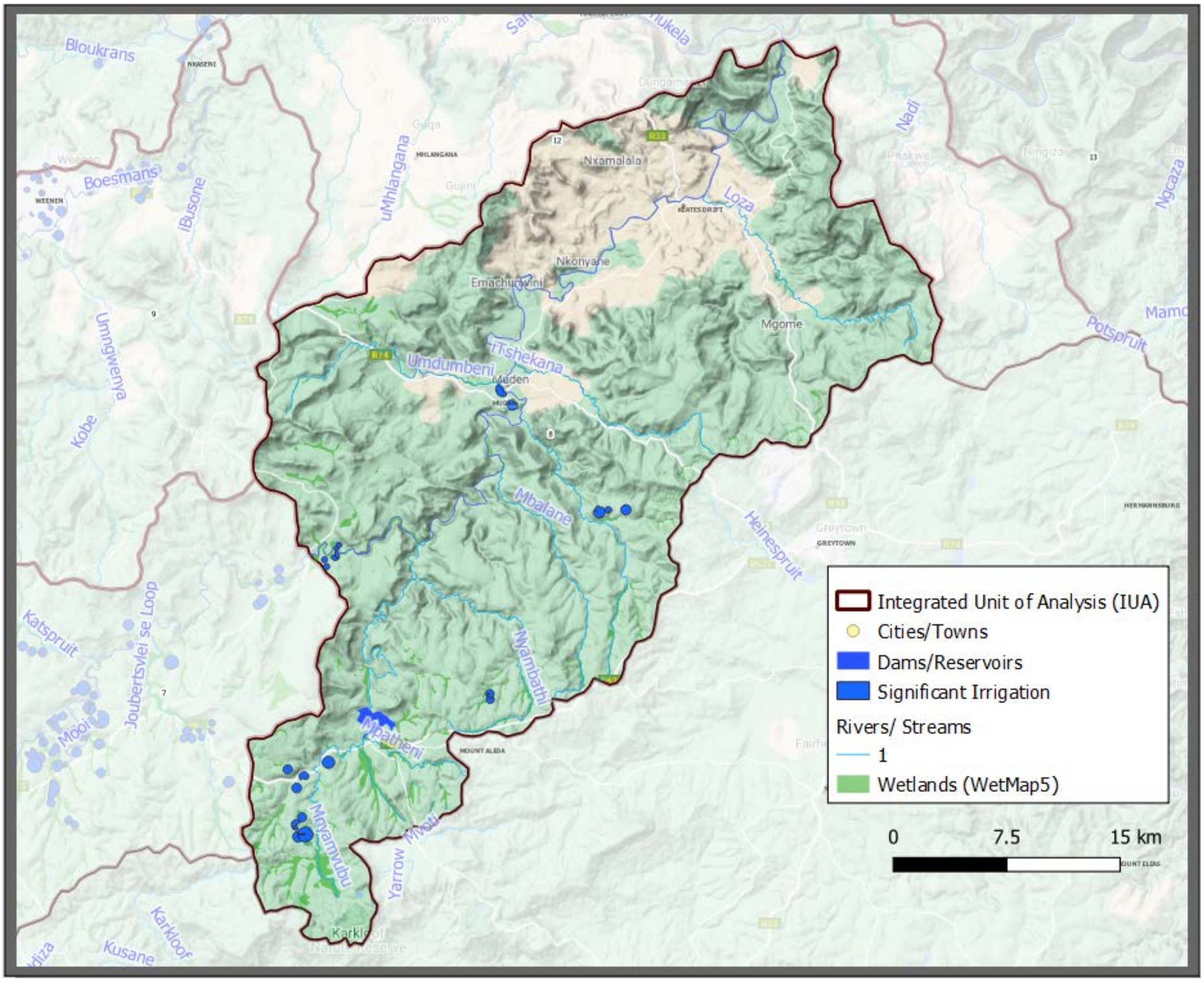


Figure 27:Locality of the demands, and ecological infrastructure are indicated for IUA 8

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.8 Environmental Effect Statement

There is currently not sufficient water available in IUA 8 to effectively supply the current demands (92% for scenario 1, 6 and 9). These demands are not expected to increase in the future. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 8 is provided in Table 58.

Table 57: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 8

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
8	EWR	0.00	0.00	0.00	0.00	431.32	431.32	439.52	441.57	0.00	439.26	441.31	0.00	445.76	448.60
8	Irrigation Demand	11.73	11.73	11.73	10.75	6.97	6.94	6.94	6.75	10.75	6.72	6.56	10.75	7.92	7.00
8	**TOTAL (Formal Economy Only)**	**11.73**	**11.73**	**11.73**	**10.75**	**6.97**	**6.94**	**6.94**	**6.75**	**10.75**	**6.72**	**6.56**	**10.75**	**7.92**	**7.00**
8	**TOTAL ALLOCATION (incl EWR)**				**10.75**	**438.29**	**438.26**	**446.46**	**448.32**	**10.75**	**445.98**	**447.87**	**10.75**	**453.68**	**455.60**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 59 describes the environmental effects as aggregated for various scenarios.

Table 58: Environmental effect statement aggregated by scenario for IUA 8

Scenario	Description	Environmental Effect in IUA 8
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** High demands for irrigation activities in the upper catchment and IUA 7 results in low flows and the inability to meet EWR requirements in IUA 8. Floods and seasonality are maintained however on average (April-Nov) not meeting the EWR. There are also some zero flows. Water Quality issues on main stem. Pathogens and nutrients from irrigation and urban activities. Tributaries are in better condition with regards to water quality. Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly hydro cycle occurs and

Scenario	Description	Environmental Effect in IUA 8
		therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. Low flows would likely impact on cultural services however the undeveloped industry results in an insignificant impact. Water quality identified would unlikely impact local use of the rivers with minor consequences due to the lack of formal recreation and ecotourism industry. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	33% of households rely on rivers/streams for primary water source	Likely	Severe	Extreme	More communities compared to IUA 7. Note the communities do not have access to formal water irrigation and depend more directly on rivers for water. The low flows result in a likely impact. The impacts on an IUA which is characteristic of high dependency (33%) of households on rivers and streams for their primary water source is severe.
Food Provisioning	The livestock grazers and the rural subsistence settlements	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
Habitats for species	Highly diverse habitats (recorded many of habitat types and varying depth classes)- similar to IUA 7.	Possible	Moderate	High	Lower Mooi there were sensitive aquatics-i.e., better conditions- No significant species. Moderate due to high diversity of habitats.

Scenario	Description	Environmental Effect in IUA 8

Fresh Water (Natural Sources)	33% of households rely on rivers/streams for primary water source	Likely	Severe	Extreme	Water quality issues identified are likely to impact on water availability and the highly dependent communities will be severely impacted.
Food Provisioning	The livestock grazers and the rural subsistence settlements	Possible	Moderate	High	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms- The presence of these communities in the IUA means consequences of impact could be moderate.
Habitats for species	Highly diverse habitats (recorded many of habitat types and varying depth classes)- similar to IUA 7.	Possible	Moderate	High	No threatened or significant species/ habitats- although high diversity habitats. - Consequence is moderate.

Wetlands

Cluster of priority wetlands in the headwaters of the catchment incl. Melmoth (protected area), Dartmoor (protected area) and Scawby (within plantations on private land-reduced flow) wetlands. Non flow impacts have been observed. There are observed reduced flows from land uses likely impacts on the habitats at Scawby wetland. The consequences of the loss of this wetland are major due to the presence of red data species. As the plantations are rain fed, the allocation of water across scenarios will not further impact these wetlands. There is a risk of water abstraction as a result of closely associated irrigation activities directly downstream of Scawby wetland (although not directly associated with impacts the extreme risk is included below). Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Habitats for species	Wattled and crowned crane habitats	Likely	Moderate	High	Reduced flows from land uses likely impacts on the habitats at Scawby Wetland. The consequences of the loss of this wetland are moderate due to the presence of red data species.

Scenario	Description	Environmental Effect in IUA 8
		Aquifers Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region. **SWSA** The flow related nature of the impacts of these scenarios results in an unlikely impact to SWSA. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 93%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.
2 (1PR)	Allocate to maintain current state (PES of C/D to C) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences low flows (some zero flows) and water quality impacts from associated land uses therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 431 million m3/a allocation to maintain the PES will drastically reduce the allowances to the demands of catchment beneficiaries compared to the previous scenarios.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of C to B/C (Rivers only). Allocate where possible to demand	The allocation of 440 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 8 is greater than the PES for IUA 8 and therefore the environmental effects are smaller in magnitude as that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	There are additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the less than scenario 2.

8.3.9 IUA 9

IUA 9, the Middle/Lower Bushmans River IUA, encompasses the Inkosi Langalibalele and Mpofana local municipalities. The IUA includes the larger city of Estcourt and smaller towns and communities of Wembesi, Bashi and Weenen. Regions of the IUA are protected through Weenen Game Reserve, Wagendrift Nature Reserve and Dalton Private Reserve. Water resources in the IUA include the Middle/Lower Bushmans River and tributaries as well as the Wagendrift dam. The population of IUA 9 is approximately 97 958 with approximately 22 801 households. This IUA contains a few high intensity irrigated agricultural hotspots which require a steady supply of water. A commercial hub around the main town of Estcourt forms the backbone of the economy, supported by small areas of high intensity agriculture, while a large contingent of the population rely on subsistence agriculture and grazing.

Key water demands in IUA 9 are summarised in Table 60.

Table 59: Key water demand categories, locations and source of water in IUA 9

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 16: Estcourt, Wembizi, Craigtown DEM 17: Weenen, Noodkamp DEM 18: Kwadamini, Kwamazel, Sobabili	DEM 16: Wagendrift Dam DEM 17: Bushmand River (Mielietuin Dam in future) DEM 18: Bushmans River
- **Irrigation demand**	Middle Bushmans and downstream of the catchment (WAG2.IRD, MNGWEN2.IRD, LOCHS2.IRD)	WAG2.IRD: Upstream Wagendrift LOCHS2.IRD: Below Wagendrift MNGWEN2.IRD: Below Wagendrift (Weenen-Mielietuin in future)

Key ecological infrastructure in IUA 9 are summarised in Table 61.

Table 60: Key aquatic ecological infrastructure identified in IUA 9

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Bushmans river and its tributaries
Wetlands	Ntabamhlope priority wetlands
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Upper catchment extending from the escarpment

The general location of the demands and ecological infrastructure are indicated in Figure 28. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

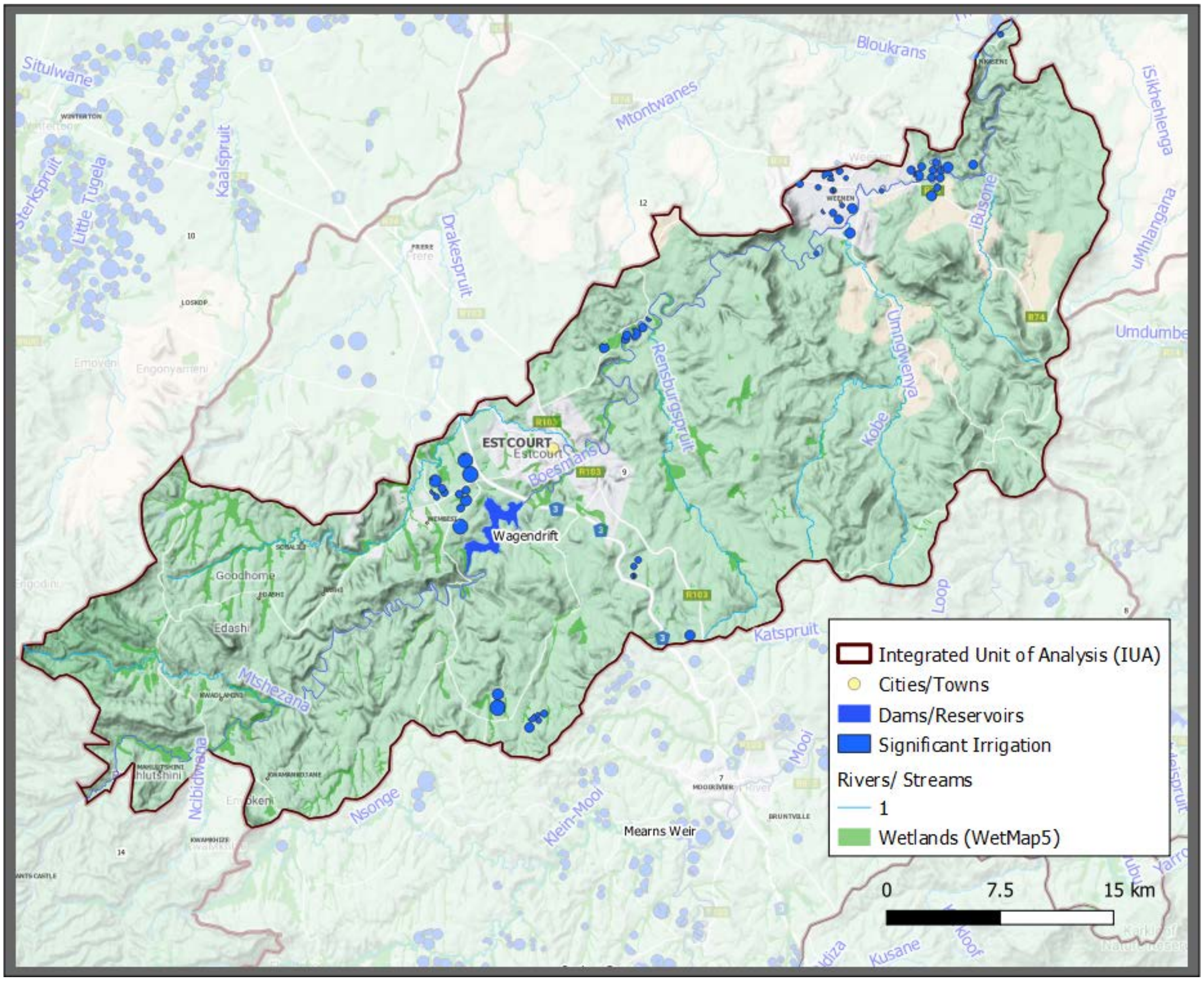


Figure 28: Locality of the demands, and ecological infrastructure are indicated for IUA 9

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.9.1 Environmental Effect Statement

There is currently not sufficient water available in IUA 9 to effectively supply the current demands (99% in scenario 1). As urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 9 is provided in Table 62.

Table 61: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 9

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
9	EWR	0.00	0.00	0.00	0.00	306.88	306.88	288.96	288.96	0.00	288.33	288.33	0.00	232.17	232.20
9	Irrigation Demand	41.47	41.47	41.47	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	39.58	39.58
9	Urban Demands	16.40	17.76	19.06	16.40	15.86	15.86	15.86	15.86	17.75	17.19	17.19	19.08	18.32	18.32
9	**TOTAL (Formal Economy Only)**	**57.87**	**59.23**	**60.54**	**57.24**	**56.70**	**56.70**	**56.70**	**56.70**	**58.59**	**58.03**	**58.03**	**59.92**	**57.90**	**57.90**
9	**TOTAL ALLOCATION (incl EWR)**				**57.24**	**363.58**	**363.58**	**345.67**	**345.67**	**58.59**	**346.36**	**346.36**	**59.92**	**290.07**	**290.10**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 63 describes the environmental effects as aggregated for various scenarios.

Table 62: Environmental effect statement aggregated by scenario for IUA 9

Scenario	Description	Environmental Effect in IUA 9
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** EWR values are currently met and exceeded in most of the catchment due to releases from Wagendrift Damand the seasonality is maintained. Key impacts of low flow, due to extensive irrigation and urban demands from Estcourt are felt at Weenen(EWR not met May to Sept). Water quality is an issue downstream of Estcourt including sewerage effluent (Nutrients), effluent from piggeries, algae growth

Scenario	Description	Environmental Effect in IUA 9
		from nutrients inputs and odours (indicating bad quality). Communities in the region have mentioned that theyavoid drinking the available surface water from the river as a result of the pollution. Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly hydro cycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may result in homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. Low flows and water quality impacts are localised to the downstream section of the reiver (below Estcourt) where the density of rural communities reduces drastically compared to the upstream section. Although an impact is likely, the consequences to non-water provisioning services will be minor resulting in low to medium risk. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	No subsistence agriculture however some informal communities downstream of Estcourt	Possible	Moderate	High	Low flows, but no zero flows would possibly impact on water availability with moderate consequences to a relatively rural catchment.
Habitats for species	High diversity of habitats (similar to 7 and 8)- Low flows drive wq issues and impact natural productivity.	Possible	Moderate	High	High diversity habitats: Consequence is moderate.

Scenario	Description	Environmental Effect in IUA 9
		(table below, continued)

Fresh Water (Natural Sources)		Likely	Moderate	High	The water quality hazard identified in this IUA results in a likely impact on water availability, however comparatively the catchment is not heavily reliant on natural systems as a primary water source and therefore consequences are moderate.
Ecotourism & recreation	Some fishing/tourism industry	Likely	Moderate	High	It is likely that reduced water quality may impact the service in the Weenen area and given the general size of this industry the consequences are seen to be moderate

Wetlands

Ntabamhlope priority wetland represents a cluster of wetlands. A portion is within communal land and heavy utilised for grazing. Erosion is the major impact from improper land use but also transformation and encroachment of plantations and alien stands.

The placement of the wetlands within the IUA and nature of impacts results in no impacts driven by changing scenarios.

Aquifers

Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region.

SWSA

The flow related nature of the impacts of these scenarios results in an unlikely impact to SWSA.

Socio-Economic Effect

Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 99%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.

Scenario	Description	Environmental Effect in IUA 9
2 (1PR)	Allocate to maintain current state (PES of D to B/C) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences low flows and water quality impacts below Estcourt from associated land uses therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as there will be an allocation of water to maintain the current PES which is especially significant in the dry seasons. The requirement of 307 million m3/a allocation to maintain the PES will drastically reduce the allowances to the demands of catchment beneficiaries compared to the previous scenarios.

Scenario	Description	Environmental Effect in IUA 9
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC (Rivers only). Allocate where possible to demand	The allocation of 288 million m3/a will ensure the TEC for rivers are met. Please note the TEC for IUA 9 is is in fact lower than the PES for IUA 9 and therefore the environmental effects are larger in magnitude as that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC of C/D (Rivers and Estuary). Allocate where possible to demand	There are additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the same as scenario 4, 7 and 10.

8.3.10 IUA 10

IUA 10, the Upper Tugela IUA, which includes Okhahlamba, Alfred Duma and Inkosi Langalibalele local municipalities. The IUA includes the agricultural towns of Winterton, Bergville, Rookdale, Spioenkop and Loskop. Protected areas include Hlathikulu Nature Reserve towards the escarpment and the Spioenkop Nature Reserve. Water resources in the IUA include the Upper Tugela River and tributaries as well as the Spioenkop and Woodstock dams. Key water transfers are from the Tugela-Vaal Transfer Scheme transferring water to the Sterkfontein dam and eventually to the Vaal system. The population of IUA 10 is approximately 166 615 with approximately 31 434 households. Widespread, dense areas of high intensity commercial agriculture, including a significant portion devoted to irrigated farmland, drives the economy of the area. Subsistence agriculture also has a significant footprint.

Key water demands in IUA 10 are summarised in Table 64.

Table 63: Key water demand categories, locations, and source of water in IUA 10

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 1: Bergville, Emmaus, Carnation Industrial, Natal Parks Board DEM 2: Rural, Jagersrust, Drakensville DEM 6: Winterton, Loskop, V13 Tertiary Rural DEM 7: Colenso, Nkanyezi, V14 Tertiary Rural	DEM 1: Woodstock, Driel and Dummy Dams DEM 2: Woodstock Dam DEM 6: Lindequespruit DEM 7: Tugela River
- **Irrigation demand**	Heavy irrigation throughout central to lower catchment (THWOOD2.IRD, TM022.IRD, THDRIE2.IRD, TM062.IRD, THSKOPa2.IRD, THSKOPb2.IRD, THSKDS2.IRD, TM08A2.IRD, THLTUG2.IRD, TM08B2.IRD, TM06_b2.IRD)	Throughout catchment
- **Transfers**	Vaal Catchment	Woodstock Dam

Key ecological infrastructure in IUA 10 are summarised in Table 65.

Table 64: Key aquatic ecological infrastructure identified in IUA 10

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Tugela river, Lindequespruit and their tributaries
Wetlands	No priority wetlands. Extensive network of smaller wetlands in the catchment
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Much of the IUA along the escarpment

The general location of the demands and ecological infrastructure are indicated in Figure 29. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

Figure 29: Locality of the demands, and ecological infrastructure are indicated for IUA 10

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.10.1 Environmental Effect Statement

There is currently not sufficient water available in IUA 10 to effectively supply the current demands (75% in scenario 1). As the urban and transfer demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 10 is provided in Table 66.

Table 65: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 10

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
10	EWR	0.00	0.00	0.00	0.00	707.01	707.01	702.21	702.78	0.00	700.64	701.33	0.00	689.38	702.02
10	Irrigation Demand	113.89	113.89	113.89	78.81	54.15	54.15	53.55	53.42	78.46	53.20	53.01	78.08	55.28	53.33
10	Transfers	630.72	630.72	1031.23	477.49	389.94	389.94	387.70	386.76	477.27	387.64	386.88	877.55	732.20	679.16
10	Urban Demands	8.34	10.14	11.44	7.57	4.35	4.35	4.45	4.38	9.33	5.74	5.74	10.53	6.78	6.65
10	**TOTAL (Formal Economy Only)**	**752.96**	**754.75**	**1156.56**	**563.86**	**448.44**	**448.44**	**445.70**	**444.56**	**565.06**	**446.58**	**445.64**	**966.17**	**794.27**	**739.14**
10	**TOTAL ALLOCATION (incl EWR)**				**563.86**	**1155.45**	**1155.45**	**1147.91**	**1147.34**	**565.06**	**1147.22**	**1146.96**	**966.17**	**1483.64**	**1441.16**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 67 describes the environmental effects as aggregated for various scenarios.

Table 66: Environmental effect statement aggregated by scenario for IUA 10

Scenario	Description	Environmental Effect in IUA 10
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** The upper section of the IUA (between Woodstock and Spioenkop Dam) where high demand results in very low flows even in high flow months when there is a maximum transfer to the Vaal. Lower IUA similar impacts result in low flows (May to August) however the gap is not as extreme as upstream. Perennially and seasonality is maintained (lower peaks but still floods).

Scenario	Description	Environmental Effect in IUA 10
		Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly hydrocycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure and smothering (algae and silt) and therefore loss of river biota. Low flow and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats. High flows may drive homogeneity of microhabitats (depth, temperature, water quality) and therefore reduced species diversity. Increased volumes will stimulate primary productivity. Low flows may possibly impact water related tourism in the IUA however the impacts would be minor. Risks to other cultural services are seen as low. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Extensive communities throughout IUA 10 (cattle etc- not much identified subsistence).	Possible	Moderate	High	Low flows, but no zero flows would possibly impact on water availability with moderate consequences to a relatively rural catchment. Not implementing EWR has similar hazard to IUA 7, 8, and 9 however at much higher risk levels.
Food Provisioning	The livestock grazers	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
Habitats for species	Habitats are diverse in this IUA- high diversity classes and depths	Possible	Moderate	High	Moderate consequence due to habitat diversity.

Wetlands

Scenario	Description	Environmental Effect in IUA 10
		No specific priority wetlands however extensive network of smaller wetlands in the catchment. Although dams and irrigation have a likely impact the non-flow or land use impacts have the predominant impact. **Aquifers** Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region. **SWSA** The flow related nature of the impacts of these scenarios result in an unlikely impact to SWSA. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 75%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.
2 (1PR)	Allocate to maintain current state (PES of D to B) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences low flows decreasing downstream in the catchment represents modified flows and therefore represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 707 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of D to C (Rivers only). Allocate where possible to demand	The allocation of 702 million m3/a will ensure the TEC for rivers are met. Please note the TEC for IUA 10 is in fact lower than the PES for IUA 10 and therefore the environmental effects are larger in magnitude to those expected in scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	There are additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts to environment are therefore similar in nature however less than scenario 2.

8.3.11 IUA 11

IUA 11, the Klip River IUA, includes the local municipalities of Alfred Duma and Okhahlamba. The major city of Ladysmith is found in the IUA with smaller communities including Driefontein and Peace Town. The Ingula Pump Storage Scheme is found in the northern reaches of the catchment. The IUA includes large areas defined as Strategic Water Source Areas along the escarpment. The population of IUA 11 is approximately 197 366 with approximately 49 304 households. Scattered irrigation agriculture and dryland agriculture, along with residential use represent the water demand in this IUA, which is relatively low. The central town of Ladysmith boasts a well-developed commercial sector.

Key water demands in IUA 11 are summarised in Table 68.

Table 67: Key water demand categories, locations and source of water in IUA 11

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 3: Ladysmith DEM 4: Ezhakeni, Pieters Industry DEM 5: Driefontein Block, Roosboom, Matiwaneskop	DEM 3: Spioenkop Dam (IUA 10) and future Quedusizi Dam DEM 4: Klipriver (downstream of Ladysmith) DEM 5: Dummy Dam Ngogo/Tatana River
- **Irrigation demand**	KLIPA2.IRD KLIPB2.IRD TM11A2.IRD TM11B2.IRD	KLIPA2.IRD (Klipriver downstream of Ladysmith) KLIPB2.IRD (Klipriver downstream of Ladysmith) TM11A2.IRD (Dummy upstream on Tatana River) TM11B2.IRD

Key ecological infrastructure in IUA 11 are summarised in Table 69.

Table 68: Key aquatic ecological infrastructure identified in IUA 11

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Klip river and its tributaries
Wetlands	No priority wetlands. Network of large wetlands in the catchment
Aquifers	Alluvial aquifers with high surface to groundwater interaction. Moderate to low shale siltstone aquifer resources.
SWSA	Limited along the escarpment

The general location of the demands and ecological infrastructure are indicated in Figure 30. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

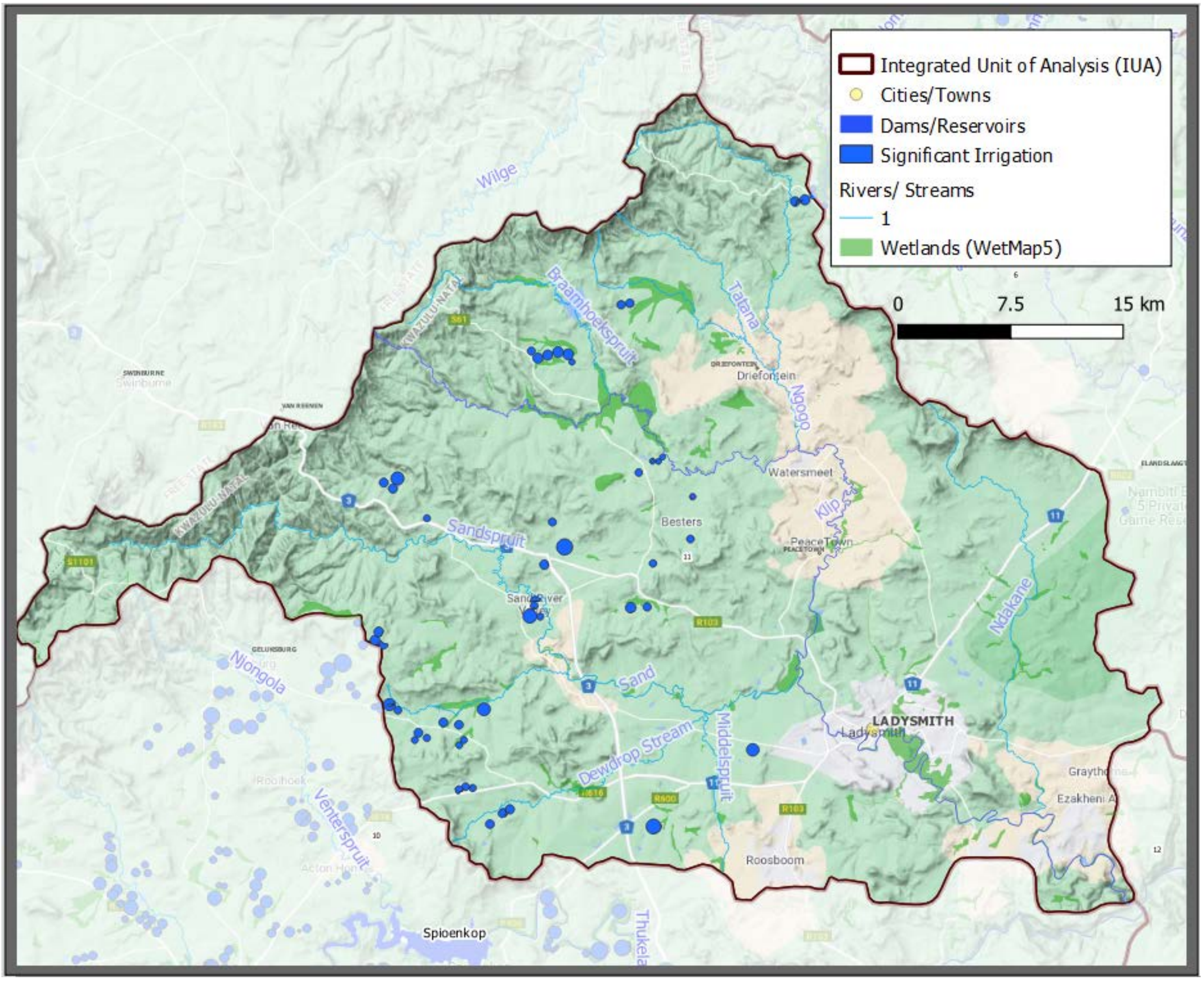


Figure 30: Locality of the demands, and ecological infrastructure are indicated for IUA 11

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.11.1 Environmental Effect Statement

There is currently not sufficient water available in IUA 11 to effectively supply the current demands (89% of scenario 1). As urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 11 is provided in Table 70.

Table 69: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 11

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
11	EWR	0.00	0.00	0.00	0.00	81.71	81.71	81.84	81.84	0.00	81.84	81.84	0.00	81.68	81.80
11	Irrigation Demand	42.66	42.66	42.66	34.69	27.09	27.09	25.48	25.32	34.09	25.48	25.32	34.03	28.70	25.89
11	Urban Demands	32.90	39.53	42.70	32.86	8.42	8.42	9.24	9.11	38.79	10.31	10.19	40.49	11.67	11.07
11	**TOTAL (Formal Economy Only)**	**75.56**	**82.19**	**85.36**	**67.55**	**35.51**	**35.51**	**34.72**	**34.44**	**72.88**	**35.79**	**35.51**	**74.52**	**40.37**	**36.96**
11	**TOTAL ALLOCATION (incl EWR)**				**67.55**	**117.22**	**117.22**	**116.56**	**116.27**	**72.88**	**117.63**	**117.35**	**74.52**	**122.04**	**118.76**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 71 describes the environmental effects as aggregated for various scenarios.

Table 70: Environmental effect statement aggregated by scenario for IUA 11

Scenario	Description	Environmental Effect in IUA 11
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** Allocating water to the demand only is not expected to have flow specific impacts in the catchment however water quality issues downstream from upper catchment are expected (sediments specifically are currently evident). Downstream of Ladysmith, not major issues noted however some increased levels of nutrients present (likely worse downstream into IUA 12).

Scenario	Description	Environmental Effect in IUA 11
		Alterations of the natural rhythm of flows directly impacts river habitats and therefore the functionality of ecosystems. Increased nutrients identified cause eutrophication in drier months which has negative impacts on ecosystem functionality however drives primary productivity. Sediments in suspension impact microhabitats by preventing light penetration and siltation which reduces heterogeneity of waterways. Sediments further impact on storage capacity of impoundments and dams. It is unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive due to nutrients). Sedimentation and nutrients are likely to have an effect (negative) on organisms within the streams (fish) which would impact fishing food provision. The presence of livestock grazers in the region but no obvious fishing subsistence means the consequences would be minor. Similarly, the general absence of traditional dwellings in the IUA means consequences of impact raw material provisioning would have insignificant consequences. It is unlikely that the water quality issues identified issues would impact the cultural services of the IUA. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Some irrigation upstream. High intensity rural settlements.	Likely	Moderate	High	The risks here to water quality are largely to the rural population living in the region. Contaminants will likely impact water available from natural sources with moderate consequences to communities.
Food Provisioning	The livestock grazers and the rural subsistence settlements	Possible	Moderate	High	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms- The presence of these communities in the IUA means consequences of impact could be moderate.
Habitats for species	High diversity of habitats- and migratory route for eels.	Likely	Moderate	High	Eels recorded here showing migration however eels are tolerant therefore conditions are not great. The consequence is moderate as no clear linkage with beneficiaries however from conservation perspective their presence is important.

Scenario	Description	Environmental Effect in IUA 11
		Wetlands No priority wetlands. Some large wetland systems throughout the IUA. The presence of informal settlements likely results in erosion and direct non flow impacts to the wetlands. This is indicated by land cover maps and the presence of baron land. The nature of impacts as per scenarios results in low risks to wetlands in the IUA. **Aquifers** No EWR and potential low flows in Alluvial systems means the recharge rate will be reduced and the low flows would impact on water availability within the groundwater resources. Reduced recharge will reduce water for wetlands and baseflow for rivers which further impact EWR. The The likelihood is possible that low flows would reduce recharge and consequence would be minor as there are no significant beneficiarioes of groundwater resources in the IUA. **SWSA** The flow related nature of the impacts of these scenarios results in an unlikely impact to SWSA. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 89%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.
2 (1PR)	Allocate to maintain current state (PES) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences impacts on water quality including sediments and nutrients from upstream irrigation and urban represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 82 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.

Scenario	Description	Environmental Effect in IUA 11
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC (Rivers only). Allocate where possible to demand	The allocation of 82 million m3/a will ensure the EWR for rivers are met. The TEC requirement for IUA 11 is slightly larger than the PES for IUA 11 and therefore the negative environmental effects will be slightly less to that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 82 million m3/a will ensure the EWR for both estuaries and rivers are met. The TEC (incl estuary) for IUA 11 is equivalent to the PES (incl estuary) for IUA 11 and therefore the environmental effects are the same as that of scenario 2.

8.3.12 IUA 12

IUA 12, the Middle Tugela IUA, includes the local municipalities of Msinga, Inkosi Langalibalele and Endumeni. The IUA includes the towns of Tugela ferry, Mhlangana and Pomeroy. A portion of Weenen Game Reserve falls within the IUA. Water resources in the IUA include the Middle Tugela River and tributaries. The population of IUA 12 is approximately 167 630 with approximately 34 418 households. A small region of mixed dryland and irrigated agriculture can be seen in the wester sector of this IUA, while subsistence agriculture is the dominant land use. The largely rural population of IUA 12 is reliant on subsistence agriculture and grazing.

Key water demands in IUA 12 are summarised in Table 72.

Table 71: Key water demand categories, locations and source of water in IUA 12

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 15: Thukela Ferry	DEM 15: Tugela River
- **Irrigation demand**	Upper catchment: TM122.IRD	TM122.IRD: Bloukransrivier

Key ecological infrastructure in IUA 12 are summarised in Table 73.

Table 72: Key aquatic ecological infrastructure identified in IUA 12

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Tugela river and its tributaries
Wetlands	No major wetlands in the IUA
Aquifers	Alluvial aquifers with high surface to groundwater interaction. Moderate to low shale siltstone aquifer resources.
SWSA	Limited SWSA within the IUA

The general location of the demands and ecological infrastructure are indicated in Figure 31. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

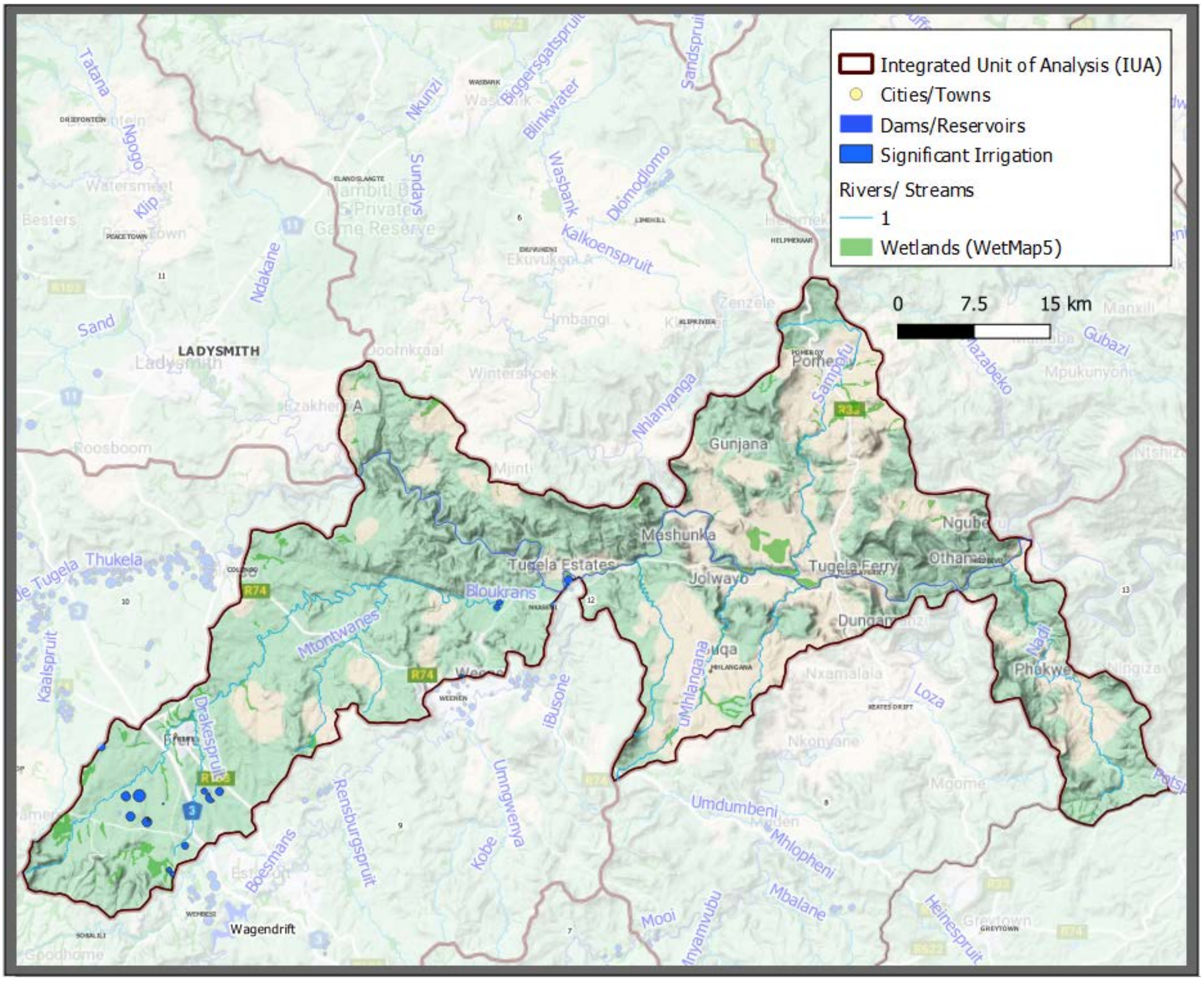


Figure 31: Locality of the demands, and ecological infrastructure are indicated for IUA 12

Note that for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.12.1 Environmental Effect Statement

There is currently not sufficient water available in IUA 12 to effectively supply the current demands (92% in scenario 1). As the urban demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 12 is provided in Table 74.

Table 73: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 12

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
12	EWR	0.00	0.00	0.00	0.00	1665.57	1665.57	1689.67	1689.64	0.00	1688.88	1689.29	0.00	1691.05	1690.68
12	Irrigation Demand	2.13	2.13	2.13	1.86	1.58	1.58	1.58	1.55	1.86	1.55	1.55	1.86	1.70	1.55
12	Urban Demands	1.10	3.84	8.50	1.10	0.95	0.95	0.95	0.95	3.85	3.31	3.28	8.51	7.95	7.32
12	**TOTAL (Formal Economy Only)**	**3.23**	**5.97**	**10.63**	**2.96**	**2.52**	**2.52**	**2.52**	**2.49**	**5.71**	**4.86**	**4.83**	**10.38**	**9.65**	**8.86**
12	**TOTAL ALLOCATION (incl EWR)**				**2.96**	**1668.10**	**1668.10**	**1692.19**	**1692.13**	**5.71**	**1693.74**	**1694.11**	**10.38**	**1700.70**	**1699.54**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 75 describes the environmental effects as aggregated for various scenarios.

Table 74: Environmental effect statement aggregated by scenario for IUA 12

Scenario	Description	Environmental Effect in IUA 12
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** Upper reaches experience extended low flow periods due to upstream extractions. Lower reaches (once the Mooi and Buffalo have joined) low flows are shorter (June-August) however remain lower than the EWR. Seasonality (unnatural hydro cycle) is maintained (peaks are good on average). This results in a modification of flow which does not align with natural flow cycles. Water quality impacts are not major compared to upstream (IUA10). Some nutrients.

Scenario	Description	Environmental Effect in IUA 12
		Alterations of the natural rhythm (hydro cycle) of flows directly impacts river habitats and therefore the functionality of ecosystems. Unnatural or modified flows lower habitat diversity across a yearly hydro cycle and therefore influences species diversity. Interactions between and within microhabitats on a temporal scale are vital to the overall stability of the system. Temporal impacts to habitats are driven by alterations of the following: - Flow Volume (Impacts depth of microhabitats or ability for species to migrate, flood events); - Flow Rate (Impacts rifles, flushes, dynamics between shallows and river banks) - Water temperature (Impacts spawning and productivity-e.g., high release in winter triggers fish spawning but unnaturally cold water impacts spawning success) - Water quality (eutrophication, microhabitats naturally vary over the year e.g., Flush events cause changes in water quality and stimulate spawning) These conditions vary naturally over time to maintain species diversity. Impacts on any trophic level could drive a cascade effect. Low flows do not flush rivers which combined with higher temperatures and increased nutrients result in exposure to and smothering from algae and silt, and therefore loss of river biota. Low flow and reduced water volume impact riparian zone through loss of overhanging vegetation and therefore loss of habitats. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Some subsistence agriculture. 41% of households rely on rivers/streams for primary water source	Possible	Severe	Extreme	The flows are low but do not reach zero. This means an impact is possible, however as the catchment population relies so heavily on these water sources the consequences to impact are severe.
Food Provisioning	The livestock grazers and the rural subsistence settlements	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.

Scenario	Description	Environmental Effect in IUA 12

Habitats for species	Habitats have high diversity (id classes and depth ranges) however presence of the endemic Tugela Labio (vulnerable IUCN).	Possible	Major	High	The Tugela Labio requires flow to survive. Species extinction is therefore a risk here and as such consequence is major
Ecotourism & recreation	Kayaking/boating/fishing activities associated with the deeper water of the Tugela	Likely	Moderate	High	It is very likely that reduced flow will impact aquatic related recreational activities. It is not clear on the significance of the tourism industry. As such consequences are seen as moderate. which consequences in this developed tourism industry would be major.

Wetlands

No major wetland systems at risk due to varying scenarios.

Aquifers

The scenarios expect low surface water flows These low flows in Alluvial systems means the recharge rate will be reduced and the low flows would impact on water availability within the groundwater resources. Reduced recharge will reduce water for wetlands and baseflow which further impact EWR. Springs would have reduced flows. This will impact the entire hydrological cycle.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	Some subsistence agriculture. 41% of households rely on rivers/streams for primary water source	Possible	Major	High	Low flow will possibly impact the water provisioning as the systems are already lower yield resources. Additional pressures on available water would exacerbate these limitations. The likelihood is possible that low flows would reduce recharge and consequence would be major as there are numerous direct community beneficiaries who rely on availability of these water resources.

Scenario	Description	Environmental Effect in IUA 12
		SWSA The flow related nature of the impacts of these scenarios results in an unlikely impact to SWSA. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 92%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.
2 (1PR)	Allocate to maintain current state (PES of D to C) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences impacts on flow through low flow periods represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 1666 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of D to B/C (Rivers only). Allocate where possible to demand	The allocation of 1690 million m3/a will ensure the EWR for rivers are met. The TEC requirement for IUA 12 is slightly larger than the PES for IUA 12 and therefore the negative environmental effects will be slightly less to that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 1690 million m3/a will ensure the EWR for both estuaries and rivers are met. There is no additional water requirement to ensure the maintenance of the estuary TEC over and above the river TEC. The impacts are therefore the same as scenario 2.

8.3.13 IUA 13

IUA 13, the Lower Tugela IUA, includes the Nkandla, uMlalazi, uMvoti and Maphumulo local municipalities. The relatively undeveloped IUA includes the towns of Jamesons Drift and Kranskop. Multiple protected areas including various nature reserves and Forest reserves are mostly in the upstream portions of the IUA. Two key water transfers are from the Tugela river through the Thukela to Mhlatuze (to Goedertrouw) and the Lower Thugela (distributed to north and south coast) transfer schemes. The population of IUA 13 is approximately 211 121 with approximately 45 923 households. No significant local demand is placed on the water resources of this IUA, with scattered subsistence agriculture being the defining characteristic. IUA 13, falling in the lower reaches of the Tugela River is, much like the greater study area, predominantly rural, relying almost exclusively on subsistence agriculture and grazing.

Key water demands in IUA 13 are summarised in Table 76.

Table 75: Key water demand categories, locations and source of water in IUA 13

Demand Category	Demand Location	Source of Water
- **Urban demands (Domestic and commercial demands)**	DEM 13: Sappi, Mandini, Thukela, Sundumbili	DEM 13:
- **Irrigation demand**	Along the Tugela River (MAND2.IRD, MHL_B2.IRD, MHL_A2.IRD)	MAND2.IRD (downstream Mhlatuze Weir) MHL_B2.IRD (Mhlatuze Weir) MHL_A2.IRD (Upstream Mhlatuze Weir)
- **Transfers**	Goedertrou Dam (Richards Bay)	Mhlatuze Weir (middle catchment)
	Coastal Bulk Water Supply	Mandini Extraction Weir (Lower Tugela- Note may be in IUA 15)

Key ecological infrastructure in IUA 13 are summarised in Table 77.

Table 76: Key aquatic ecological infrastructure identified in IUA 13

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Tugela river and its tributaries
Wetlands	Very few wetland systems
Aquifers	Moderate to low shale siltstone aquifer resources.
SWSA	Scattered SWSA's throughout the catchment

The general location of the demands and ecological infrastructure are indicated in Figure 32. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

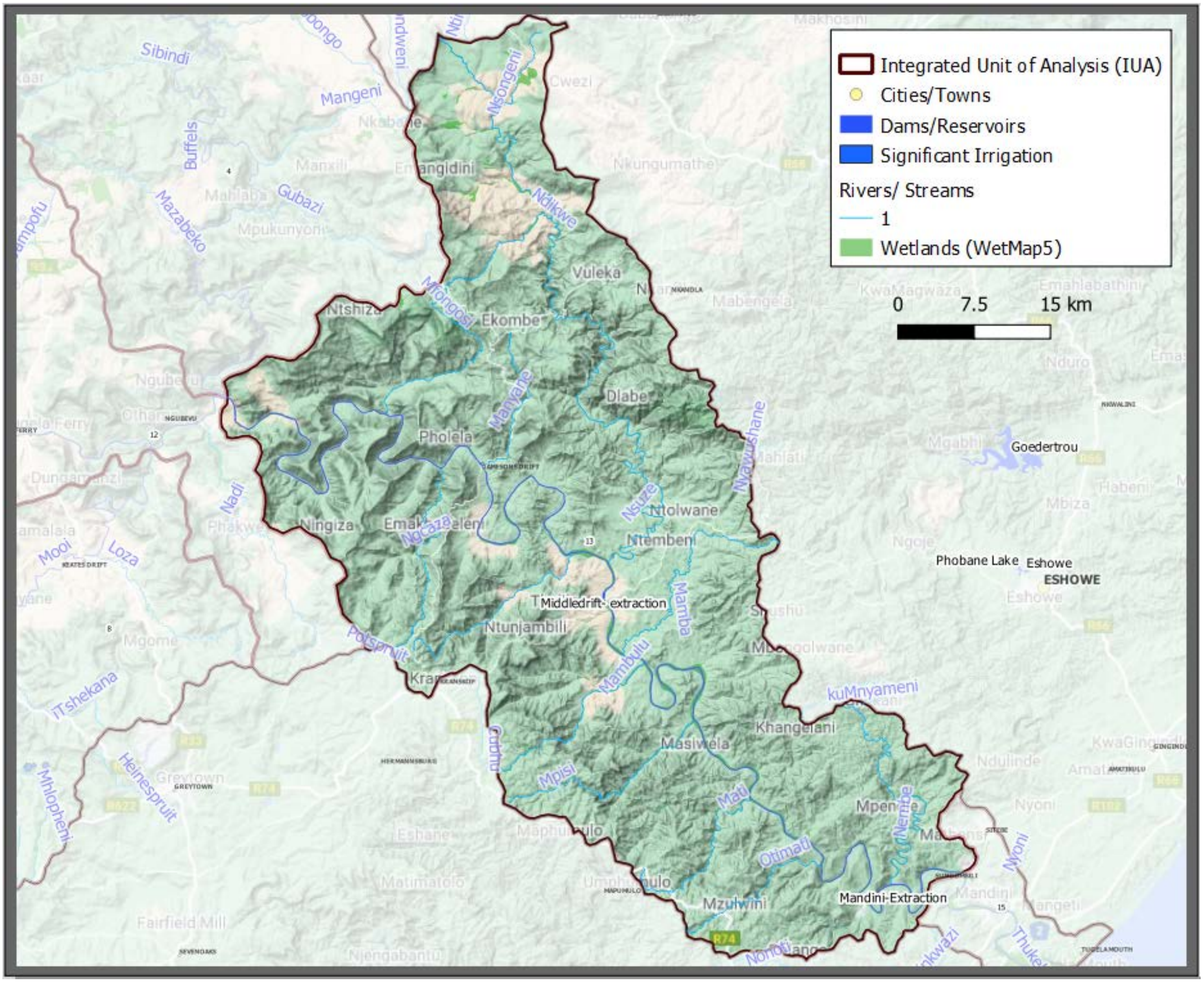


Figure 32: Locality of the demands, and ecological infrastructure are indicated for IUA 13

Please note: for the case of demands not spatially associated with a major dam or impoundment, it is assumed that the extraction point falls on the closest associated water resource. This is especially the case for irrigation demands.

8.3.13.1 Environmental Effect Statement

There is currently not sufficient water available in IUA 13 to effectively supply the current demands (97% as per scenario 1). As urban and transfer demands increase into the future, the various scenarios describe variations in water allocation between the socio economic and ecological needs over time. A summary of the water demands by beneficiaries and potential water allocation per scenario in IUA 13 is provided in Table 78.

Table 77: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 13

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
13	EWR	0.00	0.00	0.00	0.00	2426.54	2426.54	2426.63	2425.47	0.00	2427.23	2426.06	0.00	2428.87	2426.13
13	Irrigation Demand	33.27	33.27	33.27	32.83	22.52	22.55	22.74	20.40	32.83	21.85	19.68	32.83	27.44	22.33
13	Transfers	82.94	102.81	102.81	79.22	48.94	48.94	49.48	44.43	98.36	59.57	53.90	97.48	73.45	57.58
13	Urban Demands	17.01	18.54	20.22	17.00	11.86	11.86	11.95	10.82	18.54	12.55	11.23	20.21	16.84	13.69
13	**TOTAL (Formal Economy Only)**	**133.22**	**154.61**	**156.30**	**129.05**	**83.32**	**83.35**	**84.17**	**75.65**	**149.73**	**93.98**	**84.80**	**150.52**	**117.72**	**93.60**
13	**TOTAL ALLOCATION (incl EWR)**				**129.05**	**2509.86**	**2509.89**	**2510.80**	**2501.12**	**149.73**	**2521.21**	**2510.86**	**150.52**	**2546.60**	**2519.73**

The impacts of varying water allocation of the various scenarios on the environment are described below. Please note: The location of water extraction, discharge, and management within the IUA determine the likely region of impact for local and downstream ecosystems. Table 79 describes the environmental effects as aggregated for various scenarios.

Table 78: Environmental effect statement aggregated by scenario for IUA 13

Scenario	Description	Environmental Effect in IUA 13
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **Waterways (Rivers and Riparian Ecosystems)** The observed hazard in this IUA is not lack of flow but rather increased contaminants due to land uses and activities upstream. More specifically increased pathogens and nutrients (increased density of livestock) and sediments (overgrazing, trampling and erosion) are observed instream and along the riparian zone. A driving

Scenario	Description	Environmental Effect in IUA 13
		factor for reduced water quality is limited tributaries feeding into the Tugela and therefore no dilution effects can take place. Nutrients cause eutrophication in drier months and likely impacts the condition of drinking water, owing to increase algal growth. Sediment impact microhabitats by preventing light penetration and siltation which reduces heterogeneity of waterways. Pathogens directly affect quality of drinking water (communities and livestock) but no likely effect on natural systems. Results of the CRA process indicated the following high and extreme risks to associated ecosystem services.

Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Fresh Water (Natural Sources)	65% of households use natural sources as primary water source	Almost certain	Severe	Extreme	The water quality contaminants identified would directly impact the use of this water for domestic purposes. The likelihood of impact is therefore almost certain. The consequences in this catchment are severe.
Food Provisionin g	No obvious beneficiaries however the highly reliant nature of communities should be considered	Possible	Moderate	High	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms especially diversity of fish species. The presence of these communities in the IUA means consequences of impact could be moderate.
Habitats for species	Lower diversity of habitat- sandy clay and deep channels. No specifically significant species observed although the Tugela Labio is expected here. Overall higher diversity of fish species is expected in this IUA.	Possible	Moderate	High	Higher species diversity (fish etc)- at least higher than upper reaches. Habitats however are lower diversity. Water quality impacts are possible with moderate consequences.

Scenario	Description	Environmental Effect in IUA 13
		<table><tr><td>**Landscape & amenity values**</td><td>Traditional communities</td><td>Possible</td><td>Moderate</td><td>High</td><td>It is possible that increased nutrient loads and pathogens could impact this service, with the presence of traditional communities an impact would have moderate consequences</td></tr><tr><td>**Ecotourism & recreation**</td><td>Kayaking/boating/fishing</td><td>Possible</td><td>Moderate</td><td>High</td><td>It is possible that sedimentation and wq impacts would impact the tourism industry. The expected small industry results in moderate consequences</td></tr></table> **Wetlands** No major wetland systems at risk due to varying scenarios. **Aquifers** Impacts on aquifers are unlikely due to the insignificant surface to groundwater interaction of shale aquifers characteristic of the region. **SWSA** The flow related nature of the impacts of these scenarios result in an unlikely impact to SWSA. **Socio-Economic Effect** Even though the EWR is not considered the supply of water is not sufficient to supply the full demand as required by all identified beneficiaries (only 97%). As a result, water is allocated based on assurance of supply (penalties of no supply) and all beneficiaries will have reduced allocation.
2 (1PR)	Allocate to maintain current state (PES of C) in rivers. Allocate where possible to demand	Maintenance of current state of which increased contaminants due to land uses and activities upstream results in similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 2427 million m3/a allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.
3 (1PE)	Allocate to maintain current state (PES) in rivers and	There is no additional water requirement to ensure the maintenance of the estuary PES over and above the river PES. The impacts are therefore the same as scenario 2.

Scenario	Description	Environmental Effect in IUA 13
	estuary. Allocate where possible to demand	
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC of C (Rivers only). Allocate where possible to demand	The allocation of 2427 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 13 is equivalent to the PES for IUA 13 and therefore the environmental effects are the same as that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 2425 million m3/a will ensure the EWR for both estuaries and rivers are met. The TEC (incl estuaries) for IUA 13 is slightly lower than the PES (incl estuaries) for IUA 13 and therefore the environmental effects are expected to be slightly higher than that of scenario 2.

8.3.14 IUA 14

IUA 14, the Escarpment IUA, straddles the local municipalities of Okhahlamba, Inkosi Langalibalele and Mpofana. The IUA is highly undeveloped and includes no major towns. Communities, although small, are largely present in the northern reaches. Much of the IUA is protected through the Drakensberg complex of national parks, wilderness areas and nature reserves. Key water resources in the IUA include the headwaters for many tributaries to the Tugela River. The population of IUA 14 is approximately 29 297. This IUA is the least developed IUA in the larger catchment and consists of mostly protected land, which serves as a strategic source of water for the entire basin.

There are currently no water demands nor are there water demands proposed for IUA 14. As a result, the IUA is not at risk of activities proposed across the various scenarios. The IUA is therefore not assessed by scenario.

8.3.15 IUA 15

IUA 15, the Tugela Mouth Estuary IUA, is found within Mandeni local municipality. It includes the town of Mandini (portion thereof) and communities of Tugela Mouth and Sundumbili. The IUA includes various protected areas including Nature reserves and the Tugela Mouth Marine Protected Area. The population of IUA 15 is approximately 39 161 with approximately 12 818 households. High levels of industrial manufacturing and sugarcane cultivation characterise this IUA, with residential and industrial water use being a major user of water resources.

There are no current or proposed water demands for IUA 15.

Key ecological infrastructure in IUA 15 are summarised in Table 80.

Table 79: Key aquatic ecological infrastructure identified in IUA 15

Ecological Infrastructure	Focus Description
Waterways (Rivers/Streams)	Lower Tugela River flowing into the Tugela River Mouth
SWSA	The entire IUA

The general location ecological infrastructure is indicated in Figure 33. Extraction points on water resources were seen as key to understanding the downstream effects of varying scenarios on the environment (see environmental effect statement).

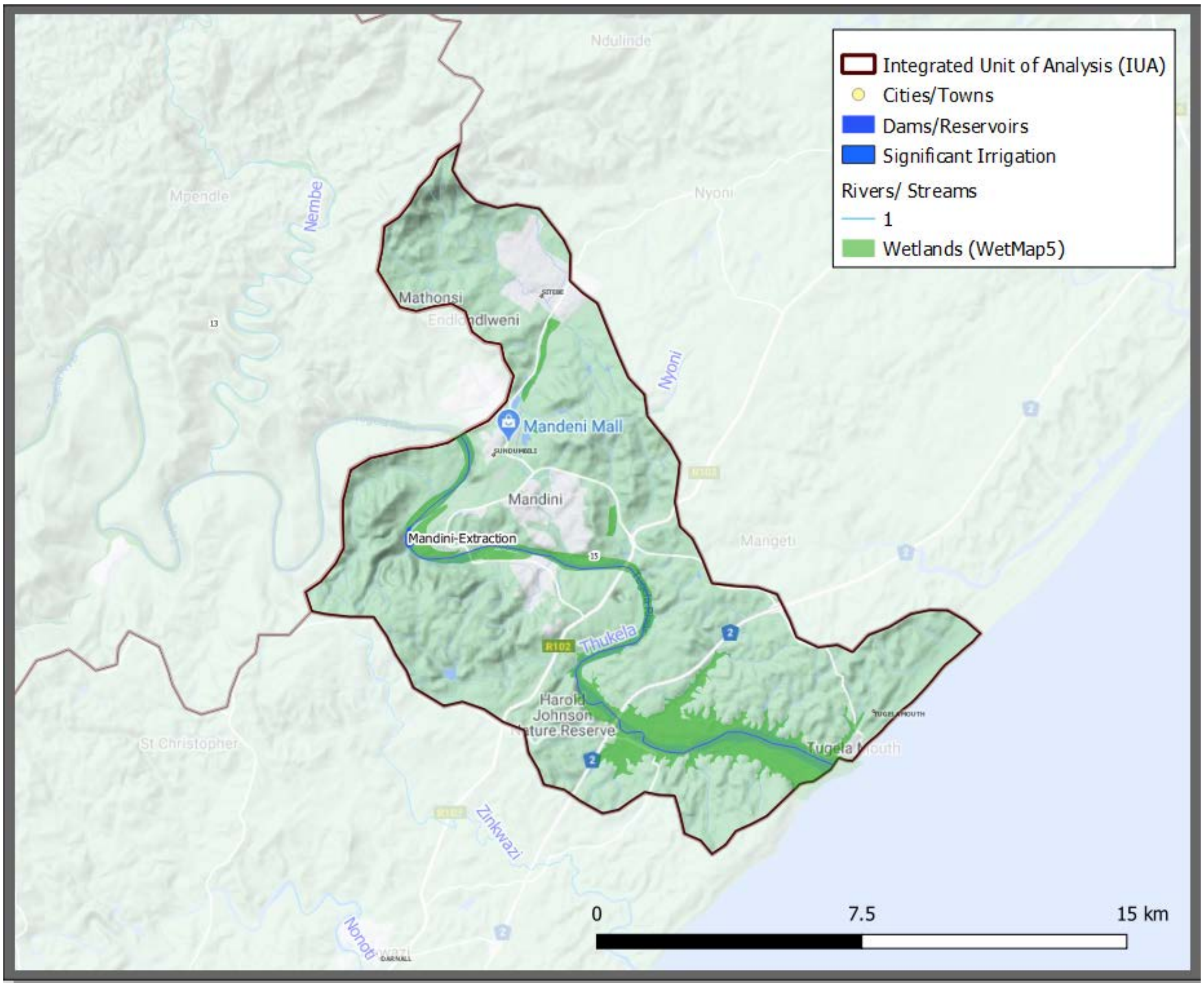


Figure 33: Locality of the demands, and ecological infrastructure are indicated for IUA 15

8.3.15.1 Environmental Effect Statement

A summary of the water demands by beneficiaries (none in this IUA) and EWR per scenario in IUA 15 is provided in Table 81.

Table 80: Aggregated summary of water demands by beneficiary and potential water allocation per scenario in IUA 15

IUA	Beneficiary	Demand (mil m³/a)			Water Allocation (mil m3/a)										
		2020	2030	2040	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
15	EWR	0.00	0.00	0.00	0.00	1473.87	2947.10	1473.87	3352.47	0.00	1473.87	3352.59	0.00	1473.87	3352.59
15	**TOTAL (Formal Economy Only)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
15	**TOTAL ALLOCATION (incl EWR)**				**0.00**	**1473.87**	**2947.10**	**1473.87**	**3352.47**	**0.00**	**1473.87**	**3352.59**	**0.00**	**1473.87**	**3352.59**

The impacts of varying scenarios on the environment are described below. Table 82 describes the environmental effects as aggregated for various scenarios.

Table 81: Environmental effect statement aggregated by scenario for IUA 15

Scenario	Description	Environmental Effect in IUA 15
1 (1N), 6 (2N) and 9 (3N)	Full allocation to demand. No EWR considered	In scenario 1, 6 and 9 the EWR is not considered as a demand i.e. allocation of water to EWR is 0. Scenario 1 reflects the current case in the uThukela catchment, as no water is currently being allocated to the EWR (2020). The zero allocation of water to the EWR does not necessarily result in zero water being used towards the maintenance of ecosystems (as assessed in 2020). The ecological use of water through excess unallocated water (in the wet season), irrigational runoff, return flows and through the distribution of water by use of waterways is independent of water management allocations. The ecological use of excess water (in a zero-allocation scenario) is however restricted in the dry season, when demand allocations significantly reduce the availability of water for ecological functioning. This lack of consideration of the EWR in water allocation has resulted in current impacts on ecological systems as can be observed in the environmental effect statement below. **The Estuary including upper Waterways (Rivers and Riparian Ecosystems)** IUA 15 experiences extreme low flows and the current EWR is not met by half due to cumulative effect of extensive upstream extractions. Water is further extracted for industrial purposed (Mandini and Sappi) within the IUA. The low flows are expected to be exacerbated in the zero EWR allocation scenario. August to October is the predominant risk for reduced baseflow. Water quality impacts include nutrients and pathogens from informal communities and overloaded WWTW at Mandini. Furthermore, contaminants from SAPPI (pulps) and Mandini. Reduced baseflow will alter the processes within the river mouth which eventually has a direct link on the estuary metasystem (Continental shelf and Tugela banks). These impacts include the following:

Scenario	Description	Environmental Effect in IUA 15
		- In a natural state the Tugela mouth is permanently open. If the mouth closes this has cascade effect on natural processes and habitats within the estuary. Decreased baseflow reduces flushing which results in accumulated fine sediments and eventually closing of the mouth. Closing of the mouth and reduced flushing exacerbates water quality issues observed and reduces desirable oxygen concentrations. The river mouth requires at least 5 to 7m^3/s to keep the mouth open. - Salinity intrusion is expanded under decreased baseflow. Under river mouth conditions there is higher tidal inflow- i.e. salinity intrusion would expand upstream. Pulps impact salinity and introduce fibres (cellulose fibres which reduce clarity of water) to the water. Eutrophication is relatively low regardless of heightened nutrient concentrations. These WQ issues coupled with the closing of the mouth would mean likely major impacts from these contaminants. Results of the CRA process have been nested in the estuarine ecological infrastructure.

Ecosystem	Ecosystem Service	Description	Likelihood of Impact	Consequence of Impact	Risk Rating	Risk Description
Estuary	Habitats for species	River mouth conditions means small intertidal zone. As flow decreases tidal zone increases until the mouth closes. This becomes flooded with freshwater which has extreme impacts on habitats for species.	Likely	Moderate	High	River mouth conditions means small intertidal zone. As flow decreases tidal zone increases which increases diversity (interesting) until the mouth closes which drops in diversity. This becomes flooded with freshwater which has extreme impacts on habitats for species (note change from natural). Habitat diversity will drop drastically with closure of the mouth.
Estuary	Ecotourism & recreation	Recreational fishermen (note MPA so specific species are catch and release);	Likely	Moderate	High	High recreational fishing but very difficult to get boats into system. - no boating due to low baseflow. The increased diversity however the fish catch would likely decrease. The likelihood of this impact is likely with moderate consequences. PLEASE NOTE: gillnetting has devastated fisheries (this is more "subsistence or poaching for resale").

Scenario	Description	Environmental Effect in IUA 15

Estuary	Educational values	Only two river mouths in SA- orange and Tugela. This means the Tugela has been the focus of many studies. It is rare and therefore has opportunity.	Unlikely	Major	High	The significance of the River Mouth system results in major consequences if impacted. The likelihood however of continued impact is unlikely (due to the current status quo)
Tugela Banks	Habitats for species	Note this represents habitats at Tugela banks- consequences are severe due to the long-term impacts and difficulty to mitigate the impacts.	Likely	Moderate	High	The fine sediments would not be flushed as often- there would be a shift from a muddy to sandy system this would limit the nutrients reaching the Tugela banks. Reduction in diversity at Tugela banks. From natural we see this happening which has caused a collapse of fisheries (as seen by commercial fishing).
Tugela Banks	Ecotourism & recreation	Tugela mouth village fish off the beach.	Likely	Moderate	High	We expect a reduction in fishing success. The village focusses on recreational fishing impacts of which would be moderate. No specific data on this but we expect the tourism industry associated with fishing to decrease.
Tugela Banks	Educational values	There has been a lot of research- between the dynamics of the river mouth and the Tugela banks.	Unlikely	Major	High	Major consequences from impacts especially from a commercial fisheries point of view.

SWSA

The flow related nature of the impacts of these scenarios results in an unlikely impact to SWSA.

Scenario	Description	Environmental Effect in IUA 15
2 (1PR)	Allocate to maintain current state (PES) in rivers. Allocate where possible to demand	Maintenance of current state of which experiences low flows and water quality impacts represents similar environmental effects compared to scenario 1, 6 and 9 (above) however to a lesser magnitude as water will be allocated to maintaining the PES throughout the year (especially significant in dry seasons). The requirement of 1474 allocation to maintain the PES will reduce the allowances to the demands of catchment beneficiaries.

Scenario	Description	Environmental Effect in IUA 15
3 (1PE)	Allocate to maintain current state (PES) in rivers and estuary. Allocate where possible to demand	The additional water allocation to maintain the estuary EWR compared to that of the river is almost double with 2947 million m3/a allocation for both the river and estuary EWR.
4 (1TR), 7 (2TR) and 10 (3TR)	Allocate to achieve TEC (Rivers only). Allocate where possible to demand	The allocation of 1474 million m3/a will ensure the EWR for rivers are met. The TEC for IUA 15 (River only) is equivalent to the PES for IUA 15 and therefore the environmental effects are the same as that of scenario 2.
5 (1TE), 8 (2TE) and 11 (3TE)	Allocate to achieve TEC (Rivers and Estuary). Allocate where possible to demand	The allocation of 3352 million m3/a will ensure the EWR for both estuaries and rivers are met. The TEC for IUA 15 (rivers and estuary) is 405 million m3/a larger than the current PES and therefore the environmental effects described above are expected to be significantly decreased.

8.4 OUTPUT

The CRA process ranked ecosystem services based on their risks to specific environmental hazards per IUA. The count of aggregated risk per ecosystem service and IUA can be seen in Table 83 and respectively Table 84.

Results show key ecosystem services at risk, according to the count of high and extreme risks, in descending order to be freshwater provisioning (Directly used by beneficiaries from natural sources), habitats for species, ecotourism and recreation and food provisioning (Table 83). These ecosystem services are ranked as being at higher risk of impact as a response to scenario implementation.

Table 82: Count of aggregated risk to ecosystem services as a result of impacts on ecological infrastructure by identified environmental hazards

Ecosystem Services	Aggregated Risk to Ecosystem Service				
	Extreme	High	Medium	Low	Total Extreme and High
Ecotourism & recreation		9	8	12	9
Educational values		3		26	3
Food Provisioning		8	7	13	8
Fresh Water (Natural Sources)	9	11	4	10	20
Habitats for species		19	7	2	19
Inspirational Value		3	1	25	3
Landscape & amenity values		3	8	18	3
Medicinal resources				29	0
Raw materials / Fibre			10	19	0

The IUA's at highest risk based on the count of high and extreme risks, in descending order include 15, 7, 13, 8 and 1 (Table 84). This is generally as a result of significant ecological infrastructure being present together with vulnerable communities that rely on ecosystem services for their wellbeing.

Table 83: Count of aggregated risk per IUA to ecosystem services as a result of impacts on ecological infrastructure by identified environmental hazards in the Thukela catchment

IUA	Aggregated Risk to Ecosystem Services per IUA				
	Extreme	High	Medium	Low	Total Extreme and High
1		6	3	8	6
2			6	13	0
3		3	3	22	3
4	1	1	2	6	2
5	1	3	5	18	4
6	2	2	4	10	4
7		9	1	17	9
8	2	5	2	18	7
9		5	7	6	5
10		3	2	4	3

IUA	Aggregated Risk to Ecosystem Services per IUA				
	Extreme	High	Medium	Low	Total Extreme and High
11		3	2	5	3
12	1	4	2	3	5
13	2	6	3	7	8
15		6	3	16	22

The steps to follow are to evaluate the ecosystem services that have been highlighted through the CRA process to be of special concern. The evaluation step looks at the magnitude of an impact, both on the demand and the EWR, and assesses it against the potential benefits of the various scenarios. The relative risks will be evaluated at a desktop level and together with specialists at the scenario trade-off workshops to follow.

9. SUMMARY OF SCENARIO EVALUATION RESULTS

Table 30 summarises the scenario evaluations.

Table 84: Summary of Scenario results

IUA	EWR site name	River	Natural MAR (10^6m^3)	TEC	EWR Requirement million m^3/a	EWR Requirement % MAR	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
1	THU_EWR23	Upper Buffalo	221.96	C	53.90	24.28%	152.04	163.985	163.985	163.760	165.557	168.75	175.969	177.536	175.38	178.738	183.704
2	May13_EWR2	Horn	21.61	C	7.16	33.15%	21.02	21.018	21.018	21.018	21.018	21.02	21.018	21.018	21.02	21.018	21.018
	THU_EWR19	Ncandu	50.83	B/C	14.23	28.00%	49.92	49.915	49.915	49.915	49.915	49.92	49.915	49.915	49.92	49.915	49.915
	May13_EWR3	Ngagane	160.12	C	40.68	25.40%	79.10	104.467	104.474	104.443	107.360	77.23	103.357	106.184	69.44	80.008	88.645
	Ngagane_dsk	Lower Ngagane	240.84	C	51.03	21.19%	148.72	174.086	174.094	174.063	176.979	146.85	172.976	175.803	139.06	149.627	158.264
3	THU_EWR13A	Middle Buffalo	626.68	C/D	134.53	21.47%	466.04	475.999	475.999	475.826	483.112	480.31	488.090	495.165	474.15	467.413	486.328
	Thukela_EWR13	Middle Buffalo	695.05	C/D	149.87	21.56%	521.48	568.259	568.258	568.099	575.427	534.70	579.236	586.370	523.90	554.191	573.509
4	Thukela_EWR14	Lower Buffalo	831.09	B/C	190.86	22.97%	640.02	687.494	687.495	687.404	694.916	653.24	698.383	705.689	642.44	673.116	692.979
5	Blood_dsk	Blood	94.71	B/C	21.14	22.32%	77.34	78.032	78.033	78.101	78.284	77.34	77.943	78.114	77.34	77.721	78.266
6	THU_EWR7A	Upper Sundays	50.69	C	17.01	33.56%	42.58	43.099	43.099	43.109	43.110	42.67	43.153	43.154	42.74	43.198	43.197
	Thukela_EWR7	Upper Sundays	90.28	C	21.43	23.73%	54.80	56.570	56.554	56.266	55.506	54.95	56.515	55.865	55.13	56.359	55.554
	Thukela_EWR8	Lower Sundays	197.03	D	47.21	23.96%	166.57	146.850	146.850	148.444	148.450	166.09	148.137	148.140	165.58	147.771	147.809
7	THU_EWR20	Nsonge/ Hlatikulu	27.13	B/C	8.02	29.55%	24.69	25.271	25.271	25.274	25.284	24.69	25.282	25.294	24.68	25.251	25.272
	EWR_Mooi_N3	Mooi	265.81	D	77.16	29.03%	90.71	154.396	154.396	152.417	156.170	88.55	150.315	154.051	96.22	155.140	167.603
	Thukela_EWR11	Mooi	301.14	B/C	113.80	37.79%	116.16	182.562	182.562	180.640	184.456	114.01	178.630	182.433	121.66	182.975	195.919
8	THU_EWR21	Mnyamvubu	31.71	B/C	4.86	15.33%	25.57	25.770	25.770	25.760	25.758	20.89	21.595	21.636	20.89	21.339	21.720
	THU_EWR12A	Mooi	361.85	C	121.15	33.48%	158.19	226.474	226.474	224.682	228.575	151.94	219.202	223.153	159.21	222.280	236.011
	Mooi_dsk	Mooi	388.66	C	126.20	32.47%	177.59	250.759	250.759	248.967	252.848	171.35	243.470	247.410	178.61	246.542	260.235
9	Thukela_EWR5	Middle Bushmans	281.45	C/D	107.45	38.18%	241.38	244.218	244.218	244.083	244.083	240.20	243.108	243.108	112.33	130.703	130.720
	THU_EWR6A	Lower Bushmans	298.37	C/D	104.71	35.09%	239.34	154.303	154.335	164.931	165.565	238.13	164.125	164.873	110.20	68.359	73.792

IUA	EWR site name	River	Natural MAR ($10^6 m^3$)	TEC	EWR Requirement		Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
					million m^3/a	% MAR											
	Thukela_EWR6	Lower Bushmans	303.14	C/D	76.37	25.19%	234.65	238.006	238.006	237.885	237.885	233.44	236.906	236.906	105.51	125.410	125.428
10	Thukela_EWR1	Upper Thukela	705.42	D	156.53	22.19%	58.77	190.781	190.781	194.324	195.622	58.53	193.664	194.982	58.39	180.682	192.830
	Thukela_EWR2	Upper Thukela	798.4	C	202.60	25.38%	111.38	270.624	270.624	274.727	276.162	107.19	273.432	274.902	105.04	259.493	273.003
	Thukela_EWR3	Little Thukela	285.2	C/D	82.02	28.76%	250.53	258.023	258.023	258.023	258.023	249.95	257.555	257.555	249.59	257.263	257.263
	Thukela1_dsk	Thukela	1145.2	C	259.97	22.70%	397.06	299.935	299.935	299.986	301.187	391.75	298.639	299.965	388.48	288.362	298.939
11	THU_EWR22*	Klip	52.44	C	13.66	26.06%	49.26	49.264	49.264	49.265	49.266	49.26	49.265	49.266	49.26	49.260	49.264
	Klip_dsk	Klip	253.09	C	68.23	26.96%	232.99	237.514	237.514	237.724	237.738	232.47	237.401	237.401	231.99	236.725	237.082
12	Thukela_EWR4A, B, C	Middle Thukela	1423.83	B/C	404.98	28.44%	632.57	833.311	833.311	838.133	839.839	629.89	839.483	841.205	339.73	612.446	682.991
	Thukela_EWR9	Middle Thukela	2050.76	D	500.35	24.40%	1154.57	1363.683	1363.683	1368.402	1370.150	1148.18	1366.728	1368.520	725.85	1023.870	1095.265
	Thukela2_dsk	Middle Thukela	2461.22	C	784.71	31.88%	1332.17	1486.578	1486.578	1489.505	1495.133	1319.53	1482.334	1488.066	904.47	1142.548	1227.635
13	Thukela_EWR15	Lower Thukela	3424	C	871.46	25.45%	2111.34	2443.385	2443.385	2446.188	2459.843	2109.15	2447.517	2461.094	1677.41	2075.381	2182.165
	THU_EWR16	Lower Thukela	3679.97	C	1557.43	42.32%	2274.79	2637.256	2637.257	2639.380	2659.143	2272.59	2643.583	2662.622	1840.86	2255.083	2376.593
14	V11A_dsk	Thukela	66.9	B			66.90	66.9	66.9	66.9	66.9	66.90	66.9	66.9	66.90	66.9	66.9
	V11B_dsk	Sithene, Thonyelana	142.69	B			142.69	142.69	142.69	142.69	142.69	142.69	142.69	142.69	142.69	142.69	142.69
	V11G_dsk	Mlambonja, Mhlwazini	191.99	B			191.99	191.99	191.99	191.99	191.99	191.99	191.99	191.99	191.99	191.99	191.99
	V13A_dsk	Little Thukela	82.32	B			82.32	82.32	82.32	82.32	82.32	82.32	82.32	82.32	82.32	82.32	82.32
	V70A_dsk	Bushmans	113.46	B			113.46	113.46	113.46	113.46	113.46	113.46	113.46	113.46	113.46	113.46	113.46
	V70B_dsk	Nsibidwana	44.16	B			44.16	44.16	44.16	44.16	44.16	44.16	44.16	44.16	44.16	44.16	44.16
	V20A_dsk	Mooi	42.9	B			42.90	42.9	42.9	42.9	42.9	42.90	42.9	42.9	42.90	42.9	42.9
	V20B_dsk	Little Mooi	10.32	B/C			10.32	10.32	10.32	10.32	10.32	10.32	10.32	10.32	10.32	10.32	10.32
15	THU_EWR17	Lower Thukela	3690.53	C	1474.88	39.96%	2262.36	2637.827	2637.828	2639.791	2661.580	2240.35	2631.958	2654.400	1808.86	2238.353	2368.315

10. PROPOSED WATER RESOURCE CLASSES

Based on the present ecological condition of water resources within the Thukela catchments, the IUA scale ESBC ECs tested are set out in Table 86.

Table 85: Aggregated EC per IUA

IUA	Catchment Area	Aggregated EC per IUA (PES)	Aggregated EC per IUA (TEC)
IUA1	Upper Buffalo	C	C
IUA2	Ngagane River	C	C/D
IUA3	Middle Buffalo	D	C/D
IUA4	Lower Buffalo	B/C	C
IUA5	Blood River	C	C
IUA6	Sundays River	C/D	C/D
IUA7	Upper Mooi River*	C/D	C/D B/C
IUA8	Lower Mooi River	C/D	C
IUA9	Middle/Lower Bushmans River	D	C
IUA10	Upper Thukela River	C/D	C/D
IUA11	Klip River	C	C
IUA12	Middle Thukela River	C	C
IUA13	Lower Thukela River	C	C
IUA14	Escarpment	B	B
IUA15	Thukela Estuary and Upper Thukela reach	C	C

* TEC=C/D for short term until uMWP-1 transfer in place, then TEC=B/C

The approach applied to determining the proposed water resource class for each of the IUAs was to follow the guidelines of the WRCS. In summary the WRCS guidelines recommend that the water resource class be determined based on the ECs of the biophysical nodes residing in an IUA. Among other methods the guidelines recommend the application of Table 87, where the percentage of biophysical nodes falling into the indicated EC groups determines the IUA's water resource class.

Table 86: Preliminary guidelines for determining the IUA class for a scenario

	Percentage (%) of nodes in the IUA falling into the indicated EC groups				
	≥ A/B	≥ B	≥ C	≥ D	< D
Class I	40	60	80	99	

Class II			40	70	95	
Class III	**Either**			30	80	
	Or				100	

Table 88 sets out the percentage of nodes falling into various ecological categories and a proposed water resources class per IUA, based on the guidelines set out in Table 87.

Table 87: IUA Classes for Thukela IUAs for ESBC (PES) scenario based on percentage representation of indicated EC groups

IUA	Percentage (%) of nodes in the IUA falling into the indicated EC groups					IUA Class for ESBC (PES) Scenario
	A or A/B	B or B/C	C or C/D	D	>D	
1		36	55	9		III
2		31.25	56.25	6.25	6.25	III
3		39.13	52.17	8.70		III
4		64.29	14.29	21.43		II
5			100.00			III
6		12.00	72.00	12.00	4.00	III
7			66.67	22.22	11.11	III
8		33.33	61.11	5.56		III
9	20.00	40.00	40.00			III
10	3.70	44.44	44.44	7.41		III
11	10.53	42.11	47.37			III
12	13.64	31.82	50.00	4.55		III
13	3.70	70.37	25.93			II
14	80.00	16.00	4.00			I
15			100			III

Table 88: IUA Class associated with the ESBC scenario

IUA	Catchment area	Aggregated Ecological Category (ESBC)	IUA Water Resource Class associated with scenario
1	Upper Buffalo	C	III
2	Ngagane River	C	III
3	Middle Buffalo	D	III
4	Lower Buffalo	B/C	II
5	Blood River	C	III
6	Sundays River	C/D	III

IUA	Catchment area	Aggregated Ecological Category (ESBC)	IUA Water Resource Class associated with scenario
7	Upper Mooi River	C/D	III
8	Mooi River	C/D	III
9	Middle/Lower Bushmans River	D	III
10	Upper Thukela River	C/D	III
11	Klip River	C	III
12	Middle Thukela River	C	III
13	Lower Thukela River	C	II
14	Escarpment	B	I
15	Thukela Estuary	C	III

Those hydro nodes within IUAs that have a higher TEC than the aggregated IUA EC may require a higher level of ecological protection than the IUA ESBC.

CONCLUSIONS

The aquatic ecosystems, including the drivers (water quality and volume) and aquatic biota of the Thukela catchment are under significant stress and on a negative trajectory due to extensive land-uses activities within the entire catchment which includes *inter alia*, extensive water use for irrigation, domestic purposes in the various catchments, return flows from domestic WWTW, from mining activities (operational and abandoned) and industrial activities. Furthermore, large dams and associated transfers to adjacent catchments have a negative impact on the flows.

In respect of the estuary, the 2020 mouth closure observations show that the period for which the mouth could be closed at a given discharge is variable and uncertain.

It is evident that siltation has occurred in the Thukela Estuary over the last 19 to 24 years. This is likely due to no recent large floods scouring the Thukela Estuary, increased fine sediment input from the catchment and reductions in low flows that can transport the fine sediment through the estuary to the coast. Management of the Thukela River system needs to be improved to prevent the siltation of the estuary. This includes changes to reduce soil erosion in the catchment, allow for higher base flow releases from dams and limit abstraction from the river channel or weirs for the middle and lower catchment.

Ongoing monitoring of the mouth, estuary bathymetry, sediment composition and river discharge for the lower Thukela River and coastal storm intensity will improve our understanding of the system and allow for adaptive management.

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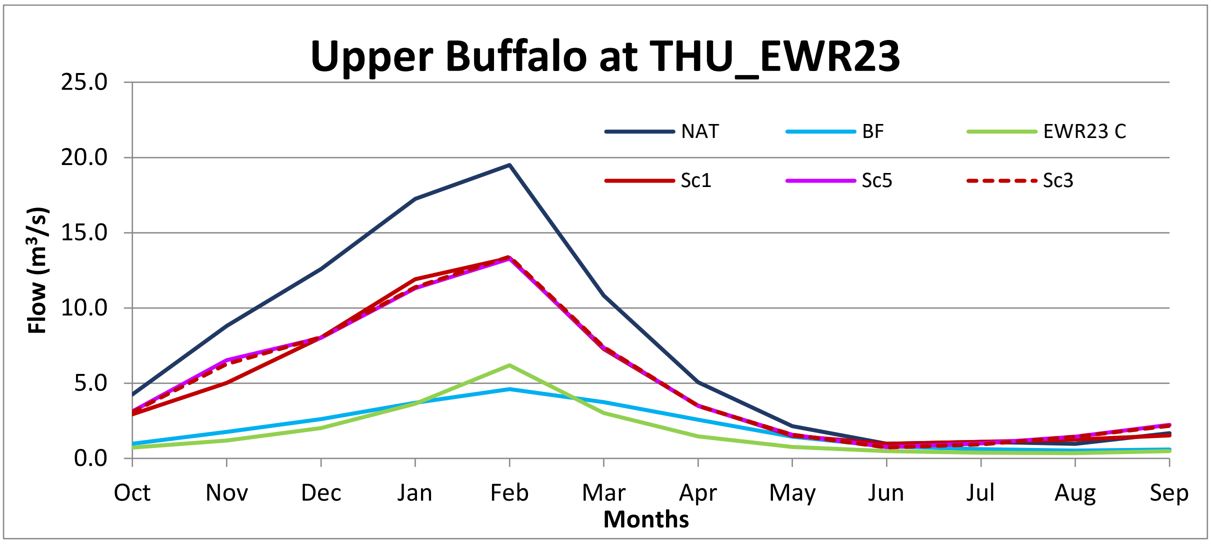
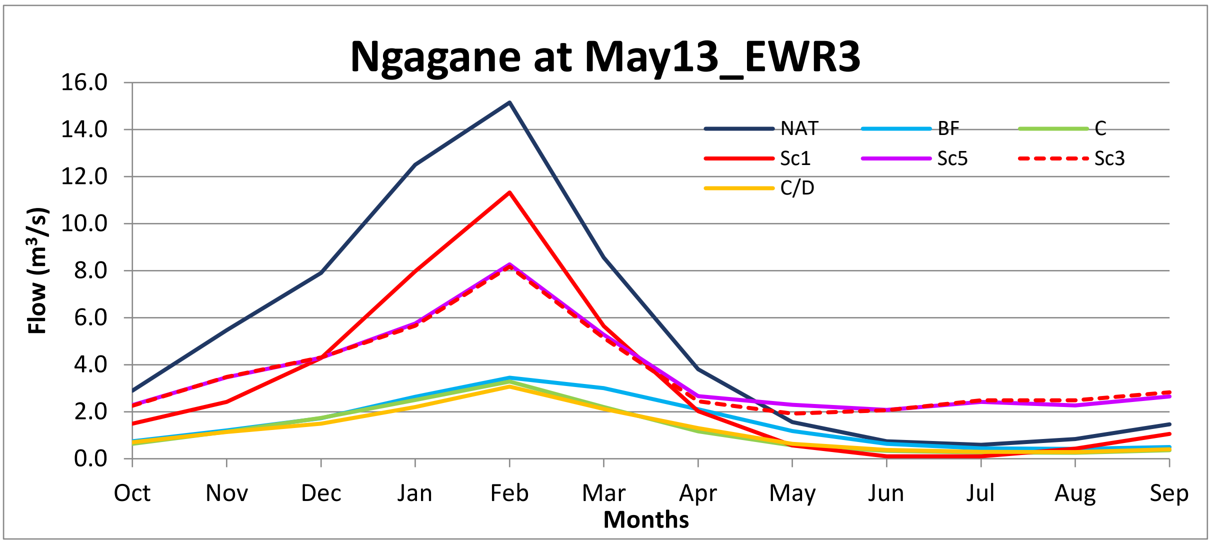
APPENDIX A:

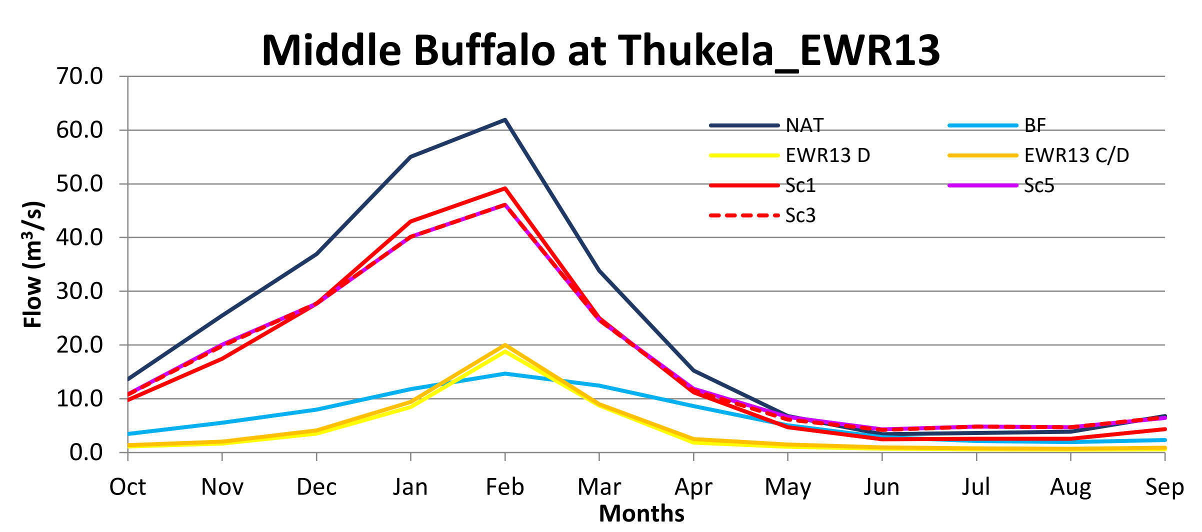
Seasonal distribution plots for selected key EWR sites per IUA



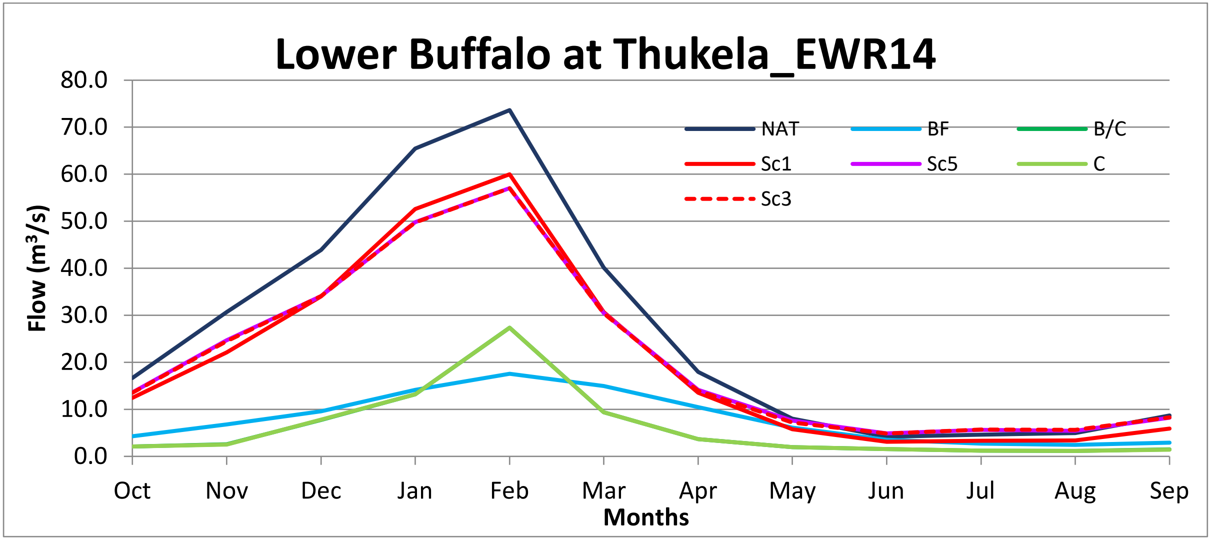
IUA1, Seasonal distribution graph for various flow scenarios at key site THU_EWR23



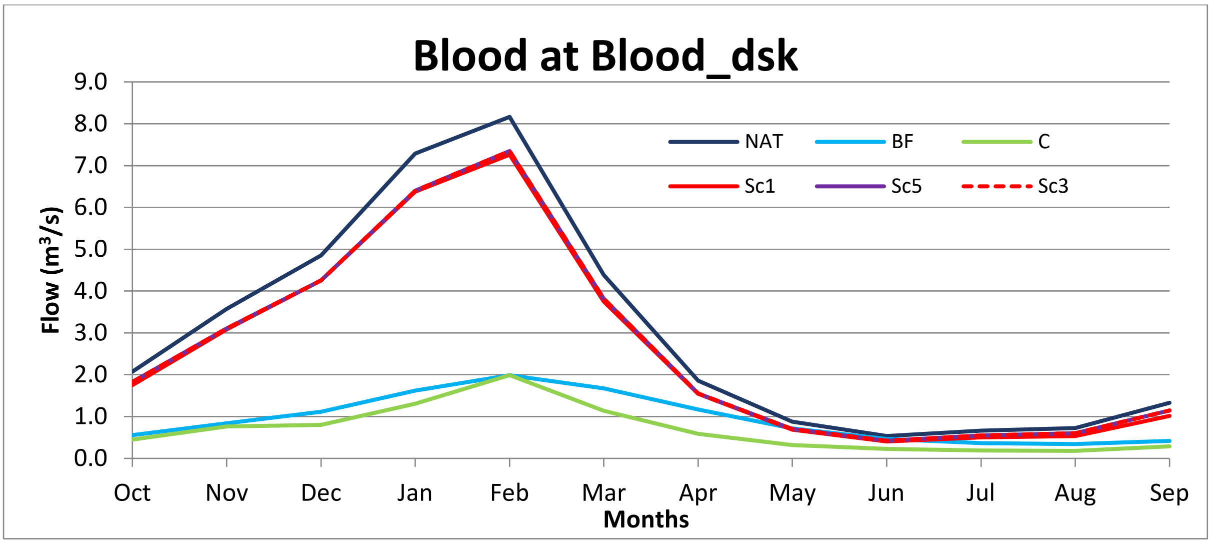
IUA2, Seasonal distribution graph for various flow scenarios at key site May13_EWR3



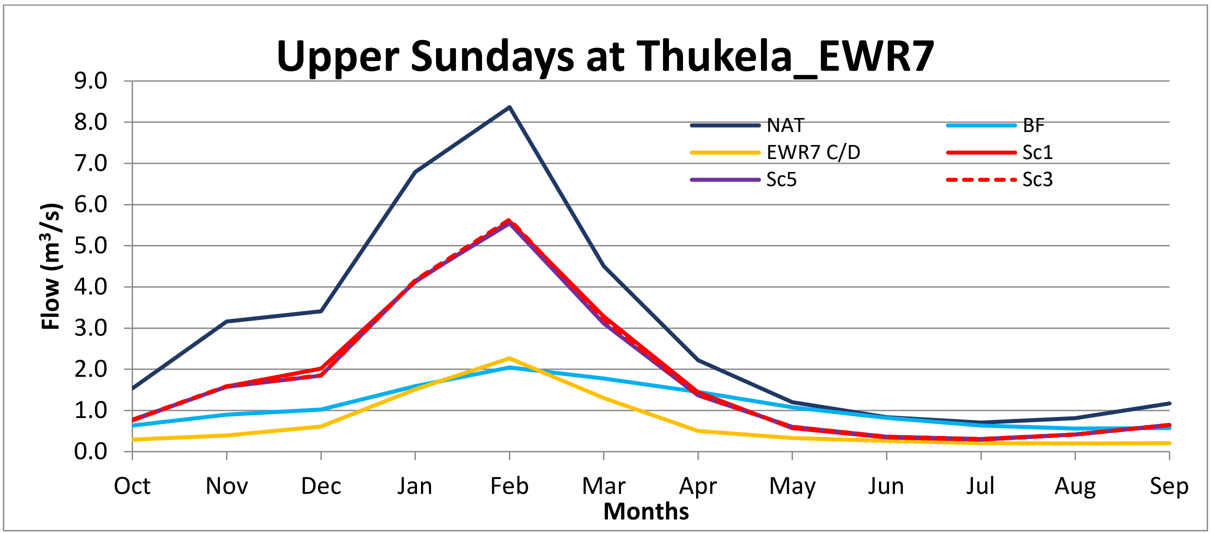
IUA3, Seasonal distribution graph for various flow scenarios at key site Thukela_EWR13



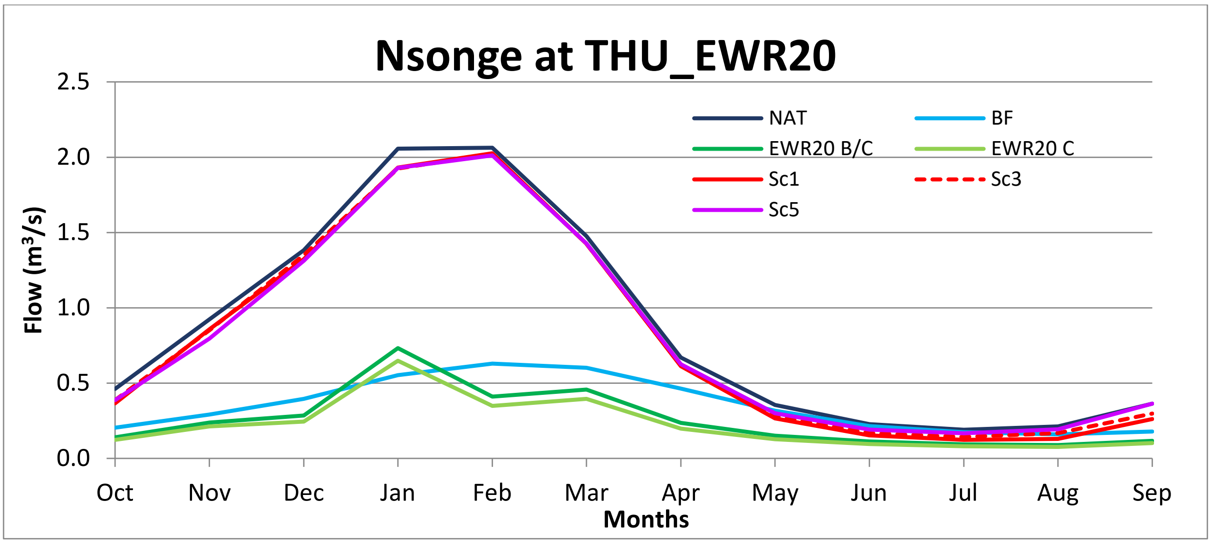
IUA4, Seasonal distribution graph for various flow scenarios at key site Thukela_EWR14



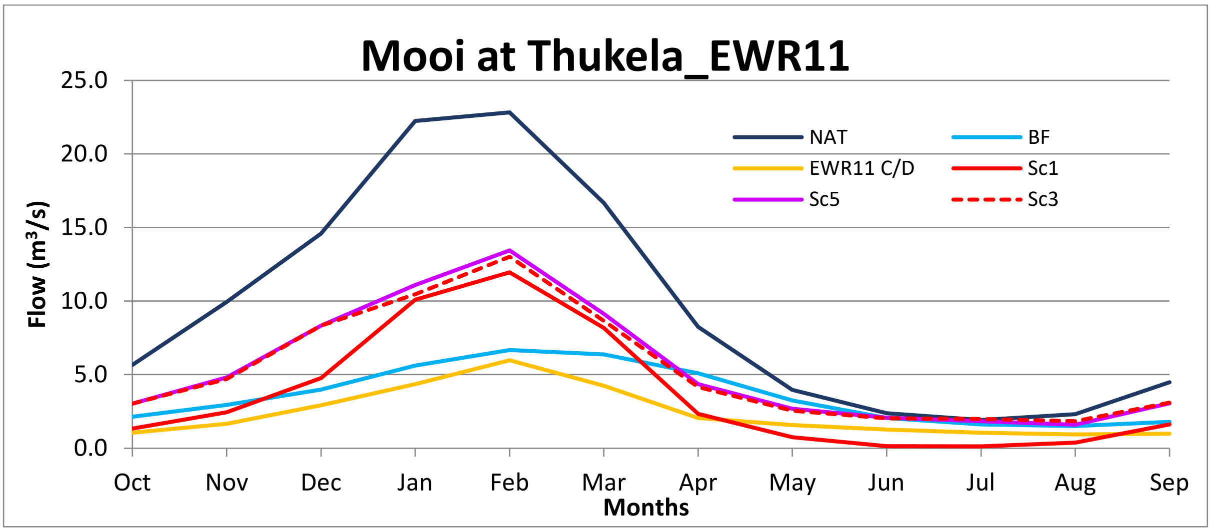
IUA5, Seasonal distribution graph for various flow scenarios at key site Blood_dsk



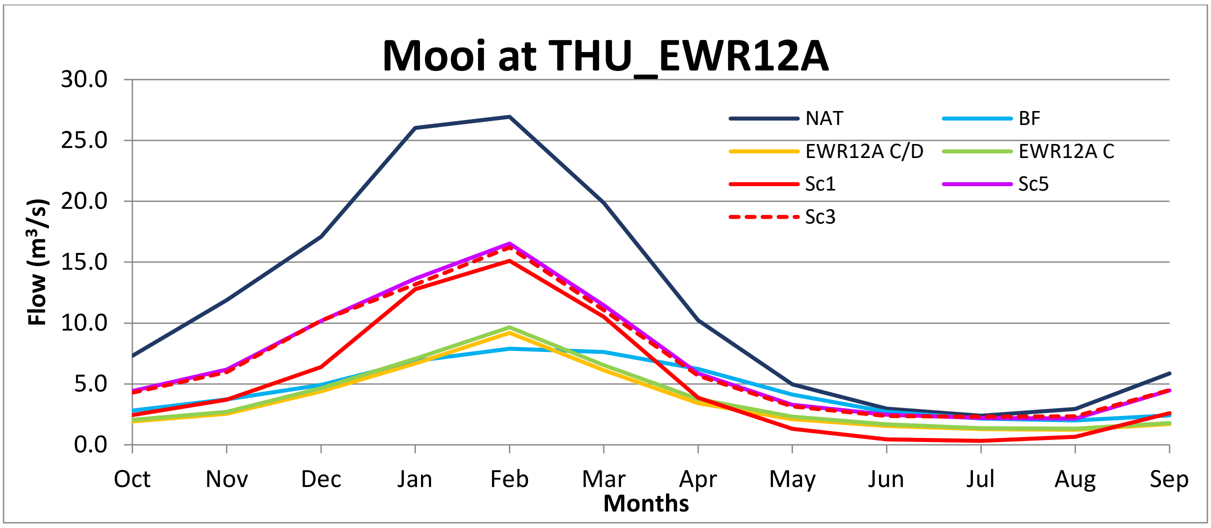
IUA6, Seasonal distribution graph for various flow scenarios at key site Thukela_EWR7



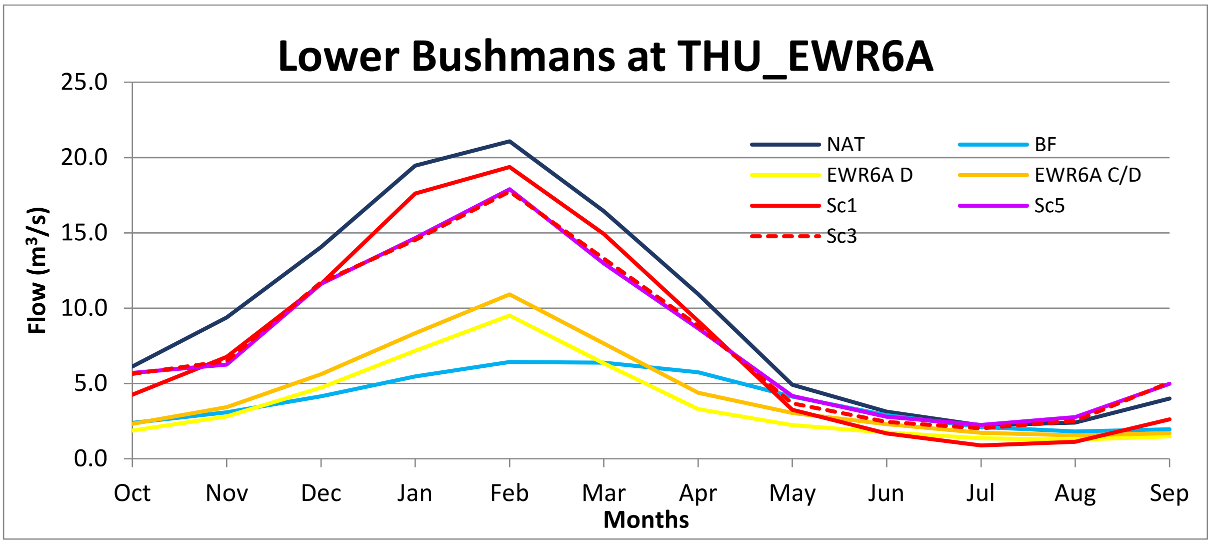
IUA7, Seasonal distribution graph for various flow scenarios at key site THU_EWR20



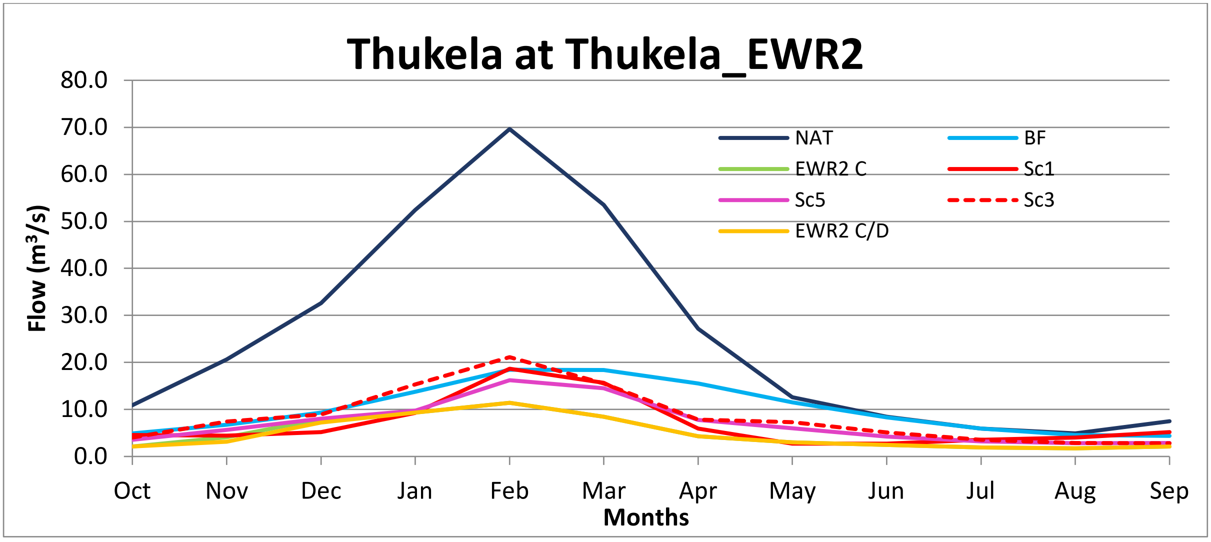
IUA7, Seasonal distribution graph for various flow scenarios at key site Thukela_EWR11



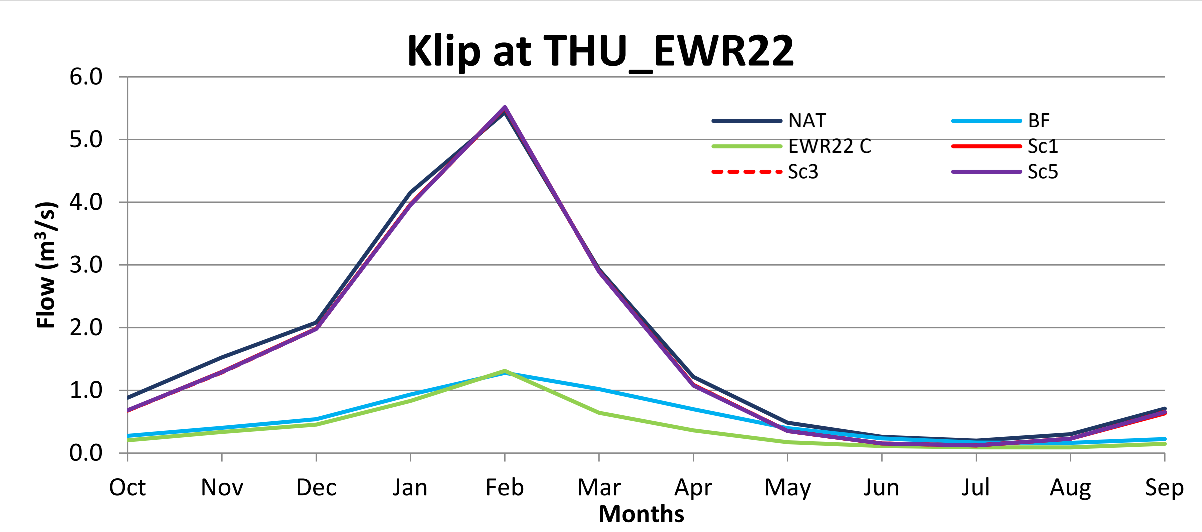
IUA8, Seasonal distribution graph for various flow scenarios at key site THU_EWR12A



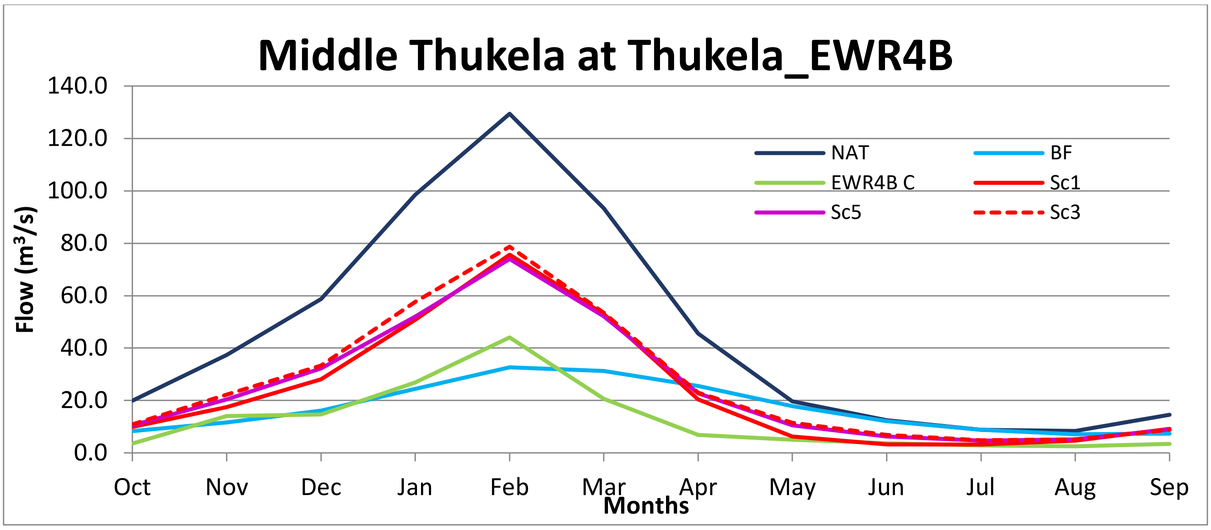
IUA9, Seasonal distribution graph for various flow scenarios at key site THU_EWR6A



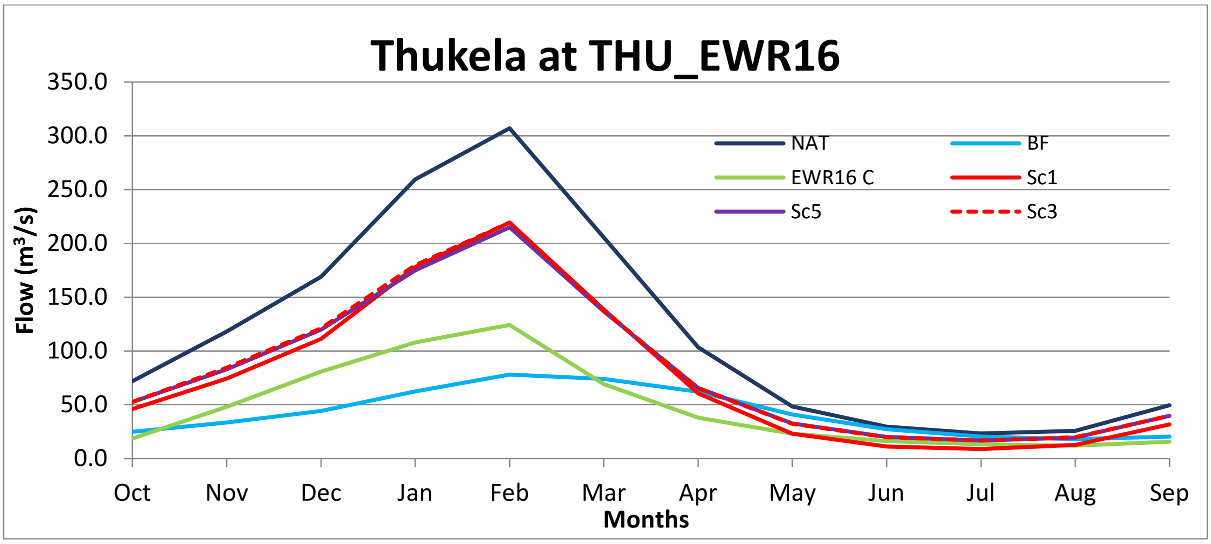
IUA10, Seasonal distribution graph for various flow scenarios at key site Thukela_EWR2



IUA11, Seasonal distribution graph for various flow scenarios at key site THU_EWR22



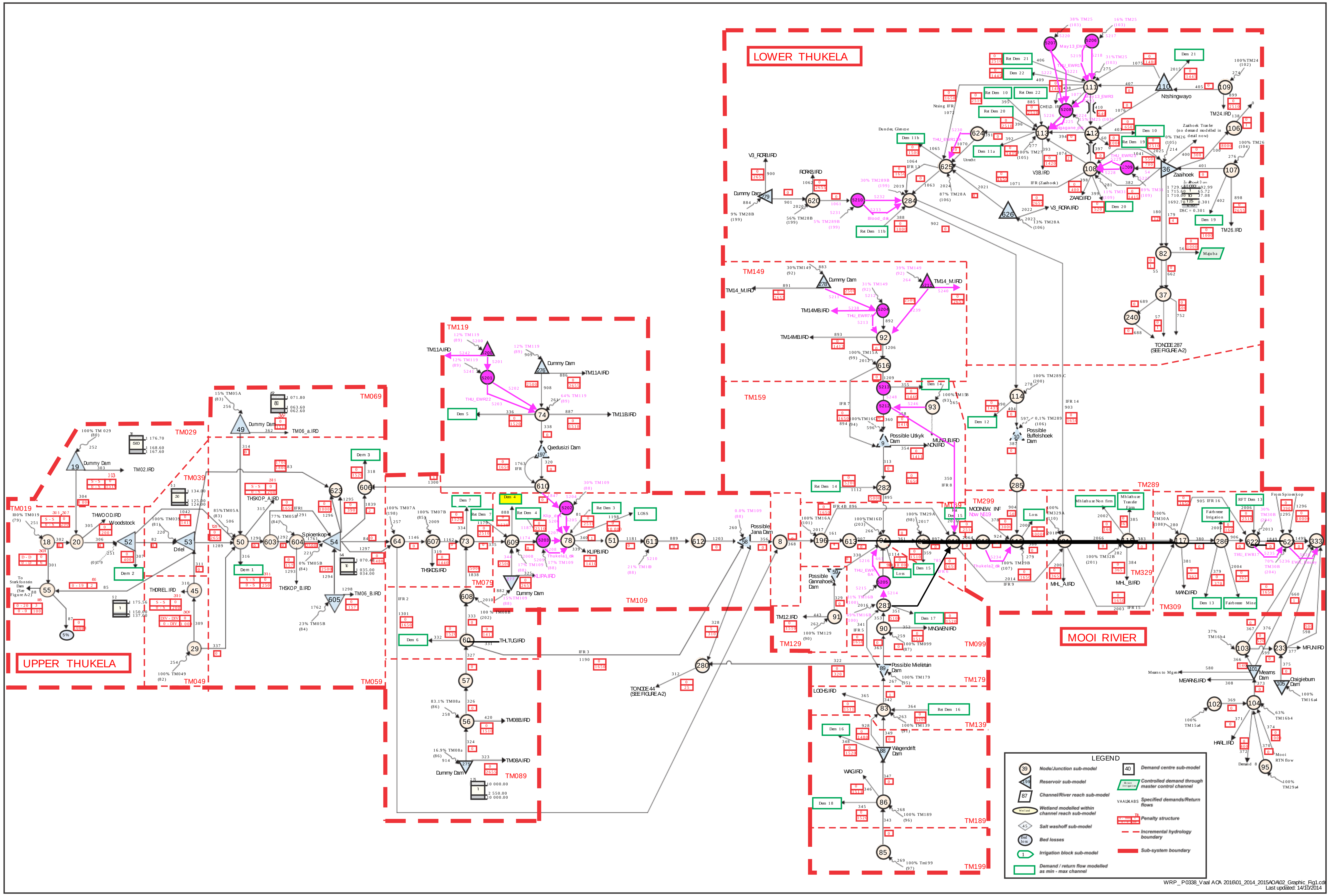
IUA12, Seasonal distribution graph for various flow scenarios at key site Thukela_EWR4B



IUA13, Seasonal distribution graph for various flow scenarios at key site THU_EWR16

APPENDIX B:

Network Diagram for revised Water Resources Planning Model



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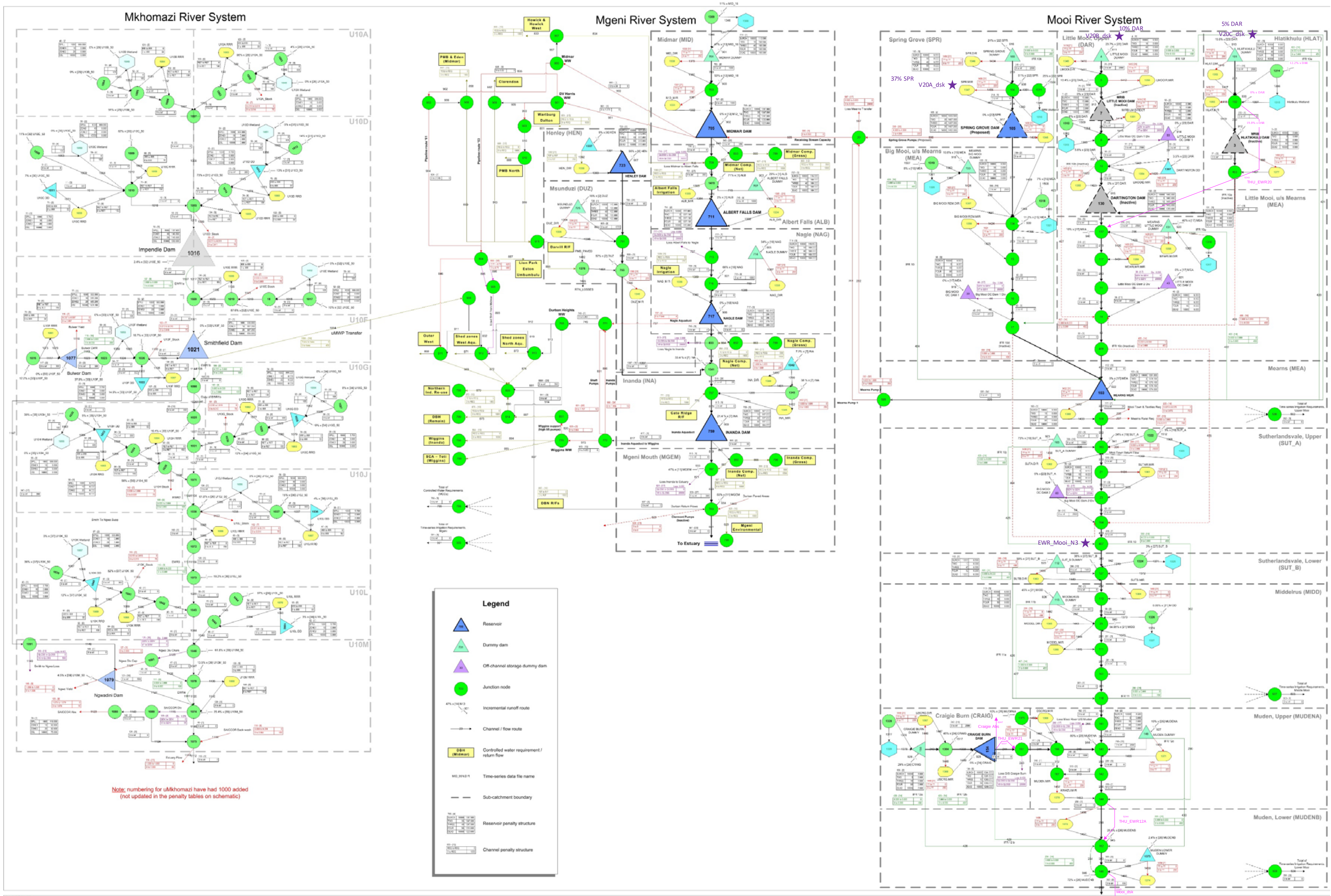
DEVELOPMENT OF OPERATING RULES FOR THE INTEGRATED VAAL RIVER SYSTEM:
VAAL ANNUAL OPERATING ANALYSIS FOR 2014/2015

WRPM Schematic Diagram: Upper Thukela and Lower Sub-systems

A-1



WRPM System Schematic Diagram for the Mooi-Mgeni River System (Scenario A)

APPENDIX C:

WRPM Analyses Results

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m^3/s)	Demand 2030 (m^3/s)	Demand 2040 (m^3/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
Ecological Water Requirements - EWRs																	
Mooi																	
302	Sut A/I-23	7	EWR_Mooi_N3	-	-	-	0.00	2.45	2.45	2.45	2.45	0.00	2.45	2.45	0.00	2.45	2.45
290	Muden A/I-29	8	Thukela_EWR11	-	-	-	0.00	3.58	3.58	3.61	3.68	0.00	3.61	3.67	0.00	3.81	3.90
429	Craig/I-28	8	IFR 12b craigieburn	-	-	-	0.00	0.15	0.15	0.16	0.16	0.00	0.15	0.15	0.00	0.16	0.15
5237	Craig/I-28	8	THU_EWR21	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
254	Muden A/I-29	8	Thukela_EWR12	-	-	-	0.00	2.33	2.33	2.33	2.33	0.00	2.33	2.33	0.00	2.33	2.33
5244	Muden A/I-29	8	THU_EWR12A	-	-	-	0.00	3.62	3.62	3.84	3.84	0.00	3.84	3.84	0.00	3.84	3.84
5243	Dar/I-27	7	THU_EWR20	-	-	-	0.00	0.22	0.22	0.25	0.25	0.00	0.25	0.25	0.00	0.25	0.26
5245	Muden B/I-30	8	Mooi_dsk	-	-	-	0.00	4.00	4.00	4.00	4.00	0.00	4.00	4.00	0.00	4.00	4.00
			sub-total				**0.00**	**16.34**	**16.34**	**16.64**	**16.70**	**0.00**	**16.63**	**16.69**	**0.00**	**16.84**	**16.93**
Thukela																	
4291	TM05B	10	Thukela_EWR 1	-	-	-	0.00	4.96	4.96	4.96	4.96	0.00	4.96	4.96	0.00	4.96	4.96
4301	TM07A	10	Thukela_EWR 2	-	-	-	0.00	6.33	6.33	6.42	6.43	0.00	6.42	6.43	0.00	6.28	6.38
4190	TM08A	10	Thukela_EWR 3	-	-	-	0.00	2.60	2.60	2.60	2.60	0.00	2.60	2.60	0.00	2.60	2.60
3896	TM16A	12	Thukela_EWR 4b	-	-	-	0.00	12.07	12.07	12.83	12.83	0.00	12.83	12.84	0.00	12.84	12.84
3341	TM09	9	Thukela_EWR 5	-	-	-	0.00	4.09	4.09	3.41	3.41	0.00	3.41	3.41	0.00	3.41	3.41
3785	TM16B	9	Thukela_EWR 6	-	-	-	0.00	2.76	2.76	2.43	2.41	0.00	2.42	2.40	0.00	1.92	1.75
5216	TM16B	9	THU_EWR6A	-	-	-	0.00	2.88	2.88	3.33	3.35	0.00	3.32	3.34	0.00	2.03	2.20
3894	TM15B	6	Thukela_EWR 7	-	-	-	0.00	0.73	0.73	0.68	0.68	0.00	0.68	0.68	0.00	0.68	0.68
5213	TM14	6	THU_EWR7A	-	-	-	0.00	0.53	0.53	0.54	0.54	0.00	0.54	0.54	0.00	0.54	0.54
3350	TM16C	6	Thukela_EWR 8	-	-	-	0.00	1.50	1.50	1.50	1.50	0.00	1.50	1.50	0.00	1.50	1.50
5014	TM29A	12	Thukela_EWR 9	-	-	-	0.00	15.86	15.86	15.85	15.85	0.00	15.86	15.85	0.00	15.86	15.86
4064	TM28A	3	Thukela_EWR 13	-	-	-	0.00	4.28	4.28	4.75	4.75	0.00	4.75	4.75	0.00	4.75	4.75
5230	TM27	3	THU_EWR13A	-	-	-	0.00	3.87	3.87	4.26	4.26	0.00	4.26	4.26	0.00	4.26	4.26
3903	TM28C	4	Thukela_EWR 14	-	-	-	0.00	6.05	6.05	6.05	6.05	0.00	6.05	6.05	0.00	6.05	6.05
5003	TM32B	13	Thukela_EWR 15	-	-	-	0.00	27.62	27.62	27.62	27.62	0.00	27.62	27.62	0.00	27.62	27.62
3905	TM30A	13	Thukela_EWR 16	-	-	-	0.00	49.33	49.33	49.33	49.30	0.00	49.35	49.32	0.00	49.40	49.32
5235	TM30B	15	THU_EWR17	-	-	-	0.00	46.74	46.74	46.74	46.74	0.00	46.74	46.74	0.00	46.74	46.74
5221	TM25	2	THU_EWR19	-	-	-	0.00	0.39	0.39	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.45
5203	TM11	11	THU_EWR22	-	-	-	0.00	0.43	0.43	0.43	0.43	0.00	0.43	0.43	0.00	0.43	0.43
5229	TM31	1	THU_EWR23	-	-	-	0.00	1.71	1.71	1.71	1.71	0.00	1.71	1.71	0.00	1.71	1.71
5219	TM25	2	May13_EWR2	-	-	-	0.00	0.23	0.23	0.23	0.23	0.00	0.23	0.23	0.00	0.23	0.23
5223	TM25	2	May13_EWR3	-	-	-	0.00	1.29	1.29	1.29	1.29	0.00	1.29	1.29	0.00	1.29	1.29
5225	TM25	2	Ngagane_dsk	-	-	-	0.00	1.62	1.62	1.62	1.62	0.00	1.62	1.62	0.00	1.62	1.62
5233	TM28B	5	Blood_dsk	-	-	-	0.00	0.58	0.58	0.68	0.68	0.00	0.67	0.68	0.00	0.66	0.68
5208	TM10	10	Thukela1_dsk	-	-	-	0.00	8.53	8.53	8.29	8.29	0.00	8.24	8.25	0.00	8.03	8.32
5206	TM10	11	Klip_dsk	-	-	-	0.00	2.16	2.16	2.16	2.16	0.00	2.16	2.16	0.00	2.16	2.16
5234	TM29B	12	Thukela2_dsk	-	-	-	0.00	24.89	24.89	24.90	24.90	0.00	24.87	24.88	0.00	24.92	24.91
5028	TM30B	15	EWR Estuary	-	-	-	0.00	0.00	46.72	0.00	59.57	0.00	0.00	59.57	0.00	0.00	59.57
			sub-total				**0.00**	**234.00**	**280.72**	**235.03**	**294.59**	**0.00**	**234.95**	**294.53**	**0.00**	**232.92**	**292.82**
			Total				**0.00**	**250.35**	**297.06**	**251.67**	**311.29**	**0.00**	**251.58**	**311.22**	**0.00**	**249.76**	**309.75**

Table C-1: Analysis Results: Domestic and Commercial Demands

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
Domestic and Commercial Demands (urban demands)																												
Mooi																												
205	MEA	7	Mooi Town & Textiles	0.08	0.08	0.08	0.07	0.04	0.04	0.04	0.04	0.07	0.04	0.04	0.07	0.05	0.04	97%	55%	56%	57%	55%	97%	55%	52%	99%	67%	59%
207	MEA	7	Mearns Rural Req	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100%	67%	67%	67%	67%	100%	67%	67%	100%	67%	67%
			sub-total	**0.68**	**0.68**	**0.68**	**0.08**	**0.04**	**0.04**	**0.05**	**0.04**	**0.08**	**0.04**	**0.04**	**0.08**	**0.05**	**0.05**	11%	6%	57%	7%	6%	11%	6%	6%	11%	8%	7%
Thukela																												
3316	TM05	10	UPPER THUKELA: DEM 1	0.06	0.08	0.09	0.06	0.03	0.03	0.03	0.03	0.08	0.04	0.04	0.09	0.05	0.05	93%	48%	52%	48%	46%	97%	52%	52%	97%	54%	53%
3307	TM01	10	UPPER THUKELA: DEM 2	0.07	0.08	0.08	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.06	0.05	0.05	72%	54%	75%	54%	54%	71%	53%	53%	71%	56%	53%
3318	TM05	11	UPPER THUKELA: DEM 3	0.27	0.44	0.48	0.27	0.11	0.11	0.11	0.11	0.41	0.13	0.13	0.41	0.14	0.13	100%	41%	41%	41%	41%	95%	30%	29%	86%	28%	27%
3888	TM05	11	UPPER THUKELA: DEM 4	0.69	0.71	0.74	0.69	0.10	0.10	0.12	0.12	0.71	0.13	0.12	0.74	0.14	0.14	100%	14%	14%	18%	17%	100%	18%	17%	100%	19%	18%
3336	TM11	11	UPPER THUKELA: DEM 5	0.09	0.11	0.13	0.09	0.06	0.06	0.06	0.06	0.11	0.07	0.07	0.13	0.09	0.08	99%	69%	70%	67%	67%	99%	66%	66%	99%	69%	65%
3332	TM08A	10	UPPER THUKELA: DEM 6	0.06	0.09	0.11	0.06	0.06	0.06	0.06	0.06	0.09	0.09	0.09	0.11	0.10	0.10	98%	98%	100%	98%	98%	98%	98%	98%	99%	98%	98%
3334	TM10	10	UPPER THUKELA: DEM 7	0.07	0.08	0.08	0.07	0.01	0.01	0.01	0.01	0.08	0.01	0.01	0.08	0.02	0.02	100%	14%	14%	18%	17%	100%	18%	18%	100%	19%	18%
3403	TM25	2	LOWER THUKELA: DEM 10	1.20	1.34	1.49	1.20	0.74	0.74	0.74	0.68	1.34	0.81	0.74	1.47	1.07	0.90	100%	62%	62%	62%	57%	100%	60%	55%	99%	72%	61%
3392	TM27	3	LOWER THUKELA: DEM 11A	0.17	0.18	0.20	0.17	0.15	0.15	0.15	0.15	0.18	0.17	0.17	0.20	0.20	0.19	100%	93%	93%	93%	92%	100%	94%	92%	100%	98%	92%
4065	TM28A	3	LOWER THUKELA: DEM 11B	0.20	0.23	0.38	0.20	0.19	0.19	0.18	0.18	0.23	0.22	0.22	0.38	0.37	0.35	100%	94%	94%	94%	93%	100%	95%	94%	100%	98%	93%
3390	TM29B	4	LOWER THUKELA: DEM 12	0.11	0.20	0.38	0.11	0.10	0.10	0.10	0.10	0.20	0.18	0.18	0.38	0.37	0.35	100%	93%	93%	93%	92%	100%	94%	92%	100%	97%	91%
3379	TM30A	13	LOWER THUKELA: DEM 13	0.54	0.59	0.64	0.54	0.38	0.38	0.38	0.34	0.59	0.40	0.36	0.64	0.53	0.43	100%	70%	70%	70%	64%	100%	68%	61%	100%	83%	68%
3355	TM15B	6	LOWER THUKELA: DEM 14	0.35	0.39	0.43	0.28	0.21	0.21	0.21	0.21	0.30	0.22	0.22	0.32	0.24	0.24	79%	60%	75%	60%	60%	77%	58%	58%	74%	57%	57%
3359	TM29A	12	LOWER THUKELA: DEM 15	0.04	0.12	0.27	0.04	0.03	0.03	0.03	0.03	0.12	0.11	0.10	0.27	0.25	0.23	100%	86%	86%	86%	86%	100%	86%	85%	100%	93%	86%
3348	TM18	9	LOWER THUKELA: DEM 16	0.48	0.52	0.55	0.48	0.48	0.48	0.48	0.48	0.52	0.52	0.52	0.56	0.56	0.56	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
3351	TM16B	9	LOWER THUKELA: DEM 17	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	100%	19%	19%	19%	19%	101%	18%	18%	100%	0%	0%
3345	TM18	9	LOWER THUKELA: DEM 18	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	100%	100%	100%	100%	100%	99%	99%	99%	101%	101%	101%
3402	TM26	1	LOWER THUKELA: DEM 19	0.07	0.10	0.12	0.06	0.05	0.05	0.05	0.05	0.08	0.07	0.07	0.10	0.10	0.09	80%	73%	91%	73%	72%	80%	75%	73%	79%	77%	73%
3399	TM31	1	LOWER THUKELA: DEM 20	0.03	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.04	0.03	0.03	100%	67%	67%	67%	61%	99%	66%	58%	99%	79%	67%
5015	TM25	2	LOWER THUKELA: DEM 21	0.14	0.14	0.14	0.14	0.11	0.11	0.11	0.11	0.14	0.11	0.11	0.14	0.12	0.11	100%	81%	81%	81%	79%	100%	80%	79%	100%	88%	81%
3409	TM25	2	LOWER THUKELA: DEM 22	0.35	0.35	0.35	0.35	0.28	0.28	0.28	0.27	0.35	0.28	0.27	0.35	0.31	0.28	100%	79%	79%	79%	77%	100%	79%	76%	100%	87%	79%
			sub-total	**5.02**	**5.80**	**6.76**	**4.90**	**3.16**	**3.16**	**3.20**	**3.07**	**5.64**	**3.64**	**3.50**	**6.50**	**4.76**	**4.35**	98%	63%	65%	64%	61%	97%	63%	60%	96%	70%	64%
			Total	**5.69**	**6.47**	**7.43**	**4.98**	**3.21**	**3.21**	**3.24**	**3.12**	**5.72**	**3.69**	**3.54**	**6.58**	**4.81**	**4.39**	87%	56%	64%	57%	55%	88%	57%	55%	89%	65%	59%

Table C-2: Analysis Results: Irrigation Demands – Thukela Catchment

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m^3/s)	Demand 2030 (m^3/s)	Demand 2040 (m^3/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
Irrigation Demands																												
Thukela																												
3305	TM01	10	THWOOD2.IRD	0.16	0.16	0.16	0.10	0.06	0.06	0.06	0.06	0.10	0.06	0.06	0.10	0.07	0.06	62%	41%	65%	40%	39%	62%	40%	39%	62%	42%	40%
3303	TM02	10	TM022.IRD	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
3310	TM04	10	THDRIE2.IRD	0.07	0.07	0.07	0.05	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.03	0.03	62%	38%	61%	38%	36%	62%	38%	36%	62%	40%	38%
3362	TM05	10	TM062.IRD	0.11	0.11	0.11	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.05	55%	44%	81%	44%	44%	55%	44%	44%	54%	44%	44%
3315	TM05	10	THSKOPa2.IRD	1.20	1.20	1.20	0.81	0.54	0.54	0.53	0.53	0.81	0.53	0.53	0.80	0.56	0.54	68%	45%	67%	44%	44%	67%	44%	44%	67%	47%	45%
4293	TM05	10	THSKOPb2.IRD	0.23	0.23	0.23	0.19	0.13	0.13	0.12	0.12	0.19	0.12	0.12	0.19	0.14	0.12	83%	56%	68%	53%	53%	83%	53%	53%	82%	61%	53%
3319	TM07	10	THSKDS2.IRD	0.13	0.13	0.13	0.13	0.01	0.01	0.01	0.01	0.13	0.01	0.01	0.13	0.02	0.02	98%	9%	9%	11%	11%	98%	11%	10%	98%	13%	12%
3323	TM08	10	TM08A2.IRD	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	99%
3325	TM10	11	KLIPA2.IRD	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	99%
3331	TM08	10	THLTUG2.IRD	0.97	0.97	0.97	0.63	0.47	0.47	0.47	0.47	0.63	0.47	0.47	0.63	0.46	0.46	65%	49%	75%	49%	49%	65%	48%	48%	64%	48%	48%
3339	TM10	11	KLIPB2.IRD	0.73	0.73	0.73	0.72	0.56	0.56	0.51	0.51	0.72	0.51	0.51	0.72	0.61	0.53	99%	76%	77%	70%	69%	99%	70%	69%	99%	84%	72%
3420	TM08	10	TM08B2.IRD	0.32	0.32	0.32	0.29	0.21	0.21	0.21	0.21	0.28	0.20	0.20	0.28	0.20	0.20	91%	66%	73%	66%	66%	90%	64%	64%	89%	63%	63%
3886	TM11	11	TM11A2.IRD	0.16	0.16	0.16	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	49%	49%	100%	49%	49%	49%	49%	49%	49%	49%	49%
3887	TM11	11	TM11B2.IRD	0.30	0.30	0.30	0.14	0.06	0.06	0.06	0.06	0.12	0.06	0.06	0.12	0.06	0.06	47%	21%	45%	20%	20%	41%	20%	20%	40%	20%	19%
4298	TM05	10	TM06_b2.IRD	0.24	0.24	0.24	0.07	0.03	0.03	0.02	0.02	0.07	0.02	0.02	0.07	0.04	0.03	27%	11%	40%	10%	10%	27%	10%	10%	27%	17%	13%
3346	TM18	9	WAG2.IRD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	99%	99%	100%	99%	99%	99%	99%	99%	99%	94%	94%
3352	TM09	9	MNGWEN2.IRD	0.75	0.75	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.72	0.72	99%	99%	100%	99%	99%	99%	99%	99%	99%	95%	95%
3354	TM15	6	NON2.IRD	0.19	0.19	0.19	0.18	0.17	0.17	0.17	0.17	0.18	0.17	0.17	0.18	0.17	0.17	94%	86%	92%	86%	86%	94%	86%	86%	94%	87%	86%
3358	TM15	6	MUNGUB2.IRD	0.18	0.18	0.18	0.12	0.08	0.08	0.08	0.08	0.12	0.08	0.08	0.12	0.08	0.08	70%	46%	67%	46%	46%	70%	46%	46%	70%	46%	46%
3365	TM13	9	LOCHS2.IRD	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.49	0.49	98%	98%	100%	98%	98%	98%	98%	98%	98%	96%	96%
3381	TM30A	13	MAND2.IRD	0.47	0.47	0.47	0.46	0.31	0.31	0.32	0.29	0.46	0.31	0.28	0.46	0.38	0.31	99%	67%	68%	68%	61%	99%	65%	59%	99%	82%	67%
3384	TM32A	13	MHL_B2.IRD	0.38	0.38	0.38	0.37	0.26	0.26	0.26	0.23	0.37	0.25	0.22	0.37	0.31	0.26	99%	68%	69%	69%	62%	99%	66%	59%	99%	83%	68%
3393	TM27	3	V3B2.IRD	0.77	0.77	0.77	0.76	0.68	0.68	0.68	0.66	0.76	0.69	0.67	0.76	0.73	0.66	99%	89%	90%	88%	86%	99%	90%	88%	99%	95%	86%
3398	TM31	1	ZAAID2.IRD	0.32	0.32	0.32	0.27	0.15	0.15	0.15	0.13	0.27	0.14	0.12	0.27	0.19	0.15	83%	46%	55%	45%	40%	84%	43%	38%	84%	58%	47%
3408	TM25	2	CHELD2.IRD	0.08	0.08	0.08	0.08	0.06	0.06	0.06	0.05	0.08	0.05	0.05	0.08	0.07	0.06	99%	69%	70%	70%	65%	99%	68%	64%	98%	81%	71%
3443	TM12	12	TM122.IRD	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.05	87%	74%	85%	74%	73%	87%	73%	73%	87%	80%	73%
3891	TM14	6	TM14_M2.IRD	0.32	0.32	0.32	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	49%	49%	100%	49%	49%	49%	49%	49%	49%	49%	49%
3893	TM14	6	TM14B2.IRD	0.36	0.36	0.36	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	12%	11%	89%	11%	11%	12%	10%	10%	11%	10%	10%
3898	TM26	1	TM262.IRD	0.10	0.10	0.10	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.06	71%	63%	88%	63%	63%	71%	66%	65%	71%	69%	64%
3899	TM24	2	TM242.IRD	0.28	0.28	0.28	0.22	0.20	0.20	0.20	0.19	0.22	0.20	0.20	0.22	0.21	0.20	81%	72%	89%	73%	70%	81%	73%	71%	81%	77%	71%
3900	TM28B	5	V3RORB2.IRD	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.13	0.13	0.12	98%	96%	98%	96%	95%	98%	96%	95%	98%	98%	95%
4062	TM28B	5	RORKB2.IRD	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.34	0.36	0.35	0.35	0.36	0.35	0.34	98%	96%	97%	95%	94%	98%	96%	95%	98%	97%	94%
5001	TM32B	13	MHL_A2.IRD	0.21	0.21	0.21	0.21	0.14	0.14	0.14	0.13	0.21	0.14	0.12	0.21	0.17	0.14	99%	68%	69%	68%	61%	99%	65%	59%	99%	83%	67%
5022	TM28A	3	V3RORA2.IRD	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	99%
			sub-total	**10.57**	**10.57**	**10.57**	**8.46**	**6.77**	**6.78**	**6.71**	**6.57**	**8.43**	**6.68**	**6.55**	**8.41**	**7.10**	**6.64**	80%	64%	80%	63%	62%	80%	63%	62%	80%	67%	63%

Table C-3: Analysis Results: Irrigation Demands – Mooi Catchment

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
Irrigation Demands																												
Mooi																												
1404	SPR	7	'SPR_DIR'	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	104%	104%	100%	104%	104%	104%	104%	102%	104%	104%	104%
1406	SPR	7	'SPR_MIR'	0.05	0.05	0.05	0.04	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.04	0.02	0.02	93%	35%	38%	40%	35%	91%	38%	33%	93%	49%	42%
1408	SPR	7	'SPR_DIRECT'	0.06	0.06	0.06	0.03	0.02	0.02	0.00	0.00	0.03	0.00	0.00	0.03	0.02	0.02	57%	29%	52%	0%	0%	57%	0%	0%	57%	38%	31%
1410	DAR	7	'MRIB LITTLE MOOI_DIR'	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	102%	101%	99%	101%	101%	102%	101%	101%	102%	102%	101%
1412	DAR	7	'MRIB LITTLE MOOI_MIR'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1414	DAR	7	'MRIB LM DIRECT_MIR'	0.04	0.04	0.04	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.01	0.00	47%	11%	24%	11%	11%	47%	11%	11%	47%	14%	11%
1416	DAR	7	'MRIB HLATIKULU_DIR'	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.01	52%	48%	93%	48%	48%	52%	48%	48%	52%	52%	48%
1418	DAR	7	'MRIB HLATIKULU_MIR'	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	75%	14%	18%	14%	14%	75%	14%	14%	75%	14%	14%
1420	DAR	7	'DAR_DIR'	0.07	0.07	0.07	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	47%	32%	68%	32%	32%	47%	32%	32%	47%	33%	32%
1422	DAR	7	'DAR_MIR'	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	41%	10%	25%	10%	10%	41%	10%	10%	41%	10%	10%
1424	MEA	7	'BIG MOOI REM_MIR'	0.05	0.05	0.05	0.03	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.02	0.01	64%	27%	42%	29%	27%	64%	27%	25%	66%	35%	29%
1426	MEA	7	'BIG MOOI REM_DIR'	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	105%	103%	98%	103%	103%	105%	103%	103%	105%	103%	103%
1428	MEA	7	'LITTLE MOOI REM_DIR'	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	105%	104%	99%	103%	103%	105%	104%	104%	105%	104%	103%
1430	MEA	7	'LITTLE MOOI REM_MIR'	0.10	0.10	0.10	0.06	0.02	0.02	0.02	0.02	0.06	0.02	0.02	0.06	0.02	0.02	62%	19%	31%	19%	19%	62%	19%	19%	62%	22%	19%
1432	MEA	7	'MEA_DIRECT'	0.08	0.08	0.08	0.05	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.04	0.03	71%	43%	60%	44%	41%	71%	41%	40%	72%	52%	44%
1434	SUT-A	7	'SUT UPPER_MIR'	0.06	0.06	0.06	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	59%	5%	8%	5%	5%	59%	5%	5%	59%	6%	3%
1436	SUT_A	7	'SUT UPPER_DIR'	0.19	0.19	0.19	0.12	0.10	0.10	0.11	0.10	0.12	0.10	0.10	0.12	0.11	0.10	61%	55%	90%	56%	55%	61%	55%	54%	61%	58%	55%
1438	SUT_B	7	'SUT LOWER_DIR'	0.05	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	73%	62%	86%	65%	62%	73%	62%	62%	73%	69%	65%
1440	SUT_B	7	'SUT LOWER_MIR'	0.11	0.11	0.11	0.03	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.01	0.00	29%	7%	23%	6%	6%	29%	6%	6%	29%	6%	4%
1442	MIDD	7	'MIDD_DIR'	0.09	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.08	0.08	0.07	92%	78%	85%	78%	77%	92%	77%	76%	92%	86%	78%
1444	MIDD	7	'MIDD_MIR'	0.14	0.14	0.14	0.05	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.05	0.01	0.01	36%	7%	19%	6%	6%	36%	6%	5%	36%	5%	3%
1446	CRAIG	8	'CRAIGIE_DIR'	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	105%	105%	100%	105%	105%	105%	105%	105%	105%	105%	105%
1448	CRAIG	8	'CRAIGIE_MIR'	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	105%	86%	73%	86%	77%	105%	77%	77%	105%	86%	77%
1450	MUDEN_A	8	'CRAIGIE DS_MIR'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61%	61%	100%	61%	61%	61%	61%	61%	61%	61%	61%
1452	MUDEN_A	8	'MUDEN A_MIR'	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06	101%	85%	84%	85%	83%	101%	83%	82%	101%	91%	83%
1454	MUDEN_A	8	'MUDEN A_DIR'	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	101%	95%	95%	95%	95%	101%	95%	95%	101%	101%	95%
1456	MUDEN_A	8	'MUDEN B_MIR'	0.21	0.21	0.21	0.18	0.08	0.08	0.08	0.07	0.18	0.07	0.07	0.18	0.10	0.08	85%	36%	42%	35%	34%	85%	33%	31%	85%	47%	37%
1459	MUDEN_B	8	'MUDEN B_DIR'	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	83%	68%	82%	68%	68%	83%	68%	68%	83%	75%	68%
			sub-total	**1.85**	**1.85**	**1.85**	**1.39**	**0.95**	**0.95**	**0.93**	**0.92**	**1.39**	**0.92**	**0.91**	**1.40**	**1.02**	**0.95**	75%	51%	68%	51%	50%	75%	50%	49%	76%	55%	51%
			Total	**12.41**	**12.41**	**12.41**	**9.85**	**7.72**	**7.72**	**7.64**	**7.49**	**9.82**	**7.60**	**7.46**	**9.81**	**8.12**	**7.59**	79%	62%	78%	62%	60%	79%	61%	60%	79%	65%	61%

Table C-4: Analysis Results: Catchment Transfers

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
Transfers																												
Mooi																												
1004			uMWP transfer	0.00	0.00	8.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.36	7.30	7.30									85%	84%	84%
585	MEA	7	MMTS total	4.50	4.50	4.50	4.26	2.50	2.50	2.57	2.47	4.32	2.64	2.54	4.08	2.46	2.11	95%	56%	59%	57%	55%	96%	59%	56%	91%	55%	47%
5004	TM30A	13	LOWER THUKELA: LTBWSS2	0.00	0.63	0.63	0.00	0.00	0.00	0.00	0.00	0.63	0.40	0.36	0.63	0.51	0.41						100%	63%	57%	100%	81%	65%
5005	TM30A	13	LOWER THUKELA: LTBWSS1	0.63	0.63	0.63	0.51	0.26	0.26	0.26	0.24	0.49	0.26	0.23	0.46	0.20	0.14	81%	42%	51%	42%	38%	78%	41%	37%	73%	32%	22%
			sub-total	**5.13**	**5.76**	**14.44**	**4.26**	**2.50**	**2.50**	**2.57**	**2.47**	**4.32**	**2.64**	**2.54**	**11.44**	**9.76**	**9.41**	83%	49%	59%	50%	48%	75%	46%	44%	79%	68%	65%
Thukela																												
3085	TM03	10	UPPER THUKELA: TRANSFER FROM DRIEL	19.00	19.00	19.00	14.78	11.89	11.89	11.82	11.79	14.77	11.82	11.79	14.76	12.10	11.84	78%	63%	80%	62%	62%	78%	62%	62%	78%	64%	62%
3088	TM01	10	UPPER VAAL: TRANSFER RATE FROM JAGERSRUST	20.00	20.00	20.00	15.14	12.37	12.37	12.29	12.26	15.13	12.29	12.27	15.13	12.57	12.31	76%	62%	82%	61%	61%	76%	61%	61%	76%	63%	62%
3312	TM10	10	UPPER VAAL: TUGELA SOUTH TO VAAL	0.00	0.00	12.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.70	10.65	9.22									100%	84%	73%
3328	TM10	10	UPPER THUKELA: JANA TO VAAL (280)	0.00	0.00	8.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.80	6.99	5.56									100%	79%	63%
3179	TM26	1	LOWER THUKELA: ZAAIHOEK TO VAAL	0.90	0.90	0.90	0.87	0.75	0.75	0.75	0.73	0.90	0.80	0.77	0.90	0.85	0.77	97%	83%	85%	83%	81%	100%	89%	86%	100%	95%	86%
3180	TM26	1	LOWER THUKELA: ZAAIHOEK TO VAAL	1.26	1.26	1.26	1.21	0.99	0.99	1.00	0.97	0.61	0.53	0.51	0.36	0.34	0.30	96%	79%	82%	79%	77%	49%	42%	41%	29%	27%	24%
3322			LOWER THUKELA: MIELIE TO VAAL	0.00	0.00	3.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.90	3.67	3.66									100%	94%	94%
3385	TM32B	13	LOWER THUKELA: MHLATUZE TRANSFER FIRM	2.00	2.00	2.00	2.00	1.29	1.29	1.31	1.17	2.00	1.24	1.12	2.00	1.62	1.28	100%	65%	65%	65%	59%	100%	62%	56%	100%	81%	64%
3400	TM26	1	LOWER THUKELA: ZAAIHOEK TRANSFER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00											
			sub-total	**43.16**	**43.16**	**68.56**	**34.00**	**27.29**	**27.29**	**27.17**	**26.92**	**33.42**	**26.68**	**26.47**	**58.55**	**48.78**	**44.95**	79%	63%	80%	63%	62%	77%	62%	61%	85%	71%	66%
			Total	**48.29**	**48.92**	**83.00**	**38.26**	**29.79**	**29.79**	**29.73**	**29.39**	**37.74**	**29.32**	**29.01**	**70.00**	**58.54**	**54.36**	79%	62%	78%	62%	61%	77%	60%	59%	84%	71%	65%
			Total	**199.26**	**203.51**	**308.62**	**160.43**	**630.46**	**723.89**	**632.80**	**750.15**	**161.62**	**632.95**	**750.39**	**260.90**	**722.00**	**826.41**	81%	316%	451%	318%	376%	79%	311%	369%	85%	234%	268%

Table C-5: Analysis Results: IUA 1

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
5229	TM31	1	THU_EWR23	-	-	-	0.00	1.71	1.71	1.71	1.71	0.00	1.71	1.71	0.00	1.71	1.71											
3402	TM26	1	LOWER THUKELA: DEM 19	0.07	0.10	0.12	0.06	0.05	0.05	0.05	0.05	0.08	0.07	0.07	0.10	0.10	0.09	80%	73%	91%	73%	72%	80%	75%	73%	79%	77%	73%
3399	TM31	1	LOWER THUKELA: DEM 20	0.03	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.04	0.03	0.03	100%	67%	67%	67%	61%	99%	66%	58%	99%	79%	67%
3398	TM31	1	ZAAID2.IRD	0.32	0.32	0.32	0.27	0.15	0.15	0.15	0.13	0.27	0.14	0.12	0.27	0.19	0.15	83%	46%	55%	45%	40%	84%	43%	38%	84%	58%	47%
3898	TM26	1	TM262.IRD	0.10	0.10	0.10	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.06	71%	63%	88%	63%	63%	71%	66%	65%	71%	69%	64%
3179	TM26	1	LOWER THUKELA: ZAAIHOEK TO VAAL	0.90	0.90	0.90	0.87	0.75	0.75	0.75	0.73	0.90	0.80	0.77	0.90	0.85	0.77	97%	83%	85%	83%	81%	100%	89%	86%	100%	95%	86%
3180	TM26	1	LOWER THUKELA: ZAAIHOEK TO VAAL	1.26	1.26	1.26	1.21	0.99	0.99	1.00	0.97	0.61	0.53	0.51	0.36	0.34	0.30	96%	79%	82%	79%	77%	49%	42%	41%	29%	27%	24%
3400	TM26	1	LOWER THUKELA: ZAAIHOEK TRANSFER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00											
			Total	**2.68**	**2.71**	**2.74**	**2.51**	**3.73**	**3.73**	**3.73**	**3.66**	**1.97**	**3.34**	**3.27**	**1.74**	**3.28**	**3.11**											

Table C-6: Analysis Results: IUA 2

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
5221	TM25	2	THU_EWR19	-	-	-	0.00	0.39	0.39	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.45											
5219	TM25	2	May13_EWR2	-	-	-	0.00	0.23	0.23	0.23	0.23	0.00	0.23	0.23	0.00	0.23	0.23											
5223	TM25	2	May13_EWR3	-	-	-	0.00	1.29	1.29	1.29	1.29	0.00	1.29	1.29	0.00	1.29	1.29											
5225	TM25	2	Ngagane_dsk	-	-	-	0.00	1.62	1.62	1.62	1.62	0.00	1.62	1.62	0.00	1.62	1.62											
3403	TM25	2	LOWER THUKELA: DEM 10	1.20	1.34	1.49	1.20	0.74	0.74	0.74	0.68	1.34	0.81	0.74	1.47	1.07	0.90	100%	62%	62%	62%	57%	100%	60%	55%	99%	72%	61%
5015	TM25	2	LOWER THUKELA: DEM 21	0.14	0.14	0.14	0.14	0.11	0.11	0.11	0.11	0.14	0.11	0.11	0.14	0.12	0.11	100%	81%	81%	81%	79%	100%	80%	79%	100%	88%	81%
3409	TM25	2	LOWER THUKELA: DEM 22	0.35	0.35	0.35	0.35	0.28	0.28	0.28	0.27	0.35	0.28	0.27	0.35	0.31	0.28	100%	79%	79%	79%	77%	100%	79%	76%	100%	87%	79%
3408	TM25	2	CHELD2.IRD	0.08	0.08	0.08	0.08	0.06	0.06	0.06	0.05	0.08	0.05	0.05	0.08	0.07	0.06	99%	69%	70%	70%	65%	99%	68%	64%	98%	81%	71%
3899	TM24	2	TM242.IRD	0.28	0.28	0.28	0.22	0.20	0.20	0.20	0.19	0.22	0.20	0.20	0.22	0.21	0.20	81%	72%	89%	73%	70%	81%	73%	71%	81%	77%	71%
			Total	**2.04**	**2.18**	**2.33**	**1.99**	**4.90**	**4.90**	**4.97**	**4.89**	**2.13**	**5.03**	**4.94**	**2.26**	**5.36**	**5.13**											

Table C-7: Analysis Results: IUA 3

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
4064	TM28A	3	Thukela_EWR 13	-	-	-	0.00	4.28	4.28	4.75	4.75	0.00	4.75	4.75	0.00	4.75	4.75											
5230	TM27	3	THU_EWR13A	-	-	-	0.00	3.87	3.87	4.26	4.26	0.00	4.26	4.26	0.00	4.26	4.26											
3392	TM27	3	LOWER THUKELA: DEM 11A	0.17	0.18	0.20	0.17	0.15	0.15	0.15	0.15	0.18	0.17	0.17	0.20	0.20	0.19	100%	93%	93%	93%	92%	100%	94%	92%	100%	98%	92%
4065	TM28A	3	LOWER THUKELA: DEM 11B	0.20	0.23	0.38	0.20	0.19	0.19	0.18	0.18	0.23	0.22	0.22	0.38	0.37	0.35	100%	94%	94%	94%	93%	100%	95%	94%	100%	98%	93%
3393	TM27	3	V3B2.IRD	0.77	0.77	0.77	0.76	0.68	0.68	0.68	0.66	0.76	0.69	0.67	0.76	0.73	0.66	99%	89%	90%	88%	86%	99%	90%	88%	99%	95%	86%
5022	TM28A	3	V3RORA2.IRD	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	99%
			Total	**1.22**	**1.27**	**1.43**	**1.20**	**9.25**	**9.25**	**10.11**	**10.09**	**1.25**	**10.18**	**10.16**	**1.42**	**10.39**	**10.30**											

Table C-8: Analysis Results: IUA 4

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
3903	TM28C	4	Thukela_EWR 14	-	-	-	0.00	6.05	6.05	6.05	6.05	0.00	6.05	6.05	0.00	6.05	6.05											
3390	TM29B	4	LOWER THUKELA: DEM 12	0.11	0.20	0.38	0.11	0.10	0.10	0.10	0.10	0.20	0.18	0.18	0.38	0.37	0.35	100%	93%	93%	93%	92%	100%	94%	92%	100%	97%	91%
			Total	**0.11**	**0.20**	**0.38**	**0.11**	**6.15**	**6.15**	**6.15**	**6.15**	**0.20**	**6.23**	**6.23**	**0.38**	**6.42**	**6.40**											

Table C-9: Analysis Results: IUA 5

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
5233	TM28B	5	Blood_dsk	-	-	-	0.00	0.58	0.58	0.68	0.68	0.00	0.67	0.68	0.00	0.66	0.68											
3900	TM28B	5	V3RORB2.IRD	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.13	0.13	0.12	98%	96%	98%	96%	95%	98%	96%	95%	98%	98%	95%
4062	TM28B	5	RORKB2.IRD	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.34	0.36	0.35	0.35	0.36	0.35	0.34	98%	96%	97%	95%	94%	98%	96%	95%	98%	97%	94%
			Total	**0.49**	**0.49**	**0.49**	**0.48**	**1.05**	**1.05**	**1.15**	**1.15**	**0.48**	**1.14**	**1.14**	**0.48**	**1.14**	**1.14**											

Table C-10: Analysis Results: IUA 6

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
3894	TM15B	6	Thukela_EWR 7	-	-	-	0.00	0.73	0.73	0.68	0.68	0.00	0.68	0.68	0.00	0.68	0.68											
5213	TM14	6	THU_EWR7A	-	-	-	0.00	0.53	0.53	0.54	0.54	0.00	0.54	0.54	0.00	0.54	0.54											
3350	TM16C	6	Thukela_EWR 8	-	-	-	0.00	1.50	1.50	1.50	1.50	0.00	1.50	1.50	0.00	1.50	1.50											
3355	TM15B	6	LOWER THUKELA: DEM 14	0.35	0.39	0.43	0.28	0.21	0.21	0.21	0.21	0.30	0.22	0.22	0.32	0.24	0.24	79%	60%	75%	60%	60%	77%	58%	58%	74%	57%	57%
3354	TM15	6	NON2.IRD	0.19	0.19	0.19	0.18	0.17	0.17	0.17	0.17	0.18	0.17	0.17	0.18	0.17	0.17	94%	86%	92%	86%	86%	94%	86%	86%	94%	87%	86%
3358	TM15	6	MUNGUB2.IRD	0.18	0.18	0.18	0.12	0.08	0.08	0.08	0.08	0.12	0.08	0.08	0.12	0.08	0.08	70%	46%	67%	46%	46%	70%	46%	46%	70%	46%	46%
3891	TM14	6	TM14_M2.IRD	0.32	0.32	0.32	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	49%	49%	100%	49%	49%	49%	49%	49%	49%	49%	49%
3893	TM14	6	TM14B2.IRD	0.36	0.36	0.36	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	12%	11%	89%	11%	11%	12%	10%	10%	11%	10%	10%
			Total	**1.39**	**1.43**	**1.47**	**0.78**	**3.41**	**3.41**	**3.37**	**3.37**	**0.80**	**3.38**	**3.38**	**0.82**	**3.39**	**3.39**											

Table C-11: Analysis Results: IUA 7

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
302	Sut A/I-23	7	EWR_Mooi_N3	-	-	-	0.00	2.45	2.45	2.45	2.45	0.00	2.45	2.45	0.00	2.45	2.45											
5243	Dar/I-27	7	THU_EWR20	-	-	-	0.00	0.22	0.22	0.25	0.25	0.00	0.25	0.25	0.00	0.25	0.26											
205	MEA	7	Mooi Town & Textiles	0.08	0.08	0.08	0.07	0.04	0.04	0.04	0.04	0.07	0.04	0.04	0.07	0.05	0.04	97%	55%	56%	57%	55%	97%	55%	52%	99%	67%	59%
207	MEA	7	Mearns Rural Req	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100%	67%	67%	67%	67%	100%	67%	67%	100%	67%	67%
1404	SPR	7	'SPR_DIR'	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	104%	104%	100%	104%	104%	104%	104%	102%	104%	104%	104%
1406	SPR	7	'SPR_MIR'	0.05	0.05	0.05	0.04	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.04	0.02	0.02	93%	35%	38%	40%	35%	91%	38%	33%	93%	49%	42%
1408	SPR	7	'SPR_DIRECT'	0.06	0.06	0.06	0.03	0.02	0.02	0.00	0.00	0.03	0.00	0.00	0.03	0.02	0.02	57%	29%	52%	0%	0%	57%	0%	0%	57%	38%	31%
1410	DAR	7	'MRIB LITTLE MOOI_DIR'	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	102%	101%	99%	101%	101%	102%	101%	101%	102%	102%	101%
1412	DAR	7	'MRIB LITTLE MOOI_MIR'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1414	DAR	7	'MRIB LM DIRECT_MIR'	0.04	0.04	0.04	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.01	0.00	47%	11%	24%	11%	11%	47%	11%	11%	47%	14%	11%
1416	DAR	7	'MRIB HLATIKULU_DIR'	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.01	52%	48%	93%	48%	48%	52%	48%	48%	52%	52%	48%
1418	DAR	7	'MRIB HLATIKULU_MIR'	0.03	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	75%	14%	18%	14%	14%	75%	14%	14%	75%	14%	14%
1420	DAR	7	'DAR_DIR'	0.07	0.07	0.07	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	47%	32%	68%	32%	32%	47%	32%	32%	47%	33%	32%
1422	DAR	7	'DAR_MIR'	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	41%	10%	25%	10%	10%	41%	10%	10%	41%	10%	10%
1424	MEA	7	'BIG MOOI REM_MIR'	0.05	0.05	0.05	0.03	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.02	0.01	64%	27%	42%	29%	27%	64%	27%	25%	66%	35%	29%
1426	MEA	7	'BIG MOOI REM_DIR'	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	105%	103%	98%	103%	103%	105%	103%	103%	105%	103%	103%
1428	MEA	7	'LITTLE MOOI REM_DIR'	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	105%	104%	99%	103%	103%	105%	104%	104%	105%	104%	103%
1430	MEA	7	'LITTLE MOOI REM_MIR'	0.10	0.10	0.10	0.06	0.02	0.02	0.02	0.02	0.06	0.02	0.02	0.06	0.02	0.02	62%	19%	31%	19%	19%	62%	19%	19%	62%	22%	19%
1432	MEA	7	'MEA_DIRECT'	0.08	0.08	0.08	0.05	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.04	0.03	71%	43%	60%	44%	41%	71%	41%	40%	72%	52%	44%
1434	SUT-A	7	'SUT UPPER_MIR'	0.06	0.06	0.06	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	59%	5%	8%	5%	5%	59%	5%	5%	59%	6%	3%
1436	SUT_A	7	'SUT UPPER_DIR'	0.19	0.19	0.19	0.12	0.10	0.10	0.11	0.10	0.12	0.10	0.10	0.12	0.11	0.10	61%	55%	90%	56%	55%	61%	55%	54%	61%	58%	55%
1438	SUT_B	7	'SUT LOWER_DIR'	0.05	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	73%	62%	86%	65%	62%	73%	62%	62%	73%	69%	65%
1440	SUT_B	7	'SUT LOWER_MIR'	0.11	0.11	0.11	0.03	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.01	0.00	29%	7%	23%	6%	6%	29%	6%	6%	29%	6%	4%
1442	MIDD	7	'MIDD_DIR'	0.09	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.08	0.08	0.07	92%	78%	85%	78%	77%	92%	77%	76%	92%	86%	78%
1444	MIDD	7	'MIDD_MIR'	0.14	0.14	0.14	0.05	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.05	0.01	0.01	36%	7%	19%	6%	6%	36%	6%	5%	36%	5%	3%
585	MEA	7	MMTS total	4.50	4.50	4.50	4.26	2.50	2.50	2.57	2.47	4.32	2.64	2.54	4.08	2.46	2.11	95%	56%	59%	57%	55%	96%	59%	56%	91%	55%	47%
			Total	**6.05**	**6.05**	**6.05**	**5.34**	**5.91**	**5.91**	**6.00**	**5.89**	**5.41**	**6.06**	**5.96**	**5.17**	**5.96**	**5.56**											

Table C-12: Analysis Results: IUA 8

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
290	Muden A/I-29	8	Thukela_EWR11	-	-	-	0.00	3.58	3.58	3.61	3.68	0.00	3.61	3.67	0.00	3.81	3.90											
429	Craig/I-28	8	IFR 12b craigieburn	-	-	-	0.00	0.15	0.15	0.16	0.16	0.00	0.15	0.15	0.00	0.16	0.15											
5237	Craig/I-28	8	THU_EWR21	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00											
254	Muden A/I-29	8	Thukela_EWR12	-	-	-	0.00	2.33	2.33	2.33	2.33	0.00	2.33	2.33	0.00	2.33	2.33											
5244	Muden A/I-29	8	THU_EWR12A	-	-	-	0.00	3.62	3.62	3.84	3.84	0.00	3.84	3.84	0.00	3.84	3.84											
5245	Muden B/I-30	8	Mooi_dsk	-	-	-	0.00	4.00	4.00	4.00	4.00	0.00	4.00	4.00	0.00	4.00	4.00											
1446	CRAIG	8	'CRAIGIE_DIR'	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	105%	105%	100%	105%	105%	105%	105%	105%	105%	105%	105%
1448	CRAIG	8	'CRAIGIE_MIR'	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	105%	86%	73%	86%	77%	105%	77%	77%	105%	86%	77%
1450	MUDEN_A	8	'CRAIGIE DS_MIR'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61%	61%	100%	61%	61%	61%	61%	61%	61%	61%	61%
1452	MUDEN_A	8	'MUDEN A_MIR'	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06	101%	85%	84%	85%	83%	101%	83%	82%	101%	91%	83%
1454	MUDEN_A	8	'MUDEN A_DIR'	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	101%	95%	95%	95%	95%	101%	95%	95%	101%	101%	95%
1456	MUDEN_A	8	'MUDEN B_MIR'	0.21	0.21	0.21	0.18	0.08	0.08	0.08	0.07	0.18	0.07	0.07	0.18	0.10	0.08	85%	36%	42%	35%	34%	85%	33%	31%	85%	47%	37%
1459	MUDEN_B	8	'MUDEN B_DIR'	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	83%	68%	82%	68%	68%	83%	68%	68%	83%	75%	68%
			Total	**0.37**	**0.37**	**0.37**	**0.34**	**13.90**	**13.90**	**14.16**	**14.22**	**0.34**	**14.14**	**14.20**	**0.34**	**14.39**	**14.45**											

Table C-13: Analysis Results: IUA 9

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
3341	TM09	9	Thukela_EWR 5	-	-	-	0.00	4.09	4.09	3.41	3.41	0.00	3.41	3.41	0.00	3.41	3.41											
3785	TM16B	9	Thukela_EWR 6	-	-	-	0.00	2.76	2.76	2.43	2.41	0.00	2.42	2.40	0.00	1.92	1.75											
5216	TM16B	9	THU_EWR6A	-	-	-	0.00	2.88	2.88	3.33	3.35	0.00	3.32	3.34	0.00	2.03	2.20											
3348	TM18	9	LOWER THUKELA: DEM 16	0.48	0.52	0.55	0.48	0.48	0.48	0.48	0.48	0.52	0.52	0.52	0.56	0.56	0.56	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
3351	TM16B	9	LOWER THUKELA: DEM 17	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	100%	19%	19%	19%	19%	101%	18%	18%	100%	0%	0%
3345	TM18	9	LOWER THUKELA: DEM 18	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	100%	100%	100%	100%	100%	99%	99%	99%	101%	101%	101%
3346	TM18	9	WAG2.IRD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	99%	99%	100%	99%	99%	99%	99%	99%	99%	94%	94%
3352	TM09	9	MNGWEN2.IRD	0.75	0.75	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.72	0.72	99%	99%	100%	99%	99%	99%	99%	99%	99%	95%	95%
3365	TM13	9	LOCHS2.IRD	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.49	0.49	98%	98%	100%	98%	98%	98%	98%	98%	98%	96%	96%
			Total	**1.84**	**1.88**	**1.92**	**1.82**	**11.53**	**11.53**	**10.96**	**10.96**	**1.86**	**10.98**	**10.98**	**1.90**	**9.20**	**9.20**											

Table C-14: Analysis Results: IUA 10

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
4291	TM05B	10	Thukela_EWR 1	-	-	-	0.00	4.96	4.96	4.96	4.96	0.00	4.96	4.96	0.00	4.96	4.96											
4301	TM07A	10	Thukela_EWR 2	-	-	-	0.00	6.33	6.33	6.42	6.43	0.00	6.42	6.43	0.00	6.28	6.38											
4190	TM08A	10	Thukela_EWR 3	-	-	-	0.00	2.60	2.60	2.60	2.60	0.00	2.60	2.60	0.00	2.60	2.60											
5208	TM10	10	Thukela1_dsk	-	-	-	0.00	8.53	8.53	8.29	8.29	0.00	8.24	8.25	0.00	8.03	8.32											
3316	TM05	10	UPPER THUKELA: DEM 1	0.06	0.08	0.09	0.06	0.03	0.03	0.03	0.03	0.08	0.04	0.04	0.09	0.05	0.05	93%	48%	52%	48%	46%	97%	52%	52%	97%	54%	53%
3307	TM01	10	UPPER THUKELA: DEM 2	0.07	0.08	0.08	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.06	0.05	0.05	72%	54%	75%	54%	54%	71%	53%	53%	71%	56%	53%
3332	TM08A	10	UPPER THUKELA: DEM 6	0.06	0.09	0.11	0.06	0.06	0.06	0.06	0.06	0.09	0.09	0.09	0.11	0.10	0.10	98%	98%	100%	98%	98%	98%	98%	98%	99%	98%	98%
3334	TM10	10	UPPER THUKELA: DEM 7	0.07	0.08	0.08	0.07	0.01	0.01	0.01	0.01	0.08	0.01	0.01	0.08	0.02	0.02	100%	14%	14%	18%	17%	100%	18%	18%	100%	19%	18%
3305	TM01	10	THWOOD2.IRD	0.16	0.16	0.16	0.10	0.06	0.06	0.06	0.06	0.10	0.06	0.06	0.10	0.07	0.06	62%	41%	65%	40%	39%	62%	40%	39%	62%	42%	40%
3303	TM02	10	TM022.IRD	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
3310	TM04	10	THDRIE2.IRD	0.07	0.07	0.07	0.05	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.03	0.03	62%	38%	61%	38%	36%	62%	38%	36%	62%	40%	38%
3362	TM05	10	TM062.IRD	0.11	0.11	0.11	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.05	55%	44%	81%	44%	44%	55%	44%	44%	54%	44%	44%
3315	TM05	10	THSKOPa2.IRD	1.20	1.20	1.20	0.81	0.54	0.54	0.53	0.53	0.81	0.53	0.53	0.80	0.56	0.54	68%	45%	67%	44%	44%	67%	44%	44%	67%	47%	45%
4293	TM05	10	THSKOPb2.IRD	0.23	0.23	0.23	0.19	0.13	0.13	0.12	0.12	0.19	0.12	0.12	0.19	0.14	0.12	83%	56%	68%	53%	53%	83%	53%	53%	82%	61%	53%
3319	TM07	10	THSKDS2.IRD	0.13	0.13	0.13	0.13	0.01	0.01	0.01	0.01	0.13	0.01	0.01	0.13	0.02	0.02	98%	9%	9%	11%	11%	98%	11%	10%	98%	13%	12%
3323	TM08	10	TM08A2.IRD	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	99%
3331	TM08	10	THLTUG2.IRD	0.97	0.97	0.97	0.63	0.47	0.47	0.47	0.47	0.63	0.47	0.47	0.63	0.46	0.46	65%	49%	75%	49%	49%	65%	48%	48%	64%	48%	48%
3420	TM08	10	TM08B2.IRD	0.32	0.32	0.32	0.29	0.21	0.21	0.21	0.21	0.28	0.20	0.20	0.28	0.20	0.20	91%	66%	73%	66%	66%	90%	64%	64%	89%	63%	63%
4298	TM05	10	TM06_b2.IRD	0.24	0.24	0.24	0.07	0.03	0.03	0.02	0.02	0.07	0.02	0.02	0.07	0.04	0.03	27%	11%	40%	10%	10%	27%	10%	10%	27%	17%	13%
3085	TM03	10	UPPER THUKELA: TRANSFER FROM DRIEL	19.00	19.00	19.00	14.78	11.89	11.89	11.82	11.79	14.77	11.82	11.79	14.76	12.10	11.84	78%	63%	80%	62%	62%	78%	62%	62%	78%	64%	62%
3088	TM01	10	UPPER VAAL: TRANSFER RATE FROM JAGERSRUST	20.00	20.00	20.00	15.14	12.37	12.37	12.29	12.26	15.13	12.29	12.27	15.13	12.57	12.31	76%	62%	82%	61%	61%	76%	61%	61%	76%	63%	62%
3312	TM10	10	UPPER VAAL: TUGELA SOUTH TO VAAL	0.00	0.00	12.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.70	10.65	9.22									100%	84%	73%
3328	TM10	10	UPPER THUKELA: JANA TO VAAL (280)	0.00	0.00	8.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.80	6.99	5.56									100%	79%	63%
			Total	**42.88**	**42.93**	**64.47**	**32.66**	**48.53**	**48.53**	**48.22**	**48.17**	**32.69**	**48.20**	**48.16**	**54.20**	**66.14**	**63.10**											

Table C-15: Results: IUA 11

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
5203	TM11	11	THU_EWR22	-	-	-	0.00	0.43	0.43	0.43	0.43	0.00	0.43	0.43	0.00	0.43	0.43											
5206	TM10	11	Klip_dsk	-	-	-	0.00	2.16	2.16	2.16	2.16	0.00	2.16	2.16	0.00	2.16	2.16											
3318	TM05	11	UPPER THUKELA: DEM 3	0.27	0.44	0.48	0.27	0.11	0.11	0.11	0.11	0.41	0.13	0.13	0.41	0.14	0.13	100%	41%	41%	41%	41%	95%	30%	29%	86%	28%	27%
3888	TM05	11	UPPER THUKELA: DEM 4	0.69	0.71	0.74	0.69	0.10	0.10	0.12	0.12	0.71	0.13	0.12	0.74	0.14	0.14	100%	14%	14%	18%	17%	100%	18%	17%	100%	19%	18%
3336	TM11	11	UPPER THUKELA: DEM 5	0.09	0.11	0.13	0.09	0.06	0.06	0.06	0.06	0.11	0.07	0.07	0.13	0.09	0.08	99%	69%	70%	67%	67%	99%	66%	66%	99%	69%	65%
3325	TM10	11	KLIPA2.IRD	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	99%	99%	100%	99%	99%	99%	99%	99%	99%	99%	99%
3339	TM10	11	KLIPB2.IRD	0.73	0.73	0.73	0.72	0.56	0.56	0.51	0.51	0.72	0.51	0.51	0.72	0.61	0.53	99%	76%	77%	70%	69%	99%	70%	69%	99%	84%	72%
3886	TM11	11	TM11A2.IRD	0.16	0.16	0.16	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	49%	49%	100%	49%	49%	49%	49%	49%	49%	49%	49%
3887	TM11	11	TM11B2.IRD	0.30	0.30	0.30	0.14	0.06	0.06	0.06	0.06	0.12	0.06	0.06	0.12	0.06	0.06	47%	21%	45%	20%	20%	41%	20%	20%	40%	20%	19%
			Total	**2.40**	**2.61**	**2.71**	**2.14**	**3.72**	**3.72**	**3.70**	**3.69**	**2.31**	**3.73**	**3.72**	**2.36**	**3.87**	**3.77**											

Table C-16: Analysis Results: IUA 12

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
3896	TM16A	12	Thukela_EWR 4b	-	-	-	0.00	12.07	12.07	12.83	12.83	0.00	12.83	12.84	0.00	12.84	12.84											
5014	TM29A	12	Thukela_EWR 9	-	-	-	0.00	15.86	15.86	15.85	15.85	0.00	15.86	15.85	0.00	15.86	15.86											
5234	TM29B	12	Thukela2_dsk	-	-	-	0.00	24.89	24.89	24.90	24.90	0.00	24.87	24.88	0.00	24.92	24.91											
3359	TM29A	12	LOWER THUKELA: DEM 15	0.04	0.12	0.27	0.04	0.03	0.03	0.03	0.03	0.12	0.11	0.10	0.27	0.25	0.23	100%	86%	86%	86%	86%	100%	86%	85%	100%	93%	86%
3443	TM12	12	TM122.IRD	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.05	87%	74%	85%	74%	73%	87%	73%	73%	87%	80%	73%
			Total	**0.10**	**0.19**	**0.34**	**0.09**	**52.90**	**52.90**	**53.66**	**53.66**	**0.18**	**53.71**	**53.72**	**0.33**	**53.93**	**53.89**											

Table C-17: Analysis Results: IUA 13

Model Channel No.	Hydrological Modelling Unit (TM no./Description)	IUA	Description	Demand 2020 (m³/s)	Demand 2030 (m³/s)	Demand 2040 (m³/s)	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE	Sc1N	Sc1PR	Sc1PE	Sc1TR	Sc1TE	Sc2N	Sc2TR	Sc2TE	Sc3N	Sc3TR	Sc3TE
5003	TM32B	13	Thukela_EWR 15	-	-	-	0.00	27.62	27.62	27.62	27.62	0.00	27.62	27.62	0.00	27.62	27.62											
3905	TM30A	13	Thukela_EWR 16	-	-	-	0.00	49.33	49.33	49.33	49.30	0.00	49.35	49.32	0.00	49.40	49.32											
3379	TM30A	13	LOWER THUKELA: DEM 13	0.54	0.59	0.64	0.54	0.38	0.38	0.38	0.34	0.59	0.40	0.36	0.64	0.53	0.43	100%	70%	70%	70%	64%	100%	68%	61%	100%	83%	68%
3381	TM30A	13	MAND2.IRD	0.47	0.47	0.47	0.46	0.31	0.31	0.32	0.29	0.46	0.31	0.28	0.46	0.38	0.31	99%	67%	68%	68%	61%	99%	65%	59%	99%	82%	67%
3384	TM32A	13	MHL_B2.IRD	0.38	0.38	0.38	0.37	0.26	0.26	0.26	0.23	0.37	0.25	0.22	0.37	0.31	0.26	99%	68%	69%	69%	62%	99%	66%	59%	99%	83%	68%
5001	TM32B	13	MHL_A2.IRD	0.21	0.21	0.21	0.21	0.14	0.14	0.14	0.13	0.21	0.14	0.12	0.21	0.17	0.14	99%	68%	69%	68%	61%	99%	65%	59%	99%	83%	67%
5004	TM30A	13	LOWER THUKELA: LTBWSS2	0.00	0.63	0.63	0.00	0.00	0.00	0.00	0.00	0.63	0.40	0.36	0.63	0.51	0.41						100%	63%	57%	100%	81%	65%
5005	TM30A	13	LOWER THUKELA: LTBWSS1	0.63	0.63	0.63	0.51	0.26	0.26	0.26	0.24	0.49	0.26	0.23	0.46	0.20	0.14	81%	42%	51%	42%	38%	78%	41%	37%	73%	32%	22%
3385	TM32B	13	LOWER THUKELA: MHLATUZE TRANSFER FIRM	2.00	2.00	2.00	2.00	1.29	1.29	1.31	1.17	2.00	1.24	1.12	2.00	1.62	1.28	100%	65%	65%	65%	59%	100%	62%	56%	100%	81%	64%
			Total	**4.22**	**4.90**	**4.96**	**4.09**	**79.59**	**79.59**	**79.62**	**79.31**	**4.75**	**79.95**	**79.62**	**4.77**	**80.75**	**79.90**											

Appendix D:
Abridged raw outputs of the CRA process

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
1	Higher flows-EWR not met	Waterway	Fresh Water (Natural Sources)	Very unlikely	Insignificant	Low	Increased flow is unlikely to impact on fresh water availability with consequences being low to positive for the flow of water provisioning services.
1		Waterway	Landscape & amenity values	Extremely unlikely	Insignificant	Low	
1		Waterway	Ecotourism & recreation	Likely	Minor	Medium	It is likely that higher flows could impact fishing areas (trout) however the consequence is minor due to the small size of the industry
1		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
1		Waterway	Food Provisioning	Likely	Minor	Medium	There is an impact, but the level is not certain. - Need a monitoring program. Minor impacts because of the beneficiaries in the catchment
1		Waterway	Raw materials / Fibre	Extremely unlikely	Minor	Low	WK: Natural veg is grassland- so it wont impact on building material and raw materials
		Waterway	Medicinal resources	Very unlikely	Minor	Low	No evidence of the presence of this service
1		Waterway	Habitats for species	Almost certain	Moderate	High	highly heterogeneity of habitats results in a almost certain impact from altered flows. The consequence of this impact would be moderate due to this diversity
1		Waterway	Inspirational Value	Extremely unlikely	Insignificant	Low	No clear linkage
1	Wetlands Reduced water volumes	Wetland	Fresh Water (Natural Sources)	Almost certain	Insignificant	Low	Less water in therefore less water out. It is certain that loss of flow will impact the environment.
1		Wetland	Food Provisioning	Likely	Minor	Medium	Likely as there are direct linkage s to productivity however as no significant informal communities perhaps consequences of this are minor.
1		Wetland	Raw materials / Fibre	Likely	Insignificant	Low	

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
1		Wetland	Medicinal resources	Likely	Insignificant	Low	
1		Wetland	Habitats for species	Likely	Moderate	High	Note number of red data bird species (CR white winged fluff tail etc). Nationally significant species. Consequence of this loss would be Moderate. The likelihood of impact however is likely as the peatlands are very rare.
1		Wetland	Landscape & amenity values	Likely	Moderate	High	The presence of high ecotourism in the region results in high landscape amenity value.
1		Wetland	Ecotourism & recreation	Likely	Moderate	High	"Lifers"- birders who specifically go to a region for key bird species. The presence of these species are a draw card here in wakkerstroom. The impacts are likely with moderate consequences on ecotourism.
1		Wetland	Educational values	Likely	Moderate	High	There is investment linked to training here directly on the wetland. Likely impacts with moderate consequences.
1		Wetland	Inspirational Value	Likely	Moderate	High	
1	Over abstraction	Aquifer	Fresh Water (Natural Sources)	Likely	Minor	Medium	Over abstraction will likely impact the water provisioning as the systems are already lower yield resources any additional abstraction would likely impact. Consequence would be minor as although it would take a few years to recover and the beneficiaries are not as numerous as IUA 10.
2	Low flows- EWR not met	Waterway	Fresh Water (Natural Sources)	Almost certain	Minor	Medium	due to presence of zero flows it is almost certain that water availability from natural sources will be impacted. Given the nature of the catchment however the consequences are expected to be minor.
2		Waterway	Landscape & amenity values	Very unlikely	Insignificant	Low	

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
2		Waterway	Ecotourism & recreation	Possible	Minor	Medium	It is possible that low flows impact ecotourism (through reduced vegetation extent) and potentially diversity and available fish stocks. The consequences are minor.
2		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
2		Waterway	Food Provisioning	Possible	Insignificant	Low	Possible negative impact through low flows however lack of direct obvious beneficiaries results in insignificant consequences
2		Waterway	Raw materials / Fibre	Possible	Insignificant	Low	Possible negative impact through low flows however lack of direct obvious beneficiaries results in insignificant consequences
2		Waterway	Medicinal resources	Possible	Insignificant	Low	Possible negative impact through low flows however lack of direct obvious beneficiaries results in insignificant consequences
2		Waterway	Habitats for species	Possible	Minor	Medium	The diversity of habitats in IUA 2 are not as high as in IUA 1 resulting in a possible impact to diversity with minor consequences.
2		Waterway	Inspirational Value	Very unlikely	Insignificant	Low	
2	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Likely	Insignificant	Low	It is likely the hazard will impact fresh water provisioning however formal water infrastructure makes consequences insignificant
2		Waterway	Food Provisioning	Unlikely	Insignificant	Low	Unlikely that the hazard will have a negative impact on primary productivity and the lack of direct obvious beneficiaries results in insignificant consequences
2		Waterway	Raw materials / Fibre	Unlikely	Insignificant	Low	
2		Waterway	Medicinal resources	Unlikely	Insignificant	Low	
2		Waterway	Habitats for species	Likely	Minor	Medium	There are specific species- which will be impacted by changing water quality and spawning-movement-

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							patterns upstream and downstream.- Macro inverts are especially impacted here. The likelihood is likely however with minor consequences
2		Waterway	Landscape & amenity values	Very unlikely	Insignificant	Low	
2		Waterway	Ecotourism & recreation	Likely	Minor	Medium	It is possible that water quality issues impact ecotourism (through smells or colours of water) and potentially diversity and available fish stocks. The consequences are minor.
2		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
2		Waterway	Inspirational Value	Very unlikely	Insignificant	Low	
2	Over abstraction	Aquifer	Fresh Water (Natural Sources)	Likely	Minor	Medium	Over abstraction will likely impact the water provisioning as the systems are already lower yield resources any additional abstraction would likely impact. Consequence would be minor as although it would take a few years to recover and the beneficiaries are not as numerous as IUA 10.
3	Higher flows- EWR not met	Waterway	Fresh Water (Natural Sources)	Almost certain	Moderate	High	Although the presence of zero flows in a highly rural landscape results in moderate consequences it is likely that the communities have access to formal water sources and therefore consequences are moderate. The likelihood is almost certain.
3		Waterway	Food Provisioning	Unlikely	Minor	Low	High flows would unlikely negatively impact on primary productivity and the presence of cattle grazers means the consequences could be positive. The EWR is not met and therefore there may be some minor impacts in the dry season
3		Waterway	Raw materials / Fibre	Unlikely	Insignificant	Low	High flows would unlikely negatively impact on primary productivity and the lack of obvious direct beneficiaries

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							results in an insignificant consequences in the sub-EWR, low flowing dry season.
3		Waterway	Medicinal resources	Unlikely	Insignificant	Low	High flows would unlikely negatively impact on primary productivity and the lack of obvious direct beneficiaries results in an insignificant consequences in the sub-EWR, low flowing dry season.
3		Waterway	Habitats for species	Almost certain	Minor	Medium	Impacts of modified flow are almost certain with minor consequences on habitats for species because of low diversity of habitats.
3		Waterway	Landscape & amenity values	Extremely unlikely	Insignificant	Low	
3		Waterway	Ecotourism & recreation	Unlikely	Minor	Low	It is unlikely that higher flows would impact on ecotourism and recreation coupled with limited water resource related tourism industry the consequences would be minor is an impact had to occur.
3		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
3		Waterway	Inspirational Value	Very unlikely	Insignificant	Low	
3	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Almost certain	Moderate	High	The extent of water quality issues results in a moderate consequence with an almost certain likelihood of impact
3		Waterway	Food Provisioning	Unlikely	Minor	Low	Unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive). It is however likely it would have an effect on organisms within the streams (fish) which would impact fishing food provision. The presence of livestock grazers in the region but no obvious fishing subsistence means that is there is an impact the consequences would be minor.
3		Waterway	Raw materials / Fibre	Unlikely	Insignificant	Low	Unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive) and

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							the lack of obvious beneficiaries of this service results in an insignificant consequence.
3		Waterway	Medicinal resources	Unlikely	Insignificant	Low	Unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive) and the lack of obvious beneficiaries of this service results in an insignificant consequence.
3		Waterway	Habitats for species	Likely	Minor	Medium	The WQ hazard is significant in this IUA- similar to IUA 1- and the likelihood of impact is rated at likely. The importance of the reach for spawning however is more significant than IUA 1 and therefore consequences of impact are rated as minor due to low heterogeneity.
3		Waterway	Landscape & amenity values	Very unlikely	Insignificant	Low	
3		Waterway	Ecotourism & recreation	Possible	Insignificant	Low	The nature of contaminants results in a possible impact. The impacts to a very small industry are insignificant
3		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
3		Waterway	Inspirational Value	Very unlikely	Insignificant	Low	
3	Water Quality hazard- THIS SYSTEM IS HEAVILY DEGRADED- Highly transformed	Wetland	Fresh Water (Natural Sources)	Very unlikely	Insignificant	Low	Note large proportion of the populations have formal water supplies. There will likely be no collection of water from pans due to elevated salinity
3		Wetland	Food Provisioning	Very unlikely	Minor	Low	
3		Wetland	Raw materials / Fibre	Extremely unlikely	Insignificant	Low	
3		Wetland	Medicinal resources	Very unlikely	Minor	Low	
3		Wetland	Habitats for species	Possible	Major	High	Note the wewtland complex may be impacted however due to the channelisation the wetland may be

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							protected. Also the high diversity of wetland types results in less likelihood of the wetland being impacted by water quality. The consequences however- especially the pans- are in good condition. The consequences would therefore be major.Note pans are very sensitive to water quality issues.
3		Wetland	Landscape & amenity values	Very unlikely	Minor	Low	
3		Wetland	Ecotourism & recreation	Very unlikely	Minor	Low	
3		Wetland	Educational values				
3		Wetland	Inspirational Value	Very unlikely	Insignificant	Low	
3	Low Flow in Aluvial system- if EWR not met	Aquifer	Fresh Water (Natural Sources)	Possible	Minor	Medium	The likelihood is possible that low flows would reduce recharge and consequence would be minor as there are no significant beneficiarioes of groundwater resources in the IUA.
5	Higher flows- EWR not met	Waterway	Fresh Water (Natural Sources)	Possible	Moderate	High	There are no zero flows however high densities of rural communities in the lower catchment. The likelihood of impact is therefore possible but with moderate consequences.
5		Waterway	Food Provisioning	Unlikely	Minor	Low	High flows would unlikely negatively impact on primary productivity and the presence of cattle grazers means the consequences could in fact be positive. The EWR is not met and therefore there may be some minor impacts in the dry season. Additionally Consequences on fish provisioning is unclear due to unclear knowledge of fish collections.
5		Waterway	Raw materials / Fibre	Unlikely	Insignificant	Low	High flows would unlikely negatively impact on primary productivity and may in fact promote primary growth.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							The presence of traditional dwellings in this region indicates these impacts would be positive
5		Waterway	Medicinal resources	Unlikely	Insignificant	Low	High flows would unlikely negatively impact on primary productivity and may in fact promote primary growth. Although there may be collection of medicinal resources, the consequences of an impact is expected to be insignificant.
5		Waterway	Habitats for species	Likely	Moderate	High	Likelihood of impact is likely due to the nature of the hazard however habitats are not as diverse as IUA 1 and are slightly limited in IUA 5. Therefore moderate consequence of an impact.
5		Waterway	Landscape & amenity values	Very unlikely	Insignificant	Low	
5		Waterway	Ecotourism & recreation	Unlikely	Minor	Low	Higher flows would likely increase primary productivity and the visual beauty of the region-it is unlikely this will impact ecotourism. The consequences will be minor
5		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
5		Waterway	Inspirational Value	Very unlikely	Insignificant	Low	
5	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Likely	Major	Extreme	Pathogens will directly impact the ability to use surface water for drinking and domestic purposes. The likelihood of an impact is therefore likely with major consequences.
5		Waterway	Food Provisioning	Possible	Minor	Medium	Impacts of pathogens on food i.e. fish or other collected organisms is possible- however no clear data is available on the collection of fish for subsistence and as such the consequence is Minor
5		Waterway	Raw materials / Fibre	Extremely unlikely	Insignificant	Low	Impacts of increased pathogens may impact organisms within the system but likely not growth of vegetation

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
5		Waterway	Medicinal resources	Extremely unlikely	Insignificant	Low	Impacts of increased pathogens may impact organisms within the system but likely not growth of vegetation
5		Waterway	Habitats for species	Very unlikely	Insignificant	Low	Very unlikely with insignificant consequences
5		Waterway	Landscape & amenity values	Very unlikely	Insignificant	Low	
5		Waterway	Ecotourism & recreation	Possible	Minor	Medium	Pathogens would possibly reduce aquatic activities however the region is relatively isolated and no major industry exists. The consequences of an impact would be minor.
5		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
5		Waterway	Inspirational Value	Very unlikely	Insignificant	Low	
5	Reduced volumes- for priority wetlands	Wetland	Fresh Water (Natural Sources)	Extremely unlikely	Insignificant	Low	
5		Wetland	Food Provisioning	Unlikely	Moderate	Medium	
5		Wetland	Raw materials / Fibre	Unlikely	Moderate	Medium	
5		Wetland	Medicinal resources	Unlikely	Minor	Low	
5		Wetland	Habitats for species	Likely	Moderate	High	Presence of key species (red data cranes) means consequences of impacts on this system. Upper reaches are stable-some deforestation and climate change
5		Wetland	Landscape & amenity values	Very unlikely	Insignificant	Low	
5		Wetland	Ecotourism & recreation	Possible	Minor	Medium	

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
5		Wetland	Educational values	Very unlikely	Insignificant	Low	
5		Wetland	Inspirational Value	Very unlikely	Insignificant	Low	
4	Water Quality Hazard	Waterway	Fresh Water (Natural Sources)	Possible	Severe	Extreme	The nature of contaminants results in a possible possible impact. The impacts on an IUA which is characteristic of high dependency (35% of households) of households on rivers and streams for their primary water source is severe.
4		Waterway	Food Provisioning	Unlikely	Minor	Low	Unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive due to nutrients). It is however likely it would have an effect on organisms within the streams (fish) which would impact fishing food provision. The presence of livestock grazers in the region but no obvious fishing subsistence means the consequences would be minor.
4		Waterway	Raw materials / Fibre	Unlikely	Insignificant	Low	Unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive due to nutrients). The presence of traditional dwellings in the IUA and the use of raw materials for construction means consequences would be positive.
4		Waterway	Medicinal resources	Unlikely	Insignificant	Low	Unlikely that the hazard will have a negative impact on primary productivity (in fact this may be positive) and the lack of obvious beneficiaries of this service results in an insignificant consequence.
4		Waterway	Habitats for species	Likely	Minor	Medium	Minor consequences due to existing poor conditions and existing homogenous habitats.
4		Waterway	Landscape & amenity values	Unlikely	Moderate	Medium	It is unlikely that WQ issues would impact the landscape and amenity value of these traditional areas. The consequence to the traditional communities are moderate.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
4		Waterway	Ecotourism & recreation	Unlikely	Insignificant	Low	
4		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
4		Waterway	Inspirational Value	Unlikely	Minor	Low	
4	Low Flow in Aluvial system- EWR not met	Aquifer	Fresh Water (Natural Sources)	Possible	Major	High	No EWR possibly impact the water provisioning as the systems are already lower yield resources. Consequence would be major as there are numerous community beneficiaries who rely on availability of water.
14	Only non-flow hazards - EWR is met	Waterway	Fresh Water (Natural Sources)	Extremely unlikely	Severe	High	Note: If water accumulated in the SWSA is impacted (wq)/lost this will have drastic influence on the entire catchment. These are through the base flow but more importantly the flood events i.e. floods (incredibly large floods) are driver of water use in the catchment (fill dams etc).
14		Waterway	Food Provisioning	Extremely unlikely	Moderate	Low	
14		Waterway	Raw materials / Fibre	Extremely unlikely	Moderate	Low	
14		Waterway	Medicinal resources	Extremely unlikely	Moderate	Low	
14		Waterway	Habitats for species	Extremely unlikely	Severe	High	Note: Currently no significant hazard
14		Waterway	Landscape & amenity values	Extremely unlikely	Major	Medium	
14		Waterway	Ecotourism & recreation	Extremely unlikely	Severe	High	
14		Waterway	Educational values	Extremely unlikely	Insignificant	Low	

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
14		Waterway	Inspirational Value	Extremely unlikely	Severe	High	
7	Low flow - EWR not met	Waterway	Fresh Water (Natural Sources)	Possible	Moderate	High	The zero flows result in a moderate consequence for communities with possible likelihood of impact
7		Waterway	Food Provisioning	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of subsistence in catchments and therefore insignificant consequences. Mostly formal agric. Needs verification.
7		Waterway	Raw materials / Fibre	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of raw materials from aquatic systems and therefore consequences are insignificant
7		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
7		Waterway	Habitats for species	Almost certain	Moderate	High	Continued impacts are almost certain- due to the existing condition the consequences oof an impact on existing habitats is moderate.
7		Waterway	Landscape & amenity values	Possible	Minor	Medium	[Perhaps at spring grove]. The low flows do not necessarily impact amenity value (more water availability). It is possible that low flows may impact market prices however the consequences are expected to be minor.
7		Waterway	Ecotourism & recreation	Likely	Moderate	High	It is very likely that reduced flow will impact aquatic related recreational activities. Of which consequences in this developed tourism industry would be moderate.
7		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
7		Waterway	Inspirational Value	Possible	Moderate	High	It is possible low flows could impact the inspirational value of midmar. The consequences of which are moderate as the greater Midlands meander as an inspiration. Think on how this impacts tourism routes. (Note compare Rosetta (thriving) and Mooi river and then winterton (thriving) and bergville)
7	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Possible	Moderate	High	Poor water quality would possibly impact water available to beneficiaries and due to the nature of water use in the catchment focussing on cattle watering this would have moderate consequences
7		Waterway	Food Provisioning	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms- there is however no clear indication of subsistence communities and therefore consequences are insignificant
7		Waterway	Raw materials / Fibre	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - there is however no clear indication of subsistence communities and therefore consequences are insignificant
7		Waterway	Medicinal resources	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - there is however no clear indication of subsistence communities and therefore consequences are insignificant
7		Waterway	Habitats for species	Almost certain	Moderate	High	Moderate as when flushing happens (which does happen) wq issues will be flushed.
7		Waterway	Landscape & amenity values	Possible	Moderate	High	Impacts on real estate values linked to aquatic resources is possible and the consequences as per

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							linked to a large ecotourism industry would be moderate.
7		Waterway	Ecotourism & recreation	Likely	Moderate	High	It is likely that the WQ hazard would impact the fishing stocks in the region. The consequences would be moderate due to the size of the industry
7		Waterway	Educational values	Unlikely	Insignificant	Low	No evidence of the presence of this service
7		Waterway	Inspirational Value	Possible	Moderate	High	WQ issues could possible impact inspirational services through introduced odours and colours. This would have a moderate consequence on the regional tourism economy.
7	Decreased flow-	Wetland	Fresh Water (Natural Sources)	Unlikely	Minor	Low	The impacts of reduced flow will likely be felt in the main channel with associated wetlands. The likelihood of an impact is relatively unlikely as water can be accessed from adjacent wetland systems not associated with the reduced flow. Consequences would be minor. However the impacts of decreased flow would be specific to a specific channel. note many of the wetlands may be unimpacted. This introduces resilience to the maintenance of ecosystem services.
7		Wetland	Food Provisioning	Possible	Insignificant	Low	
7		Wetland	Raw materials / Fibre	Possible	Insignificant	Low	
7		Wetland	Medicinal resources	Possible	Insignificant	Low	
7		Wetland	Habitats for species	Unlikely	Minor	Low	The dymanics of the wetland cluster means resilience of habitats would be high. Low flow impacts would likely impact specific wetlands but not all, resulting in

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							an unlikely impact on habitats. The consequences similarly would be minor.
7		Wetland	Landscape & amenity values	Extremely unlikely	Insignificant	Low	
7		Wetland	Ecotourism & recreation	Extremely unlikely	Insignificant	Low	
7		Wetland	Educational values	Extremely unlikely	Insignificant	Low	
7		Wetland	Inspirational Value	Extremely unlikely	Insignificant	Low	
8	Low flow - EWR not met	Waterway	Fresh Water (Natural Sources)	Likely	Severe	Extreme	Note: More communities compared to IUA 7. Note the communities do not have access to formal water irrigation and depend more directly on rivers for water. The low flows results in a likely impact. The impacts on an IUA which is characteristic of high dependency (33%) of households on rivers and streams for their primary water source is severe.
8		Waterway	Food Provisioning	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
8		Waterway	Raw materials / Fibre	Possible	Minor	Medium	Low flows would possibly impact on primary productivity. The presence of communities that use these materials means the consequences could be minor.
8		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
8		Waterway	Habitats for species	Possible	Moderate	High	Note-lower mooi there were sensitive aquatics-i.e. better conditions- but nothing unique from an economic linkage. Moderate due to high diversity of habitats.
8		Waterway	Landscape & amenity values	Unlikely	Insignificant	Low	
8		Waterway	Ecotourism & recreation	Likely	Insignificant	Low	Low flows would likely impact on recreational activities however the undeveloped industry results in an insignificant impact.
8		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
8		Waterway	Inspirational Value	Unlikely	Insignificant	Low	
8	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Likely	Severe	Extreme	Water quality issues identified are likely to impact on water availability and the highly dependent communities will be severely impacted.
8		Waterway	Food Provisioning	Possible	Moderate	High	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms- The presence of these communities in the IUA means consequences of impact could be moderate.
8		Waterway	Raw materials / Fibre	Possible	Minor	Medium	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - The presence of communities that use these materials means the consequences could be minor.
8		Waterway	Medicinal resources	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - however there is no clear indication of the use of medicinal resources from

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							aquatic systems and therefore consequences are insignificant
8		Waterway	Habitats for species	Possible	Moderate	High	Nothing specifically unique- although high diversity habitats.- Consequence is moderate.
8		Waterway	Landscape & amenity values	Unlikely	Insignificant	Low	
8		Waterway	Ecotourism & recreation	Unlikely	Minor	Low	local use of the rivers would unlikely be impacted with minor consequences due to the lack of formal recreation and ecotourism industry.
8		Waterway	Educational values	Very unlikely	Insignificant	Low	
8		Waterway	Inspirational Value	Likely	Insignificant	Low	
8	Scawby has flow related impacts- potentially reduced flow	Wetland	Fresh Water (Natural Sources)	Unlikely	Major	High	The high reliance of communities on water resources results in major consequences if the water rpovisioning service is impacted. The likelihood that there will be a reduction in flow as a result of plantations is unlikely.
8		Wetland	Food Provisioning	Possible	Insignificant	Low	
8		Wetland	Raw materials / Fibre	Possible	Insignificant	Low	
8		Wetland	Medicinal resources	Possible	Insignificant	Low	
8		Wetland	Habitats for species	Likely	Moderate	High	Reduced flows from land uses likely impacts on the habitats at scawby wetland. The consequences of the loss of this wetland are moderate due to the presence of red data species.
8		Wetland	Landscape & amenity values	Extremely unlikely	Insignificant	Low	
8		Wetland	Ecotourism & recreation	Extremely unlikely	Insignificant	Low	

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
8		Wetland	Educational values	Extremely unlikely	Insignificant	Low	
8		Wetland	Inspirational Value	Extremely unlikely	Insignificant	Low	
9	Low flows - EWR not met	Waterway	Fresh Water (Natural Sources)	Possible	Moderate	High	Low flows, but no zero flows would possibly impact on water availability with moderate consequences to a relatively rural catchment. Note: Wembezi community at Estcourt (intensive community all the way up to IUA 14). Wembezi likely formal water supply-[needs confirmation]. Some brickworks in downstream (Not clear on source of water). Note: Estcourt factory. Hydrocarbons, oils etc. Improper land use in upper catchment causes extensive erosion- this coupled with increased flows results in siltation into wagendrift dam. Note: The towns of Estcourt and Weenen, with associated domestic wastewater treatment works; extensive rural villages; subsistence and formal agriculture and irrigation along the river; tourism; natural areas (portion of the Weenen Nature Reserve) in lower reaches; PES: C
9		Waterway	Food Provisioning	Possible	Minor	Medium	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences. The impacts however are only seen in the lower catchment (weenen) and therefore consequences are minor.
9		Waterway	Raw materials / Fibre	Possible	Minor	Medium	Low flows would possibly impact on primary productivity. The presence of communities that use these materials means the consequences could be

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							minor even with the impacts only being seen at Weenen.
9		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
9		Waterway	Habitats for species	Possible	Moderate	High	Nothing specifically unique- although high diversity habitats.- Consequence is moderate.
9		Waterway	Landscape & amenity values	Unlikely	Insignificant	Low	
9		Waterway	Ecotourism & recreation	Likely	Minor	Medium	It is likely that reduced flow may impact the fishing and recreational services in the weenen area and given the general size of this industry the consequences are seen to be minor
9		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
9		Waterway	Inspirational Value	Unlikely	Insignificant	Low	
9	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Likely	Moderate	High	The water quality hazard identified in this IUA results in a likely impact on water availability, however comparatively the catchment is not heavily reliant on natural systems as a p[primary water source and therefore consequences are moderate.
9		Waterway	Food Provisioning	Possible	Major	High	Together with low flows the WQ hazard would possibly impact on primary productivity- The presence of communities in the IUA means consequences of impact could be major.
9		Waterway	Raw materials / Fibre	Possible	Minor	Medium	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - The presence of

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							communities that use these materials means the consequences could be minor.
9		Waterway	Medicinal resources	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
9		Waterway	Habitats for species	Almost certain	Minor	Medium	Note there is not much left there- no fish caught and macro inverts were highly tolerant. So perhaps not much to lose. Note this feeds into other ES. Note not much there so consequence is minor.
9		Waterway	Landscape & amenity values	Possible	Minor	Medium	Impacts on real estate values linked to aquatic resources is possible and the consequences as per linked to a large ecotourism industry would be minor.
9		Waterway	Ecotourism & recreation	Likely	Moderate	High	It is likely that reduced water quality may impact the service in the weenen area and given the general size of this industry the consequences are seen to be moderate
9		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
9		Waterway	Inspirational Value	Possible	Minor	Medium	Impacts on ecosystems as linked to the ecotourism industry woul be possible with minor impacts.
10	Low flow - EWR not met	Waterway	Fresh Water (Natural Sources)	Possible	Moderate	High	Low flows, but no zero flows would possibly impact on water availability with moderate consequences to a relatively rural catchment. Note: Between Woodstock dam and Spionkop- for all scenarios (except 1, 6 and 9), we expect the state of environment to improve. Not implementing EWR has similar hazard to IUA 7, 8, and 9 however at much

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							higher risk levels. Note: Agriculture and irrigation along Thukela River; towns of Bergville, Winterton, Colenso with associated domestic wastewater treatment works (elevated nutrients); large natural areas; irrigation, extensive tourism Note: Extensive rural villages and subsistence agricultural along Little Tugela Note: Spioenkop Nature Reserve; linked to Thukela-Vaal transfer; supply to Ladysmith; tourism; prioritised wetlands Water transfers are from the Tugela-Vaal Transfer Scheme transferring water to the Sterkfontein dam and eventually to the Vaal system Note: Water quality is good (Volume of water helps this manage nutrient loads).
10		Waterway	Food Provisioning	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
10		Waterway	Raw materials / Fibre	Possible	Minor	Medium	Low flows would possibly impact on primary productivity. The presence of communities that use these materials means the consequences could be minor.
10		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							use of medicinal resources from aquatic systems and therefore consequences are insignificant
10		Waterway	Habitats for species	Possible	Moderate	High	Moderate consequence due to habitat diversity.
10		Waterway	Landscape & amenity values	Unlikely	Minor	Low	
10		Waterway	Ecotourism & recreation	Possible	Minor	Medium	Low flows may possibly impact water related tourism in the IUA however the impacts would be minor.
10		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
10		Waterway	Inspirational Value	Unlikely	Minor	Low	
10	Over abstraction	Aquifer	Fresh Water (Natural Sources)	Likely	Moderate	High	Over abstraction will likely impact the water provisioning as the systems are already lower yield resources any additional abstraction would likely impact. Consequence would be moderate as it would take a few years to recover and the beneficiaries are numerous in the IUA.
11	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Likely	Moderate	High	Note: The risks here to water quality are largely to the population living in the region. Contaminants will likely impact water available from natural sources with moderate consequences to communities. Note: Extensive agriculture and irrigation; extensive villages and subsistence agriculture along the Klip. Ngula pump storage. Note: Town of Ladysmith and Ezakheni with associated domestic wastewater treatment works; Ladysmith industrial areas; Ndakane River that confluences with Klip River upstream Ezakheni is a PES: B; Klip River PES: C. Some NFEPA wetlands

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
11		Waterway	Food Provisioning	Possible	Moderate	High	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms- The presence of these communities in the IUA means consequences of impact could be moderate.
11		Waterway	Raw materials / Fibre	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - The presence of communities that use these materials is not clear resulting in an insignificant consequence.
11		Waterway	Medicinal resources	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
11		Waterway	Habitats for species	Likely	Moderate	High	Note: Eels recorded here showing migration however eels are tolerant therefore conditions are not great. therefore consequence is moderate as no clear linkage with beneficiaries however from conservation perspective their presence is important.
11		Waterway	Landscape & amenity values	Unlikely	Minor	Low	
11		Waterway	Ecotourism & recreation	Likely	Minor	Medium	Sedimentation and nutrient loads are likely to impact on the service however again the size of the industry results in a minor consequence
11		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
11		Waterway	Inspirational Value	Unlikely	Minor	Low	

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
11	Over abstraction	Aquifer	Fresh Water (Natural Sources)	Likely	Moderate	High	Over abstraction will likely impact the water provisioning as the systems are already lower yield resources any additional abstraction would likely impact. Consequence would be moderate as although it would take a few years to recover and there are numerous agricultural beneficiaries.
11	Low Flow in Aluvial system- if EWR not met	Aquifer	Fresh Water (Natural Sources)	Possible	Minor	Medium	The likelihood is possible that low flows would reduce recharge and consequence would be minor as there are no significant beneficiarioes of groundwater resources in the IUA.
6	Low flow - EWR not met	Waterway	Fresh Water (Natural Sources)	Likely	Severe	Extreme	Low flow would likely impact the highly dependent communities in the catchment (32% source water from rivers and streams). the consequences of impact would therefore be severe. Note: Check where the Gme reserve sits in terms of Sundays. Note: Wetlands are highly transformed in upper reaches of the catchment for agriculture [Check with Gary]
6		Waterway	Food Provisioning	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
6		Waterway	Raw materials / Fibre	Possible	Minor	Medium	Low flows would possibly impact on primary productivity. The presence of communities that use these materials means the consequences could be minor
6		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
6		Waterway	Habitats for species	Possible	Minor	Medium	Minor consequence as EWR is being met-CHECK WITH RETHA
6		Waterway	Landscape & amenity values	Unlikely	Insignificant	Low	
6		Waterway	Ecotourism & recreation	Possible	Insignificant	Low	It is possible that low flows would impact the tourism industry with insignificant consequences
6		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
6		Waterway	Inspirational Value	Unlikely	Insignificant	Low	
6	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Possible	Severe	Extreme	Sedimentation could possibly impact the use of water by communities but consequences would be severe due to their high dependence on these systems.
6		Waterway	Food Provisioning	Possible	Minor	Medium	Together with low flows the WQ hazard would possibly impact on primary productivity through sedimentation. Sedimentation would likely be relatively slow to impact the system and consequences therefore minor.
6		Waterway	Raw materials / Fibre	Possible	Insignificant	Low	Together with low flows WQ hazard would possibly impact on primary productivity through increased siltation. This would not impact primary productivity of raw materials to a large degree and consequences are thus insignificant.
6		Waterway	Medicinal resources	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity through siltation -there is however no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
6		Waterway	Habitats for species	Likely	Moderate	High	High agriculture results in likely likelihood. Moderate consequence due to diversity of habitats.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
6		Waterway	Landscape & amenity values	Unlikely	Moderate	Medium	It is unlikely that sediments would impact on amenity values, but with the presence of traditional communities an impact would have moderate consequences
6		Waterway	Ecotourism & recreation	Unlikely	Insignificant	Low	it is unlikely that sediments would impact the tourism services with insignificant consequences
6		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
6		Waterway	Inspirational Value	Unlikely	Minor	Low	
6	Over abstraction	Aquifer	Fresh Water (Natural Sources)	Likely	Moderate	High	Over abstraction will likely impact the water provisioning as the systems are already lower yield resources any additional abstraction would likely impact. Consequence would be moderate as it would take a few years to recover and there are numerous agricultural and direct community beneficiaries beneficiaries.
12	Low flow - EWR not met	Waterway	Fresh Water (Natural Sources)	Possible	Severe	Extreme	
12		Waterway	Food Provisioning	Possible	Moderate	High	Low flows would possibly impact on primary productivity and the presence of grazers and rural settlements means there could be moderate consequences.
12		Waterway	Raw materials / Fibre	Possible	Minor	Medium	Low flows would possibly impact on primary productivity. The presence of communities that use these materials means the consequences could be minor.
12		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
12		Waterway	Habitats for species	Possible	Major	High	. Note labio also needs flow to move- Note check with Wynand?- Here species extinction is a risk here and as such consequence is major
12		Waterway	Landscape & amenity values	Unlikely	Moderate	Medium	It is unlikely that low flows would impact on amenity values, but with the presence of traditional communities an impact would have moderate consequences
12		Waterway	Ecotourism & recreation	Likely	Moderate	High	It is very likely that reduced flow will impact aquatic related recreational activities. It is not clear on the significance of the tourism industry. As such consequences are seen as moderate. which consequences in this developed tourism industry would be major.
12		Waterway	Educational values	Unlikely	Insignificant	Low	No evidence of the presence of this service
12		Waterway	Inspirational Value	Unlikely	Minor	Low	
12	Low Flow in Aluvial system- EWR not met	Aquifer	Fresh Water (Natural Sources)	Possible	Major	High	Low flow will possibly impact the water provisioning as the systems are already lower yield resources. Additional pressures on available water would exacerbate these limitations. The likelihood is possible that low flows would reduce recharge and consequence would be major as there are numerous direct community beneficiaries beneficiaries who rely on availability of water.
13	Low flow - EWR not met	Waterway	Fresh Water (Natural Sources)	Possible	Severe	Extreme	The IUA is highly vulnerable to impacts in water availability as 65% of households rely in rivers and streams as their primary source of water. Consequences of impacts are therefore severe. Although there are no zero flows in the year, there is a possible likelihood that low flows could impact on these communities.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							Note high vulnerability in these regions. No major evidence of subsistence agriculture in these regions. Note: The commercial sugarcane agriculture starts being evident in the lower portions. This means irrigation starts. The water is sourced directly from river to irrigate fields. It is likely this is prevalent in the area for sugar cane irrigation. Note: No obvious recreation however the size of the river in the region means there may be activities. Perhaps at Tugela Ferry? check Note: Main stem above Middeldrift; River is in a PES: C; smaller villages with subsistence agriculture; Middeldrift pump station; likely to be used for increased volumes for Richards Bay (continuous supply) Note: Main stem below Middeldrift; PES: B category; smaller villages with subsistence agriculture along the river.
13		Waterway	Food Provisioning	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity. As there are relatively low presence of subsistence settlements and livestock grazers the consequence is insignificant. High diversity of fish species is however expected here and it is possible that communities rely on these fisheries. No evidence is available.
13		Waterway	Raw materials / Fibre	Possible	Minor	Medium	Low flows would possibly impact on primary productivity. The presence of communities that use these materials means the consequences could be minor.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
13		Waterway	Medicinal resources	Possible	Insignificant	Low	Low flows would possibly impact on primary productivity however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
13		Waterway	Habitats for species	Possible	Moderate	High	The low flows will have possible impacts and moderate consequence due to the low diversity of habitats- note potentially high diversity of fish however.
13		Waterway	Landscape & amenity values	Unlikely	Moderate	Medium	It is unlikely that low flows would impact on amenity values, but with the presence of traditional communities an impact would have moderate consequences
13		Waterway	Ecotourism & recreation	Likely	Moderate	High	It is very likely that reduced flow will impact aquatic related recreational activities. It is not clear on the significance of the tourism industry. As such consequences are seen as moderate. which consequences in this developed tourism industry would be major.
13		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
13		Waterway	Inspirational Value	Unlikely	Minor	Low	
13	Water quality hazard	Waterway	Fresh Water (Natural Sources)	Almost certain	Severe	Extreme	The water quality contaminants identified would directly impact the use of this water for domestic purposes. The likelihood of impact is therefore almost certain. The consequences in this catchment are severe.
13		Waterway	Food Provisioning	Possible	Moderate	High	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would boost primary productivity of vegetation but impact the availability of organisms especially diversity of fish species- The presence of these communities in the IUA means consequences of impact could be moderate.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
13		Waterway	Raw materials / Fibre	Possible	Minor	Medium	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - The presence of communities that use these materials means the consequences could be minor.
13		Waterway	Medicinal resources	Possible	Insignificant	Low	The WQ hazard would possibly impact on primary productivity together with low flows- the nutrients would likely boost primary productivity - however there is no clear indication of the use of medicinal resources from aquatic systems and therefore consequences are insignificant
13		Waterway	Habitats for species	Possible	Moderate	High	Higher species diversity (fish etc)- at least higher than upper reaches. Habitats however are lower diversity.
13		Waterway	Landscape & amenity values	Possible	Moderate	High	It is possible that increased nutrient loads and pathogens could impact this service, with the presence of traditional communities an impact would have moderate consequences
13		Waterway	Ecotourism & recreation	Possible	Moderate	High	It is possible that sedimentation and wq impacts would impact the tourism industry. The expected small industry results in moderate consequences
13		Waterway	Educational values	Very unlikely	Insignificant	Low	No evidence of the presence of this service
13		Waterway	Inspirational Value	Unlikely	Minor	Low	
15	Reduction in base flow	Estuary	Fresh Water (Natural Sources)	Extremely unlikely	Insignificant	Low	Note: Fluvial movement of muds from mouth to continental shelf offshore- supporting big fisheries esp prawns Note: The fisheries issue is also important for migration further up into the tugela river. Note: Look at national biodiv assessment to id

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							contribution of tugela to estuary (volume or MAR)- Gavin to send something through.
15		Estuary	Food Provisioning	Almost certain	Minor	Medium	As the mouth closes every year (in recent years) it is almost certain that the reduced baseflows will cause continued closing on an annual basis. As the river mouth only closes for a few days per year this the consequences on fisherier are likely in the short term are minor. NOTE- the long term impacts from these closures are not clear and may be more severe- requires confirmation.
15		Estuary	Raw materials / Fibre	Extremely unlikely	Insignificant	Low	If mouth closes there would be backflooding which would drive increased primary productivity of freshwater vegetation. Impacts will likely not effect other abiotic elements (clays and muds)
15		Estuary	Medicinal resources	Very unlikely	Minor	Low	
15		Estuary	Habitats for species	Likely	Moderate	High	River mouth conditions means smal intertidal zone. As flow decreases tidal zone increases which increases diversity (interesting) untill the mouth closes which drops in diversity. This becomes flooded with freshwater which has extreme impacts on habitats for species (note change from natural). Habitat diversity will drop drastically with closure of the mouth.
15		Estuary	Landscape & amenity values	Likely	Minor	Medium	Fish catch would decrease which would likely impact amenity values- this could influence the value of properties. The land values however are relatively low and as such impacts may be minor consequences.
15		Estuary	Ecotourism & recreation	Likely	Moderate	High	High recreational fishing but very difficult to get boats into system.- no boating due to low baseflow. The increased diversity however the fish catch would likely decrease. The likelihood of this impact is likely with

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
							moderate consequences. PLEASE NOTE: gilnetting has devastated fisheries (this is more "subsistence or poaching for resale").
15		Estuary	Educational values	Unlikely	Major	High	The significance of the River Mouth system results in major consequences if impacted. The likelihood however of continued impact is unlikely (due to the current status quo)
15		Estuary	Inspirational Value	Unlikely	Insignificant	Low	Diversity will increase and pulses are maintained so the aesthetics are unlikely to be impacted with insignificant consequences.
15	Reduction in base flow and impacts on the Tugela Banks	Tugela Banks	Fresh Water (Natural Sources)	Extremely unlikely	Insignificant	Low	
15		Tugela Banks	Food Provisioning	Extremely unlikely	Insignificant	Low	
15		Tugela Banks	Raw materials / Fiber	Extremely unlikely	Insignificant	Low	
15		Tugela Banks	Medicinal resources	Extremely unlikely	Insignificant	Low	
15		Tugela Banks	Habitats for species	Likely	Moderate	High	The fine sediments would not be flushed as often-there would be a shift from a muddy to sandy system this would limit the nutrients reaching the tugela banks. Reduction in diversity at tugela banks. From natural we see this happening which has caused a colapse of fisheries (as seen by commercial fishing).
15		Tugela Banks	Ecotourism & recreation	Likely	Moderate	High	We expect a reduction in fishing success. The village focusses on recreational fishing impacts of which would be moderate. No specific data on this but we expect the tourism industry associated with fishing to decrease.

IUA	Env Hazard	Ecological Infrastructure	Final Ecosystem Service at Risk	Likelihood	Consequence	Risk	Notes for potential impact analysis:
15		Tugela Banks	Landscape & amenity values	Likely	Minor	Medium	Fish catch would decrease which would likely impact amenity values- this could influence the value of properties. The land values however are relatively low and as such impacts may be minor consequences. Note the linkage here is not clear.
15		Tugela Banks	Inspirational Value	Extremely unlikely	Insignificant	Low	
15		Tugela Banks	Educational values	Unlikely	Major	High	Major consequences from impacts especially from a commercial fisheries point of view.
15	Water Quality Hazard	Estuary	Fresh Water (Natural Sources)	Extremely unlikely	Insignificant	Low	
15		Estuary	Raw materials / Fiber	Extremely unlikely	Insignificant	Low	
15		Estuary	Medicinal resources	Extremely unlikely	Insignificant	Low	
15		Estuary	Landscape & amenity values	Possible	Insignificant	Low	
15		Estuary	Ecotourism & recreation	Possible	Insignificant	Low	Note linked to reduction in flow- the reduction in species for fishing would likely be negligible.
15		Estuary	Educational values	Extremely unlikely	Minor	Low	The educational value is in the flow dynamics and therefore water quality will be extremely unlikely water quality would impact on this flow. If it did it would have minor.
15		Estuary	Inspirational Value	Unlikely	Insignificant	Low	The system is already a relatively turbid system. Meaning the impacts may not be sig nificant. The system still flushes and therefore no filament rot and odours or colouyr changes