Report no. RDM/WMA04/00/CLA/0420

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: LINKING THE SOCIO-ECONOMIC AND ECOLOGICAL VALUE AND CONDITION OF THE WATER RESOURCES

FINAL

September 2020

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems

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

LINKING THE SOCIO-ECONOMIC AND ECOLOGICAL VALUE AND CONDITION OF THE WATER RESOURCES

WP 11255

Study Report No.

RDM/WMA04/00/CON/CLA/0420

September 2020

FINAL

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Published by

Department of Water and Sanitation
Private Bag X313
Pretoria, 0001
Republic of South Africa

Tel: (012) 336 7500/ +27 12 336 7500
Fax: (012) 336 6731/ +27 12 336 6731

This report is to be cited as:

Department of Water and Sanitation, South Africa. September 2020. Determination of Water Resource Classes and associated Resource Quality Objectives in the Thukela Catchment: Report on the Linking the Socio-Economic and Ecological Value and Condition of the Water Resources. Final Report No: RDM/WMA04/00/CON/CLA/0420

Prepared by:

Golder Associates Africa in association with Prime Africa

Title:	*Linking of the Socio-Economic and Ecological Value and Condition of the Water Resources*
Authors:	*J Mulders, J Crafford, L Boyd and P Moodley*
Project Name:	*Determination of Water Resource Classes and associated Resource Quality Objectives in the Thukela Catchment: WP 11255*
DWS Report No:	*RDM/WMA04/00/CON/CLA/0420*
Status of Report:	*Final*
First Issue:	*August 2020*
Final Issue:	*September 2020*

Approved for the Professional Service Provider by:

………………………………………………… ……………………………………………

Trevor Coleman *Date*

Project Director, Golder Associates

DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems

Approved for DWS by:

………………………………………………… ……………………………………………

Mohlapa Sekoele *Date*

Project Manager: Water Resource Classification

………………………………………………… ……………………………………………

Mkhevu Mnisi *Date*

Scientific Manager: Water Resource Classification

………………………………………………… ……………………………………………

Lebogang Matlala *Date*

Director: Water Resource Classification

DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

REPORT INDEX	REPORT NUMBER	REPORT TITLE
1.0	RDM/WMA04/00/CON/CLA/0119	Inception Report
2.0	RDM/WMA04/00/CON/CLA/0120	Water Resources Information and Gap Analysis Report
3.0	RDM/WMA04/00/CON/CLA/0220	Specialist Workshops Report
4.0	RDM/WMA04/00/CON/CLA/0320	Status Quo and Integrated Units 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

TERMINOLOGY AND ABBREVIATIONS

Acronym	Description
CICES	Common International Classification of Ecosystem Services
DWS	Department of Water and Sanitation
EI	Ecological Infrastructure
ESV	Ecosystem Service Valuation
EWR	Ecological Water Requirement
GDP	Gross Domestic Product
GVA	Gross Value Added
IDZ	Industrial Development Zone
IEM	Integrated Economic Model
IPBES	International Panel on Biodiversity and Ecosystem Services
IUA	Integrated Unit of Analysis
KZN	KwaZulu-Natal
MA	Millennium Assessment
NEM: PAA	National Environmental Management: Protected Areas Act of 57
QSAM	Quasi Social Accounting Matrix
RQOs	Resource Quality Objectives
SAM	Social Accounting Matrix
SEEA	System of Environmental-Economic Accounting
SEcT	Socio-Economic Comparison Tool
SWSA	Strategic Water Source Areas
TEEB	The Economics of Ecosystems and Biodiversity
WMA	Water Management Area
WRCS	Water Resource Classification System

EXECUTIVE SUMMARY

The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned the study, the Determination of Water Resource Classes and associated Resource Quality Objectives in the Thukela Catchment. The purpose of this study is to coordinate the implementation of the Water Resource Classification System (WRCS) in the Thukela in order to determine water resources classes and resource quality objectives for all significant water resources.

In terms of the water resource classification 7 step process, Step 2 requires an analysis of the relationships that link the change in the configuration of scenarios to a resulting change in economic value and social wellbeing. At this step, the methodologies were used to establish the Integrated Economic Model (IEM) architecture and populate the modules using the best available data that represents the baseline scenario. The IEM developed here will be used in the valuation step to inform the evaluation of scenarios at a later stage in the classification process.

It is to be noted that the classification process, overall, assesses several future water resource management scenarios (still to be defined). These scenarios may impact water resources and aquatic ecosystem services in different ways, either positively or negatively. These impacts need to be evaluated in terms of its effects on human wellbeing. There are several ways in which these effects may be evaluated. These include comparative risk assessment; valuation of water use in the economy as measured by GVA (Gross Value Added) and valuation of ecosystem services that are not already internalised in the GVA measure. The final selection of the most appropriate evaluation methods can only be done once the management scenarios and their bio-physical impacts are known.

An important feature of this catchment area is presence of the Strategic Water Source Areas (SWSAs) of the escarpment and Drakensberg mountain range. SWSAs are defined as areas that supply a disproportionate amount of mean annual runoff to a geographical region of interest. The geographic region of interest is in fact South Africa making the SWSAs present in the catchment represent highly crucial water source areas at a national scale.

Other important aquatic ecological infrastructure include all water resources as defined by the Water Act (1998), *i.e*. including watercourses, surface water, estuaries, or aquifers. At the outflow of the Thukela catchment is the highly important Thukela estuary which provides highly important estuarine ecosystem services. The Thukela system also plays an important role in driving key marine processes.

Priority aquatic ecosystem services linked to the socio-economics of the Thukela were identified to include the following:

- Fresh Water Provisioning;
- Water Quantity Regulating;
- Food, Raw Materials and Wild Collected Products Provisioning;
- Erosion Regulation;
- Water Quality Regulation: Purification and Waste Management;

- Spiritual, Landscape and Amenity Services;
- Tourism and Recreational Services; and
- Biodiversity Support.

Other ecosystem services categories that may be at risk in future water resource management scenarios will also be assessed.

The primary ecosystem service in the Thukela catchment is water provisioning, which is fundamental to the effective functioning of the key economic sectors of the region, including agriculture, agricultural manufacturing, households, and the government sector.

It is also important to note that a large proportion of the formal output of the catchment area, as measured by GVA is dependent on aquatic ecosystem services provided within the catchment. From a formal economy perspective, the Thukela catchment contributes an estimated R79.3 billion of GVA to the economy of South Africa. This economy is predominantly rural in nature and represents an estimated 1.9% of the national GDP of R4.17 trillion (Stats SA 2017). The largest sectors include the government sector, agriculture, and hotels and restaurants which represent 14.5%, 10.3% and 4.9% contribution.

There is likely an important informal economy with a large dependence on a variety of aquatic ecosystem services. As a result, ecosystem services have been demonstrated to provide significant contributions to socio-economic wellbeing to both formal and informal economy beneficiaries within the catchment.

With much of this activity being linked to the informal economy, careful consideration is given to the impact a change in ecosystem services may have on the livelihoods of these communities.

Within the formal economy, agriculture and agricultural manufacturing sectors contribute significantly. This provides some indication of the level of reliance of these industries on water provisioning. Households represent the largest purchasers of water in monetary terms, even though agricultural sector consumes a larger portion of volume.

This report defines the linkages between water resources and human wellbeing and sets out the methodology to be followed for assessing the management scenarios in the project steps to follow.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX 1: DECISION ANALYSIS FRAMEWORK

APPENDIX 2: RESULTS OF THE QSAM FOR THE THUKELA CATCHMENT

1 INTRODUCTION

1.1 BACKGROUND

The Department of Water and Sanitation (DWS) is progressively underway with the process to set water resources classes for all water resource systems in South Africa to ensure their protection and sustainable use. The Thukela River Catchment in KwaZulu-Natal is the current river system being classified, the second of the Pongola to Mtamvuma Water Management rea (WMA). The significant water resources in the Mvoti to Umzimkulu catchment have been classified and Resource Quality Objectives (RQOs) set.

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). The implementation of RDM is intended to ensure comprehensive protection of all water resources. Once the water resource classes and the Reserve have been established, RQOs are established to give effect to these.

The Chief Directorate: Water Ecosystems is underway with the study, 'Determination of Water Resource Classes (WRC) and associated RQOs in the Thukela Catchment'.

1.2 PURPOSE OF THE STUDY

The main objective of this study is to co-ordinate the implementation of the Water Resource Classification System (WRCS) (Regulation 810) and to undertake the implementation of the RQO determination procedure (7 step process) in the Thukela Catchment for all significant water resources (including rivers, groundwater, wetlands and estuary). The setting of water resource classes and associated RQOs is aimed at facilitating sustainable use of the catchment's water resources, balanced with maintenance or improvement of ecological integrity. Protection of strategic water resources and specifically water source areas is of critical importance in the Thukela Catchment.

This study is reliant on the preliminary Reserve determination studies undertaken for the rivers, groundwater and the estuary in the Thukela Catchment and is guided by other water resource management initiatives in the catchment.

Successful determination of the water resource classes and RQOs is also dependent on the buy-in and agreement of stakeholders on the selected scenarios through consultative processes. Specialist technical assessment and stakeholder engagement are thus key components of the process.

1.3 PURPOSE OF THE REPORT

Following delineation of integrated units of analysis and status quo assessment, linking the value and condition of the water resources is the next step required in terms of the water resource classification procedure (Figure 1).

This step requires that the quantification of the relationships that links socio-economic and ecological value and condition of water resources, the selection of those linkages that are considered as priority and determination of the scoring system to be used to evaluate the catchment scenarios in later steps of the process. The purpose of the report is to document the outcome of this assessment and present the results of Integrated Economic Model (IEM) developed for the Thukela catchment towards demonstrating socio-economic and ecological linkages. The linkages are described in respect of the delineated integrated units of analysis, which is also the units of spatial scale at which the scenario evaluation will be undertaken. The fifteen IUAs delineated for the Thukela catchment are shown in Figure 2.

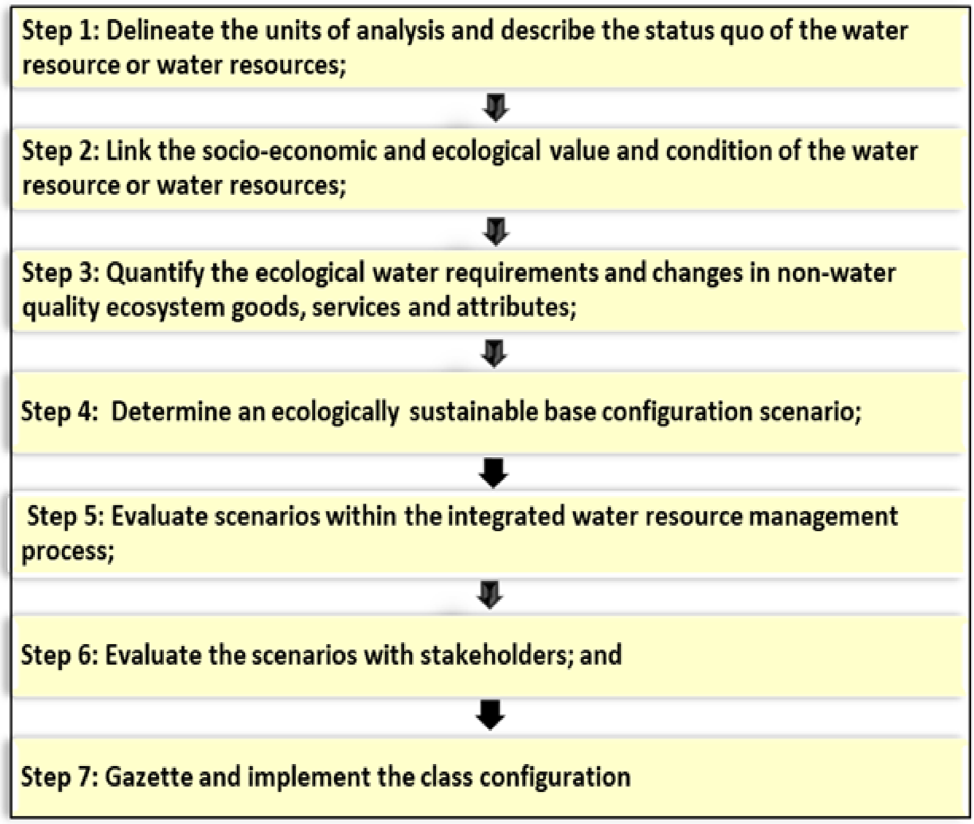

Figure 1: Water Resource Classification Process (Regulation 810 of Government Gazette 33541)

1.4 STUDY AREA OVERVIEW

The study area is the catchment of the Thukela River illustrated in Figure 3. The Thukela River catchment is the largest river system within the Pongola to Mtamvuma Water Management Area (WMA 4). The Thukela catchment drains an area of 29 040 km^2, rising on the escarpment of the Drakensberg and flowing approximately 512 km through the eastern slopes, the midlands and discharging into the Indian Ocean, via the Thukela estuary, situated some 95 km north of Durban.

The Thukela Catchment has two main drainage systems: Upper Thukela and Buffalo rivers. This is attributed to the great Thukela Fault which runs in an east-west direction through the catchment as far as Colenso. The topography of the Thukela River Catchment varies dramatically, ranging from steep areas to gentle slopes. The Thukela Catchment lies predominantly in the KwaZulu-Natal Province, except for a narrow strip in the extreme north which falls in Mpumalanga Province.

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

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

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

Major tributaries into the Thukela River from the south include:

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

The resources of the Thukela River are predominantly used to support requirements for water in other parts of the country, with large transfers of water to neighbouring catchments. The river is relied upon for transfers into the Vaal System, and to the Mhlatuze catchment to its north and Mooi-Mgeni system to its south. The major dams within the catchment include Woodstock, Spioenkop, Zaaihoek, Driel Barrage, Ntshingwayo, Craigie Burn, Quedusizi, Spring Grove and Wagendrift Dams. However, for the most part, the Thukela River remains largely unregulated. The Ingula Pump Storage scheme is also located in the headwaters of the Klip River. The catchment includes the major towns of Newscastle, Dundee, Ladysmith and Escourt.

Most people in the catchment are dependent on agriculture for their livelihood. Subsistence farming is practised on communal land, which covers much of the catchment area. The catchment also includes a paper mill at Mandini, close to the estuary. Irrigation is a significant water use and occurs mainly in the upper reaches of the catchment. Coal mining is also predominant in the Thukela Catchment. The main mining area is the Buffalo River catchment. A number of other commodities such as sand and dolerite are also mined. The economy of the Newcastle area is heavily dependent on the mining activity.

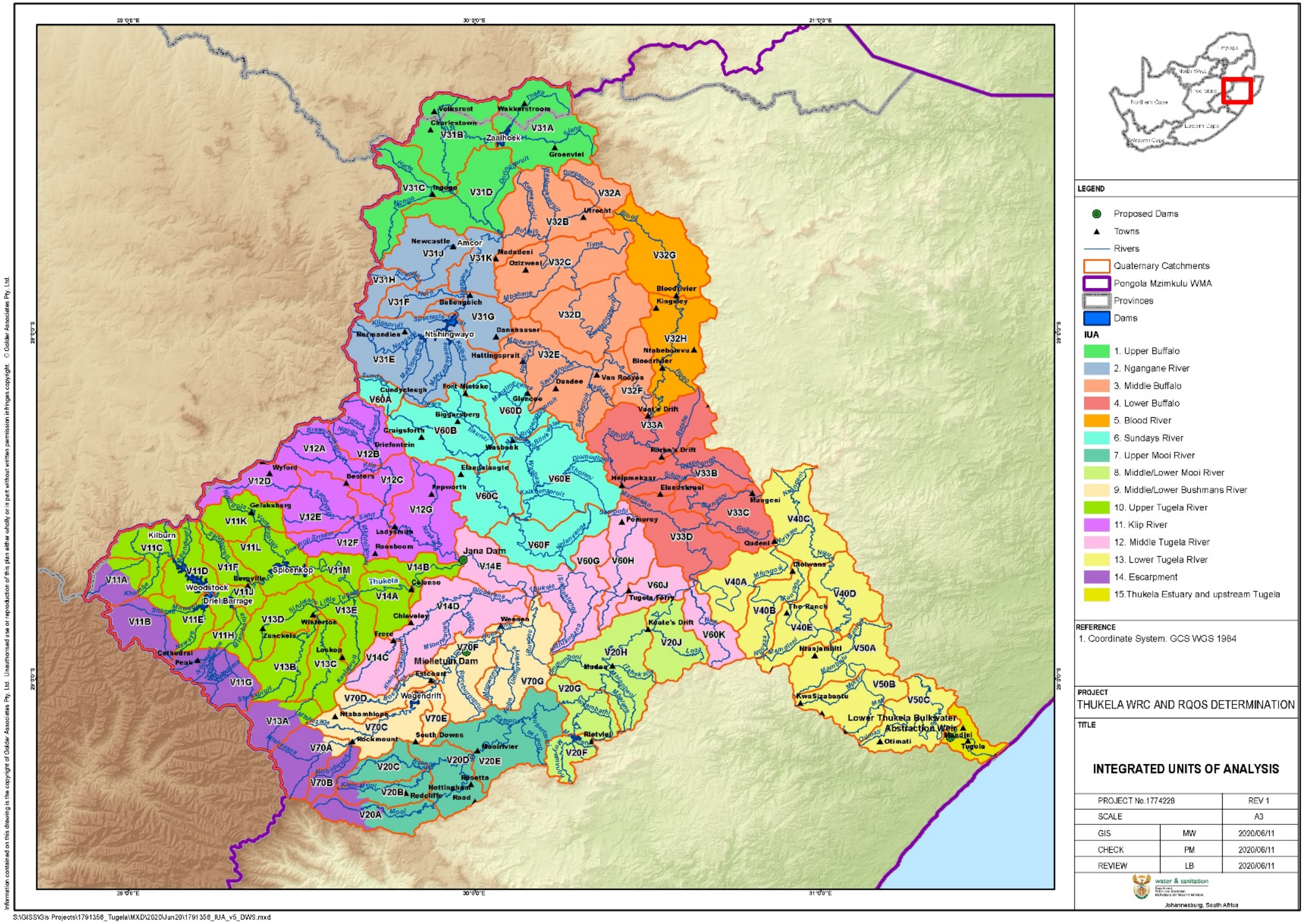

Figure 2: IUAs delineated for the Thukela catchment

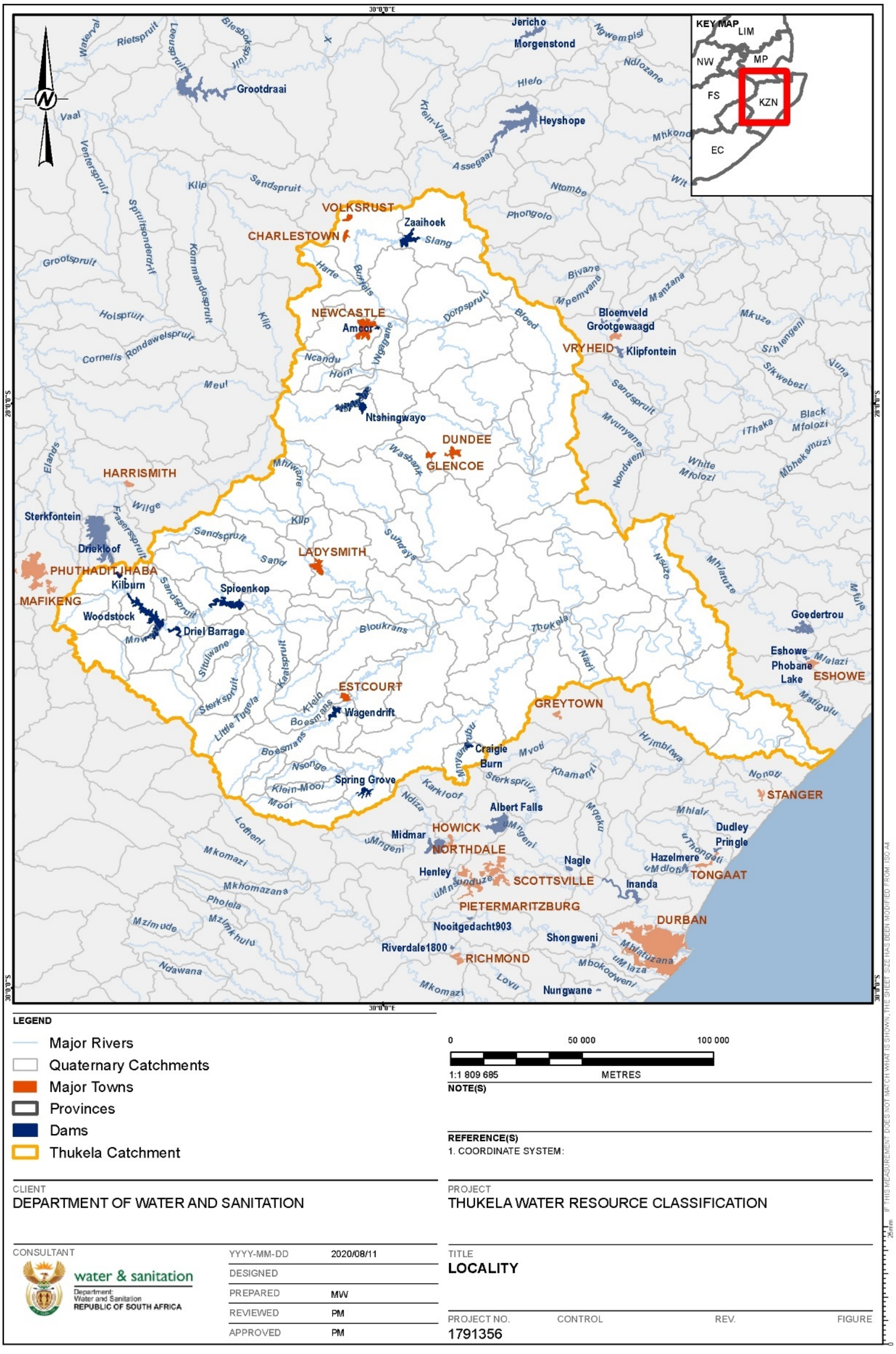

Figure 3: Thukela Catchment – Study Area

1.6 RATIONALE FOR STEP 2

As natural features in the landscape, ecosystems provide environmental, social, and economic benefits to communities. The value of ecosystems in providing these free ecosystem services to a range of formal and informal beneficiaries has been vigorously demonstrated and there is ever growing recognition of their importance to human well-being at multiple scales (Perrings 2006, Freeman 2003, Pearce et. al. 2005, Dasgupta 2008 and 2010, Mäler 1991, MEA 2005, 2007, TEEB 2010, WAVES 2013).

Impacts or changes to ecosystems (or Ecological Infrastructure) alters the ability to supply valuable services to beneficiaries. Ecological infrastructure refers here to functioning ecosystems that deliver valuable services to people such as fresh water, water and climate regulation, cultural services and soil formation (SANBI 2012). Ecological infrastructure is the nature-based equivalent of built or hard infrastructure which includes features such as wetlands, rivers and other watercourses, forests and entire catchments.

The classification of the cause and effect relationships (or linkages) between ecological infrastructure and beneficiaries of ecosystem services is vital to appropriately manage natural resources in a sustainable manner. Appropriate natural resource management maximises natural benefits and opportunities towards contributing to optimal socio-ecological and economic well-being. The classification of these linkages requires an understanding of the role that ecological infrastructure and the presence of beneficiaries (at a landscape, local and regional scale) plays in the delivery of ecosystem services (See Annexure 1 for Decision Analysis Framework).

An established approach to defining these linkages is through the use of Ecosystem Services Frameworks as formalised and refined through initiatives such as the Millennium Ecosystem Assessment (MEA 2005, MEA 2010), The Economics of Ecosystems and Biodiversity (TEEB 2013) and the Final Ecosystem Goods and Services Classification System (Landers and Nahlik 2013). This approach is refined through the use of complimentary economic tools and methodologies such as environmental economic accounting (specifically water resource accounting) and quasi input-output modelling.

The aim of this assignment was to demonstrate the linkages between the socio-economic and ecological value and condition of water resources as they currently stand in the Thukela catchment.

Demonstrating these linkages required the application and integration of the numerous socio-ecological, and econometric methodologies. This integration required the development of Ecosystem Services Classification and Modelling, Physical and Financial Water Accounts and Quasi-Social Accounting Matrix (QSAM) for the Thukela catchment. The results were the development of an Integrated Economic Model (IEM) for the Thukela catchment towards demonstrating socio-economic and ecological linkages.

The identification of linkages through the development of the IEM is a precursor to quantifying these linkages, which will be conducted further along in the 7 step classification process in the scenario evaluation step. At that step, through the use of ecosystem service valuation the natural benefits provided by ecosystems will be quantified in socio-economic terms. This socio-economic yard stick will allow for a comparison of trade-offs to development towards understanding the costs of environmental damage and restoration to the economy. Furthermore, by understanding the flow of services from the environment to beneficiaries, decision makers will be empowered to identify opportunities towards maximising of the natural benefits received. The opportunities may include the improvement in functionality of a system or even provide support services or infrastructure necessary for sustainable utilisation by beneficiaries.

2 APPROACH

It should be noted that this linkage step will be used to inform the evaluation of scenarios at a later stage in the classification process. This step aimed to develop the IEM and demonstrate linkages between the ecological and the socio-economic baseline in the Thukela catchment.

The overall project works towards defining several management scenarios for future water resource management. These scenarios are typically focussed on management of water flows, water pollution and aquatic habitat management. The classification process relies on several methodologies for evaluating these scenarios, primarily hydrological modelling, ecological requirements and resource economic analyses. The economic analyses need to integrate with the outcomes of the hydrology and ecological requirements. The methodology referred to in Figure 3 has been described in a WRC study from 2018 that reviewed the Socio-Economic Guidelines for Water Resource Classification and Development of an Improved Decision Support Tool (Naidoo *et al*. 2018).

The broad approach taken to develop the IEM is provided in Figure 4. Key inputs, components and outputs of the process include the following:

- The drivers of change, which in this report represents the current baseline scenario. This component will eventually represent various scenarios which will drive changes in the relationships defined at this point;
- The ecological responses to change in development scenario, which in this case are quantified change to hydrological (flows) and ecological (condition) indicators;
- The classification of socio, ecological and economic characteristics within the target catchment linked to the effects of varying response inputs. The classification process was done through the use of three modular tools (described below), which through the IEM linked ecological responses to changing scenarios with a socio-economic response;
    - The ecosystem services valuation module aims to link the presence and condition of ecological infrastructure with key beneficiaries through the use of ecosystem services frameworks;
    - The Water Account module aims to define the use of water through physical flows and financial transactions.
    - The QSAM module aims to quantify the size of the Thukela economy. The QSAM combines the suppliers and consumers of economic products into a single matrix (table of interacting economic sectors) in order to determine the magnitude of the macro-economic indicators of the Thukela economy.
- The socio-economic response to change in development scenario, which in this case is presented through key economic indicators such as GVA, jobs and value of ecosystem services. At this point the socio-economic response represents the current status-quo of the catchment.

The approach taken for the development of the IEM is described in WRC Report K5/2465 in Naidoo *et al*. 2018)

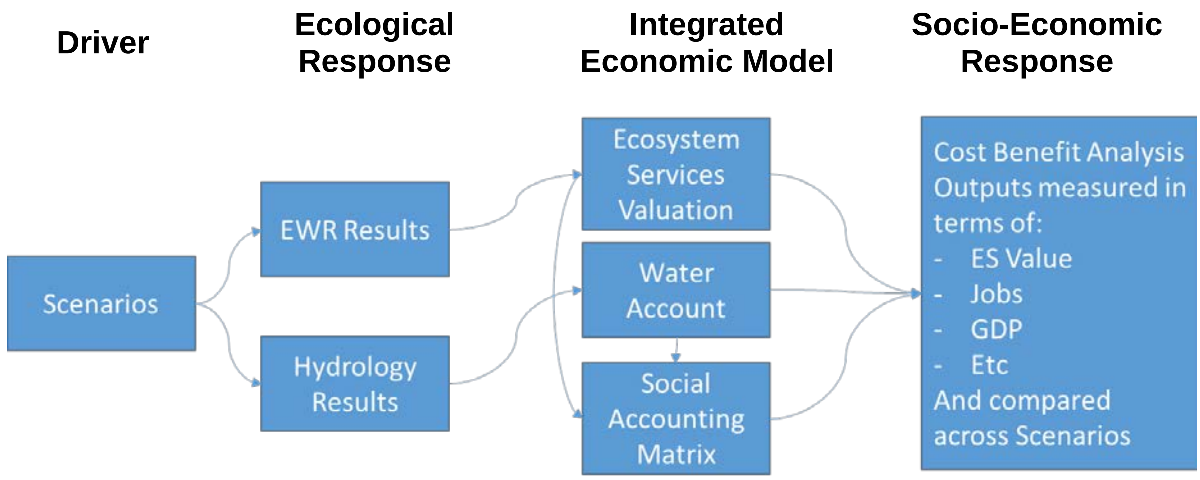

Figure 4: Framework to the development of the Integrated Economic Model

Towards ensuring a robust and defendable output, this approach uses well established methodologies that have been formalised through the literature. At this point of the 7 step classification process the methodologies are used to establish the IEM architecture and populate the modules using the best available data obtained at a desktop level. The IEM will be updated as additional primary data becomes available.

2.1 ECOSYSTEM SERVICES VALUATION MODULE

The Ecosystem Services Valuation Module functions to standardise the identification, quantification and prioritisation of services towards assessing the value of ecosystem services present within the catchment. The four components, as presented in the Decision Analysis Framework (see Appendix 1), form the focus of the module.

The Socio-Economic Comparison Tool (SEcT) (Naidoo *et al*. 2017) was used as the platform from which to frame relationships between various components. Although inputs drew largely from data collected (and presented) in the status-quo report (Step 1), additional data inputs were identified and included where necessary. Key data that were used as inputs into the module include the following:

- The presence of Ecological Infrastructure (EI) segregated into type, extent and condition per IUA;
- The socio-economic wellbeing of communities within the catchment represented by demographic breakdowns and spatial indicators of land use per IUA as well as indicators of vulnerability and wellbeing;
- Classification of beneficiaries per IUA into representative beneficiary categories present within standard Social Accounting Matrix (SAM). These were further segregated into formal and informal recipients of ecosystem services.

Utilising the data inputs, ecosystem services were prioritised against the risk of impact on socio-economic wellbeing through impact to ecological infrastructure. The process involved undertaking a comparative risk assessment per IUA looking at the likelihood and consequences of impact to beneficiaries. The resulting output is a prioritised list of Ecosystem Services that are spatially aggregated across the catchment.

Overall, a cost-benefit analysis approach will be followed, comparing the various management scenarios to the status quo. The specific valuation techniques to be applied would thus be informed by the management scenarios and the outcomes of the ecological water requirements.

2.2 ECOSYSTEM SERVICES FRAMEWORK SELECTION

Since the inception of the Millennium Ecosystem Assessment (2005), there have been a number of frameworks to further disaggregate and classify the benefits people derive from ecosystem services, so as to allow for a thorough assessment of the economic value of these benefits. Amongst these are The Economics of Ecosystems and Biodiversity (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, 2013), and the framework developed by the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019) (Frameworks are described in Table 1).

While each of these frameworks attempts to build upon one another, they essentially follow a similar logic, where ecosystem services and the benefits derived by beneficiaries are classified into three broad categories, namely: provisioning services, where human derive direct material benefit in the form of nutrition, energy sources, and raw materials (including biochemical and genetic materials); regulation, where direct and indirect benefits are derived in the form of regular flows of biotic and abiotic components of ecosystems which allow for the regular, effective functioning of ecosystems; and cultural services, where an intangible benefit is received in terms of intellectual, spiritual and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure.

A fourth category is added in some cases to distinguish between regulating or supporting services in a specific delineated ecosystem, and the global system as a whole. This may include the maintenance of options (IPBES); genetic diversity, biodiversity, and habitat (MA, TEEB, IPBES); and large scale planetary processes, such as nutrient cycling and soil formation (MA) and evolutionary or biological processes (IPBES). These frameworks contain essentially the same services and processes, differing only slightly in where or how these processes are classified.

Two key distinctions are explicitly defined by the IPBES, which are tacitly implied within the other frameworks. These relate to the manner in which benefits to people are derived from ecosystem services, and the role played by social and cultural factors in the valuation of these benefits. Firstly, regarding the benefits derived from ecosystems, the IPBES framework explicitly considers and distinguishes between the conversion of ecosystem services to benefits in terms of “nature’s contributions to people” or the role that ecosystem services play in relation to the human institutional and physical systems, and the neutral processes whereby human systems derive benefits from natural systems without the need for any conversion or additional effort, defined as “nature’s gifts to people”. The second distinction of the IPBES framework relates to the manner in which it explicitly emphasises the importance of relational value of the benefits derived by different social and cultural groups from ecosystem services. Both these distinctions, while valuable, can be seen as implicit within the preceding frameworks of the MA, TEEB, and CICES. In the economic valuation of benefits derived from ecosystem services, specialists must consider the benefits received from the natural systems in relation to the value they represent in the social, cultural and economic systems in which they occur. It is understood by the former classifications, that it is the interplay between the human and natural systems in which the value of benefits to humans can be defined. There is value in the explicit acknowledgement of the interactive role played by the various social, economic and cultural systems with the ecosystems under review irrespective of the specific classification utilised. Ecosystem services were considered in this analysis as per TEEB Framework (TEEB 2013).

2.3 WATER ACCOUNTING MODULE

The overall approach will be that of a cost-benefit analysis of the various management scenarios. Thus, any future scenarios that envisage transfers out, would be analysed based on changes in flow, eco-classification and other relevant impacts. The outputs of these analyses would be integrated into the resource economics analyses.

For comparison of the valuation of water transfers in the receiving catchments, we will use a Water Accounting approach. This would estimate the use of water in the economy as measured by GVA. This approach has already been used by DWS to value transfers into the Vaal River system.

The Thukela catchment supports various water users. It is important to identify these users and quantify the volumes of water they use in order to understand the water economy within the catchment and understand water availability for future events which includes increased volumes of transfers to neighbouring catchments. This is done through water accounts. Water accounts framework follows the System of Environmental-Economic Accounting (SEEA) Central Framework. The SEEA Central Framework is an international statistical standard for environmental-economic accounting.

The structure of water accounts refers to the nomenclature of the sectors (or statistical units) in the water value chain that engage in water transactions. The structure of the accounts captures the water economy and reflects the relevant components of the water value chain.

In implementing the water accounts, it is essential to understand and define the statistical units of the economy as they interact with each other and with the natural environment. The economy abstracts water from the environment. Water is exchanged and used within the economy and discharged into the environment.

Table 1: Review and comparison of popular Ecosystem Service Frameworks commonly utilised in classifying natural benefits

Ecosystem Services Typology as per MA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES 2018; Diaz *et al* 2018, Kadykalo *et al* 2019)
Focus on framing Ecosystem Services	Focus on framing Ecosystem Services	Focus on framing Ecosystem Services in hierarchical system	Focus on framing the benefits. This drives the consideration of variation in benefits between groups of beneficiaries.
Provisioning Services - Food - Fresh Water - Fiber - Fuelwood - Genetic resources - Biochemicals	**Provisioning Services** - Food - Fresh water - Raw materials - Genetic resources - Medicinal resources - Ornamental resources	**Provisioning** - Nutrition o biomass o water - Materials o biomass, fibre o water - Energy o biomass based energy sources o mechanical energy	**Material NCP (includes non-material elements)** - Energy - Food and feed - Materials, companionship and labour - Medicinal, biochemical and genetic resources
Regulating Services - Climate Regulation - Disease Regulation - Water Regulation - Water Purification	**Regulating Services** - Air quality regulation - Climate regulation - Moderation of extreme events - Regulation of water flows - Waste treatment - Erosion prevention - Maintenance of soil fertility - Pollination - Biological control	**Regulation and Maintenance** - Mediation of wastes, toxics, and other nuisances o mediation by biota o mediation by ecosystems - Mediation of flows o Mass o Liquids o gaseous/airflows - Maintenance of physical, chemical and biological conditions o lifecycle maintenance, habitat and gene pool protection o pest and disease control o soil formation and composition	**Regulating NCP** - Habitat creation and maintenance - Pollination and dispersal of seeds and other propagules - Regulation of air quality - Regulation of climate - Regulation of ocean acidification - Regulation of freshwater quantity, location and timing - Regulation of freshwater and coastal water quality - Formation, protection and decontamination of soils and sediments - Regulation of hazards and extreme events

Ecosystem Services Typology as per MA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES 2018; Diaz *et al* 2018, Kadykalo *et al* 2019)
		o water conditions o atmospheric composition and climate regulation	- Regulation of detrimental organisms and biological processes
Cultural Services - Aesthetic values - Spiritual/ religious values - Educational - Recreation and ecotourism - Inspirational - Sense of place - Cultural heritage	**Cultural and Amenity Services** - Recreation, mental and physical health - Tourism - Aesthetic appreciation - Spiritual experience and sense of place	**Cultural Services** - Physical and intellectual interactions with ecosystems and land-/seascapes o Physical and experiential interactions o Intellectual and representational interactions - Spiritual, symbolic and other interactions with ecosystems and land-/seascapes o Spiritual and/or emblematic o Other cultural outputs	**Non-Material NCP (includes material elements)** - Learning and inspiration - Physical and psychological experiences - Supporting identities
Supporting Services - Nutrient Cycling - Soil Formation - Primary Production - Habitat - Biodiversity	**Habitat Services** - Habitat for species - Maintenance of genetic diversity		**Material, Non-material and Regulating NCP** - Maintenance of options **Nature (Intrinsic) e.g.:** - Genetic Diversity, Species diversity - Evolutionary and ecological processes - Gaia, Mother Earth - Animal welfare / rights

Water accounts consist of physical and monetary accounts. Both physical and monetary accounts are based on supply and use tables (SUTs), published by StatsSA. Physical water flow accounts provide information on the volumes of water exchanged between the environment and the economy (abstraction and returns) and water exchanged within the economy. The rows represent the supply, and the columns represent the end-use. This information is used to identify beneficiaries of water provisioning services. Monetary accounts have a similar structure to the physical account but it measures water transactions in monetary terms.

A key function of the use of the Water Account is to ensure the consideration of the transfers out of the Thukela catchment to supply users in adjacent catchments. The upper headlands of the Thukela catchment is a strategic water resource catchment for the country, as the system has numerous water transfers to the neighbouring catchments, particularly the Vaal catchment, supporting the Gauteng economy. The following are the current transfers from the Thukela catchment (Figure 5):

- Water from Woodstock dam in the upper Thukela which flows into Sterkfontein dam which is situated in the Vaal catchment.
- Water exported to the upper reaches of the Vaal River Supply Area from Zaaihoek Dam for use at the Majuba Power Station, and for transfer to Grootdraai Dam. Water is transferred via a system of pump stations and pipelines from the Zaaihoek Dam in the Slang River to Majuba Power Station in the Mpumalanga Province. Surplus water is released into the Vaal River to flow into Grootdraai Dam, thus increasing the capacity of the Vaal River system.
- The Thukela River System supports inter-basin transfers to the Mgeni River System. This Scheme, pumps water from a weir in the Mooi River (at confluence with little Mooi River) through a pipeline system into the headwaters of the Lions River from where it flows into Midmar Dam, which is part of the Mgeni System.
- Spring Grove dam on the Mooi River transfers water into Mpofan River which also flows into the Midmar Dam
- Middeldrift Scheme, taking water from the lower Thukela River to the headwaters of the Mhlathuze River Catchment. The scheme is used to maintain the water level in Goedertrouw Dam to secure supply to users during droughts.
- The Lower Thukela Water Supply System and Thukela pipeline project further supports the Mooi-Mgeni system taking water (55 Ml/d) from the lower Thukela River at Mandini. There is an option to upgrade to 110 Ml/d.

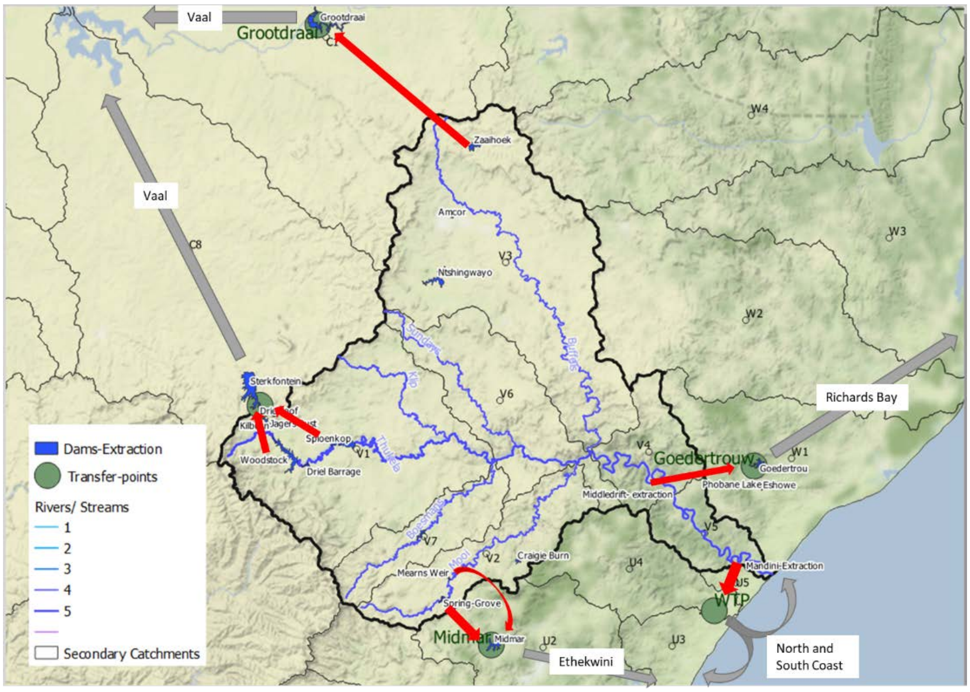

Figure 5: Water transfer scheme localities from the Thukela catchment to surrounding catchments

2.4 QUASI-SOCIAL ACCOUNTING MATRIX MODULE

A Social Accounting Matrix (SAM) is a well-established macro-economic modelling tool, which has been used in several WRCS studies in the past. A SAM quantifies all transactions between sectors and actors in the economy, in a specific calendar year. The sectors and actors include primary (predominantly agriculture, forestry and mining), secondary (predominantly manufacturing) and tertiary (all service sectors) sectors, as well as consumption by households and trade outside of the economy.

The underlying data used to construct a SAM is official economic data provided by Statistics SA. The SAM can be restructured into a modelling tool through which the impact of water resource management scenarios can be evaluated.

A Thukela Quasi-Social Accounting Matrix (QSAM) was developed with the aim to quantify the size of the Thukela economy. The QSAM module was developed from the Supply and Use tables published by Statistics South Africa (Stats SA) in 2019 for the year 2017. The first step was to develop the Input-output table. An Input-Output table is a representation of national or regional economic accounts that records how industries produce and trade between themselves (i.e., flows of goods and services). The flows for input are recorded in the columns of the Input-Output table and the outputs are included in the rows of the table. These flows are recorded in a matrix, simultaneously by origin and destination (OECD, 2006).

An input-output analysis is the standard method for measuring the propagation effects of changes in final demand for a product in an industry or sector (Surugiu, 2009). The Input-Output table was then extended into a QSAM by incorporating labour (compensation of employees) and households. The QSAM is a square matrix of transactions between the rows (incomes) and columns (expenditures) of the matrix representing the various sector accounts. In the square format of a QSAM the total receipts must equal total payments for each of its accounts (van Seventer & Davies, 2019). The QSAM may be used to evaluate the socio-economic impact of exogenous changes to the Thukela catchment economy.

The macro-economic indicators estimated in the QSAM model for the Thukela catchment are Gross Value Added (GVA) and Compensation to Employees as described in Table 2.

Table 2: Macro-economic indicators estimated in the economic model

Indicator	Unit	Description
Gross Value Added (GVA)	Rand Millions	Economic productivity metric measuring the contribution of Loskop scheme to the economy
Compensation to Employees	Rand Millions	Component of the GDP measuring the change in total salaries paid

The QSAM model also estimates economic multipliers from the Leontief inverse matrix. Multipliers indicate the increase in final income arising from the expenditures within economic sectors.

The methodology followed to build the QSAM for the Thukela catchment is illustrated in Figure 6.

The major economic sectors of the Thukela catchment were identified using information sourced from the socio-economic profiles and spatial economic overviews of the district municipalities that fall within the catchment. Stats SA Census 2011 data was used to determine the total number employed per sector (formal and informal) and together with the Stats SA quarterly employment statistics information the total average salaries per sector were calculated. The Thukela GVA was determined per sector based on the national QSAM GVA to compensation of employees' proportion. These values were used to construct the Thukela QSAM. Finally, the multipliers were derived from the QSAM.

The aim of the QSAM is to combine the suppliers and consumers of economic products in a single matrix (table of interacting economic sectors) in order to determine the magnitude of the macro-economic indicators (See Appendix 2).

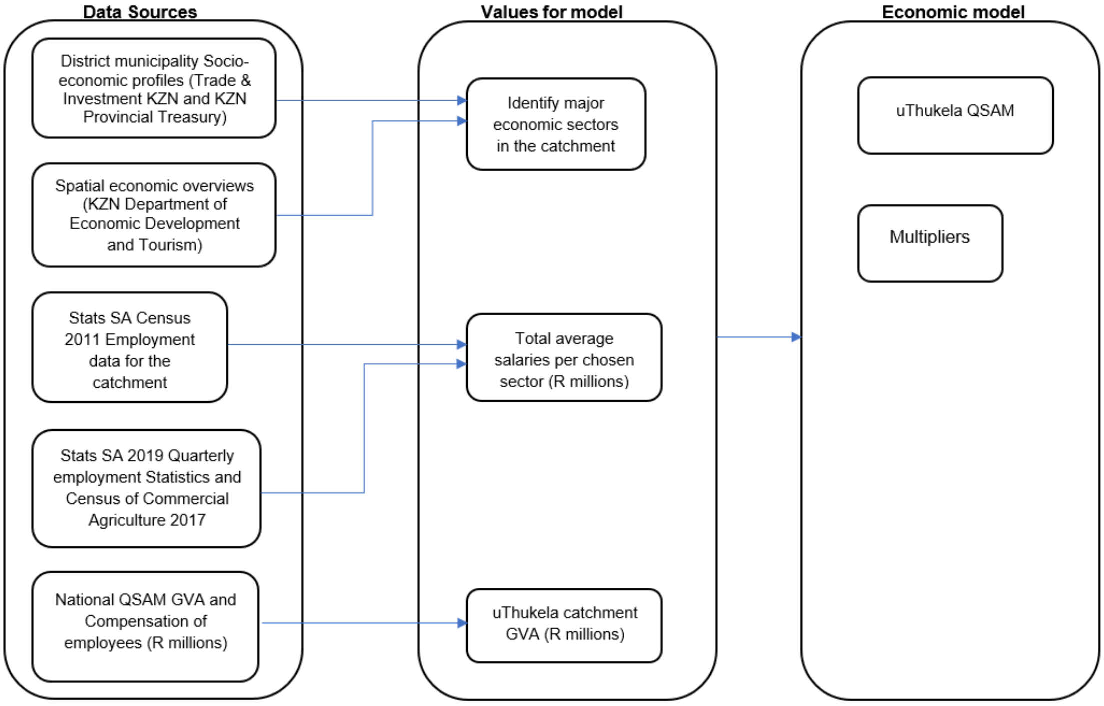

Figure 6: Schematic representation of the methodology used for the economic model development

3 RESULTS

3.1 Ecosystem Services Valuation Module

The catchment is divided into four general Socio-Economic Zones. These zones broadly represent variation between socio-economic drivers, well-being and characteristics of beneficiaries of ecosystem services across the catchment. Based on this variation, and variation in distribution of ecological infrastructure, each zone benefits to varying degrees from the flow and direct use of ecosystem services. Variation between beneficiaries is further subdivided into formal and informal users.

Formal beneficiaries are defined here as beneficiaries whose use of consumptive ecosystem services (provisioning services) are regulated through formal structures (i.e. require a water use license or municipality to extract or use water). The formal beneficiaries in the catchment include municipalities, agricultural, manufacturing, mining, government services, electricity and water, real estate and business and urban households. Informal beneficiaries include beneficiaries of services that are not formally regulated and are attributed to the subsistence use of resources in relatively undeveloped regions and on traditional land. These informal beneficiaries are associated with rural communities of whom livelihoods are closely associated with benefits from natural ecosystems.

In a relatively undeveloped catchment such as the Thukela, the consequences on ecosystem services flow of management may vary greatly between beneficiary type. The relatively large rural populations are especially vulnerable to changes in ecosystem service delivery. The spatial distribution of these beneficiaries in relation to ecological infrastructure was assessed to reveal the spatial orientation of ecosystem service flow and type.

Although all of the ecosystem services are present in one form or another within the catchment, only key ecosystem services were selected to be included in the IEM development process. Ecosystem services to include were pre-empted based on likely management scenarios and the likelihood and consequence these scenarios may have on the flow of ecosystem services. It must be noted that during the scenario evaluation phase, if an ecosystem service is put at risk that has not been included in this report, it will be retroactively included and considered.

Key ecosystem services identified and prioritised across the Thukela catchment as per IUA include:

- Fresh Water Provisioning;
- Water Quantity Regulation;
- Food, Raw Materials and Wild Collected Products Provisioning;
- Erosion Regulation;
- Water Quality Regulation: Purification and Waste Management;
- Spiritual, Landscape and Amenity Services;
- Tourism and Recreational Services; and
- Biodiversity Support.

3.1.1 Fresh Water Provisioning

Key Ecological infrastructure:	**Rivers, Streams, Dams and Aquifers**
Beneficiaries:	Agriculture, Households, Manufacturing, Mining, Government Services, Forestry, Transfers (Adjacent catchments)
Use:	Direct use value

Water provisioning is a predominant ecosystem service provided to beneficiaries within the Thukela catchment. The basin is characteristic of a range of formal and informal beneficiaries of the fresh-water provisioning service.

The water transfers from the Thukela basin represent the largest allocation of water originating in the basin. These transfers supply domestic, agricultural and industrial users in the adjacent Vaal and uMvoti-uMzimkulu and Usutu-Mhlathuze catchments. Particular value is to the economic hub of Gauteng, as well as neighbouring Durban, Richards Bay and smaller coastal regions.

Behind the water transfers, commercial agriculture is the largest consumer of water in the catchment. While annual crop cultivation relies primarily on seasonal rains, irrigated agriculture is largely dependent on water abstraction from dams, rivers and streams. The total area currently under agricultural use is approximately 540 000ha of which at least 8% (41,000ha) is irrigated. The remainder land falls under dryland (predominantly, wheat, maize, soya and potatoes), grazing or subsistence agriculture (which may be informally irrigated). Irrigation therefore represents the chief water user within the catchment with 305 million m^3 /a (Water Resources Planning Model) water being supplied through various irrigation schemes (mostly vegetables). Irrigated agriculture is situated within IUAs 1, 2, 3, 5, 7,9, 10 and 12. The predominant irrigation schemes are situated in the Upper Thukela (Spioenkop Dam); Mooi (Spring Grove, Mearns Weir and Craigie Burn Dam); the Boesmans (Wagendrift Dam) and the Buffalo (Ntshingwayo Dam).

Subsistence agriculture, while likely consisting of mainly annual crops, may contain a mixture of dryland and irrigated crops. The irrigation supplied to these crops is likely informal requiring the manual transfer of water from streams or rivers to the fields. The IUAs in which notable subsistence agriculture is found include 3, 4, 5, 6, 10, 12, 13 and 14.

The Thukela basin is home to approximately 414 321 households, totalling approximately 1 848 000 people which represent the beneficiaries that use approximately 98 million m^3 /a (53 million m^3 /a is allocated to indigent households *i.e.* non-revenue water) (DWS No Drop System). Households can be subdivided into those with formal water distribution infrastructure (*i.e*. piped tap water) and those without. The distribution of households with operational piped tap water is skewed towards the upper and western regions, tending to be largely concentrated around towns.

Scattered rural settlements are widespread throughout the basin, being generally skewed towards the southern and eastern parts of the catchment. A significant proportion of this population has limited or no access to piped water, needing to rely on informal sources of water, often directly from the ecological infrastructure of rivers and streams. This may be due to either formal water distribution infrastructure in bad condition or requiring maintenance or perhaps a lack of this infrastructure therefore driving communities to source water from alternative sources. Impacted infrastructure could include silted dams, non-compliant WWTW (Blue and Green Drop) or inefficient distribution infrastructure. For those people that rely on sourcing their water directly from rivers and streams, the condition and flow in these source channels are vitally important.

There are four key industrial hubs in the Thukela basin. These are based in the towns of Newcastle, Estcourt, Ladysmith, and Sitebe (in IUAs 2, 9, 11, and 15, respectively). Of these, Newcastle is the largest, although Sitebe, is set to expand as it is located in an Industrial Development Zone (IDZ). A wide range of heavy, and light manufacturing and commercial activities take place, all of which require a constant, uninterrupted supply of water, which is generally supplied through formal municipal water distribution systems. Due to the predominant size of the agricultural industry in the catchment, it is likely that agriculture related manufacturing represents the largest proportion of water allocation as required for production.

Although there are significant coal mining operations, with most mines located in the northern portion of the basin, mainly in IUA 2 but also prevalent in IUA 3 and 6, this activity is generally a net water producer; pumping water out of the mined areas. It should be noted, however that the effluent from industrial and mining activities is important to take into consideration for its effect on downstream users, as is indicated under the water purification service description.

Changes to allocation of water within the system may affect different beneficiaries in a variety of ways. Greater allocation of water to commercial or industrial activities, and to transfers, may have a significant impact on some informal water users, although most of these rely on smaller tributaries above the main water courses. Similarly, the state of formal water distribution infrastructure will influence the flow of these water provisioning benefits to their final intended beneficiaries.

3.1.2 Water Quantity Regulation

The eco-classification process plays an important role in integrating various parameters of flow, geomorphology, water chemistry and others and recommending ecological classification scenarios are various Ecological Water Requirements (EWR) sites in the WMA. From the resource economics perspective, our challenge is to interpret the consequences and likelihoods of these scenarios on beneficiaries.

Key ecological infrastructure:	**Wetlands, SWSAs**
Beneficiaries:	Households, Agriculture, Industry
Use:	Indirect use value

Water quantity regulation is a significant ecosystem service provided by ecosystems within the Thukela catchment, especially in the context of the greater South African region. The catchment contains a large proportion of Strategic Water Source Areas (SWSAs) which represent sourcing areas for water that supplies not only the basin but also adjacent basins with valuable fresh water.

The service is linked to the ability of the catchment to capture precipitation through various processes. Healthy, intact soils are vital for effective infiltration, with the escarpment, grasslands, woodlands and forests being the primary ecological infrastructure associated with this ecosystem service.

The bulk of precipitation is captured throughout the wet season in the summer months by the surface SWSAs along the escarpment and Drakensburg range. Strategic Water Source Areas SWSAs are defined as areas that supply a disproportionate amount of mean annual runoff to a geographical region of interest. The geographic region of interest is in fact South Africa making the SWSAs present in the catchment represent highly crucial water source areas at a national scale.

These SWSAs represent key ecological infrastructure in this regulating service are primarily located in IUAs 1, 2, 5, 8, 10, 11, and 14.

The grassy slopes of these areas, along with the widespread wetlands situated in the foothills, are integral to the provision of water to the rest of the basin. Other ecological infrastructure associated with water quantity regulation includes wetlands and aquifers that are found downstream of the SWSAs.

The SWSAs and associated wetlands play a key role in regulating water flow facilitating a constant supply of water to the rest of the basin throughout the year. Wetlands play the additional function of mitigating flooding events by slowing flood water, allowing it to infiltrate, and releasing it in a more regular flow.

Notable flow regulating ecological infrastructure lie in the upper catchment, just below the escarpment. Of primary importance are IUA 1, with the Groenkloof and Wakkerstroom wetlands, along with the Zaaihoek Dam; IUA 2, with widespread wetlands and the Ntshingwayo Dam; IUA 5, with its large wetland complex at the head of the Blood River.

Domestic users require a constant supply of water throughout the year. This is mostly facilitated by municipal infrastructure. However, a large portion of households in the Thukela basin rely on rivers and streams for their daily water needs. The ecosystem service of water flow regulation is particularly important for these users, who would be unable to continue their way of life if the rivers and streams they rely on were to run dry, even if only for a short period during the year. As suggested in the previous section, upgrading or investment into water distribution infrastructure may mitigate these risks. Many households are also situated along riverbanks, and by mitigating the potential effects of flooding, water regulation ensures their protection.

The bulk of commercial agricultural activity in the Thukela basin is comprised of dryland crop cultivation, which relies primarily on seasonal rains. Irrigated agriculture, however, often relies on direct abstraction from rivers and streams, both playing a role in regulating water flow, and relying on a steady supply. A change in water allocation towards water transfers could this affect these beneficiaries negatively.

The cascading effect of a healthy river system supports provisioning and regulating services in the entire system. Particular consideration is through the interactions with estuaries through facilitating the spawning cycle of a number of fish species which rely on the nutrients in the outflow of the river into the sea.

A key concept to note here are the water requirements associated with effective functioning of aquatic ecosystems within the catchment known as the Ecological Water Requirements (EWR). The EWR represents a base flow that is necessary for ecosystem functioning. The management and maintenance of the EWR is vital to ensure long term sustainable development of the catchment and its natural resources. This consideration is key when determining the upper limits of development and water extraction scenarios and therefore limit specific types of development activities across varying ecosystems and catchments.

3.1.3 Erosion Control/Soil Stability

Key ecological infrastructure:	**Grasslands, Wetlands, Forests, Rivers, Estuary**
Beneficiaries:	Commercial and subsistence agriculture (multiple indirect beneficiaries)
Use:	Indirect use value

Erosion control is an intermediary service and is therefore integral to other final ecosystem goods and services and is linked to water quantity regulation services. “Vegetation cover prevents soil erosion and ensures soil productivity through natural biological processes such as nitrogen fixation” (FAO, 2020), and is thus linked to the food provisioning services discussed above.

The main ecological infrastructure associated with soil stability and erosion control is healthy terrestrial systems, wetlands and indigenous forests. This is particularly true of areas with significant slopes and undulating or extreme topography. While soil stability is of vital importance throughout the catchment, IUAs 4, 5, 6, 8, 10, 12, 13 and 15 have been identified as being of particular significance for the prevention of erosion to protect food and water security. A significant region of particular concern of risk to erosion is the highly erosive soils associated with the Masocheni Formation which are found in IUA 2. These soils will be considered in the risk assessment to follow during the scenario evaluation step.

These IUAs exhibit high levels of subsistence agriculture, which is often where the highest prevalence of erosion is found. While commercial farmers possess the knowledge and resources to mitigate for the dangers of soil erosion, this is not always the case for subsistence farmers. Many of these communities also inhabit slopes, where the danger of erosion is exaggerated.

As is clear from the above, subsistence farmers are the primary beneficiaries of the regulating service of erosion control, due to their reliance on healthy, intact soil to grow their food. Commercial agriculture also derives indirect use value from this service, as stable soils form the basis of their productive capacity.

Changes to water allocation is unlikely to have a major effect on the beneficiaries of this ecosystem service, although effective erosion control may in fact have a net benefit on the overall quantity of water for allocation, due to the water capturing quality of healthy vegetated slopes.

3.1.4 Water Quality Regulation: Purification and waste management

Key ecological infrastructure:	**Wetlands, Aquifers, Rivers**
Beneficiaries:	Government Services, Households, Manufacturing, Agriculture, Mining (Multiple indirect beneficiaries)
Use:	Direct/indirect use value

Ecological infrastructure associated with water purification and waste management are primarily wetlands, but also includes rivers and streams. Wetlands act as natural water filters. By slowing the flow of water they allow particulate matter to settle, while many of the aquatic plants found in wetlands are even capable of extracting chemical pollutants from the water. Natural watercourses of streams and rivers also play a role in purifying water, as vortices and eddies further purify and oxygenate water.

It may be said that the main beneficiaries of natural water purification services are regional and local water boards, who would otherwise have to invest considerable funds into the man-made infrastructure necessary for water purification. This benefit is also carried forward to private and commercial water users, through lower water tariffs and naturally pure water. Treated wastewater released by municipalities into the environment is also further purified by natural systems.

Low income and rural communities are once again one of the primary beneficiaries, as they rely on the water they collect from rivers and streams being clean. While formal beneficiaries often have the means to improve water quality, informal beneficiaries do not always have the means to identify alternative sources of water and may need to divert valuable resources to water purification before consumption is possible.

Industry, particularly industries which produce significant amounts of contaminated effluent also benefit greatly from the purification services provided by the natural environment. While polluting industries are required to treat their effluent before releasing it back into watercourses, further purification by natural systems ensures that water users downstream is of a higher quality than it otherwise may be, externalising some of the costs of purification for these industries.

Key ecosystems providing water quality regulation services to beneficiaries are those positioned downstream of land uses that are known to impact water quality negatively. This being ecosystems that receive contaminated water resources from upstream impacts, typically more industrialised land uses, and provide regulated or treated water to downstream beneficiaries. For this reason, in the Thukela we do not expect water quality ecosystem services to have significant value high in the escarpment (as the water is not contaminated at that point), but rather see this service adding value to beneficiaries in the central regions of the catchment prior to supplying the less developed regions of the catchment.

The ecological infrastructure of primary importance for the quality regulation of water in the Thukela catchment include the wetland systems which lie downstream from a number of coal mining operations, and particularly the wetland system just below the industrial hub of Newcastle; the wetlands and widely meandering Boesmans River below the small industrial hub of Estcourt; and the wetlands downstream of Ladysmith.

If wetlands dry up due to insufficient flow, their ability to perform the purification services may be impaired. It is thus important that any changes to water allocation consider the health of these systems in their design.

3.1.5 Food, Raw Materials and Wild Collected Products Provisioning

Key ecological infrastructure:	**Grasslands, Rivers, Wetlands, Dams, Estuary**
Beneficiaries:	Rural households, subsistence agriculture, agricultural sector (livestock grazers)
Use:	Direct use value

With both commercial and subsistence agriculture being widespread throughout the Thukela Basin, the ability of the land to provide food provisioning services is of major importance to the region. Fertile soil, particularly in the western region of the basin, along with sufficient water, as discussed above, provides the ideal conditions for food cultivation. Grasslands also provide grazing for cattle, which is of particular importance to subsistence farmers.

The most commercially productive areas of the basin appear to be found in IUAs 2, 3, 5, 7, and 10 as can be seen from the density of agricultural activity in these regions. Commercial agriculture derives the highest quantifiable benefit from the ability of the land to provide the necessary conditions for a range of crops to be cultivated and is the main economic driver in a number of municipalities throughout the region. It should be noted, however that only a portion of the value in agriculture can be linked to this ecosystem service, as significant additional inputs are required for the cultivation of commercial crops.

Subsistence agriculture, although less easily quantifiable, is arguably even more important as it is the primary source of nutrition for rural populations, which comprise a large number of the people in region. This is likely largely comprised of staple crop and vegetable cultivation, as well as widespread grazing of cattle and goats. Aside from the IUAs already mentioned, particularly IUAs 3, 5, and 10, subsistence agriculture is also densely concentrated in IUAs 4 and 13, as well as 6 and 12.

The benefits of food production also extend beyond only the agricultural industry itself and subsistence farmers. Significant economic value is also added in secondary processing of agricultural products, providing an income for a large number of households and industries throughout the region, and facilitating further economic development.

With regards to more rural communities, it is likely that wild collected food also contributes to their food security, while wood collected from the wild is often a primary source of fuel. Other wild harvested medicinal products and foodstuffs from the surrounding environment may also be traded in the informal economy.

It is not expected that changes to water allocation policies would affect beneficiaries of wild harvested food and materials considerably. Reduced water flow may however affect harvesting of fish in rivers and have greater impacts on ecosystems associated with the Thukela mouth estuary. Changes to flow regime would impact on processes such as sedimentation and flood events, the period for which the mouth is open (impacting salinity gradients and access by species) and inputs to marine systems from inland. Impacts on these processes would greatly impact the provisioning services supported by the estuarine system.

3.1.6 Cultural, Spiritual and Amenity Value

Key ecological infrastructure:	**Ecological Infrastructure within Traditional homelands, the Drakensberg escarpment, protected areas and the coastline**
Beneficiaries:	Households, real estate activities
Use:	Direct use value

A significant portion of the Thukela basin is home to rural communities for whom the region is inextricably linked to their cultural identity and sense of place. This indirect non-use, or existence, value is present with much of the history and traditional knowledge of the Zulu people being linked to the greater region, while also holding historical value for other groups of South Africans as well.

Primarily IUAs 4, 5, 6, 12 and 13, as well as parts of IUAs 9,10 and 14, are identified to hold significant existence value for the local communities, as is evidenced by scattered clusters of rural settlements and land tenure patterns. It is likely that the people in these communities have been tied to those areas of land for many generations, and that many of their spiritual beliefs and cultural practices are linked to features of the landscape.

The inhabitants of these communities are likely also more heavily reliant on the other life-sustaining ecosystem services discussed above, as they are generally quite isolated, and thus have largely not been connected to infrastructure such as piped water, waste removal, and other services associated with economic development. These communities thus hardly engage in the formal economy and may not even be particularly active in the informal economy. Areas of significant historical importance such as Isandlwana may also be considered as having particular cultural value.

Amenity value is also considered here, with places of particular natural beauty which drive increased property values and are attractive to developmental activities such as real estate development. IUA's exhibiting value in this regard include 7, in the sought after Midlands Meander area; 14, where the scenic areas of the Drakensburg are located; and 15, which includes coastal properties.

IUA 14 contains the Drakensberg Parks which are recognised as World Heritage Sites. This results in key policies attributed to this region governing the protection of cultural and natural heritage. The Drakensberg Special Case Area Plan (SCAP) is a key policy as well as the Norms and Standards for landscape characterisation which must be considered when evaluating management scenarios effecting IUA 14.

3.1.7 Recreational and Ecotourism

Key ecological infrastructure:	**Escarpment, Rivers, Wetlands, Dams, protected areas, the Tugela estuary and the coastline**
Beneficiaries:	Local populations, Tourists, Hotels & Restaurants
Use:	Direct use value

Tourism has been identified as a key economic driver in many parts of the Thukela basin. This cultural ecosystem service "includes both benefits to visitors and income opportunities for nature tourism service providers" (FAO, 2020). This direct use value is associated with a wide range of ecological infrastructure, including natural pristine landscapes, comprised of mountains, rivers, wetlands, and coastal areas, particularly those which host a diversity of plant and animal life.

Three specific categories of tourism are identified being business, historic and eco-tourism. The former, business tourism, although will reflect on the size of the tourism industry is not necessarily linked to ecosystems. Business tourism industry is expected to centre around major economic hubs such as Newcastle, Ladysmith, Estcourt and Sitebe. Historical tourism, including battlefield routes (Rourke’s Drift and Isandlwana) throughout the central region of the catchment. Historical tourism is not necessarily linked to ecosystems however the undeveloped nature of these landscapes likely causes historical tourism to overlap with ecotourism. The eco-tourism industry is directly related to the presence of healthy ecosystems and undeveloped ecological infrastructure such as those found in the Drakensberg, Midlands, Protected Areas (government and private) and along the coast.

The Drakensburg is a significant asset, drawing a large number of tourists, both domestically and from around the world. The Maloti-Drakensberg Park is a transnational property composed of the uKhahlamba Drakensberg National Park in South Africa and the Sehlathebe National Park in Lesotho and is a declared World Heritage Site meaning the escarpment is both protected under NEM:PAA and the World Heritage Act. IUA 14 is therefore of particular importance. Over seventy percent of the area of this IUA is comprised of protected areas, including Giants Castle Nature Reserve and the Ukhahlamba-Drakensburg Nature Reserve.

Other notable IUAs with significant recreational and tourism activity or potential include IUA 7, playing host to a portion of the popular Midlands Meander tourist route, and IUA 15, where the Thukela mouth is situated. Further, all but IUAs 4, 5 and 6 contain at least one protected area. Aquatic recreational activities such as boating, river rafting, kayaking, fishing, and diving (mostly the estuary) also attract tourists and holiday makers to both inland and coastal aquatic systems within the greater catchment. Trout fishing represents a significant activity drawing economic activity to the natural river stretched within the province. The maintenance of the trout fishing industry relies on good quality healthy river ecological infrastructure.

Beneficiaries deriving value from this service include those visiting and, possibly more importantly, the local communities in which these attractions are situated. A number of local municipalities note their aspiration to further develop their tourism industry as a way of boosting economic activity.

Tourists and holiday makers derive pleasure from engaging in activities such as hiking, game viewing, bird watching in the many protected areas throughout the region. It is widely accepted that spending time in nature provides significant psychological and emotional benefits, as well as the obvious physical benefits gained from the more active pastimes.

Communities around tourism hotspots are the primary local beneficiaries of the value created by these areas. These include local hoteliers, tour operators and tour guides, as well as curio manufacturers, and the support staff employed by the tourism industry, particularly in hotels and restaurants.

Changes to water allocation my affect some of these beneficiaries. If river flow is reduced this could lead to a reduction in the potential for aquatic activities along the major water courses, although dams would likely be unaffected. An important consideration is the impact of reduced flow on the ecological integrity of the estuary, and thus its value to visitors.

3.1.8 Biodiversity Support

Key ecological infrastructure:	**Undeveloped biodiversity corridors, ecosystem margins**
Beneficiaries:	Agriculture, households, (Multiple indirect beneficiaries)
Use:	Indirect non-use value

Support of biodiversity, including biological control, is another important, but often overlooked service provided by healthy ecosystems, and intrinsically linked to many of the other services discussed here. Biodiversity has far reaching benefits to human-natural systems, such as maintaining a balance between parasites, pests, and their predators; maintaining healthy populations of pollinators; and fostering the necessary conditions for many of the food species, particularly fish species, which form a key part of human nourishment.

In this respect, key biodiversity hotspots include the protected areas as well as significant ecological features such as those found in IUA 14 and 15. The Thukela estuary, represents a significant feature that plays an integral role in the regulation and support of biotic processes. The nutrient rich water flowing into the sea supports and drives lifecycles of a number of commercially valuable aquatic species (fish, crab, eel and prawns).

The beneficiaries of this service are widespread and diverse. Agriculture benefits through the natural control of pests and parasites, saving costs on pesticides and animal dips. Healthy populations of pollinators also increase crop yields. Households benefit through the reduced prevalence of disease, and it follows that healthcare systems also benefit from a healthier population.

Reduction of flow may have significant effects on the ability of certain areas of the catchment to provide biodiversity support services. An important consideration is the impact of reduced flow on the ecological integrity of the estuary, and thus it’s value to the propagation of fish species.

3.1.9 Consolidated Beneficiaries

Beneficiaries, as per those identified through the QSAM, of prioritised ecosystem services were consolidated per ecosystem service (Table 3). The value of the ecosystem services to each beneficiary varies depending on the size of the sector, the magnitude of environmental contribution received and the dependency of the sector on the benefit.

Table 3: Ecosystem Service linkages with QSAM beneficiaries in the Thukela catchment

Intermediate Ecosystem Service	Final Ecosystem, Services	General Sector	QSAM Beneficiary Class
Water Quality Regulation Water Quantity Regulation	Food Provisioning	Informal Households	Non-observed, informal, non-profit, households
		Agriculture	Agriculture
	Fresh Water (Water quantity) Provisioning	Households	Non-observed, informal, non-profit, households
			Households
		Agriculture	Agriculture (Irrigation)
		Forestry	Forestry
		Manufacturing	Food

Intermediate Ecosystem Service	Final Ecosystem, Services	General Sector	QSAM Beneficiary Class
Erosion and Soil Regulation			Beverages and tobacco
			Tanning and dressing of leather
			Paper
			Other chemical products, man-made fibres
			Rubber
			Plastic
			Glass
			Basic iron and steel, casting of metals
			Basic precious and non-ferrous metals
			Machinery and equipment
			Electrical machinery and apparatus
			Radio, television, communication equipment and apparatus
			Motor vehicles, trailers, parts
			Other transport equipment
			Furniture
			Manufacturing n.e.c, recycling
		Mining	Mining of coal and lignite
			Other mining and quarrying
		Government Services	Electricity, gas, steam, and hot water supply
			Collection, purification, and distribution of water
			Sewage and refuse disposal
	Raw Materials Provisioning	Informal Households	Non-observed, informal, non-profit, households,
	Medicinal resources Provisioning	Informal Households	Non-observed, informal, non-profit, households,
	Landscape & amenity values	Households	Non-observed, informal, non-profit, households,
			Households
			Real estate activities
	Ecotourism & recreation	Accommodation	Hotels and restaurants
		Recreation/Activities	Recreational, cultural, and sporting activities

3.2 Approach to the Ecosystem Service Valuation Step

The ecosystem service valuation process, to be completed further along in the 7 step classification process, will be conducted during the scenario evaluation step. The scenarios will include a range of management scenarios over a temporal scale to be tested against the baselines and linkages determined here. Through the use of inputs developed by all specialists and identifying key responses to scenarios by ecological infrastructure and their driving processes, ecosystem services at risk of impact will be identified. Only ecosystem services identified to be at risk due to implementation of management scenario will be valued. The valuation process will in this way, function to allow for the evaluation of trade-offs between management scenarios and therefore aid in the determination of water resource class per IUA.

As a point of departure, to obtain preliminary insights into the value of ecosystem services in the region a study commissioned by SANBI *et. al.* (2017) entitled “Towards a method for accounting for ecosystem services and asset value: Pilot accounts for KwaZulu-Natal, South Africa, 2005-2011", will be discussed here. The study focussed on Kwa-Zulu Natal and aimed to provide a first set of monetary ecosystem accounts at a sub-national scale in South Africa, following SEEA EEA guidelines. The Thukela catchment comprises almost a third of the study area and therefore the study provides valuable insights into the subject at hand.

Ecosystem service types valued broadly followed the Millennium Assessment and CICES frameworks and results of the valuation are summarised in the following table:

Class	Ecosystem Service	Annual Flow Value R millions / annum (2011)	Asset Value R millions*
Provisioning	1. Wild Resources	3 180	28 440
	2. Animal production	2 636	42 700
	3. Cultivation	19 258	311 961
Cultural	4. Nature-based tourism	2 282	36 972
	5. Property value	1 327 (68% in eThekwini Metro)	21 508
Regulating	6. Carbon storage and sequestration	3 632 (SA)	58 846
	7. Pollination	47	772
	8. Flow regulation (maintenance of base flows)	981	15 903
	9. Sediment retention	67	1 089
	10. Water quality amelioration	16	259
	11. Flood attenuation	23	380
TOTAL		**33 453**	**518 835**

**Discount rate of 3.66% and time period of 25 years*

The total value of ecosystem services equated to 7.4% of the provincial GDP (in 2011) with key sectors as beneficiaries (by percentage) including the agriculture, forestry and fisheries (55%), households (24%), the environment (11%), trade, catering and accommodation (7%). These proportions illustrate the relative benefits received and therefore can indicate the proportion of loss of value to sectors, and households, through impacts on ecosystems. The results further illustrate the magnitude of support that natural services provide to the socio-economics of the catchment.

A keynote here is that the study did not include estuarine services, of which are key to the in the assessment of scenarios in the Thukela classification process.

3.3 Water Accounting Module

In the absence of the Reconciliation strategy for Thukela, several data sources were used to have first glimpse of the water economy. Mgeni water infrastructure master plans. DWS National Water Resource Strategy (NWRS, 2004) report and preliminary hydrological study was used to populate the physical water account.

Table 4: Data sources used to populate the physical water accounts

Data points	Source	Year
Available water; Domestic and industrial requirements	NWRS	2004

Data points	Source	Year
Transfer to Middledrift scheme and lower Thukela bulk water scheme	In communication with DWS officials	2020
Transfer to Mgeni-Mooi River scheme; Thukela-Vaal scheme;	Mgeni water infrastructure master plans (Buffalo system and upper Thukela system)	2020
Irrigation (cultivated)	The project's hydrological preliminary data	2020

Development of water accounts provides a means to determine water requirements for local users within the catchments. The account determines water availability, and this is crucial as this catchment supports its neighbouring catchments. When developing scenarios, the account will be used to determine whether the increase in water transfers will result in local water users receiving less water, and if that is the case, what is the economic value for the receiving catchments versus the local users.

Withdrawal sheet in Table 5 was used to demonstrate the water accounts. The withdrawal sheet show volumes of water consumed and returned flows by major local users which includes agriculture, domestic and bulk industries. The withdrawal sheet also shows abstracted volumes to the Vaal, Mgeni and Mhlathuze catchment through numerous transfer schemes.

Due to the absence of reconciliation strategy, data sources were from different years and this affected the accuracy of the water account. For the account to be updated regularly, continuous reporting of major users is necessary. It should be noted that this preliminary water account, and physical and monetary water account will be concluded once the hydrological study in this project is completed.

Table 5: Withdrawal sheet for Thukela Catchment

Units = million m^3/a

<table>
<tr><td rowspan="8">Surface water: 3700</td><td rowspan="2">Cultivated
305</td><td>Consumed:274</td><td rowspan="4">Total consumed: 1030</td></tr>
<tr><td>Returned: 31</td></tr>
<tr><td rowspan="2">Urban and rural domestic use 83</td><td>Consumed: 60</td></tr>
<tr><td>Returned: 23</td></tr>
<tr><td rowspan="2">Mining and bulk industry: 46</td><td>Consumed: 37</td><td rowspan="4">Total returned: 63</td></tr>
<tr><td>Returned: 9</td></tr>
<tr><td rowspan="2">Total Transfers: 659
Thukela-Vaal: 377
Zaaihoek dam: 88
Mooi-uMgeni :141
Middeldrift scheme: 33
Lower Thukela water scheme:20</td><td>Consumed: 659</td></tr>
<tr><td>Returned:0</td></tr>
</table>

Table 6: Physical Water Account

						Distributors			Industry Groups							Transfers out					Residual
				Inland water resources																	
Physical units (Million m³/a)			Environment	Surface water (MAR)	Groundwater	DWS	Water Boards	Municipalities	Agriculture	Domestic	Mining and bulk industry	Electricity	Non-revenue Water	Other	Domestic	Thukela-Vaal (Woodstock-Sterkfontein)	Zaaihoek dam (Vaal, Volksrust and Majuba power station)	Mooi-Mgeni Transfer Scheme Phase 1 and 2 (Midmar dam)	Middeldrift scheme (Goedertrou w dam)	Lower Thukela bulk water scheme	
Environment	Collection of precipitation			3 685	15																
	Inland water Yield	Surface water (MAR)				3 685										377	88	141	33	20	
		Groundwater				15															
Distributors	DWS		737						305			0									
	Water Boards										46										105,7
	Municipalities		23							83											360
Industry Groups	Agriculture		31							4											
	Mining and bulk industries		9																		
	Electricity		0																		
	Other																				
	Domestic																				
Return to sea																					3032

3.4 Quasi-Social Accounting Matrix Module

In the Thukela catchment the largest contribution to GVA is from the government sector which represents 14.5% of the Thukela economy; employs an estimated 41,500 people and annually spends 9.97 billion rand. Agriculture plays an important role in the catchment and its GVA contributes 10.3% to the Thukela economy and employs an estimated 43,800 people. The Thukela QSAM and multipliers will be used in evaluating the various scenarios based on the relevant expenditures per sector for each scenario.

4 DEMONSTRATING LINKAGES

The Thukela catchment is characteristic of a range of ecological infrastructure which provide a range of natural benefits to a range of formal and informal beneficiaries. Through the development of the IEM, several key linkages and insights have been revealed.

The Thukela catchment contributes an estimated R79.3 billion to the economy of South Africa. This economy is relatively small representing only 1.9% of the national GDP of R4.17 trillion (Stats SA 2017). The largest sectors include the government sector, agriculture, hotels and restaurants and real estate activities which represent 14.5%, 10.3%, 4.9% and 4.9% contribution to the catchment respectively (See Appendix 2).

29 of the 56 sectors identified to be operating within the Thukela catchment can be directly linked as beneficiaries of ecosystem services. The links are predominantly through the provisioning and regulation of much needed fresh water, but also through the cultural services, including tourism and recreation, and landscape amenity values. These 29 sectors constitute 45% of total GVA (R35 billion GVA) and provide approximately 125 000 jobs. Although the value added by the 29 sectors in their entirety cannot be directly attributed to ecosystem services, the support these services provide through enabling or opportunity benefits, is significant. The natural contributions can therefore be linked as a proportion of the total size of the sectors.

The value of ecosystem services, as a proportion of the total size of a specific sector will vary between sectors depending on their reliance on the service. The value contribution, for example to the irrigated agriculture sector (as a highly water reliant sector) will be significantly larger than that of the glass manufacturing, for instance (whose reliance on water for production is not as high as agriculture).

Where the management of water is concerned, the agricultural (specifically irrigated agriculture), agricultural manufacturing, households, and government sectors were highlighted as key contributors to the water economy in the Thukela. These contributions indicate linkages between the requirements of fresh-water provisioning services on the sectors themselves and therefore indicate linkages between production and natural benefits. An important note is that these contributions to the water economy do not, directly translate to the quantity of water utilised by a sector, as each sector faces a different tariff for the water they purchase. Tourism, as a formal sector that is prominent in the catchment, although not a significant water consumer, is directly underpinned by cultural services provided by ecosystems present. Water provisioning services includes natural water and treated water.

The agricultural sector is comprised of dryland, irrigated and livestock agriculture of which the latter two are directly reliant on water provisioning services. The economic contribution of the agricultural sector to the water economy is 24.8% (natural water financial transactions) which at a quarter is a large contribution, only second to the agricultural manufacturing industry. This reliance on raw water is largely due to irrigation demand, which is observed to represent a significant proportion of the agricultural industry in the Thukela catchment. The agriculture sector, by total GVA, is the largest sector within the Thukela catchment relying heavily on water provisioning services. The sector contributes 10.3% to the Thukela total GVA, and provides an estimated 44,000 jobs, making it a valuable economic driver of total socio-economic wellbeing of the catchment.

Agricultural manufacturing represents a group of economic sectors which are involved in manufacturing goods from raw materials sourced directly from agriculture. These include the food processing, beverage and tobacco, tanning and dressing of leather, and paper production industries. Agricultural manufacturing contributes to the catchment's water economy through the purchase of both natural water (raw water) and distributed water (treated water), representing 28.8% of total water purchases, in financial terms. This illustrates the relatively high reliance of water provisioning in this sector's functioning. The broader manufacturing sector is responsible for 11.3% of all treated water transactions. Although this is a relatively lower proportion of total transactions, the combined reliance on water resources invariably links this sector with water provisioning services. Although the agricultural manufacturing sector is relatively small representing only 3.75% of the total Thukela GVA it provides an estimated 6,800 jobs which, as described above, is directly supported by the water provisioning services.

Households represent the largest purchaser of treated water, accounting for 38.8% of the total distributed treated water purchases. It is noteworthy that households are such a large user of water in the catchment and reveals the relatively low level of economic development and diversity of sectors with agriculture and manufacturing playing predominant roles in the water economy.

The government sector here refers to the use of water in government operations such as but not limited to the maintaining of municipal infrastructure and parks (please note this sector excludes water distribution, collection and purification operations; and the education and health sectors). This sector contributes 22.5% of total treated water transactions. Accounting for 14.5% of the region's GVA, the total government sector represents the largest economic sector in Thukela. Although its role in both the water economy and the broader economy is significant, the water management component of the government sector is likely only a small percentage of its contribution to GVA, and likely does not draw substantial value from the water provisioning services utilised.

Tourism is a key economic driver in the catchment and is represented here by the Hotel and restaurant and the Recreational, cultural and sporting activities sectors. The linkage with water provisioning services are not as clear as the sectors described above with the sectors associated with tourism representing only 3.9% of total transactions in the water economy (treated water). A significant proportion of the ecotourism facilities located within the catchment however obtain their water directly from the rivers (raw water) (Personal-Comm Ezemvelo KZN Wildlife). The linkages with cultural ecosystem services provided by key ecological infrastructure on the other hand is clearer, with direct linkages to the presence of ecological features associated with tourism and recreational activities, such as the

Drakensberg escarpment, protected areas (both government and private), large dams, the midlands, the coast, and the Thukela estuary. The total sector is observed to make a relatively large contribution, at 4.9%, to catchment GVA, providing 10,700 jobs. Although the bulk of the sector is not fully reliant on cultural ecosystem services (due to the presence of historical and business tourism), it is likely, due to the charismatic nature of the Drakensberg and other environmental features, that a significant proportion of the sector can be directly linked to natural benefits associated with recreational activities.

Although linkages between beneficiaries within the Thukela catchment have been demonstrated and linked with the opportunity value of water, the total opportunity value is in fact underestimated when only looking at sectors within the Thukela catchment. The various water transfers out of the catchment provide additional linkages to beneficiaries which represent increased opportunity value to sectors in the greater region.

The catchment has a highly rural character and the economy is relatively small from a formal economic perspective. There is an important informal economy. These beneficiaries reside specifically within the rural and traditionally owned land which constitutes approximately 26% of the catchment extent and 44% of the total population. These beneficiaries are characteristic of rural communities with generally reduced wellbeing from the perspective of reduced access to services, infrastructure development, employment and education. As a result, subsistence-based livelihoods are prevalent within these communities having intimate relationships with the natural systems represented by direct linkages to a broader range of ecosystem services. The benefits are realised predominantly through provisioning of food, collection of raw materials, medicine and fresh water, regulation of water and soils and cultural and spiritual services provided by the traditionally significant landscape.

The dynamic relationship observed here is twofold: Firstly, the value of these natural benefits to communities who rely directly on them, coupled with limited access to alternatives translates very differently to Rands and Cents compared to economic production. For instance, the value of drinking water (which is necessary for survival) vs the value of irrigation water (which is necessary for production). Secondly, the cause and effect relationships economic development and social wellbeing need to be carefully balanced when implementing management scenarios that influence these beneficiaries. For instance, although increased water allocation to industry may create jobs (economic wellbeing), this could translate in reduced condition of ecosystems and therefore impact on these vulnerable communities (reduced social-wellbeing). Conversely, water management that increases flow (reduced extraction) would likely benefit these vulnerable communities through increased ecosystem services flow.

The linkages between ecosystems and socio-economics of the catchment demonstrated here provide valuable insights into the dynamic relationship between ecosystems and beneficiaries of the services they provide.

5 WAY FORWARD

The analysis above demonstrates the socio-economic structure of the catchment is highly reliant on various ecosystem services. Given this contributing role that ecosystems provide to the wellbeing of the catchment it is vital that ecosystem services be considered and included in the evaluation of scenarios step to follow in the 7 step water resource classification process. The assessment of development scenarios in the next step will provide insights into the impact of the development scenarios on the ecological value, water resources availability, corresponding socio-economics and associated quality objectives. The ecosystem services valuation approach will be utilised towards evaluating trade-offs against varying water management scenarios. The approach will identify ecosystem services at risk, and value these to support informed allocation of water resource class per IUA.

6 REFERENCES

Abaqulusi Local Municipality, 2019. 2019-2020 Final Integrated Development Plan Review. Vryheid. Government Press

Alfred Duma Local Municipality, 2019. Integrated Development Plan 2019/2020. Ladysmith. Government Press.

Andrew N. Kadykalo, María D. López-Rodriguez, Jacob Ainscough, Nils Droste, Hyeonju Ryu, Giovanni Ávila-Flores, Solen Le Clec'h, Marcia C. Muñoz, Lovisa Nilsson, Sakshi Rana, Priyanka Sarkar, Katharina J. Sevecke & Zuzana V. Harmáčková (2019) Disentangling 'ecosystem services' and 'nature's contributions to people', Ecosystems and People, 15:1, 269-287, DOI: 10.1080/26395916.2019.1669713

Bhagwan, J (Ed). 2009. Compendium of best practices in water infrastructure asset management. Global Water Coalition. Available from the WRC Research Hub.

Census 2011 Statistical Release. 2012. Statistics South Africa. Pretoria

Cilliers, J., Cilliers, S. 2016. Planning for Green Infrastructure – Options for SA Cities. Unit for Environmental Sciences and Management North-West University, Potchefstroom. ISBN: 978-0-620-72315-2.

DAFF. 2015. National Crop Boundaries. Department of Agriculture, Forestry and Fisheries (DAFF)

Dannhauser Local Municipality, 2018. Integrated Development Plan 2018/2019. Dannhauser. Government Press

Dasgupta. P. (2010). The Place of Nature in Economic Development. Handbook of Development Economics. Volume 5, Pages 4039-5061 (2010). Chapter 74. Pages 4977-5046. Edited by Dani Rodrik and Mark Rosenzweig. ISBN: 978-0-444-52944-2.

DEA. 2018. South African National 2018 Land Cover Dataset. Department of Environmental Affairs (DEA)

Díaz S, Demissew S, Joly C, Lonsdale WM, Larigauderie A (2015) A Rosetta Stone for Nature's Benefits to People. PLoS Biol 13(1): e1002040. doi:10.1371/journal.pbio.1002040

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson R, Molnar Z, Hill R, Chan K, Baste I, Brauman K, Polasky S, Church A, Lonsdale M, Larigauderie A, Leadley P, van Oudenhoven A, van der Plaat F, Schroter M, Lavorel S, Aumeeruddy-Thomas Y, Bukvareva E, Davies K, Demissew S, Erpul G, Failler P, Guerra C, Hewitt C, Keune H, Lindley S, Shirayama Y (2018) Assessing nature's contributions to people. Science 359:270–272

Dr Pixley Ka Isaka Seme Local Muicipality, 2019. Final IDP Review 2019/20. Volksrust. Government Press

eMadlangeni Local Municipality, 2019. Final Integrated Development Plan 2019/20. Utrecht. Government Press

eNdumeni Local Municipality, 2017. Integrated Development Plan 2017/18 -2021/22. Dundee. Government Press

Food and Agriculture Organization of the United Nations (FAO), 2020. Official Website: Ecosystem Services and Biodiversity. Accessed 4 August 2020. Available at: http://www.fao.org/ecosystem-services-biodiversity

Freeman AM. 2003. The measurement of environmental and resource values: theory and methods, RFF Press.

Impendle Municipality, 2018. Draft 2018/2019 to 2021/2022 IDP. Impendle. Government Press

Haines-Young, R. and Potschin, M. (2013): Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012. EEA Framework Contract No EEA/IEA/09/003

Inkosi Langalibalele Local Municipality, 2019. Draft Integrated Development Plan Review 2019_2020. Estcourt. Government Press

IPBES (2018) Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Europe and Central Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. In: Fischer M, Rounsevell M, Torre-Marin Rando A, Mader A, Church A, Elbakidze M, Elias V, Hahn T, Harrison P, Hauck J, Martín-López B, Ring I, Sandström C, Sousa Pinto I, Visconti P, Zimmermann V, Christie M (eds). IPBES Secretariat, Bonn, Germany

KwaDukuza Municipality, 2019. Integrated Development Plan (IDP). Stanger. Government Press

Mäler, K.-G. (1991). The production function approach. In: Vincent, J.R. Crawford, E.W. and Hoehn, J.P. (Eds.). Valuing Environmental Benefits in Developing Countries. Special Report 29. Michigan State University, East Lansing, pp. 11–32.

Mandeni Municipality, 2019. Integrated Development Plan 2019 – 2020 Review. Mandeni. Government Press

Maphumulo Municipality, 2017. 2017 - 2022 Integrated Development Plan for Maphumulo Local Municipality: 2019/20 Review (Adopted). Maphumulo. Government Press

MEA (Millennium Ecosystem Assessment). 2005. Ecosystems and human well-being: current state and trends, Volume 1. Edited by R. Hassan, R. Scholes and N. Ash. World Resources Institute. Island Press, Washington.

MEA (Millennium Ecosystem Assessment). 2007. Overview of the Millennium Ecosystem Assessment. http://www.millenniumassessment.org/en/About.aspx

Mpofana Local Municipality, 2015. Integrated Development Plan 2015/16. Mooi River. Government Press

Msinga Municipality, 2018. Msinga Municipality Integrated Development Plan 2018/19 Review. Tugela Ferry. Government Press

Naidoo, N., Mülders, J., Maila, D., Harris, K., Crafford, J. 2017. Review of Socio-Economic Guidelines for Water Resource Classification and Development of an Improved Decision Support Tool. WRC Report K5/2465

Ndwedwe Municipality, 2019. Final 2019/2020 Integrated Development Plan (IDP) Review. Ndwedwe. Government Press

Newcastle Local Municipality, 2020. IDP, Budget and PMS Draft Process Plan (2020/21). Newcastle. Government Press

Nkandla Local Municipality, 2019. Nkandla IDP 2019/2020 Review. Nkandla. Government Press

Nqutu Local Municipality, 2018. Integrated Development Plan 2018/19. Nqutu. Government Press

Okhahlamba Local Municipality, 2019. Okhahlamba Integrated Development Plan 2019-2020. Bergville. Government Press

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 2006. Input output analysis in an increasingly globalised world: Applications of OECD's harmonized international tables. STI/Working Paper 2006/7. OECD.

Perrings, C. (2006). Ecological Economics after the Millennium Assessment. International Journal of Ecological Economics & Statistics (IJEES).Fall 2006, Vol. 6, No.F06; Int. J. Ecol. Econ. Stat.; 8-22

Stats SA. 2017. Census of commercial agriculture, 2017 Financial and production statistics.

Surugiu, C., 2009. The Economic Impact of Tourism. an Input-Output Analysis. Romanian Journal of Economics, Vol. 29, Issue 2/2009, pp. 142-161, Available online: http://www.revecon.ro/articles/2009-2/2009-2-8.pdf.

TEEB (2010). The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington.

TEEB. 2013. The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels; Ramsar Secretariat, Gland.

Turpie, J.K., Letley, G., Schmidt, K., Weiss, J., O'Farrell and Jewitt, D. 2020. Towards a method for accounting for ecosystem services and asset value: Pilot accounts for KwaZulu-Natal, South Africa, 2005-2011. Available at: https://seea.un.org/content/knowledge-base

uMngeni Local Municipality, 2019. Draft 2019/2020 Integrated Development Plan Review-MTREF Budget and Performance Management System Process Plan. Howick. Government Press

Umvoti Local Municipality, 2019. Umvoti Final 2019/2020 IDP Review. Greytown. Government Press

Van Deventer, H., Smith-Adao, L., Mbona, N., Petersen, C., Skowno, A., Collins, N.B., Grenfell, M., Job, N., Lötter, M., Ollis, D., Scherman, P., Sieben, E. & Snaddon, K. 2018. South

African National Biodiversity Assessment 2018: Technical Report. Volume 2a: South African Inventory of Inland Aquatic Ecosystems (SAIIAE). Version 3, final released on 3 October 2019. Council for Scientific and Industrial Research (CSIR) and South African National Biodiversity Institute (SANBI): Pretoria, South Africa. Report Number: CSIR report number CSIR/NRE/ECOS/IR/2018/0001/A; SANBI report number http://hdl.handle.net/20.500.12143/5847.

Van Seventer, D. & Davies, R. 2019. A 2016 social accounting matrix for South Africa with an occupationally disaggregated labour market representation. UNU-WIDER

WAVES. Wealth accounting and the valuation of ecosystem services. Washington: Wealth accounting and the valuation of ecosystem services, 2013. Available from: http://www.wavespartnership.org/waves/

.

APPENDIX 1: THE DECISION ANALYSIS FRAMEWORK

THE DECISION ANALYSIS FRAMEWORK

Demonstrating the linkages between ecological value and condition of the water resources and the socio-economic classification utilised an ecosystem services approach which is framed by the Decision Analysis Framework. The Framework allows for the assessment of the implications of different catchment configuration scenarios at an IUA level on economic prosperity, social wellbeing and ecological condition.

This Framework is based on the interaction of four components (as have been defined in the socio-economic status-quo report) (Figure A1):

1) Ecological infrastructure (EI);
2) Ecosystem services;
3) Human wellbeing; and
4) Economic production.

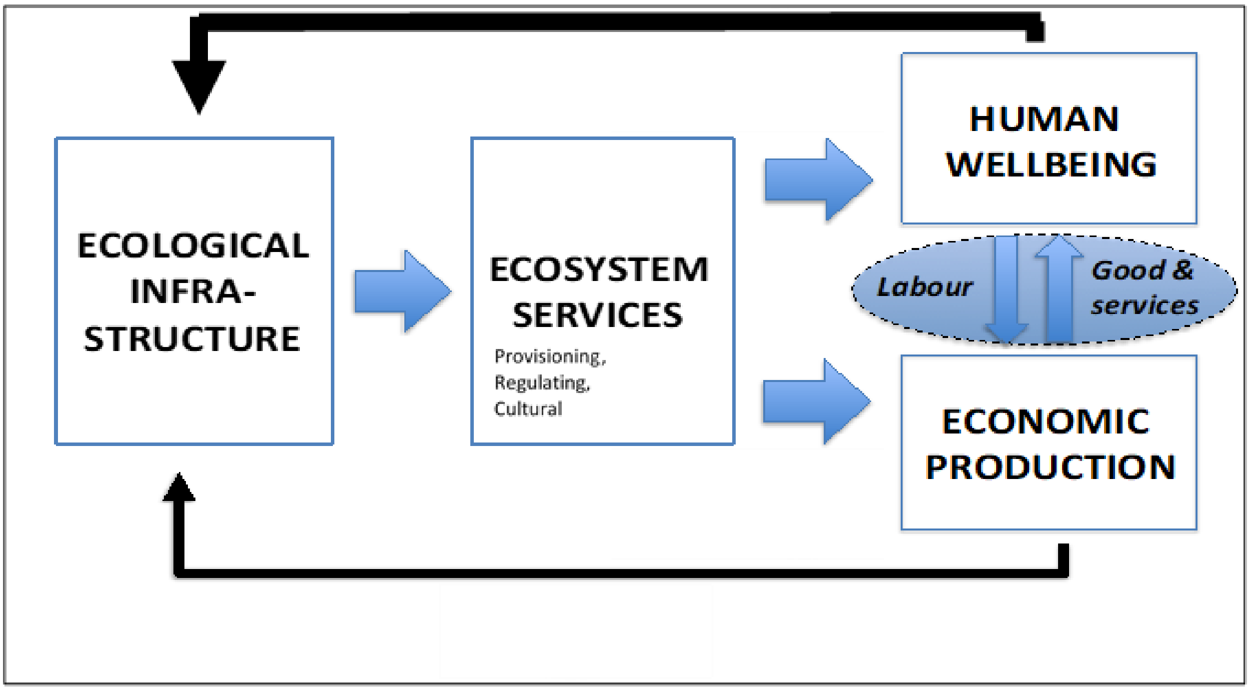

Figure A1: Schematic representation of the Decision Analysis Framework used to inform the assessment of the implications of different catchment configuration scenarios

Ecological infrastructure refers to naturally functioning ecosystems that deliver valuable ecosystem services to people, such as fresh water, climate regulation, soil formation and disaster risk reduction. In the case of catchment management, ecological infrastructure could include aquifers, wetlands and sub-catchments. The supply of ecosystem services is dependent on the type, condition and extent of the EI. EI in a good ecological condition would theoretically provide a robust flow of ecosystem services while EI in an impacted condition would deliver a less robust set of ecosystem services. The supply of ecosystem services is further dependent on the presence of beneficiaries, communities or economic sectors, in the landscape.

Figure A1 illustrates how aquatic ecosystem services are provided directly and indirectly to communities which influence human wellbeing and to the economy through providing natural services. Economic production however may have a negative impact on ecological infrastructure through activities such as over abstraction or pollution, which in turn has an impact on the delivery of ecosystem services. The same relationship exists with communities and ecological infrastructure, but to a lesser degree. The relationship between human wellbeing and economic production can be described in economic terms, with households providing labour into economic sectors, which provide goods and services in return.

The Decision Support Framework represents a significant simplification of the assessment process, and although still complex, and requires transdisciplinary collaboration.

APPENDIX 2: RESULTS OF THE QSAM FOR THE THUKELA CATCHMENT

Results of the QSAM for the Thukela catchment

Table A2: Economic indicators of the Thukela QSAM

Sector	GVA estimate R millions	Employment	Total salaries (average) R millions	Multipliers
Government	11,464	41,547	9,971	4.27
Agriculture	8,153	43,832	2,127	3.67
Hotels and restaurants	3,879	10,695	1,758	3.74
Real estate activities	3,863	1,189	285	4.55
Land transport, transport via pipe lines	3,811	6,664	1,200	3.88
Forestry	3,473	6,490	1,713	3.62
Financial intermediation	3,292	7,107	1,876	4.96
Tanning and dressing of leather	3,170	5,767	1,275	3.87
Wholesale trade, commission trade	2,774	8,794	1,445	4.00
Electricity, gas, steam and hot water supply	2,670	2,214	797	4.29
Coke oven, petroleum refineries	2,447	2,291	506	3.23
Retail trade	2,362	7,085	1,164	4.47
Construction	2,341	5,729	1,199	3.59
Other business activities	2,316	7,141	1,714	4.25
Beverages and tobacco	1,923	4,581	1,013	3.71
Footwear	1,563	5,767	1,275	3.28
Insurance and pension funding	1,561	2,942	706	5.34
Spinning, weaving and finishing of textiles	1,451	5,767	1,275	3.78
Recreational, cultural and sporting activities	1,385	3,197	767	3.96
Knitted, crouched fabrics, wearing apparel, fur articles	1,347	5,767	1,275	3.69
Health and social work	1,344	2,838	681	4.03
Sale, maintenance, repair of motor vehicles	1,254	4,064	731	4.44
Mining of coal and lignite	1,145	1,092	288	4.21
Food	1,053	2,291	506	4.01
Sawmilling, planning of wood, cork, straw	1,007	2,454	543	4.21
Paper	926	2,454	543	3.87
Auxiliary transport	806	2,255	406	3.88
Rubber	757	2,291	506	3.50
Education	705	1,239	297	4.18
Non-metallic minerals	597	1,473	326	3.44
Manufacturing n.e.c, recycling	423	491	109	3.64
Collection, purification and distribution of water	321	409	98	5.08
Air transport	310	541	97	3.48
Non-observed, informal, non-profit, households,	254	30,425	91	4.09
Basic precious and non-ferrous metals	239	736	163	3.92

Sector	GVA estimate R millions	Employment	Total salaries (average) R millions	Multipliers
Activities to financial intermediation	220	4,954	149	5.48
Electrical machinery and apparatus	212	884	195	3.48
Machinery and equipment	212	736	163	3.59
Basic iron and steel, casting of metals	210	736	163	3.97
Research and experimental development	204	317	76	4.18
Other chemical products, man-made fibres	184	764	169	3.61
Plastic	184	764	169	3.62
Mining of metal ores	178	217	78	3.91
Fabricated metal products	175	736	163	3.88
Glass	171	764	169	3.79
Post and telecommunication	167	280	67	3.66
Renting of machinery and equipment	148	291	70	4.49
Furniture	139	491	109	3.97
Motor vehicles, trailers, parts	131	491	109	3.17
Other transport equipment	122	491	109	3.50
Other mining and quarrying	108	858	45	4.18
Computer and related activities	76	280	67	3.83
Activities of membership organisations	34	68	16	4.20
Other activities	30	66	16	4.18
Radio, television, communication equipment and apparatus	28	98	22	3.31
Sewerage and refuse disposal	18	30	7	4.27