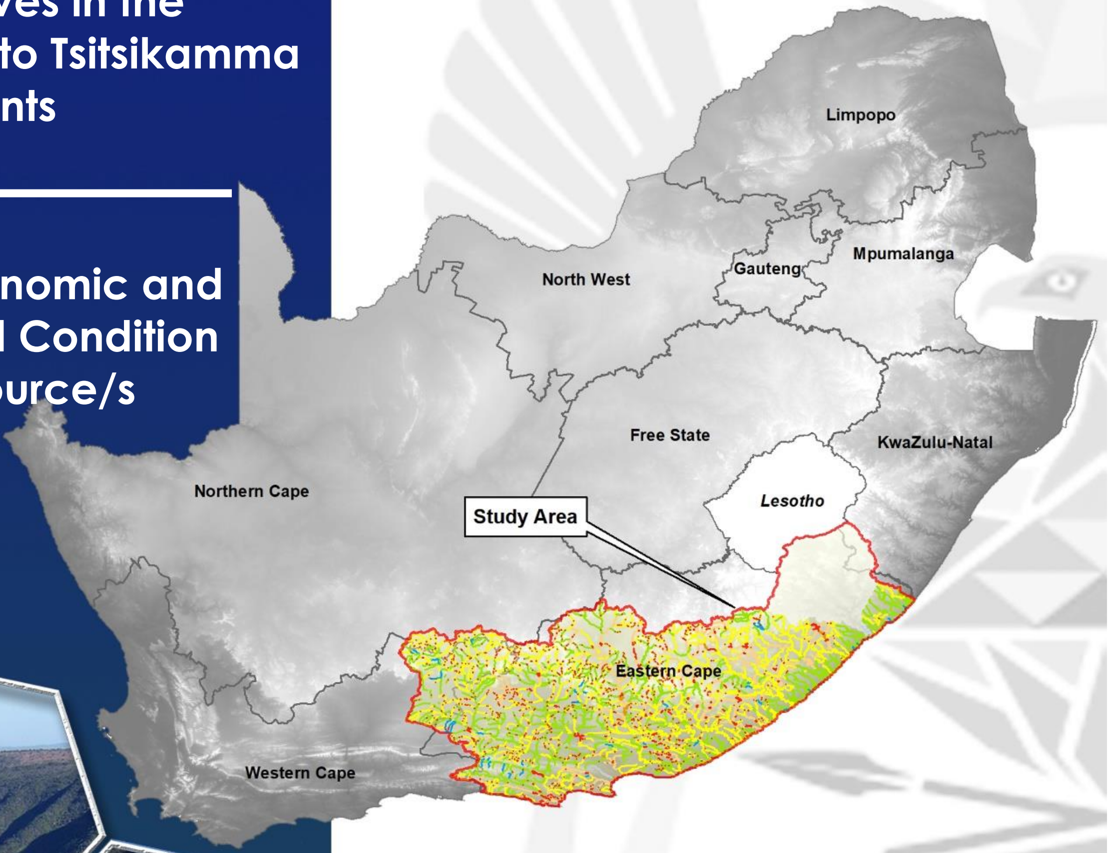
DEPARTMENT OF WATER AND SANITATION

Determination of Water Resource Classes, Reserve and the Resource Quality Objectives in the Keiskamma and Fish to Tsitsikamma Catchments

WP11354
Linking the Socio-Economic and Ecological Value and Condition of the Water Resource/s



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Executive Summary

The Department of Water and Sanitation, through the Chief Directorate: Water Ecosystems Management (CD: WEM), has initiated a study for the determination of Water Resource Classes, Reserve and associated Resource Quality Objectives for the identified significant water resources in the Keiskamma and Fish to Tsitsikamma catchments. The water resource components included for this study are rivers, wetlands, groundwater and estuaries. The Reserve determination includes both the water quantity and quality of the Ecological Water Requirements (EWR) and Basic Human Needs (BHN). This will ensure the availability of water required to protect aquatic systems and that the essential needs of individuals that are directly dependent on these water resources.

In terms of the water resource classification process, Step 2 requires that the quantification of the relationships that link the change in the configuration of scenarios to a resulting change in economic value and social wellbeing, be defined. This includes rationalisation of those values, by selecting a subset on which efforts can be concentrated for evaluating catchment configuration scenarios and, determination of the scoring system to be used to evaluate the catchment scenarios in later steps of the process. This report addresses these three objectives by demonstrating the linkages methods between the socio-economic and ecological value and condition of water resources as they currently stand in the Keiskamma and Fish to Tsitsikamma catchment.

The majority of the study area falls within the Eastern Cape province, with small portions in 2 Local municipalities from Western Cape (Beaufort West and George LM) and one local municipality from Northern Cape (i.e., one ward in Ubuntu LM). The population of the catchment was 5.87 million in 2021 (2011 Stats SA census adjustments) and the population is predominately Xhosa speaking. According to Stats SA Community Survey 2016, the Eastern Cape had the highest households with no access to piped water, at 24.9% and nationally it was at 10.1%.

Keiskamma and Fish to Tsitsikamma catchment is mainly rural with a few urban areas in East London, Gqeberha (Port Elizabeth), and Makhanda (Grahamstown). According to Stats SA 2021, the Eastern Cape had the highest unemployment rate, at 47.1% and nationally it was at 34.9%. The province also had the highest agricultural households, at 27.9% and nationally it was at 13.8%. Subsistence agriculture is mainly livestock, poultry, food crops and vegetable production.

The Eastern Cape contributed a GDP of approximately R312 billion in the second quarter of 2021 which is a contribution of 7.7% to the total national GDP (ECSECC, 2021). The economy is mainly supported by the tertiary sector (wholesale and retail trade, tourism and communications), followed by the sectors of manufacturing (large proportion by the automotive subsector), agriculture and agro-processing. In 2020 the tertiary sector accounted for 80.8% of the provincial gross value added (GVA) and the secondary sector 17.3% (largely the automotive manufacturing sector), followed by the primary sector (agriculture and to lesser extent mining) accounting for 1.9% (ECSECC, 2020).

As a highly rural catchment, ecosystem services have been demonstrated to provide significant contributions to socio-economic wellbeing to both formal and informal economy beneficiaries within the catchment.

Ecosystem services linked to the socio-economics of the Keiskamma and Fish to Tsitsikamma were identified to include the following:

1. Fresh water provisioning;
2. Water quantity regulating;
3. Food, raw materials and wild collected products provisioning;
4. Erosion regulation;
5. Water quality regulation: purification and waste management;
6. Spiritual, landscape and amenity services;
7. Tourism and recreational services; and
8. Biodiversity support.

Predominant ecological infrastructure identified to supply these services included estuaries; national parks (i.e., Addo Elephant and Camdeboo, and Mount Zebra); the water source infrastructure itself; represented mainly by surface waters of rivers and streams; groundwater and wetlands and grasslands.

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

Although it is understood that economic productivity of key sectors is not fully reliant on ecosystem services, it is acknowledged that a proportion of the output be attributed directly to the services provided by ecological infrastructure within the catchment. This is especially true for the water provisioning services provided in a strategic water source area such as the Keiskamma and Fish to Tsitsikamma.

Findings show that the agriculture and agricultural manufacturing sectors contribute significantly to the formal water economy through their purchases of both raw and treated water. This provides some indication of the level of reliance of these industries on water provisioning, although care should be taken in interpreting these results, as the contribution to the water economy, in financial terms, does not directly link to the volume of water required by each sector. Households, for instance, represent the largest purchasers of water in monetary terms, even though the agricultural sector consumes a larger portion of volume. This raises interesting challenges for the overall valuation of these ecosystem services.

Careful consideration should be given to the impact a change in ecosystem services may have on the livelihoods of these communities, as this catchment is mainly rural. This will be further expanded upon as scenarios come into focus.

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LIST OF ACRONYMS

BHN	Basic Human Needs
CBA	Critical Biodiversity Areas
CD: WEM	Chief Directorate: Water Ecosystems Management
CRA	Comparative Risk Assessment
CVB	Channelled valley bottom
DRDLR	Department of Rural Development and Land Reform
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EFZ	Estuarine Functional Zone
EI	Ecological Importance
EIS	Ecological Importance and Sensitivity
ES	Ecological Sensitivity
ESA	Ecological Support Areas
EWR	Ecological Water Requirements
FEPA	Freshwater Ecosystem Priority Areas
FSA	Fish Support Area
GDP	Gross Domestic Product
GIS	Geographic Information System
GW	Groundwater
HGM	Hydro-geomorphic
IBA	Important Bird Areas
IES	Integrated Estuary Score
IUA	Integrated Unit of Analysis
LSRWUA	Lower Sundays River Water User Association
MAP	Mean Annual Precipitation
MPA	Marine Protected Areas
NBA	National Biodiversity Assessment
NMBM	Nelson Mandela Bay Municipality
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act
NWM5	National Wetland Map 5
PES	Present Ecological State

RDM	Resource Directed Measures
RQO	Resource Quality Objectives
RU	Resource Units
SANBI	South African National Biodiversity Institute
SWSA	Strategic Water Source Areas
SW	Surface water
UVB	Unchannelled valley bottom
WARMS	Water use Authorization and Registration Management System
WCDS	Waste Discharge Charge System
WMA	Water Management Area
WR2012	Water Resources 2012
WRC	Water Research Commission
WRCS	Water Resources Classification System
WSS	Water Supply System
WWTW	Wastewater Treatment Works
IEM	Integrated Economic Model

1. Rationale

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. Informed 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 Keiskamma and Fish to Tsitsikamma 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, Water Accounts and Quasi-Social Accounting Matrix (QSAM) for the Keiskamma and Fish to Tsitsikamma catchment. The results were the development of an Integrated Economic Model (IEM) for the Keiskamma and Fish to Tsitsikamma 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 WRCS 7 step 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

Please note: This linkage step will be used to inform the evaluation of scenarios at a later stage in the WRCS process, this step aimed to develop the IEM and demonstrate linkages between the ecological and the socio-economic baseline in the Keiskamma and Fish to Tsitsikamma catchment.

The broad approach taken to develop the IEM is provided in Figure 2-1. Key inputs, components and outputs of the process include the following:

1. 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;
2. The ecological responses to change in development scenario, which in this case are quantified change to hydrological (flows) and ecological (condition) indicators;
3. 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;
    a. The ecosystem services valuation model aims to link the presence and condition of ecological infrastructure with key beneficiaries through the use of ecosystem services frameworks;
    b. The Water/water Quality Account module aims to define the use of water through physical flows and financial transactions. This allows analysis on how economic changes impact the environment and conversely how changes in water availability/quality impact the economy;
    c. The QSAM module aims to quantify the size of the Keiskamma and Fish to Tsitsikamma 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 Keiskamma and Fish to Tsitsikamma economy.
4. 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.

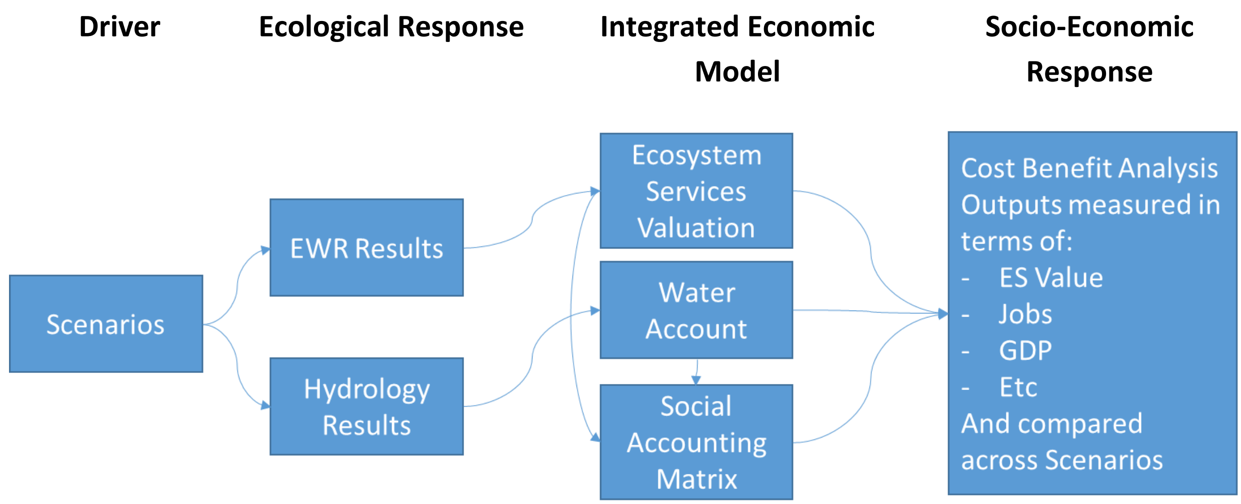

Figure 2-1: Approach to the development of the Integrated Economic Model that Demonstrates the Socio-Economic Linkages in the Keiskamma and Fish to Tsitsikamma Catchment (Arrows indicate flow of data from input to output)

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 WRCS 7 step 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 Framework Selection

Since the inception of the Millennium Ecosystem Assessment in 2005, several frameworks have been developed to better categorize and disaggregate the benefits that people receive from ecosystem services, enabling a full evaluation of their economic value. These include the framework created by the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019), The Economics of Ecosystems and Biodiversity (TEEB, 2010), and the Common International Classification of Ecosystem Services (CICES, 2013). (Frameworks are described in Table 2-1). While each of these frameworks attempts to build upon one another, they essentially follow a similar logic, where ecosystem services and the benefits derived therefrom 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 largescale 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. The ecosystem services that were considered in this analysis are as per **TEEB Framework** (TEEB 2013).

Table 2-1: 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
- fibre
- Fuel wood
- Genetic resources
- Biochemicals
	Provisioning Services
	- Food
	- Fresh water
	- Raw materials
	- Genetic resources
	- Medicinal resources
	- Ornamental resources
		Provisioning
		- Nutrition
		  ◦ biomass
		  ◦ water
		- Materials
		  ◦ biomass, fibre
		  ◦ water
		- Energy
		  ◦ biomass based energy sources
		  ◦ 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
		- Mediation of flows
		  ◦ Mass
		  ◦ Liquids
		  ◦ gaseous/airflows
		- Maintenance of physical, chemical and biological conditions
		  ◦ lifecycle maintenance, habitat and gene pool protection
			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

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)
		◦ pest and disease control ◦ soil formation and composition ◦ water conditions ◦ atmospheric composition and climate regulation	- Regulation of freshwater and coastal water quality Formation, protection and decontamination of soils and sediments Regulation of hazards and extreme events 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 ◦ Physical and experiential interactions ◦ Intellectual and representational interactions - Spiritual, symbolic and other interactions with ecosystems and land-/seascapes ◦ Spiritual and/or emblematic ◦ 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

2.2 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, form the focus of the module. The Socio-Economic Comparison Tool (SEcT) (Naidoo et al. 2017) is used as the platform from which to frame relationships between various components. Although inputs draw largely from data collected (and presented) in the status-quo report (DWS,2022), additional data inputs were identified and included where necessary. Key data that are used as inputs into the module include the following:

1. The presence of Ecological Infrastructure (EI) segregated into type, extent and condition per IUA;
2. 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;
3. 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 will be prioritised against the risk of impact on socio-economic wellbeing through impact to ecological infrastructure. The process involves undertaking a Comparative Risk Assessment (CRA) 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 study area.

2.3 Q-SAM

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 though which the impact of water resource management scenarios can be evaluated.

A Keiskamma and Fish to Tsitsikamma Quasi-Social Accounting Matrix (QSAM) was developed with the aim to quantify the size of the Keiskamma and Fish to Tsitsikamma economy. The QSAM module was developed from the Supply and Use tables published by Statistics South Africa (Stats SA) in March 2022 for the year 2019. 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 Keiskamma and Fish to Tsitsikamma catchment economy.

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

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

Indicator	Unit	Description
Gross Value Added (GVA)	Rand Millions	Economic productivity metric measuring the contribution of Keiskamma and Fish to Tsitsikamma 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 Keiskamma and Fish to Tsitsikamma catchment is illustrated in Figure 2-2 below.

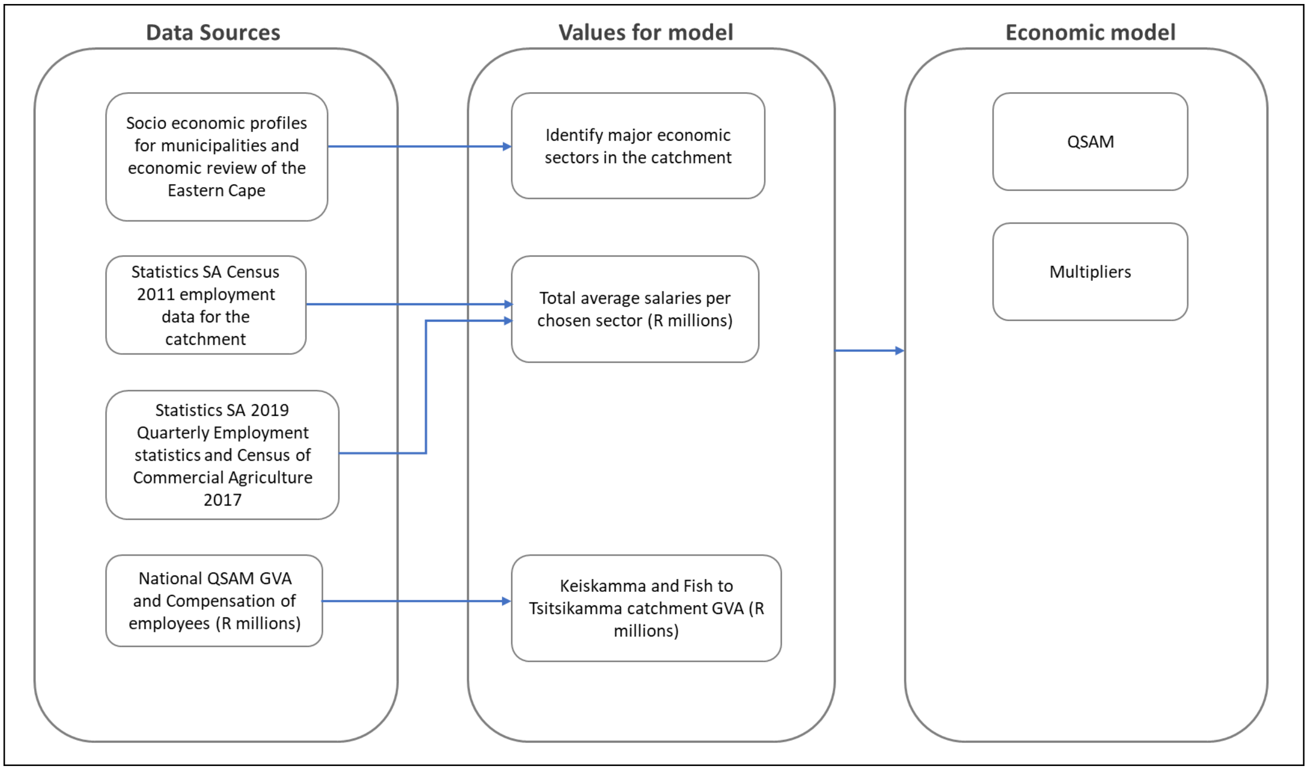

Figure 2-2: Schematic representation of the methodology used for the economic model development

The major economic sectors of the Keiskamma and Fish to Tsitsikamma 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 Keiskamma and Fish to Tsitsikamma GVA was determined per sector based on the national QSAM GVA to compensation of employees' proportion. These values were used to construct the Keiskamma and Fish to Tsitsikamma 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.

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3. Results

3.1 Ecosystem Services in the Keiskamma and Fish to Tsitsikamma catchment

The catchment is divided into 19 Integrated Unit of analysis (IUAs). These IUAs 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 IUA 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., Water Use Authorisation or municipality to extract or use water). The formal beneficiaries in the catchment include municipalities, agricultural, manufacturing, mining, government services, power generation, 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.

The consequences on ecosystem services flow of management may vary between each beneficiary type. The 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 that these scenarios may have on the flow of ecosystem services. Please note: 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 Keiskamma and Fish to Tsitsikamma catchment include:

1. Fresh Water Provisioning;
2. Water Quantity Regulation;
3. Food, Raw Materials and Wild Collected Products Provisioning;
4. Erosion Regulation;
5. Water Quality Regulation: Purification and Waste Management;
6. Spiritual, Cultural, Landscape and Amenity Services;
7. Tourism and Recreational Services; and
8. Biodiversity Support.

3.1.1 *Fresh Water Provisioning*

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

Water provisioning is a predominant ecosystem service provided to beneficiaries within the Keiskamma and Fish to Tsitsikamma catchment. There are a range of formal and informal beneficiaries of the fresh-water provisioning service.

There are several large and small dams within the catchment and these provide mainly for irrigation, but also for local domestic and rural water use purposes. Commercial agriculture is a large consumer of water in the catchment and the sector is predominantly situated on the coastline (i.e., region P, K, N M, L9), except for the Fish River (Q catchment) with large areas of irrigation along the mainstem and lower reaches of the tributaries. While annual crop cultivation relies primarily on seasonal rains, irrigated agriculture is largely dependent on water abstraction from dams, rivers and streams as well as the transferred water from Gariep Dam (Upper Orange) to the Great Fish, Little Fish and lower Sundays Rivers. The estimated total area that is under irrigation is just under 133,000ha. The rest of the agricultural land within the catchment falls under dryland, grazing or subsistence agriculture (this may be informally irrigated). Irrigation represents one of the main water users within the catchment with approximately 797 million m^3 /a (based on WR2012 and consumption rates) water being supplied through various irrigation schemes. Irrigated agriculture is situated within all of the IUA's, apart from IUA 17, 18 and 19 which include the lower Mbashe, lower Mthatha and the Pondoland coastal Rivers.

Subsistence agriculture, while it is likely to consist mainly of annual crops, may contain a mixture of dryland and irrigated crops. The irrigation supplied to these crops is likely informal, which requires the manual transfer of water from streams or rivers to the fields. The catchment has a notable subsistence agriculture area, with large areas covering the eastern region (I, e., T and S regions) of the catchment.

The Keiskamma and Fish to Tsitsikamma catchment is home to a population of approximately 6 million people which represent the beneficiaries that use water. 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 largely concentrated around cities and towns.

The catchment is mainly rural with a few large urban areas in East London, Gqeberha, Mthatha and Makhanda. A significant proportion of the rural 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 WWTWs (48 plants in critical state according to 2021 Green Drop assessment) or inefficient distribution infrastructure. For those people that rely on sourcing their water directly from rivers and streams (i.e., predominately in region T and parts of the S catchment), the condition and flow in these source channels are vitally important.

There are two key industrial hubs within the Keiskamma and Fish to Tsitsikamma catchment located in the Buffalo City Metropolitan Municipality and the Nelson Mandela Bay Metropolitan Municipality areas. Two of South Africa's Special Economic Zones (SEZ) are located here, East London Industrial Development Zone (supported by the Port of East London) and the Coega Industrial Development Zone (at the Port of Ngqura in Gqeberha). Both areas have well-established manufacturing industries, with the automotive industry playing a significantly large role. The wide range of heavy, and light manufacturing and commercial activities taking place, all require a constant, uninterrupted supply of water, which is generally supplied through formal municipal water distribution systems. Due to the large size of the agricultural industry in the catchment, it is likely that agriculture related manufacturing also represents a large proportion of water allocation as required for production.

The mining operations within the catchment are predominantly quarrying, mineral and sand mining. It should be noted that sand mining may pose a threat to estuary condition, and this particularly affects IUA_M01 in the Gqeberha and IUA_T03in the Lower Mthatha.

The largest water transfer into the catchment is the water transferred into the catchment from the Gariep Dam to the upper reaches of the Great Fish River. This water is used mainly for irrigation and some domestic use by towns. Water is also transferred to lower Sundays River for irrigation (Darlington Dam)

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, may have a significant impact on some informal water users, although most of these rely on smaller tributaries above the main water courses or groundwater. Similarly, the state of formal water distribution infrastructure will influence the flow of these water provisioning benefits to their final intended beneficiaries.

Water availability also has an impact on several hydropower stations in the catchments. The stations are non-dispatchable hydro power stations, which means they cannot be turned on or off to meet fluctuating electricity needs. While primarily peaking stations, they also operate as base load when water is available. They further impact on the ecology of the associated rivers through changes in seasonality and/or constant flows that are released from dams for the operation of the hydropower stations. The hydropower stations in the study area are two stations on the Mthatha River (T2 catchment), and during dry season the flow of the stations is augmented by releases from Mthatha Dam. There are additional stations on the Mbashe River (T1 catchment) supplemented by water transferred from the Tsomo River (S5 catchment)and one hydropower station downstream of Ncora Dam on the Tsome River.

3.1.2 *Water quantity regulation (Flow Regulation)*

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

Key ecological infrastructure:	Wetlands, Surface & Groundwater Strategic Water Source Areas (SWSAs)
Beneficiaries:	Households, Agriculture, Industry, Aquatic Ecosystems
Use:	Indirect use value

Water quantity regulation is an ecosystem service provided by ecosystems within the Keiskamma and Fish to Tsitsikamma catchment. The catchment contains several Strategic Water Source Areas 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 Strategic Water Source Areas (SWSAs). Strategic Water Source Areas (SWSAs) are defined as areas that supply a disproportionate amount of mean annual runoff to a geographical region of interest. These SWSAs represent key ecological infrastructure in this regulating service. Other ecological infrastructure associated with water quantity regulation includes wetlands and aquifers that are found within or downstream of the SWSAs.

Domestic users require a constant supply of water throughout the year. This is mostly facilitated by municipal infrastructure. However, there is a large proportion of households in the catchment that rely on rivers and streams or groundwater for their daily water needs. Groundwater usage in this catchment is relatively high, and according to DWS WARMS database, the larger users appear to be focussed on the western half of the catchment, particularly in the Karoo, as well as the southern coastal areas. Groundwater use of >1 000 000m^3/annum is associated with town supply to towns of Pearston, Middelburg, Graaff-Reinet and Aberdeen. Several towns rely solely on groundwater and these include Nieu-Bethesda, Aberdeen, Jansenville, Riebeeck East, Alexandria, Boknes, Cannon Rocks, Paterson, Kenton-on-Sea, Tarkastad, Hofmeyr, Steynsburg and Middelburg. Current estimated groundwater use for the catchment is 149Mm^3/annum.

The ecosystem service of water flow regulation is particularly important for these users (i.e., region N, L, S, and T), 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 commercial agricultural activity of dryland crop cultivation in the Keiskamma and Fish to Tsitsikamma catchment 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 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 the base flows and floods that are 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. The assessment of the consequences of management/ development scenarios on water requirements of the aquatic ecosystems as well as the user requirements are undertaken as part of the trade-off task utilising the linkages identified in this report.

3.1.3 *Erosion control/Soil Stability*

Key ecological infrastructure:	**Grasslands, Wetlands, Forests, Rivers, Estuaries**
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. Soil stability is of vital importance throughout the catchment, with some IUAs being of particular significance for the prevention of erosion to protect food and water security. Any regions within the catchment with potentially erosive soils will be considered in the risk assessment to follow during the scenario evaluation step.

This may be in IUAs that 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 and the associated riparian areas. 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 to the acceptable discharge standards 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, 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 Keiskamma and Fish to Tsitsikamma catchment include the wetland systems.

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; Estuaries**
Beneficiaries:	Rural households, subsistence agriculture, agricultural sector (livestock grazers)
Use:	Direct use value

With both commercial and subsistence agriculture being widespread throughout the Keiskamma and Fish to Tsitsikamma catchments, the ability of the land to provide food provisioning services is of major importance to the region. Fertile soil, along with sufficient water, as discussed above, provides the ideal conditions for food cultivation. Grasslands also provide grazing for livestock, which is of particular importance to subsistence farmers.

There are several commercially productive areas in the Keiskamma and Fish to Tsitsikamma catchment. 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 one of the main economic drivers 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 the region. This is likely largely comprised of staple crop and vegetable cultivation, as well as widespread grazing of cattle and goats.

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.

There are 251 coastal drainage systems within the study area, comprising 154 estuaries and a further 97 microsystems. A large number of estuaries are adjacent to Marine Protected Areas (MPA). Estuarine system attributes to important regulating services.

- Habitat type and extent, in particular with respect to primary production;
- Salinity regulation; with respect to species diversity; and
- Nutrient cycling, with respect to primary production.

Nutrient levels strongly influence fish stock (i.e., fish biomass and biological production). Fresh water systems therefore plays an important functional biodiversity role in connecting terrestrial and estuarine system processes and components to marine-based species dynamics.

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 river mouth estuaries. 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, protected areas and the coastline**
Beneficiaries:	Households, real estate activities
Use:	Direct use value

A significant portion of the Keiskamma and Fish to Tsitsikamma catchment 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 Xhosa people being linked to the greater region, while also holding historical value for other groups of South Africans as well.

Areas with clusters of rural settlements and land tenure patterns are expected to hold significant existence value for the local communities. 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.

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. IUAs exhibiting value in this regard include those close to nature reserves or scenic areas and those with coastal properties (i.e., Addo Elephant, Tsitsikamma, Garden Route, Mountain Zebra)

Primary Catchment L includes a portion of the Cape Floral Region which is a World Heritage Site. This results in key policies attributed to this region governing the protection of cultural and natural heritage.

3.1.7 *Recreational and Ecotourism*

Key ecological infrastructure:	**Rivers, wetlands, dams, protected areas, estuaries, 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 Keiskamma and Fish to Tsitsikamma catchment. 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, namely business, historic and eco-tourism. The business tourism, although it 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 Buffalo City and Nelson Mandela Bay. Historical tourism, including memorials or museums or other historic sites, 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 Protected Areas (government and private) and along the coast.

The Keiskamma and Fish to Tsitsikamma catchment includes several national parks, nature reserves (provincial and private), protected areas and heritage sites which all contribute towards attracting tourists to the region. The National Parks include Addo Elephant in IUA 6 (IUA_N01), Tsitsikamma and Garden Route in IUA 1 (IUA_K01), and Mountain Zebra in IUA 9 (IUA_Q02) and are a significant asset, drawing a tourists, both domestically and from around the world. Provincial Nature Reserves include Mkambati in IUA 19 (IUA_T04), Hluleka, Dwesa-Cwebe in IUA 17 (IUA_T02), Hamburg in IUA 11 (IUA_R01), Great Fish in IUA 9 (IUA_Q02), Mpofu, Groendal in IUA 4 (IUA_M01), Baviaanskloof in IUA 3 (IUA_L01), Formosa IUA 1 (IUA_K01), and Doubledrift. The Private Nature Reserves include for example Black Eagle Nature Reserve.

Aquatic recreational activities such as boating, river rafting, kayaking, fishing, and diving (mostly the estuary areas) also attract tourists and holiday makers to both inland and coastal aquatic systems within the greater catchment.

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 have aspirations 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 and quality 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 estuaries, and thus their 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. 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 in various IUAs. The estuaries within the catchment, represent significant features that play 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 or constant flows (i.e. Great Fish River) 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 estuaries, and thus their 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 3-1). 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 3-1: Ecosystem Service linkages with QSAM beneficiaries in the Keiskamma and Fish to Tsitsikamma catchment

Intermediate Ecosystem Service	Final Ecosystem Services	General Sector	QSAM Beneficiary Class
• Water Quality Regulation • Water Quantity Regulation • Erosion and Soil 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
			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	Other mining and quarrying
		Government Services	Electricity, gas, steam and hot water supply

Intermediate Ecosystem Service	Final Ecosystem Services	General Sector	QSAM Beneficiary Class
			Collection, purification and distribution of water
			Sewerage 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 WRCS 7 step process, will be conducted during the scenario evaluation step. The scenarios will include a range of management and ecological 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 scenarios 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.

Ecosystem service types will be valued broadly following the MA and CICES frameworks and results of the valuation will be summarised. An example of the structure is provided in the table below.

Table 3-2: Ecosytem valuation step, post CRA process

Class	Ecosystem Service	Annual Flow Value R millions / annum	Asset Value R millions
Provisioning	1. Wild Resources	Values to be estimated	Values to be estimated
	2. Animal production		
	3. Cultivation		
Cultural	4. Nature-based tourism		
	5. Property value		
Regulating	6. Carbon storage and sequestration		
	7. Pollination		
	8. Flow regulation (maintenance of base flows)		
	9. Sediment retention		
	10. Water quality amelioration		
	11. Flood attenuation		

The total value of ecosystem services will be estimated and compared to the provincial GDP and the key sectors as beneficiaries (proportion in percentage) will be determined. Sectors are likely to include the agriculture, forestry and fisheries, households, the environment, trade, catering and accommodation. These proportions will 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 will further provide information on the magnitude of support that natural services provide to the socio-economics of the catchment.

3.3 Quasi-Social Accounting Matrix Module

The majority of the study area falls within the Eastern Cape Province. The Eastern Cape contributed a GDP of approximately R312 billion in the second quarter of 2021, which is a contribution of 7.7% to the total national GDP (ECSECC, 2021Q2). The GDP of Keiskamma and Fish to Tsitsikamma contributed an estimated R280 billion based on 2016 ECSECC municipal economic data.

Table 3-3 shows that in the Keiskamma and Fish to Tsitsikamma catchment the largest contribution to GVA is from the government sector which represents 26% of the Keiskamma and Fish to Tsitsikamma economy. Financial services, trade and industry and manufacturing sectors contributed 20%, 19% and 12% respectively to the Keiskamma and Fish to Tsitsikamma GDP. Agriculture plays a minor role in the catchment and its GVA contributes 1.5% to the Keiskamma and Fish to Tsitsikamma economy. The QSAM and multipliers will be used in evaluating the various scenarios based on the relevant expenditures per sector for each scenario.

Table 3-3 The Keiskamma and Fish to Tsitsikamma GDP per sector (preliminary based on data from ECSECC, 2016)

Economic Sectors	GVA contribution (R billions) based on 2016 GDP data	Percentage contribution
Agriculture	4	1.5%
Mining	0.4	0.1%
Manufacturing	34	12%
Electricity	6	2%
Construction	12	4%
Trade	52	19%
Transport	25	9%
Finance	55	20%
Community services	73	26%
Other	20	7%
Total GDP	279	

In 2021Q2 the tertiary sector accounted for 81.4% of the provincial gross value added (GVA) and the secondary sector 16.7% (largely the automotive manufacturing sector), followed by the primary sector (agriculture and to lesser extent mining) accounting for less than 2% (ECSECC, 2021Q2).

In the Eastern Cape, the Sarah Baartman district municipality region (Kouga, Kou-Kamma, Dr Beyers Naude, Sundays River Valley, Blue Crane Route, Makana and Ndlambe local municipalities) has the largest contribution to the national commercial agriculture income at 3.9% (Stats SA, 2020). The Eastern Cape accounts for 12.3% in terms of land use area of the national commercial agricultural land.

4. Demonstrating linkages

The Keiskamma and Fish to Tsitsikamma 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 Keiskamma and Fish to Tsitsikamma catchment contributes an estimated R279 billion (preliminary based on data from ECSECC, 2016) to the economy of South Africa. This economy is relatively small representing only 5.8% of the national GDP of R4.8 trillion (Stats SA 2018). The largest sectors include the government sector, agriculture, hotels, restaurants and real estate, and manufacturing activities which represent 26%, 20%, 19% and 12% contribution to the catchment total GVA respectively.

The links of economic sectors to ecosystem services 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. Although the value added by the 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 Keiskamma and Fish to Tsitsikamma catchment. 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. 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 Keiskamma and Fish to Tsitsikamma catchment. The agriculture sector, by total GVA, is the largest sector within the catchment that relies heavily on water provisioning services. The sector contributes R 4 billion to the Keiskamma and Fish to Tsitsikamma total GVA.

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 linkages with cultural ecosystem services provided by key ecological infrastructure have direct linkages to the presence of ecological features associated with tourism and recreational activities, such as estuaries, national parks (i.e., Addo Elephant and Camdeboo, and Mount Zebra) and other nature reserves (both government and private). This sector is part of the total Trade sector which makes a large contribution of R52 billion to catchment GVA.

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. 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. Conclusion

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 5-1):

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

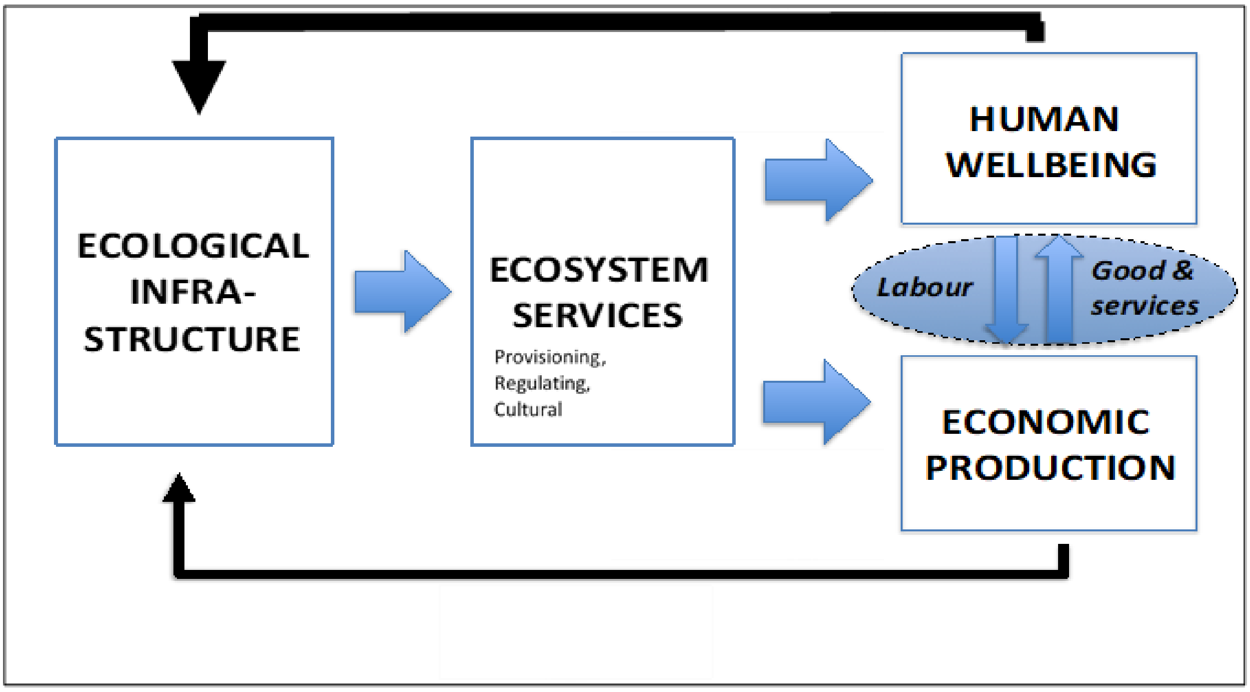

Figure 5-1: Schematic representation of the Decision Analysis Framework used to inform the assessment of the implications of different catchment configuration scenarios

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 5-1 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.

6. *Way Forward*

6.1 Ecosystem Services Valuation: Comparative Risk Assessment

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 WRCS 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 the water resource class per IUA.

The process involves undertaking a Comparative Risk Assessment (CRA) per IUA looking at the likelihood and consequences of impacts to beneficiaries. The resulting output is a prioritised list of Ecosystem Services that are spatially aggregated across the study area.

The CRA process involves defining the following linkages in the chain of causality:

1) **Environmental hazard:** The environmental hazard is the environmental stressor which drives change. The hazard is identified as the input which initiates the chain of causality and is determined through the changes initiated through varying scenarios. Examples in this case include decreased surface water flow through abstraction from rivers. Note the environmental hazard would vary between ecological infrastructure and across scenarios.

2) **Environmental effect statement:** The environmental effect statement describes the physical impacts that the environmental hazard has on specific ecological infrastructure. In line with the example above, this would describe that decreased surface water flow would modify natural flow processes and restrict primary productivity within the channel and riparian areas.

3) **Risk rating of ecosystem services.** The risk to the flow of ecosystem services is assessed in terms of the likelihood and consequences of impact by the identified environmental effect on the specific ecological infrastructure providing the service. The process is further detailed below:

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

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

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

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

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

The likelihood of an impact is the change in possibility that a specific scenario will have an impact on the EI and therefore the benefits received. The likelihood rating framework can be seen in Table 6-1. The consequence of the scenario is the change in the service from the environmental effect of the scenario on the exposed EI. A consequence rating framework can be seen in Table 6-2. Likelihood and consequence categories are chosen for each ES. It is important that the certainty is recorded to ensure transparency of the level of confidence in categories chosen. Risks are then automatically ranked according to risk levels (see Table 6-3). A description of each risk is given (Risk Statement) which includes the underlying chain of causality between environmental effect and its consequence to ensure transparency of the ranking process.

Table 6-1: Qualitative and quantitative classes of likelihood of impacts (environmental effect, or resultant change in the flow of an ecosystem service) of a scenario having an ecological consequence to a service from EI. Adapted from the classification adopted by the IPCC (2007)

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

Table 6-2: Qualitative measures of consequence to ecosystem services arising from impacts linked to scenarios. Adapted from the classification adopted by the IPCC (2007)

Consequence rating	Level of consequence	Environmental effect
Severe	1	Substantial permanent loss of environmental service, requiring mitigation or offset.
Major	2	Major effect on the EI or service, that will require several years to recover, and substantial mitigation.

Moderate	3	Serious effect on the EI or service, that will take a few years to recover, but with no or little mitigation.
Minor	4	Discernable effect on the EI or service, but with rapid recovery, not requiring mitigation.
Insignificant	5	A negligible effect on the EI or service.

Table 6-3: Levels of risk, assessed as the product of likelihood and consequence in the event of an environmental effect on EI. Adapted from the classification adopted by the IPCC (2007)

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

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

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

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

6.1.1 *Water Quality Account*

Water Quality account provides information on the state of the quality of water resources. Water quality account assists in reporting consequences of economic development that results in ecological degradation. The account will only be developed should there be a scenario that requires incorporating impact water quality in the catchment's economy.

Water quality relates to two types of regulating ecosystem services: water purification and waste assimilation. In the first instance, aquatic ecosystems have a natural ability to purify water and can therefore receive polluted water up to a certain threshold. Beyond that threshold it is not able to "treat" water, however, it can still function as a sink for pollutant load, hence the waste assimilation service. The waste assimilation service is a unique form of ecosystem service in that nature consequently serves as a "waste disposal area" for pollution load produced by anthropogenic activities. In both instances, we are dealing with the effects of water pollution on the economy.

Two broad approaches exist for internalising the effects of poor water quality into the economy. The first requires the analysis of damage caused by water pollution. This could include increased treatment costs downstream, reduced agricultural production, higher costs of maintenance, increased risk of water-related health costs, and so forth.

The second approach estimates the costs of treating polluted water and/or effluent to acceptable limits. The first approach is a bottom-up highly site-specific, and highly data intensive. The second approach is a top-down approach and is better suited to the WRCS process.

Water pollution abatement costs can be estimated if a marginal abatement cost curve is available. Such a curve is a multivariate mathematical-statistical function, which should ideally be developed, based on empirical data sourced from the particular catchment area within which the pollution problem is located. The marginal abatement cost curve relates a set of independent variables to the cost of water pollution abatement. The Waste Discharge Charge System (WDCS) have identified five sets of water quality measures including salinity, pH, nutrient load, chemical oxygen demand (COD) and heavy metals, and these would thus form the independent variables of the abatement cost curve.

Water quality impact valuation through load modelling

The cost of water pollution can be estimated by estimating the water quality externality benefits enjoyed by polluting industries. This can be accomplished by identifying the:

- most important water quality indicators representing the pollution associated with these activities,
- water treatment technologies required for the reduction of these identified pollutants,
- target water quality objectives for the identified pollutants and estimating the cost of treating to RQO requirements.

Linkage to RQOs

Damaging human activities are considered to be the discharge of wastes with pollutant concentrations that exceed the RQO of the identified pollutant. Therefore, central to the WRCS process is the setting of target concentrations (referring to recommended resource-directed value (RRDV) or effluent concentration) to achieve in-stream resource quality objectives applicable to the water resource class, as well as maximum allowable resource-directed values (MARDV) in order to achieve the upper limit of the in-stream quality associated with the resource class for each water pollutant.

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