Deliverable 5.6

Implementation report for Inkomati-Usuthu CS

Lead: JAWS
Date: February 2025

Project Deliverable

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Title
Deliverable 5.6: Implementation report for the Inkomati-Usuthu Case Study

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Abstract

This Deliverable (D5.6) presents the implementation of the Inkomati-Usuthu Case Study throughout the first 42 months of NEXOGENESIS (September 2021-February 2025). It summarises activities related to the different Work Packages of the project, and outcomes related to: governance assessment, conceptual and system dynamics modelling, and stakeholder engagement. The Deliverable builds on Milestones 15 and 23, synthesizing the case study coordination and execution, and highlighting lessons learned and experiences to date.

Keywords

Inkomati-Usuthu, case studies, stakeholder engagement, policies, models, implementation, roadmap, lessons learned, recommendations

Abbreviations/Acronyms

CAP	Common Agricultural Policy
CS	Case Study
DFFE	Department of Forestry, Fisheries and Environment
DSS	Decision Support System
IUCMA	Inkomati Usuthu Catchment Management Agency
IUWMA	Inkomati Usuthu Water Management Area
JAWS	**Jones & Wagener**
MS	Milestone
NEPAT	NExus Policy Assessment Tool
NWRS	National Water Resource Strategy
SANBI	South African National Biodiversity Institute
SDM	Systems Dynamics Models
SH	Stakeholders
WP	Work Package

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1 Introduction

1.1 Project Summary

Water, energy, food, and ecosystems (WEFE) are interconnected and comprise a coherent system (nexus), which is characterized by complexity and modulated by climatic and socio-economic drivers. In the nexus, economic development (including optimal trade, market, and policy solutions) is hampered by resource constraints and their interconnectedness. In addition, the adoption of a sectoral approach in developing and implementing policies may affect nexus characteristics, which in turn can affect decision-making and policy formulation/implementation.

NEXOGENESIS (NXG) develops and validates:

a) a coherent cross-sectoral policy-making framework at different scales addressing climate and socio-economic change, as well as stakeholder behaviour and transboundary (diplomacy) issues, developed for and validated by stakeholders, policymakers, and academics.

b) a Self-Learning Nexus Assessment Engine (SLNAE) exploiting reinforcement learning and supporting streamlining water-related policies into the WEFE nexus.

c) a visual tool to assist in easily assessing WEFE impacts: the WEFE Nexus Footprint, which accompanies the SLNAE.

> Please note that the Self-Learning Nexus Assessment Engine (SLNAE) is hereafter referred to as the NExus/NExogenesis Policy Assessment Tool (NEPAT). This is because this new term is more intuitive for non-project/non-expert readers.

NXG applies its approach to *five case studies (CS): four European and one in Southern Africa* (Figure 1). Through these CSs, strong stakeholder engagement and validation of output, the project aims to improve policies and policy-making processes to enhance cooperation and help the EU achieve targets related to the Water Framework Directive, the greener Common Agricultural Policy (CAP), Green Deal ambitions, as well as ambitions on water diplomacy.

The five CSs cover diverse spatial, social and cultural characteristics and a history of development challenges. They also feature strong WEFE nexus relations, with the potential for disruption from policy implementation, and allow for an assessment of how water-related policy can be streamlined into the nexus. They allow for out-scaling to broader regions and, due to the diversity of cases, and the coherent framework, wider-scale out-scaling to other regions globally will be possible. Dedicated CS partners offer access to stakeholder consultation at different tiers, ensuring maximum engagement and project impact. As part of this deliverable (D5.6), the focus will be on CS5 (Inkomati Usuthu).

Figure 1: Map of the case studies
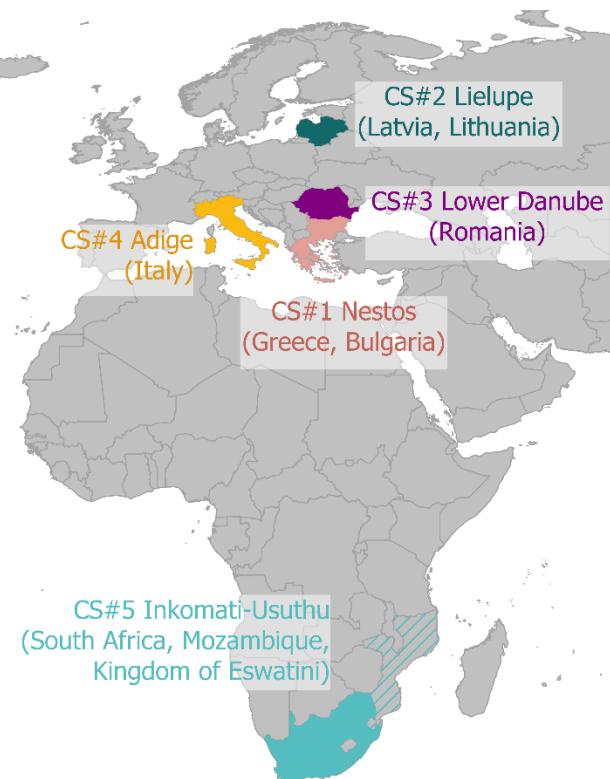
A detailed description of the CS including a list of main nexus challenges is provided in milestone (MS) 2: *Roadmap for Case Study Work/Activities in NEXOGENESIS*, which also presents deadlines/timings of different activities for the CS.

1.2 Goals of the report

This report builds on MS23 and summarises the CS implementation and stakeholder co-creation activities from month 1 to month 41 (September 2021 - January 2025). It further synthesizes the CS coordination and execution led by WP5 and concludes with emerging CS-specific lessons learned and experiences. The Deliverable specifically summarises: CS activities outlined in the NXG Roadmap (MS2), the communication activities relevant for CSs presented in the NXG Internal Communication Plan (MS5), the SH identification process to generate the stakeholder register for each CS described in the NXG Stakeholder Register (MS6), and the monitoring activities outlined in the NXG monitoring plan (MS8). Note that KPIs and risks are being reported by the manager of the NXG (WP7). A full description of the case study co-ordination process in WP5 is provided in Annex 1.

1.3 Methodology to build the report

A transdisciplinary co-creation approach has been incorporated to integrate knowledge and experiences at different levels within the project by applying an iterative process for building, refining, and improving this second intermediate report. The document has been developed during months 36 - 40 of the project to summarize the CS implementation and stakeholder co-creation activities.

The initial outline for this deliverable was informed by the structure of Milestones 15 and 23 and further adjusted through collaboration between the CS and WP5. After the document structure's initial creation, the report structure was sent to WP5 for review. Following approval by WP5, the report was compiled by the CS and WP5. After receiving all inputs, the deliverable was sent to all WP leads for comments, before final submission.

2 Description of the case study

2.1 Basic characteristics

The Inkomati-Usuthu Water Management Area (IUWMA) is situated on the eastern boundary of South Africa. The catchments of the Inkomati and Usuthu Rivers are transboundary, with some areas of the catchment classified as strategic water source areas (SWSAs). The Inkomati sub-catchment is divided into the following sub-areas, Upper and Lower Inkomati, Sabie-Sand and the Crocodile, while the Usuthu is treated as one area. Vital attributes of this area include agriculture, industry, mining, eco-tourism, forestry, and nature conservation. Forestry and *Irrigation-based agriculture provide approximately 60% of the jobs in the WMA and utilise the majority of the water in the WMA; 21% and 31% for forestry and agricultural irrigation, respectively" (IUCMA APP 2020/21).*

Based on the spatial data associated with the 2011 Census (StatsSA 2011) together with the 2021 Mid-year population estimates (StatsSA 2021), the population in the IUWMA was estimated to be 2.3 million in 2021, consisting of urban, semi-urban and rural areas. In 2012 it was estimated that the Gross Geographic Product (GGP) of the IUWMA was approximately R9 billion per annum and made up about 0.3% of South Africa's Gross Domestic Product (GDP) (DWA, 2012). The manufacturing and mining sectors were the most significant contributors.

Water resource management in the IUWMA is administered by the Inkomati-Usuthu Catchment Management Agency (IUCMA) in terms of Section 78 of the National Water Act (NWA) 36 of 1998.

A map of the CS area is provided in *Figure 2*.

Figure 2: IUCMA Locality Map

IUCMA Locality Map
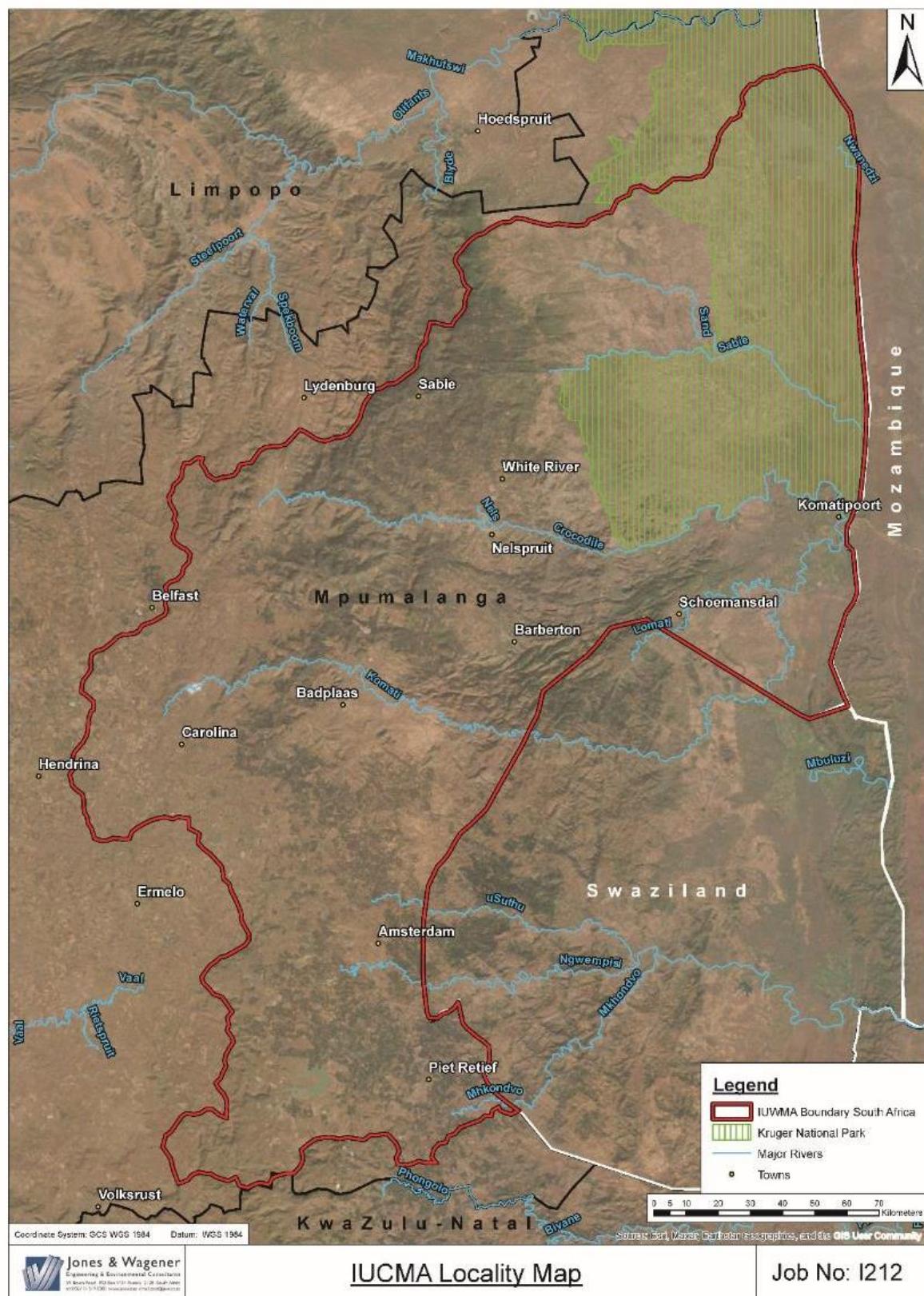
2.2 Description of the nexus components

2.2.1 Water

The Inkomati sub-catchment has rainfall that varies from over 1200 mm/annum along South Africa's eastern escarpment, which forms the western border of the sub-catchment, to 400 mm/annum in the east of the Inkomati sub-catchment. The Crocodile, Sabie and Uanetza rivers, which form part of the Inkomati system, flow through the Kruger National Park, and subsequently into Mozambique (see Figure 3). The Komati River system flows through Eswatini (previously Swaziland), back into South Africa, where the crocodile river flows into the Komati River. The Komati River then flows through Mozambique, before flowing into the Indian Ocean.

The Usuthu sub-catchment has rainfall that ranges between 550 mm in its eastern areas to 850 mm on the western areas. The Usuthu river catchment flows into Eswatini , partly into the northern portion of the KwaZulu-Natal Province, and then through Mozambique.

Figure 3: Map of the dominant rivers that form the IUWMA (from IUCMA)
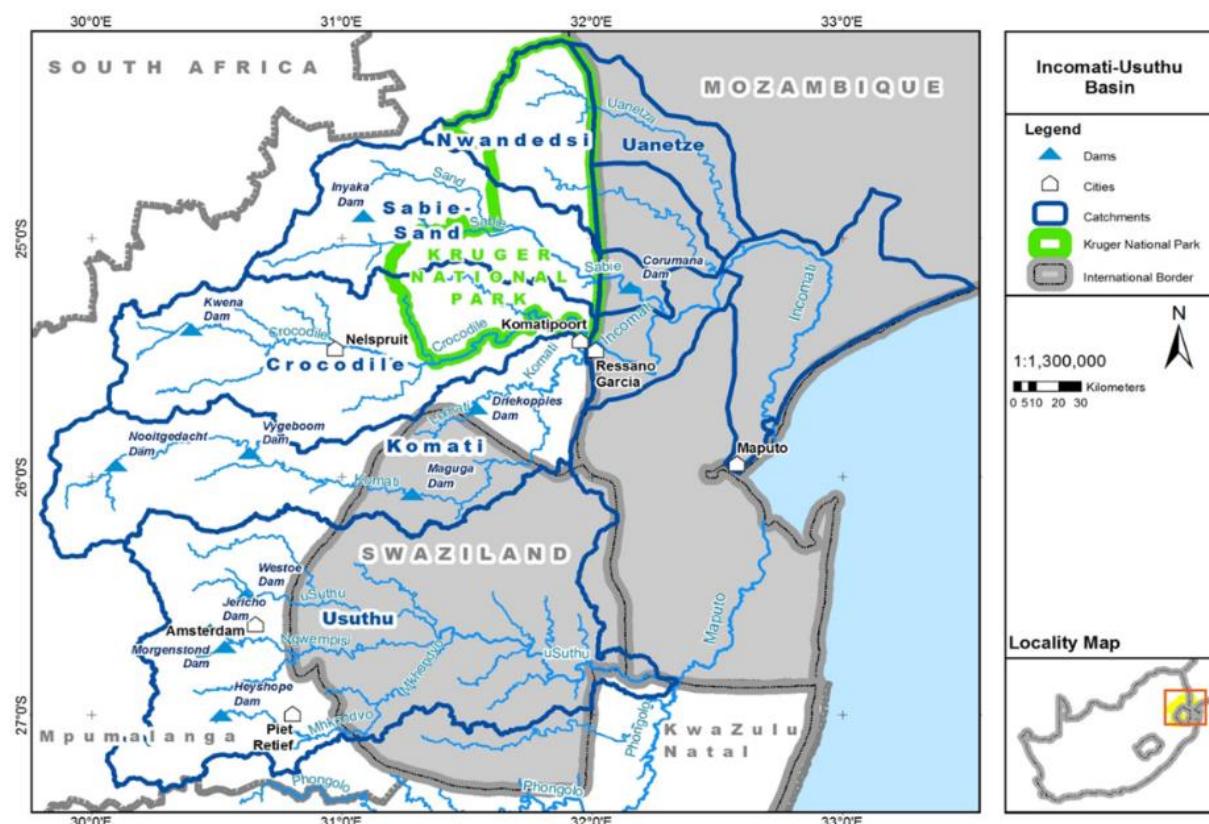
The water resources in the IUWMA are over-allocated. The key challenges affecting water quality in the IUWMA are due to industrial and mining activities and the poor state of water services authorities' sewage infrastructure. Pollution of the resource is by, inter alia, the contamination of sewage (e.g. from overflows, spills and leakages or by discharge of untreated/partially treated sewage into the resource) and the decanting of mining effluents, polluted stormwater or leachates into the water resources (IUCMA, 2021b).

A map of the water resources within the IUWMA is provided in *Figure 4*.

Figure 4: IUCMA Water Component Map

IUCMA Water Component Map

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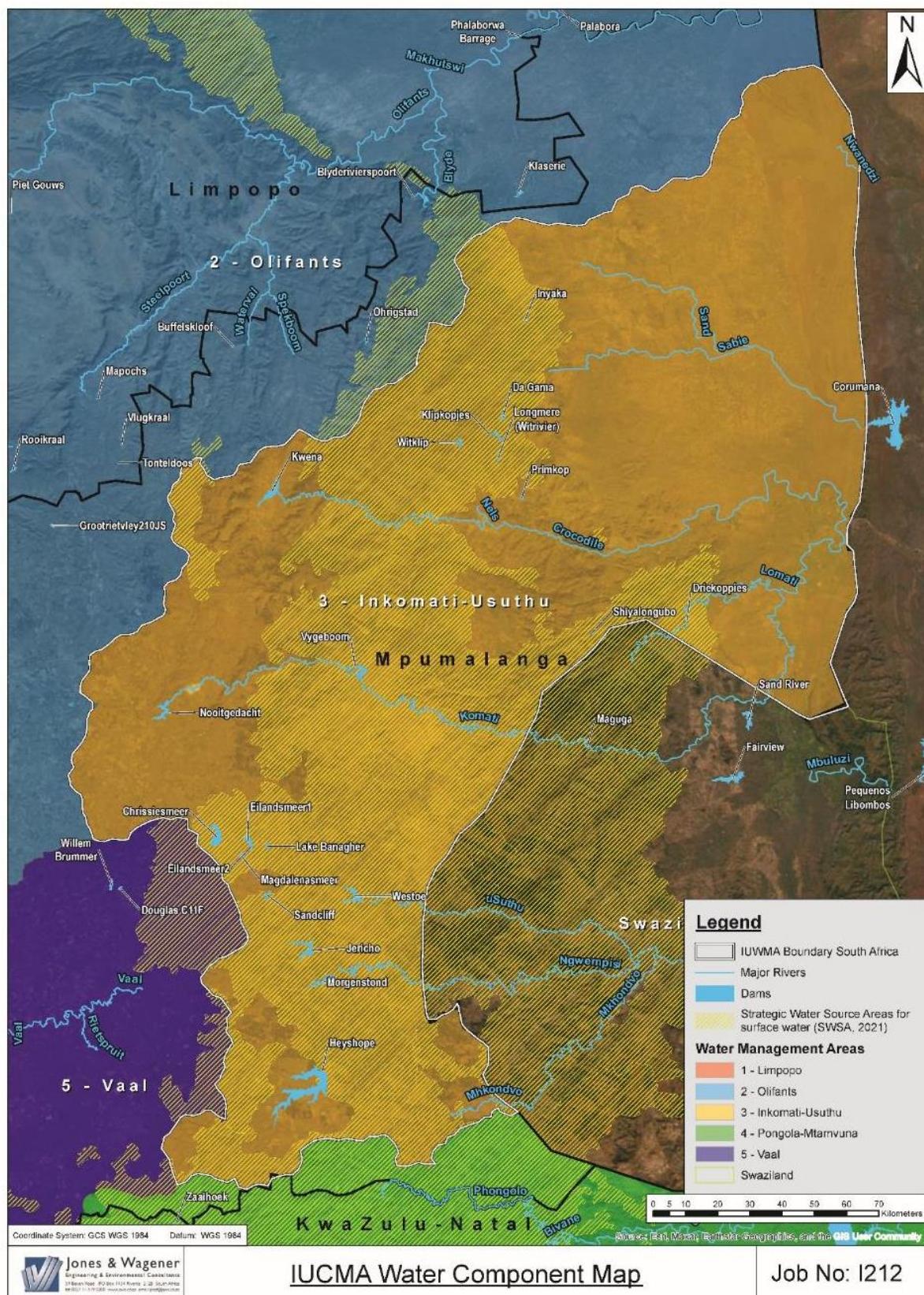
2.2.2   Energy

There are no coal-fired power stations or large-scale renewable energy systems in the IUWMA. South Africa has a national energy grid. All power produced on a national scale is fed into the grid and then distributed. The power needs of the IUWMA are therefore primarily provided by the national grid i.e. energy is produced outside of, and imported into, the IUWMA. There are a number of approved applications for renewable energy generation (solar and wind) within the catchment, however, construction of these facilities has not yet commenced.

Water for energy is exported from the IUWMA, in the form of inter-basin transfers, to Eskom, the state-owned power-producer. Eskom is classified as a Strategic Water User in the National Water Resource Strategy (NWRS). As a result, Eskom is supplied with water to support coal-fired electricity generation processes at a 99.5% assurance level.

Raw water is utilised for cooling, steam generation, ashing, washing and air emission abatement. Water is supplied by various water schemes or sub-systems to Eskom. These include the Komati Water Scheme, which includes the Vygeboom and Nooitgedacht dams (*Figure* 5), and the Usutu and Usutu-Vaal Water Schemes, which include the Jericho, Westoe, Morgenstond and Heyshope dams.

Eskom has a bulk water use licence for 360.3 million Ml per annum. This licence includes 11 power stations and also allows for possible future use of water at the Underground Coal Gasification (UCG) plant near Majuba. The licence is valid until 31 October 2025 and can be reviewed at a five-year interval. Eskom's water usage between 2008 and 2018 averaged at 320 000 Ml per annum (Eskom, 2018). Table 1 indicates which water schemes are able to supply the various power stations.

Figure 5: Eskom's water supply system (Eskom, 2018)
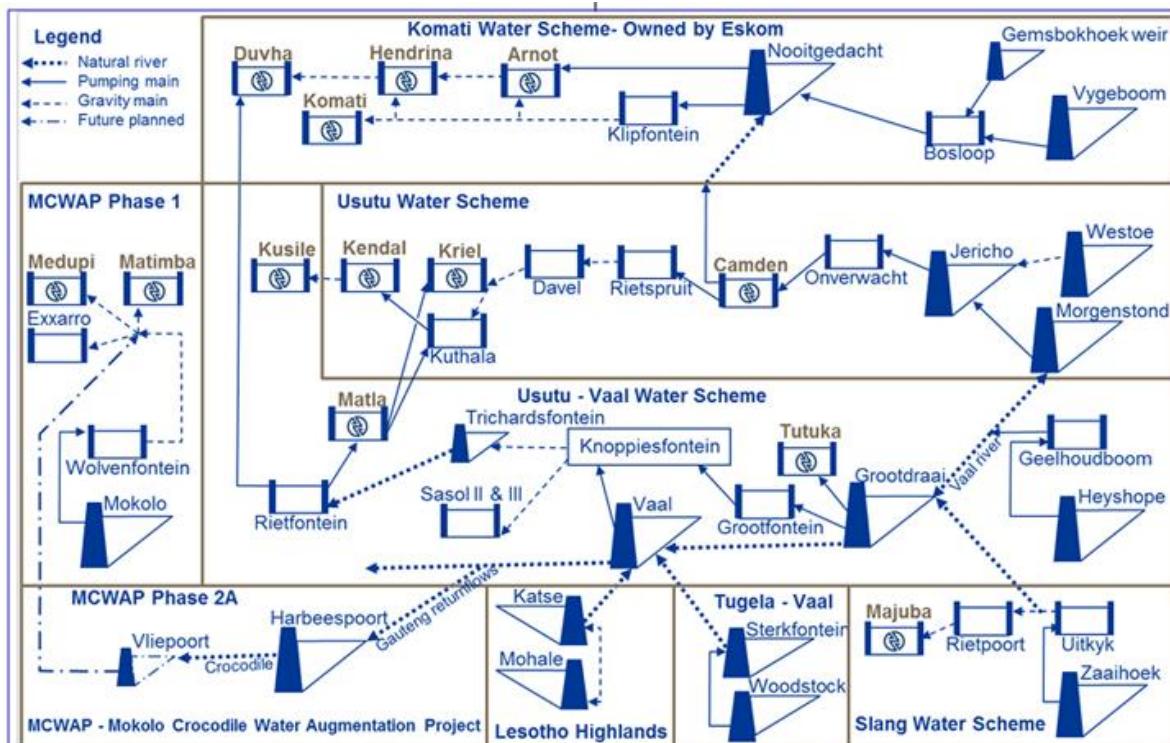
Table 1: Water schemes per power station (Eskom, 2018)

Water User	Water Scheme	
Arnot	Vaal River Eastern Sub-System	Komati
Duvha *		Komati
Hendrina		Komati
Komati		Komati
Camden		Usutu
Kriel *		Usutu
Transfer to Komati		Usutu
Tutuka		Usutu-Vaal Phase I
Matla		Usutu-Vaal Phase I
Kriel *		Usutu-Vaal Phase I
Duvha *		Usutu-Vaal Phase I
Kendal		Usutu-Vaal Phase I
Kusile		Usutu-Vaal Phase I
Heyshope to Grootdraai		Usutu-Vaal Phase II
Heyshope to Usutu		Usutu-Vaal Phase II
Majuba		Slang
Transfer to Grootdraai		Slang
Lethabo	Vaal	
Grootvlei	Vaal	
Transfer to Usutu-Vaal	Vaal	
Matimba	MCWAP	
Medupi *	MCWAP	

A map focused on the energy component of the WEFE Nexus is provided in *Figure 6*. Maps of solar and wind potential in the area are provided in *Figure 7*.

Figure 6: IUCMA Energy Component Map

IUCMA Energy Component Map

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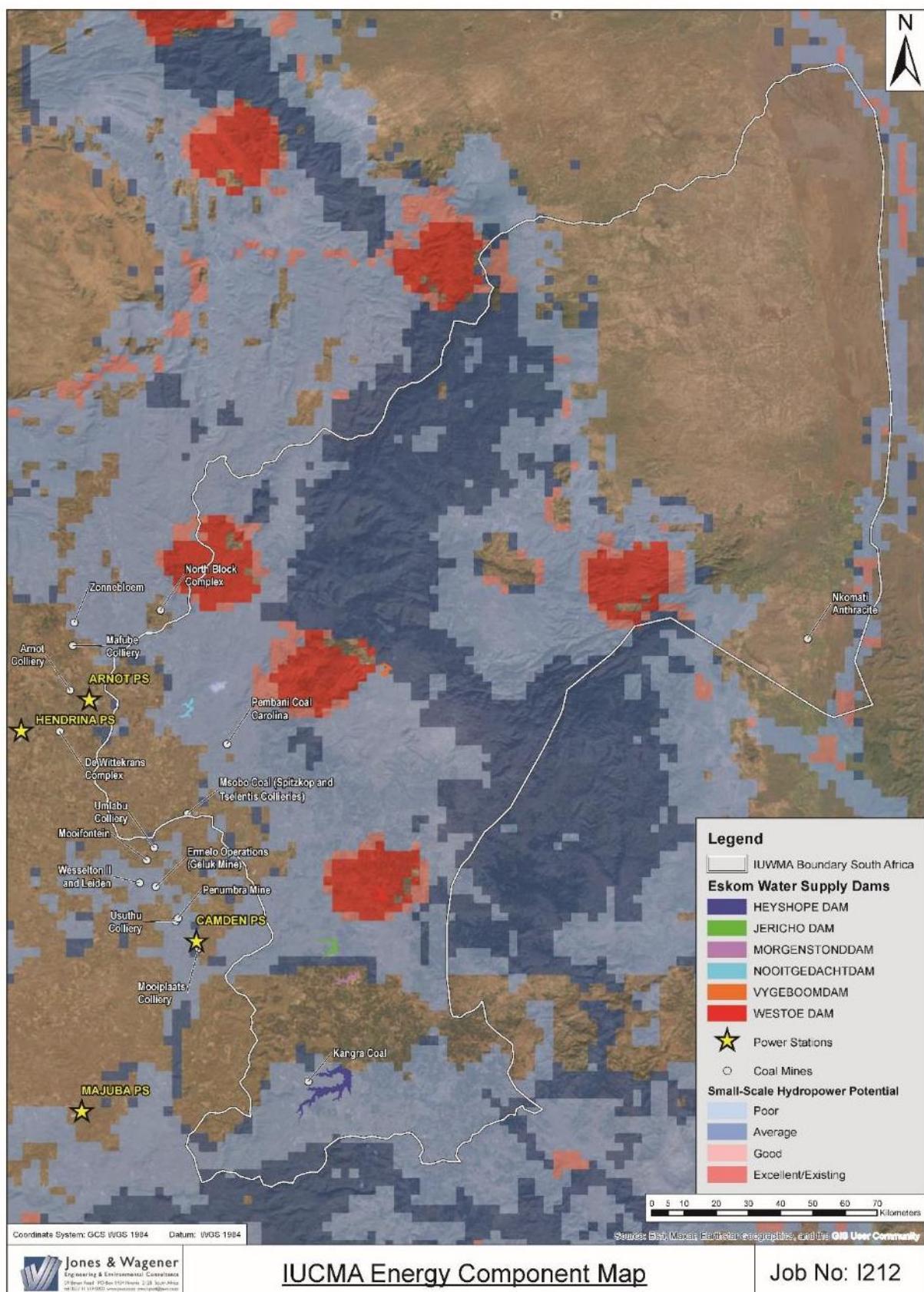
Figure 7: Solar and Wind Potential in the IUCMA

Solar and Wind Potential in the IUCMA
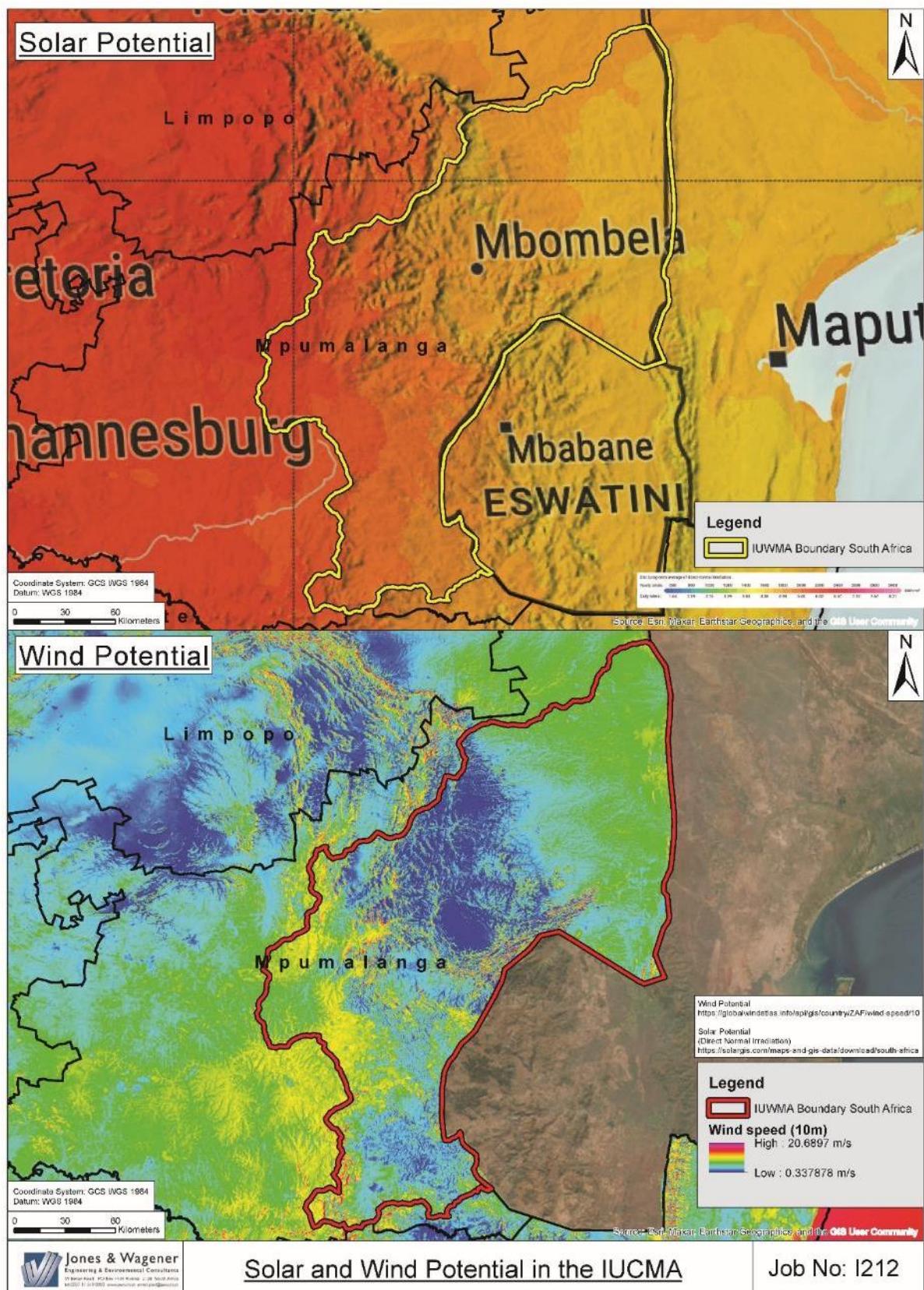
2.2.3　　Food

Agriculture is prevalent in the IUWMA, with much of the food production being by means of irrigation. Citrus, macadamia nuts, maize, soya and sugar are grown on a large scale. In many cases, these crops are grown for export. Land conversions from agriculture (where fertile soils are present) to domestic use and mining are increasing in the IUWMA. Other land conversions include forestry to agriculture. There is also a significant degree of subsistence agriculture within this WMA. A map of the food component of the WEFE nexus is provided in *Figure* 8.

Figure 8: IUCMA Food Component Map
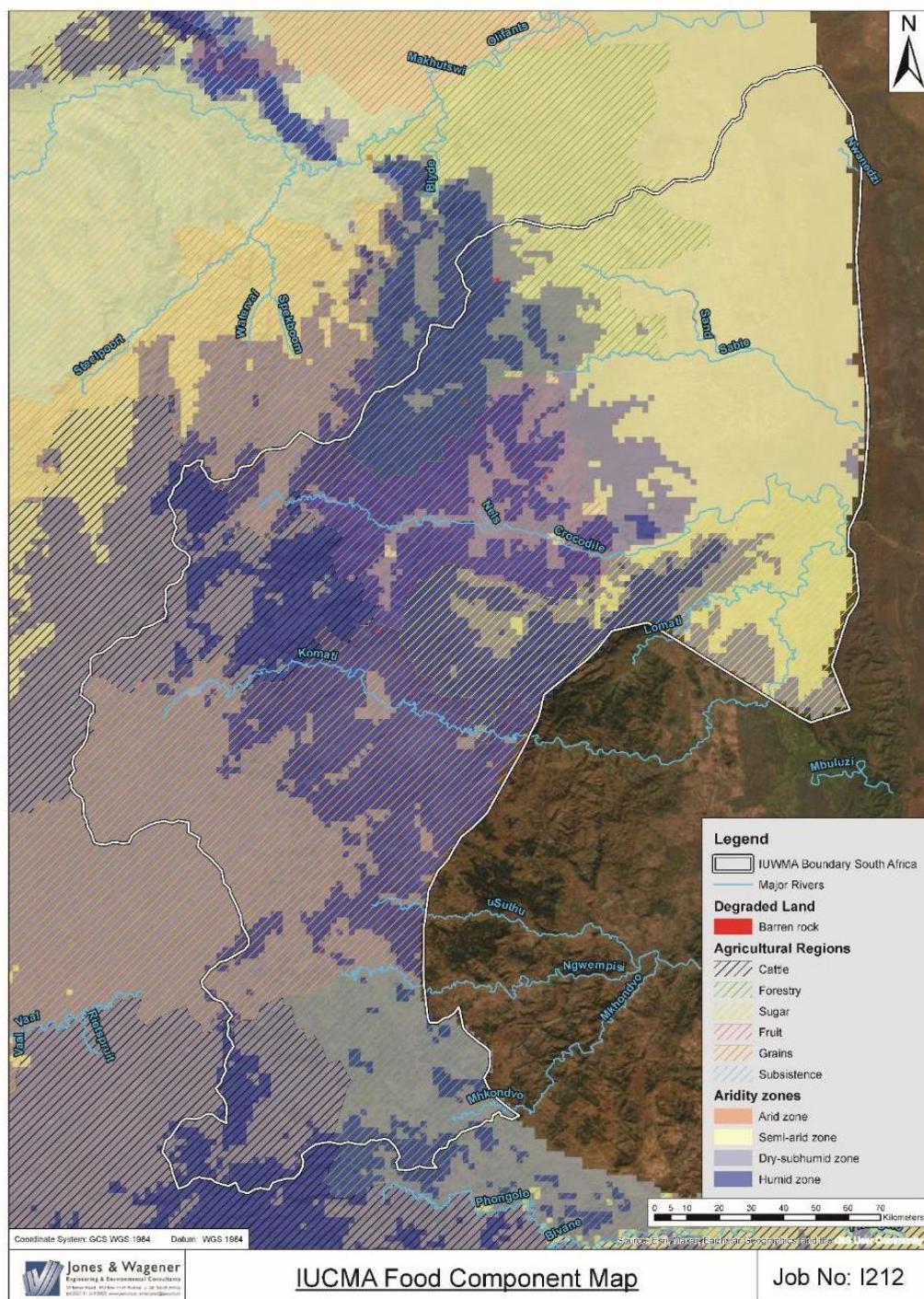
2.2.4   Ecosystems

Runoff from the Sabie-Sand and the Crocodile sub-areas flow through the Kruger National Park, and subsequently into Mozambique. The Kruger National Park forms part of the Great Limpopo Transfrontier Park, including both Mozambique and Zimbabwe. A map representing the important ecosystem aspects has been provided in *Figure* 9.

Figure 9: IUCMA Ecosystem Component Map

IUCMA Ecosystem Component Map

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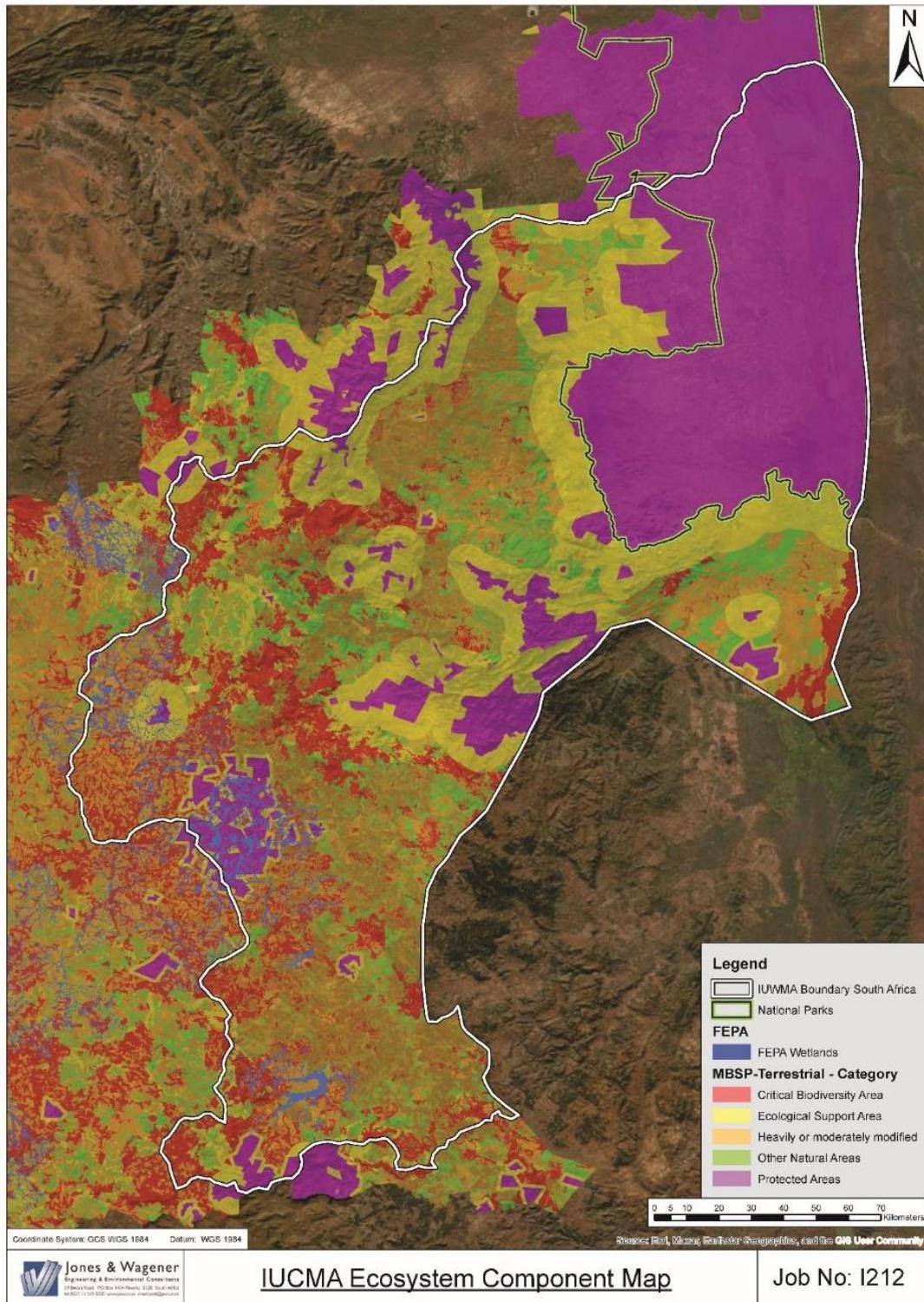
3 Implementation of CS work in WPs 1-6

This section describes the activities conducted in the Jiu CS within each WP of NEXOGENESIS. *Figure 10* provides an overview of the NXG approach, showing the outputs from each WP and how the WPs are connected. A full list of all individual activities performed during the project can be found in Annex 2.

Figure 10: Overview of the NXG approach, showing the main activities in WP1-6 and the connections between WPs (figure produced by Sabina Khan, UFZ)
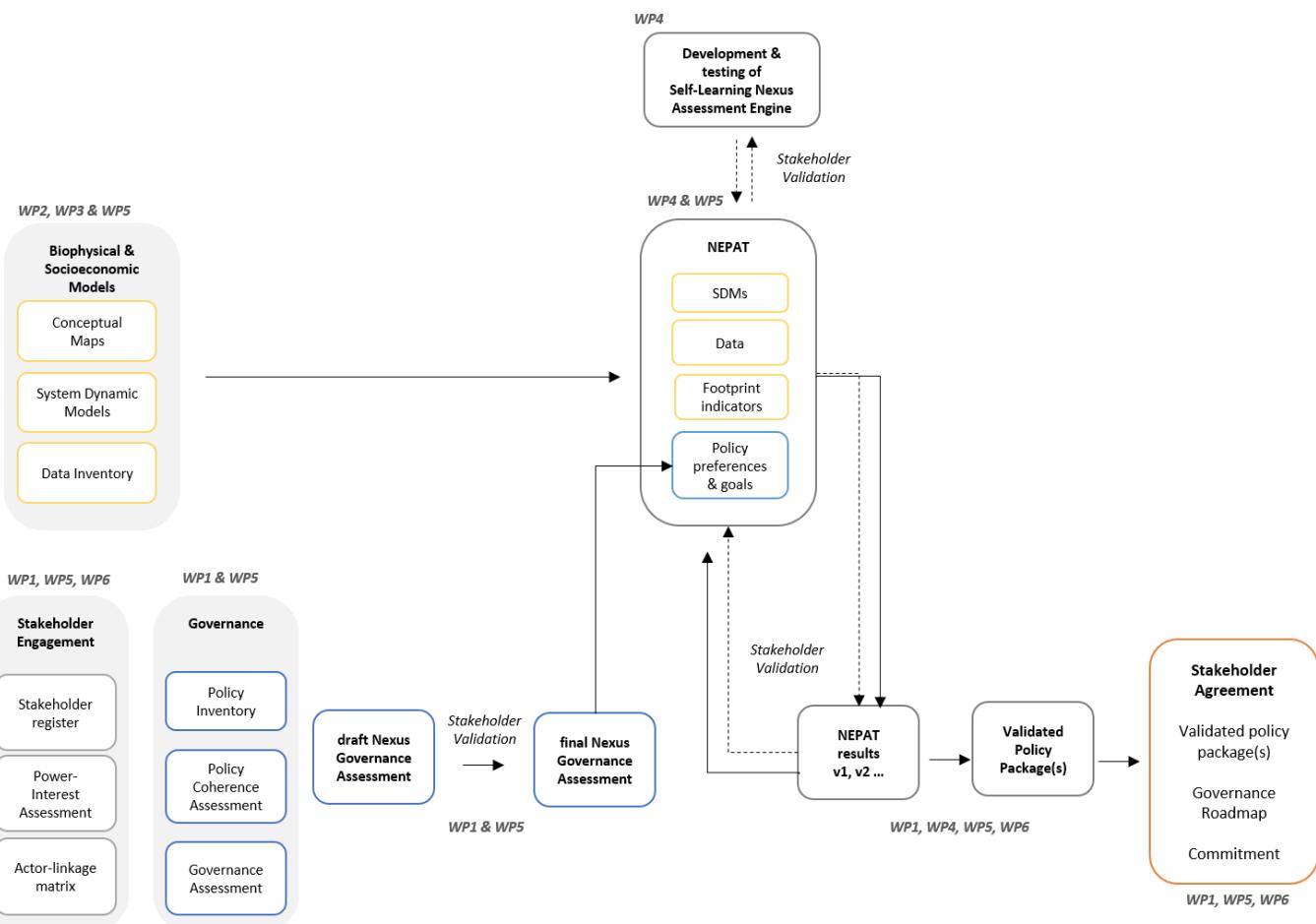
3.1 From stakeholder perception to nexus governance assessment (WP1)

3.1.1 Governance assessment in the CS

The policy inventory and coherence template were populated with policies that are relevant to the IUWMA. The goals, instruments and level of integration with each WEFE sector were included in this template. These policies were presented to the stakeholders in workshop 1. Stakeholders provided inputs on the proposed policies and indicated additional policies to be

considered. It was then decided to narrow down the policies to those most relevant in terms of the time period and the catchment area and those containing quantitative targets that could be used in the modelling process. Following this workshop, the first section of the policy packages template was completed, and the identified policies and their targets were then validated with stakeholders in workshop 2.

The governance assessment interviews were held between 13 and 24 February 2024. These interviews were held with stakeholders from each sector at a local to national scale. The interviews were used to conduct the governance assessment for the case study. Policy recommendations received during the interviews were used to inform policy selection. WP1 has further elaborated on the results, and a deeper insight into the level of integration and existing policy gaps can be found in D1.2 Governance and Policy Assessment in the Case Studies. A summary of the results of the assessment is provided below.

The current governance system is 'restrictive' towards WEFE nexus governance due to a lack of:

- Coherence of actors and networks, and resources and responsibilities; and
- Intensity of action of strategies and instruments, and responsibilities and resources.

The barriers identified included:

- Few policies are inherently and purposely cross-sectoral;
- Low awareness of the need for cross-sectoral management in government departments;
- Lack of communication and cooperation between actors of different sectors; and
- Non-compliance and lacking accountability leading to inactions.

However, a number of levers were identified, which included:

- Short-term flexibility of the governance system which results in high adaptive capacity;
- Sustainable Development Goals as an entry point for cross-sectoral management;
- Multi-level cross-sectoral governance with regional and local levels showing good potential for more WEFE nexus orientation; and
- Match between the scale of governance structures and the scale of bio-geophysical systems.

A policy coherence assessment was also undertaken by WP1 where the sectoral coherence between the identified policies was identified. The initial assessment results were presented to an expert group of stakeholders (made up of one stakeholder from each sector, however, the energy sector was not represented). Feedback from these stakeholders was used to update the policy coherence assessment and to assist with selection of relevant policies. A summary of the results of the assessment are provided below:

- High level of policy coherence between the water and ecosystem sectors;
- Policies from the ecosystem sector create most policy coherence;
- Cross-sectoral policies are in place, with policies from the land/soil and food sector showing strong integration with many other sectors; and
- In practice, the impacts of coherence found in the policies are diminished by illegal activities and the lack of coordination by different authorities with overlapping responsibilities.

3.1.2 Integrating nexus governance and policy knowledge into modelling and NEPAT

The development of the necessary policy knowledge began in 2022. The CS leads developed an inventory of policies relevant to the WEFE nexus. During the first two stakeholder workshops, the policy inventory was discussed with the stakeholders to obtain feedback and obtain valuable policy knowledge from stakeholders.

Further to this, the relevant policy documents were consulted to extract the necessary policy knowledge. Through this process the goals/targets to be included in the NEPAT were determined. In addition to the targets the policy impacts were determined using the quantitative policy knowledge obtained from policy documents. When the policy document did not contain the relevant quantitative information required to determine the policy impacts, stakeholders with the relevant knowledge were consulted together with applicable literature.

The validated policy instruments' quantitative impacts on SDM variables were incorporated into the SDMs and subsequently the NEPAT. To date the impact of policy instruments and associated SDM results have undergone two rounds of validation with the aid of the NEPAT.

3.1.3 Co-creation of policy packages, governance roadmap

Similar to the development of policy knowledge, the co-creation process began in 2022. Following the initial development of the policy inventory, it underwent a rigorous process of co-creation and validation with stakeholders. During the first two stakeholder engagement workshops:

- The stakeholders provided feedback on the policy inventory, detailing which policies are not relevant to the IUCMA and indicating what further policies should be considered.
- The stakeholders provided inputs into the targets and impacts associated with the policies.

In addition to the stakeholder workshops, bilateral sessions were held with select stakeholders to obtain inputs into the conceptual maps and provide inputs into the policy instruments.

After obtaining stakeholder inputs to the policy inventory, the instruments and quantitative targets were refined based on the policy knowledge obtained. Thereafter, during the third stakeholder workshop which was held virtually on 5 June 2023:

- A recap of the identified policy instruments was provided to stakeholders;
- Stakeholders discussed the significance of each policy instrument; and
- Stakeholders selected the preferred policy instruments to form a set of validated policy instruments to be included in the NEPAT.

The final, validated set of policies is presented in D1.3 *Policies for the Self-Learning Nexus Assessment Engine* (p.15). A key challenge related to targets was the translation of qualitative targets to quantitative targets that could be used in the tool. At this stage, the validated policy instruments impacts were quantified using policy knowledge and incorporated into the SDM and subsequently into the NEPAT.

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Following the validation of policy instruments the aim was to progress towards the identification of a stakeholder validated policy package and the associated governance roadmap. To support this during workshop 4 stakeholders were introduced to:

- The NEPAT Tool and requested to make use of the tool to implement policy instruments and assist in validating the results thereof.
- The governance roadmaps, detailing what the roadmap would comprise of and how they would assist in achieving policy implementation.
- Potential opportunities to secure a stakeholder agreement, as identified during initial discussions held with WP1.

Due to the scepticism surrounding binding contracts in South Africa, it was determined that a simple, non-binding stakeholder agreement would be more suitable for CS5. A stakeholder agreement will be further discussed following workshop 5, in the form of bilateral sessions with targeted stakeholders and will be informed by aspects of the governance roadmaps of the validated policy packages.

To proceed towards a stakeholder agreement, it is critical for stakeholders to validate the desired policy package and populate the governance roadmaps associated with the validated policy package during workshop 5. On 17 October 2024 as a prelude to the in-person workshop 5, a virtual session was held to:

- Guide stakeholders through a working example using the NEPAT to achieve a desired set of goals.
- Provide stakeholders with an opportunity to rank goals/targets based on importance within the catchment using Mentimeter.

Following the virtual session, two in-person workshops were held with stakeholders, one session in Mbombela (within the catchment) and a second session in Pretoria. Using a co-creation approach, the objectives of the workshops were:

- Stakeholders to validate the goals that the policy package should work towards achieving.
- Using the DSS to identify a potential set of policies that could assist in achieving the desired set of goals.
- Stakeholders to discuss the suggested policy instruments and identify any changes to the set of policy instruments that would constitute a user-validated policy package.
- Stakeholders to provide inputs into governance roadmaps for policies that are likely to form part of the validated policy package.

Following the workshop, it was clear that stakeholders had agreed to a set of three policy instruments, with some uncertainty on potentially a fourth policy related to food security. In addition two of the four governance roadmaps received significant inputs from stakeholders, during the workshop and through four bilateral sessions, one with the IUCMA, one with the DFFE and one with SANBI.

Bilateral sessions will be held to validate the fourth policy instrument related to food security that could form part of the validated policy package and to develop the governance roadmaps for the remaining two policies.

3.2 From biogeophysical modelling to baseline scenarios

3.2.1 Current state of WEFE nexus components in Inkomati-Usuthu CS

Water

Current

Currently, water is overallocated in the IUWMA. Water restrictions are consistently in place due to the water systems' stress. Dam storage in the IUWMA is not sufficient to meet demand. Stringent environmental and health and safety regulations make it challenging to develop the required dam capacity. The dominant water users in the IUWMA are irrigation, ecological water requirements, forestry and inter-basin transfers to Eskom. Land conversions and mining also contribute to the overallocation of water resources. Water quality is also of concern in select areas, specifically as a result of coal mining, untreated sewage release and poorly managed wastewater treatment plants.

Future

Under a changing climate, water availability is predicted to decrease, impacting upon both the physical and socio-economic environment. A decrease in water availability could result in ecological flows not being met and, therefore, the disappearance of critical ecosystems. With a decrease in water availability comes a decrease in the amount of water that can be used for agricultural and energy production. A decrease in agricultural produce will result in threatened food security and job losses. A decrease in energy production could lead to job losses as companies cannot sustain themselves with unreliable or no electricity supply. In addition to the decrease in water availability, the increase in demand due to population growth will put further pressure on over-allocated water resources. Other problems that may be experienced as a result of climate change are increased pollution events (due to low flow periods limiting dilution of contaminants) and flooding.

Energy

Current

The energy production sector is integral in the IUWMA. The coal reserves in the catchment are required for mining to provide energy security for South Africa. With the scale of this sector comes socio-economic stability due to the jobs provided by this sector. However, mismanagement of Eskom, the national electricity provider, has resulted in power cuts becoming a common occurrence across the country, impacting the livelihoods of many, including the agricultural and water sectors. Irrigation programmes are disrupted, and water services are interrupted. The storage of energy is also an issue faced across the catchment and country. Currently, a few small-scale renewable energy projects exist in the catchment. Should coal-fired energy production continue at the current level, climate change effects will only be exacerbated.

Future

Energy production in the catchment under a changing climate could shift to renewable energy, particularly wind and solar. The catchment's water systems are unsuitable for large-scale hydroelectric power plants.

Food

Current

The IUWMA contains fertile land that is exploited for agricultural purposes in order to meet the food security requirements of South Africa and export requirements. A growing population has resulted in land conversion from agriculture to domestic. Conversion from agricultural or virgin land to mining is also common in the catchment due to coal reserves underlying fertile land. Conversions from forestry to macadamia nut farming are increasing in the catchment. Farmers have begun to adopt new irrigation methods, such as drip and micro irrigation, to prevent the overuse of water resources due to limited availability.

Future

A changing climate could result in less water being available for the irrigation of crops, resulting in decreased food availability and exports. Food security will be threatened, and therefore, livelihoods will be disrupted. A potential shift to crops more resilient to drier conditions could occur. In addition, socio-economically there is a projected increase in population, which will lead to higher food demand and could potentially put food security at risk.

Ecosystems

Current

Within the IUWMA, protected areas have been assigned and are fiercely monitored and controlled. One of the most well-known examples is the Kruger National Park game reserve. Ecosystems are also protected through a variety of other assigned protected areas, including the National Freshwater Ecosystem Priority Areas, the Critical Biodiversity Areas and the SWSAs. With both agriculture and mining activities prevalent in this area, impacts on water quality and overall environmental health are high. Poor sanitation and untreated sewage released into wetlands / protected areas is also an issue experienced in the catchment. Alien invasive species interfere with ecosystems in the catchment. Programmes have been implemented to manage the alien invasives, however, results are not clear at this stage.

Future

With a predicted decrease in water availability and the resultant potential increase in pollution events, ecosystems will be negatively affected in the future. Projected increases in population will place increasing pressure on ecosystems.

3.2.2 Co-creation of technical and transdisciplinary

WP2 provided a list of available *biogeophysical indicators associated with the Inkomati-Usuthu CS*. From this list, relevant indicators were selected and used to inform the conceptual maps developed in association with WP3. The datasets associated with the selected indicators were provided by WP2 and used in developing the baseline scenario and models. In addition to this, during engagement workshops and focus sessions held with various SHs, the selected

indicators were discussed, as were the indicators and models the SHs had available. The available data from SHs included:

- Water balance models for the Inkomati-Usuthu basin.
- Various water quality indicators.
- Water quantity indicators and transboundary water quantity requirements.
- Biodiversity indicators.

The relevance of the indicators received from the SHs was assessed and, where appropriate, considered for use to inform the baseline scenario. SHs were further engaged to understand water use allocations within the basin, transboundary requirements, agricultural data, and the forestry sector. This information, where applicable, was incorporated into the Systems Dynamic Models (SDMs).

Furthermore, WP3 was consulted and provided guidance on developing the causal loop diagrams, which culminated in developing the SDMs with WP3's assistance. During this process, the CS gained significant insight into the development of the models and assisted WP3 in translating the information and case study knowledge into the development of the SDMs.

In addition, the CS has been in consultation and will continue to be in consultation with WP4 on implementing the models in the NEPAT. WP4 suggested that the user is allowed to vary the policy start date. This suggestion was implemented in the SDMs. In addition, the Case Study has consulted WP4 on the ability of the NEPAT to handle the implementation of the policy instruments with the assistance of WP3.

WP1 has further provided guidance to the CS on implementing the policy instruments within the SDMs and the quantification thereof. This, combined with the policy knowledge gained from stakeholders and from literature where applicable, was implemented into the SDMs and, ultimately, into the NEPAT. Following this, the SDMs and NEPAT have gone through two rounds of validation with stakeholders' input on the results of the SDMs and policy implementation within the SDMs as presented in the NEPAT.

Furthermore, WP1 and key stakeholders have been consulted and will be further consulted with regard to the implementation of a River Contract/Stakeholder agreement. WP1 and stakeholders have assisted with identifying what is possible within the basin and, furthermore, what is feasible based on stakeholder feedback.

3.3 From conceptual model to complexity science modelling and WEFE nexus footprint (WP3)

3.3.1 Overview of interrelationships among WEFE nexus components

For the Inkomati-Usuthu CS irrigation is a critical activity that impacts numerous WEFE Nexus components. Irrigation is a significant water use that enhances food security. Energy is required to power the irrigation systems. This has a knock-on effect in a country with unreliable

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baseload electricity due to the national utility's challenges. During the SH focus session with the IUCMA, it was noted that many farmers are irrigating at night due to the load shedding (rolling blackouts) that occurs during the day. One advantage in this regard is that application efficiencies are significantly higher during the night. The electricity load shedding has led larger farmers to transition to solar power generation and, in some cases, hydropower. Others have turned to diesel or petrol generators.

Water from several dams within the IUWMA is transferred out of the WMA for use during coal-fired power generation. However, Eskom has had to stop mining activities upstream of some of these dams because the coal mines have a negative impact on the water quality, and the utility requires very good quality water for its purposes. The irony is that Eskom requires a constant supply of both coal and good-quality water.

Poor water quality and reduced water quantities have a negative impact on biodiversity. The water quality is impacted by mining, agriculture and poorly managed wastewater treatment plants (and diffuse *E. coli* sources). Transboundary water commitments are also dependent upon good water quality and reliable flows.

3.3.2   Main WEFE nexus challenges

Critical WEFE nexus challenges for the Inkomati-Usuthu CS include:

- Equitable access to WEFE resources is a key challenge within the IUWMA. Significant disparities in socio-economic standards still plague South Africa, which consistently has one of the highest Gini coefficients in the world.
- Lack of formal housing for some sectors of the population leads to poor socio-economic circumstances and also negative impacts on downstream water quality (due to inadequate sanitation) and air quality (due to the burning of food and parafin).
- The overallocation of water resources limits development. In the same way that a reliable energy supply enables economic development, so too does access to water resources.
- With global commitments to move towards a lower carbon economy and the call for this change to be a Just Transition, replacing coal-sector jobs (both direct and indirect) with renewable sector (and other) jobs is imperative.
- Impacts on ecosystems and downstream users due to poor water quality caused by mismanagement of water treatment facilities, lack of infrastructure provision and maintenance and challenges associated with monitoring industrial / mining discharges.
- Due to water quality deterioration, algal blooms are occurring in areas not previously affected. The algal blooms are an indicator of excessive nutrient loading of water bodies. This is often driven by poorly treated or untreated sewage, which has other ecosystem and health impacts on downstream users and systems.
- Upstream activities, e.g. sand mining (legal and illegal) and coal mining, impacting water quality and subsequently sensitive ecosystems within the Kruger National Park.
- Several stakeholders indicated that the effects of climate change within the IUWMA are being seen regularly. The number of days with temperatures exceeding 35°C and 40°C is consistently increasing each year. Hail is falling in locations where it was not previously experienced. Certain bird species are migrating further south than they previously did.

- Unreliable baseload energy supply from the national utility affects all sectors of the economy, from eco-tourism to mining, agriculture to manufacturing, and forestry to water supply. Ironically, the coal-fired power stations depend on various secondary industries and mining and water supply networks.

3.3.3 Conceptual model

Following workshop 1, it was evident that land is a crucial driver of the WEFE Nexus within this case study. Land use, land conversions, and prospecting and mining applications were key topics of discussion during this workshop. Population is a driver of land uses, i.e. demand for electricity, food, and water. These different land uses in turn, result in varied impacts, from climate change to pollution. Following workshop 1, an interim-level conceptual map was initially developed for the IUWMA. Subsequently, using inputs from stakeholders a macro-level conceptual map was developed where the various interlinkages between the WEFE components were highlighted.

The conceptual maps were presented to stakeholders in subsequent workshops to obtain feedback on the indicators and interlinkages. The final conceptual maps were converted into causal loop diagrams and subsequently informed the SDMs. The conceptual maps developed during the first two workshops for IUWMA are depicted in Figure 11 to Figure 15. In Figure 11 the major connections between nexus sectors are shown, with the details appearing in the sectoral sub-maps Figure 12 to Figure 15. All the stages of the conceptual model development and the approach adopted are analytically described in *Deliverable 3.1: Conceptual models completed for all case studies (pp.50-55).*

Figure 11: High-level conceptual map for the Inkomati-Usuthu case study

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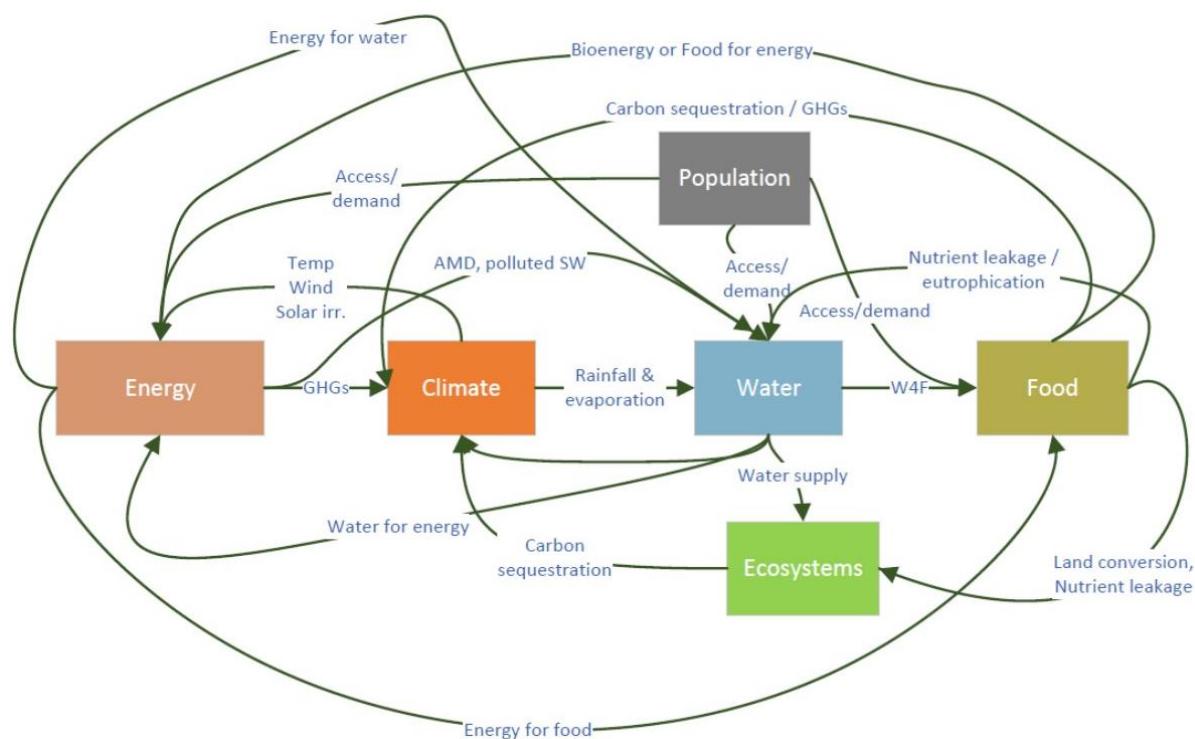
Figure 12: Water sector map of the Inkomati-Usuthu case study.
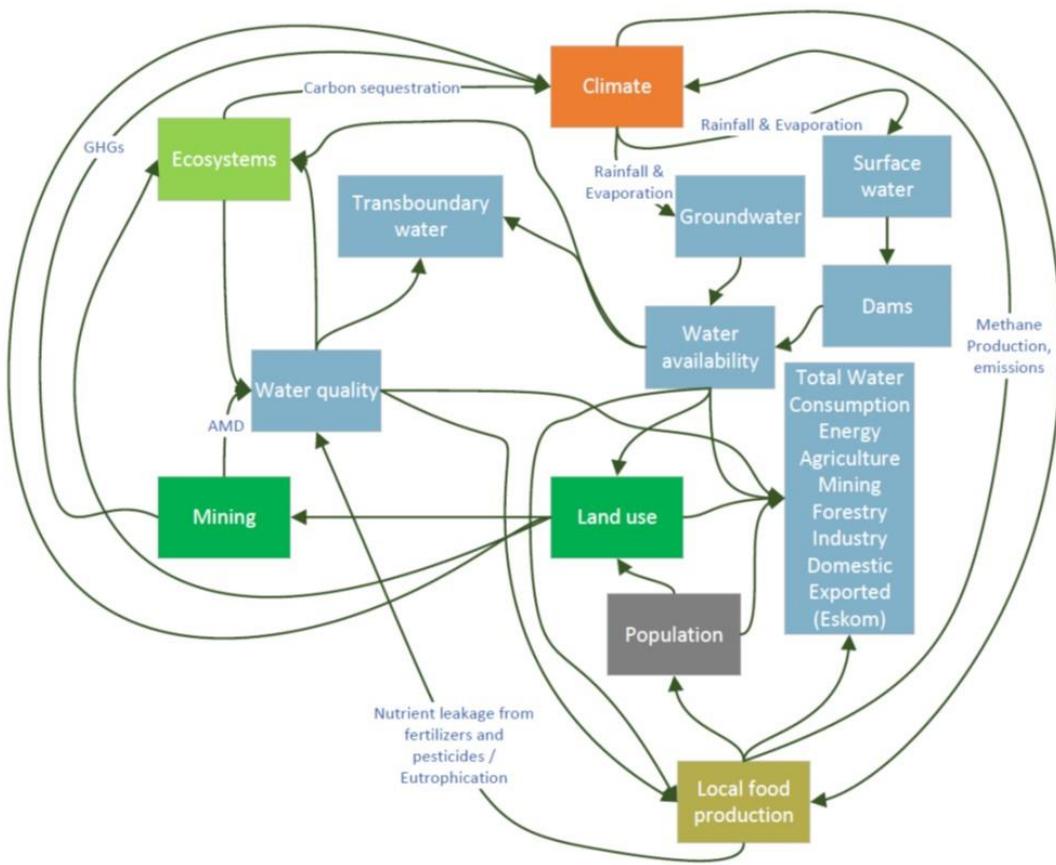
Figure 13: Food sector map of the Inkomati-Usuthu case study.
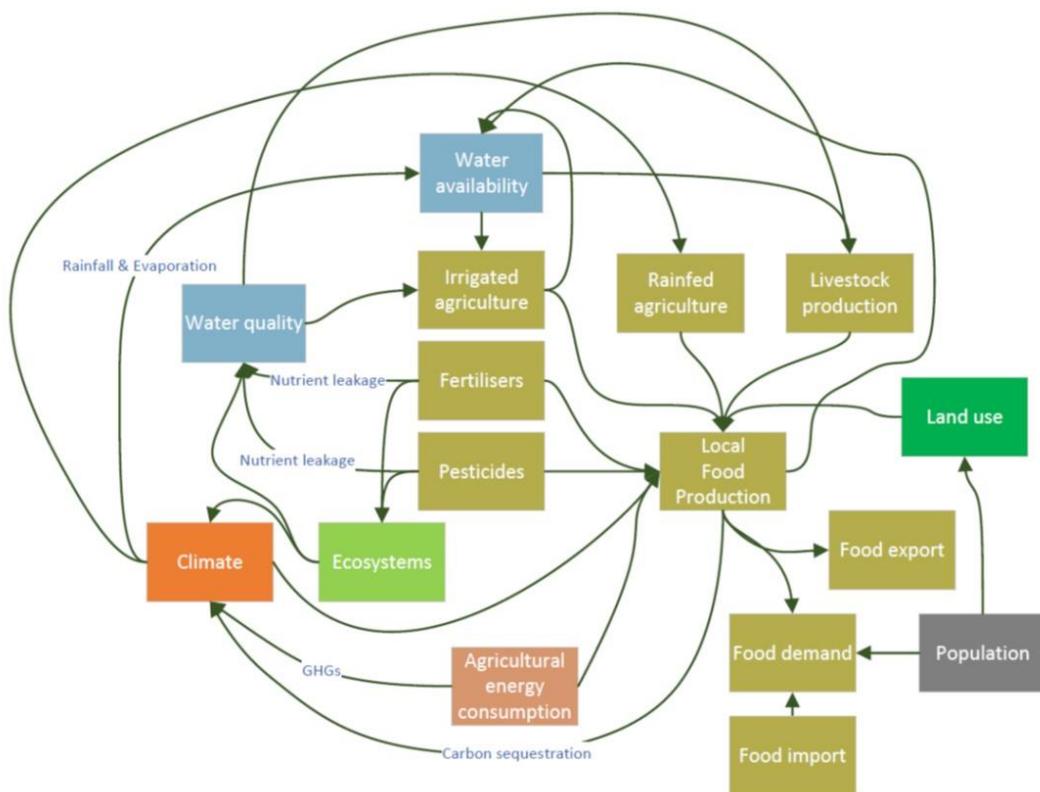
Figure 14: Energy sector map of the Inkomati-Usuthu case study.
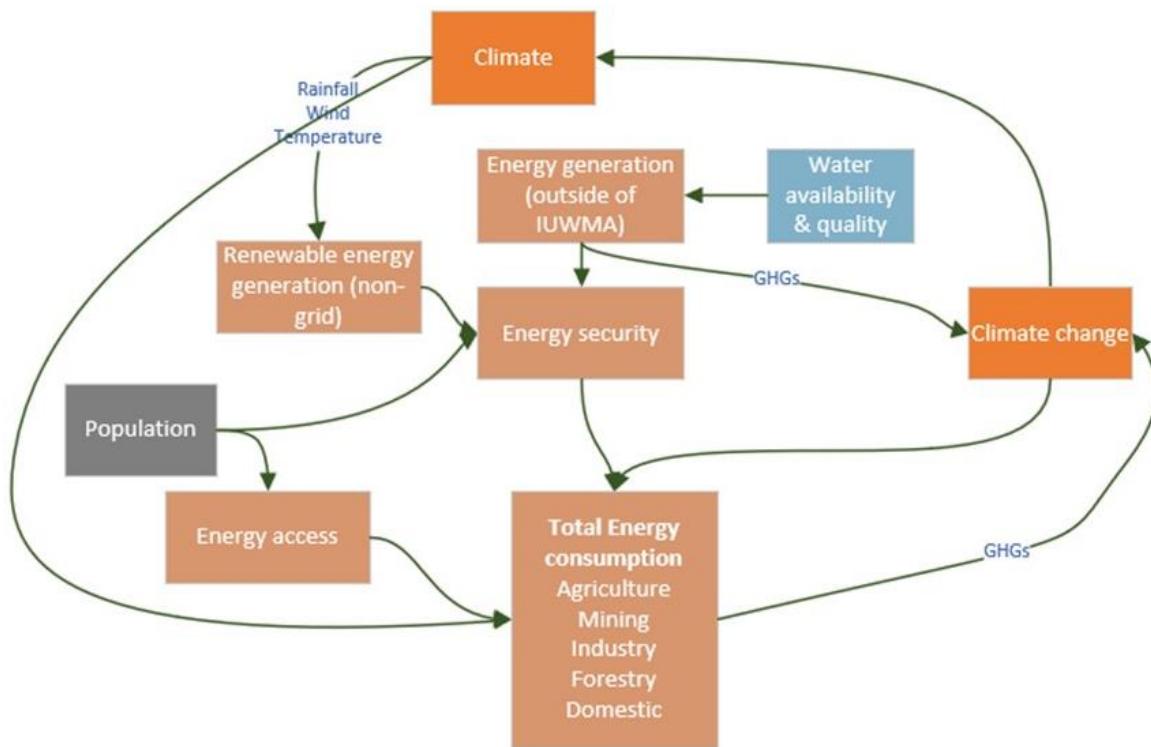
*Figure 15: Ecosystems sector map of the Inkomati-Usuthu case study.*
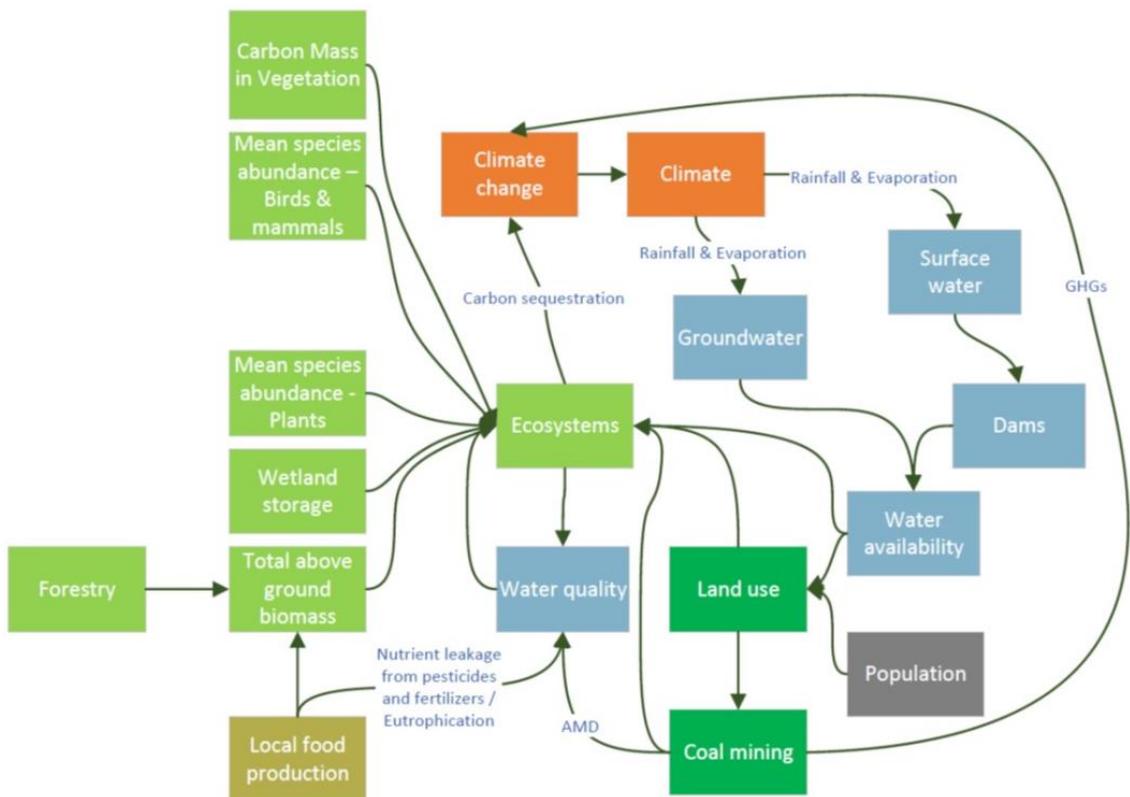
3.3.4   System Dynamic Modelling Approach

The conceptual maps were used to inform the causal loop diagrams, which were developed with the assistance of WP3. The causal loop diagrams formed the basis for the structuring of the SDM. With the assistance of WP3, the SDMs were developed for the reference scenarios. The SDM was populated with the data from WP2 together with local data where applicable to develop the SDMs associated with the four reference scenarios described in Table 2. During this process, certain indicators were excluded from the SDMs due to a lack of relevant data to inform the SDMs. The data identification and descriptions for all case studies are reported fully in *Deliverable 3.3 Final report on the application of biophysical models and stakeholder recommendations*.

Table 2: Reference scenario descriptions (As described in the NEPAT)

Representative Concentration Pathways	
Scenario	**Description**
RCP 2.6	Characterized by declining CO_2 emissions to reach net zero after 2050, followed by varying levels of net negative CO_2 emissions. Under this potential best scenario, global CO_2 emissions are cut severely with strong mitigation effort to keep radiative forcing to 2.6 W/m2 and raising temperatures below 2 °C by the end of the century, in accordance with Paris Agreement goals.
RCP8.5	Prolonged and high fossil fuel development, and consequently strong increases in CO_2 emissions, throughout the 21st century. It is considered a potential worst-case outcome, with current CO_2 emission levels roughly doubling by 2050 and continuing afterward, with radiative forcing reaching 8.5 W/m2 and average global temperature rising 4–5 °C above preindustrial levels by 2100.
Shared Socioeconomic Pathways	
Scenario	**Description**
SSP2	The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceed unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall, the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly, and challenges to reducing vulnerability to societal and environmental changes remain.
SSP4	Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor-intensive, low-tech economy. Social cohesion degrades, and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle- and high-income areas.

With the assistance of WP1, input from stakeholders and extensive research the impacts of validated policy instruments on the various SDM variables were quantified. These impacts were provided to WP3 and were incorporated into the SDMs. Furthermore, the SDMs were modified to allow the user to change the policy implementation date. The SDMs were then provided to WP4 to be implemented in the NEPAT.

The results for the reference scenarios were also provided to WP3, who were responsible for the development of the visualisation tool, the WEFE Footprint, as well as the module created within the SDM for the modelling of the WEFE footprint.

The first preliminary version of the Inkomati-Usuthu case study SDM is available in Deliverable 3.4: *Complexity science models implemented for all the Case Studies: Prototypes and explanatory report/manual for each CS methodology*.

The SDMs have since been revised to include the policy instruments and undergone various updates as part of the validation process. The SDM has been implemented in the NEPAT. The SDM and NEPAT are under continuous validation and will be updated as required.

3.4 From nexus governance and complexity science modelling to nexus policy assessment tool (NEPAT) (WP4)

3.4.1 Identification of relevant policy packages which sustain initial development of NEPAT

The identification of the stakeholder-validated policy packages began with the initial co-creation of the policy instruments (existing and desired) together with WP1 and stakeholders during the first two stakeholder engagement workshops and within smaller focus sessions with select stakeholders. Thereafter during the third stakeholder engagement workshop, stakeholders validated the set of policy instruments that would inform the NEPAT. In addition to the validated policy instruments, with the aid of WP1, targets and objectives of the identified policies have been incorporated into the NEPAT.

The validated policy instruments' impacts were incorporated into the SDMs and subsequently into the NEPAT by WP4. In addition to the policy impacts, WP4 assisted with incorporating the targets/goals into the NEPAT. The DSS has further been developed based on the SDMs and the targets.

As discussed previously, to date, the SDMs have undergone two rounds of results validation with the assistance of the NEPAT and stakeholder feedback. This validation is to ensure that the policy instruments are functioning as expected. The SDMs are currently being updated and will be implemented in the NEPAT. In addition to the SDMs the NEPAT was updated based on the first validation process, together with the DSS. The NEPAT and DSS will subsequently be updated based on the results of the second round of validation and updated SDMs.

During the fifth stakeholder engagement workshop, the NEPAT, together with the DSS, was used to help identify a set of policy instruments that would assist in achieving the desired set

of goals outlined during the workshops. The critical goals desired to be achieved by the stakeholders were:

- Maintain food security within the catchment.
- Maintain minimum maintenance flows (Ecological and Basic Human Needs)
- Achieve renewable energy targets as per the 2023 draft Integrated Resource Plan.

Stakeholders indicated that potentially a fourth goal to increase protected areas should be considered.

Stakeholders workshopped the set of policy instruments suggested by the DSS that would move towards achieving the desired set of goals. Following the two workshops, it was clear that the stakeholders agreed that the following policy instruments would be critical:

- Reparation of water distribution and treatment systems - Investment in reparation of water distribution and treatment infrastructure and maintaining and monitoring these systems to prevent leakage.
- Development of renewable energy sector - Renewable Energy Independent Power Producer Procurement (power purchase programme) that encourages renewable energy development.
- Secure SWSAs – Secure SWSA status to ensure surface water protection.

There was no indication of which policy instrument was preferred to assist in ensuring food security is maintained. Further investigation into the results of the DSS and NEPAT will be explored to understand the impacts of the relevant policy instruments on this goal. Following this, bilateral sessions will be held with stakeholders to identify the food-related policy instrument that could form part of the validated policy package.

This will culminate in developing the governance roadmaps for the validated policy package and provide guidance on potential stakeholder agreements.

3.5 Stakeholder engagement and stakeholder workshops (WP5)

3.5.1 Summary of engagement approach

Table 3 provides an overview of the engagement approach to date for the Inkomati Usuthu case study.

Table 3: Overview of engagement activities

	Co-exploration	Co-design	Co-development		
	Information	**Consultation**	**Involvement**	**Collaboration**	**Empowerment**
Stakeholder category (expected - given NXG aim)	All stakeholders informed	Attempted to consult with all stakeholders	Attempted to involve stakeholders from all levels in the development of project aspects	Attempts at direct collaboration with local policy makers and high-level policy makers from the sectors	At this stage, attempts to empower stakeholders at all levels through involvement and communication has taken place.
Power and Interest (PI)	Kept all stakeholders engaged by information sharing and invitations to workshops	Attempted to consult all stakeholders to understand the WEFE nexus in the catchment and get input on what is desired by all levels	Attempted to involve all stakeholders to understand the WEFE nexus in the catchment and get input on what is desired by all levels	Attempted to collaborate with policymakers at a local and high-level to provide ideas and promote the necessary changes desired by stakeholders	Attempting to empower all stakeholders to become involved in making the desired changes and maintaining these changes
CS focus and activity	Emails, workshops	Emails, workshops, focus groups	Emails, workshops, focus groups	Focus group sessions, workshops	Focus group sessions, workshops

3.5.2 Summary of workshops

WP5 supports the application of the NXG approach in the CS. NXG builds on co-creation, both within the consortium and with stakeholders. Thus, CS workshops with stakeholders are an important building block of the stakeholder engagement strategy. Table 4 summarises the content, experiences and lessons learned in the workshops. A summary of the gender balance of participants is provided below the table.

Table 4: Summary of workshops, including main goals, structure, outcomes, experiences and lessons learned

Work shop No.	Goals	Structure, activities	Main outcomes	Experiences (positive/ negative)	Lessons learned
1	Introduce project; policy feedback, issues in IUWMA	Virtual, mapping of issues, policies, indicators	Policies and indicators to be considered	Negative: Too short Positive: Significant interest and engagement shown	Mind mapping software is useful to visualise suggestions/comments. A physical meeting may be beneficial for connections to be established
2	Present and receive feedback on conceptual maps, policies and targets and selected indicators	Physical meeting, break-out groups	Input into the CMs, desired targets and indicators from stakeholders	Negative: Could have been about an hour longer to include survey response and prevent rushing of last topic. Positive: Engagement from all stakeholders and connections established.	Break-out groups were successful. A hybrid meeting may be better to involve stakeholders who cannot travel.
3	Validate policy instruments, provide feedback on the governance assessment and discuss the current stakeholder engagement process	Virtual meeting Break-out rooms Plenary sessions	Selection of policy instruments Feedback on the governance assessment results. Feedback on the current stakeholder engagement	Negative: Little engagement due to the online nature of the workshop Too long Positive: High attendance	Virtual meetings scheduled for a long time are challenging to get the required engagement. Break-out rooms require the use of a facilitator to ensure the workshop runs smoothly.
4	Discuss and get feedback on the SDMs, NEPAT and SH agreements	Hybrid meeting Plenary sessions Menti questionnaires/ activities	Feedback on the SDMs Consideration of presentation of results for further engagement with stakeholders Feedback on NEPAT Identification of potential	Negative: Low attendance due to time of year and external ongoing consultations Positive: Good engagement from participants	Hybrid meetings are important as they allow for involvement of as many stakeholders as possible, especially those who may not be able to join in person

Work shop No.	Goals	Structure, activities	Main outcomes	Experiences (positive/ negative)	Lessons learned
			stakeholder agreements		
5 (virtual session)	Present a guided tour of the NEPAT with the aid of a case study example, showcase the decision support system, and perform a goal ranking exercise with stakeholders.	Virtual meeting Breakout rooms Menti questionnaires/activities	Stakeholder knowledge on the NEPAT and its functioning Identification of key goals	Positive: Good attendance and engagement Negative: Time was too short to allow stakeholders to engage with the tool fully. However, the link to the tool and educational material was shared with stakeholders for further exploration following the workshop.	The NEPAT is a complex tool for stakeholders who have not encountered it before or been involved in its development. Therefore, additional time to explore the tool with stakeholders online or in person is important.
5 (in-person sessions)	Validation of Policy Package, governance roadmap development and stakeholder landscape recap	In-person meetings (one in Mbombela – access to catchment stakeholders; and one in Centurion – national department access) Breakout rooms, plenary sessions	Ranking of goals in terms of importance and indication of potential policy package Update to compiled governance roadmap Increased understanding of stakeholder landscape at present	Positive: Good attendance in Centurion (all sectors represented). Possible agreements discussed. Engagement was very good, particularly in the Centurion meeting. Negative: Lower attendance in Mbombela (catchment stakeholders). No policy package agreed to, however this will be informed by discussions during the workshop and further developed through bi-lateral sessions following the workshop.	As stakeholders are not always able to travel loing distance between Mbombela and Centurion/Pretoria, the use of two separate workshops was useful to include both sets of stakeholders. The project team will summarise the findings from each workshop and provide this to all stakeholders.

Workshop No.	Males	Females
Workshop 1	26	17
Workshop 2	10	4
Workshop 3	19	19
Workshop 4	7	7
Workshop 5 (virtual)	9	10
Workshop 5 (in-person, combined for both sessions)	3	6

3.5.3   Summary of the effects of the engagement activities

Initial engagement included inviting the stakeholders to the first workshop via email. A broadcast-style email was used due to the large number of potential stakeholders. In this case, a more personal email would have been too time-consuming.

Following the first workshop, a narrowing down of potential stakeholders to interested stakeholders was completed. A broadcast-style email was sent out announcing the second workshop, although it was possible to send personal emails and make calls to follow up on attendance. Stakeholder commitment and interest increased following the second workshop that was held in person. Representation of the nexus domains was high for water, and less for biodiversity. However, representation of the food and energy sectors was low. An attempt was made prior to the second workshop to increase the attendance of stakeholders in these sectors.

Following this, additional effort was placed on increasing attendance by under-represented stakeholders. The increased attention to the energy and food sectors resulted in an increase in food sector stakeholders. However, the energy sector is still very much under-represented. During workshop 5 however, there was representation by Eskom, the parastatal power producer. However, despite efforts, there is still little to no engagement from the Department of Mineral Resources and Energy or coal mining entities. It should be noted that other stakeholders have indicated the lack of representation of these parties at various other forums and stakeholder engagement meetings within the catchment.

It was also established that stakeholders would like to see an increase in more powerful actors at the national level getting involved in the project. Subsequently, additional effort is being placed on trying to arrange bilateral meetings with more powerful actors. Further efforts are being pursued to exploit existing stakeholder relationships to establish connections with more powerful actors. The intention is to use the NEPAT and Governance Roadmaps as tools to capture the attention of more powerful actors and equip them with the tools necessary to implement policies that may affect the desired impacts within the catchment.

The third workshop was held virtually. Attendance at this workshop was high; however, engagement was not as high, which may have resulted from the workshop length and virtual format. The fourth stakeholder workshop was hybrid, however, attendance, both in-person and online, was not as high as expected. This could be due to the timing of the workshop,

which was held shortly before a series of public holidays and (unintentionally) at the same time as the consultations with regard to the update of the National Water Act were underway. Although attendance numbers were low, engagement was high, especially with stakeholders who attended in person. This also assisted with increasing engagement from stakeholders who had joined virtually.

To try and overcome the issues regarding attendance and engagement, the fifth workshop was split into three parts, namely a virtual NEPAT exploration session and two in-person sessions (one in the case study area and one in the area in which national departments are located). The use of the virtual session boosted attendance of the workshop and was also used to encourage attendance of the in-person sessions. In order to bring awareness of the workshop 5 activities, a newsletter was distributed to all stakeholders following the issuance of calendar invitations, and a social media post was released. Attendance of the virtual session was increased with representation from each sector, and engagement from all sectors was good.

The subsequent in-person workshops had improved attendance, and although a water-centric group of stakeholders attended the first workshop, there was representation in the second workshop from the four WEFE sectors. There was increased engagement during these in-person workshops resulting in significant steps towards a validated policy package and the identification of tangible outcomes and actions to be included in the Governance Roadmaps to assist in the implementation of two of the policy instruments.

Focus sessions have been held with the Department of Water and Sanitation, IUCMA, SANBI and Department of Forestry, Fisheries and the Environment. These have been beneficial in delving deeper into issues and data availability in the catchment. These sessions have assisted in building relationships with the stakeholders and links to other stakeholders have been made through these sessions.

Interviews with stakeholders from all sectors from a local to regional scale were held in order to assist with conducting the governance assessment. These interviews helped to forge and strengthen relationships with the stakeholders. Detailed information on the case study and the national context was also gleaned from these interviews, which helped to identify specific priorities that should be focused on.

A policy coherence assessment session was held with experts from each sector; however, the energy sector was not represented even though specific efforts were made to include the sector in this session. This session also helped to strengthen relationships with the stakeholders as they were specifically chosen to impart their knowledge with the team. In-depth knowledge of each sector (when looking at the identified coherences) was shared by each stakeholder.

A NEPAT Exploration session was held by WP4 to introduce stakeholders to the NEPAT tool. Despite communication efforts attendance from CS5 stakeholders was low. To ensure that stakeholders did not feel like they had been left out from the NEPAT discussion and to ensure there is an understanding about the tool and its potential, as well as to get feedback from the potential users of the tool, the NEPAT was presented again in the fourth stakeholder workshop. Stakeholders seemed interested in the tool but may have found it slightly overwhelming/ intimidating as they were not able to experiment with it themselves but were only shown how it works. However, the link to the website and instructions to assist with familiarising stakeholders with the tool were provided to the stakeholders. WP4 also used the workshop to gather feedback from stakeholders to modify and improve the tool.

A serious of governance roadmaps is in the process of being developed. During the workshop 5 in-person sessions, the governance roadmaps for two policies were explored with stakeholders. In addition to this, bilateral sessions with key stakeholders are taking place. At this point, one session with the IUCMA has been held to specifically discuss the policy cycle for the policy '*Investment in reparation of water distribution and treatment infrastructure and in maintenance and monitoring of these systems to prevent leakage'*. Two sessions were held to discuss the policy on SWSAs one with a key stakeholder from the DFFE and one with a key stakeholder at SANBI.

Adjusting the SH engagement plan

Stakeholder feedback that may have an impact on the stakeholder engagement plan includes:

- The incorporation of a roadmap for the project to better understand the objectives and steps to reach these objectives. Stakeholders would like to know 'what they are getting themselves into' and the benefits of getting involved. In subsequent workshops a project roadmap was presented to stakeholders detailing what work was concluded within the project as well as the way forward for the project. In the later sessions the incorporation of stakeholder inputs was also indicated on the roadmap.
- Stakeholders believe that the public sector agricultural stakeholders are under-represented.
- Stakeholders believe that stakeholders from organisations that promote indigenous / traditional knowledge should be included.
- Stakeholders recommended that a project-wide virtual event should be organised toward the end of the project (with a political inflection) that brings together key decision makers from the various case studies. Key results could be presented, and stakeholders could exchange strategies for implementation.
- Stakeholders encouraged the use of the hybrid meeting method for future workshops.

Two stakeholders from Eskom attended workshop 5, increasing energy sector representation in the project. Invitations to bi-lateral sessions, if deemed necessary, or invitations to the final workshop of the project will be sent to the public energy sector in an attempt to increase participation. In terms of traditional/indigenous stakeholders, due to budget, capacity and time constraints, the inclusion of these stakeholders in the project was not considered feasible however the value and local knowledge that these stakeholders can add is acknowledged and it is recommended that traditional/indigenous stakeholders be approached when conducting future research projects. Through the use of bilateral sessions, the project has been able to engage with higher power stakeholders. It is envisaged to attempt to have bilateral sessions with additional high-power stakeholders leading up to workshop 6.

The hybrid format was followed for workshop 4 and was considered for workshop 5. However, in order to engage with all stakeholders effectively, it was decided to hold a virtual session demonstrating the NEPAT, followed by two in-person sessions, one in Mbombela (located within the catchment) and one in Centurion (located in close proximity to national government offices). This approach allowed for increased participation in the workshop, and effective engagement with all stakeholders.

NEXOGENESIS
STREAMLINING WATER RELATED POLICIES

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3.6 From policy recommendations to impact maximisation (WP6)

During the initial phases of the project, a top-tier stakeholder indicated that there are a significant number of studies and research underway and completed within the IUWMA, with many of these projects having little to no impact on the ground. It was emphasised that implementation and action would be required to ensure the project would have a lasting impact.

Throughout the NXG project, a core group of dedicated stakeholders has shown significant interest in the project. To ensure that stakeholders' requests were considered throughout the project and to minimise the fatigue resulting from constant requests for input, stakeholders were provided with results at every opportunity.

It was evident from workshop five and various bilateral sessions that stakeholders are beginning to see value in the project's outputs:

- The use of the NEPAT and the associated WEFE footprint have highlighted synergies and trade-offs to policy implementation. This has highlighted or re-emphasised the value of cross-sectoral collaboration.
- The workshops have provided useful forums for cross-sectoral discussions and meaningful connections. This has also allowed stakeholders to form or strengthen ties across different sectors and some stakeholders indicated that they are now working closely with colleagues in other sectors. Some stakeholders seemed excited about taking Nexus thinking forward in the work that they do.
- Investigating the governance roadmaps has allowed stakeholders to critically assess the bottlenecks to policy implementation and where they could assist in streamlining policy implementation.
- Additionally, stakeholders identified the relevant parties that should be responsible for various actions and outcomes within the governance roadmaps and have committed to make the necessary introductions.
- The DSS results have provided stakeholders with a starting point to identify a policy package that could achieve a desired set of goals.
- The case study leads have been invited to present the NEPAT and governance roadmaps at the IUCMA catchment forums and SANBI's technical advisory group for the implementation of the SWSAs in May 2025.
- A stakeholder from the IUCMA has shown particular interest in the project's approach to Stakeholder engagement and is interested in following a similar approach to stakeholder engagement within the catchment during catchment management forums.

In addition to exploiting the opportunities above and to ensure that a lasting impact is achieved within the Inkomati Usuthu Water Management Area, further efforts to engage with more powerful actors at the national level will be explored. This will place NXG project outputs in the right hands to ensure the necessary impacts are achieved within the catchment and provide opportunities for a potential stakeholder agreement that could have lasting impacts within the catchment.

4 Lessons learned and experiences

4.1 Implementing the SHE plan

There are steps that provided guidance on identifying stakeholders who should be involved, when in the project they should be involved and for what aspect the respective stakeholders will be best suited. The steps also provided guidance on how to keep our stakeholders engaged during the project. These steps include:

- Identification of stakeholders including name, position, email address, expectations/driving factors.
- Categorisation and differentiation: Selecting relevant tiers and categories.
- Differentiation of stakeholders based on Power-Interest.
- Analysis of stakeholder relationships using actor-linkage matrices.

The steps were not always strictly followed. For example, in some cases all stakeholders were included in discussions regarding issues that are specific to stakeholders from a given sector or level. Stakeholders from different sectors and levels are often able to view issues from a different perspective and are often able to identify aspects that could have been overlooked. Where required, stakeholders who were not able to attend the workshop and are critical for specific aspects of the case study are targeted for focus sessions. One example is meetings to go through the detail of the governance roadmaps with stakeholders who could influence decision makers.

The evaluations have allowed the CS leaders to identify stakeholder needs in terms of information sharing and workshop methods. During discussions with other CS leads, ideas on potential discussions with stakeholders were identified and methods to encourage engagement with stakeholders were shared.

4.2 Reflecting on/improving the SHE process

- In-person meetings allow for better engagement with SHs than virtual meetings, however due to the scale of the catchment and location of SHs, the virtual meetings allow for greater attendance.
- Workshops where activities were held interested the stakeholders and participation was improved.
- SHs want to see results and therefore sharing of deliverables and results are important. However, the display of the results needs to be carefully considered to get the correct message across to SHs and to assist with understanding the available results.
- Although most of our stakeholders are fluent in English, South Africa has 11 official languages, and some stakeholders would have benefited from translating communications into different languages. However, the challenge is to select the appropriate languages, as translation into all 11 official languages would not be feasible.
- Additionally, being a developing country, not all stakeholders have access to internet and electricity. Therefore, other modes of communication could have been considered.

- When introducing a complex tool such as NEPAT, stakeholders require an extended period of time to work through the tool with the NXG team to fully understand the tool's functionalities. The team has allowed for additional sessions with stakeholders where necessary to work through the tool's functionalities due to the limited time available during the workshop 5 virtual session.

4.3 Integrating sectors in the NEPAT

The main challenges pertaining to integrating the sectors into the NEPAT relate to the complexities of the nexus. It was evident from early on that capturing all of the intricacies of the nexus would not be achievable. Throughout the project, efforts were focussed on modelling the critical aspects of the nexus where feasible.

One of the early challenges experienced when developing the SDMs was related to obtaining the necessary local data at a catchment scale:

- Data is often available based on administrative boundaries, not at a catchment scale.
- Often, data is available from stakeholders. However, the data has an economic value to the stakeholders, and they are not always willing to share the information.
- Data such as imports and exports of food is available nationally, but there is little to no information available at a catchment scale.

In addition to the challenges with regard to data, there has been limited involvement from the energy sector and mining. This limited involvement from these sectors made it challenging to fully map the intricacies of the energy sector. Additionally, the impacts of mining on other sectors is often closely guarded information due to the economic benefits associated with mining. The lack of information and mining-related policies resulted in the omission of mining and its impacts on the Nexus within the SDM for the IUWMA. It is recommended that mining is considered for future model development within the IUWMA.

4.4 Using the tools

The stakeholders have expressed both interest and excitement in the outcomes associated with the case study and tools such as the models, SDM and NEPAT. These tools have value both to aid in understanding and also have credibility due to the data driven approach. The stakeholders have however stressed that in order for the tools to bridge the gaps and help with understanding the Nexus, the tools need to be intuitive, simple to use and relevant. The use of visualisations such as a composite indicator "Footprint" with the WEFE nexus as its guiding framework will assist in ease of use and understanding the Nexus. Further to this, the stakeholders reiterated the importance of the tools and policy recommendations reaching the competent authorities, combined with the ability to interpret and implement the policy packages required.

The stakeholders have been involved in a session to introduce the NEPAT held by WP4, as well as in the workshop 5 virtual session. As the attendance of the WP4 NEPAT session was low for our case study, a portion of the fourth workshop was also focused on introducing the tool to the stakeholders and getting a feel for their initial thoughts. In the workshop 5 in-person sessions the CS lead demonstrated the use of the NEPAT and DSS to target specific goals.

Validation of the tool's results is critical in establishing stakeholder confidence in the tool, its results and the resulting recommendations.

4.5 Motivating stakeholders to use the NEPAT

To ensure that stakeholders engage with the tools developed as part of the project it is critical that the tool is intuitive to work with. Stakeholders should be provided with access to tutorials on using the final tool. The presentation of results must also be intuitive and understandable, sufficient information must be provided to communicate the impact of different policy packages and reference scenarios, while ensuring that the results provided do not confuse the stakeholders. One stakeholder emphasised the value of short format videos to quickly and effectively communicate information. Online videos and tutorials are available for many aspects of the project.

The workshop five virtual sessions focused on presenting the NEPAT functionalities to stakeholders. Based on the level of engagement with stakeholders during this session, it seems that stakeholders were motivated to engage further with the tool. It was indicated that the tool provides a good visual indicator for the trade-offs we are not necessarily aware of or helps with visualising the trade-offs that we are aware exist.

It is also essential that the NEPAT is presented to stakeholders with the ability to implement changes to current policy regimes. The challenge is to maintain the interest of the high-power policy-making stakeholders. However, existing relationships between the case study leaders and essential stakeholders may be beneficial once the tool is ready for exploitation. Careful introduction of the ready-to-use tool to these SHs will be important.

The case study is motivating the SHs to stay involved in the tool development and make use of the tool, but it is ultimately up to the stakeholders to share the tool with those they deem relevant and to make the effort to ensure the tool works for them.

The case study leads have been invited to present the tool at the catchment management forum which will provide further exposure of the tool, and may result in motivating additional stakeholders to engage with the tool and make use of the relevant outputs.

4.6 The overall NXG co-creation approach

Stakeholder engagement has been instrumental in understanding the constraints, challenges and general nature of the IUWMA. A key reason for selecting this case study is that it has a well-developed Catchment Management Agency (CMA), i.e. the IUCMA. This assumption has been proved to be correct, and the adoption of competent CMAs across South Africa would be hugely advantageous for all citizens.

Interpretation of data that has been provided by WP2 was initially challenging, but as the project has progressed, communication improved. In order for a project of this magnitude with so many partners to succeed it is important for an open line of communication to be established between WPs and CSs to allow for ease of clarifying any information received. It is also important that the CS team 'ground-truth' data to assess whether it is relevant and representative.

Workshops such as the one held in Berlin provide a great opportunity for brainstorming with all role players. Workshops help develop and share ideas in resolve issues and challenges within the case study, based on similar challenges experience by other case studies. In the

workshop clarity was provided on certain deliverables and aspects of the project that were not clear.

Throughout the project it has become evident that there are often partners within the consortium with tools and skills who can assist in achieving specific tasks. Communication of challenges and/or problems with the greater consortium can assist in finding resolutions more timeously. There is a wealth of knowledge and skills within the consortium that is sometimes overlooked.

For this project the models are developed at a catchment level, however data and information are often only available on an administrative level which makes the obtaining of the data considerably more challenging and often requires significant processing to transform the data to a catchment level. The catchment level makes sense in terms of the water related aspects, however, when it comes to food and energy most of the information and data is available based on administrative boundaries. Additionally, the implementation of policies is in general at an administrative boundary level.

Annex 1: WP5 – Description of Case Study Coordination

WP5 supports the implementation of the NXG approach in the five CSs through:

a) the development of a roadmap that guides the work of CSs in NXG.

b) the management of internal communication between CSs and WPs.

c) the development and implementation of a stakeholder engagement strategy.

d) the continuous coordination and monitoring of all CSs activities.

Special emphasis is placed on the provision of guidelines and training to support stakeholder engagement processes in the five CSs, as stakeholders provide valuable inputs to the WPs (WP1-4). The WP5 guidance leads to better integration of the project results coming from the different WPs. This work helps to maximize the impact of the project (WP6).

The work of WP5 is complementary to the co-creation processes undertaken in WP1. The co-creation processes ensure the coordination of WPs1, 2, 3, 4 and in particular the timely and effective flow of information between the technical WPs (2, 3, 4) and the policy and governance work package (WP1) based on the input received from stakeholders from CSs. As such, WP5 work connects all the other WPs in the project. An overview of the links between WP5 and other WPs is presented in Figures 7 and 8 in Milestone 2 (MS2) - *Roadmap for Case Study Work/Activities in NEXOGENESIS*.

WP5 is responsible for five (5) tasks, seven (7) deliverables and six (6) related milestones with specific dates and timelines during months 1-48. A timeline of these WP5 activities can be found in MS2 - Roadmap for Case Study Work/Activities in NEXOGENESIS, Figure 9. They all require close collaboration of the WP5 team with each CS lead and coordination with other WPs. CS leaders play a critical role in co-developing the guiding documents (e.g., the CS roadmap) by expressing their needs, their preferred mode of communication, their ability to contribute with local knowledge, and by validating the developed guidelines, documents, and roadmap.

The first milestone of WP5 (MS2 – Roadmap for Case Study Work/Activities in NEXOGENESIS) concerns the development of a roadmap for CS work with the aim of guiding CSs in NXG and, more particularly, their contribution to each WP. It constitutes a timeline for all relevant activities described in relation to the work and needs of all relevant WPs (WP1-4).

The second milestone of WP5 (MS5 – Internal Communication Strategy) is a practical resource that fosters the communication between CS leaders and WP leaders but also supports the exchange of relevant information/experience among the leaders of different CSs, as further explained below.

The third milestone of WP5 (MS6 – Stakeholder Register) presents the stakeholder (SH) identification process to generate the SH register for each CS. This document reports on the steps and considerations given to CS leads to identify the respective relevant SHs. It also provides preliminary results for each CS including the categorization of different SH groups according to their engagement interest and function.

The fourth milestone (MS8 – CS Monitoring Plan) includes activities to enable WP5 to monitor the CSs' work and potential amendment actions (if needed, in the case of delayed work). Its

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aim is to facilitate the progress of the CS activities, thereby ensuring a successful implementation of the project work in each CS.

The fifth milestone (MS15 – Intermediate report on case study implementation and co-creation activities) provides detailed internal monitoring of case study implementation activities during months 1-18 of the project (September 2021-December 2022).

The sixth milestone (MS23 –Milestone 23: Intermediate report on case study implementation and co-creation activities for the Inkomati-Usuthu Water Management Area CS) provides detailed internal monitoring of CS implementation activities during months 19-36 of the project (January 2022-August 2024).

Annex 2: Schedule of all activities performed

The following table provides an overview of the activities performed up to January 2025.

Date	Type of Activity	Purpose	Participants
24 May 2022	Stakeholder Workshop 1	To start the stakeholder engagement process, build relationships & share the project details	JAWS, IHE, stakeholders from WEFE sectors
20 Sept 2022	Review of socio-economic/biophysical data		JAWS
11 Oct 2022	Policy inventory & coherence (first draft)	Provide applicable policies (including their objectives and instruments) and the assessment of their role in the WEFE sectors	JAWS, KWR
14 Oct 2022	Focus Session (DWS: Water quality)	Confirm issues in the catchment, data availability	JAWS
19 Oct 2022	Focus Session (IUCMA)	Confirm issues in the catchment, data availability	JAWS, IUCMA
20 Oct 2022	Stakeholder Workshop 2	To discuss and get inputs on the conceptual maps, policies and targets, the WEFE nexus with stakeholders and filling in of the stakeholder engagement evaluation survey	JAWS, UU,
20 Oct 2022	Decide on WEFE Nexus Indicators		JAWS
27 Oct 2022	Focus Session (DWS: Water quantity)	Confirm issues in the catchment, data availability	JAWS, DWS
03 Nov 2022	Submit updated conceptual maps	After multiple review process with IHE and stakeholders, updated CMs were submitted	IHE, JAWS
30 Jan 2023	Completion of Causal Loop Diagrams and inputs into MS11	Causal Loop diagrams were completed to assist in the development of the	JAWS, IHE

Date	Type of Activity	Purpose	Participants
		Systems Dynamics Models (SDMs)	
13 Feb 2023 – 24 Feb 2023	Stakeholder interviews for governance assessment	Interview stakeholders from different sectors from local to national level for the purpose of conducting the governance assessment	WP1, JAWS
24 May 2023	Policy Coherence Expert Session	Session with experts from each sector to present the policy coherence spreadsheet and get feedback	WP1, JAWS
5 Jun 2023	Stakeholder Workshop 3	To validate the policy instruments, provide feedback on the governance assessment and discuss the SH engagement process	JAWS
28 Jul 2023	Submission of validated policy instruments	Finalise the SH validated instruments to go into the NEPAT	JAWS
Jul – Dec 2023	Sourcing local data from SH and various local databases	Obtain local data to feed into the SDMs	JAWS
Jul – Dec 2023	Collaboration with WP3 on SDM development	Development of the CS SDMs to feed into the NEPAT	JAWS/IHE
17 Dec 2023	Submission of Base Case SDMs to WP4	To Allow WP4 to start translating SDMs for the NEPAT	JAWS/IHE
Jan – Apr 2024	Quantification and linking of SH Validated Policy Instruments to SDM Variables	To allow WP3 to incorporate the policy instruments into the SDM	JAWS, WP1
11 Jan 2024	Berlin Workshop	Discussions regarding stakeholder engagement between all case studies	All case studies/WP1/WP5
16 Feb 2024	Submission of draft SDMs including the implementation of policy packages to WP4	To allow WP4 to translate policy packages for alignment with the NEPAT	JAWS, IHE
Feb – Apr 2024	Quantification of targets/goals for the implementation of the NEPAT	To assist WP4 in the implementation of the NEPAT for the CS	JAWS

Date	Type of Activity	Purpose	Participants
21 Feb 2024	NEPAT Exploration Session	Introduce the SHs to the NEPAT tool and get feedback	WP3
19 Mar 2024	Stakeholder Workshop 4	To discuss and get inputs on the SDMs, NEPAT and SH agreements.	JAWS
13 Apr 2024	Submission of Final Policy Packages to WP3 for updating the SDMs	To Allow WP3 to update SDMs including policy instruments	JAWS
13 Apr 2024	Submission of targets/goals to WP4	To Allow WP3 to incorporate CS goals into the NEPAT	JAWS
17 Apr 2024	Submission of updated SDMs, including policy instruments, to WP4	To Allow WP4 to apply the NEPAT to the CS	JAWS, IHE
Apr – Aug 2024	Continuous engagement with WP4 on the implementation of the SDMs, policies and targets/goals in the NEPAT	To ensure the successful implementation of the CS in the NEPAT Tool	JAWS, IHE, WP4
17 September 2024	Bilateral session with the IUCMA – Governance Roadmap	To confirm the policy cycle for the policy 'Investment in reparation of water distribution and treatment infrastructure and in maintenance and monitoring of these systems to prevent leakage'.	JAWS, WP1
17 Oct 2024	WS 5 – Virtual Session	To have an in-depth exploration session with stakeholders, including using a case study example to demonstrate NEPAT functions.	JAWS, IHE, WP5, WP1, WP4
17 Oct – 6 Dec 2024	First round of Validation of NEPAT & SDM results.	To validate the results of the SDMs presented in the NEPAT and ensure that the implementation of policy instruments were as expected.	JAWS, WP3 (IHE) & WP4
6 Dec 2024 – 6 Jan 2025	Update SDM, NEPAT & DSS	Based on the validation of the results, the SDMs were updated and	WP3 (IHE) & WP4

Date	Type of Activity	Purpose	Participants
		subsequently the NEPAT was updated.	
6 - 22 Jan 2025	Second round of Validation of NEPAT & SDM results.	To validate the results of the updated SDMs presented in the NEPAT and ensure that the implementation of policy instruments were as expected.	JAWS, WP3 (IHE) & WP4
23 Jan 2025	Bilateral session with the SANBI – Governance Roadmap	To confirm the policy cycle for the policy 'Assign Surface Water Strategic Areas as Protected Areas.'	JAWS, WP1
23 – 25 Jan 2025	Update SDM, NEPAT & DSS	Based on the second validation of the results, the SDMs were updated, and subsequently, the NEPAT was updated.	WP3 (IHE) & WP4
28 & 29 Jan 2025	SH Engagement Workshop 5	Validation of Policy Package, governance roadmap development and stakeholder landscape recap.	JAWS, WP1 & WP5
29 Jan 2025	Bilateral session with the DFFE – Governance Roadmap	To confirm the policy cycle for the policy 'Assign Surface Water Strategic Areas as Protected Areas.'	JAWS, WP1