DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems Management

DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE UPPER ORANGE RIVER CATCHMENT

STATUS QUO AND DELINEATION OF INTEGRATED UNITS OF ANALYSIS AND RESOURCE UNITS REPORT WP 11422

Study Report No.

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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

REPORT INDEX	REPORT NUMBER	REPORT TITLE
1.0	RDM/WMA13/00/CON/CLA/0123	Inception Report
2.0	RDM/WMA13/00/CON/CLA/0124	Water Resources Information and Gap Analysis Report
3.0	RDM/WMA13/00/CON/CLA/0224	**Status Quo and delineation of Integrated Units of Analysis and Resource Units Report**

TERMINOLOGY AND ABREVIATIONS

Acronym	Description
AEH	Aquatic Ecosystems Health
BHN	Basic Human Needs
BYC	Borehole yield classification
CBA	Critical Biodiversity Areas
CD: WEM	Chief Directorate: Water Ecosystems Management
CMB	Chloride mass balance
CRR	Cumulative Risk Rating
DCVB	Discontinuously Channelled Valley-Bottom
CMA	Catchment Management Agency
DFFE	Department of Forestry, Fisheries and the Environment
DRDLR	Department of Agriculture, Land Reform and Rural Development
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FSC	Full Storage Capacity
GDP	Gross Domestic Product
GRA	Groundwater Resources Assessment
GRU	Groundwater Resource Unit

Acronym	Description
ha	hectare
HGM	Hydrogeomorphic
HSS	Hillslope Seep
IDP	Integrated Development Plan
IUA	Integrated Unit of Analysis
IVRS	Integrated Vaal River System
IWRM	Integrated Water Resource Management
JBS	Joint Basin Survey
KPA	Key Performance Area
LHWP	Lesotho Highlands Water Project
LM	Local Municipality
MAR	Mean Annual Run-off
mm/a	Millimetres per annum
mamsl	Meters above mean sea level
MEA	Millennium Ecosystem Assessment
MIRAI	Macroinvertebrate Response Assessment Index
MM	Metropolitan Municipality
Mm^3	Million cubic metres
m.o.l	Minimum operating level
NCMP	National Chemical Monitoring Programme
NCWQ	National Chemical Water Quality
NEMP	National Eutrophication Monitoring Programme
NFEPA	National Freshwater Ecosystem Priority Areas

Acronym	Description
nMAR	natural Mean Annual Run-off
NMMP	National Microbiological Monitoring Programme
ORP	Orange River Project
ORS	Orange River System
ORASECOM	Orange-Senqu River Commission
OSAEH	ORASECOM Aquatic Ecosystems Health (monitoring site ID prefix)
PAH	Polycyclic Aromatic Hydrocarbons
PES	Present Ecological State
POP	Persistent Organic Pollutants
QC	Quaternary Catchment
REMP	River Eco-Status Monitoring Programme
RQOs	Resource Quality Objectives
RDM	Resource Directed Measures
RQIS	Resource Quality Information Services
RUs	Resource Units
SEZ	Socioeconomic Zones
SI	Stress Index
SQ	Sub-quaternary
SwIUA	Surface water integrated units of analysis
SWSA	Strategic Water Source Area
SWSA-gw	Groundwater Strategic Water Source Area
SWSA-sw	Surface Water Strategic Water Source Area
TDS	Total Dissolved Solids

Acronym	Description
TEEB	The Economics of Ecosystems and Biodiversity
UCVB	Unchanneled Valley-Bottom
VB	Valley-Bottom
WC/WDM	Water conservation/ water demand management
WEM	Water Ecosystems Management
WMA	Water Management Area
WQ	Water quality
WQPL	Water quality Planning Limits
WRCS	Water Resource Classification System
WRPM	Water Resource Planning Model
WRU	Wetland Resource Unit
WWTW	Wastewater Treatment Works

EXECUTIVE SUMMARY

The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) initiated a study for the determination of Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River catchment in October 2023.

The purpose of this study is to coordinate the implementation of the determination of water resource classes and associated resource quality objectives for all significant water resources as part of implementing the Water Resource Classification System (WRCS) in the Upper Orange River catchment.

The determination of the water resource classes is necessary to facilitate a balance between protection and use of water resources. In determining the class, it is important to recognise that different water resources will require different levels of protection which requires due consideration of the social and economic needs of competing interests by all who rely on the water resources. The classification process is applied taking account of the local conditions, socio-economic imperatives, and system dynamics within the context of the catchment, and in the case of the Upper Orange River catchment, will consider aspects related to the Lower Orange River catchments as well as the Vaal River System, as they are all integrated. The process will therefore also require a wide range of complex trade-offs to be assessed and evaluated at several scales.

The first step of the Classification process is to assess status quo of water resources and delineate the units of analysis i.e. the spatial units that will be defined as a network of significant water resources.

The purpose of this report is therefore to describe the status of the water resources in the Upper Orange River catchment in terms of the water resource systems, the ecological characteristics, the socio-economic conditions, and the community well-being. Water resource description and characterisation based on water resource operation and management, location of significant water resource infrastructure (including proposed infrastructure), water resource characteristics and condition, groundwater resources, water quality and distinctive functions of the catchments in context of the larger system have been assessed and the findings are documented here. The socio-economic analysis of the catchment has also been undertaken and a perspective is presented in the report.

This information was then used to delineate socio-economic zones And Integrated Unit of Analysis (IUAs) and provide background information to assist with the Ecological Water Requirements (EWR) quantification step that is to follow. In addition, this report presents proposed resource units, for the ultimate setting of resource quality objectives.

Integrated Units of Analysis (IUAs)

Each integrated unit of analysis (IUA) represents a homogenous area which requires its own specification of the water resource class. The process followed in terms of IUA delineation is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification

procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, February 2007).

Delineation of IUAs is required as it would not be appropriate to set the same water resource class for all water resources in a catchment. The delineation of a catchment into IUAs for the purpose of determining the water resource class is done primarily according to a number of socio-economic criteria and drainage region (catchment area) boundaries. IUAs are thus a combination of socio-economic zones and watershed boundaries (DWA, 2007). Ecological information also plays a role in the delineation. The following were considered for delineation of IUAs within the Upper Orange River catchment:

- Socio-economic zones (SEZs)
- Catchment area boundaries (drainage regions and water resource systems)
- The resolution of the hydrological analysis and available water resource network configurations within the water resource models
- Location of significant water resource infrastructure
- Land use characteristics
- Distinctive functions of the catchments in context of the larger system
- The Present Ecological State (PES) of each biophysical node was considered, the type of impacts and the homogeneity of the status and impacts
- The practicalities of the existing model setup and network in terms of the scenario evaluation of each IUA
- Present status of water resources, and
- Stakeholder input and review.

IUA Delineation Results

Ten IUAs have been delineated for the Upper Orange River catchment. The results of the delineation are tabled below and illustrated in Figure E1. Detail descriptions of each IUA is presented in the report.

IUA	Description	Quaternary
1	Golden Gate	D21D and a portion of D21A along South Africa/ Lesotho border
2	Caledon/ Leeu River	D21E, D21F, D21G; portion of D21C; D22A, D22B; portions of D21H and D22C along the SA/ Lesotho border; Portions of D22D, D22G, D22H, D22L, Portion of D23A, D23C, D23D and portion of D23E
3	Caledon River	D23F, D23G, D23H, D23J, D24A, D24B, D24C, D24D, D24E, D24F, D24G, D24H, D24J, D24K and D24L
4	Kraai River	D13A – D13M

IUA	Description	Quaternary
5	Upper Orange River	D12A – D12F, D14A – D14K, Portions of D15G, D15H, D18K and D18L
6	Gariep Dam	D34A, D34B, D34C, D34D, D34E, D34F, and D34G, D35A, D35B, D35C, D35D, D35E, D35F, D35J, D35G, D35H, D35K
7	Seeikoei River	D32A, D32B, D32C, D32D, D32E, D32F, D32G, D32H, D32J, D32K
8	Vanderkloof Dam	D33A – D33K (along main stem Orange River); D31A – D31E
9	Upper Modder River	C52A, C52B, C52C, C52D, C52E, C52F and C52G
10	Modder/ Riet River	C51A, C51B, C51C, C51D, C51E, C51F, C51G, C51H, C51J, C51K, C51L, C51M, C52H, C52J, C52K and C52L

Preliminary Resource Units Delineation Outcomes

Considering the IUAs delineated, and integration of the status quo components discussed in the report, as well as expert knowledge and discussions with specialists, catchment water resource managers and the DWS study team, 40 surface water resource units (RUs) tabled below and illustrated in Figure E2, have been preliminary delineated for the Upper Orange River catchment.

RU Number	Resource Unit Description	Quaternary catchments
IUA 1: Golden Gate		
1.1	Little Caledon River with Caledon River in the D21A portion in SA	D21D and a portion of D21A along SA/ Lesotho border
IUA 2: Caledon/ Leeu River		
2.1	Little Caledon River and Caledon River along the Lesotho Border including tributaries Moolmanspruit and Meulspruit, and the Meulspruit Dam	D21E, portion of D21C; D22A and D22B; portions of D21H and D22C along the SA/ Lesotho border
2.2	Swartspruit and Brandwater River, tributaries of the Caledon River	D21F and D21G
2.3	Caledon River along the Lesotho Border to the Leeu River confluence including tributaries: Modderpoortspruit, Tenniskopspruit, Tweelingspruit, Appledorespruit and Bokpoortspruit, including Cathcartdrift Dam	Portions of D22D; D22H; D22L, Portion of D23A, and portion of D23E
2.4	Leeu River and tributaries Klein-Leeu River and Mokopu River, and including Lovedale and Newberry dams	D23C, D23D
2.5	Armenia Dam on the Leeu River	D23C
2.6	Mopeli River and tributaries: Rantsho River, Morakabi River, McCabesspruit, Beytelspruit and Modderpoortspruit, and Mopeli Dam	D22G

RU Number	Resource Unit Description	Quaternary catchments
IUA 3: Caledon		
3.1	Caledon River and tributaries Klipspruit, Rietspruit, Nuwejaarspruit and Bloemspruit	D23H, D23J, D23G and D23F
3.2	Welbedacht Dam in the Caledon Nature Reserve	D23J
3.3	Caledon River and tributaries Boesmanskopspruit, Vaalspruit, Wilgeboomspruit, Vinkelspruit, Grahamstadspruit, Sandveld, Skulpspruit, Slykspruit and Hartbeesfontein	D24D, D24E, D24F, D24G, D24H and D24J; D24K and D24L
3.4	Caledon River and tributaries Klipspruit, Elandspruit, Witspruit and Blaasbalkspruit	D24A, D24B, D24C
3.5	Egmont Dam	D24A
IUA 4: Kraai River		
4.1	Kraai River and tributaries Malpas River, Riflespruit, Bokspruit, Koffiehoekspruit, Bamboeshoekspruit, Sterkspruit, Klein-Wildebeesspruit, Diepspruit, Three Drifts, Joggemspruit, Vlooikraalspruit, Langkloofspruit, Rytjiesvlaktespruit, Vrouenshoekspruit, Noodshulpspruit, Vaalhoek River, Saalboomspruit, Wasbankspruit and Wolwespruit	D13A, D13B, D13C, D13D, D13E, D13F, D13G and D13K
4.2	Holspruit and tributarie Braklaagtespruit, Leeuspruit, Skulpspruit and Telemachusspruit	D13J and D13H
4.3	Kraai River and tributaries Windvoelspruit, Bossielaagtespruit, Oslaagte, Rondefonteinspruit, Klipspruit ad Elandspruit	D13M and D13L
IUA 5: Upper Orange River		
5.1	Sterkspruit and tributaries Mlangeni River, Mbongo River and Kromspruit	D12B
5.2	Jozana's Hoek Dam on the Sterkspruit	Upper D12B
5.3	Orange River and tributaries Tele River along the Lesotho border, Blikana River, KwaSijora, Pelendaba, Mantikoana River, Deklerkspruit, Worsfonteinspruit, Hendrik Smitstroom, Bamboespruit, Wilgespruit, Gryskopspruit, Winnaarspruit, Knoffelspruit, Beeskraalspruit, Nuwejaarpspruit, Kop-en-pootjiespruit and Wilgerspruit	D18K, Portions of D15G, D15H and D18L in SA, D12A, D12C, D12D, D12E, D12F
5.4	Stormbergspruit and tributaries Wonderhoekspruit, Wilgespruit, Klein-Buffelsvleispruit, Witkopspruit, Barnardspruit, Mooiplaasspruit, Elandslaagte and Wikopspruit	D14B, D14C, D14D, D14E, D14F, D14G and D14H
5.5	Orange River and tributaries Gladdegrond, Melkspruit, Sanddrifspruit, Modderbuirspruit and Palmietspruit	D14A, D14J and D14K
IUA 6: Gariep		
6.1	Gariep Dam	D35H and D35K
6.2	Orange River and tributaries Rooirantjies, Oudagspruit, Winnaarbakespruit, Brandspruit, Broekspruit, Bossiespruit, Swarthoekspruit and Brakspruit	D35A, D35B, D35C, D35D, D35E, D35F and D35G
6.3	Main stem Orange River between Gariep and Vanderkloof dams	D34A, D34E, D34F and D34G
6.4	Orange River and tributaries Suurbergspruit, Donkerpoortspruit, Oorlogspruit, Klipfonteinspruit, Rietkuilspruit and Vanderwaltfonteinspruit	D35J, D34A, D34B, D34C, D34D, D34E, D34F and D34G

RU Number	Resource Unit Description	Quaternary catchments
IUA 7: Seekoei River		
7.1	Seekoei River	D32A, D32B, D32C, D32D, D32E, D32F, D32G, D32H, D32J and D32K
IUA 8: Vanderfkloof Dam		
8.1	Vanderkloof Dam	D31E
8.2	Orange River below Vanderkloof Dam	D33A
8.3	Orange River mainstem	D33A, D33B, D33C, D33D, D33E, D33F, D33H, D33J and D33K (along mainstem)
8.4	Tributaries draining to the Orange River on RU8.3 Knapsak River, Hondeblaf River, Berg River, Lemoenspruit	D31A, D31B, D31C, D31D, D33A, D33B, D33C, D33D, D33E, D33F, D33H, D33J and D33K
IUA 9: Upper Modder		
9.1	Rustfontein Dam on the Modder River	C52A
9.2	Modder River and Klein Modder and Kgabanyane Dam (Groothoek Dam) on the Kgabanyane River, with tributaries: Gannaspruit, Krompsruit, Bo-Kromspruit, Wildebeespruit and Grootpan	C52A and C52B
9.3	Modder River and tributaries Steynspruit, Korannespruit, Koringspruit, Matjiesspruit, Osspruit, Bloemspruit, Renosterspruit, Doringspruit, Rietspruit and Stinkhoutspruit	C52C, C52D, C52E, C52F and C52G
9.4	Krugersdrif Dam on the Modder River at the outlet of quaternary catchment C52G	C52G
IUA 10: Modder/ Riet Rivers		
10.1	Modder River and tributaries Klein Kaalspruit and Kaalspruit	C52H, C52J, C52K and C52L
10.2	Riet River and tributaries: Fouriespruit and tributaries including Fouriespruit Dam, X River and tributaries up and downstream of the Tierpoort Dam; Riet River to confluence with Kromellenboogspruit	C51A, C51B, C51C, C51D, C51E and C51F
10.3	Kromellenboogspruit and tributaries Vanzylspruit and Prosesspruit to confluence with the Riet River	C51G and C51H
10.4	Riet River	C51J and C51K
10.5	Mainstem Riet River to Vaal River confluence	C51L and C51M
10.6	Tierpoort Dam	C51D
10.7	Kalkfontein Dam	C51J

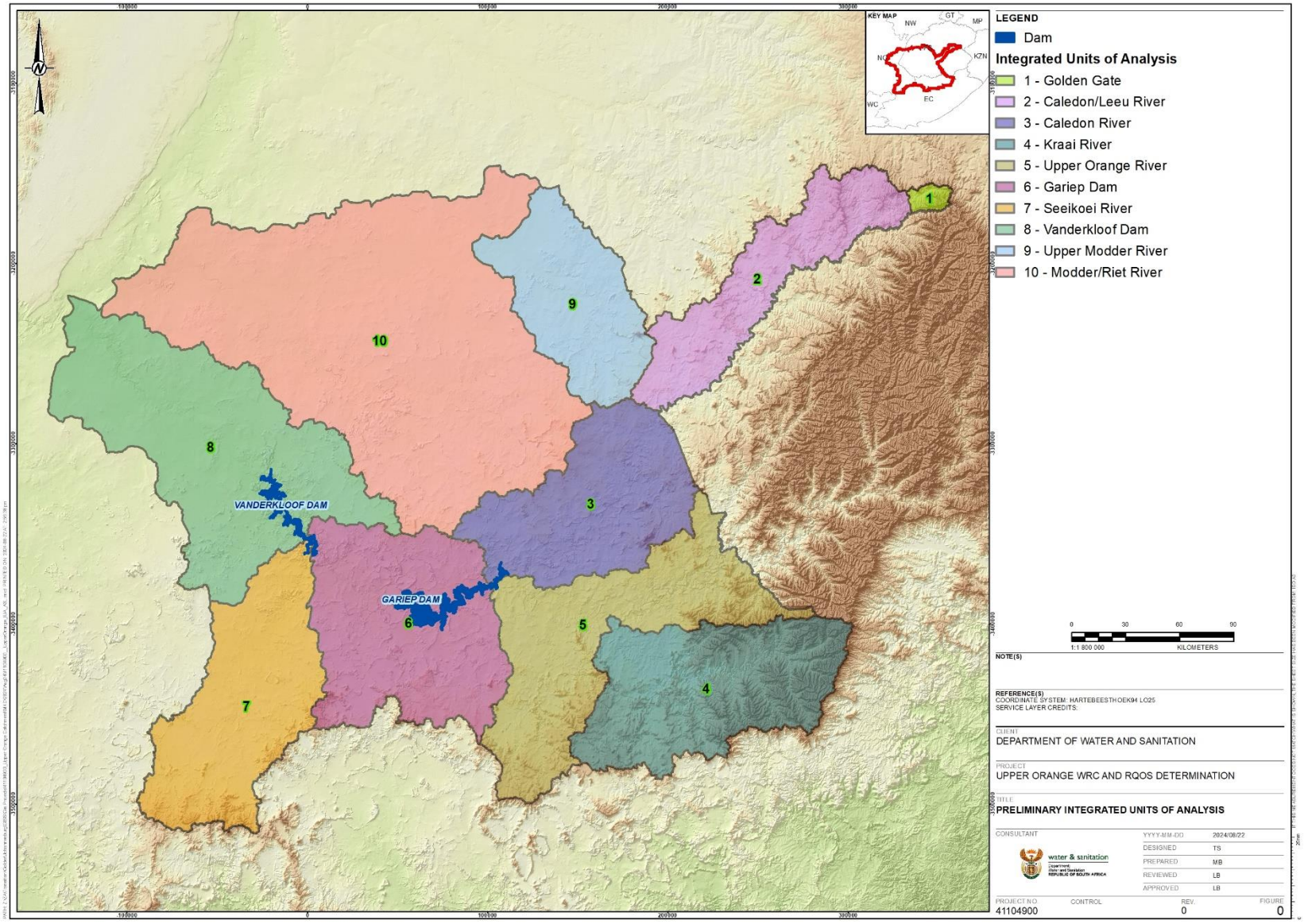

Figure E1: Preliminary Integrated Units of Analysis

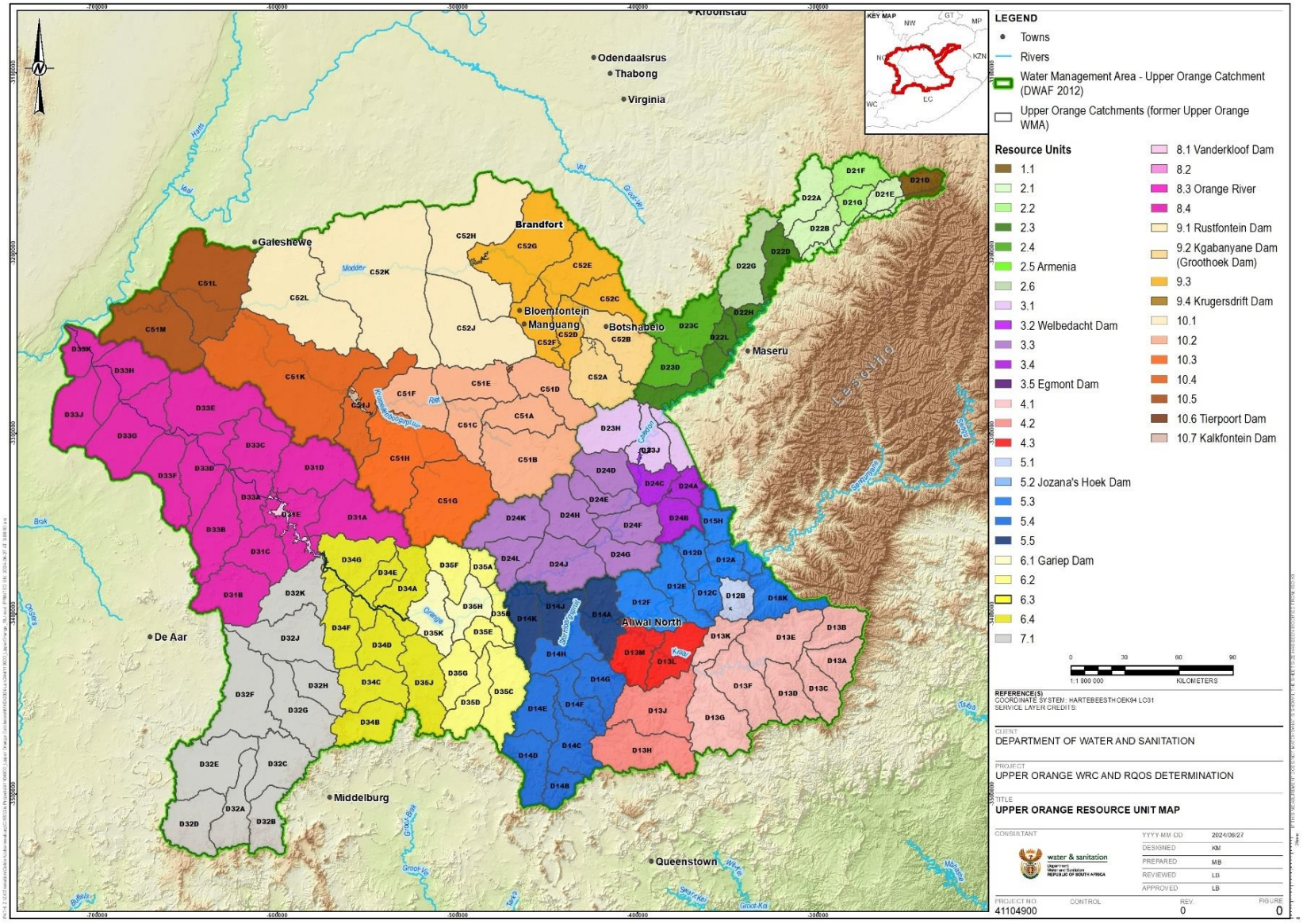

Figure E2: Preliminary Resource Units

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1 INTRODUCTION

1.1. Background

The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) is presently undertaking a study to determine Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River catchment which falls within the Orange/ Vaal Water Management Area (WMA 04).

Water Resource Classification, the Reserve and Resource Quality Objectives (RQOs) are protection-based measures that make up Resource Directed Measures (RDM), the protection principles contained in Chapter 3 of the National Water Act (Act No. 36 of 1998). Resource Directed Measures are intended to ensure comprehensive protection of all water resources. Protection relates to the quantity and quality (overall health) of the water resource. An important consideration in the determination of RDM is that they should be technically sound, scientifically credible, practical, and affordable. Once the water resources class and the Reserve have been established, RQOs are determined to give effect to those water resource classes and the Reserve. The DWS has progressively set water resources classes for all water resource systems in South Africa to ensure their protection and sustainable use and the Orange River System (ORS) is the last system that requires classification and setting of RQOs.

1.2. Purpose of the Study

The main objective of the study is to coordinate the implementation of the determination of water resources classes and associated resource quality objectives for all significant water resources in the Upper Orange River catchment within the Vaal-Orange Water Management Area (WMA04) as described in the revised reconfiguration that was gazetted as part of the National Water Resources Strategy 3 (NWRS3) under Gazette Notice 49225, dated 1 September 2023, in accordance with the Water Resource Classification System (WRCS)(DWA, 2010), and determine the associated RQOs for the prioritised units. This is aimed at facilitating the management and regulation of water resources to ensure efficient and sustainable use, a balance between protection and use, while maintaining ecological integrity and specifically maintaining or improving the present ecological state (PES) of the water resources, in the Upper Orange River catchment.

Appropriate integration with water resource planning and management processes, as well as cooperation among stakeholders, will be key success factors in setting the water resource classes and RQOs. The outcomes of the process will result in the protection framework for the catchment that will guide actions, interventions, and needs, to ensure a sustainable water resource system that is able to balance water use and protection.

1.3. Purpose of this Report and Report Outline

The purpose of this report is to describe resources and systems, water use, economy, river and wetland ecology, water quality concerns and ecosystem services and attributes. This information

has been used to define the preliminary integrated units of analysis (IUAs), also presented in this report, as well as the preliminary resource units delineated.

IUAs are the spatial units that will be defined as significant water resources. Each IUA represents a homogenous socio-economic area which requires its own specification of a water resource class. Based on the preliminary IUAs delineated, preliminary Resource Units (RUs) and biophysical nodes will be identified for different levels of Ecological Water Requirements (EWR) assessment and setting of RQOs.

This task therefore describes the baseline information for the decision-making to be undertaken within the integrated water resource management (IWRM) framework for the catchment to set the water resource classes and RQOs.

1.4. Study Area Overview

The Orange River catchment (Figure 1) area comprises the Upper Orange and Lower Orange River catchments within the Vaal-Orange River Water Management Area (WMA04).

This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States, Lesotho, South Africa, Namibia and Botswana. The Orange River originates in Lesotho where it is known as the Senqu River, flows into South Africa and Namibia with Molopo River in Botswana joining the Orange River. The main stem flows west approximately 2 200 km, where it flows into the Orange River Mouth and into the Atlantic Ocean at Alexander Bay. The Orange River is of critical importance to South Africa in that it augments the Vaal River System through the Lesotho Highlands Water Project and supplies the economic heartland of South Arica as well as supplying water to the Eastern Cape via the Gariep Dam to Great Fish transfer scheme.

It also supplies thermal power stations on the Highveld, irrigation schemes covering large areas along the Vaal, middle and lower portions of the Orange River, as well as hydroelectric power generation at the two large dams (Gariep and Vanderkloof). An estimated 15 million people are dependent on secure water supplies from this basin.

Land use in the Upper Orange River catchments of the WMA is mainly under natural vegetation with livestock farming as main economic activity and extensive areas under dry land cultivation, mostly to produce grains, in the north-eastern parts. The Modder Riet catchment is dominated by agricultural activities, with limited mining, and a few urban centres. Large areas under irrigation for the growing of grain and fodder crops have been developed along the main rivers, mostly downstream of irrigation dams. Mangaung (Bloemfontein), Botshabelo and Thaba ‘Nchu as well as Maletswai (Aliwal North) represent the main urban and industrial developments in the catchment. Smaller towns include Clarens, Ficksburg, Hobhouse, Fouriesburg, Hlohlolwane (Clocolan), Winnie Mandela (Brandfort), Ladybrand, Vanstadensrus, Wepener, Smithfield, Hanover and Noupoort. Two large hydropower stations have been constructed at Gariep and Vanderkloof dams.

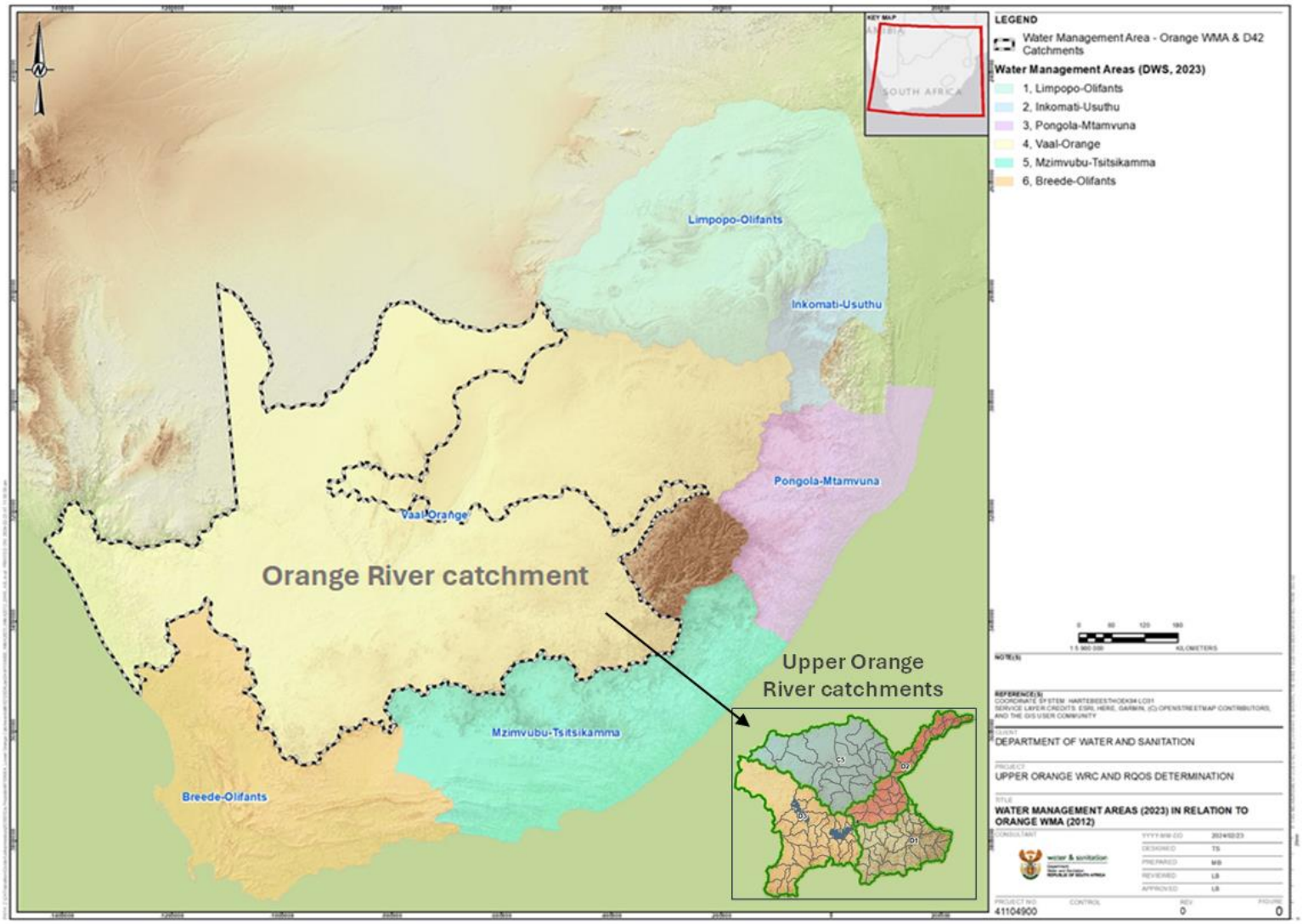

Figure 1: Orange River Catchment within Vaal-Orange WMA (WMA04) in South Africa

2 STATUS QUO: WATER RESOURCES AND SYSTEMS ANALYSIS

2.1. Description of Water Resources

The Upper Orange River catchment comprises four sub-catchments stretching across the Northern Cape, Free State and Eastern Cape provinces and across three ecoregions, the Eastern Escarpment Mountains, Nama Karoo and Highveld (Figure 2):

- The Caledon River from its headwaters and its tributaries to the Gariep Dam (Secondary catchment D2)
- The Orange River from the Lesotho Border to the Gariep Dam, including the main tributaries namely Kornetspruit, Sterkspruit, Stormbergspruit and Brandwaterspruit, and the Kraai River catchment (D1 secondary catchment), and
- The Orange River from the Gariep Dam, through Vanderkloof Dam to Marksdrift weir, just before the confluence with the Vaal River, including the Seekoei River in the south (D3 secondary catchment), and
- The Modder-Riet River (main tributaries of the Vaal River system) in the north (C5 secondary catchment). Although the Modder/Riet rivers are tributaries to the Vaal River, this catchment and related sub-systems are seen as part of the Orange River System due to transfers and support from the Orange to the Modder/Riet catchment.

Groundwater occurrences in the Upper Orange River catchment occurs predominantly as shallow (<65 m thick) aquifer systems in the Karoo Supergroup sedimentary sequence (as primary rock formation). In most of the water management area, secondary Karoo Dolerite intrusions in the form of (i) sub-vertical dikes and (ii) semi-horizontal sills are present which enhances the yield potential of the primary aquifer system. In a few cases, specific aquifer yield potentials can be significantly enhanced by occasional flooding of local surface water drainages, especially where these drainages are mature and alluvial sedimentation has developed overlying the Karoo rocks.

There are seven wetland types, often in wetland complexes: flats, floodplains, depression wetlands, unchanneled valley-bottom wetlands, seeps, and channelled valley bottom wetlands. There are several high-altitude wetland complexes that are characterised by unique vegetation assemblages.

2.1.1. Catchment Boundaries

To enable improved representation of the water resources situation in the WMA, and to facilitate the applicability and better use of information for strategic management and planning purposes, the area has been divided into sub-areas. Delineation of the sub-areas was based on practical considerations such as size and location of sub-catchments, homogeneity of natural characteristics, location of pertinent water infrastructure, such as dams, and economic development. Four sub-areas were identified (Figure 2).

The sub-catchments, associated rivers, catchment areas and quaternary catchments are listed in Table 1 and illustrated in Figure 2.

Table 1: Sub-catchment areas of the Upper Orange River catchment

Secondary Catchment	Tertiary Catchment	Quaternary catchments	Main River/(s)	Catchment area[(1)] (km^2)	
				Gross	Net
C5	C51	C51A – H, C51J - M	Fouriespruit, Ruisterspruit, Ospoortspruit, Kromellemboogspruit, Rietspruit	17 449	12 166
	C52	C52A – H, C52J - L	Wildebeesspruit, Sepane, Osspruit, Modder River	17 366	8 572
D1	D12	D12A - F	Winnaarspruit, Kromspruit, Wilgespruit	2 967	2 967
	D13	D13A – H; D13J - M	Bell, Langkloofspruit, Dierspruit, Wasbankspruit, Holspruit, Skulpspruit, Kraai River	9 354	9 354
	D14	D14A – H, D14J and K	Orange River	6 145	6 145
	D15	Portions of D15G and H	Makhaleng (lower reaches shared with Lesotho), Unnamed tributaries	846	846
	D18	Portion of D18L and K	Tele (shared with Lesotho), Blikana	1 545	1 545
D2	D21	D21D, D21E, D21F, D21G, portion of D21A and D21H	Caledon River Little Caledon	1 659	1 659
	D22	D22A, D22B, portions of D22C and D22D, D22G, portions of D22H and D22J	Meulspruit, Brandwater/ Groot, Rantsho; Mopeli	4 369	4 369
	D23	Portion of D23A, E, F and G; D23C, D23D, D23H, D23J	Montsoane, Maseng, Tsoaning Leeurivier, Retspruit	4 910	4 910
	D24	D24A – G, D24H, D24J - L	Witspruit, Wilgeboomspruit, Grahamstadspruit, Slykspruit, Edon	6 614	6 614

Secondary Catchment	Tertiary Catchment	Quaternary catchments	Main River/(s)	Catchment area[(1)] (km^2)	
				Gross	Net
			River, Skulpspruit		
D3	D31	D31A - E	Bergrivier, Orange River,	4 910	4 396
	D32	D32A – H, D32J and K	Seeikoeirivier	9 081	9 081
	D33	D33A – D33K	Orange River	9 598	3 404
	D34	D34A - G	Orange River	5 020	5 020
	D35	D35A – H, D35J and K	Brandspruit, Brakspruit, Bossiespruit, Suurbergspruit, Orange River	5 638	5 638

[1]WR2012 data

The Caledon River (also called the Mohokare River along the Lesotho/ South Africa border) forms the north-western boundary of Lesotho with South Africa and is the first major tributary of the Orange River with their confluence in the upper reaches of the Gariep Dam. Other large tributaries that contribute to the flow in the Upper Orange River catchment are the Makhaleng (although only the lower reaches within South Africa) and Kraai Rivers. Although the Seekoei River has a large catchment, the runoff is very low as it forms part of the drier Karoo area.

The Modder and Riet Rivers, tributaries of the Vaal River are also part of the study area due to the interconnectedness of these systems through water transfers.

The main storage dams in the Upper Orange River catchments are Gariep and Vanderkloof dams on the Orange River. Smaller dams in the study area are Welbedacht Dam in the Caledon River, Rustfontein, Mockes, and Krugersdrift Dams in the Modder River with the Tierpoort and Kalkfontein Dams in the Riet River. The Gariep Dam, Vanderkloof Dam, Orange-Fish Tunnel, Orange Vaal transfer canal and Orange-Riet Canal system are all part of the Orange River Project.

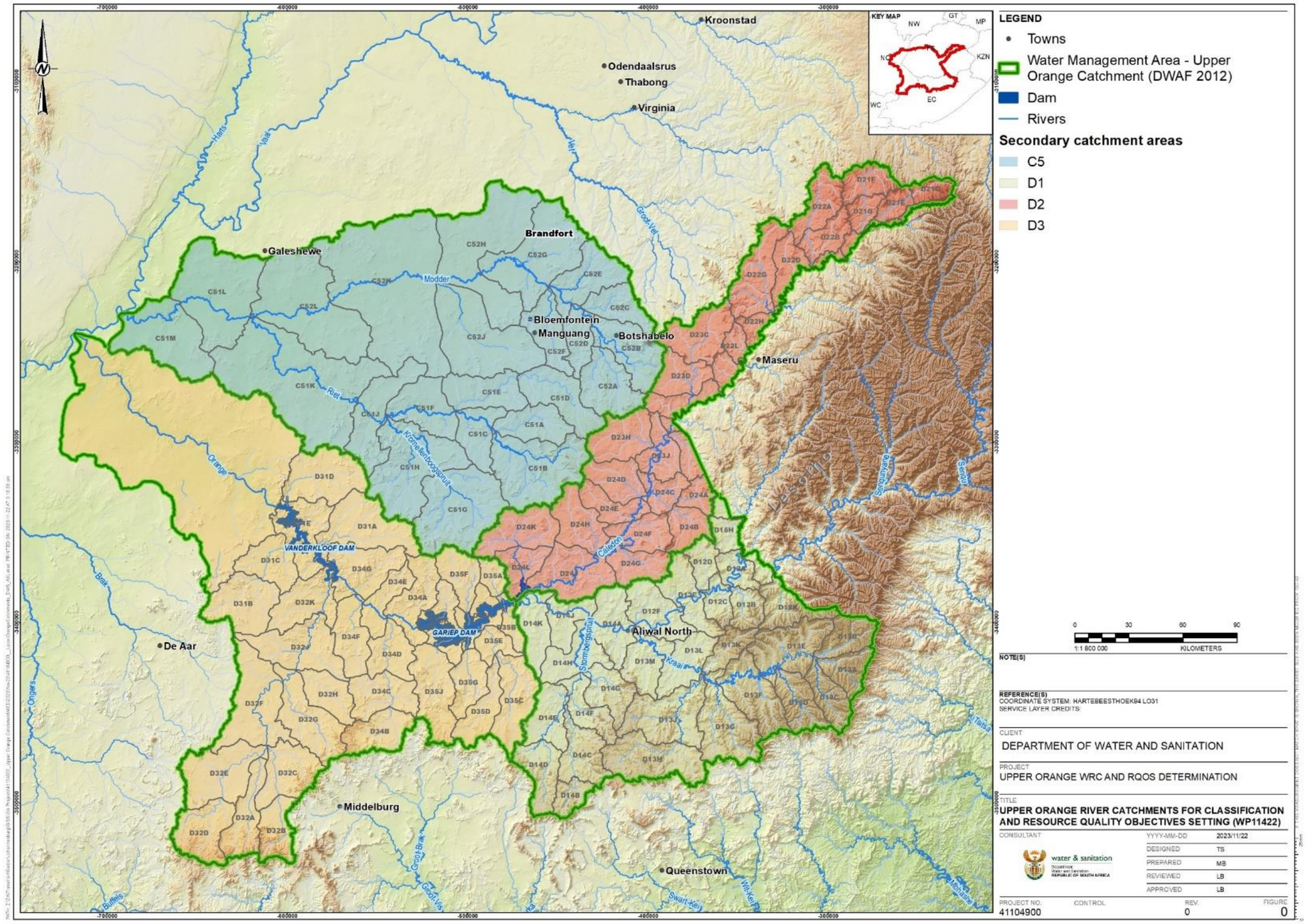

Figure 2: Upper Orange River catchment – Study Area extent and Locality (South African Portion)

2.1.2. Strategic Water Source Areas

Parts of the Upper Orange River catchment have been identified and delineated as strategic water source areas (SWSA) in South Africa (WRC, 2018). Water source areas, also referred to as Water Towers (Viviroli et al., 2007), are natural areas that provide disproportionate (i.e., relatively large) volumes of surface water run-off compared to adjacent lowland areas, and/ or groundwater water per unit area, or which meet critical social, economic and environmental water requirements and provide water security. Strategic Water Source Areas (SWSAs) are a subset of water source areas that are considered of strategic significance for water security (WRC, 2018).

Surface water SWSAs are found in areas with high rainfall and produce most of the runoff. These are located predominantly along the eastern side of South Africa, particularly along the Drakensberg escarpment from the Eastern Cape though to Limpopo and are the source of most of the major river systems, such as the Orange River.

Water source areas are critical because they produce large volumes of water that sustain people locally and regionally and, in the case of groundwater, are often the only sustainable and reliable water source.

In terms of WRC (2018), SWSAs have been identified and delineated if the area of land either:

(a) supplies a disproportionate amount of mean annual surface water runoff in relation to their size and are considered nationally important; or

(b) has a high groundwater recharge and are locations where the groundwater forms a nationally important resource; or

(c) meets both criteria (a) and (b).

Groundwater Strategic Water Source Areas (SWSA-gw)

A SWSA-gw can be defined as an area with high groundwater availability (high recharge and storativity) where groundwater represents an important resource – sole source potential. These are therefore delineated wherever criteria 1 or 2 overlap with criteria 3, 4 or 5. It is also important to note that in addition, even if only criterion 5 is met, the area is also considered a SWSA-gw. This is to include current and/or future groundwater sources to areas of national economic significance (WRC, 2018).

Additionally, areas with high groundwater availability only (i.e., meet criteria 1 or 2) could be considered areas with high groundwater potential, and areas with high groundwater use only (meet criteria 3 or 4) could be considered areas where groundwater is an important resource and in certain cases the sole source (WRC, 2018).

It is also noted that the Directorate: Reserve Determination has initiated a project in April 2024 with the main topic being the update of the methodology and refinement of the Strategic Groundwater Source Areas. The project is expected to run until March 2027. Contact has been

made with the Professional Service Provider (PSP), Umvoto, and liaison with the project team to ensure that relevant aspects are addressed in both studies, will continue.

Thirty-seven (37) SWSA-gw were identified at national level with a further 20 at sub-national level. The areas delineated in the Upper Orange River catchment are:

- National SWSA-gw
    - Central Pan belt covering an area of 3,368 km^2 across quaternary catchments C52K, C52J, C52H, C52G, C52F and C52D, and
    - Portions of the De Aar Region which covers an area of 2,475 km^2 in D32F.
- Sub-national SWSA-gw
    - Small portions of the Eastern Upper Karoo which covers an area of 6,131 km^2 in D32B, D32C and D32G.
    - Small portions of the Eastern Upper Karoo which cover an area of 3,371 km^2 in D13A (475), D13B (533), D13E (1031), D13K (397) and D18K (935).

The five criteria used to delineate groundwater SWSAs are described in Table 2.

Table 2: Summary of criteria and thresholds for Groundwater SWSA delineation (WRC, 2018)

Criteria	Description	Threshold	Motivation
1	Recharge as mm/a (GRA II, (DWAF, 2006a))	>65 mm/a	Corresponds to >50% national recharge volume
2	Ratio of recharge per 1 km2 grid cell compared to the average recharge of the secondary catchment	>1.5	Threshold set iteratively and subjectively
3	Registered groundwater use (WARMS) as l/s per km^2 (Kernel function)	>0.3 l/s/km^2	Threshold set iteratively and subjectively
4	Towns/village clusters with groundwater sole supply, for current domestic water supply, mapped as points with 10 km radius.	None (i.e., all areas included)	All areas are relevant, no threshold to be met
5	Groundwater resource unit used for current or future supply to an area of national economic importance, and groundwater control areas	None (i.e., all areas included)	National interest

Surface Water Strategic Water Source Area (SWSA-sw)

The total area of the national SWSA-sw in the southern African region is 124,075 km^2 (10% of the region) and provides a mean annual run-off (MAR) of 24,954 million m^3 (50% of the total), which has been increased with the addition of the sub-nationally important Pondoland Coast and Zululand Coast SWSA-sw to an area of about 148,478 km^2 (12% of the area) and provide a MAR of 29,354 million m^3 (59% of the total) (WRC, 2018).

The South African SWSA-sw area covers approximately 96,129 km^2 (8% of the total area) and provide a MAR of 19,379 million m3 (39% of the national volume). The greatest volume of MAR is generated by the Southern Drakensberg (9% of national and transboundary MAR), followed by the Eastern Cape Drakensberg and the Boland (WRC, 2018).

The areas of the SWSA-sw within Lesotho and Swaziland are 18,570 km^{2}and 9,376 km^2, respectively. The total MAR for Lesotho is about 4,445 million m^3 and the portions of the SWSAs that fall within Lesotho (Eastern Cape, Southern, Northern and Maloti Drakensberg, totalling 61% of Lesotho's area) generate about 3,522 million m^3 or 79% of that county's MAR, highlighting the importance of these areas that contribute to the Vaal-Orange Water Management Area (WRC, 2018).

The main SWSA-sw in the Upper Orange River catchments are a portion in the Maloti Drakensburg SWSA in quaternary catchment D21A and portions of the Eastern Cape Drakensburg SWSA in quaternary catchments D18K, D18L, D12B, D13E, D13K, D13 A, B and C and D13F.

Figure 3 illustrates the groundwater and surface water relevant to the Upper Orange River catchments.

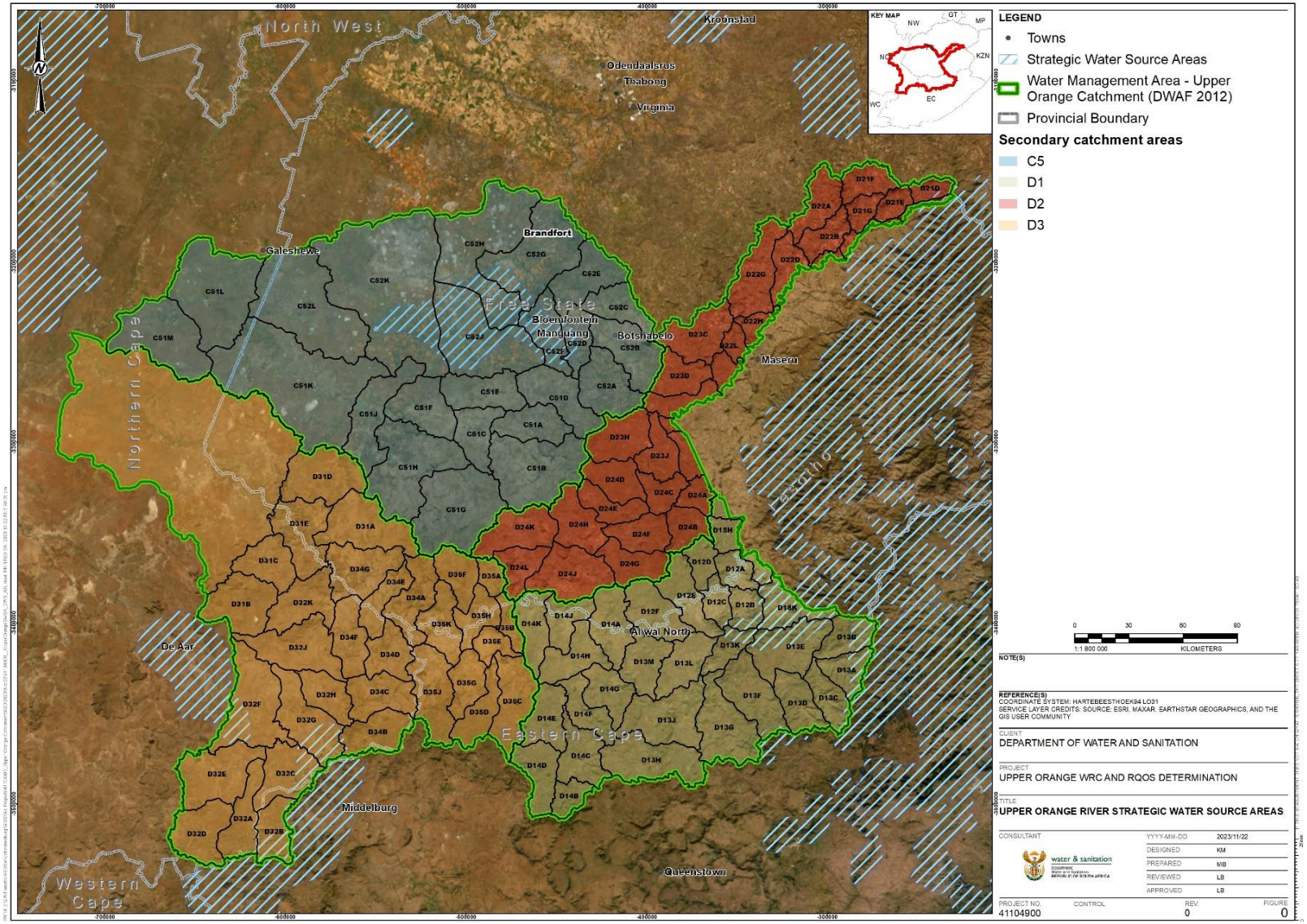

Figure 3: Strategic Water Source Areas in the Upper Orange River catchments

2.1.3. Climate change

The DWS National Integrated Water Information System (NIWIS) dashboard relate to Climate Change indicators including changes in temperature, wet spells, dry spells, irrigation demand, potential evaporation, mean annual precipitation and streamflow. The available climate change data used is at quinary scale (i.e. sub-division of the quaternary).

The climate change related impacts in respect of rainfall and streamflow for the Upper Orange River catchments based on the DWS National Integrated Water Information System (NIWIS) data are described in the sections to follow.

The climate change phenomenon has a significant impact on the annual [required] replenishment of groundwater resources due to assumed changed rainfall patterns. Groundwater recharge estimates are an important factor in the algorithms used for groundwater resources classification, i.e., the stress index, and subsequently the estimation of “allocable” groundwater per quaternary catchment. Groundwater recharge is driven by specific factors, i.e., (i) rainfall intensities (mm over time) and (ii) rainfall depths (total depths per rainstorm).

Overall, the rainfall is expected to decrease between 0% to 9% in almost all areas except for marginal increases (1% - 3%) expected in the Kraai River catchment. the streamflow is expected to reduce by between 10% and 69% throughout the catchment, with the Riet River catchments showing the most drastic decrease.

2.1.3.1. Modder Riet Catchments

Rainfall in the Riet sub-catchment (tertiary catchment C51) ranged from 349 - 613 mm/a for the period 1975 – 2006 and ranges from 320 - 595 mm/a for the period 2016 - 2045 with percentage change of 8% decrease to no change for the two periods. The streamflow for the period 1975 – 2006 ranged from 35 - 196 m^3/s and for the period 2016 – 2045 ranges from 14.5 to 156 m^3/s with percentage change ranging from -69% to -16%.

Rainfall in the Modder sub-catchment (tertiary catchment C52) ranged from 395 - 619 mm/a for the period 1975 – 2006 and ranges from 366 - 590 mm/a for the period 2016 - 2045 with percentage change of 8% decrease to 1% increase the two periods. The streamflow for the period 1975 – 2006 ranged from 34 - 217 m^3/s and for the period 2016 to 2045 ranges from 14.8 to 168 m^3/s with percentage change ranging from -56% to -14%.

The data are illustrated in Figure 4 showing the higher level of rainfall and streamflow in the Modder catchment and highlighting the considerable streamflow decreases expected.

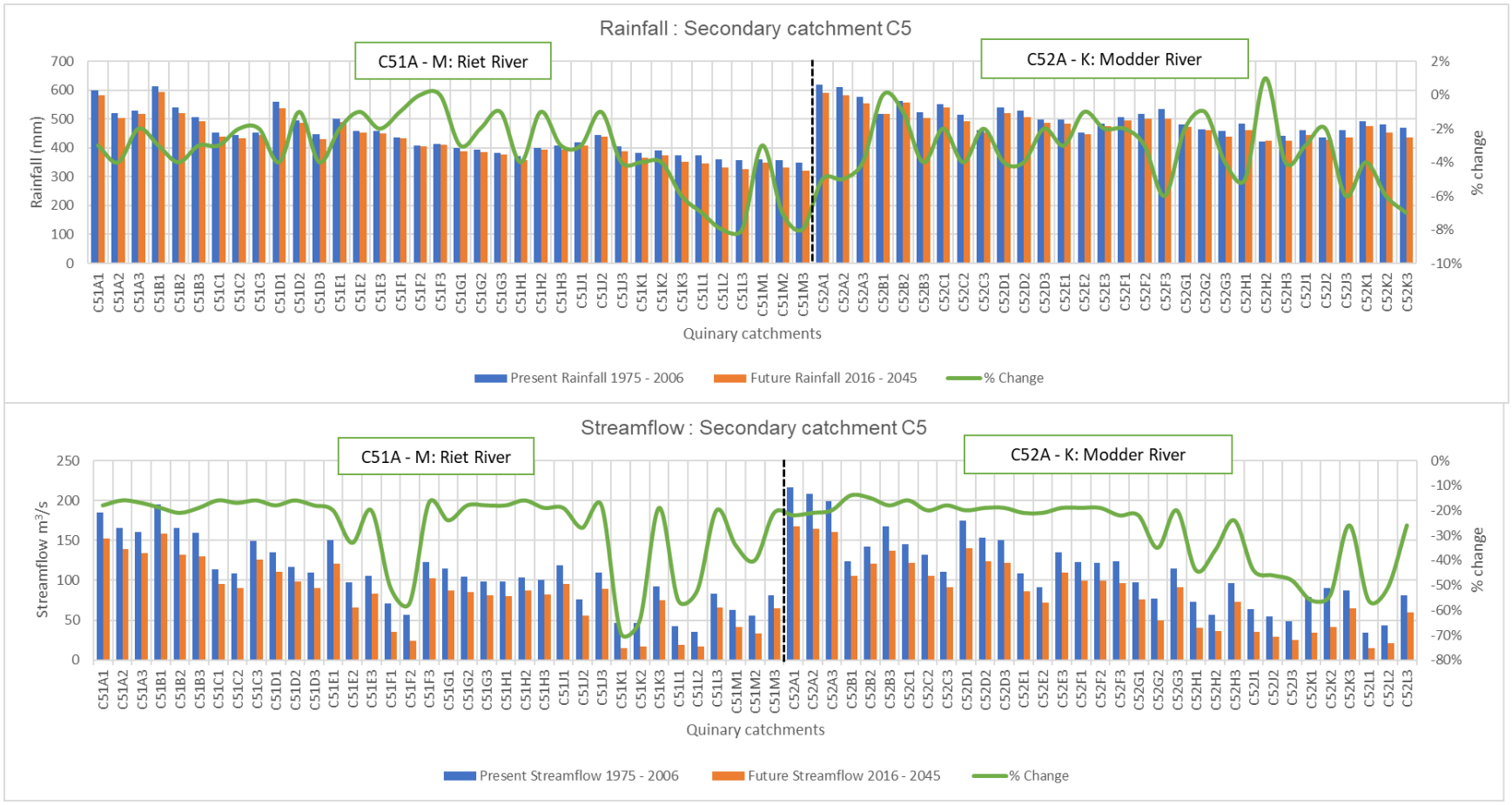

Figure 4: Climate change aspects for rainfall and streamflow for the Modder-Riet catchments

2.1.3.2. Caledon to Gariep Dam Catchments

Rainfall in the D21 tertiary catchment of the Caledon River sub-catchment (ranged from 720 - 846 mm/a for the period 1975 – 2006 and ranges from 704 - 839 mm/a for the period 2016 - 2045 with percentage change of 5% to 1% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 136 to 284 m^3/s and decreasing to 101 - 252 m^3/s for the period 2016 - 2045 with percentage change ranging from -28% to -11%.

Rainfall in the D22 tertiary catchment of the Caledon River sub-catchment ranged from 691 - 878 mm/a for the period 1975 – 2006 and ranges from 827- 498 mm/a for the period 2016 - 2045 with percentage change of 7% to 2% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 97 to 217 m^3/s and decreasing to 59 - 192 m^3/s for the period 2016 - 2045 with percentage change ranging from -41% to -10%.

Rainfall in the D23 tertiary catchment of the Caledon River sub-catchment ranged from 522 - 767 mm/a for the period 1975 – 2006 and ranges from 498 - 714 mm/a for the period 2016 - 2045 with percentage change of 7% to 1% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 69 to 187 m^3/s and decreasing to 39 - 125 m^3/s for the period 2016 - 2045 a percentage change ranging from -43% to -17%.

Rainfall in the D24 tertiary catchment of the lower reaches of the Caledon River sub-catchment just upstream of Gariep Dam, ranged from 413 - 638 mm/a for the period 1975 – 2006 and ranges from 391 - 594 mm/a for the period 2016 - 2045 with percentage change of 9% to 2% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 48 to 208 m^3/s and decreasing to 23 - 155 m^3/s for the period 2016 - 2045 a percentage change ranging from -53% to -16%.

The data are illustrated in Figure 5 showing the higher rainfall in the upper Caledon along the Lesotho border reducing towards the Gariep Dam, and highlighting the considerable streamflow decreases expected, even in the upper Caledon River.

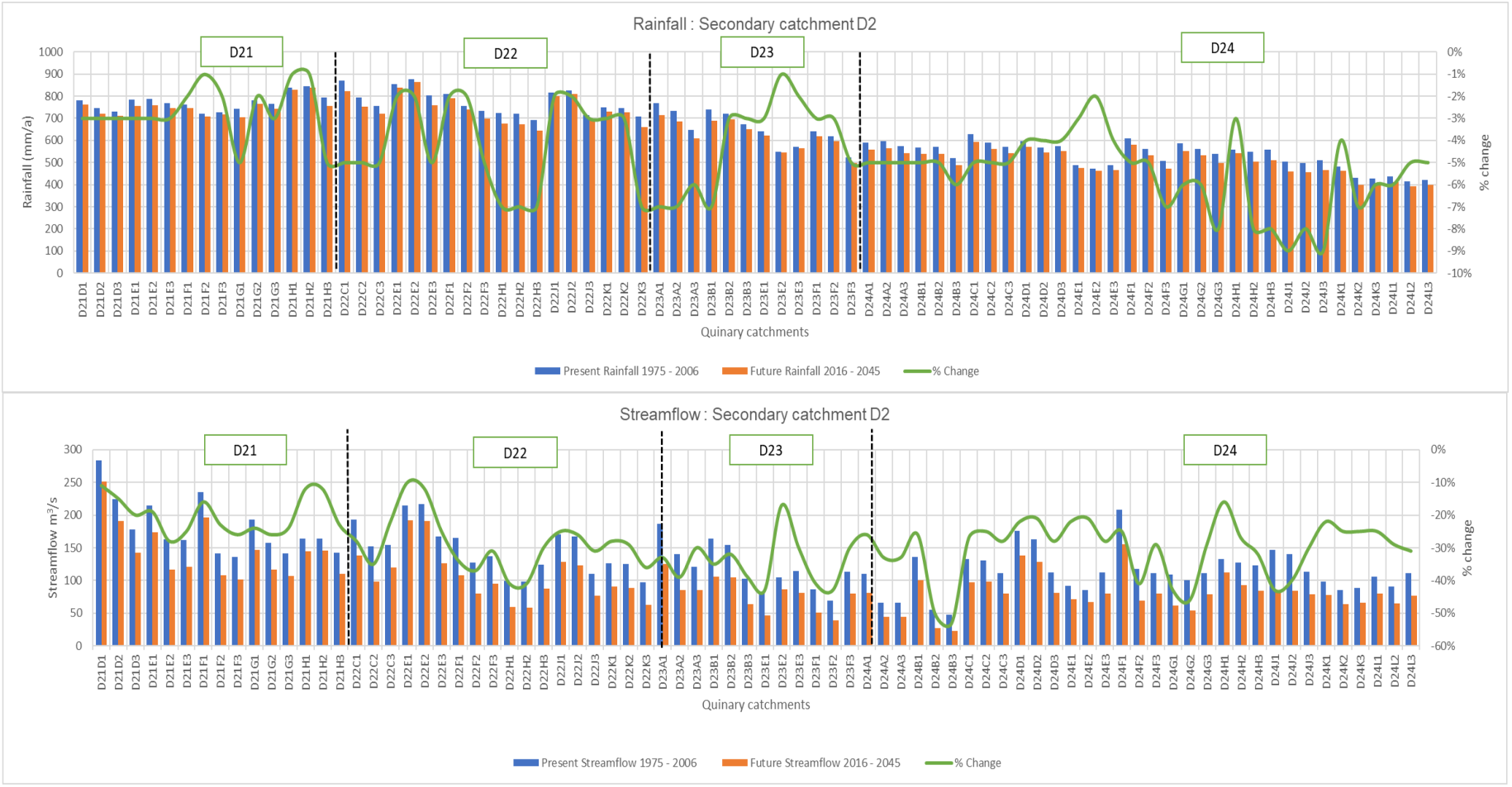

Figure 5: Rainfall and streamflow changes for the D2 secondary catchment (Caledon River)

2.1.3.3. Orange River to Gariep Dam including Kraai River Catchments

Rainfall in the D12 tertiary catchment of the Orange River sub-catchment (ranged from 555 - 856 mm/a for the period 1975 – 2006 and ranges from 513 - 822 mm/a for the period 2016 - 2045 with percentage change of 8% to 4% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 69 to 277 m^3/s and decreasing to 36 - 193 m^3/s for the period 2016 - 2045 with percentage change ranging from -52% to -14%.

Rainfall in the D18K and L quaternary catchments in the upper reaches of the Kraai River sub-catchment (ranged from 739 - 838 mm/a for the period 1975 – 2006 and ranges from 694 - 808 mm/a for the period 2016 - 2045 with percentage change of 6% to 4% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 155 to 187 m^3/s and decreasing to 98 - 130 m^3/s for the period 2016 - 2045 with percentage change ranging from -37% to -23%.

Rainfall in the D13 tertiary catchment of the Kraai River sub-catchment (ranged from 499 - 854 mm/a for the period 1975 – 2006 and ranges from 485 - 824 mm/a for the period 2016 - 2045 with percentage change of 8% to 2% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 49 to 240 m^3/s and decreasing to 30 – 175 m^3/s for the period 2016 - 2045 with percentage change ranging from -56% to -23%.

Rainfall in the D14 tertiary catchment of the Orange River sub-catchment including the Stormbergspruit tributary (ranged from 425 - 582 mm/a for the period 1975 – 2006 and ranges from 399 - 589 mm/a for the period 2016 - 2045 with percentage change of 8% to 3% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 68 to 149 m^3/s and decreasing to 33 to 95 m^3/s for the period 2016 - 2045 with percentage change ranging from -52% to -18%.

The data are illustrated in Figure 6 showing the higher rainfall in the upper catchments reducing towards the Gariep Dam, and highlighting the considerable streamflow decreases expected, even in the upper catchments.

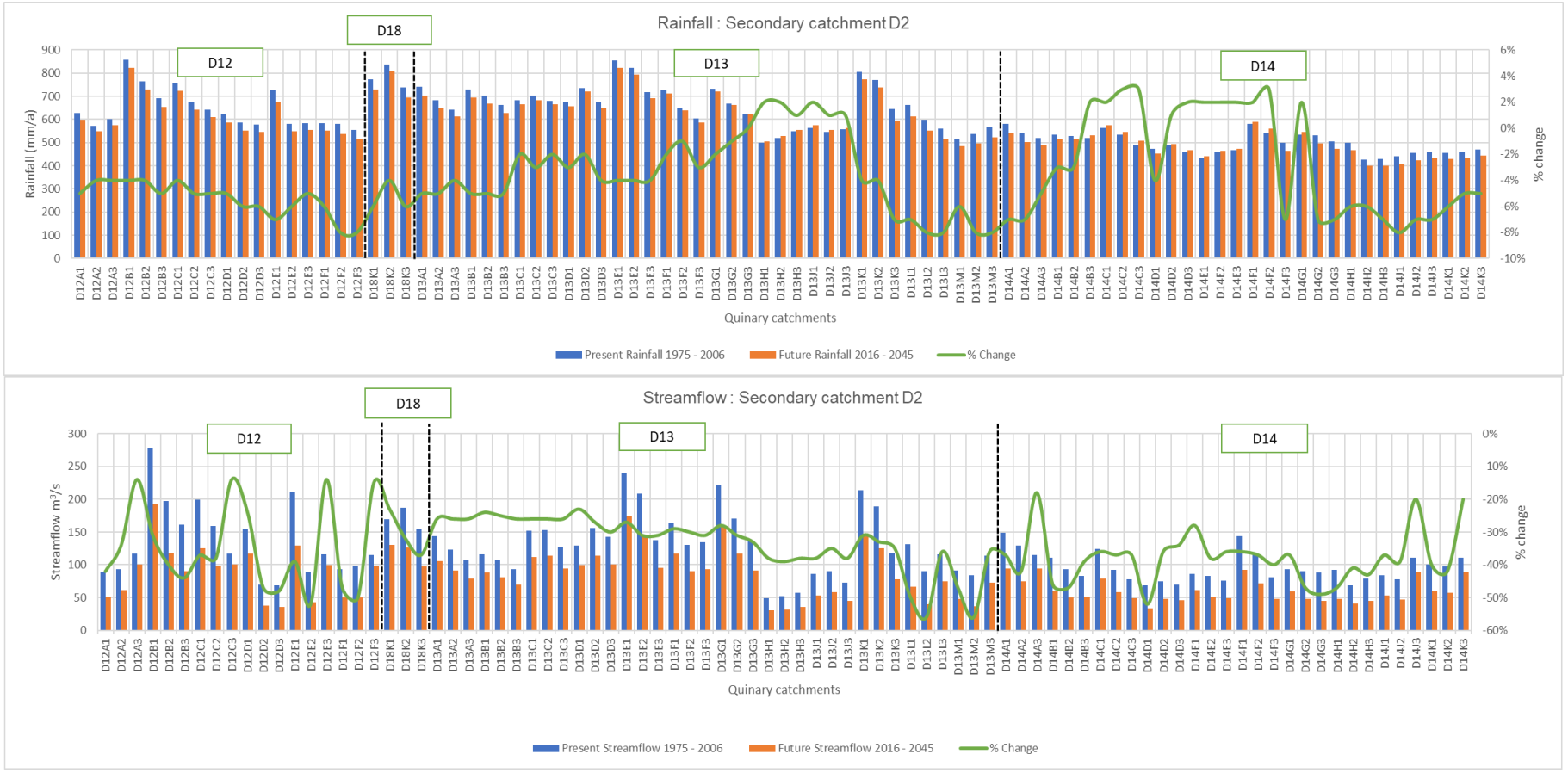

Figure 6: Rainfall and streamflow changes expected for the D1 secondary catchment - Orange River to Gariep Dam including Kraai River catchments

2.1.3.4. Gariep Dam to Vaal River confluence

Rainfall in the D35 tertiary catchment of the Orange River catchments around and including Gariep Dam ranged from 377 - 461 mm/a for the period 1975 – 2006 and ranges from 359 - 443 mm/a for the period 2016 - 2045 with percentage change of 6% to 2% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 87 - 168 m^3/s and decreasing to 58 - 131 m^3/s for the period 2016 - 2045 with percentage change ranging from -41% to -19%.

Rainfall in the D34 tertiary catchment of the Orange River between Gariep and Vanderkloof dams ranged from 310 - 468 mm/a for the period 1975 – 2006 and ranges from 298 - 451 mm/a for the period 2016 - 2045 with percentage change of 4% to 1% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 54- 191 m^3/s and decreasing to 37 - 145 m^3/s for the period 2016 - 2045 with percentage change ranging from -34% to -23%.

Rainfall in the D32 tertiary catchment which includes the Seekoei River, and tributaries ranged from 284 - 397 mm/a for the period 1975 – 2006 and ranges from 261 - 383 mm/a for the period 2016 - 2045 with percentage change of 9% to 1% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 36 to 119 m^3/s and decreasing to 19 to 82 m^3/s for the period 2016 - 2045 with percentage change ranging from -51% to -26%.

Rainfall in the D31 tertiary catchment of the Orange River sub-catchments around and including Vanderkloof Dam (ranged from 312 - 386 mm/a for the period 1975 – 2006 and ranges from 292 - 377 mm/a for the period 2016 - 2045 with percentage change of 8% to 2% decrease for the two periods. The streamflow for the period 1975 – 2006 ranged from 47 - 120 m^3/s and decreasing to 27 - 86 m^3/s for the period 2016 - 2045 with percentage change ranging from -43% to -21%.

Rainfall in the D33 tertiary catchment of the Orange River sub-catchments from Vanderkloof Dam to the confluence with the Vaal River (ranged from 222 - 379 mm/a for the period 1975 – 2006 and ranges from 204 - 367 mm/a for the period 2016 - 2045 with percentage change of 8% decrease to remaining similar for the two periods. The streamflow for the period 1975 – 2006 ranged from 8 - 110 m^3/s and decreasing to 5 to 80 m^3/s for the period 2016 - 2045 with percentage change ranging from -45% to -22%.

The data are illustrated in Figure 7 showing the considerably lower rainfall in the catchment compared to the upper catchments of the Caledon, Orange and Kraai rivers rainfall in the upper catchments, and highlighting the considerable streamflow decreases expected.

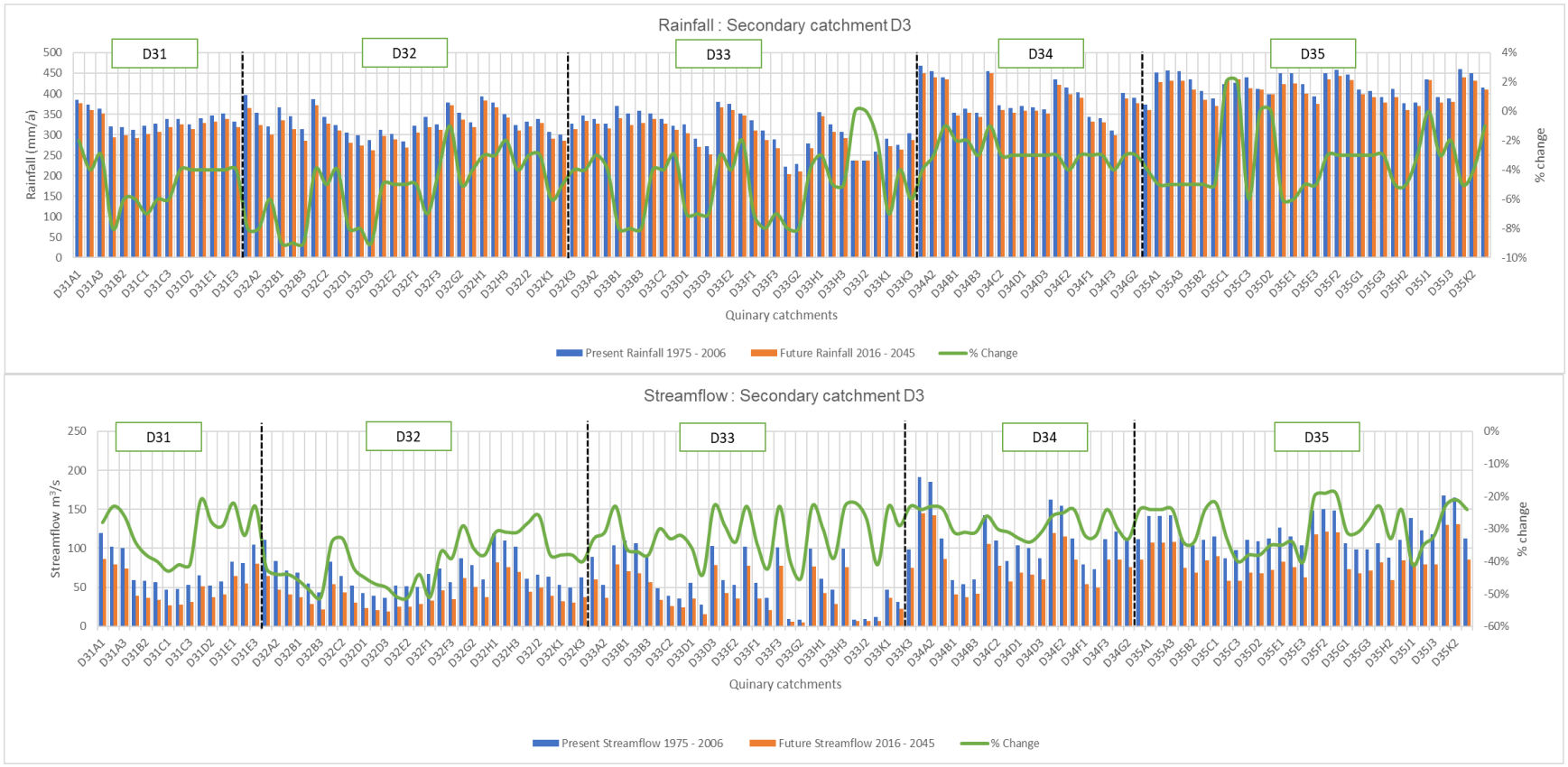

Figure 7: Rainfall and streamflow changes expected for the D3 secondary catchment including the Gariep and Vanderkloof dams

2.2. Description of Water Resource Systems and Analysis

2.2.1. Overview

As noted in earlier sections of the report, the Vaal and Orange WMAs have been merged into a single water management area. The boundary of the Vaal WMA has been extended to include the Orange WMA to form the single Vaal-Orange WMA (WMA04). The Vaal-Orange Catchment Management Agency (CMA) has been established for the whole of the Vaal and the Orange WMA areas. The third edition of the National Water Resources Strategy (NWRS III) notes that although the Vaal-Orange CMA is established as a single juristic entity (due to common features such as in and out water transfer requirements), there are also nuanced differences coupled with the sheer size of the WMA that will require a regionalised operational model (NWRS, 2023).

The Orange River originates in Lesotho where it is known as the Senqu River. The main stem flows west approximately 2 200 km, where it flows into the Orange River Mouth and into the Atlantic Ocean at Alexander Bay.

It is of critical importance to South Africa in that it augments the Vaal River System through the Lesotho Highlands Water Project and supplies the economic heartland of South Arica as well as supplying water to the Eastern Cape via the Gariep to Great Fish transfer scheme. It also supplies thermal power stations on the Highveld, irrigation schemes covering large areas along the Vaal, middle and lower portions of the Orange River as well as hydroelectric power generation at the two large dams (Gariep and Vanderkloof). Some 15 million people are dependent on secure water supplies from this basin and the Orange River Mouth Estuary in the Lower Orange River catchment in Alexander Bay, a RAMSAR site, relies on the flows from the upper river reaches.

The Orange-Senqu River basin is therefore a highly complex and integrated water resource system with numerous large inter-basin transfers which allow water to be moved from one part of the basin to another as well as into and out of neighbouring basins. The system is regulated by more than thirty-one major dams. Two of these major dams are situated in Lesotho, five in Namibia and 24 in South Africa. The largest five are the Gariep, Vanderkloof, Sterkfontein, Vaal and Katse Dams (ORASECOM, 2020).

The Orange-Senqu River basin is clearly one of the most developed and certainly most utilised river basins in the Southern African Development Community Region, with at least 9 major intra - and inter - basin water transfer schemes. It also includes several transfers into and out of the basin and requires the inclusion of parts of other neighbouring river basins into the water resources analysis and modelling setup.

2.2.2. Surface Water Infrastructure

There are many dams in the Upper Orange River catchment. Table 3 summarises the major, as well as certain smaller dams in the catchment. The large number of dams is a driver in respect of reduced or unnatural flows.

In addition, several dams in the Senqu, Ongers, Hartbees and Fish River sub-catchments as well as the Molopo sub-system (Namibia) are relevant to the overall model's set-up (Table 3).

Table 3: Major and minor dams in the Upper Orange River catchments (Source ORASECOM, 2020 & 2012)

Dam name	Sub-catchment	Associated River	Purpose	Live full supply capacity (million m^3)
Gariep	Upper Orange	Orange	Major storage dam – irrigation, domestic, hydropower, transfer to Eastern Cape and recreation	5 342
Vanderkloof		Orange	Major storage dam – irrigation, domestic, hydropower and recreation	3 188
Armenia		Leeu River	Small storage dam for irrigation and domestic (Town of Hobhouse)	13.2
Egmont		Off-channel (Witspruit River)	Small storage dam for irrigation	8.8
Welbedacht		Caledon	Small storage dam for irrigation and domestic with transfer to Bloemfontein	5.42*
Knellpoort Dam		Off-channel in the Rietspruit	Off channel storage dam in the Rietspruit catchment for domestic use to support water requirements of Mangaung because of the silting of Welbedacht Dam	138.4
Rustfontein		Modder	Small storage dam for domestic and irrigation	72.6
Mockes		Modder	Small storage dam for domestic	4.63
Krugersdrift		Modder	Small storage dam for irrigation	71.19
Tierpoort		Riet	Small storage dam for irrigation	34.5
Kalkfontein		Riet	Small storage dam for irrigation	319.6
Katse	Senqu	Semena River	Used as part of the Lesotho Highlands Water Project to transfer water to Vaal system	1 950
Mohale		Senqunyane River		938.6
Maqalika		Caledon	Caledon/Mohokare Maseru supply system	3.7
Metolong		Southern Phuthiatsana		64
Smartt Syndicate	Ongers	Ongers	Part of the Smart Syndicate Supply System, which supports irrigation	101

Dam name	Sub-catchment	Associated River	Purpose	Live full supply capacity (million m^3)
Victoria Wes		Brak	Supplies a water treatment works (domestic water supply).	3.66
Modderpoort,	Hartbees River	Rietfontein	To supply irrigation demands.	12.3
Loxton		Unnamed tributary of Brak River	Used for irrigation and domestic water supply	3.4
Van Wyksvlei		Unnamed tributary Carnarvonleegte River	Supply irrigation	143.1
Rooiberg		Hartbees River	Supply irrigation demands	3.65
Daan & Tilda Viljoen dams	Molopo sub-system Namibia	Black Nossob River	Water is pumped from the Daan Viljoen Dam into the Tilda Viljoen Dam which is a pumped storage dam	0.43 (Daan) 1.25 (Tilda)
Otjivero		White Nossob River	To supply water to Gobabis and Omitara in conjunction with the Daan Viljoen and Tilda Viljoen Dams	9.8 (main dam) 7.8 (silt trap dam)
Hardap	Fish River	Fish River	Water is supplied to Mariental via a purification plant downstream of the dam and then gravity fed 20 km to a reservoir at Mariental. The dam also provides for a 2 000-ha irrigation scheme by means of 16 km of concrete lined canals and pipelines. Also used for flood absorption to protect the town of Mariental.	294.6
Naute		Löwen River	Water is treated at the dam via a 1.9-km pipeline to the water treatment plant. Then the purified water reaches the town of Keetmanshoop via a 44 km pipeline. Water is also provided for a 270-ha irrigation scheme via a 2 km gravity pipeline.	83.58
Neckartal		Fish River	Provide water for 5,000 ha of irrigation	857

**15.47, however dam is highly silted and the current FSC is 5.418 million m^3*

There are three major water supply systems within the Orange Senqu, *viz*:

- Lesotho Highlands Water Project (LHWP) Phase I. It is noted that Phase II is currently in the planning phase. Implementation was planned for 2022 however this has been delayed) (Senqu-System)
- Orange River Project (ORP) (Gariep and Vanderkloof dams and related supply area).
- Greater Bloemfontein water supply system (Caledon-Modder System).

Main Water Transfer infrastructure:

Storage and inter-basin transfers are necessary because of the mismatch between location of abundant water resources and the location of the largest demands centres. Assuring water to sustain agriculture and other economic activities and domestic needs, necessitates bulk storage and transmission of water to places and at times when it would otherwise not be available.

The Orange-Senqu River basin is a highly complex and integrated water resource system, characterised by a high degree of regulation and several major inter-basin transfer schemes to manage the resource availability between areas of relatively high rainfall and the areas of greatest water requirements (ORASECOM, 2020). The infrastructure involves most of the largest water storage dams in Southern Africa as well as the associated transmission infrastructure, transmitting water to more than 250 major demand centres that are in some cases located outside of the Orange-Senqu River basin through intra and inter basin transfers (ORASECOM, 2012).

The largest intra-basin transfer is the transfer of water from the Lesotho highlands to the Vaal sub-basin. The largest inter-basin transfers include the Thukela-Vaal, Orange-Fish, Usutu-Vaal, the Inkomati transfers as well as the Vaal Eastern sub-system augmentation project, assisting with transfers to the Upper Olifants from the Vaal (ORASECOM, 2020).

The water transfer to the Vaal River System serves as the main water resource used to supply the Gauteng area, the economic hub of South Africa, as well as many coal-fired power stations in the Vaal and Upper Olifants catchment, used to supply the bulk of the energy requirements within South Africa (DWS, 2015). As result of all these transfer systems connected to the Vaal system, the Vaal System is referred to as the Integrated Vaal River System (IVRS), which then includes all the Vaal System related transfers.

The main existing water resources infrastructure associated with water transfers and bulk water supply schemes to users outside of the catchment are summarised in Table 4 and indicated in Figure 8.

Table 4: Major Transfers in the Orange-Senqu System (sources: ORASECOM 2020 &2012, DWS 2015, DWA 2009)

Scheme	Purpose	Capacity
Lesotho Highlands Water Project (LHWP)	To augment South Africa's water supply via a transfer to the Vaal River catchment (and it is therefore classified as part of the Vaal River System), in addition to generating electricity for Lesotho.	780 million m^3

Scheme	Purpose	Capacity
Caledon Modder Transfer 1: Novo Transfer Scheme	Supports the water supply to Bloemfontein, Mangaung, Botshabelo, Thaba 'Nchu, Dewetsdorp, Reddersburg and Edenburg.	Maximum capacity of 2.2 m^3/s
Caledon Modder Transfer 2: Welbedacht Dam to Bloemfontein	Novo Transfer Scheme transfers water from Knellpoort Dam to Rustfontein Dam in the upper reaches of the Modder River basin. This is done via the Novo Pump Station at Knellpoort Dam (29.7 km of pipeline and 12 km of river channel). The Novo Transfer Scheme is then linked to the Mazelspoort Scheme downstream on the Modder River. See Figure 9	1.29 m^3/s.
Orange-Fish Tunnel transfers	To divert water to the Eastern Cape for irrigation, urban (including Grahamstown and Nelson Mandela Metro) and industrial use. See Figure 10	620 million m^3/a; 53 m^3/s
Orange-Riet Transfer	Water from the Vanderkloof Dam via the Vanderkloof Main Canal transferring water to the Riet River catchment. Figure 12 illustrates the irrigation scheme at the confluence of the Riet and Modder rivers. The scheme is used mainly for irrigation, but also supplies urban requirements of Koffiefontein, Ritchie and Jacobsdal	260 million m^3/a
Orange Vaal Transfer Scheme	To mitigate shortages and high salinity issues at Douglas Weir on the Lower Vaal River	Ranges from 120 to 142 million m^3/a, depending on the water level and water quality in the Vaal River
Lower Orange to Springbok and Kleinzee	Springbok Regional Water Supply Scheme: Supplies the towns of Springbok, O'Kiep, Carolusberg and Kleinzee, along with local mining demands, with treated water from Henkries Purification Works (Henkriesmond)	Maximum pump capacity of 0.315 (m^3/s)
Pelladrift Water Supply Scheme	Supplies water to Pofadder, Pella and mines at Aggeneys and Black Mountain (operated by Pella Water Board). Water is abstracted and transported by two pipelines, one supplying local farmers and the towns of Pofadder and Pella, and the other supplying domestic use for the small town of Aggeneys, but more importantly for industrial use for the base metals mine, Black Mountain at Aggeneys.	4.7 million m^3
Port Nolloth	Supplies via a pipeline leading off from the Orange River at Alexander Bay for domestic use, a small fishing harbour and small-scale diamond mining	To confirm

Scheme	Purpose	Capacity
Future transfer from Makhaleng Dam in Lesotho to South Africa and Gaborone in Botswana	Two options from Makhaleng Dam exists; a high transfer of 186 million m^3/a and a low transfer of 97 million m^3/a. These volumes to Gaborone also include water requirements for domestic use in Lesotho as well as for towns in the RSA along the pipeline route.	In the order of 186 million m^3/a
Gariep Dam, Vanderkloof Dam and the Neusberg Hydropower Scheme	Operational when supplying downstream users	Gariep Dam serves to generate hydropower (Eskom), capable of providing up to 360 MW of electricity at a flow rate of 800 m^3/s. Vanderkloof Dam can produce up to 240 MW of electricity at a discharge flow rate of 400 m^3/s. Neusberg Dam can produce up to 10 MW

Figure 13 illustrates the irrigation scheme downstream of the Vanderkloof Dam.

Figure 8: Transfers in Orange -Senqu River basin (DWS Reconciliation Strategy for the Orange River Water Supply System, DWS 2015)

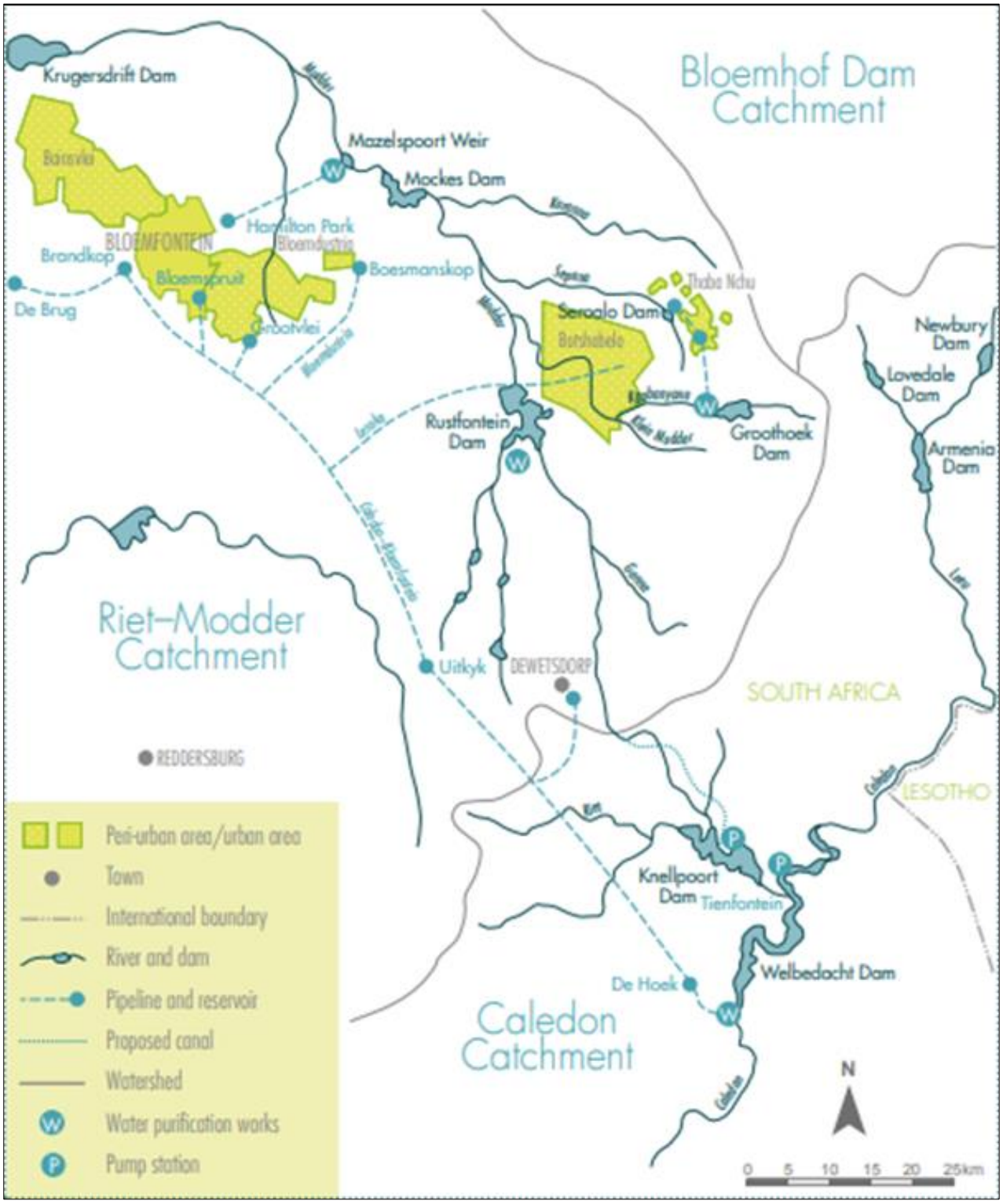

Figure 9: Caledon–Modder Transfer Scheme (ORASECOM, 2007a)

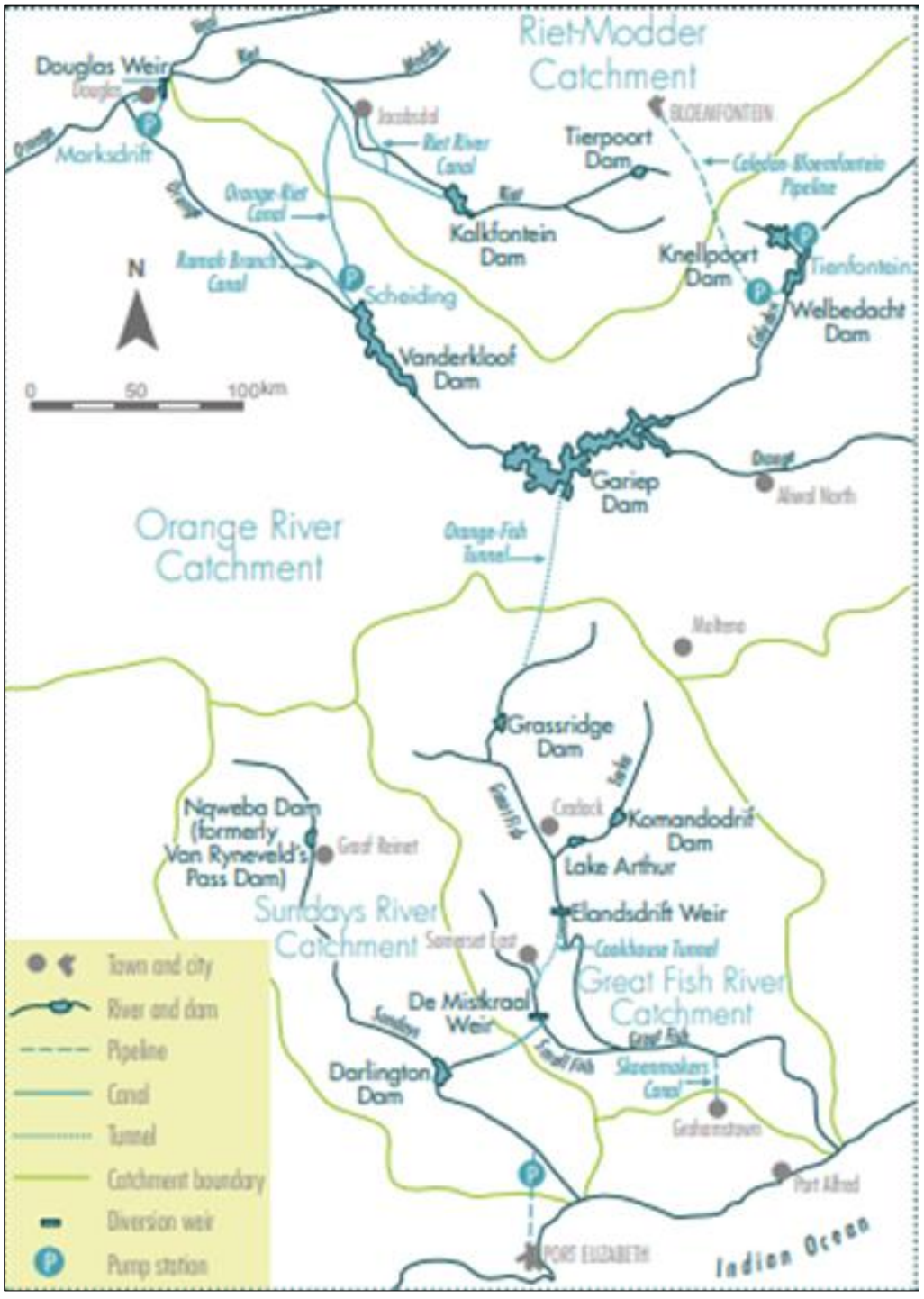

Figure 10: Orange-Fish Tunnel Transfer (source: ORASECOM, 2007a)

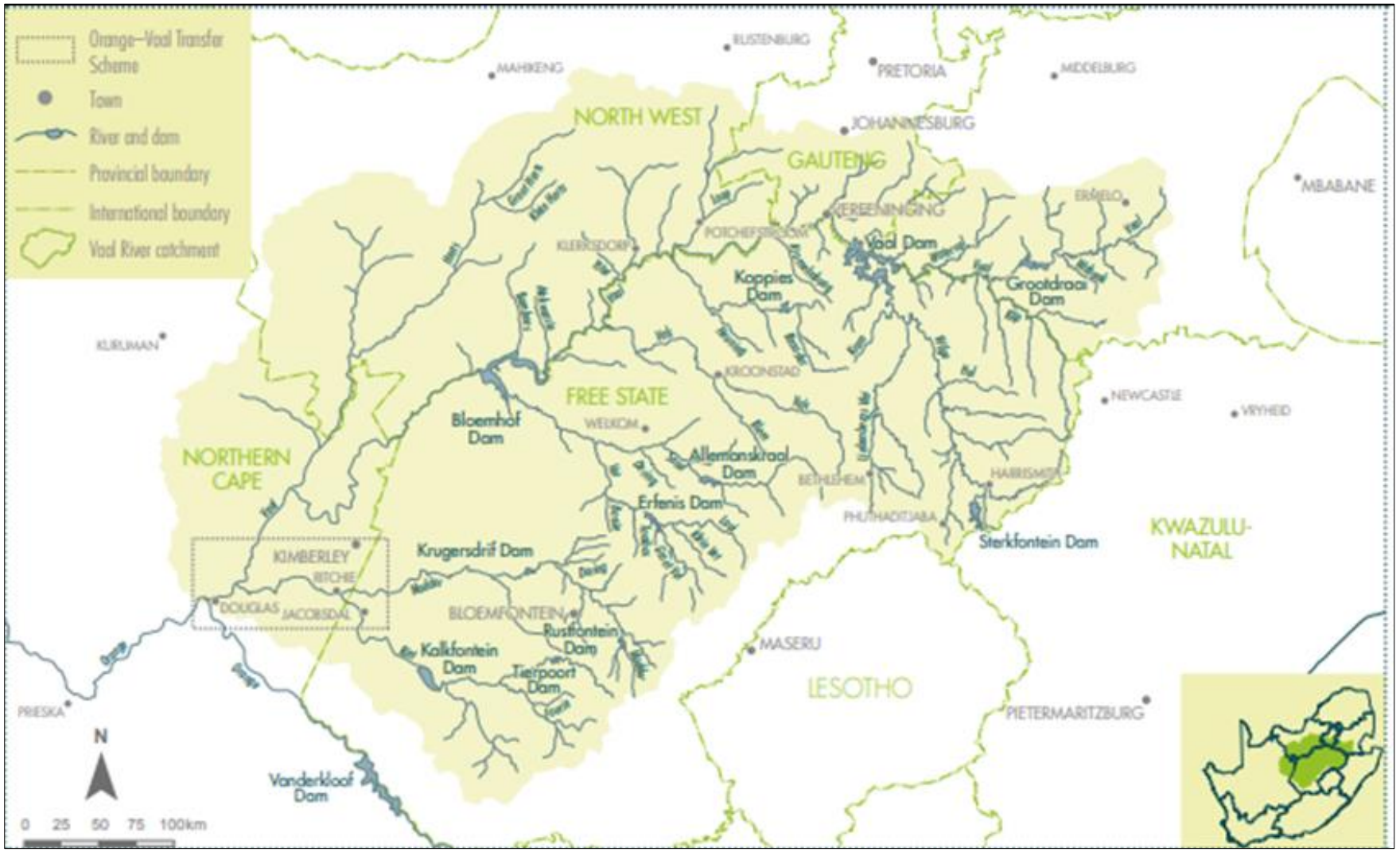

Figure 11: Orange Vaal Transfer Scheme (source: ORASECOM, 2007)

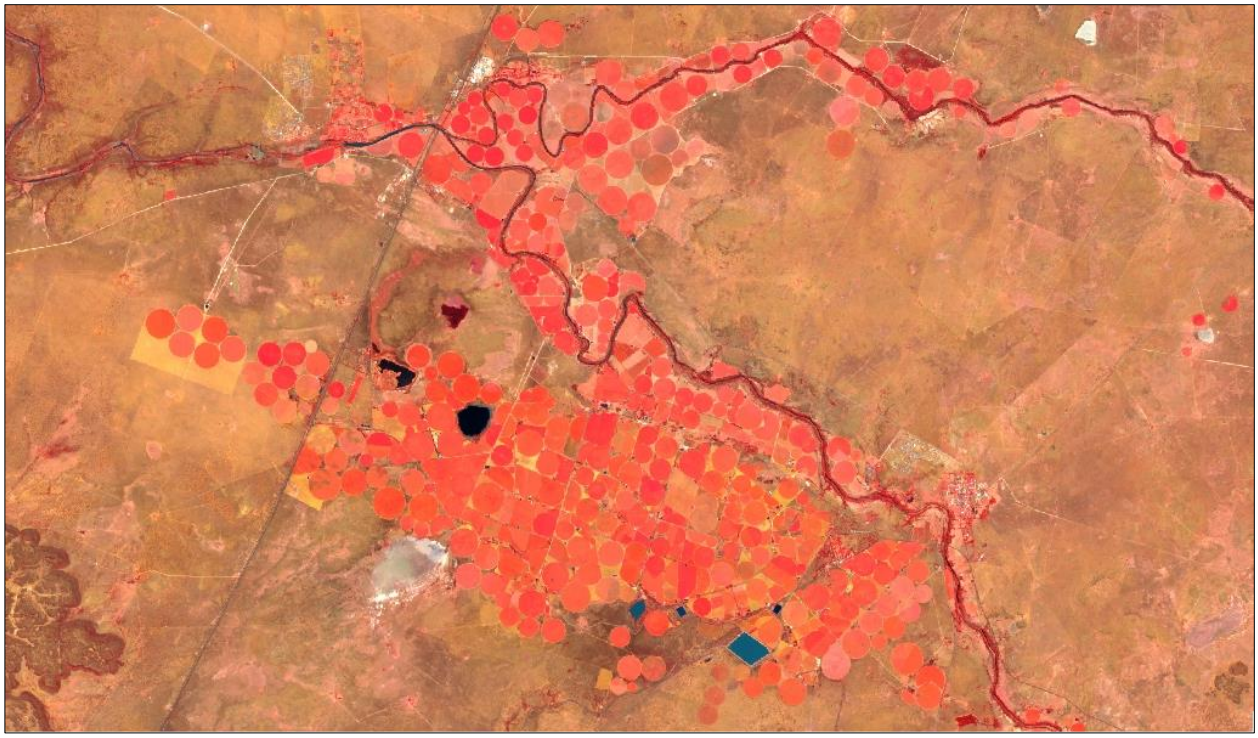

Figure 12: Irrigation scheme at the confluence of the Riet and Modder rivers illustrated with a false colour Sentinal-2 satellite image composite (bands 8, 4 and 3) where red indicates healthy vegetation.

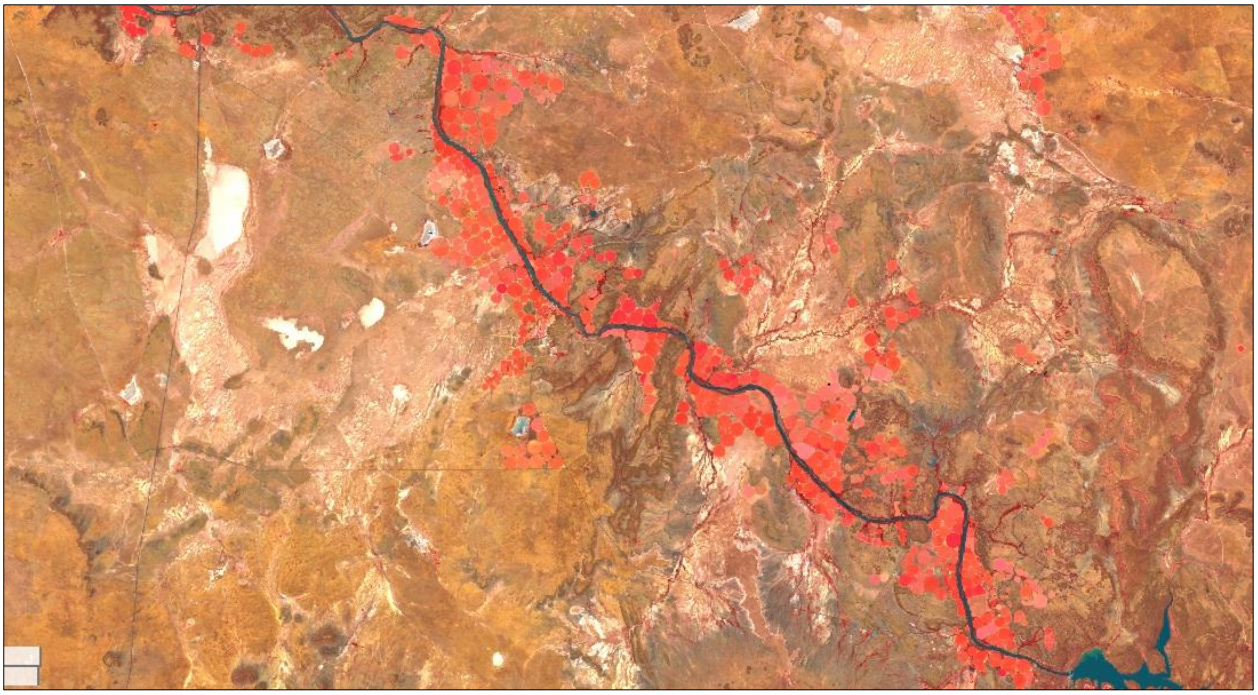

Figure 13: Irrigation scheme downstream of the Vanderkloof Dam illustrated with a false colour Sentinal-2 satellite image composite (bands 8, 4 and 3) where red indicates healthy vegetation.

2.2.3. Current general operation of the Upper Orange System

Vaal River Component

The Bloemhof sub-system forms the core of the Integrated Vaal River System and includes Grootdraai Dam, Vaal Dam, Vaal Barrage, Bloemhof Dam and Sterkfontein Dam as the main storage dams as well as Woodstock and Driel Barrage in the Upper Thukela that forms part of the Thukela transfer system. The operating rules used for the Bloemhof sub-system include the following:

- Grootdraai Dam does not support Vaal Dam. Only spills from Grootdraai can, therefore, be utilised by Vaal Dam. Grootdraai Dam is used mainly to supply SASOL and Eskom power stations with water.
- Transfers from Tugela continue until Sterkfontein Dam is full
- Sterkfontein Dam starts to support Vaal Dam only when Vaal Dam is at 18% or lower storage.
- Vaal Dam releases water to support the abstractions at Balkfontein for Central Vaal (previously Sedibeng and Bloem Water) and at Midvaal for Midvaal Water if local runoff and spills are insufficient.
- Vaal Dam only starts to support Bloemhof Dam when Bloemhof reaches its minimum operating level (m.o.l).

All the smaller sub-systems located on the tributaries of the Vaal River are included in the hydrological datasets used for the water resources planning/ yield models. The latest demands, as they apply are imposed on these sub-systems. These sub-systems do not support the Bloemhof sub-system and only spills from these sub-systems enter the Bloemhof sub-system and can contribute to the Bloemhof sub-system yield. These sub-systems include:

- Schoonspruit sub-system includes the Schoonspruit Government Water Scheme comprising Rietspruit and Elandskuil dams, and Johan Neser dam (as part of the Klerksdorp Irrigation Board).
- Sand-Vet sub-system including Allemanskraal and Erfenis dams as part of the Sand-Vet Water User Association.
- Renoster sub-system with Koppies Dam, and
- Mooi River sub-system that includes the Mooi River Government Scheme comprising of Klerkskraal, Boskop and Lakeside dams as well as the Klipdrift Irrigation scheme using Klipdrift Dam in the Loopspruit River, a tributary of the Mooi River.

Operating rules for these stand-alone schemes (sub-systems) are developed to allow them to be operated as individual systems without supporting the main Vaal system.

For the Lower Vaal sub-system, Bloemhof Dam is used to support various demands downstream of the dam. The largest of these demands is that of the Vaalharts Irrigation scheme, which also

generates a considerable volume of return-flows. The different stand-alone sub-systems in the Lower Vaal were treated in the same manner as those located in the Middle and Upper Vaal. These stand-alone sub-systems include:

- Wentzel Dam sub-system on the Upper Harts River
- Taung Dam sub-system on the Middle Harts River, and
- Spitskop Dam sub-system on the Lower Harts River receiving return-flows from the Vaalharts scheme.

The Orange River Component

Although the Modder/ Riet rivers are tributaries to the Vaal River, this catchment and related sub-systems are seen as part of the Orange River System due to transfers and support from the Orange to the Modder/ Riet catchment.

The Orange River System includes two major water supply systems, the Orange River Project (ORP) and the Caledon Modder sub-systems. The ORP comprises Gariep and Vanderkloof dams with its entire supply area, covering the Eastern Cape Sundays/Fish area, the entire Orange River from Gariep Dam to the river mouth at Alexander Bay and Oranjemund as well as transfers to the Riet/Modder.

The ORP sub-system is set up so that the Vaal River system is not used to support any of the demands in the Orange River as the Vaal River is in practice operated as such. The Vaal River system is supported by several transfer systems and the operating rules were therefore developed to minimise the spilling of expensive transferred water into the Orange River. Spills from the Vaal can also not be utilized by Lower Orange demands as in practice the total demand for the Lower Orange is released from Vanderkloof Dam, without taking into account inflows from the Vaal as the Vanderkloof releases take approximately one month to reach the river mouth. It is also noted that one of the recommendations of the ORP Annual Operating Analysis is to develop Real-time systems that account for the inflows from the Vaal to reduce the releases from the Vanderkloof dam.

The demands in the Eastern Cape as well as demands between Gariep and Vanderkloof dams can only be supplied from Gariep Dam. The remainder of the demands imposed on the ORP is supplied from Vanderkloof Dam with support from Gariep Dam. Releases from these two dams into the river to supply downstream demands are simultaneously used to generate hydropower. The releases from Vanderkloof Dam follows the monthly distribution pattern of the demands downstream which is mainly driven by irrigation, thus high requirements in the summer and low requirements in the winter. For hydro-power purposes an inverse pattern is in general required as the power demand in the winter is higher than in the summer. To accommodate this requirement, the release pattern from Gariep Dam follows the inverse pattern of the irrigation requirement, allowing more power to be generated in the winter months from Gariep Dam. The monthly distribution pattern is then again corrected by the releases from Vanderkloof Dam located not far

downstream of Gariep Dam. The volume of water released from Gariep Dam is however limited to the total downstream requirement plus the short-term surplus available in the system. The surplus available over the short-term is determined every year by means of a detailed water resource planning model (WRPM) analysis and it depends on the storage level and the total demand imposed on the two dams in the particular year under consideration.

To protect the users that can only obtain water from Gariep Dam, the operating rule dictates that releases in support of Vanderkloof Dam will not take place when Gariep Dam is below 15% of its live storage. The only releases that will then be made from Gariep Dam will the water required to supply the users between Gariep and Vanderkloof Dam. When Vanderkloof Dam reaches its minimum operating level (m.o.l.) releases will again be made from Gariep Dam in support of Vanderkloof Dam, keeping Vanderkloof just above its minimum operating level.

The minimum operating levels for hydro-power generation purposes are in both dams slightly higher than the minimum operating levels for releases in support of the demands in Eastern Cape (Orange Fish tunnel intake) in Gariep Dam and the releases into the Vanderkloof main canal. For yield purposes the lower minimum operating levels were used in both dams to determine the maximum yield available for the users, not for hydro-power purposes. None of the dams located upstream of Gariep Dam in the Caledon or in the Senqu basin are used to support the ORP.

The Caledon/Modder sub-system comprise the Knellpoort and Welbedacht dams in the Caledon River catchment with Rustfontein and Mockes dams in the Modder River catchment. This sub-system is used to supply Bloemfontein, Mangaung, Botshabelo, Thaba N'chu and several other small towns with water.

The bulk of the water supplied from the Caledon/Modder sub-system comes from the Caledon due to significantly higher runoff produced in the Caledon catchment. To be able to obtain the maximum possible yield from the combined system (Caledon plus Modder River dams) specific operating rules were developed to achieve this. These operating rules also consider the limited transfer capacities from Knellpoort to Rustfontein Dam and from Welbedacht Dam to Bloemfontein. The operating rule therefore dictates that water is taken first from Welbedacht Dam to the maximum capacity of the transfer system. When there is not sufficient water in Welbedacht Dam, releases will be made from Knellpoort Dam to support the maximum transfer rate from Welbedacht Dam. This will be followed by taking water from Mockes Dam until Mockes reaches 25% storage level. At that Level releases will be made from Rustfontein Dam in support of Mockes, keeping Mockes at its 25% live storage level. When Rustfontein drops below its 90% live storage level, transfers from Knellpoort to Rustfontein starts at the maximum transfer capacity of the system. Tierfontein pumping should only stop when Knellpoort Dam reaches 90% gross storage level trying not to exceed the 90% storage level in Knellpoort Dam. Transfers from Knellpoort to Rustfontein must try to keep Rustfontein between 23% and 30%. As some demands can only be supplied from Rustfontein Dam, an operating level at 5% of its live storage was introduced in Rustfontein Dam at which releases in support of Mockes Dam will stop. The

remainder of the storage in Mockes Dam below the 25% level will then be used. Only when Mockes Dam reaches its minimum operating level will releases from Rustfontein Dam in support of Mocked Dam be made.

Knellpoort Dam is an off-channel storage dam and is filled mainly by means of water pumped from Tienfontein pump station in the Caledon River. The operating rule dictates that whenever sufficient water is available in the Caledon River, water must be pumped into Knellpoort Dam until Knellpoort Dam reaches its 90% storage level. Only then pumping will be stopped.

It is however important to note that whenever any of the transfer or pump capacities changes, the operating rule will need to be revised.

Several stand-alone sub-systems are located in the Modder/Riet catchment. These stand-alone sub-systems are treated in the same manner as those located in the Middle and Upper Vaal and including:

- Krugersdrift Dam on Modder River
- Groothoek Dam on a tributary of the Modder River
- Tierpoort Dam Upper Riet River tributary, and
- Kalkfontein Dam on the Riet River.

Several stand-alone sub-systems are also found in the Upper and Lower Orange River catchments which are operated as stand-alone systems that are not used to support any of the ORP demands. These typically include:

- Caledon/Mohokare Maseru supply system, river abstraction and off channel storage (Maqalika Dam), with Metolong Dam recently completed
- Ongers sub-system, including Smartt Syndicate and Victoria Wes dams
- Hartbees River sub-system including Modderpoort, Loxton, Van Wyksvlei and Rooiberg dams
- Molopo sub-system RSA including Lotlamoreng, Setumo and Disaneng dams
- Molopo sub-system Namibia including Daan & Tilda Viljoen and Otjivero dams, and
- Fish River sub-system (Namibia) including Hardap and Naute dams with Neckartal Dam of which the construction just started.

The Senqu Component

The Senqu catchment includes only one major water supply system referred to as the Lesotho Highlands Water Project (LHWP) used to transfer water to the Vaal system. This system currently comprises Katse and Mohale dams as well as the Matsoku diversion weir.

The operating rules are set up in such a manner that Katse and Mohale dams are not able to support Gariep and Vanderkloof dams. Only spills and environmental releases from these dams

can flow into Gariep Dam. The transfer rate of 780.19 million m^3/a (in a clandar year) is applicable to the Lesotho Highlands project. The operating rule between Katse and Mohale dams dictates that water is first taken from Katse Dam to supply the full transfer to the Vaal until Katse Dam reaches the 86% storage level. Below this level Mohale Dam starts to support Katse Dam. The flow volume from Mohale Dam to Katse Dam is controlled by the tunnel capacity and the difference in the water level between Katse and Mohale dams. Available river flow is diverted from Matsoku Weir to Katse Dam, after allowing for environmental requirements downstream of Matsoku Weir. There are no smaller sub-systems currently existing in the Senqu catchments except for several run-off river abstractions for small towns and villages in the catchment.

2.2.4. Water Availability

Fifty seven percent of the natural runoff is generated in Lesotho and 33% in the Upper Orange River catchment and the remaining 10% in the Lower Orange River catchment (DWS, 2015). Although the surface water resources of the Orange River are already heavily regulated through the many large dams in the system, potential has been identified for the re-regulation of releases from Vanderkloof Dam as well as the storage of more flood flows from the Upper Orange and Vaal Rivers. These options could contribute to the improved management of the Orange/Vaal River System, and facilitate more water being made available for use.

The water requirement projections for the Orange System with water conservation/ water demand management (WC/WDM) is summarized in Table 5 (ORASECOM, 2020).

Table 5: Water Requirements in the Orange-Senqu system (ORASECOM, 2020)

Description	Million m^3/a	
	2018	**2020**
Orange-Senqu		
Total Irrigation Demands	2 183	2 174
Total Domestic/ Urban	294	292
Transfer from Katse Dam to Vaal Dam	780	780
Total River and Operating requirements	1 083	1 083
Demand Imposed Gariep & Ven Der Kloof	3343	3325
Total Orange River Demand	**4 339**	**4 329**
Namibia: Fish, Nossob, Auob and Lower Orange River		
Total Irrigation Water Requirements	107.5	109.5
Total Urban Water Requirements	14.7	15.0
Total Mining Water Requirements - Only Lower Orange	19.5	19.2
Total Water Requirements	**141.7**	**143.6**
Botswana: Molopo River		
Total Irrigation Water Requirements	10.0	10.0
Total livestock requirements	9.0	9.0
Total Mining Water Requirements	7.6	12.0
Total Urban Water Requirements	28.0	29.0

Description	Million m^3/a	
	2018	**2020**
Total Water Requirements	**54.6**	**60.0**
Lesotho: Senqu/Caledon River		
Total Irrigation Demands	6.7	6.7
Total Domestic/Industrial Demands	38.4	51.3
Transfer to Lesotho Botswana and RSA from Makhaleng	0.0	0.0
Total Water Requirements	**45.2**	**58.1**

The following measures were envisaged for the Orange River system (South African portion) in the Orange River Reconciliation Strategy (2015) to maintain a water balance between the water needs and availability up to the year 2050 (DWS, 2015):

- Water required to supply the current and future social and economic activities as well as supporting the transfer to the Vaal River system, will have to come from within the Orange/Senqu basin. It was found that transferring water from a neighbouring basin (e.g. Mzimvubu measures) will be too expensive.
- The existing Ecological Water Requirements (EWRs) needs to be maintained and to avoid immediate large negative socio-economic implications additional releases towards an alternative EWR can only be implemented as soon as the new dam (at Vioolsdrift) is commissioned. Further optimisation of the EWR in combination with the proposed augmentation options is recommended.
- Groundwater, if available, should be prioritised as the first choice to augment the water resources of towns and communities located far from the Orange River.
- All water requirements can be balanced by availability through the implementation of the following measures:
    - Shared utilisation of LHWP Phase II between the Vaal River and Orange River systems is an essential measure to postpone large capital expenditure that would otherwise be required at the same time Polihali Dam becomes operational.
    - Plan and implement WC/WDM in the domestic and irrigation water use sectors for the domestic/ industrial water use sector, and in the irrigation water use sector (target date was 2020).
    - The introduction of a mechanism whereby water, saved through water use efficiency, especially in agriculture, can be made available to other water users in the system.
    - Limit operational losses through real time monitoring of river flows in the Orange and Vaal rivers to maximise the beneficial use of the spillages from the Vaal River System (target implementation date was 2016), and
    - Utilising a greater portion of Vanderkloof Dam's storage capacity by lowering the minimum operating level in the dam. This measure required pumping infrastructure which had to be in place by 2022.

- Implementation of the EWR would require further actions to be implemented sooner, *inter alia*, commissioning of Vioolsdrift Dam sooner, increasing yield of the system by raising of Gariep Dam or building of Verbeeldingskraal Dam, adjusting the assurances of supply to downstream water users.

Analysis of the Orange River water supply systems indicate that they will soon be in deficit (if not already) and several intervention options in addition to those outlined above are required to be able to maintain a positive water balance over the planning period (2025-2050) (DWS, 2015). The significant delay in the development of the LHWP Phase II, one of the critical major infrastructure developments able to ensure a sustainable and secure water supply to the Vaal River System is a major concern. However, the LHWP Phase II while addressing the deficits in the IVRS will result in a decrease in the yield available from the ORP. This presents additional supply constraint to the users downstream of Vanderkloof Dam, which will require further interventions and actions. This is further compounded by the additional growth in water requirements of Namibia from Vioolsdrift and Botswana from the Vaal Gamagara Water Supply Scheme. These will increase the current demand load on the system and might impact on existing users.

There has also been a significant impact on the flow regime at the Orange River Mouth and the meeting of the EWRs due to the highly developed nature of the system but also the availability of yield in the system to supply this requirement. Releases from the existing storage dams that only partly addresses the problem are expected to significantly impact on the system yield, resulting in deficits in the supply to current users. With the current infrastructure in place, it is almost impossible to supply the EWRs at the estuary, due to the distance of almost 1 400km from Vanderkloof Dam to Alexander Bay. Thus, the intervention option of the building of Vioolsdrift Dam, to serve as a regulation dam for the EWR releases, but also a water supply dam for the expansion of the irrigation in Namibia.

An update of the Reconciliation Strategy for the Central Planning Area comprising the Orange and Integrated Vaal River Water Supply Systems Orange WMAs, was initiated by the DWS: National Water Resources Planning Directorate in 2021. However, this study which would have provided an updated water balance, intervention and management options and planning scenarios for the future has been delayed and the availability of study information and reports could not be confirmed.

3 STATUS QUO: SOCIO-ECONOMIC AND ECOSYSTEMS SERVICES

3.1. Demographics and Socioeconomics Profile

The Upper Orange River catchment stretches across an area that covers parts of the Free State, Northern Cape, and Eastern Cape provinces, with the largest proportion within the Free State province. The estimated total population of the Upper Orange River catchment study area was approximately 1.4 million in 2023 with about 476,000 households (Stats SA 2011 Census adjusted). The predominant language spoken includes Sesotho (72.3%) followed by Afrikaans (10.3%) in the Free State province; Afrikaans (54,6%), followed by Setswana (35.7%) and IsiXhosa (4.5%) in the Northern Cape; and IsiXhosa (81.8%), followed by Afrikaans (9.6%) and English (4.8%) in the Eastern Cape (Stats SA, Census 2022).

The population density is highest in the Mangaung Metropolitan Municipality (MM) which includes the city of Bloemfontein and several urban settlements in and around the larger towns within the Upper Orange River catchment (Figure 14). Other densely populated areas include those where there are several rural settlements, and this is particularly in the former homeland areas within the northern part of Senqu Local Municipality in the Eastern Cape.

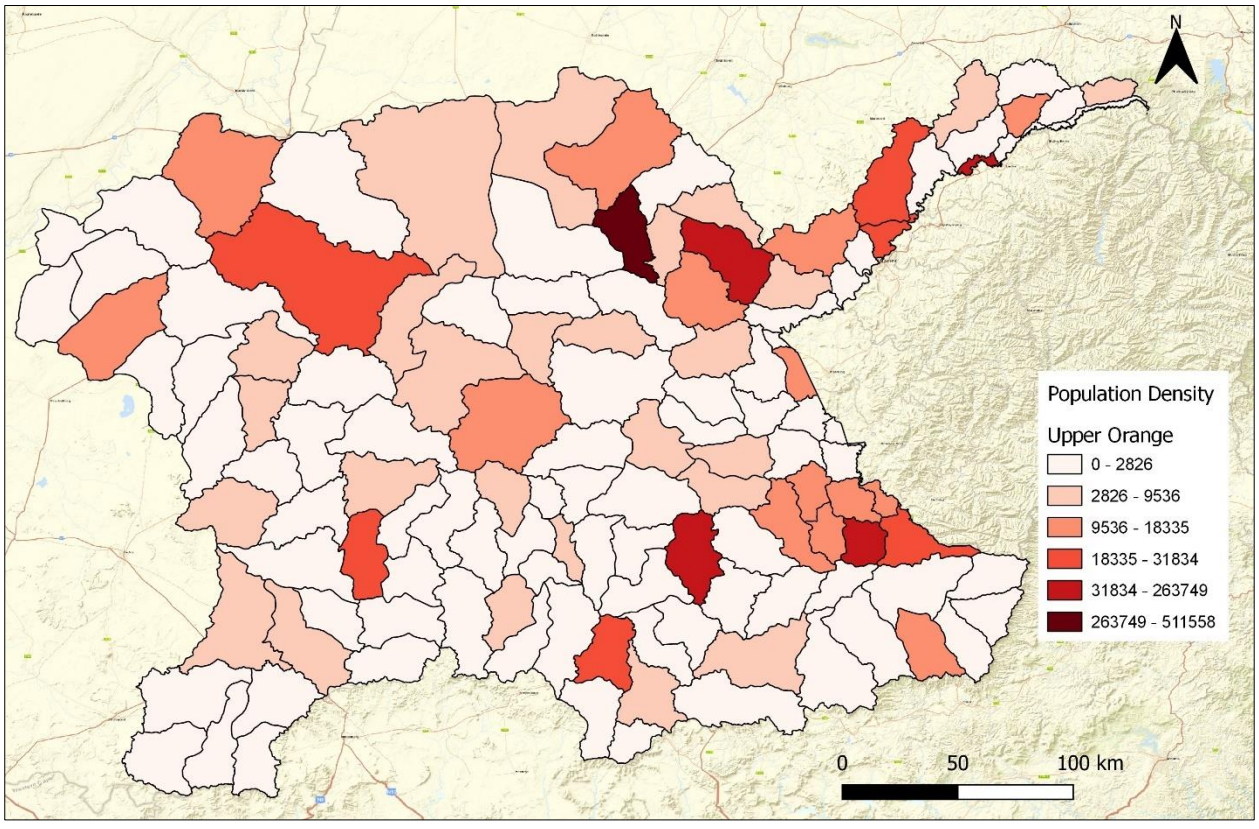

Figure 14: Population density of the Upper Orange River catchment

The Upper Orange River catchment area intersects with nine district and 26 local municipalities within the Free State, Northern Cape and Eastern Cape provinces (Figure 15). In the Free State

there are four district municipalities (Lejweleputswa, Mangaung, Thabo Mofutsanyane and Xhariep) and 11 local municipalities. The Northern Cape part of the catchment includes two districts (Frances Baard and Pixley ka Seme) and seven local municipalities, and the Eastern Cape includes three districts (Chris Hani, Joe Gqabi and small parts of one municipality of Sarah Bartman) and eight local municipalities. The catchment has several large dams including the large Gariep and Vanderkloof storage dams, and a variety of other dams and impoundments that support the local economy and also provide water transfer into neighbouring catchments. A key water transfer is the Orange-Fish Tunnel that transfers water from the Gariep Dam to the Eastern Cape Sundays and Fish rivers.

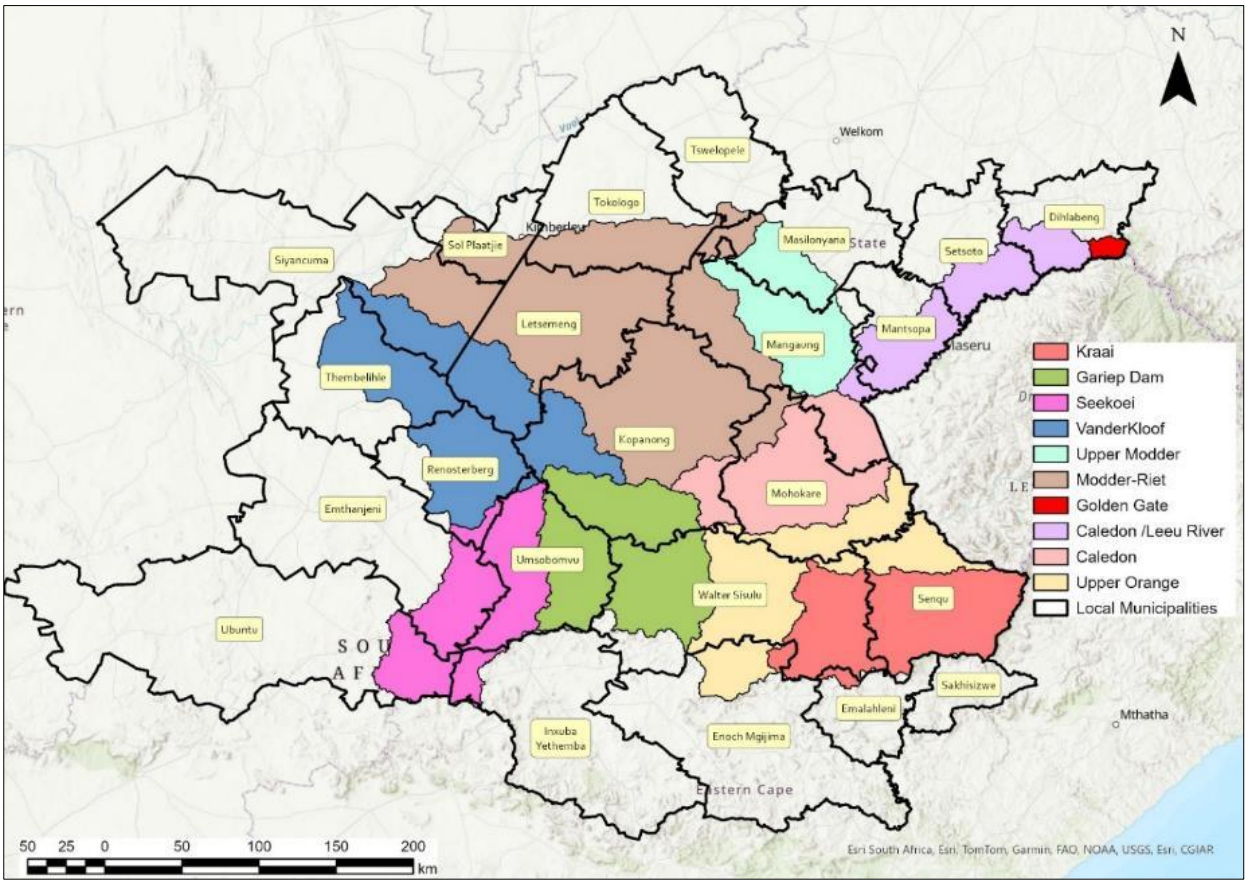

Figure 15: Locality of local municipalities in the Upper Orange River catchment

Bloemfontein, the largest city and the capital of the Free State province is included in the Upper Orange River catchment in the Mangaung Metropolitan Municipality. The catchment includes several densely populated rural settlements and small towns throughout the catchment. There are a number of larger towns including Botshabelo, Thaba Nchu, Ficksburg, Brandfort, Petrusburg, Koffiefontein and Ladybrand in the Free State; Colesberg, Petrusville, Phillipstown and Hopetown in the Northern Cape; and Barkly East and Maletswai (Aliwal North) in the Eastern Cape. The unemployment rate within the catchment ranges from 12.2% to 34.4% (NT, 2021).

The majority (98%) of population within the catchment has access to formal water sources (Piped water in the dwelling, piped water in the yard, communal tap water <200m from household, communal tap water >200 m) and only 2% of the population of the catchment source water from informal water sources including boreholes, springs, rain-water tanks, rivers or streams, dams, pools or stagnant water and other water sources (Figure 16).

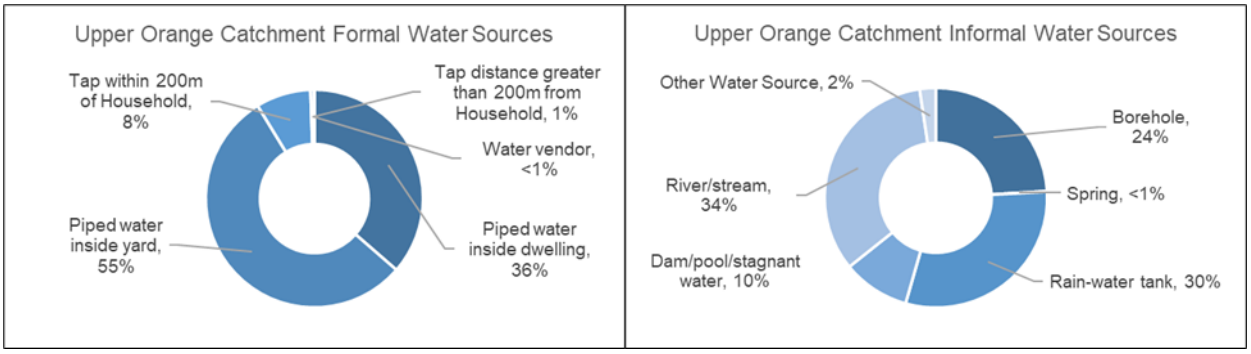

Figure 16: Access to water services in the Upper Orange River catchment (DWS, 2023)

3.2. Economic Sectors

The main economic contributions in the Upper Orange River catchment are from the tertiary sector in the financial services sector (20%), followed by wholesale and retail trade, catering and accommodation sector (17%). Tourism sector activity in the catchment includes cultural-historic, events (such as sporting and festivals), leisure related activities and agri-tourism.

Manufacturing and construction sectors (secondary sectors) play an important role with the main centres being in the Mangaung Metropolitan Municipality and some of the larger towns within the catchment. Manufacturing is mainly in the light manufacturing and service orientated industries, brick manufacturing, agro-processing and food, beverages and tobacco products.

While agriculture's contribution to Gross Domestic Product (GDP) (4%) is not large it is still one of the key economic activities within the catchment with extensive livestock farming, dryland and irrigation agriculture.

The mining sector is relatively small (1% contribution to GDP) with the main mining activities from alluvial diamond mining, salt works, sand mining and quarrying.

The approximate contributions to GDP and employment of the Upper Orange River catchment area were estimated based on the municipalities in which it lies and their proportional GDP contributions (Table 6 and Table 7).

Table 6: Economic sectors in the Upper Orange River catchment and the estimated contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R9,402	4%
Mining	R3,072	1%
Manufacturing	R29,730	12%
Electricity & water	R8,679	3%
Construction	R14,163	6%
Wholesale & retail trade; catering and accommodation	R44,642	17%
Transport & communication	R31,044	12%
Financial services	R51,052	20%
General government	R38,040	15%
Community, social & personal services	R25,648	10%
Total GDP	**R255,473**	**100%**

Table 7: The estimated employment by economic sector in the Upper Orange River catchment (Estimated using NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	44,866	11%
Mining	1,678	<1%
Manufacturing	23,202	6%
Electricity & water	1,722	<1%
Construction	22,538	5%
Wholesale & retail trade; catering and accommodation	97,120	23%
Transport & communication	17,476	4%
Financial services	57,218	14%
General government	69,827	17%
Community, social & personal services	80,539	19%
Total Employment	**416,184**	**100%**

3.3. Ecological Infrastructure

The Upper Orange River catchment is characterized by several key water resources, including wetlands, strategic water source areas (SWSA), and rivers. Within the catchment, there are notable dams such as the Gariep Dam, Vanderkloof Dam, Mockes Dam, Rustfontein Dam, Krugersdrift Dam, Kalkfontein Dam, and Tierpoort Dam. The main rivers in the area consist of the

Orange River, Caledon River, Leeu River, Kraai River, Seekoei River, Modder River, Riet River, and their respective tributaries.

The Upper Orange River catchment encompasses several strategic water source areas. These areas are located in the northeastern, lower western, upper eastern, and upper central extents of the catchment.

The catchment is renowned for its diverse array of wetlands, which are dispersed throughout the region. These wetlands encompass a wide range of types, including seeps, floodplains, channelled and unchanneled valley bottoms, discontinuously channelled valley bottoms, and endorheic wetlands. The presence of such a varied collection of wetland types plays a vital role in shaping the unique ecological composition and promoting biodiversity within the catchment.

Among the notable protected areas in the catchment are the Golden Gate Highlands National Park in the upper eastern part, and Mokala National Park, and Vaalbos National Park on the western side. Additionally, the catchment is home to a variety of nature reserves scattered throughout the catchment. These protected areas and nature reserves play a crucial role in conserving and safeguarding the catchment's diverse ecosystems.

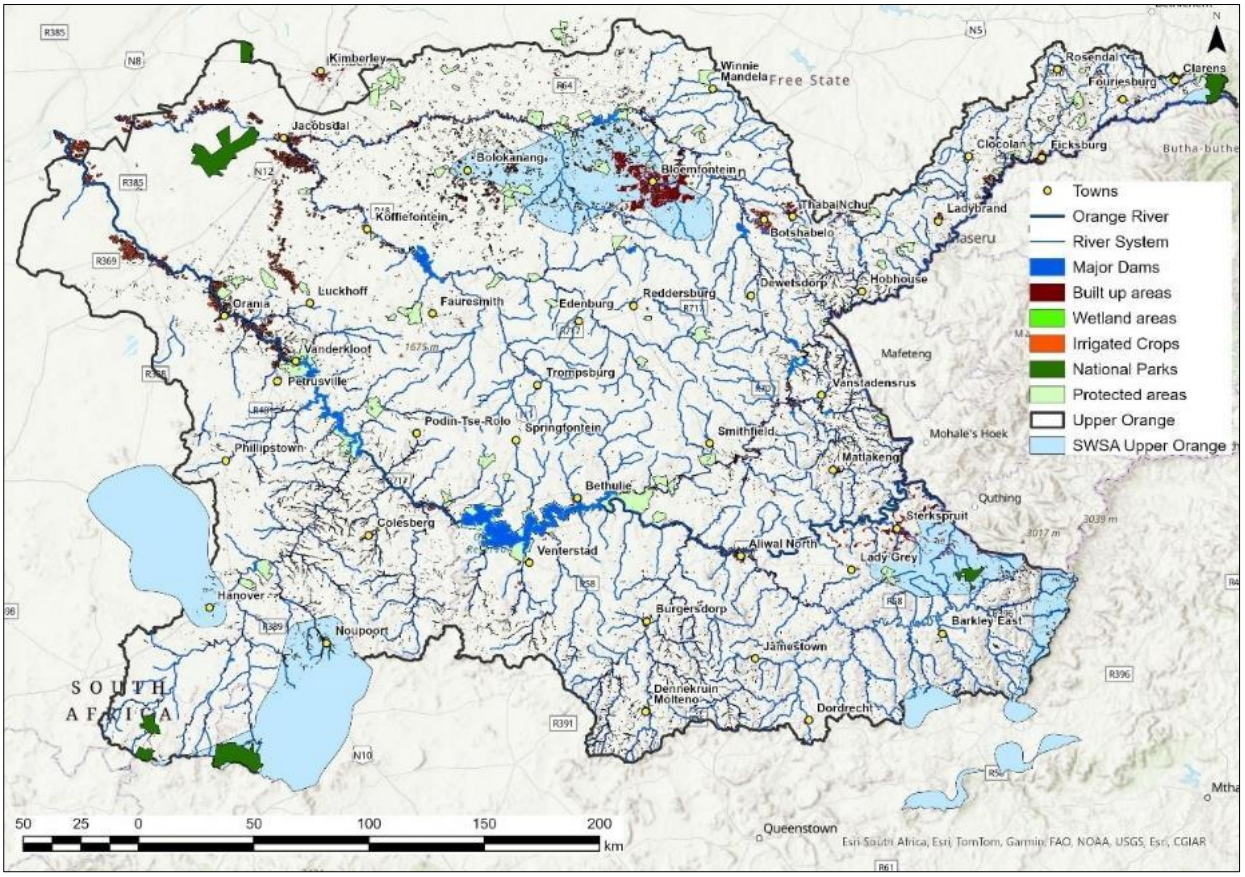

Figure 17: Ecological infrastructure within the Upper Orange River catchment

3.4. Ecosystem Services Sensitivity

Ecosystems Defined

Ecosystem services refer to the benefits that humans obtain from ecosystems. The concept gained prominence following the publication of the Millennium Ecosystem Assessment (MEA) in 2005, which evaluated the implications of ecosystem changes on human well-being. This comprehensive study, conducted from 2001 to 2005, involved over 1,360 global experts and offered an up-to-date scientific evaluation of the world's ecosystems, their services, and the scientific foundation for sustainable conservation and usage. Subsequent to this, several frameworks have sought to further break down and categorize these benefits. These include The Economics of Ecosystems and Biodiversity (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, 2013), and the framework developed by the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019). Despite each framework's attempt to build upon its predecessors, they all essentially follow a similar rationale. They classify ecosystem services into four primary 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). Provisioning services of the wetland landscapes support food production, provide fish, medicines, timber, fibre, fodder, water and other products that support livelihoods, provide income opportunities and contribute to regional GDP.
- **Regulating services**, are the 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. Various water regulation, sediment and nutrients regulation, storm and flood protection and micro-climate regulation services exist. They provide benefits to the inhabitant to the landscapes and well as beneficiaries in adjacent and downstream areas. Regulating services are not valued directly in the economy, rather their values can be thought of as an insurance value. This is because these services underpin the production of provisioning and cultural services, or alternative mitigate risks that would regulating on economic damage costs if not mitigated.
- **Cultural services** are intangible benefit is received in terms of intellectual, spiritual and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure. These are the services that underlie recreation and tourism values, benefiting local communities, domestic tourist and international tourists. Wetland landscape of the nature of these studied here are often home to sacred or spiritual areas, which is also an important example of cultural services. The value of eco-tourism can be estimated using various techniques. Spiritual and inspirational value are more difficult to value.
- A fourth category of **ecosystem service** is added in some frameworks to distinguish the importance of specific habitats within a delineated ecosystem. This may include the maintenance areas of uniqueness (as envisaged under the IPBES); areas of unique genetic diversity, **biodiversity**, and habitat (as envisaged under the TEEB); and unique

combinations of supporting and regulating services (as envisaged under the MA). From an ecosystem service valuation perspective, when certain areas or habitats are especially unique, such assets are so rare that it is regarded as non-substitutable. Substitutability in economics is the degree to which an asset is substitutable for another asset. The distinctive characteristics of the landscapes identified here provides a globally unique blend and magnitude of ecosystem services produced that arguable qualifies these landscapes as non-substitutable asset classes.

Ecosystem Service Sensitivity

Ecosystem services encompass the diverse benefits that humans derive from healthy ecosystems, while ecosystem sensitivity denotes the susceptibility of an ecosystem to disruptions or changes in its environment. This sensitivity reflects the extent to which an ecosystem responds to disturbances, whether natural or human induced. These concepts are identified using two primary approaches. The first approach focuses on understanding the benefits derived from ecological infrastructure, while the second approach infers the flow of ecosystem services by analysing the spatial relationship between potential beneficiaries and ecological infrastructure.

In defining sensitivity, we consider general categories of ecosystem services, including provisioning, regulating, and cultural services. During the catchment classification process, we place particular emphasis on the water provisioning service for inclusion in the sensitivity analysis.

In the Upper Orange River catchment, we have conducted preliminary assessments to identify key ecosystem services. These services encompass various aspects, including water provisioning services facilitated by the network of rivers, tributaries, and strategically important water source areas which are included in Water Research Commission Report No. TT 754/2/18 (Le Maitre et al, 2018)(Figure 18).

To illustrate, the Upper Orange River catchment is characterized by several wetlands such as seeps, floodplain, channelled valley bottom (VB) and unchanneled valley bottom (VB) discontinuously channelled valley bottom (VB), and depressions which are basins in arid zones that vary in size and have formed through different processes (i.e., endorheic wetlands) (De Klerk et al, 2016). While these wetlands are often located above the groundwater table, they experience seasonal or perennial surface water inundation. These areas play a crucial role in providing both provisioning and regulating services beyond water, which significantly impact rural livelihoods. Additionally, the catchment's complex ecosystems contribute to cultural services that benefit the broader economy.

Figure 18 highlights protected areas, such as the Golden Gate Highlands National Park, Balloch Protected Environment, Oviston Nature Reserve area, and Mokala National Park, all of which hold formal national park status in South Africa. In this assessment, these areas are considered sensitive and contribute to the provision of cultural services.

To gain a better understanding of the distribution and potential of ecosystem services, we conducted an exercise to map the ecological infrastructure and assess the socio-economic status

quo. This mapping exercise aimed to identify the likely flows of ecosystem services within the region. By considering the presence of ecological infrastructure and the current socio-economic conditions, this assessment provides valuable insights into the potential benefits and services that the ecosystem can offer to the communities and environment of the study IUAs.

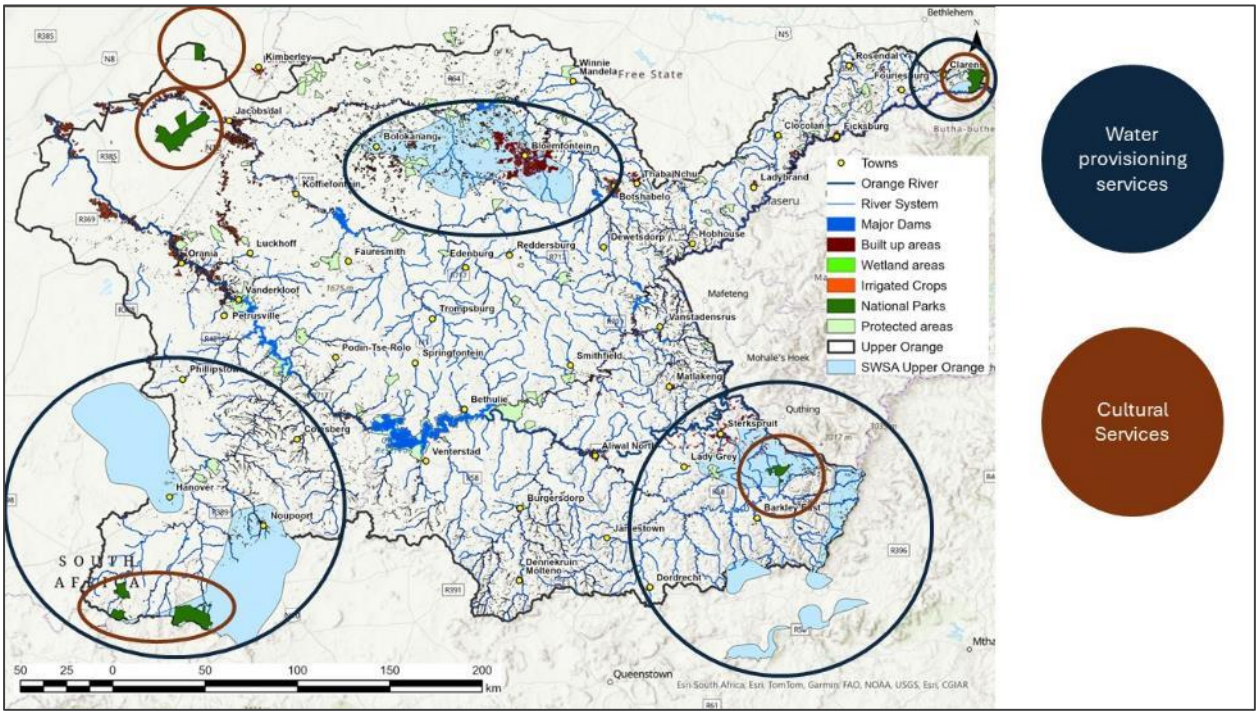

Figure 18: Ecosystem Service Sensitivity Areas in the Upper Orange River catchment

3.5. Socioeconomic Zones

Socio-Economic Zones (SEZ) are defined as zones of relatively homogenous socio-economic characteristics and dependencies to the services provided by associated aquatic ecosystems. In other words, areas that represent a relatively similar mix of social wellbeing and economic drivers for the purposes of providing input into the IUA delineation process.

The SEZ's were categorised through the regional classification of the catchment in terms of economic activities, social demographics and wellbeing and ecological features. The process included three steps as shown in Figure 19.

Step 1: Land Use Assessment

A land cover classification process was conducted that allowed for the understanding of physical features in the catchment. Physical features included natural features such as rivers, wetlands, catchments, ridges and mountains but also transformed land associated with land uses such as mining, agriculture and towns and settlements (urban and rural).

Step 2: Economic Assessment

The economic assessment allowed for an understanding of the key economic drivers within each region. Each municipality within the catchment was investigated and profiled in terms of economic sectors. This process assisted in understanding the presence and variability of economic drivers across the catchment.

Step 3: Social Assessment

The social assessment allowed for an understanding the demographic characteristics across the catchment. Census data by ward was used to investigate the general level of wellbeing of resident populations in terms of access to services (as a proxy for development), primary source of water, employment, population density, employment, income, and education.

The catchment was delineated into five SEZ's including and defined as the following:

The Mixed-Use Zone: This zone features a blend of land uses, including tourism in the Gariep Dam area and game farms in the Philippolis area. Agricultural activities, primarily livestock farming, with some irrigation agriculture along the Orange River are also present. A hydroelectric power plant is located next to Gariep Dam. The zone includes small towns with a relatively low population density and moderate access to water sources and wastewater treatment facilities.

The Rural Zone: This zone represents a rural area with distinctly low levels of development and only a few formal economic drivers. Key sources of livelihood include irrigation and dryland agriculture, as well as some livestock farming. The region has the lowest population densities and a low proportion of residents with access to sanitation and piped water. Residents rely on a mix of formal and informal water sources.

Agriculture and Tourism Zone: The main land uses in this zone are agriculture and tourism. Mixed agriculture is practiced here, along with tourism activities around the town of Clarens and the Caledon Nature Reserve. The zone has a medium population density and adequate access to services such as sanitation and piped water.

Commercial Development Zone: This zone is characterized by extensive built-up areas, including the metropolitan city of Bloemfontein. The zone hosts industries, mining, and agricultural activities. It has a high population density, with residents enjoying relatively high access to services and infrastructure.

Agricultural and Mining Zone: This zone features less intensive land use, primarily focused on agriculture, with a high prevalence of irrigation and commercial farming along the Orange, Riet, and Modder Rivers. There is also mining activity near the town of Hobhouse. Mining activities are significant in these areas and consists of diamond mining (kimberlite and alluvial). The population density is lower than in the commercial zone, with greater access to formal water sources compared to informal ones.

The SEZ's provided the socio-economic input into IUA delineation to appropriately group IUA's based on similar water use objectives to ensure, as far as possible, appropriate catchment management approaches and objectives.

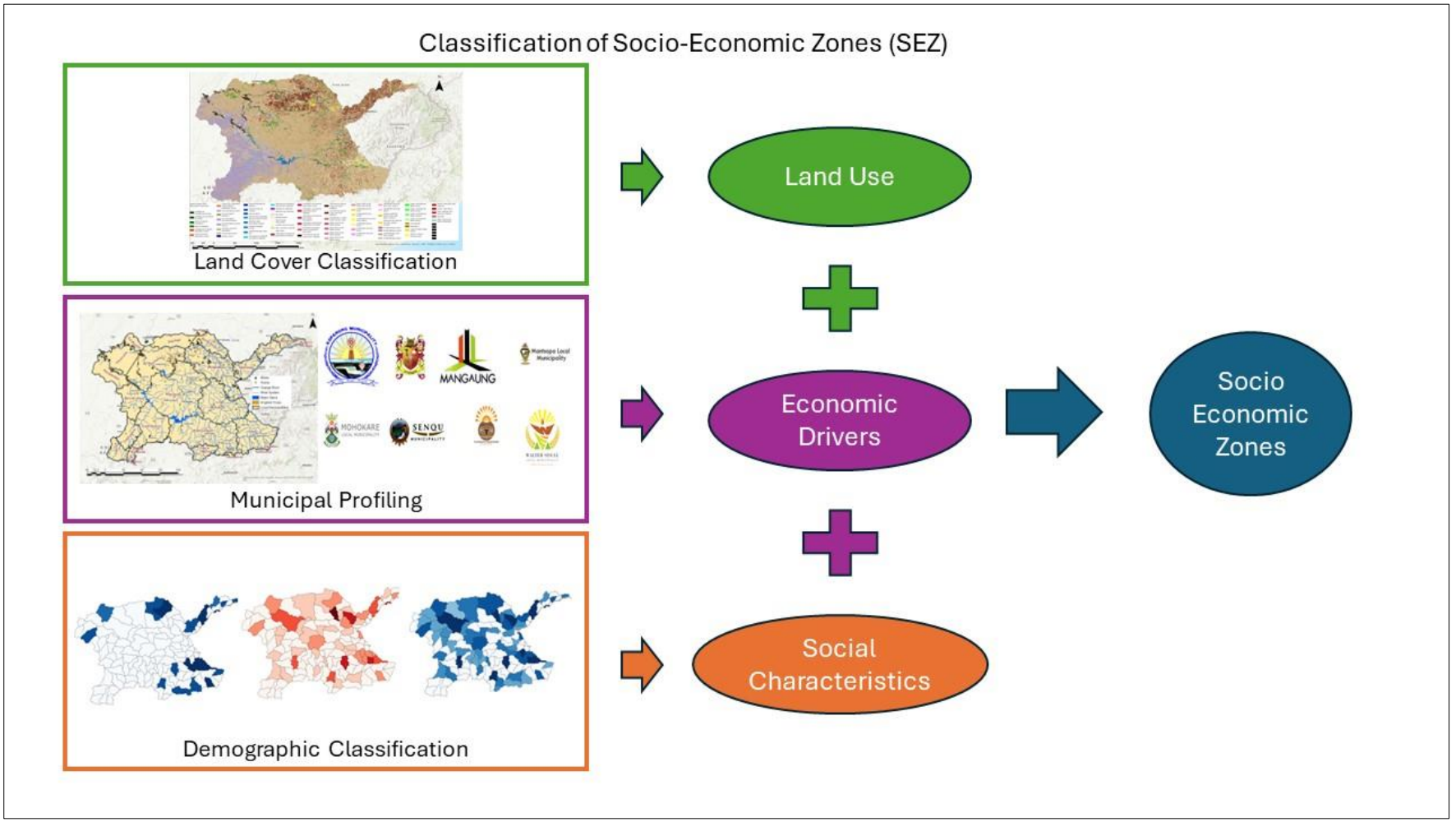

Figure 19: Schematic representation of Socio-Economic Zone delineation process

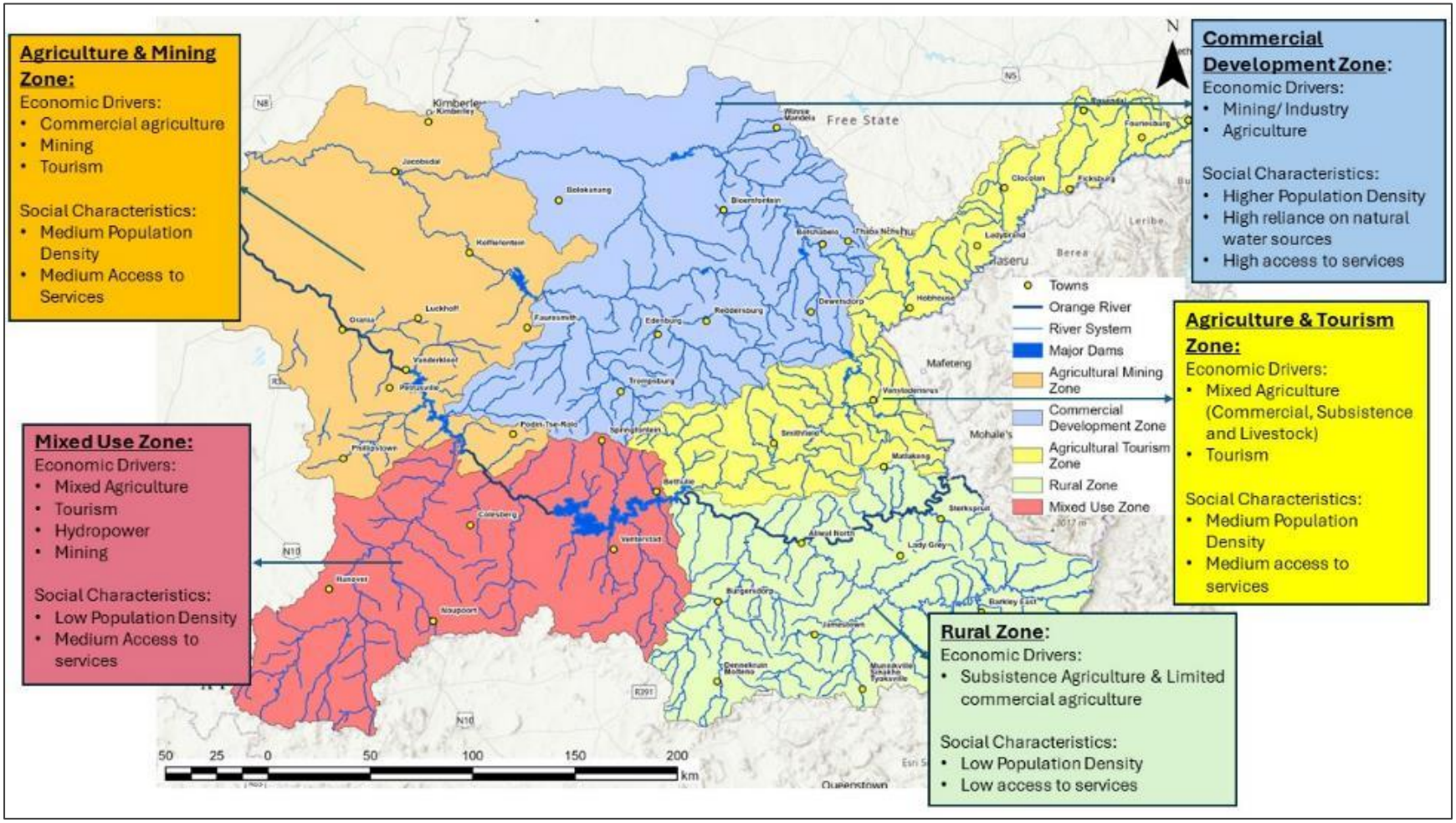

Figure 20: Socio-Economic Zones within the Upper Orange River catchment study area

4 STATUS QUO: RIVERS

4.1. Description

Table 8 presents the main rivers and tributaries within the Upper Orange River catchments. These have been identified for classification and associated RQO determination. Significant rivers may be important from a use or ecological perspective due to expected changes in their condition in response to water quantity or water quality variation.

Each of the rivers within the network has been characterised in the sections to follow to determine how they are to form part of the defined network of significant water resources in terms of integrated Units of Analysis (IUA) delineation. The objective of capturing the suite of biophysical and ecological features of the rivers is to assess their uniqueness and significance to include each one as part of the defined network and to establish nodes that characterise the target catchment's rivers at different scales.

Table 8: Identified network of significant rivers in the Upper Orange River catchments

Secondary Catchment	Tertiary Catchment	Quaternary catchments	Main River/(s)
C5	C51	C51A – H, C51J - M	Fouriespruit, Ruisterspruit, Ospoortspruit, Kromellemboogspruit, Rietspruit
	C52	C52A – H, C52J - L	Wildebeesspruit, Sepane, Osspruit, Modder River
D1	D12	D12A - F	Winnaarspruit, Kromspruit, Wilgespruit
	D13	D13A – H; D13J - M	Bell, Langkloofspruit, Dierspruit, Wasbankspruit, Holspruit, Skulspruit, Kraai River
	D14	D14A – H, D14J and K	Orange River
	D15	Portions of D15G and H	Makhaleng (lower reaches shared with Lesotho), Unnamed tributaries
	D18	Portion of D18L and K	Tele (shared with Lesotho), Blikana
D2	D21	D21D, D21E, D21F, D21G, portion of D21A and D21H	Caledon River Little Caledon
	D22	D22A, D22B, portions of D22C and D22D, D22G, portions of D22H and D22J	Meulspruit, Brandwater/ Groot, Rantsho; Mopeli
	D23	Portion of D23A, E, F and G; D23C, D23D, D23H, D23J	Montsoane, Maseng, Tsoaning Leeurivier, Retspruit

Secondary Catchment	Tertiary Catchment	Quaternary catchments	Main River/(s)
	D24	D24A – G, D24H, D24J - L	Witspruit, Wilgeboomspruit, Grahamstadspruit, Slykspruit, Edon River, Skulpspruit
D3	D31	D31A - E	Bergrivier, Orange River,
	D32	D32A – H, D32J and K	Seeikoei River
	D34	D34A - G	Orange River
	D35	D35A – H, D35J and K	Brandspruit, Brakspruit, Bossiespruit, Suurbergspruit, Orange River

4.2. River Characterisation

The status of the rivers within the Upper Orange River catchment have been characterised based on their eco-regions, geomorphological zonation, present ecological state, ecological importance and sensitivity (EIS) and hydrological character. This characterisation has provided a basis to the IUA delineation.

4.2.1. Ecoregions

Eco-regional classification allows for the grouping of rivers according to similarities. The available information has been used to delineate eco-region boundaries at a broad scale for South Africa. Eco-regions derived from terrain and vegetation, with altitude, rainfall, runoff variability, air temperature, geology and soil were delineated and thirty-one Level I Eco-regions were identified for South Africa (Kleynhans et al., 2005). The next level, Level II, which used the same attributes but included more detail at a finer resolution was defined in 2007 (Kleynhans et al., 2007).

While eco-regions descriptions tend to be based on physical and vegetation attributes, the assumption is that the biota within an eco-region are likely to be similar.

The eco-regions that are found to occur in the Upper Orange River catchment include Highveld, Eastern Escarpment Mountains and Nama Karoo areas that are described in Table 9 (Kleynhans et al., 2005) are illustrated in Figure 21.

Table 9: Eco-regions that characterise the Upper Orange River catchment (Kleynhans et al., 2005)

Level I	Level II	Distribution in the catchment	Description
11 - Highveld	11.03 11.08 11.10	Modder and Riet River catchments	Plains with a moderate to low relief, as well as various grassland vegetation types (with moist types present towards the east and drier types towards the west and south), define this high lying region.

Level I	Level II	Distribution in the catchment	Description
			• Mean annual precipitation: Rainfall varies from low to moderately high, with an increase from west to east. • Coefficient of variation of annual precipitation: Moderately high in the west, decreasing to low in the east. • Drainage density: Mostly low, but medium in some areas. Stream frequency: Low to medium. • Slopes <5%: >80%, but 20-50% in a few hilly areas. • Median annual simulated runoff: Moderately low to moderate, and • Mean annual temperature: Hot in the west and moderate in the east.
15 – Eastern Escarpment Mountains	15.02 15.03 15.06	Caledon and Orange River in upper reaches	This high lying region is characterized by closed hills, mountains with moderate and high relief with prominent escarpments towards the east. The vegetation consists of a range of grassland types with Afro Mountain and Alti Mountain Grassland being the defining types. • Mean annual precipitation: Moderate to very high. • Coefficient of variation of annual precipitation: Very low to moderate. • Drainage density: Medium. • Stream frequency: Medium high. • Slopes <5%: Generally, <20%. • Median annual simulated runoff: Moderate to very high. • Mean annual temperature: Very low to moderate.
18 – Drought Corridor	18.03 18.04		Lowlands, hills and mountains with moderate and high relief, and closed hills and mountains with moderate and high relief, are characteristic of this region. Southeastern Mountain Grassland and Eastern Mixed Nama Karoo are the dominant vegetation types. • Mean annual precipitation: Generally low. • Coefficient of variation of annual precipitation: Moderately high to high. • Drainage density: Low but medium in some areas. • Stream frequency: Low/medium to medium high. \ • Slopes <5%: Varies from <20% to 50-80%. \Median annual simulated runoff: Mostly low to moderate.

Level I	Level II	Distribution in the catchment	Description
			• Mean annual temperature: Moderate to high.
26 – Nama Karoo	26.01 26.02 26.03	Lower reaches of the Riet and Orange rivers	Topography is diverse but plains with a moderate to high relief and lowlands, hills and mountains with moderate to high relief are dominant. Vegetation consists almost exclusively of Nama Karoo types. • Mean annual precipitation: Moderate/low in the east, decreasing to arid in the west. • Coefficient of variation of annual precipitation: Moderate/high in the east to very high in the west. • Drainage density: Generally low, but medium to high in some parts. • Stream frequency: Low/medium but significant areas with low/high and high frequencies. • Slopes <5%: Mostly >80% to 50-80%, but significant areas with 20-50% and <20%. • Median annual simulated runoff: Moderate/low in the east, decreasing to arid in the west. • Mean annual temperature: Moderate/low in the east, increasing to moderate/high in the west.
29 – Southern Kalahari	29.02	Lower reaches of the Modder and Riet sub-catchments	Terrain morphological types consist of plains with low to moderate relief in the east, and open hills, lowlands and mountains with moderate to high relief in the west. The western part of the region consists of dune hills. • Mean annual precipitation: Moderate/low in the east, decreasing to arid in the west. • Coefficient of variation of annual precipitation: Moderate/high in the east to very high in the west. • Drainage density: Low in the east to medium in the west. • Stream frequency: generally low/medium, but with patches medium/high. • Slopes <5%: Generally >80 in the east, >20-50% in the west with patches <20%. • Median annual simulated runoff: Low/moderate in the east to very low in the west. Mean annual temperature: Moderate/high to high.

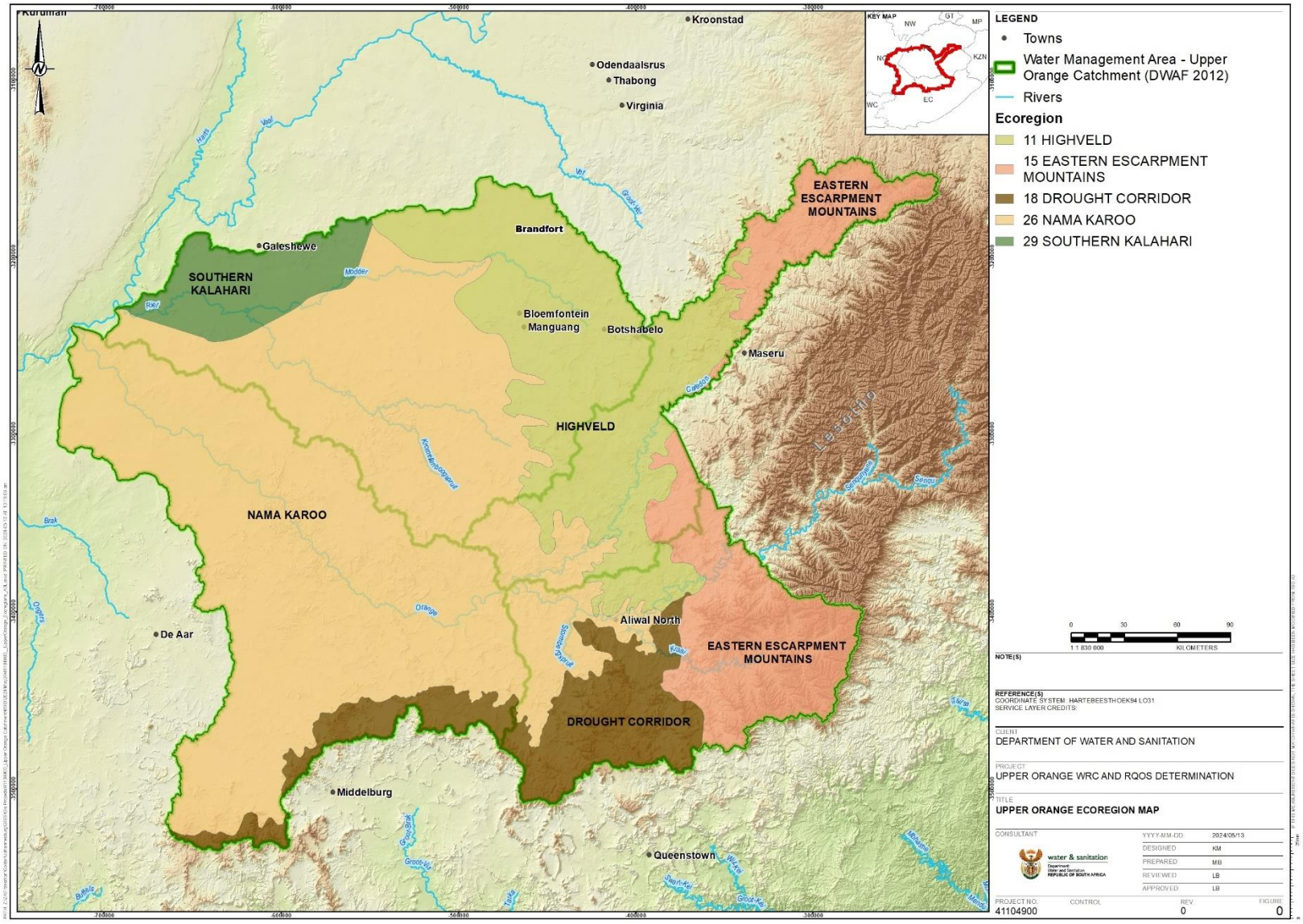

Figure 21: Eco-regions in the Upper Orange River catchments

4.2.2. Geomorphology

Geomorphic Zones

River gradient is a good indicator of river geomorphology and can be classified into geomorphic zones (Rowntree and Wadeson, 1999). Steep sections are often characterised by confined valleys, large bed materials and limited pool-type habitats. In contrast, gentler gradient channels are characterised by broad valleys, fine bed sediment and long pool-type habitats and floodplains. The zonation's and descriptions are presented in Table 10 and the river classifications based on slope in Figure 22 for the Upper Orange River catchment. The mainstem rivers in the Upper Orange River catchment are of a low gradient and classified as either Lower Foothills or Lowland Rivers based on the reach gradient. Localised resistant sills or dykes can rejuvenate the profiles, leading to localised steepening of the river gradient, as is seen along confined gorge sections. The tributaries draining into the upper Orange River largely fall in the Lower Foothills to Upper Foothills, with the upper headwater sections falling in the steeper zones (transitional and mountain streams).

Table 10: Geomorphic Zones as described by Rowntree and Wadeson (1999)

Zone	Zone Class	Gradient class	Characteristic channel feature
Zonation associated with a 'normal' profile			
Source Zone	S	Not specified	Low gradient, upland plateau, or upland basin able to store water. Spongy or peaty hydromorphic soils
Mountain Headwater Stream	A	>0.1	A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.
Mountain Stream	B	0.04 – 0.099	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Transitional	C	0.02 – 0.039	Moderately steep stream dominated by bedrock or boulder. Reach types include plane-bed, pool-rapid or pool-riffle. Confined or semi-confined valley floor with limited floodplain development.
Upper Foothills	D	0.005 – 0.019	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow floodplain of sand, gravel, or cobble often present.

Zone	Zone Class	Gradient class	Characteristic channel feature
Lower Foothills	E	0.001 – 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
Lowland River	F	0.0001 – 0.0009	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increased silt content in bed or banks.

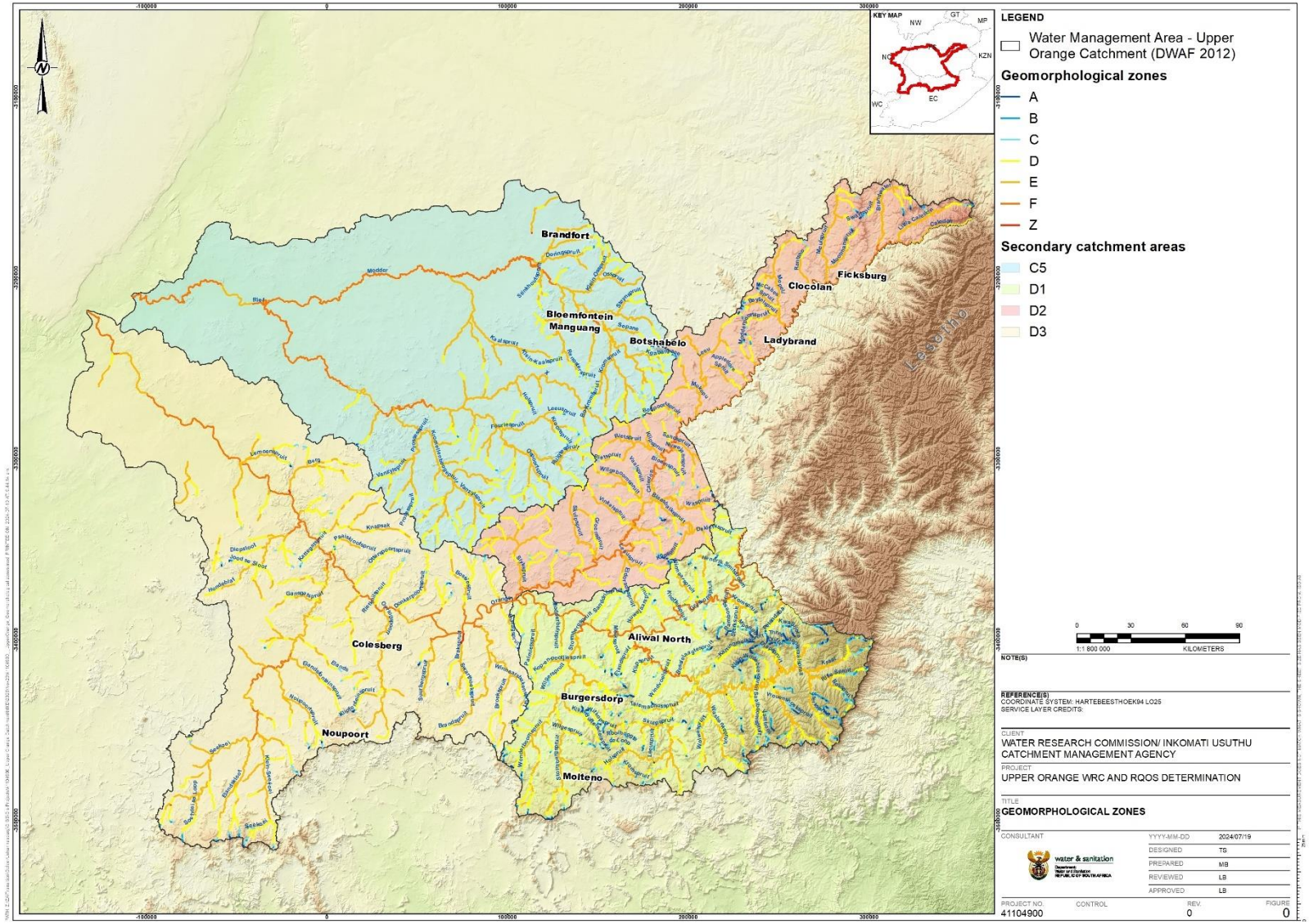

Figure 22: Geomorphic zones for the Upper Orange River catchment

Sediment dynamics

Because of its high suspended sediment load, the Orange River is among the continent's most turbid rivers (Compton and Maake, 2007). In areas with relatively high rainfall and little vegetation cover, erodible soils formed from Karroo sedimentary rocks (mudstones and shales of the Stormberg and Beaufort groups) account for most of the sediment that is eroded (Compton and Maake, 2007; Kriel, 1972). Compton et al. (2010) approximate that farming and grazing practices on soils derived from the Karoo sedimentary rocks result in a tenfold increase in sediment output. According to Compton et al. (2010), their estimation suggests that the comparatively modest sediment delivery ratios could result in a 100-fold increase in erosion rate. As the silting of the Welbedacht Dam indicates, the Caledon River is the primary supplier of fine suspended sediment to the upper Orange River (Compton and Maake, 2007).

High erosion potential is found along the eastern and higher-lying portions of the watershed as can be seen in Le Roux et al. (2008)'s basin-wide soil erosion risk map (Figure 23). This is consistent with studies that reveal considerable soil loss on Karroo sedimentary rocks, where rainfall is often intense and vegetation cover is low, and observations of high turbidity along the Caledon River.

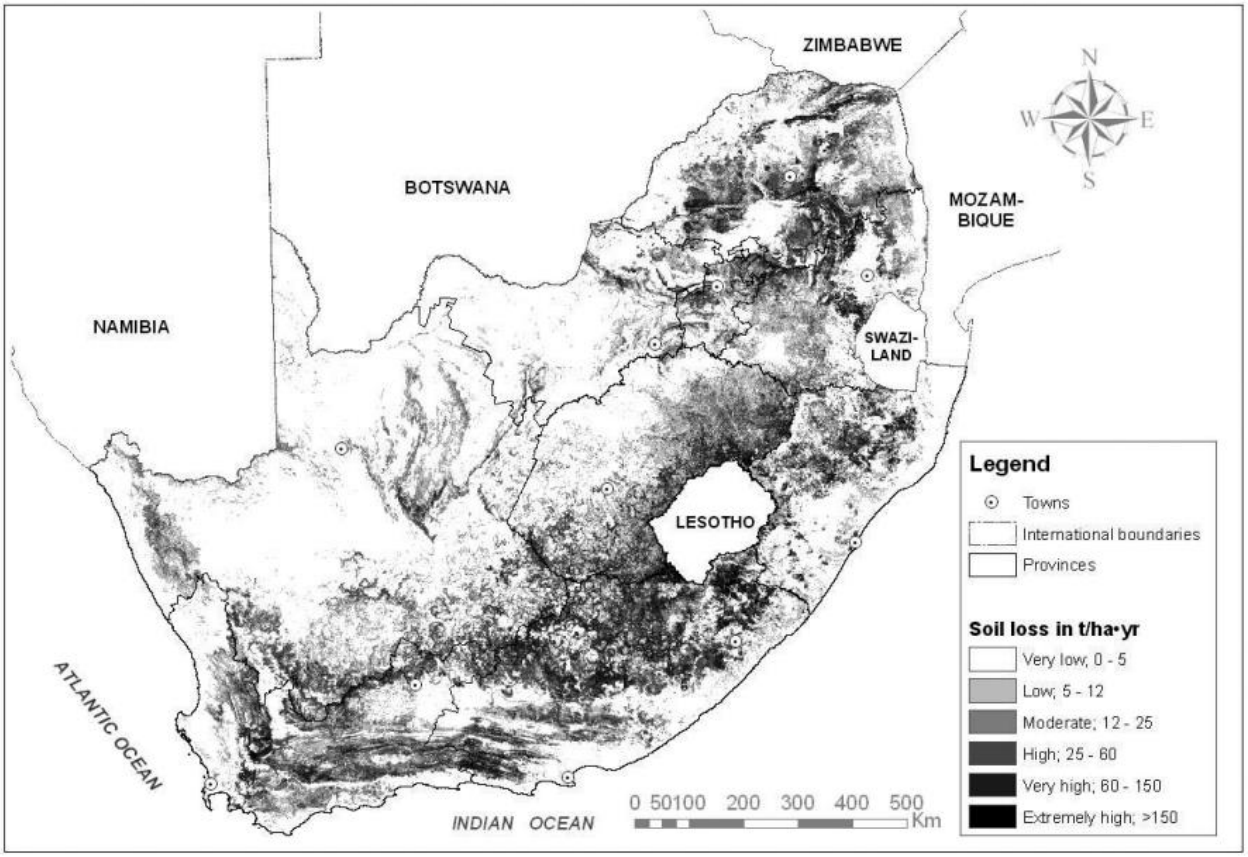

Figure 23: Water erosion risk model for South Africa (Le Roux et al., 2008)

The Welbedacht Dam, located in the Caledon River, traps fine sand-sized material (0.1 mm), with the finer particles mostly remaining in suspension and being transported downstream (De Villiers and Basson, 2007). 90% of the annual sediment volume reporting to the Gariep Dam is estimated to be deposited behind the dam (Kriel, 1972). The Gariep and Vanderkloof dams contain most of the coarse silt, sand, and gravel deposits (Compton and Maake, 2007).

The summer high flows are when most sediment is transported and deposited, and as the rainy season draws to an end, sediment concentrations decrease as the sediment sources are depleted and the energy to erode and transport sediment is reduced (Slabbert, 2007). Suspended sediment can be transferred by inter-basin transfers. Water from the often-turbid Caledon River is transferred to the Knellpoort Dam and released into the Modder River via the inter-basin transfer, however as sedimentation occurs within the Knellpoort Dam, the inter-basin transfer from the Caledon to the Modder River does not raise the turbidity of the Modder River considerably (Slabbert, 2007). The Modder River's sediment loads may rise as a result of channel erosion caused by bed and bank erosion below the Caledon-Modder outfall, and the eroded sediment will be caught by dams downstream (Slabbert, 2007).

Land cover and land use change have impacted river morphology. Over the past 70 years, there has been river straightening and braiding along the Bell River, a headwater tributary of the Kraai River. This has occurred because of increased catchment sediment input and exotic woody vegetation that has stabilized and narrowed the meandering river channel, driving river avulsions and straightening (Rowntree and Dollar, 1996). There has been no discernible change in rainfall patterns over the past century, thus the change in river behaviour is primarily attributable to human settlement (land cover change), exotic woody vegetation and overgrazing (increase in sediment yield) (Dollar and Rowntree, 1995).

Due to the significant alteration of flows and longitudinal sediment supply, river channels downstream of dams frequently undergo modification. Because of the considerable reduction in the sediment load, bed and bank erosion was predicted downstream of the Gariep Dam (Kriel, 1972). As a result of decreased flow variability downstream of the Gariep Dam, riparian vegetation invaded the channel bars, stabilizing them and causing the active channel to narrow (Rountree, 2011). A 5% decrease in channel width is reported by Beck and Basson (2003) downstream of Gariep Dam.

Blanket sediment deposition along reaches affected by damming can lower the geodiversity of habitats. This was the case for the lower Seekoei River, within the inundation zone of the Gariep Dam, where channel geodiversity (channel form and substrate) within the inundation zone of dams and weirs is largely uniform and featureless (Dollar, 2005). Impoundments likely contribute to this habitat degradation along tributaries and the mainstem rivers, which are widespread in the Upper Orange River catchments, leading to a loss of geomorphic habitat diversity.

Sediment quality

Fine sediment is often a vector for various toxins, such as metals and Persistent Organic Pollutants (POP) and Polycyclic Aromatic Hydrocarbons (PAH). To date, three Joint Basin Surveys (JBS) have been conducted throughout the Orange River basin.

In 2010 the Upper Orange sites showed low concentrations of POPs. Sites with high PAH concentrations were associated with pyrogenic sources, typically either coal or smelter operations associated with Industrial areas, as is found around Maseru in Lesotho. Concentrations of POPs were relatively low in the sediment, but PAHs associated with industrial areas in Lesotho (Sites 54 – Caledon downstream of Maseru and 60 - Kelekeque) were of concern (Bouwman et al., 2011). The tributaries of the Caledon River where several commercial orchards are located show a presence of metolachlor and atrazine herbicides (grass and broad leaf weed control) associated with sediment (George, 2014). Unfortunately, the tributaries were not named, but were located between Ficksburg and Hobhouse.

Several studies have looked at metal pollutants in sediment in the Upper Orange River basin. Bouwman and Pieters (2011) collected sediment from 61 sites across the larger Orange River basin in 2010. Pollution levels were highest along the eastern part of the basin (Upper Orange and Vaal), decreasing towards the west (Lower Orange). The highest levels were observed for the Riet and Modder Rivers and two sites in Lesotho. The metals that warrant further investigation were selenium (Se), arsenic (As) and Cr (chromium) due to relatively high observed concentrations. In general, the observed metal concentrations in sediment in 2010 were below the sediment quality guideline threshold (low probability of toxic effect) used for the Netherlands (Bouwman et al., 2011).

The main areas of concern within the Upper Orange basin were as follows (copied from Bouwman and Pieters (2011)):

- The areas associated with the Riet River and Koranna Spruit (JBS Sites 14 – Lower Riet; 39 Modder; 41 – Koranna; 43 – Riet upstream of Modder confluence and 44 - Kromellenboog) due to a combination of higher-than-average levels of several elements,
- The Caledon and Malibamatso Rivers draining into the Senqu and Orange-Senqu Rivers (JBS Sites 49 – Orange upstream of Gariep Dam; 50 – Stormberg; 55 – Upper Caledon; 57 – Malibamatso) due to a combination of higher-than-average levels of several elements.

Metal and persistent organic pollutants (POPs) monitoring of sediment was included in the JBS2 study (2015). Based on the Bouwman and Pieters (2011) study, only 16 sites of concern in the Orange River catchment (Sites in Upper Orange River catchment: Site 11 – Orange upstream of Douglas; 39 – Modder upstream of Krugersdrif Dam; 51 – Orange upstream of Stormberg confluence; 55 – Upper Caledon and 60 – Caledon/ Kelekeque in the Upper Orange River catchment) were included in the JBS2 study of 2015.

The results of the monitoring suggest a deterioration of the sediment quality (POPs, PAH and elemental concentrations) between 2010 and 2015 for many of the sites (Bouwman and Pieters,

2015). The overall pattern regarding sediment pollution remains the same despite the variability in elemental concentrations that were measured for 2010 and 2015.

For the 2021 JBS3 study, sediment pollution decreased somewhat, and it was ascribed to the preceding large floods that possibly scoured and diluted fine sediment deposits to some extent. Nevertheless, high levels of metals were noted in the upper Caledon River (site 55 in previous studies) and the Orange River upstream of Douglas (Previous site 11) (GroundTruth, 2022). POPs were relatively high for the Orange River downstream of the Vanderkloof Dam (Site 40) (GroundTruth, 2022).

Geomorphic ecostatus assessment and flow requirements

Geomorphic assessments were done in 2010 and 2011 by Rountree for the upper Orange and lower Vaal River sites and by GroundTruth in 2022 (Table 11).

The assessment included the geomorphological eco-classification (descriptions of available data, the reference condition, the current condition, the present ecological state category, and trends) and determining flow requirements (based on morphological queues, sediment transport modelling, geomorphologically effective flows where conditions allowed). Fieldwork was done during the low flows of 2010 and 2021. Available historical air photos were used to help reconstruct the pre-dam river planform.

Table 11: Site data and Geomorphological scores for the 2010, 2011 and 2022 GAI assessments

Catchment area	Quaternary catchment	PES	Source
Orange River at Hopetown (O1)	-	C/D (59%)	Rountree (2011)
Upper Caledon River (C5)	-	C (68%)	Rountree (2011)
Lower Caledon River (C6)	-	C/D (54.6 %)	Rountree (2011)
Kraai River (K7)	-	A/B (90.6%)	Rountree (2011)
Riet (EWR19)	-	C	Rountree (2010)
Middle Caledon	D23A	D (52%)	DWS (2023)
Sterkspruit	D12B	D (47%)	DWS (2023)
Upper Orange	D12F	C (61%)	DWS (2023)
Lower Caledon	D24G	C (62%)	DWS (2023)
Seekoei	D32J	C (78%)	DWS (2023)
Upper Riet	C51F	C (73%)	DWS (2023)
Upper Modder	C52B	D (49%)	DWS (2023)
Lower Kraai	D13M	C (76%)	DWS (2023)
Lower Orange	D33K	C (64%)	DWS (2023)

4.2.3. Present Ecological State

Present Ecological State (PES) represents how the ecological condition of a river has been modified from its natural or appropriate reference conditions i.e., the rivers health and integrity. The measure is based on water quality variables, biotic indicators and habitat information that has been collected. Results are classified on a 6-point scale, from Category A (Largely Natural) to Category F (Critically Modified).

The PES of a river is expressed in terms of various components:

- Drivers: physico-chemical variables, geomorphology and hydrology,
- Biological responses: fish, riparian vegetation and aquatic macroinvertebrates, as well as
- An integrated state, the EcoStatus.

Different processes are followed for each component to assign a category ranging from an A to an F category (Table 12). Ecological evaluation against the expected reference conditions, followed by integration of the categories of each component, provides a description of the Ecological Status or EcoStatus of a river. The EcoStatus can therfore be defined as the total of the features and characteristics of the river (instream and riparian zones) that influence its ability to support an appropriate natural vegetation and animal life. This ability relates directly to the capacity of the system to provide a variety of goods and services (Modified from Kleynhans and Louw, 2007).

Table 12: Ecological category (EC) descriptions

Ecological Category	Description
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

The PES is a broad qualitative assessment of both the instream and riparian components of a river. In 2013, the DWS published a national database of the PES/EIS of sub-quaternary (SQ) river reaches throughout the country that was based on a modified desktop level eco-classification. This desktop Present Ecological State (PES) was derived from a combination of expert knowledge and available information for the sub-quaternary reach levels. This PES/EIS database was used as the basis of the surface water maps to represent the ecological state component. The final modelled information in the front-end model for each primary catchment is available from the Directorate: Resource Quality Information Services (D: RQIS), DWS.

Ecological Importance/ Ecological Sensitivity (EI/ES or EIS)

The Ecological Importance (EI) of a river is an expression of its importance to the maintenance of biological diversity and ecological functioning on local and wider scales, while ecological sensitivity (ES) (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration in the assessment of ecological importance and sensitivity. The categorisation is as: very low, low, moderate, high and very high.

In summary, EI and ES are assessed to obtain an indication of the water resources' vulnerability to environmental modification within the context of the PES. This would relate to the ability of the river reach to endure, resist and ability to recover from various forms of human use.

It is noted that this database is currently being revised through a separate project, however the update will only be available towards the end of 2024. Should it be found that there are marked changes in the integrated PES that is determind, then this will be updated and a second edition report produced, and the changes will be incorporaged in the Ecological Water Requirements Report in Novemeber 2024, and the relevant scenarios that will be modelled.

For this report, information was extracted in a master spreadsheet for each primary catchment that incorporates the PES/EIS results. The PES results for the Upper Orange River catchments are presented in the sub-sections to follow.

The Upper Orange River catchment includes 779 SQ river reaches. Figure 24 presents the PES as an ecological category for the SQ river reaches. Much of the catchment is in a C PES ecological category (408 river reaches, 52.4%), indicating moderate modification, with ecosystem functionality still largely intact. 162 river reaches (21%) are in a B ecological category indicating a largely natural state. 192 reaches (25%) are in an ecological category D state indicating large modifications. Many of the river reaches in the areas in and around the Mangaung Metropolitan Municipality are in a D state and in cases, an E ecological category. The Bloem River has a reach that is in an F category. This is downstream of the domestic wastewtaer treatment works, and it is noted that raw sewage is common.

More detail on the PES per secondary catchment is provided in the following sections. The driver of the PES ecological category is indicated for rivers in a C category or below, i.e. if not in a natural (A) or largely natural state (B). In terms of the driver descriptors, flow impact refers to modification

of stream flow, water quality refers to physico-chemical modifications to the river reach and non-flow impact refers to instream habitat and/or riparian/wetland continuity and zone modifications.

In addition to the PES and EI/ES data Ecological Water Requirements (EWR) sites data collected during the recently completed High confidence Reserve determination study is included in section 4.2.4.

Further biological data collected for the ORASECOM Joint Basin Study 3 (JBS3) for the Upper Orange River catchment that will contribute depth to this study within the Upper Orange River catchment particularly with regards to water quality (including diatoms), fish, macroinvertebrates, and riparian vegetation is also included as overall scores (Section 4.2.5.1).

In addition, the latest quarterly routine monitoring results undertaken by the DWS River Eco-Status Monitoring Programme (REMP), during which macroinvertebrates are recorded to assess the health and integrity of selected river systems in the Upper Orange River catchment, are included in section 4.2.5.2.

The sites from the various moniyoring programmes set out in Table 13 are overlapping.

Table 13: Overlapping sites

River	JBS3 site	Upper Orange EWR site	REMP site
Middle Modder	OSAEH_11_18	UO_EWR07_I	C5MODD-SANNA
Lower Riet	OSAEH_29_5	UO_EWR09_I	C5RIET-DEKRA
Upper Riet	OSAEH_26_10	-	C5RIET-IFR03
Lower Kraai	OSAEH_26_11	UO_EWR08_I	D1KRAA-ALIWA
Lower Modder	OSAEH_11_19	UO_EWR06_R	
Caledon	OSAEH_26_8		-
Orange	OSAEH_26_3	UO_EWR10_I	D3ORAN-MARKS
Little Caledon	-	UO_EWR01_R	D2LCAL-EWR01
Brandwater	-	UO_EWR02_R	D2GROO-FARM1

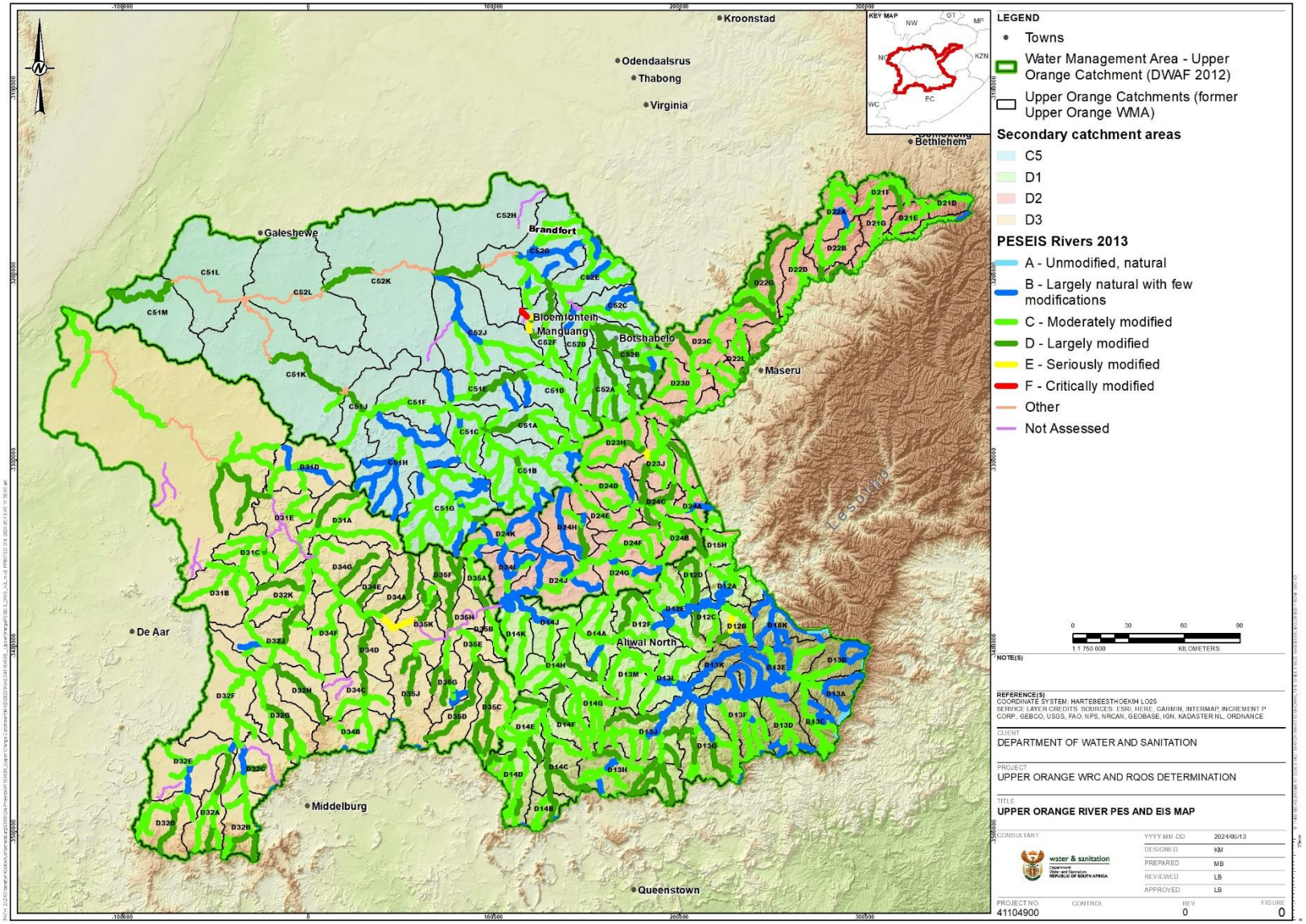

Figure 24: PES categorisation of rivers in the Upper Orange River catchments

4.2.3.1. D2 Secondary catchment: Caledon River

The D2 secondary catchment includes the Caledon River and tributaries up to Gariep Dam. There are many dams in the catchment that is also highly impacted by the sediment emanating from Lesotho. The dams include many small dams such as Meulspruit, Mopeli, Lovedale, Newberry, and Cathcartdrift and the larger dams Armenia, Welbedacht, Knellpoort and Egmont. The dams have a large impact on the flow in the rivers resulting in habitat modification.

In this respect, 63% of the rivers are in an ecological category D, and 18% in ecological category C. Category B rivers (18%) are found in the upper Caledon in the Golden Gate National Park and tributaries of the Caledon River in quaternary catchments D24H, K, L and J, reaches of the Groenspruit, Skulpspruit and Slykspruit.

Table 14: PES and conditions or PES Driver for the D2 secondary catchment

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D21A-03178	Caledon	B	Largely natural with few modifications
D21A-03194	Caledon	B	Largely natural with few modifications
D21A-03207	Caledon	C	Moderately modified, water quality and flow
D21C-03286	Caledon	C	Moderately modified, water quality and flow
D21C-03293	Caledon	C	Moderately modified, water quality and flow
D21D-03094	Little Caledon	C	Moderately modified, water quality and flow
D21E-03127	Unnamed tributary	C	Moderately modified, water quality and flow
D21E-03142	Little Caledon	C	Moderately modified, water quality and flow
D21F-03007	Brandwater	C	Moderately modified, water quality and flow
D21F-03011	Brandwater	C	Moderately modified, water quality and flow
D21F-03046	Swartspruit	C	Moderately modified, water quality and flow
D21F-03054	Unnamed tributary	D	Largely modified, water quality and reduced flow
D21G-03101	Brandwater	C	Moderately modified, water quality and flow
D21H-03278	Caledon	C	Moderately modified, water quality and flow
D21H-03300	Caledon	B	Largely natural with few modifications
D21H-03313	Caledon	C	Moderately modified, water quality and flow
D21H-03340	Caledon	C	Moderately modified, water quality and flow
D22A-03005	Unnamed tributary	C	Moderately modified, water quality and flow
D22A-03081	Unnamed tributary	C	Moderately modified, water quality and flow
D22A-03105	Meulspruit	C	Moderately modified, water quality and flow
D22A-03152	Unnamed tributary	B	Largely natural with few modifications
D22A-03173	Meulspruit	C	Moderately modified, water quality and flow
D22B-03214	Moolmanspruit	C	Moderately modified, water quality and flow
D22B-03442	Meulspruit	D	Largely modified, water quality and reduced flow
D22C-03437	Caledon	D	Largely modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D22C-03483	Caledon	D	Largely modified, water quality and reduced flow
D22C-03502	Caledon	C	Moderately modified, water quality and flow
D22C-03524	Caledon	C	Moderately modified, water quality and flow
D22D-03304	Rantsho	C	Moderately modified, water quality and flow
D22D-03415	Caledon	C	Moderately modified, water quality and flow
D22D-03550	Caledon	C	Moderately modified, water quality and flow
D22D-03585	Caledon	C	Moderately modified, water quality and flow
D22G-03255	Mopeli	D	Largely modified, water quality and reduced flow
D22G-03463	Mopeli	D	Largely modified, water quality and reduced flow
D22G-03466	Morakabi	D	Largely modified, water quality and reduced flow
D22G-03474	Morakabi	D	Largely modified, water quality and reduced flow
D22G-03499	Unnamed tributary	D	Largely modified, water quality and reduced flow
D22G-03562	McCabes Spruit	C	Moderately modified, water quality and flow
D22G-03629	Beytelspruit	D	Largely modified, water quality and reduced flow
D22G-03649	Unnamed tributary	D	Largely modified, water quality and reduced flow
D22G-03661	Mopeli	C	Moderately modified, water quality and flow
D22G-03691	Unnamed tributary	C	Moderately modified, water quality and flow
D22G-03714	Modderpoortspruit	D	Largely modified, water quality and reduced flow
D22G-03732	Mopeli	D	Largely modified, water quality and reduced flow
D22G-03741	Modderpoortspruit	C	Moderately modified, water quality and flow
D22H-03781	Caledon	C	Moderately modified, water quality and flow
D22H-03815	Caledon	D	Largely modified, water quality and reduced flow
D22H-03821	Caledon	C	Moderately modified, water quality and flow
D22L-03856	Tenniskopspruit	C	Moderately modified, water quality and flow
D22L-03889	Tweelingspruit	C	Moderately modified, water quality and flow
D22L-04004	Tweelingspruit	D	Largely modified, water quality and reduced flow
D22L-04017	Caledon	D	Largely modified, water quality and reduced flow
D23A-04014	Unnamed tributary	C	Moderately modified, water quality and flow
D23A-04026	Appledore Spruit	C	Moderately modified, water quality and flow
D23A-04069	Caledon	D	Largely modified, water quality and reduced flow
D23A-04143	Caledon	C	Moderately modified, water quality and flow
D23A-04182	Caledon	C	Moderately modified, water quality and flow
D23A-04189	Caledon	C	Moderately modified, water quality and flow
D23C-03701	Leeu	C	Moderately modified, water quality and flow
D23C-03823	Klein-Leeu	D	Largely modified, water quality and reduced flow
D23C-03842	Leeu	C	Moderately modified, water quality and flow
D23C-03888	Unnamed tributary	C	Moderately modified, water quality and flow
D23D-03963	Mokopu	C	Moderately modified, water quality and flow
D23D-03973	Leeu	C	Moderately modified, water quality and flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D23D-04107	Unnamed tributary	C	Moderately modified, water quality and flow
D23D-04128	Mokopu	C	Moderately modified, water quality and flow
D23E-04171	Caledon	C	Moderately modified, water quality and flow
D23E-04213	Leeu	C	Moderately modified, water quality and flow
D23E-04225	Bokpoortspruit	C	Moderately modified, water quality and flow
D23E-04232	Caledon	C	Moderately modified, water quality and flow
D23E-04261	Caledon	D	Largely modified, water quality and reduced flow
D23E-04265	Caledon	C	Moderately modified, water quality and flow
D23E-04346	Caledon	C	Moderately modified, water quality and flow
D23F-04361	Caledon	C	Moderately modified, water quality and flow
D23G-04424	Sandspruit	D	Largely modified, water quality and reduced flow
D23G-04501	Montsoane	D	Largely modified, water quality and reduced flow
D23G-04518	Unnamed tributary	C	Moderately modified, water quality and flow
D23H-04310	Klipspruit	C	Moderately modified, water quality and flow
D23H-04333	Unnamed tributary	C	Moderately modified, water quality and flow
D23H-04386	Rietspruit	C	Moderately modified, water quality and flow
D23H-04416	Rietspruit	D	Largely modified, water quality and reduced flow
D23H-04464	Rietspruit	E	Seriously modified, water quality and reduced flow
D23H-04467	Rietspruit	C	Moderately modified, water quality and flow
D23H-04469	Rietspruit	E	Seriously modified, water quality and reduced flow
D23J-04339	Unnamed tributary	C	Moderately modified, water quality and flow
D23J-04433	Caledon	C	Moderately modified, water quality and flow
D23J-04443	Caledon	C	Moderately modified, water quality and flow
D23J-04453	Caledon	C	Moderately modified, water quality and flow
D23J-04484	Nuwejaarspruit	C	Moderately modified, water quality and flow
D23J-04523	Caledon	C	Moderately modified, water quality and flow
D23J-04531	Caledon	D	Largely modified, water quality and reduced flow
D23J-04583	Bloemspruit	C	Moderately modified, water quality and flow
D24A-04672	Boesmanskopspruit	C	Moderately modified, water quality and flow
D24A-04744	Witspruit	B	Largely natural with few modifications
D24A-04783	Witspruit	B	Largely natural with few modifications
D24A-04787	Unnamed tributary	C	Moderately modified, water quality and flow
D24B-04812	Klipspruit	C	Moderately modified, water quality and flow
D24B-04830	Unnamed tributary	D	Largely modified, water quality and reduced flow
D24B-04840	Elandspruit	C	Moderately modified, water quality and flow
D24B-04869	Klipspruit	C	Moderately modified, water quality and flow
D24C-04644	Unnamed tributary	D	Largely modified, water quality and reduced flow
D24C-04692	Witspruit	D	Largely modified, water quality and reduced flow
D24C-04739	Witspruit	D	Largely modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D24C-04740	Witspruit	C	Moderately modified, water quality and flow
D24C-04757	Witspruit	C	Moderately modified, water quality and flow
D24C-04764	Unnamed tributary	D	Largely modified, water quality and reduced flow
D24C-04768	Blaasbalkspruit	C	Moderately modified, water quality and flow
D24D-04553	Wilgeboomspruit	C	Moderately modified, water quality and flow
D24D-04569	Vaalspruit	B	Largely natural with few modifications
D24D-04624	Unnamed tributary	C	Moderately modified, water quality and flow
D24D-04657	Wilgeboomspruit	C	Moderately modified, water quality and flow
D24D-04718	Caledon	C	Moderately modified, water quality and flow
D24D-04738	Unnamed tributary	C	Moderately modified, water quality and flow
D24D-04756	Vaalspruit	B	Largely natural with few modifications
D24E-04658	Vinkelspruit	C	Moderately modified, water quality and flow
D24E-04769	Caledon	C	Moderately modified, water quality and flow
D24E-04883	Caledon	C	Moderately modified, water quality and flow
D24F-04843	Grahamstadspruit	C	Moderately modified, water quality and flow
D24F-04849	Unnamed tributary	C	Moderately modified, water quality and flow
D24F-04872	Caledon	C	Moderately modified, water quality and flow
D24F-04895	Grahamstadspruit	C	Moderately modified, water quality and flow
D24F-04935	Unnamed tributary	C	Moderately modified, water quality and flow
D24F-04973	Caledon	C	Moderately modified, water quality and flow
D24G-04958	Caledon	C	Moderately modified, water quality and flow
D24G-05025	Leeuspruit	B	Largely natural with few modifications
D24G-05042	Leeuspruit	C	Moderately modified, water quality and flow
D24G-05045	Leeuspruit	B	Largely natural with few modifications
D24G-05058	Eldoradospruit	C	Moderately modified, water quality and flow
D24G-05094	Unnamed tributary	C	Moderately modified, water quality and flow
D24H-04686	Skulpspruit	B	Largely natural with few modifications
D24H-04794	Unnamed tributary	C	Moderately modified, water quality and flow
D24H-04806	Unnamed tributary	B	Largely natural with few modifications
D24H-04835	Groenspruit	D	Largely modified, water quality and reduced flow
D24H-05022	Skulpspruit	C	Moderately modified, water quality and flow
D24J-04984	Unnamed tributary	B	Largely natural with few modifications
D24J-05000	Unnamed tributary	B	Largely natural with few modifications
D24J-05016	Caledon	C	Moderately modified, water quality and flow
D24J-05031	Caledon	C	Moderately modified, water quality and flow
D24J-05093	Caledon	B	Largely natural with few modifications
D24J-05107	Caledon	C	Moderately modified, water quality and flow
D24J-05117	Unnamed tributary	B	Largely natural with few modifications
D24K-04780	Unnamed tributary	B	Largely natural with few modifications

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D24K-04798	Unnamed tributary	C	Moderately modified, water quality and flow
D24K-04818	Unnamed tributary	B	Largely natural with few modifications
D24K-04848	Unnamed tributary	C	Moderately modified, water quality and flow
D24K-04860	Unnamed tributary	B	Largely natural with few modifications
D24K-04876	Slykspruit	C	Moderately modified, water quality and flow
D24K-04881	Unnamed tributary	C	Moderately modified, water quality and flow
D24K-04901	Unnamed tributary	B	Largely natural with few modifications
D24K-04916	Unnamed tributary	B	Largely natural with few modifications
D24K-04919	Slykspruit	B	Largely natural with few modifications
D24K-04930	Unnamed tributary	B	Largely natural with few modifications
D24K-04932	Unnamed tributary	C	Moderately modified, water quality and flow
D24K-04941	Unnamed tributary	B	Largely natural with few modifications
D24K-04950	Unnamed tributary	C	Moderately modified, water quality and flow
D24L-04970	Slykspruit	B	Largely natural with few modifications
D24L-04981	Unnamed tributary	B	Largely natural with few modifications
D24L-05014	Unnamed tributary	B	Largely natural with few modifications
D24L-05034	Unnamed tributary	C	Moderately modified, water quality and flow
D24L-05052	Unnamed tributary	B	Largely natural with few modifications
D24L-05073	Unnamed tributary	B	Largely natural with few modifications
D24L-05100	Slykspruit	C	Moderately modified, water quality and flow
D24L-05156	Caledon	B	Largely natural with few modifications

4.2.3.2. D1 Secondary catchments: Orange River from the Lesotho Border to the Gariep Dam, incukding the Kraai River sub-catchment

The D1 secondary catchment includes the Orange River from the Lesotho border to Gariep Dam and includes the Kraai River sub-catchment. Fifty five percent of the rivers in this area are in an ecological category C, followed by ecological category B (29%) and then ecological category D (16%).

The only ecological category A rivers are the Tele River in quaternary catchment D18K, and an unnamed tributary in quaternary catchment D13A, a tributary in the upper reaches of the Bokspruit, both in the Eastern Cape Drakensburg surface water strategic water source areas.

The upper reaches of the Kraai River and its tributaries are predominantly in an ecological category B, changing to ecological category C further downstream. The ecological category D rivers are associated with the extensive agricultural activities and rural villages.

The Sterkspruit in quaternary catchment D12B is an ecological category E, seriously modified due to the extensive rural development, the town of Sterkspruit, as well as the upstream Jozana's Hoek Dam that impacts the downstream flow resulting in habitat modification.

Table 15: PES and conditions or PES Driver for the D1 secondary catchment

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D12A-05065	Orange	C	Moderately modified, water quality and reduced flow
D12A-05080	Hendrik Smitstroom	C	Moderately modified, water quality and reduced flow
D12A-05144	Orange	B	Largely natural with few modifications
D12B-05232	Kromspruit	C	Moderately modified, water quality and reduced flow
D12B-05262	Kromspruit	C	Moderately modified, water quality and reduced flow
D12B-05297	Sterkspruit	E	Seriously modified, water quality and reduced flow
D12B-05411	Mpongo	B	Largely natural with few modifications
D12B-05414	Mhlangeni	D	Largely modified, water quality and reduced flow
D12C-05164	Orange	B	Largely natural with few modifications
D12C-05222	Orange	B	Largely natural with few modifications
D12C-05256	Orange	B	Largely natural with few modifications
D12C-05263	Bamboesspruit	C	Moderately modified, water quality and reduced flow
D12C-05284	Unnamed tributary	D	Largely modified, water quality and reduced flow
D12D-04976	Gryskopspruit	D	Largely modified, water quality and reduced flow
D12D-05086	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D12D-05214	Gryskopspruit	B	Largely natural with few modifications
D12E-05062	Winnaarspruit	C	Moderately modified, water quality and reduced flow
D12E-05163	Knoffelspruit	C	Moderately modified, water quality and reduced flow
D12E-05218	Orange	B	Largely natural with few modifications
D12E-05248	Orange	B	Largely natural with few modifications
D12E-05291	Orange	B	Largely natural with few modifications
D12E-05370	Wilgespruit	C	Moderately modified, water quality and reduced flow
D12F-05170	Beeskraalspruit	D	Largely modified, water quality and reduced flow
D12F-05210	Nuwejaarspruit	C	Moderately modified, water quality and reduced flow
D12F-05251	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D12F-05294	Orange	B	Largely natural with few modifications
D12F-05311	Nuwejaarspruit	D	Largely modified, water quality and reduced flow
D12F-05348	Orange	C	Moderately modified, water quality and reduced flow
D12F-05430	Orange	C	Moderately modified, water quality and reduced flow
D13A-05617	Rifle Spruit	B	Largely natural with few modifications
D13A-05679	Bokspruit	C	Moderately modified, water quality and reduced flow
D13A-05712	Bokspruit	B	Largely natural with few modifications
D13A-05829	Unnamed tributary	A	Unmodified, natural
D13A-05837	Unnamed tributary	A	Unmodified, natural
D13B-05440	Unnamed tributary	B	Largely natural with few modifications
D13B-05468	Unnamed tributary	B	Largely natural with few modifications
D13B-05474	Kraai	C	Moderately modified, water quality and reduced flow
D13C-05672	Sterkspruit	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D13C-05701	Sterkspruit	C	Moderately modified, water quality and reduced flow
D13C-05797	Unnamed tributary	B	Largely natural with few modifications
D13C-05802	Sterkspruit	C	Moderately modified, water quality and reduced flow
D13C-05845	Koffiehoekspruit	B	Largely natural with few modifications
D13C-05856	Koffiehoekspruit	C	Moderately modified, water quality and reduced flow
D13C-05868	Unnamed tributary	B	Largely natural with few modifications
D13C-05892	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13C-05902	Bamboeshoekspruit	C	Moderately modified, water quality and reduced flow
D13C-05910	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13C-06005	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13C-06008	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13D-05725	Langkloofspruit	B	Largely natural with few modifications
D13D-05751	Unnamed tributary	B	Largely natural with few modifications
D13D-05766	Langkloofspruit	C	Moderately modified, water quality and reduced flow
D13D-05813	Vrouenshoekspruit	C	Moderately modified, water quality and reduced flow
D13D-05843	Langkloofspruit	C	Moderately modified, water quality and reduced flow
D13D-05941	Langkloofspruit	C	Moderately modified, water quality and reduced flow
D13D-05962	Rytjiesvlaktespruit	C	Moderately modified, water quality and reduced flow
D13D-06009	Rytjiesvlaktespruit	B	Largely natural with few modifications
D13D-06023	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13D-06026	Langkloofspruit	B	Largely natural with few modifications
D13D-06027	Unnamed tributary	B	Largely natural with few modifications
D13E-05438	Joggemspruit	C	Moderately modified, water quality and reduced flow
D13E-05455	Vlooikraalspruit	B	Largely natural with few modifications
D13E-05483	Three Drifts	C	Moderately modified, water quality and reduced flow
D13E-05488	Diepspruit	B	Largely natural with few modifications
D13E-05535	Unnamed tributary	B	Largely natural with few modifications
D13E-05541	Joggemspruit	C	Moderately modified, water quality and reduced flow
D13E-05563	Klein-Wildebeesspruit	B	Largely natural with few modifications
D13E-05592	Diepspruit	B	Largely natural with few modifications
D13E-05604	Kraai	B	Largely natural with few modifications
D13E-05629	Kraai	C	Moderately modified, water quality and reduced flow
D13E-05647	Kraai	B	Largely natural with few modifications
D13E-05703	Kraai	B	Largely natural with few modifications
D13E-05708	Kraai	B	Largely natural with few modifications
D13F-05599	Unnamed tributary	B	Largely natural with few modifications
D13F-05664	Kraai	B	Largely natural with few modifications
D13F-05704	Kraai	B	Largely natural with few modifications

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D13F-05728	Kraai	B	Largely natural with few modifications
D13F-05736	Kraai	B	Largely natural with few modifications
D13F-05788	Saalboomspruit	C	Moderately modified, water quality and reduced flow
D13F-05810	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13F-05873	Vaalhoek	B	Largely natural with few modifications
D13F-05881	Noodshulpspruit	C	Moderately modified, water quality and reduced flow
D13F-05887	Saalboomspruit	C	Moderately modified, water quality and reduced flow
D13F-05903	Vaalhoek	C	Moderately modified, water quality and reduced flow
D13G-05716	Kraai	B	Largely natural with few modifications
D13G-05806	Wasbankspruit	B	Largely natural with few modifications
D13G-05913	Wolwespruit	C	Moderately modified, water quality and reduced flow
D13G-05916	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13G-05918	Wasbankspruit	B	Largely natural with few modifications
D13G-05985	Wolwespruit	D	Largely modified, water quality and reduced flow
D13G-05993	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13G-05996	Wasbankspruit	D	Largely modified, water quality and reduced flow
D13G-06140	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13G-06150	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13G-06173	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13G-06225	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13H-06042	Rooihoogte se Loop	D	Largely modified, water quality and reduced flow
D13H-06067	Holspruit	C	Moderately modified, water quality and reduced flow
D13H-06105	Holspruit	B	Largely natural with few modifications
D13H-06119	Holspruit	D	Largely modified, water quality and reduced flow
D13H-06121	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13H-06129	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13H-06144	Holspruit	C	Moderately modified, water quality and reduced flow
D13H-06152	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13H-06157	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13H-06189	Kromspruit	C	Moderately modified, water quality and reduced flow
D13H-06196	Holspruit	C	Moderately modified, water quality and reduced flow
D13H-06199	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13H-06217	Unnamed tributary	B	Largely natural with few modifications
D13H-06228	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13J-05741	Holspruit	B	Largely natural with few modifications
D13J-05827	Telemachusspruit	D	Largely modified, water quality and reduced flow
D13J-05871	Holspruit	B	Largely natural with few modifications
D13J-05917	Skulpspruit	C	Moderately modified, water quality and reduced flow
D13J-05931	Skulpspruit	B	Largely natural with few modifications

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D13J-05933	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13J-05935	Holspruit	C	Moderately modified, water quality and reduced flow
D13J-05943	Skulpspruit	C	Moderately modified, water quality and reduced flow
D13J-05952	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D13J-05975	Braklaagtespruit	C	Moderately modified, water quality and reduced flow
D13J-05978	Skulpspruit	C	Moderately modified, water quality and reduced flow
D13J-05992	Leeuspruit	C	Moderately modified, water quality and reduced flow
D13J-05995	Holspruit	C	Moderately modified, water quality and reduced flow
D13J-06034	Unnamed tributary	D	Largely modified, water quality and reduced flow
D13J-06052	Holspruit	C	Moderately modified, water quality and reduced flow
D13K-05454	Karringmelkspruit	B	Largely natural with few modifications
D13K-05718	Kraai	B	Largely natural with few modifications
D13L-05485	Bossielaagtespruit	C	Moderately modified, water quality and reduced flow
D13L-05521	Oslaagte	C	Moderately modified, water quality and reduced flow
D13L-05625	Kraai	C	Moderately modified, water quality and reduced flow
D13L-05630	Rondefonteinspruit	C	Moderately modified, water quality and reduced flow
D13L-05640	Kraai	B	Largely natural with few modifications
D13L-05646	Kraai	B	Largely natural with few modifications
D13L-05650	Kraai	B	Largely natural with few modifications
D13L-05674	Windvoelspruit	C	Moderately modified, water quality and reduced flow
D13M-05442	Kraai	C	Moderately modified, water quality and reduced flow
D13M-05493	Kraai	C	Moderately modified, water quality and reduced flow
D13M-05524	Elandspruit	C	Moderately modified, water quality and reduced flow
D13M-05565	Kraai	C	Moderately modified, water quality and reduced flow
D13M-05591	Klipspruit	C	Moderately modified, water quality and reduced flow
D14A-05192	Sanddrifspruit	C	Moderately modified, water quality and reduced flow
D14A-05233	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14A-05350	Orange	C	Moderately modified, water quality and reduced flow
D14A-05366	Orange	C	Moderately modified, water quality and reduced flow
D14A-05386	Orange	C	Moderately modified, water quality and reduced flow
D14A-05424	Orange	C	Moderately modified, water quality and reduced flow
D14A-05459	Melkspruit	B	Largely natural with few modifications
D14A-05498	Unnamed tributary	B	Largely natural with few modifications
D14A-05499	Melkspruit	C	Moderately modified, water quality and reduced flow
D14B-06326	Stormbergspruit	C	Moderately modified, water quality and reduced flow
D14B-06340	Unnamed tributary	D	Largely modified, water quality and reduced flow
D14B-06479	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14B-06489	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14C-05863	Stormbergspruit	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D14C-05990	Wilgespruit	C	Moderately modified, water quality and reduced flow
D14C-06017	Stormbergspruit	D	Largely modified, water quality and reduced flow
D14C-06151	Wonderhoekspruit	D	Largely modified, water quality and reduced flow
D14C-06184	Stormbergspruit	D	Largely modified, water quality and reduced flow
D14D-06068	Bamboesbergspruit	C	Moderately modified, water quality and reduced flow
D14D-06073	Wonderboomspruit	D	Largely modified, water quality and reduced flow
D14D-06084	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14D-06092	Unnamed tributary	D	Largely modified, water quality and reduced flow
D14D-06127	Wonderboomspruit	not assessed	Part of the dam
D14D-06134	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14D-06136	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14D-06137	Wonderboomspruit	C	Moderately modified, water quality and reduced flow
D14D-06343	Bamboesbergspruit	D	Largely modified, water quality and reduced flow
D14D-06356	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14D-06441	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14D-06454	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14E-05733	Buitendagspruit	D	Largely modified, water quality and reduced flow
D14E-05760	Buitendagspruit	D	Largely modified, water quality and reduced flow
D14E-05796	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14E-05804	Wonderboomspruit	C	Moderately modified, water quality and reduced flow
D14E-05823	Wonderboomspruit	C	Moderately modified, water quality and reduced flow
D14E-05853	Wonderboomspruit	C	Moderately modified, water quality and reduced flow
D14E-05920	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14E-05950	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14E-05979	Unnamed tributary	D	Largely modified, water quality and reduced flow
D14E-05981	Wonderboomspruit	not assessed	100% inundated
D14E-05989	Wonderboomspruit	C	Moderately modified, water quality and reduced flow
D14E-06025	Wonderboomspruit	C	Moderately modified, water quality and reduced flow
D14F-05684	Stormbergspruit	D	Largely modified, water quality and reduced flow
D14F-05819	Klein-Buffelsvleispruit	D	Largely modified, water quality and reduced flow
D14F-05880	Witkopspruit	C	Moderately modified, water quality and reduced flow
D14F-05915	Klein-Buffelsvleispruit	C	Moderately modified, water quality and reduced flow
D14G-05642	Barnardspruit	C	Moderately modified, water quality and reduced flow
D14G-05668	Barnardspruit	C	Moderately modified, water quality and reduced flow
D14G-05676	Barnardspruit	C	Moderately modified, water quality and reduced flow
D14G-05737	Mooiplaasspruit	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D14G-05744	Witkopspruit	C	Moderately modified, water quality and reduced flow
D14G-05776	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14G-05786	Mooiplaasspruit	C	Moderately modified, water quality and reduced flow
D14G-05793	Witkopspruit	C	Moderately modified, water quality and reduced flow
D14G-05808	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D14H-05372	Stormbergspruit	C	Moderately modified, water quality and reduced flow
D14H-05478	Stormbergspruit	C	Moderately modified, water quality and reduced flow
D14H-05501	Brandkopspruit	D	Largely modified, water quality and reduced flow
D14H-05513	Kop-en-pootjiespruit	C	Moderately modified, water quality and reduced flow
D14H-05602	Stormbergspruit	C	Moderately modified, water quality and reduced flow
D14H-05605	Stormbergspruit	C	Moderately modified, water quality and reduced flow
D14H-05623	Wilgerspruit	C	Moderately modified, water quality and reduced flow
D14J-05224	Orange	B	Largely natural with few modifications
D14J-05259	Orange	C	Moderately modified, water quality and reduced flow
D14J-05355	Modderbulrspruit	C	Moderately modified, water quality and reduced flow
D14K-05204	Orange	B	Largely natural with few modifications
D14K-05228	Orange	B	Largely natural with few modifications
D14K-05277	Palmietspruit	C	Moderately modified, water quality and reduced flow
D14K-05288	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D15G-04784	Mantikoana	C	Moderately modified, water quality and reduced flow
D15H-04878	Deklerkspruit	C	Moderately modified, water quality and reduced flow
D15H-04889	Makhaleng	C	Moderately modified, water quality and reduced flow
D15H-04944	Makhaleng	C	Moderately modified, water quality and reduced flow
D15H-04945	Worsfonteinspruit	C	Moderately modified, water quality and reduced flow
D15H-04995	Makhaleng	C	Moderately modified, water quality and reduced flow
D18K-05157	Tele	B	Largely natural with few modifications
D18K-05187	Tele	B	Largely natural with few modifications
D18K-05201	Tele	B	Largely natural with few modifications
D18K-05203	Unnamed tributary	B	Largely natural with few modifications
D18K-05265	Tele	B	Largely natural with few modifications
D18K-05268	Blikana	B	Largely natural with few modifications
D18K-05359	Tele	B	Largely natural with few modifications
D18K-05368	Pelandaba	B	Largely natural with few modifications
D18K-05371	Blikana	B	Largely natural with few modifications
D18K-05376	Tele	A	Unmodified, natural
D18K-05393	KwaSijora	B	Largely natural with few modifications
D18K-05407	KwaNomlengaba	B	Largely natural with few modifications
D18K-05413	Sidwadwa	B	Largely natural with few modifications
D18L-05017	Orange	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D18L-05067	Orange	C	Moderately modified, water quality and reduced flow

4.2.3.3. D3 Secondary catchment: Orange River

The D3 secondary catchment includes the Orange River and the Seekoei River and tributaries. The Gariep and Vanderkloof dams cause unnatural flow in the reach between the dams and downstream.

The predominant ecological category in this catchment is a category C (74%), with category B (8%) and category D (12%). There are a number of reaches that were not assessed because of river flow between and downstream of the two dams.

The Seekoei River and tributaries has many weirs and small farm dams that impact the flow along the river resulting in highly impacted habitat.

Table 16: PES and conditions or PES Driver for the D3 secondary catchment

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D31A-04670	Unnamed tributary	D	Largely modified, water quality and reduced flow
D31A-04691	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31A-04786	Knapsak	C	Moderately modified, water quality and reduced flow
D31A-04788	Knapsak	C	Moderately modified, water quality and reduced flow
D31A-04831	Knapsak	C	Moderately modified, water quality and reduced flow
D31B-05039	Hondeblaf	C	Moderately modified, water quality and reduced flow
D31B-05044	Jood se Sloot	C	Moderately modified, water quality and reduced flow
D31B-05074	Hondeblaf	C	Moderately modified, water quality and reduced flow
D31B-05079	Hondeblaf	B	Largely natural with few modifications
D31B-05089	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31B-05091	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31C-04847	Hondeblaf	C	Moderately modified, water quality and reduced flow
D31C-04857	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31C-04924	Hondeblaf	C	Moderately modified, water quality and reduced flow
D31C-04925	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31C-04954	Diepsloot	C	Moderately modified, water quality and reduced flow
D31C-04975	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31C-04977	Unnamed tributary	D	Largely modified, water quality and reduced flow
D31C-04982	Hondeblaf	C	Moderately modified, water quality and reduced flow
D31C-04985	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31C-04998	Unnamed tributary	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D31D-04420	Berg	C	Moderately modified, water quality and reduced flow
D31D-04446	Unnamed tributary	B	Largely natural with few modifications
D31D-04470	Berg	C	Moderately modified, water quality and reduced flow
D31D-04530	Berg	B	Largely natural with few modifications
D31D-04573	Unnamed tributary	B	Largely natural with few modifications
D31D-04585	Unnamed tributary	B	Largely natural with few modifications
D31D-04586	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31E-04677	Orange	not assessed	River reach in Vanderkloof Dam
D31E-04688	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31E-04726	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D31E-04778	Unnamed tributary	not assessed	Ephemeral
D31E-04821	Orange	not assessed	River reach in Vanderkloof Dam
D31E-04824	Orange	not assessed	River reach in Vanderkloof Dam
D31E-04841	Hondeblaf	not assessed	Ephemeral
D31E-04937	Orange	not assessed	River reach in Vanderkloof Dam
D31E-04968	Orange	not assessed	River reach in Vanderkloof Dam
D31E-04971	Kattegatspruit	C	Moderately modified, water quality and reduced flow
D32A-06085	Elandskloof	D	Largely modified, water quality and reduced flow
D32A-06317	Elandskloof	C	Moderately modified, water quality and reduced flow
D32A-06335	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32A-06513	Unnamed tributary	D	Largely modified, water quality and reduced flow
D32A-06518	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32B-06330	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32B-06360	Klein-Seekoei	C	Moderately modified, water quality and reduced flow
D32B-06548	Klein-Seekoei	D	Largely modified, water quality and reduced flow
D32B-06549	Seekoei	D	Largely modified, water quality and reduced flow
D32B-06578	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32B-06589	Unnamed tributary	D	Largely modified, water quality and reduced flow
D32B-06590	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32C-05988	Klein-Seekoei	C	Moderately modified, water quality and reduced flow
D32C-06016	Unnamed tributary	not assessed	Ephemeral
D32C-06047	Klein-Seekoei	B	Largely natural with few modifications
D32C-06154	Unnamed tributary	D	Largely modified, water quality and reduced flow
D32C-06188	Klein-Seekoei	B	Largely natural with few modifications
D32C-06195	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32C-06210	Klein-Seekoei	C	Moderately modified, water quality and reduced flow
D32D-06318	Seekoei	C	Moderately modified, water quality and reduced flow
D32D-06331	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32D-06361	Seekoei	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D32D-06400	Soetvlei se Loop	D	Largely modified, water quality and reduced flow
D32D-06420	Seekoei	C	Moderately modified, water quality and reduced flow
D32D-06460	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32E-05959	Seekoei	C	Moderately modified, water quality and reduced flow
D32E-06011	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32E-06012	Seekoei	B	Largely natural with few modifications
D32E-06160	Seekoei	B	Largely natural with few modifications
D32E-06174	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32E-06193	Seekoei	B	Largely natural with few modifications
D32E-06268	Unnamed tributary	not assessed	Ephemeral
D32F-05441	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32F-05574	Seekoei	C	Moderately modified, water quality and reduced flow
D32F-05645	Seekoei	C	Moderately modified, water quality and reduced flow
D32F-05857	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32F-05901	Seekoei	C	Moderately modified, water quality and reduced flow
D32G-05534	Seekoei	C	Moderately modified, water quality and reduced flow
D32G-05651	Noupoortspruit	C	Moderately modified, water quality and reduced flow
D32G-05775	Noupoortspruit	D	Largely modified, water quality and reduced flow
D32G-05782	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32G-05948	Unnamed tributary	D	Largely modified, water quality and reduced flow
D32G-05949	Noupoortspruit	C	Moderately modified, water quality and reduced flow
D32G-06007	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32G-06010	Noupoortspruit	C	Moderately modified, water quality and reduced flow
D32H-05575	Elandsfonteinspruit	D	Largely modified, water quality and reduced flow
D32J-05237	Seekoei	D	Largely modified, water quality and reduced flow
D32J-05312	Seekoei	D	Largely modified, water quality and reduced flow
D32J-05328	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32J-05336	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32J-05420	Seekoei	C	Moderately modified, water quality and reduced flow
D32J-05435	Unnamed tributary	B	Largely natural with few modifications
D32J-05449	Unnamed tributary	B	Largely natural with few modifications
D32J-05451	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32J-05458	Elands	C	Moderately modified, water quality and reduced flow
D32J-05476	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D32J-05481	Seekoei	C	Moderately modified, water quality and reduced flow
D32K-05026	Seekoei	C	Moderately modified, water quality and reduced flow
D32K-05088	Unnamed tributary	D	Largely modified, water quality and reduced flow
D32K-05179	Seekoei	C	Moderately modified, water quality and reduced flow
D32K-05181	Gansgatspruit	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D33A-04561	Orange	D	Largely modified, flow
D33A-04668	Orange	D	Largely modified, flow
D33A-04689	Unnamed tributary	D	Largely modified, flow
D33B-04557	Unnamed tributary	D	Largely modified, flow
D33B-04752	Unnamed tributary	not assessed	Ephemeral
D33B-05021	Unnamed tributary	not assessed	Ephemeral
D33B-05023	Unnamed tributary	not assessed	Ephemeral
D33B-05059	Unnamed tributary	not assessed	Ephemeral
D33B-05068	Unnamed tributary	not assessed	Ephemeral
D33C-04235	Unnamed tributary	C	Moderately modified, flow
D33C-04437	Unnamed tributary	C	Moderately modified, flow
D33C-04458	Lemoenspruit	C	Moderately modified, flow
D33C-04483	Lemoenspruit	C	Moderately modified, flow
D33C-04552	Lemoenspruit	C	Moderately modified, flow
D33C-04564	Orange	D	Largely modified, flow
D33F-04344	Unnamed tributary	not assessed	Ephemeral
D33F-04615	Unnamed tributary	not assessed	Ephemeral
D33F-04635	Unnamed tributary	not assessed	Ephemeral
D33G-04051	Orange	C	Moderately modified, flow
D33J-03947	Unnamed tributary	C	Moderately modified, flow
D33K-03723	Orange	C	Moderately modified, flow
D34A-04993	Donkerpoortspruit	D	Largely modified, water quality and reduced flow
D34A-05196	Orange	C	Moderately modified, water quality and reduced flow
D34A-05282	Orange	E	Seriously modified, flow
D34B-05861	Oorlogspoort	C	Moderately modified, water quality and reduced flow
D34B-05867	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D34C-05627	Unnamed tributary	not assessed	Ephemeral
D34C-05675	Unnamed tributary	not assessed	Ephemeral
D34C-05682	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D34C-05756	Oorlogspoort	C	Moderately modified, water quality and reduced flow
D34C-05759	Klipfonteinspruit	C	Moderately modified, water quality and reduced flow
D34C-05785	Oorlogspoort	C	Moderately modified, water quality and reduced flow
D34D-05314	Oorlogspoort	D	Largely modified, water quality and reduced flow
D34E-05040	Rietkuilspruit	D	Largely modified, water quality and reduced flow
D34E-05154	Orange	C	Moderately modified, water quality and reduced flow
D34E-05280	Orange	C	Moderately modified, water quality and reduced flow
D34F-05174	Orange	C	Moderately modified, water quality and reduced flow
D34F-05206	Vanderwaltsfontein-spruit	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D34F-05364	Vanderwaltsfontein-spruit	C	Moderately modified, water quality and reduced flow
D34F-05377	0	C	Moderately modified, water quality and reduced flow
D34G-04911	Paaiskloofspruit	C	Moderately modified, water quality and reduced flow
D34G-04940	Otterspoortspruit	D	Largely modified, water quality and reduced flow
D34G-04986	Orange	C	Moderately modified, water quality and reduced flow
D34G-04999	Orange	not assessed	River reach is in the Vanderkloof Dam
D35A-05033	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D35A-05038	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D35A-05083	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35B-05239	Orange	not assessed	River reach in the Gariep Dam
D35B-05279	Oudagspruit	C	Moderately modified, water quality and reduced flow
D35C-05491	Broekspruit	D	Largely modified, water quality and reduced flow
D35C-05641	Winnaarsbakenspruit	C	Moderately modified, water quality and reduced flow
D35C-05698	Broekspruit	D	Largely modified, water quality and reduced flow
D35C-05894	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35C-05896	Broekspruit	D	Largely modified, water quality and reduced flow
D35D-05554	Brandspruit	D	Largely modified, water quality and reduced flow
D35E-05401	Broekspruit	C	Moderately modified, water quality and reduced flow
D35F-04961	Bossiespruit	D	Largely modified, water quality and reduced flow
D35F-04994	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35F-05027	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35F-05085	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35F-05167	Bossiespruit	D	Largely modified, water quality and reduced flow
D35G-05443	Brakspruit	C	Moderately modified, water quality and reduced flow
D35G-05579	Brakspruit	D	Largely modified, water quality and reduced flow
D35G-05580	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35G-05686	Brakspruit	D	Largely modified, water quality and reduced flow
D35G-05688	Swarthoekspruit	C	Moderately modified, water quality and reduced flow
D35G-05730	Swarthoekspruit	C	Moderately modified, water quality and reduced flow
D35G-05732	Unnamed tributary	B	Largely natural with few modifications
D35G-05789	Unnamed tributary	B	Largely natural with few modifications
D35G-05790	Unnamed tributary	B	Largely natural with few modifications
D35H-05148	Orange	not assessed	River reach in Gariep Dam
D35H-05369	Orange	not assessed	River reach in Gariep Dam
D35H-05389	Orange	not assessed	River reach in Gariep Dam
D35J-05509	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35J-05529	Suurbergspruit	D	Largely modified, water quality and reduced flow
D35K-05133	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35K-05140	Unnamed tributary	C	Moderately modified, water quality and reduced flow

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
D35K-05198	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35K-05225	Unnamed tributary	C	Moderately modified, water quality and reduced flow
D35K-05253	Unnamed tributary	D	Largely modified, water quality and reduced flow
D35K-05340	Orange	not assessed	River reach in Gariep Dam
D35K-05403	Orange	not assessed	River reach in Gariep Dam
D35K-05423	Suurbergspruit	C	Moderately modified, water quality and reduced flow

Non-Governmental Organisation, Gariep Watch monitoring – Hopetown monitoring site (Clean Stream, 2021)

The Non-Governmental Organisation (NGO), Gariep Watch, has undertaken biological monitoring at several sites along the Orange River. The site in the Upper Orange River catchment is at Hopetown, downstream of Vanderkloof Dam and the Hopetown wastewater treatment works and was monitored in October 2021 (Clean Stream, 2021). The results indicated:

- Instream habitat integrity was estimated to be in a moderately to largely modified condition - category C/D.
- Riparian habitat integrity was estimated to be in a largely to seriously moderately modified category C. The most notable impacts on habitat integrity were associated with:

  Instream zone:

  - Water abstraction was indicated as having a large impact due to the upstream users, including irrigation (abundance of centre pivots), potable water supply to towns (Hopetown, Orania), abstraction/ diversions into the irrigation canal at Vanderkloof Dam, and increased evapotranspiration associated with dams and weirs.
  - Flow modification was indicated as having large a large impact because of the large upstream dams, specifically Vanderkloof Dam, smaller farm dams and weirs.
  - Bed modification was indicated as having large a large impact due to excessive algal growth because of nutrient enrichment and sedimentation from general catchment erosion, and bank erosion, which is aggravated by livestock trampling and grazing, and
  - Water quality was indicated as having large a moderate impact that is related to irrigation return flows, partly- and untreated sewage discharges from upstream municipalities, livestock farming and runoff from human settlements.

  Riparian zone:

  - Vegetation removal was noted as large and primarily associated with agricultural activities (grazing and riparian vegetation removal for fields) and cutting down of trees (local communities, fishermen).
  - Exotic vegetation was noted as moderate due to the presence of alien vegetation, especially in transformed or disturbed areas with abundant Bluegums.

- Bank erosion was noted as moderate, associated with overgrazing and trampling by livestock, as well as altered flood regimes and flows, and
- As for the instream zone, water abstraction and flow modification were noted as large, and water quality was noted as moderate.

Macroinvertebrates assessment

The South African Scoring System (SASS5) and Macro-invertebrate Response Assessment Index (MIRAI) biotic indices were applied for macroinvertebrates. The SASS5 index is a valuable site-specific monitoring tool while the MIRAI provides the ecological classification (Present Ecological State - PES) of a site.

- The SASS5 score of 97 and ASPT (5.11) calculated indicated deteriorated biotic conditions.
    - The habitat indices (IHAS and habitats suitability and availability index) indicated adequate habitat conditions and hence the relatively low SASS5 and ASPT values were possibly indicative of altered water quality. It must also be emphasised that high flows during the survey (and especially recently inundated habitat due to increase in water level) may have reduced sampling success and hence also impacted the SASS5 protocol results.
    - The MIRAI protocol revealed a score of 61% calculated, falling in a category C/D (moderately/largely modified). The MIRAI metrics confirmed that water quality deterioration especially impacted the invertebrate assemblage negatively, followed by habitat and flow alterations. Compliance to macroinvertebrate monitoring metrics (TPC's) were marginal (50%), confirming moderate conditions prevailing.

Fish assessment

Six of the eleven expected indigenous fish species and no alien species were sampled during the October 2021 survey (Clean Stream, 2021). In summary, the fish assemblage indicates that this site is currently in a moderately to largely modified state (Category C/D). Indigenous species richness and relative abundance was moderate, and compliance to TPC's also moderate. The fish assemblage highlighted potential impacts from altered flow regimes and water quality deterioration (Clean Stream, 2021).

The most abundant species were *L. aeneus, L. capensis* and *E. paludinosus*, while *A. sclateri* and *C. gariepinus* were relatively scarce. Deteriorated external fish health (lesions, parasites, injuries) was evident in many fish at the site with especially a large proportion of *L. capensis* individuals exhibiting anomalies (13.7% of individuals), notably higher than the general guideline of < 2%. This may be indicative of deteriorating conditions such as altered rocky habitats, altered flow regimes and water quality (Clean Stream, 2021).

- A Fish Assemblage Integrity Index (FAII) score of 41% was calculated falling in a category D.
- A Fish Response Assessment Index (FRAI) score of 59% was calculated falling in an ecological category C/D with the following metrics of concern highlighted:

- Response of species with preference for fast-shallow habitats: potential response to flow modification and water abstraction.
- Response of species with preference for vegetation: response to altered flow regime and potential water quality alteration (nutrient enrichment).
- Response of species moderately intolerant to no-flow conditions: potential response to altered flow regime.
- Response of species moderately intolerant to modified water quality: response to water quality deterioration.
- Response of species with requirement for movement between reaches: migratory impact of various dams and weirs.

- Application of the October 2021 survey results to the EcoSpecs/TPC approach indicated moderate (70%) compliance to monitoring TPC's set for this reach. The TPC's indicated potential lower abundance than expected and one of the indicator species for instream vegetation being absent, indicating potential impacts on this habitat (altered flow and water quality)(Clean Stream, 2021).

4.2.3.4. C5 Secondary catchment: Modder and Riet Rivers

The C5 Secondary catchment includes the Modder and Riet rivers to the confluence with the Vaal River, approximately 27km upstream of the confluence with the Orange River. This catchment includes several dams: Kgabanyane, Rustfontein and Mockes dam sin the upper reaches of the Modder River, with Krugersdrift Dam downstream of Bloemfontein; and the Tierpoort, Rietwater and Kalkfontein dams on the Riet River and tributaries, impacting the flow in these catchments, and ultimately resulting in habitat modification.

Fifty eight percent (58%) of the rivers in this catchment are in a C ecological category, followed by ecological category B rivers (25%) predominantly in the upper reaches of the Riet River tributaries and to a lesser extent in the Modder catchment. The Modder River and tributaries in and around the Mangaung Metropolitan Municipal area are predominantly in a D ecological category, with the Bloemspruit seriously (ecological category E), and in cases critically modified (ecological category F) due to poor quality sewage discharges in its upper reaches.

Downstream of the urban impacts, agriculture is dominant and the predominantly ecological category D rivers are highly impacted by extensive irrigation and other agricultural activities.

Table 17: PES and conditions or PES Driver for the C5 secondary catchment

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C51A-04263	Leeuspruit	C	Moderately modified, water quality and reduced flows
C51A-04269	Fouriespruit	D	Largely modified, water quality and reduced flows
C51A-04297	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51A-04323	Fouriespruit	C	Moderately modified, water quality and reduced flows
C51A-04336	Fouriespruit	C	Moderately modified, water quality and reduced flows
C51A-04352	Kroonspruit	C	Moderately modified, water quality and reduced flows

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C51A-04354	Riet	D	Largely modified, water quality and reduced flows
C51A-04389	Fouriespruit	D	Largely modified, water quality and reduced flows
C51B-04393	Riet	C	Moderately modified, water quality and reduced flows
C51B-04422	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04425	Riet	C	Moderately modified, water quality and reduced flows
C51B-04439	Riet	C	Moderately modified, water quality and reduced flows
C51B-04442	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04447	Riet	C	Moderately modified, water quality and reduced flows
C51B-04454	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04466	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04476	Ruigtespruit	C	Moderately modified, water quality and reduced flows
C51B-04486	Ruigtespruit	B	Largely natural with few modifications
C51B-04487	Unnamed tributary	B	Largely natural with few modifications
C51B-04497	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04511	Ospoortspruit	D	Largely modified, water quality and reduced flows
C51B-04520	Ruigtespruit	B	Largely natural with few modifications
C51B-04548	Ospoortspruit	C	Moderately modified, water quality and reduced flows
C51B-04558	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04559	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04567	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04574	Riet	C	Moderately modified, water quality and reduced flows
C51B-04667	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04676	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04678	Ospoortspruit	B	Largely natural with few modifications
C51B-04702	Unnamed tributary	B	Largely natural with few modifications
C51B-04717	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04720	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04728	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51B-04748	Unnamed tributary	B	Largely natural with few modifications
C51C-04264	Riet	C	Moderately modified, water quality and reduced flows
C51C-04267	Riet	C	Moderately modified, water quality and reduced flows
C51C-04322	Unnamed tributary	B	Largely natural with few modifications
C51C-04366	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51C-04373	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51C-04377	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51C-04440	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51C-04441	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51D-04043	X	C	Moderately modified, water quality and reduced flows
C51D-04127	Unnamed tributary	B	Largely natural with few modifications

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C51D-04266	X	C	Moderately modified, water quality and reduced flows
C51D-04283	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51E-04040	X	D	Largely modified, water quality and reduced flows
C51E-04062	Unnamed tributary	B	Largely natural with few modifications
C51E-04078	X	C	Moderately modified, water quality and reduced flows
C51E-04080	X	D	Largely modified, water quality and reduced flows
C51E-04087	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51E-04145	Holspruit	B	Largely natural with few modifications
C51E-04216	X	C	Moderately modified, water quality and reduced flows
C51F-04071	Riet	C	Moderately modified, water quality and reduced flows
C51F-04236	Riet	C	Moderately modified, water quality and reduced flows
C51F-04300	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51F-04357	Unnamed tributary	B	Largely natural with few modifications
C51F-04358	Unnamed tributary	B	Largely natural with few modifications
C51G-04550	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04580	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04589	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04596	Unnamed tributary	B	Largely natural with few modifications
C51G-04612	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04622	Unnamed tributary	B	Largely natural with few modifications
C51G-04640	Unnamed tributary	B	Largely natural with few modifications
C51G-04648	Vanzylspruit	C	Moderately modified, water quality and reduced flows
C51G-04663	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04671	Unnamed tributary	B	Largely natural with few modifications
C51G-04707	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04719	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04725	Vanzylspruit	C	Moderately modified, water quality and reduced flows
C51G-04727	Vanzylspruit	C	Moderately modified, water quality and reduced flows
C51G-04733	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04734	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04735	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04749	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04759	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04761	Unnamed tributary	B	Largely natural with few modifications
C51G-04779	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04790	Unnamed tributary	B	Largely natural with few modifications
C51G-04801	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04804	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04809	Unnamed tributary	C	Moderately modified, water quality and reduced flows

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C51G-04813	Unnamed tributary	D	Largely modified, water quality and reduced flows
C51G-04832	Unnamed tributary	B	Largely natural with few modifications
C51G-04856	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04864	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51G-04870	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51G-04871	Unnamed tributary	B	Largely natural with few modifications
C51H-04284	Kromellenboogspruit	B	Largely natural with few modifications
C51H-04376	Kromellenboogspruit	B	Largely natural with few modifications
C51H-04414	Prossesspruit	C	Moderately modified, water quality and reduced flows
C51H-04429	Unnamed tributary	B	Largely natural with few modifications
C51H-04450	Kromellenboogspruit	C	Moderately modified, water quality and reduced flows
C51H-04456	Unnamed tributary	B	Largely natural with few modifications
C51H-04503	Unnamed tributary	B	Largely natural with few modifications
C51H-04524	Prosesspruit	C	Moderately modified, water quality and reduced flows
C51H-04540	Vanzylspruit	B	Largely natural with few modifications
C51H-04541	Prosesspruit	B	Largely natural with few modifications
C51H-04588	Vanzylspruit	B	Largely natural with few modifications
C51H-04619	Unnamed tributary	B	Largely natural with few modifications
C51H-04636	Unnamed tributary	B	Largely natural with few modifications
C51H-04637	Prosesspruit	B	Largely natural with few modifications
C51J-03946	Riet	D	Largely modified, water quality and reduced flows
C51J-04219	Riet	C	Moderately modified, water quality and reduced flows
C51J-04299	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51K-03878	Riet	D	Largely modified, water quality and reduced flows
C51K-04210	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C51M-03519	Riet	D	Largely modified, water quality and reduced flows
C52A-03984	Kromspruit	C	Moderately modified, water quality and reduced flows
C52A-03995	Modder	D	Largely modified, water quality and reduced flows
C52A-04048	Bo-Kromspruit	C	Moderately modified, water quality and reduced flows
C52A-04081	Kromspruit	D	Largely modified, water quality and reduced flows
C52A-04088	Gannaspruit	C	Moderately modified, water quality and reduced flows
C52A-04123	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52A-04154	Bo-Kromspruit	C	Moderately modified, water quality and reduced flows
C52A-04157	Modder	C	Moderately modified, water quality and reduced flows
C52A-04203	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52A-04205	Modder	D	Largely modified, water quality and reduced flows
C52B-03782	Sepane	D	Largely modified, water quality and reduced flows
C52B-03819	Modder	D	Largely modified, water quality and reduced flows
C52B-03854	Klein-Modder	D	Largely modified, water quality and reduced flows

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C52B-03873	Modder	D	Largely modified, water quality and reduced flows
C52B-03911	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52B-03922	Kgabanyane	D	Largely modified, water quality and reduced flows
C52B-03926	Kgabanyane	C	Moderately modified, water quality and reduced flows
C52B-03954	Kgabanyane	C	Moderately modified, water quality and reduced flows
C52B-03968	Kgabanyane	C	Moderately modified, water quality and reduced flows
C52B-03970	Unnamed tributary	B	Largely natural with few modifications
C52B-03971	Wildebeesspruit	D	Largely modified, water quality and reduced flows
C52B-03989	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52B-04041	Unnamed tributary	D	Largely modified, water quality and reduced flows
C52B-04054	Unnamed tributary	D	Largely modified, water quality and reduced flows
C52B-04068	Wildebeesspruit	C	Moderately modified, water quality and reduced flows
C52B-04096	Unnamed tributary	D	Largely modified, water quality and reduced flows
C52B-04101	Wildebeesspruit	D	Largely modified, water quality and reduced flows
C52B-04109	Unnamed tributary	D	Largely modified, water quality and reduced flows
C52C-03561	Steynspruit	B	Largely natural with few modifications
C52C-03577	Steynspruit	B	Largely natural with few modifications
C52C-03619	Korannaspruit	C	Moderately modified, water quality and reduced flows
C52C-03633	Unnamed tributary	B	Largely natural with few modifications
C52C-03654	Korannaspruit	C	Moderately modified, water quality and reduced flows
C52D-03681	Modder	not assessed	Backup from Mockes Dam
C52D-03726	Matjiespruit	B	Largely natural with few modifications
C52D-03736	Modder	C	Moderately modified, water quality and reduced flows
C52D-03755	Koringspruit	C	Moderately modified, water quality and reduced flows
C52D-03758	Modder	C	Moderately modified, water quality and reduced flows
C52E-03307	Klein-Osspruit	B	Largely natural with few modifications
C52E-03326	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52E-03371	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52E-03420	Klein-Osspruit	D	Largely modified, water quality and reduced flows
C52E-03424	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52E-03427	Unnamed tributary	B	Largely natural with few modifications
C52E-03430	Klein-Osspruit	C	Moderately modified, water quality and reduced flows
C52E-03460	Osspruit	C	Moderately modified, water quality and reduced flows
C52E-03478	Osspruit	C	Moderately modified, water quality and reduced flows
C52E-03480	Osspruit	C	Moderately modified, water quality and reduced flows
C52E-03496	Modder	C	Moderately modified, water quality and reduced flows
C52E-03498	Osspruit	B	Largely natural with few modifications
C52E-03586	Modder	C	Moderately modified, water quality and reduced flows
C52E-03600	Modder	not assessed	Backup from Maselspoort weir

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C52E-03646	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52F-03560	Renosterspruit	D	Largely modified, water quality
C52F-03728	Bloemspruit	F	Critically / Extremely modified; water quality (sewage)
C52F-03752	Bloemspruit	D	Largely modified, water quality and reduced flows
C52F-03760	Bloemspruit	E	Seriously modified, water quality (sewage)
C52F-03763	Renosterspruit	C	Moderately modified, water quality and reduced flows
C52F-03766	Unnamed tributary	not assessed	Not a river
C52F-03797	Unnamed tributary	D	Largely modified, water quality and reduced flows
C52F-03802	Unnamed tributary	not assessed	Not a river
C52F-03808	Unnamed tributary	E	Seriously modified, water quality and reduced flows
C52F-03809	Unnamed tributary	D	Largely modified, water quality and reduced flows
C52F-03820	Renosterspruit	C	Moderately modified, water quality and reduced flows
C52F-03940	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52F-03942	Renosterspruit	C	Moderately modified, water quality and reduced flows
C52G-03109	Aardoringspruit	C	Moderately modified, water quality and reduced flows
C52G-03257	Keeromspruit	C	Moderately modified, water quality and reduced flows
C52G-03305	Doringspruit	B	Largely natural with few modifications
C52G-03335	Rietspruit	B	Largely natural with few modifications
C52G-03350	Unnamed tributary	B	Largely natural with few modifications
C52G-03361	Doringspruit	B	Largely natural with few modifications
C52G-03380	Doringspruit	B	Largely natural with few modifications
C52G-03404	Modder	C	Moderately modified, water quality and reduced flows
C52G-03447	Unnamed tributary	B	Largely natural with few modifications
C52G-03462	Modder	C	Moderately modified, water quality and reduced flows
C52G-03465	Modder	D	Largely modified, water quality and reduced flows
C52G-03472	Stinkhoutspruit	C	Moderately modified, water quality and reduced flows
C52G-03521	Unnamed tributary	B	Largely natural with few modifications
C52G-03523	Stinkhoutspruit	C	Moderately modified, water quality and reduced flows
C52G-03570	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52G-03571	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52H-03053	Unnamed tributary	not assessed	Not connected
C52H-03155	Modder	D	Largely modified, water quality and reduced flows
C52J-03503	Kaalspruit	B	Largely natural with few modifications
C52J-03733	Kaalspruit	B	Largely natural with few modifications
C52J-03762	Unnamed tributary	B	Largely natural with few modifications
C52J-03792	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52J-03794	Kaalspruit	C	Moderately modified, water quality and reduced flows
C52J-03795	Unnamed tributary	not assessed	River ends up in a depression
C52J-03886	Kaalspruit	C	Moderately modified, water quality and reduced flows

Sub-quaternary (SQ) reach	River	Present Ecological State	Condition or PES Driver (if below a B category)
C52J-03905	Unnamed tributary	C	Moderately modified, water quality and reduced flows
C52J-03936	Klein-Kaalspruit	C	Moderately modified, water quality and reduced flows
C52K-03183	Modder	D	Largely modified, water quality and reduced flows

4.2.3.5. Conclusion

The sub-quaternary reaches of similar PES and/or of similar reasons for the PES related to land use and impacts have formed a basis for the IUA delineation as areas of homogenous PES and impacts are more suited to be managed together.

4.2.4. EWR Site information

The ecological water requirements sites (EWR) included in the Reserve study (DWS, 2023) and that will be used in this study are set out in Table 18 and illustrated in Figure 25 and comprise:

- 10 Intermediate sites
- 6 Rapid III EWR sites, and
- 25 Field verification sites (only diatoms, in situ water quality and IHI).

A summary of the results for each of the sites are included in Table 18.

Table 18: Ecological Water Requirements (EWR) sites and associated results

EWR site code	River	Quaternary catchment	Co-ordinates		PES	EI	ES	REC	nMAR (Mm^3) at EWR site	Catchment area (km^2)
INTERMEDIATE EWR SITES										
UO_EWR01_I	Middle Caledon	D22D	-28.909102	27.784924	D/E	Moderate	Moderate	D	674	5 185
UO_EWR02_I	Sterkspruit	D12B	-30.51784446	27.3690799	D	Moderate	Moderate	C/D	30.7	293
UO_EWR03_I	Upper Orange	D12F	-30.65288889	26.8230496	D	Moderate	Moderate	D	4 259.5	27 578
UO_EWR04_I	Lower Caledon	D24J	-30.28011493	26.6530603	D	Moderate	Moderate	C/D	1	353.6
UO_EWR05_I	Seekoei	D32J	-30.53390069	24.9625368	C	Moderate	Moderate	C	24.3	8 318
UO_EWR06_I	Upper Riet	C51F	-29.53478727	25.5244957	C	High	Moderate	C	105.2	5 247
UO_EWR07_I	Upper Modder (Sannaspos)	C52G	-29.160017	26.572492	D	Low	Moderate	C	61	1 696
UO_EWR08_I	Lower Kraai	D13M	-30.69007	26.74157	C	High	High	B/C	719	9 354
UO_EWR09_I	Lower Riet	C51L	-29.026963	24.512919	C	Very high	High	B/C*	373.8	33 785
UO_EWR10_I	Lower Orange	D33K	-29.1448547	23.6914039	C	Moderate	Moderate	C	6674.2	99 297
RAPID 3 EWR SITES										
UO_EWR01_R	Little Caledon	D21D	-28.557796	28.405709	C	High	High	B/C	25.9	252
UO_EWR02_R	Brandwater (Groot)	D21G	-28.68034	28.139926	C	High	Moderate	B/C	56	700
UO_EWR03_R	Mopeli	D22G	-29.101205	27.570751	D	Moderate	Moderate	C/D	49.4	950
UO_EWR04_R	Upper Kraai	D13E	-30.85179	27.77689	C	High	High	B	200.9	1 525
UO_EWR05_R	Wonderboomspruit	D14E	-31.005262	26.341938	D	Moderate	Moderate	C/D	25.9	1 336
UO_EWR06_R	Middle Modder (Soetdoring)	C52H	-28.807191	26.109695	D	High	Moderate	C/D	113.7	6 000
FIELD VERIFICATION SITES (only diatoms, *in situ* water quality and IHI)										
UO_EWR01_FV	Meulspruit	D22B	-28.8857	27.83494	D	Moderate	Moderate	D	63.6	457
UO_EWR02_FV	Witspruit	D24C	-30.0083	26.92832	C/D	Moderate	Moderate	C	21.7	979
UO_EWR03_FV	Gryskopspruit	D12D	-30.3396	27.17688	C	Moderate	Moderate	C	7.5	139
UO_EWR04_FV	Karringmelkspruit	D13K	-30.8118	27.2665	B	Very high	High	B	25.9	211
UO_EWR05_FV	Bokspruit	D13A	-30.8847	27.88456	B/C	Moderate	High	B	60.4	409
UO_EWR06_FV	Holspruit	D13J	-30.9953	27.05664	C	High	Moderate	C	36.9	2 311
UO_EWR07_FV	Sterkspruit, tributary of the Kraai	D13C	-30.9176	27.80075	C	Moderate	High	B/C	47.6	517
UO_EWR08_FV	Bell	D13B	-30.8526	27.78656	B/C	Moderate	High	B	72.5	533
UO_EWR09_FV	Groenspruit	D24H	-30.2412	26.5613	C/D	Moderate	Moderate	C	5.02	215
UO_EWR10_FV	Skulpspruit	D24H	-30.2344	26.51134	C	Moderate	Moderate	C	7.8	333
UO_EWR11_FV	Fouriespruit	C51A	-29.6712	26.07439	C	High	Moderate	C	13.8	560
UO_EWR12_FV	Renoster	C52F	-29.1163	26.3287	D/E	Moderate	Moderate	D	7.9	485
UO_EWR13_FV	Os-spruit	C52E	-28.9392	26.51141	B/C	High	Moderate	B/C	8.6	650
UO_EWR14_FV	Hondeblaf	D31C	-30.2051	24.71803	B	Low	Moderate	B	2	1 231
UO_EWR15_FV	Tributary of VanZylspruit	C51G	-30.0312	25.78646	C	High	Moderate	C	1.9	73
UO_EWR16_FV	Slykspruit	D24L	-30.393	26.12093	B/C	Moderate	Moderate	B/C	5.1	12 851
UO_EWR17_FV	Langkloofspruit	D13D	-30.9541	27.60613	B/C	High	High	B	43.8	572
UO_EWR18_FV	Wasbankspruit	D13G	-31.1555	27.28444	C	Moderate	High	B/C	16.5	248
UO_EWR19_FV	Lower Modder	C52K	-28.8917	25.65645	C/D	Very high	High	C	156.8	7 580
UO_EWR20_FV	Upper Kromellenboog	C51G	-30.0663	25.68106	B	Moderate	Moderate	B	9.3	367
UO_EWR21_FV	Lower Kromellenboog	C51H	-29.6536	25.43507	C	Moderate	Moderate	B/C	85.1	3
UO_EWR22_FV	Tele	D18K	-30.4486	27.58234	C	Moderate	Moderate	C	142.3	920
UO_EWR23_FV	Upper Orange	D12A	-30.3988	27.34299	C/D	High	Moderate	C	4 115.1	24 850
UO_EWR24_FV	Makhaleng	D15G	-30.1641	27.39825	C/D	Moderate	Moderate	C/D	524.5	2 998

Note: *Although the flows as per the Vaal comprehensive study were specified for a D category, they were checked and identified to be adequate to maintain the PES of a C (DWS, 2023); nMAR – natural Mean Annual Run-off; Mm^3: million cubic meters

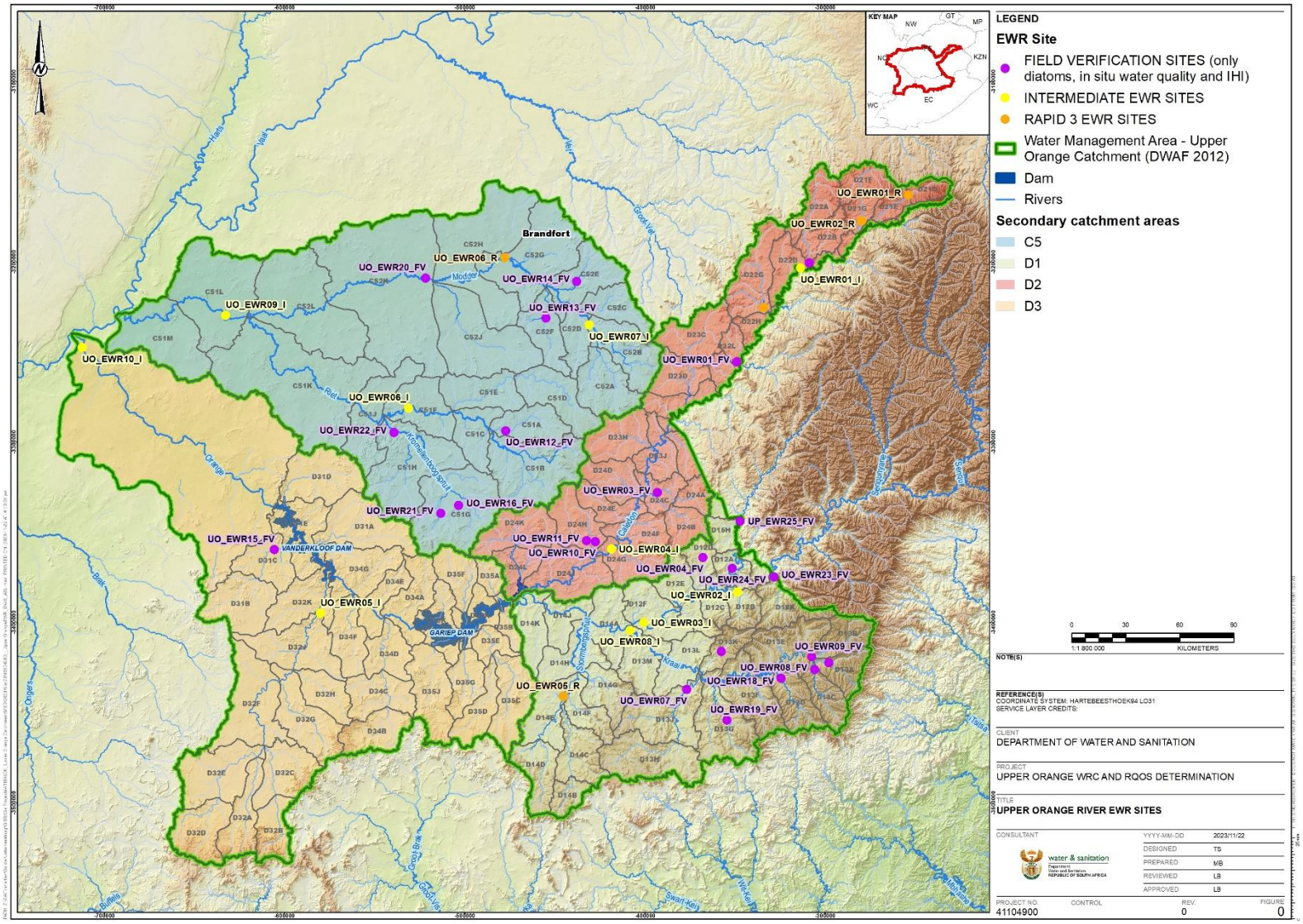

Figure 25: Location of EWR sites and Rapid assessments undertaken in the Upper Orange River catchments

4.2.5. Biological data

The following sections describe the additional biological monitoring that is taking place in the catchment.

4.2.5.1. ORASECOM Studies (JBS3)

ORASECOM has initiated numerous studies across the basin. A study was commissioned in 2009 to assess existing relevant environmental flow studies for the entire Orange River Basin (Dickens, 2009). Since that study, ORASECOM undertakes a Joint Basin Survey (JBS) every five (5) years, which commenced in 2010 (first of its iterations – JBS1) (ORASECOM, 2009). The JBS focusses on the aquatic ecosystem health (AEH) from source to sea through the Basin. The second survey was conducted in 2015 (JBS2) (ORASECOM, 2016), followed by the third iteration (JBS3) conducted recently from October 2021 and completed in 2023 (ORASECOM, 2023).

The objective of the JBS is to generate an understanding of the ecological trends of the Orange-Senqu River Basin, and to contribute to the establishment of standardised forms of collecting, processing, and disseminating data or information regarding water quality, pollution and health of the River System.

The JBS includes the Upper Orange River catchment, within the wider basin, relevant for this study. Thus, information, data and knowledge gathered from these programmes will further contribute depth to this study within the Upper Orange River catchment particularly with regards to water quality (including diatoms), fish, macroinvertebrates, and riparian vegetation.

The JBS3 sites and associated ecological categories for the Upper Orange River catchment are listed in Table 19.

Table 19: JBS3 monitoring sites (ORASECOM, 2023)

Code	River	Latitude	Longitude	Ecological Category
OSAEH_11_18	Modder	-29.16067	26.57225	C
OSAEH_11_19	Modder	-28.80722	26.10694	C/D
OSAEH_26_10	Riet	-29.57527	25.70805	D - not fully assessed
OSAEH_29_5	Riet	-29.02696	24.51292	E
OSAEH_15_1	Caledon	-28.72313	28.15575	C/D - not fully assessed
OSAEH_15_6	Caledon	-29.37106	27.40529	C/D
OSAEH_11_20	Leeuspruit	-29.51769	27.12968	C
OSAEH_15_2	Matsuko	-29.2341	28.56182	D - not fully assessed
OSAEH_15_3	Senqu	-30.06558	28.40896	D/E
OSAEH_15_5	Senqunyane	-30.02106	28.18295	E
OSAEH_11_22	Orange	-30.50472	27.21398	D - not fully assessed

Code	River	Latitude	Longitude	Ecological Category
OSAEH_26_11	Kraai	-30.69007	26.74157	D - not fully assessed
OSAEH_26_13	Stormbergspruit	-30.65017	26.46516	E
OSAEH_26_14	Orange	-30.57142	26.45166	D
OSAEH_26_8	Caledon	-30.42757	26.30501	C/D
OSAEH_26_15	Orange	-30.50378	25.24003	D
OSAEH_26_12	Seekoei	-30.37358	25.00095	D - not fully assessed
OSAEH_26_2	Orange	-29.64357	24.21554	D - not fully assessed
OSAEH_26_3	Orange at Marksdrift weir	-29.14207	23.69191	D/E

4.2.5.2. River Eco status Monitoring Programme (REMP[1])

The DWS conducts a quarterly routine monitoring program known as River Eco status Monitoring Programme (REMP[1]), during which macroinvertebrates are recorded to assess the health and integrity of selected river systems in the Upper Orange River catchment. These REMP sites are detailed in Table 20, with the latest ecological categories for the macroinvertebrate community as per the latest run Macroinvertebrate Response Assessment Index (MIRAI), received from the Resource Quality Information Services (RQIS) Department from DWS.

Table 20: DWS REMP sites within the Upper Orange River catchment (DWS RQIS[1])

DWS REMP Site	River	Latitude	Longitude	Ecoregion	Geozone	Ecological category
Secondary Catchment C5						
C5KORA-MOCKU	Korannaspruit	-29.08584	26.633841	11.03	E	No longer monitored
C5MODD-MODDE	Modder	-29.028882	24.638277	29.02	F	C/D
C5MODD-SANNA	Modder	-29.16111	26.57194	11.03	E	D
C5MODD-SOETD	Modder	-28.80722	26.10694	11.08	F	No longer monitored
C5RIET-DEKRA	Riet	-29.02778	24.51306	29.02	E	C
C5RIET-IFR03	Riet	-29.57528	25.70805	26.01	E	D
C5RIET-LILYD	Riet	-29.02696	24.51292	29.02	E	No longer monitored
C5RIET-JACOB	Riet	-29.09972	24.69889	29.02	F	C

[1] REMP (River Eco-status Monitoring Programme) - formerly RHP (River Health Programme), RQIS (Resource Quality Information Services) - Department of Water and Sanitation - South Africa - (dws.gov.za)

DWS REMP Site	River	Latitude	Longitude	Ecoregion	Geozone	Ecological category
C5RIET-RICHI	Riet	-29.044898	24.587063	29.02	F	No longer monitored
C5VANZ-DWNWR	VanZylspruit	-30.1108306	25.8497194	26.03	E	C
Secondary catchment D1						
D1KRAA-ALIWA	Kraai	-30.69007	26.74157	26.03	F	C
Secondary catchment D2						
D2CALE-EWR03	Caledon	-28.7225	28.1509	15.01	F	No longer monitored
D2CALE-LADYB	Caledon	-29.395	27.422	15.01	F	No longer monitored
D2GROO-FARM1	Brandwater	-28.68056	28.13972	15.01	E	D
D2LCAL-WILGE	Little Caledon	-28.50154	28.58132	15.03	D	C
D2LCAL-EWR01	Little Caledon	-28.52694	28.48306	15.03	E	C/D
D2LCAL-EWR02	Little Caledon	-28.611389	28.30194	15.01	E	C
D2LEEU-EWR06	Leeu	-29.52167	27.13583	11.03	E	D/E
D2GLEN-GLENR	Glen Reenen	-28.50758	28.61612	15.03	C	B/C
D2RIBB-RIBBO	Ribbok Spruit	-28.618083	28.583678	15.03	C	C
D2RIBB-UWWTW	Ribbok Spruit	-28.50952	28.58344	15.03	D	C
D2RIBB-DWWTW	Ribbok Spruit	28.50853	28.58273	15.03	D	C
Secondary catchment D3						
D3ORAN-HOPET	Orange	-29.6	24.08778	26.01	F	C
D3ORAN-MARKS	Orange	-29.141709	23.692039	26.01	F	D

4.2.6. Hydrological Character

Hydrological Index values determined by Hughes and Hannart (2003) are used to characterise hydrological variability at a quaternary catchment level throughout South Africa. The hydrological index is based on an input time series of natural monthly flow volumes using a combination of monthly coefficients of variation (CV) and an index of baseflow contribution to total flow (Table 21). Higher values imply rivers with variable and unreliable flow regimes.

The CV Index is based on the sum of the average coefficient of variation for the three main wet season months and the three main dry season months.

Table 21: Hydrological Index

Class	Coefficient of Variation Index	Hydrological character
Class I	CV_Index 1-4	Perennial
Class II	CV_Index 5	Seasonal
Class III	CV_Index 6 - 9	Ephemeral

The Orange and Caledon rivers and their main tributaries are perennial rivers (CV_ Index for all rivers ranging from 1 to 4), with some of the smaller tributaries being seasonal (CV_ Index 5). Tributaries in quaternary catchments D31E which drains to Vanderkloof Dam, D32C and E in the Seekoei River sub-catchment, D33B and F which drain to the Orange River downstream of Vanderkloof Dam and a tributary in D34C which drains to the Oorlogspoort River which ultimately drains to the Orange River reach between Gariep and Vanderkloof dams, are classed as ephemeral, with a CV_Index 6 to 9.

4.2.7. Protected Areas

Figure 26 illustrates those areas that have been designated protected areas of which the Gariep Nature Reserve being the largest. A porton of the Golden gate National Park falls in the upper reaches of the Caledon River catchment. There are many other smaller protected areas scattered throughout the sub-catchnments.

In addition to the protected aeas, critical biodiversity areas (CBA) and ecological support areas have been designated at provincial level. CBAs are required to meet biodiversity targets for ecosystems, species and ecological processes, as identified in a systematic biodiversity plan. Ecological support areas are not essential for meeting biodiversity targets but play an important role in supporting the ecological functioning of Critical Biodiversity Areas and/or in delivering ecosystem services. Critical biodiversity areas and ecological support areas may be terrestrial or aquatic and are illustrated in Figure 27.

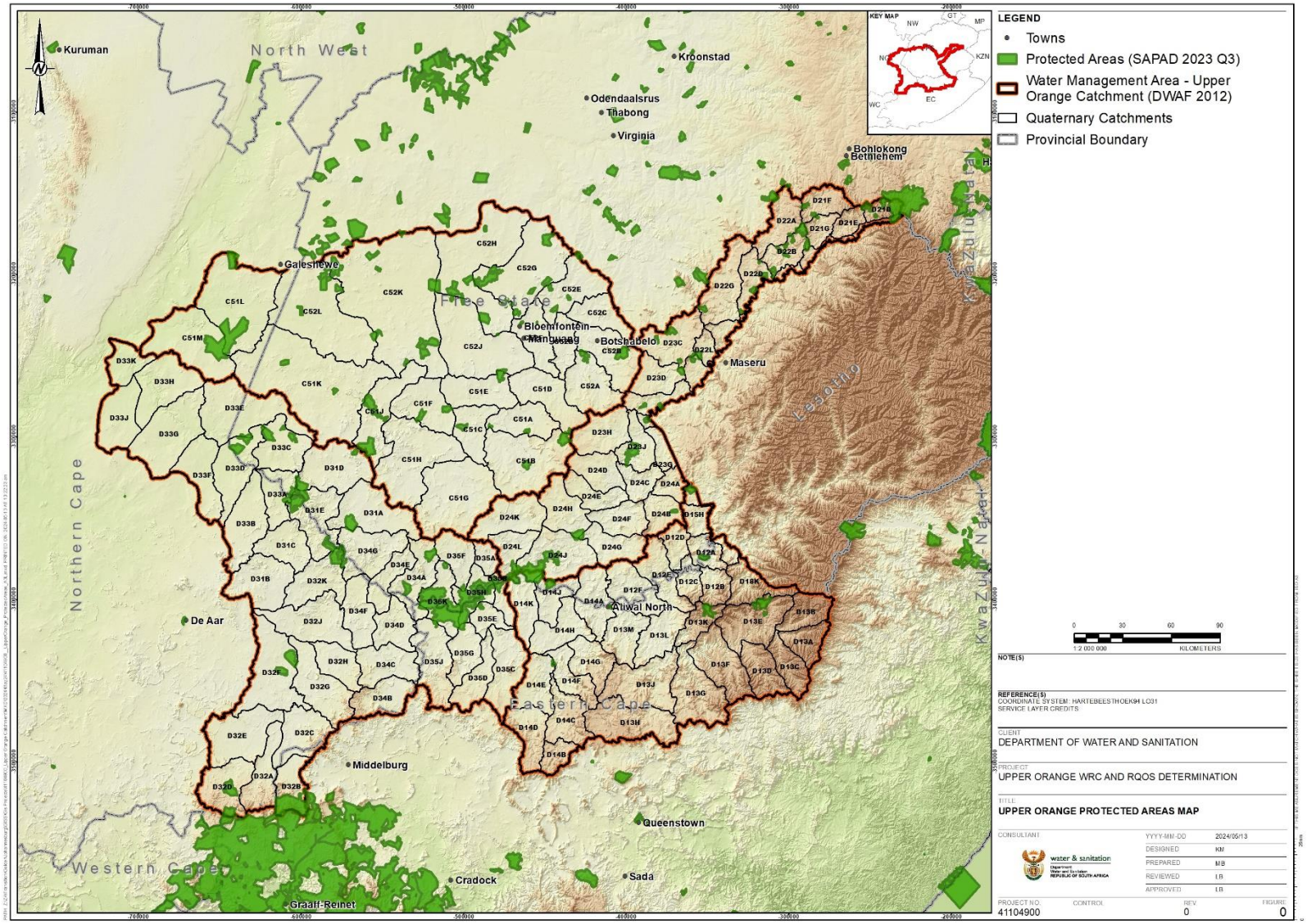

Figure 26: Designated Protected Areas within the Upper Orange River catchment

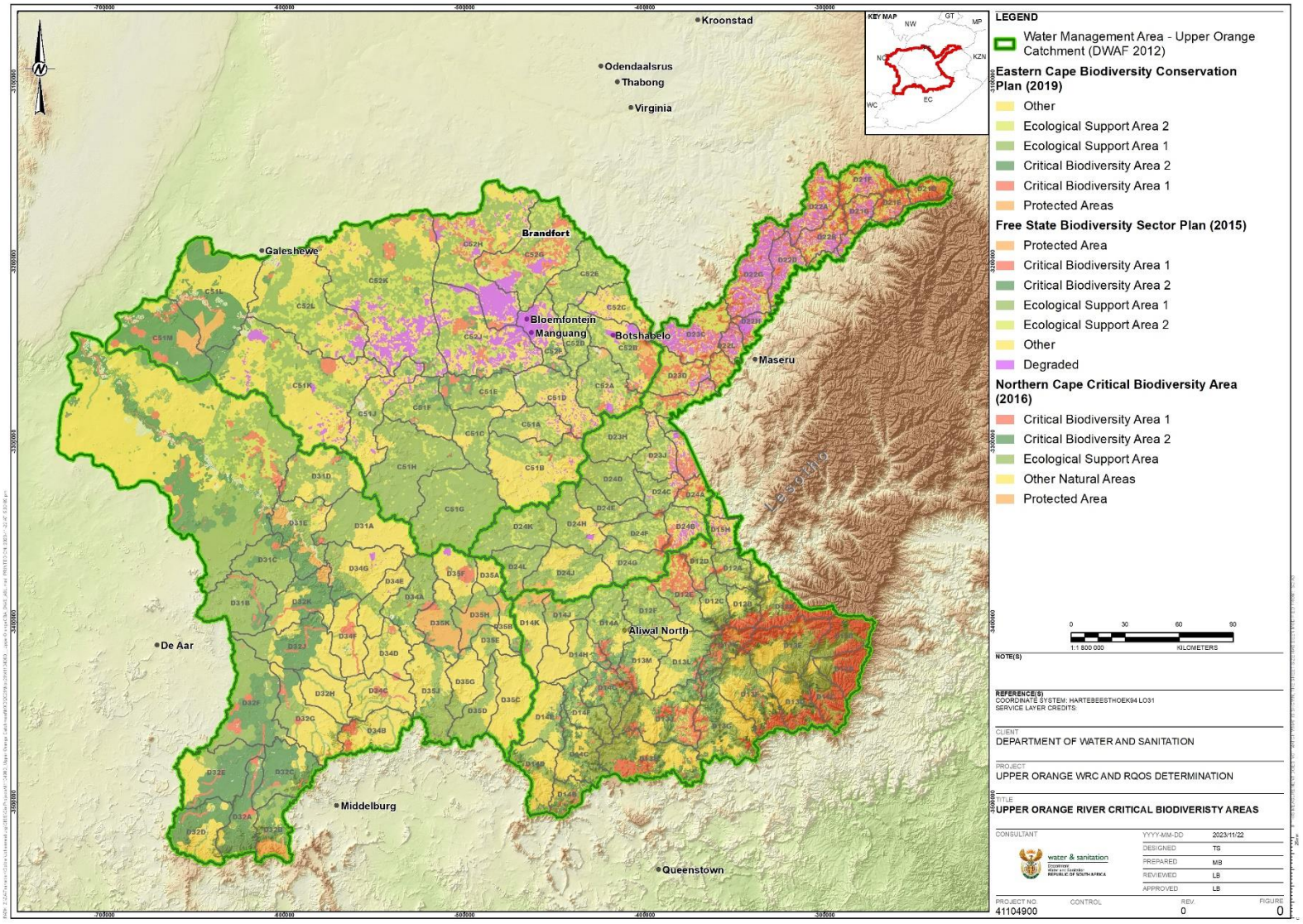

Figure 27: Critical Biodiversity and Ecological Support Areas within the Upper Orange River catchment

4.2.8. National Freshwater Ecosystem Priority Areas (NFEPA)

South Africa's freshwater ecosystems are diverse, ranging from sub-tropical in the northeastern part of the country, to semi-arid and arid in the interior, to the cool and temperate rivers of the fynbos.

Freshwater ecosystems refer to all inland water bodies whether fresh or saline, including rivers, lakes, wetlands, sub-surface waters and estuaries.

NFEPA provides guidance on how many rivers, wetlands and estuaries, and which ones, should remain in a natural or near-natural condition. It supports the implementation of the National Water Act, the Biodiversity Act and the Protected Areas Act.

The NFEPA for the Upper Orange River catchment are illustrated in Figure 28 and shows that the Kraai River sub-catchment and the Stormbergspruit and tributaries are predominantly categorised as Freshwater Ecosystem Priority Areas, with may upstream protection areas.

Rehabilitation FEPAs are noted in quaternary catchments D23A, D23J and D24C in the Caledon River catchment, and in quaternary catchments D13A and D13C in the Kraai River catchment, as well as a small area in C51G in the upper reaches of the Riet River.

Fish support areas are noted in quaternary catchment D23C and D23D in the Leeu River sub-catchment of the Caledon River, and the Orange River downstream of Vanderkloof Dam to the confluence with the Vaal River.

The Seekoei sub-catchment is also important as an upstream protected area to support the FEPAs in the downstream areas.

The map illustrates how degraded the Modder and Riet River catchments area, except for the upper reaches of the Riet River.

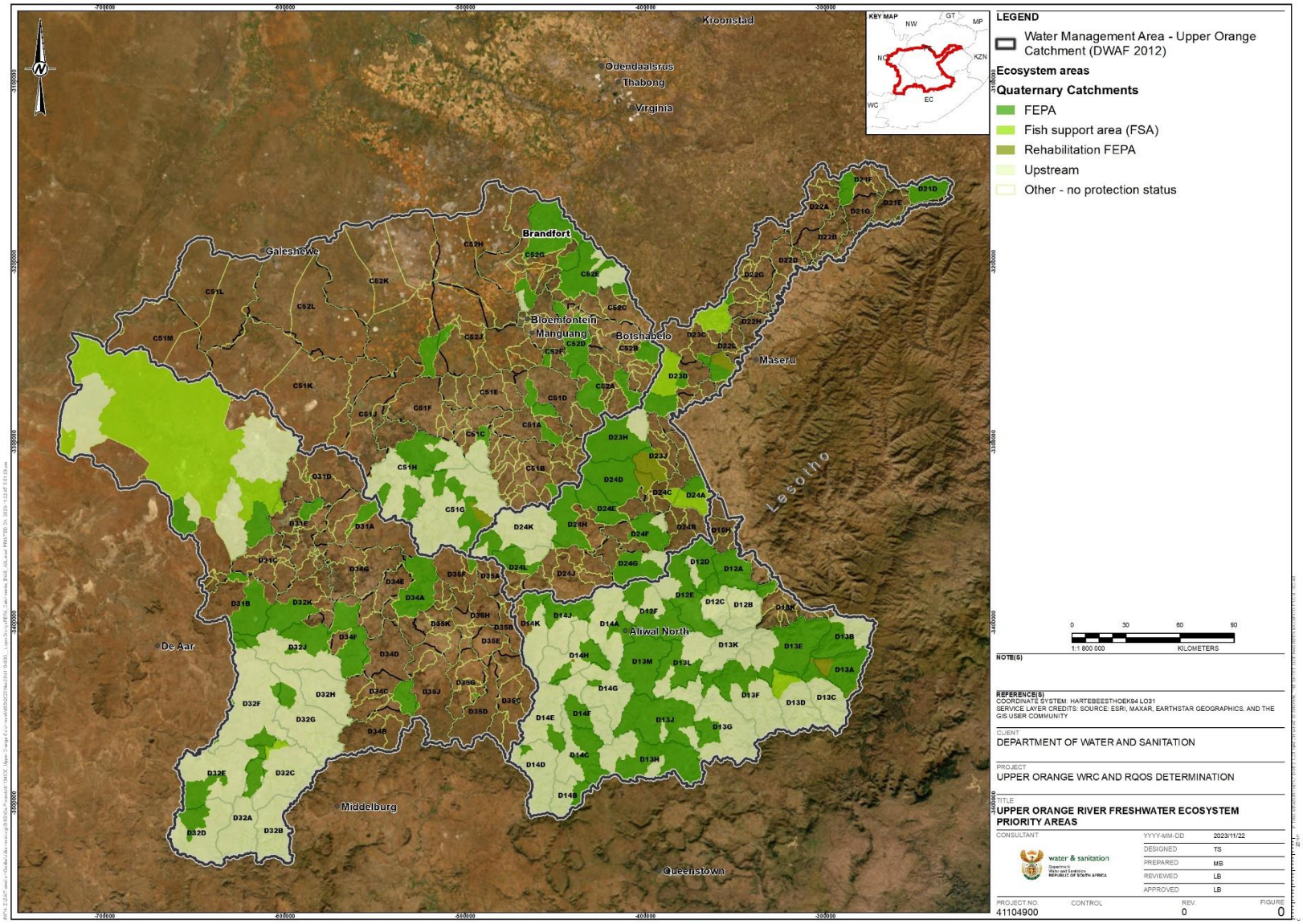

Figure 28: Upper Orange River Freshwater Ecosystem Priority Areas

5 STATUS QUO: GROUNDWATER

5.1. Overview

The Upper Orange River catchment is situated in semi-arid to subtropical regions of South Africa with typical continental climate conditions – extreme day/night and summer/winter temperature differences. The climate conditions in the catchment are characterised by a warmer and drier northwestern part to a cooler and wetter southeastern part. The upper reaches of the catchment are influenced by the Drakensberg Mountain Complex – (i) temperatures (much cooler). (ii) rainfall (higher/more frequent), and (iii) frequent windy conditions.

These climate conditions have a dominant pattern in the rainfall patterns and depths – the higher (elevation (meters) above mean sea level, mamsl) and frequency of occurrences of high rainfall inputs. i.e., >35 mm/occurrence.

The use of groundwater is a function of (i) groundwater quality type, (ii) aquifer type (intermediate, fracture, and fractured & weathered), (iii) aquifer potential (borehole yield classification) (iv) potential groundwater recharge (rainfall depths). Most water supply schemes have been developed for sole water supplies – one or 10 boreholes per water user/property to one or more well fields per water use entity (*viz*., municipalities, mines, or irrigation scheme).

Water users are (i) rural towns (population <30 000), (ii) shallow open cast mines (own consumption and dewatering) and (iii) agricultural irrigation schemes[2], plus several thousand individual boreholes used on a daily interval for domestic and stock water supplies. Larger towns/cities such as Bloemfontein (±600,000 population, quaternary catchment C52F), Colesburg (±24,250 population, quaternary catchment D34F), and Botshabelo (±219,508 population, quaternary catchment C52B) do have water supplies from surface water and groundwater resources. Other towns are dependent on groundwater resources, i.e., Philipstown (4,100 population, quaternary catchment D31B), Dealesville (±6,580 population, quaternary catchment C52H), Burgersdorp (±19,320 population, quaternary catchment D14E), and Barkly East (±12,100 population, quaternary catchment D13D).

Groundwater quality in the catchment varies significantly and is affected by (i) natural (geological), (ii) climatological and (iii) anthropogenic effects: *i.e*.,

(i.) Salinity affected by specific sedimentary rock formations, i.e., marine tillite and mudrock;
(ii.) Some aquifer systems need frequent fresh rainwater recharge to “flush” or “dilute” aquifer systems, *i.e*., dolomite, banded ironstone, quartzite, and sandstone formations; and
(iii.) Groundwater pollution due to poor solid waste management (rock/waste dumps), poor leachate management (tailings storage facilities), and poor wastewater management (water treatment work discharges).

Groundwater use, *viz*. abstraction from the aquifer system varies significantly over the water management areas. Critical cases where groundwater is pumped for large irrigation water supply, municipal water supplies and dewatering of underground mine workings results in

[2] (NB., excluding the large surface water irrigation schemes along the Upper Orange River and Caledon River).

depletion (lowering) of the aquifer saturation levels triggering unsustainable aquifer conditions and in some cases deterioration of the groundwater qualities.

5.2. Description

A concise explanation has been compiled in the 2024 groundwater resource unit assessment (Groundtruth, 2024) and These include fluvio-deltaic mudstones, siltstones, and sandstones with dolerite ring dyke intrusions. Formation groundwater storage and flow are functions of porosity. Primary effective porosities are low due to sediment cementation and the fine-grained nature of the sediment, as well as compaction and high mudstone contents. Secondary porosities are enhanced by fracturing and dolerite dyke intrusion. The highest borehole yields are associated with the fractured dolerite and thick sandstone contacts and where these contacts are covered by alluvium. The alluvium plays an important role to enhance recharge to the subsurface lithologies. The borehole yields are variable in the catchment and range from 0.1 L/s to >5.0 L/s, dependent on the underlying geological group.

5.2.1. Geology

The regional geology is dominated by the Karoo Supergroup sedimentary rocks that were deposited in a primary pre-Karoo Basin with a surface area of 200,000 km^2 (Aarnes et al., 2011, cited in Groundtruth, 2024). The Karoo Supergroup was formed through sedimentation within an intra-cratonic, foreland basin on Gondwanaland, during the Carboniferous, Permian, Triassic, and early Jurassic ages, about 300 Ma to 160 Ma ago (cited in Groundtruth, 2024: Truswell, 1970). The main Karoo Basin covers a large part of the central and eastern parts of South Africa, and runs according to Du Toit (1954, cited in Groundtruth, 2024:), the southern African Karoo Basin attains it's a maximum thickness in the southern parts of the Northern Cape Province and Lesotho.

The Upper Orange River catchment is covered exclusively by the Karoo Supergroup sedimentary rocks. Widespread volcanism ended the Karoo sedimentation during the early Jurassic Age (Tankard et al., 1982, cited in Groundtruth, 2024:). According to Botha (et al., 1998), magmatic activity is divided into two phases, i.e., an extrusive phase associated with the outpour of Drakensberg lavas, as well as the intrusive phase associated with numerous linear dolerite dykes/sills and kimberlites in the Karoo formations. The intrusion of dolerite dykes resulted in the formation of fractures and contact metamorphism within the sedimentary host rock (Aarnes et al., 2011, cited in Groundtruth, 2024).

5.2.2. Hydrogeology, Aquifer Types and Vulnerability

Groundwater occurs in a wide range of aquifer systems and can be grouped into shallow and deep [as per depth to aquifer saturation (water) level] aquifer systems. These aquifers are sensitive to land use activities, especially the shallow aquifers to surface pollution, and they play an important role supplying a base flow contribution to especially the upper surface water sections of the drainages. Their contribution to wetlands, especially unchanneled valley bottom wetland systems.

The aquifers include three [of the four] major Aquifer Types specified under the Geohydrological Map Series of South Africa (2006) they are as follows:

- Intergranular aquifer type – unconsolidated to semi-consolidated alluvial sediments along the middle to lower reaches of the tertiary-secondary river systems;
- Fractured aquifer type – hard rock formations, (*i.e.*, amygdaloidal andesitic lavas, diamictite, sandstone/ mudrock and Karoo Dolerite intrusive rocks {circular sills, lateral sills and various semi-vertical/oblique dykes, continental basaltic lavas), fall into this category, representing the deeper parts (>65 mbgl) of the aquifer systems; and
- Fractured and Intergranular (weathered) type – weathered version of the hard rock formations (*i.e.*, amygdaloidal andesitic lavas, diamictite, sandstone/ mudrock and Karoo Dolerite intrusive rocks (circular sills, lateral sills, and various semi-vertical/oblique dykes, and continental, basaltic lavas) fall into this category and represents the bulk of the aquifer types present in the catchment, representing the shallower (<65 mbgl) parts of the aquifer systems.

No specific groundwater vulnerability status assessment was conducted in the past on a local, quaternary catchment scale – this will have to be addressed in this study. It is foreseen that the DRASTIC methodology developed by Lynch *et al* (1994, cited in DWS, 2016 will be used a baseline aquifer vulnerability assessment. The methodology is based on the following algorithm:

DRASTIC INDEX = DrDw + RrRw+ ArAw+ SrSw+ TrTw+ IrIw

The [proposed] parameters weights of each of the above-mentioned terms are:

- Depth to groundwater (Dw) – a weight of 5;
- Recharge (Rw) – a weight of 4;
- Aquifer media (Aw) – a weight of 3;
- Soil media (Sw) – a weight of 2;
- Topography (% slope) (Tw) – a weight of 1; and
- Impact of vadose zone (Iw) – a weight of 5.

The estimated DRASTIC values along the eastern boundary of the Lower Orange WMA are above the “calculated” MODERATE DRASTIC INDEX) OF 145 – it is therefore assumed that the vulnerability indices for the Upper Orange WMA will be [at least] of the same order/higher in the southern part of the catchment, viz., the Kraai River, Upper Orange River, Stormbergspruit, and the Seekoei River catchments.

5.3. Status

During 2024 Groundwater Reserve Determination an assessment of the “Allocable Groundwater" indicated that the groundwater reserve in seven (7) quaternary catchments are over allocated (Allocable GWater is <0.0 Mm^3/a) – indicating that the EWR component is relatively high (i.e., almost equal to rainfall recharge. These were noted in the upper Kraai River and a few quaternary catchments along the Stormbergspruit. The remainder of the catchment’s “Allocable Groundwater” varies from 3.54 Mm^3/a to 41 Mm^3/a.

It is, however, clear that the groundwater base flow estimates are probably too high as in some cases these baseflow values is higher than the groundwater recharge values – there should be a logic explanation for this phenomenon.

The groundwater levels (aquifer saturation levels) of the catchment varies between 2.5 metres below ground level (mbgl) to 50 mbgl, however, the mean water level depth is in the order of 20 to 25 mbgl. These water level estimates are [unfortunately based on historic datasets, i.e., pre-2000 times. The effect of climate change(s)/variations since ca. 1995 could lower these groundwater levels due to lower groundwater recharge values.

There are 38 groundwater quality monitoring sites (merely equipped water supply boreholes at farms (domestic/stock water), schools, hospitals or police stations, and rural village water supply schemes. The time series water quality datasets shows that the long-term hydrochemistry status shows stable water quality conditions with a few long-term rising/decreasing trends. Seasonal oscillations, however, occurs at several monitoring sites, and demonstrates the importance of annual/bi-annual effective recharge conditions – as the decreased TDS values noted after May 2017 shown in Figure 29. This illustration also shows the impact of rainfall recharge on the water quality composition, i.e., significant decrease in the TDS and nitrate concentrations after the 2017 winter season.

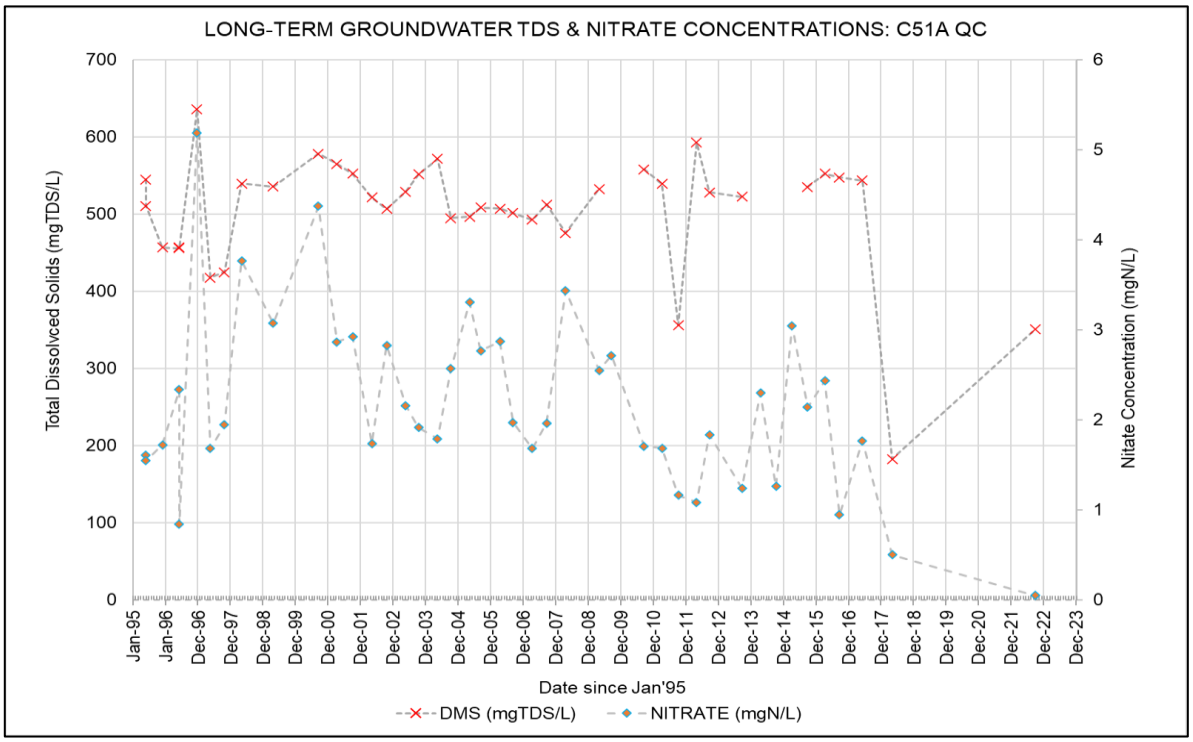

Figure 29: Total Dissolved Solids (TDS) trend for Quaternary Catchment C51A (GRU 3)

5.3.1. Recharge

Recharge figures for the Upper Orange River catchment were estimated for the 2024 (GroundTruth) Groundwater Reserve Determination study (DWS, 2024). The latter study, however, stated that 'Based on the available data, the Recharge toolkit (DWS, 2000) was used to determine recharge per quaternary catchment'. This assessment used the chloride mass balance (CMB) methodology to calculated annual groundwater recharge based a XX mm/a estimation – a mean/median value of 20 mm/a was used and based on the groundwater TDS-concentrations. This estimation is regarded (by this study) as high and is probably not "as high" as 20 mm/a in the northwestern parts of the catchment (northeast of a diagonal line

between Brandfort [northeast] and Phillipstown [southwest]. It is not sure if the approximation of chloride concentrations in the Upper Orange River catchment area has been adopted for the elevated primary chloride concentrations present in the Ecca Group sediments – could be 2½-times higher than background (natural) chloride concentrations. The total groundwater recharge volume is in the order of ±2,000 Mm^3/a. (DWS, 2024).

5.3.2. Water levels

Groundwater levels in the Upper Vaal Catchment varies between shallow (<10 mbgl) and moderately deep (45±10 mbgl). Water levels depths in the upper part of the catchment, i.e., groundwater resource units (GRUs) are generally <20 mbgl, and gradually gets deeper to ±50 mbgl in the lower part of the catchment, i.e., GRUs. The GRUs are indicated in Figure 39.

Groundwater level depths are a function of the topographic elevations and water levels will vary substantially due to the relief profiles of each quaternary catchment – deepest along the quaternary catchment boundary and shallowest at the associated drainage system discharging the catchment.

5.3.3. Contribution to baseflow

Baseflow contributions driven/generated by each quaternary catchment were assessed for the 2024 Reserve Determination (DWS, 2024) and was based on estimations/measurements of the “lowest average monthly flows” – thus, indicating the 100% of the lowest monthly flows were regarded as the groundwater contribution to the total baseflow estimates. These values would represent at least the minimum ecological water requirements for a specific quaternary catchment.

The Maximum Groundwater Baseflow contribution was estimated as ±65 Mm^3/a, and the minimum was estimated as <0.1 Mm^3/a. These values, based on the individual quaternary catchment estimations will be accepted for the remaining resource directed measures, i.e., water resource classification and the quality objective settings.

5.3.4. Groundwater use

Groundwater use figures for the Upper Orange River catchment are available in the 2024 Reserve Determination assessment, however, the source of this data is not specified and is probably from earlier groundwater use assessments, e.g., the Groundwater Resource assessment II (GRA II) assessment conducted by DWS in the early 2000’s. It is therefore outdated if these values were not updated during the 2024 assessment. These figures will have to re-specified/calculated for this water resource classification and RQOs study.

5.3.5. Groundwater quality

According to the available information on groundwater quality in the Upper Orange River catchment , the water quality (ITO total dissolved solids, in mgTDS/L) varies between 450 mgTDS/L (Class 1 water quality type) and 3,250 mgTDS/L (Class 3 water quality type) – the latter category is probably related to the high primary (natural) salinity of the lower

sedimentary sequence of the Karoo Supergroup formations, i.e., the Dwyka Tillite and the Ecca Mudrocks.

Groundwater quality in the catchment varies significantly and is affected by the following conditions:

- Natural/primary conditions, i.e.,
  - Geological, e.g., Salinity affected by specific sedimentary rock formations, i.e., marine tillite and mudrock.
  - In the Upper Orange River catchment, this is applicable to the lower formation groups in the Karoo Supergroup sequence, e.g., the Dwyka (marine) Tillites and the Ecca (marine) mudrocks.
- Climatological conditions, i.e.,
  - Aquifer systems need frequent rainwater recharge to “flush” or “refresh” the water quality of the water bearing rock formations, i.e., tillite, mudrock and silty sandstone formations.
  - Generally, this process occurs on an annual base in the subtropical/tropical climate regions in southern Africa, however, in the semi-arid and arid northwestern parts of South Africa, this process has not been an annual event since 1974 – ‘76.
  - The recurrence rate groundwater recharge events of 1:5 to 7-years is probably more realistic for the northwestern part of the study area.
- Anthropogenic effects, i.e.,
  - Groundwater pollution due to poor solid waste management (rock/waste dumps), poor leachate management (tailings storage facilities), and poor wastewater management (water treatment work discharges).

The groundwater quality for the Upper Orange River catchment as assessed from the available groundwater quality data is illustrated in Figure 30. This map (DWS, 2024) shows the background water quality in electrical conductivity (mS/m) and is referenced as Figure 5 in the 2024 Reserve Determination report by GroundTruth Environmental & Engineering, dated 21 February 2024).

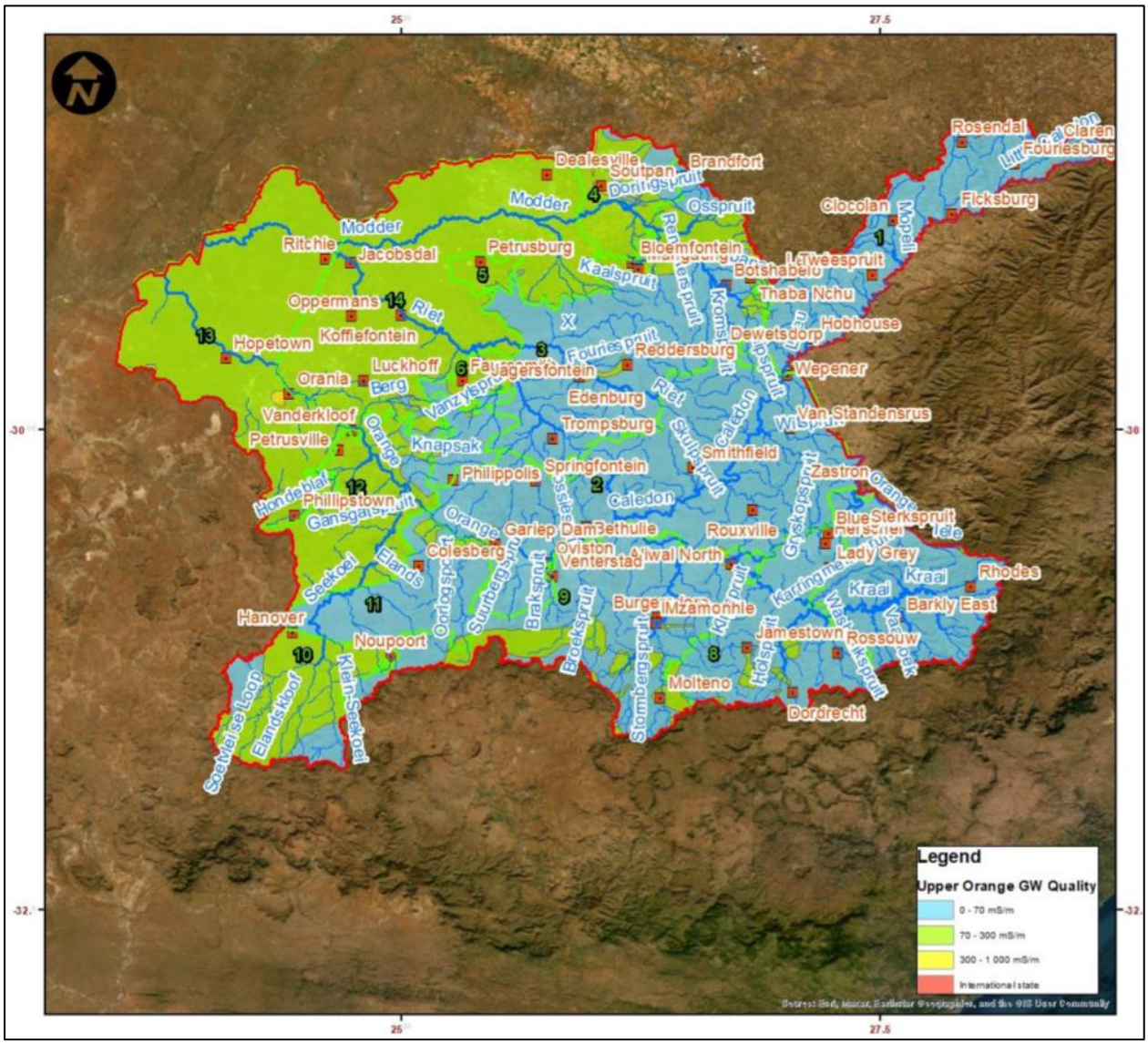

Figure 30: Map showing background ground water quality (as electrical conductivity in mS/m) in the Upper Orange River catchment

6 STATUS QUO: WETLANDS

6.1. Overview

Use was made of the National Wetland Map 5 (NWM5) (Van Deventer *et al*., 2018) and the DWS Reserve Determination Study (DWS, 2022) to identify and map the significant wetland resources in the Upper Orange River catchment.

The Upper Orange River catchment covers an area of approximately 10,352,148 ha and is considered the second-largest catchment in South Africa. However, according to the NWM5 dataset (Van Deventer *et al*., 2018) wetland habitat (including rivers) only covers an area of approximately 139,046.90 hectares (ha), thus only 1% of the Upper Orange River catchment is covered in watercourse/ wetland habitat.

6.1.1. General Description of Wetlands

Based on the NWM5 and the results of the DWS Reserve Determination Study (DWS, 2022), five different hydrogeomorphic (HGM) wetland types have been described as occurring in the Upper Orange River WMA. These include:

- Seeps
- Depressions/ Pans
- Floodplains
- Channelled Valley Bottom systems; and
- Unchanneled Valley Bottom systems.

Riverine systems were also mapped and categorized as wetland/watercourse types by the NWM5 (Van Deventer *et al*., 2018) and were thus included in the overall calculations of wetland area for this study.

Depression/pan wetlands were found to be the most extensive wetland type within the Upper Orange River catchment, making up 51% of the total wetland habitat mapped (Table 30). Their characteristics are largely associated with a combination of geology, rainfall and temperature (DWS, 2022). Riverine systems made up the second most extensive wetland/ watercourse type mapped in the catchment (39%). Floodplain and Channelled Valley Bottom wetlands covered 3% and 4% of the catchment area respectively. Most of these systems were associated with the main systems running through the catchment such as Caledon, Modder, Riet, Kraai, Seekoei and Orange rivers.

The wetlands within the Upper Orange River catchment occur across five ecoregions, described in Section 4.2.1 and illustrated in Figure 21, and seven different bioregions, illustrated in Figure 31. The largest bioregion in the catchment is the Dry Highveld Grassland Bioregion followed by the Upper Karoo Bioregion. The bulk of the wetlands are found within the two main bioregions- Dry Highveld Grassland and Upper Karoo bioregion.

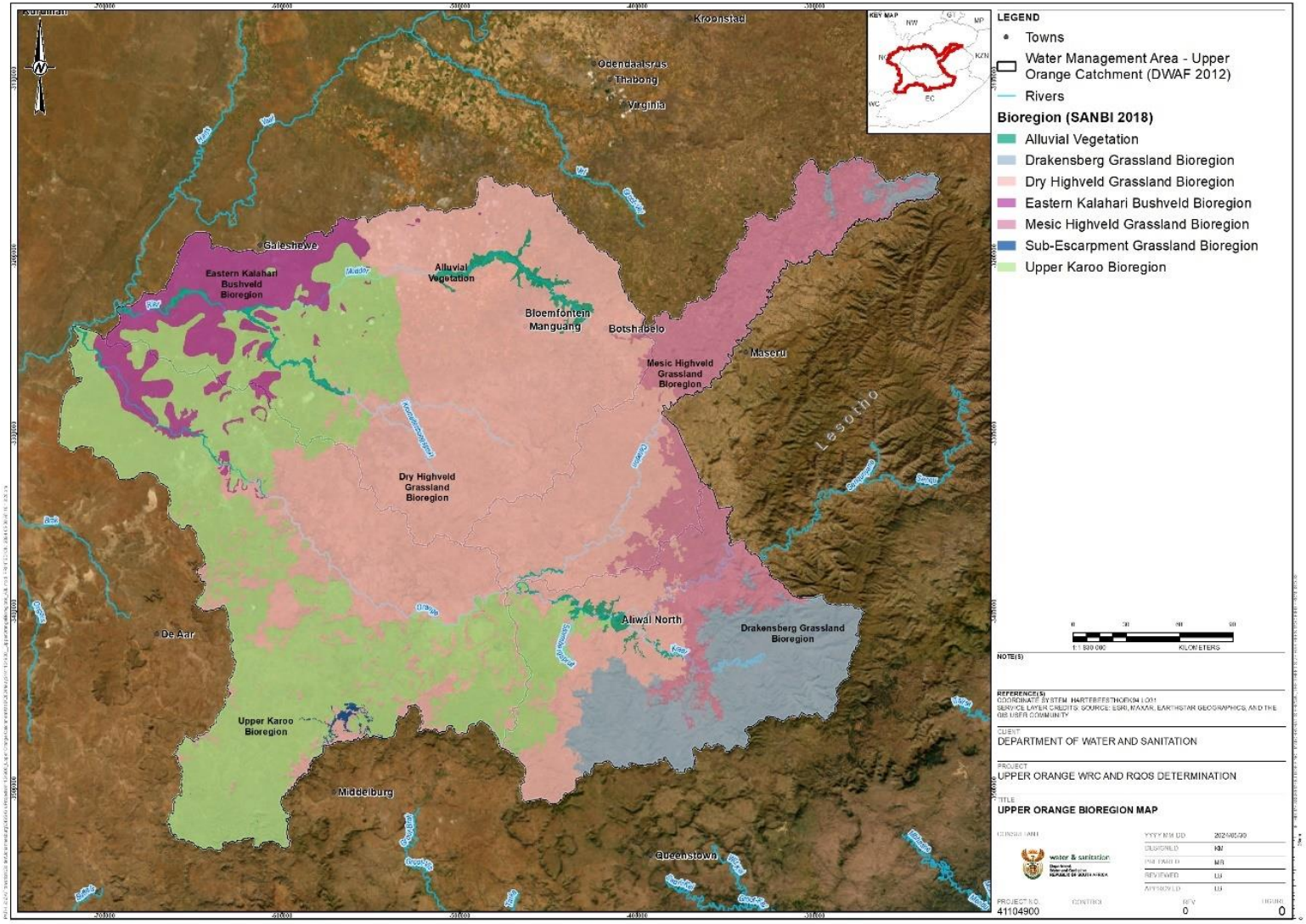

Figure 31: Bioregions in the Upper Orange River catchment

6.1.2. Priority wetlands

The DWS (2022) Reserve Determination Study, mapped several wetland systems within the Upper Orange River catchment which were grouped into twelve wetland resource units. These are illustrated in Figure 32 per integrated unit of analysis (IUA), the delineation of which is described later in section 8, except for IUA 1 and IUA 6. The IUA with the most mapped priority wetlands is IUA 10 (cluster of large depression wetlands). The priority wetlands mapped per each IUA include (sourced from DWS, 2022).

Brandwater floodplain, a medium-sized floodplain wetland fed by an upstream catchment that is over 76 000 hectares (ha) in size, a large proportion of which is cultivated. The Brandwater floodplain is located at the toe of the Brandwater River, approximately 1.5km upstream of its confluence with the Caledon River.

Soutpan Depression wetland complex, a large complex of depression wetlands located at IUA 10 and consists of a total of 27 depression wetlands ranging in size from 6 ha to 1 800 ha. Most of these depression wetlands are endorheic and have no clear outward-flowing connection to river systems.

Philipstown unchanneled valley-bottom (UCVB) wetland complex, a wetland complex approximately 190 ha and a depression wetland approximately 1 100 ha in size found at IUA 8. The upstream catchment areas of both wetland units are in a relatively natural condition with little to no human impact.

Wolwespruit headwaters, a wetland complex comprising a series of UCVB wetlands which are fed by multiple hillslope seep (HSS) wetlands, covering an area of approximately 420 ha within IUA 4. This forms the headwaters of the Wolwespruit River. The valley-bottom (VB) wetlands have been extensively dammed, with over 15 dams along the length of the mainstem valley. Cranes were noted within this wetland complex, predominantly within the VB systems and it is assumed that these wetlands are used as a foraging site by both crane species and possibly also a breeding site for the Crowned Cranes.

Klein-Wildebeespruit wetland complex, a wetland complex located along the Klein Wildebeesspruit and the unnamed river to the east of the Klein-Wildebeesspruit, comprising a series of VB wetlands which amount to approximately 950 ha, fed by many seep wetlands totalling an estimated 450 ha. These two large wetland complexes are tributaries of the Kraai River and are therefore key in providing ecosystem services such as water quality enhancement and sediment trapping. This wetland complex system is found in IUA 4.

Luckhof depression wetland complex, a wetland complex comprising a series of depression wetlands that are hydrologically connected via surface and groundwater at IUA 8. These depression wetlands range in size from 7 ha to 1 200 ha. These fluvially connected wetlands flow in a south-easterly direction into the Lemoenspruit River which is a tributary of the Orange River. These wetlands form unique features in the broader landscape and provide important habitats for both fauna and flora.

Kaalspruit wetland complex, a wetland complex comprising several depression wetlands, and a discontinuously channelled valley-bottom (DCVB) wetland located along the Kaalspruit River, a tributary of the Modder River within the IUA 9. A unique feature in this complex is a

depression wetland nested within the channelled valley-bottom (CVB) wetland, which is a relatively unique and rare situation.

Aardoringspruit, a large wetland complex that includes a large wetland flat and a DCVB wetland which encompasses the Aardoringspruit River. The confluence of the Aardoringspruit and Keeromspruit Rivers occurs within the wetland resource unit (WRU), from which the Rietspruit flows. It is unusual to find a wetland flat in this part of the country. The Aardoringspruit wetland complex is found at IUA 9.

Rantsho wetland complex, a wetland complex approximately 275 ha in size located between the R26 Road and the Mohokare (Caledon) River on the Rantsho River within IUA 2. The wetland complex is unique in that it consists of three VB hydrogeomorphic (HGM) unit types which have formed because of a unique geomorphic setting and a unique set of geomorphic processes. VB wetlands, specifically FP and UCVB wetlands are typically able to provide ecosystem services to a greater degree than the other HGM units. A series of VB wetlands is unique and can provide significant streamflow regulating services.

Jagersfontein DCVB wetland, located in IUA 10, a large contiguous series of wetlands that originate from four different river/ watercourse systems and coalesce into a VB wetland. The wetland type can be considered a DCVB wetland as the channels are not consistent throughout the HGM unit.

Barkley Pass wetland complex, a significant wetland complex consisting of multiple VB and HSS wetlands which, in total, spread across an area of approximately 230 ha. This large wetland complex is situated on a tributary of the Langkloofspruit River which is a tributary of the Kraai River – an extremely important water source for the Orange River, found in IUA 4.

Tiffindell Seep, located in IUA 4, is a high-altitude wetland complex comprising a series of HSS and VB wetlands that cover a total area of 190 ha located at approximately 2 000 mamsl and is therefore characterised by a unique vegetation assemblage. The remote nature of these wetlands has resulted in the catchments remaining relatively natural.

Additional wetlands, not prioritised as part of the Reserve study, but nonetheless important are:

Maletswai, CVB/UVB wetland complex, that is moderately disturbed, the wetland complex still contains extensive intact areas and is likely to have a high importance in terms of water quality enhancement, particularly given that much of the runoff from Maletswai (Aliwal North) town passes through this wetland complex before entering the Orange River.

Sandspruit wetland, which, given that the entire runoff from the town of Wepener and the discharge from the town's WWTW pass through this still reasonably intact wetland before entering the Caledon River, its importance in terms water quality enhancement is likely to be high.

Otto du Plessis Pass wetland UCVB and CVB, with extensive hillslope seeps is an unusually large wetland for its high altitude. Much of the wetland vegetation remains intact.

Gordonville CVB/UVB that is severely eroded, but with flood-out portions where sediment is currently accumulating. It is representative of many other similarly impacted wetlands in the landscape.

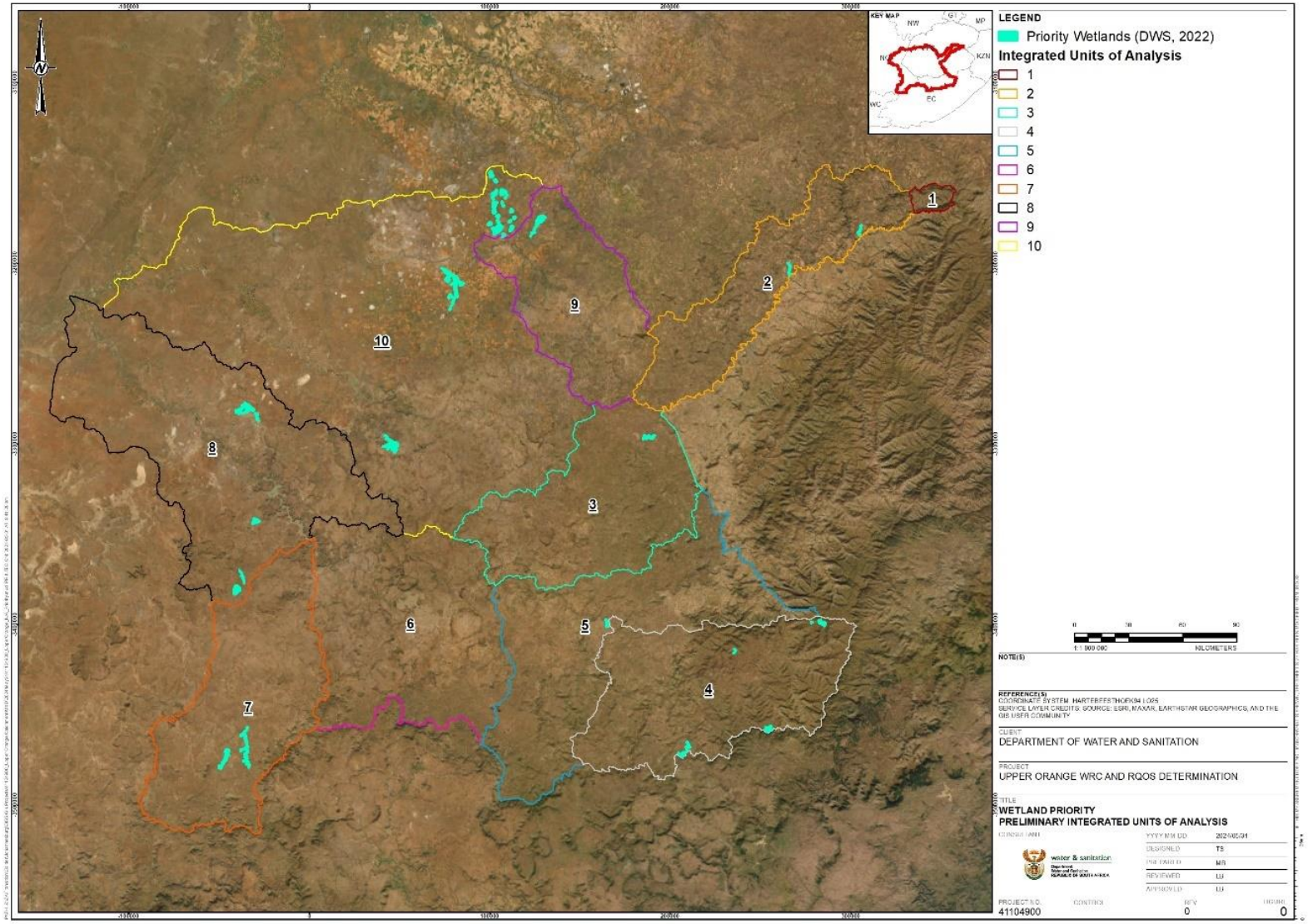

Figure 32: Priority wetlands mapped in the Upper Orange River catchment (DWS, 2022)

6.1.3. General Conditions of Wetlands

Use was made of the National Wetland Map 5 (Van Deventer *et al*., 2018) and the results of the Reserve Determination Study (DWS, 2022) to provide a general description of the condition of the wetlands in each of the delineated IUAs. A summary of wetland conditions per IUA is provided in Table 22. It is important to point out that field verification of the wetlands was limited to the priority wetlands highlighted in the Reserve Determination Study (DWS, 2022), thus the general description of most of the wetlands in the Upper River Catchment was taken from the NWM5 dataset and may not be an accurate representation of the actual current ecological state of the rest of the wetlands not prioritized. It should thus be seen as indicative and only provides a broad-scale perspective of the likely condition of the wetland systems in each IUA.

Based on the NWM5 (Van Deventer et al., 2018), 30% of the wetlands in the catchment are considered to be in a relatively natural or near natural (PES A/B) state (Table 22). This infers that little to no changes to the original wetland condition has occurred in the wetland. Approximately 10% of the wetlands in the catchment are considered moderately modified (PES C), while only 21% of the wetlands are considered to be in a largely to seriously modified state (PES D/E/F) (Figure 33). The largely to seriously modified state is largely due to the multiple land use impacts in the catchment such as irrigated commercial croplands, bare areas associated with mining operations and populated areas (hardened surfaces), poor land use management practices and overgrazing (DWS, 2022).

The majority of largely to critically modified wetlands are mapped in IUA 2 - Caledon/ Leeu where the dominant land use is agriculture including irrigation (crops and livestock farming; mix of irrigation and dryland agriculture) and Tourism. Urban areas (towns) and agricultural activities at IUA 9 also contributed to the largely to critically modified state of the wetlands mapped in the IUA.

Table 22: Wetland condition summary per IUA (source: GIS coverage of Van Deventer et al., 2018)

IUA	Area (ha)	Extent of wetlands (ha) in IUA	Wetland Condition A/B		Wetland Condition C		Wetland Condition D/E/F	
			ha	%	ha	%	ha	%
Golden Gate (1)	30 718	43.53	-	0%	31.91	73%	4.70	11%
Caledon/ Leeu River (2)	631 886	3 022.03	619.22	20%	427.85	14%	1,615.11	53%
Caledon (3)	822 797	4 935.94	476.27	10%	2,646.64	54%	370.43	8%
Kraai River (4)	934 709	4 902.46	916.69	19%	555.45	11%	987.64	20%
Upper Orange River (5)	1 024 091	6 904.29	154.84	8%	99.22	1%	214.67	3%
Gariep Dam (6)	1 064 786	4 090.80	177.73	24%	7.28	0%	139.45	3%
Seekoei River (7)	915 159	9 811.74	914.23	2%	130.73	1%	480.01	5%
Vanderkloof Dam (8)	1 449 349	36 231.46	7,830.19	0%	1,021.21	3%	5,879.17	16%
Upper Modder River (9)	632 039	6 122.45	1,859.07	8%	678.49	11%	2,837.00	46%
Modder/Riet Rivers (10)	2 846 614	62 982.20	29,145.03	9%	8,498.05	13%	16,243.03	26%
	10 352 148	**139 046.90**	**42,093.27**	**30%**	**14,096.83**	**10%**	**28,771.20**	**21%**

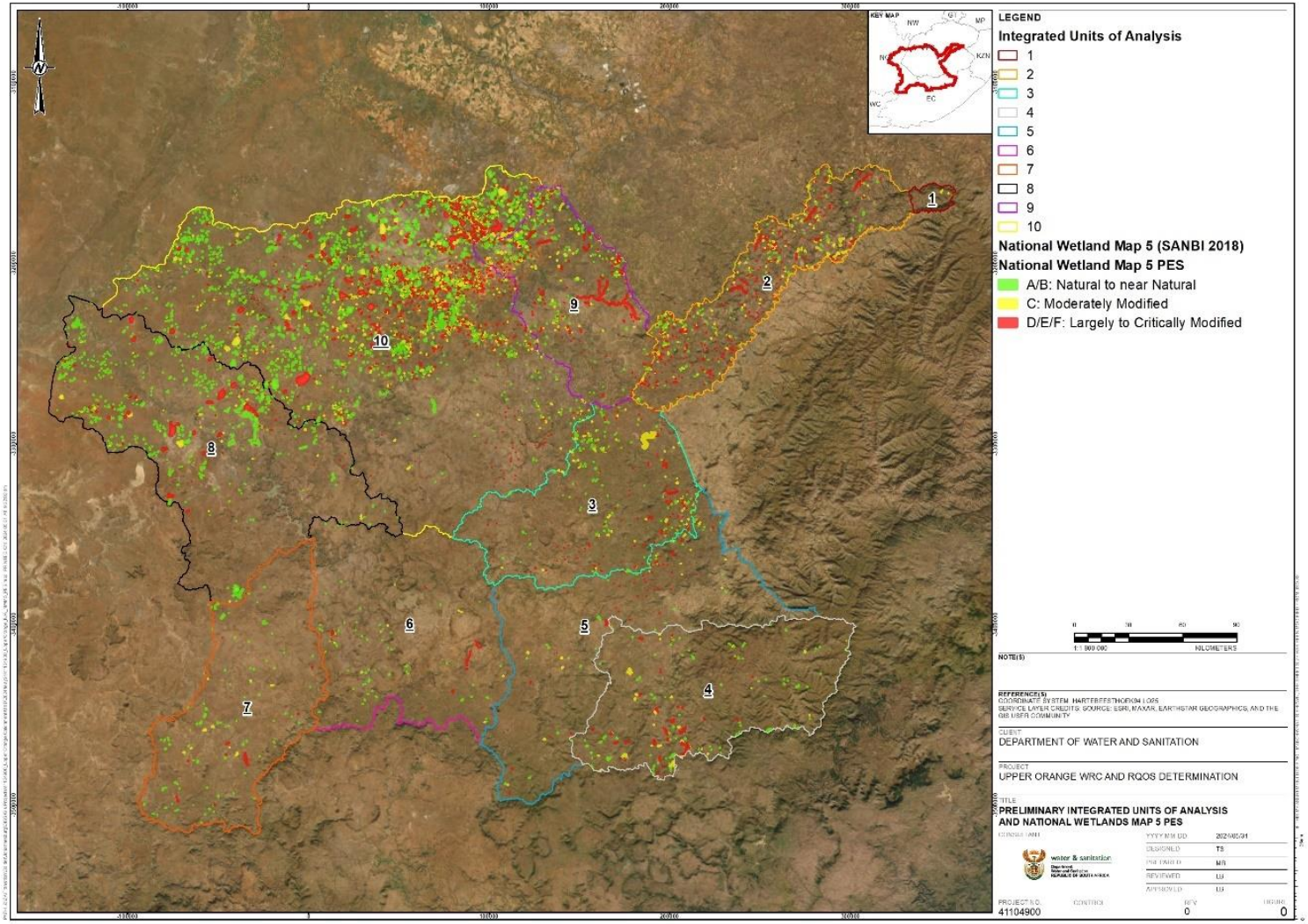

Figure 33: Present Ecological State of wetlands in the Upper Orange River catchment (NMW5, 2018)

7 STATUS QUO SURFACE WATER QUALITY

7.1. Background

As part of the status quo assessment task an overview water quality assessment was undertaken to provide a snapshot of the water quality in the Upper Orange River catchment considering historical and existing information (DWS water quality data). The aim of the assessment was to obtain an understanding of the current situation and in doing so identify the water quality areas of concern (hot spots) that have a potential influence on the delineation of IUAs and for the future analyses of water resource classification scenarios and that will inform the development of RQOs for the Upper Orange River catchment.

Assessment of the present water quality status quo was based on assessing the fitness for use of the water for key water users, namely irrigation water use, livestock water use, domestic water use, and aquatic ecosystems. Fitness for use is a scientific judgement, involving objective evaluation of available evidence, of how suitable the quality of the water is for its intended use. Water quality can therefore only be expressed in terms of fitness for use. Water quality assessment to determine fitness for use is based on assessment of chemical, physical and microbiological water quality of a water resource against an objective that has been set for the water resource, depending on the requirements of the specific water users, such as recreational, aquatic ecosystem, industrial use and domestic.

This implies that there is a user, and that it is known how the user is affected by changes in water quality. Water quality can be determined to be ‘good’, ‘threatened’ or ‘impaired’. As there is no clear definition or hard line that separates these ratings, the assessment determines its suitability for a purpose or purposes, or in relation to the control of defined impacts on water quality. Water Quality Planning Limits (WQPLs) reflects the decision on the definition of “good” and “impaired” water quality.

- Water resources rated as *good* water quality generally support all designated users in the resource.
- Water resources rated as *threatened* generally support all the designated users, but one or more of those uses may become impaired in the future (i.e., water quality may be exhibiting a deteriorating trend) if pollution/source control actions are not taken, and
- Water resources rated as *impaired* usually cannot support one or more of the designated users.

The South African Water Quality Guidelines (DWAF, 1996) currently serve as an assessment system to rate the quality of water resources. In terms of the guidelines narrative descriptions are used to express the judgements about fitness for use of the water for the different user groups in the absence of any water quality objectives:

- Ideal: Desirable water quality; target water quality range (TWQR)
- Acceptable: Suitable for long-term use
- Tolerable: Usually for a limited period only

- Unacceptable: Unfit for use

The descriptions are related to an associated effect of a particular water quality variable on a water user category (domestic, agriculture, recreation, aquatic ecosystem and industry).

The assessment of the water resource to rate its current water quality status in terms of fitness for use and associated water quality range usually supports or links to water quality management related targets and goals to a management action or objective that is required (Figure 34).

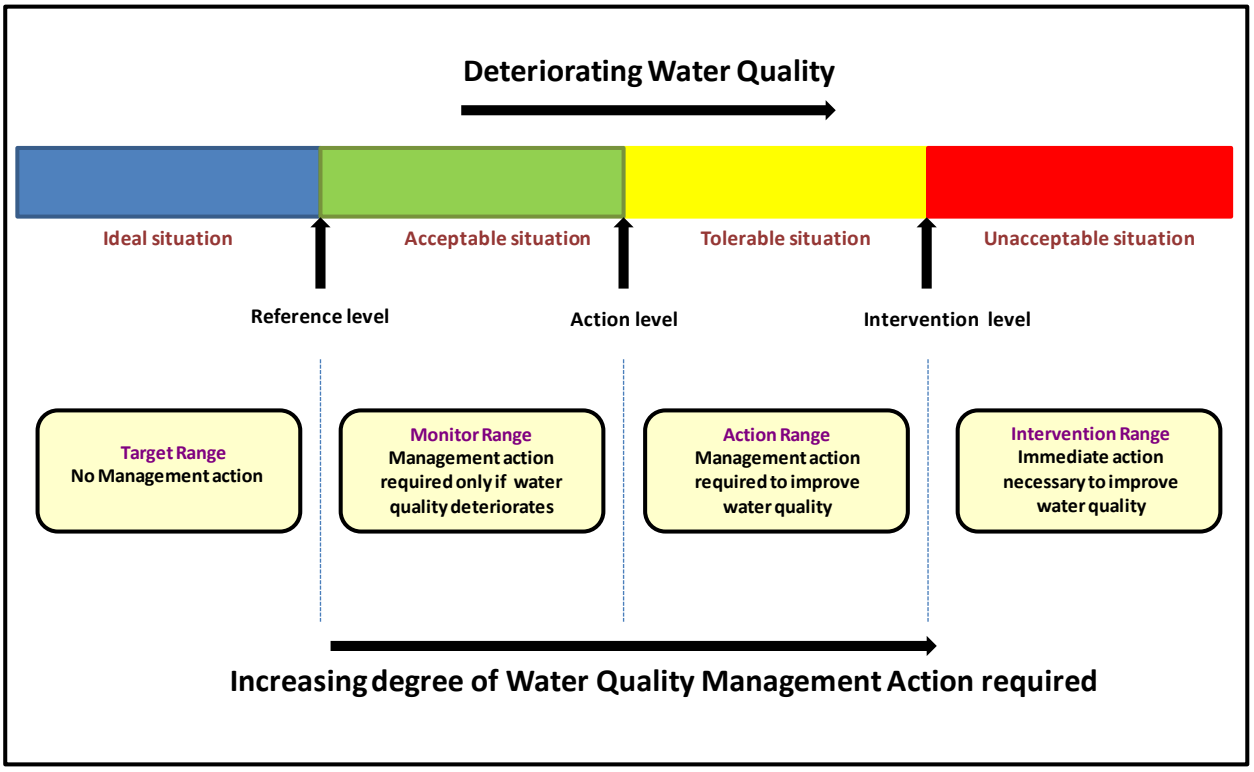

Figure 34: Relationship between assessment rating and degree of water quality management action required

In the Upper Orange River catchment, the major water user is agriculture with extensive irrigation along the mainstem Caledon River, Orange River and the Modder and Riet rivers as illustrated in Figure 35, which also highlights the extensive urban area in the Botshabelo and Mangaung area. There are a few diamond mines in the C5 secondary catchment, however return-flows from irrigation, run-off from urban areas and discharges from wastewater treatment works as the major drivers of water quality deterioration in the catchment. It is noted that the high sediment loads also emanate from the tributaries in Lesotho to the Caledon River because of over grazing.

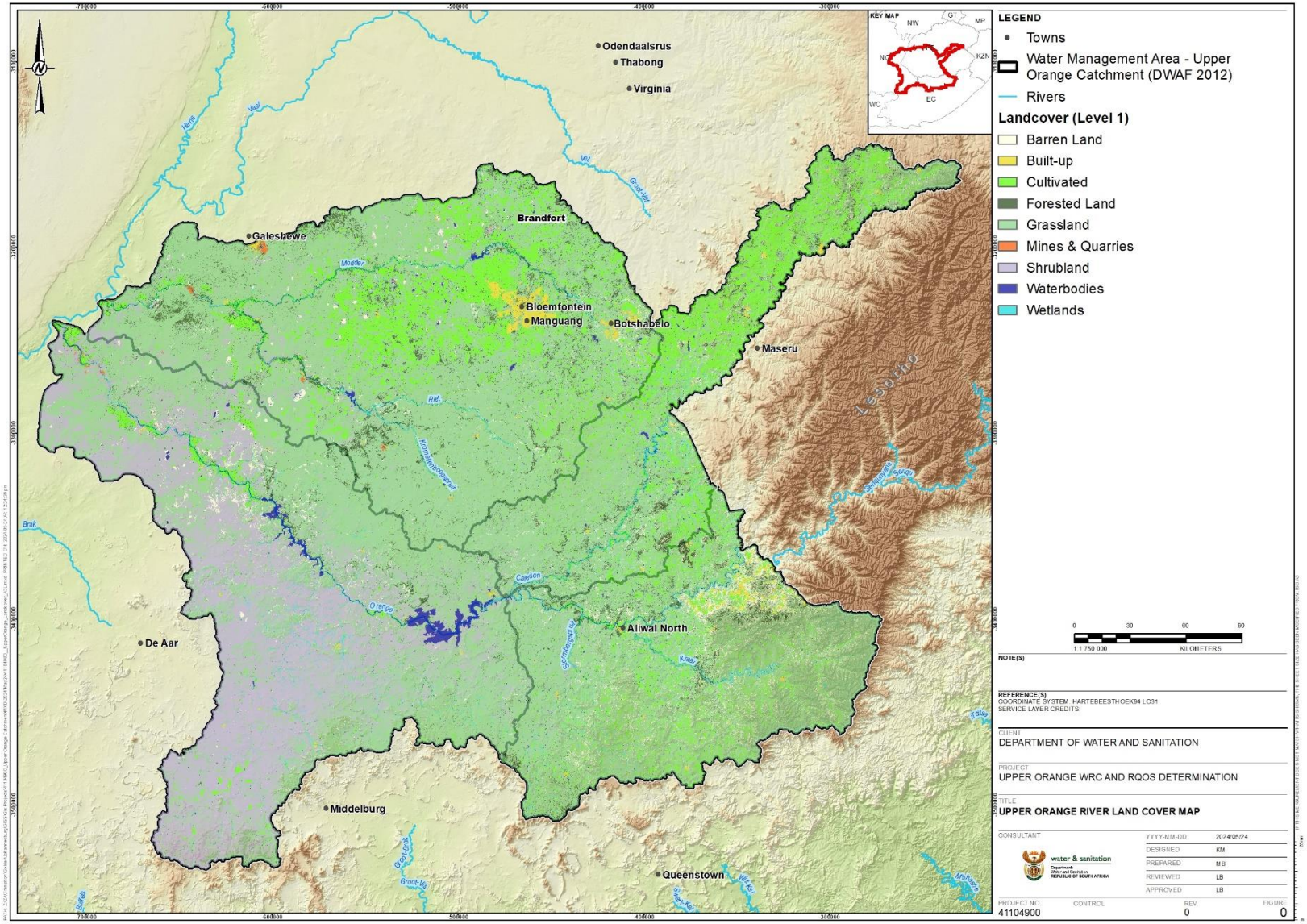

Figure 35: Land cover map

7.2. Water quality assessment criteria

The water quality criteria used for the assessment of chemical and physical water quality in the Upper Orange River (Table 23) were derived using the Resource Water Quality Objectives (RWQOs) Model (Version 4.0) (DWAF, 2006) which uses as its basis the South African Water Quality Guidelines (DWAF, 1996), Quality of Domestic Water Supplies: Assessment Guide, Volume 1 (WRC, 1998) and Methods for determining the Water Quality Component of the Reserve (DWAF, 2008) and are based on the strictest water user criteria, therefore representing conservative values. With respect to ionised ammonia, the General and Special Standard Effluent limit was applied due to the absence of an available water quality limit value. The fitness for use is described using four water quality categories: Ideal (blue), Acceptable (green), Tolerable (yellow), and Unacceptable (red) for concentrations greater than the upper boundary of the Tolerable range.

Table 23: Water quality criteria used to assess the present water quality status

Variable	Units	Bound	Ideal	Acceptable	Tolerable	Unaccep-table
Calcium (Ca)	mg/l	Upper	10	80	80	<80
Chloride (Cl)	mg/l	Upper	40	120	175	<175
Total Dissolved Solids DMS (TDS)	mg/l	Upper	200	350	800	<800
Electrical Conductivity (EC)	mS/m	Upper	30	50	85	<85
Fluoride (F)	mg/l	Upper	0.7	1	1.5	<1.5
Potassium (K)	mg/l	Upper	25	50	100	<100
Magnesium (Mg)	mg/l	Upper	70	100	100	<100
Sodium (Na)	mg/l	Upper	70	92.5	115	<115
Ionised Ammonia (NH_4-N)	mg/l	Upper	0.015	0.044	0.073	<0.073
Nitrate (NO_3-N)	mg/l	Upper	6	10	20	<20
pH	units	Upper	≤8	≤8.4	≤8.4	
		Lower	≥6.5	≥6.5	≥6.5	
Orthophosphate (PO_4-P)	mg/l	Upper	0.025	0.075	0.125	<0.125
Sulphate (SO_4)	mg/l	Upper	80	165	250	<250

7.3. Data sources

Data received from the Department's Resource Quality Information Services (RQIS) water quality database, the Water Management System (WMS), as well as data from the National Chemical Monitoring Programme (NCMP), the National Microbiological Monitoring Programme (NMMP) and the National Eutrophication Monitoring Programme (NEMP) have been used as the primary source of the water quality data for the analysis. In terms of water quality data assessment, the

water quality monitoring stations and related information are largely concentrated on main stem river and tributaries. Data gaps exist for many of the smaller tributary catchments.

Historical data for water quality monitoring points in the study area were obtained for the period 2013 to 2023. The monitoring points within the Upper Orange River catchment are primarily located on the main stem Orange River and some in the upper reaches of the major tributaries.

29 Registered points have monitoring data for rivers (and canals) and springs/eyes that are within the last 5 years, and 97 points within the last 10 years, of which 37 sites relate to discharges from wastewater treatment works (WWTW). It is noted that the frequency and extent of monitoring varies considerably. Monitoring sites are illustrated in Figure 36.

The WMS database primarily includes monitoring data for electrical conductivity, total dissolved salts (TDS), pH, sodium, magnesium, calcium, hardness, potassium, fluoride, chloride, sulphate, phosphate as P, total alkalinity as $CaCO_3$, ammonium as N, nitrate/ nitrite as N, and chemical oxygen demand. Trace metal analysis is seldom performed as part of this routine monitoring. Total suspended solids and turbidity are also not monitored. For the purposes of this study, the indicator variables set out in Table 26 above were used to assess status quo. No *E. coli* data was available on the DWS database to assess microbiological status, however the Green Drop assessment, results for which are described in section 7.6 includes this impact on the water resources.

Gaps in the data are noted for the following rivers:

- Modder-Riet River System (C5)
  - C51B – Upstream of Riet River from Ruigtespruit and Ospoortsrpuit
  - C51D – Tierpoort Dam catchment along Bo-Komspruit River
- Senqu-Orange River System before Caledon River Confluence (D1)
  - D12F – Nuwejaarspruit River
  - D13A – Bokspruit River
  - D13B – Upper Reaches of the Kraai River from Malpas and Rhodes
  - D13C – Sterkspruit River
  - D13E – Kraai River to Klein Wildebeesspruit River
  - D13F – Vaalhoek River
  - D13G – Wasbankspruit River
  - D13M – Kraain River from Roodewal to Elandspruit near Maletswai (Aliwal North)
  - D14B – Upper reaches of Stormberg Spruit to Molteno Dam
  - D14D – Bamboesspruit to Wonderboomspruit River confluence
  - D14F – Klein-Buffelspruit to Stormbergspruit before Barnardpspruit confluence
  - D14G – Brandspruit River
  - D14K – Palmietspruit along Orange River
  - D15H – Downstream of Kornetspruit to Orange River at Little Tafelberg
- Caledon River System
  - D22B – Meulspruit downstream of Harmonia to Caledon River

While there are sampling gaps, additional samples will be taken and analysed and considering the similar land-uses, the current data will be adequate to set appropriate water quality related RQOs.

7.4. Compliance Assessment

The water quality compliance assessment undertaken was based on the routine monitoring data collected by the DWS over the past 10 years. Statistics of the water quality status at monitored points for the period 2013 to 2023 was assessed by categorising the current water quality state using the fitness for use criteria set out in Table 23. For the sampling points listed in Appendix A, the 50th percentile (median), 5th and 95th percentile statistics were calculated and assessed against the criteria to determine compliance. Percentiles are descriptive statistics. The median statistic is representative of average water quality conditions, the 5th percentile statistic means that 5 percent of the concentrations were lower or equal to the statistic, and the 95th percentile represents the high concentrations observed at the sampling point.

Table 24 summarises the water quality compliance assessment undertaken against the water quality criteria per secondary catchment for the monitoring sites assessed.

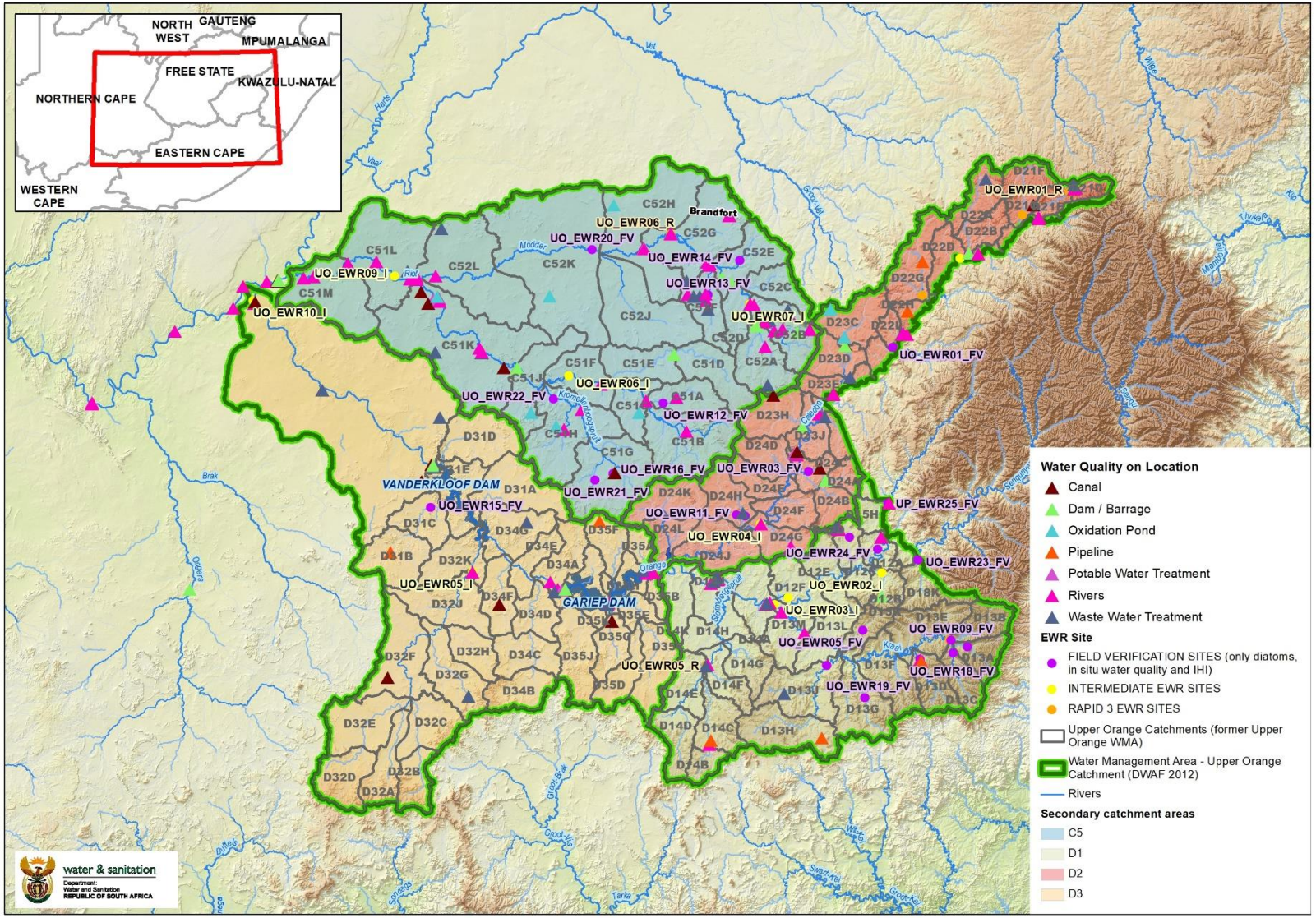

Figure 36: Surface water monitoring sites

7.4.1. Caledon River (D2 Secondary catchment)

The Caledon/ Mohokare River from its headwaters and tributaries to the Gariep Dam includes tertiary catchments D21, D22, D23 and D24. The major concerns in the catchment relate to the sediment emanating from Lesotho due to overgrazing and impacts from elevated nutrients from poor performing WWTW and to a less extent from urban run-off. Further nutrient contributions would emanate from return-flows from irrigation.

Table 24 shows that 90% of ionised ammonia and 73% of orthophosphate results in this catchment are within the unacceptable levels highlighting he concerns related to the poor performing WWTW and urban run-off.

Electrical conductivity and nitrate levels are also a concern with 46% of the electrical conductivity data, and 48% of the nitrate data falling in the tolerable to unacceptable range. pH is also noted to be predominantly >pH 8.5, so alkaline.

7.4.2. Orange River from Lesotho border to Gariep Dam (D1 Secondary catchment)

The Orange River from the Lesotho Border to the Gariep Dam includes the main tributaries namely Kornetspruit, Sterkspruit, Stormbergspruit and Brandwaterspruit, as well as the Kraai River catchment. The monitoring sites are limited in the Kraai River catchment.

The areas of concern in this catchment relate to the impacts from extensive rural villages and subsistence agriculture with some irrigation return-flows, as well as the urban impacts from the town of Maletswai (Aliwal North) and other smaller towns, and the associated WWTW.

Table 24 shows that 90% of ionised ammonia and 76% of orthophosphate results in this catchment are within the unacceptable levels highlighting the concerns related to the poor performing WWTW and run-off from urban and to a lesser extent rural villages.

Electrical conductivity and nitrate levels are also a concern with 52% (38% unacceptable) of the electrical conductivity data, and 47% of the nitrate data falling in the tolerable to unacceptable range. pH is also noted to be predominantly >pH 8.5, so alkaline.

7.4.3. The Orange River from the Gariep Dam, through Vanderkloof Dam to Marksdrift weir (D3 secondary catchment)

This area includes the Orange River from the Gariep Dam, through Vanderkloof Dam to Marksdrift weir, just before the confluence with the Vaal River including the Seekoei River in the south. Monitoring sites are limited in the Seeikoei River catchment.

The areas of concern in this catchment relate to the impacts from rural villages and subsistence agriculture, however far less intensive than in D1 and D2, with extensive irrigation return-flows downstream of the dams and along the Orange River mainstem.

Table 24 shows that 83% of ionised ammonia and 79% of orthophosphate results in this catchment are within the unacceptable levels highlighting the concerns related to the upstream poor performing WWTW and run-off from urban and to a lesser extent rural villages.

Electrical conductivity and nitrate levels are also a concern with 67% (42% unacceptable) of the electrical conductivity data, and 53% of the nitrate data falling in the tolerable to unacceptable range, likely related to the irrigation return-flows. pH is also noted to be predominantly >pH 8.5, so alkaline.

As part of the NGO Gariep Watch's October 2021 monitoring (Clean Stream, 2021), the following aspects were relevant to the monitoring site downstream of Vanderkloof Dam and the Hopetown WWTW, and considering that the conditions are still similar, are likely still relevant:

In-situ *water quality* measurements taken during the October 2021 survey measured the following:

- *Electrical Conductivity: 19mS/m*
- *pH: 7.1 – within the target for fish health (DWAF, 1996)*
- *Oxygen saturation 74.8%*
- *Dissolved Oxygen: 6.3mg/L - above the minimum guideline (>5mg/l) as set by Kempster et al. (1982) and should therefore not be limiting to aquatic biota*
- *Water temperature 18.6 °C*
- *Turbidity (visual): Slightly turbid*
- *Flow (visual): Moderate (96m3/s at Vanderklood Dam outflow at DWS weir D3H012)*
- *It is noted that the Gariep Watch quarterly monitoring program showed that Escherichia coli values increased to a database-high of 649 colony forming units /100 mL at the De Bron locality downstream of Hopetown during September 2021.*
- *Sediment analyses indicated that most variables were below the detection limit, however, the following elements are at levels above detection level and that may be of concern as they are marginally above the strictest South African water quality guideline (DWAF, 1996), where a limit is available: calcium, magnesium, sodium, potassium, manganese, strontium, iron, barium, silicon, phosphorous, gallium and titanium.*
- *Sediment toxicity test performed for site Hopetown was classified as having a "slight*
- *acute/chronic environmental toxicity hazard" (Class II) based on the 30% growth inhibition effect (chronic) and 40% mortality effect (acute) noted during the Heterocypris incongruens testing (Clean Stream, 2021).*

Diatoms have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution, as well as for general water quality. The results indicate that the biological water quality in October 2021 was classified as Good and the SPI score was 14.7 (B/C Ecological Category). Salinity concentrations and nutrient levels were elevated while organic load was low, as reflected by the PTV score of 2%. Further analysis of the various indices within OMNIDIA suggested that pollution levels were moderate in October 2021 (Clean Stream, 2021).

During the October monitoring event, the diatom community was dominated by species with an affinity for good water quality with high oxygenation rates, and low nutrient levels. These species usually flourish in moderate to high velocity waters and included *Cymbella excise* and *Achnanthidium* species. Most other dominant species had a preference for moderate water quality and elevated electrolyte content (Clean Stream, 2021).

Elevated nutrient levels were reflected by the dominance of *Stephanodiscus minutulus* which occurred in highest abundance. This species is found in strongly polluted water with high electrolyte content. *Nitzschia dissipata* was also dominant, which has an intermediate tolerance for nutrient levels and is an indicator of alkaline, hard water (calcium-based salinity). The dominance of this species indicates possible increased in salinity concentration. *Diatoma vulgaris* was also dominant and is found in mesotrophic to eutrophic waters with average electrolyte content; an alkalibiontic species and key indicator associated with pH change. No valve deformities were noted suggesting that metal toxicity was below detection limits or bioavailability was limited (Clean Stream, 2021).

7.4.4. Modder/ Riet River catchments (C5 secondary catchment)

The Modder-Riet River (main tributaries of the Vaal River system) in the north is the most impacted area. This catchment is well covered for surface water monitoring.

The areas of concern in this catchment relate predominantly to the impacts from the extensive urban areas of Mangaung Metropolitan Municipality. The impacts of the many poor performing domestic WWTW are highlighted by the data. Table 24 shows that 97% of ionised ammonia and 93% of orthophosphate data in this catchment are within the unacceptable levels.

Electrical conductivity and nitrate levels are also a concern with 46% of the electrical conductivity data in the tolerable range and 45% in the unacceptable range. pH is also noted to be predominantly >pH 8.5, so alkaline, and this catchment has a percentage of all the other parameters in the unacceptable range: calcium (4%), chloride (20%), potassium (2%), magnesium (13%), sodium (23%), and sulphate (7%).

7.5. Overview Status

Overall, the major areas of concern relate to nutrient enrichment, and associated expected microbiological contamination, from poorly preforming wastewater treatment works and run-off from urban areas, specifically in C5 secondary catchment. The latest Green Drop scores are summarised in section 7.6 to follow and support the water quality data assessment.

Further nutrient loads are also expected from irrigation return-flows.

Table 24: Summary of water quality compliance to the water quality criteria per secondary catchment

Sub-catchment	Calcium (mg/l)				Chloride (mg/l)				Total Dissolved Salts (mg/l)				Electrical Conductivity			
C5 - Modder Riet Rivers	96%			4%	17%	57%	6%	20%	4%	13%	67%	17%	4%	4%	46%	45%
D1 - Senqu-Orange River	100%				77%			23%	17%	67%		17%	24%	24%	14%	38%
D2 - Caledon River	100%				94%			6%	58%		42%		53%		13%	33%
D3 - Orange River Main Stem (DS Caledon)	100%				78%		11%	11%	56%	22%	11%	11%	29%	4%	25%	42%
Ideal	10				40				200				30			
Acceptable	80				120				350				50			
Tolerable	80				175				800				85			
Unacceptable	>80				>175				>800				>85			

Sub-catchment	Flouride (mg/l)				K				Magnesium (mg/l)				Sodium (mg/l)			
C5 - Modder Riet Rivers	76%		21%	3%	70%	23%	6%	2%	75%	12%	13%		49%	21%	8%	23%
D1 - Senqu-Orange River	100%				100%				92%		8%		85%			15%
D2 - Caledon River	92%			8%	94%			6%	94%		6%		94%			6%
D3 - Orange River Main Stem (DS Caledon)	89%			11%	100%				100%				89%			11%
Ideal	0.7				25				70				70			
Acceptable	1				50				100				92.5			
Tolerable	1.5				100				100				115			
Unacceptable	>1.5				<100				>100				>115			

Sub-catchment	Ionised Ammonia (mg/l)				Nitrate (mg/l)				pH			Orthophospate (mg/l)			
C5 - Modder Riet Rivers	0%	0%	3%	97%	51%	21%	23%	6%	17%	19%	64%	4%	1%	1%	93%
D1 - Senqu-Orange River	0%	0%	10%	90%	40%	13%	27%	20%	5%	19%	76%	10%	14%	76%	
D2 - Caledon River	0%	3%	7%	90%	42%	11%	32%	16%	6%	26%	68%	3%	20%	3%	73%
D3 - Orange River Main Stem (DS Caledon)	0%	4%	13%	83%	18%	29%	29%	24%	4%	29%	67%	8%	13%	79%	
Ideal	0.015				6				≤8 and ≥ 6.5			0.025			
Acceptable	0.044				10				≤8.4 and ≥ 6.5			0.075			
Tolerable	0.073				20				≤8.4 and ≥ 6.5			0.125			
Unacceptable	>0.073				>20							>0.125			

Sub-catchment	Sulphate (mg/l)			
C5 - Modder Riet Rivers	72%	13%	7%	7%
D1 - Senqu-Orange River	100%			
D2 - Caledon River	100%			
D3 - Orange River Main Stem (DS Caledon)	100%			
Ideal	80			
Acceptable	165			
Tolerable	250			
Unacceptable	>250			

7.6. Green Drop Assessment

The Green Drop scores provide an indication of potential water quality impacts of the wastewater treatment works (WWTW) on the receiving water resources, specifically in relation to microbiological quality and nutrients. The higher the CRR, the worse the situation is. The results indicate that the WWTWs in the Upper Orange River catchment are a threat to water quality.

The relevant DWS Green Drop Reports for the Free State, Eastern Cape and Northern Cape (DWS, 2022) were reviewed to obtain an assessment of the status of wastewater services in the Eastern Cape, Northern Cape and Free State Provinces which fall within the Upper Orange River catchment. The Green Drop audit scores indicate poor performance by almost all wastewater treatment works in the catchment, with low Green Drop scores and high cumulative risk (Table 25).

Wastewater systems qualify for Green Drop Certification status when achieving an audit score of ≥90%, and this score is related to the following key performance areas (KPA):

- *KPA A: Capacity Management* (15%) with respect to registration of the WWTW and process controllers, maintenance, engineering and management, and scientific capacity, where relevant.
- *KPA B: Environmental Management* (15%) with respect to risk management, operational monitoring, compliance (effluent) monitoring, sludge classification and monitoring and laboratory credibility.
- *KPA C: Financial Management* (20%) with respect to wastewater operations cost determination, energy demand, operations & maintenance budget, operations & maintenance expenditure, and supply chain management of services and treatment products.
- *KPA D: Technical Management* (20%) with respect to wastewater treatment works design capacity management, process audit, sewer main inspection, wastewater asset register, and bylaws and enforcement (local regulation)
- *KPA E: Effluent and Sludge Compliance* (30%) with respect to monitoring data submission to DWS, water use authorisation, effluent quality compliance and, where needed, sludge quality compliance.

It is important to note that if such systems fail to achieve ≥90% in microbiological and/or chemical compliance, the system would be disqualified from Certification and the score adjusted to 89%.

Microbiological quality is selected for its importance in safeguarding the health of the downstream users and the integrity of the water resource. The presence of pathogens and bacteriological indicators in the final effluent implies that disinfection and nutrient removal operations of a WWTW are not optimised or functional; and chemical quality is selected for its negative impact on the water quality of the receiving waterways into which WWTW release final effluent. The presence of nitrogen and phosphate causes enrichment of inland and coastal waters. This leads to low-

oxygen waters and dominance of certain algae and organisms, which leads to biodiversity losses, loss of fishery resources, seagrass, corals, and other aquatic life.

The cumulative risk rating (CRR) relates to a rating of the hydraulic design capacity of the treatment plant in ML/day, operational flow as % of the installed design capacity, the number of non-compliant effluent quality parameters at point of discharge to receiving water body and number of technical skills gaps (supervision, operation, maintenance) in terms of Regulation 2834 and Draft Regulation 813.

Risk is calculated for each system using a formula: CRR = (A x B) + C + D, where:

A = Hydraulic design capacity of the treatment plant in megalitres per day (ML/d)

B = Operational flow as % of the installed design capacity

C = Number of non-compliant effluent quality parameters at point of discharge to receiving water body

D = Number of technical skills gaps (supervision, operation, maintenance) in terms of Regulation 2834 and Draft Regulation 813.

Considering the data summarised in Table 25 not one of the WWTW in the Upper Orange River catchment has achieved Green Drop Status. Only 7 of the 56 WWTW assessed received a Green Drop score higher than 50% and only 9 a CRR% of less than 50%. These scores indicate the potential for high microbiological and chemical contamination downstream of all the WWTW.

Table 25: Green Drop scores and Cumulative Risk Rating for Wastewater Treatment Works in the Upper Orange (DWS, 2022)

Province	Local Municipality	WWTW Name	WWTW Process Type	System Design capacity (ML/d)	Resource discharged to	Green Drop score - 2021	Cumulative Risk Rating - 2021
Free State	Dihlabeng	Clarens STW	Oxidation ponds	2.5	Little Caledon River	52	47
Free State	Dihlabeng	Fouriesburg STW	Oxidation ponds	No data	Caledon River	No data	65*
Free State	Dihlabeng	Rosendal STW	Oxidation ponds	No data		No data	65*
Eastern Cape	Emalahleni	Dordrecht	Oxidation ponds	2.8	Anderson Dam	27	82
Eastern Cape	Gariep	Venterstad	Activated sludge	1	Natural Pan	44	77
Eastern Cape	Gariep	Oviston	Activated sludge	0.2	Gariep Dam	37	94
Eastern Cape	Gariep	Burgersdorp	Activated sludge	2.5	Stormberg River	35	94
Eastern Cape	Inkwanca	Molteno	Maturation Ponds	2.7	Stormberg River	51	88
Free State	Kopanong	Fauresmith STW1	Oxidation ponds	1	Riet River	16	94
Free State	Kopanong	Edenburg	Oxidation ponds	No data	Riet River	41	47
Free State	Kopanong	Bethulie	Oxidation ponds	No data	Orange River	44	47
Free State	Kopanong	Philippolis	Oxidation ponds	0.5	No data	52	47
Free State	Kopanong	Jagersfontein	Oxidation ponds	2.2	Re-use	14	94
Free State	Kopanong	Gariepdam	Oxidation ponds	1	Natural Pan	12	94
Free State	Kopanong	Reddersberg STW1	Oxidation ponds	1	Fouriespruit	16	94
Free State	Kopanong	Springfontein	Oxidation ponds	0.5	Bossiespriuit	49	47
Free State	Kopanong	Trompsberg (New)	Oxidation ponds	0.7	Tributary of the Van Zylsspruit	46	47
Free State	Letsemeng	Petrusburg	Oxidation ponds	2	Evaporation ponds	61	47
Free State	Letsemeng	Luckhoff STW	Oxidation ponds	0.95	Riet River	46	47
Free State	Letsemeng	Jacobsdal STW	Oxidation ponds	1.5	Riet River	33	88
Free State	Letsemeng	Koffiefontein	Oxidation ponds	2.5	Riet River	29	94
Free State	Letsemeng	Mine (Koffiefontein)	Oxidation ponds	No data	Riet River	29	94
Free State	Letsemeng	Oppermansgronde	Oxidation ponds	0.5	Evaporation ponds	26	94
Eastern Cape	Maletswai	Jamestown	Oxidation ponds	0.75	No discharge	68	65

Province	Local Municipality	WWTW Name	WWTW Process Type	System Design capacity (ML/d)	Resource discharged to	Green Drop score - 2021	Cumulative Risk Rating - 2021
Eastern Cape	Maletswai	Aliwal North	Activated sludge	3	Orange River	40	68
Free State	Mangaung	Bloemspruit	Activated sludge	56	Bloemspruit	32	84
Free State	Mangaung	Bainsvlei	Oxidation ponds	5	Unknown stream to farmer	35	68
Free State	Mangaung	Welvaart	Oxidation ponds	5	Kaalspruit	32	77
Free State	Mangaung	Northern Works	Oxidation ponds	5	Bree River	30	68
Free State	Mangaung	Bloemdustria	Oxidation ponds	0.9	Renosterspruit	30	82
Free State	Mangaung	Suid-oostelike (dewetsdorp Pad)	Oxidation ponds	0.05	No data	24	94
Free State	Mangaung	North-eastern WWTW	Activated sludge	20	Irrigation - botanical gardens and farmer	32	77
Free State	Mangaung	Van Stadensrus	Oxidation ponds	0.03	Unknown	33	83
Free State	Mangaung	Botshabelo STW	Activated sludge	20	Small Modder River	36	77
Free State	Mantsopa	Ladybrand STW	Oxidation ponds	17.5	Cathcart Dam	29	96
Free State	Mantsopa	Hobhouse	Oxidation ponds	0.5	No discharge	31	82
Free State	Mantsopa	Thaba Patchoa	Oxidation ponds	No data	No discharge	33	83
Free State	Masilonyana	Brandfort	Oxidation ponds	No data	No data	11	100
Free State	Masilonyana	Soutpan STW	Oxidation ponds	1	Small Modder River	18	94
Free State	Mohokare	Rouxville	Oxidation ponds	1.5	Caledon River	24	94
Free State	Mohokare	Smithfield	Oxidation ponds	1	Caledon River	30	82
Free State	Mohokare	Zastron STW	Oxidation ponds	1	Montagu Dam	15	94
Free State	Naledi (now part of Mangaung)	Dewetsdorp STW	Oxidation ponds	0.05	No data	24	94
Free State	Naledi (now part of Mangaung)	Wepener STW	Oxidation ponds	2	Caledon River	21	94
Eastern Cape	Senqu	Sterkspruit	Oxidation ponds	0.2	Sterkspruit	39	94
Eastern Cape	Senqu	Lady Grey	Oxidation ponds	1.84	No data	70	65

Province	Local Municipality	WWTW Name	WWTW Process Type	System Design capacity (ML/d)	Resource discharged to	Green Drop score - 2021	Cumulative Risk Rating - 2021
Eastern Cape	Senqu	Barkley East (New)	Oxidation ponds	0.6	Langkloof River	48	71
Eastern Cape	Senqu	Barkley East (old)	Oxidation ponds	0.728	Langkloof River	57	53
Eastern Cape	Senqu	Herschel	Activated sludge	0.7	No data	36	100
Free State	Setsoto	Clocolan	Oxidation ponds	4.2	Mopedi River	24	88
Free State	Setsoto	Ficksburg STW	Activated sludge	12.2	Caledon River	14	96
Free State	Tokologo	Dealesville STW	Oxidation ponds	0.8	No discharge	46	47
Northern Cape	Umsobomvu	Noupoort	Oxidation ponds unlined	0.18	Zeeikoei River	17	94
Northern Cape	Umsobomvu	Colesburg	Oxidation ponds unlined	2.4	Orange River	18	88
Northern Cape	Umsobomvu	Norvalspont	Oxidation ponds unlined	0.142	No information	17	94

*average data for the local municipality

8 INTEGRATED UNITS OF ANALYSIS

8.1. Delineation of IUAs

Integrated Units of Analysis (IUA) are spatial units that are defined as significant water resources. The objective of defining IUAs is to establish broad scale units for assessing the socio-economic implications of different catchment configuration scenarios and to report on the ecological conditions at a sub-catchment scale (DWA, 2007a).

Delineation of units of analysis is required as it would not be appropriate to set the same water resource class for all water resources in a catchment. The delineation of a catchment into IUAs for the purpose of determining the water resource classes for significant rivers is done primarily according to a number of socio-economic criteria and drainage region (catchment) boundaries. IUAs are thus a combination of socio-economic zones and watershed boundaries (DWA, 2007b). Ecological information and biophysical characteristics also play a role in the delineation.

8.1.1. Approach

The process followed in terms of IUA delineation is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, 2007b).

In the IUA delineation process overlaying the required data does not necessarily result in a logical and clear delineation and expert judgement, a consultative process and local knowledge may be required for the final delineation of the IUAs. The practicalities of dealing with numerous significant water resources and associated tributaries within one study must also be considered to determine a logical and practical set of IUAs.

8.1.2. Delineation

The following suite of characteristics was analysed, assessed, and reviewed for delineation of the preliminary IUAs within the Upper Orange River catchment:

- Socio-economic zones (SEZs)
- Catchment area boundaries (drainage regions and water resource systems)
- The resolution of the hydrological analysis and available water resource network configurations within the water resource models, and the practicalities of the existing model setup and network in terms of the future scenario evaluation for each IUA.
- Location of significant water resource infrastructure.
- Land use characteristics.
- Distinctive functions of the catchments in context of the larger system.
- The Present Ecological State (PES) of each biophysical node was considered, the type of impacts and the homogeneity of the status and impacts.

- Present status of water resources.

8.1.3. Integrated Units of Analysis (IUA) Descriptions

Based on the SEZs described in Chapter 3, and the assessment of the information and considerations outlined in the other chapters and sub-chapters, ten IUAs have been delineated for the Upper Orange River catchments. The availability of representative EWR sites within each IUA, catchment boundaries and modelling nodes included in the WRPM were also considered. Overlaying these aspects and data has resulted in the delineation of the IUAs which are similar for the various components perspective, and which can be managed as an entity, in addition comprising a logical unit for which scenarios can be designed and evaluated. These are further described in the sub-chapters to follow.

The ten IUAs delineated are listed in Table 26 and illustrated in Figure 37. The identified IUAs were delineated in collaboration with the DWS project team and will only be finalised once further comment has been received and incorporated as relevant, from broader stakeholders.

Table 26: IUAs delineated in the Upper Orange River catchment

IUA	Description	Quaternary
1	Golden Gate	D21D and a portion of D21A along South Africa/ Lesotho border
2	Caledon/ Leeu River	D21E, D21F, D21G; portion of D21C; D22A, D22B; portions of D21H and D22C along the SA/ Lesotho border; Portions of D22D, D22G, D22H, D22L, Portion of D23A, D23C, D23D and portion of D23E
3	Caledon River	D23F, D23G, D23H, D23J, D24A, D24B, D24C, D24D, D24E, D24F, D24G, D24H, D24J, D24K and D24L
4	Kraai River	D13A – D13M
5	Upper Orange River	D12A – D12F, D14A – D14K, Portions of D15G, D15H, D18K and D18L
6	Gariep Dam	D34A, D34B, D34C, D34D, D34E, D34F, and D34G, D35A, D35B, D35C, D35D, D35E, D35F, D35J, D35G, D35H, D35K
7	Seeikoei River	D32A, D32B, D32C, D32D, D32E, D32F, D32G, D32H, D32J, D32K
8	Vanderkloof Dam	D33A – D33K (along main stem Orange River); D31A – D31E
9	Upper Modder River	C52A, C52B, C52C, C52D, C52E, C52F and C52G
10	Modder/ Riet River	C51A, C51B, C51C, C51D, C51E, C51F, C51G, C51H, C51J, C51K, C51L, C51M, C52H, C52J, C52K and C52L

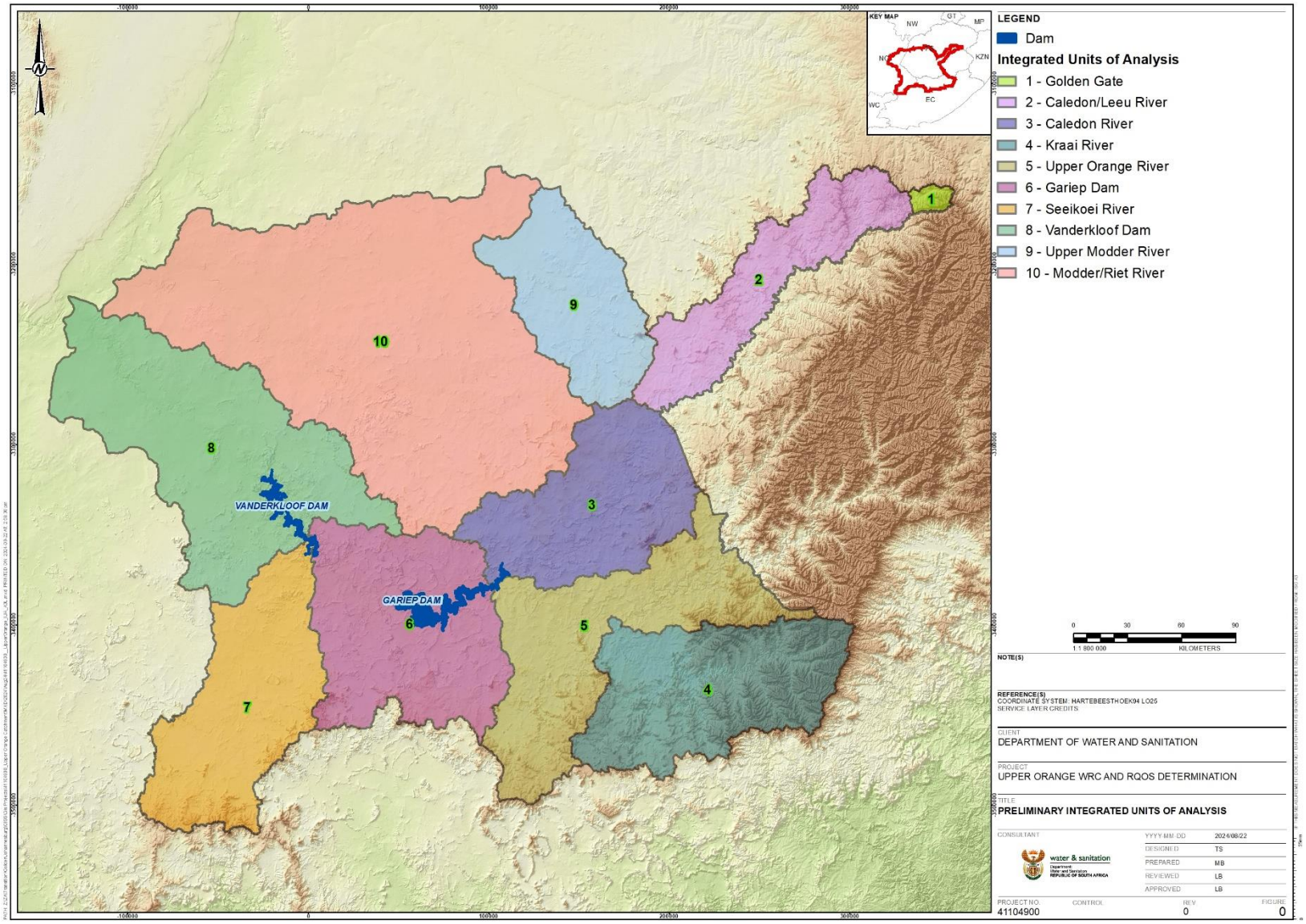

Figure 37: Preliminary Integrated Units of Analysis

8.2. Wetlands per IUA

The resulting map of the wetlands was used during the IUA workshop to support the IUA delineations. An indication of wetlands per IUA is provided in Figure 32 with a summary of the extent of wetlands per type, and a list of the preliminary Priority Wetlands per IUA, indicated in Table 27. The preliminary Priority Wetland list was sourced from the high confidence Reserve Determination Study (DWS, 2022). The list of Preliminary Priority Wetlands may be updated as more information on the wetlands within each IUA is collected during the study.

Based on the IUA delineation, the IUA with the largest number of wetlands is IUA 08 (Vanderkloof Dam) with 2.5% of wetland habitat relative to the size of the IUA, followed by IUA 10 (Modder/Riet), with 2% of wetland habitat. IUA 10 also has the highest number of priority wetlands (Figure 38). The IUA with the least wetlands mapped is IUA 1 (0.14%), which is also the smallest IUA in size (approx. 43.53 ha) (Table 27).

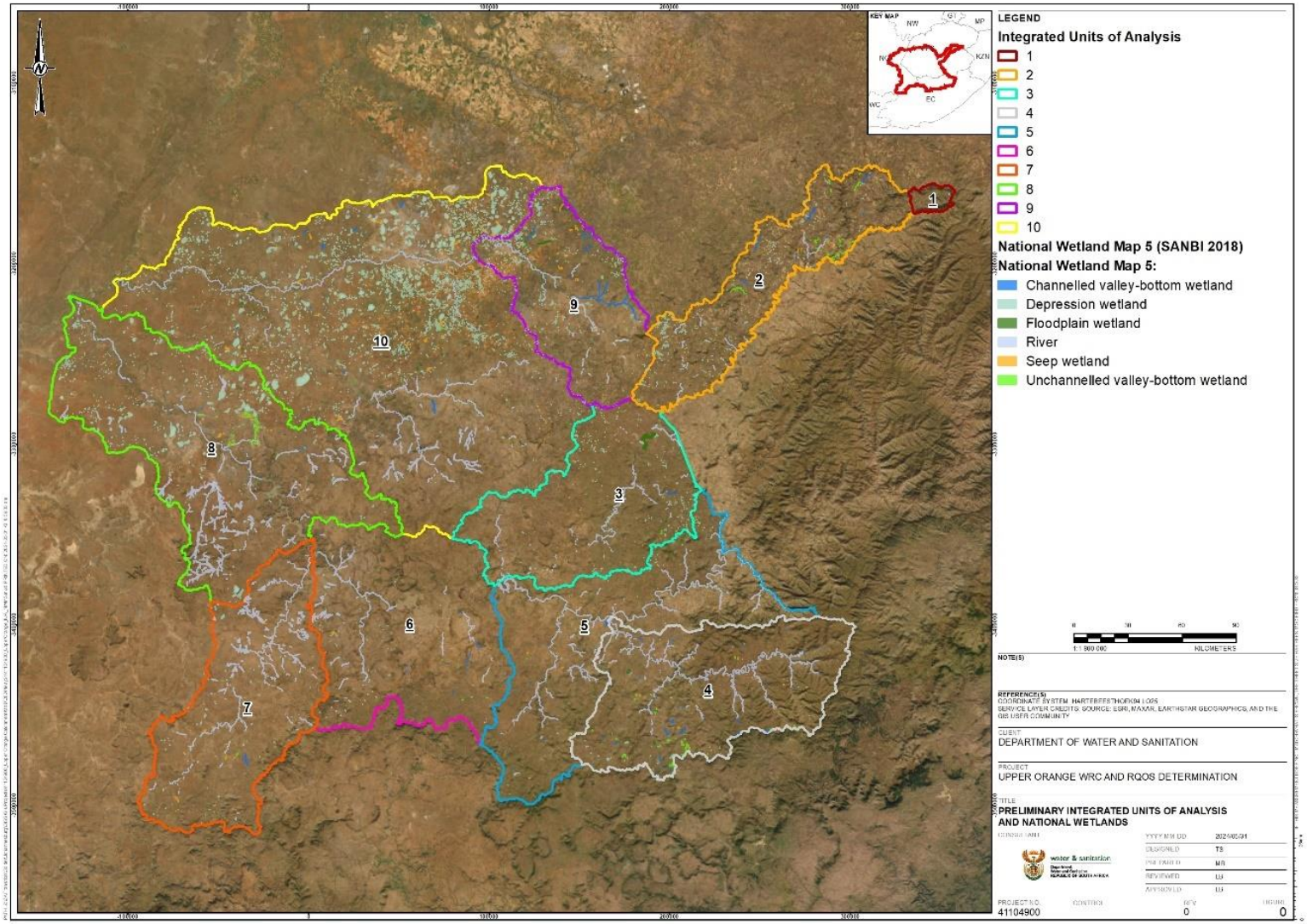

Figure 38: Map showing the extent of wetlands mapped per IUA (compiled from GIS coverage of Van Deventer et al., 2018)

Table 27: Wetland extent (area) and percentage of area per IUA (source: GIS coverage of Van Deventer *et al*., 2018) Also indicated is a preliminary list of Priority Wetlands per IUA verified from DWS (2022)

Catchment (IUA)	Area (ha)	Area of wetlands in IUA (ha)	% Wetland area in IUA	Depression		Floodplain		Seep		Channelled VB		Unchanneled VB		River		Preliminary List of Priority Wetlands (DWS,2022)
				ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	
Golden Gate(1)	30,718	43.53	0.14%	-	-	34.63	0.11	-	-	1.99	0.01	-	-	6.92	0.02	• None prioritised
Caledon/ Leeu River (2)	631,886	3 022.03	0.48%	1 170.17	0.19	-	-	109.18	0.02	681.96	0.11	700.88	0.11	359.84	0.06	• Brandwater floodplain • Rantsho wetland complex
Caledon (3)	822 797	4 935.94	0.60%	887.86	0.11	2 509.67	0.31	12.45	0.00%	40.67	0.0	42.69	0.01	1 442.61	0.18	• Sandspruit wetland
Kraai River (4)	934 709	4 902.46	0.52%	555.53	0.06	407.61	0.04	199.88	0.02	743.24	0.08	553.52	0.06	2 442.68	0.26	• Tiffindell Seep • Klein-Wildebeespruit wetland complex • Luckhof depression wetland complex • Otto du Plessis Pass wetland UCVB and CVB • Wolwespruit headwaters • Barkley Pass wetland complex
Upper Orange River (5)	1 024 091	6 904.29	0.67%	142.31	0.01	99.41	0.01	39.66	0.00	150.59	0.01	36.76	0.00	6 435.56	0.63	• Maletswai, CVB/UVB wetland complex
Gariep Dam (6)	1 064 786	4 090.80	0.38%	126.75	0.01	-	-	92.34	0.01%	63.29	0.01	42.08	0.00%	3 766.34	0.35	• None prioritised
Seekoei River (7)	915 159	9 811.74	1.07%	804.37	0.09	-	-	308.67	0.03%	352.70	0.04	59.23	0.01%	8 286.77	0.91%	• Gordonville CVB/UVB
Vanderkloof Dam (8)	1 449 349	36 231.46	2.50%	13 937.18	0.96	-	-	199.71	0.01	101.23	0.01	492.45	0.03%	21 500.89	1.48	• Philipstown unchanneled valley-bottom (UCVB) wetland complex
Upper Modder River (9)	632 039	6 122.45	0.97%	2 859.67	0.45	418.69	0.07	246.91	0.04	1 813.85	0.29	35.45	0.01%	747.89	0.12	• Aardoringspruit • Kaalspruit wetland complex
Modder/Riet Rivers (10)	2 846 614	62 982.20	2%	50 721.99	2	156.05	0.00	1 873.43	0.00	999.72	0.00	134.91	0.00	9 096.09	0.00%	• Soutpan Depression wetland complex • Jagersfontein DCVB wetland
	10 352 148	**139 046.90**	**1%**	**71 205.83**	**51%**	**3 626.05**	**3%**	**3 082.23**	**2%**	**4 949.23**	**4%**	**2 097.96**	**2%**	**54 085.60**	**39%**	

8.3. Groundwater Resource Units

8.3.1. Delineation

The Upper Orange River catchment consist of 129 Quaternary Catchments. The quaternary catchment demarcations are based on their internal surface water drainage patterns/systems. For the Upper Orange River catchment, the quaternary catchments were classified/grouped into ten (10) clusters which represents the ten (10) Integrated Units of Analysis (IUAs)(Table 26).

Generally, the groundwater aquifer systems do not fit perfectly into the quaternary catchment demarcations, however, in the case of the Upper Orange River catchment, the geological formations are quite horizontal and the exploited aquifer systems are regarded as merely shallow systems (i.e., <65 mbgl). From a groundwater flux “point of view”, it is expected that groundwater flow will mimic the topography and report to the local surface water domain – as can be seen in the large groundwater flow contribution(s) to the baseflows in the surface water systems.

8.3.2. Previous hydrogeological delineations

The 2024 Reserve Determination study consulted the approach followed by earlier studies conducted by the Water Research Commission (cited in the Resource Units Report (DWS, 2022)). Using datasets generated by the Water Research Commission (WRC 2012, cited in DWS, 2024), groundwater resource units’ delineation for the Upper Orange River catchment used the following criteria:

- Aquifer Type: The catchment has two basic aquifer types, i.e. fractured as well as fractured and intergranular.
- Borehole Yield: Borehole yields for the two aquifer types were further subdivided into borehole yields >2.0l/s and borehole yields <2.0l/s.
- Groundwater Quality: In terms of groundwater quality, the Upper Orange River catchment has two broad subdivisions, i.e. groundwater quality with ECs <100 mS/m and groundwater quality with ECs between 100 – 300mS/m – but in some cases in the order of 500-600 mS/m.
- Stressed catchments: The study area has several stressed quaternary catchments, defined as catchments where the groundwater recharge is less than the sum of groundwater abstraction, groundwater contribution to baseflow and basic human needs (BHN).
- Groundwater Recharge: The catchment was further subdivided based on groundwater recharge criteria. A recharge threshold value of 20mm/annum was used to differentiate between high recharge (>20mm/annum) and low recharge (<20mm/annum).

8.3.3. Current (updated) hydrogeological delineations for Groundwater Resource Units

For this classification and RQOs study, the groundwater resource unit demarcations used in the reserve determination study were regrouped to correlate with the surface water integrated units of analysis (SwIUAs) where possible – this approach is to foresee that the groundwater and surface water classification and RQOs are included under the same overarching delineations required for the application of the National Water Act (groundwater use licensing and protection).

This updated and correlated groundwater resource unit grouping is illustrated in Figure 39. Where the groundwater characteristics are significantly different, sub-divisions were included inside the SwIUA demarcation(s). In extreme cases, based on the groundwater borehole yield model, separate sub-divisions were used and the GRU then includes two or more quaternary catchments from two/three SwIUAs (see GRU 9.2 that consists of two quaternary catchments from two surface water IUAs).

8.3.4. Delineation Approach and results

8.3.4.1. *Groundwater Resource Category*

A groundwater resource classification should be based on the following criteria:

- Groundwater quantity classification:
  - Borehole yield class (BYC);
  - Aquifer system's Stress Indices (SIs); and
  - Allocable groundwater.
- Groundwater Quality classification:
  - Hydrochemical characteristics; and
  - Aquifer vulnerability (in terms of deterioration of groundwater quality due to land use activities).

Based on the groundwater qualities in the Upper Orange River catchment, an assessment done for the 2024 Reserve Determination study, (i) aquifer Stress Indices and (ii) allocable groundwater volumes were estimated.

The information on groundwater quality is limited and many quaternary catchments do not have any recent groundwater quality references (since about 1995). However, based on the rainfall patterns, surface water quality information and the aquifer characteristics (rock formations), it is assumed that extrapolations from quaternary catchments with sufficient water quality data would be possible and will be applied for the WRC and RQOs assessment to come (this study/assessment). Using the available data, the groundwater quality criteria fall merely in the Class 0 (Good) to Class 3 (Marginal) water quality types. This assessment is based on [quite] old water quality information, i.e., the 2006 DWS Geohydrological Maps Series. An update is therefore required, and it is foreseen that several Class 3 (Poor) and very likely, Class 4 (Unacceptable) water quality types will be present especially where large groundwater volumes are used for bulk wate supplies for irrigation and municipal wastewater discharges. It is expected that elevated nitrates will be one of the constituents of concern to be noted.

Quaternary Catchments with Marginal to Poor (and probably Unacceptable) water quality criteria, as well as stressed groundwater quantities, especially Allocable Groundwater volumes in GRUs, and for that matter, the surface water Integrated Units of Analysis (IUAs) will be classified as hot spots where water resource classification and RQOs should be used to prevent further deterioration of the groundwater resources, and where possible set conditions to recover from these impacts.

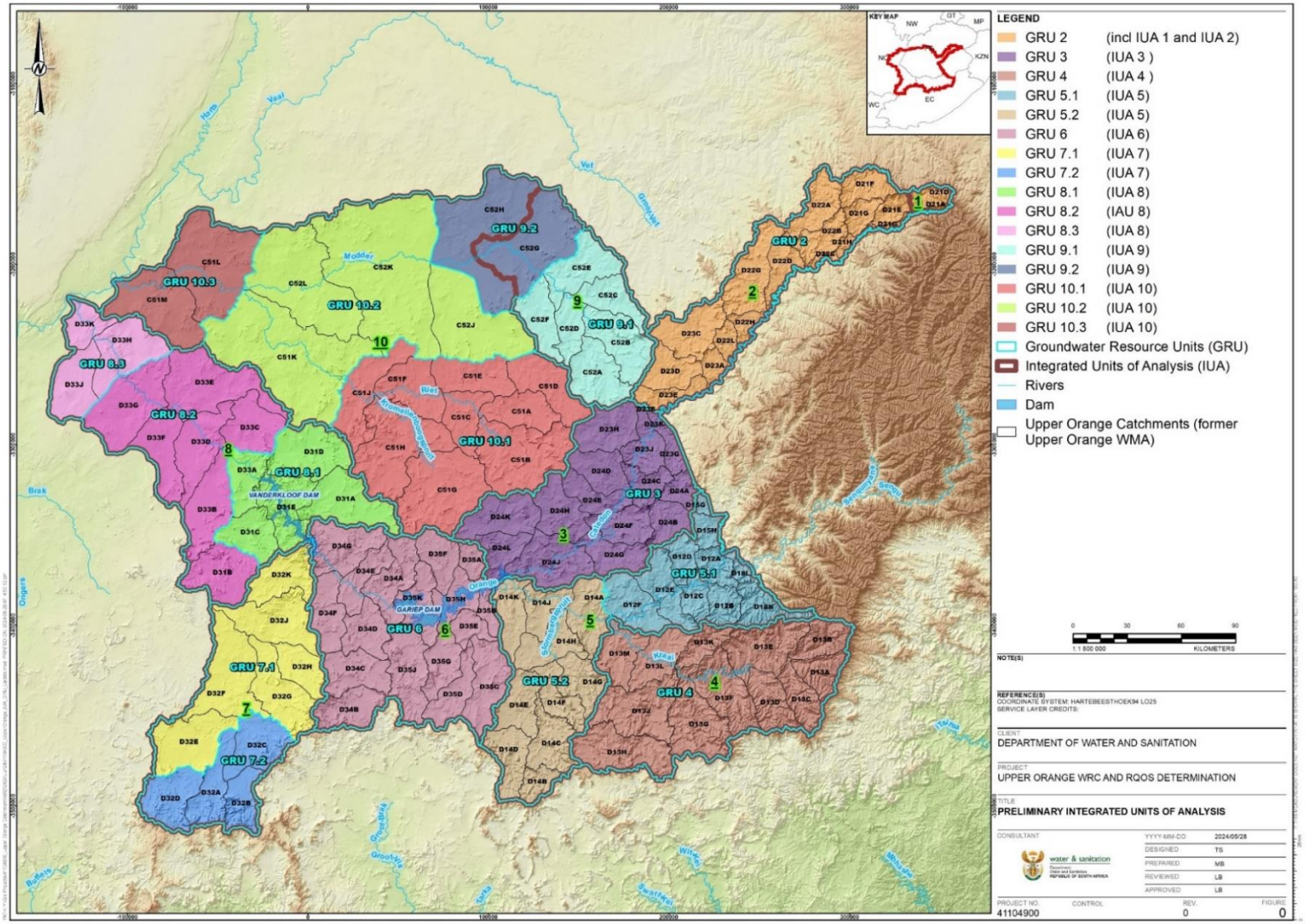

Figure 39: Delineation of Groundwater Resource Units (including Sw-IUAs)

8.3.4.2. *Groundwater Reserve*

The groundwater Reserve determination for the Upper Orange River catchment was conducted in 2024 as part of a High Confidence Reserve Determination study of the Upper Orange WMA by JG Afrika (Pty) Ltd. for Ground Truth Environment & Engineering, 2024. The 2024 groundwater use figures for the Upper Orange River catchment were estimated at ±132 Mm^3/a are consumed – based on the WRC (2012) assessment – cited in the Ground Truth 2024 Reserve Determination assessment (DWS, 2024). According to this estimation, 80% is used for agriculture supplies, 13% is used for agricultural livestock and 3% for municipal purposes – the municipal use is probably much higher in those municipalities where water reticulation systems have been upgraded to "in-house" water supplies. In the drier western and southern parts of the catchment, groundwater is the main source of water for rural domestic supplies and stock watering.

This 2024 reserve determination created "Allocable" Groundwater volumes which are questionable in many instances and will have to be evaluated considering the expected long-term climate variations that are becoming more notable in the semi-arid regions of southern Africa.

8.3.4.3. *Localised pollution*

As mentioned above, groundwater quality data for the Upper Orange River catchment are lacking general coverage in the catchment, however, there are indications that local groundwater resources are impacted by poor management of waste and wastewater from all towns and villages.

8.3.4.4. *Stress Index/Hotspots*

Both criteria indicated that the groundwater quantities in the Upper Orange River catchment are classified "Natural" (5% SI[3]) to "Good" (<20% SI), however, there are a few QUATERNARY CATCHMENT s where the groundwater quantities fall in the "Poor to Seriously Modified" (60& to 70% SI). ITO groundwater quantities, hotspots identified were:

- GRU 9.2 (IUA 9: C52G & IUA 10: C52H); and
- GRU 10.2 (IUA 10: C52J & C52K).

ITO ground water qualities, hotspots identified were:

- GRU 5.2 (IUA 5: D14A);
- GRU 9.2 (IUA 9: C52H)[4];
- GRU 5.2 (IUA 5: D14A); and
- GRU 10.2 (IUA 10: C51M)♦.

8.3.4.5. *Contribution to baseflow (as applicable)*

[3] A Stress Index of 50% indicates that 50% of the long-term recharged water is groundwater used.
[4,♦] Ecca Group (marine) mudrocks, and area known for several salt mines (salt pans).

For the 2024 Reserve Determination, only monthly surface flow data was available for 129 quaternary catchments, and consequently the traditional baseflow separation techniques could not be applied – instead, (quoted from DWS, 2024) … "the technique considers the monthly flow during dry months, specifically extracting the lowest average monthly flows during dry months. A desktop analysis was conducted using these lowest monthly flows as a proxy for baseflow". In this assessment, a sensitivity analysis was conducted to determine the significance of the differences between three options. The results indicated an insignificant difference, and therefore an average of the results from the three options were used to determine the baseflow.

The Upper Orange-Senqu River basin coincides with a major transboundary aquifer, the Karoo Sedimentary Aquifer. The Stormberg Group of the Karoo Supergroup underlying the trans-boundary area comprises horizontal to sub-horizontal dipping sedimentary rocks of the Burgersdorp, Molteno, Elliot and Clarens Formations. Estimated groundwater contribution(s) to the surface water systems in the upper parts of the Catchment, i.e., IUA3, 4 and 5 is expected to be high, e.g., for quaternary catchment D13E (GRU-IUA 4) was estimated as ±65 Mm^3/a (DWS, 2024). Further downstream, GRU-IUA 6, the groundwater contribution is much lower at ±0.75 Mm^3/a.

8.4. Preliminary Surface Water Resource Units

Considering the IUAs delineated, and integration of the status quo components discussed in the above chapters, as well as expert knowledge and discussions with specialists, catchment water resource managers and the DWS study team, 40 surface water resource units (RUs) have been preliminary delineated for the Upper Orange River catchment. The RUs are listed and described in Table 28 and illustrated in Figure 40: Preliminary Resource Units delineated. The resource units will form the basis of the RQO determination process once the water resource classes have been set.

Table 28: Preliminary surface water Resource Units

RU Number	Resource Unit Description	Quaternary catchments
IUA 1: Golden Gate		
1.1	Little Caledon River with Caledon River in the D21A portion in SA	D21D and a portion of D21A along SA/ Lesotho border
IUA 2: Caledon/ Leeu RIver		
2.1	Little Caledon River and Caledon River along the Lesotho Border including tributaries Moolmanspruit and Meulspruit, and the Meulspruit Dam	D21E, portion of D21C; D22A and D22B; portions of D21H and D22C along the SA/ Lesotho border
2.2	Swartspruit and Brandwater River, tributaries of the Caledon River	D21F and D21G
2.3	Caledon River along the Lesotho Border to the Leeu River confluence including tributaries: Modderpoortspruit, Tenniskopspruit, Tweelingspruit, Appledorespruit and Bokpoortspruit, including Cathcartdrift Dam	Portions of D22D; D22H; D22L, Portion of D23A, and portion of D23E

RU Number	Resource Unit Description	Quaternary catchments
IUA 1: Golden Gate		
2.4	Leeu River and tributaries Klein-Leeu River and Mokopu River, and including Lovedale and Newberry dams	D23C, D23D
2.5	Armenia Dam on the Leeu River	D23C
2.6	Mopeli River and tributaries: Rantsho River, Morakabi River, McCabesspruit, Beytelspruit and Modderpoortspruit, and Mopeli Dam	D22G
IUA 3: Caledon		
3.1	Caledon River and tributaries Klipspruit, Rietspruit, Nuwejaarspruit and Bloemspruit	D23H, D23J, D23G and D23F
3.2	Welbedacht Dam in the Caledon Nature Reserve	D23J
3.3	Caledon River and tributaries Boesmanskopspruit, Vaalspruit, Wilgeboomspruit, Vinkelspruit, Grahamstadspruit, Sandveld, Skulpspruit, Slykspruit and Hartbeesfontein	D24D, D24E, D24F, D24G, D24H and D24J; D24K and D24L
3.4	Caledon River and tributaries Klipspruit, Elandspruit, Witspruit and Blaasbalkspruit	D24A, D24B, D24C
3.5	Egmont Dam	D24A
IUA 4: Kraai River		
4.1	Kraai River and tributaries Malpas River, Riflespruit, Bokspruit, Koffiehoekspruit, Bamboeshoekspruit, Sterkspruit, Klein-Wildebeesspruit, Diepspruit, Three Drifts, Joggemspruit, Vlooikraalspruit, Langkloofspruit, Rytjiesvlaktespruit, Vrouenshoekspruit, Noodshulpspruit, Vaalhoek River, Saalboomspruit, Wasbankspruit and Wolwespruit	D13A, D13B, D13C, D13D, D13E, D13F, D13G and D13K
4.2	Holspruit and tributarie Braklaagtespruit, Leeuspruit, Skulpspruit and Telemachusspruit	D13J and D13H
4.3	Kraai River and tributaries Windvoelspruit, Bossielaagtespruit, Oslaagte, Rondefonteinspruit, Klipspruit ad Elandspruit	D13M and D13L
IUA 5: Upper Orange River		
5.1	Sterkspruit and tributaries Mlangeni River, Mbongo River and Kromspruit	D12B
5.2	Jozana's Hoek Dam on the Sterkspruit	Upper D12B
5.3	Orange River and tributaries Tele River along the Lesotho border, Blikana River, KwaSijora, Pelendaba, Mantikoana River, Deklerkspruit, Worsfonteinspruit, Hendrik Smitstroom, Bamboespruit, Wilgespruit, Gryskopspruit, Winnaarspruit, Knoffelspruit, Beeskraalspruit, Nuwejaarpspruit, Kop-en-pootjiespruit and Wilgerspruit	D18K, Portions of D15G, D15H and D18L in SA, D12A, D12C, D12D, D12E, D12F
5.4	Stormbergspruit and tributaries Wonderhoekspruit, Wilgespruit, Klein-Buffelsvleispruit, Witkopspruit, Barnardspruit, Mooiplaasspruit, Elandslaagte and Wikopspruit	D14B, D14C, D14D, D14E, D14F, D14G and D14H
5.5	Orange River and tributaries Gladdegrond, Melkspruit, Sanddrifspruit, Modderbuirspruit and Palmietspruit	D14A, D14J and D14K
IUA 6: Gariep		
6.1	Gariep Dam	D35H and D35K

RU Number	Resource Unit Description	Quaternary catchments
IUA 1: Golden Gate		
6.2	Orange River and tributaries Rooirantjies, Oudagspruit, Winnaarbakespruit, Brandspruit, Broekspruit, Bossiespruit, Swarthoekspruit and Brakspruit	D35A, D35B, D35C, D35D, D35E, D35F and D35G
6.3	Main stem Orange River between Gariep and Vanderkloof dams	D34A, D34E, D34F and D34G
6.4	Orange River and tributaries Suurbergspruit, Donkerpoortspruit, Oorlogspruit, Klipfonteinspruit, Rietkuilspruit and Vanderwaltfonteinspruit	D35J, D34A, D34B, D34C, D34D, D34E, D34F and D34G
IUA 7: Seekoei River		
7.1	Seekoei River	D32A, D32B, D32C, D32D, D32E, D32F, D32G, D32H, D32J and D32K
IUA 8: Vanderfkloof Dam		
8.1	Vanderkloof Dam	D31E
8.2	Orange River below Vanderkloof Dam	D33A
8.3	Orange River mainstem	D33A, D33B, D33C, D33D, D33E, D33F, D33H, D33J and D33K (along mainstem)
8.4	Tributaries draining to the Orange River on RU8.3 Knapsak River, Hondeblaf River, Berg River, Lemoenspruit	D31A, D31B, D31C, D31D, D33A, D33B, D33C, D33D, D33E, D33F, D33H, D33J and D33K
IUA 9: Upper Modder		
9.1	Rustfontein Dam on the Modder River	C52A
9.2	Modder River and Klein Modder and Kgabanyane Dam (Groothoek Dam) on the Kgabanyane River, with tributaries: Gannaspruit, Krompsruit, Bo-Kromspruit, Wildebeespruit and Grootpan	C52A and C52B
9.3	Modder River and tributaries Steynspruit, Korannespruit, Koringspruit, Matjiesspruit, Osspruit, Bloemspruit, Renosterspruit, Doringspruit, Rietspruit and Stinkhoutspruit	C52C, C52D, C52E, C52F and C52G
9.4	Krugersdrif Dam on the Modder River at the outlet of quaternary catchment C52G	C52G
IUA 10: Modder/ Riet Rivers		
10.1	Modder River and tributaries Klein Kaalspruit and Kaalspruit	C52H, C52J, C52K and C52L
10.2	Riet River and tributaries: Fouriespruit and tributaries including Fouriespruit Dam, X River and tributaries up and downstream of the Tierpoort Dam; Riet River to confluence with Kromellenboogspruit	C51A, C51B, C51C, C51D, C51E and C51F
10.3	Kromellenboogspruit and tributaries Vanzylspruit and Prosesspruit to confluence with the Riet River	C51G and C51H
10.4	Riet River	C51J and C51K
10.5	Mainstem Riet River to Vaal River confluence	C51L and C51M
10.6	Tierpoort Dam	C51D
10.7	Kalkfontein Dam	C51J

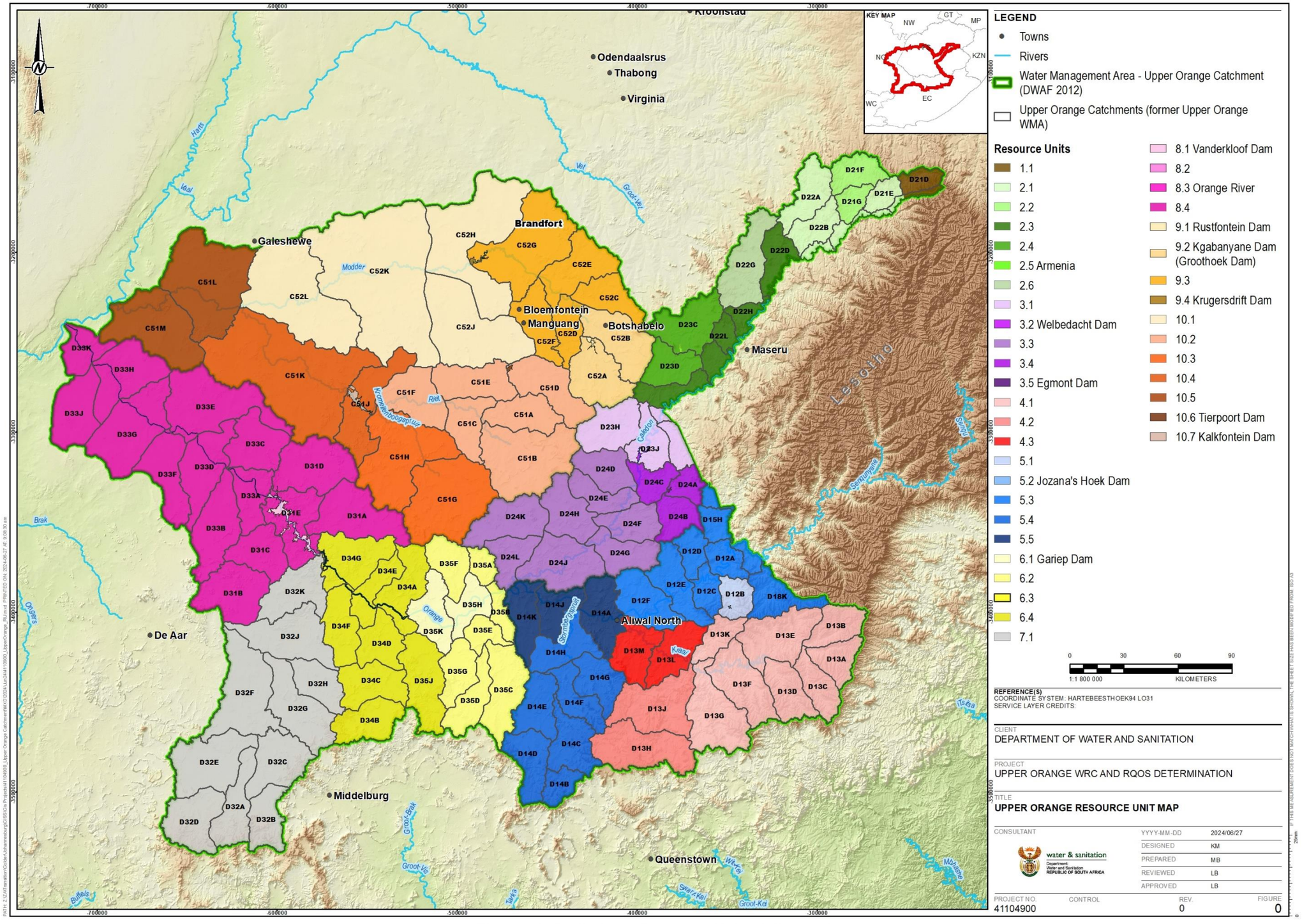

Figure 40: Preliminary Resource Units delineated

9 DESCRIPTION OF INTEGRATED UNITS OF ANALYSIS

9.1. IUA 1: Golden Gate

IUA 1 comprises Little Caledon and Caledon rivers in the Golden Gate Highlands National Park to the outlet of quaternary catchment D21D at the town of Clarens.

Rationale

The IUA delineation is based on the Little Caledon River reach, and the Caledon in the portion of D21A along the Lesotho border, being in good condition because of the location in the national park. This is a logical break in the system because of the national park boundary and before the Little Caledon and Caledon rivers confluence in IUA 2.

IUA Overview

IUA 1 falls only into quat D21D and a portion of D21A and lies within Dihlabeng LM in the Free State province. There is only one main town in the IUA which is the town of Clarens. Most of the area within this IUA falls into the protected area of the Golden Gate National Park with other protected areas including Eureka Nature Reserve, De Ark Game Ranch, Mount Horeb Estate and Clarens Private Nature Reserve adjacent to the town of Clarens.

The main water resources in this IUA include the Caledon River forming the border with Lesotho and the Little Caledon River that runs through the IUA. The IUA falls within the agriculture and tourism socio-economic zone, with tourism being the key economic activity within this IUA.

Table 29 summarises the salient features of IUA 1, and Figure 41 gives an overview of boundaries and features in IUA 1.

Table 29: IUA 1 - Golden Gate description

IUA 1: Golden Gate	Description
Quaternaries	D21D and a portion of D21A
Ecoregion	Eastern Escarpment Mountains
Geozones	A: A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools
	B: Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools.
	C: Moderately steep stream dominated by bedrock or boulder.
	D: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
Main Rivers	Little Caledon River and Caledon River in the portion of D21A along the Lesotho border

IUA 1: Golden Gate	Description
Tributaries	Unnamed tributaries
Land use	• Predominantly natural • Tourism - Golden Gate National Park in the upper half of the IUA with several lodges, hotels and tarred roads • Town of Clarens with the Clarens wastewater treatment works (WWTW) • Agriculture in lower catchment of the quaternary catchment; small game farms; may be limited abstraction from the Caledon for subsistence agriculture;
EWR sites	UO_EWR 01_R on the Little Caledon River at the outlet of the IUA
Additional biological monitoring sites	DWS REMP sites: • D2LCAL-WILGE • D2LCAL-EWR01 • D2GLEN-GLENR • D2RIBB-UWWTW • D2RIBB-DWWTW
Dams/ infrastructure	None on main stem river
PES	The current PES is a C, however it is likely to be higher and the team will consider doing a diatom sample as it leaves the park to assess this.
Groundwater zone/ resource unit	GRU2 (Groundwater conditions similar in IUA 1 and IUA2). Upper part of the Karoo Supergroup formations with merely silty sandstones/ siltstones and limited intrusive Karoo Dolerite features.
Wetlands	Channelled valley bottom wetlands
Water Quality hotpots/ Water Use	• Tourism activities • Overgrazing in Lesotho causing erosion which leads to sedimentation in the rivers • Town of Clarens • Clarens Wastewater Treatment Works (WWTW) – critical risks rating (CRR) of 47% - low risk and showed improvement in the 2021 GD assessment.
SWSA	River SWSA (not currently designated, however it has been identified as important)

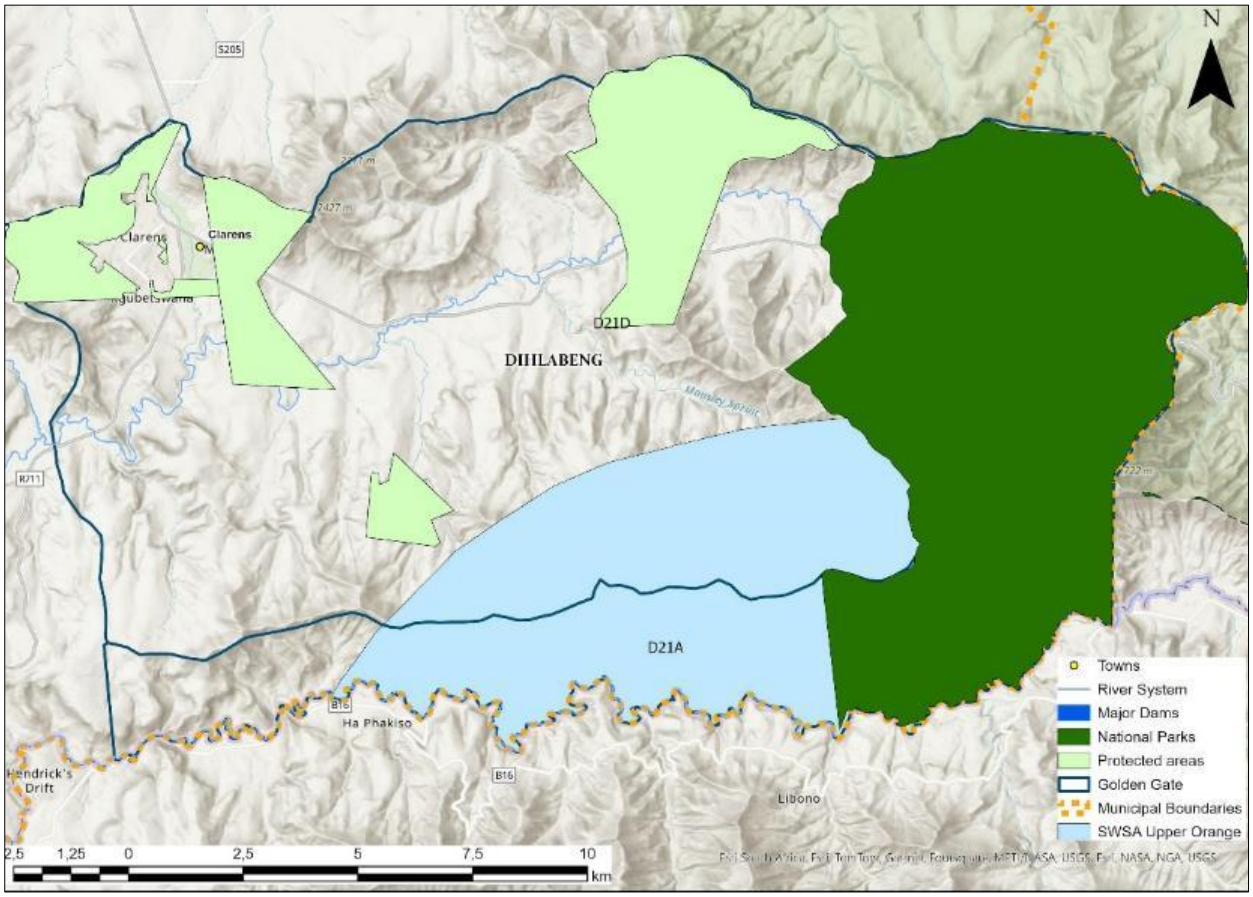

Figure 41: Overview of boundaries and features in IUA 1 of the Upper Orange River catchment

Socio-economic profile

Demographics and socio-economic profile

The population is estimated as 7,976 (Stats SA Census 2011 adjusted) with approximately 3,119 households. Approximately 6.2% of the population has a higher education and 10.7% have no schooling (Stats SA Census 2022 based on Dihlabeng local municipality data). The unemployment rate in IUA 1 is estimated as 23% if reflecting the municipal rate (NT, 2021).

The majority of the population (99%) have access to formal water services (Figure 42) with approximately 43% having access to piped water inside their dwelling, 47.6% with access to piped water inside the yard, 7.7% have access to a communal tap within 200m of their household and the remaining 1.6% have access to a communal tap more than 200m from their household or source water from a water vendor. In this IUA 1% of the population source their water from informal sources and all source water from boreholes.

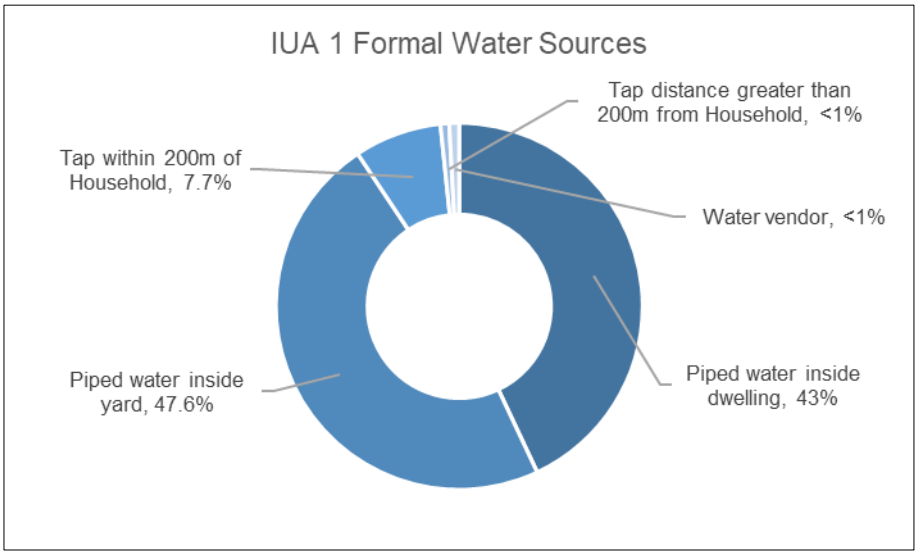

Figure 42: Access to water services in IUA 1

Economic Sectors

The key land use for IUA 1 is the residential settlement of Clarens and several farms adjacent to the Little Caledon and Caledon rivers (Figure 43). The other important land use and economic activity is from tourism. The main economic drivers and municipality information within IUA 1 is set out in Table 30.

Table 30: Economic drivers relevant to IUA 1

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDP 2020/2021)
Dihlabeng	Clarens is the only town within this IUA. The area in the IUA is characterised by some agriculture (mainly livestock farming and game farming) adjacent to the Little Caledon and Caledon rivers. The main economic activity within the IUA is tourism in the scenic town of Clarens often referred to as the “Switzerland of South Africa” and in the surrounding protected areas and the Golden Gate National Park about 20km from Clarens.

The contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 31 and Table 32.

Table 31: Economic sectors in IUA 1 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R9	8%
Mining	R0	0%
Manufacturing	R20	17%
Electricity & water	R2	2%
Construction	R6	5%

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Wholesale & retail trade; catering and accommodation	R22	20%
Transport & communication	R10	9%
Financial services	R18	16%
General government	R15	13%
Community, social & personal services	R10	9%
Total GDP	R114	100%

Table 32: The estimated employment by economic sector for IUA 1 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	586	67%
Mining	0	0%
Manufacturing	22	3%
Electricity & water	1	0.1%
Construction	16	2%
Wholesale & retail trade; catering and accommodation	82	9%
Transport & communication	11	1%
Financial services	39	4%
General government	50	6%
Community, social & personal services	62	7%
Total Employment	869	100%

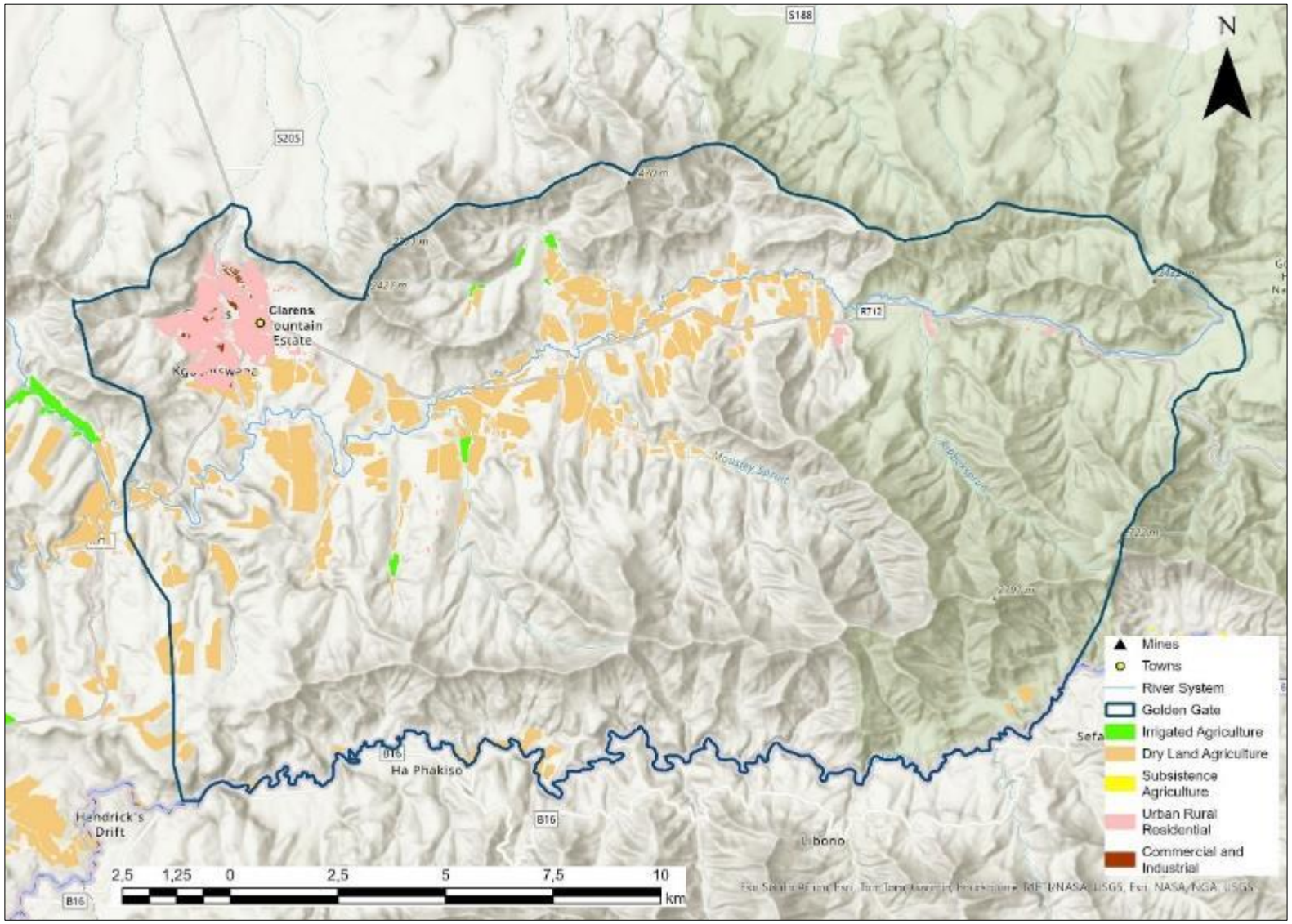

Figure 43: Land Use by land cover in IUA 1 in the Upper Orange River catchment (DFFE, 2020)

Ecosystem Services

IUA 1 is situated in the northeastern extent of the Upper Orange River catchment, sharing a boundary with Lesotho. Within this IUA, the Clarens community benefits from aquatic and terrestrial ecological infrastructure associated with the Caledon River, Little Caledon River, their tributaries, and channelled valley bottom wetlands (Figure 44). Additionally, IUA 1 is home to the Golden Gate Highlands National Park, a protected area that plays a crucial role in biodiversity conservation and the provision of cultural services. It is worth noting that this area comprises a SWSA.

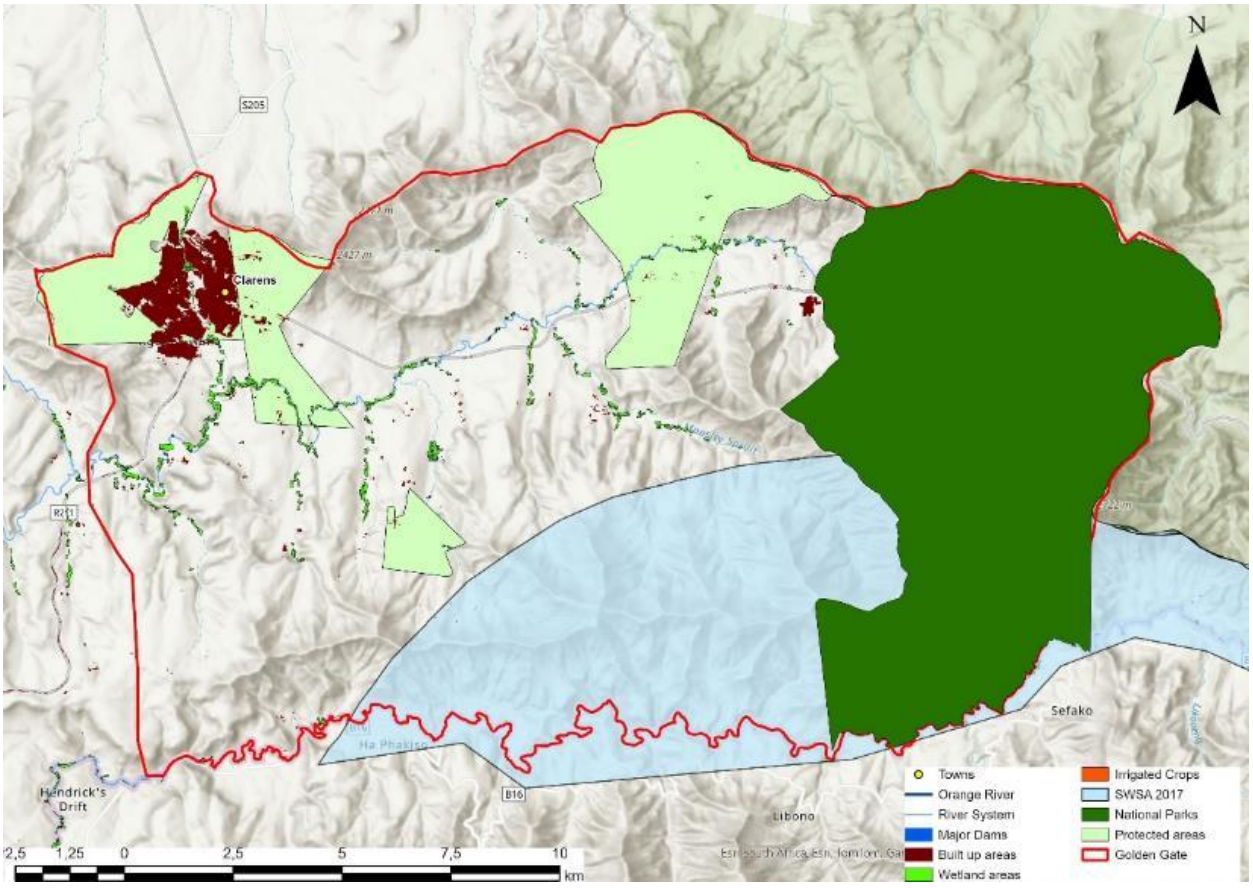

Figure 44: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 1 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 33).

Table 33: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 1 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Caledon River and tributaries; Little Caledon River and tributaries; channelled VB wetland	The Caledon River, Little Caledon River, and their tributaries have significance to the Clarens Community by providing fish.	**Households, Society**
	Fresh Water	Caledon River and tributaries; Little Caledon River and tributaries; channelled VB wetland	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Clarens community.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Raw materials	Channelled VB wetlands	Significance to subsistence farmers	**Agriculture; Households, Society**
	Medicinal resources	Channelled VB wetlands	Significance to rural communities	**Households, Society**
Regulating	**Climate regulation**	Channelled VB wetlands	Major significance to global beneficiaries	**Society**
	Water quantity regulation	Channelled VB wetlands; SWSA	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Clarens community.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	Channelled VB wetlands; SWSA	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Clarens community.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Caledon River and tributaries; Little Caledon River and tributaries; channelled VB wetland	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Caledon River and tributaries; Little Caledon River and tributaries;	Major significance to commercial agriculture sector	**Agriculture; Households**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		channelled VB wetland		
Cultural	**Landscape & amenity values**	Protected Areas (Golden Gate Highlands National Park); Caledon River and tributaries; Little Caledon River and tributaries; channelled VB wetland	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas (Golden Gate Highlands National Park); Caledon River and tributaries; Little Caledon River and tributaries; channelled VB wetland	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**
	Maintenance of genetic diversity	Protected Areas (Golden Gate Highlands National Park); Caledon River and tributaries; Little Caledon River and tributaries; channelled VB wetland	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Upper part of the Karoo Supergroup formations with merely silty sandstones/siltstones and limited intrusive Karoo Dolerite features. Relatively high groundwater recharge (±20 mm/a, 360 Mm^3/a), but also high contribution to baseflow. Groundwater quality Class 0 (Ideal water quality type), and borehole yield class (BYC) is a d3-Class (i.e.,0.5 – 2.0 L/s). Groundwater use is low (stress index are a Natural Condition) and Allocable ground water still ±270 Mm^3/a.

9.2. IUA 2: Caledon/ Leeu River

IUA 2 comprises the Caledon River below the Golden Gate Highlands National Park along the Lesotho Border and the many tributaries up to the Leeu River tributary where it confluences with the Caledon River at the outlet of quaternary catchment D23E.

Rationale

The IUA delineation is based on the sub-catchments along of the Caledon River along the Lesotho Border to the Leeu River, with similar land use and extensive degradation, and high sediment loads into the Caledon from the Lesotho tributaries. This is a logical break in the system upstream of the Welbedacht Dam and where the Caledon flows south westerly away from the Lesotho border towards Gariep Dam.

IUA Overview

The IUA is situated adjacent to the Caledon River along the border with Lesotho and comprises 18 quaternary catchments (eight full quaternary catchment and the portion of the other 10 quaternary catchments that lie within South Africa). There are several protected areas scattered through the IUA. The towns in the IUA include Fouriesburg, Ficksburg, Clocolan, Ladybrand, Tweespruit and Hobhouse. The IUA falls within parts of the local municipalities of Dihlabeng, Setsoto, Mantsopa and a small portion of Mangaung (settlement areas with subsistence agriculture).

The key water resources include the Caledon River along the border with Lesotho, the Little Caledon and Leeu rivers. The IUA falls within the agriculture and tourism socio-economic zone of the catchment area. Land use is mainly for agriculture (irrigation, dryland, and mixed agriculture) and urban land use.

Table 34 summarises the salient features of IUA 1, and Figure 45 gives an overview of boundaries and features in IUA 2.

Table 34: IUA 2 - Caledon/ Leeu River

IUA 2: Caledon/ Leeu River	Description
Quaternaries	D21E, D21F and D21G; portion of D21C; D22A and D22B; portions of D21H and D22C along the SA/ Lesotho border; Portions of D22D, D22G, D22H; D22L, Portion of D23A, D23C, D23D and portion of D23E; D22B; and D23C
Ecoregion	Eastern Escarpment Mountains and Highveld
Geozones	D: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
Main Rivers	Caledon River along the Lesotho Border
Tributaries	Little Caledon, Brandwater, Moolmanspruit, Meulspruit, Rantsho River, Morakabi/ Mopeli River, Beytelspruit, McCabes Spruit, Modderpoort-spruit, Tenniskopspruit, Tweelingspruit, Appledore Spruit, Mokopu River, Bokpoortspruit and Leeu River

Land use	• Extensive agriculture including dryland cultivation and irrigation (crops and livestock farming)
	• Tourism
	• Towns and associated WWTW
	  ○ Ficksburg
	  ○ Fouriesburg
	  ○ Clocolan
	  ○ Ladybrand
	  ○ Hobhouse

EWR site	• UO_EWR 01_R • UO_EWR 02_R • UO_EWR 03_R • UO_EWR 01_I • UO_EWR 02_FV

Additional biological monitoring sites	• JBS3 sites:
	  ○ OSAEH_15_1
	  ○ OSAEH_11_22
	• REMP sites:
	  ○ D2CALE-EWR03
	  ○ D2GROO-FARM1
	  ○ D2LCAL-EWR02

IUA 2: Caledon/ Leeu River	Description

Infrastructure/ Dams	• D22B: Meulspruit Dam (FSC: 2.6 Mm3) on the Meulspruit;
	• D23C: Armenia Dam (FSC: 14.02 Mm3) on the Leeu River – small storage dam for irrigation
	• Small farm dams:
	  ○ Lucretia Dam
	  ○ Lovedale Dam
	  ○ Wonderkop Dam
	  ○ Newbury's Gift Dam

PES	C/D (an unnamed tributary of the Meulspruit = B)
Groundwater	GRU2 (includes IUAs 1 and 2). Upper part of the Karoo Supergroup formations with merely silty sandstones/siltstones and limited intrusive Karoo Dolerite features
Wetlands	• D21E, F and G: channelled VB, seeps and floodplain • D22A and B: depression and channelled VB • ***Brandwater Floodplain (prioritised for Reserve, 2023) – D21G*** • Channelled VB noted in all quaternary catchments but most dominant in D23C • Depression wetlands - D23C and D22A • Small floodplain in D23D • Valley head seeps in D23C and D23A • Unchanneled VB and flat in D23A • ***Rantsho wetland complex (prioritised for Reserve, 2023) – D22G,*** unique in that it consists of three valley-bottom hydrogeomorphic (HGM) unit types which have formed because of a unique geomorphic setting and a unique set of geomorphic processes. A series of VB wetlands is unique and can provide significant streamflow regulating services.

WQ hotpots/Use	• Sediments from Maseru and surrounding areas,
	• Irrigation return-flows
	• Towns and associated poor performing WWTW:
	  ○ Ficksburg: CRR 96% - critical risk
	  ○ Fouriesburg: CRR 65% - medium risk
	  ○ Clocolan: CRR 80% - high risk
	  ○ Ladybrand: CRR 73% - high risk
	  ○ Hobhouse: 82% - high risk

SWSA	None

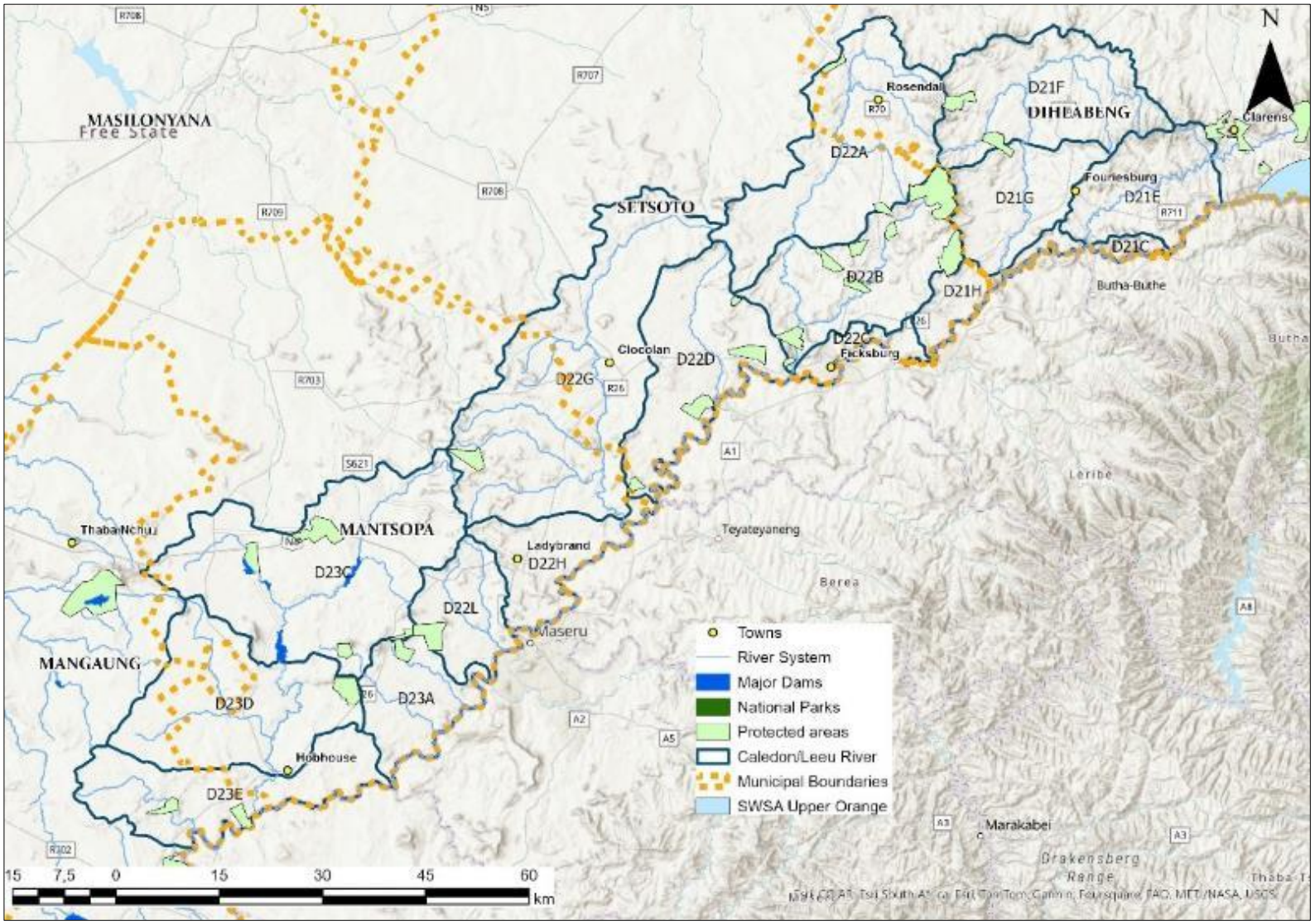

Figure 45: Overview of boundaries and features in IUA 2 of the Upper Orange River catchment

Demographics and Socio-Economic Profile

The population is estimated as 139,026 (Stats SA Census 2011 adjusted) with approximately 46,994 households. Approximately 9.6% of the population has a higher education and 5% of the population has no schooling (Stats SA Census 2022 based on municipal data averaging for municipalities falling within the IUA). The unemployment rate within IUA 2 is estimated at 24% (NT, 2021).

Most of the population in the IUA has access to formal water sources (97.5%) and the remaining population (2.5%) rely on informal water sources. In relation to formal water sources (Figure 46), 71.7% of the population have access to piped water inside their yard and 23.6% to piped water inside their dwelling, 4.5% of the population have access to a communal tap within 200m of the household and less than 1% have access to a communal tap more than 200m from the household or through a water vendor. Informal water sources in the IUA (Figure 46) include boreholes (87.5%), rain-water tanks (1.5%), dams, pools or stagnant water (2.3%), rivers or streams (2.5%) and other sources (6.2%). In IUA 2 people are mainly housed in formal dwellings with the proportion ranging from 83% to 91% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

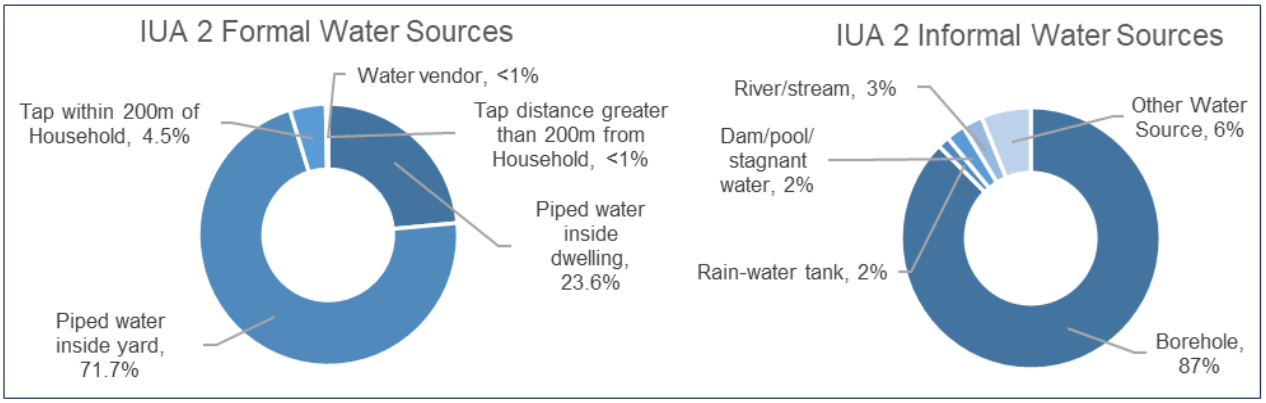

Figure 46: Access to water services in IUA 2

Economic sectors

The main land use in IUA 2 is mixed agriculture with farming practices including irrigation farming, dryland farming and livestock farming (Figure 47). There are two sand mining operations in the IUA south of the town of Hobhouse in quaternary catchment D23E.

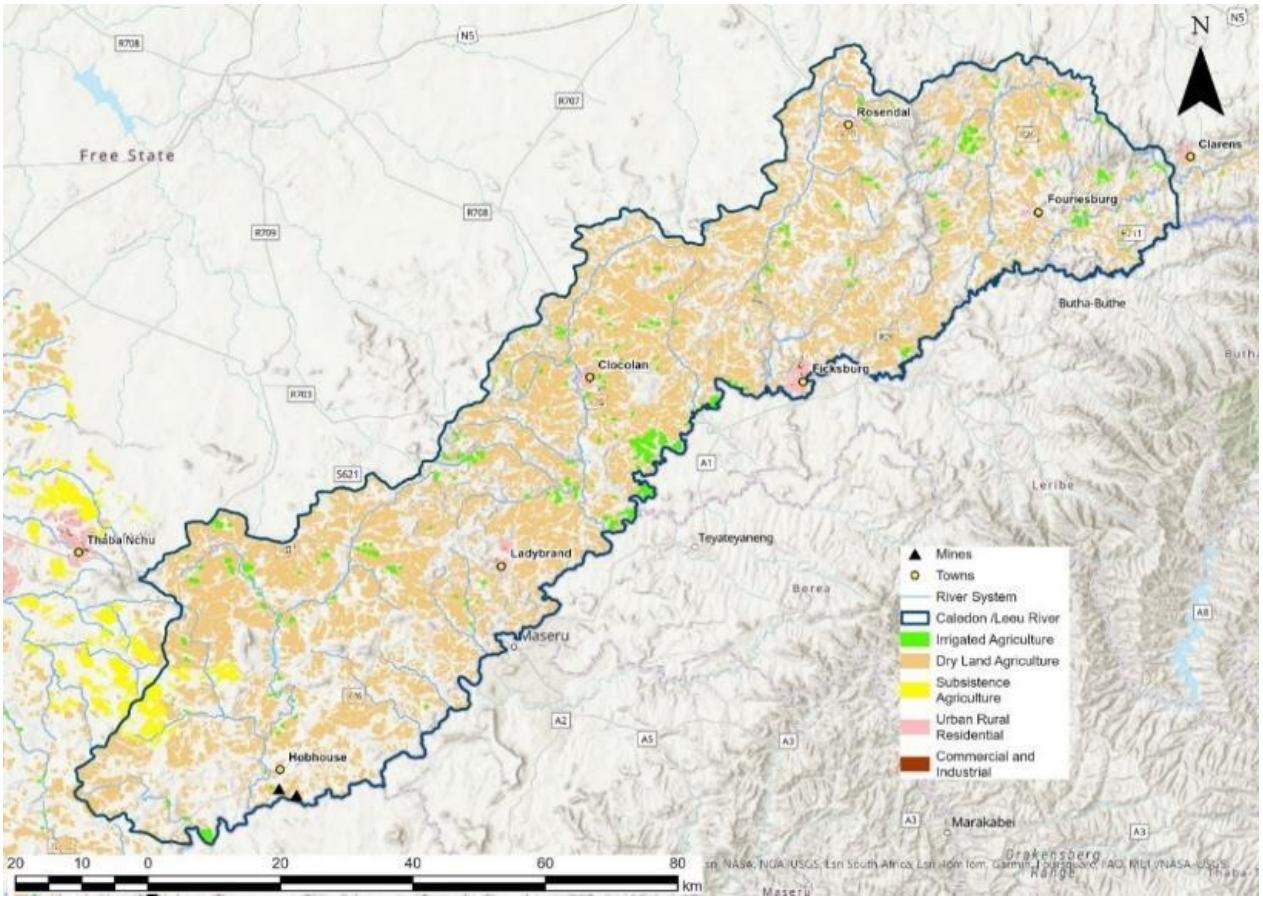

Figure 47: Land Use by land cover in IUA 2 in the Upper Orange River catchment (DFFE, 2020)

The main economic drivers of municipalities falling within IUA 2 are set out in Table 35.

Table 35: Economic drivers relevant to IUA 2

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2021, 2022 and 2023)
Dihlabeng	The main towns are Fouriesburg and Rosendal. Key economic activity is from agriculture and in particular crops farming such as vegetables (asparagus and various others), fruit (such as cherries and apples), pastures and other field crops (e.g. sunflowers). Other agriculture includes livestock farming with sheep and cattle.
Setsoto	Main towns included within the IUA are Clocolan and Ficksburg. The main economic activity is mixed agriculture including dryland and irrigated crop farming and livestock faming (including dairy). Important crops grown include asparagus, apples and cherries and grains such as maize and wheat. Tourism also plays a role and includes the cherry and steam chain festivals in Ficksburg.

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2021, 2022 and 2023)
	A small contribution from manufacturing in this part of the IUA from clothing factory and food processing in Ficksburg.
Mantsopa	This part of the IUA includes the towns of Ladybrand, Tweespruit and Hobhouse. The Main economic activities include crop and livestock farming. There is one irrigation scheme, the Leeu river scheme from the Armenia Dam in D23C. The area around Tweespruit is one of the highest sunflower production areas of the Free State. The town also has a large silo complex. A small amount of game farming also takes place within the IUA. Manufacturing activities in Ladybrand include meat processing and wool processing facilities. A small contribution from mining at two sand mines in D23E near Hobhouse.
Mangaung	Villages or settlements in this IUA include Balaclava and Klipfontein. This area is characterised by subsistence agriculture.

In IUA 2 the estimated contribution of the economic sectors to the Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 36 and Figure 48.

Table 36: Economic sectors in IUA 2 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R4,292	22%
Mining	R56	0.3%
Manufacturing	R1,650	8%
Electricity & water	R171	1%
Construction	R993	5%
Wholesale & retail trade; catering and accommodation	R4,197	21%
Transport & communication	R968	5%
Financial services	R1,906	10%
General government	R2,652	14%
Community, social & personal services	R2,755	14%
Total GDP	R19,640	100%

Table 37: The estimated employment by economic sector for IUA 2 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	10,728	29%
Mining	38	0.1%
Manufacturing	1,883	5%
Electricity & water	85	0.2%
Construction	1,529	4%
Wholesale & retail trade; catering and accommodation	7,982	21%
Transport & communication	1,200	3%
Financial services	2,980	8%
General government	4,800	13%
Community, social & personal services	6,236	17%
Total Employment	37,459	100%

Ecosystem Services

This area is home to several protected areas that serve as biodiversity hotspots and cultural hubs. Moreover, it is intersected by major water bodies such as the Caledon River, little Caledon River, Leeu River, and additional smaller tributaries like Brandwater, Moolmanspruit, Meulspruit, Rantsho River, Morakabi/Mopeli River, Beytelspruit, McCabes Spruit, Modderpoort-spruit, Tenniskopspruit, Tweelingspruit, Appledore Spruit, Mokopu River, and Bokpoortspruit, all of which are primary water sources providing crucial ecosystem services such as fresh water provision and climate change regulation (Table 38). Notably, IUA 2 encompasses the Rantsho wetland complex, a significant wetland area within the Upper Orange River catchment. This IUA also includes other types of wetlands such as channelled valley bottomed, seeps and floodplain, endorheic, and unchanneled valley bottomed wetlands.

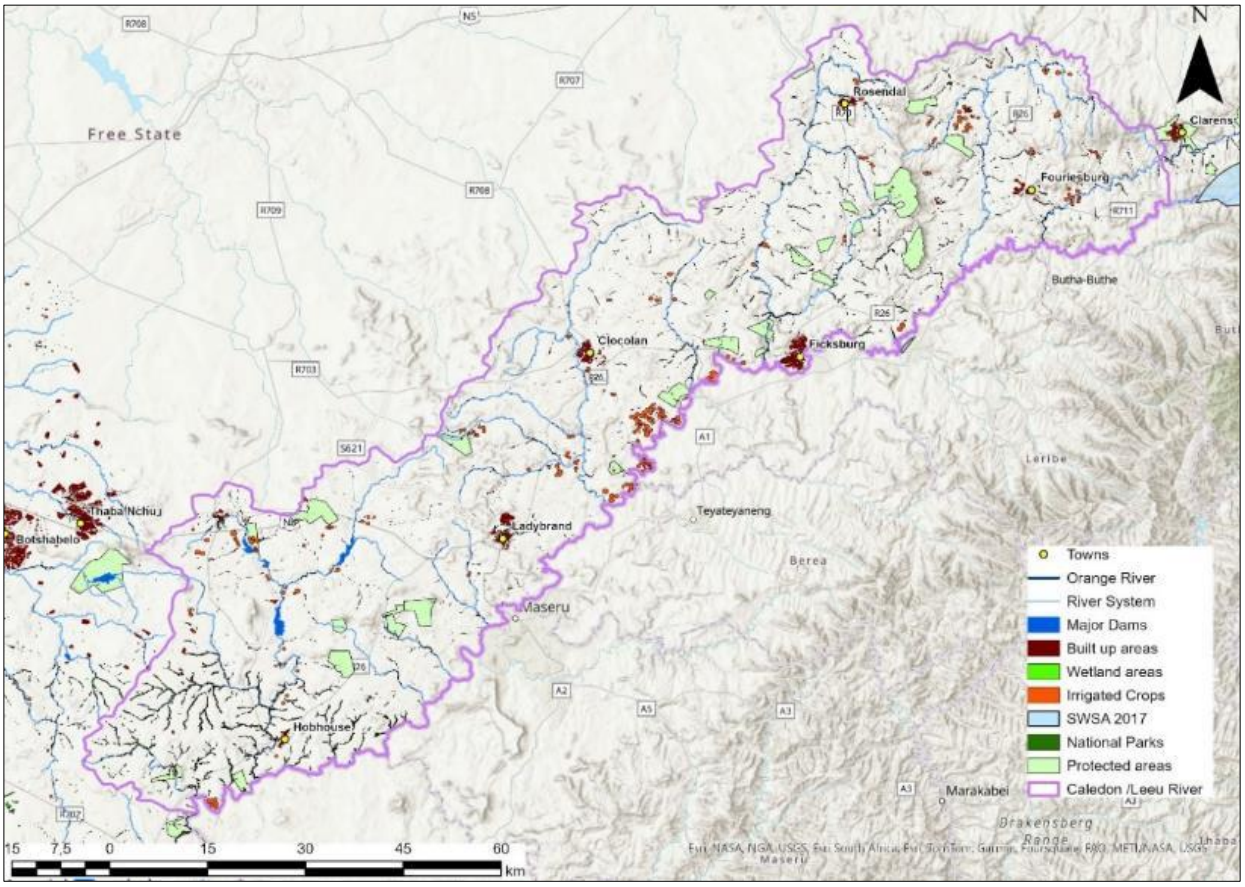

Figure 48: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 2 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 38).

Table 38: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 2 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and	The Caledon River, Little Caledon River, Leeu River and their tributaries has significance to the communities of the IUA by providing fish.	**Households, Society**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		unchanneled VB wetlands		
	Fresh Water	Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Fouriesburg, Ficksburg, Clocolan, and Ladybrand communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Raw materials	Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Significance to subsistence farmers	**Agriculture; Households, Society**
	Medicinal resources	Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Significance to rural communities	**Households, Society**
Regulating	**Climate regulation**	Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Major Significance to Global Beneficiaries	**Society**
	Water quantity regulation	Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Fouriesburg, Ficksburg, Clocolan, and Ladybrand communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification	Rantsho wetland complex; channelled VB; seeps and	Major significance: Commercial agriculture and irrigation activity throughout	**Agriculture; Mining; Manufacturing;**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	& waste management	floodplain; endorheic; and unchanneled VB wetlands	the IUA, specifically for the Fouriesburg, Ficksburg, Clocolan, and Ladybrand communities.	**Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas; Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas; Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	Maintenance of genetic diversity	Protected Areas; Caledon River and tributaries; Little Caledon River and tributaries; Leeu River and tributaries; Rantsho wetland complex; channelled VB; seeps and floodplain; endorheic; and unchanneled VB wetlands	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

As for IUA 1: Relatively high groundwater recharge (±20 mm/a, 360 Mm^3/a), but also high contribution to baseflow. Groundwater quality Class 0 (Ideal water quality type), and borehole yield class (BYC) is a d3-Class (i.e.,0.5 – 2.0 L/s). Groundwater use is low (stress index are a Natural Condition) and Allocable ground water still ±270 Mm^3/a.

9.3. IUA 3: Caledon

IUA 3 comprises the Caledon River and its tributaries, from the point where it drains away from the Lesotho border to the confluence with the Orange River, upstream Gariep Dam.

Rationale

The IUA delineation is based on the sub-catchments along of the Caledon River along the Lesotho Border to the Leeu River, with similar land use and extensive degradation, and high sediment loads into the Caledon from the Lesotho tributaries. This is a logical break in the system upstream of the Welbedacht Dam and where the Caledon flows south westerly away from the Lesotho border towards Gariep Dam.

IUA Overview

IUA 3 comprises 14 quaternary catchments and falls into parts of the metropolitan municipality of Mangaung and local municipalities of Mohokare and Kopanong (not populated) within the Free State province. The main towns in the IUA include Wepener, Vanstadensrus, Smithfield and Rouxville.

Table 39 summarises the salient features in the IUA and Figure 49 gives an overview of boundaries and features in IUA 3.

Table 39: IUA 3 - Caledon

IUA 3: Caledon	Description
Quaternaries	D23H, D23J and D23F, D23J, D23H, D24A, D24B, D24C, D24D, D24E, D24F, D24G, D24H, D24J, D24K and D24L
Ecoregion	Highveld and Nama Karoo
Geozones	D: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F: Low gradient alluvial fine bed channel, typically regime reach type
Main Rivers	Caledon River
Tributaries	Klipspruit, Rietspruit River, Nuwejaarspruit, Bloemspruit, Klipspruit, Elandspruit, Witspruit, Blaasbalkspruit, Boesmanskopspruit, Vaalspruit, Wilgeboomspruit, Vinkelspruit, Grahamstadspruit, Sandveld, Skulpspruit, Slykspruit and Hartbeesfontein
Land use	• Main towns and associated WWTW o Vanstadensrus o Wepener on Sandveld River o Smithfield on Skulpspruit (tributary) and • Caledon Nature Reserve around the Welbedacht Dam and Tussen-die-Riviere Nature Reserve in the lower reaches of the Caledon River • Irrigated agriculture dominates along the main river and tributaries. • There are also transfers from Caledon River, e.g. to Modder from the Welbedacht Dam, through Rietspruit. • Welbedacht Water Treatment Works
EWR sites	• UO_EWR 03_FV • UO_EWR 10_FV • UO_EWR 11_FV • UO_EWR 04_I
Additional biological monitoring sites	• TBCR4-E1 Bolikela in D23F (transboundary site) • JBS3: OSAEH_26_8
Dams	• Egmont Dam (FSC: 8.8 Mm^3) in D24A • Welbedacht Dam (FSC: 5.5 Mm^3) in D24C on the Caledon River - Small storage dam for irrigation and transfer to Bloemfontein; the dam is highly silted • Knellpoort Dam (off-channel) in Rietspruit sub-catchment (FSC: 138.4 Mm^3) in D23H • Rolandshoek Dam on the Blaasbak River (FSC: 5,4 Mm^3) in D24C • Vanstadensrus Dam (FSC: 1.8 Mm^3) in D24C • Smithfield Dam on the Groenspruit (FSC: 4.64 Mm^3)
PES	Predominantly C/D

IUA 3: Caledon	Description
Groundwater	GRU3. Upper part of the Karoo Supergroup formations with merely silty sandstones/siltstones and large intrusive Karoo Dolerite features (circular sills)
Wetlands	• Channelled VB and flat in D23H • Seeps in D23H and D23J • Floodplain wetland and flat around the Welbedacht Dam • Channelled VB throughout • Seeps throughout • Floodplain wetland along the Caledon River • Depression wetlands in D24F along the Caledon River • Flats in D23H and D23J • Floodplain wetland along the Caledon River at the confluence with the Orange River into Gariep Dam
WQ hotpots/Use	• Mainly irrigation along river, thus return-flows possible. • Sedimentation • Main towns and associated poor performing WWTW: o Vanstadensrus WWTW: CRR 94% - critical risk o Wepener WWTW: CRR 94% - critical risk o Smithfield WWTW: CRR 82% - High risk
SWSA	None

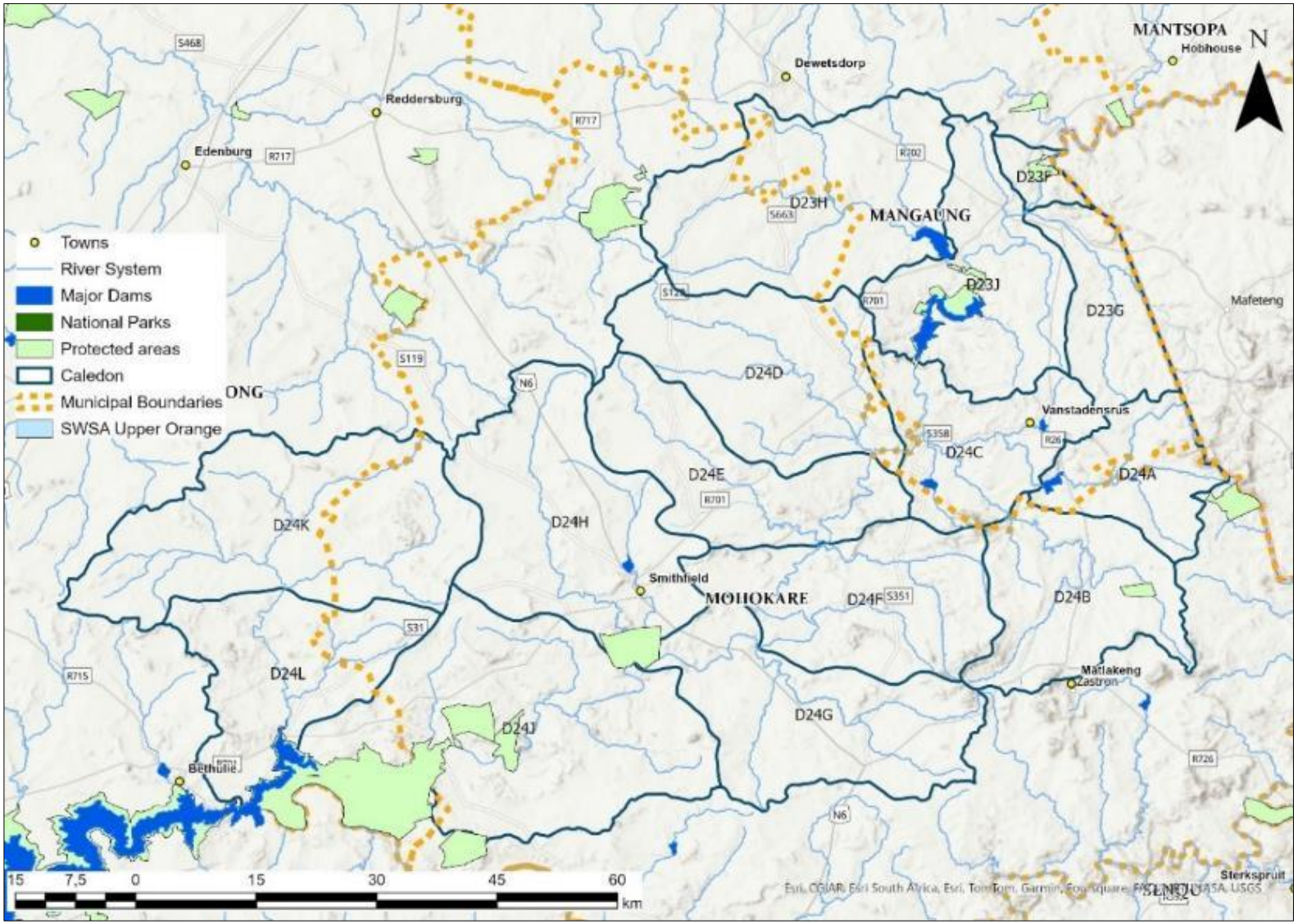

Figure 49: Overview of boundaries and features in IUA 3 of the Upper Orange River catchment

The key water resources in the IUA include the Caledon River and several tributaries and six dams including the Welbedacht Dam, Egmont Dam, Knellpoort Dam, Rolandshoek, Vanstadensrus Dam and Smithfield Dam. The Caledon Modder transfer system transfers water from the Caledon River and Welbedacht Dam on the river via pipeline to the Bloemfontein region. There are several protected areas within the IUA with larger areas including Caledon Nature Reserve adjacent to the Welbedacht Dam and part of the Tussen-die-Riviere Game Farm in quaternary catchments D24J and L. Irrigated agricultural activities occurring along the Caledon and its tributaries. The IUA falls within the agriculture and tourism socio economic zone.

Demographics and socio-economic profile

The population is estimated as 35,770 (Stats SA Census 2011 adjusted) with approximately 12,953 households. Approximately 10.9% of the population has a higher education and 6.6% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate was estimated as 21% (NT, 2021).

The whole population within this IUA has access to formal water services (Figure 50), with 76.3% having access to piped water inside their yard, 20.3% with access to piped water inside their dwellings, and 3.3% with access to a communal tap is within 200m of the household. People are mainly dwelling in formal dwellings with the proportion exceeding 90% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

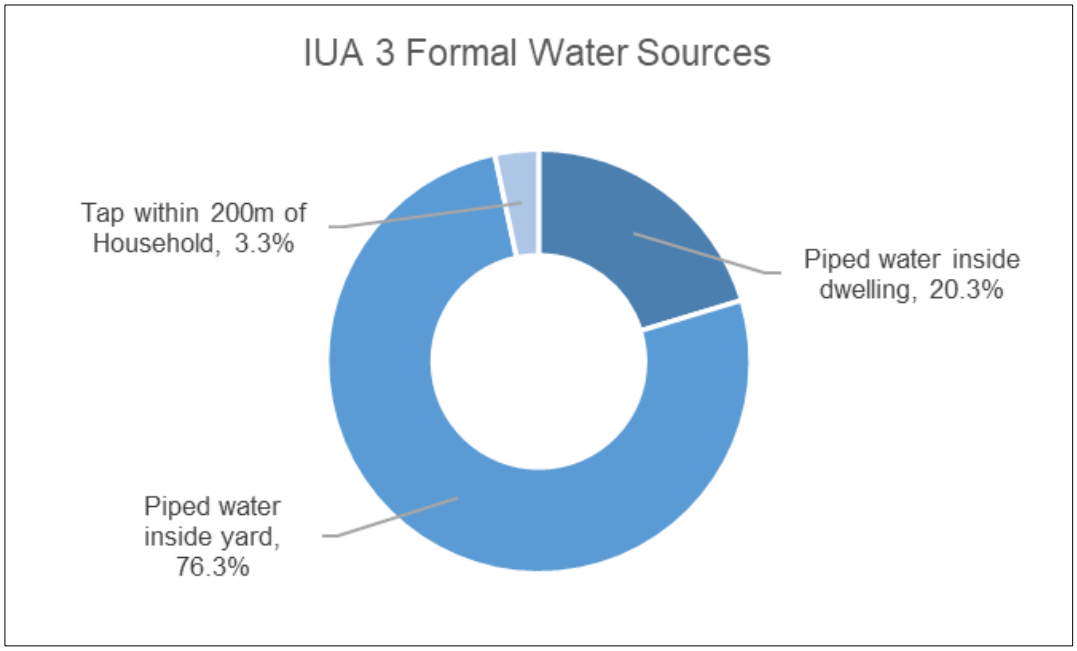

Figure 50: Access to water services in IUA 3

Economic Sectors

Land use and economic activities within IUA include irrigation agriculture along the Caledon River and its tributaries, extensive livestock farming (cattle and sheep for wool and meat) and game farming. Other economic land uses include agri-tourism with game farming and eco-tourism in the various protected areas and urban areas (Figure 51). There are a few sand mines in the upper western part of the IUA in quaternary catchment D23G and D23J.

The main economic drivers of municipalities falling within IUA 3 are set out in Table 40.

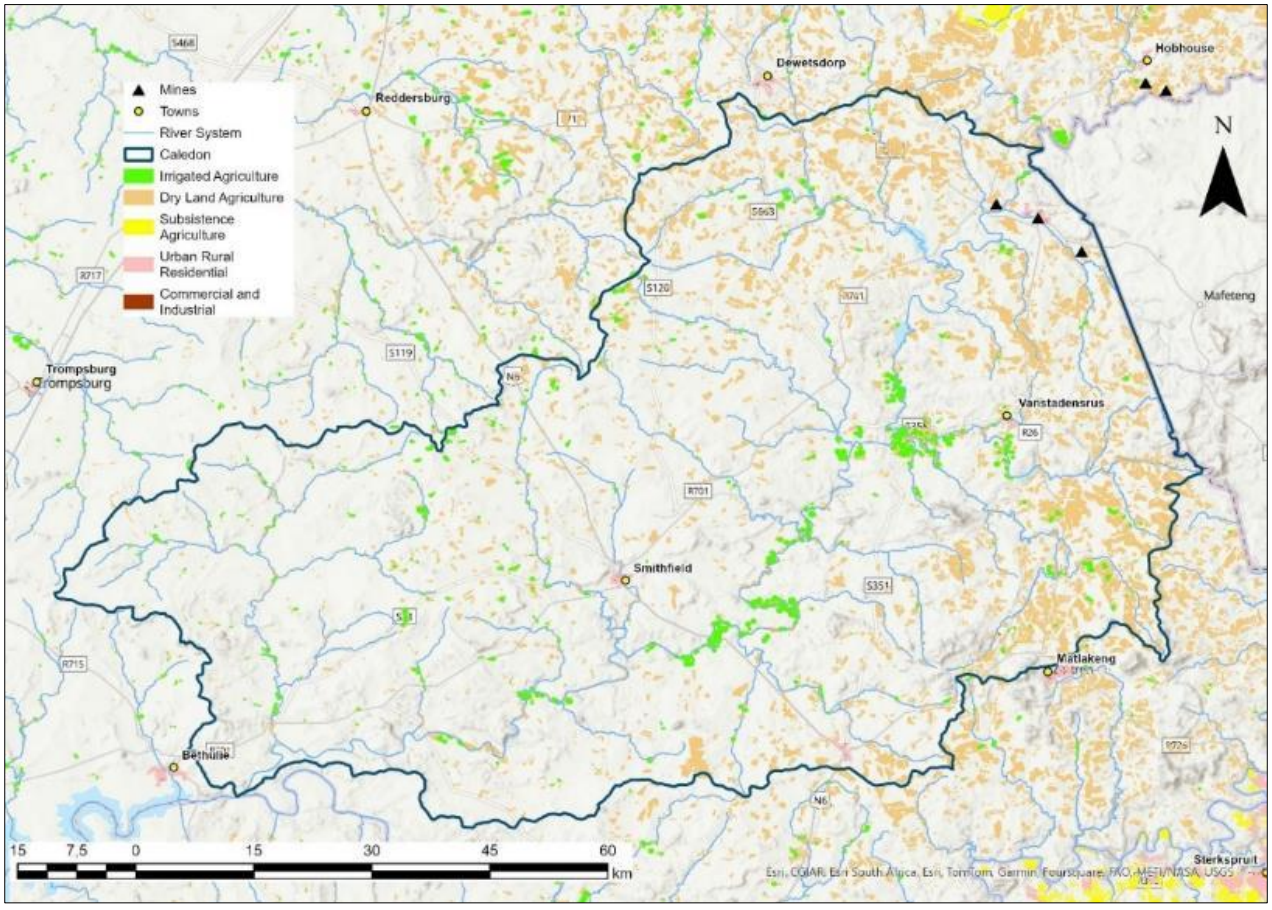

Figure 51: Land Use by land cover in IUA 3 in the Upper Orange River catchment (DFFE, 2020)

Table 40: Economic drivers relevant to IUA 3

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2006, 2021, 2022 & 2023, DRDLR, 2020)
Mangaung (Metropolitan Municipality)	Towns in this IUA include Wepener and Vanstadensrus. Economic activities include agriculture with mainly livestock production (sheep, cattle) and game ranching and dryland production of grains and oilseed crops. IUA 3 also includes irrigated agriculture along the Caledon River and its tributaries of crops such as potatoes and grains. The area

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2006, 2021, 2022 & 2023, DRDLR, 2020)
	includes the Egmont Dam near Vanstadensrus which serves the Wittespruit irrigation scheme. Another economic sector is tourism in the nature reserves and with various historical memorials and national monuments in Wepener and the town is also a gateway into Lesotho due to its proximity to Van Rooyen's border post. An additional contribution is from sand mining in the area.
Mohokare	The main town in the IUA is Smithfield. This part of the IUA is characterised by agriculture, mainly livestock farming and some game farming, with some intensive crop agriculture along the Caledon River and tributaries. A small economic contribution from the manufacturing sector in terms of furniture and food and beverages. Tourism activity within the game reserves (Boschpoort Game Reserve and Kanimo Game Reserve) and the private Letsatsi Reserve.
Kopanong	There are no towns in the IUA. Some tourism economic activity from the Tussen-die-Riviere Nature reserve in lower part of quaternary catchment D24L.

In IUA 3, the estimated contribution of the economic sectors to the Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 41 and Table 42.

Table 41: Economic sectors in IUA 3 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R1,406	1%
Mining	R964	1%
Manufacturing	R12,970	12%
Electricity & water	R3,931	4%
Construction	R5,668	5%
Wholesale & retail trade; catering and accommodation	R18,502	17%
Transport & communication	R14,206	13%
Financial services	R23,149	22%
General government	R15,542	15%
Community, social & personal services	R10,459	10%
Total GDP	R106,797	100%

Table 42: The estimated employment by economic sector for IUA 3 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	2,166	20%
Mining	80	1%
Manufacturing	498	5%
Electricity & water	37	0%
Construction	516	5%
Wholesale & retail trade; catering and accommodation	2,606	24%
Transport & communication	404	4%
Financial services	1,246	11%
General government	1,335	12%
Community, social & personal services	1,995	18%
Total Employment	10,885	100%

Ecosystem Services

Located in the eastern extent of the Upper Orange River catchment, IUA 3 showcases a diverse range of aquatic and terrestrial ecological infrastructure that is interconnected with the Caledon River, its tributaries, and various wetland types, including channelled valley bottom, flat, seeps and floodplain wetlands (Figure 52). These ecosystems provide invaluable ecosystem services that greatly benefit multiple communities, including Wepener, Smithfield, Vanstadensrus and Rouxville in the Free State province. Furthermore, the region encompasses several protected areas, such as Mohokare Game Reserve, Caledon Nature Reserve, Boschpoort Game Reserve, Kanimo Game Reserve, Letsatsi Private Reserve and part of the Tussen-die-Riviere Game Farm, as well as significant SWSA like Welbedacht and a section of the Gariep Dam. These protected areas and SWSA not only contribute to cultural services but also act as crucial infrastructure for the provision of water resources within the area.

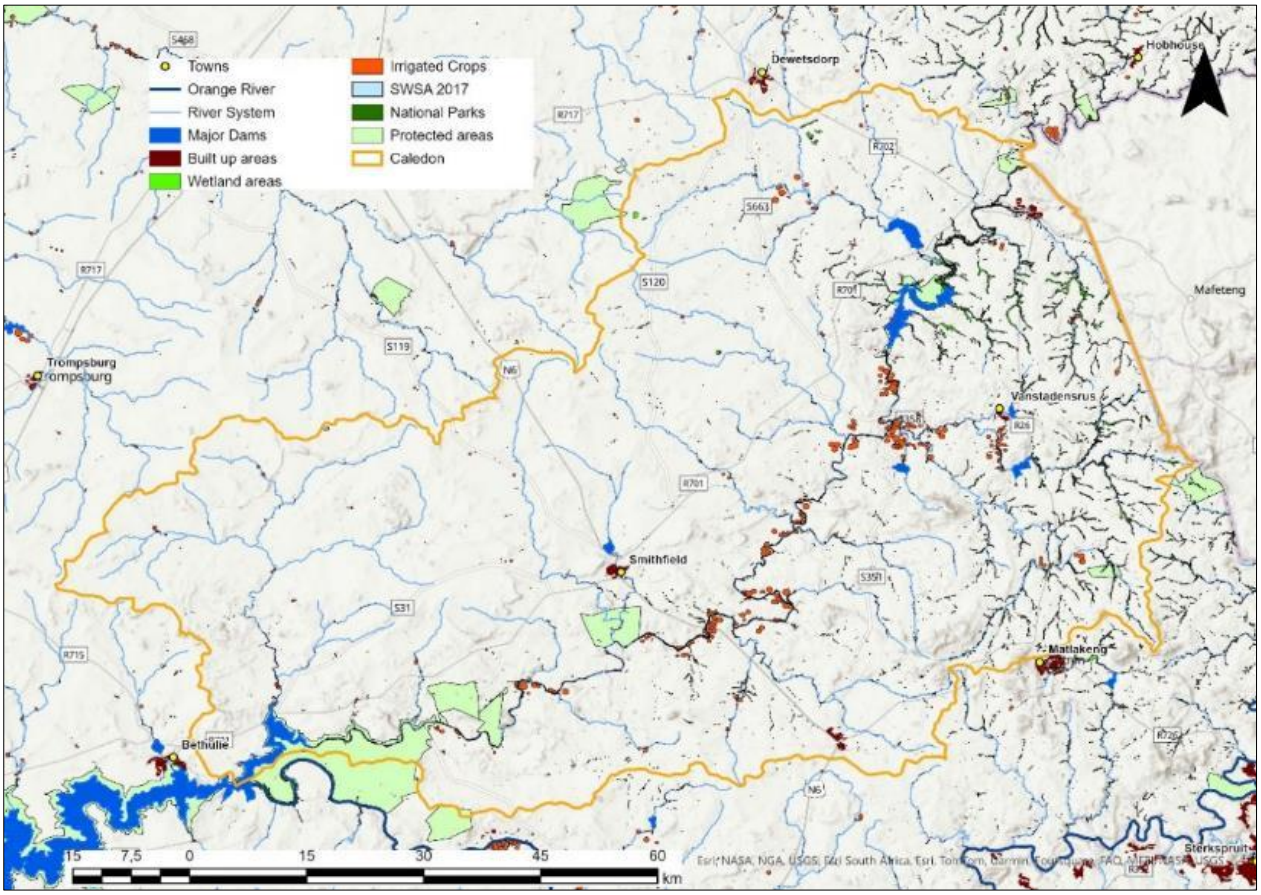

Figure 52: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 3 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 43).

Table 43: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 3 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Caledon River and its tributaries; channelled VB, seeps and floodplain wetlands.	The Caledon River has significance to the Wepener, Smithfield, Vanstadensrus and Rouxville communities by providing fish.	**Households, Society**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	Fresh Water	Caledon River and its tributaries; channelled VB, seeps and floodplain wetlands.	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the town communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Raw materials	Channelled VB, Seeps and Floodplain wetlands	Significance to subsistence farmers	**Agriculture; Households, Society**
	Medicinal resources	Channelled VB, Seeps and Floodplain wetlands	Significance to rural communities	**Households, Society**
Regulating	**Climate regulation**	Channelled VB, Seeps and Floodplain wetlands	Major significance to global beneficiaries	**Society**
	Water quantity regulation	Channelled VB, Seeps and Floodplain wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Wepener, Smithfield, Vanstadensrus and Rouxville communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	Channelled VB, Seeps and Floodplain wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Wepener, Smithfield, Vanstadensrus and Rouxville communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Caledon River and its tributaries; channelled VB, seeps and floodplain wetlands.	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Caledon River and its tributaries; channelled VB, seeps and floodplain wetlands.	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas; Caledon River and its tributaries; channelled VB,	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	Educational values and inspirational services	seeps and floodplain wetlands.		
Biodiversity	**Critical habitat & range restricted species**	Protected Areas; Caledon River and its tributaries; channelled VB, seeps and floodplain wetlands.	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**
	Maintenance of genetic diversity	Protected Areas; Caledon River and its tributaries; channelled VB, seeps and floodplain wetlands.	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Relatively high groundwater recharge (±20 mm/a, 159 Mm^3/a), but also high contribution to baseflow (27 Mm^3/a). Groundwater quality Class 0 (Ideal water quality type), and borehole yield class (BYC) is a d3-Class (i.e.,0.5 – 2.0 L/s). Groundwater use is low (stress index are a Natural Condition) and Allocable ground water still ±129 Mm^3/a.

9.4. IUA 4: Kraai River

IUA 4 comprises the Kraai River and tributaries to outlet of quaternary catchment D13M, before the confluence with the Orange River.

Rationale

The IUA delineation is based on the sub-catchment of the Kraai, with similar land use and large areas of critical biodiverse and natural areas that are still in good condition and require protection, with portions of the catchment strategic water source areas. The logical break is therefore at the confluence with the Orange River.

IUA Overview

The IUA lies entirely within the Eastern Cape province comprising 12 quaternary catchments that fall within parts of the local municipalities of Senqu, Walter Sisulu, Emalahleni and Enoch Mgijima. The main towns in the IUA include Jamestown, Dordrecht, Barkly East, and hamlets of Rhodes and Rossouw. The main water resources in the IUA include the Kraai River which flows through the IUA to the confluence with the Orange River and there are numerous tributaries. Parts of the Eastern Cape Drakensberg Strategic Water Source Area (SWSA) falls on the edges of the western part of the IUA. Two protected areas fall in the upper western part of the IUA and include the Lammergeier Highlands Nature Reserve and the Balloch Protected Environment. This IUA falls into the rural socio-economic zone.

Table 44 and the sections to follow gives an overview of the IUA, and Figure 53 gives an overview of boundaries and features in IUA 4.

Table 44: IUA 4 - Kraai River

IUA 4: Kraai River	Description
Quaternaries	D13A – D13M
Ecoregion	Predominantly Eastern Escarpment Mountains, small portions are in the Drought Corridor and NamaKaroo.
Geozones	A (upper reaches): A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools
	B (upper reaches): Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools.
	C (upper reaches): Moderately steep stream dominated by bedrock or boulder.
	D: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F (lower reaches towards the confluence with the Orange River): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Kraai River
Tributaries	Bokspruit, Langkloofspruit, Rytjieiesvlaktespruit, Vaalhoek, Wesbankspruit, Wilgespruit, Kromspruit, Holspruit, Braklaaglespruit, Skulspruit, Telemachusspruit, Kamingmelkspruit, Oslaagte, Elandspruit, Sterkspruit, Koffiehoekspruit, Bamboeshoekspruit, Vrouenshoekspruit, Vlooikraalspruit, Three Drifts, Diepspruit, Joggemspruit, Klein-Wildebeesspruit, Saalboomspruit, Noodshulpspruit, Saalboomspruit, Wasbankspruit, Wolwespruit, Rooihoogte se Loop, Kromspruit, Skulpspruit, Leeuspruit, Karringmelkspruit, Bossielaagtespruit, Rondefonteinspruit, Windvoelspruit, Elandspruit, Klipspruit
Land use	• Scattered rural settlements • Cultivation (irrigated and dry land crops) and predominantly subsistence farming

IUA 4: Kraai River	Description
EWR site	• UO_EWR08_I • UO_EWR05_FV • UO_EWR07_FV • UO_EWR08_FV • UO_EWR09_FV • UO_EWR18_FV • UO_EWR19_FV
Additional biological monitoring sites	REMP: • D1KRAA-ALIWA JSB3: • OSAEH_26_11
Infrastructure/ Dams	Small farm dams in western portion of the IUA in the tributaries in quaternary catchments: D13G, H, J, M and L
PES	A (SWSA), B - C
Groundwater	GRU 4 (IUA 4). Middle part of the Karoo Supergroup formations with merely sandstones/siltstones and large intrusive Karoo Dolerite features (circular sills) and sub-vertical dykes features present. Several QUATERNARY CATCHMENT s shows negative water balances (high baseflow figures).
Wetlands	• Unchanneled continuous valley bottom and hillslope seeps - ***Tiffendell Seep wetland complex (category A) in D13B,*** a high-altitude wetland complex - 2 000 mamsl, characterised by a unique vegetation assemblage; ***and Wolwespruit headwaters wetland complex (UCVB and HSS)(category C),*** a foraging site for both crane species and possibly also a breeding site for the Crowned Cranes • Channelled VB in D13E, including ***Klein-Wildebeespruit wetland complex (CVB and HSS)(category D)***, key for providing ecosystem services such as water quality enhancement and sediment trapping • Seeps in D13C, D, E G, K and J • Unchanneled valley bottom wetlands in D13C, D, E G, K, H and J, D35C and D • Channelled VB in D13C, D, E G, K, H and J, D35C and D
WQ hotpots/Use	• Limited irrigation return-flows • Run-off from rural areas • Limited sedimentation
SWSA	SWSA-sw: Eastern Cape Drakensburg in D13A, D13A, D13E and D13K

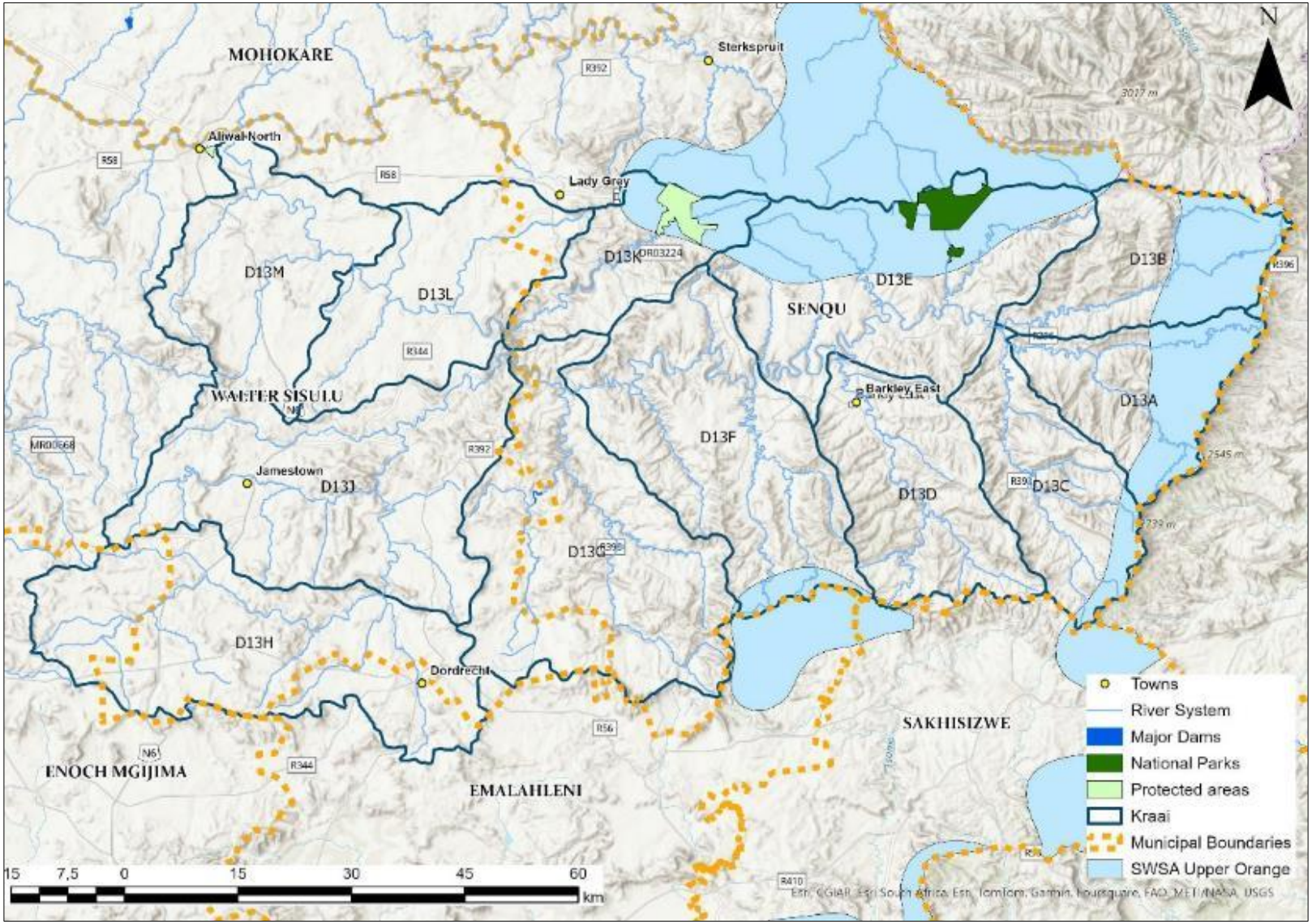

Figure 53: Overview of boundaries and features in IUA 4 of the Upper Orange River catchment

Demographics and socio-economic profile

The population is estimated as 28,845 (Stats SA Census 2011 adjusted) with approximately 7,062 households. Approximately 6.5% of the population has a higher education and 10.4% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate was estimated as 28% (NT, 2021).

A large proportion (85%) of the population in the IUA have access to formal water sources and the remaining 15% rely on informal water sources (Figure 54). In relation to formal water sources 44.8% of the population has access to piped water within their yards, 21.9% have piped water access within their dwellings, 27.3% have access to communal taps within 200m of the household whereas 5.5% of the population have access to a communal tap more than 200m from their household. Most of the population relying on informal water sources are sourcing water from rivers or streams (37.8%), followed by rain-water tanks (33.9%), boreholes (15.1%), dams, pools or stagnant water sources (12.6%) and less than 1% from springs (Figure 54). The population dwelling in formal dwellings ranges from a proportion of 83% to 96% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

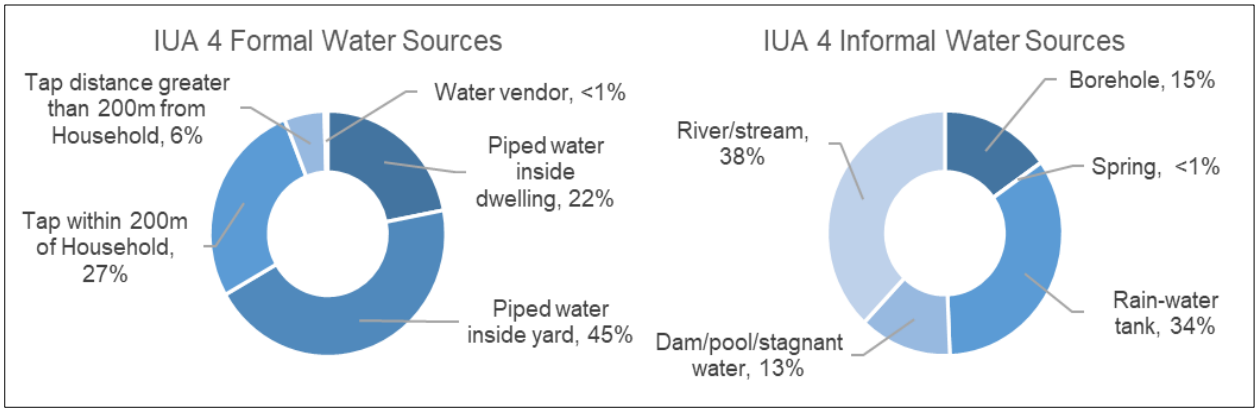

Figure 54: Access to water services in IUA 4

Economic Sectors

The main land uses and economic activity in IUA 4 includes residential settlements or towns, agriculture and to a limited extent tourism (Figure 55). The main agricultural activity is from livestock farming, followed by dryland agriculture and there is some irrigation agriculture occurring along parts of the Kraai River and tributaries. The main economic drivers and municipalities falling within IUA 4 are set out in Table 45.

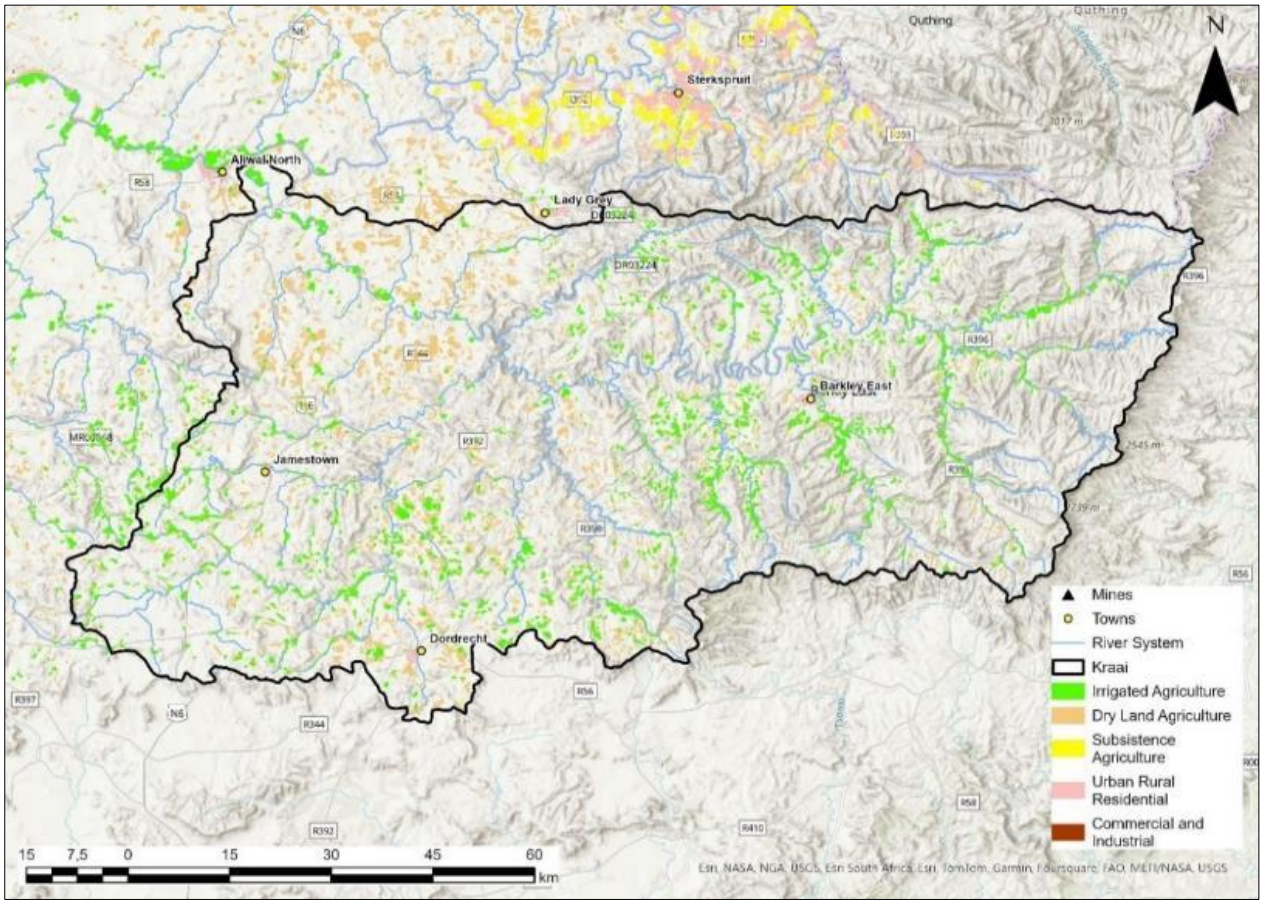

Figure 55: Land Use by land cover in IUA 4 in the Upper Orange River catchment (DFFE, 2020)

Table 45: Economic drivers relevant to IUA 4

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023)
Senqu	The towns in the IUA include Barkly East and hamlets of Rossouw and Rhodes. A key economic driver is agriculture with livestock farming predominating and consisting of sheep (for wool), cattle and goats and poultry farming. Cultivation agriculture is mainly dryland (maize, beans, sorghum and cabbage) and a small area of irrigation agriculture (lucerne, grains) mainly along the Kraai river and its tributaries. Activities within the tourism sector include adventure and agricultural tourism, self-drive routes for 4x4 enthusiasts and some hunting. South Africa's ski resort Tiffendell is near Rhodes. The main water use is for urban and agriculture activities.
Walter Sisulu	The main town in the IUA is Jamestown (James Calata).

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023)
	Economic activities include livestock agriculture of sheep and cattle and crop farming of wheat. Irrigation agriculture is practiced mainly along the Kraai river. The main water use is for urban and agriculture activities.
Emalahleni	The only town within this IUA is Dordrecht Main economic activities within the town and surrounding areas where some farming takes place, manufacturing of clay bricks and tourism with hiking trails and museums and some flyfishing. The main water use is for urban use in the part of the municipality with this IUA.
Enoch Mgijima	No towns in this IUA. There is some agricultural activity.

In IUA 4 the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 46 and Table 47.

Table 46: Economic sectors in IUA 4 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R116	4%
Mining	R17	1%
Manufacturing	R228	8%
Electricity & water	R43	2%
Construction	R273	10%
Wholesale & retail trade; catering and accommodation	R435	16%
Transport & communication	R185	7%
Financial services	R447	16%
General government	R738	26%
Community, social & personal services	R325	12%
Total GDP	R2,808	100%

Table 47: The estimated employment by economic sector for IUA 4 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	1,779	16%
Mining	26	0%
Manufacturing	279	2%

Economic Sector	Employment by economic sector (number of people)	% contribution
Electricity & water	33	0%
Construction	737	7%
Wholesale & retail trade; catering and accommodation	2,314	21%
Transport & communication	293	3%
Financial services	790	7%
General government	2,339	21%
Community, social & personal services	2,671	24%
Total Employment	11,262	100%

Ecosystem Services

This IUA is situated in the southeastern extent of the Upper Orange River catchment. It showcases a range of aquatic and terrestrial ecological infrastructure (Figure 56), including the Kraai River and its tributaries, as well as seeps and unchanneled VB wetlands. These ecological infrastructures provide vital ecosystem services to the towns of Barkly East, Dordrecht, and Jamestown. Additionally, the IUA is home to protected areas such as the Balloch Protected Environment and Lammergeier Highlands Nature Reserve, which hold significant cultural and biodiversity value. There are SWSAs located in the northeast, east, and south of this IUA, adding to its importance in terms of water resources.

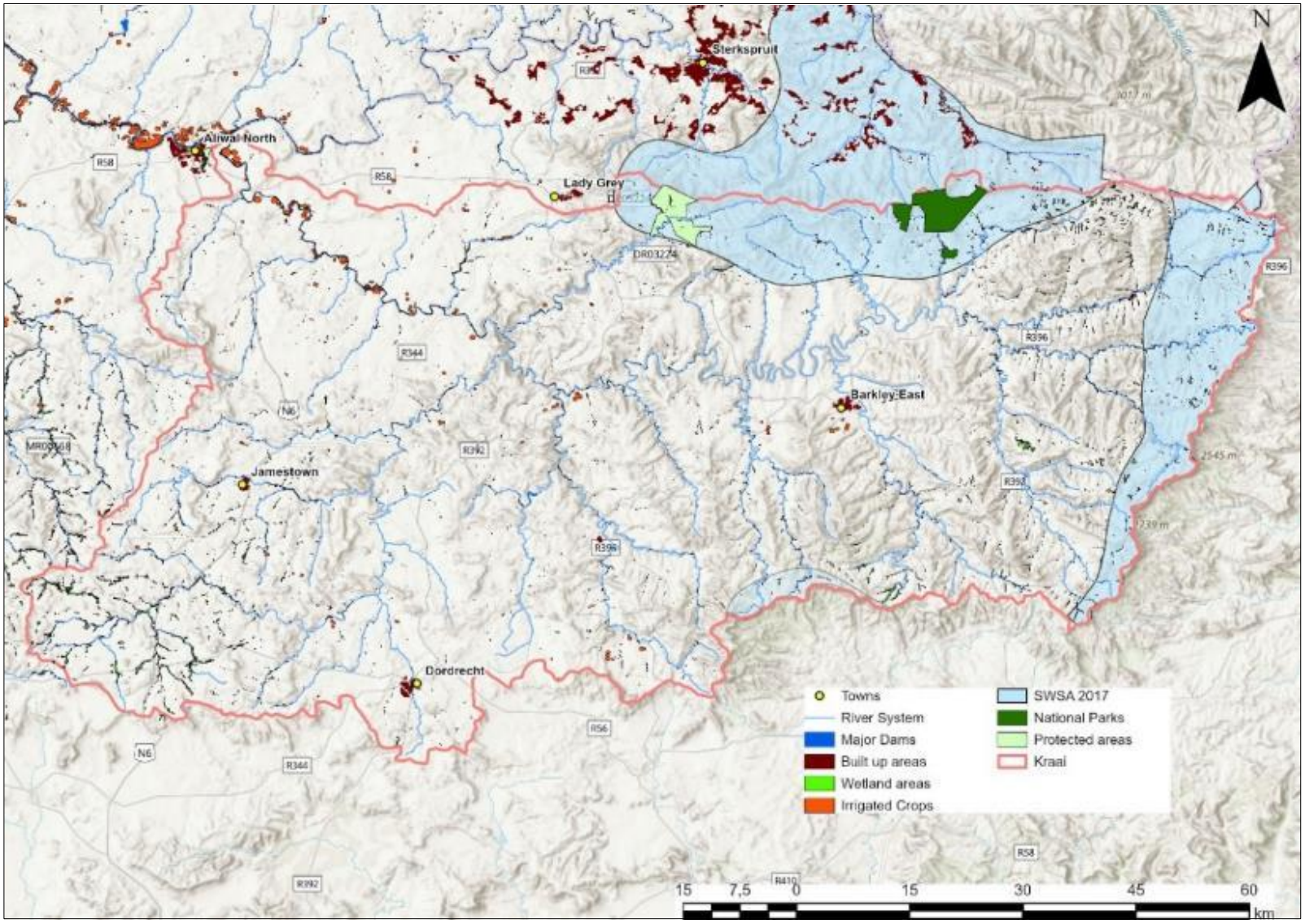

Figure 56: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 4 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 48).

Table 48: Key ecosystem services with corresponding ecological infrastructure, beneficiaries, and sector in IUA 4 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	Food	Kraai River and its tributaries; seeps and unchanneled VB wetlands	The Kraai River is of significance to the Barkly East, Dordrecht and Jamestown Communities by providing fish.	Households, Society
	Fresh Water	Kraai River and its tributaries; seeps and unchanneled VB wetlands	Major significance: Commercial agriculture and irrigation activity in parts of the IUA, specifically for the Barkly East, Dordrecht and Jamestown communities.	Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households
	Raw materials	Seeps and unchanneled VB wetlands	Significance to subsistence farmers	Agriculture; Households, Society
	Water quantity regulation	Strategic water source area; seeps and unchanneled VB wetlands	Major significance: Commercial agriculture and irrigation activity in parts of the IUA, specifically for the Barkly East, Dordrecht and Jamestown communities.	Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households
	Water purification & waste management	Strategic water source area; seeps and unchanneled VB wetlands	Major significance: Commercial agriculture and irrigation activity in parts of the IUA, specifically for the Barkly East, Dordrecht and Jamestown communities.	Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households
	Erosion control/ Soil stability	Kraai River and its tributaries; seeps and unchanneled VB wetlands	Major significance to commercial agriculture sector	Agriculture
	Biological control	Kraai River and its tributaries; seeps and unchanneled VB wetlands	Major significance to commercial agriculture sector	Agriculture; Households
Cultural	Landscape & amenity values	Protected Areas (Balloch Protected Environment & Lammergeier Highlands Nature Reserve); Kraai River and its tributaries; seeps	Major Significance: To tourism industry and rural communities through cultural value	Households; Tourism; Society
	Ecotourism & recreation			
	Educational values and			

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	inspirational services	and unchanneled VB wetlands		
Biodiversity	Critical habitat & range restricted species	Protected Areas (Balloch Protected Environment & Lammergeier Highlands Nature Reserve); Kraai River and its tributaries; seeps and unchanneled VB wetlands	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	Society; Tourism
	Maintenance of genetic diversity	Protected Areas (Balloch Protected Environment & Lammergeier Highlands Nature Reserve); Kraai River and its tributaries; seeps and unchanneled VB wetlands	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	Households, Society

Groundwater

Moderate to high groundwater recharge (~20 mm/a, 277 Mm^3/a), with high contribution to baseflow (baseflow indicated as higher-than recharge). Groundwater quality Class 0 (Ideal water quality type), and borehole yield class (BYC) is a d3-Class (i.e.,0.5 – 2.0 L/s). Groundwater use is low (stress index are a Natural Condition) and Allocable groundwater is in question due to proposed high contribution to baseflow.

9.5. IUA 5: Upper Orange River

IUA 5 comprises the Upper Orange from Lesotho border to Caledon confluence at Griep Dam, including Stormbergspruit.

Rationale

The IUA delineation is based on the sub-catchment of the Upper Orange River between the Lesotho border and the Gariep Dam, with similar land use and predominantly similar ecoregions. The logical break is therefore at the inflow to the Gariep Dam.

IUA Overview

IUA 5 falls partly into the Free State and partly in the Eastern Cape province, comprises 20 quaternary catchments and lies in parts of the four local municipalities of Mohokare, Senqu, Walter Sisulu and Enoch Mgijima. The main towns include Zastron, Sterkspruit, Maletswai (Aliwal North), Lady Grey, Molteno and Burgersdorp.

The main water resources in the IUA includes the main stem of the Orange River and several tributaries and part of the Eastern Cape Drakensberg Strategic Water Source Area falls within quaternary catchments D18K and parts of D18L, D12A and D12B. A few small, protected areas are found in the IUA including Mayaputi Private Nature Reserve (D12A), Highlands Safari Lodge (D15H), Buffelspruit Nature Reserve (D14A, Aliwal North), The Mountain Nature Reserve (D14E), Thaba Ghale Game Farm (D14J) and parts of the Tussen-die-Riviere Game Farm (D14K). This IUA falls mainly into the rural socio-economic zone.

Table 49 summarises the salient features in IUA 5, and Figure 57 gives an overview of boundaries and features in IUA 5.

Table 49: IUA 5 - Upper Orange River

IUA 5: Upper Orange River	Description
Quaternaries	D12A – D12F; D14A – D14K; D15H and D18K
Ecoregion	Highveld and a small portion in the Nama Karoo
Geozones	B (few in upper reaches): Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools.
	C (few in upper reaches): Moderately steep stream dominated by bedrock or boulder.
	D (many of the tributaries): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E: Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F (Orange River main stem): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Orange River (upstream from the Caledon confluence and Stormbergspruit)
Tributaries	Tele, border with (Lesotho), Sterkspruit, Makhaleng (lower reach), Stormberg, Wonderboomspruit
Land use	• Extensive subsistence agriculture (cultivation with limited irrigation, and extensive livestock grazing) in the upper portions • Irrigation along the river in the middle to lower portions • Sand mining (on main stem) • Towns: ○ Zastron

IUA 5: Upper Orange River	Description
	○ Aliwal North (Maletswai) ○ Burgersdorp ○ Witkop ○ Stormberg, and ○ Molteno
EWR site	• Main stem Orange River: UO_EWR02_I (Sterkspruit), UO_EWR03_I (Upper Orange) • Tributary: UO_EWR05_R (Wonderboomspruit) • UO_EWR23_FV (Tele) • UO_EWR25_FV (Makhaleng) • UO_EWR24_FV (Upper Orange) • UO_EWR03_FV (Gryskopspruit)
Additional biological monitoring sites	• JBS3 (2021): ○ OSAEH 11_22 (Orange) ○ OSAEH 26_14 (Orange) ○ OSAEH 26_13 (Stormberg)
Infrastructure/ Dams	• Main stem Orange (Lesotho – Khatze, Polihali (proposed), Makhaleng Dam (proposed) • Jozannashoek Dam (upper reaches Sterkspruit – D12B) • JI De Bruin Dam (D14C) (Klein-Buffelspruit) • Many small farm dams on the tributaries and specifically in the D14 tertiary catchment
PES	Reserve results: • UO_EWR02_I: D • UO_EWR03_I: D • UO_EWR05-R: D • UO_EWR03_FV: C • UO_EWR23_FV: C/D • UO_EWR24_FV: C/D • UO_EWR25_FV: D
Groundwater	GRU 5.1 and GRU 5.2. Middle to Upper part of the Karoo Supergroup formations with merely sandstones/siltstones and large intrusive Karoo Dolerite features (circular sills) and sub-vertical dykes features present.
Wetlands	• Small areas of depression wetlands • Channelled valley bottomed wetland around the town of Aliwal North • Small areas of seeps • No prioritised wetlands
WQ hotpots/Use	• Towns and associated poor performing WWTW: ○ Zastron WWTW: CRR 94% - critical risk ○ Aliwal North WWTW: CRR 68% - medium risk ○ Burgersdorp: CRR 94% - critical risk ○ Molteno WWTW: CRR 88% • Irrigation return-flows • Run-off from the extensive rural villages • Overgrazing of livestock leading to sedimentation
SWSA	SWSA-sw (Eastern Cape Drakensberg) in D18K

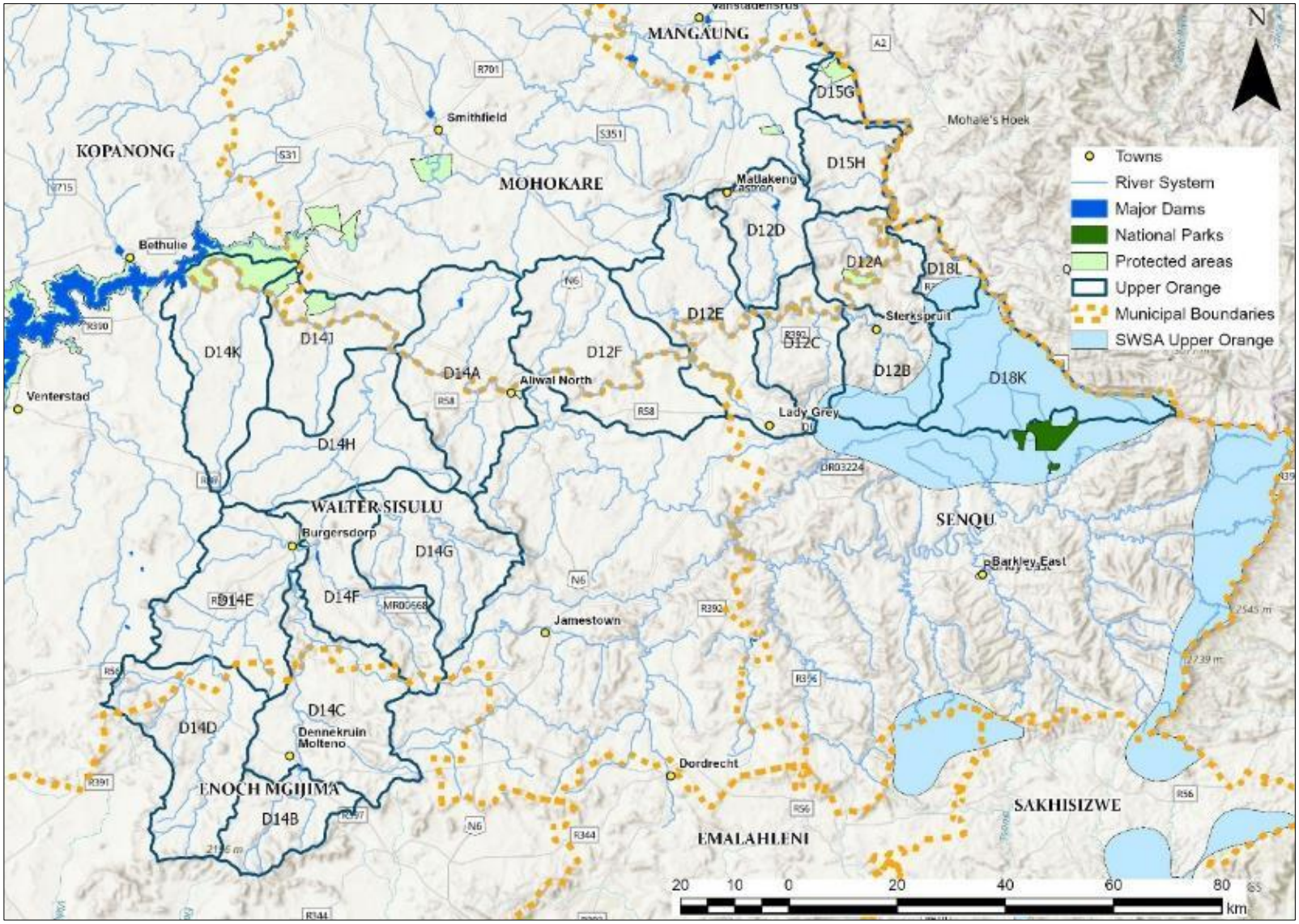

Figure 57: Overview of boundaries and features in IUA 5 of the Upper Orange River catchment

Demographics and socio-economic profile

The total population of IUA 5 is estimated as 201,339 (Stats SA Census 2011 adjusted) with approximately 54,454 households. Approximately 8.7% of the population has a higher education and 8.9% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate was estimated as 26% (NT, 2021).

In this IUA 90% of the population has access to formal water sources and 10% rely on informal water sources. In relation to formal water sources (Figure 58), 48.7% of the population have access to piped water within their yards, 25.9% have access to piped water within their dwellings, 21.8% have access to a communal tap within 200m of their household and 3.5% have access to a communal tap more than 200m from their household. The Informal water sources (Figure 58) are largely from rivers or streams (40%) followed by rain-water tanks (36.7%) and boreholes (12.5%) or from dams, pools or stagnant water (10.8%)(Figure 58). The population dwelling in formal dwellings ranges from a proportion of 88% to 96% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

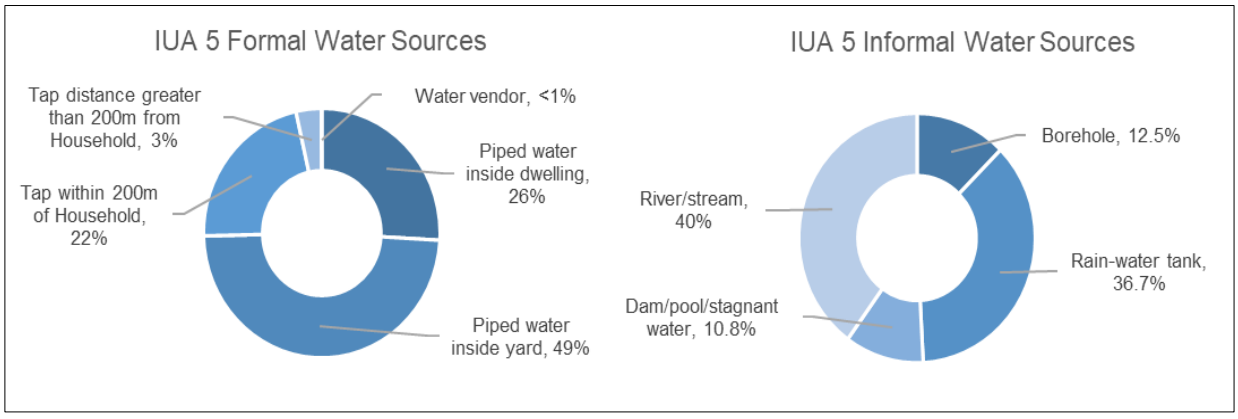

Figure 58: Access to water services in IUA 5

Economic Sectors

The IUA area consists mainly of small towns and numerous settlements with associated economic activity. Large areas within the eastern part of the IUA are utilised for subsistence farming (mixed agriculture). There is some commercial irrigation agricultural activity along the Orange River and some of the river tributaries and livestock agriculture in this IUA. The land use is illustrated in Figure 59. The main economic drivers and municipalities falling within IUA 4 are set out in Table 50.

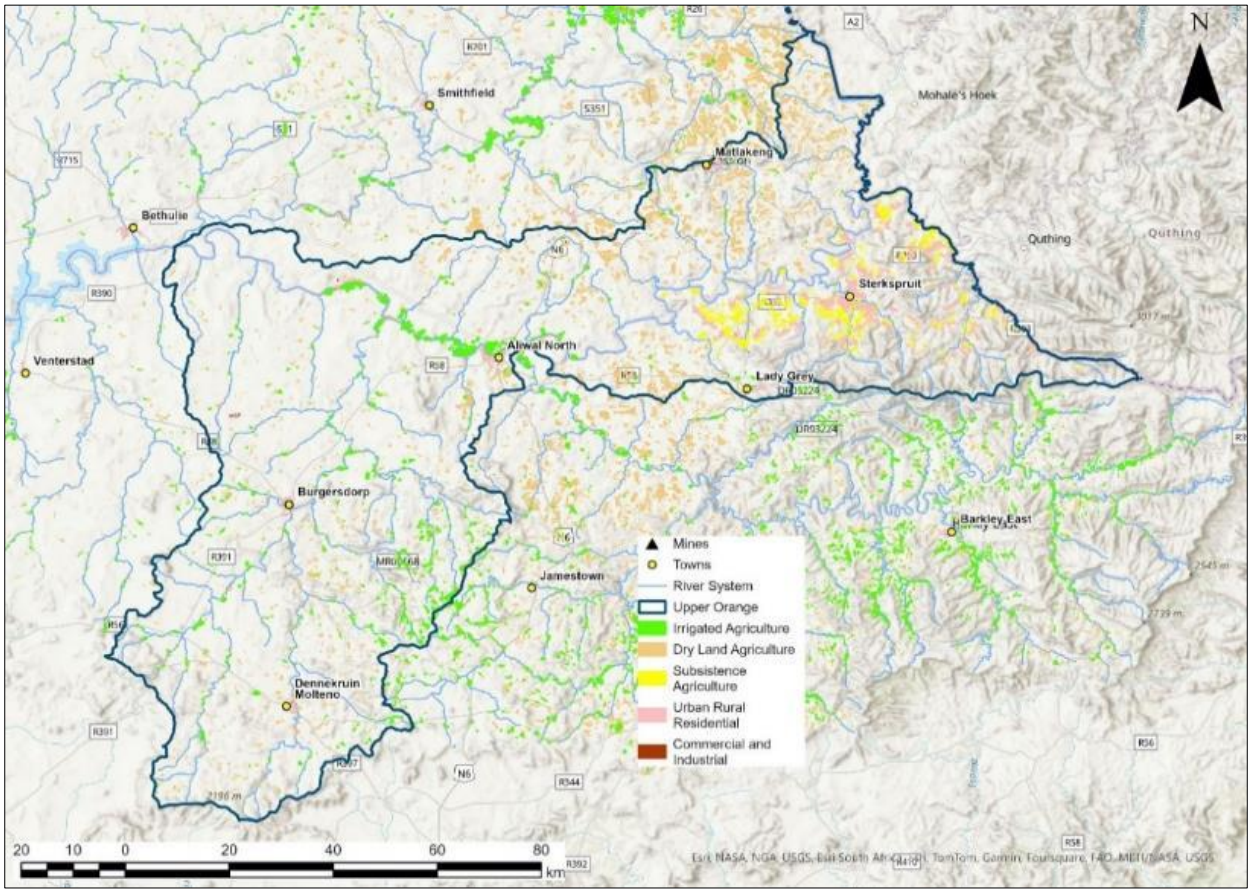

Figure 59: Land Use by land cover in IUA 5 in the Upper Orange River catchment (DFFE, 2020)

Table 50: Economic drivers relevant to IUA 5

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023 and District Profiles)
Senqu	The towns in the IUA include the main urban Sterkspruit and small urban hamlet of Hershel. The rest of the area has numerous villages. The main economic activity is from livestock agriculture. There are large areas of subsistence agriculture in this IUA.
Walter Sisulu	The main towns in the IUA are Maletswai (Aliwal North) and Burgersdorp. Economic activities include livestock agriculture of sheep, pigs and cattle, with sheep dominating. There are also some ostrich farms. Irrigation agriculture is practiced along the Orange River with crops such as maize wheat, cabbage, potatoes, lucerne and pasture. Tourism activities in particular in Maletswai with the hot mineral springs' spa resort and Buffelspruit Game Reserve. There are also war memorials in the area and several agri-tourism guest farms.

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023 and District Profiles)
	Manufacturing activity includes animal feed production in Burgersdorp and various commodities, goods and products in the business centre of Maletswai with trade to nearby towns in the Free State. The main water use is for urban and agriculture activities.
Enoch Mgijima	The main town in the IUA is Molteno. Key economic drivers in this area include livestock agriculture of sheep and Angora goats in commercial and communal farming areas. Some manufacturing in this IUA with the RCL Foods factory producing the well-known Oma Rusks in Molteno. Other economic activities from tourism in the area. There are historical sites and buildings in Molteno, one of the oldest railway stations and San rock art within the local municipality area of this IUA and hunting farms.
Mohokare	The main town in the IUA is Zastron and the small town of Goedemoed. Main economic activity includes agriculture which is predominantly stock farming (sheep and cattle), some dryland crop farming and some irrigated crop cultivation along the Orange River. There is also some game farming in the IUA and fish processing near Zastron. Another economic sector in the IUA is tourism particularly around Zastron. Zastron has the famous Eye of Zastron which is a nine-meter hole through a sandstone rock and there is also bushman art in the area on various farms. Other tourist attractions include the Maloti mountains, hunting and there are various nature reserves.

The contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 51 and Table 52.

Table 51: Economic sectors in IUA 5 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R430	5%
Mining	R108	1%
Manufacturing	R1,092	13%
Electricity & water	R133	2%
Construction	R653	8%
Wholesale & retail trade; catering and accommodation	R1,307	16%
Transport & communication	R553	7%
Financial services	R1,286	16%
General government	R1,910	23%
Community, social & personal services	R802	10%

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Total GDP	R8,274	100%

Table 52: The estimated employment by economic sector for IUA 5 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	5,670	19%
Mining	74	0%
Manufacturing	1,132	4%
Electricity & water	92	0%
Construction	1,636	5%
Wholesale & retail trade; catering and accommodation	6,280	21%
Transport & communication	750	2%
Financial services	2,569	8%
General government	5,945	19%
Community, social & personal services	6,397	21%
Total Employment	30,546	100%

Ecosystem Services

This IUA is situated partly in the Eastern Cape and partly in the Free State, with Lesotho bordering it in the northeast. Within IUA 5, notable locations include the towns of Sterkspruit, Zastron, Lady Grey, Maletswai (Aliwal North), Burgersdorp, and Molteno. The Orange River and its tributaries serve as the primary water resource in this area. Additionally, there are several endorheic pans/wetlands that contribute to the ecological infrastructure within the IUA (Figure 60), providing essential ecosystem services. There are numerous protected areas predominantly located in the northwestern extent of this IUA, with a SWSA situated in the east of IUA 5 (Figure 60).

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 53).

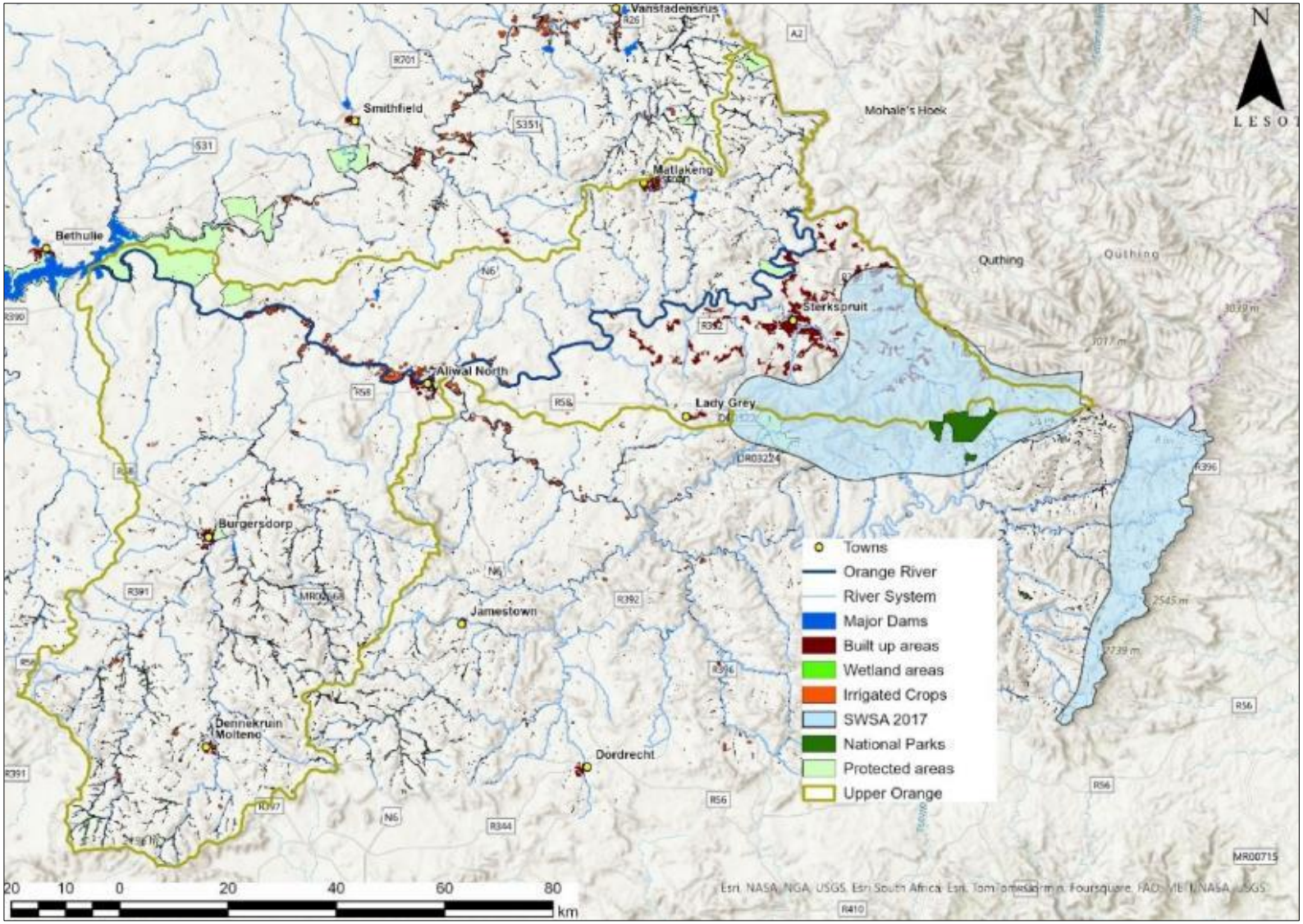

Figure 60: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 5 in the Upper Orange River catchment

Table 53: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 5 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Orange River and its tributaries; endorheic pans/wetlands	The Orange River is of significance to the Sterkspruit, Lady Grey, Maletswai (Aliwal North), Burgersdorp and Molteno communities by providing fish.	**Households, Society**
	Fresh Water	Orange River and its tributaries; endorheic pans/wetlands	Major significance: Commercial agriculture and irrigation activity along the Orange River and tributaries in the IUA, specifically for the Sterkspruit, Lady Grey, Maletswai (Aliwal North), Burgersdorp and Molteno communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Raw materials	Endorheic pans/wetlands	Significance to subsistence farmers	**Agriculture; Households, Society**
	Medicinal resources	Endorheic pans/wetlands	Significance to rural communities	**Households, Society**
	Water quantity regulation	Endorheic pans/wetlands; Strategic water source area	Major significance: Commercial agriculture and irrigation activity along the Orange River and tributaries in the IUA, specifically for the Sterkspruit, Lady Grey, Maletswai (Aliwal North), Burgersdorp and Molteno communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	Endorheic pans/wetlands; Strategic water source area	Major significance: Commercial agriculture and irrigation activity along the Orange River and tributaries in the IUA, specifically for the Sterkspruit, Lady Grey, Maletswai (Aliwal North), Burgersdorp and Molteno communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Orange River and its tributaries; endorheic pans/wetlands	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Orange River and its tributaries; endorheic pans/wetlands	Major significance to commercial agriculture sector	**Agriculture; Households**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Cultural	**Landscape & amenity values**	Protected Areas; Orange River and its tributaries; endorheic pans/wetlands	Major significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas; Orange River and its tributaries; endorheic pans/wetlands	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**
	Maintenance of genetic diversity	Protected Areas; Orange River and its tributaries; endorheic pans/wetlands	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Moderate to high groundwater recharge (~20 mm/a, 430 Mm^3/a), with contribution to baseflow (430 Mm^3/a. Groundwater quality Class 0 (Ideal water quality type), and borehole yield class (BYC) is a d3-Class (i.e.,0.5 – 2.0 L/s). Groundwater use is low (stress index are a Natural Condition) and Allocable ground water at ±67 Mm^3/a.

9.6. IUA 6: Gariep Dam

IUA 5 comprises the Orange River downstream of the confluence with the Caledon up to the Vanderkloof Dam.

Rationale

The IUA delineation is based on the tributary catchments draining to Gariep Dam and the tributary catchments draining to the and the Orange River downstream of the dam.

IUA Overview

The IUA comprises 17 quaternary catchments situated within the Free State, Eastern Cape and Northern Cape provinces in the local municipalities of Kopanong, Walter Sisulu and Umsobomvu respectively. The main towns in the IUA include Bethulie, Springfontein, Venterstad and Colesberg. Notable villages include Gariep Dam, Oviston and Norvalspont.

The main water resources in the IUA include the main stem of the Orange River and five tributaries. The large Gariep storage dam (largest in South Africa) is in this IUA and the surrounding protected areas of the Gariep Nature Reserve and Oviston Nature Reserve. The Orange-Fish Tunnel water transfer scheme from the Gariep Dam to the Fish and Sundays rivers in the Eastern Cape in support of irrigation and urban or industrial requirements particularly in the Algoa Water Supply Area. Other smaller protected areas include the Brakfontein Reserve and Merino Private Nature Reserve in the Free State. This IUA lies within the mixed-use socio-economic zone of the Upper Orange River catchment.

Table 54 summarises the salient aspects for the IUA and Figure 61 shows an overview of the boundaries and features in IUA 6.

Table 54: IUA 6 - Gariep Dam

IUA 6: Gariep Dam	Description
Quaternaries	D34B, D34C, D35J, D35G, D35D, D35C, D35E, D35B, D35A, D35F, D35H, D35K, D34D, D34F, D34A, D34G
Ecoregion	Nama Karoo
Geozones	D (many of the tributaries): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E (many of the tributaries): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F (Orange River main stem): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Orange River main stem
Tributaries	Oorlogspruit, Brakspruit, Broekspruit, Otterspoortspruit, Suurbergspruit,
Land use	• Gariep Dam (Orange-Fish transfer and hydropower) • Gariep Nature Reserve • Doornkloof Provincial Nature Reserve • Livestock grazing • Irrigation below the dam
EWR site	None

IUA 6: Gariep Dam	Description
Additional biological monitoring sites	No current sites, however, this river reach will be considered for future assessment, if possible
Infrastructure/ Dams	• Gariep Dam (FSC: 4,903.5Mm^3) • Many small dams
PES	JBS3 site • OSAEH_26_15
Groundwater	GRU 6.0. Middle part of the Karoo Supergroup formations with merely sandstones/siltstones and large intrusive Karoo Dolerite features (circular sills) and sub-vertical dykes features present. Aquifer system classified as a fractured type.
Wetlands	• Few depression wetlands in D34B, C, D and F • Seeps in D34B and D34F
WQ hotpots/Use	Irrigation return-flows Wastewater treatment works
SWSA	None

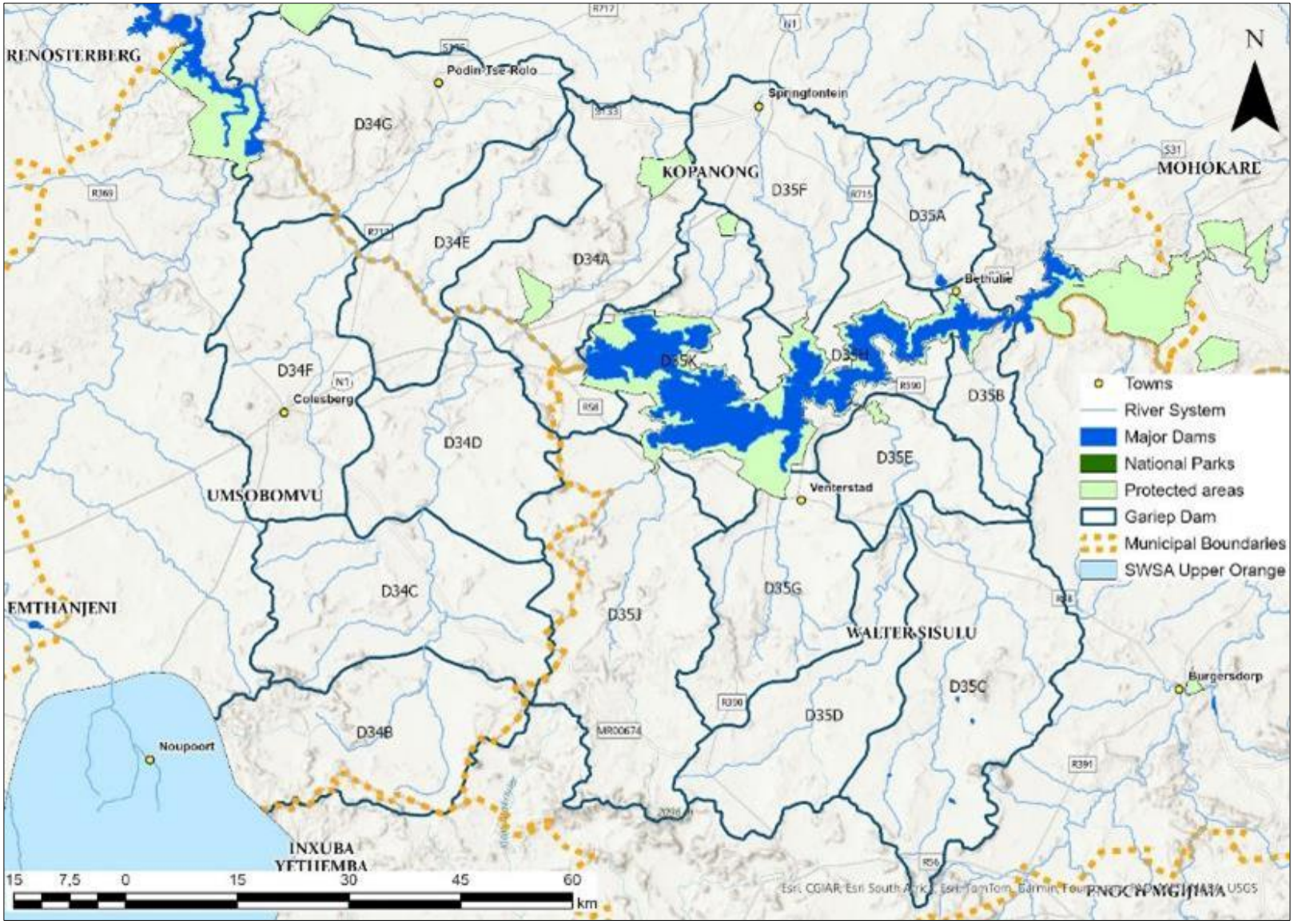

Figure 61: IUA 6 – Overview of boundaries and features in IUA 6 of the Upper Orange River catchment

Demographics and socio-economic profile

The total population of IUA 6 is estimated as 46,977 (Stats SA Census 2011 adjusted) with approximately 15,635 households. Approximately 7.8% of the population has a higher education and 9.3% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate was estimated as 23% (NT, 2021).

The entire population in IUA 6 have access to a formal water source, with 54% having access to piped water inside their yards, 40% having access to piped water inside their dwellings and the remaining 6% have access to a communal water tap within 200m of their households (Figure 62). The people in the IUA are mainly dwelling in formal dwellings with a proportion of 94% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

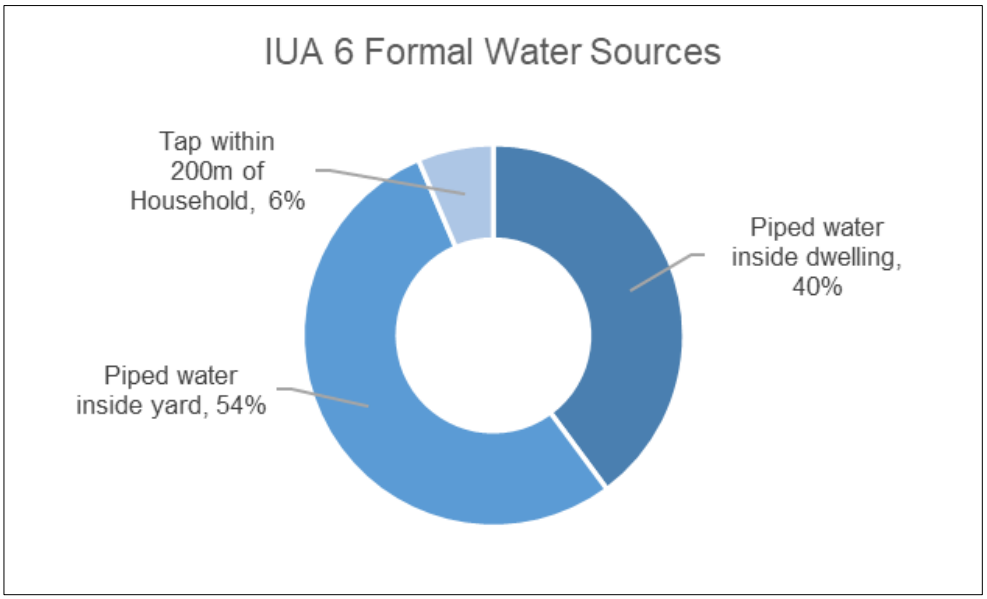

Figure 62: Access to water services in IUA 6

Economic Sectors

Land use and important economic sectors within the IUA include irrigation and dryland agriculture as well as extensive livestock farming (Figure 63). An important sector includes tourism including tourism of cultural, historical and nature perspective in the IUA. The main economic drivers and municipalities falling within IUA 4 are set out in Table 55.

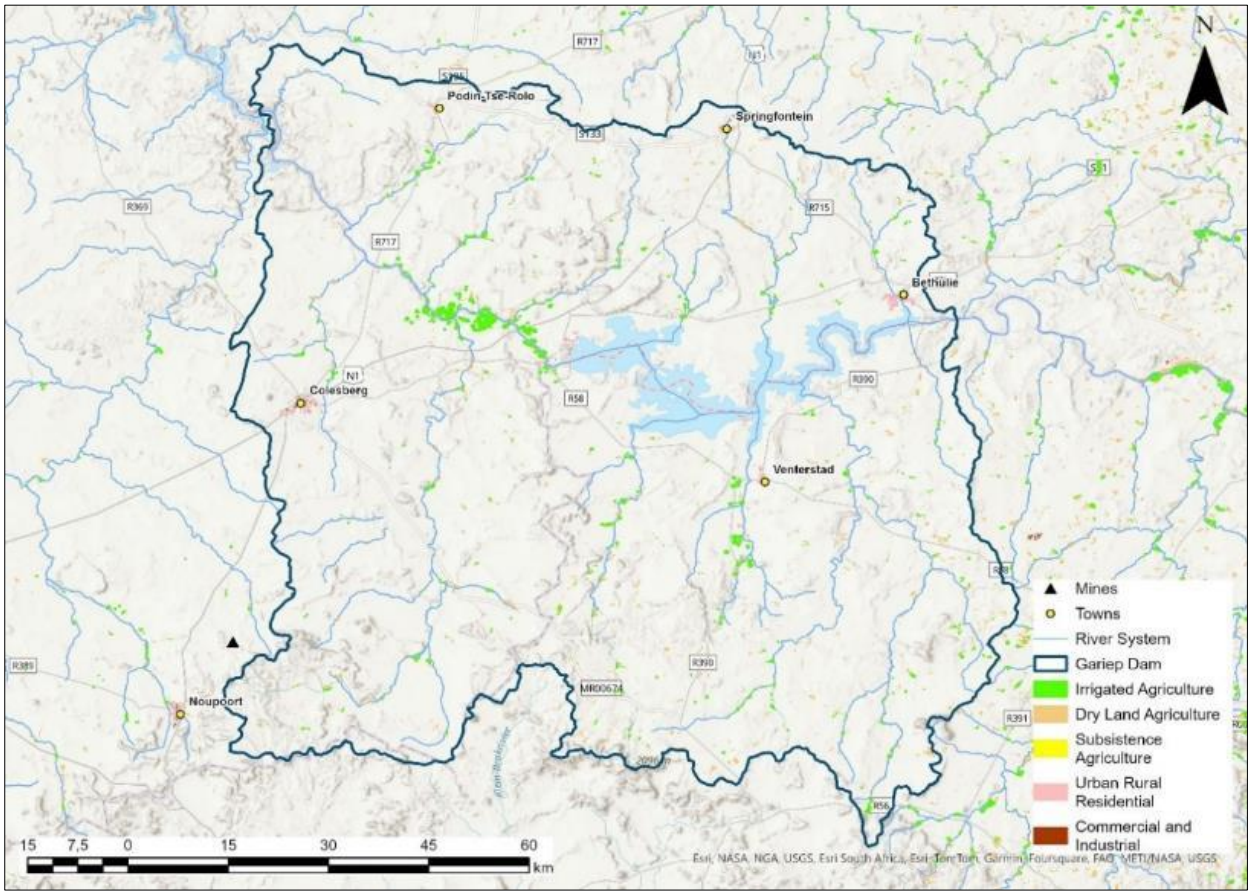

Figure 63: Land Use by land cover in IUA 6 in the Upper Orange River catchment (DFFE, 2020)

Table 55: Economic drivers relevant to IUA 6

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023 and District Profiles)
Kopanong	The towns included in the IUA are Bethulie, Springfontein and the villages of Gariepdam, Oranjekrag, Waterkloof and Philippolis. Key economic driver includes agriculture with extensive livestock farming of sheep and cattle. Irrigation agriculture takes place mainly along the Orange River and tributaries. In the town of Bethulie there is also a fish hatchery for production of fingerlings. Springfontein serves as an important railway junction. The other main economic driver is tourism. Tourism in and around the Gariep Dam (angling and water sport) and nature reserves. Bethulie is on the Xhariep Dam tourist route, known for the 1.2km DH Steyn Bridge connecting the Free State to the Cape province and the Anglo-Boer war memorial sites. Various holiday farms, resorts (near the dam) and game farms are further tourist attractions. The town of Philippolis has festivals and various historical buildings of interest.

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023 and District Profiles)
Walter Sisulu	Towns and villages within the IUA include Venterstad and Oviston. The main economic activities within the IUA include livestock farming of cattle and sheep and some dryland and other crop farming along the river tributaries. Other key economic activity is from tourism in the Gariep Dam region including the Oviston Nature Reserve and Gariep Nature Reserve. The Gariep hydro power station is located downstream of the dam in Quaternary catchment D34A
Umsobomvu	The IUA includes the main town of Colesberg and the smaller village of Norvalspont. The main economic drivers in this IUA include agriculture and tourism. Agriculture is dominated by sheep (merino) and horse farming. There are many horse stud farms in the greater Colesberg region. Tourism is particularly in and around the town of Colesberg which is a midway point for tourists travelling from Gauteng to Cape Town. The town of Norvalspont has the site of an Anglo-Boer war concentration camp. There are several guest farms within the IUA and along the Orange River.

In IUA 6 the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 56 and Table 57.

Table 56: Economic sectors in IUA 6 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R385	10%
Mining	R92	2%
Manufacturing	R356	9%
Electricity & water	R157	4%
Construction	R343	9%
Wholesale & retail trade; catering and accommodation	R625	16%
Transport & communication	R322	8%
Financial services	R524	14%
General government	R690	18%
Community, social & personal services	R321	8%
Total GDP	R3,815	100%

Table 57: The estimated employment by economic sector for IUA 6 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	3,197	22%
Mining	46	0.3%
Manufacturing	422	3%
Electricity & water	63	0%
Construction	988	7%
Wholesale & retail trade; catering and accommodation	3,206	22%
Transport & communication	342	2%
Financial services	1,236	9%
General government	2,442	17%
Community, social & personal services	2,436	17%
Total Employment	14,376	100%

Ecosystem Services

IUA 6 boasts several protected areas, with the notable inclusion of the Oviston Reserve, home to the Gariep Dam. The Orange River, along with its tributaries, and the Gariep Dam, which straddles the border between the Free State and Eastern Cape provinces, serve as the primary water sources for the area. It is important to note that no significant groundwater points have been identified within IUA 6. Figure 64 shows the locality of ecological infrastructure, cultivation, national parks, and protected areas.

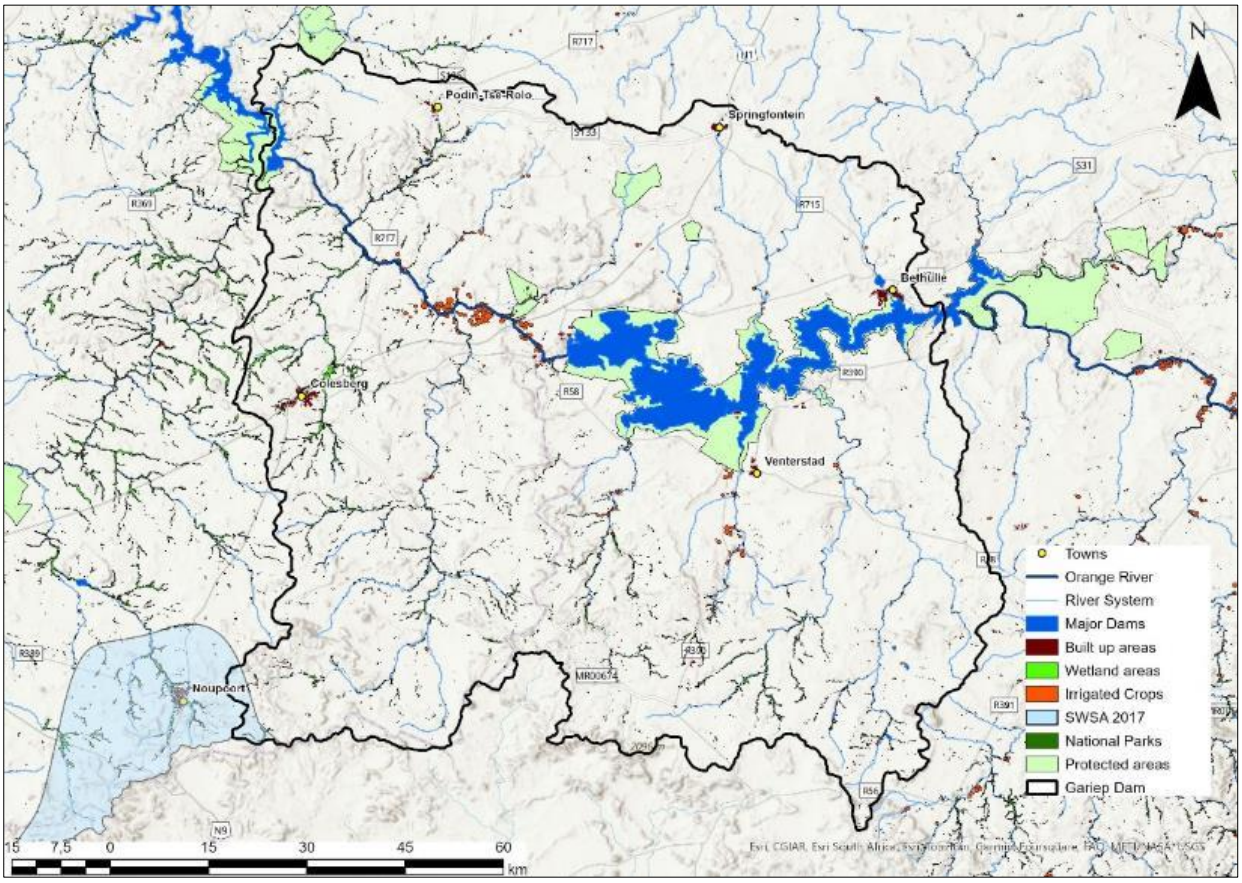

Figure 64: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 6 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 58).

Table 58: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 6 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Orange River and its tributaries; Endorheic pans/wetlands	The Orange River is of significance to the Venterstad, Bethulie, Springfontein and Colesberg communities by providing fish.	**Households, Society**
	Fresh Water	Orange River and its tributaries;	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		Endorheic pans/wetlands	Venterstad, Bethulie, Springfontein and Colesberg communities.	
	Erosion control/ Soil stability	Orange River and its tributaries; Endorheic pans/wetlands	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Orange River and its tributaries; Endorheic pans/wetlands	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas (Oviston nature reserve area, etc.); Orange River and its tributaries; Endorheic pans/wetlands	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas (Oviston nature reserve area, etc); Orange River and its tributaries; Endorheic pans/wetlands	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**
	Maintenance of genetic diversity	Protected Areas (Oviston nature reserve area, etc); Orange River and its tributaries; Endorheic pans/wetlands	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Moderate to high groundwater recharge (<20 mm/a, 131 Mm^3/a), with contribution to baseflow becoming lower (±15 Mm^3/a. Groundwater quality Class 0 (Ideal water quality type), but parts of QUATERNARY CATCHMENT s D34D, D35J and D35D have Class 1/2 water quality types. Borehole yield class (BYC) is a b3-Class (i.e.,0.5 – 2.0 L/s), a d3-Class (i.e., 0.5-2.0 L/s) in the Colesburg (quaternary catchment D34F), with a d4-BYC in GRU D35K (Gariep Dam quaternary catchment). Groundwater use is low (i.e. <13 Mm^3/a, with stress index are a Natural to Good Conditions) and Allocable ground water at ±104 Mm^3/a.

9.7. IUA 7: Seekoei River

IUA 7 comprises the quaternary catchments of the Seekoei River sub-catchment to its confluence with the Orange River.

Rationale

The IUA delineation is based on the tributary catchments draining to Gariep Dam and the tributary catchments draining to the and the Orange River downstream of the dam.

IUA Overview

The IUA is situated on the lower western part of the Upper Orange River catchment comprising 10 quaternary catchments lying predominantly in the Northern Cape province and a small portion within the Eastern Cape province. These quaternary catchments fall within the local municipalities of Umsobomvu, Emthanjeni, Ubuntu and Renosterberg in the Northern Cape and Inxuba Yethemba of the Eastern Cape. The main towns in the IUA include Hanover and Noupoort.

The main water resources in the IUA are the Seekoei river and several tributaries. There are strategic Water Source Areas (SWSA) in part of D32F and then one covering parts in Noupoort region in quaternary catchments D32G and stretches into parts of D32C and D32B. The protected areas in this IUA include High Karoo Park Protected Environment (D32D), parts of the Compassberg Protected Environment (D32B), the Hanover Aardvark Nature Reserve and Karoo Gariep Nature Reserve in quaternary catchment D32F and the Doornkloof Provincial Nature Reserve in the upper part of the IUA in D32K. The IUA falls mainly into the mixed-use socio-economic zone with land use mainly from mixed agriculture and mining.

Table 59 summarises salient aspects of the IUA and Figure 65 gives an overview of boundaries and features in IUA 7.

Table 59: IUA 7 - Seekoei River

IUA 7: Seekoei River	Description
Quaternaries	D32A, D32B, D32C, D32D, D32E, D32F, D32G, D32H, D32J, D32K
Ecoregion	Small portion on the Drought Corridor bur predominantly in the Nama Karoo ecoregion.
Geozones	B (few in upper reaches): Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools.
	C (few in upper reaches): Moderately steep stream dominated by bedrock or boulder.
	D (few of the tributaries): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E (tributary reaches and most of the Seeikoei River mainstem): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F (few reaches of the main stem Seeikoei River): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Seekoei River
Tributaries	Elands, Elandsfonteinspruit, Klein-Seekoei, Noupoortspruit, Elandskloof
Land use	• Main activity is livestock farming mainly with sheep for wool and meat. • Rural and livestock agriculture • Main towns Hanover and Noupoort and associated WWTW
EWR site	• UO_EWR05_I (D32J)
Additional biological monitoring sites	None
Infrastructure/ Dams	No major dams, however many small farm dams and weirs
PES	C

IUA 7: Seekoei River	Description
Groundwater	GRU 7.1 & GRU 7.2 Middle part of the Karoo Supergroup formations with merely sandstones/siltstones and limited intrusive Karoo Dolerite features (laminar/flat sills) and sub-vertical dykes features present. Aquifer system classified as fractured and fractured & weathered types. Contributions to baseflow in surface water systems limited to the main drainage systems. Local areas where alluvial accumulations close the main river systems act is surface water-groundwater systems (conjunctive flows during wet-dry seasons. SWSA-gw area in D32B
Wetlands	• Few depression wetlands throughout • Few seeps in D32E • At the EWR site in D32K– blue cranes in wetland area
WQ hotpots/Use	• Limited run-off from livestock agriculture • Urban run-off from the towns if Hanover and Norvalspont • Hanover WWTW (no discharge) – CRR: 94% • Norvalspont WWTW – CRR: 94%

Figure 65: IUA 7 – Overview of boundaries and features in IUA 7

Demographics and socio-economic profile

IUA 7 has the second lowest population density within the Upper Orange River catchment and the total population is estimated as 14,344 (Stats SA Census 2011 adjusted) with approximately 3,840 households. Approximately 7.3% of the population has a higher education and 9.6% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate was estimated as 25% (NT, 2021).

The population of this IUA all have access to a formal water source with 49% having access to piped water within their yards, 45% have access to piped water inside their dwellings and the remaining 6% have access to a communal tap within 200m of their households (Figure 66). Most of the population are dwelling in formal dwellings in the IUA ranging from 92% to 95% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

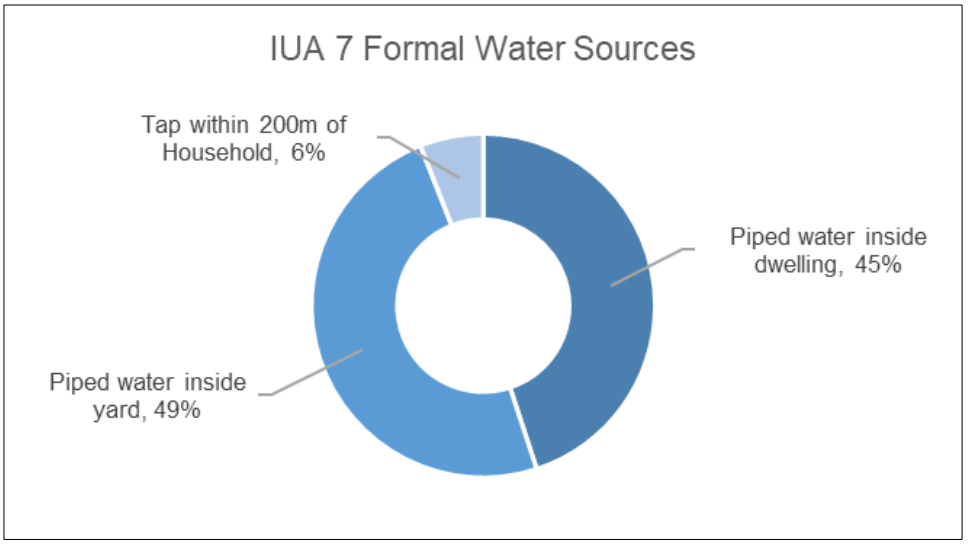

Figure 66: Access to water services in IUA 7

Economic Sectors

The land use and main economic sectors within this IUA include the residential areas of the towns and agriculture with extensive livestock farming mainly of sheep (for meat and wool and sheep breeding) (Figure 67). In D32H there is a small alluvial diamond mine. The main economic drivers within the municipalities falling within IUA 8 are set out in Table 60.

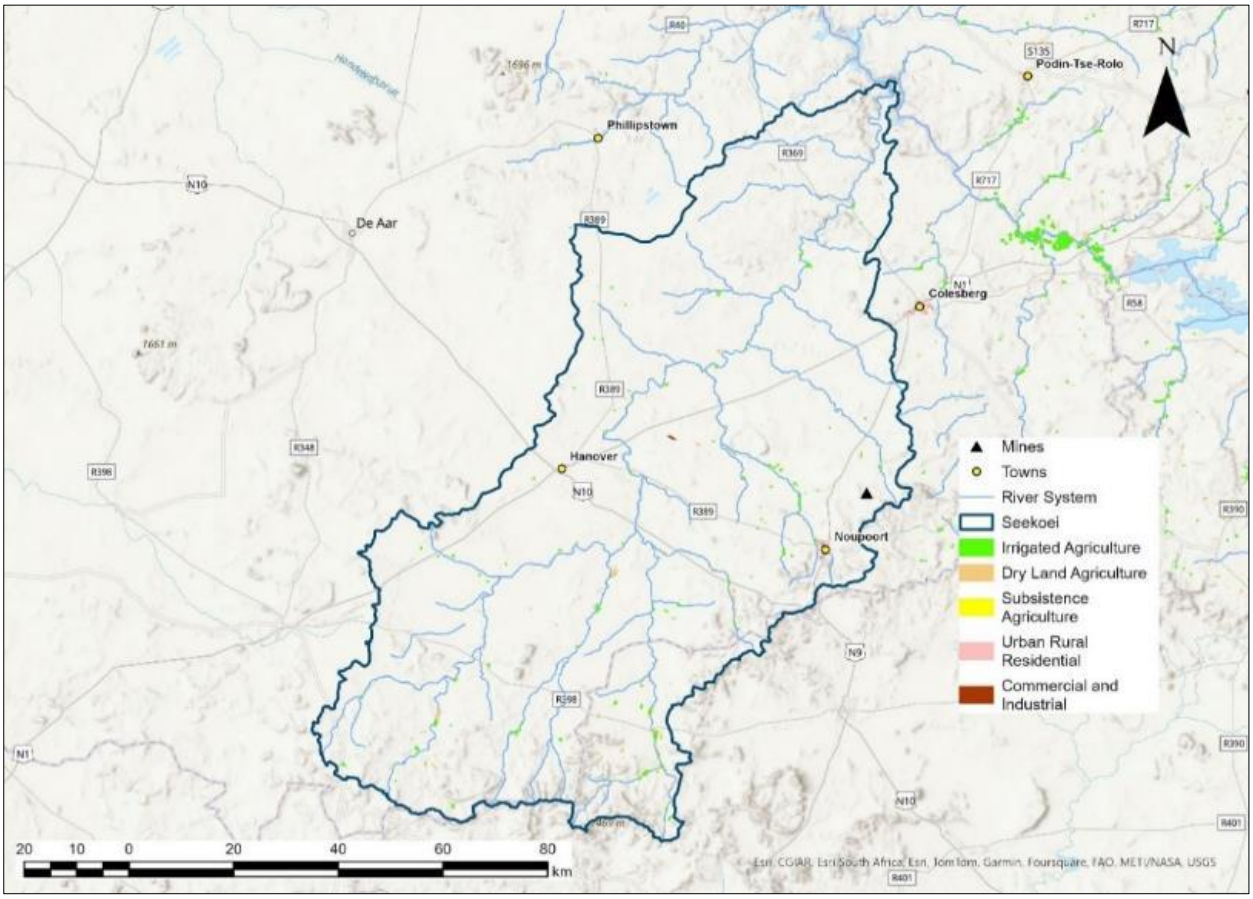

Figure 67: Land Use by land cover in IUA 7 in the Upper Orange River catchment (DFFE, 2020)

Table 60: Economic drivers relevant to IUA 7

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023 and District Profiles)
Emthanjeni	The main town in the IUA is Hanover. Key economic activities include extensive stock farming of sheep (mutton and wool farming of particularly Merino sheep) and tourism. Tourism is mainly in the historic town of Hanover, home to various artists and craftspeople and in the surrounding nature reserves including Hanover Aardvark Nature Reserve and Karoo Gariep Nature Reserve.
Umsobomvu	The main town in the IUA is Noupoort. The main economic activity is from livestock farming of sheep. The Noupoort Wind Farm is located a few kilometres west of the town of Noupoort in quaternary catchment D32G. There is an open cast alluvial diamond mine located north-east of Noupoort in quaternary catchment D32H.

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2017, 2022, 2023 and District Profiles)
	Some tourism at guest farms or lodges and the historical Anglo Boer War Blockhouse in Noupoort.
Ubuntu and Inxuba Yethemba	There are no towns within this part of the IUA. The main economic drivers here are from some agriculture and from tourism in the Compassberg Protected Environment, Mountain Zebra-Camdeboo Protected Environment and the High Karoo Park Protected Environment and guest farms.

In IUA 7 the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 61 and Table 62.

Table 61: Economic sectors in IUA 7 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R103	7%
Mining	R5	0%
Manufacturing	R60	4%
Electricity & water	R81	6%
Construction	R121	9%
Wholesale & retail trade; catering and accommodation	R166	12%
Transport & communication	R207	15%
Financial services	R268	19%
General government	R285	20%
Community, social & personal services	R100	7%
Total GDP	R1,395	100%

Table 62: The estimated employment by economic sector for IUA 7 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	638	13%
Mining	2	0%
Manufacturing	174	4%
Electricity & water	29	1%
Construction	415	9%
Wholesale & retail trade; catering and accommodation	988	21%
Transport & communication	187	4%
Financial services	531	11%
General government	1,132	24%

Economic Sector	Employment by economic sector (number of people)	% contribution
Community, social & personal services	713	15%
Total Employment	4,809	100%

Ecosystem Services

IUA 7 is in the southwestern part of the Upper Orange River catchment. Within this region, the towns of Noupoort and Hanover stand out as notable locations. These towns benefit from the aquatic and terrestrial ecological infrastructure, closely linked to the Seekoei River and its tributaries. The area is further enriched by the presence of protected environments, including a small section of the Mount-Zebra Camdeboo protected area, High Karoo Park, and the Compassberg protected environment. These protected areas not only contribute to the preservation of biodiversity but also offer valuable cultural services. Additionally, IUA 7 is known for its SWSA, further highlighting the region's significance in terms of water resources (Figure 68).

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 63).

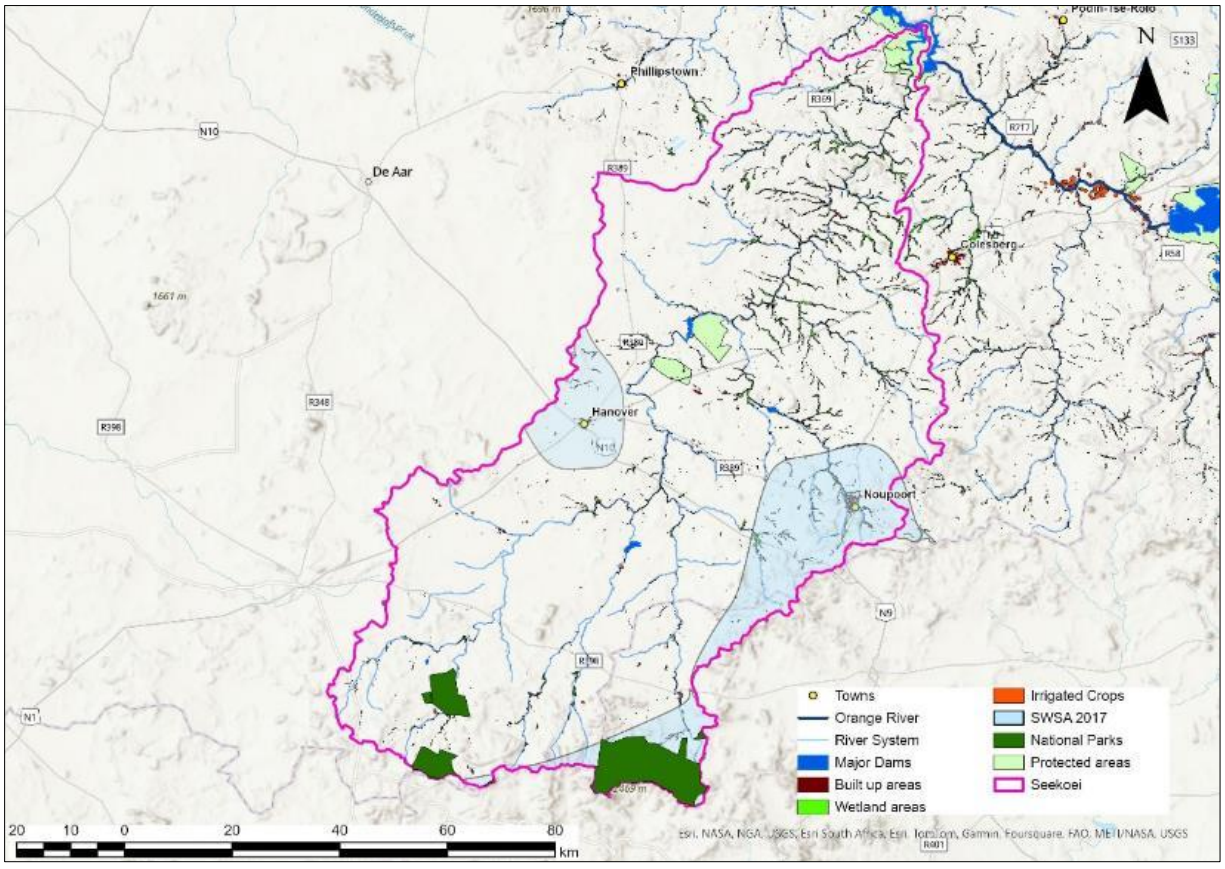

Figure 68: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 7 in the Upper Orange River catchment

Table 63: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 7 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Seekoei River its tributaries	The Seekoei River and its tributaries is of significance to the Noupoort and Hanover Communities by providing fish.	**Households, Society**
	Fresh Water	Seekoei River and its tributaries	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the, Noupoort and Hanover communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water quantity regulation	Strategic water source area	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Noupoort and Hanover communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	Strategic water source area	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Noupoort and Hanover communities.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Seekoei River and its tributaries;	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Seekoei River and its tributaries	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas (Mount-Zebra Camdeboo protected area, High Karoo Park, and the Compassberg protected environment); Seekoei River and its tributaries	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas (Mount-Zebra Camdeboo protected area, High Karoo Park, and the Compassberg protected environment); Seekoei River and its tributaries	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	Maintenance of genetic diversity	Protected Areas (Mount-Zebra Camdeboo protected area, High Karoo Park, and the Compassberg protected environment); Seekoei River and its tributaries	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Moderate to low groundwater recharge (<20 mm/a, 430 Mm^3/a), with low contribution to baseflow (7 Mm^3/a. Groundwater quality Class 1/2 (Good/Marginal water quality type) in GRU 7.2, and the northern part of GRU 7.1 – probably related to primary salinity in the aquifer rock formation. Borehole yield class (BYC) is a b3-Class (i.e.,0.5 – 2.0 L/s in a fractured aquifer system), and a d3-Class (i.e., 0.5-2.0 L/s in a fractured & weathered aquifer system). Groundwater use is low (stress index are merely a Natural Condition) and Allocable ground water at ±85 Mm^3/a.

9.8. IUA 8: Vanderkloof Dam

IUA 8 comprises the quaternary catchments of the Vanderkloof Dam sub-catchment as well as the downstream sub-catchments of the Orange River mainstem to its confluence with the Vaal River.

Rationale

The IUA delineation is based on the tributary catchments draining to Vanderkloof Dam and the tributary catchments draining to Orange River downstream of the dam to the Vaal River confluence being of a similar land use and ecoregion, as well as a fish support area along the full reach to the Vaal River confluence.

IUA Overview

The IUA is situated along the upper western border of the Upper Orange River catchment and comprises 15 quaternary catchments. These lie within parts of six local municipalities including, Siyancuma, Thembelihle, Renosterberg and a small part of Umsobomvu in the Northern Cape and Kopanong and Letsemeng of the Free State province. The main towns in the IUA include Orania, Hopetown, Petrusville, Vanderkloof, Phillipstown, and Luckhoff.

The main water resources in the IUA include the main stem of the Orange River and several

tributaries. The IUA includes the Vanderkloof Dam and the Rolfontein Provincial Nature Reserve, Tuinhoek Reserve and Grasberg Reserve adjacent to the dam. Other protected areas within the IUA include parts of the Doornkloof Provincial Nature Reserve and several other private nature reserves. This IUA falls into the agriculture and mining socio-economic zone with land use mainly irrigated agriculture and some mining.

Table 64 gives an overview of the key aspects in IUA 8 and Figure 69 illustrates the boundaries and main features.

Table 64: IUA 8 – Vanderkloof Dam

IUA 8: Vanderkloof Dam	Description
Quaternaries	D33A – D33K
Ecoregions	Nama Karoo
Geozones	D (tributary reaches): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E (tributary reaches): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F (predominantly along the Orange River): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Orange River
Tributaries	Various unnamed tributaries
Land use	• Vanderkloof Dam (transfer to Riet River catchment and hydropower) • Extensive Irrigation downstream and at the outlet of the IUA • Hopetown and associated WWTW
EWR site	• UO_EWR10-I • UO_EWR15-FV

Additional biological monitoring sites	• JBS3 sites:
	  ○ OSAEH_26_2
	  ○ OSAEH_26_3
	• REMP sites
	  ○ D3ORAN-HOPET
	  ○ D3ORAN-MARKS

Infrastructure/ Dams	Vanderkloof Dam (FSC: 3,092.4 Mm^3) - major storage dam – irrigation, domestic, hydropower and recreation
PES	Predominantly C, some D's and some unassessed areas

IUA 8: Vanderkloof Dam	**Description**
Groundwater	GRU 8.1, GRU 8.2 and GRU 8.3 (based on decreasing recharge and ground water quality. Middle and Lower parts of the Karoo Supergroup formations with merely sandstones/siltstones (Beaufort Group) and mudrock (Ecca Group). Limited intrusive Karoo Dolerite features (laminar/flat sills) and sub-vertical dykes features present. Aquifer system classified as fractured and fractured & weathered types. Contributions to baseflow in surface water systems limited to the main drainage systems.

Wetlands	• Unchanneled Valley Bottom wetlands
	  ○ ***Philipstown UCVB wetland complex (C)*** provides important habitat diversity.
	• Channelled valley bottomed wetlands
	• Hillslope seeps
	  ○ ***Barkley Pass wetland complex (UCVB, CVB and HSS) (A)*** located at approximately 2 000 mamsl, characterised by a unique vegetation assemblage, representative of rare intactness for wetlands in South Africa.
	• Depression wetlands throughout with ***Luckhof depression wetland complex (B)*** which forms a unique feature in the broader landscape and provides important habitats for both fauna and flora

WQ hotpots/Use	• Return-flows from irrigation • Limited urban run-off from Hopetown • Hopetown WWTW (poor performance) – CRR: 82%
SWSA	None

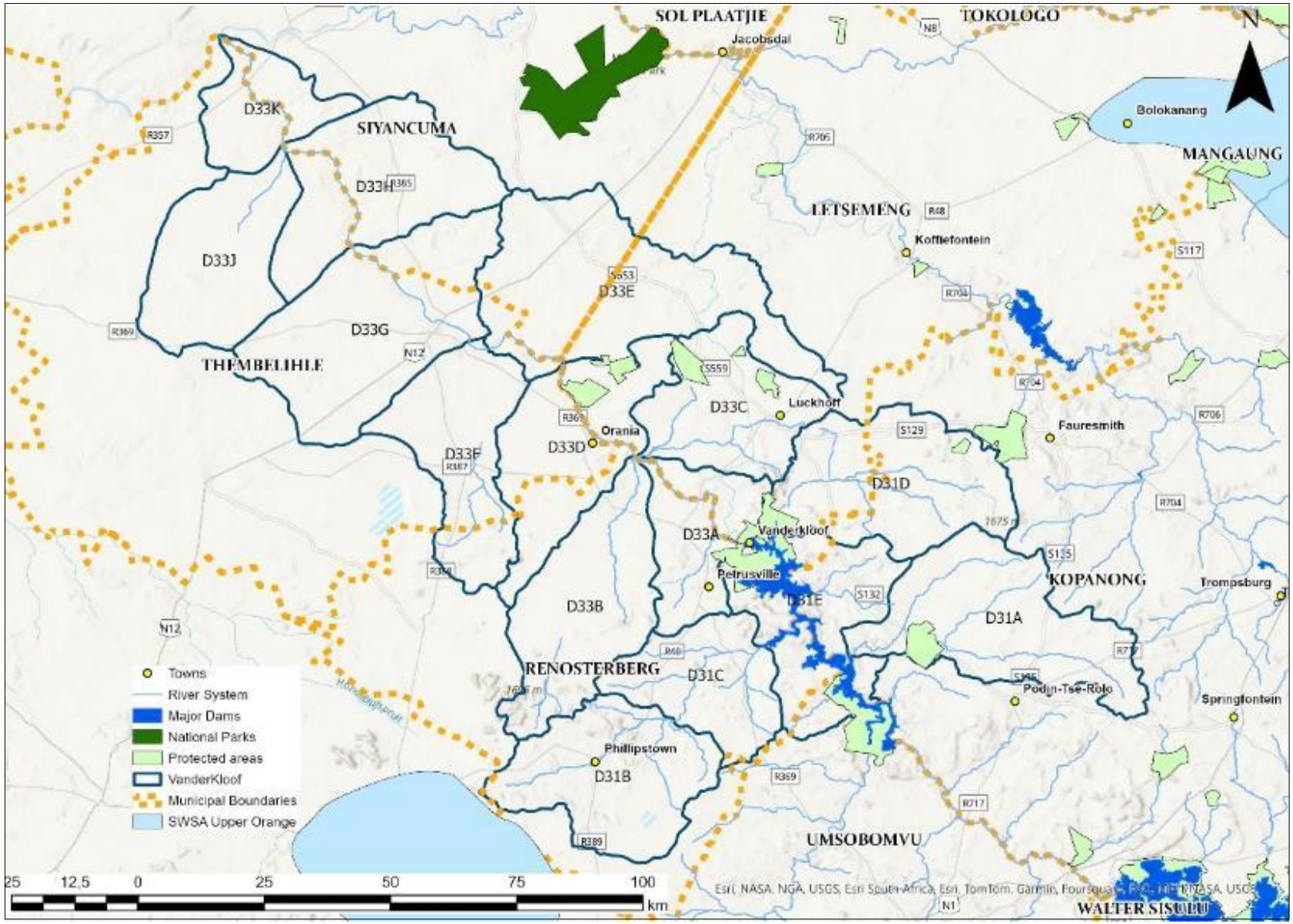

Figure 69: Overview of boundaries and features in IUA 8 of the Upper Orange River catchment

Demographics and socio-economic profile

The total population of IUA 8 is estimated as 32,577 (Stats SA Census 2011 adjusted) with approximately 9,674 households. Approximately 6.7% of the population has a higher education and 10.3% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate was estimated as 21% (NT, 2021).

The majority of the population (99%) in the IUA have access to formal water sources and only 1% rely on informal water sources. Approximately 49% of the population has access to piped water source inside their yard, 44% have access to formal piped water inside their dwellings and 7% have access to ta communal tap within 200m of their households (Figure 70). In relation to informal water sources 65% of the population have access through boreholes, 13% rely on rivers or streams and 22% rely on other water sources (Figure 70). People in the IUA dwelling in formal dwellings range from as low as 68% to as high as 95% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

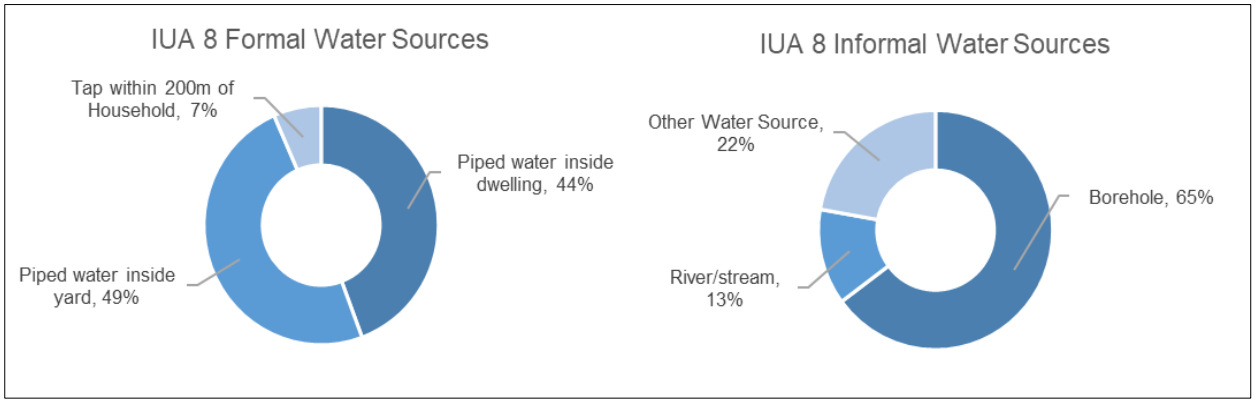

Figure 70: Access to water services in IUA 8

Economic Sectors

This IUA's land use and economic activity is characterised by intensive irrigation agriculture and livestock and game farming. There is some mining land use from alluvial diamond mines in the upper western part of the IUA. Some salt manufacturing and there are several pans within the IUA (Figure 71). Tourism plays a role (cultural, historical and from a nature perspective) in particular the towns and along the Orange River, at the Vanderkloof Dam and in the various nature reserves in the IUA. The main economic drivers within the municipalities falling within IUA 8 are set out in Table 65.

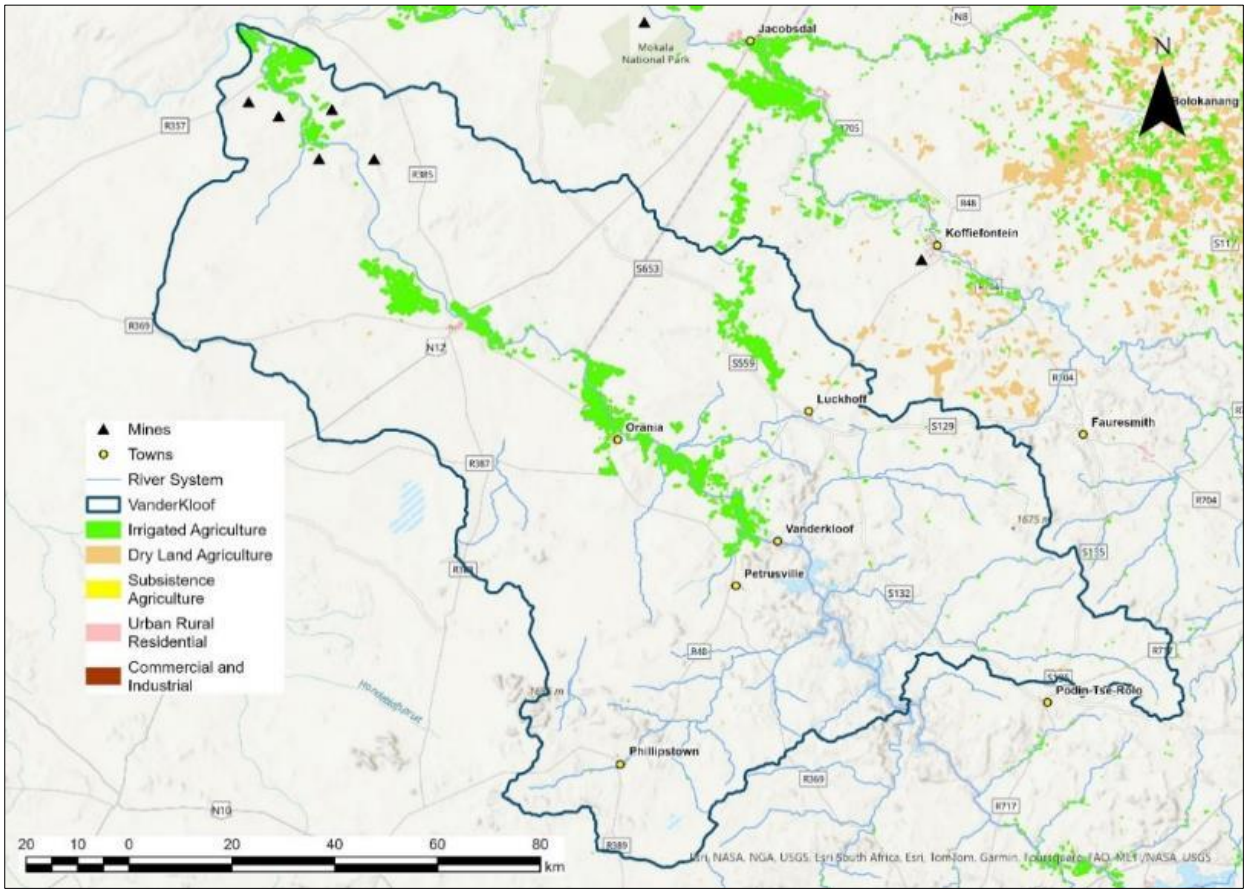

Figure 71: Land Use by land cover in IUA 8 in the Upper Orange River catchment (DFFE, 2020)

Table 65: Economic drivers relevant to IUA 8

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2015, 2022, 2023 and District Profiles)
Siyancuma	No main towns. The area has rural villages and farm settlements. Economic activity is mainly irrigation agriculture along the Orange River to the confluence with the Vaal River where cereals and vegetable crops are grown. There is a contribution to manufacturing at Salt Lake, a private farm that has a salt manufacturing plant. The area has two alluvial diamond mines in D33H and D33K.
Thembelihle	The towns include Hopetown and Orania. Economic activities include livestock farming of sheep and goats and intensive irrigation agriculture along the Orange River. The main crops include grains, vegetables and pecan nuts.

Local Municipality	Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2015, 2022, 2023 and District Profiles)
	Another economic river is from alluvial diamond mining in D33J and D33K with three mines. Tourism activities along the Orange River and in the towns of Orania and Hopetown and surrounding area. Some manufacturing in Hopetown mainly related to agro-processing and there small manufacturing companies in Orania including a small light steel manufacturing company.
Renosterberg	The towns in the IUA include Petrusville, Vanderkloof and Phillipstown. A key economic activity is intensive irrigation agriculture of grains and vegetables along the Orange River downstream of the Vanderkloof Dam. Other agricultural activities include some livestock farming of sheep and game farming. Other economic activity is from tourism particularly the Vanderkloof Dam for angling and water sports. There is also the Doornkloof and Rolfontein nature reserves adjacent to the dam. Historical and cultural sites from the Anglo-Boer war. The Vanderkloof Dam hydroelectric plant lies in quats D31E and D33A providing power in peak or emergency periods and for when excess water poses flood risk it is used for base load power.
Kopanong	No towns within this part of the IUA and the main economic activity is from tourism in the areas adjacent to the Orange River and up to the Vanderkloof Dam including various lodges, private reserves and guest farms and hunting.
Letsemeng	Only one small town of Luckhoff in this IUA that serves as an agricultural service centre. The main economic activity is from intensive irrigation agriculture along the Orange River and irrigation canals and some livestock farming.

In IUA 8 the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 66 and Table 67.

Table 66: Economic sectors in IUA 8 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R421	19%
Mining	R104	5%
Manufacturing	R120	5%
Electricity & water	R153	7%
Construction	R192	9%
Wholesale & retail trade; catering and accommodation	R290	13%

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Transport & communication	R215	10%
Financial services	R224	10%
General government	R332	15%
Community, social & personal services	R147	7%
Total GDP	R2,197	100%

Table 67: The estimated employment by economic sector for IUA 8 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	3,087	33%
Mining	54	1%
Manufacturing	271	3%
Electricity & water	63	1%
Construction	763	8%
Wholesale & retail trade; catering and accommodation	1,494	16%
Transport & communication	191	2%
Financial services	709	8%
General government	1,463	16%
Community, social & personal services	1,262	13%
Total Employment	9,357	100%

Ecosystem Services

IUA 8 is located in the western region of the catchment where the Vanderkloof Dam is situated. Notable locations within IUA 8 include the towns of Petrusville, Phillipstown, Luckhoff, Vanderkloof, Orania, and Hopetown. The main sources of water in this zone are the Orange River and its tributaries and the Vanderkloof Dam. Additionally, within the IUA there are the Doornkloof and Rolfontein Provincial Nature Reserves which are situated upstream and downstream of the dam, respectively. A few smaller protected areas within IUA 8 include Grootfontein Private Nature Reserve, Thanda Thula Reserve, Roodepoortjie 144 and the Zoutpansdrif 246 area all situated north of the Orange River (Figure 72).

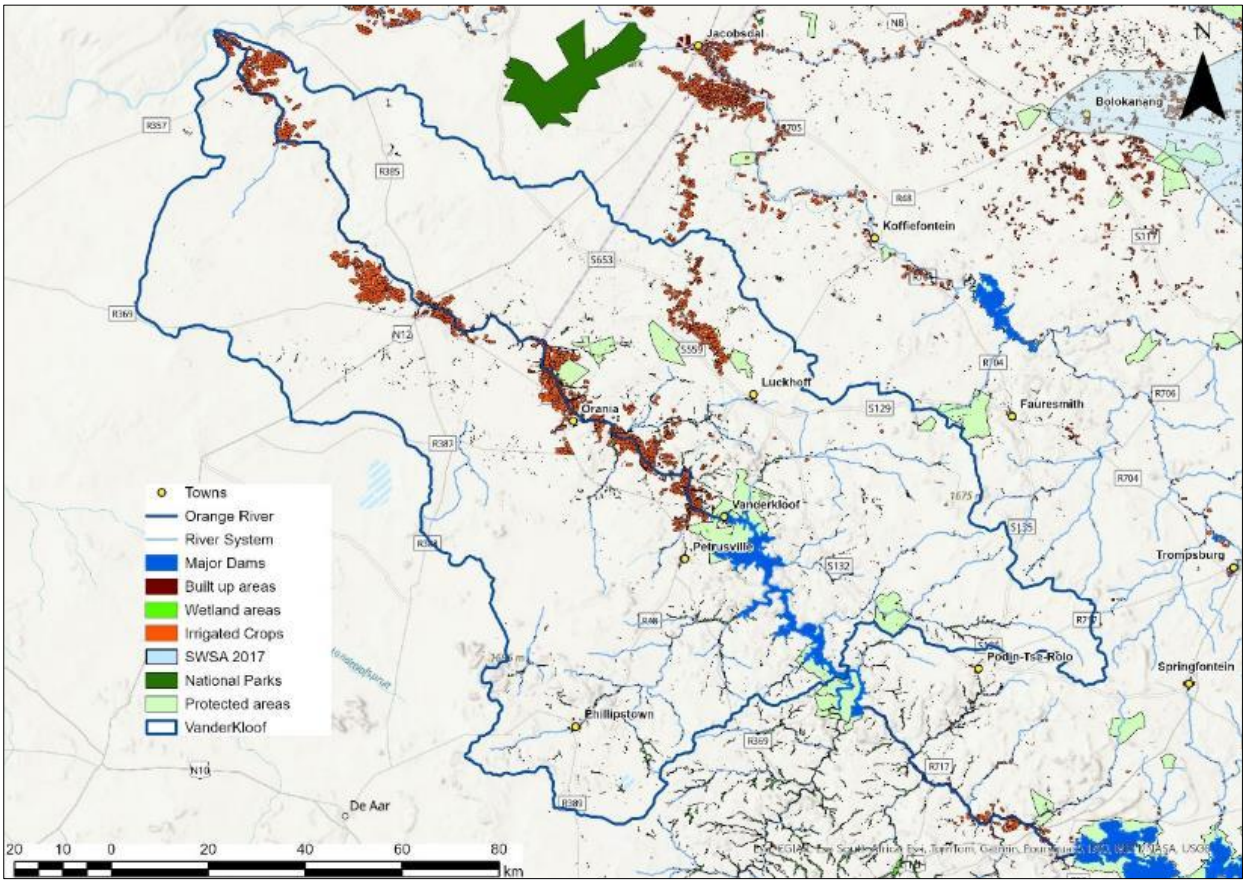

Figure 72: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 8 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 68).

Table 68: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 8 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Orange River and its tributaries	The Orange River is of significance to the Petrusville, Phillipstown, Luckhoff, Vanderkloof, Orania and Hopetown Communities by providing fish.	**Households, Society**
	Fresh Water	Orange River and its tributaries	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Petrusville, Phillipstown,	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
			Luckhoff, Vanderkloof, Orania and Hopetown communities in South Africa.	
Regulating	**Climate regulation**	Orange River and its tributaries	Major Significance to Global Beneficiaries	**Society**
	Water quantity regulation	Orange River and its tributaries	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Petrusville, Phillipstown, Luckhoff, Vanderkloof, Orania and Hopetown communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	-	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Petrusville, Phillipstown, Luckhoff, Vanderkloof, Orania and Hopetown communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Orange River and its tributaries	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Orange River and its tributaries	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas (The Doornkloof and Rolfontein Provincial Nature Reserves; Grootfontein Private Nature Reserve; Thanda Thula Reserve; Gemsbokpark Private Nature Reserve; Roodepoortjie 144; and the Zoutpansdrif 246); Orange River and its tributaries	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas (The Doornkloof and Rolfontein Provincial Nature Reserves; Grootfontein Private Nature Reserve; Thanda Thula Reserve;	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		Gemsbokpark Private Nature Reserve; Roodepoortjie 144; and the Zoutpansdrif 246); Orange River and its tributaries		
	Maintenance of genetic diversity	Protected Areas (The Doornkloof and Rolfontein Provincial Nature Reserves; Grootfontein Private Nature Reserve; Thanda Thula Reserve; Gemsbokpark Private Nature Reserve; Roodepoortjie 144; and the Zoutpansdrif 246); Orange River and its tributaries	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Moderate to low groundwater recharge (<10 mm/a, 164 Mm^3/a), with low contribution to baseflow (8 Mm^3/a. Groundwater quality Class 1/2 (Good/Marginal water quality type), and borehole yield class (BYC) is a b3-Class (i.e.,0.5 – 2.0 L/s in a fractured aquifer system), and a d3-Class (i.e., 0.5-2.0 L/s in a fractured & weathered aquifer system). Groundwater use is low (±4 Mm^3/a stress index are merely a Natural Condition) and Allocable ground water at ±153 Mm^3/a.

Groundwater conditions (specifically the BYC and quality) in GRU 8.3 are different due to pre-Karoo Supergroup formations present in the GRU area. BYC are a b2/b3 (0.1-0.5/0.5-2.0 L/s) Classes.

9.9. IUA 9: Upper Modder River

IUA 9 comprises the quaternary catchments of the upper catchment area of Modder River with its tributaries to the IUA outlet at the Krugersdrift Dam.

Rationale

The IUA delineation is based on the tributary catchments draining to upper reaches of the Modder River, which is predominantly within the highly impacted Mangaung Metropolitan Municipality, so an urban socioeconomic zone in the Highveld ecoregion.

IUA Overview

This IUA comprises of 7 quaternary catchments and lies between Mangaung Metropolitan Municipality and Masilonyana Local Municipality in the Free State province. Bloemfontein metro is the main city in the Free State province and lies mostly within this IUA. The main towns and populated settlements include Bloemfontein, Botshabelo, Dewetsdorp, and Winnie Mandela. There are many other townships, villages and farms within the IUA.

The key water resources in the IUA include the Modder River and many tributaries. The dams in the IUA include Rustfontein Dam, Mockes Dam, Moutloatsi Dam, Setlogelo Dam, and Krugersdrift Dam. There are a few protected areas within the Mangaung metropolitan municipal area and several within Masilonyana local municipal area. The IUA falls within the commercial development socio-economic zone, with industry activity and agricultural activity alongside the rivers and mixed agriculture in other areas of the IUA.

Table 69 summarises the salient features of IUA 9 and Figure 73 gives an overview of the IUA boundaries and features.

Table 69: IUA 9 - Upper Modder River

IUA 9: Upper Modder River	Description
Quaternaries	C52G, C52E, C52C, C52F, C52D, C52B and C52A
Ecoregions	Highveld
Geozones	D (upper tributary reaches): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E (tributary reaches): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	F (predominantly along the Modder River mainstem upstream of Krugersdrift Dam): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Upper Modder River
Tributaries	Renosterspruit, Bloemspruit, Bree River, Bo-Kromspruit, Kromspruit, Gannaspruit, Wildebeespruit, Kgabanyane River, Osspruit, Klein-Osspruit, Doringspruit and Stinkhoutspruit
Land use	• Mangaung Metropolitan Municipality - urban Area (Towns) • Agricultural areas (dryland, and some irrigation, in the lower portions of the Modder catchment around Krugersdrift Dam • Extensive subsistence agriculture in the upper reaches of the IUA

IUA 9: Upper Modder River	Description
EWR site	• UO_EWR14_FV • UO_EWR13_FV • UO_EWR07_I • UO_EWR06_R

Additional biological monitoring sites	• JBS3 site
	  ○ OSAEH_11_18
	• REMP site
	  ○ C5MODD-SANNA

Dams	• Kgabanyane Dam (FSC: 15.4 Mm^3) in C52B on the Modder River • Rustfontein Dam (FSC: 75.05 Mm^3) in C52A on a tributary of the Modder River - small storage dam for domestic and irrigation use • Mockes Dam (FSC: 4.16 Mm^3) in C52D on the Modder River - small storage dam for domestic and irrigation • Krugersdrift Dam (FSC: 73.44 Mm^3) in C52G at the IUA outlet
PES	C & D (and F in Renoster and Bloemspruit)
Groundwater	GRU 9.1 and GRU 9.2. Middle (Beaufort sandstones/siltstones) to Lower (Ecca mudrocks) parts of the Karoo Supergroup formations and moderate intrusive Karoo Dolerite features (laminar sills) and sub-vertical dykes features present. Aquifer system classified as a fractured & weathered type. Groundwater quality, especially in the Ecca Group mudstones has an elevated primary salinity signature due to the marine sedimentary environment during deposition in the middle Karro Period. Several large salt(pan) mines are present in GRU 9.2 and the northern part of GRU 9.1.
Wetlands	• Depression wetlands in C52G • Discontinuous channelled valley bottom and floodplain wetlands in upper reaches in C52C and C52G ○ ***Aardoringspruit wetland complex (DCVB and F)(ecological category C)*** - a large wetland complex that includes a large wetland flat and a DCVB wetland which encompasses the Aardoringspruit River - unusual to find a wetland flat in this part of the country.

WQ hotpots/Use	• Urban run-off from Botshabelo and Bloemfontein
	• Poor performing wastewater treatment works:
	  ○ Northeastern WWTW (20ML/d) (effluent for irrigation) – CRR: 77%
	  ○ Sterkwater WWTW (20ML/d) (Renosterspruit) – CRR: 86%
	  ○ Bloemdustria (0.9 ML/d) (Renosterspruit) – CRR: 82%
	  ○ Bloemspruit WWTW (56 ML/d) (Bloemspruit) – CRR: 84%
	  ○ Northern Works WWTW (5ML/d) (Bree River) – CRR: 68%
	  ○ Bainsvlei WWTW (5ML) (effluent for irrigation) – CRR: 68%
	  ○ Botshabelo WWTW (20 ML/d) (Small Modder River) – CRR: 77%

SWSA	SWSA-gw across quaternaries C52D, C52F and C52G

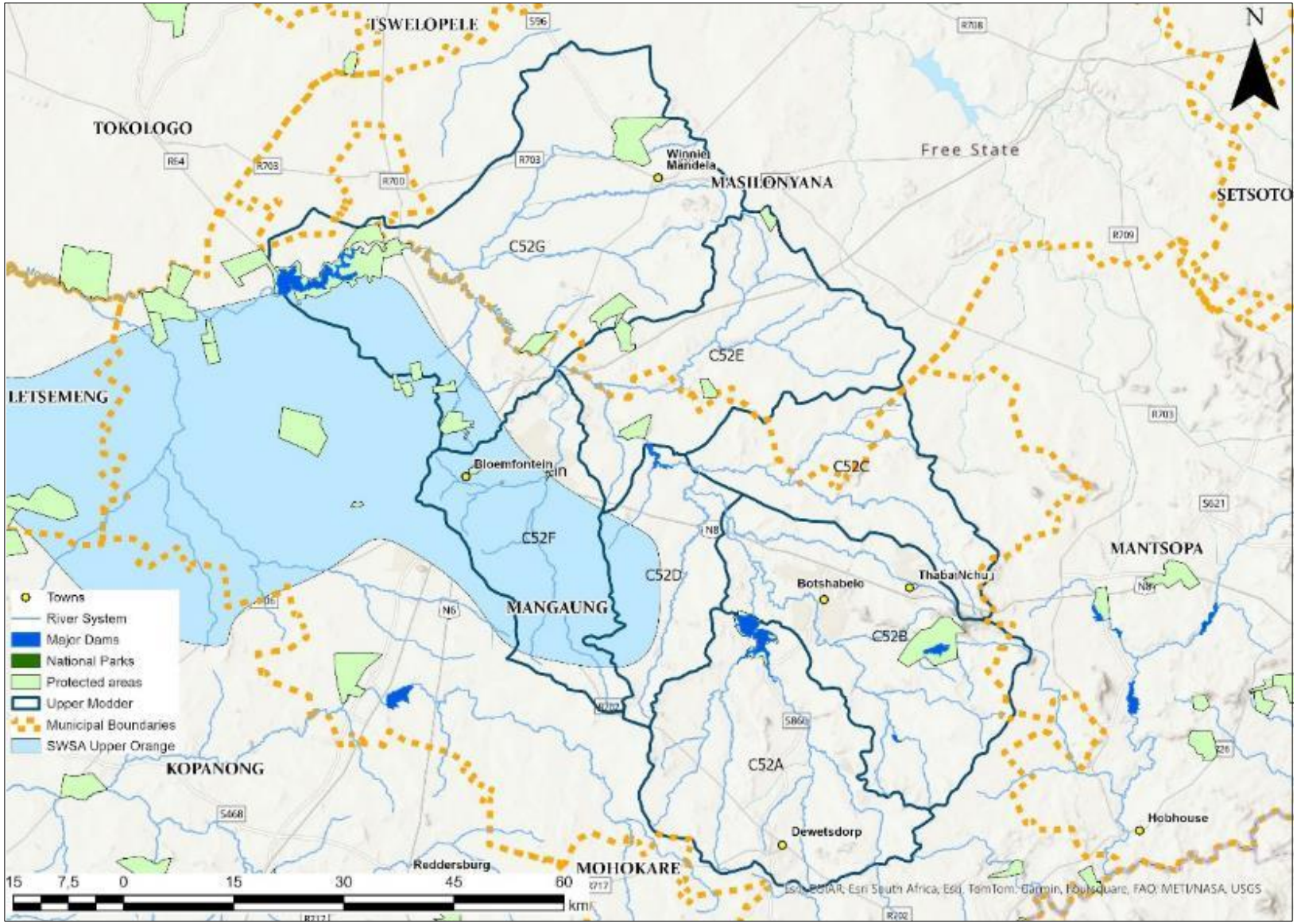

Figure 73: Overview of boundaries and features in IUA 9 of the Upper Orange River catchment

Demographics and socio-economic profile

The population of IUA 9 is estimated as 811,000 people (Stats SA Census 2011 adjusted) with approximately 288,500 households The average household size is three people per household. In IUA 9, approximately 9.6% of the population have higher education and approximately 4% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within IUA 9 is estimated 28% (NT, 2021).

Almost 100% of residents within IUA 9 have access to formal water services with only approximately 500 people with informal water supply (29% boreholes and 71% from other water sources). Approximately 40% of the population have access to piped water inside their dwelling, 54% of the population have access to piped water in their yards, and 6% have access to a communal tap water within 200m of their household (Figure 74). Most of the population are dwelling in formal dwellings with a proportion of over 90% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

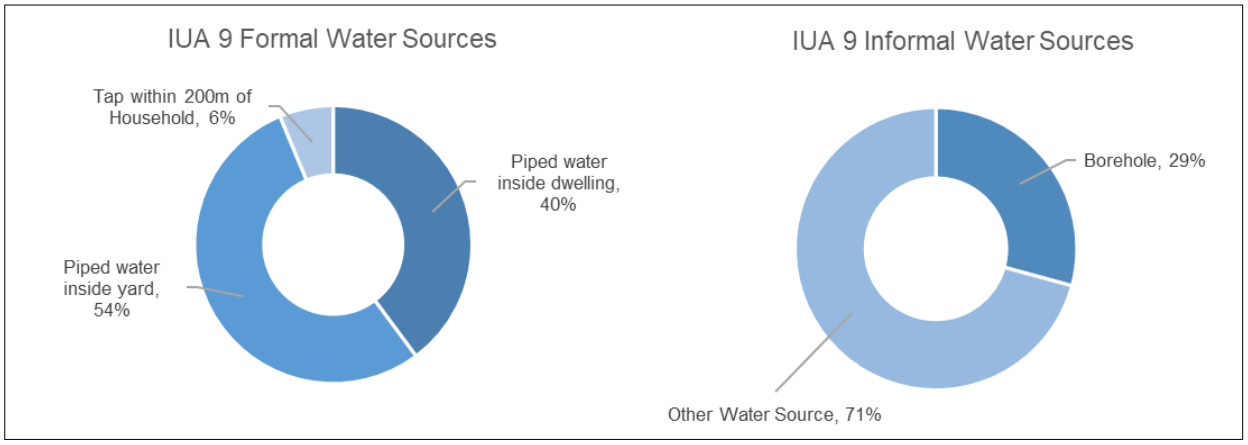

Figure 74: Access to water services in IUA 9

Economic Sectors

The key land use in IUA 9 is residential settlements in Bloemfontein, Botshabelo, Dewetsdorp, Winnie Mandela and villages around the IUA (Figure 75). The area is characterised by subsistence farming (mixed crops and cattle) around the villages and settlements and commercial agriculture along the Modder River and tributaries and livestock farming with cattle. The main economic drivers and municipalities falling within IUA 9 are set out in Table 70.

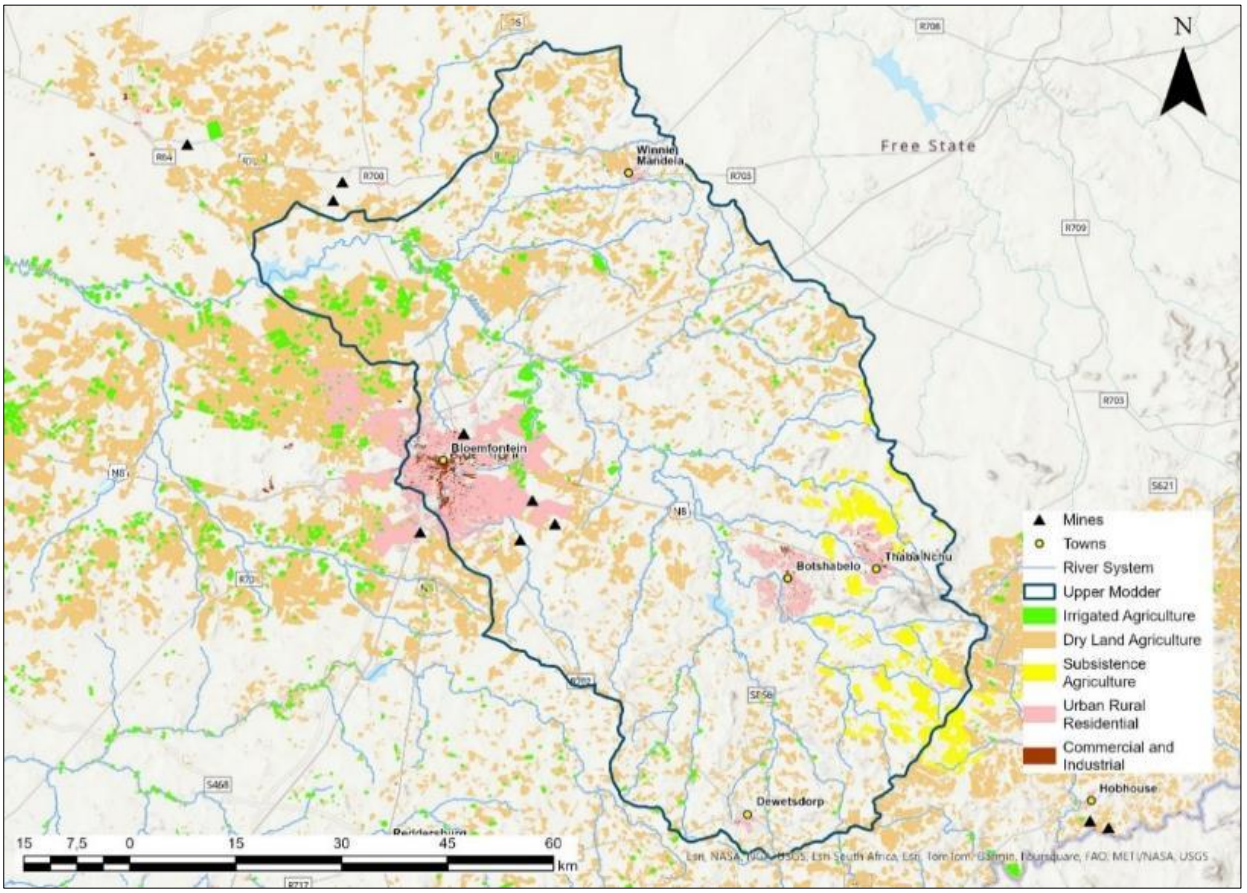

Figure 75: Land Use by land cover in IUA 9 in the Upper Orange River catchment (DFFE, 2020)

Table 70: Economic drivers relevant to IUA 9

Local Municipality	Description of economic sectors and activity of importance in the IUA ((Municipal IDPs 2022, 2023)
Mangaung Metropolitan Municipality	Bloemfontein is the main economic area of this part of the IUA and the capital city of the Free State province. Key economic activity includes agriculture (irrigation and dryland and livestock) in this part of the IUA. Crops such as maize and to a lesser extent sorghum, wheat and sunflowers. There are quarry mining activities for gravel and limestone near Bloemfontein and industry or manufacturing activities. Tourism activity around Bloemfontein and nearby areas along the Modder River mainly related to cultural-historic, leisure and agri-tourism. Agriculture and domestic use are the main users of water in this part of the IUA.
Masilonyana	Winnie Mandela is the main settlement in the IUA. There is some agriculture (mixed) activity scattered across the area. Irrigation agriculture occurs along the Modder River and tributaries.

Local Municipality	Description of economic sectors and activity of importance in the IUA ((Municipal IDPs 2022, 2023)
	Agriculture and domestic use are the main users of water in this section of the IUA

In IUA9 the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 71 and Table 72.

Table 71: Economic sectors in IUA 9 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R1,276	1%
Mining	R1,051	1%
Manufacturing	R12,741	12%
Electricity & water	R3,843	4%
Construction	R5,512	5%
Wholesale & retail trade; catering and accommodation	R18,023	17%
Transport & communication	R13,896	13%
Financial services	R22,679	22%
General government	R15,205	15%
Community, social & personal services	R10,209	10%
Total GDP	R104,435	100%

Table 72: The estimated employment by economic sector for IUA 9 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	9,262	3%
Mining	953	0%
Manufacturing	17,495	7%
Electricity & water	1,222	0%
Construction	14,526	5%
Wholesale & retail trade; catering and accommodation	66,261	25%
Transport & communication	13,230	5%
Financial services	44,437	17%
General government	46,720	17%
Community, social & personal services	53,619	20%
Total Employment	267,725	100%

Ecosystem Services

This IUA is known for its numerous significant protected areas and valuable aquatic resources. Notable protected areas within IUA 9 include the Soetdoring Nature Reserve, Dawn Valley Private Nature Reserve, Franklin Private Nature Reserve, Bergkraal Reserve, Kopano Nokeng area, Karee Reserve, De Kuilen Private Nature Reserve, Wag 'n Bietjie Private Nature Reserve, Kareefontein Private Nature Reserve, Auch Macoy Game Reserve, Grasslands Safaris, and a section of the Blesbok Private Nature Reserve (Figure 76). These protected areas contribute to the conservation and preservation of the natural environment within IUA 9. In terms of aquatic resources, the IUA is home to the Modder River and its tributaries. Additionally, various types of wetlands, including endorheic, channelled VB, and discontinuously channelled VB wetlands, have been observed within this IUA. These wetlands form an essential part of the ecological infrastructure. The main dams in the area, including Mockes Dam, Rustfontein Dam, and Krugersdrift Dam, play a vital role in the water supply of IUA 9. They serve as integral components of the region's water infrastructure, ensuring a reliable water source for the area. In the western part of IUA 9, there is also a SWSA of importance, further highlighting the significance of this region in terms of water resources.

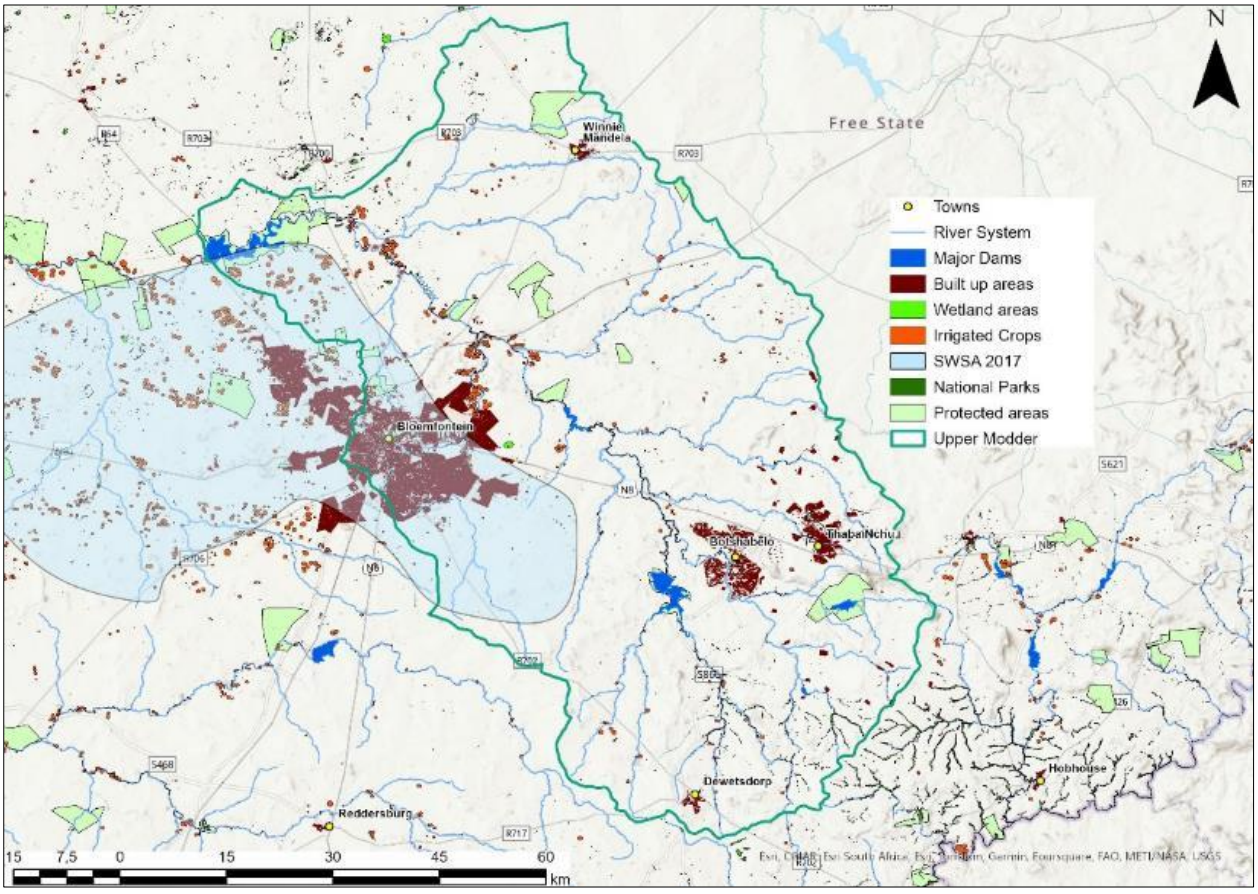

Figure 76: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 9 in the Upper Orange River catchment

Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 73).

Table 73: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 9 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Modder River and its tributaries	The Modder River is of significance to the Bloemfontein, Botshabelo and Thaba Nchu, Dewetsdorp, Bolokanang and Winnie Mandela Communities by providing fish.	**Households, Society**
	Fresh Water	Modder River and its tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Bloemfontein, Botshabelo and Thaba Nchu, Dewetsdorp, Bolokanang and Winnie Mandela communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water quantity regulation	Strategic water source area; endorheic, channelled VB, and discontinuously channelled VB wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Bloemfontein, Botshabelo and Thaba Nchu, Dewetsdorp, Bolokanang and Winnie Mandela communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	Strategic water source area; endorheic, channelled VB, and discontinuously channelled VB wetlands	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Bloemfontein, Botshabelo and Thaba Nchu, Dewetsdorp, Bolokanang and Winnie Mandela communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Modder River and its tributaries; endorheic, channelled VB, and discontinuously	Major significance to commercial agriculture sector	**Agriculture**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		channelled VB wetlands		
	Biological control	Modder River and its tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas (Soetdoring Nature Reserve, Dawn Valley Private Nature Reserve, Franklin Private Nature Reserve, Bergkraal Reserve, Kopano Nokeng area, Karee Reserve, De Kuilen Private Nature Reserve, Wag 'n Bietjie Private Nature Reserve, Kareefontein Private Nature Reserve, Auch Macoy Game Reserve, Grasslands Safaris, and a section of the Blesbok Private Nature Reserve); Modder River and its tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Biodiversity	**Critical habitat & range restricted species**	Protected Areas (Soetdoring Nature Reserve, Dawn Valley Private Nature Reserve, Franklin Private Nature Reserve, Bergkraal Reserve, Kopano Nokeng area, Karee Reserve, De Kuilen Private Nature Reserve, Wag 'n Bietjie Private Nature Reserve, Kareefontein Private Nature Reserve, Auch Macoy	The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species.	**Society; Tourism**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		Game Reserve, Grasslands Safaris, and a section of the Blesbok Private Nature Reserve); Modder River and its tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands		
	Maintenance of genetic diversity	Protected Areas (Soetdoring Nature Reserve, Dawn Valley Private Nature Reserve, Franklin Private Nature Reserve, Bergkraal Reserve, Kopano Nokeng area, Karee Reserve, De Kuilen Private Nature Reserve, Wag 'n Bietjie Private Nature Reserve, Kareefontein Private Nature Reserve, Auch Macoy Game Reserve, Grasslands Safaris, and a section of the Blesbok Private Nature Reserve); Modder River and its tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

Moderate to low groundwater recharge (<10 mm/a, 166 Mm^3/a), with low contribution to baseflow (13 Mm^3/a. Groundwater quality Class 0 (Ideal water quality type) in the upstream part of GRU 9.1 and a Class 1/2 in the centre part of GRU 9.1 (around the upstream section of the Modder River. Borehole yield class (BYC) is a d2/d3-Class (i.e.,0.1-0.5/0.5-2.0 L/s in a fractured & weathered aquifer system). Groundwater use is moderate (±36 Mm^3/a, and the stress index in GRU 9.1 is a Natural to Good Condition, but in the GRU 9.2, it is a Fair to Poor Condition) and Allocable ground water at ±116 Mm^3/a.

9.10. IUA 10: Modder-Riet Rivers

IUA 10 comprises the quaternary catchments of the Modder River downstream of Krugersdrift Dam on the outskirts of Bloemfontein to the confluence of the Riet River and including the Riet River to the confluence of the Vaal River.

Rationale

The IUA delineation is based on the tributary catchments being in predominantly the Nama Karoo ecoregion, with a portion in the Southern Kalahari ecoregion.

IUA Overview

IUA 10 comprises 16 quaternary catchments and the largest area within the IUA lies within the Free State province and in parts of the local municipalities of Lestemeng, Kopanong, Tokologo, and Mangaung. The rest of the IUA lies within the Northern Cape province and falls within parts of the local municipalities of Sol Plaaitjie and Siyancuma. The towns of the IUA include Reddersburg, Edenburg Trompsburg, Jagersfontein, Fauresmith, Koffiefontein, Jacobsdal, Petrusburg and Ritchie. The IUA has several other townships, villages, and farms.

The key water resources in the IUA include the Riet River, Modder River, and many tributaries. The dams include Kalkfontein Dam and the Tierpoort Dam. There are numerous protected areas scattered within the IUA including several private game reserves and farms and many private nature reserves. There are two National parks which include the Mokala Game Reserve across quaternary catchments C51M an C51L and the Vaalbos National Park in the northern part of C51L. This IUA falls within two socio-economic zones, the agriculture and mining zone (western part of the IUA) and the commercial development zone (eastern part of the IUA). The land use consists of agricultural activity especially in the north of the IUA and along the Riet and Modder rivers and there is some mining activity in the IUA.

Table 74Table 69 summarises the salient features for the IUA and Figure 77 gives an overview of boundaries and features in IUA 10.

Table 74: IUA 10 - Modder/ Riet Rivers

IUA 10: Modder-Riet Rivers	Description
Quaternaries	C51M, C51L, C51K, C51J, C51F, C51H, C51G, C51C, C51B, C51A, C51E and C52L, C52K, C52J, C52H
Ecoregions	Nama Karoo ecoregion, with a portion in the Southern Kalahari ecoregion
Geozones	D (upper tributary reaches): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.
	E (tributary reaches): Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types.

IUA 10: Modder-Riet Rivers	Description
	F (predominantly along the Modder River mainstem downstream of Krugersdrift Dam and the Riet River from the confluence with the Kromellenboogspruit): Low gradient alluvial fine bed channel, typically regime reach type.
Main Rivers	Modder and Riet rivers
Tributaries	Kromellenboogspruit, Vanzylspruit, Prosesspruit, Ruigtedspruit, Ospoortspruit, Kroonspruit, Fouriespruit and Holspruit
Land use	Irrigation agriculture along the Riet River and diamond mine at Koffiefontein
EWR site	• UO_EWR09_I • UO_EWR06_I

Additional biological monitoring sites	• JBS3 sites
	  ○ OSAEH_26_10
	  ○ OSAEH_26_5
	• REMP sites
	  ○ C5RIET-DEKRA
	  ○ C5RIET-IFR03
	  ○ C5RIET-LILYD
	  ○ C5RIET-JACOB
	  ○ C5RIET-RICHI
	  ○ C5VANZ-DWNWR

Dams	• Rietwater Dam (FSC: 1.95 Mm^3), a small storage dam at the outlet of D51A • Kalkfontein Dam (FSC: 325.2 Mm^3) on the Riet River in C51J – small storage dam for irrigation • Tierpoort Dam (FSC: 34 Mm^3) on the Riet River in C51J - small storage dam for irrigation
PES	C and D
Groundwater	GRU 10.1 and GRU 10.2. Middle (Beaufort sandstones/siltstones) and Lower (Ecca mudrocks) parts of the Karoo Supergroup formations and moderate intrusive Karoo Dolerite features (laminar sills) and sub-vertical dykes features present. Aquifer system classified as a fractured & weathered type in GRU 10.1, and a fractured aquifer system in GRUs 10.2. Groundwater quality, especially in the Ecca Group mudstones has an elevated primary salinity signature due to the marine sedimentary environment during deposition in the middle Karro Period. Several large salt(pan) mines are present in GRU 102 and includes the large groundwater irrigation scheme at Petrusburg (central part of quaternary catchment C52K. GRU 10.3 consists of pre-Karoo Supergroup rock formations and the aquifer characteristics are different ITO BYC (and qualities)

IUA 10: Modder-Riet Rivers	Description
Wetlands	• Extensive depression wetlands throughout the IUA ○ ***Soutpan depression wetland complex (ecological category B) -*** salt pans support vegetation that is distinct from the surrounding vegetation. • Discontinuous channelled valley bottom and channelled valley bottom wetlands ○ ***Kaalspruit wetland complex (CVB, DCVB and D)(ecological category C) -*** unique feature in this complex is a depression wetland nested within the channelled valley-bottom ○ ***Jagersfontein DCVB wetland*** in C51H on the Kromellenboogspruit (this was categorised as an ecological category C for the Reserve studies but may have been impacted by the Jagersfontein spill, and may need to be reassessed) • Few seeps in C52K and C51K
WQ hotpots/Use	• Irrigation return-flows • Mining impacts from the diamond mines in the Riet River catchment, specifically C51H, C51K and C51L.
SWSA	SWSA-gw across D52J, D52H and D52K

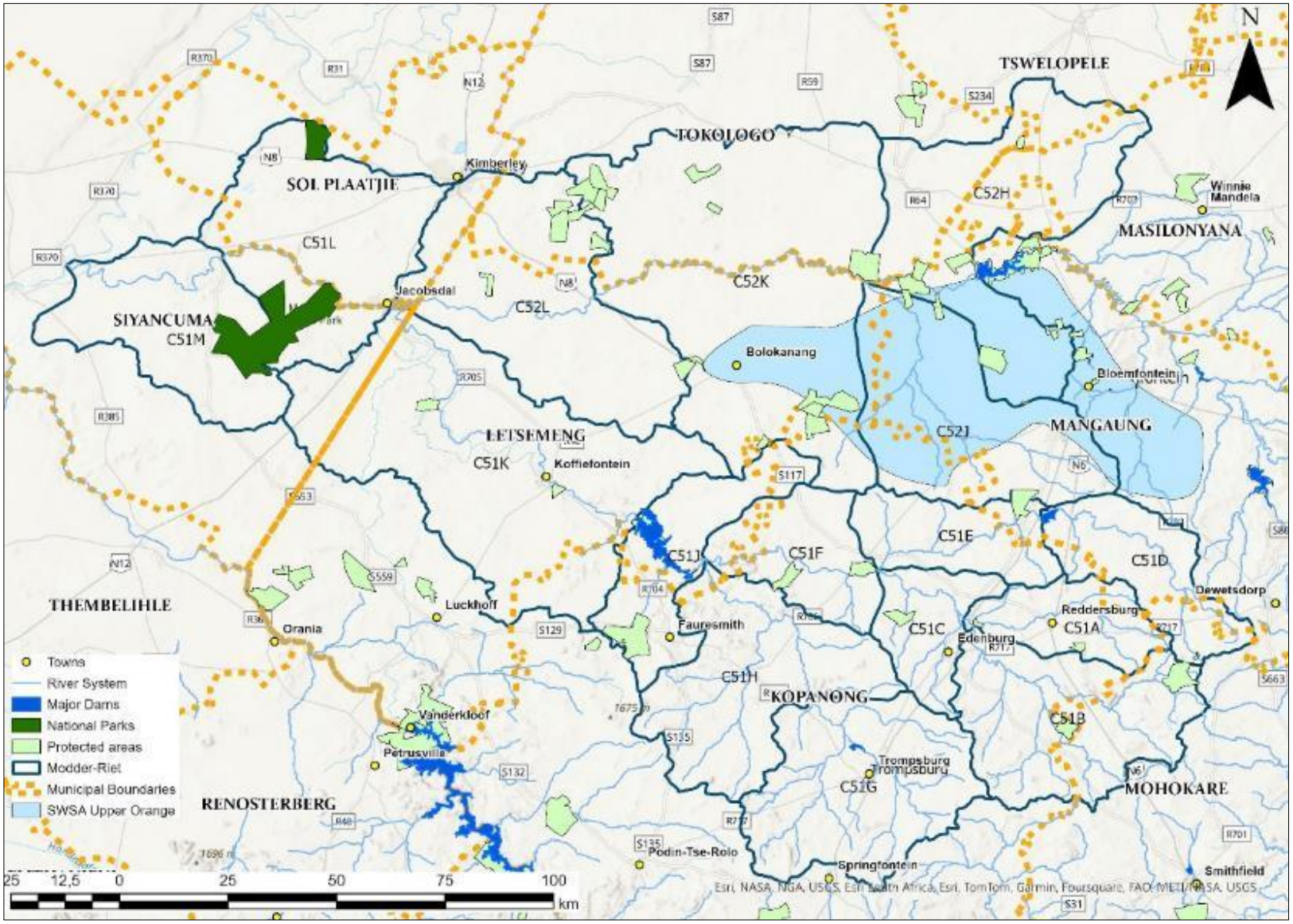

Figure 77: Overview of boundaries and features in IUA 10 of the Upper Orange River catchment

Demographics and socio-economic profile

The population of IUA 10 is estimated as 101,300 people (Stats SA Census 2011 adjusted) with approximately 36,500 households. In IUA 10, approximately 8% of the population have a higher education and approximately 8% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within IUA 10 is estimated 22% (NT, 2021).

Just under 100% of residents within IUA 10 have access to formal water services less than 1% of people rely on informal water supply (78% boreholes and 22% rely on dams or pools or stagnant water). Approximately 52% of the population which have piped water in their yards, 43% of the population have access to piped water inside their dwelling and 5% have access to a communal tap water within 200m of their household (Figure 78). The population dwelling in formal dwellings ranges from a proportion of 74% to 94% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

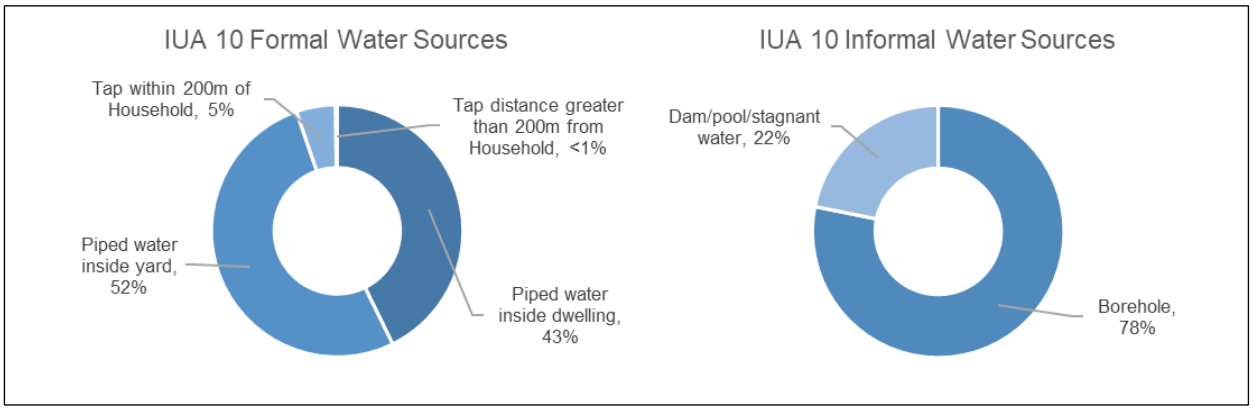

Figure 78: Access to water services in IUA 10

Economic Sectors

The key land use for IUA 10 is within the main residential settlements in Fauresmith, Reddersburg, Edenburg, Trompsburg, Jagersfontein, Petrusburg, Koffiefontein and villages around the IUA (Figure 79). An important land use and economic activity is from agriculture including irrigation agriculture along the major rivers and livestock farming of sheep. Another land use and economic activity is from alluvial diamond mining within the IUA. The main economic drivers and municipalities falling within IUA 10 are set out in Table 75.

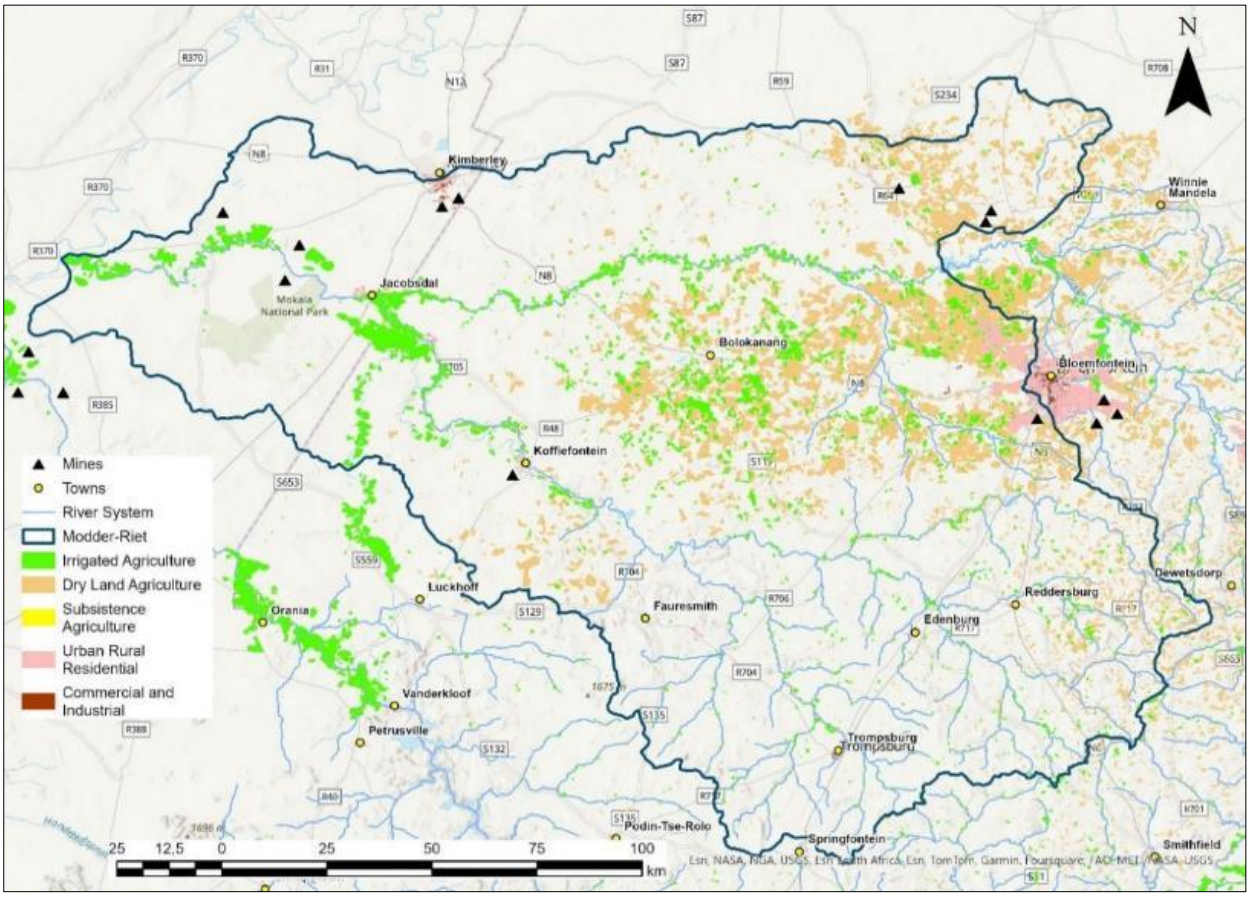

Figure 79: Land Use by land cover in IUA 10 in the Upper Orange River catchment (DFFE, 2020)

Table 75: Economic drivers relevant to IUA 10

Local Municipality	Description of economic sectors and activity of importance in the IUA
Letsemeng	The towns in this IUA include Jacobsdal, Koffiefontein, Oppermansdorp and Petrusburg. The main economic driver is agriculture in this section of the IUA. Agriculture includes intensive irrigation agriculture along the Modder River, some dryland agriculture, poultry farming, and livestock farming of sheep and goats. Crop farming includes crops such as maize, wheat, grapes, lucerne, groundnuts and potatoes (and other vegetables). There is an open cast diamond mine in Koffiefontein. Some tourism within the IUA in the protected areas and Koffiefontein area. Agriculture and domestic use are the main users of water in this section.
Kopanong	The main towns in the IUA include Jagersfontein, Fauresmith, Edenburg, Trompsburg and Reddersburg.

Local Municipality	Description of economic sectors and activity of importance in the IUA
	The main economic drivers are from agriculture and diamond mining activities in this section of the IUA. Agriculture includes some irrigation agriculture along the Modder River and other dryland crop agriculture. There is also livestock farming of particularly sheep and Trompsburg as the second-largest sheering barn in the country. Agriculture and domestic use are the main users of water in this section of the IUA
Mangaung	There are small towns and villages in this area. The economic activities include mixed agriculture in this section of the IUA and salt mining.
Tokologo	The main town is Dealesville and there are a few small villages and settlements in the IUA. There is agriculture in this section of the IUA. Agriculture and settlements are the main users of water
Sol Plaatjie	Only a small area falls within this IUA and includes the town of Ritchie. The key economic activity is from irrigation agriculture in quat C51L along the Riet River. There are two alluvial diamond mines in this area (C51L). Some tourism in the Vaalbos National Park, guest farms and the Magersfontein Game Lodge and a few Anglo-Boer war memorial sites.
Siyancuma	Therea are no towns within this area of the IUA. Key land use and economic driver from intensive irrigation agriculture along the Riet River with cereals, grains and vegetable crops. There is an alluvial diamond mine north of the Mokala National Park (C51L). The other economic activity is from tourism in the Mokala National Park.

In IUA 10 the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 76 and Table 77.

Table 76: Economic sectors in IUA 10 and the contribution to GDP (NT, 2021)

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Agriculture, forestry and fishing	R965	16%
Mining	R675	11%
Manufacturing	R494	8%
Electricity & water	R164	3%
Construction	R401	7%

Economic Sector	GDP by economic sector (R million)	% GDP contribution
Wholesale & retail trade; catering and accommodation	R1,074	18%
Transport & communication	R483	8%
Financial services	R551	9%
General government	R669	11%
Community, social & personal services	R521	9%
Total GDP	R5,998	100%

Table 77: The estimated employment by economic sector for IUA 10 (NT, 2021)

Economic Sector	Employment by economic sector (number of people)	% contribution
Agriculture, forestry and fishing	7,751	26.8%
Mining	404	1.4%
Manufacturing	1,027	3.6%
Electricity & water	98	0.3%
Construction	1,412	4.9%
Wholesale & retail trade; catering and accommodation	5,906	20.4%
Transport & communication	868	3.0%
Financial services	2,682	9.3%
General government	3,599	12.5%
Community, social & personal services	5,150	17.8%
Total Employment	28,897	100.0%

Ecosystem Services

IUA 10 is centrally located within the Upper Orange River catchment and encompasses several towns. The area is enriched by the presence of protected areas, such as the Mokala National Park and Vaalbos National Park, which provide valuable cultural and biodiversity services within this IUA. The region is home to the Modder River and the Riet River, along with their tributaries, which play a vital role in the aquatic and terrestrial ecological infrastructure. These water sources contribute significantly to the overall ecosystem of the area. Furthermore, there are various types of wetlands, including endorheic, channelled VB, and discontinuously channelled VB, which form an integral part of the ecological infrastructure. In the eastern part of the IUA, there is an important SWSA. Additionally, two dams within this IUA serve as the main sources of water supply (Figure 80).

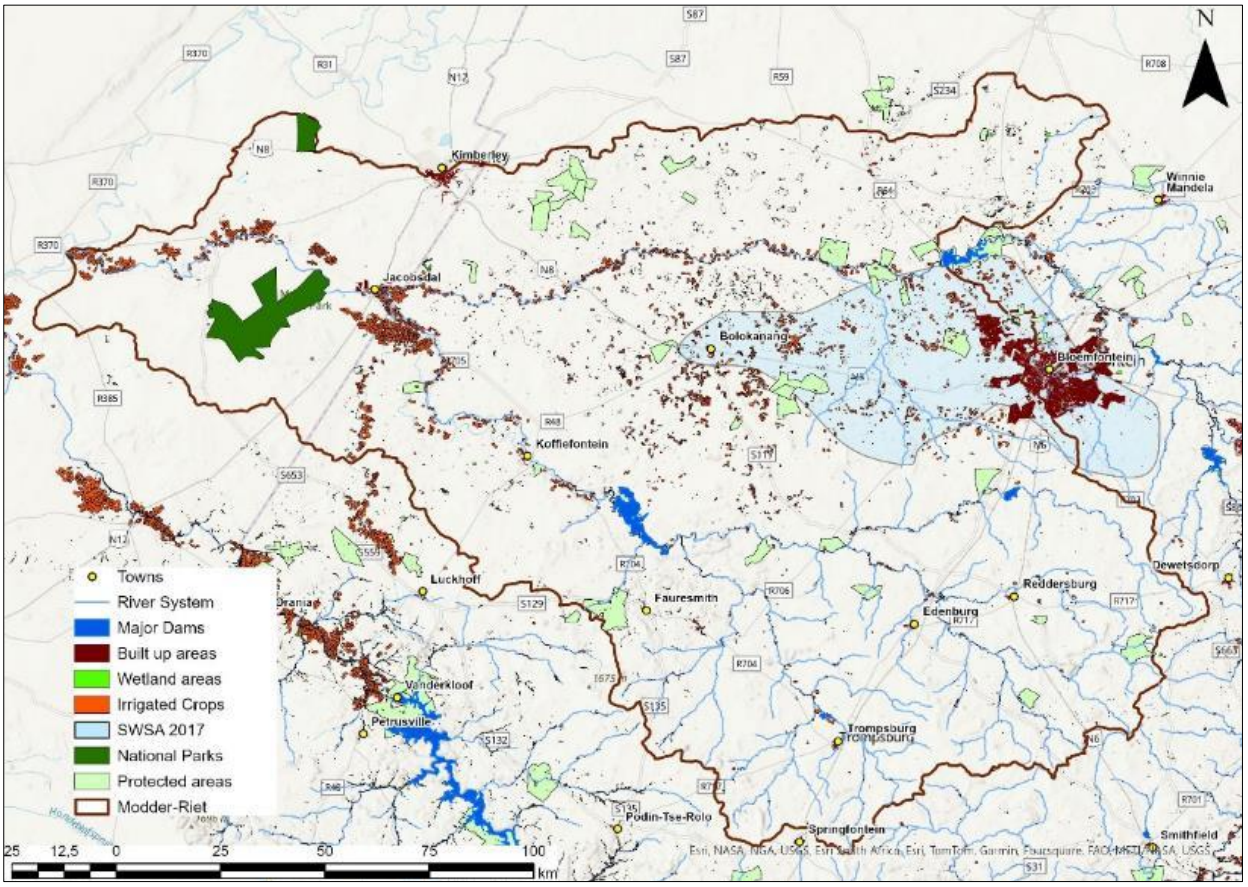

Figure 80: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 10 in the Upper Orange River catchment

A mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 78).

Table 78: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 10 in the Upper Orange River catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
Provisioning	**Food**	Modder and Riet River, and their tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands.	The Modder and Riet River is of significance to the Trompsburg, Reddersburg, Edenburg, Jaggerfontein, Fauresmith, Koffiefontein and Jacobsdal Communities by providing fish.	**Households, Society**
	Fresh Water	Modder and Riet River, and their tributaries;	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically	**Agriculture; Mining; Manufacturing;**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
		endorheic, channelled VB, and discontinuously channelled VB wetlands.	for the Trompsburg, Reddersburg, Edenburg, Jaggerfontein, Fauresmith, Koffiefontein and Jacobsdal communities in South Africa.	**Electricity and Water; Tourism; Households**
	Water quantity regulation	Strategic water source areas; endorheic, channelled VB, and discontinuously channelled VB wetlands.	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Trompsburg, Reddersburg, Edenburg, Jaggerfontein, Fauresmith, Koffiefontein and Jacobsdal communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Water purification & waste management	Strategic water source areas; endorheic, channelled VB, and discontinuously channelled VB wetlands.	Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Trompsburg, Reddersburg, Edenburg, Jaggerfontein, Fauresmith, Koffiefontein and Jacobsdal communities in South Africa.	**Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households**
	Erosion control/ Soil stability	Modder and Riet River, and their tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands.	Major significance to commercial agriculture sector	**Agriculture**
	Biological control	Modder and Riet River, and their tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands.	Major significance to commercial agriculture sector	**Agriculture; Households**
Cultural	**Landscape & amenity values**	Protected Areas (Mokala National Park and Vaalbos National Park); Modder and Riet River, and their tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands.	Major Significance: To tourism industry and rural communities through cultural value	**Households; Tourism; Society**
	Ecotourism & recreation			
	Educational values and inspirational services			
Bi	**Critical habitat &**	Protected Areas (Mokala National	The area holds major significance for flora and fauna	**Society; Tourism**

Key Ecosystem Service		Key Ecological Infrastructure	General Beneficiaries	Sector (12 Sectors)
	range restricted species	Park and Vaalbos National Park); Modder and Riet River, and their tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands.	species, as it provides essential habitat for range-restricted species and supports the migration of various species.	
	Maintenance of genetic diversity	Protected Areas (Mokala National Park and Vaalbos National Park); Modder and Riet River, and their tributaries; endorheic, channelled VB, and discontinuously channelled VB wetlands.	The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation.	**Households, Society**

Groundwater

GRUs 10.1 and -10.2: Moderate to low groundwater recharge (<10 mm/a, 342 Mm^3/a), with low contribution to baseflow (21.84 Mm^3/a. Groundwater quality Class 2/3 (Good/Marginal water quality type), and borehole yield class (BYC) is a b2/b3/d2-Class (i.e.,0.1-0.5 L/s/0.5-2.0 L/s/0.1-0.5L/s in a fractured and fractured & weathered aquifer system). Groundwater use is moderate (±81 Mm^3/a, and the stress index is a Good to Fair Condition, and Allocable ground water at ±239 Mm^3/a.

10 CONCLUSIONS

This report presents the findings of the status quo assessment for the water resources of the Upper Orange River catchment. Based on review of existing reports from previous studies, available information and literature, results from data assessment and analysis, and discussions held with DWS personnel, specialists, as well as stakeholders in the catchment, a perspective of the characteristics, nature, attributes, condition, and key aspects of the Upper Orange River water resources is provided. This forms a basis for the understanding of the catchment, the status and use of water resources and the assessment of the socio-economic profile that exists.

It can be concluded that the Upper Orange River is a hard-working, well-regulated river supporting numerous socio-economic activities, towns and livelihood within the catchment, as well as in adjacent catchments. It forms part of a larger integrated and complex system of water resource infrastructure and system operation inter-linked to other catchments, WMAs and countries. The catchment also includes several conservation and protected areas. The setting of water resource classes will require that all these aspects are taken into consideration.

The status quo indicates that overall, the water resources have been considerably impacted, with many localised areas of impact related to the land uses, including high sediment loads that emanate from Lesotho to the Caledon River, and to a lesser extent, to the Orange River. This has resulted in silting of dams, reducing their capacity considerably.

Overall, the present ecological state is largely a C category, with fewer areas that are in a B category, and several reaches in a D category (largely modified). There are two reaches in the upper reaches of the Kraai River catchment that are in an A category. A few river reaches within the highly urbanised areas of Mangaung Metropolitan Municipality are categorised as E and F, as well the portion of the Orange River between Gariep and Vanderkloof dams.

Flow and water quality impacts have been identified along the mainstem Caledon and Orange rivers and on the major tributaries. The water quality aspects relate predominantly to salinity and nutrients, and based on the Green Drop report data for all the wastewater treatment works in the catchment, microbiological data will also be a concern.

The flow is regulated by the releases from Gariep and Vanderkloof dams that are related to the transfers and hydropower and downstream Lower Orange River requirements, for both international obligations and maintenance of the Orange River Estuary which is a designated RAMSAR site. There are upstream areas that are designated strategic water source areas for surface water as well as areas with the C52 and D32 tertiary catchments which lie within groundwater strategic water source areas.

Considering the recently completed high confidence Reserve study undertaken, wetland complexes have been well mapped and characterised, and twelve wetland complexes have been prioritised. The information available for wetlands is therefore of a high confidence to support the setting of RQOs. Water quality data has also found to be of a confidence level that is suitable for setting RQOs.

Groundwater occurrences in the Upper Orange River catchment occurs predominantly as shallow (<65 m thick) aquifer systems in the Karoo Supergroup sedimentary sequence (as primary rock formation). In most of the water management area, secondary Karoo Dolerite intrusions in the form of (i) sub-vertical dikes and (ii) semi-horizontal sills are present which enhances the yield potential of the primary aquifer system. In a few cases, specific aquifer yield potentials can be significantly enhanced by occasional flooding of local surface water drainages, especially where these drainages are mature and alluvial sedimentation has developed overlying the Karoo rocks.

Groundwater quality in the catchment varies significantly and is affected by (i) natural (geological), (ii) climatological and (iii) anthropogenic effects, the latter being related predominantly to poor sanitation facilities in the catchment. Groundwater abstraction from the aquifer system varies significantly over the water management areas. Critical cases where groundwater is pumped for large irrigation water supply, municipal water supplies and dewatering of underground mine workings results in depletion (lowering) of the aquifer saturation levels triggering unsustainable aquifer conditions and in some cases deterioration of the groundwater qualities.

There are seven wetland types, often in wetland complexes: flats, floodplains, depression wetlands, unchanneled valley-bottom wetlands, seeps, and channelled valley bottom wetlands. There are several high-altitude wetland complexes that are characterised by unique vegetation assemblages.

Based on the detailed evaluations undertaken, socio-economic zones, integrated units of analysis and resource units have been delineated as the basis for the determination of water resource classes and ultimately the setting of appropriate resource quality objectives.

It is noted that overall, the data and information is adequate to use and with feedback and comment obtained from stakeholders will inform the final set of IUAs presented in this report, and these will be finalised for the process of quantifying the ecological water requirements and setting water resource classes.

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APPENDIX A: Surface Water Monitoring Sites

Table A1: Surface Water Monitoring Sites

Surface monitoring site ID	Description	Type	n	Latitude	Longitude
C51 - RIET RIVER					
C51 90816	Riet River at Kromdraai/Rietwater (NCWQ NCMP)	Rivers	334	-29.6581	25.97333
C51 90817	Richie Klipdrift 109 - at U/S Side of Weir on Riet River (NCWQ NCMP)	Rivers	838	-29.0422	24.6
C51 90819	At Estate Biesiesbult Aucampshoop on Riet River (NCWQ NCMP)	Rivers	753	-28.96	24.2425
C51 90835	At Zoutpansdrift on Riet River (NCWQ NCMP nemp NEMP)	Rivers	1512	-29.0333	23.98333
C51 86106	Philippia Kalkfontein Dam Weir for Spilway Discharge on Riet T (NCWQ)	Rivers	7	-29.4722	25.20667
C51 88779	At Jacobsdal Bridge on Rietrivier	Rivers	66	-29.1411	24.76892
C51 188235	Ditlhake Township Koffiefontein on Rietrivier (NMMP)	Rivers	438	-29.3946	25.00503
C51 189016	Koffiefontein at R48 Road Bridge on Rietrivier	Rivers	63	-29.4127	25.01728
C51 189020	Doorns at Modderrivier R29 Road Bridge on Rietrivier	Rivers	55	-29.0378	24.62481
C51 189022	Rietkuil 21 - at 704 (706) Road Bridge on Prosesspruit	Rivers	62	-29.8061	25.49594
C51 189023	Slagkraal 594 - at R706 Road Bridge on Rietrivier	Rivers	58	-29.5759	25.71075
C51 189026	Lockshoek 192 - at R706 Road Bridge on Kromellenboogspruit	Rivers	63	-29.7043	25.60008
C51 189047	Davidsrust Eindpunt on Rietrivier	Rivers	58	-29.1563	24.77292
C51 189096	Taaibosch Fontein Scholtzburg Barrage on Rietrivier	Rivers	53	-29.0267	24.04269
C51 191175	Schutse Kama 103 - downstream of Lillydale on Rietrivier	Rivers	59	-28.9534	24.40785
C51 191200	Bellevue 413 - downstream of Reddersburg WWTW on Fouriespruit	Rivers	54	-29.6406	26.15331
C51 90830	at Rietrivier Sett. Jacobsdal on Orange-Riet Canal (NCWQ NCMP)	Canal	458	-29.1406	24.75667
C51 90834	Kalkfontein Dam on Riet River: Left Canal (NCWQ)	Canal	592	-29.4969	25.22139

Surface monitoring site ID	Description	Type	n	Latitude	Longitude
C51 189078	Mayville 400 - Balancing Dam Outlet to Oranje-Riet (Sarel Hayward) Canal	Canal	59	-29.1658	24.70519
C51 190123	Phambile Rietrivier Settlement East 387 on Drainage Canal (NMMP)	Canal	116	-29.1067	24.6654
C51 191172	Weltevrede 710 - at S555 Road Bridge on Left Main Canal from Kalkfontein Dam	Canal	55	-29.4931	25.1457
C51 191429	Trompsburg Gruisfontein 35 - at Final Oxidation Pond on Trompsburg WWTW	Canal	39	-30.0265	25.79518
C52 - MODDER RIVER					
C52 90811	At Likatlong / Sannaspos on Modder River (NCWQ NCMP)	Rivers	822	-29.1603	26.57333
C52 90812	At Bishop S Glen on Renosterspruit	Rivers	19	-28.9847	26.34194
C52 90813	At Shannon Valley on Renosterspruit (NCWQ)	Rivers	645	-29.1444	26.31806
C52 90820	Modder River at Tweerivier (NCWQ)	Rivers	569	-29.0433	24.64083
C52 90823	Kgabanyane River at Bedford up Stream Groothoek D (NCWQ)	Rivers	196	-29.2856	26.92194
C52 90829	At Kromdraai on Klein Modder Rivier	Rivers	8	-29.2428	26.67194
C52 90831	Doorns 131 - Tweerivier 129 - at Modderrivier downstream Nico Smith Bridge on Modder River (NCWQ NCMP)	Rivers	886	-29.0286	24.63839
C52 90833	Krugersdrift Dam on Modder River: downstream Weir (NCWQ NCMP)	Rivers	1007	-28.8833	25.95028
C52 90836	Cypress 89 - at Glen on Modder River (NCWQ NCMP)	Rivers	775	-28.9491	26.32099
C52 90837	At Bishops Glen on Renosterspruit (NCWQ)	Rivers	558	-28.9667	26.33306
C52 187233	Diepwater 227 - on Modderrivier (NCWQ)	Rivers	209	-29.3756	26.66556
C52 182329	Botshabelo 3 at Bridge downstream of Pse Outflow (NMMP)	Rivers	1263	-29.2428	26.67367
C52 182330	Botshabelo 2 Final City Exit Point upstream of Pse Outflow (NMMP)	Rivers	1264	-29.238	26.682
C52 182332	Botshabelo 1 Runs Through Suburb Collecting Residential Waste (NMMP)	Rivers	1254	-29.2953	26.715
C52 188085	Loch Logan at Gazebo on Bloemspruit (NMMP)	Rivers	487	-29.1143	26.21044

Surface monitoring site ID	Description	Type	n	Latitude	Longitude
C52 188182	Selosesha (Seroala) Dam at Inlet on Sepane (NMMP)	Rivers	372	-29.2054	26.79977
C52 189013	Midway at N8 Bridge on Bloemspruit	Rivers	58	-29.1114	26.31353
C52 189015	Glen at Road Bridge on Modder	Rivers	57	-28.9555	26.33533
C52 189017	Palmietfontein at Botshabelo Dam on Klein Modder Rivier	Rivers	56	-29.2498	26.65775
C52 189019	Stoom Hoek 826 - Soetdoring at R700 Road Bridge on Modderrivier	Rivers	56	-28.807	26.10925
C52 189027	Likatlong / Sannaspos at Farm Road Bridge on Sepane	Rivers	58	-29.1635	26.59508
C52 189076	Rooidam on Modderrivier	Rivers	53	-29.0259	24.74956
C52 191145	Brandfort Townlands 720 - downstream of Brandfort WWTW on Keeromspruit	Rivers	52	-28.7101	26.44644
C52 191156	Brandfort Townlands 720 - upstream of Brandfort WWTW on Keeromspruit	Rivers	16	-28.7113	26.44713
C52 191171	Uitvlugt West 2810 - at Road Bridge downstream of Krugersdrift Dam on Modderrivier	Rivers	60	-28.8853	25.95604
C52 183712	2826CC00026 Florisbad Warm Bath (N_GW)	Spring/Eye	44	-28.7678	26.07
C52 90832	Rustfontein Dam on Modder River: Left Canal/River	Canal	6	-29.2708	26.61667
C52 187232	De Wetskom 452 - on Novo Canal (NCWQ)	Canal	66	-29.6242	26.71667
D21, D22, D23 and D24 - CALEDON RIVER					
D21 101808	Caledonspoort 190 the Poplars 199 at the Poplars on Little Caledon River (NCWQ NCMP)	Rivers	822	-28.6949	28.23487
D21 187244	Caledonspoort on Caledon River (NCWQ)	Rivers	15	-28.69	28.23
D21 191335	The Poplars 199 - 500M U/S of Caledonspoort Bridge - on Caledon Rivier	Rivers	54	-28.6962	28.23884
D21 191336	Pietersdal 1207 - D/S of WWTW at Road Bridge on Little Caledon River	Rivers	56	-28.5394	28.43126
D21 191337	Pietersdal 1207 - U/S of Clarens WWTW at Bank of Little Caledon River	Rivers	56	-28.5348	28.43936
D21 191347	Fouriesburg - at Fouriesburg WWTW Maturation Dam (Oxidation Pond)	Canal	56	-28.6267	28.19997

Surface monitoring site ID	Description	Type	n	Latitude	Longitude
D22 101815	Caledon River at Ficksburg/ Ficksburg Bridge (NCWQ NCMP)	Rivers	581	-28.8833	27.89
D22 187060	Tributary of Caledon at Riverside Lodge (NMMP)	Rivers	335	-29.2937	27.4625
D22 191353	Moordkop 215 - 550M D/S of Maseru Border Post Bridge on Caledon River	Rivers	50	-29.3021	27.45628
D22 191354	Riverside 927 - 1KM U/S of Maseru Border Post Bridge on Caledon River	Rivers	50	-29.2945	27.46477
D23 101810	Caledon River at Wilgedraai/Hobhouse (NCWQ NCMP)	Rivers	201	-29.6156	27.06528
D23 101817	Caledon River at Wilgedraai/Hobhouse (NCWQ NCMP)	Rivers	893	-29.6092	27.06556
D24 86337	Welbedacht 285 - at Gauging Weir on Caledon River D/S of Welbedachtdam	Rivers	15	-29.9256	26.86
D24 101816	Caledon River at Kommissiedrift (NCWQ NCMP)	Rivers	621	-30.2792	26.65417
D24 193325	Downstream Rouxville Sewage Treatment Works	Rivers	51	-30.3932	26.83306
D24 191366	Rouxville Dorpsgronden van Rouxville 108 - at Rouxville Wastewater Treatment Works	Canal	52	-30.3942	26.83175
D24 191380	Vanstadensrus - at Vanstadensrus Wastewater Treatment Works	Canal	41	-29.9901	26.99529
KRAAI RIVER and ORANGE RIVER					
D12 101793	Orange River at Oranjedraai (NCWQ NCMP)	Rivers	1456	-30.3361	27.35944
D12 191410	Verliesfontein 354 - 200M D/S of Zastron WWTW on Gryskopspruit	Rivers	51	-30.3001	27.11402
D12 191423	Verliesfontein 354 - 200M U/S of Zastron WWTW on Gryskopspruit	Rivers	51	-30.299	27.10571
D13 101795	Kraai River at Roodewal (NCWQ NCMP GEMS)	Rivers	1366	-30.8306	26.92139
D13 191431	Barkly East - 1KM D/S of Barkly East WWTW at Road Bridge on Langkloof	Rivers	52	-30.9548	27.6069
D13 191432	Barkly East - 400M U/S of Barkly East WWTW on Langkloof River	Rivers	52	-30.9664	27.61672
D14 101788	Wonderboom/Stormberg Spruit at Diepkloof/Burgersdorp (NCWQ NCMP)	Rivers	975	-31.0008	26.35306
D14 101789	Orange River at Maletswai (Aliwal North) (NCWQ NCMP)	Rivers	2318	-30.6797	26.7125

Surface monitoring site ID	Description	Type	n	Latitude	Longitude
D14 191387	Aliwal North - 400M D/S of Maletwai (Aliwal North) WWTW on Orange River	Rivers	49	-30.6877	26.6896
D14 191414	Goedemoed Oudefontein 14 - 2KM D/S of Goedemoed WWTW on Oranjerivier	Rivers	48	-30.5871	26.3647
D14 191415	Goedemoed Deelfontein 237 - 2KM U/S of Goedemoed WWTW on Oranjerivier	Rivers	48	-30.5668	26.41359
D14 89868	3026DA00035 Maletswai (Aliwal North) (N_GW)	Spring/Eye	56	-30.7156	26.71472
D15 101791	Kornet Spruit at Maghaleen (NCWQ NCMP)	Rivers	1389	-30.1601	27.40124
D31, D32, D33, D34 and D35 - ORANGE RIVER					
D32 101829	Seekoei River at de Eerste Poort (NCWQ NCMP)	Rivers	618	-30.5342	24.96194
D32 191312	Hanover - at Canal Flowing from Hanover WWTW to Open Field	Canal	41	-31.0719	24.46012
D33 101827	Orange River at Dooren Kuilen (downstream of D3R003) (NCWQ NCMP)	Rivers	919	-29.9911	24.72444
D33 101832	Kareekloof 1184 Vanderkloof Dam - on Right Bank Canal (NCWQ NEMP)	Canal	371	-29.9869	24.72224
D33 193476	Petrusville WWTW at Final Oxidation Pond	Canal	51	-30.0736	24.6653
D34 101828	Roodepoort on Orange River (NCWQ NCMP)	Rivers	1687	-30.5839	25.41972
D34 191285	Colesburg - at Colesburg WWTW at Oxidation Pond Overflow	Canal	43	-30.6985	25.12074