

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**

**WATER RESOURCES INFORMATION
AND GAP ANALYSIS REPORT
WP 11422**

Study Report No.

RDM/WMA13/00/CON/CLA/0124

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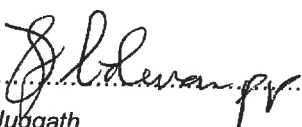
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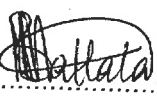
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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

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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

TERMINOLOGY AND ABBREVIATIONS

Acronym	Description
AEH	Aquatic Ecosystems Health
BHN	Basic Human Needs
CD: WEM	Chief Directorate: Water Ecosystems Management
DCVB	Discontinuously Channelled Valley-Bottom
DFFE	Department of Forestry, Fisheries and the Environment
DMRE	Department of Mineral Resources and Energy
DRDLR	Department of Rural Development and Land Reform
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EFR	Environmental Flow Requirements
EGSAs	Ecosystem Goods, Services and Attributes
ES	Ecosystem Services
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FBIS	Freshwater Biodiversity Information System
FMP	Flow Management Plan
FP	Floodplain
GDP	Gross Domestic Product
GHS	General Household Surveys
GIS	Geographic Information System
GRU	Groundwater Resource Unit
ha	Hectare

Acronym	Description
HGM	Hydrogeomorphic
HSS	Hillslope Seep
IDP	Integrated Development Plan
IFR	Instream Flow Requirements
IHI	Index of Habitat Integrity
IWUI	Integrated Water Use Index
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
JBS	Joint Basin Survey
KTP	Kgalagadi Transfrontier Park
LHWP	Lesotho Highlands Water Project
LSS	Large Sample Survey
masl	Meters above sea level
MEA	Millennium Ecosystem Assessment
MIRAI	Macroinvertebrate Response Assessment Index
Mm ³	Million cubic metres
NAP	National Action Plan
NCMP	National Chemical Monitoring Programme
NEMP	National Eutrophication Monitoring Programme
NFEPA	National Freshwater Ecosystem Priority Areas
NMMP	National Microbiological Monitoring Programme
NWSKS	National Water Service Knowledge System
NT	National Treasury

Acronym	Description
ORASECOM	Orange-Senqu River Commission
PES	Present Ecological Sate
PSP	Professional Service Provider
QSAM	Quasi Social Accounting Matrix
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
QC	Quaternary Catchment
RDM	Resource Directed Measures
RQIS	Resource Quality Information Services
RUs	Resource Units
SAM	Social Accounting Matrix
SANBI	South African National Biodiversity Institute
SeCT	Socio-Economic Classification Tool
StatsSA	Statistics South Africa
SW-GW	Surface water - groundwater
SWSA	Strategic Water Source Area
TDA	Transboundary Diagnostic Analysis
TEEB	The Economics of Ecosystems and Biodiversity
WARMS	Water Use Authorisation and Registration System
UCVB	Unchanneled Valley-Bottom
VB	Valley-Bottom
WMA	Water Management Area
WMS	Water Management System
WQ	Water Quality

Acronym	Description
WQT	Water Quality Total Dissolved Salts
WRCS	Water Resource Classification System
WRPM	Water Resource Planning Model
WRU	Wetland Resource Unit
WRYM	Water Resource Yield Model

EXECUTIVE SUMMARY

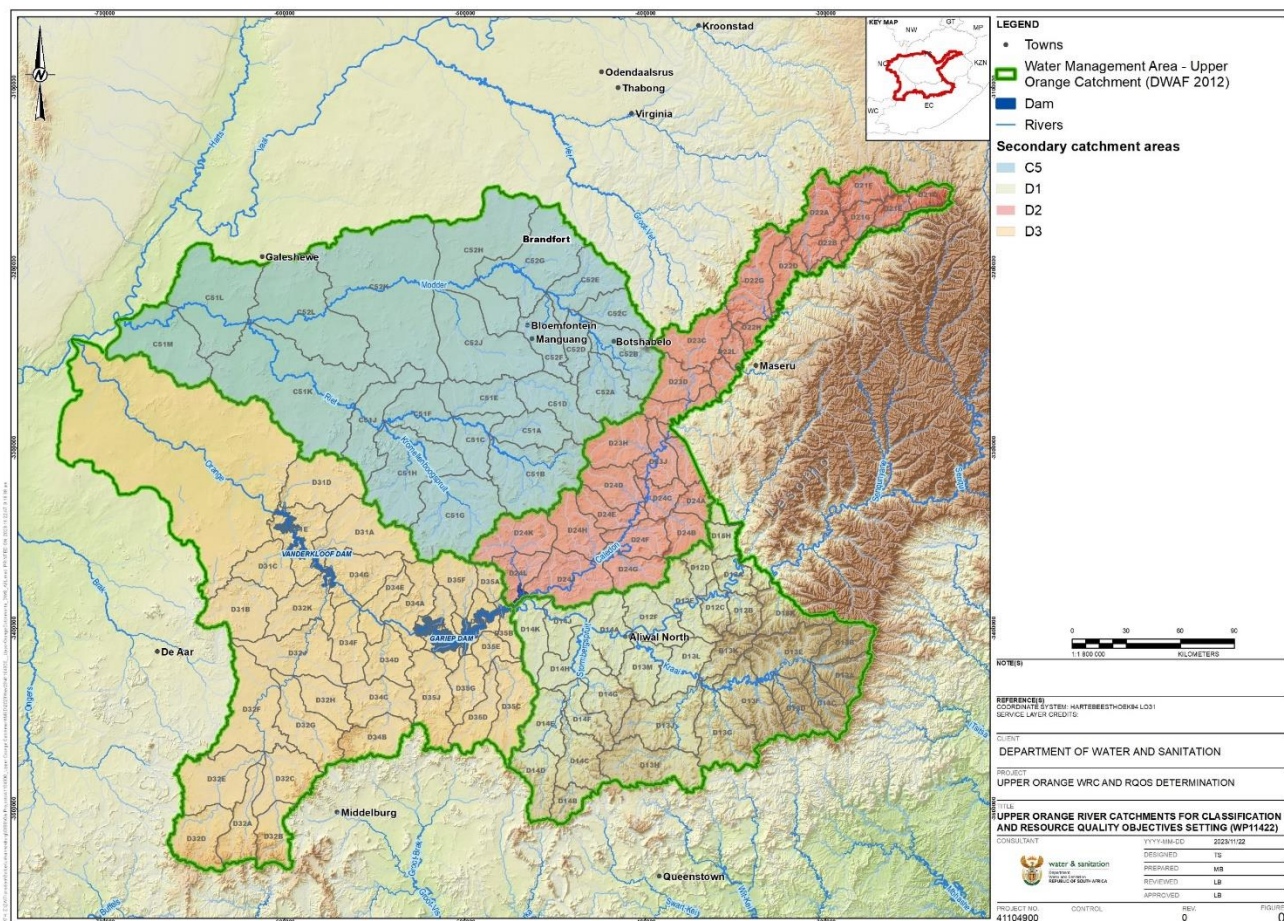
The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) has initiated a study for the determination of Water Resource Classes and associated Resource Quality Objectives in the Upper Orange River Catchment.

The main objective of the study is to coordinate the implementation of the water resources classification system in order to classify 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, and determine the associated Resource Quality Objectives (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.

The Orange River catchment area comprises the Upper Orange and Lower Orange 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, namely 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 catchment is divided into four distinct sub-areas, indicated in the figure below, stretching across the Northern Cape, Free State and Eastern Cape provinces and further across three ecoregions, the Eastern Escarpment Mountains, Nama Karoo and Highveld:

- 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, Stormbergespruit 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.



Two large hydropower stations have been constructed at Gariep and Vanderkloof dams. The surface water resources of the Upper Orange River catchment are used to support requirements for water in other parts of the country with large transfer schemes both from and within this WMA. These include transfers from the Senqu River (Lesotho Highlands Water Project) through the Katse and Mohale dams and the planned Polihali Dam, to the Upper Vaal catchments of the Vaal-Orange WMA, the Orange-Fish Tunnel from Gariep Dam to the Mzimvubu- Tsitsikamma WMA, transfer from Caledon River via Knellpoort Dam (off-channel) to the greater Bloemfontein area for domestic and industrial use, transfers from Vanderkloof Dam and at Marksdrift Weir to the Riet River catchment for mainly irrigation purposes and the Orange-Vaal Transfer to the Lower Orange River catchments. Transfer from Muela Dam in Lesotho to the Caledon River is used during droughts to supply water to Maseru and surrounding areas.

There are several wetland types in the Upper Orange Catchment including floodplain wetlands, depression wetlands, unchanneled valley-bottom wetlands, and hillslope seep wetlands.

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.

This report briefly describes information and data from previous studies that will inform various aspects of the water resource classification process and setting of RQOs in the Upper Orange River Catchment.

The gap analysis identifies where additional work may be needed, and specifically where additional Rapid or desktop Reserves will be required. Specific recommendations are made as to the collection of additional data and/or the extrapolation of existing data.

The Upper Orange River catchment has had many studies undertaken, with the latest being the comprehensive Reserve determination that will be finalised in March 2024. The data collected and the scenarios run as part of the EWR determination will support this classification study.

The major data gaps identified include recent surface water quality data for some of the catchments and inadequate baseline groundwater attributes: (i) water levels, (ii) water quality, (iii) rainfall data, (iv) water use figures, and (v) aquifer saturation levels.

These will be filled as far as possible by undertaking site visits and taking samples to augment the existing data.

Socio-economic information data gaps are predominantly around the delay in the latest census figures.

The results of the high confidence Reserve study are considered adequate for the information requirements of this study, however the aspects related to the Flow Management Plan and the proposed EWR sites will be further assessed and taken forward as part of the classification study. However possible additional EWR sites for the Orange River and tributary catchment include potential sites on the upper reaches of the Caledon River before the confluence with the Little Caledon River; tributaries of the Kraai River in D13 and Riet River in C51; and the lower reaches of the Orange River near Marksdrift weir.

Overall, there is adequate data to undertake the water resources classification and set RQOs for the Upper Orange River at a high confidence level.

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1 INTRODUCTION

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

Water Resource Classification, the Reserve and Resource Quality Objectives (RQOs) are protection-based measures that make up Resource Directed Measures (RDM), the protection principles contained in Chapter 3 of the National Water Act (Act No. 36 of 1998). The classification system and the Reserve are intended to ensure comprehensive protection of all water resources.

1.1. Study Objective

The main objective of the study is to coordinate the implementation of the water resources classification system in order to classify 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, and determine the associated Resource Quality Objectives (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.

1.2. Purpose of this Report

The purpose of the Water Resource Information and Gap Analysis Report is to document the identified key gaps relevant to the determination of the water resource classes and RQOs in the Upper Orange River Catchment, based on current information and data from previous studies undertaken.

The report briefly describes information and data from previous studies that will inform various aspects of the water resource classification process and setting of RQOs in the Upper Orange River Catchment.

The gap analysis identifies where additional work may be needed, and specifically where additional Rapid or desktop Reserves will be required. Specific recommendations are made as to the collection of additional data and/or the extrapolation of existing data.

The report also includes a description of the most recent water resource models and their applicability to using them in the scenarios assessments.

2 STUDY AREA

The Orange River catchment (Figure 1) area comprises the Upper Orange and Lower Orange catchments within the Vaal-Orange River Water Management Area (WMA04), indicated by the darker outline in Figure 1.

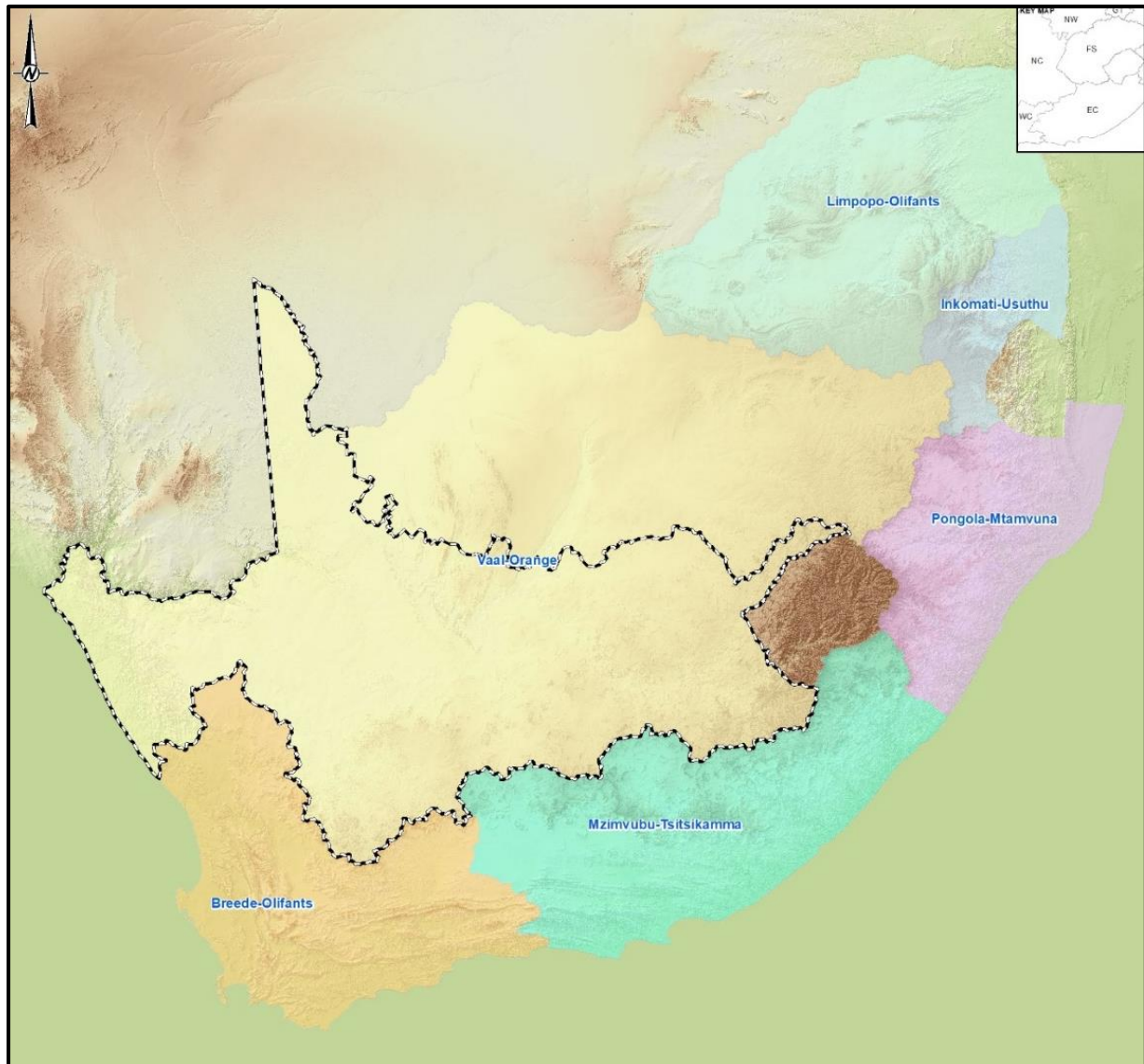


Figure 1: Orange River Catchment within Vaal- Orange WMA (WMA04) in South Africa

This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States, namely 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 Africa 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 Orange Rivers 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.

This catchment is divided into four distinct sub-areas, stretching across the Northern Cape, Free State and Eastern Cape provinces and further across three ecoregions, the Eastern Escarpment Mountains, Nama Karoo and Highveld:

- 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, Stormbergespruit 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.

The study area comprises 129 quaternary catchments, including the secondary catchments D1, D2, D3 and C5 (Figure 2). The sub-catchments, associated rivers, catchment areas and quaternary catchments are listed in Table 1 and illustrated in Figure 2. It is noted that not every river is mentioned in the table, however these will be detailed in the status quo assessment.

The Caledon River (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, tributary 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.

Land use in the Upper Orange area 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 represent the main urban and industrial developments in the catchment. Smaller towns include Aliwal North, Ficksburg Ladybrand, Clocolan, Colesburg and Noupoot.

Two large hydropower stations have been constructed at Gariep and Vanderkloof dams.

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 catchment 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, as indicated in Table 1 and illustrated in Figure 2. These areas will be further sub-divided when the Integrated Units of Analysis (IUA) are defined.

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, Ospootspruit, Kromellenboogspruit, Riet River	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, Skulspruit, 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

Secondary Catchment	Tertiary Catchment	Quaternary catchments	Main River/(s)	Catchment area ⁽¹⁾ (km ²)	
				Gross	Net
	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, Grahamstadspuit, Slyspruit, Edon River, Skulpspruit	6 614	6 614
D3	D31	D31A - E	Bergrivier, Orange River,	4 910	4 396
	D32	D32A – H, D32J and K	Seeikoeirivier	9 081	9 081
	D34	D34A - G	Orange River	5 020	5 020
	D35	D35A – H, D35J and K	Brandspruit, Brakspruit, Bossiespruit, Suurbegspruit, Orange River	5 638	5 638

¹WR2012 data

Dams in the Upper Orange River catchment are briefly described in Table 2.

Table 2: Major Dams in the Upper Orange River catchment

Dam name	Quaternary catchment	Associated River	Purpose	Full storage capacity (Mm ³)*	Surface area (km ²)
Gariep	D34A	Orange	Major storage dam – irrigation, domestic, hydropower, transfer to Eastern Cape and recreation	4,903.5	352.162
Vanderkloof	D31E /D33A	Orange	Major storage dam – irrigation, domestic, hydropower and recreation	3,092.4	133.402
Armenia	D23C	Leeu River	Small storage dam for irrigation	13.3	3.933
Egmont	D24A	Off-channel (Witspruit River)	Supplementing water supply to Bloemfontein	9.1	9.854
Welbedacht	D24C	Caledon	Small storage dam for irrigation and transfer to Bloemfontein	5.5	10.185
Rustfontein	C52A	Modder	Small storage dam for domestic and irrigation	72.2	11.585
Mockes	C52D	Modder	Small storage dam for domestic	4.16	1.5
Krugersdrift	C52H	Modder	Small storage dam for irrigation	71.5	18.525
Tierpoort	C51E	Riet	Small storage dam for irrigation	34.0	9.11

Dam name	Quaternary catchment	Associated River	Purpose	Full storage capacity (Mm ³)*	Surface area (km ²)
Kalkfontein	C51J	Riet	Small storage dam for irrigation	325.2	37.697

*Mm³: million cubic metres

Hydropower

Two large hydropower stations have been constructed at Gariep and Vanderkloof dams.

Inter-basin transfers

The surface water resources of the Upper Orange River catchment are used to support requirements for water in other parts of the country with large transfer schemes both from and within this WMA. These include transfers from the Senqu River (Lesotho Highlands Water Project) through the Katse and Mohale dams and the planned Polihali Dam, to the Upper Vaal catchments of the Vaal-Orange WMA, the Orange-Fish Tunnel from Gariep Dam to the Mzimvubu- Tsitsikamma WMA, transfer from Caledon River via Knellpoort Dam (off-channel) to the greater Bloemfontein area for domestic and industrial use, transfers from Vanderkloof Dam and at Marksdrift Weir to the Riet River catchment for mainly irrigation purposes and the Orange-Vaal Transfer to the Lower Orange River catchments.

Transfer from Muela Dam in Lesotho to the Caledon River is used during droughts to supply water to Maseru and surrounding areas (DWA, 2009).

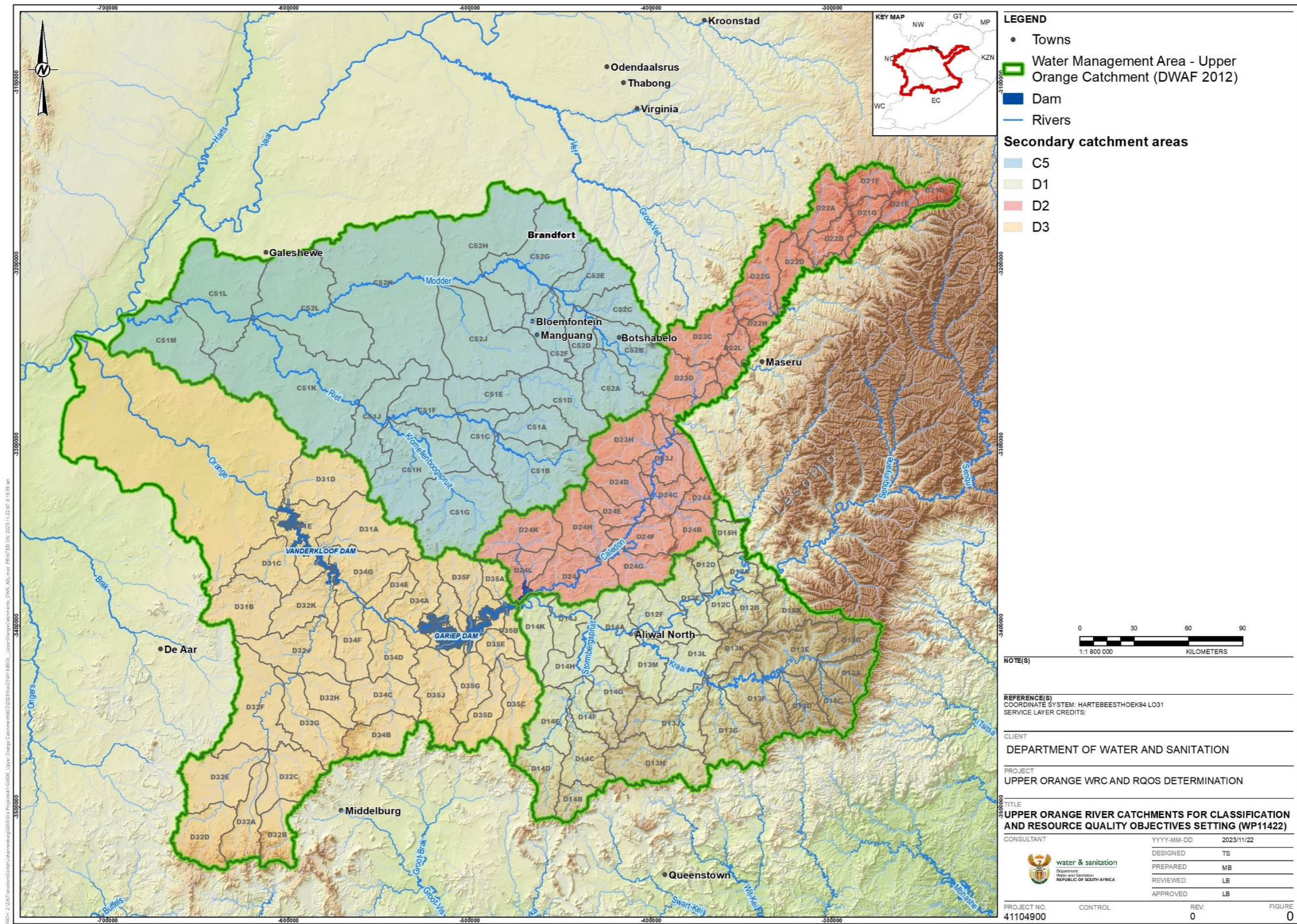


Figure 2: Upper Orange River catchment – Study Area extent and Locality (South African portion)

2.1. Water Resource Components

This study focuses on the classification of significant water resources in the Upper Orange River catchment. This will include an identified network of significant resources comprising the rivers, dams, wetlands and pans, and groundwater resources within the catchment.

- **Rivers:** The significant rivers to be classified within defined integrated unit of analysis (IUA) will be identified and confirmed during the status quo phase. This will, as a first step, comprise the main stem river and tributary catchments of the Upper Orange River catchment (the South African portion) including:
 - 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 catchment (D1 secondary catchment), including the main tributaries:
 - Kornetspruit
 - Sterkspruit
 - Stormbergespruit
 - Brandwaterspruit, and
 - Kraai River
 - 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
 - Modder-Riet River (main tributaries of the Vaal River system) in the north (C5 secondary catchment).
- **Wetlands/Pans:** There are several wetland types in the Upper Orange Catchment including floodplain wetlands, depression wetlands, unchanneled valley-bottom wetlands, and hillslope seep wetlands. Most of the wetland complexes described in the Reserve study (DWS, 2023) Report number RDM/WMA13/00/CON/COMP/0922, have been impacted by cultivation, however there are some areas that are still natural. The wetland areas include the following priority wetland complexes identified by the high confidence Reserve study:
 - Brandwater floodplain
 - Soutpan depression wetland complex,
 - Philipstown unchannelled valley-bottom (UCVB) wetland complex
 - Wolwespruit headwaters wetland complex
 - Klein-Wildebeespruit wetland complex
 - Luckhof depression wetland complex
 - Kaalspruit wetland complex
 - Aardoringspruit a large wetland complex
 - Rantsho wetland complex
 - Jagersfontein DCVB wetland

- Barkley Pass wetland complex
- Tiffindell Seep
- **Groundwater:** 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.

The aquifer systems in the Upper Orange River Catchment consists of the following aquifer types with an indication of Borehole Yield Classes (BYC as per DWAF (1997 – 2003) – Geohydrological Map Series), i.e., Fractured rock aquifers – variation of water bearing zones in the rock package (Aquifer Type "b"); and Fractured and intergranular – merely the shallower parts of the water bearing formation where weathering of the rock formation has enhanced the water bearing potential (Aquifer Type "d").

On average the Borehole Yield Class (5 categories between 0.0 and >5.0 L/s) of the Upper Orange catchment aquifers fall in the 0.5 – 2.0 L/s range, i.e., Class 3.

Several, localized areas are present where relatively high (i.e., above a Borehole Yield Classes 4 [2.0-5.0 L/s and >5.0 L/s respectively]) groundwater yields occur that are related to the following geological combinations:

1. Quaternary Limestone (calcrete basins), i.e., the Bolokaneng (Petrusburg) Kalkveld Aquifer system (b5)
2. Karoo Supergroup (P-Trb, mudrock) in association of Karoo Dolerite (Jd intrusions), i.e., Poding-tse-Rolo (Phillipolis), and Maphodi (Springfontein) areas (b4-d4, d4 and respectively)
3. Karoo Supergroup (P-Trb, sandstone) in association with Karoo Dolerite (Jd intrusions), i.e., Kuyasa (Colesburg) and Nozizwe (Venterstad) (d4), and
4. Karoo Supergroup (P-Trb, sandstone) in association with Karoo Dolerite (Jd intrusions large cap-dolerite sills enhancing surface runoff to low-lying terrains where aquifer recharge is enhanced), i.e., KwaZamuxolo (Noupoort) (d4).

Other aquifer types that are present, but on a much smaller scale, are:

- Karst rock aquifers – where shallow secondary limestone (viz., calcrete) has been partially dissolved creating sufficient storage for rainwater recharge (Aquifer Type "c");
- Intergranular Aquifers where groundwater-surface water interaction is present – alluvial sediments of fluvial origin overlying parts of the basement fractured aquifers, (Aquifer Types "d" and "b" combinations; and

- Karoo Dolerite “Contact Zone” aquifer – a special type of local aquifers with exceptionally high yield potential. Classifies as an (special) Aquifer Type “b”, however, the yields could be as high as 10 L/s down to 100 mbgl.

The borehole yield class for the latter aquifer types are “4” or “5” (or 2.0-5.0L/s or >5.0 L/s).

A wide range of aquifer systems are present in the study area – it is foreseen that existing datasets will be upgraded with the latest groundwater information, i.e., from recent projects and monitoring programme datasets. Upgrading of the groundwater use as per WARMS will have to be considered as it is the only direct source of larger water use figures. Groundwater use by local municipalities and irrigation systems are regarded as bulk water supply schemes and their present status and impact(s) need to be assessed.

Groundwater quality of the Karoo Supergroup rock aquifers is highly variable and a function of the recurrence rate of aquifer storage recharge – which could be impacted (viz., becoming less effective) by climate variation(s). Groundwater quality is becoming a concern for bulk water supply to municipalities that are merely using “sole source” water supply schemes.

Groundwater quality in the Upper Orange catchment varies from ‘Ideal to Marginal’ however there are several “hot spot” areas where the groundwater quality is characterised by (i) high salinity due to natural conditions and (ii) impacted due to anthropogenic pollution, i.e., mining, agriculture, industrial and municipal waste pollution. These sites will be highlighted specifically in the RQO assessment providing guidelines supported by numeric ranges and associated narratives to improve the water quality conditions.

It is also necessary to address the natural and/or induced toxicity of the groundwater resources. Elevated levels of nitrate and fluoride have been noted in several areas – these dissolved constituents represent health risks especially where the groundwater resource is a sole water supply source.

3 INFORMATION SOURCES

The information that has been reviewed originates from several studies of which the most important are listed here. Further detailed assessment is underway and will support the status quo assessment.

3.1. Studies currently in progress

The most recent and/or current studies that will support this study include, but are not limited to:

- High confidence Reserve determination currently underway for surface water, groundwater, and wetlands for the Upper Orange catchment. The study will be completed end of March 2024, after which all results will be available for the continuation of this study.
- The Joint Basin Survey, the third iteration (JBS3), whereby aquatic ecosystem health is monitored throughout the Orange-Senqu River Basin conducted by the Orange-Senqu River Commission (ORASECOM).
- Transboundary Resource Quality Objectives (RQO) undertaken by GroundTruth for ORASECOM. Study completed in February 2024.
- Updating of the 2014 desktop PES/ EIS database for the Orange-Vaal catchments.
- ORASECOM E-Flow study being undertaken by Sherman and Brown, currently in progress to update the E-Flow sites, which includes ecological and associated hydrological sites for 3 sites, and hydrological only for 4 sites. This project is still in the early phases and will be included as appropriate as the study progresses.
- Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River.

3.2. Previous Studies

Previous studies undertaken in the Upper Orange catchment area that will support the water resource classification and RQOs project are listed in Table 3.

Table 3: Previous Studies undertaken within the Orange River Catchment

Study Name	Brief description	Date	Integrated Process - applicability	Comment
ORASECOM Joint Baseline Survey-3: Baseline Water Resources Quality State of the Orange-Senqu River System	The JBS is conducted every five years in the Orange-Senqu River Basin, focusing on the monitoring of Aquatic Ecosystem Health (AEH). This study for the Upper Orange River catchment will utilise the latest available data on surface water (physical- chemical and diatoms) and AEH (fish, macroinvertebrates, and riparian vegetation) that will be relevant for this study. (ORASECOM, 2023a).	2021/2022	<ul style="list-style-type: none"> Step 2: Status quo assessment and delineation of the study area into IUAs. Step 3: Quantify BHN and EWR, and Step 6: Determine RQOs 	Supporting information to catchment understanding and water resource quality
ORASECOM Integrated Water Resources Management Plan for the Orange-Senqu River Basin (Phase 3)	The 10-year basin-wide Integrated Water Resources Management (IWRM) Plan covering the period 2015-2024. It has focused on defining and prioritizing ORASECOM's actions and activities over the next ten years. It builds on Phase I and II of the IWRM Plan. The IWRM Plan identified strategic objectives and action areas.	2014	<ul style="list-style-type: none"> Step 2: Supporting information to catchment understanding and water resource situation assessment, and Step 4: Evaluation of scenarios 	Supporting information to catchment perspective Basis to developing planning scenarios (strategic perspectives)
Water Resource Planning Systems, Orange River: Assessment of Water Quality Data Requirements for Water	Assessment of Water Quality Data Requirements for Water Quality	2014	<ul style="list-style-type: none"> Step 2: Supporting information to 	Supporting information to catchment understanding

Study Name	Brief description	Date	Integrated Process - applicability	Comment
Quality Planning Purposes, Water Quality Monitoring and Status Quo Report: Upper and Lower Orange Water Management Areas, (WMAs 13 and 14)	Planning Purposes, Water Quality Monitoring and Status Quo		catchment understanding and water resource situation assessment, and <ul style="list-style-type: none"> • Step 6: Determine RQOs 	and water resource quality
ORASECOM 2020-2021 Hydrological Season Synoptic Report on Surface Water Hydrology in the Orange Senqu Basin	The study addressed the compilation of a synoptic report of the 2020-2021 Seasonal (Annual) Surface Water Hydrology of the Orange-Senqu River Basin. The report focuses on surface water quantity information.	2022	<ul style="list-style-type: none"> • Step 2: Status quo assessment • Step 4: Evaluation of scenarios 	
DWS High Confidence Reserve study for the Upper Orange River catchment	High Confidence Reserve study for the Upper Orange River catchment for surface water, wetlands, and groundwater in accordance with the WRCS to determine of ecological water requirements and the basic human needs Reserve for the water resources (surface and groundwater) in the Upper Orange River catchment.	In progress to be completed in March 2024	<ul style="list-style-type: none"> • Step 3: Quantify BHN and EWR • Step 4: Evaluation of scenarios 	Basis to developing planning scenarios (strategic perspectives)

Study Name	Brief description	Date	Integrated Process - applicability	Comment
Reserve study - Upper Orange Rivers Integrated WUI IEI RU Level RS_FEPA_BG	Excel spreadsheet to determine integrated water use index vs an integrated ecological index considering, Reserve level, biota, hydraulics, IHI, VEGRAI, geomorphology, water quality and diatoms in rivers in quaternary catchments	2023	<ul style="list-style-type: none"> Resource Units delineation 	Assist with the preliminary resource units' delineation
ORASECOM Environmental Flow Requirements of the Orange–Senqu River and major tributaries	ORASECOM, 2011 and DWS, 2016. The ORASECOM study included four sites on the upper Orange at Hopetown, Upper Caledon, Lower Caledon and Lower Kraai rivers. EWRs were determined on an intermediate level. The same sites were included for the 2016 study.	2011 and 2016	<p>Step 3: Quantify BHN and EWR</p> <p>Step 4: Evaluation of scenarios</p>	
DWS Integrated Water Quality Management Strategy	Department of Water Affairs (DWA), 2009. Development of an Integrated Water Quality Management Strategy for the Upper and Lower Orange River Water Management Areas, Desktop Catchment Assessment Study: Upper Orange Water Management Area (WMA 13 and 14)	2009	<ul style="list-style-type: none"> Step 2: Status quo assessment and delineate study area into IUAs Step 6: Determine RQOs 	Supporting information to catchment understanding and water resource quality (historical)
DWS Development of Reconciliation Strategies for Large Bulk Water	The Reconciliation Strategy presents a reconciliation of water availability and requirements in the	2015	Step 2: Status quo assessment and	Supporting information to catchment perspective

Study Name	Brief description	Date	Integrated Process - applicability	Comment
Supply Systems: Orange River – Final Reconciliation Strategy	<p>Orange River catchment and based on the water balance, intervention options are presented. The study included amongst others, the following specialist reports:</p> <ul style="list-style-type: none"> • International obligations • Current and future Water Requirements • Urban Water Conservation and Water Demand Management • Irrigation Demands and Water Conservation/Water Demand Management • Surface Water Hydrology and System Analysis • Water Quality, and • Reserve Requirement Scenarios and Scheme Yield. 		<p>delineate study area into IUAs</p> <p>Step 4: Evaluation of scenarios</p>	<p>Basis to developing planning scenarios (strategic perspectives)</p>
ORASECOM Transboundary Preliminary Diagnostic Analysis (TDA)	<p>Orange Senqu-River Basin. Preliminary Transboundary Diagnostic Analysis. Adopted by ORASECOM in April 2008. Report details the key transboundary issues of the Orange-Senqu basins, provides an analysis of these issues, documents the findings in</p>	2008	<p>Step 2: Status quo assessment and delineate study area into IUAs</p> <p>Step 4: Evaluation of scenarios</p>	<p>Supporting information to catchment understanding and actions that are being/ have been considered.</p>

Study Name	Brief description	Date	Integrated Process - applicability	Comment
	terms of the causal chain analysis and looks at knowledge gaps.		Step 6: Determine RQOs	
ORASECOM Orange Senqu-River Basin Transboundary Diagnostic Analysis (TDA)	<p>Orange Senqu-River Basin Transboundary Diagnostic Analysis: Final Draft Adopted by ORASECOM in April 2013.</p> <p>The report provides a scientific and technical basis for the identification and prioritisation of key issues concerning the degradation of aquatic ecosystems in the Orange–Senqu River basin.</p>	2013	<p>Step 2: Status quo assessment and delineate study area into IUAs</p> <p>Step 4: Evaluation of scenarios</p> <p>Step 6: Determine RQOs</p>	Supporting information to catchment understanding and actions that are being/ have been considered.
ORASECOM National Action Plan for the Orange-Senqu Basin in South Africa	National Action Plans (NAP) are strategic implementation plans to address priority environmental concerns in specific parts of the Orange–Senqu River Basin. The NAPs are closely related to the basin-wide Orange–Senqu Integrated Water Resources Management (IWRM) plan.	2014	<p>Step 2: Status quo assessment and delineate study area into IUAs</p> <p>Step 6: Determine RQOs</p>	Supporting information to catchment understanding and actions that are being/ have been considered.
DWS Water Quality Total Dissolved Salts (WQT) Modelling and Water Resource Planning Model (WRPM) setup requirements for the Orange River	The study included a calibrated WQT Model for the Orange River and the configuration and testing of the WRPM for the Orange River System	2012	Step 4: Evaluation of scenarios	

Study Name	Brief description	Date	Integrated Process - applicability	Comment
DWS Orange River: Assessment of water quality data requirements for planning purposes: Upper and Lower Orange Water Management Areas (WMAs 13 and 14).	Reports detailing the water quality status quo of the Upper and Lower Orange WMAs based on historical data and a snapshot survey and proposed resource water quality objectives for the Orange River. The study also proposed monitoring sites and a programme for water quality.	2011	Step 2: Status quo assessment and delineate study area into IUAs Step 6: Determine RQOs	
Support to Phase 3 of the ORASECOM Basin-wide integrated Water Resources Management Plan, Work Package 4A – Economic analysis of water based on water accounting for the Orange-Senqu Basin	The study provides information of the implications of water accounting in the Orange-Senqu Basin how effectively water is being managed. Includes: <ul style="list-style-type: none"> • Background information on the basin • Analysis of water accounting • Information on water foot printing Analysis of water in the economy	2014	Step 2: Status quo assessment and delineate study area into IUAs Step 4: Evaluation of scenarios	
ORASECOM Orange River Integrated Water Resources Management Plan – Demographics	Provides information relating to demography, economic activity including the transfer schemes and	2007	Step 2: Status quo assessment and	

Study Name	Brief description	Date	Integrated Process - applicability	Comment
and Economic Activity in the four Orange Basin States	the major economic sectors and water use in the basin.		delineate study area into IUAs	
Statistics South Africa (Stats SA) National Census 2022 and 2016 General household survey (population densities)	The South African National Census of 2022 is the 4 th comprehensive census conducted by Stats SA. Phase 1 released in October 2023 provides a range of indicators at national, provincial, and municipal level	2022 2016	Step 2: Status quo assessment and delineate study area into IUAs	Phase 2 release will include electronic data and more in-depth reports
Stats SA Supply and Use Tables and GDP publication	Provide economic contribution values for sectors within the economy	2019 2023 (GDP publications)	Step 2: Status quo assessment and delineate study area into IUAs Step 4: Evaluation of scenarios	
Local Municipality Integrated Development Plans (IDPs)	Provides information on a local municipal level of economic activities and population	Latest (varies 2019 to 2023)	Step 2: Status quo assessment and delineate study area into IUAs	
National Treasury (NT) Municipal Socio-Economic Profiles	Provides statics and values for aspects relating to population and economy of local municipalities	2019	Step 2: Status quo assessment and delineate study area into IUAs	

Study Name	Brief description	Date	Integrated Process - applicability	Comment
DFFE, SA National Land Cover	Maps showing the latest land use or land cover within South Africa to aid in understanding the catchment	2020	Step 2: Status quo assessment and delineate study area into IUAs	
DFFE, Protected Areas of SA	Map detailing the protected areas in South Africa. To assist in understanding the catchment	2023	Step 2: Status quo assessment and delineate study area into IUAs	
DWS Catchment boundaries	Map data to delineate the boundaries of the catchment	2017	Step 2: Status quo assessment and delineate study area into IUAs	
Support to Phase 3 of the ORASECOM Basin-wide integrated Water Resources Management Plan, Work Package 4A – Economic analysis of water based on water accounting for the Orange-Senqu Basin	<p>The study provides information of the implications of water accounting in the Orange-Senqu Basin how effectively water is being managed. Includes:</p> <ul style="list-style-type: none"> • Background information on the basin • Analysis of water accounting • Information on water foot printing <p>Analysis of water in the economy</p>	2014	<p>Step 2: Status quo assessment and delineate study area into IUAs</p> <p>Step 4: Evaluation of scenarios</p>	

Study Name	Brief description	Date	Integrated Process - applicability	Comment
<p>Water Resources of South Africa, Study (WR2012). WRC Project No. K5/2143/1</p>	<p>Baseline Report identifying the following attributes for a number of Groundwater Resource Units (GW_RUs):</p> <ul style="list-style-type: none"> • Aquifer Types (Primary, Secondary and Karst) • Groundwater Use; (WARMS + expert knowledge) • SWSA (Groundwater and SW-GW_interaction) • Sole Source Groundwater Supplies • Groundwater Stress and Factors. 	<p>2007 (cited only) and 2012</p>	<p>Step 2 and Steps 4 and 5.</p>	<p>This dataset in incorporated into the next Study Report (WP11343). Unfortunately, the basic groundwater information, i.e., (i) Use (taking of water, (ii) rainfall input, (iii) water level responses, and (iv) water quality is not [even] at least representative of the whole WMA.</p>
<p>A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment: WP11343</p> <p>Basic Human Needs Report (RDM/WMA13/00/CON/COMP/0822)</p>	<p>The overall purpose of the study is to determine the Reserve for priority rivers, wetlands and groundwater areas at a high level of confidence in the Upper Orange Catchment. This assessment (and report) pertains specifically to the quantification of the BHN for the Upper Orange Catchment. The BHN is determined across all the quaternary catchments of the study area.</p>	<p>Oct 2022</p>	<p>Information for Step 2 were addressed.</p>	<p>Dataset not adequate to support QC-level RDM assessment. Lack of (i) aquifer water levels, (ii) rainfall depths, (iii) water qualities, and (iv) water use (abstractions).</p>

Study Name	Brief description	Date	Integrated Process - applicability	Comment
<p>A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment: WP11343.</p> <p>Wetland Report (RDM/WMA13/00/CON/COMP/0922)</p>	<p>The purpose of this report was to document the data, information, approaches followed and results of the Rapid Reserve Determination for the selected wetland resource units (WRUs) for the Upper Orange River project area.</p>	<p>Nov 2022</p>	<p>This wetland report addressed Steps 3 and 5 of the Reserve determination process.</p>	<p>A special groundwater-wetland study was conducted in the</p>
<p>A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment: WP11343.</p> <p>Resource Units Report (RDM/WMA13/00/CON/COMP/0422)</p>	<p>The delineation of priority groundwater resource units was based on (i) quaternary catchment boundaries, (ii) aquifer type (primary aquifer, secondary aquifer, karst aquifer), (iii) borehole yields groundwater quality, (iv) stressed catchments (catchments where the groundwater recharge is less than the sum of groundwater abstraction, groundwater contribution to baseflow and basic human needs), (v) groundwater recharge and (vi) geo-political boundaries (logistical, management and functional).</p>	<p>Feb 2022</p>	<p>This Resource Unit report forms part of Steps 1 and 2 of the integrated framework that was used for this study (DWS, 2017), with the purpose to identify the priority Resource Units (RUs) for rivers, wetlands and groundwater where higher confidence results will be available.</p>	<p>A total of 14 GRUs were identified – a combination of (i) surface water, (ii) groundwater and (iii) wetland features. Six (6) were classified as prioritised GRUs.</p> <p>The final selected RUs from an integration perspective includes the Upper Kraai River (rivers wetlands, groundwater), Upper Seekoei River (wetlands and groundwater and to a lesser extent rivers) and the Modder River (wetlands and</p>

Study Name	Brief description	Date	Integrated Process - applicability	Comment
				groundwater and water quality).
Groundwater Survey Report (JBS3)	The report covers the transboundary aquifers between South Africa, Namibia, and Botswana. Nine (9) boreholes were visited for conducting a local hydrocensus of the boreholes. Only one of the selected boreholes were situated in the RSA.	June 2022	Not relevant to this study.	The RSA borehole is situated in the Tswalu Private Game reserve, Northern Cape (Lower Vaal WMA, QC D42C)
A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment: WP11343 Groundwater Report (RDM/WMA13/00/CON/COMP/1022)	Groundwater component of a High Confidence Reserve Determination Study for the Upper Orange Catchment. Assessment of the present status of monitoring data for each Groundwater Resource Unit (GRU) to determine data availability and potential use for subsequent detailed assessments, and assessment of the Reserve, using the Groundwater Quantification and Qualitative approach – this activity will seek to establish the volume of groundwater that contributes to sustaining the EWR and BHN and to establish groundwater quality at GRU aspect to Quaternary based level. This is a necessary pre-	Feb 2024	Step 2: Status quo assessment and delineate study area into IUAs	The report was made available at the end of February 2024, and the PSP Study team is currently reviewing the data.

Study Name	Brief description	Date	Integrated Process - applicability	Comment
	requisite to determining the quantity and quality of groundwater potentially available for allocation to users and potential users.			

3.3. On-going monitoring programmes

There are ongoing monitoring programmes being undertaken, whereby data and information will be sourced from a biological perspective for this study. These include:

- **The River Eco-Status Monitoring Programme (REMP)**

DWS has an on-going River Eco-Status Monitoring Programme (REMP), a component of the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP). The REMP focuses on the monitoring of the ecological conditions in river ecosystems as it is reflected by the system drivers and biological responses (instream and riparian). Aquatic macroinvertebrates are monitored on a quarterly basis during this programme. Thus, the SASS5 data and categories will be available for the study area upon request and will be included in the Macroinvertebrate Response Assessment Index (MIRAI), as additional data for the hydrological year. This will form part of step 3: Quantify BHN and EWR and step 6: Determine RQOs of the integrated process followed.

- **Freshwater Biodiversity Information System (FBIS)**

This is an on-line platform with biotic data available (fish, macroinvertebrates, and diatom data) that will be used where relevant for the purpose of this study, to supplement the baseline data. This platform is managed by the South African National Biodiversity Institute (SANBI). <https://freshwaterbiodiversity.org/> accessed on (15 February 2024). This will form part of step 3 and step 6 of the integrated process.

- **SANParks routine monitoring**

SANParks conducts routine monitoring at locations within the Golden Gate Highlands National Park and Mokala National Park, from a water quality and aquatic macroinvertebrate perspective. This data will be requested to supplement the data required for the MIRAI for the hydrological year and which also forms part of step 3 and step 6 of the integrated process.

4 INFORMATION REVIEW

4.1. RESERVE STUDIES

Several Reserve studies have been undertaken for the Upper Orange River catchment over the past two decades and are being used to inform the High Confidence Reserve study for the Upper Orange River catchment for surface water, wetlands, and groundwater in accordance with the WRCS, that was initiated in August 2021 to be completed by March 2024. The Reserves undertaken during the following studies have been included, as relevant, in the High Confidence Reserve study:

- Rapid level 3 studies undertaken pre 2005 on the main stem Caledon River and tributaries, however there is little information available for this study.
- An intermediate Environmental Flow Requirements (EFR) study undertaken for ORASECOM in 2010 which included a site on the Kraai River, two sites on the Caledon River and one site on the Orange River at Hopetown (ORASECOM, 2010). Although information available from this study was used to improve the confidence of the results of the Reserve study, additional EWR sites on an intermediate and rapid levels were selected to provide a more comprehensive assessment of the EWRs.
- A rapid level III Reserve undertaken at four EWR sites for the Modder/ Riet system has been included in the current high confidence Reserve study and additional surveys were undertaken to provide ecological input for the management of this highly regulated system.
- A high confidence study undertaken at four sites on the Seekoei River from 2006 to 2010. Available information was used to enhance the confidence in the final Reserve of the Seekoei River (Seaman et al., 2009).
- A comprehensive site selected on the lower reaches of the Riet River (originally part of the Modder/Riet study) as part of the Vaal comprehensive Reserve study in 2006 to 2010 (DWA, 2010a, DWA, 2010b).
- Ad hoc rapid level 3 studies for water resource developments, including tributaries of the Karringmelkspruit and Wilgespruit in D12E and D13K; and on the main stem Caledon River in D22D.

The outputs from the current Reserve study will therefore be used in the classification of the water resources and the determination of RQOs. The EWR sites included in the Reserve study are set out in

Table 4 and illustrated in Figure 3 and are comprised of:

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

Table 4: Ecological Water Requirements (EWR) sites

RU	EWR site code	River	Quaternary catchment	Co-ordinates	
INTERMEDIATE EWR SITES					
R_RU04	UO_EWR01_I	Middle Caledon	D22D	-28.909102	27.784924
R_RU01	UO_EWR02_I	Sterkspruit	D12B	-30.51784446	27.3690799
R_RU02a	UO_EWR03_I	Upper Orange	D12F	-30.65288889	26.8230496
R_RU05	UO_EWR04_I	Lower Caledon	D24J	-30.28011493	26.6530603
R_RU06	UO_EWR05_I	Seekoei	D32J	-30.53390069	24.9625368
R_RU08	UO_EWR06_I	Upper Riet	C51F	-29.53478727	25.5244957
R_RU09a	UO_EWR07_I	Upper Modder (Sannaspos)	C52G	-29.160017	26.572492
R_RU03	UO_EWR08_I	Lower Kraai	D13M	-30.69007	26.74157
R_RU10	UO_EWR09_I	Lower Riet	C51L	-29.026963	24.512919
R_RU07	UO_EWR10_I	Lower Orange	D33K	-29.1448547	23.6914039
RAPID 3 EWR SITES					
R_RU13	UO_EWR01_R	Little Caledon	D21D	-28.557796	28.405709
R_RU14	UO_EWR02_R	Brandwater (Groot)	D21G	-28.68034	28.139926
R_RU16	UO_EWR03_R	Mopeli	D22G	-29.101205	27.570751
R_RU11a	UO_EWR04_R	Upper Kraai	D13E	-30.85179	27.77689
R_RU12	UO_EWR05_R	Wonderboomspruit	D14E	-31.005262	26.341938
R_RU09b	UO_EWR06_R	Middle Modder (Soetdoring)	C52H	-28.807191	26.109695
FIELD VERIFICATION SITES (only diatoms, <i>in situ</i> water quality and IHI)					
R_RU04	UO_EWR01_FV	Middle Caledon	D23A	-29.368925	27.405189
R_RU30	UO_EWR02_FV	Meulspruit	D22B	-28.885731	27.834944
R_RU31	UO_EWR03_FV	Witspruit	D24C	-30.00826	26.928315
R_RU22	UO_EWR04_FV	Gryskopspruit	D12D	-30.339629	27.176878
R_RU26	UO_EWR05_FV	Karringmelk-spruit	D13K	-30.811765	27.264973
R_RU23	UO_EWR06_FV	Bokspruit	D13A	-30.88469	27.884557
R_RU27	UO_EWR07_FV	Holspruit	D13J	-30.995316	27.056639
R_RU11b	UO_EWR08_FV	Sterkspruit (tributary of Bell/ Kraai)	D13C	-30.917621	27.800753
R_RU11c	UO_EWR09_FV	Bell	D13B	-30.852601	27.786557
R_RU32a	UO_EWR10_FV	Groenspruit	D24H	-30.24119	26.5613
R_RU32b	UO_EWR11_FV	Skulpspruit	D24H	-30.23444	26.51134
R_RU18	UO_EWR12_FV	Fouriespruit	C51A	-29.671211	26.074393
R_RU37	UO_EWR13_FV	Renoster	C52F	-29.11632	26.328701
R_RU21	UO_EWR14_FV	Osspruit	C52E	-28.93917	26.511411
R_RU33	UO_EWR15_FV	Hondeblaf	C31C	-30.205138	24.71803
R_RU40	UO_EWR16_FV	Tributary van Zyl	C51G	-30.031203	25.786463
-	UO_EWR17_FV*	Slykspruit	D24L	tbc	tbc

RU	EWR site code	River	Quaternary catchment	Co-ordinates	
R_RU11d	UO_EWR18_FV	Langkloofspruit	D13D	-30.954126	27.606129
R_RU25	UO_EWR19_FV	Wasbankspruit	D13G	-31.15554	27.284442
R_RU39	UO_EWR20_FV	Lower Modder	C52K	-28.89166	25.656445
R_RU19a	UO_EWR21_FV	Upper Kromellenboog	C51G	-30.066282	25.681056
R_RU19b	UO_EWR22_FV	Lower Kromellenboog	C51H	-29.6536	25.43507
R_RU41	UO_EWR23_FV	Tele	D18K	-30.448588	27.582337
R_RU02b	UO_EWR24_FV	Orange	D12A	-30.398757	27.342987
R_RU42	UP_EWR25_FV	Maghaleng	D15H	-30.16412	27.398251

*tbc – to be confirmed as part of the status quo assessment

4.1.1. Scenarios from the Reserve study

As part of the Reserve study, management scenarios were identified using mainly the Reconciliation Strategy developed by DWS in 2014 for the Orange River as well as the IWRMP developed through ORASECOM. Additional scenarios, specifically relevant to the ecological function or well-being of the water resources, e.g., the operation of releases from the larger dams identified for this classification study, will be considered. These selected scenarios include proposed dams, as identified in the Reconciliation Strategy and which were used to guide the selection of EWR sites on downstream river reaches.

This enabled the assessment of the ecological consequences of altered flows from the dams and to optimise releases from the dams. The final set of selected scenarios for the evaluation of ecological consequences have recently been modelled using the existing Water Resources Yield Model (WRYM) configuration as used in the 2019 study that was undertaken to prepare a strategy and plan for climate resilient water resources in the basin. The scenarios identified as part of the Reserve study are listed in Table 5.

Table 5: Scenarios identified as part of the Reserve study

Number	Code	Description
Sc1	PRS1	Present day without EWR
Sc2	PRS2	Present day with EWR for REC
Sc3	FUT1	2040 Polihali, Makhaleng Dam and pipeline from dam to Botswana, Pipeline from Gariep to Bloemfontein, Caledon weirs without EWR
Sc4	FUT2	2040 Polihali, Makhaleng Dam and pipeline from dam to Botswana, Pipeline from Gariep to Bloemfontein, Caledon weirs with EWR=REC, estuarine requirements
Sc5	FUT3	2060 Polihali, Makhaleng Dam and pipeline, Pipeline from Gariep, Caledon weirs, Verbeedingskraal on upper Orange, Vioolsdrift on lower Orange, without EWR

Number	Code	Description
Sc6	FUT4	2060 Polihali, Makhaleng Dam and pipeline, Pipeline from Gariep, Caledon weirs, Verbeeldingskraal on upper Orange, Vioolsdrift on lower Orange, with EWR=REC, estuarine
Sc7	WQ	Present day with EWR for REC (Sc2) with progressive water quality decline

The results of the various socio-economic and ecological consequences of the proposed scenarios are complete. It will be these scenarios that will be further evaluated and assessed for the purpose of this classification study.

4.1.2. Flow Management Plan from the Reserve study

The EWR Quantification Report, Report No: RDM/WMA13/00/CON/COMP/1323 from the Upper Orange Reserve determination study examined the ecological repercussions of the Gariep and Vanderkloof Dams, the principal structures impacting the main stem of the Orange River from a conceptual Flow Management Plan (FMP) perspective, rather than quantifying the EWRs.

In the Upper Orange catchment, the establishment of the Gariep and Vanderkloof dams opened in 1971 and 1977 respectively and covering areas of 352 km² and 133.4 km² respectively, have been the largest driver of change over the last century. The dams were founded as reservoirs for a multitude of uses, including domestic and industrial supply. However, the primary purpose of both is to supply water for hydroelectric power generation and for agricultural use via irrigation (ORASECOM, 2022).

The report highlights that for a river to function in a healthy state it requires a range of flows from extreme low/drought flows to extreme floods covering the full spectrum of volumes of flow with specific magnitudes, frequencies, durations, and timing that are comparable to the natural situation. Impoundments alter the flow and flooding regime of river systems through controlled release rates, overflow, and release for hydro-electric schemes. As a result, though the establishment of large dams has a range of effects on a river system, including barriers to migration and fragmentation of habitat, nutrient loading, trapping sediment, flooding riparian habitat, biodiversity reduction and facilitating invasion by alien species, the primary driver of most of the impacts is the alterations to flow (Choi et al. , 2005; Poff & Hart, 2002; Wang et al. , 2019; Wu et al. , 2019). This is especially the case when the dam releases are associated with hydroelectric power generation (Botelho et al., 2017; Manyari & de Carvalho Jr, 2007), as is the case in the Upper Orange River catchment at the Gariep and Vanderkloof dams.

The main objective of the conceptual FMP was to assess the immediate action plan and understand the significant ecological impacts arising from hydropeaking activities in the sacrificial zones, situated between the dams and immediately downstream of the Vanderkloof Dam. This assessment considered changes in flood frequencies as well as constant flows and higher than natural flows during the dry season. The goal was to provide guidance to the DWS regarding the optimal conditions necessary to achieve a more favourable ecological state within the system

using the biological information from the JBS3 surveys. This classification study will continue the process of this conceptual FMP, providing further guidance regarding appropriate baseflow types and the structure of releases required to enhance the ecological well-being of the ecosystem going forward.

In addition to this analysis, the report includes an exploration focused on devising the conceptual FMP that outlines proposed action plans, encompassing immediate measures and short-term strategies (spanning 0 to 5 years), which will be integrated into this classification study.

Furthermore, the report addresses medium-term plans (covering 5 to 20 years) and long-term strategies (extending beyond 20 years). These plans will undergo re-evaluation and reassessment as part of this classification study. The strategies are summarised in Table 6.

Table 6: Description of actions to be undertaken for the Flow Management Plan

Timeframes	Description of actions to be undertaken
Short-term (0 – 5 years)	<ul style="list-style-type: none"> • No changes to flow, given that no changes to the current flow regime are possible as a result of the current demand for electricity. • Conducting any emergency interventions identified in immediate assessment of the catchment. • Analysis of the impacts of the dams from a social and environmental perspective will include assessment of historical data, especially any data from prior to construction, to aid in identifying the impacts dam-related flow changes have had. • The overall synthesis of previous assessments, this current high confidence Reserve study, the balance between the social and environmental needs must be considered in defining the goals. <i>All of these can be accomplished through the water resource classification study, where specific scenarios will be identified to be assessed to inform the ultimate Water Resource Class and management of the system.</i> • Use the information from the assessments to design a monitoring network that will involve assessment of physical, chemical, and biological aspects, as well as hydraulic and hydrological assessment of the river for the determination of EWRs. <i>This conceptual plan should be converted into a quantitative plan during the Classification process of the Upper Orange River.</i> Between the desktop assessments and foundation of monitoring, a detailed, informed, longitudinal profile of dam flow impacts can be developed. This will serve to identify zones of impact and allow delineation of sacrificial zones, as well as models of how flow changes will affect different regions downstream; and • Working with Eskom, DWS Planning and Regional officials to define the plans for the planned, necessary power generation regime and establishing the necessary flow requirements for planned releases for irrigation, domestic/ industrial and estuarine requirements downstream of the dams over the next 20 years. All EWR recommendations will necessarily be compromises between ecological requirements and the requirements for power generation and irrigation (as the major drivers of flow requirements from the dams).

Timeframes	Description of actions to be undertaken
<p>Medium-term (5 – 20 years)</p>	<ul style="list-style-type: none"> • Continuation of the active physical, chemical, and biological monitoring. • Research and synthesis of the literature to develop best practice flow management protocols below large dams based on international standards and practices. • Based on monitoring and hydraulic and hydrological assessments, develop hydrological models to simulate environmental outcomes of various flow change scenarios. • Based on best practice research, EWR model scenarios, and the cost-versus-benefit analysis, establish an ideal interim flow management plan. The plan will then need to factor in what flow regime changes are possible based on Eskom's capacity and potential compromises on downstream irrigation and other needs, as well as the overall operation of the system with the planned Vioolsdrift Dam in the lower reaches of the Orange River. Ultimately, an interim flow management plan accounting for what is possible can be implemented. Some changes to flow may be possible. • Once the interim EWR recommendations are developed and implemented, ongoing monitoring will allow for analysis of efficacy and adaptive management. Re-evaluation of the ecological potential for possible improvements in the sacrificial zones. Over the course of the medium-term implementation and monitoring, assess whether the sacrificial zones have any viable remediation or re-purposing options; and • Based on best practice, EWR modelling, the cost-versus-benefit analysis, monitoring the efficacy of the interim EWR implementation, and the potential for changes to the flow regime, an ideal, long-term scenario should be designed.
<p>Long-term (>20 years)</p>	<ul style="list-style-type: none"> • The priority in the long-term is implementation of the ideal scenario recommended flow management plan. By doing so, restoration of the entire reach can begin. This will aim to minimise or completely negate the need for any sacrificial zones. • Continue monitoring for adaptive management. The monitoring framework will need to be most intensive (i.e., covering the most parameters at the highest spatial and temporal resolution) over the short-term. However, it can be refined to monitoring priority indicator activities at reduced frequency over the course of the medium-term. Over the medium-term, the monitoring framework will need continual analysis and adjustment to find a balance between the ideal spatial and temporal resolution for sampling, the best (i.e., most representative, or necessary) suite of parameters to be measured, and the available budget. Ultimately, in the long-term, monitoring will be refined to an efficient, reduced protocol of the key target metrics that are representative of the success of the EWR implementation. It is highly likely that pressures and drivers on the system will shift and change over time, especially considering rapid climate change. Therefore, ongoing monitoring will be essential to continually keep track of the state of the system and the need for interventions; and • Retroactively reassess the accuracy of the initial cost-versus-benefit analysis for the interim EWR strategy. This will inform a renewed cost-versus-benefit analysis for the long-term implementation of the ideal scenario.

4.1.3. Biophysical Nodes

The resource units defined as part of the Reserve Study for the Upper Orange River tributaries, are represented by the assessments undertaken for the priority river RUs included desktop, rapid 3 and intermediate level of detail. For selected RUs with a high Ecological Importance and Sensitivity and still in a good present state, with no or little water use or where water quality impacts from wastewater treatment works (WWTW), field verification assessments were undertaken to provide additional confidence in the desktop Ecological Water Requirements. Overall, a total of 39 priority RUs for rivers were selected, as described in DWS Report Number: RDM/WMA13/00/CON/COMP/0422, and will support the classification process and RQOs determination:

- 10 Intermediate
- 6 Rapid III; and
- 25 field verification assessments.

4.1.4. ORASECOM Environmental Flow Requirements

As part of the Phase III ORASECOM basin wide integrated resources management plan study (ORASECOM, 2014), the environmental flow requirements were determined at 8 different sites along the Orange River and major tributaries.

A study is currently in progress to update the E-Flow sites, which include ecological (E) and associated hydrological (H) sites. This project is still in the early phases and will be included as appropriate as the study progresses and the PSP responsible for undertaking the project will be included on the stakeholder database. The sites set out in Table 7 may have relevance for this project.

Table 7: Proposed E-Flows sites for transboundary project

Site ID	Quaternary catchment	Co-ordinates	Site in relation to DWS weirs	Notes
TBCR4-H1	D23E	-29.61444° S 7.06517° E	Wilgerdraai at D2H022	Approximately mid-way between UO_EWR01_I and UO_EWR04_I
TBCR4-E1	D23F	-29.6651° S 27.0205° E	Bolikela	Approximately 15km downstream of D2H022
TBOR2-H3	D14A	-30.67721°S 26.70639°E	Aliwal North at D1H003	Approximately 12km downstream of UO_EWR03_I, and 4km D/s of the confluence with the Kraai River
TBOR2-H2	D32J	-30.534598°S 24.962768°E	De Eerstespoort at D3H015	=UO_EWR05_I
TBOR2-E4	D13B	-30.8306°S 26.92056° E		At site EFR K7; approximately 25km upstream of UO_EWR04_R
TBOR2-E2	D32J	-30.53390° S 24.96253° E		=UO_EWR05_I
TBOR2-H4	D13L	-30.830406°S 26.921010°E	Roodewal at D1H011	Approximately 30km upstream of UO_EWR08_I, and 100km

Site ID	Quaternary catchment	Co-ordinates	Site in relation to DWS weirs	Notes
				downstream of UO_EWR04_R on the Upper Kraai River
TBOR2-H1	D33K	-29.1552° S 23.71948° E	Marksdrift at D3H008	=UO_EWR10_I
TBOR2-E1	D33D	-29.5713° S 24.0731° E	Near Hopetown	Approximately 50km upstream of the site EFR 01 at Hopetown in D33G
TBOR2-H5	D14B	-31.42225° S 26.35345° E	Molteno at D1H10	At outlet of quaternary catchment in upper reaches of the Stormbergspruit
TBMR5-H1	D15G	30.16444° S 27.39578° E	Kornetspruit at Maghaleen at D1H006	=UP_EWR25_FV
TBSR6-H1	D12A	30.33527° S 27.35458° E	AT D1H009	Approximately 12 km upstream of UO_EWR24_FV

4.1.5. Conclusions to the EWR information review

The following can be summarised in terms of the information review for the EWR sites:

- i. The results of the high confidence Reserve study are considered adequate for the information requirements of this study, however the aspects related to the Flow Management Plan and the proposed EWR sites will be further assessed and taken forward as part of the classification study.
- ii. Depending on the final IUA delineation and selected priority RUs, additional EWR sites might be identified. The relevant information to quantify the EWRs for these will be a combination of extrapolation using information from EWR sites in the same ecoregion level 2 and geomorphic zones and biological data from JBS3 and REMP surveys. Where no biological information is available, field surveys will be undertaken.
- iii. Most of the mainstem Orange River and major tributaries have been assessed on an Intermediate or Rapid III level. However, no new biological information (surveys pre-2011) is available for the upper reaches of the Caledon River before the confluence with the Little Caledon River and depending on the IUA delineation, surveys might be required.
- iv. For some of the smaller tributaries where only field verifications were undertaken, a Rapid III level assessment will be required, especially for tributaries of the Kraai River in D13 and Riet River in C51. Surveys to be undertaken as part of the updating of the 2011-14 desktop PES/EIS database might also infill some of these gaps.
- v. The Intermediate EWR site (EWR10_I) on the lower reaches of the Orange River near Marksdrift weir, will require further hydraulic data. During the Reserve study, only a single hydraulic measurement could be undertaken, hampering the confidence at this site. Owing to floods and high velocities, the site could not be accessed during other survey opportunities.

Figure 3 illustrates the locations of the EWR sites for the high confidence Reserve study and Figure 4 illustrates the levels of assessment of the priority river resource units prioritised for the Reserve study (DWS, 2022).

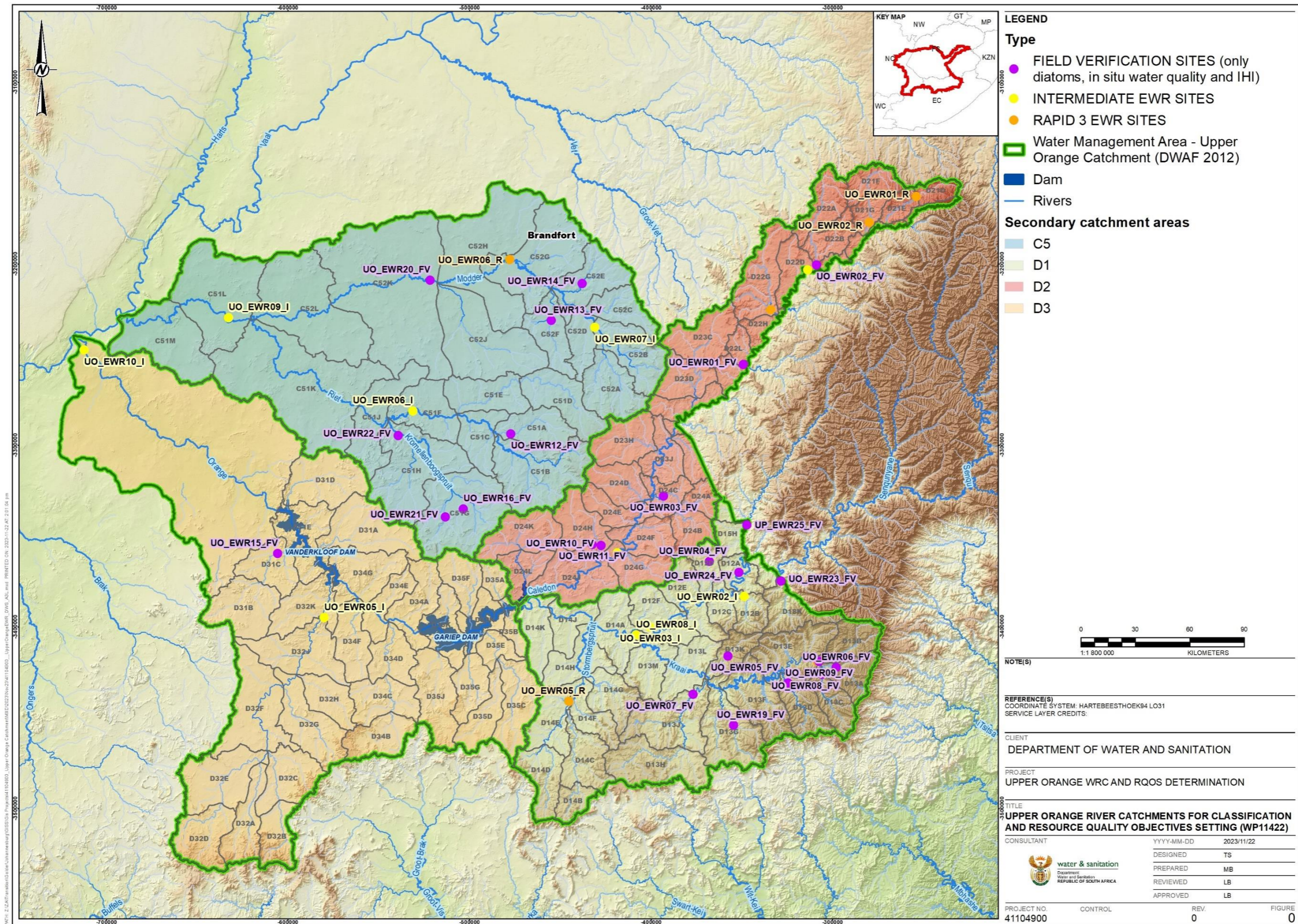


Figure 3: Upper Orange River EWR sites (Source: DWS, 2022)

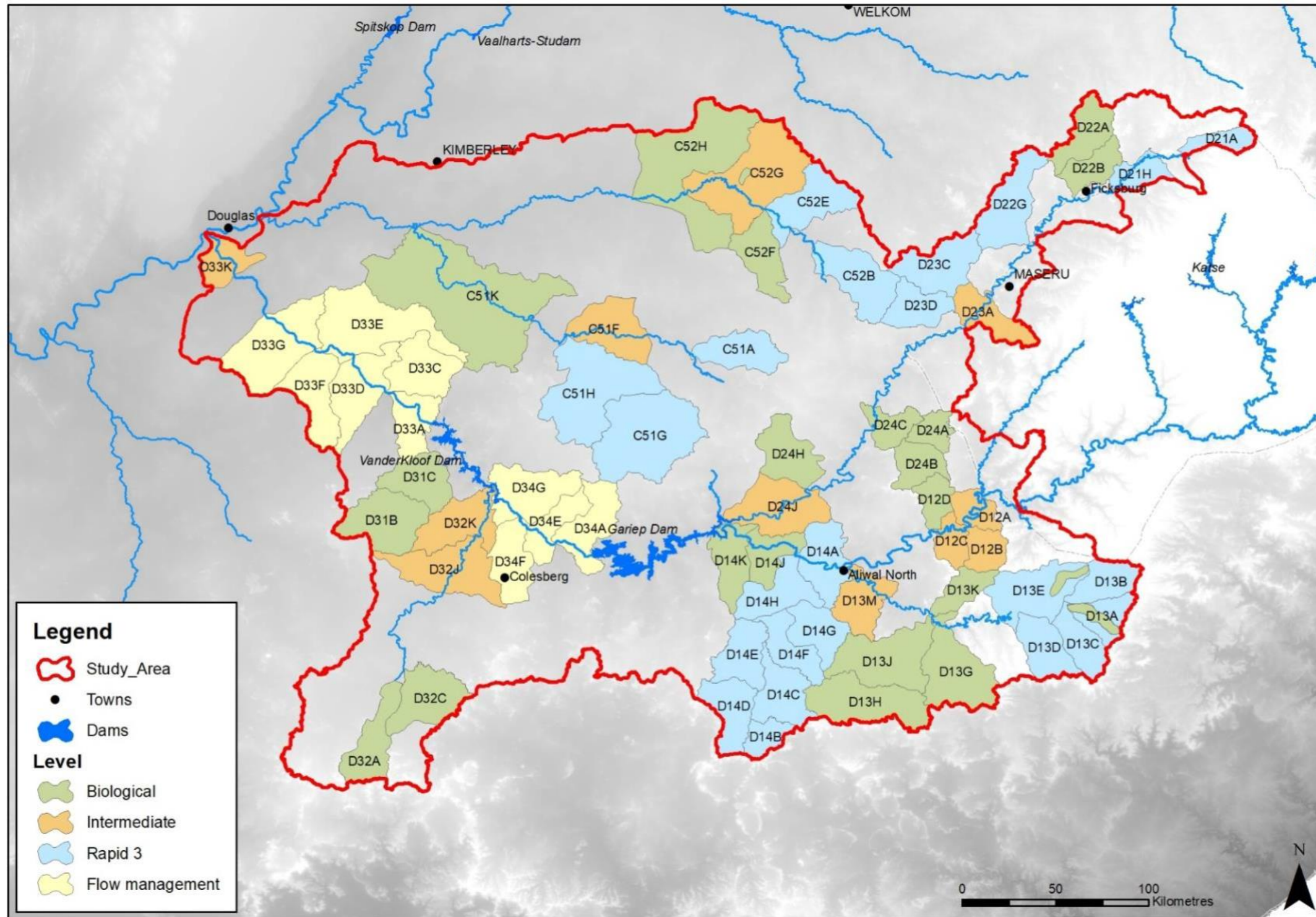


Figure 4: Map indicating the levels of assessment of the priority river RUs (Source: DWS, 2022)

4.2. BIOLOGICAL DATA

4.2.1. 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). Subsequent to 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 catchment particularly with regards to water quality (including diatoms), fish, macroinvertebrates, and riparian vegetation.

The JBS3 sites for the Upper Orange River catchment are listed in Table 8.

Table 8: JBS3 monitoring sites (ORASECOM, 2023)

Code	River	Latitude	Longitude
OSAEH_11_18	Modder	-29.16067	26.57225
OSAEH_11_19	Modder	-28.80722	26.10694
OSAEH_26_10	Riet	-29.57527	25.70805
OSAEH_29_5	Riet	-29.02696	24.51292
OSAEH_15_1	Caledon	-28.72313	28.15575
OSAEH_15_6	Caledon	-29.37106	27.40529
OSAEH_11_20	Leeuspruit	-29.51769	27.12968
OSAEH_15_2	Matsuko	-29.2341	28.56182
OSAEH_15_3	Senqu	-30.06558	28.40896
OSAEH_15_5	Senqunyane	-30.02106	28.18295
OSAEH_11_22	Orange	-30.50472	27.21398
OSAEH_26_11	Kraai	-30.69007	26.74157
OSAEH_26_13	Stormbergsspruit	-30.65017	26.46516
OSAEH_26_14	Orange	-30.57142	26.45166
OSAEH_26_8	Caledon	-30.42757	26.30501

Code	River	Latitude	Longitude
OSAEH_26_15	Orange	-30.50378	25.24003
OSAEH_26_12	Seekoei	-30.37358	25.00095
OSAEH_26_2	Orange	-29.64357	24.21554
OSAEH_26_3	Orange	-29.14207	23.69191

4.2.2. River Ecostatus Monitoring Programme (REMP)

The DWS conducts a quarterly routine monitoring program known as River Ecostatus Monitoring Programme (REMP), 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 9.

Most REMP sites are monitored, unless affected by factors such as flooding, high flows, dry conditions, or access constraints. When the time comes, the most recent data from the last hydrological year will be extracted from the REMP site MIRAI, which will be requested from DWS regional offices, to supplement the data for this study.

Table 9: DWS REMP sites within the Upper Orange River catchment

DWS REMP Site	River	Latitude	Longitude	Ecoregion	Geozone
Secondary Catchment C5					
C5KORA-MOCKU	Korannaspruit	-29.08584	26.633841	11.03	E
C5MODD-MODDE	Modder	-29.028882	24.638277	29.02	F
C5MODD-SANNA	Modder	-29.16111	26.57194	11.03	E
C5MODD-SOETD	Modder	-28.80722	26.10694	11.08	F
C5RIET-DEKRA	Riet	-29.02778	24.51306	29.02	E
C5RIET-IFR03	Riet	-29.57528	25.70805	26.01	E
C5RIET-LILYD	Riet	-29.02696	24.51292	29.02	E
C5RIET-JACOB	Riet	-29.09972	24.69889	29.02	F
C5RIET-RICHI	Riet	-29.044898	24.587063	29.02	F
C5VANZ-DWNWR	VanZylspruit	-30.1108306	25.8497194	26.03	E
Secondary catchment D1					
D1KRAA-ALIWA	Kraai	-30.69007	26.74157	26.03	F
Secondary catchment D2					
D2CALE-EWR03	Caledon	-28.7225	28.1509	15.01	F
D2CALE-LADYB	Caledon	-29.395	27.422	15.01	F
D2GROO-FARM1	Brandwater	-28.68056	28.13972	15.01	E
D2LCAL-WILGE	Little Caledon	-28.50154	28.58132	15.03	D

DWS REMP Site	River	Latitude	Longitude	Ecoregion	Geozone
D2LCAL-EWR01	Little Caledon	-28.52694	28.48306	15.03	E
D2LCAL-EWR02	Little Caledon	-28.611389	28.30194	15.01	E
D2LEEU-EWR06	Leeu	-29.52167	27.13583	11.03	E
D2GLEN-GLENR	Glen Reenen	-28.50758	28.61612	15.03	C
D2RIBB-RIBBO	Ribbok Spruit	-28.618083	28.583678	15.03	C
D2RIBB-UWWTW	Ribbok Spruit	-28.50952	28.58344	15.03	D
D2RIBB-DWWTW	Ribbok Spruit	28.50853	28.58273	15.03	D
Secondary catchment D3					
D3ORAN-HOPET	Orange	-29.6	24.08778	26.01	F
D3ORAN-MARKS	Orange	-29.141709	23.692039	26.01	F

It must be noted in relation to the REMP monitoring, that during the macroinvertebrate assessments, in situ water quality parameters must be recorded and added to the data base (standard protocol). Apart from the IHI assessment during the survey, some notes and comments on the sites condition and catchment condition must be added to the reports. At the very least upstream and downstream photographs must be included and where possible, some photographs of impacts on or near the site (e.g. sand mining, erosion, removal of natural vegetation on the riverbanks or nearby large-scale activities e.g. mining, cultivation or houses near the rivers.

Furthermore, fish surveys must be conducted every three years (ideal time gap). It is recommended that the sites are monitored on a rotational basis (i.e. a few every year) to ensure the load is distributed. In a large river such as the Orange River, electro fishing is not sufficient to record all species in the system. The larger rheophilic species keep to deeper pools which are neglected, as it takes more time to survey. For the Orange River it is recommended that the fish surveys must include in addition to the electro fishing, cast nets, seine nets and fyke nets must be employed during the surveys.

It will be important to follow the protocol to effectively monitor the fish populations and community diversity. This will entail sampling more than one biotope (i.e. multiple pools, rapids, riffles) to ensure that “species is achieved. It is important that fyke nets are set overnight to ensure effective sampling with the nets. The approach that must be follow the “species saturation curve” to sample until no new species is collected.

4.2.3. Corresponding biological sites throughout the Upper Orange catchment

Several sites identified in the JBS3 (Table 8), Upper Orange Reserve determination study (Table 4), and the DWS REMP sites (Table 9) overlap, resulting in a substantial dataset of biological data. These overlapping sites are listed in Table 10.

Table 10: Corresponding JBS3, Upper Orange Reserve determination study and the DWS REMP 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

4.2.4. FBIS

Both aquatic macroinvertebrate and fish data is further continuously being added to the FBIS which will be retrieved for the purpose of this study. Refer to Table xx for all macroinvertebrate- and fish related data extracted from FBIS. The FBIS data for fish will be taken from the site or nearby sites, briefly described in Table 11 (within the ecoregion) to ensure the list of expected species is as comprehensive as possible. This additional dataset will complement the information already obtained and to be collected from the field surveys, coupled with data from the JBS3, Reserve study and continued REMP.

Table 11: FBIS data for macroinvertebrates

FBIS Sites	River	Latitude	Longitude
Secondary Catchment C5			
C5RENO-BISHO	Renosterspruit	-28.96667	26.31917
C5KMOD-BOTSH	Klein Modder River	-29.25389	26.65583
C5MODD-CONFL	Modder River	-29.02833	24.63833
C5MODD-PERD2	Modder River	-28.99306	25.08056
C5BOKR-RUSTF	Wildehyndespruit	-29.37417	26.57083
C5TIER-TIERP	Meyerspruit	-29.50389	25.94722
C5KORA-MOCK2	Korannaspruit	-29.08083	26.59139
C5KORA-MOCKE	Korannaspruit	-29.08028	26.59333

FBIS Sites	River	Latitude	Longitude
C5SEPA-SEPAN	Sepane River	-29.16306	26.59528
C5KROM-CRIET	Kromellenboogspruit	-29.65361	25.435
C5FOUR-KALKF	Fouriespruit	-29.66944	26.07239
C5RIET-EWR09	Vanzylspruit	-30.11083	25.84972
C5GANN-CMODD	Gannaspruit	-29.45444	26.73472
C5RIET-KOFFI	Riet River	-29.41944	24.90861
C5VAAL-EUR18	Riet River	-29.02723	24.51294
C5KLEI-BOTSH	Klein Modder River	-29.25	26.6575
C5RENO-BLOEM	Renosterspruit	-28.96694	26.33222
C5MODD-GLENS	Modder River	-28.84917	26.18667
C5RIET-IFR01	Riet River	-29.02778	24.51306
C5SEPA-THABA	Sepane River	-29.16333	26.59503
C5MODD-DEWET	Karreefonteinspruit	-29.59028	26.70694
C5MODD-KRUGE	Modder River	-28.88667	25.95528
C5OSSP-MOCKE	Osspruit	-28.97639	26.47
Secondary catchment D1			
None			
Secondary catchment D2			
D2CALE-EWR03	Caledon River	-28.7222	28.15083
D2CALE-JIMFO	Caledon River	-29.7108	26.98583
D2GROO-FARM1	Grootspruit	-28.6806	28.13972
D2LCAL-EWR01	Little Caledon River	-28.5269	28.48306
D2LEEU-EWR06	Leeu River	-29.5217	27.13583
D2CALE-LADYB	Caledon River	-29.395	27.422
D2LCAL-WILGE	Little Caledon River	-28.50154	28.58132

FBIS Sites	River	Latitude	Longitude
D2LCAL-EWR02	Little Caledon River	-28.611389	28.30194
D2GLEN-GLENR	Glen Reenen River	-28.50758	28.61612
D2RIBB-RIBBO	Ribbokspruit	-28.618083	28.58368
D2RIBB-UWWTW	Ribbokspruit	-28.50952	28.58344
D2RIBB-DWWTW	Ribbokspruit	28.50853	28.58273
Secondary catchment D3			
D3ORAN-VANDE	Orange River	-29.5764	24.07417

4.3. WATER QUALITY

The Department’s Resource Quality Information Services (RIQS) water quality database, which includes the following national monitoring programmes data, will be used as the primary source of the water quality data for the analysis.

- National Chemical Monitoring Programme (NCMP)
- National Eutrophication Monitoring Programme (NEMP), and
- National Microbiological Monitoring Programme (NMMP)

This will be supplemented by the JBS3 data, and other sources such as the Green Drop Reports and ORASECOM studies.

In terms of water quality data assessment, the water quality monitoring stations and related information are largely concentrated on main stem rivers and tributaries. Data gaps potentially exist for the smaller tributary catchments which are identified as high PES and ecological importance and sensitivity. There may therefore be gaps in that monitoring points may not be in prioritised RUs and the adequacy and reliability of data might be a gap.

Water user requirements and water quality impacts are key in understanding the extent of impacted areas and for the development of RQOs and numerical limits. Lack of recent monitoring information to assess baseline in smaller catchments is therefore a gap.

The water quality in the Orange River catchment is highly variable due to a combination of natural factors such as rainfall, evaporation, geology and soils, and anthropogenic factors which cause man-made changes to the chemistry of the rivers in the basin.

The main threats to water quality in the Orange River have been identified as altered flow regime, with the Upper Orange River catchment being highly altered, including reduced flow from Lesotho due to the Lesotho Highlands Water Project (LHWP), the Welbedacht and Knellpoort dams in the Caledon catchment, and the Gariiep and Vanderkloof dams on the Orange River; nutrient

enrichment; increased salinity from irrigation return flows in the lower reaches below Vanderkloof Dam and the Modder/ Riet river catchments; microbial contamination from urban settlements and poorly operated wastewater treatment works, and elevated sediment in the system.

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 CaCO₃, ammonium as N, nitrate + nitrite as N, chemical oxygen demand (COD), and *Escherichia coli*. No trace metal or organic analysis is performed as part of this routine monitoring. For the purposes of this study, the certain indicator variables will be used to assess status quo and for RQO determination.

The monitoring points of the NCMP and data available through the NEMP within the Upper Orange River catchment are located at sites set out in Table 12 and illustrated in Figure 5 in relation to the EWR sites. Data for canals and pipelines will be assessed as it may give an indication of the water quality for specific rivers where no other water quality monitoring sites are available.

The map also highlights the WWTW sites which are all water quality hot spots. The latest Green Drop Status Reports for the Free State and Eastern Cape (DWS, 2021) will be used to in this respect.

Further monitoring sites, such as those for the National Microbiological Monitoring Programme (NMMP), and associated data will be sourced as the project progresses and mapped accordingly.

Table 12: Water quality monitoring sites and data availability for rivers, dams, canals and pipelines

Station ID	Tertiary Drainage	Latitude	Longitude	Monitoring Active	Total Number of Samples	Start Date	End Date	Comments
Rivers								
D3H015Q01	D32	-30.534167	24.961944	Yes	1267	1981/02/04	2024/01/19	Good data availability
D3H013Q01	D34	-30.583889	25.419722	Yes	3503	1976/09/30	2024/01/19	Good data availability
D1H011Q01	D13	-30.830556	26.921389	Yes	2032	1967/02/13	2024/01/18	Good data availability
D1H003Q01	D14	-30.679722	26.7125	Yes	3058	1968/06/14	2024/01/18	Good data availability
D1H009Q01	D12	-30.336111	27.359444	Yes	2534	1963/03/12	2024/01/17	Good data availability
D1H006Q01	D15	-30.160091	27.40124	Yes	2579	1975/05/27	2024/01/17	Good data availability
D2H022Q01	D23	-29.615556	27.065278	Yes	432	1988/11/06	2024/01/17	Moderate data availability
D2H037Q01	D23	-29.609167	27.065556	Yes	2116	1995/10/31	2024/01/17	Good data availability
C5H056	C52	-29.37555556	26.66555556	Yes	431	2009/08/14	2024/01/16	Good data availability
D2H012	D21	-28.69485	28.23487	Yes	1422	1971/09/24	2024/01/16	Good data availability
D2H036Q01	D24	-30.279167	26.654167	Yes	1196	1993/05/12	2024/01/16	Good data availability
C5H022Q01	C52	-29.285556	26.921944	Yes	491	1986/06/10	2024/01/15	Moderate data availability
D2H035Q01	D22	-28.883333	27.89	Yes	1065	1994/08/09	2024/01/15	Good data availability
C5H053Q01	C52	-28.94911	26.32099	Yes	1908	1995/09/18	2024/01/08	Good data availability
C5H035Q01	C52	-29.028629	24.638389	Yes	1755	1992/11/02	2023/11/02	Good data availability
C5H016Q01	C51	-28.96	24.2425	Yes	1017	1970/06/08	2023/11/01	Good data availability
C5H048Q01	C51	-29.033333	23.983333	Yes	3404	1990/08/10	2023/11/01	Good data availability
D3H012Q01	D33	-29.991111	24.724444	Yes	1493	1971/08/11	2023/10/24	Good data availability
C5H014	C51	-29.042222	24.6	Yes	1609	1992/11/02	2023/10/05	Good data availability
D1H001Q01	D14	-31.000833	26.353056	Yes	1917	1967/02/13	2023/07/06	Good data availability
C5H012Q01	C51	-29.658056	25.973333	Yes	655	1975/12/21	2023/06/09	Good data availability
C5H007Q01	C52	-29.144444	26.318056	Yes	2074	1972/06/13	2023/06/09	Good data availability
C5H039Q01	C52	-28.883333	25.950278	Yes	2598	1979/08/21	2023/06/09	Good data availability
C5H003Q01	C52	-29.160278	26.573333	Yes	2391	1987/08/26	2023/06/05	Good data availability
C5H054Q01	C52	-28.966667	26.333056	Yes	1586	1995/09/25	2023/06/05	Good data availability
88779	C51	-29.14113889	24.76891667	Yes	178	1994/03/02	2023/05/08	Good data availability
189015	C52	-28.9555	26.33533333	Yes	173	2012/11/19	2023/05/08	Good data availability
191171	C52	-28.88531	25.95604	Yes	195	2010/05/07	2023/05/08	Good data availability
D3H008Q01	D33	-29.161667	23.696389	Yes	3957	1966/03/29	2023/04/24	Good data availability
D2H033	D24	-29.925556	26.86	No	32	2011/09/15	2022/06/22	Low data availability but fairly recent
189019	C52	-28.807	26.10925	Yes	170	2010/05/07	2021/11/18	Moderate data availability
189020	C51	-29.03775	24.62480556	Yes	158	2012/11/27	2020/02/19	Moderate data availability
189047	C51	-29.15630556	24.77291667	Yes	172	2010/02/25	2015/03/24	Data is outdated but will be used to indicate historic trends
189076	C52	-29.02594444	24.74955556	Yes	150	2012/11/27	2015/03/24	Data is outdated but will be used to indicate historic trends
189096	C51	-29.02669444	24.04269444	Yes	149	2011/09/02	2015/03/23	Data is outdated but will be used to indicate historic trends
191175	C51	-28.95341	24.40785	Yes	166	2009/08/14	2015/03/23	Data is outdated but will be used to indicate historic trends
189016	C51	-29.41269444	25.01727778	Yes	181	2009/08/14	2015/03/17	Data is outdated but will be used to indicate historic trends
189022	C51	-29.80608333	25.49594444	Yes	173	2009/08/14	2015/03/17	Data is outdated but will be used to indicate historic trends
189023	C51	-29.57594444	25.71075	Yes	177	2011/09/23	2015/03/17	Data is outdated but will be used to indicate historic trends
189026	C51	-29.70430556	25.60008333	Yes	174	2009/08/14	2015/03/17	Data is outdated but will be used to indicate historic trends
191336	D21	-28.53938	28.43126	Yes	163	2012/11/20	2015/03/16	Data is outdated but will be used to indicate historic trends
189013	C52	-29.11141667	26.31352778	Yes	163	2010/05/07	2015/03/12	Data is outdated but will be used to indicate historic trends
189017	C52	-29.24980556	26.65775	Yes	168	2012/11/19	2015/03/12	Data is outdated but will be used to indicate historic trends
189027	C52	-29.16347222	26.59508333	Yes	167	2012/11/19	2015/03/12	Data is outdated but will be used to indicate historic trends
191145	C52	-28.71008	26.44644	Yes	132	2010/05/07	2015/03/12	Data is outdated but will be used to indicate historic trends
191353	D22	-29.3021	27.45628	Yes	143	2013/03/05	2015/03/04	Data is outdated but will be used to indicate historic trends
191354	D22	-29.29445	27.46477	Yes	142	2013/03/05	2015/03/04	Data is outdated but will be used to indicate historic trends
191431	D13	-30.95484	27.6069	Yes	144	2012/07/05	2015/02/18	Data is outdated but will be used to indicate historic trends
191432	D13	-30.96641	27.61672	Yes	150	2012/07/05	2015/02/18	Data is outdated but will be used to indicate historic trends
191200	C51	-29.64058	26.15331	Yes	151	2012/11/18	2015/02/17	Data is outdated but will be used to indicate historic trends
191410	D12	-30.30014	27.11402	Yes	146	2012/11/29	2015/02/17	Data is outdated but will be used to indicate historic trends
191423	D12	-30.29904	27.10571	Yes	145	2012/11/29	2015/02/17	Data is outdated but will be used to indicate historic trends
191387	D14	-30.68769	26.6896	Yes	138	2012/07/05	2015/02/17	Data is outdated but will be used to indicate historic trends
191414	D14	-30.58707	26.3647	Yes	140	2013/03/26	2015/02/17	Data is outdated but will be used to indicate historic trends
191415	D14	-30.56677	26.41359	Yes	141	2013/03/26	2015/02/17	Data is outdated but will be used to indicate historic trends
193325	D24	-30.393196	26.83306	Yes	148	2012/11/29	2015/02/17	Data is outdated but will be used to indicate historic trends

Station ID	Tertiary Drainage	Latitude	Longitude	Monitoring Active	Total Number of Samples	Start Date	End Date	Comments
191335	D21	-28.69616	28.23884	Yes	154	2012/11/20	2015/02/12	Data is outdated but will be used to indicate historic trends
191337	D21	-28.53477	28.43936	Yes	151	2012/11/20	2015/02/12	Data is outdated but will be used to indicate historic trends
191156	C52	-28.71126	26.44713	Yes	50	2010/05/07	2015/02/05	Data is outdated but will be used to indicate historic trends
D2H039	D21	-28.69	28.23	Yes	39	2012/04/17	2014/06/11	Data is outdated but will be used to indicate historic trends
C5H018Q01	C52	-29.043333	24.640833	Yes	637	1971/05/03	2013/05/27	Data is outdated but will be used to indicate historic trends
188235	C51	-29.39455556	25.00502778	Yes	608	2005/04/08	2013/03/26	Data is outdated but will be used to indicate historic trends
182329	C52	-29.242833	26.673667	Yes	1694	2000/02/15	2013/03/26	Data is outdated but will be used to indicate historic trends
182330	C52	-29.238	26.682	No	1696	2000/02/15	2013/03/26	Data is outdated but will be used to indicate historic trends
182332	C52	-29.295333	26.715	No	1688	2000/02/15	2013/03/26	Data is outdated but will be used to indicate historic trends
188085	C52	-29.11425	26.210444	Yes	689	2004/07/14	2013/03/26	Data is outdated but will be used to indicate historic trends
188182	C52	-29.205367	26.799767	Yes	480	2004/11/02	2013/03/26	Data is outdated but will be used to indicate historic trends
187060	D22	-29.293667	27.4625	No	433	2003/02/05	2013/03/26	Data is outdated but will be used to indicate historic trends
C5H023Q01	C52	-29.286111	26.764167	Yes	282	1983/07/27	2011/08/23	Data is > 20 years old, and will not be used
D3H002Q01	D35	-30.536944	25.985833	No	379	1965/07/21	2008/12/17	Data is > 20 years old, and will not be used
C9H011Q01	C92	-29.049167	23.769722	No	77	1979/10/22	2001/05/08	Data is > 20 years old, and will not be used
C5H008Q01	C51	-29.812222	26.212222	No	37	1972/03/18	1999/02/16	Data is > 20 years old, and will not be used
D3H011Q01	D35	-30.532778	26.026111	No	31	1979/12/04	1999/02/10	Data is > 20 years old, and will not be used
D3H004Q01	D34	-30.621111	25.464444	No	181	1971/07/23	1998/11/15	Data is > 20 years old, and will not be used
C5H015Q01	C52	-28.8075	26.112222	No	172	1967/01/22	1996/07/22	Data is > 20 years old, and will not be used
C9H007Q01	C92	-29.043333	23.837222	No	130	1966/03/29	1995/05/18	Data is > 20 years old, and will not be used
D2H028Q01	D23	-29.779167	26.889444	No	84	1992/10/20	1993/11/09	Data is > 20 years old, and will not be used
D2H020Q01	D22	-29.301667	27.487778	No	155	1982/09/21	1991/03/05	Data is > 20 years old, and will not be used
D2H001Q01	D23	-29.715278	26.983333	No	341	1955/02/04	1984/10/02	Data is > 20 years old, and will not be used
D1H010Q01	D14	-31.406667	26.368333	No	169	1975/11/28	1981/03/30	Data is > 20 years old, and will not be used
D3H010Q01	D35	-30.690556	25.763611	No	43	1970/12/02	1980/05/07	Data is > 20 years old, and will not be used
D1H007Q01	D13	-30.726944	26.782778	No	268	1974/06/04	1975/07/25	Data is > 20 years old, and will not be used
Dam / Barrage								
D3R002Q01	D34	-30.623056	25.507222	Yes	3517	1971/01/08	2024/01/19	Good data availability
D3R002Q01	D34	-30.623056	25.507222	Yes	3517	1971/01/08	2024/01/19	Good data availability
D1R001Q01	D12	-30.636667	27.369167	Yes	320	1998/03/24	2024/01/17	Moderate data availability
D2R004Q01	D24	-29.908889	26.860556	Yes	1787	1975/02/22	2024/01/16	Good data availability
D2H034	D22	-28.88055556	27.835	Yes	203	2012/03/28	2024/01/15	Moderate data availability
C5R004Q01	C52	-28.883333	25.956111	Yes	1870	1975/03/10	2023/12/08	Good data availability
D2R001Q01	D24	-30.052222	27.028611	Yes	966	1975/02/22	2023/07/05	Good data availability
D2R002Q01	D23	-29.3641	27.129	Yes	949	1972/10/26	2023/07/04	Good data availability
C5R007Q01	C52	-29.050556	26.461667	Yes	1667	1987/05/22	2023/07/03	Good data availability
C5R001Q01	C51	-29.421667	26.136389	Yes	2117	1972/10/27	2023/06/09	Good data availability
C5R006Q01	C52	-29.029167	26.408333	Yes	1760	1987/03/18	2023/06/09	Good data availability
D2R006Q01	D23	-29.78129722	26.88916389	Yes	1120	1989/07/03	2023/06/06	Good data availability
C5R003Q01	C52	-29.2713	26.6161	Yes	2283	1968/05/19	2023/06/05	Good data availability
C5R005Q01	C52	-29.302778	26.848889	Yes	2171	1981/03/03	2023/06/05	Good data availability
D3R003Q01	D31	-29.991	24.7321	Yes	2300	1971/07/24	2023/05/25	Good data availability
D3R003Q01	D31	-29.991	24.7321	Yes	2300	1971/07/24	2023/05/25	Good data availability
C9R003Q01	C92	-29.043333	23.836944	Yes	4247	1977/10/03	2023/05/22	Good data availability
C9R003Q01	C92	-29.043333	23.836944	Yes	4247	1977/10/03	2023/05/22	Good data availability
189021	C52	-29.02855556	26.40661111	Yes	172	2012/11/19	2023/05/08	Moderate data availability
C5R002Q01	C51	-29.4959	25.2223	Yes	2305	1968/04/02	2018/06/21	Data is outdated but will be used to indicate historic trends
C5R002Q01	C51	-29.4959	25.2223	Yes	2305	1968/04/02	2018/06/21	Data is outdated but will be used to indicate historic trends
191170	C51	-29.49836	25.22271	Yes	161	2010/02/25	2015/03/17	Data is outdated but will be used to indicate historic trends
189024	C52	-29.26988889	26.60872222	Yes	173	2012/11/19	2015/03/12	Data is outdated but will be used to indicate historic trends
D3R002Q02	D34	-30.623056	25.507222	No	513	1974/01/28	2008/01/10	Data is outdated but will be used to indicate historic trends
D3R001Q01	D35	-30.487778	25.973889	No	252	1978/02/28	1999/07/07	Data is > 20 years old, and will not be used
D3R002Q03	D34	-30.623056	25.507222	No	555	1974/01/28	1989/09/19	Data is > 20 years old, and will not be used
Canal								
C5H055	C52	-29.62416667	26.71666667	Yes	155	2012/03/29	2024/01/16	Good data availability
C5H030Q01	C51	-29.140556	24.756667	Yes	1069	1994/04/19	2023/11/02	Good data availability
C9H017Q01	C92	-29.04533056	23.83591944	Yes	2926	1992/12/10	2023/05/22	Good data availability
C9H025Q01	C92	-29.04719444	23.83847778	Yes	2426	1995/12/13	2023/05/22	Good data availability
C9H019Q01	C92	-29.04331111	23.83224167	Yes	2923	1992/12/09	2023/04/24	Good data availability
D3H019Q01	D33	-29.1529	23.702	Yes	114	1995/02/15	2022/09/26	Good data availability

Station ID	Tertiary Drainage	Latitude	Longitude	Monitoring Active	Total Number of Samples	Start Date	End Date	Comments
D2R004K01	D24	-29.908889	26.860556	No	134	1981/09/14	2022/08/16	Good data availability
C5H040Q01	C51	-29.496944	25.221389	Yes	1581	1981/12/02	2018/06/28	Data is outdated but will be used to indicate historic trends
D3H024Q01	D33	-29.9869	24.72224	Yes	815	1979/12/12	2017/11/09	Data is outdated but will be used to indicate historic trends
189078	C51	-29.16577778	24.70519444	Yes	170	2009/08/14	2015/03/24	Data is outdated but will be used to indicate historic trends
191172	C51	-29.49307	25.1457	Yes	163	2012/11/18	2015/03/17	Data is outdated but will be used to indicate historic trends
191347	D21	-28.62669	28.19997	Yes	159	2012/11/20	2015/03/16	Data is outdated but will be used to indicate historic trends
191312	D32	-31.07186	24.46012	Yes	120	2013/06/19	2015/02/19	Data is outdated but will be used to indicate historic trends
193476	D33	-30.073624	24.665302	Yes	154	2012/11/18	2015/02/19	Data is outdated but will be used to indicate historic trends
191285	D34	-30.69847	25.12074	Yes	131	2013/06/19	2015/02/19	Data is outdated but will be used to indicate historic trends
191429	C51	-30.0265	25.79518	Yes	114	2013/07/10	2015/02/18	Data is outdated but will be used to indicate historic trends
193063	D35	-30.78416	25.78514	Yes	146	2012/07/05	2015/02/18	Data is outdated but will be used to indicate historic trends
191366	D24	-30.39423	26.83175	Yes	135	2012/11/29	2015/02/17	Data is outdated but will be used to indicate historic trends
191380	D24	-29.99008	26.99529	Yes	121	2013/06/19	2015/02/17	Data is outdated but will be used to indicate historic trends
190123	C51	-29.10665	24.6654	Yes	132	2010/10/14	2013/03/26	Data is outdated but will be used to indicate historic trends
D2H024Q01	D24	-30.052222	27.028611	No	230	1977/11/09	1993/11/09	Data is > 20 years old, and will not be used
D2H025Q01	D23	-29.363889	27.131667	No	72	1980/02/04	1993/10/11	Data is > 20 years old, and will not be used
D3H022Q01	D35	-30.626389	25.507222	No	72	1972/09/20	1977/06/08	Data is > 20 years old, and will not be used
Pipeline								
191341	D22	-28.92923	27.56787	Yes	155	2012/11/12	2015/03/04	Data is outdated but will be used to indicate historic trends if needed
191360	D22	-29.18483	27.48839	Yes	152	2012/11/12	2015/03/04	Data is outdated but will be used to indicate historic trends if needed
191330	D31	-30.43198	24.48195	Yes	148	2012/11/28	2015/02/19	Data is outdated but will be used to indicate historic trends if needed
191430	D13	-31.36464	27.03601	Yes	147	2012/11/29	2015/02/18	Data is outdated but will be used to indicate historic trends if needed
191436	D13	-30.96535	27.61313	Yes	146	2012/07/05	2015/02/18	Data is outdated but will be used to indicate historic trends if needed
191422	D14	-31.38595	26.37657	Yes	137	2013/03/19	2015/02/18	Data is outdated but will be used to indicate historic trends if needed
191334	D35	-30.27573	25.7076	Yes	120	2013/06/18	2015/02/18	Data is outdated but will be used to indicate historic trends if needed

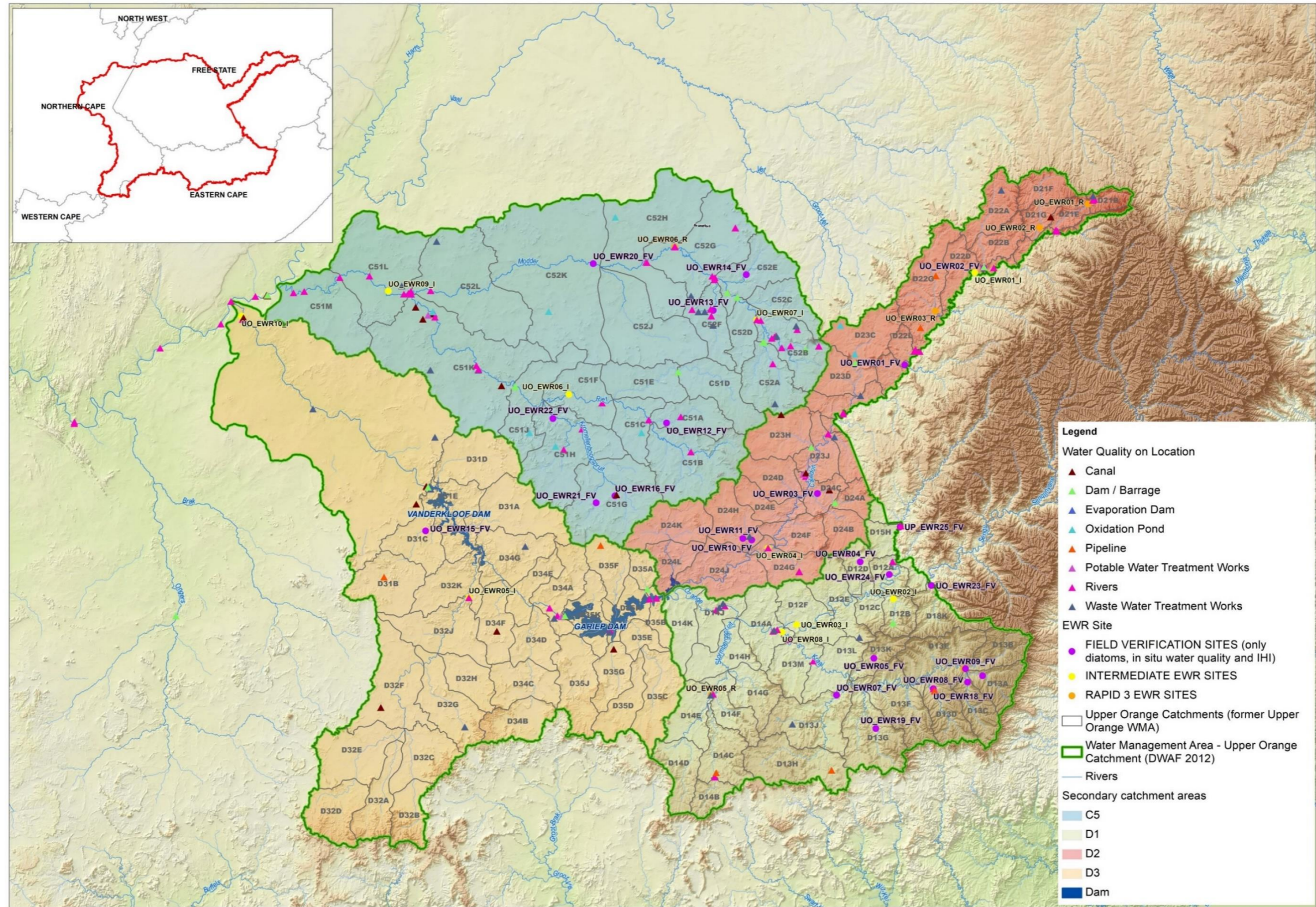


Figure 5: DWS monitoring sites

4.4. WETLANDS

The wetland areas included in the Reserve determination (DWS, 2020) highlighted the priority wetland complexes briefly described in Table 13, however the classification study will review this study and assess where further wetlands may need to be prioritised, especially along the rivers.

Figure 6 illustrates the wetlands that are distributed throughout the catchment from the latest wetlands map, National Wetlands Map 5 (NWM5)(SANBI, 2018). It is noted that SANBI is in the process of updating this map.

Table 13: Wetlands prioritised for the Upper Orange River Reserve determination (DWS, 2020)

Name	Quaternary catchment	Latitude and Longitude	Associated River/ Groundwater Area	Wetland description	Wetland type
Brandwater floodplain	D21G	28°43'48.03"S 28°06'49.33"E	Brandwater River	A medium-sized floodplain (FP) 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.	Floodplain (FP) wetland
Soutpan depression wetland complex	C52H	28°43'48.03"S 28°06'49.33"E	N/A	Comprises 27 depression wetlands ranging in size from 6 ha to 1 800 ha. The largest of these wetlands is known as Soutpan and is an active salt mine as the name implies. Unique features of these depression wetlands, as a complex, provide important habitat diversity in an otherwise relatively homogenous landscape. According to the Mucina and Rutherford (2006) vegetation classification, these salt pans support vegetation that is distinct from the surrounding vegetation.	Depression wetlands
Philipstown unchannelled valley-bottom (UCVB) wetland complex	D31B	30°29'03.80"S 24°37'01.38"E	Hondeblaf River	Wetland complex approximately 190 ha and a depression wetland approximately 1 100 ha in size. The upstream catchment areas of both wetland units are in a relatively natural condition with little to no human impact. The depression wetland provides important habitat diversity in an otherwise relatively homogenous landscape.	Unchannelled valley-bottom (UCVB) wetland

Name	Quaternary catchment	Latitude and Longitude	Associated River/ Groundwater Area	Wetland description	Wetland type
Wolwespruit headwaters	D13G	27°33'30.68"S 30°31'40.58"E	Wolwespruit	Wetland complex comprising a series of UCVB wetlands which are fed by multiple hillslope seep (HSS) wetlands, covering an area of approximately 420 ha. 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.	UCVB wetlands; hillslope seep (HSS) wetlands
Klein-Wildebeespruit wetland complex	D13E	30°49'30.78"S 27°27'54.22"E	Klein-Wildebeespruit	Wetland complex located along the Klein Wildebeespruit and the unnamed river to the east of the Klein-Wildebeespruit, 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	Valley bottom and seep wetlands
Luckhof depression wetland complex	D33C	29°38'02.89"S 24°39'00.21"E	Lemoenspruit	Wetland complex comprising a series of depression wetlands that are hydrologically connected via surface and groundwater. These depression wetlands range in size from 7 ha to 1 200 ha. These fluviually connected wetlands flow in a south-easterly direction into the Lemoenspruit River which is a	Depression wetlands

Name	Quaternary catchment	Latitude and Longitude	Associated River/ Groundwater Area	Wetland description	Wetland type
				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	C52G	28°59'52.00"S 25°50'03.80"E	Kaalspruit	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. 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.	Depression wetlands; discontinuously channelled valley-bottom (DCVB) wetland
Aardoringspruit	C52G	28°42'36.67"S 26°17'42.21"E	Rietspruit	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.	Wetland flat and a DCVB wetland
Rantsho wetland complex	D22G	28°55'59.70"S 27°43'14.61"E	Rantsho River	Wetland complex approximately 275 ha in size located between the R26 Road and the Mohokare (Caledon) River on the Rantsho River. 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	VB hydrogeomorphic (HGM) unit types

Name	Quaternary catchment	Latitude and Longitude	Associated River/ Groundwater Area	Wetland description	Wetland type
				than the other HGM units. A series of VB wetlands is unique and can provide significant streamflow regulating services.	
Jagersfontein DCVB wetland	C51H	29°49'01.45"S 25°28'32.13"E	Prosesspruit	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.	DCVB wetland
Barkley Pass wetland complex	D13D	27°33'30.68"S 30°31'40.58"E	Rytjiesvlaktespruit	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. The wetlands are high up in their catchment and are therefore not impacted significantly by catchment-related impacts. The WRU is located at approximately 2000 m above sea level and is characterised by a unique vegetation assemblage. The vegetation is dominated by <i>Carex acutiformis</i> , <i>Kylinga erecta</i> , <i>Cyperus longus</i> and <i>Eleocharis dregeana</i> with some additional species that are unique to high-altitude wetlands. In addition, this wetland complex is relatively intact as it is situated at the head of a catchment in a remote location. These wetlands are representative of rare intactness for wetlands in South Africa.	VB and HSS wetlands

Name	Quaternary catchment	Latitude and Longitude	Associated River/ Groundwater Area	Wetland description	Wetland type
Tiffindell Seep	D13B	30°40'33.81"S 27°57'24.79"E	Kraai River	A high-altitude wetland complex comprising a series of HSS and VB wetlands which cover a total area of 190 ha located at approximately 2 000 m above sea level (masl) and is therefore characterised by a unique vegetation assemblage. The remote nature of these wetlands has resulted in the catchments remaining relatively natural.	HSS and VB wetlands

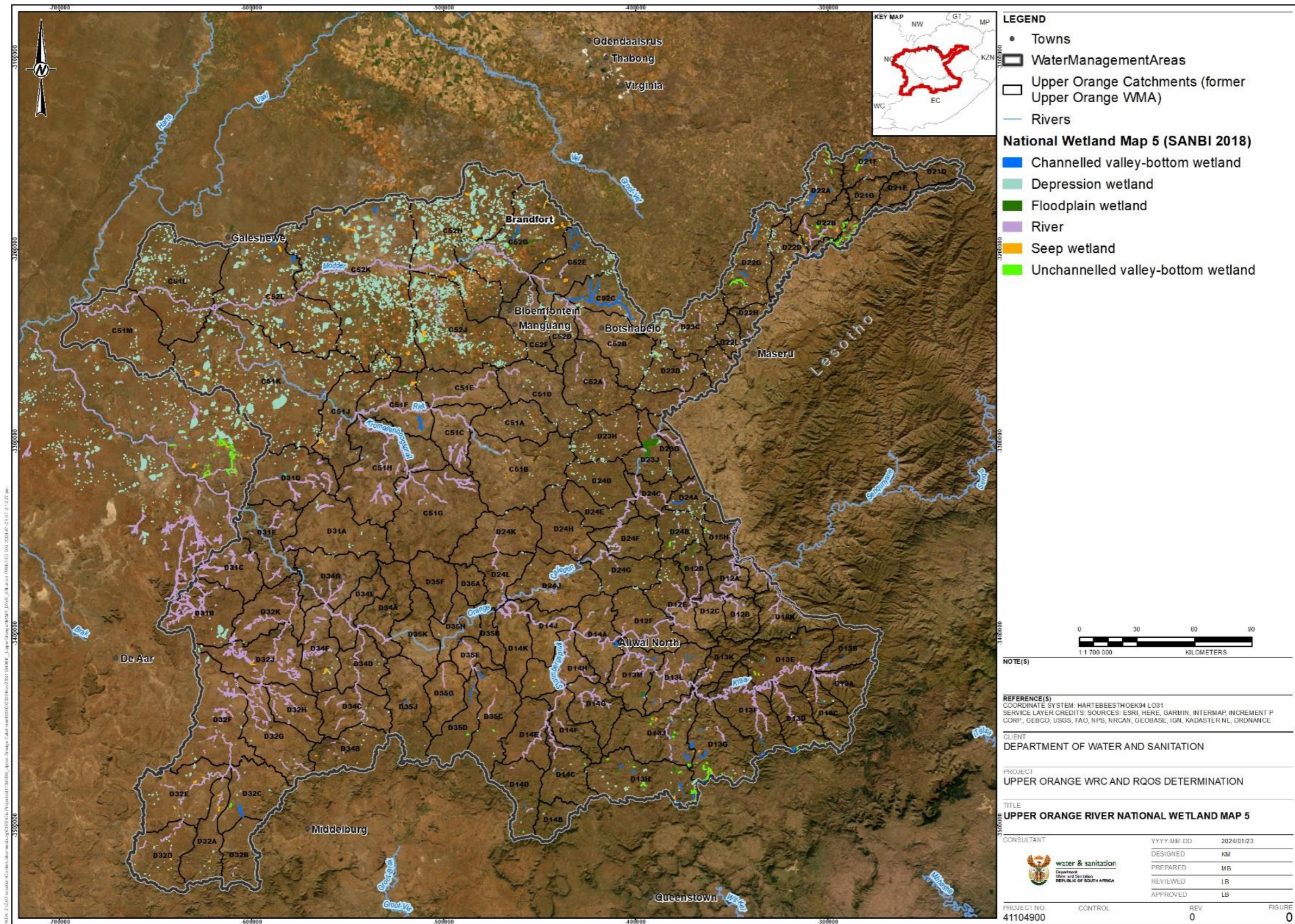


Figure 6: Wetland map for the Upper Orange catchments from NWM5 (SANBI 2018)

4.5. GROUNDWATER

The number of water resource studies for the Upper Orange WMA, including groundwater as one of the disciplines investigated, are sparse. Two WRC reports dated 2007 and 2012 deal with general descriptions of water resources as part of the WR2012 assessments.

A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment: WP11343 – this study includes the following groundwater related aspects:

- Basic Human Needs Report:
 - Population (figures) by water source includes “Groundwater” for the Local Municipalities in the Upper Orange WMA and a listing of the “Basic Human Needs Groundwater Reserve “requirements by quaternary catchment (population figures were sourced from the latest available population census data – 2011 census data and this will have to be updated to at least 2023 figures, using a population growth rate of 1.8%/year.
 - Note: Only population growth is available for use in this WQC and RQOs assessment.
- Groundwater Survey Report (JBS 3):
 - This report deals with the groundwater/surface water interaction from a water quality perspective in four regional-scale transboundary aquifer systems;
 - Nine (9) boreholes were selected in the Joint Basin Survey – only one (1) borehole is included in the Upper Orange WMA, i.e., GW4 (BH5229) at the Twee Revieren Camp along the Nossob River, Kgalagadi Trans frontier Park (KTP).
 - Note: This study [unfortunately] does not contribute to this part of the RDM study in the Upper Orange WMA.
- Final Wetland Report:
 - Depression wetlands are common wetland types in the study area and their characteristics are largely associated with a combination of geology (hydrogeological conditions), rainfall, and temperature.
 - Twelve (12) wetland resource units (in 12 QCs) have been identified, however, no information on groundwater conditions at these sites was researched.
 - A combination of surface water, groundwater and resulting wetland conditions along the Kraai River (QCs D13A and D13M).
 - Note: This study [unfortunately] does not contribute to this part of the RDM study in the Upper Orange WMA.
- Resource Units Report:

- Delineation of groundwater resource units were based on QC boundaries with specific groundwater data attributes (i.e., aquifer types and borehole yields).
- The groundwater attributes are proposed values for the Groundwater Rus (14) and one GRU represents several QCs, i.e., for GW_RU02 contains 47 QCs (this is a concern and indicates that groundwater attributes for individual QC assessments are limited/non-existing).
- This report included an assessment of the groundwater conditions in the Upper Orange WMA to the level where 14 GRUs could be identified of which 6 have been prioritized along with possible integration with surface water sources and wetlands.
- Four groundwater areas have been classified as part of Strategic Water Resource Areas – The criteria and values for this demarcation will have to be assessed.
- Quantification of Ecological Water Requirements:
 - Therefore, the purpose of this study is to determine the Reserve (quantity and quality of the EWR and BHN) for priority rivers, wetlands and groundwater areas at a high level of confidence in the Upper Orange Catchment – however, this report does not address the groundwater reserve determination per QCs.
 - Baseflow separations were undertaken for selected intermediate (10 sites) and rapid (6 sites) to obtain the groundwater contribution to surface flows (setting of baseflows (viz., maintenance flows) for the rivers. Maintenance Low Flows and Drought Low Flows are available for EWR site (specific QC) – Overall confidence is “Moderate”.
 - A special section of this EWR report deals with “Interaction Between Surface water (Rivers and Wetlands) and Groundwater for the Kraai River (D13A – D13M). The site used for this assessment was GRU7. (this is merely a “conceptual” study with limited groundwater related attributes).

The required groundwater attributes to evaluate the groundwater component for the QCs are not available, however, a total of 14 groundwater resource units were identified in the Feb’22 Resource Units Report. The groundwater attributes required for the reserve determination are, therefore, generalized information which can’t be used for QC-level classifications.

The current Reserve Determination Study for the Upper Orange WMA deals mostly with the surface water component and wetlands – the latter features were well addressed, however, the role of groundwater in these wetlands was not specifically addressed except where it was noted that there was a groundwater/surface water and wetlands interaction.

The final groundwater Reserve Determination Report as part of the WP11343 package, referenced as RDM/WMA13/00/CON/ COMP/1022 – has been received and the groundwater team are busy reviewing the data and methodology used.

The WRC and RQOs assessments require reviewing and verification of the following basic RDM attributes (see Table 14):

Table 14: Groundwater related attributes required for water resource classification and RQOs quantification

Attribute	Available	Comments
Basic QC detail (area, MAP, MAE & MAR).	Yes.	MAP needs to be updated and verified in terms of climate variation impacts.
Geological background (rock formations).	Yes, detailed description of lithological units linked with proposed GRUs.	Already demarcated for GRUs, preliminary based on aquifer rock characteristics (as per the EWR study in 2016).
QC prioritisation verified in terms of groundwater use.	WARMS dataset only. Groundwater use needs to be updated up to 2023.	Could be difficult if WARMS dataset is not timely updated. Satellite imagery assessment might be required in specific cases. NB – Need to update “Allocable Groundwater” figures.
Present Status Category (A to F)	Needs to be updated to 2023.	Based on (i) groundwater quality status (48 long-term monitoring sites available in 38 QCs) and (ii) groundwater aquifer saturation levels (several 100 sites available but require trend analyses to extrapolate to +2000 times). Complex work required to update correctly(!).
Groundwater Dependency (by all users).	No, need to be assessed.	Needs to be updated using water level variations – might be difficult for all QCs (data). Need to update available datasets to 2023 status – this is a risk.
Groundwater EWR status (per QC)	No, it needs to be assessed.	Required for RQOs evaluation – probably not available at QC level.
Basic Human Needs (based on population and number of Schedule 1 water users).	Estimations are done for GRUs only.	2011 population figures need to be updated to 2023 (+1.8%/a). Two BHN categories will be used: (i) 25L/c/d where no formal water supply system is available, and (ii) a 200 L/c/d was applied.
Groundwater Component in the Total Reserve estimation.	No, the existing dataset is outdated	Need to assess the impact of lower rainfall in the WMA as it will significantly alter this value.

Attribute	Available	Comments
	for Upper Orange River catchments.	
Rainfall data (at least from 1995 to 2023).	No.	Need to obtain this from other sources, i.e., Agriculture Research Unit. Need a complete long-term rainfall dataset for at least each RU.
Internal Strategic Perspectives	Yes, needs to be evaluated – not specifically used by WP11343 research teams.	None – it may be outdated.
Hydrology information: <ul style="list-style-type: none"> ▪ Baseflow. 	Yes, only for specific QCs.	Need to use regional scale evaluations, i.e. Pitman, Hughes, and Van Tonder baseflow results.
Hydrogeological information: <ul style="list-style-type: none"> ▪ Harvest Potential ▪ Exploitation Potential ▪ Recharge ▪ Hydrochemistry ▪ Water levels ▪ Borehole yields. 	Yes, but hydro-chemistry and water levels need to be updated to 2023 data.	The components of the hydrological information may not be available for individual QCs.
Impact of climate change/ variation(s).	Indirectly (updated rainfall depths).	It has been noted by several hydrological studies and monitoring programmes that there has been a change in the rainfall depths and patterns since 1974. Much lower rainfall depths, and in many cases, rainfall events dropped significantly in the Upper Orange WMA region. Such cases will seriously impact on groundwater recharge figures. An updated rainfall dataset is required.
Aquifer Vulnerability analysis: <ul style="list-style-type: none"> ▪ Depth to groundwater 	No specific dataset except historic NGA (DWS) datasets.	Some attributes need to be updated. NGA datasets need to be assessed.

Attribute	Available	Comments
<ul style="list-style-type: none"> ▪ Recharge rate (net recharge); Aquifer media; ▪ Soil media ▪ Topography ▪ Impact on vadose zone. ▪ Hydraulic Conductivity). 		

Time bounded groundwater information, i.e., time series monitor data, is required to assess/specify a 2024 “version” of WRC and RQOs values/narratives for the Upper Orange catchment, therefore, this process requires [at least] the following (updated) attributes per QCs:

- Water level depths (depth to the water table from land surface).
- Groundwater abstraction volumes from borehole schemes and single users.
- Status and/or variation of effective rainfall (rainfall pattern(s) and rate(s)).
- Effective aquifer recharge values – recent rainfall time series data to verify effective recharge events.
- Groundwater quality status.

In our current search for updated groundwater information, a vast amount of historic groundwater level information has been obtained [viz., from the DWS NGA system]. It would be possible to conduct trend analyses on this data and compare the results with recent water level observations. Extrapolation(s) to nearby QCs could be considered if they have insufficient water level datasets. It is expected that this aspect will require dedicated extrapolation applications.

Long-term groundwater quality data is available for 38 QCs spread over the Upper Orange WMA. The hydrochemical characteristics will have to be extrapolated to adjacent QCs if necessary.

Updated groundwater use figures will be sourced from DWS (WARMS database). Where required, updating of these water-use figures will be correlated with (i) new WARMS information, and/or (ii) physical observations (on-site hydrocensus or satellite imagery).

Recent rainfall figures seem to be a concern based on the availability from organizations collating these datasets.

Updated rainfall data from the Upper Orange River catchments are required. This data is required to prepare rainfall data statistics for (i) future rainfall trends and (ii) cumulative rainfall departure analyses. It is expected that long-term rainfall depths have changed, and one can’t use historic [higher levels] rainfall depths to provide realistic groundwater resource classifications and quality

objectives. It is foreseen that “down-scaling” of groundwater potential and sustainability will be necessary for the Upper Orange WMA.

The number of groundwater studies related to (i) groundwater exploration, (ii) aquifer evaluations, or (iii) groundwater use developments in the Free State Region were minimal, if any. The groundwater quality monitoring programmes, are, however, maintained and water quality data until 2021 were noted in the results. Information from large basin studies such as the JBS 3 study on groundwater-surface water relationships is available, however, having limited information relating to the water resource classification and RQOs.

Specific attributes such as groundwater level trends and water quality status/trends have been acquired from the Department’s groundwater assessment/monitoring programs and currently assessed for use in this study.

To conclude:

A wide range of aquifer systems are present in the study area – it [unfortunately] seems that recently the basic hydrogeological data such as (i) groundwater use/borehole, (ii) water quality-type analysis, (iii) aquifer recharge figures, (iii) local rainfall depths, (iv) actual population figures, (v) groundwater dependency, and (vi) local baseflow figures, are not readily available. Upgrading of the groundwater use as per Water Use Authorization Registration and Management System (WARMS) will have to be considered as it is the only direct source of larger water use figures. Groundwater use by local municipalities and irrigation systems are regarded as bulk water supply schemes and their present usage (abstraction figures), quality/quantity status and impact(s) need to be verified.

One of the important aspects of this study guiding the proposed resource quality objectives, will be the groundwater quality and quantity trends – this will require long-term groundwater monitoring data. It is assumed that regional monitoring programs by DWS, water services providers, and authorized water users (*viz.*, as per water use license audits) should provide this information, but that extrapolation to adjacent QCs will have to be considered.

It should be noted that a significant concern that has disseminated during the last 15 to 20-years of groundwater resources assessment is “the long-term average rainfall depths” used for groundwater recharge estimations (in general). Annual groundwater recharge is one of the “ruling factors” when RQOs as specified. Generally, quantification of groundwater availability is based on normally “average” rainfall since 50-years ago which [probably] does not represent the current sporadic rainfall depths/patterns anymore.

Climate variation in southern Africa has a direct impact on the long-term sustainability of the aquifer systems in the study area. It has been documented that effective aquifer storage recharge is not an annual phenomenon currently and is probably a one-in-five-to seven-year event. Groundwater resources can therefore not be managed according to an annual rainfall recharge figure – or at least reduce the general annual recharge values by a factor <1.0. This aspect should be considered with great care in this study.

4.6. WATER RESOURCES MODELS AND SYSTEM ANALYSIS

The system analysis supports the scenario evaluation step of the water resource classification process. Scenario evaluation requires that the system demands and the EWR requirements are assessed to confirm that all user requirements are met, as well as assessing the risks presented to the system based on the varying ecological and socio-economic configurations for each integrated unit of analysis (IUA).

The models and supporting hydrology are available for the Upper Orange River catchment and can be adopted for this study, taking into consideration what may already have been undertaken for the Reserve study.

The hydrology prepared as part of the ORASECOM study included the assessment of 16 hydrological zones, 3 of which are related to the Upper Orange catchment, and the Modder and Riet rivers catchment which will form part of this classification study, even though it falls within the Vaal River System. These 16 hydrological zones included 207 hydrology time series files which were assessed. The hydrological zones were given a general confidence rating based on data availability in preparation of the hydrology. The hydrology is generally considered to have a good confidence rating. These hydrological zones are shown in Figure 7 as taken from DWS (DWA, 2013).

The system models applied to the analysis include the Water Resources Planning Model (WRPM) and Water Resources Yield Model (WRYM). These models are used for determining dam yields, system balances and assessing the impacts of development scenarios, and have also been used for a variety of water resource analyses throughout the country for many years.

The models were updated for the ORASECOM studies and then further improved as part of the Orange Reconciliation Study undertaken in 2015. The WRYM will be used to confirm the yield of the systems identified for further investigations, as well as to assess the various management scenarios, as part of the water resource classification task.

The model used for the Reserve determination included all the intermediate and Rapid III EWR sites for evaluation of the scenarios, including the latest estuarine requirements. However, only a few field verification sites were included and will have to be adjusted if any of the remaining field verification sites or new sites are to be assessed. Hydrological time series are available for the period 1920 to 2004, with the 2019 water use demands. The related operating rules and system management procedures for the Orange River System have also been updated and provide further confidence to the process as part of this study.



Figure 7: 16 Hydrological modelling zones of the Orange River Catchment (source DWA, 2013)

4.7. SOCIO-ECONOMICS

The purpose of the socio-economic component of the WRCS is to assess the economic prosperity and social well-being implications of different catchment configuration scenarios while utilising the 7-step WRCS procedure. The component assesses and demonstrates the value of ecosystem services (ES) and the economic consequences of water planning scenarios and, how they relate to social well-being.

Previous Studies that will be reviewed include but are not limited to:

- ORASECOM Water accounts for the Orange River System, Report No. ORASECOM 011/2014 (ORASECOM, 2014)
- Socio-economic report on Upper Orange River: Reserve determination (DWS, 2023), and
- Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River (DWS, 2015)

The water accounts for the Orange River catchment work conducted in 2014 as part of the ORASECOM Basin-wide Integrated Water Resources Management Plan Study, provides a study report and a water accounts database. The study reviewed different water accounting models and estimated the basin water accounts and describes the water users, water supply and demand and the economic value thereof. This provides useful data and information that will be used for the socio-economic component and understanding the value of ecosystem services in the Upper Orange catchment. Specific information pertaining to South Africa and the Upper Orange catchment will be used in the analysis.

The DWS studies from 2004 specifically relate to the then, Upper Orange WMA. They include general overviews of the WMA and useful information on water resource availability and utilisation, land use, economic activities, environment and social aspects that will be used in understanding the catchment and contributing to determining the delineation of key socio-economic zones within the Upper Orange River catchments.

The water demand and requirements from the DWS 2015 Reconciliation Strategies for the Orange River will be used in assisting with delineation of socio-economic zones that will feed into the delineation of the IUAs and it will also be used during the economic model development for scenario evaluation in Step 4 of the WRCS study.

The objective of the Socio-Economic Outline Report (RDM/WMA13/00/CON/COMP/1123) compiled for the High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment (DWS, March 2023) was to present an overview of the socio-economic context of the study area. The report profiles the socio-economic conditions and well-being of the communities of the Upper Orange Catchment area with a particular focus on socio-economic water use and cultural importance. The socio-economic profile provides the baseline for evaluating the social consequences of potential operational flow scenarios.

The ecosystem services and economic analysis to be developed during the scenarios will further be supported by inputs from: surface and ground water; hydrological; and wetland specialist reports to be conducted in this study.

Table 15 lists the data sources will also be used to analyse socio-economic status of the study area.

Table 15: Data required to conduct Socio-Economic Analysis

Data required	Possible Source	Scale
Latest Population densities, social status	National Census 2022 data (Stats SA)	Ward Level, Provincial, Municipal
Catchment demographic, economic activities, water resources and water use	ORASECOM studies from Orange River Integrated Water Resources Management Plan	Catchment level
Latest Land Use/Cover	DFFE (egis.environment.gov.za)	National
Protected Areas of SA	DFFE (egis.environment.gov.za)	National
Economic contributors	Stats SA, IDPs, MSEPs	Provincial, Municipal
Catchment boundary	DWS	National
Water resource	South African National Biodiversity Institute (SANBI)	National
Towns and cities	Department of Forestry, Fisheries and the Environment (DFFE)(egis.environment.gov.za)	National
Mining	Department of Mineral Resources and Energy	National
Satellite Imagery	Google Earth™	National

5 GAP IDENTIFICATION

Section 4 highlights the data/ information availability and accessibility for the components/ steps that comprise the water resource classification and RQO processes. The gaps are discussed in the sections that follow based on the information review conducted.

5.1. Rivers

The assessment of the data and information availability for the rivers component is described in Table 16, with the gap analysis summary detailed in Table 17.

Table 16: Data/ Information availability for the Rivers Component

Aspect	Data Availability	Suitability (confidence)	Other Sources
Site information: EWR site details	Yes	Available for all sites	
EWRs (all sites)	Yes	Intermediate, Rapid III and field verification sites with various levels of information available	REMP, JBS2 and JBS3
Rule and Tab tables	Yes	For REC only at all the EWR and field verification sites	
Basic Human Needs (BHN)	Yes	Outdated, based on 2011 Census data	StatsSA 2023 census data (available potentially March 2024)
Water Quality Ecological specifications	Yes (limited)	Based mainly on diatoms	JBS3, FBIS (diatoms),
Biota	Yes	Intermediate, Rapid III EWR sites and Filed verification sites	REMP, JBS2 and JBS3, FBIS
Riparian vegetation	Yes	Intermediate EWR sites	JBS2 and JBS3, FBIS
PES/ EI/ ES	Yes	Mainly 2011-14 data, 2024 updates available towards end of 2024 so will have a moderate confidence level	
Water Quality	Yes (limited)	Moderate confidence on major tributaries but is limited on smaller tributaries	DWS national environmental monitoring programmes: NCMP,

Aspect	Data Availability	Suitability (confidence)	Other Sources
		and at the headwaters of catchments.	NEMP, NMMP. External monitoring data, where made available; Green Drop Reports

Table 17 summarises the gaps for rivers considering the data and information assessment.

Table 17: Gap analysis for Rivers based on information/ data assessment

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Hydraulics	Only available for intermediate and rapid 3 sites	If any additional sites are identified where scenario assessments are required, hydraulic surveys will need to be undertaken	Undertake hydraulic surveys where required
BHN	Available from the recently completed high confidence Reserve determination study, however the data was from the 2011 census, so may be inaccurate	Inaccurate BHN provision in scenario assessment, influence the setting of the water resource class	Update population in terms of the latest Census data that should be available in March 2024.
EWRs for the system	Maybe on smaller tributaries, depending on final IUA delineation and RU identification	Gap in the scenario modelling for these catchments in terms of IWRM context.	Rapid assessments are proposed to be undertaken at additional sites to address potential EWR gaps.
PES	None, updated PES from Reserve study at EWR sites and from 2024 PES/ EIS database updates	-	-
Riparian vegetation	The Reserve study included riparian vegetation assessments for the intermediate sites, and rapid Habitat Integrity assessments for the Rapid	It is not expected that there will be any concerns.	Any additional sites surveyed will include a rapid Habitat Integrity Assessment.

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
	Ill and Field verification sites.		
Rule and tab tables	Only for REC, not PES or alternative categories	No quantified EWRs with high confidence if other categories to be included	Determine EWRs for other categories through biological interpretations and not only extrapolation/estimation
Catchment scenarios	Additional scenarios might be considered, and dam release capacities were not considered with specification of floods/freshets	Not all scenarios included and unrealistic flood requirements	Interpret ecological consequences for any additional scenarios and obtain dam release capacities to adjust floods/freshets where necessary
Water Quality	Limited or lack of baseline monitoring data on some rivers from the NCMP, and NEMP. Water quality impacts at local scale are not necessarily well understood.	Impacted areas/hotspots may be missed, or adequate protection measures may not be identified if is not available to indicate status.	Further data sources are being investigated to obtain additional water quality monitoring data such as those of the local municipalities and other users in the WMA, or other programmes. Ad hoc samples will be taken in the catchment. It is proposed that the DWS Regional personnel will assist in this task; also looking at the data from the NMMP.

The available data, and that which will be sourced and used in the study will allow classification of the water resources and the associated RQOs that will be set will therefore be realistic and achievable.

5.1.1. Proposed additional sites for Rapid Reserve/ biological assessment

Based on the preliminary information assessment the following additional sites, briefly described in Table 18 have been identified as Rapid Reserve assessments to be undertaken for the Upper Orange River Catchment to fill gaps in EWRs. It is noted that the PES/ ES update study currently in progress will also add to the data for the Rapid Reserve/ biological assessments.

Table 18: Identified rivers for Rapid Reserve/ biological assessment

Site	River	Quaternary Catchment	Relevance
1	Tributaries of the Kraai River in tertiary catchment D13: <ul style="list-style-type: none"> • Sterkspruit/ Bokspruit • Langkloofspruit • Holspruit 	<ul style="list-style-type: none"> • D13A/ D13C • D13D • D13J 	<ul style="list-style-type: none"> • Biological to improve confidence • Linked to wetlands, biological and hydraulics • Extensive land use upstream, biological to assess impacts
2	Upper Caledon, upstream Little Caledon confluence	D21A	Data outdated from pre-2011
3	Upper Seekoei/ Little Seekoei/ Elandskloof	D32A, D32C, or D32D	Biological surveys to improve confidence
4	Upper Riet tributaries: <ul style="list-style-type: none"> • Upper Riet/ Kromellenboog/ Prosesspruit 	C51B, C51G, C51H	Limited information, biological to assess impacts
5	Witspruit	D24C	Biological to improve confidence in field verification site
6	Lower Orange, Marksdrift	D33K	Only 1 hydraulics and biological survey due to floods. Additional surveys will improve confidence as this site is the main outlet of Upper Orange

5.1.2. Water Resource Modelling

The review of data and information availability to undertake the water resource modelling for the scenario evaluation step of the classification process is described in Table 19 and the gaps identified are summarised in Table 20.

Table 19: Data/Information availability for the water resources modelling

Aspect	Data Availability	Suitability (confidence)	Other Sources
WRPM	Yes	Moderate to High confidence	Scenarios from the Reserve studies
WRYM	Yes	Moderate to High confidence	

Aspect	Data Availability	Suitability (confidence)	Other Sources
Model versions	The latest version is 2018, as well as runs done for the Reserve	Moderate to high	Reserve study inputs
Development data (demands)	Data is available	2019 water use demands were used for the Reserve	
Hydrology	Yes	Hydrological time series are available for the period 1920 to 2004.	The related operating rules and system management procedures for the Orange River System have also been updated and provide further confidence to the process as part of this study.
System configuration	Yes	Moderate to high confidence	
Network setup	Yes	Diagrams are available in the latest studies undertaken.	
Water supply volumes	Yes	Moderate to high confidence	
Water reconciliation assessment for catchment	Yes	Latest reports (2015) are available	

Table 20: Gaps analysis of water resource modelling component based on information assessment

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
WRPM	No gaps noted		
WRYM			

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Planning scenarios	No gaps noted, will use the scenarios set for the Reserve, however, will update as necessary should more recent considerations come into play		Updated mode based on the new scenarios
Water supply volumes (current future)	No gaps noted		
Reconciliation strategy	No gaps noted		
Municipal Water requirements	No gaps noted		

The data and available models are adequate to undertake scenario modelling to set water resource classes and associated RQOs that are feasible.

5.1.2.1. Hydrology

The natural hydrology was developed for the period 1920 to 2004, for the whole Orange River System. This hydrology was used for the latest Reconciliation Strategy update and the hydrology built into the WRPM/ WRYM will therefore be used.

The related operating rules and system management procedures for the Orange River System have also been updated and provide further confidence to the process as part of this study.

5.1.3. Wetlands

The assessment of the data and information availability for the wetland's component is described in Table 21 and the gaps identified are summarised in Table 22.

Table 21: Data/Information availability for Wetlands component

Aspect	Data Availability	Suitability (confidence)	Other Sources
Wetland identification	National Wetland Map 5 (Van Deventer <i>et al.</i> , 2018) - (GIS layer)	Medium confidence and requires desktop verification of key systems using available imagery	It is noted that the National Wetland Map 6 is in process of being compiled and an attempt will be made

Aspect	Data Availability	Suitability (confidence)	Other Sources
	NFEPA wetland layer (Nel <i>et al.</i> , 2011) - (GIS layer) DWS Reserve determination study (2022)		to get the draft maps from SANBI through the DWS Project Team.
Wetland delineation	As above	Medium confidence based on the latest Reserve studies	
Wetland typing	As above	Medium confidence based on the latest Reserve studies	
Wetland categorisation (PES and IS)	PES or similar surrogate data only available for some systems and at a desktop level. No IS data available.	Low to medium confidence for some of the wetlands based on the latest Reserve studies	More detailed studies of specific wetland systems if available
Initial Priority Wetland identification	High	High confidence but may require additional mapping for areas not prioritised as part of the Reserve study	
Additional Priority Wetland identification	Supported by the above plus the latest NWM6, when available, and site visits.	Medium to high confidence but probably requires updated mapping and PES assessments	Other wetland studies or knowledge of specific systems as recommended or identified during the stakeholder workshops

Table 22: Gap analysis of Wetlands component based on the information assessment

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Mapping of Priority wetlands	Available from the Reserve study however additional sites may be needed		To be developed as part of study

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Delineation and typing of Priority Wetlands	As above	Will require updating for all the Priority Wetlands	Updated desktop mapping of the Priority Wetlands to be undertaken as part of study where appropriate
Ecological categorisation of the Priority Wetlands	Present Ecological State (PES) and Importance and Sensitivity (IS) information may not be available for all systems.	May not be able to determine the REC from available data for additional sites prioritised	Surrogate databases and information sources will be used where appropriate to derive general state and importance and sensitivity indicators where possible. This will be used to derive the REC where appropriate / possible.

5.1.4. Groundwater

The assessment of the data and information availability for the groundwater component is described in Table 23 and the gaps identified are summarized in Table 24.

Table 23: Data/ Information availability for the groundwater component

Aspect	Data Availability	Suitability (confidence)	Other Sources
Groundwater recharged	Yes, but incomplete dataset (most QCs are excluded).	Moderate to high	None.
BHN Reserve (Groundwater ♦)	Yes, from joint studies in Upper Orange catchments.	High	Recent population census will improve values.
Groundwater quality status	Yes, but incomplete QC coverage (only data for 38 QCs).	Moderate to high	None, or new hydrocensus survey.
Water level depths	Yes, but incomplete dataset (most QCs are excluded).	Moderate	None, or new hydrocensus survey.
Groundwater contributions to river baseflows.	Yes, by only qualified from joint studies in Upper Orange catchments.	Low	None, or new hydrocensus survey.

Aspect	Data Availability	Suitability (confidence)	Other Sources
Groundwater use.	Yes, but historical dataset only	Low	None, or new hydrocensus survey.
Groundwater use (and Stress Index variables).	Yes, but incomplete dataset (most QCs are excluded)	Low	None, or new hydrocensus survey.
Resource Units.	Yes, from joint studies in Upper Orange catchments.	High	No comment.
Reserve	Groundwater Reserve determination report/ data	High	Groundwater Report RDM/WMA13/00/CON/COMP/0422 currently under review
Demarcation of surface water/ground-water interaction.	Groundwater RUs with surface water and wetland interaction	Medium	Yes, Vegter dataset.
Aquifer Saturation status.	No	None	None, or new hydrocensus survey.
Satellite Imagery	Yes (Google Earth Pro)	Yes	Not required.
Quantitative Stress.	No	None	Land use and vulnerability assessment (GIS).

♦ A groundwater dependence rate (%) of the population per quaternary catchment will be calculated using on average 25 L/cap d⁻¹ (rural regions) to 200 L/cap d⁻¹ (towns reliant on groundwater).

Table 24: Gap analysis of the groundwater component based on the information assessment

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Groundwater use	WARMS dataset is not thoroughly updated, not verified.	Incomplete calculation of actual groundwater use (impact on water balances in a QC).	Update WARMS, or a hydrocensus survey.
Water levels	Merely historic datasets – lack of “modern” data.	Incorrect estimation of aquifer vulnerability and aquifer stresses.	A physical hydrocensus survey to collate actual “modern” measurements. This may not require that each QC is covered. Adjacent long-term “historic” datasets can be

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
			applied to estimate water levels in adjacent QCs.
Groundwater Quality	Merely historic datasets – lack of “modern” data.	Estimations of groundwater vulnerability and long-term water quality trends.	A hydrocensus survey in areas where insufficient data is available.
Groundwater recharge values (rainfall)	Rainfall data and groundwater chloride concentrations (recharge by Chloride Mass Balance)	Insufficient coverage of basic groundwater attribute in water balance estimations.	Obtain actual rainfall datasets for all weather stations in Upper Orange WMA, if not already available in joint studies.
Groundwater use data	Borehole use figures where WARMS dataset is insufficient.	Incomplete estimations of groundwater component right through assessment process for water resource classification (WRC) and resource quality objectives (RQOs).	Hydrocensus of groundwater use. Apart from the WARMS dataset, no other use data is available unless a hydrocensus is conducted.

To conclude, the lack of recent groundwater information and time series hydrogeological data puts the groundwater component of the water resources classification and RQOs determination in a critical state as most of the basic hydrogeological attributes to perform this assessment is simply not available. This condition will be addressed by extrapolating from existing more complete datasets and an attempt will be made to do ad hoc sampling to at least get some recent data, but due to local physical changes, this method is not always a good solution.

5.1.5. Socioeconomics

This section reports on the data required to do the socio-economic assessment and proposes alternative sources should the recommended data not be available. These data requirements are to fulfil each task in the socio-economic component of the project. Further detail specific to each of these tasks is provided in the sections that follow.

5.1.5.1. Task 1: Determination of Catchment Status-quo & Determination of IUAs

The data required to determine the status quo of the catchment and to contribute towards determining IUAs is summarised in Table 25. The data for this task is predominantly spatial in nature. It also includes Stats SA Census data. The currently available data from the latest Stats SA census 2022 is from the first phase (i.e., Provincial, and municipal level) of data releases. Phase 2 release will include electronic data (i.e., ward level) and more in-depth reports and is

expected by end of March 2024. If this data is not available when the status-quo of the IUA report is due other data sources will be initially used such as Stats SA mid-year population estimates, General Household Surveys (GHS) and the and DWS- National Water Services Knowledge System (NWSKS). This will then be updated as soon as the detailed 2022 Census data is available. Detailed agricultural data to be used will be obtained from Department of Rural Development and Land Reform. Any other relevant data sources that are available will be used.

Table 25: Recommended data requirements for describing the socio-economic status, key drivers and general spatial features across a catchment

Data Required	Possible Source	Data/ Information Availability	Suitability (confidence)	Other Sources
Latest Population densities	National Census 2022 data (Stats SA)	Yes (2022 phase 1)	High (but incomplete until the detailed data release by Stats SA later in 2024)	Municipal non-financial census; Household surveys, DWS (NWSKS)
Latest Land Use/Cover	DFFE National Land cover (https://egis.environment.gov.za/)	Yes (2020)	High	
Catchment boundaries	Department of Water and Sanitation (DWS)	Yes (2017)	High	
Water resources (SWSA)	South African National Biodiversity Institute (SANBI)	Yes (2017)	High	
Towns and cities	Department of Forestry, Fisheries and the Environment (DFFE) (egis.environment.gov.za)	Yes	High	
Latest Protected Areas	DFFE National Land cover (https://egis.environment.gov.za/)	Yes (2023)	High	
Satellite Imagery	Google Earth™	Yes	High	
Economic contributors	Stats SA / GDP publications	Yes (2019 / 2023)	High	
Agriculture	Department of Rural Development and Land Reform (DRDLR)	Yes (2017)	High	

5.1.5.2. Task 2: Describe communities and their well-being

Indicators such as employment status, household income, access to water services, and education level describes the social well-being of communities. This data is mainly sourced from Stats SA census. Data required to undertake this task is given in Table 26. As catchment boundaries are not aligned with municipal and ward boundaries, the challenge will be to make sure there is not under/over estimation of social well-being indicators per IUAs that are to be delineated. This can be mitigated by analysing spatial planning of a municipal ward on Google earth, make a decision on what percentage of the ward population will fall into the IUA.

Table 26: Recommended indicators for describing social wellbeing of IUAs

Data Required	Possible Source	Data/Information Availability	Suitability (confidence)	Other Sources/ Mitigation of Gap
Household Income	Stats SA Census	Yes (2022 – phase 1 release)	Low – only high-level information at municipal level	Municipal non-financial census; General Household surveys. Phase 2 data release is expected in 2024 and the analysis can be updated once data is available.
Access to water services				
Education level				
Source of water per household				
Household Income				
Employment Status				

5.1.5.3. Task 3: Describe the Use and Value of Water

Utilising and understanding of physical and monetary water accounts helps to assess the use and value of water in the catchment. The data that is used to develop monetary accounts is from municipal financial census which includes water sales by the municipality from different sectors and the data is available through Stats SA (Table 27).

The physical water account is developed through data typically sourced through documents such as reconciliation strategies. DWS developed the water reconciliation strategy for the Orange River in 2014. In this study the monetary accounts will also be used together with the inputs from the greater classification process (i.e. hydrological and groundwater specialist studies) to develop the physical account. The general approach is that the volume of water utilised will be determined by calculating monetary values with water tariff per sector in the catchment (Table 23). Furthermore, there have been studies conducted by ORASECOM on water accounting and these will be an additional source of catchment specific data and information to facilitate understanding.

The water accounts information will be feed into the Scenario Development step of the study when developing the mitigation plans for the different scenarios.

Table 27: Data required to develop Monetary water account

Data Required	Type of Data
General Household Surveys (GHS)	Qualitative information on service delivery
Census of Agriculture	Crop water use data at Magisterial District level
Large Sample Survey (LSS) – Electricity, gas and water supply	Water volumes used water purchases
LSS – Manufacturing	Water purchases
Supply and Use Tables	Monetary transitions for water use sectors defined in the supply use tables
Survey of Actual Capital Expenditure of Municipalities	No direct relevant information
Survey of Actual Capital Expenditure of National Government, Provincial Government and Extra-budgetary and Funds	No direct relevant information
Financial Census of Municipalities	Water purchases by municipalities Water sales by municipalities
Non-Financial Census of Municipalities	Number of consumer units served

Table 28: Data required to develop the physical water account

Data Required	Possible source
Source of water and water users	Data from current specialist studies (Hydrology, and Water Resource modelling). Additional data and understanding from DWS Reconciliation strategy for Orange River (2014). ORASECOM studies. DWS validation studies within the Orange Catchment and water use license applications.
Volume of groundwater extracted and used	Inputs from the Groundwater part of this study
Volume of water used in the electricity industry	Stats SA Electricity LSS
Water supply by water boards in the country	Water boards annual reports

Total mean annual runoff, flows between catchments and other countries	Inputs from our hydrological component of the classification study
System input volume per municipality	DWS (No drop system)

5.1.5.4. Task 4: Develop an Inventory of Aquatic Ecosystem Services

Following on from task 1, the purpose of this step is to identify the aquatic ecosystem services (ES) within the catchment at an IUA level and broadly determine the demand of these services by communities and the economic sectors that utilize them (Table 29).

Table 29: Indicators required to develop aquatic ecosystem services

Data Required	Methodology to be used	Data/ Information availability	Significance/ confidence
Ecosystem Service Flow Data	Millennium Ecosystem Assessment: Ecosystems and Human Well-Being (MEA) The Economics of Ecosystems and Biodiversity for Water and Wetlands (TEEB)	Ecological infrastructure: <ul style="list-style-type: none"> Land data from task 1 (i.e., rivers, groundwater dams, wetland, agriculture, vegetation) Inputs from other specialist studies (i.e., wetlands, fish, water quality, estuaries, riparian vegetation, etc.) Beneficiaries: <ul style="list-style-type: none"> Information and data from task 2 on IUA level Water resource users from task 3 on IUA level 	High confidence in existing data

5.1.5.5. Task 5: Quasi-Social Accounting Matrix

The Social Accounting Matrix (SAM) is a well-established macro-economic modelling tool which may be restructured into a modelling tool. The impact of water resource management scenarios can be evaluated using this modelling tool. In this task, two Quasi Social Accounting matrices (QSAM) will be developed, one is a national QSAM (quantifies the South African economy) and the other will be a QSAM which reflects or quantifies the size of the Upper Orange River Catchment economy. The data required is listed in Table 30.

Table 30: Data required to develop Quasi Social Accounting matrices

Data Required	Possible Source	Data/Information Availability	Suitability (confidence)
National QSAM	Stats SA	Supply and Use Tables published in 2023 for year	High confidence

Data Required	Possible Source	Data/Information Availability	Suitability (confidence)
		2019. This is the latest published available data.	
Orange River QSAM	National QSAM Provincial data Stats SA	This QSAM will be built from the basis of the national QSAM. Data from the socio-economic profiles, growth & development plans and spatial economic overviews of the district municipalities that fall within the catchment. Quarterly employment statistics information. These are published every quarter. Annual economic reports. Census of Agriculture. Data available is from 2017 when full census was done.	High confidence in existing data

5.1.5.6. Task 6: Evaluate Scenarios

The input from all the relevant parallel workstreams of the study will be key to this task. The data inputs are required for the evaluation of scenarios and therefore all gaps identified in other workstreams will be relevant for this step.

5.1.5.7. Gap identification

The gaps in data required to complete the socio-economic component are summarised in Table 31.

Table 31: Gaps analysis of the Socio-Economic component based on the information assessment

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Socio Economic Status	Release of the meta data as part of Phase 2 Stats SA Census data release for more detailed population information at ward level	Under estimation of population densities within the catchment	Use Stats SA municipal non-financial and household surveys and DWS NWSKS as preliminary information until the data release after which data and information can be updated.

Aspect	Gap Identified	Potential Consequence to outputs	Proposed Intervention
Communities and their well-being	Latest information of employment status, water sources and access at catchment level will need meta data from Phase 2 Census 2022 data	Under or overestimation of social well-being and vulnerability at IUA level.	Use Stats SA municipal non-financial and household surveys and DWS NWSKS as preliminary information until the data release after which data and information can be updated.

6 SUMMARY OF KEY GAPS

6.1. Potential Data Gaps

Based on the preliminary analysis undertaken potential information and data gaps that may exist relate to the following aspects:

- Adequate and recent surface water quality data for the catchment
- Groundwater data:
 - The lack of baseline groundwater attributes, i.e., (i) water levels, (ii) water quality, (iii) rainfall data, (iv) water use figures, and (v) aquifer saturation levels, influence the calculation of values/parameters for the water resource classification (WRC) and resource quality objectives (RQOs). This shortage puts a serious question on the standard of the product and certain measures, to such a degree that site specific hydrocensus surveys would probably be necessary to rectify the lack of physical groundwater data.
- Socio-economic information:
 - At municipal or catchment level
 - Physical water account for the sub-catchment (Water use data *i.e.* Volume of water used by sectors, municipal water use, transfers data, groundwater extractions, wastewater volumes)
 - Ward level population data, as the meta data for 2022 census data is not yet available
 - Health Data by municipality for the catchment, and
 - Recent Macro-Economic Classification Data for the catchment.
- Possible additional EWR sites for the Orange River and tributary catchment.

The potential identified risks that could have an influence of the execution and completion of the tasks in respect of the classification of water resources in the Upper Orange River catchment are listed in Table 32: Possible identified risks and uncertainties.

As the process will be undertaken with the best available current information, which is quite extensive and recent, the risks are very low, with the biggest risks being the limited surface water

quality data and groundwater data. The project team will, as far as possible, mitigate any risks within the current scope, time and budget of the project.

The project team will inform the DWS Water Resource Classification Directorate timeously in the unlikely event of a key constraint being encountered.

In addition to those risks/ limitations set out in Table 32, the Reserve Study noted the following considerations, and it is proposed that these be taken forward in the classification and RQOs study:

- Tributaries within catchments D15 (Makhaleng) and D18 (Tele) are high up in the Upper Orange River Catchment along the border of South Africa and Lesotho. The Reserve study has noted that the tributaries are high in sediment and salts that impact the upper reaches of the Orange River. The Reserve study conducted resource stress scoring in terms of water use, quality and the Integrated Water Use Index (IWUI), coupled with the Integrated Ecological Index (IEI), and the scoring indicated that most of these rivers (tributaries) came out with a biological river level approach.

The Department agreed with GroundTruth (PSP) that the areas are not easily accessible and could be a challenge from a monitoring perspective. This would also be a limitation for the classification and RQOs setting. The Reserve study confirmed that these catchments would be included in the Final EWR report (along with these said limitations) on a desktop level. The PSP visited these two rivers (mainstem Tele and Makhaleng) to collect diatoms and undertake a habitat integrity assessment to determine the PES. It is unlikely that any hydrology/ hydraulics will be undertaken for the classification.

- Owing to approximately 790 sub-reaches identified within the Upper Orange catchment, and the aim of the Reserve study being to optimise assessment of the whole catchment – although realistically and within budget, the Reserve study team proposed a method to eliminate some of the many “unnamed tributaries”, many with a Present Ecological State (PES) of a C or below. The resource stress scoring considering water use, quality and the Integrated Water Use Index (IWUI), coupled with the Integrated Ecological Index (IEI) was used. The results indicated that several of these unnamed tributaries came out with a biological river level approach. The study proposed eliminating these unnamed tributaries and rather retaining those reaches which are associated with a water use with a high IWUI score, and which were identified to require a Rapid 3 or higher-level approach.

The results will be used and taken forward for the classification study in the prioritisation exercise, ensuring however that all areas of the catchment are represented.

- Hydropower releases from Gariep and Vanderkloof Dams

The severely modified flow along the Orange River between Gariep and Van Der Kloof Dam, primarily due to the hydropower releases from Gariep Dam, is having a negative impact on the biodiversity of the river. Furthermore, there are limited options for changes to the flows between these dams. Therefore, one of the considerations was to consider

this as part of the Reserve and aim to influence the release curve for the Gariep Dam developed annually for hydropower and downstream demands. The most feasible option was to optimise releases by developing a Flow Management Plan (FMP) which will seek to achieve a sensitivity and setting of achievable EWRs. Information from the JBS3 survey was used to inform the FMP. It is proposed that the FMP be taken forward in this study. Hydraulics cross-sections might be required for this.

- Aquatic Monitoring

SASS5 sampling was only carried out in available and accessible habitats, as per the standard SASS5 protocol (i.e., there must be flowing water, ideally all substrate types/ biotopes present, no flood conditions and wadeable water depth), and according to health and safety protocols. It is also noted that the REMP does not get undertaken in times of floods or high velocities. Aspects such as elevated flows and lack of habitat may impact on results and the ability to sample. It was also noted that diatoms can only be collected when suitable substrate exists in-stream which is generally not an issue as there is generally always some available.

It was noted that in terms of fish sampling, sites were stratified according to importance based on available velocity-depth and cover types, and intensive fish sampling was only carried out at the selected sites. Specific fish sampling techniques were carried out in relation to site specific conditions (e.g., larger systems required fyke netting/ seine netting over longer periods compared to smaller systems where basic electro-shocking sampling and cast netting sufficed).

Table 32: Possible identified risks and uncertainties

Task description	Risk	Risk description	Risk Implication	Risk mitigation	Risk Owner & Timelines
Models' set-up	Setting up system model and provision of natural and present-day hydrology data	If any new sites are included in WRCS, then model will have to be adjusted and re-tested.	None, it will be easy to update the models with the new data	Low risk as the model was set up for the Reserve study to provide information at all the selected EWR sites and will be used as is unless new sites are added. Assess and include data for new sites.	Study Team, no changes to timelines
Socio-economic assessment	Limited/ old data	The following data is limited: Ward level population data, as the meta data for 2022 census data is not yet available, health Data by municipality for the catchment; and recent Macro-Economic Classification Data for the Upper catchment.	Socio-economics data that may be marginally inaccurate, however this is unlikely to impact the integrated development zones determined and the scenarios assessments for the classification.	Use the most recent data	Study Team
EWR Quantification	A very low risk as for the Reserve the process to select appropriate EWR sites was comprehensive and additional sites were included as field verifications on the smaller tributaries and EWR determined on a desktop level.	There may be a need to undertake additional sites assessments.	None, assessment of a few sites has been allowed for in the proposal.	Assess and include data for new sites	Study Team

Task description	Risk	Risk description	Risk Implication	Risk mitigation	Risk Owner & Timelines
EWR Quantification	Only biological data at certain sites so hydraulic cross-sections not done	The Reserve study proposed a conceptual Flow Management Plan (FMP) downstream Gariep and Vanderkloof dams with initial interpretation of biological data for immediate evaluation.	Inaccurate hydraulics data that could impact the determination of quantity RQOs	The Reserve study indicated that the WRCS should undertake more rigorous assessment and include as trade-off with socio-economic component. Selected sites will be identified for hydraulic cross-sections to be undertaken and interpreted in more detail.	Study Team
EWR Quantification	Understanding the latest planned developments	The Caledon is a shared resource with Lesotho (upper reaches of Makhalleng and Senqu in Lesotho) and there is a need to ensure the latest planned developments are included accurately.	Inaccurate scenarios assessments.	Some were included as part of the Reserve study, but it will be good to ensure that the final planned dam/ weir sizes and abstractions are used.	Study Team in collaboration with DWS planning Directorate, and relevant ORASECOM representatives
RQOs	Classes and RQOs for the shared resources	Shared resource objectives need to be aligned.	RQOs that are not aligned for shared resources	Link with the ORASECOM transboundary RQO project and get buy in from Lesotho -possibly a Task Team meeting with ORASECOM representatives to agree on a way forward; the study team will also connect and liaise with	DWS and Study teams in collaboration with ORASECOM representatives on the RQO

Task description	Risk	Risk description	Risk Implication	Risk mitigation	Risk Owner & Timelines
				the Transboundary E-flows team.	
Surface water quality assessment	Inadequate current water quality data	Limited and in some cases no water quality data for sites in the catchment	An accurate description of the water quality in some of the catchments may lead to incorrect classification and RQOs determined.	DWS RQIS will be contacted. Additional samples will be taken for water quality assessment and further water quality data from other institutions/ organisations will be sourced. Budget has been included for several samples and any gaps will be prioritised.	Study Team during the first quarter of 2024
Groundwater Assessment	Not sufficient groundwater quantity data coverage	Spatial coverage is a function of exploration exercises – merely hotspot information is available	Underestimation of excessive groundwater uses not measurable	Obtain information from public and [where possible] private sources. Remote sensing sources should be considered. All groundwater monitoring networks to be searched including the DWS Geohydrological Monitoring and Assessment.	Study Team
	Not sufficient groundwater quality data coverage	Poor water quality protection is a concern which could increase the salinity status of aquifer systems	Underestimation of the water quality status and trends of productive aquifer systems. may lead to incorrect	Institutional reports on water quality available, however the data is limited. Propose to work with R/O and prioritise	

Task description	Risk	Risk description	Risk Implication	Risk mitigation	Risk Owner & Timelines
			classification and RQOs determined.	specific sites where samples can be collected to augment the current data.	

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