**DEPARTMENT OF WATER AND SANITATION**

**Chief Directorate: Water Ecosystems Management**

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

## STATUS QUO AND DELINEATION OF INTEGRATED UNITS OF ANALYSIS AND RESOURCE UNITS REPORT
## WP 11438

**Study Report No.**

**RDM/WMA14/00/CON/CLA/0224**

**September 2024**

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| | | |

# TERMINOLOGY AND ABREVIATIONS

| Acronym | Description |
|---|---|
| BIF | Banded Ironstone Formation |
| BHN | Basic Human Needs |
| BYC | Borehole Yield Class |
| CD: WEM | Chief Directorate: Water Ecosystems Management |
| CV | Coefficients of variation |
| CVB | Channelled Valley-Bottom |
| DIN | Dissolved Inorganic Nitrogen |
| DIP | Dissolved Inorganic Phosphorus |
| DWAF | Department of Water Affairs and Forestry |
| DWS | Department of Water and Sanitation |
| EC | Ecological Category |
| ECRU | Estuarine and Coastal Research Unit |
| EFZ | Estuarine Functional Zone |
| EHI | Estuarine Health Index |
| ES | Ecosystem Services |
| EIS | Ecological Importance and Sensitivity |
| EWR | Ecological Water Requirements |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| GRA | Groundwater Resources Assessment |
| GRU | Groundwater Resource Unit |
| HGM | Hydrogeomorphic |
| IUA | Integrated Unit of Analysis |

| Acronym | Description |
|---|---|
| IPBES | International Panel on Biodiversity and Ecosystem Services |
| JBS | Joint Basin Survey |
| IWRMP | Integrated Water Resources Management Plan |
| masl | Meters above sea level |
| LM | Local Municipality |
| LHWP | Lesotho Highlands Water Project |
| MAP | Mean Annual Precipitation |
| MAE | Mean Annual Evaporation |
| MEA | Millennium Ecosystem Assessment |
| MSL | Mean Sea Level |
| $Mm^3$ | Million cubic metres |
| NFEPA | National Freshwater Ecosystem Priority Areas |
| NWA | National Water Act |
| ORS | Orange River System |
| ORP | Orange River Project |
| ORASECOM | Orange-Senqu River Commission |
| PES | Present Ecological Sate |
| PSC | Present Status Category |
| PSU | Practical Salinity Units |
| RDM | Resource Directed Measures |
| REC | Recommended Ecological Category |
| RQIS | Resource Quality Information Services |
| RQOs | Resource Quality Objectives |
| RUs | Resource Units |

| Acronym | Description |
|---|---|
| SANBI | South African National Biodiversity Institute |
| SEZ | Socio-Economic Zones |
| SI | Stress Index |
| SQ | Sub-quaternary |
| SWSA | Strategic Water Source Area |
| TEEB | The Economics of Ecosystems and Biodiversity |
| WARMS | Water Use Authorisation and Registration System |
| UCVB | Unchannelled Valley-Bottom |
| VB | Valley-Bottom |
| WMA | Water Management Area |
| WMS | Water Management System |
| WQPLs | Water Quality Planning Limits |
| WRCS | Water Resource Classification System |
| WRPM | Water Resource Planning Model |
| WRYM | Water Resource Yield Model |
| WWTWs | Wastewater Treatment Works |

# 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 Lower Orange River Catchment. The determination of the water resource classes is necessary to facilitate a balance between protection and use of water resources. The water resource classification system is applied taking account of the local conditions, socio-economic imperatives and system dynamics within the context of the catchment. The process also requires a wide range of complex trade-offs to be assessed and evaluated at a number of scales.

The Orange River catchment, comprising of the Upper Orange and Lower Orange catchments and forming part of the recently gazetted Vaal-Orange WMA (WMA04), is the largest catchment in the country. This catchment covers nearly 50% of the country and forms part of the Orange-Senqu River Basin. It encompasses all of Lesotho, as well as a significant portion of South Africa, Botswana and Namibia. The Orange-Senqu River basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 1 million km$^2$. The Orange River is an international resource shared by these four countries. It is the largest river in South Africa and has significant interdependencies with other WMAs in addition to other countries. The two main tributaries are the Senqu/Upper Orange (Lesotho/South Africa) and the Vaal rivers. At the confluence of the Upper Orange and Vaal rivers at Douglas, the Orange River flows in a westerly direction approximately 2 200km to the west coast entering the Atlantic Ocean through the Orange River Estuary at Alexander Bay. A smaller tributary, the Fish River (from Namibia), joins the Orange River in the Lower Orange catchment.

Other tributaries are the Ongers, Sak and Hartbees rivers from the south draining from the Karoo, the Molopo and Nossob Rivers in Namibia, Botswana and the Northern Cape Province which have not contributed to the Orange River in recorded history as the stream bed is impeded by sand dunes (DWS, 2015); and the Fish River draining the southern part of Namibia.

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

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

This information was then used to delineate socio-economic zones, integrated units of analysis (IUAs) and associated resource units which provide the basis for the next steps of the classification process and the setting of water resource classes. The report presents the delineated preliminary IUAs for the Lower Orange catchment and provides related information and descriptions pertaining to each IUA. The preliminary IUAs will be finalised following stakeholder consultation.

**Integrated Units of Analysis (IUAs)**

Each integrated unit of analysis (IUA) represents a homogenous area which will require its own specification of the water resource class. The process followed in terms of IUA delineation was that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, February 2007).

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

The following was considered for delineation of IUAs within the Lower Orange Catchment:

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

Groundwater resource units (GRUs) were delineated within the surface water IUAs, except where a few quaternary catchments with significantly different hydrogeological characteristics were mapped.

The criteria for the GRUs were based on similar hydrogeological characteristics within the IUAs *i.e.*:

- Aquifer types (*viz*., Intergranular, Fractured, Karts or Fractured & Intergranular);

- Groundwater Regions (*i.e*., the so-called Vegter Groundwater Regions, 2001);
- Aquifer recharge depths (*i.e*., rainfall inputs in annual averages); and
- Borehole Yield Class (*i.e*., estimated sustainable borehole yields in L/s).

Other criteria such as (i) groundwater quality (*i.e*., electrical conductivities in mS/m) (ii) water use, and (iii) depths (meters below ground level (mbgl)) to static water level, were found to be highly variable throughout the quaternary catchments, therefore, a very low weight (<5%) was allocated during the GRU delineation procedure. These parameter variations were merely related to physical/natural characteristics of the groundwater systems in the Lower Orange-Lower Molopo River Catchment.

**IUA Delineation Results**

Ten IUAs have been preliminarily delineated for the Lower Orange catchment. The results of the delineation are tabled below and illustrated in Figure E1. Detailed descriptions of each IUA are presented in the report.

**Table E1: Preliminary Integrated Units of Analysis (IUAs) in the Lower Orange River catchment**

| IUA | Delineation | Quaternary Catchment |
|---|---|---|
| **1** | Orange from Vaal confluence to Augrabies Waterfall | C92C, D71A, D71B, B71C, D71D, D72A, D72B, C72C, D73B, D73C, D73D, D73E, D73F, ~80%D81A |
| **2** | Downstream Augrabies to Pella | Portion of D81A – D81G |
| **3** | Pella to Vioolsdrift weir | D82A – D82G |
| **4** | Downstream Vioolsdrift to Orange River Mouth | D82H, D85J, D82K, D82L |
| **5** | Orange River Mouth | Estuarine Functional Zone boundary in D82L |
| **6** | Ongers/Brak | D61A, D61B, D61C, D61D, D61E, D61F, D61G, D61H, D61J, D61K, D61L, D61M, D62A, D62B, D62C, D62D, D62E, D62F, D62G, D62H, D62J |
| **7** | Hartbees/Sak | D52 - D58 |
| **8** | Coastal Area | F10A to F60A |
| **9** | Upper Molopo and Upper Kuruman | D41B, D41C, D41D, D41E, D41F, D41H, D41K, D41G, D41M |
| **10** | Lower Kuruman and Lower Molopo | D42A, D42B, D42C, D42D, D42E, D81C |

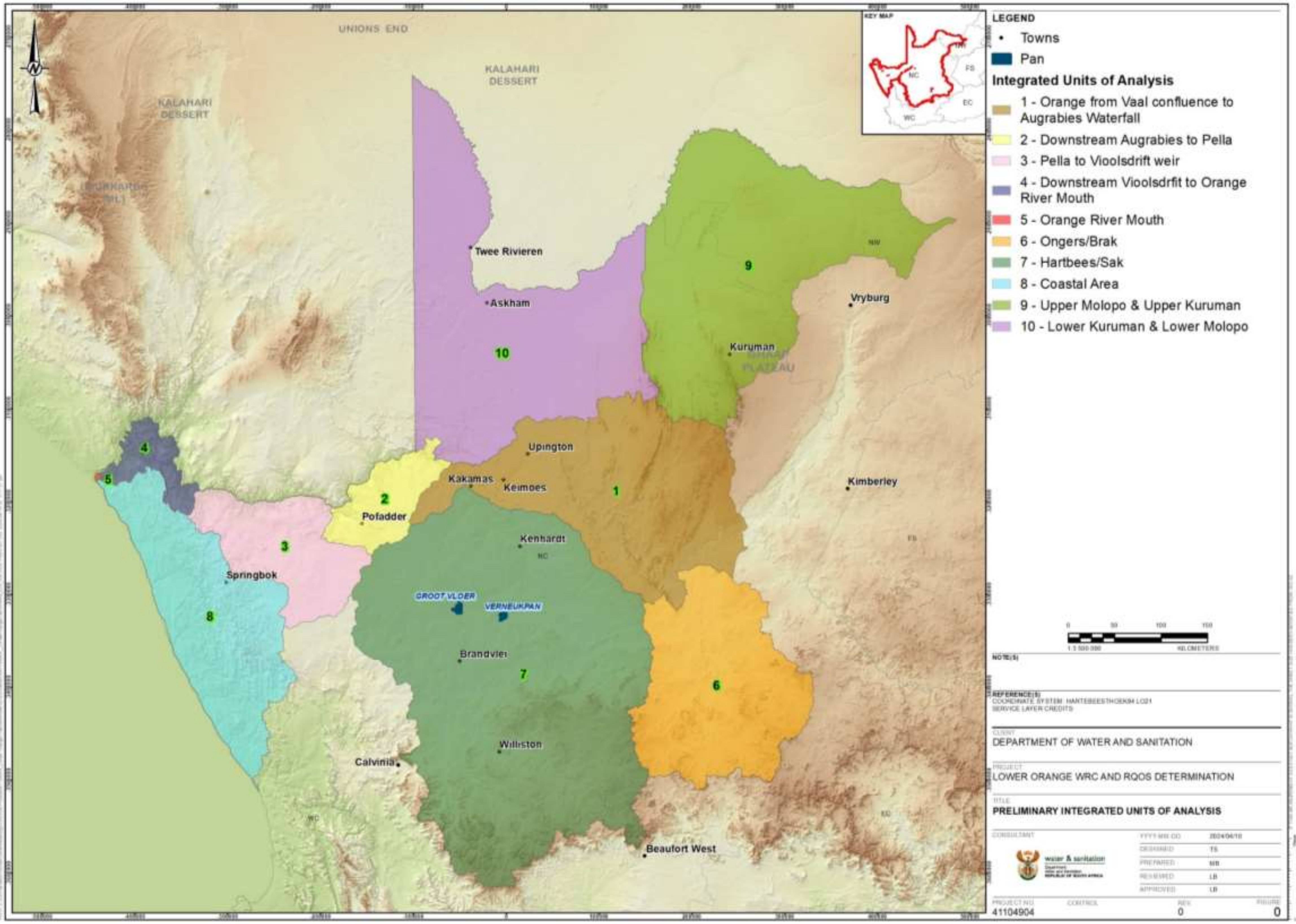


**Figure E1: IUAs delineated in the Lower Orange Catchment**

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# 1 INTRODUCTION

The Chief Directorate: Water Ecosystems Management (WEM) of the Department of Water and Sanitation (DWS) is underway with a study for the determination of Water Resource Classes and associated Resource Quality Objectives (RQOs) in the Lower Orange River Catchment.

Water Resource Classification, the Reserve and 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) (NWA). 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 Lower Orange Catchment within the Vaal-Orange Water Management Area (WMA 4) 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 Lower Orange 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 balances use and protection.

## 1.2. Purpose of this Report

The purpose of the Status Quo and delineation of Integrated Units of Analysis (IUA) and Resource Units (RU) Report is to describe and define the current status quo of the water resources in the study area (rivers, groundwater, wetlands and estuaries) and present the socio-economic assessment of the catchment area. Based on this analysis and understanding, the report presents the delineation of preliminary IUAs for water resource classification. Sections 2 – 8 outline the various approaches adopted during this task and provides the findings of the various status quo assessments and socio-economic analyses. Section 9 and 10 provides information on the delineated IUAs and resources and a description per IUA. References are listed in Section 12.

The steps to be undertaken as required in terms of the 7 step WRCS integrated framework are indicated in Figure 1, with this report comprising the output of Step 2.

**Step 1: Confirm, quantify and finalise EWRs (concurrently with Step 2);**

**Step 2: Describe status quo and delineate the study area into Integrated Units of analysis (IUAs);**

**Step 3: Identify and model scenarios within IWRM, and evaluate with stakeholders ;**

**Step 4: Determine water resource classs based on catchment configurations for identified scenarios;**

**Step 5: Determine resource quality objectives (narrative and numerical limits) (priority resource units, sub-components and indicators);**

**Step 6: Agree on water resource classes and RQOs with stakeholders;**

**Step 7: Finalise and prepare integrated gazette template and implementation plan**

**Figure 1: Water resource classes and RQOs determination in the Lower Orange Catchment (integrated process in adherence to Regulation 810 of Government Gazette 33541**)

## 1.3. Study Area Overview

The Orange River catchment, comprising the Upper Orange and Lower Orange catchments and forming part of the recently gazetted Vaal-Orange WMA (WMA04), is the largest catchment in the country (Figure 2). This catchment covers nearly 50% of the South Africa and forms part of the Orange-Senqu River Basin. It encompasses all of Lesotho, as well as a significant portion of South Africa, Botswana and Namibia. The Orange-Senqu River basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 1 million km$^2$. Co-operation amongst the Orange River Basin countries is facilitated through the Orange-Senqu River Commission (ORASECOM), with membership by the basin countries.

The geographic extent of the Lower Orange catchment area largely corresponds with that of the Northern Cape Province, with very small components falling within the Western Cape, Northwest and Free State Provinces on the southern and eastern boundaries respectively. The Lower Orange catchment is the most downstream of covering the Orange -Vaal River Basin, with most of its water requirements being met from releases from major dams in the Upper Orange catchment. It also borders on three other water management areas. The Orange River is also the main river in this water management area.

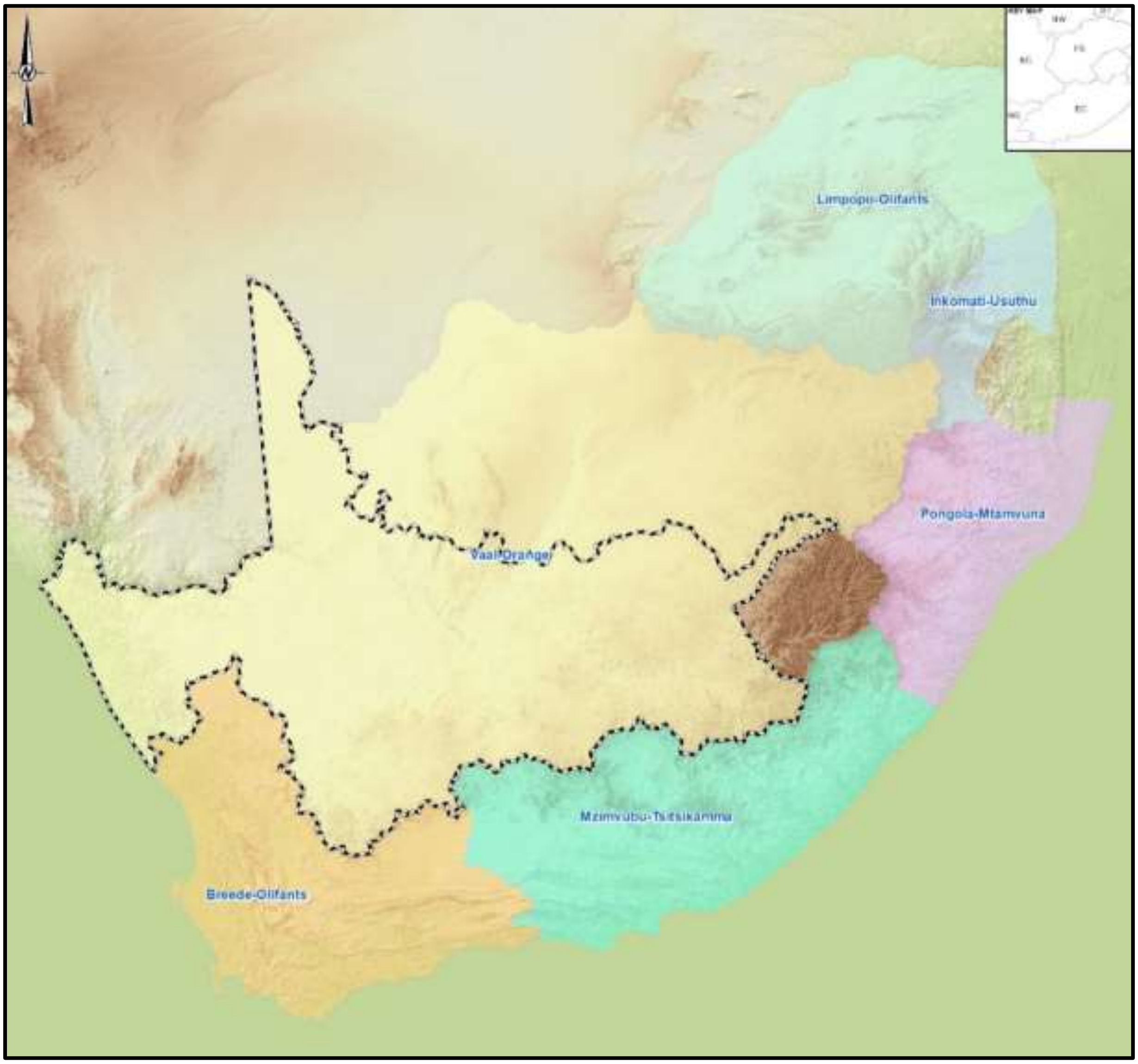



**Figure 2: Orange River Catchment within Vaal- Orange WMA (WMA04) in South Africa**

The Orange River is the largest river in South Africa and has significant interdependencies with other WMAs as well as other countries. The two main tributaries are the Senqu/Upper Orange (Lesotho/South Africa) and the Vaal rivers. The headwaters of the Senqu rise in the Maluti mountain range in Lesotho Highlands, while the Vaal River, rises on the eastern highveld escarpment in north-east South Africa.

At the confluence of the Upper Orange and Vaal rivers at Douglas, the Lower Orange River flows in a westerly direction to the west coast entering the Atlantic Ocean at Alexander Bay. A smaller tributary, the Fish River (draining the southern part of Namibia), joins the Orange River in the Lower Orange catchment. Other tributaries are the Ongers, Sak and Hartbees, Molopo and Nossob Rivers in Namibia, Botswana and the Northern Cape.

The Ongers, Sak and Fish River tributaries drain arid and semi-arid regions. The flows in these rivers are very infrequent and will only contribute to the Orange River's flow during periods of relatively high rainfall. The contribution from these rivers to the firm yield of the Orange River is small (DWS, 2015). There are a number of highly intermittent water courses along the coast which drain directly to the ocean.

Water is abstracted for irrigation, urban and mining use along the main stem of the Orange River at various points, and for stock watering in the Kalahari. Water is also transferred via pipelines to the Aggenys mines and to the town of Springbok. The main towns in the catchment area include Upington, Springbok, Pofadder, Kakamas, Keimoes, De Aar, Prieska, Kenhardt, Sutherland Brandveli and Williston. Irrigation is by far the dominant water use sector in the Lower Orange, representing 90% of the total requirements for water. Economic activity is largely concentrated along the Orange River, with several towns located on the banks of the river, and at mining developments.

Mining operations in the Lower Orange include underground and surface mines as well as quarries. Products of the mining industry in the Lower Orange are predominantly alluvial diamonds, copper and salt. Base metals are also mined. There are a few quarries providing stone aggregate and gravel. Minerals and water from the Orange River are the key elements for economic development in the region. There are no large urban developments or power stations in the catchment. Due to the arid climate, no afforestation occurs.

Groundwater is an extremely valuable source in the Lower Orange catchment. It is the most important source of bulk water supply to local towns and rural settlements where it is the primary source (Ongers, Hartbees, Kuruman and Molopo sub-catchments). Among the more valued natural resources in the river basin is a transboundary Ramsar protected wetland at the mouth of the Orange River. Important nature conservation areas include the Kgalagadi Transfrontier Park, the Ai-Ais-Richtersveld Transfrontier Park, and the Augrabies Falls National Park.

The Orange River is of critical importance to South Africa in that it augments the Vaal River System through the Lesotho Highlands Water Project and supplies the economic heartland of South Arica. It also supplies thermal power stations on the Highveld, irrigation schemes covering large areas along the Vaal, middle and lower Orange Rivers, and domestic water to millions of people dependent on secure water supplies from this basin.

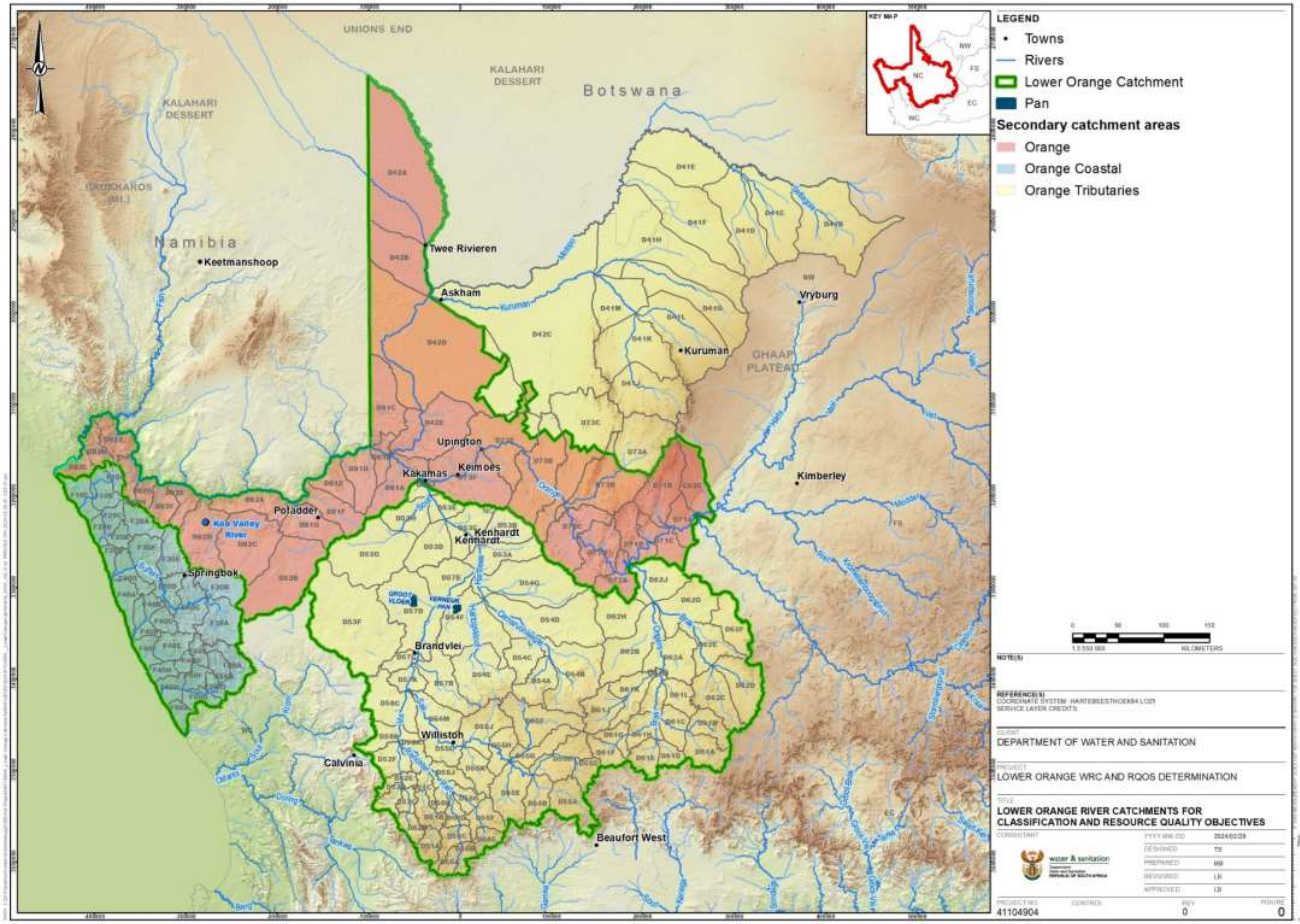



**Figure 3: Lower Orange River catchment – Study Area extent and Locality (South African Portion)**

# 2 STATUS QUO: WATER RESOURCES AND SYSTEM ANALYSIS

## 2.1. Description of Water Resources

The Lower Orange includes the stretch of the Orange River between the Orange-Vaal confluence and Alexander Bay. The Orange River, which forms a green strip in an otherwise arid but beautiful landscape, also forms the border between South Africa and Namibia, flowing over a distance of approximately 550 km. The Lower Orange catchment is the largest, but also the driest and most sparsely populated catchment in South Africa. The area is characterised by a harsh climate with minimal rainfall and prolonged droughts, sometimes to be terminated by severe flooding. The area is mostly arid with rainfall varying from 400mm in the east to 50mm on the west coast. Rainfall usually occurs during late summer to autumn. The topography of the area is in general flat, including large pans or endhoreic areas that do not contribute to runoff reaching the main Orange River. The average mean annual potential evaporation for this area is 2600 mm/a (DWS, 2016).

The two main tributaries of the Orange River are the Senqu/Upper Orange (Lesotho/South Africa) and the Vaal rivers. The headwaters of the Senqu rise in the Maluti mountain range in Lesotho Highlands, while the Vaal River, rises on the eastern highveld escarpment in north-east South Africa. At the confluence of the Upper Orange and Vaal rivers at Douglas, the Orange River flows in a westerly direction approximately 2 200 km to the west coast entering the Atlantic Ocean through the Orange River Estuary at Alexander Bay. The major tributaries from the north include:

- the Molopo, Kuruman and Nossob Rivers in Namibia, Botswana and the Northern Cape Province; and
- the Fish River draining the southern part of Namibia.

Major tributaries to the Lower Orange River from the south draining the Karoo include:

- the Ongers River,
- the Sak River, and
- the Hartbees River.

The lower Orange River discharges via the Orange River Estuary, a delta type river mouth which comprises a distributor channel system between sand banks covered with pioneer vegetation, a tidal basin and the saltmarsh on the south bank of the mouth. The Orange River Estuary lies along the town of Alexander Bay and is of national importance.

The Lower Orange catchment include five other estuaries of national importance which are the Buffels, Sout, Swartlintjies, Spoeg and Groen estuaries. These smaller Buffels, Sout, Swartlintjies, Spoeg and Groen estuaries are all classified as Arid Predominantly Closed estuaries.

Groundwater in the Lower Orange catchment occurs in a large range of aquifer systems varying from younger semi-consolidated (Cenozoic) sedimentary sequences, large spatial sequences of Karoo Supergroup (Paleozoic) and Nama Group (Namibian) sedimentary sequences that overly highly variable meta-sedimentary and metamorphic rocks towards the lower part of the Lower

Orange. Aquifers within the study area include intergranular, fractured contact-zone, fractured hard rock, fractured and intergranular and karst aquifer systems.

Six wetland types have been identified in the Lower Orange Catchment. They include seeps, depressions (pans), unchanneled valley bottom, channelled valley bottom, floodplain and flats, which are associated with major rivers in the catchment (Orange, Molopo, Auob and Nossob). Wetlands systems are associated with the Orange River mouth (which is a RAMSAR site).

High priority depressions/pans are numerous in the catchment, some of which are extensive (e.g. Verneuk Pan, Grootvloer, Boesmankop and Bitterputs - in excess of thousands of hectares (DWS, 2016)). Floodplains are typically restricted to in-channel features and do not consist of typical meandering floodplains on riverbanks. Channelled valley bottom wetlands are most prevalent in the eastern and central extents of the Orange tributaries secondary catchment area, and southern extent of the Orange coastal secondary catchment area, associated with the Brak and Buffels River catchments respectively. Seeps also occur at a lower density in the catchment, with most extensive areas being situated along the headwaters of the Harts and Vis rivers.

### 2.1.1. Catchment Boundaries

The Lower Orange is the only river mainstem making up the lower D drainage region comprising of the secondary drainage regions D4 to D8 (refer to Figure 3). It comprises only the South African portion of the Lower Orange River Catchment that includes the tertiary catchment areas portions of C92B, C92C, portions of D41, D42, D51 to D58, D61, D62, D71 to D73 (excluding some portions D73), D81, D82 and primary catchment F with some exclusions as set out in Table 1 (and shown in Figure 3). The lower portions of quaternary catchments C92B and C92C (lower Vaal) are included in this catchment as it follows the boundary of the Orange Vaal Water User Association. Quaternary catchment F60A is also included.

**Table 1: Sub-catchment areas of the Lower Orange River catchment**

| Secondary Catchment | Tertiary Catchment | Quaternary catchments | River/s | Catchment area(1) ($km^2$) | |
|---|---|---|---|---|---|
| | | | | Gross | Net |
| C9 | C92 | C92B, C92C | Vaal | 3938 | 1324 |
| D4 | D41 | D41B-M | Molopo, Kuruman | 54 045 | 30173 |
| | D42 | D42A- D42E | Molopo, Kuruman, Nossob, Auob | 33898 | 31872 |
| D5 | D51 | D51A-D51C | Renoster, Dorps, Kariega, Boesmanfontein se laagte | 2192 | 2192 |
| | D52 | D52A-D52F | Vis, Visrivier-oos, Visrievier-wes, Muiskraal, Kookfontein, Hottentotsfontein se Laagte | 2750 | 2750 |
| | D53 | D53A-D53J | Hartbees, Mottels, Klein-Lat, Rugseers, Rooiput se Leegte, Rougas se Loop, Driekop se, Tuins, Graafwaters, Sandnoute, Rietfontein, Brulkolk se | 23050 | 20527 |

| Secondary Catchment | Tertiary Catchment | Quaternary catchments | River/s | Catchment area[1] (km²) | |
|---|---|---|---|---|---|
| | | | | Gross | Net |
| | | | Holte, Soutputs, Souts se Laagte, Steenkampsvlei se Holte | | |
| | D54 | D54A-D54G | Hartbees, Holsloot, Kalksloot, Carnarvonleegte, Boesak, Bitterpoortloop, Renosterpoort se Leegte, Bloudrif, Ysterdoringspan, Botterslaagte, Vernuekpan, Hartogskloof, Bloubosleegte, Keelafsnyleegte, Brandholteloop, Bastersput se Leegte, Lekkerleleegte, Elandsfontein | 23622 | 15640 |
| | D55 | D55A-D55M | Sak, Brak, Sout, Klein-Sak, Rietfontein, Damfontein se, Klein-Brak, Slangfontein, Soutpoort, Reitzvilleleegte, Kareebergleegte, Alarmleegte, Stofkraalleegte, Platkuil, Gansvlei, Palmietfontein se Loop, Draaiwal se Leegte, Beeswaterleegte, Hongerkloof se Leegte, Ploegfontein se Leegte, Witleegte, Rietfonteinleegte, Tulbaghlaagte, Wielkolkslaagte | 19398 | 19225 |
| | D56 | D56A-D56J | Riet, Portugals, Klein-Riet, Wolwe, Nuweveld, Karee, Elands, Valslaagte, Leenderts | 6303 | 6303 |
| | D57 | D57A-D57E | Sak, Soutsloot, Swartbosleegte, Rooidam se Laagte, Soutsloot, Kettingkop se Laagte, Knapsaklaagte, Bosduiflaagte | 10165 | 6197 |
| | D58 | D58A-D58C | Vis, Renoster, Klein-Vis, Dassiesstraatlaagte | 763 | 763 |
| D6 | D61 | D61A-D61M | Ongers, Brak, Klein-Brak, Lakenrivier, Brakpoort, Pretoriuskuil se Leegte, Visgatspruit, Vis, Groen, Biesiekuilleegte, Gaafwaterspruit | 13405 | 12426 |
| | D62 | D62A-D62J | Ongers, Brak, Sand, Elandsfontein, Renostervleispruit, Hondeblafspruit | 20328 | 12178 |
| D7 | D71 | D71A-D71D | Orange, Withoekskloof, Lanyon spruit | 7390 | 4792 |
| | D72 | D72A-D72C | Prieska, Karabeeloop, Rooiloop, Kat, Marydale | 6742 | 5714 |
| | D73 | D73A-D73F | Orange, Sout, Brak, Groenwaterspruit, Skeifonteinspruit, Soutloop, Eselfontein, Helbrandleegte, Kareeboom, Vaalputs, Kameel, Neusspruit | 25968 | 11080 |

| Secondary Catchment | Tertiary Catchment | Quaternary catchments | River/s | Catchment area[(1)] ($km^2$) | |
|---|---|---|---|---|---|
| | | | | Gross | Net |
| D8 | D81 | D81A-D81G | Orange, Slang, Brak, Brabees, Wegsteek se Laagte, Bak, Bul, Nous, Kaboep, Koeiamlaagte, Goob se Laagte | 12809 | 10975 |
| | D82 | D82A-D82L | Orange, Mik, Fontein se, Nam se Laagte, Kirrie, Matjies, Koubank, Kosies, Geelfontein, Groen, Kahams, Abiekwa, Gannakouriep, Bloubos, Annis, Khubus | 20212 | 18185 |
| F | F10 | F10A-F10C | Holgat, Gaigas, Kook | 2725 | 1335 |
| | F20 | F20A-F20E | Kamma, Kwaganap | 3137 | 2899 |
| | F30 | F30A-F30G | Buffels, Brak, Gasab, Papkuils, Klein-Nou, Jaagleegte, Drodab, Melk, Wolwepoort, Skaap, Doring, Stry | 9756 | 9460 |
| | F40 | F40A-F40H | Wildeperdehoek se Brak, Swartlintjies, Spoeg, Bitter, Brand, Outeep | 5346 | 3783 |
| | F50 | F50A - F50G | Hartbees, Groen, Swart-Doring | 4869 | 4600 |
| | F60 | F60A | Brak | 572 | 386 |

[1]WR2012 data (Gross catchment refers to the total area; Net catchment is the reduced area where the rainfall does not report as runoff)

The Lower Orange catchment has been divided into three sub-areas for water resource planning analysis based on watershed boundaries. These are described in Table 2 and shown in Figure 4. 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 and economic development. These sub-areas have no administrative weighting (DWS, 2004).

**Table 2: Sub-areas of the Lower Orange catchment**

| Sub-area | Description | Tertiary drainage regions | Catchment area[(1)] ($km^2$) |
|---|---|---|---|
| **Orange** | The catchment of the lower Orange River over the whole of its length through the catchment, together with minor tributaries of Fish and Molopo. | D41, D42, D7, D8 and C92 | 165 002 |
| **Orange Tributaries** | The catchment of comprising the catchments of the Ongers and Hartebees Rivers and of smaller tributaries of Sak and Brak. | D50 and D60 | 121 976 |
| **Orange Coastal** | The catchment of the mostly dry water courses which lead directly to the ocean (includes the smaller estuaries) | F10, F20, F30, F40, F50 and F60A | 26 405 |

[1]WR2012 data

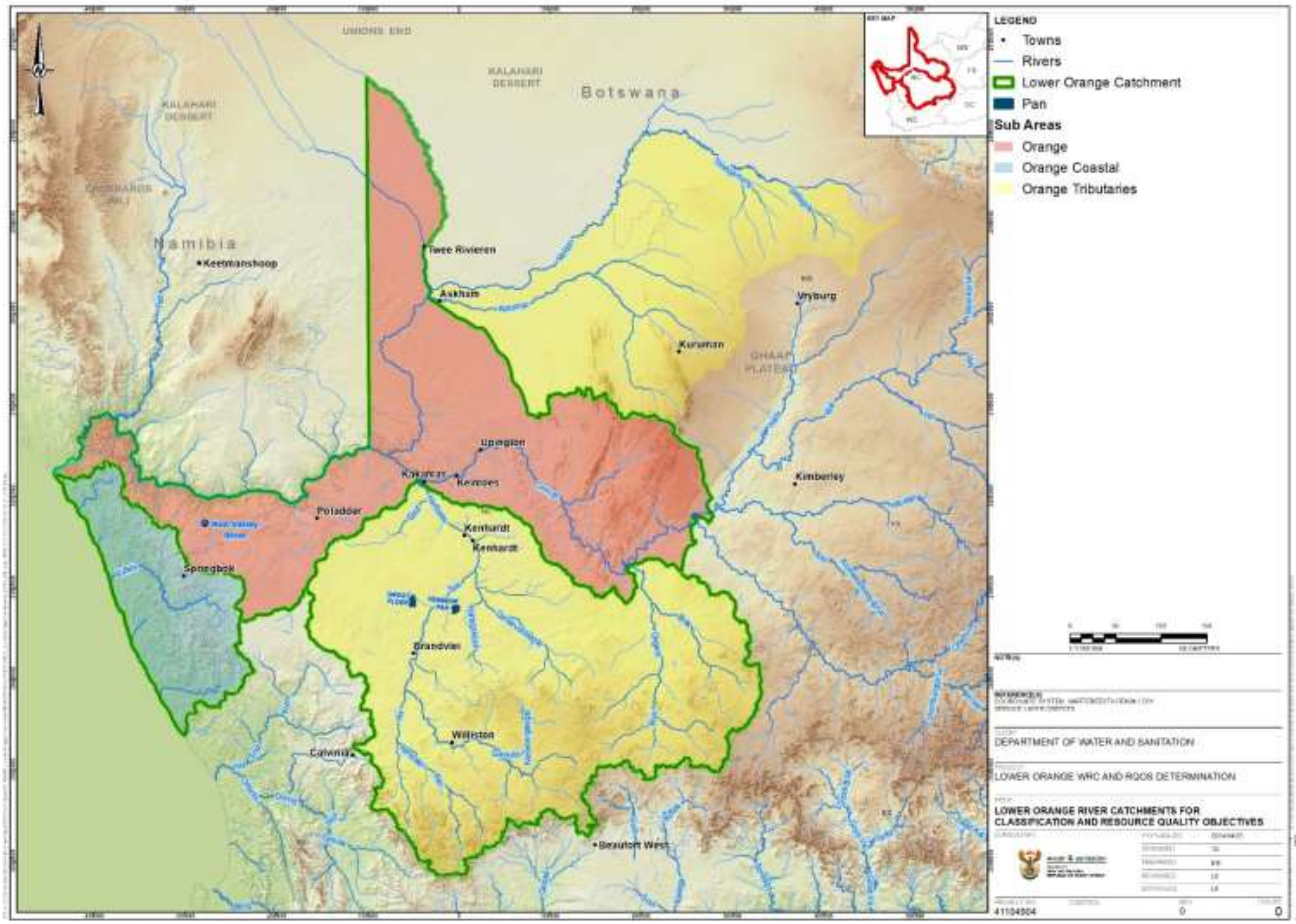



**Figure 4: Key sub-areas of the Lower Orange catchment**

### 2.1.2. Strategic Water Source Areas

Parts of the catchment area of the Lower Orange catchment have been identified and delineated as strategic water source areas (SWASAs) in South Africa (WRC, 2018).

Water source areas (or "Water Towers" as they are also referred to) are natural areas that provide disproportionate (*i.e.* relatively large) volumes of surface water and/or groundwater water per unit area, or which meet critical social, economic and environmental water requirements and provide water security. Strategic Water Source Areas (SWSAs) are a subset of water source areas that are considered of strategic significance for water security (WRC, 2018). Surface-water SWSAs are found in areas with high rainfall and produce most of the runoff. Groundwater SWSAs includes areas that contribute to the baseflow in their areas, areas of high recharge (>65mm/a) or recharge ratio (1.5), serve as groundwater source linked to water supply systems for towns/village clusters (>50%), groundwater use >0.3 l/s/km$^2$ or groundwater supply to area of national economic significance.

Water source areas are critical because they produce large volumes of water that sustain people locally and regionally and, in the case of groundwater, are often the only sustainable and reliable water source. In terms of WRC (2018), SWSAs have been identified and delineated if the area of land either:

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

(b) has a high groundwater recharge, serves as a sole water source and are locations where the groundwater forms a nationally important resource; or

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

Within the Lower Orange catchment, only groundwater SWSAs are present of either national or sub-national importance (Table 3). Groundwater from groundwater SWSAs tends to be used locally.  In the Lower Orange groundwater serves as the sole source of water to many towns and settlements supplying more than 50% of use.

**Table 3: Groundwater Strategic Water Source Areas in the Lower Orange Catchment**

| Number | Groundwater SWSA | National or Sub-national | Area (km$^2$) |
|---|---|---|---|
| 6 | De Aar Region | National | 2475 |
| 7 | Eastern Kalahari A | National | 2010 |
| 8 | Eastern Kalahari B | National | 2656 |
| 18 | Northern Ghaap Plateau | National | 6274 |
| 26 | Sishen/Kathu | National | 4827 |
| 27 | Southern Ghaap Plateau | National | 6542 |
| 41 | Carnarvon | Sub-national | 659 |
| 45 | Kamieskroon | Sub-national | 3 314 |
| 46 | Komaggas Cluster | Sub-national | 364 |

| Number | Groundwater SWSA | National or Sub-national | Area (km$^2$) |
|---|---|---|---|
| 48 | Loxton | Sub-national | 397 |
| 51 | Port Nolloth | Sub-national | 592 |
| 53 | Sutherland | Sub-national | 1253 |

### 2.1.3. Climate change

The climate change related impacts in respect of rainfall for the Lower Orange catchment based on the DWS National Integrated Water Information System (NIWIS) data supplied by the DWS (https://www.dws.gov.za/niwis2/ClimateChange), are illustrated in Figure 6. The figures illustrate rainfall for the period 1975 – 2006 and predicted rainfall ranges for the period 2016 – 2045. The rainfall falls within the range of 63 mm to over 496 mm/a.

Table 4 illustrates the percentage rainfall change for the sub-quaternary catchments (quinaries) for the period 1975 to 2006 compared to the period 2016 to 2045 (DWS, NIWIS).

The percentage rainfall change ranges between a decrease of 13% rainfall to an increase of 24% for the lower Orange River from Vioolsdrift to the Mouth. The biggest increase (24%) is expected to be seen in the western coastal catchment areas, specifically F10-60A areas. The Ongers, Hartbees, Sak, Molopo Rivers, and Orange mainstem are expected to experience a 7% - 13% rainfall decrease. Most of the catchment area is expected to experience a decrease in rainfall of more than 1%, with the tributary catchments of the Hartbees are expected to experience changes between 0% to an increase of 3% in D51C, D52B-D, D52F, D53A-B, D53F, D54G, D55K, D56, D57, D58D-H, D57A, D57C, D58B, D58F.

The Phase II of the ORASECOM Basin Wide Integrated Water Resources Management Plan Study included a work package (Work Package 4) to assess global climate change as related to the Orange-Senqu Basin (ORASECOM, 2011). The objective of the assessment was to downscale the results of global climate simulations according to the energy technology emission scenario for the Orange River basin in Southern Africa (IPCC, 2000). The downscaling was carried out by two complementary approaches: One uses the dynamical regional climate model CCLM, whereas second model (STAR II) uses a statistical method. The regional climate models CCLM and STAR were used in order to determine characteristics of the future climate in the Orange River basin, up to the year 2060 (ORASECOM, 2011).

The results of the assessment, indicate that for the period up to 2060, CCLM predicts a temperature increase for the whole basin. For parts of the basin, the temperature increase is projected to be larger than 2°C. For the rainfall, CCLM predicts a decrease throughout the river basin, but due to the validation results, this prediction was not considered to be reliable.

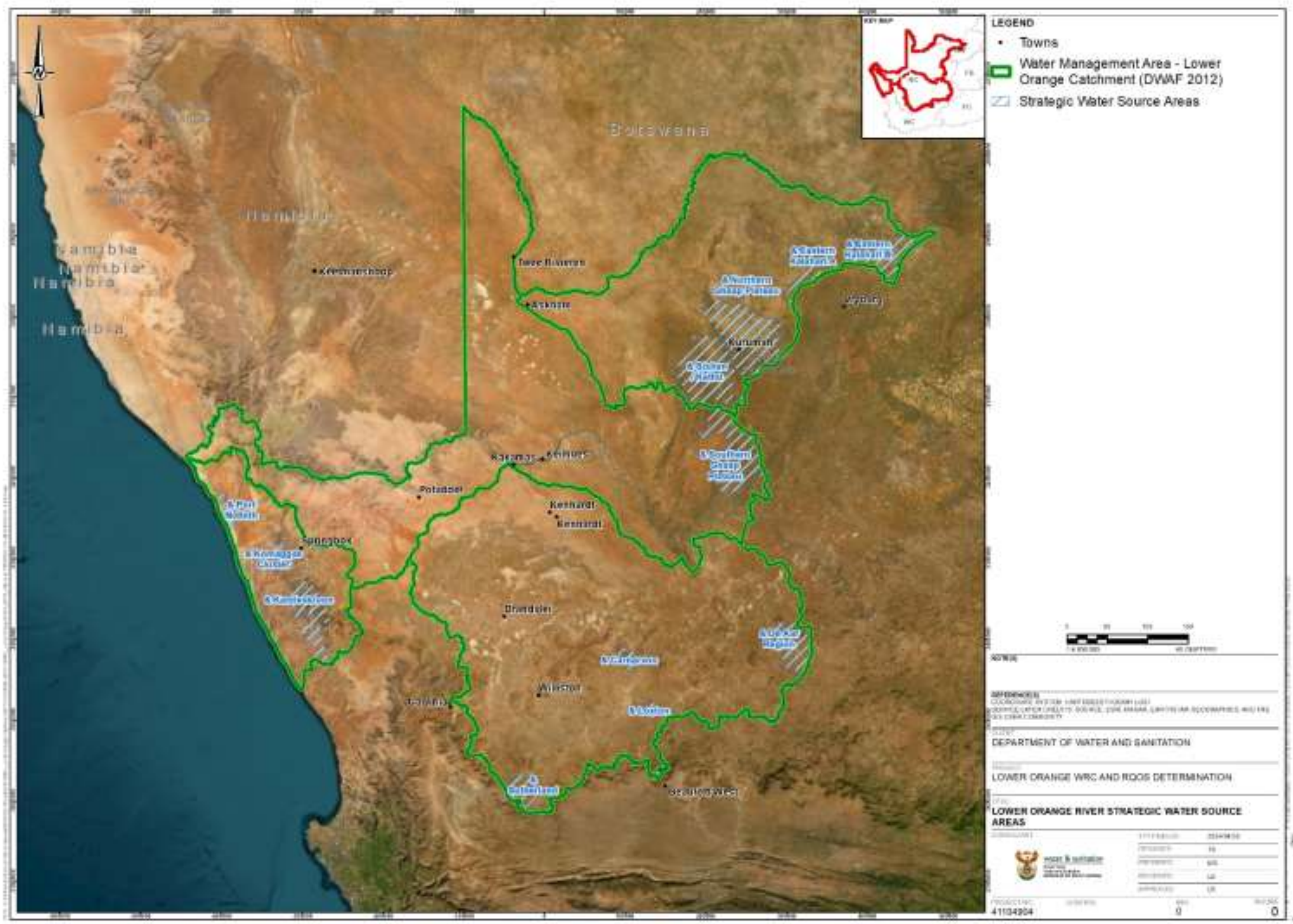



**Figure 5: Strategic Water Source Areas delineated within the Lower Orange Catchment**

For the period 2011 to 2060, in an average scenario the STAR predicts that the temperature in the Orange River basin will increase by over 2°C, with the strongest increase in the centre of the basin (especially in the southern Kalahari) and the smallest at the Orange River Mouth. The analysis results in a small decrease of annual rainfall (down to -80mm/a) for most of the Orange/Senqu river basin. The rainfall decrease is evenly spread across the basin. The dry season scenario indicates a decrease of 140mm/a in rainfall and the wet season a decrease 100mm/a. For the scenarios run, all indicated an increase in rainfall in eastern Lesotho and in the east of South Africa of 80mm/a (ORASEOM, 2011).

**Table 4: Percentage change in Rainfall for the Orange catchment for the period 1975 to 2006 and the future period 2016 - 2045**

| Quinary Catchment | % change (1975 -2006) compared to 2016 -2045 | Quinary Catchment | % change (1975 -2006) compared to 2016 - 2045 | Quinary Catchment | % change (1975 - 2006) compared to 2016 -2045 | Quinary Catchment | % change (1975 -2006) compared to 2016 - 2045 |
|---|---|---|---|---|---|---|---|
| F10A1 | 14% | D41F1 | 1% | D55B3 | -7% | D61M2 | -9% |
| F10A2 | 15% | D41F2 | 7% | D55C1 | -9% | D61M3 | -12% |
| F10A3 | 15% | D41F3 | 3% | D55C2 | -9% | D62A1 | -12% |
| F10B1 | 22% | D41G1 | 4% | D55C3 | -9% | D62A2 | -13% |
| F10B2 | 23% | D41G2 | 5% | D55D1 | -12% | D62A3 | -13% |
| F10B3 | 21% | D41G3 | 0% | D55D2 | -8% | D62B1 | -6% |
| F10C1 | 24% | D41H1 | 0% | D55D3 | -9% | D62B2 | -6% |
| F10C2 | 24% | D41H2 | 2% | D55E1 | -2% | D62B3 | -7% |
| F10C3 | 24% | D41H3 | 3% | D55E2 | -1% | D62C1 | -5% |
| F20A1 | 13% | D41J1 | -2% | D55E3 | -1% | D62C2 | -6% |
| F20A2 | 12% | D41J2 | -1% | D55F1 | -12% | D62C3 | -6% |
| F20A3 | 20% | D41J3 | -3% | D55F2 | -11% | D62D1 | -6% |
| F20B1 | 19% | D41K1 | -2% | D55F3 | -8% | D62D2 | -6% |
| F20B2 | 10% | D41K2 | -2% | D55G1 | -11% | D62D3 | -5% |
| F20B3 | 10% | D41K3 | -6% | D55G2 | -12% | D62E1 | -7% |
| F20C1 | 23% | D41L1 | 1% | D55G3 | -8% | D62E2 | -8% |
| F20C2 | 23% | D41L2 | -2% | D55H1 | -9% | D62E3 | -7% |
| F20C3 | 20% | D41L3 | -1% | D55H2 | -9% | D62F1 | -8% |
| F20D1 | 18% | D41M1 | -3% | D55H3 | -9% | D62F2 | -8% |
| F20D2 | 10% | D41M2 | -2% | D55J1 | -9% | D62F3 | -9% |
| F20D3 | 10% | D41M3 | -8% | D55J2 | -5% | D62G1 | -6% |
| F20E1 | 11% | D42A1 | 4% | D55J3 | -6% | D62G2 | -6% |
| F20E2 | 12% | D42A2 | 0% | D55K1 | 0% | D62G3 | -11% |
| F20E3 | 11% | D42A3 | 0% | D55K2 | 0% | D62H1 | -5% |
| F30A1 | 16% | D42B1 | -1% | D55K3 | 1% | D62H2 | -4% |
| F30A2 | 0% | D42B2 | 1% | D55L1 | -1% | D62H3 | -7% |

| Quinary Catchment | % change (1975 -2006) compared to 2016 -2045 | Quinary Catchment | % change (1975 -2006) compared to 2016 - 2045 | Quinary Catchmen t | % change (1975 - 2006) compare d to 2016 -2045 | Quinary Catchmen t | % change (1975 -2006) compared to 2016 - 2045 |
|---|---|---|---|---|---|---|---|
| F30A3 | 2% | D42B3 | 1% | D55L2 | -4% | D62J1 | -11% |
| F30B1 | -3% | D42C1 | -1% | D55L3 | -3% | D62J2 | -11% |
| F30B2 | -1% | D42C2 | -2% | D55M1 | -6% | D62J3 | -8% |
| F30B3 | 9% | D42C3 | -3% | D55M2 | -2% | D71A1 | -2% |
| F30C1 | 21% | D42D1 | -1% | D55M3 | -3% | D71A2 | 0% |
| F30C2 | 8% | D42D2 | -4% | D56F1 | -2% | D71A3 | -5% |
| F30C3 | 4% | D42D3 | -2% | D56F2 | 3% | D71B1 | -4% |
| F30D1 | 7% | D42E1 | -1% | D56F3 | 2% | D71B2 | -1% |
| F30D2 | 13% | D42E2 | 0% | D56G1 | 1% | D71B3 | 0% |
| F30D3 | 15% | D42E3 | -1% | D56G2 | 1% | D71C1 | -3% |
| F30E1 | 4% | D51A1 | -2% | D56G3 | 1% | D71C2 | -3% |
| F30E2 | 19% | D51A2 | -1% | D56H1 | -2% | D71C3 | -3% |
| F30E3 | 21% | D51A3 | -2% | D56H2 | 1% | D71D1 | -4% |
| F30F1 | 21% | D51B1 | -3% | D56H3 | 1% | D71D2 | -6% |
| F30F2 | 21% | D51B2 | -4% | D56J1 | 0% | D71D3 | -6% |
| F30F3 | 21% | D51B3 | -4% | D56J2 | 1% | D72A1 | -3% |
| F30G1 | 13% | D51C1 | 1% | D56J3 | 1% | D72A2 | -5% |
| F30G2 | 13% | D51C2 | 0% | D56A1 | 5% | D72A3 | -8% |
| F30G3 | 12% | D51C3 | 0% | D56A2 | 4% | D72B1 | -4% |
| F40A1 | 6% | D52A1 | -1% | D56A3 | 2% | D72B2 | -4% |
| F40A2 | 5% | D52A2 | -1% | D56B1 | 1% | D72B3 | -5% |
| F40A3 | 10% | D52A3 | 0% | D56B2 | -3% | D72C1 | -6% |
| F40B1 | 13% | D52B1 | -4% | D56B3 | -4% | D72C2 | -2% |
| F40B2 | 13% | D52B2 | 2% | D56C1 | 5% | D72C3 | -2% |
| F40B3 | 13% | D52B3 | 0% | D56C2 | -1% | D73B1 | -4% |
| F40C1 | 11% | D52C1 | 0% | D56C3 | 2% | D73B2 | -4% |
| F40C2 | 5% | D52C2 | 1% | D56D1 | -3% | D73B3 | -5% |
| F40C3 | 12% | D52C3 | -3% | D56D2 | 2% | D73D1 | -4% |
| F40D1 | 13% | D52D1 | 1% | D56D3 | -2% | D73D2 | -1% |
| F40D2 | 8% | D52D2 | 0% | D56E1 | 1% | D73D3 | -3% |
| F40D3 | 9% | D52D3 | -2% | D56E2 | 2% | D73E1 | 0% |
| F40E1 | 16% | D52E1 | 0% | D56E3 | 2% | D73E2 | -2% |
| F40E2 | 5% | D52E2 | -3% | D57A1 | 1% | D73E3 | -2% |
| F40E3 | 5% | D52E3 | -2% | D57A2 | 1% | D73F1 | 1% |
| F40F1 | 6% | D52F1 | -1% | D57A3 | 2% | D73F2 | -3% |
| F40F2 | 8% | D52F2 | -1% | D57B1 | -5% | D73F3 | 0% |
| F40F3 | 12% | D52F3 | 0% | D57B2 | -5% | D81A1 | -1% |

| Quinary Catchment | % change (1975 -2006) compared to 2016 -2045 | Quinary Catchment | % change (1975 -2006) compared to 2016 - 2045 | Quinary Catchmen t | % change (1975 - 2006) compare d to 2016 -2045 | Quinary Catchmen t | % change (1975 -2006) compared to 2016 - 2045 |
|---|---|---|---|---|---|---|---|
| F40G1 | 17% | D53A1 | -2% | D57B3 | -9% | D81A2 | -2% |
| F40G2 | 17% | D53A2 | -1% | D57C1 | 0% | D81A3 | -2% |
| F40G3 | 16% | D53A3 | -5% | D57C2 | 0% | D81B1 | 1% |
| F40H1 | 9% | D53B1 | -2% | D57C3 | 1% | D81B2 | 0% |
| F40H2 | 9% | D53B2 | -1% | D57D1 | -4% | D81B3 | -1% |
| F40H3 | 14% | D53B3 | -4% | D57D2 | -4% | D81C1 | -4% |
| F50A1 | -2% | D53C1 | -2% | D57D3 | -3% | D81C2 | -4% |
| F50A2 | -3% | D53C2 | -5% | D57E1 | -6% | D81C3 | -8% |
| F50A3 | 12% | D53C3 | -5% | D57E2 | -4% | D81D1 | -5% |
| F50B1 | 17% | D53D1 | -7% | D57E3 | -5% | D81D2 | 0% |
| F50B2 | 11% | D53D2 | -7% | D58A1 | -4% | D81D3 | 1% |
| F50B3 | 12% | D53D3 | -7% | D58A2 | -1% | D81E1 | -5% |
| F50C1 | 13% | D53E1 | -3% | D58A3 | 0% | D81E2 | -7% |
| F50C2 | 13% | D53E2 | -2% | D58B1 | 0% | D81E3 | -7% |
| F50C3 | 13% | D53E3 | -2% | D58B2 | 0% | D81F1 | -5% |
| F50D1 | 13% | D53F1 | -7% | D58B3 | 0% | D81F2 | -7% |
| F50D2 | 14% | D53F2 | 1% | D58C1 | 1% | D81F3 | -9% |
| F50D3 | 13% | D53F3 | 1% | D58C2 | 0% | D81G1 | -6% |
| F50E1 | 12% | D53G1 | -4% | D58C3 | 3% | D81G2 | -8% |
| F50E2 | 17% | D53G2 | -4% | D61A1 | -8% | D81G3 | -7% |
| F50E3 | 17% | D53G3 | -6% | D61A2 | -7% | D82A1 | -7% |
| F50F1 | 11% | D53H1 | -2% | D61A3 | -7% | D82A2 | -7% |
| F50F2 | 12% | D53H2 | -3% | D61B1 | -6% | D82A3 | -6% |
| F50F3 | 13% | D53H3 | -3% | D61B2 | -7% | D82B1 | -6% |
| F50G1 | 14% | D53J1 | -3% | D61B3 | -8% | D82B2 | -4% |
| F50G2 | 11% | D53J2 | -3% | D61C1 | -9% | D82B3 | -7% |
| F50G3 | 15% | D53J3 | -3% | D61C2 | -9% | D82C1 | -6% |
| F60A1 | 14% | D54A1 | -9% | D61C3 | -8% | D82C2 | -3% |
| F60A2 | 20% | D54A2 | -8% | D61D1 | -7% | D82C3 | -9% |
| F60A3 | 20% | D54A3 | -9% | D61D2 | -9% | D82D1 | 4% |
| F60B1 | 10% | D54B1 | -7% | D61D3 | -7% | D82D2 | 4% |
| F60B2 | 15% | D54B2 | -8% | D61E1 | -7% | D82D3 | 2% |
| F60B3 | 17% | D54B3 | -12% | D61E2 | -12% | D82E1 | 4% |
| F60C1 | 13% | D54C1 | -8% | D61E3 | -9% | D82E2 | 1% |
| F60C2 | 17% | D54C2 | -8% | D61F1 | -12% | D82E3 | -2% |
| F60C3 | 18% | D54C3 | -11% | D61F2 | -12% | D82F1 | 6% |
| F60D1 | 9% | D54D1 | -3% | D61F3 | -13% | D82F2 | 6% |

| Quinary Catchment | % change (1975 -2006) compared to 2016 -2045 | Quinary Catchment | % change (1975 -2006) compared to 2016 - 2045 | Quinary Catchment | % change (1975 - 2006) compared to 2016 -2045 | Quinary Catchment | % change (1975 -2006) compared to 2016 - 2045 |
|---|---|---|---|---|---|---|---|
| F60D2 | 15% | D54D2 | -11% | D61G1 | -12% | D82F3 | 5% |
| F60D3 | 19% | D54D3 | -5% | D61G2 | -12% | D82G1 | 6% |
| F60E1 | 13% | D54E1 | -9% | D61G3 | -12% | D82G2 | 4% |
| F60E2 | 14% | D54E2 | -4% | D61H1 | -12% | D82G3 | 4% |
| F60E3 | 14% | D54E3 | -5% | D61H2 | -12% | D82H1 | 14% |
| D41B1 | -1% | D54F1 | -9% | D61H3 | -12% | D82H2 | 14% |
| D41B2 | -1% | D54F2 | -5% | D61J1 | -13% | D82H3 | -4% |
| D41B3 | 0% | D54F3 | -4% | D61J2 | -13% | D82J1 | 13% |
| D41C1 | 0% | D54G1 | -1% | D61J3 | -8% | D82J2 | 13% |
| D41C2 | 3% | D54G2 | -1% | D61K1 | -12% | D82J3 | -10% |
| D41C3 | 1% | D54G3 | -5% | D61K2 | -7% | D82K1 | 14% |
| D41D1 | 2% | D55A1 | -5% | D61K3 | -7% | D82K2 | 14% |
| D41D2 | 4% | D55A2 | -6% | D61L1 | -6% | D82K3 | 13% |
| D41D3 | 5% | D55A3 | -7% | D61L2 | -12% | D82L1 | 16% |
| D41E1 | 4% | D55B1 | -2% | D61L3 | -11% | D82L2 | 17% |
| D41E2 | 4% | D55B2 | -2% | D61M1 | -9% | D82L3 | 18% |
| D41E3 | 8% | | | | | | |

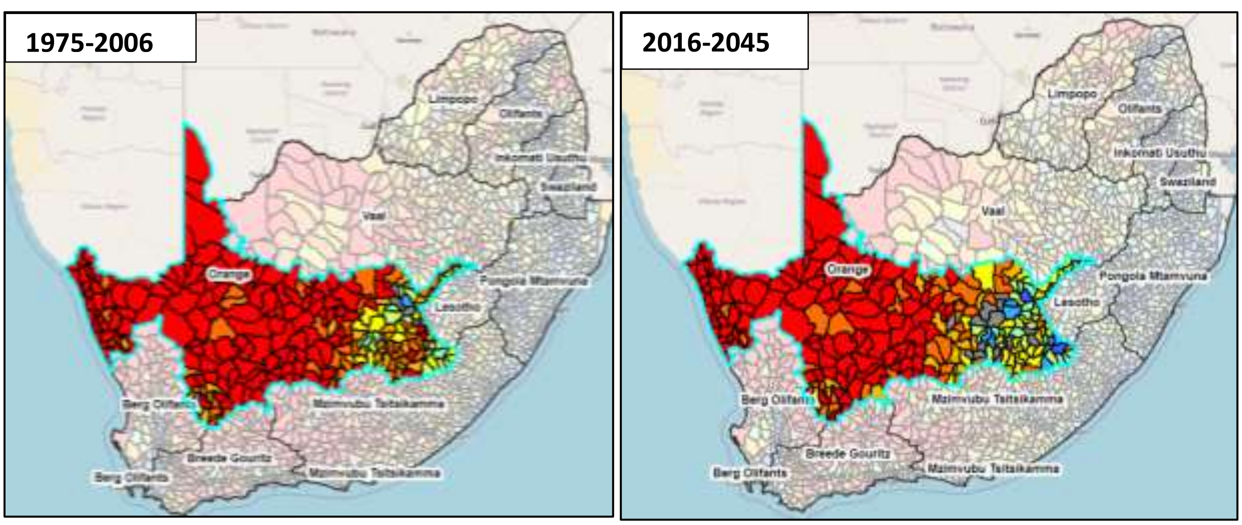



**Figure 6: Rainfall for the period 1975 – 2006 and predicted rainfall ranges for the period 2016 – 2045.**

## 2.2. Description of Water Resource Systems and Analysis

### 2.2.1. Overview

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

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

### 2.2.2. Surface Water Infrastructure

***Dams:***

There are a number of major in the Orange-Senqu System, such as the Katse and Mohale dams in Lesotho, as well as the Gariep Dam and the Vanderkloof Dam in South Africa. The system also includes a number of minor dams mainly supporting irrigation water use (Table 5 and Figure 7).

The Gariep Dam (5 432 $Mm^3$) and Vanderkloof Dam (3 188 $Mm^3$) on the Orange River within South Africa are the largest storage dams in the Orange-Senqu River system. Both dams are used to regulate the river flow for irrigation purposes as well as to generate hydro-electricity during the peak demand periods with a combined installed capacity of 600 MW (DWS, 2015). Releases from Vanderkloof Dam into the Orange River are dictated by the downstream flow requirements. The tributaries downstream of the Vaal confluence in the Lower Orange are the Molopo-Nossob sub-basin system. Surface flow from this system has not reached the main stem of the Orange River as far back as can be recorded. Further downstream, the Fish River sub-basin, entirely located within Namibia accounts for the two (Hardap, Naute Dams) of the five dams regulating the flows from Namibia into the Orange River.

There is very limited regulation capacity in the Lower Orange catchment. Although no large dams are present in the Lower Orange catchment, Boegoeberg, Neusberg and Vioolsdrift storage weirs are used for the regulation of flows into canal systems for irrigation purposes.

Vioolsdrift Dam is a proposed new water resource development that is planned on the Lower Orange River (DWS, 2015). Studies show that this re-regulation dam will provide the most savings in operational requirements and will contribute to the Orange River Mouth's ecological water requirements.

**Table 5: Dams in the Orange-Senqu system (Source ORASECOM, 2020 & 2012)**

| Dam name | Sub - catchment | Rivers | Purpose | Live Full supply Capacity (million $m^3$) |
|---|---|---|---|---|
| Gariep | Upper Orange | Orange | Major storage dam – irrigation, domestic, hydropower, transfer to Eastern Cape and recreation | 5 342 |
| Vanderkloof | | Orange | Major storage dam – irrigation, domestic, hydropower and recreation | 3188 |
| Armenia | | Leeu River | Small storage dam for irrigation | 13.2 |
| Egmont | | Off-channel (Witspruit River) | Supplementing water supply to Bloemfontein | 8.8 |
| Welbedacht | | Caledon | Small storage dam for irrigation and transfer to Bloemfontein | 15.47 |
| Rustfontein | | Modder | Small storage dam for domestic and irrigation | 72.6 |
| Mockes | | Modder | Small storage dam for domestic | 4.63 |
| Krugersdrift | | Modder | Small storage dam for irrigation | 71.19 |
| Tierpoort | | Riet | Small storage dam for irrigation | 34.5 |
| Kalkfontein | | Riet | Small storage dam for irrigation | 319.6 |
| Katse | Senqu | Semena River | Used as part of the Lesotho Highlands Water Project to transfer water to Vaal system | 1 950 |
| Mohale | | Senqunyane River | | 938.6 |
| Maqalika | | Caledon | Caledon/Mohokare Maseru supply system | 3.7 |
| Metolong | | Southern Phuthiatsana | | 64 |
| Smartt Syndicate | Ongers | Ongers | Part of the Smart Syndicate Supply System, which supports irrigation | 101 |
| Victoria Wes | | Brak | Flood control and groundwater recharge | 3.66 |
| Modderpoort, | Hartbees River | Rietfontein | To supply irrigation demands. | 12.3 |
| Loxton | | Un named tributary of Brak River | Used for irrigation and domestic water supply | 3.4 |
| Van Wyksvlei | | Unnamed tributary Carnarvonleegte River | Supply irrigation | 143.1 |
| Rooiberg | | Hartbees River | Supply irrigation demands | 3.65 |
| Daan & Tilda Viljoen dams | Molopo sub-system Namibia | Black Nossob River | Water is pumped from the Daan Viljoen Dam into the Tilda Viljoen | 0.43 (Daan) 1.25 (Tilda) |

| Dam name | Sub - catchment | Rivers | Purpose | Live Full supply Capacity (million $m^3$) |
|---|---|---|---|---|
| | | | Dam which is a pumped storage dam | |
| Otjivero | | White Nossob River | To supply water to Gobabis and Omitara in conjunction with the Daan Viljoen and Tilda Viljoen Dams | 9.8 (main dam)<br>7.8 (silt trap dam) |
| Hardap | Fish River | Fish River | Water is supplied to Mariental via a purification plant downstream of the dam and then gravity fed 20 km to a reservoir at Mariental. The dam also provides for a 2 000-ha irrigation scheme by means of 16 km of concrete lined canals and pipelines. Also used for flood absorption to protect the town of Mariental. | 294.6 |
| Naute | | Löwen River | Water is treated at the dam via a 1.9-km pipeline to the water treatment plant. Then the purified water reaches the town of Keetmanshoop via a 44 km pipeline. Water is also provided for a 270 ha irrigation scheme via a 2 km gravity pipeline. | 83.58 |
| Neckartal | | Fish River | Provide water for 5,000 ha of irrigation | 857 |

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

- LHWP phase I (Phase II currently in planning phase – implementation was planned for 2022 however this has been delayed).
- Orange River Project (ORP) (Gariep and Vanderkloof dams and related supply area).
- Greater Bloemfontein water supply system.

*The Phase I of the LHWP*: This consists of Katse, and Mohale Dams, Matsoku Weir and associated conveyance tunnels and is currently used only in support of the Integrated Vaal River System. Only environmental releases are made from Katse and Mohale dams to the Orange River. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam has been delayed. This project once implemented will result in a reduction in the yield of the ORP (Gariep and Vanderkloof dams) to an extent that it will result in a negative water balance in the

ORP. This will require a yield replacement dam in the Orange River, to regain the positive water balance (ORASECOM, 2020).

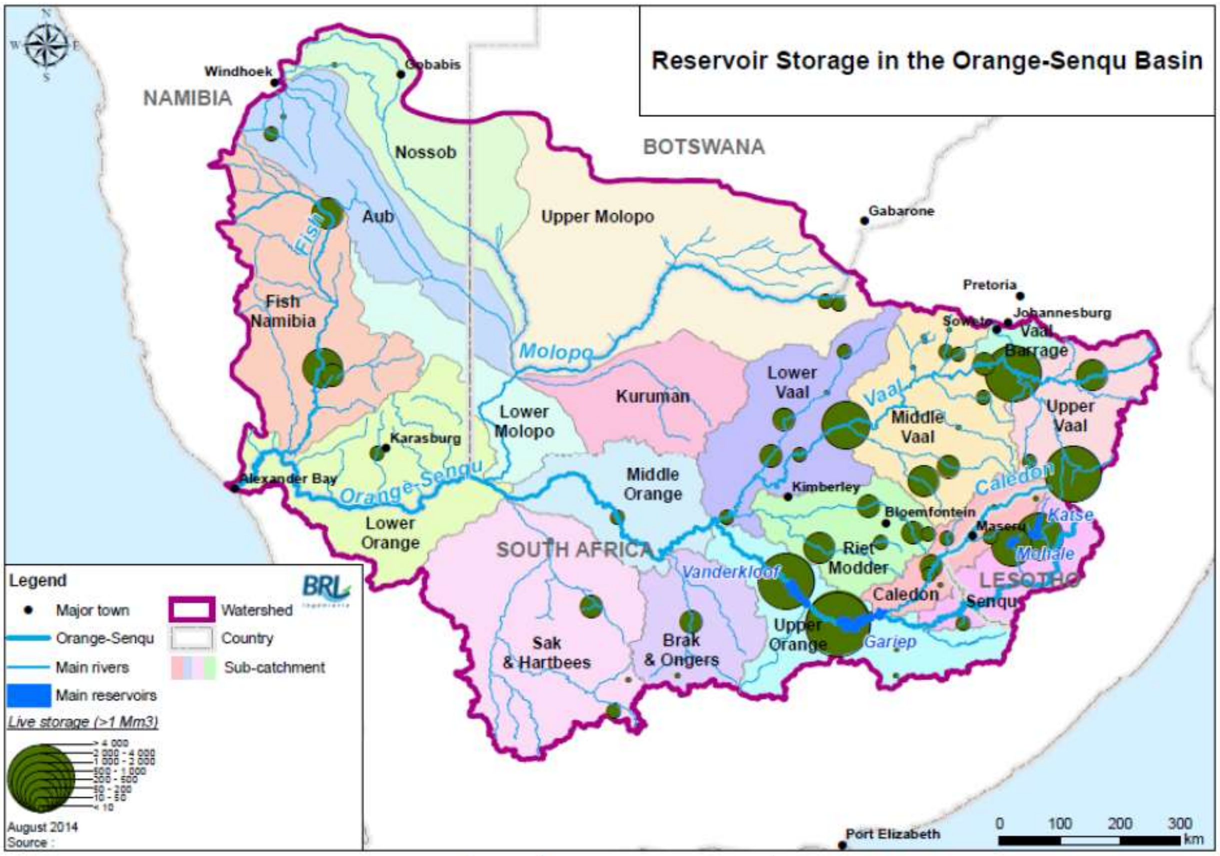



**Figure 7: Location and size of reservoir storage in the Orange-Senqu Basin (ORASEOM, 2014)**

*The ORP*: This supplies all the water requirements along the Orange River from Gariep Dam to the Orange River Mouth. These include all the irrigation, urban, mining, environmental, requirements, river requirements, etc. Except for the releases through the Orange-Fish tunnel and those into the Vanderkloof Canals, all the releases from Gariep and Vanderkloof dams, used to support downstream users, are made through the hydropower turbines directly into the Orange River. These river releases are therefore used to simultaneously generate hydropower.

*The Greater Bloemfontein system*: This system also located in the larger Orange Senqu system, uses Welbedacht and Knellpoort Dams in the Caledon River as resources from where water is transferred to the Modder River catchment. This sub-system is used to supply part of the water requirements of Bloemfontein, Botshabelo, Thaba N'chu and other small users. Water treated at Welbedacht Dam is transferred to Bloemfontein and small users, while raw water from Knellpoort Dam is transferred via the Novo Transfer scheme to Rustfontein Dam in the upper reaches of the Modder River. Rustfontein Dam is then used to supply Botshabelo and Thaba Nchu. Rustfontein

Dam supports Mockes Dam, from where water is released to Maselspoort Weir, where it is abstracted and supplied to Bloemfontein.

***Main Water Transfer infrastructure:***

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

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

The large Vanderkloof Dam is the most downstream storage on the Orange-Senqu mainstream, situated around 1 380 km upstream of the river mouth at Alexander Bay and since the contributions of tributaries downstream of this dam are either small or highly seasonal, the flow regime in the Lower Orange catchment is largely driven by releases from this dam (DWS, 2015). The largest intra-basin transfer is the transfer of water from the Lesotho highlands to the Vaal sub-basin. The largest inter-basin transfers include the Thukela-Vaal, Orange-Fish, Usutu-Vaal, the Inkomati transfers as well as the Vaal Eastern sub-system augmentation project, assisting with transfers to the Upper Olifants from the Vaal (ORASECOM, 2020).

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

As part of this study consideration would need to be given to the system operation and management to better meet the ecological flow pattern required at the Orange River Mouth and to consider releases as a means of managing the algal blooms that develop in the lower reaches of the Orange (DWS, 2015). The main existing water resources infrastructure associated with water transfers and bulk water supply schemes to users outside of the catchment are summarised in Table 6 and indicated in Figure 8.

**Table 6: Major Transfers in the Orange-Senqu System (sources: ORASECOM 2020&2012, DWS 2015, DWA 2009).**

| Scheme | Purpose | Capacity |
|---|---|---|
| Lesotho Highlands Water Project (LHWP) | To augment South Africa's water supply via a transfer to the Vaal River catchment (and it is therefore classified as part of the Vaal River System), in addition to generating electricity for Lesotho. | 780 million $m^3$ |
| Caledon Modder Transfer 1: Novo Transfer Scheme | Supports the water supply to Bloemfontein, Mangaung, Botshabelo, Thaba N'chu, Dewetsdorp, Reddersburg and Edenburg.<br><br>Novo Transfer Scheme transfers water from Knellpoort Dam to Rustfontein Dam in the upper reaches of the Modder River basin. This is done via the Novo Pump Station at Knellpoort Dam (29.7 km of pipeline and 12 km of river channel). The Novo Transfer Scheme is then linked to the Mazelspoort Scheme downstream on the Modder River. | Maximum capacity of 2.2 $m^3/s$ |
| Caledon Modder Transfer 2: Welbedacht Dam to Bloemfontein | | 1.29 $m^3/s$. |
| Orange-Fish Tunnel transfers | To divert water to the Eastern Cape for irrigation, urban (including Grahamstown and Nelson Mandela Metro) and industrial use. | 620 million $m^3/a$; 53$m^3/s$ |
| Orange-Riet Transfer | Water from the Vanderkloof Dam via the Vanderkloof Main Canal transferring water to the Riet River catchment.<br>The scheme is used mainly for irrigation, but also supplies urban requirements of Koffiefontein, Ritchie and Jacobsdal | 260 million $m^3/a$ |
| Orange Vaal Transfer Scheme (Figure 9) | To mitigate shortages and high salinity issues at Douglas Weir on the Lower Vaal River | Ranges from 120 to 142 million $m^3/a$, depending on the water level and water quality in the Vaal River |
| Lower Orange to Springbok and Kleinzee | Springbok Regional Water Supply Scheme: Supplies the towns of Springbok, O'Kiep, Carolusberg and Kleinzee, along with local mining demands, with treated water from Henkries Purification Works (Henkriesmond) | Maximum pump capacity of 0.315 ($m^3/s$) |

| Scheme | Purpose | Capacity |
|---|---|---|
| Pelladrift Water Supply Scheme | Supplies water to Pofadder, Pella and mines at Aggeneys and Black Mountain (operated by Pella Water Board).<br>Water is abstracted and transported by two pipelines, one supplying local farmers and the towns of Pofadder and Pella, and the other supplying domestic use for the small town of Aggeneys, but more importantly for industrial use for the base metals mine, Black Mountain at Aggeneys. | 4.7 mil $m^3$ |
| Port Nolloth | Supplies via a pipeline leading off from the Orange River at Alexander bay for domestic use, a small fishing harbour and small-scale diamond mining | To confirm |
| Future transfer from Makhaleng Dam in Lesotho to South Africa and Gaborone in Botswana | Two options from Makhaleng Dam exists; a high transfer of 186 million $m^3$/a and a low transfer of 97 million $m^3$/a. These volumes to Gaborone also include water requirements for domestic use in Lesotho as well as for towns in the RSA along the pipeline route. | In the order of 186 million $m^3$/a |
| Gariep Dam, Vanderkloof Dam and the Neusberg Hydropower Scheme | Operational when supplying downstream users | Gariep Dam serves to generate hydropower (eskom), capable of providing up to 360 MW of electricity at a flow rate of 800 $m^3$/s.<br>Vanderkloof Dam can produce up to 240 MW of electricity at a discharge flow rate of 400 $m^3$/s.<br>Neusberg Dam can produce up to 10 MW |


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

### *Water Resource Developments*

The Lower Orange River provides a significant resource to the Northern Cape Province, and is used for industrial, agricultural, recreational and domestic purposes. While most of the Province is unsuitable for dryland cropping, the Orange River Valley, especially at Upington, Keimoes and Kakamas, is an intensively cultivated grape and fruit growing country. The major user of the Northern Cape's freshwater resources is the irrigated agriculture sector, being the largest water user. Mining activities consists mainly of the extracting of alluvial diamonds and a variety of minerals (zinc, etc.).

The Orange River Project is the largest water supply scheme and comprises of a large number of sub-schemes that are all supplied from the same resource, Gariep and Vanderkloof dams in the Upper Orange. Approximately 75 million m³/a is supplied to irrigators located in Namibia along the Lower Orange River (*DWS 2024, personal communication: Study inception meeting, 20240206 and PMC meeting 1, 20240319*).

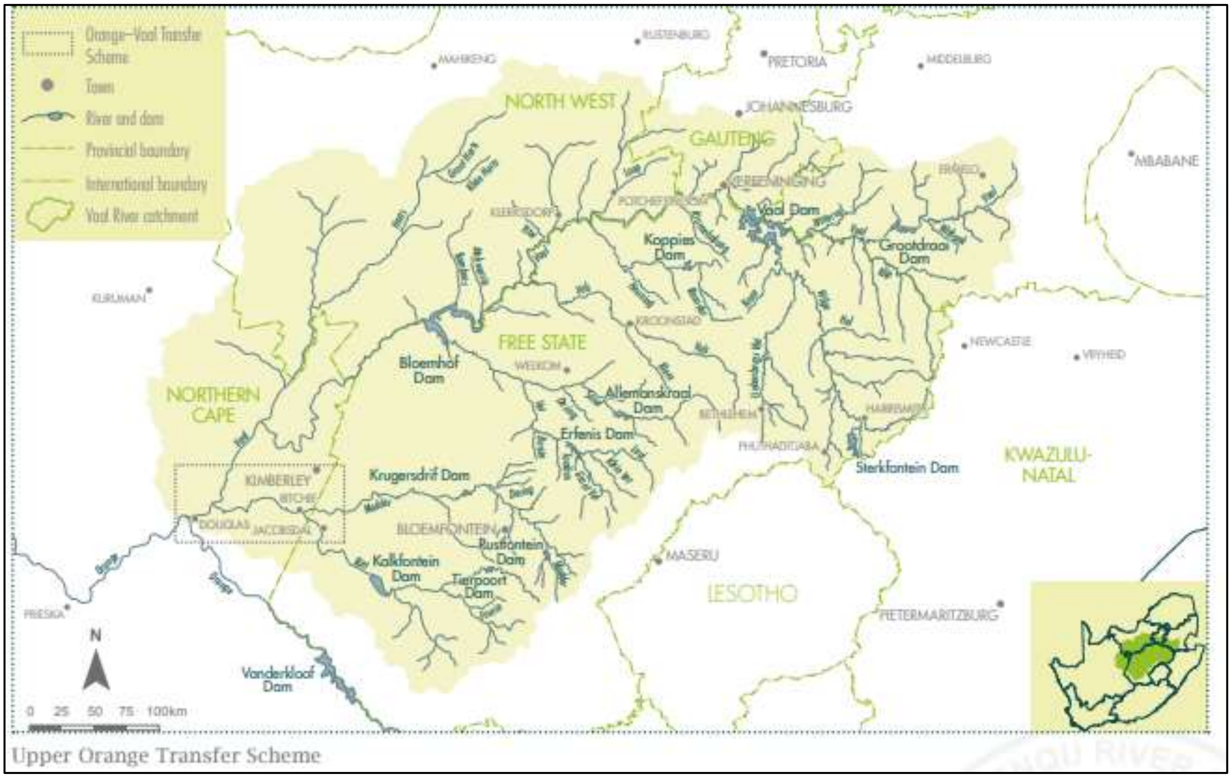



**Figure 9:** **Orange Vaal Transfer Scheme (ORASECOM, 2012)**

**Main irrigation Schemes:**

There are several irrigation schemes (Figure 13). The main irrigation schemes in the Orange River catchment (from the confluence of the Orange and Vaal Rivers) are (ORASECOM 2020):

- **Douglas Irrigation Scheme**: Located at the downstream end of the Vaal River (see Figure 10 below for an illustration). This scheme receives water from the Vaal River, supplemented with releases from the Orange River via the Orange-Vaal Transfer Scheme (Figure 10).
- **Middle Orange Irrigation Area:** (Modder/Riet Irrigation Scheme): Includes irrigators along the riparian zone, from Hopetown to Boegoeberg Dam (Figure 11).
- **Boegoeberg Irrigation Scheme**: Boegoeberg Dam (storage weir) is located about 150 km upstream of Upington in the Lower Orange River and is the major structure supporting the releases to the Boegoeberg irrigation area. Sedimentation has decreased the capacity of the reservoir from its original 34,7 million m³ to only 20,7 million m³. The Boegoeberg Canal is a 172 km long canal on the left bank with a capacity of 9,76 m³/s. Water for irrigation is supplied to the Noord-Oranje Irrigation Board as well as to the Gariep Settlement. The Boegoeberg Canal on the left bank also supplies water to the Rouxville West Scheme.
- **Upington Irrigation Scheme**: There are many islands in the Orange River in the vicinity of Upington, where irrigation has been practiced as far back as 1883. These irrigation areas are now controlled by the Upington Irrigation Board.

**Figure 10: Irrigation scheme at the confluence of the Vaal and Orange rivers at Douglas illustrated with a false colour Sentinal-2 satellite image composite (bands 8, 4 and 3) where red indicates healthy vegetation.**

- **Kakamas Irrigation Scheme**: (Figure 12). The area of operation stretches on both sides of the Orange River from Neusberg Weir in the east to just downstream of the Augrabies Waterfall in the west. The scheme consists of the Neusberg and Marchand Weirs in the Orange River, 75.4 km concrete main canals, 68.9 km concrete secondary canals, 44 km open storm water and subsurface drainage canals and 23 km of subsurface pipe drains.
- **Onseepkans Irrigation Scheme**: Onseepkans irrigation area is supplied through a canal on the left bank of the Orange River. The capacity of this canal is unknown, but it supplies water to 314 ha of irrigation land.
- **Namakwaland Irrigation Area**: The water for the Namakwaland Irrigation Area is abstracted from the Orange River. Water is released from Vanderkloof Dam to supply users in this area. The scheduled area is about 2 439 ha.
- **Vioolsdrift and Noordoewer Irrigation Scheme** (South Africa and Namibia): Vioolsdrift and Noordoewer irrigation areas are supplied through a canal system fed by the Vioolsdrift Weir on the Orange River. The scheduled irrigation area for Vioolsdrift (South Africa) amounts to 600 ha and for the Noordoewer (Namibia) area, 284 ha. This scheme has been transferred to, and is operated by, the Vioolsdrift and Noordoewer Joint Water Authority.

**Figure 11: Irrigation scheme along the Riet River illustrated with a false colour Sentinal-2 satellite image composite (bands 8, 4 and 3) where red indicates healthy vegetation.**

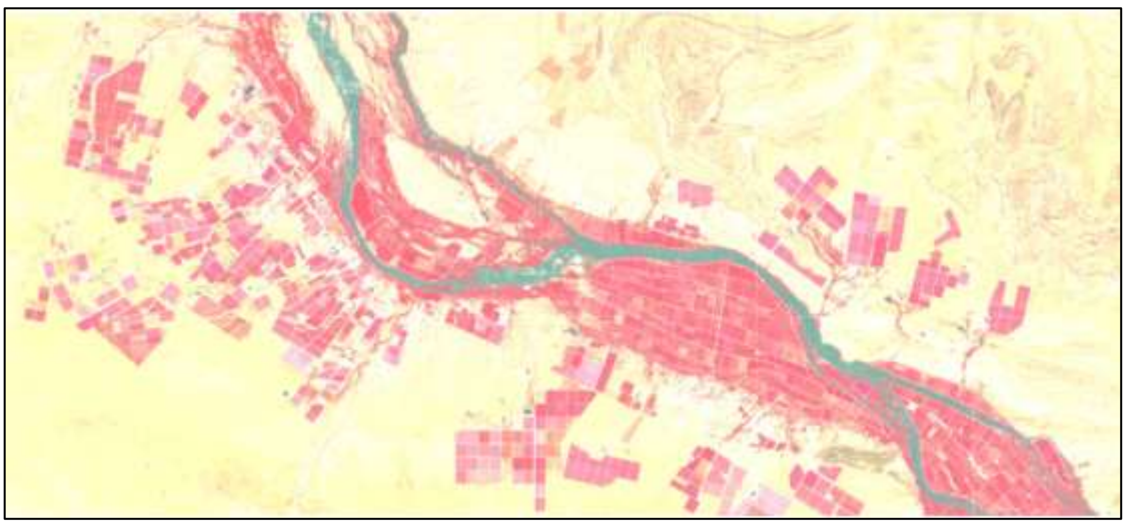


**Figure 12: Kakamas Irrigation scheme along the Lower Orange River illustrated with a false colour Sentinal-2 satellite image composite (bands 8, 4 and 3) where red indicates healthy vegetation).**

**Water Supply Schemes:**

Most of the domestic, urban and mining requirements for water in the catchment are in the Lower Orange River mainstem sub-area (ORASECOM, 2020). In addition, water is transferred from the Orange River for urban and mining use to the Orange Coastal sub-area. Water requirements in the Orange Coastal sub-area are very small and are mainly associated with towns such as Springbok, Steinkopf and Port Nolloth as well as the mines in the area. The water supply schemes in the Lower Orange River catchment are listed in Table 7 and indicated in Figure 13.

**Table 7: Major Water Supply Schemes in the Lower Orange (ORASECOM, 2012)**

| Water Supply Scheme | Description |
|---|---|
| Karos – Geelkoppen Rural Water Supply Scheme | Upstream of Upington – stock watering |
| Kalahari- West Rural Water Supply Scheme | Treated water for stock watering and domestic supply, north of Upington |
| Pelladrift Water Supply Scheme | Water supply to Pella, Poffadder and Aggeneys and Black Mountain Mines (operated by Pella Water Board) |
| Springbok Regional Water Supply Scheme | Supplies towns of Springbok, O'Kiep, Carolusburg and Kleinsee, along with local mines. |

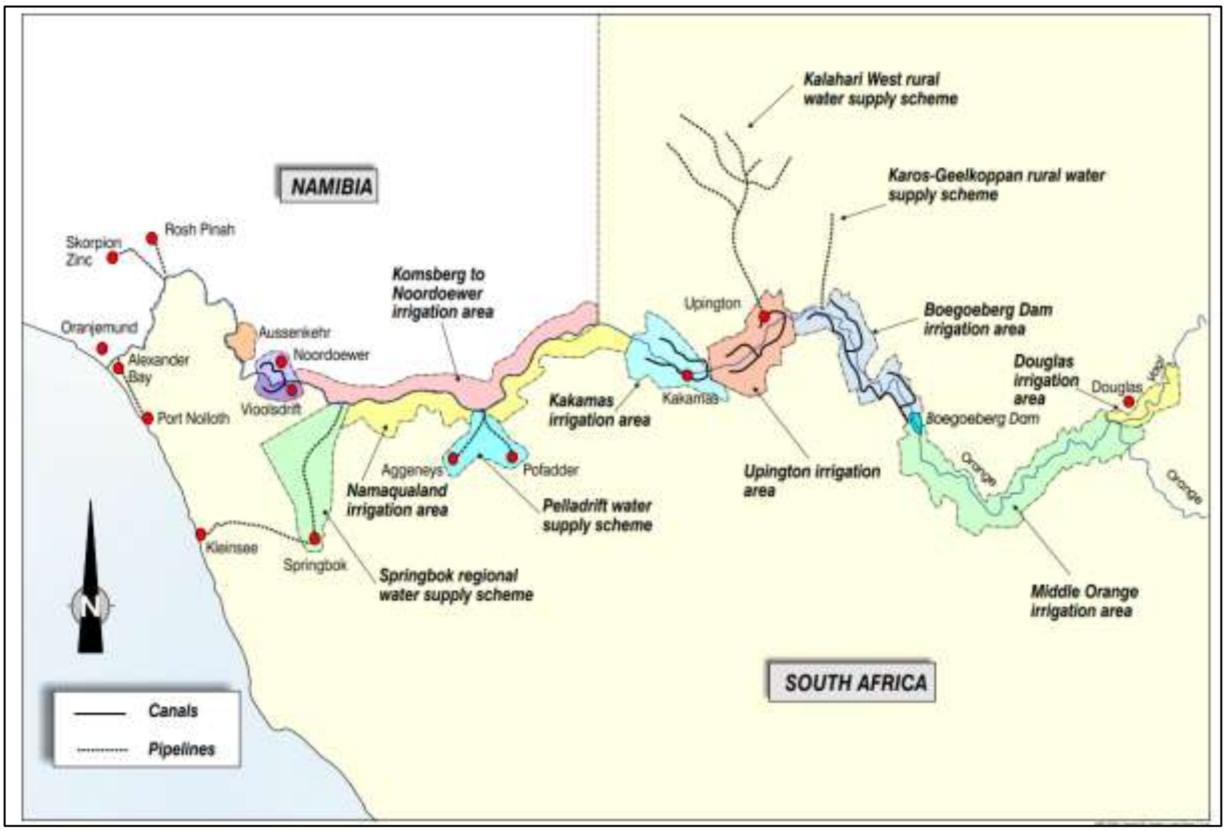



**Figure 13: Irrigation and water supply schemes in the Lower Orange Catchment (DWS, 2004)**

### 2.2.3. Water Availability

Almost all of the surface water runoff generated in the larger Orange River catchment is generated in the Upper Orange catchment. The bulk of the surface water in the Lower Orange catchment is therefore found in the main stem of the Orange River, with virtually all the surface water flowing into the Lower Orange River from the Upper Orange and Lower Vaal catchments (ORASECOM, 2020). Tributaries downstream of the Orange/Vaal confluence such as the Ongers, Sak and Fish (Namibia) rivers are draining arid and semi-arid regions. The flows in these rivers are very infrequent and it is expected that their flows only contribute to the Orange River's flow during periods of relative high flows in the Orange River. The individual yield contribution of these rivers to the Orange River is relatively small. The runoff generated from the Fish River in Namibia only enters the main Orange River close to the river mouth. As far as surface water is concerned, the two large sub-systems within the study basin, the Lesotho Highlands Water Project (LHWP) and the Orange River Project (ORP) (Gariep & Vanderkloof dams), are providing most of the available yield within the Orange-Senqu system.

Gariep and Vanderkloof dams are both used to supply all the irrigation, urban, mining and environmental requirements in the Lower Orange. Only a few smaller dams are located on the main tributaries in the lower catchment. These include Smartt Syndicate Dam on the Ongers River and Van Wyksvlei Dam on the Carnarvonleegte.

As indicated, there are also several diversion weirs in the Orange River of which Boegoeberg (20 million m³ storage) is the largest. Reliable estimates of the surface water resources in the Upper Orange and Vaal River catchment are therefore of extreme importance for the Lower Orange and highlight the interdependencies of the catchment areas.

Groundwater utilisation is of major importance across wide areas in the Lower Orange catchment and often constitutes the only source of water (DWS, 2015). It is mainly used for rural domestic supplies, stock watering and water supplies to towns off the main stem of the Orange. These resources need to be properly managed and developed. As a result of the low rainfall, recharge of groundwater is limited, and only small quantities can be abstracted on a sustainable basis. Artificial recharge of groundwater is practised in some areas where water from small dams is transferred through pipelines into boreholes located in the area of recharge of the main production boreholes (DWS, 2004).

In the Orange Tributaries sub-area 60% to 70% of the available water is supplied from groundwater sources. Groundwater also constitutes an important source of water for rural water supplies in the Orange River, although it's only a small proportion of the total available water. Much of the groundwater abstracted near the river (Orange sub-area), is recharged from the river and could also be accounted for as surface water. Groundwater availability in the coastal region is extremely limited as a result of the lack of rainfall. There is a strong risk of seawater intrusion into coastal aquifers close to the sea. Groundwater management, monitoring and borehole maintenance is required in the Lower Orange to improve the water availability and usage (DWS, 2015).

Development of the Vioolsdrift Dam in the Lower Orange River has been identified for the re-regulation of releases from Vanderkloof Dam as well as the storage of flood flows mainly from the Upper Orange and Vaal Rivers and to a lesser extent also from the flows generated in the Lower

Orange (DWS, 2015). This would contribute to the improved management of the Orange- Vaal River System, and facilitate more water being made available for use. No meaningful potential for surface water regulation exists in the Orange Coastal sub-area (DWS, 2004).

Irrigation is by far the dominant water use sector in the Lower Orange catchment area, representing 94% of the total requirement for water. Water requirements for urban, rural and mining use respectively represent 3%, 2% and 1% of the total water requirement in the catchment (DWS, 2015). Virtually all of the irrigation developments situated along the main stem of the Orange River, are dependent on water abstractions from the river. With most of the irrigation being for high value orchard type crops, much of the water is required at a relatively high assurance of supply.

Limited irrigation is also practised along some of the main tributaries (Orange Tributaries sub-area). Irrigation in this region is generally opportunistic and at a very low assurance of supply, with most of the area only planted in years of high runoff when sufficient water is available. Some of the water abstracted for irrigation from the Orange River drains back to the river as return flows, for potential use downstream (or as part of the freshwater requirements for the estuary) (DWS, 2015).

**Return flows:**

The return flows in the Orange River System (ORS) are in general small from urban/industrial and mining sectors, except for the Greater Bloemfontein sub-system (ORASECOM, 2020). Some of the water supply schemes divert water far from the mainstem Orange, thereby almost no return flows return back into the main Orange River. These typically include areas such as Kleinsee, Springbok, Pofadder, Aggeneys and Port Nolloth along the Lower Orange. The return flows generated by the water supplied via Orange-Fish tunnel transfer from Gariep Dam to eight small towns as well as Port Elizabeth in the Eastern Cape are as such not available for use in the Orange River.

The irrigation sector has significant return flow volume and it is estimated as 200 million $m^3/a$ at 2018 development level, which is currently used by downstream users (ORASECOM, 2020). Hydropower is generated by releases from the Gariep Dam, Vanderkloof Dam and the Neusberg Hydropower Scheme, which is operational when supplying downstream users (ORASECOM, 2020).

A proportion of the water used in urban areas is also used non-consumptively and again becomes available as effluent. At the larger centres in close proximity of the river, most or all of the effluent is discharged back to the river after treatment. Effluent from smaller towns typically evaporates from maturation ponds or may be absorbed by irrigation and infiltration.

The water requirement projections for the Orange System with WC/WDM is summarized in Table 8 (ORASECOM, 2020).

**Table 8: Water Requirements in the Orange-Senqu system (ORASECOM, 2020)**

| Description | Million m³/a | |
|---|---|---|
| | 2018 | 2020 |
| **Orange-Senqu** | | |
| Total Irrigation Demands | 2 183 | 2 174 |
| Total Domestic/ Urban | 294 | 292 |
| Transfer from Katse Dam to Vaal Dam | 780 | 780 |
| Total River and Operating requirements | 1 083 | 1 083 |
| Demand Imposed Gariep & Ven Der Kloof | 3343 | 3325 |
| **Total Oranage River Demand** | **4 339** | **4 329** |
| **Namibia: Fish, Nossob, Auob and Lower Orange River** | | |
| Total Irrigation Water Requirements | 107.5 | 109.5 |
| Total Urban Water Requirements | 14.7 | 15.0 |
| Total Mining Water Requirements - Only Lower Orange | 19.5 | 19.2 |
| **Total Water Requirements** | **141.7** | **143.6** |
| **Botswana: Molopo River** | | |
| Total Irrigation Water Requirements | 10.0 | 10.0 |
| Total livestock requirements | 9.0 | 9.0 |
| Total Mining Water Requirements | 7.6 | 12.0 |
| Total Urban Water Requirements | 28.0 | 29.0 |
| **Total Water Requirements** | **54.6** | **60.0** |
| **Lesotho: Senqu/Caledon River** | | |
| Total Irrigation Demands | 6.7 | 6.7 |
| Total Domestic/Industrial Demands | 38.4 | 51.3 |
| Transfer to Lesotho Botswana and RSA from Makhaleng | 0.0 | 0.0 |
| **Total Water Requirements** | **45.2** | **58.1** |

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

- Water required to supply the current and future social and economic activities as well as supporting the transfer to the Vaal River system, will have to come from within the Orange/Senqu basin. It was found that transferring water from a neighbouring basin (e.g. Mzimvubu measures) will be too expensive.
- The existing Ecological Water Requirements (EWRs) needs to be maintained and to avoid immediate large negative socio-economic implications additional releases towards an alternative EWR can only be implemented as soon as the new dam (at Vioolsdrift) is commissioned. Further optimisation of the EWR in combination with the proposed augmentation options is recommended.
- Groundwater, if available, should be prioritised as the first choice to augment the water resources of towns and communities located far from the Orange River.

- All water requirements can be balanced by availability through the implementation of the following measures:
  - Shared utilisation of LHWP Phase II between the Vaal River and Orange River systems is an essential measure to postpone large capital expenditure that would otherwise be required at the same time Polihali Dam become operational;
  - Plan and implement WC/WDM in the domestic and irrigation water use sectors for the domestic/industrial water use sector and in the irrigation water use sector need to be achieved (target date was 2020);
  - The introduction of a mechanism whereby water, saved through water use efficiency, especially in agriculture, can be made available to other water users in the system;
  - Limit operational losses through real time monitoring of river flows in the Orange and Vaal rivers to maximise the beneficial use of the spillages from the Vaal River System (target implementation date was 2016), and
  - Utilising a greater portion of Vanderkloof Dam's storage capacity by lowering the minimum operating level in the dam. This measure required pumping infrastructure which has to be in place by 2022.
- Implementation of the EWR during would require further actions to be implemented to sooner, *inter alia*, commissioning of Vioolsdrift Dam sooner, increasing yield of the system by raising of Gariep Dam or building of Verbeeldingskraal Dam, adjusting the assurances of supply to downstream water users.

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

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

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

### 2.2.4. System Analysis

The Lower Orange catchment is a component of the extended Orange and Vaal River Systems, which has been the subject of various water balance and reconciliation studies in the past. Due to the inter-dependencies of the Upper and Lower Orange catchments, it is necessary to consider the overall water balance and system analyses for the entire Orange River System. The Lower Orange catchment is part of the total Orange River System and thus planning and operations must be considered as part of the whole system. The management of the Orange River Overarching system is undertaken at the national level by the DWS. The system is currently operated to achieved the maximum yield benefit of the system.

The system models applied to the water resource system analysis of the Orange River system 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.

For the Orange-Senqu system, the existing model setups and supporting hydrology is available and can be adopted for system analyses for the water resource classification scenarios. It also includes several transfers into and out of the basin and the inclusion of parts of other neighbouring river basins into the water resources analysis and modelling setup. The related system operation and management procedures for the Orange River System have also been updated and provide further confidence to the process. The model output and applications include:

- The WRYM provides historic and stochastic yields available from a specific resource or combined set of resources. The model is used to assess which operating rule provides the highest yield for a scheme and is used to determine short term yield capabilities based on varying starting storages of the resource.
- The WRPM uses the results of the WRYM to carry out future projection scenarios based on increasing demands and potential scheme augmentations. Short term operation is carried out based on starting storages and the model provides results of whether or not the scheme can expect a shortfall or surplus in a 5-to-10-year operating period. Longer projection periods assess whether the planned future schemes are sufficient to supply users at their required assurance levels and when new intervention options will be required to achieve this over the long term.

The WRPM will be applied to in the water resource classification scenario evaluation task. Most of the WRYM and WRPM model setups for the Lower Orange are rated to be at medium, medium high to high confidence.

The hydrological data, has been updated and extended as part of the ORASECOM Integrated Water Resources Management Plan (IWRMP) Phase 2 study and Phase 3 (ORASECOM, 2014), applied for all the areas upstream of the Orange-Vaal confluence and the main stem Orange and covers an 85-year period from 1920 to 2004 hydrological years. The hydrology information in the upstream catchments is generally of high to very high confidence. The hydrology prepared as part of the ORASECOM study included the assessment of 16 hydrological zones, 4 of which are located within the Lower Orange. These 16 hydrological zones included 207 hydrology time series files which have been assessed. These combined catchments and related monthly flow records were configured in the WRYM and WRPM networks for yield and planning analysis purposes. Hydrological information is available at quaternary catchment scale from the river-runoff modelling and calibration that was undertaken during Phase 2 of the ORASECOM study. The hydrological zones have been 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 14 as taken from DWS (DWA, 2013). A summary of the hydrology for the Lower Orange is presented in Table 9 (DWS, 2013).

**Table 9: Summary of the hydrology per sub catchment in the Lower Orange (incremental runoff).**

| Sub catchment | | Natural runoff (million $m^3$) | Percentage of total natural runoff (%) |
|---|---|---|---|
| Lower Orange Mainstem | D72, D73, D81, D82 | 135 | 1 |
| Fish | D46 | 739 | 6 |
| Molopo | D41, D42, D43, D44, D45 | 135 | 1 |
| Lower Orange Tributaries | D61, D62, D51-D58 | 162 | 1 |
| Lower Vaal | C31, C32, C33, D91, D92 | 191 | 2 |
| Upper Orange | D13, D14, D31, D32, D33, D34, D35, D21-D24 | 1191 | 10 |

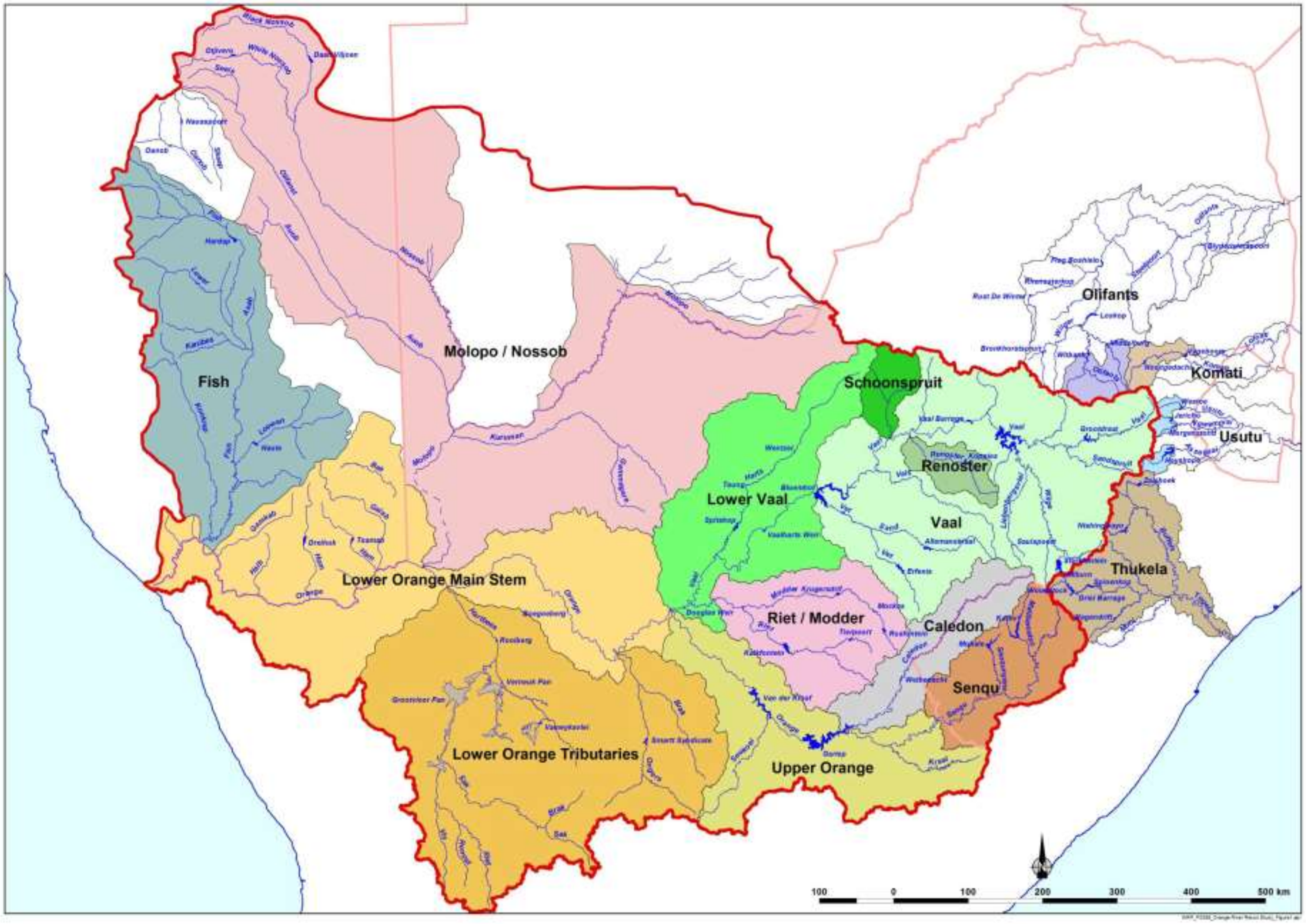



**Figure 14: 16 Hydrological modelling zones of the Orange River Catchment (DWA, 2013)**

# 3 STATUS QUO: SOCIO-ECONOMIC AND ECOSYSTEMS SERVICES

## 3.1. Demographics and Socioeconomics Profile

A large proportion of the Lower Orange Catchment falls within the Northern Cape province, with a small portion in the upper east region area within the North-West province, and a very small portion in part of one municipality in the Western Cape. The estimated total population of the Lower Orange catchment study area was 1.05 million in 2023 with approximately 346,000 households (Stats SA 2011 Census adjusted). The population density varies within the catchment (Figure 15) with higher density in the upper north-east region and along the Orange river. The predominant language spoken within the Northern Cape is Afrikaans (54,6%), followed by Setswana (35.7%) and IsiXhosa (4.5%) (Stats SA, Census 2022).

The Lower Orange River Catchment covers an area that comprises 27 different local municipalities (LMs) in the Northern Cape, North West and Western Cape Provinces (Figure 16). The area of the catchment lying within the Northern Cape province includes 20 out of the 26 local municipalities of this province covering all or parts of these municipal boundary areas. These Northern Cape local municipalities fall within four (some with low population densities) out of the five District municipalities (DM) of the province (Namakwa, Pixley ka Seme, Z F Mgcawu and John Taolo Gaetsewe).

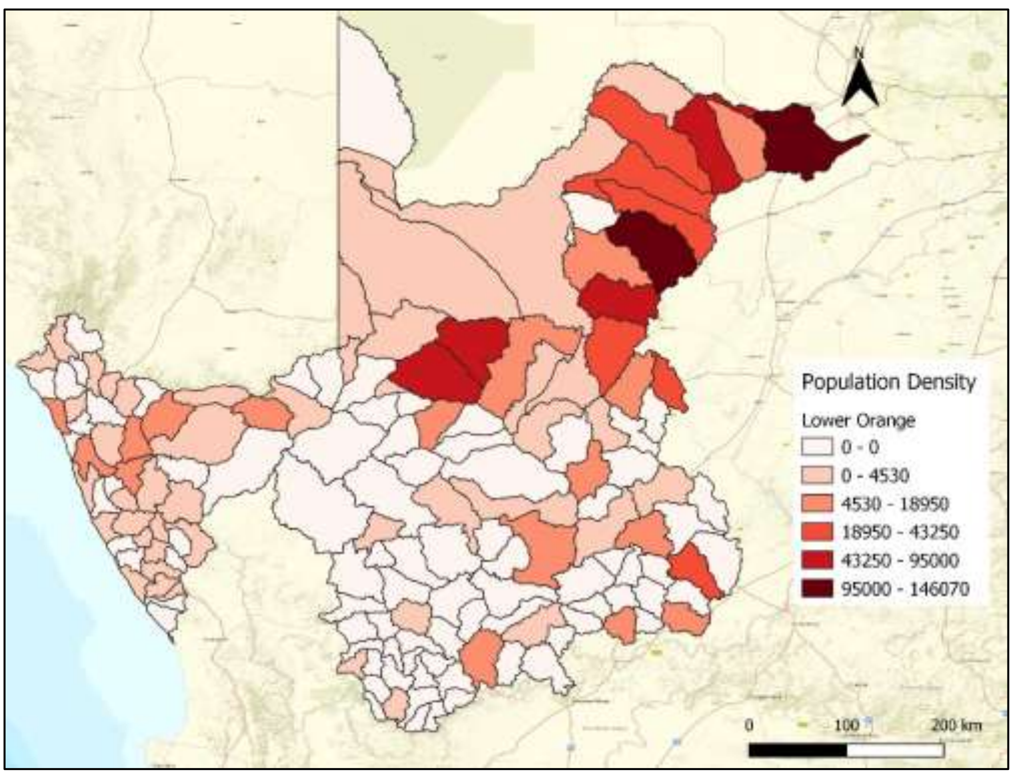



**Figure 15: Population density of the Lower Orange Catchment**

A small part of the North West province falls within the catchment and includes parts of five local municipalities (one in the Dr Ruth Segomotsi Mompati DM and the other four within the Ngaka Modiri Molema DM). A very small section of the Western Cape province (5% of Matzikama LM) also forms part of the catchment on the west coast. Parts of two quaternary catchments fall within the Beaufort West LM of the Western Cape and these are largely rural with no population.

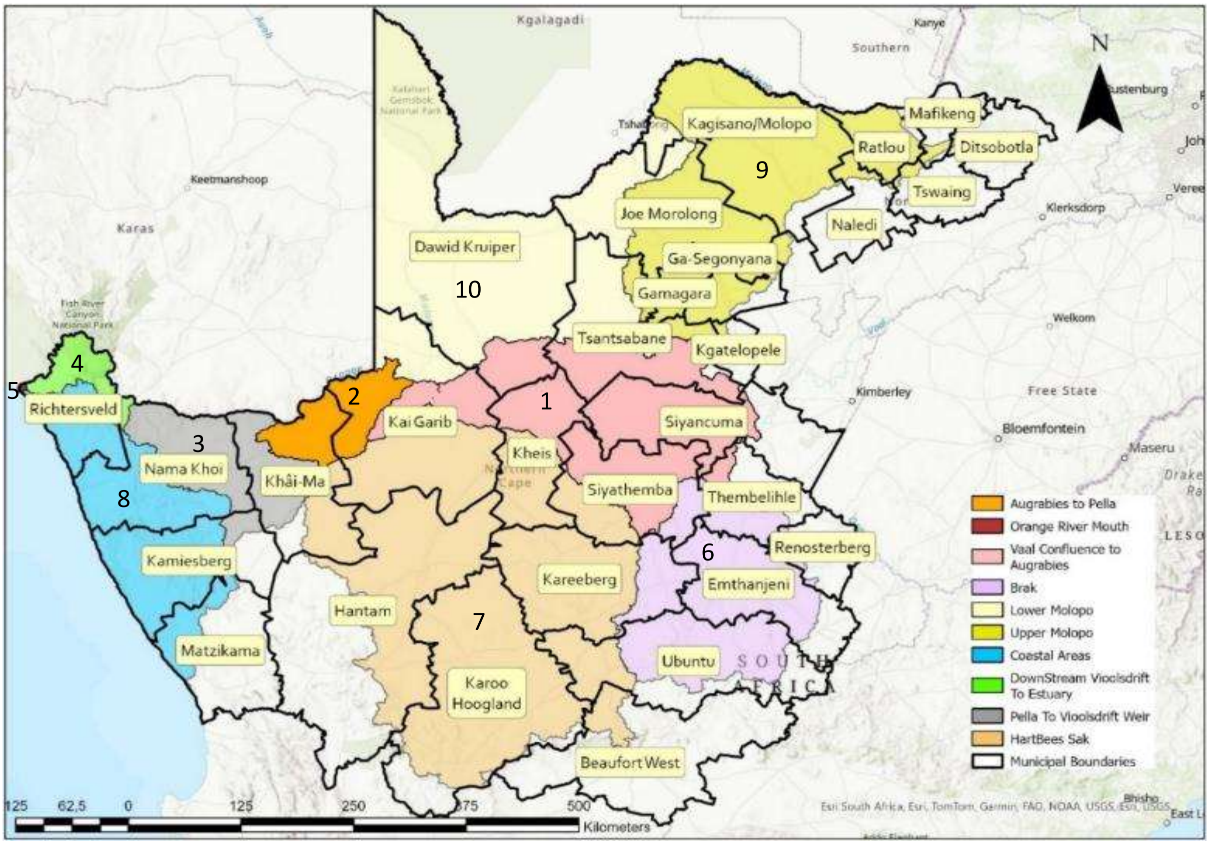



**Figure 16: Locality of local municipalities in the Lower Orange Catchment**

The catchment has many rural settlements, small towns and scattered villages. Much of the area is dry and arid with little development. Many of the larger towns and urban areas are found adjacent to the Orange River or near to the larger mines within the catchment. There are no cities within the catchment, however, does include Upington, the second largest town in the Northern Cape. The unemployment rate within the catchment ranges from 10.46% to 44.34% (NT, 2021).

Most (95%) of population within the catchment has access to formal water sources (Piped water in the dwelling, piped water in the yard, tap water <200m from household, tap water >200 m) and 5% of the population of the catchment source water from informal water sources including boreholes, rain-water tanks, rivers or streams, dams and other water sources (Figure 17).

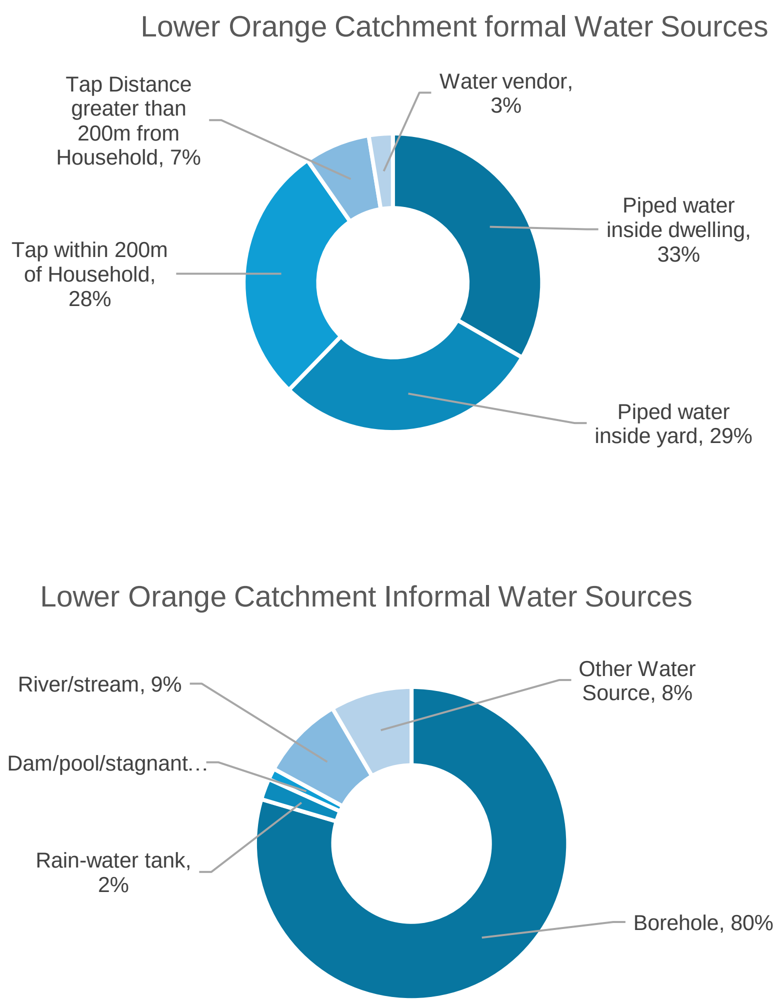



**Figure 17: Access to water services within the Lower Orange catchment**

## 3.2. Economic Sectors

Mining contributes an estimated 35% to the catchment's total GDP and agriculture 10% (Table 10). The tertiary sectors including the tourism sector contributing 10% each. Tourism in the catchment occurs along the Orange River and in the main National Parks across the catchment including Augrabies National Park, Namakwa National Park, Kgalagadi Transfrontier Park and several smaller nature reserves scattered in the catchment.

The manufacturing sector is quite small and is focussed particularly on agro-processing within the food and beverage sector and manufacturing businesses supporting the mining sector (DEDaT NC, 2015).

The approximate contributions to employment of the Lower Orange catchment area were estimated based on the municipalities in which it lies and their proportional GDP contributions (Table 11).

**Table 10: Economic sectors in the Lower Orange Catchment and the estimated contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R7,862 | 10% |
| Mining | R28,814 | 35% |
| Manufacturing | R4,116 | 5% |
| Electricity & water | R1,978 | 2% |
| Construction | R3,626 | 4% |
| Wholesale & retail trade; catering & accommodation | R8,089 | 10% |
| Transport & communication | R7,340 | 9% |
| Financial services | R8,183 | 10% |
| General government | R8,161 | 10% |
| Community, social & personal services | R4,134 | 5% |
| **Total GDP** | **R82,302** | **100.0%** |

**Table 11: The estimated employment by economic sector in the Lower Orange catchment (Estimated using NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 57,803 | 26% |
| Mining | 14,032 | 6% |
| Manufacturing | 8,350 | 4% |
| Electricity & water | 752 | 0.3% |
| Construction | 10,853 | 5% |
| Wholesale & retail trade; catering & accommodation | 42,025 | 19% |
| Transport & communication | 7,274 | 3% |
| Financial services | 18,715 | 8% |
| General government | 33,444 | 15% |
| Community, social & personal services | 30,935 | 14% |
| **Total Employment** | **224,181** | **100%** |

## 3.3. Ecological infrastructure

As described in Section 2.1 key water resources of the Lower Orange catchment include wetlands, groundwater and rivers. There are no significant dams within catchment. The main rivers include the Orange River and its tributaries and the Molopo River and tributaries. There are many ephemeral rivers throughout the Lower Orange catchment.

There are several strategic water sources (groundwater) areas in the catchment in the western part, in the upper eastern and lower eastern parts of the catchment and in the lower central regions (described further in Section 2.1.2). The wetlands in the Lower Orange catchment include saltmarsh and floodplain areas found in the upper western parts of the catchment near the Orange River and its tributaries, valley bottom and floodplain wetlands in the lower eastern regions. The Lower Orange catchment includes several ephemeral wetlands within the catchment (discussed further in Section 6).

There are large extents of protected landscapes within the catchment especially those along the western side. Various nature reserves are also found scattered within the catchment. Additionally, there is a Ramsar site near the mouth of the Orange River.

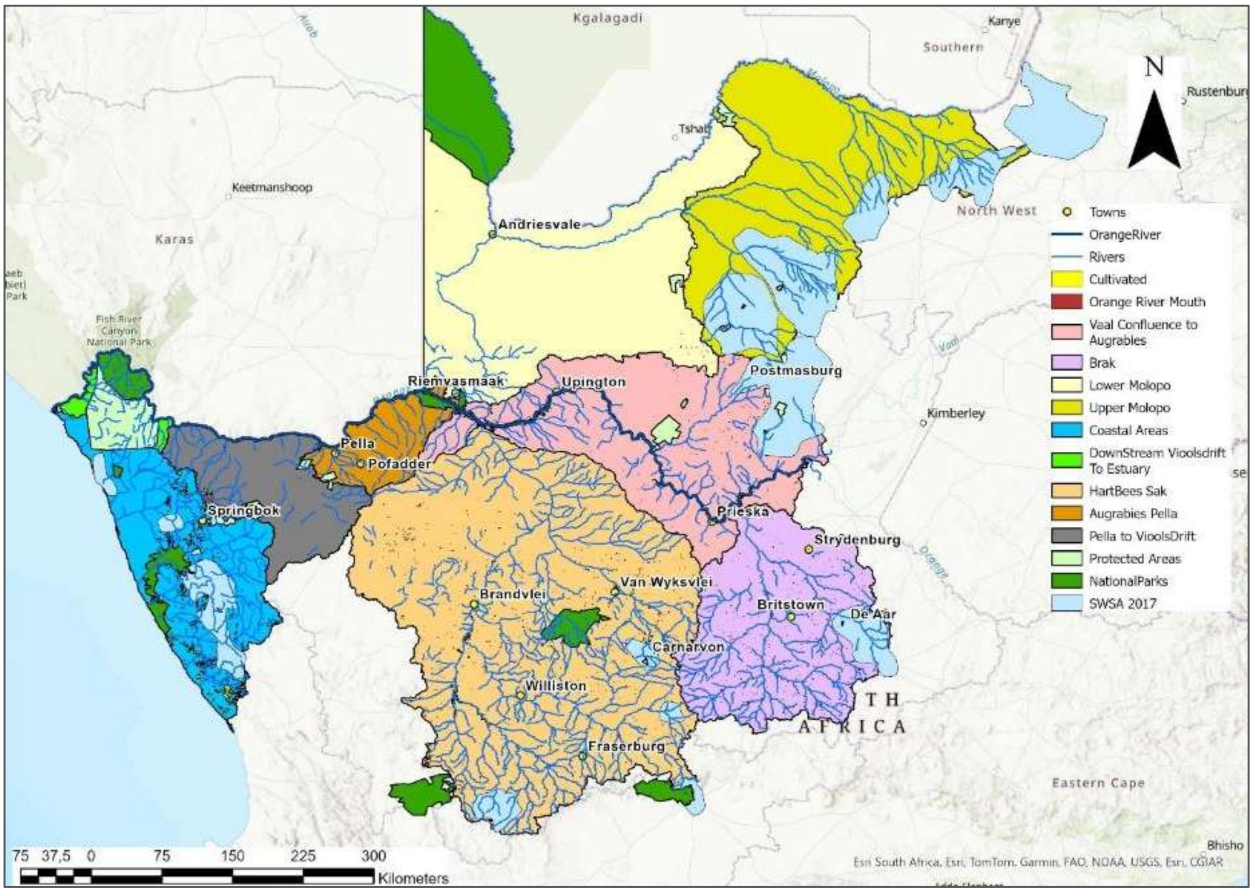



**Figure 18: Ecological infrastructure within the Lower Orange catchment**

## 3.4. Ecosystem Services Sensitivity

### 3.4.1. Ecosystem Services Defined

Ecosystem services refer to the benefits that humans obtain from ecosystems. The concept gained prominence following the publication of the Millennium Ecosystem Assessment (MEA) in 2005, which evaluated the implications of ecosystem changes on human well-being. This comprehensive study, conducted from 2001 to 2005, involved over 1,360 global experts and offered an up-to-date scientific evaluation of the world's ecosystems, their services, and the scientific foundation for sustainable conservation and usage. Subsequent to this, several frameworks have sought to further break down and categorize these benefits. These include The Economics of Ecosystems and Biodiversity (TEEB) (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, 2013), and the framework developed by the International Panel on Biodiversity and Ecosystem Services (IPBES) (IPBES, 2019). Despite each framework's attempt to build upon its predecessors, they all essentially follow a similar rationale.

They classify ecosystem services into four primary categories, namely:

- **Provisioning services**, where human derive direct material benefit in the form of nutrition, energy sources, and raw materials (including biochemical and genetic materials). Provisioning services of the wetland landscapes support food production, provide fish, medicines, timber, fibre, fodder, water and other products that support livelihoods, provide income opportunities and contribute to regional GDP.
- **Regulating services**, are the indirect benefits are derived in the form of regular flows of biotic and abiotic components of ecosystems which allow for the regular, effective functioning of ecosystems. Various water regulation, sediment and nutrients regulation, storm and flood protection and micro-climate regulation services exist. They provide benefits to the inhabitant to the landscapes and well as beneficiaries in adjacent and downstream areas. Regulating services are not valued directly in the economy, rather their values can be thought of as an insurance value. This is because these services underpin the production of provisioning and cultural services, or alternative mitigate risks that would regulating on economic damage costs if not mitigated.
- **Cultural services** are intangible benefits received in terms of intellectual, spiritual and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure. These are the services that underlie recreation and tourism values, benefiting local communities, domestic tourist and international tourists. Wetland landscapes of the nature of these studied here are often home to sacred or spiritual areas, which is also an important example of cultural services. The value of eco-tourism can be estimated using various techniques. Spiritual and inspirational value are more difficult to value.
- A fourth category of ecosystem service is added in some frameworks to distinguish the importance of specific habitats within a delineated ecosystem. This may include the maintenance areas of uniqueness (as envisaged under the IPBES); areas of unique genetic diversity, **biodiversity**, and habitat (as envisaged under the TEEB); and unique combinations of supporting and regulating services (as envisaged under the MA). From an ecosystem service valuation perspective, when certain areas or habitats are especially unique, such assets are so rare that it is regarded as non-substitutable. Substitutability in economics is the degree to which an asset is substitutable for another asset. The distinctive characteristics of the landscapes identified here provides a globally unique blend and magnitude of ecosystem services produced that arguably qualifies these landscapes as non-substitutable asset classes.

### 3.4.2. Ecosystem Service Sensitivity

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

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

In the Lower Orange catchment, we have preliminarily identified several key ecosystem services. These include water provisioning services provided by the network of rivers, tributaries, and strategic groundwater sources (Figure 19). Complex ecosystems offer provisioning and regulating services. For instance, the Orange Mouth estuary is a significant wetland area, and most wetlands[1] in the region are ephemeral. Provisioning services, other than water, are expected to significantly impact rural livelihoods, while regulating services will benefit the broader economy (Figure 19).

Cultural services are indicated by the distribution of protected areas, tourism activities, and the demographic composition of local communities (Figure 19). These cultural services contribute to the overall ecosystem value of the region.

To gain a better understanding of the distribution and potential of ecosystem services, we conducted an exercise to map the ecological infrastructure and assess the socio-economic status quo. This mapping exercise aimed to identify the likely flows of ecosystem services within the region. By considering the presence of ecological infrastructure and the current socio-economic conditions, this assessment provides valuable insights into the potential benefits and services that the ecosystem can offer to the communities and environment of the catchment areas.

[1] **Ephemeral wetlands**: are isolated without a permanent inlet or outlet, but at certain times may overflow.
**Floodplain wetlands**: ecosystems that are distinct from but associated with the adjacent river channel itself.
**Salt marshes**: are littoral wetlands that experience periodic inundation and drainage due to the ingress of saline water from tidal movements. The marshy nature of the area is attributed to the presence of soil consisting of substantial amounts of deep muck and peat (National Ocean Service, n.d)

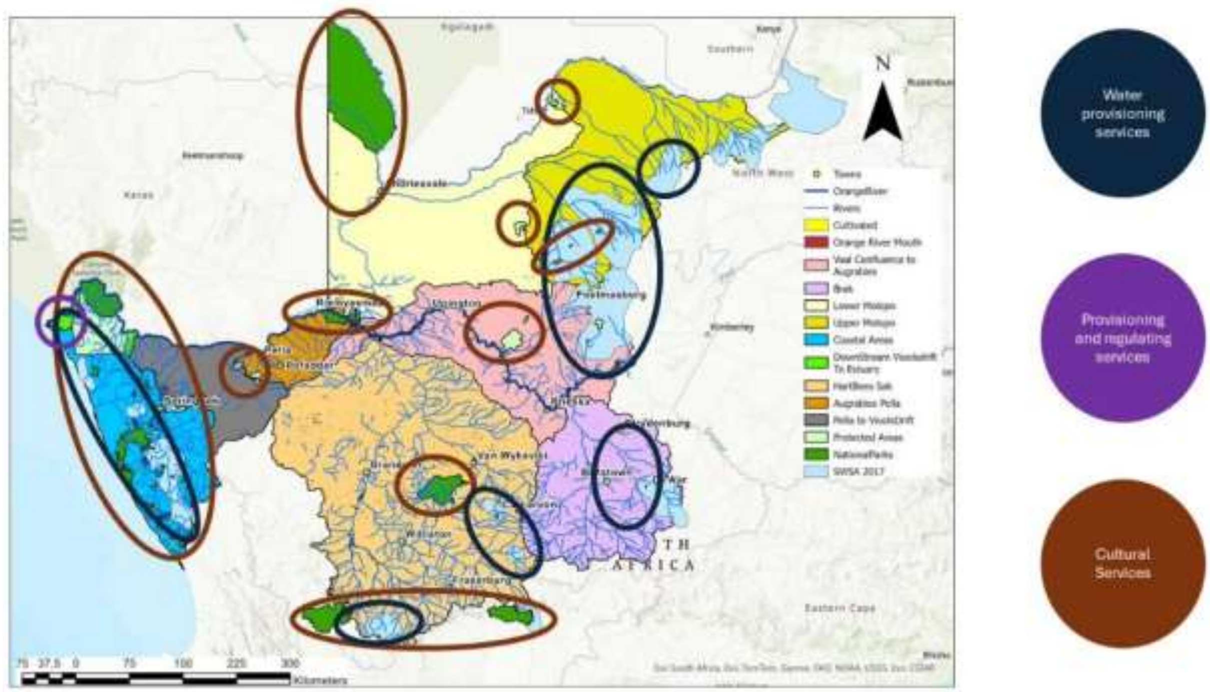



**Figure 19: Ecosystem Service Sensitivity Areas in the Lower Orange Catchment**

## 3.5. Socioeconomic Zones

### 3.5.1. Delineation Process

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

The SEZ's were categorised through the regional classification of the catchment in terms of economic activities, social demographics and wellbeing and ecological features. The process included three steps as shown in Figure 20.

**Step 1: Land Use Assessment**

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

**Step 2: Economic Assessment**

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

**Step 3: Social Assessment**

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

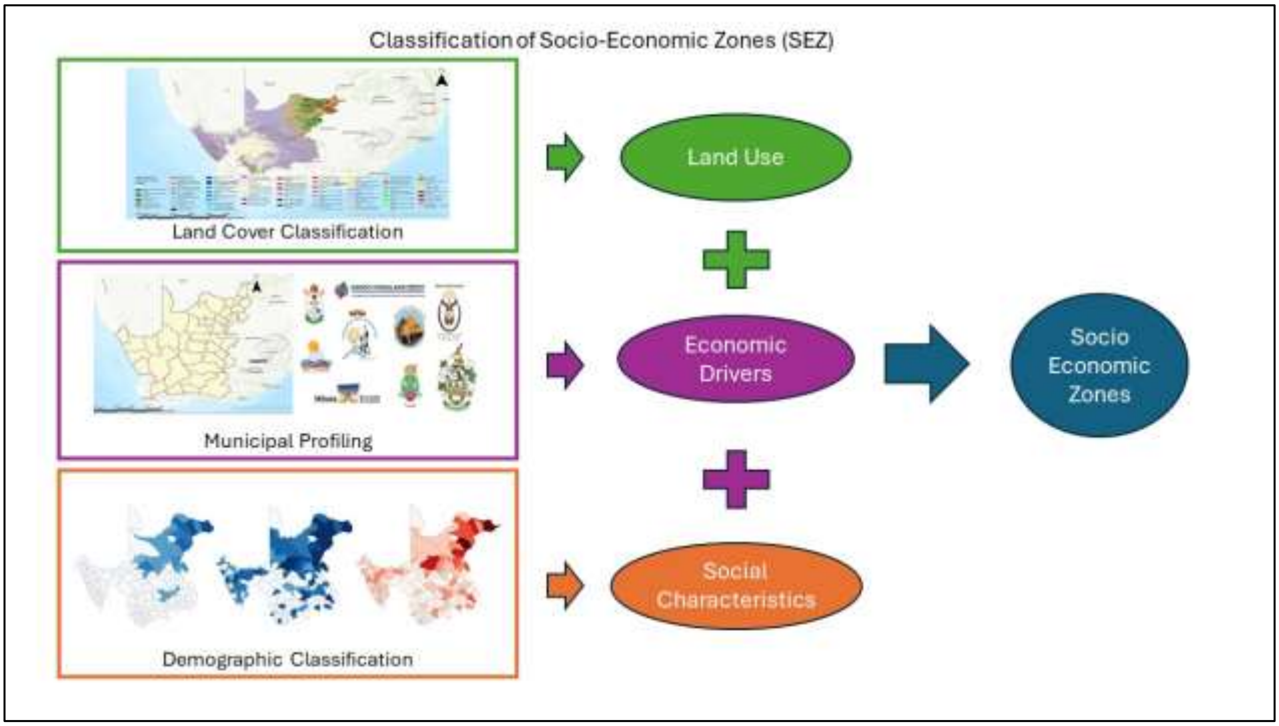



**Figure 20: Schematic representation of Socio-Economic Zone delineation process**

### 3.5.2. Delineated Socio-Economic Zones

Due to the large extent of the Lower Orange catchment study area, there are multiple Socio-Economic Zones. There are five Socio-Economic Zones that have been delineated with the majority of them being mixed-use due to the agriculture and mining activities happening in the area (Figure 21). The zones are defined as follows:

- The Agricultural Zone: Most of the land in this area is used for agriculture, with a few sand mines scattered around. There is a large proportion of irrigation and agricultural areas adjacent to the Orange River. The area contains three main towns and is densely populated. The majority of the agriculture taking place is commercial, and people living in these areas have adequate access to services.
- Mining Zone: The predominant land use in this area is mining. The mining activities taking place are alluvial diamond mining and iron ore mines. There is also some agriculture taking

place in the area. The surrounding towns in the area are densely populated and the residents have mixed access to piped water and wastewater services.

- Mixed Use Zone 1: The zone includes relatively high-intensity land uses such as mining and industrial manufacturing, as well as agriculture (irrigated, commercial, and subsistence) and tourism. The area is heavily mined, particularly for sand and alluvial diamonds. There is also Namaqua National Park, which attracts tourists to the area. The region is highly populated due to all the activity taking place and the proximity to public facilities.
- Mixed Use Zone 2: The area is sparsely populated because there is little activity in the area. There are not many towns, therefore the area can be called rural; nonetheless, there is some commercial sheep farming and mining going on in the zone.
- Mixed Use Zone 3: The zone comprises relatively high-intensity land uses, such as mining, agriculture (irrigated, commercial, and subsistence), and tourism. Kgalagadi Transfrontier Park is responsible for the area's tourism. The neighborhood is densely populated, and many individuals have access to utilities such as piped water and wastewater services.

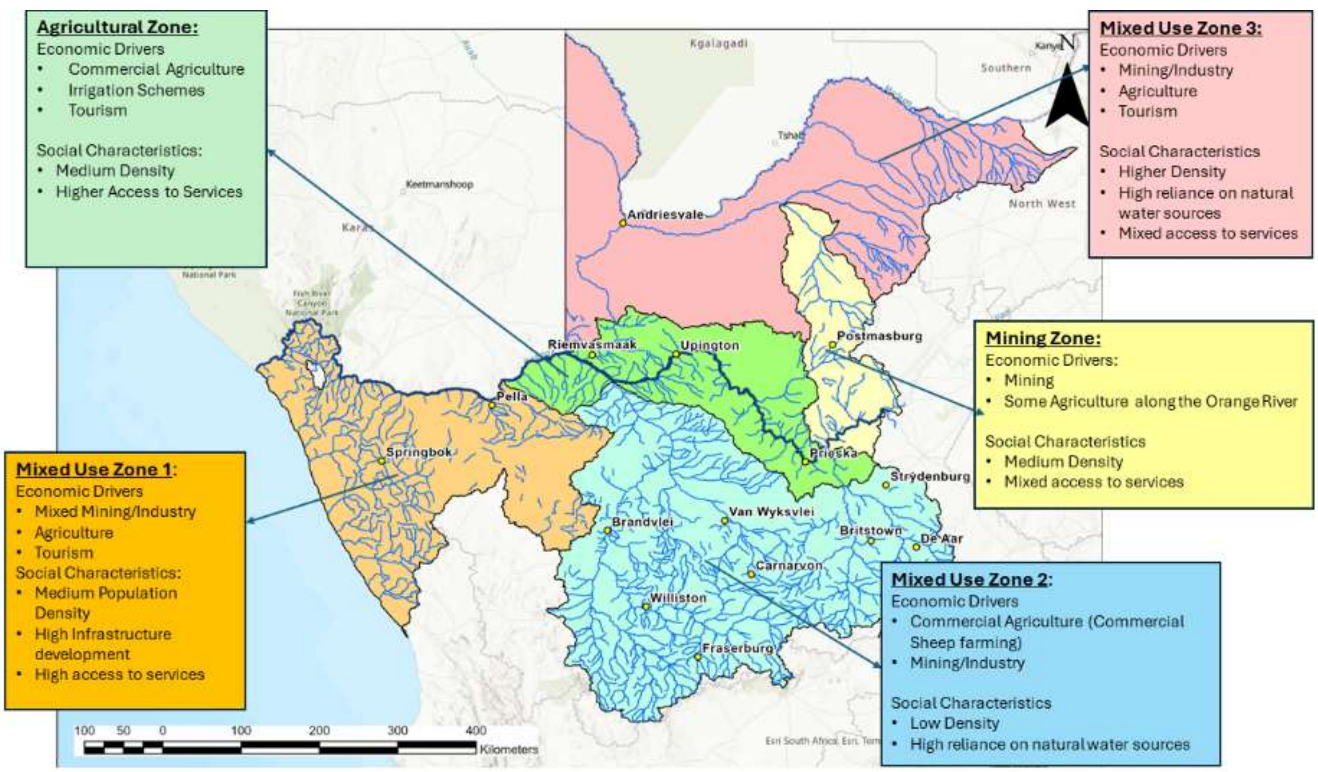



**Figure 21: Socio-Economic Zones within the Lower Orange Catchment study area**

# 4 STATUS QUO: RIVERS

## 4.1. Description

Table 12 presents the mainstem rivers with associated tributaries within the Lower Orange Catchment that comprise the network of rivers identified for classification and associated RQO development. The rivers may be important from a water use perspective or ecological perspective due to expected change in their condition in response to water quantity or water quality variation or the need to be protected. Each of the rivers within the network has been characterised in the following sections to understand their status, priority and condition. The objective of capturing the suite of biophysical and ecological features of the rivers is to assess their uniqueness and significance and to establish nodes that characterise the target catchment's rivers at different ecological scales.

**Table 12: Identified network of significant rivers in the Lower Orange Catchment**

| Sub-catchment | Quaternary | Main river | Major Tributaries (South African Portion) |
|---|---|---|---|
| C92 | C92B, C92C | Vaal | |
| D41 | D41B-M | Molopo | Kuruman, Ga-Mogara, Moshaweng, Phephane |
| D42 | D42A, D42B, D42C, D42D, D42E | Molopo | Nossob, Auob |
| D5 | D51, D52, D53, D54, D55, D56, D57, D58 | Hartbees | Sak, Vis, Riet, Klein-Riet, Sout, Renoster, Brak, Gansvlei, Rugseers, Lekkerleleegte, Bastersout se Leegte, Carnarvonleegte |
| D6 | D61, D62 | Brak | Ongers, Groen, Brak, Klein-Brak,Visgat, Graafwaterspruit, Elandsfontein, Renostervleispruit |
| D7 | D71, D72, D73 | Orange | Hartbees, Brak, Soutloop |
| D8 | D81A-G, D82A-L | Orange | Molopo |
| F10 | F10A-F10C | Holgat | Gaigas, Kook |
| F20 | F20A-F20E | Kamma | |
| F30 | F30A-F30G | Buffels | Stry, Skaap, Brak, Gasab |
| F40 | F40A-F40H | Spoeg, Swartlintjies, Bitter | Wildeperdehoek se Brak, Brand,Outeep |

| Sub-catchment | Quaternary | Main river | Major Tributaries (South African Portion) |
|---|---|---|---|
| F50 | F50A - F50G | Groen | Swart-Doring, Hartbees |
| F60 | F60A | Brak | |

## 4.2. River Characterisation

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

### 4.2.1. Ecoregions

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

While eco-regions descriptions tend to be based on physical and vegetation attributes, the assumption is that the biota (ecological character) within an eco-region are likely to be similar. The eco-regions that are found to occur in the Lower Orange River Catchment described in Table 13 (Kleynhans *et al*., 2005, DWA, 2008) are illustrated in Figure 22, and have been used to guide the delineation of the IUAs.

**Table 13: Eco-regions that characterise the Lower Orange River Catchment**

| Eco-region | Level II | Distribution in catchment | Description |
|---|---|---|---|
| 11: Highveld | 11.08 | D41B | This eco-region is characterized by plains with moderate relief. Vegetation types include dry sandy highveld grassland. The altitude ranges between 1300-1700 meters above sea level (masl). Rainfall is concentrated in mid-late summer, with a MAP of 400 to 500mm. Mean annual air temperatures are between 12°C and 20°C. |
| 18: Drought Corridor | 18.01, 18.02, 18.03, 18.04 | D61A, D61D, D61E | Lowlands, hills and mountains with moderate and high relief, and closed hills and mountains with moderate and high relief, are |

| Eco-region | Level II | Distribution in catchment | Description |
|---|---|---|---|
| | | | characteristic of this region. Southeastern Mountain Grassland and Eastern Mixed Nama Karoo are the dominant vegetation types. The altitude ranges between 300-1900 masl. Rainfall is concentrated in late to very late summer, with a MAP of 100 to 500mm. Mean annual temperatures range between 10°C and 20°C. |
| 21: Great Karoo | 21.01, 21.02, 21.03. 21.04, 21.05 | D55A | Plains with low to moderate relief are often distinctive, significant areas with closed hills and mountains with moderate to high relief are present. The dominant vegetation types are Central Nama Karoo and Great Nama Karoo. The altitude ranges between 300-1700 masl. Rainfall is concentrated in very ate summer, with a MAP of 0 to 500mm. Mean annual temperatures range between 10°C and 20°C. |
| 25: Western Coastal Belt | 25.01; 25.02; 25.03 | Coastal zones of Orange Coastal Sub-area (F10-F60A) | This eco-region (coastal) is characterized by plains with low to moderate relief, Vegetation types consist of succulent Karoo types. The Olifants, Doring, Sout, Groen and Buffalo rivers traverse this region while the Orange River flows through the northern part.<br>The altitude ranges between 0-700 masl. Rainfall is concentrated in winter, with a MAP of 0 to 200mm. Mean annual air temperatures are between 16°C and 22°C. |
| 26: Nama Karoo | 26.01; 26.02; 26.03; 26.04; 26.05 | Dominates the Lower Orange mainstem River sub-area to Vioolsdrift and the Hartbees and Brak catchment areas | This region is very diverse with lowlands, hills and mountains with moderate and high relief, as well as closed hills and mountains with moderate and high relief, being the defining characteristics. The vegetation is dominated by Bushmanland Nama Karoo, mixed Nama Karoo, Succulent Karoo and mountain Renosterveld. The altitude ranges between 300masl and 1700masl. Rainfall is concentrated in late summer to winter, with a MAP of 0 to 500mm. Mean annual air temperatures range between 12°C to 20°C. |
| 27: Namaqua Highlands | 27.01 | Much of the Orange coastal sub-area (upper portions of catchments F10-F60A). Orange | Plains with Closed Hills, Mountains; Moderate and High Relief. The vegetation consists of Upland succulent Karro as the dominant type, and Lowland succulent Karoo, Mountain Renosterveld and patches Mountain Fynbos. The altitude ranges predominantly between 100masl and 1300masl. Rainfall is |

| Eco-region | Level II | Distribution in catchment | Description |
|---|---|---|---|
| | | mainstem D82J and D82K quaternary catchments. | concentrated winter, with a MAP of 0 to 200mm. Mean annual air temperatures range between 12°C to 20°C. |
| 28: Orange River George | 28.01 | Orange River, from D73F to D82G. | This eco-region is characterized Closed Hills; Mountains; Moderate and High Relief. Vegetation types include Orange River Nama Karoo as the predominant type and Upland Succulent Karoo. The altitude ranges between 0masl and 1100masl. Rainfall is concentrated in very late summer to winter, with a MAP of 0 to 100mm. Mean annual air temperatures range between 16°C to 22°C. |
| 29: Southern Kalahari | 29.01; 29.02 | Lower part of the Vaal at the confluence; Molopo, Kuruman and Nosob (seasonal). | Terrain morphological types consist of plains with low to moderate relief in the east, and open hills, lowlands and mountains with moderate to high relief in the west. The western part of the region consists of dune hills. Vegetation types include Shrubby Kalahari Dune Bushveld, Kalahari Plains Thorn Bushveld, Kimberley Thorn Bushveld as the predominant types. Altitude varies from 500 to 1700masl. Rainfall is concentrated in mid to very late summer, with a MAP of 0 to 500mm. Mean annual air temperatures range between 14°C to 22°C. |
| 30: Ghaap Plateau | 30.01 | Eastern borders of the Molopo catchment (D41D, D41F, D41G, D41H, D41L, D71A, D71C) | Terrain morphological types consist of plains with low to moderate relief. Vegetation types include Kalahari Plains Thorn bushveld, Orange River Nama Karoo, Kalahari Mountain Bushveld and Kimberly Thorn Bushveld. The altitude ranges between 900masl and 1700masl. Rainfall is concentrated in late summer, with a MAP of 200 to 500mm. Mean annual air temperatures range between 16°C to 20°C. |

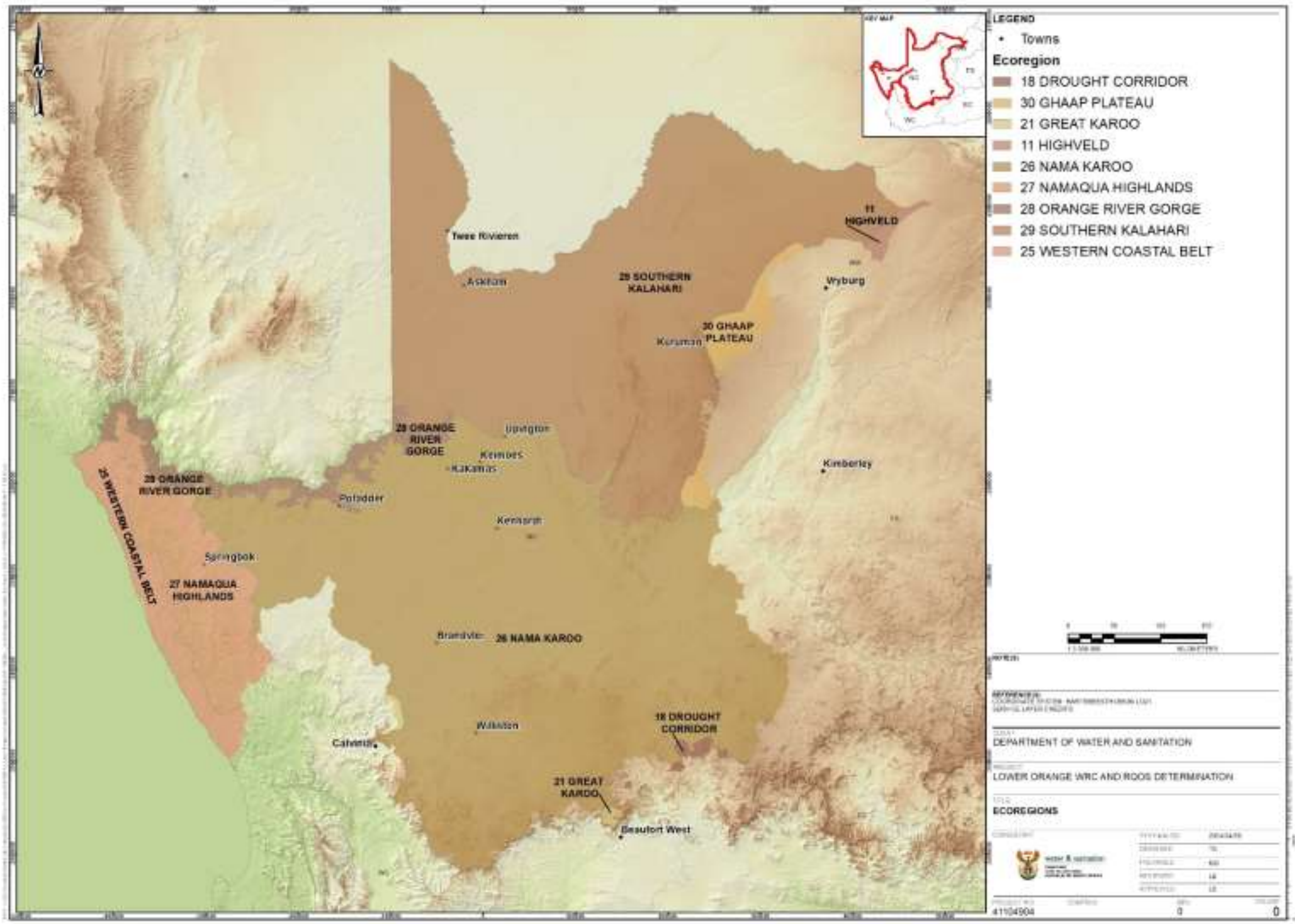



**Figure 22: Ecoregions within the Lower Orange River Catchment**

### 4.2.2. Geomorphology

Geomorphology provides a basis of classification for the purpose of describing the physical habitat of riparian and aquatic ecosystems, as it encompasses the physical processes which have shaped the river channel. Rivers and streams change naturally along their lengths with respect to temperature, depth, current speed, substratum, turbidity and chemical composition. The longitudinal physical and chemical changes can be used to classify the reaches of rivers. Rowntree and Wadeson (1999) have developed a zonal classification system for Southern African rivers modified from Noble and Hemens (1978). In their classification, an attempt was made to give each zone a geomorphological definition in terms of distinctive channel morphological units and reach types. After working in a number of different rivers around the country, it has become clear that channel gradient is an accurate indicator of channel characteristics and that probable or expected difference can be identified from an analysis of gradients (Table 14).

The concept of river zonation recognises the longitudinal changes in river characteristics associated with the river long profile. In a graded system there is a natural progression from mountain stream through foothill stream to lowland river. On the basis of channel features ten geomorphological zone classes have been defined and are described in Table 14. The zones are areas within a catchment which can be considered as homogenous with respect to flood runoff and sediment production.

**Table 14: Geomorphological zonation of South African river channels (Adapted from Rowntree and Wadeson, 1999) (DWS 2007b)**

| Zone Class | Zone | Gradient Class | Characteristic Features |
|---|---|---|---|
| S | Source Zone | Not specified | Low gradient, upland plateau, or upland basin able to store water. Spongy or peat hydromorphic soils |
| A | Mountain Headwater Stream | >0.1 | A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades. |
| B | Mountain Stream | 0.04 – 0.099 | Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool. |
| C | Transitional | 0.02 – 0.039 | Moderately steep stream dominated by bedrock or boulder. Reach types include plane-bed, pool-rapid or pool-riffle. Confined or semi-confined valley |

| Zone Class | Zone | Gradient Class | Characteristic Features |
|---|---|---|---|
| | | | floor with limited floodplain development. |
| D | Upper Foothills | 0.005 – 0.019 | Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow floodplain of sand, gravel or cobble often present. |
| Dr | Rejuvenated bedrock cascades | >0.02 | Moderate to steep gradient, confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades and pool-rapid. |
| E | Lower Foothills | 0.001 – 0.005 | Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Floodplain often present. |
| F | Lowland River | 0.0001 – 0.0009 | Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increased silt content in bed or banks. |
| Er | Rejuvenated Foothills | 0.001 – 0.02 | Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge; characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro-channel activated only during infrequent flood events. A limited flood- plain may be present between the active and macro-channel. |

The geomorphological zones that occur in the Lower Orange catchment and their extent are listed below and shown Figure 23. The upper and lower foothills (class D and E) are dominant river geomorphological classes in the catchment. The zones are a consideration for delineation of the IUAs (in respect of the ecological component – river character and habitat).

- Zone Class A: Mountain Headwater Stream – 0.32%
- Zone Class B: Mountain Stream – 0.91%
- Zone Class C: Transitional – 3.12%
- Zone Class D: Upper Foothills – 32.92%
- Zone Class E: Lower Foothills – 47.77%
- Zone Class F: Lowland River – 12.46%

The availability of a suitable habitat is a critical criterion for ecosystem health, which is influenced channel and riparian geomorphology. Thus, processes that drive channel morphology and geomorphology are a key driver of ecosystem processes (and thus the PES of a river reach). The ecological status for geomorphology is assessed in terms of changes to the geomorphological system, which consider:

- system connectivity,
- reach sediment balance,
- channel resistance, and
- morphological change.

*Instream Habitat Continuity Modification*: Any modifications that indicate the potential that either longitudinal or lateral instream connectivity may have been changed from the reference. Modifications include physical fragmentation, e.g. inundation by weirs or dams.

*Riparian/Wetland Habitat Continuity Modification*: An assessment of modifications that indicate the potential that riparian/wetland connectivity (both lateral and longitudinal) may have been changed from the reference state. Modifications could include physical fragmentation, e.g. inundation by weirs, dams; physical removal for farming, mining, etc, presence of roads, or urban areas.

*Instream Habitat Modification (Channel/Habitat Modification)*: Modifications that indicate the potential that instream habitats may have been changed from the reference and includes consideration of the functioning of instream habitats and processes, as well as habitat for instream biota.

*Riparian/Wetland Zone Modification*: Modifications that indicate the potential that riparian/wetland zones may have been changed from the reference in terms of structure and composition that influence ecological functions and processes. Considerations could include possible changes in occurrence and structure due to flow modification and physical changes as a result of agriculture, mining, urbanization, inundation, etc.

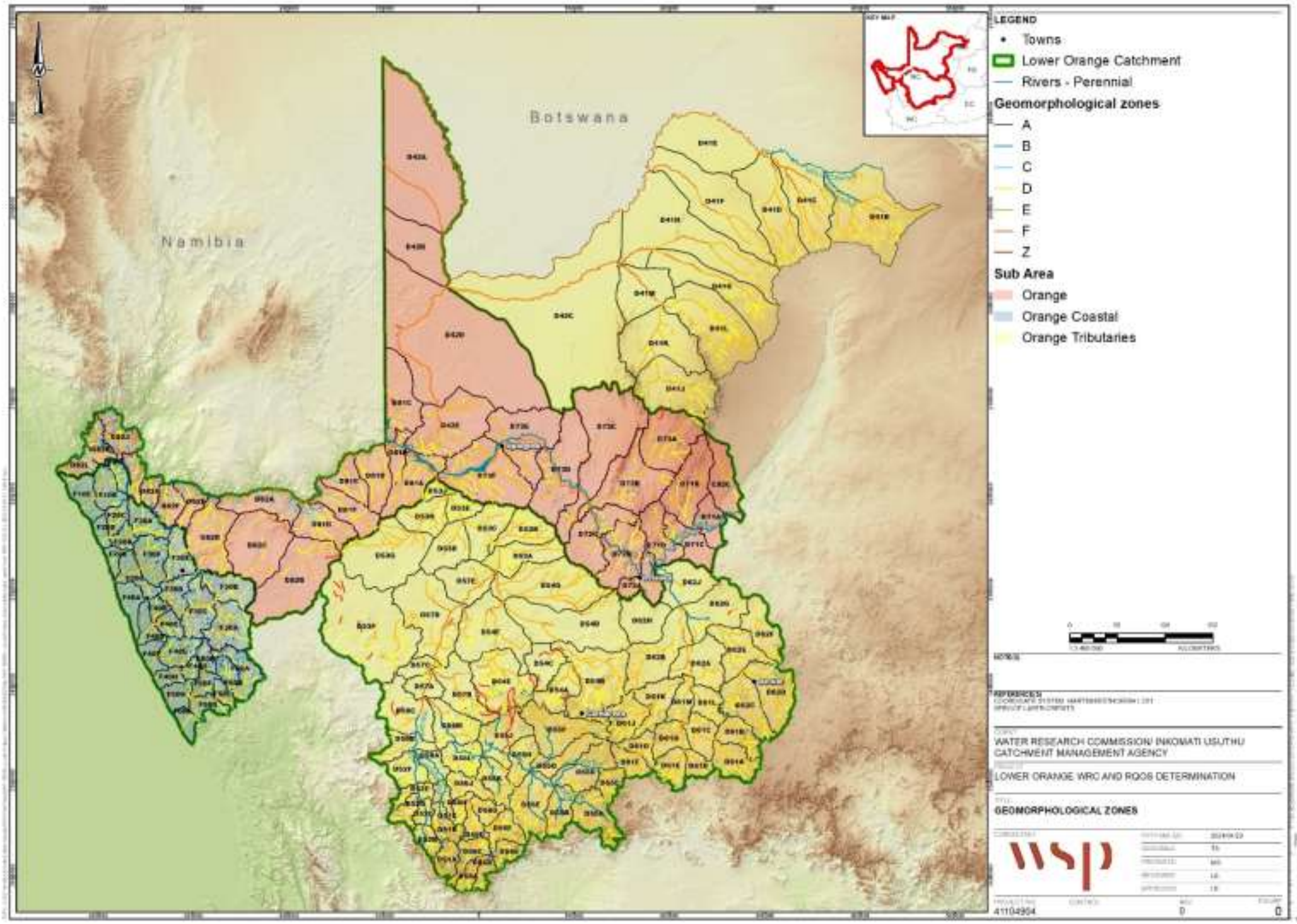



**Figure 23: Geomorphological Zones in the Lower Orange River Catchment**

### 4.2.3. Present Ecological Status

The Present Ecological Status (PES) of a water resource refers to its present ecological condition relative to the perceived natural reference condition (pre-development/historical). The ability of a water resource to continue providing ecosystem goods and services is determined, to a large degree, by its present ecological condition. The PES (health or integrity) considers various biophysical attributes of rivers. The purpose of the determining the PES is to is gain insights into the causes and sources of the deviation of the instream biophysical attributes from the reference condition. This provides the information needed to derive future ecological objectives for the river, as well to manage the flow and non-flow impacts.

In essence the PES represents an ecologically integrated state of a river (the ecosystem health). The state of a river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology) which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation and aquatic invertebrates).

The measure of PES is based on the drivers and responses and habitat information that has been collected. Results are classified on a 6-point scale, from Category A (Largely Natural) to Category F (Critically Modified). Different processes are followed for each component to assign a category ranging from an A to an F category (Table 15). Ecological evaluation against the expected reference conditions, followed by integration of the categories of each component, provides a description of the Ecological Status or EcoStatus of a river. The EcoStatus can thus be defined as the total of the features and characteristics of the river (instream and riparian zones) that influence its ability to support an appropriate natural vegetation and animal life. This ability relates directly to the capacity of the system to provide a variety of goods and services (Modified from Kleynhans and Louw, 2007), which are considered in the classification of water resource resources.

**Table 15: Description of the Ecological categories**

| Ecological Category | Description |
|---|---|
| A | Unmodified, natural. |
| B | Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged. |
| C | Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. |
| D | Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred. |
| E | Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive. |

| Ecological Category | Description |
|---|---|
| F | Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. |

The PES is a very broad qualitative assessment of both the instream and riparian components of a river. In 2013, the DWS published a national database of the PES/EIS of Sub-quaternary (SQ) river reaches throughout the country that was based on a modified desktop level eco-classification. A combination of expert knowledge and available information on the sub-quaternary reach levels were used to derive the Desktop Present Ecological State (PES). This PES/EIS database was used as the basis of the surface water maps to represent the ecological state component. The final modelled information in the front-end model for each primary catchment is available from the Directorate: Resource Quality Information Services (D: RQIS), DWS. Information was extracted in a 'master spreadsheet' for each primary catchment that incorporates the PES/EIS results. The objective of the PES/EIS is to provide desktop level information on ecological issues as it relates to the protection and management of river reaches. The PES results for the Lower Orange catchment are presented in the sub-sections to follow. While the 2013 database information has been relied upon for this report to understand the ecological state of the rivers in the catchment, the DWS in association with the Water Research Commission (WRC) is currently underway with a project to update the PES database (PES/EIS 2025). The results of this process and the updated database will however only be available in later 2025. Should information from this project be available earlier to support the water resource classification and RQO development process in the Orange it will be adopted.

The Lower Orange catchment includes 1 459 sub-quaternary (SQ) river reaches, however the PES was only assessed for 654 SQ reaches (45% of catchment), with the remaining reaches being ephemeral or episodic. Figure 24 presents the PES ecological categories (EC) for the SQ river reaches assessed. Much of the catchment that was assessed is in a C PES ecological category (278 river reaches), indicating moderate modification, with ecosystem functionality still largely intact. A number of river reaches (42%) are in a good ecological condition in catchment, *i.e.* in a largely natural state (B present ecological state). A portion of the rivers (14%) in the Molopo, Sak, Vis, Buffels and Orange River catchments are largely modified (D present ecological state), due to the impacts from land use, abstractions, weirs, development and associated activities, while only 4 river reaches within the Kuruman and Orange rivers sub-catchments are in a seriously modified state (PES of an E category). No reaches are critically modified (F category). More detail on the PES per secondary catchment is provided in the following sections. The driver of the PES ecological category is indicated for rivers in a C category or below, *i.e.* if not in a natural (A) or largely natural state (B). In terms of the driver descriptors, flow impact refers to modification of stream flow, water quality refers to physico-chemical modifications to the river reach and non-flow impact refers to instream habitat and/or riparian/wetland continuity and zone modifications.

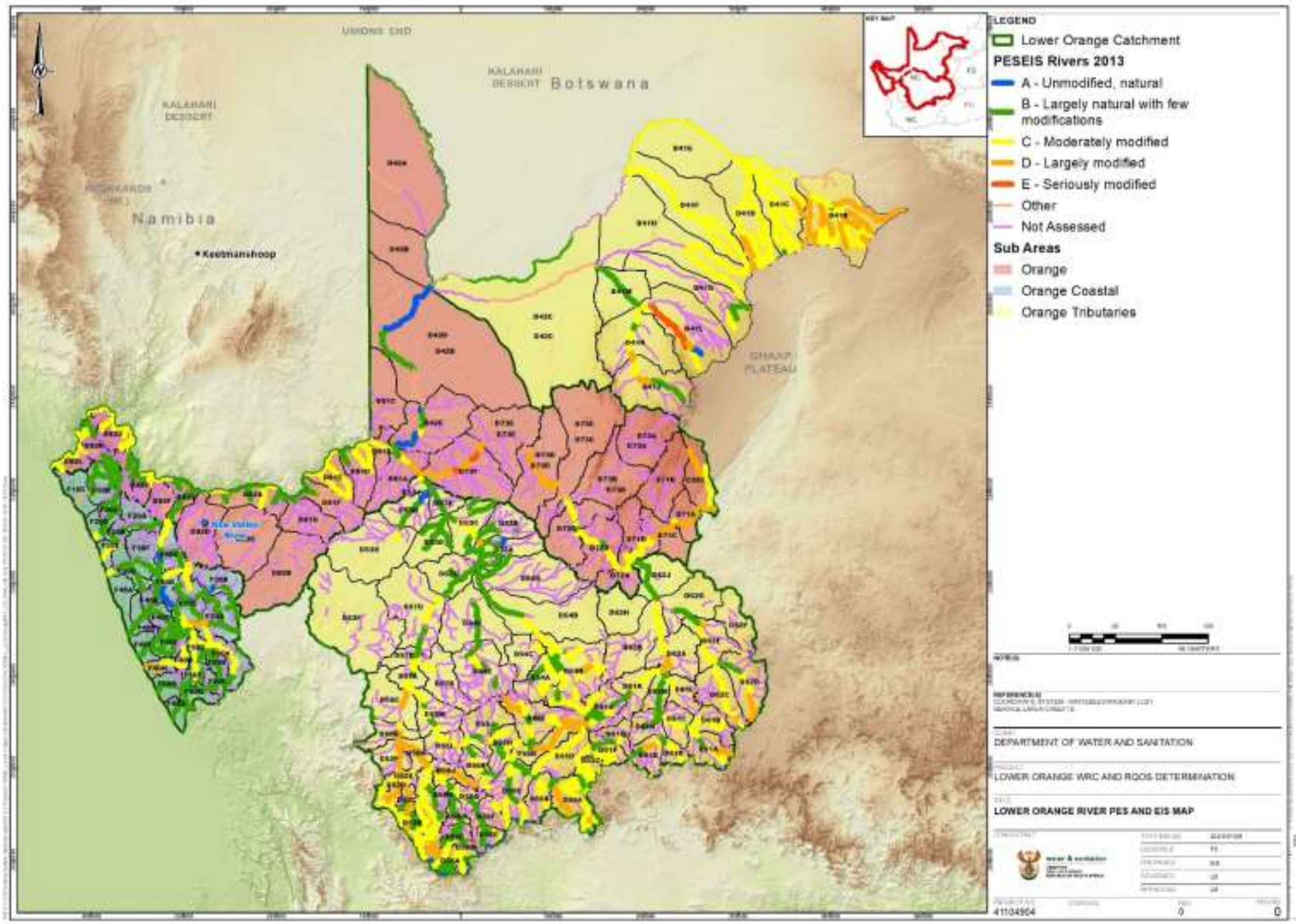



**Figure 24: Present Ecological Status of the Rivers in the Lower Orange River Catchment**

#### 4.2.3.1. D41 and D42 Catchment: Molopo and Kuruman Rivers

The D41 and D42 tertiary catchments include the Molopo River and its tributaries the Kuruman, Nossob and Auob rivers to the confluence with the Orange River. The PES was assessed for 104 sub-quat reaches of a total of 186. The rivers in the sub-catchment (D41B-M; D42A - D42E) are in a good to moderate ecological condition, falling largely within an B, C or D PES ecological category, with the exception of the upper reaches of the Kuruman and an unnamed tributary, which are the only E category river reaches (Table 16).

This is due to flow and non-flow (riparian zone and instream modification or continuity) impacts related small weirs, instream dams, land use and erosion. A large part of the area includes ephemeral or episodic rivers which were not assessed. The lower reaches of the Molopo are in a largely natural or natural state (A and B category PES).

**Table 16: PES and condition or PES Drivers for D41 and D42 – Molopo and Kuruman Rivers**

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D41B-01075/mheelo | Mheelo | Not assessed | Ephemeral |
| D41B-01115 | Logagane | C | Flow, non-flow (riparian) |
| D41B-01182 | Mareetsane | D | Flow, water quality, non-flow (instream) |
| D41B-01209 | Mosita se Laagte | D | Flow, water quality, non-flow (instream) |
| D41B-01289 | Unnamed | C | Non-flow |
| D41B-01291 | Morokwa | D | Water quality, Non-flow related (instream) |
| D41B-01321 | Unnamed | D | Flow, non-flow (riparian/instream) |
| D41B-01355 | Mosime | C | Non-flow (riparian/wetland) |
| D41B-01363 | Thutlwane | C | Water Quality, Non-flow (riparian/wetland) |
| D41B-01393 | Tlhakajen | C | Non-flow (riparian/wetland), Water quality |
| D41B-01407 | Setlagole | C | Water quality, Non-flow related (riparian/wetland) |
| D41B-01410 | Rangolwane | D | Non-flow related (riparian/wetland), water quality |
| D41B-01416 | Unnamed | D | Water quality, Non-flow (riparian/instream) |
| D41B-01427 | Unnamed | C | Flow, non-flow (instream) |
| D41B-01428 | Unnamed | C | Non-flow (riparian/wetland/instream), flow |
| D41B-01431 | Madibeng | C | Flow, Non-flow (instream/riparian/wetland), water quality |
| D41B-01441 | Sepane | D | Water quality, Non-flow (riparian/wetland) |
| D41B-01444 | Tlhalatau | C | Non-flow (riparian/wetland) |
| D41B-01239 | Mareetsane | B | Largely Natural |
| D41B-01265 | Koedoespruit | C | Flow, non-flow (riparian/wetland) |
| D41B-01312 | Koedoespruit | D | Flow, non-flow (riparian/wetland/instream) |
| D41B-01329 | Thutlwane | C | Non-flow (riparian/wetland/instream), water quality |
| D41B-01336 | Setlagole | D | Flow, non-flow (riparian/wetland/instream), water quality |
| D41B-01391 | Unnamed | C | Flow, non-flow (instream) |
| D41B-01392 | Madibeng | C | Flow, water quality |
| D41B-01398 | Unnamed | C | Water quality, Non-flow (riparian/wetland) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D41B-01075/Molopo | Molopo | C | Flow, water quality |
| D41B-01201 | Setlagole | C | Flow, water quality |
| D41B-01249 | Madibeng | D | Flow, non-flow (riparian/wetland/instream) |
| D41B-01279 | Setlagole | B | Largely Natural |
| D41B-01284 | Setlagole | C | Water quality, Non-flow (riparian/wetland) |
| D41B-01322 | Madibeng | D | Flow, non-flow (riparian/wetland/instream) |
| D41B-01115/Molopo | Molopo | C | Non-flow (riparian/wetland/instream) |
| D41B-01122/Molopo | Molopo | C | Flow, non-flow (riparian/wetland/instream) |
| D41B-01122/Setlagole | Setlagole | D | Flow, non-flow (riparian/wetland/instream) |
| D41B-01190 | Setlagole | C | Water quality, Non-flow (riparian/wetland), flow |
| D41C-01152 | Valslaagte | C | Non-flow (riparian/wetland) |
| D41C-01184 | Koedoeboslaagte | C | Water quality, Non-flow (riparian/wetland) |
| D41C-01204 | Matlapeng | D | Water quality, Non-flow (riparian/wetland/instream) |
| D41C-01243 | Doringlaagte | C | Water quality, Non-flow (riparian/wetland) |
| D41C-01278 | Hoogmoedlaagte | C | Non-flow (riparian/wetland) |
| D41C-01293 | Disipi | C | Non-flow (riparian/wetland) |
| D41C-01451 | Khudunkgwelaagte | C | Non-flow (riparian/wetland) |
| D41C-01454 | Unnamed | C | Non-flow (riparian/wetland) |
| D41C-01061 | Wildebeeshoringlaagte | C | Non-flow (riparian/wetland), water quality |
| D41C-01206 | Disipi | C | Non-flow (riparian/wetland) |
| D41C-01218 | Khudunkgwelaagte | C | Non-flow (riparian/wetland) |
| D41C-01244 | Khudunkgwelaagte | C | Non-flow (riparian/wetland) |
| D41C-01048 | Wildebeeshoringlaagte | C | Non-flow (riparian/wetland), water quality |
| D41C-01111 | Valslaagte | C | Non-flow (riparian/wetland), water quality |
| D41C-01139 | Khudunkgwelaagte | C | Non-flow (riparian/wetland), water quality |
| D41C-01010 | Molopo | C | Water quality, flow |
| D41D-01385 | Unnamed | C | Non-flow (instream habitat), water quality |
| D41D-01434 | Unnamed | C | Non-flow (riparian/wetland), water quality |
| D41D-01582 | Phaposane | C | Non-flow (instream habitat), water quality |
| D41D-01583 | Unnamed | C | Non-flow (riparian/wetland), water quality |
| D41D-01624 | Unnamed | C | Non-flow (instream habitat), water quality |
| D41D-01647 | Ganyesa | D | Non-flow (instream habitat), water quality |
| D41D-01229 | Tlakgamenglaagte | C | Non-flow (riparian/wetland), water quality |
| D41D-01230 | Ganyesalaagte | C | Non-flow (riparian/wetland), water quality |
| D41D-01380 | Tlakgamenglaagte | C | Non-flow (riparian/wetland), water quality |
| D41D-01461 | Ganyesalaagte | D | Flow, Water quality, Non-flow (riparian/wetland/instream) |
| D41D-01065 | Tlakgamenglaagte | C | Non-flow (riparian/wetland) |
| D41D-01031 | Tlhakgameng | C | Non-flow (riparian/wetland) |
| D41E-00841 | Molopo | C | Flow, Water quality, Non-flow (riparian/wetland/instream) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D41E-00873 | Molopo | C | Flow, Water quality, Non-flow (riparian/wetland/instream) |
| D41F-01240 | Tlapeng | C | Water quality, Non-flow (riparian/wetland/instream) |
| D41F-01388 | Phepane | C | Non-flow (riparian/wetland), water quality |
| D41F-01020 | Phepane | C | Non-flow (riparian/wetland), water quality |
| D41G-01871 | Unnamed | Not assessed | Ephemeral |
| D41G-01873 | Matlhotshaneng | Not assessed | Ephemeral |
| D41G-01921 | Unnamed | Not assessed | Ephemeral |
| D41G-02002 | Unnamed | Not assessed | Ephemeral |
| D41G-02034 | Unnamed | Not assessed | Ephemeral |
| D41G-02041 | Unnamed | B | Largely Natural |
| D41G-02054 | Unnamed | B | Largely Natural |
| D41G-02056 | Moshaweng | C | Non-flow (riparian/wetland) |
| D41G-01834 | Moshaweng | Not assessed | Ephemeral |
| D41G-01859 | Matlhotshaneng | Not assessed | Ephemeral |
| D41G-01956 | Moshaweng | Not assessed | Ephemeral |
| D41G-02000 | Moshaweng | Not assessed | Ephemeral |
| D41G-02001 | Moshaweng | Not assessed | Ephemeral |
| D41G-02047 | Moshaweng | Not assessed | Ephemeral |
| D41G-01632 | Moshaweng | Not assessed | Ephemeral |
| D41H-01500 | Kgokgole | C | Flow, non-flow (riparian/wetland), water quality |
| D41H-01587 | Lolwaneng | C | Flow, Water quality, Non-flow (riparian/wetland/instream) |
| D41H-01335 | Kgokgole | Not assessed | Ephemeral |
| D41H-01548 | Moshaweng | Not assessed | Ephemeral |
| D41H-01145 | Molopo | Not assessed | Episodic |
| D41J-02430 | Unnamed | Not assessed | Episodic |
| D41J-02504 | Unnamed | Not assessed | Episodic |
| D41J-02511 | Olifantsloop | Not assessed | Episodic |
| D41J-02554 | Unnamed | Not assessed | Episodic |
| D41J-02604 | Unnamed | Not assessed | Episodic |
| D41J-02608 | Unnamed | Not assessed | Episodic |
| D41J-02620 | Unnamed | Not assessed | Episodic |
| D41J-02650 | Ga-Mogara | Not assessed | Episodic |
| D41J-02536 | Ga-Mogara | B | Largely Natural |
| D41J-02543 | Unnamed | Not assessed | Episodic |
| D41J-02558 | Ga-Mogara | B | Largely Natural |
| D41J-02419 | Ga-Mogara | C | Non-flow (riparian/wetland) |
| D41J-02464 | Ga-Mogara | D | Non-flow (riparian/wetland) |
| D41J-02531 | Ga-Mogara | B | Largely Natural |
| D41K-02181 | Witleegte | Not assessed | Episodic |
| D41K-02240 | Vlermuisleegte | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D41K-02313 | Dooimansholte | Not assessed | Episodic |
| D41K-02357 | Ga-Mmatshephe | Not assessed | Episodic |
| D41K-02068 | Ga-Mogara | C | Non-flow (riparian/wetland) |
| D41K-02141 | Ga-Mogara | B | Largely Natural |
| D41K-02167 | Ga-Mogara | C | Non-flow (riparian/wetland) |
| D41K-02311 | Ga-Mogara | C | Non-flow (riparian/wetland) |
| D41K-02366 | Ga-Mogara | D | Non-flow (riparian/wetland) |
| D41L-02009 | Unnamed | Not assessed | Episodic |
| D41L-02012 | Unnamed | Not assessed | Episodic |
| D41L-02032 | Logobate | Not assessed | Episodic |
| D41L-02149 | Unnamed | Not assessed | Episodic |
| D41L-02158 | Unnamed | Not assessed | Episodic |
| D41L-02174 | Unnamed | Not assessed | Episodic |
| D41L-02230 | Unnamed | Not assessed | Episodic |
| D41L-02231 | Unnamed | Not assessed | Episodic |
| D41L-02267 | Unnamed | Not assessed | Episodic |
| D41L-02279 | Unnamed | Not assessed | Episodic |
| D41L-02292 | Unnamed | Not assessed | Episodic |
| D41L-02300 | Matlhwaring | Not assessed | Episodic |
| D41L-02303 | Unnamed | E | Non-flow (riparian/wetland) |
| D41L-02307 | Ga-Masepa | Not assessed | Episodic |
| D41L-02309 | Unnamed | Not assessed | Not a river |
| D41L-02312 | Manyeding | Not assessed | Episodic |
| D41L-02333 | Kuruman | A | Natural/Close to natural |
| D41L-02349 | Unnamed | C | Non-flow (riparian/wetland) |
| D41L-02064 | Kuruman | E | Non-flow (riparian/wetland), water quality |
| D41L-02173 | Matlhwaring | Not assessed | Episodic |
| D41L-02191 | Manyeding | Not assessed | Episodic |
| D41L-02225 | Matlhwaring | Not assessed | Episodic |
| D41L-02229 | Matlhwaring | Not assessed | Episodic |
| D41L-02264 | Manyeding | Not assessed | Episodic |
| D41L-02273 | Matlhwaring | Not assessed | Episodic |
| D41L-02299 | Kuruman | D | Non-flow (riparian/wetland), water quality |
| D41L-01906 | Matlhwaring | Not assessed | Episodic |
| D41L-02042 | Kuruman | C | Non-flow (riparian/wetland) |
| D41L-02048 | Matlhwaring | Not assessed | Episodic |
| D41L-02069 | Matlhwaring | Not assessed | Episodic |
| D41L-02103 | Matlhwaring | Not assessed | Episodic |
| D41L-02138 | Matlhwaring | Not assessed | Episodic |
| D41L-02145 | Matlhwaring | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D41L-02168 | Matlhwaring | Not assessed | Episodic |
| D41M-01756 | Kuruman | B | Largely Natural |
| D42A-01082 | Nossob | Not assessed | Episodic |
| D42A-01198 | Auob | Not assessed | Episodic |
| D42B-01652 | Nossob | Not assessed | Episodic |
| D42C-01918 | Kuruman | Not assessed | Episodic |
| D42C-01754 | Molopo | B | Largely Natural |
| D42C-01940 | Molopo | A | Natural/Close to natural |
| D42D-02123 | Molopo | Not assessed | Episodic |
| D42D-01899 | Molopo | A | Natural/Close to natural |
| D42D-02283 | Molopo | B | Largely Natural |
| D42E-02491 | Unnamed | Not assessed | Episodic |
| D42E-02598 | Unnamed | Not assessed | Episodic |
| D42E-02655 | Unnamed | Not assessed | Episodic |
| D42E-02656 | Doringdam | Not assessed | Endorheic |
| D42E-02709 | Unnamed | Not assessed | Episodic |
| D42E-02723 | Unnamed | Not assessed | Episodic |
| D42E-02787 | Unnamed | Not assessed | Episodic |
| D42E-02891 | Unnamed | Not assessed | Episodic |
| D42E-02931 | Unnamed | Not assessed | Episodic |
| D42E-02938 | Unnamed | Not assessed | Episodic |
| D42E-02958 | Unnamed | Not assessed | Episodic |
| D42E-03009 | Unnamed | Not assessed | Episodic |
| D42E-03056 | Unnamed | Not assessed | Episodic |
| D42E-03092 | Unnamed | Not assessed | Episodic |
| D42E-03120 | Unnamed | Not assessed | Episodic |
| D42E-03129 | Unnamed | Not assessed | Episodic |
| D42E-02606 | Unnamed | Not assessed | Episodic |
| D42E-02674 | Unnamed | Not assessed | Episodic |
| D42E-02774 | Unnamed | Not assessed | Episodic |
| D42E-02896 | Unnamed | Not assessed | Episodic |
| D42E-02738 | Molopo | A | Natural/Close to natural |
| D42E-02812 | Molopo | B | Largely Natural |
| D42E-02893 | Molopo | C | Non-flow (riparian/wetland) |
| D42E-02913 | Molopo | A | Natural/Close to natural |
| D42E-03047 | Molopo | B | Largely Natural |
| D42E-03060 | Molopo | B | Largely Natural |
| D42E-03064 | Molopo | A | Natural/Close to natural |
| D42E-03065 | Molopo | A | Natural/Close to natural |
| D42E-03087 | Molopo | A | Natural/Close to natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D42E-03103 | Molopo | A | Natural/Close to natural |

#### 4.2.3.2. D7 Secondary catchment: Orange River from the Vaal Confluence to confluence with the Hartbees

The D7 secondary catchment incorporates the Orange River from its confluence with the Vaal River to the Hartbees River confluence. The sub-catchment includes a number of small tributaries, which are predominantly ephemeral (72% not assessed). The PES of the sub-quat reaches of this middle portion of the Orange River are predominantly in a C or D ecological category, indicating changes in ecosystem functions due land use activities (Table 17). Flow impacts and changes to the instream/riparian habitat and biota are responsible for the predominantly modified systems (D category). The Orange River in D73F, the reaches between Upington and Kakamas are in an E ecological category related to flow, non-flow and some water quality impact.

**Table 17: PES and condition or PES Drivers for D7 – Orange River (Vaal to Hartbees confluences)**

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D71A-03473 | Withoekskloof | Not assessed | Ephemeral |
| D71A-03610 | Orange | D | Water quality, flow, Non-flow (instream habitat) |
| D71A-03638 | Unnamed | Not assessed | Ephemeral |
| D71A-03865 | Orange | C | Water quality, flow |
| D71A-03870 | Orange | D | Water quality, flow |
| D71B-03073 | Unnamed | Not assessed | Ephemeral |
| D71B-03097 | Unnamed | Not assessed | Ephemeral |
| D71B-03386 | Unnamed | Not assessed | Ephemeral |
| D71B-03409 | Unnamed | Not assessed | Ephemeral |
| D71B-03490 | Unnamed | Not assessed | Ephemeral |
| D71B-03516 | Unnamed | Not assessed | Ephemeral |
| D71B-03587 | Unnamed | Not assessed | Ephemeral |
| D71B-03598 | Unnamed | Not assessed | Ephemeral |
| D71B-03620 | Unnamed | Not assessed | Ephemeral |
| D71C-03717 | Lanyon Spruit | Not assessed | Ephemeral |
| D71C-03784 | Unnamed | Not assessed | Ephemeral |
| D71C-03874 | Orange | D | Water quality, flow |
| D71C-03883 | Unnamed | Not assessed | Ephemeral |
| D71C-03901 | Unnamed | Not assessed | Ephemeral |
| D71C-03960 | Unnamed | Not assessed | Ephemeral |
| D71C-04010 | Unnamed | Not assessed | Ephemeral |
| D71C-04047 | Lanyon Spruit | Not assessed | Ephemeral |
| D71D-03575 | Diep | Not assessed | Ephemeral |
| D71D-03965 | Unnamed | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D71D-04003 | Orange | C | Flow, non-flow (riparian/wetland) |
| D71D-04075 | Orange | C | Flow |
| D71D-04119 | Unnamed | Not assessed | Ephemeral |
| D71D-04122 | Unnamed | Not assessed | Ephemeral |
| D71D-04124 | Orange | C | Flow |
| D71D-04165 | Orange | C | Flow, non-flow (riparian/wetland) |
| D71D-04218 | Orange | C | Flow, non-flow (riparian/wetland) |
| D72A-04156 | Unnamed | Not assessed | Ephemeral |
| D72A-04169 | Orange | C | Flow, non-flow (riparian/wetland) |
| D72A-04276 | Orange | C | Flow, non-flow (riparian/wetland |
| D72A-04313 | Orange | D | Flow, non-flow (riparian/wetland), Water quality |
| D72A-04399 | Prieska | Not assessed | Ephemeral |
| D72A-04402 | Karabeeloop | Not assessed | Ephemeral |
| D72A-04492 | Unnamed | Not assessed | Ephemeral |
| D72A-04499 | Unnamed | Not assessed | Ephemeral |
| D72B-03805 | Rooiloop | Not assessed | Ephemeral |
| D72B-03837 | Droe | Not assessed | Ephemeral |
| D72B-03841 | Unnamed | Not assessed | Ephemeral |
| D72B-03933 | Unnamed | Not assessed | Ephemeral |
| D72B-03941 | Orange | C | Flow |
| D72B-03975 | Unnamed | Not assessed | Ephemeral |
| D72B-03981 | Unnamed | Not assessed | Ephemeral |
| D72B-04019 | Rooiloop | Not assessed | Ephemeral |
| D72B-04035 | Orange | C | Flow |
| D72B-04059 | Orange | C | Flow |
| D72B-04070 | Orange | B | Largely Natural |
| D72B-04106 | Orange | C | Flow |
| D72B-04116 | Unnamed | Not assessed | Ephemeral |
| D72B-04146 | Unnamed | Not assessed | Ephemeral |
| D72B-04158 | Orange | C | Flow |
| D72B-04175 | Kat | Not assessed | Ephemeral |
| D72B-04268 | Orange | C | Flow |
| D72B-04273 | Orange | C | Flow |
| D72B-04287 | Unnamed | Not assessed | Ephemeral |
| D72C-03621 | Unnamed | Not assessed | Ephemeral |
| D72C-03720 | Orange | C | Flow |
| D72C-03761 | Unnamed | Not assessed | Ephemeral |
| D72C-03825 | Unnamed | Not assessed | Ephemeral |
| D72C-03872 | Unnamed | Not assessed | Ephemeral |
| D72C-03877 | Orange | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D72C-03880 | Unnamed | Not assessed | Ephemeral |
| D72C-03891 | Orange | C | Flow |
| D72C-03924 | Orange | B | Largely Natural |
| D72C-03938 | Marydale | Not assessed | Ephemeral |
| D72C-04000 | Orange | C | Flow |
| D72C-04050 | Unnamed | Not assessed | Ephemeral |
| D73A-02677 | Unnamed | Not assessed | Ephemeral |
| D73A-02698 | Unnamed | Not assessed | Ephemeral |
| D73A-02705 | Groenwaterspruit | Not assessed | Ephemeral |
| D73A-02775 | Unnamed | Not assessed | Ephemeral |
| D73A-02784 | Unnamed | Not assessed | Ephemeral |
| D73A-02792 | Unnamed | Not assessed | Ephemeral |
| D73A-02793 | Unnamed | Not assessed | Ephemeral |
| D73A-02809 | Unnamed | Not assessed | Ephemeral |
| D73A-02933 | Unnamed | Not assessed | Ephemeral |
| D73A-02965 | Unnamed | Not assessed | Ephemeral |
| D73A-02992 | Unnamed | Not assessed | Ephemeral |
| D73A-03010 | Unnamed | Not assessed | Ephemeral |
| D73A-03061 | Unnamed | Not assessed | Ephemeral |
| D73A-03070 | Skeifonteinspruit | Not assessed | Ephemeral |
| D73A-03074 | Skeifonteinspruit | Not assessed | Ephemeral |
| D73A-03095 | Skeifonteinspruit | Not assessed | Ephemeral |
| D73A-03096 | Skeifonteinspruit | Not assessed | Ephemeral |
| D73B-02919 | Unnamed | Not assessed | Ephemeral |
| D73B-03121 | Soutloop | Not assessed | Ephemeral |
| D73B-03144 | Soutloop | Not assessed | Ephemeral |
| D73B-03276 | Unnamed | Not assessed | Ephemeral |
| D73B-03328 | Unnamed | Not assessed | Ephemeral |
| D73B-03444 | Unnamed | Not assessed | Ephemeral |
| D73B-03491 | Soutloop | Not assessed | Ephemeral |
| D73B-03538 | Unnamed | Not assessed | Ephemeral |
| D73B-03617 | Orange | C | Flow |
| D73B-03630 | Orange | C | Flow |
| D73B-03634 | Unnamed | Not assessed | Ephemeral |
| D73C-03738 | Unnamed | Not assessed | Ephemeral |
| D73C-03764 | Unnamed | Not assessed | Ephemeral |
| D73C-03810 | Unnamed | Not assessed | Ephemeral |
| D73D-02743 | Unnamed | Not assessed | Ephemeral |
| D73D-03158 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73D-03201 | Eselfontein | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D73D-03202 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73D-03234 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73D-03267 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73D-03268 | Elmboog Sloot | Not assessed | Ephemeral |
| D73D-03357 | Unnamed | Not assessed | Ephemeral |
| D73D-03378 | Unnamed | Not assessed | Ephemeral |
| D73D-03397 | Unnamed | Not assessed | Ephemeral |
| D73E-02740 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73E-02760 | Unnamed | Not assessed | Ephemeral |
| D73E-02937 | Unnamed | Not assessed | Ephemeral |
| D73E-02957 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73E-03043 | Matjies | Not assessed | Ephemeral |
| D73E-03072 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73E-03091 | Unnamed | Not assessed | Ephemeral |
| D73E-03240 | Unnamed | Not assessed | Ephemeral |
| D73E-03242 | Unnamed | Not assessed | Ephemeral |
| D73F-02996 | Helbrandleegte | Not assessed | Ephemeral |
| D73F-03000 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73F-03032 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73F-03040 | Unnamed | Not assessed | Ephemeral |
| D73F-03051 | Helbrandkloofspruit | Not assessed | Ephemeral |
| D73F-03131 | Unnamed | Not assessed | Ephemeral |
| D73F-03133 | Donkerhoekspruit | Not assessed | Ephemeral |
| D73F-03135 | Unnamed | Not assessed | Ephemeral |
| D73F-03138 | Unnamed | Not assessed | Ephemeral |
| D73F-03151 | Orange | E | Flow, non flow (riparian/wetland continuity and mod.) |
| D73F-03165 | Unnamed | Not assessed | Ephemeral |
| D73F-03193 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73F-03204 | Helbrandkloofspruit | Not assessed | Ephemeral |
| D73F-03235 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73F-03271 | Olienhout | Not assessed | Ephemeral |
| D73F-03291 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73F-03292 | Kareeboom | Not assessed | Ephemeral |
| D73F-03297 | Orange | C | Flow, non flow (riparian/wetland continuity ) |
| D73F-03325 | Kareeboom | Not assessed | Ephemeral |
| D73F-03327 | Unnamed | Not assessed | Ephemeral |
| D73F-03347 | Orange | E | Flow, non flow (riparian/wetland continuity and mod.) |
| D73F-03358 | Orange | D | Flow, non-flow (riparian/wetland continuity ) |
| D73F-03360 | Vaalputs | Not assessed | Ephemeral |
| D73F-03364 | Sout | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D73F-03365 | Vaalputs | Not assessed | Ephemeral |
| D73F-03373 | Unnamed | Not assessed | Ephemeral |
| D73F-03376 | Sout | Not assessed | Ephemeral |
| D73F-03377 | Brak | Not assessed | Ephemeral |
| D73F-03387 | Unnamed | Not assessed | Ephemeral |
| D73F-03389 | Kareeboom | Not assessed | Ephemeral |
| D73F-03393 | Orange | D | Flow, non flow (riparian/wetland continuity ) |
| D73F-03417 | Unnamed | Not assessed | Ephemeral |
| D73F-03421 | Kameel | Not assessed | Ephemeral |
| D73F-03432 | Neusspruit | Not assessed | Ephemeral |

#### 4.2.3.3. D8 Secondary catchment: Orange River from Kakamas to the Orange River Mouth

The D8 sub-catchment comprises the lowest reach of the Orange River, from the D81A quaternary catchment to the mouth at Alexander Bay. The PES of sub-quaternary reaches assessed (26%) are predominantly in a B and C ecological category (Table 18), indicating basic ecosystem functions are still predominantly unchanged, and a general good condition of the river. The drivers of ecological condition are linked to flow and non-flow impacts, which are likely driven by irrigation, abstraction water uses and presence of weirs within the river reaches. A small portion of the Orange River in D81A catchment below Kakamas has a PES of a D category. The condition is driven by low flows and modifications to the riparian and instream habitat.

**Table 18: PES and condition or PES Drivers for D8 – Orange River (from Kakamas to Orange River Mouth)**

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D81A-03148 | Orange | B | Largely Natural |
| D81A-03174 | Kamkierie | Not assessed | Ephemeral |
| D81A-03199 | Orange | C | Flow |
| D81A-03239 | Orange | C | Flow |
| D81A-03241 | Brabees | Not assessed | Ephemeral |
| D81A-03244 | Unnamed | Not assessed | Ephemeral |
| D81A-03245 | Unnamed | Not assessed | Ephemeral |
| D81A-03269 | Orange | D | Flow, Non-flow (riparian/wetland mod.) |
| D81A-03311 | Orange | D | Flow, Non-flow (riparian/wetland mod.) |
| D81A-03367 | Orange | D | Flow, Non-flow (riparian/wetland mod.) |
| D81A-03369 | Slang | Not assessed | Ephemeral |
| D81A-03406 | Brabees | Not assessed | Ephemeral |
| D81A-03413 | Unnamed | Not assessed | Ephemeral |
| D81A-03484 | Brabees | Not assessed | Ephemeral |
| D81A-03506 | Wegsteek se Laagte | Not assessed | Ephemeral |
| D81A-03624 | Unnamed | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D81A-03625 | Banksvlei se Holte | Not assessed | Ephemeral |
| D81B-02959 | Kourop | Not assessed | Ephemeral |
| D81B-03079 | Orange | C | Flow |
| D81B-03130 | Orange | C | Flow |
| D81B-03140 | Orange | C | Flow |
| D81B-03172 | Bul | Not assessed | Ephemeral |
| D81B-03333 | Bul | Not assessed | Ephemeral |
| D81B-03338 | Unnamed | Not assessed | Ephemeral |
| D81C-02630 | Bak | Not assessed | Ephemeral |
| D81C-02669 | Brak | Not assessed | Ephemeral |
| D81C-02680 | Unnamed | Not assessed | Ephemeral |
| D81C-02682 | Unnamed | Not assessed | Ephemeral |
| D81C-02700 | Bak | Not assessed | Ephemeral |
| D81C-02874 | Unnamed | Not assessed | Ephemeral |
| D81C-02911 | Bak | Not assessed | Ephemeral |
| D81D-03093 | (only Orange) | C | Flow |
| D81D-03118 | (only Orange) | C | Flow |
| D81D-03164 | (only Orange) | B | Largely Natural |
| D81D-03329 | Kantbrogas se Laagte | Not assessed | Ephemeral |
| D81D-03330 | Nous | Not assessed | Ephemeral |
| D81D-03412 | Waholtesruit | Not assessed | Ephemeral |
| D81D-03416 | Unnamed | Not assessed | Ephemeral |
| D81E-03200 | (only Orange) | C | Flow |
| D81E-03349 | (only Orange) | C | Flow |
| D81F-03445 | (only Orange) | B | Largely Natural |
| D81F-03721 | (only Orange) | Not assessed | Ephemeral |
| D81F-03768 | Unnamed | Not assessed | Ephemeral |
| D81F-03827 | Koeiamlaagte | Not assessed | Ephemeral |
| D81F-03834 | Kaboep | Not assessed | Ephemeral |
| D81F-03929 | Kaboep | Not assessed | Ephemeral |
| D81F-03962 | Unnamed | Not assessed | Ephemeral |
| D81F-03990 | Koeiamlaagte | Not assessed | Ephemeral |
| D81G-03731 | T_Goob se Laagte | B | Largely Natural |
| D81G-03747 | Unnamed | Not assessed | Ephemeral |
| D81G-03789 | Unnamed | Not assessed | Ephemeral |
| D81G-03803 | Unnamed | Not assessed | Ephemeral |
| D81G-03804 | T_Goob se Laagte | Not assessed | Ephemeral |
| D81G-03813 | Unnamed | Not assessed | Ephemeral |
| D81G-03840 | Unnamed | Not assessed | Ephemeral |
| D81G-03852 | Unnamed | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D81G-03855 | T_Goob se Laagte | Not assessed | Ephemeral |
| D81G-03910 | Unnamed | Not assessed | Ephemeral |
| D81G-03921 | T_Goob se Laagte | Not assessed | Ephemeral |
| D81G-03928 | T_Goob se Laagte | Not assessed | Ephemeral |
| D81G-03943 | Unnamed | Not assessed | Ephemeral |
| D81G-03996 | T_Goob se Laagte | Not assessed | Ephemeral |
| D81G-04006 | Unnamed | Not assessed | Ephemeral |
| D82A-03580 | (only Orange) | B | Largely Natural |
| D82A-03588 | (only Orange) | C | Flow |
| D82A-03595 | (only Orange) | B | Largely Natural |
| D82A-03607 | Fontein se | B | Largely Natural |
| D82A-03653 | Orange | C | Flow |
| D82A-03675 | (only Orange) | B | Largely Natural |
| D82A-03773 | Unnamed | Not assessed | Ephemeral |
| D82A-03779 | Mik | Not assessed | Ephemeral |
| D82B-04153 | Unnamed | Not assessed | Ephemeral |
| D82B-04159 | Unnamed | Not assessed | Ephemeral |
| D82B-04162 | Unnamed | Not assessed | Ephemeral |
| D82B-04167 | Nam se Laagte | Not assessed | Ephemeral |
| D82B-04193 | Nam se Laagte | Not assessed | Ephemeral |
| D82B-04234 | Nam se Laagte | Not assessed | Ephemeral |
| D82B-04246 | Unnamed | Not assessed | Ephemeral |
| D82B-04280 | Unnamed | Not assessed | Ephemeral |
| D82B-04438 | Unnamed | Not assessed | Ephemeral |
| D82B-04777 | Unnamed | Not assessed | Ephemeral |
| D82C-03846 | Unnamed | Not assessed | Ephemeral |
| D82C-04152 | Unnamed | Not assessed | Ephemeral |
| D82C-04174 | Kirrie | Not assessed | Ephemeral |
| D82C-04394 | Unnamed | Not assessed | Ephemeral |
| D82D-03653 | (only Orange) | C | Flow |
| D82D-03772 | Karis | Not assessed | Ephemeral |
| D82D-03783 | Unnamed | Not assessed | Ephemeral |
| D82D-03848 | Sabies | Not assessed | Ephemeral |
| D82D-04217 | Unnamed | Not assessed | Ephemeral |
| D82D-04233 | Unnamed | Not assessed | Ephemeral |
| D82D-04260 | Kirrie | Not assessed | Ephemeral |
| D82D-04262 | Unnamed | Not assessed | Ephemeral |
| D82D-04279 | Koeries | Not assessed | Ephemeral |
| D82D-04350 | Unnamed | Not assessed | Ephemeral |
| D82D-04353 | Unnamed | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D82D-04372 | Unnamed | Not assessed | Ephemeral |
| D82E-03531 | Matjies | Not assessed | Ephemeral |
| D82E-03540 | (only Orange) | B | Largely Natural |
| D82E-03546 | (only Orange) | B | Largely Natural |
| D82E-03655 | Unnamed | Not assessed | Ephemeral |
| D82E-03662 | Unnamed | Not assessed | Ephemeral |
| D82F-03522 | Koubank | Not assessed | Ephemeral |
| D82F-03531 | Orange | C | Flow |
| D82F-03594 | Koubank | Not assessed | Ephemeral |
| D82F-03601 | Charliesfontein | Not assessed | Ephemeral |
| D82F-03604 | Kowiep | Not assessed | Ephemeral |
| D82F-03674 | Kosies | Not assessed | Ephemeral |
| D82F-03864 | Unnamed | Not assessed | Ephemeral |
| D82F-03868 | Groendoring | Not assessed | Ephemeral |
| D82G-03477 | (only Orange) | C | Flow |
| D82G-03508 | (only Orange) | B | Largely Natural |
| D82G-03522 | Orange | C | Flow |
| D82G-03525 | Unnamed | Not assessed | Ephemeral |
| D82G-03613 | Geelfontein | Not assessed | Ephemeral |
| D82G-03627 | Groen | Not assessed | Ephemeral |
| D82H-03251 | Kahams | Not assessed | Ephemeral |
| D82H-03262 | Bak | Not assessed | Ephemeral |
| D82H-03279 | (only Orange) | B | Largely Natural |
| D82H-03319 | Kahams | Not assessed | Ephemeral |
| D82H-03355 | (only Orange) | B | Largely Natural |
| D82H-03441 | Unnamed | Not assessed | Ephemeral |
| D82H-03468 | Unnamed | Not assessed | Ephemeral |
| D82H-03527 | Stinkfontein se | Not assessed | Ephemeral |
| D82H-03553 | Unnamed | Not assessed | Ephemeral |
| D82J-02869 | (only Orange) | C | Flow |
| D82J-02886 | Orange | C | Flow |
| D82J-02906 | Noms | Not assessed | Ephemeral |
| D82J-02907 | Kouams | Not assessed | Ephemeral |
| D82J-03022 | (only Orange) | C | Flow |
| D82J-03026 | (only Orange) | C | Flow |
| D82J-03028 | Abiekwa | Not assessed | Ephemeral |
| D82J-03068 | Abiekwa | Not assessed | Ephemeral |
| D82J-03071 | Gannakouriep | Not assessed | Ephemeral |
| D82J-03110 | Unnamed | Not assessed | Ephemeral |
| D82J-03116 | Gannakouriep | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D82J-03124 | (only Orange) | C | Flow |
| D82J-03128 | Unnamed | Not assessed | Ephemeral |
| D82K-00000 | Orange | B | Largely Natural |
| D82K-02994 | (only Orange) | B | Largely Natural |
| D82K-02999 | Unnamed | Not assessed | Ephemeral |
| D82K-03001 | Bloubos | Not assessed | Ephemeral |
| D82K-03084 | (only Orange) | C | Flow |
| D82K-03123 | Dabie | Not assessed | Ephemeral |
| D82K-03166 | (only Orange) | Not assessed | Ephemeral |
| D82K-03175 | Orange | B | Largely Natural |
| D82K-03185 | Khubus | Not assessed | Ephemeral |
| D82K-03187 | Unnamed | Not assessed | Ephemeral |
| D82K-03188 | Annis | Not assessed | Ephemeral |
| D82K-03192 | Khubus | Not assessed | Ephemeral |
| D82K-03208 | Annis | Not assessed | Ephemeral |
| D82K-03218 | Annis | Not assessed | Ephemeral |
| D82K-03219 | Unnamed | Not assessed | Ephemeral |
| D82K-03223 | Orab | Not assessed | Ephemeral |
| D82K-03246 | Annis | Not assessed | Ephemeral |
| D82L-03166 | Orange | C | Flow |
| D82L-03238 | (only Orange) | C | Flow |
| D82L-03298 | ORANGE | C | Flow |
| D82L-03312 | Unnamed | Not assessed | Ephemeral |
| D82L-03314 | (only Orange) | C | Flow |
| D82L-03332 | Unnamed | Not assessed | Ephemeral |
| D82L-03342 | Unnamed | Not assessed | Ephemeral |
| D82L-03426 | Unnamed | Not assessed | Ephemeral |

#### 4.2.3.4. D5 Secondary catchment: Hartbees

The D5 catchment includes the Hartbees as the main river with the Sak, Vis, Riet, Klein-Riet, Sout, Renoster, Brak, Gansvlei, Rugseers, Lekkerleleegte, Bastersout se Leegte and Carnarvonleegte as tributary sub-catchments. The D5 secondary catchment includes 599 sub-quat reaches, with a large number being ephemeral, endhoreic or episodic. The PES of 280 sub-quaternary reaches (47%) were assessed. The sub-quaternary reaches are predominantly in a B and C ecological category, indicating basic ecosystem functions are still predominantly unchanged, with a good ecological condition. The ecological condition is largely related to non-flow impacts of riparian and instream zone modification or continuity or low flows. A small percentage of the reaches within the Sak sub-catchments (and Vis, Renoster and Gansvlei) are in a D category (Table 19).

### Table 19: PES and condition or PES Drivers for D5 catchment

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D51A-07271 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D51A-07302 | Renoster | C | Non-flow (riparian/wetland mod) |
| D51A-07361 | Renoster | C | Flow, non-flow (riparian/instream), water quality |
| D51A-07413 | Dorps | D | Flow, non-flow (riparian/wetland) |
| D51A-07457 | Dorps | D | Flow, non-flow (riparian/wetland, instream) |
| D51A-07477 | Unnamed | D | Flow, non-flow (riparian/wetland, instream) |
| D51B-06782 | Renoster | C | Water quality, flow, non flow |
| D51B-06923 | Kariega | C | Non-flow (riparian/wetland/instream) |
| D51B-06943 | Renoster | C | Water quality, flow, non flow |
| D51B-07105 | Unnamed | B | Largely Natural |
| D51B-07208 | Renoster | C | Non-flow (riparian/wetland/instream), flow, water quality |
| D51C-06594 | Renoster | C | Non-flow (riparian/wetland), water quality, flow |
| D51C-06793 | Boesmanfontein se Laagte | B | Largely Natural |
| D52A-07274 | Vis | D | Non-flow (riparian/wetland), water quality, flow |
| D52A-07488 | Visrivier-Oos | C | Non-flow (riparian/wetland mod) |
| D52A-07492 | Visrivier-Wes | D | Non-flow (riparian/wetland/instream) |
| D52B-07118 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52B-07131 | Klein-Vis | B | Largely Natural |
| D52B-07166 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D52B-07168 | Vis | C | Non-flow (riparian/wetland con) |
| D52B-07250 | Unnamed | B | Largely Natural |
| D52B-07288 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D52B-07322 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D52C-06869 | Unnamed | Not assessed | Episodic |
| D52C-06874 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52C-06920 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52C-06927 | Unnamed | B | Largely Natural |
| D52D-06761 | Muiskraal | D | Water quality, Non-flow (riparian/wetland/instream) |
| D52D-06975 | Unnamed | C | Non-flow (riparian/wetland) |
| D52D-06997 | Muiskraal | C | Non-flow (riparian/wetland/instream) |
| D52E-06638 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D52E-06669 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D52E-06677 | Kookfontein | C | Flow, non flow (instream) |
| D52E-06694 | Unnamed | Not assessed | Episodic |
| D52E-06700 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52E-06725 | Vis | C | Non-flow (riparian/wetland) |
| D52E-06758 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52F-06306 | Vis | C | Water Quality |
| D52F-06325 | Vis | D | Non-flow (riparian/wetland), water quality |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D52F-06327 | Rooivlak se Laagte | Not assessed | Episodic |
| D52F-06455 | Unnamed | Not assessed | Episodic |
| D52F-06486 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52F-06580 | Unnamed | Not assessed | Episodic |
| D52F-06587 | Hottentotsfontein se Laagte | Not assessed | Episodic |
| D52F-06591 | Vis | D | Non-flow (riparian/wetland), water quality |
| D52F-06595 | Hottentotsfontein se Laagte | Not assessed | Episodic |
| D53A-04033 | Mottels | Not assessed | Episodic |
| D53A-04097 | Unnamed | Not assessed | Episodic |
| D53A-04099 | Hartbees | D | Non-flow (riparian/wetland), flow |
| D53A-04100 | Mottels | B | Largely Natural |
| D53A-04103 | Mottels | Not assessed | Episodic |
| D53A-04113 | Mottels | Not assessed | Episodic |
| D53A-04126 | Unnamed | A | Natural/Close to Natural |
| D53A-04140 | Mottels | B | Largely Natural |
| D53A-04186 | Mottels | Not assessed | Episodic |
| D53A-04197 | Hartbees | B | Largely Natural |
| D53A-04206 | Unnamed | Not assessed | Episodic |
| D53A-04238 | Unnamed | B | Largely Natural |
| D53A-04285 | Hartbees | B | Largely Natural |
| D53A-04286 | Unnamed | B | Largely Natural |
| D53A-04303 | Hartbees | B | Largely Natural |
| D53A-04306 | Klein-Lat | Not assessed | Episodic |
| D53A-04308 | Dam se Leegte | Not assessed | Episodic |
| D53A-04309 | Lat | B | Largely Natural |
| D53A-04345 | Lat | B | Largely Natural |
| D53A-04382 | Hartbees | B | Largely Natural |
| D53A-04387 | Hartbees | B | Largely Natural |
| D53B-03712 | Rugseers | Not assessed | Episodic |
| D53B-03734 | Unnamed | Not assessed | Episodic |
| D53B-03746 | Unnamed | Not assessed | Episodic |
| D53B-03801 | Rugseers | Not assessed | Episodic |
| D53B-03828 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-03858 | Rugseers | Not assessed | Episodic |
| D53B-03890 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-03892 | Rugseers | B | Largely Natural |
| D53B-03894 | Rugseers | Not assessed | Episodic |
| D53B-03895 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-03907 | Unnamed | Not assessed | Episodic |
| D53B-03948 | Rooiput se Leegte | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D53B-03958 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-03972 | Rugseers | B | Largely Natural |
| D53B-03978 | Rooiput se Leegte | B | Largely Natural |
| D53B-03980 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-03999 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04007 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04009 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04016 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04037 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04049 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04066 | Rooiput se Leegte | Not assessed | Episodic |
| D53B-04104 | Hartbees | C | Flow |
| D53C-03648 | Sandnoute | B | Largely Natural |
| D53C-03666 | Unnamed | Not assessed | Episodic |
| D53C-03682 | NRougas se Loop | B | Largely Natural |
| D53C-03775 | Sandnoute | Not assessed | Episodic |
| D53C-03778 | NRougas se Loop | Not assessed | Episodic |
| D53C-03807 | Hartbees | B | Largely Natural |
| D53C-03847 | Unnamed | Not assessed | Episodic |
| D53C-03885 | Hartbees | C | Non-flow (riparian/wetland), flow, water quality |
| D53C-04093 | Driekop se | B | Largely Natural |
| D53D-03879 | Tuins | B | Largely Natural |
| D53D-03909 | Unnamed | B | Largely Natural |
| D53D-03959 | Tuins | B | Largely Natural |
| D53D-04022 | Tuins | B | Largely Natural |
| D53D-04031 | Graafwaters | B | Largely Natural |
| D53E-03557 | Hartbees | B | Largely Natural |
| D53E-03626 | Unnamed | Not assessed | Episodic |
| D53E-03639 | Hartbees | B | Largely Natural |
| D53E-03640 | Unnamed | Not assessed | Episodic |
| D53E-03685 | Unnamed | Not assessed | Episodic |
| D53E-03744 | Hartbees | B | Largely Natural |
| D53E-03791 | Hartbees | B | Largely Natural |
| D53E-03798 | Unnamed | Not assessed | Episodic |
| D53E-03816 | Hartbees | B | Largely Natural |
| D53F-04378 | Unnamed | Not assessed | Endorheic |
| D53F-04579 | Unnamed | Not assessed | Endorheic |
| D53F-04673 | Unnamed | Not assessed | Endorheic |
| D53F-04785 | Rietfontein | Not assessed | Endorheic |
| D53F-05096 | Unnamed | Not assessed | Endorheic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D53G-03887 | Unnamed | Not assessed | Episodic |
| D53G-03944 | Brulkolk se Holte | Not assessed | Episodic |
| D53G-03976 | Brulkolk se Holte | Not assessed | Episodic |
| D53G-03991 | Steenkampsvlei se Holte | Not assessed | Episodic |
| D53G-03992 | Unnamed | Not assessed | Episodic |
| D53G-03997 | Unnamed | Not assessed | Episodic |
| D53G-04024 | Soutputs se Laagte | Not assessed | Episodic |
| D53G-04025 | Unnamed | Not assessed | Episodic |
| D53G-04028 | Sout | B | Largely Natural |
| D53G-04045 | Sout | C | Non-flow (instream) |
| D53G-04046 | Die Kraal se Laagte | Not assessed | Episodic |
| D53G-04058 | Soutputs se Laagte | Not assessed | Episodic |
| D53G-04077 | Unnamed | Not assessed | Episodic |
| D53G-04085 | Unnamed | Not assessed | Episodic |
| D53G-04094 | Unnamed | Not assessed | Episodic |
| D53G-04108 | Unnamed | Not assessed | Episodic |
| D53G-04132 | Soutputs se Laagte | Not assessed | Episodic |
| D53G-04142 | Steenkampsvlei se Holte | Not assessed | Episodic |
| D53G-04150 | Unnamed | Not assessed | Episodic |
| D53G-04168 | Unnamed | Not assessed | Episodic |
| D53G-04176 | Soutputs se Laagte | Not assessed | Episodic |
| D53H-03564 | Sout | A | Natural/Close to Natural |
| D53H-03651 | Sout | B | Largely Natural |
| D53H-03705 | Unnamed | Not assessed | Episodic |
| D53H-03749 | Droegrond se laagte | Not assessed | Episodic |
| D53H-03757 | Unnamed | Not assessed | Episodic |
| D53H-03836 | Sout | B | Largely Natural |
| D53H-03839 | Unnamed | Not assessed | Episodic |
| D53H-03871 | Unnamed | Not assessed | Episodic |
| D53H-03875 | Unnamed | Not assessed | Episodic |
| D53H-03897 | Sout | B | Largely Natural |
| D53H-04030 | Sout | B | Largely Natural |
| D53J-03408 | Hartbees | C | Non-flow (riparian/wetland), flow |
| D53J-03458 | Hartbees | B | Largely Natural |
| D53J-03469 | Unnamed | Not assessed | Episodic |
| D53J-03512 | Marais | Not assessed | Episodic |
| D53J-03542 | Unnamed | Not assessed | Episodic |
| D53J-03544 | Unnamed | Not assessed | Episodic |
| D53J-03554 | Hartbees | Not assessed | Episodic |
| D54A-05241 | Holsloot | C | Non-flow (instream) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D54A-05272 | Holsloot | B | Largely Natural |
| D54A-05287 | Unnamed | B | Largely Natural |
| D54A-05418 | Holsloot | B | Largely Natural |
| D54A-05421 | Unnamed | C | Non-flow (riparian/wetland/instream) |
| D54A-05427 | Kalksloot | B | Largely Natural |
| D54A-05434 | Holsloot | B | Largely Natural |
| D54A-05500 | Kalksloot | B | Largely Natural |
| D54A-05522 | Unnamed | Not assessed | Episodic |
| D54A-05572 | Unnamed | Not assessed | Episodic |
| D54A-05593 | Unnamed | C | Non-flow (instream mod) |
| D54A-05595 | Unnamed | Not assessed | Episodic |
| D54A-05619 | Unnamed | Not assessed | Episodic |
| D54A-05653 | Unnamed | C | Non-flow (instream/riparian/wetland) |
| D54A-05706 | Unnamed | Not assessed | Episodic |
| D54A-05724 | Unnamed | Not assessed | Episodic |
| D54B-04978 | Carnarvonleegte | C | Non-flow (instream/riparian/wetland) |
| D54B-05119 | Unnamed | Not assessed | Episodic |
| D54B-05123 | Unnamed | Not assessed | Episodic |
| D54B-05125 | Unnamed | C | Non-flow (instream mod) |
| D54B-05129 | Unnamed | Not assessed | Episodic |
| D54B-05151 | Unnamed | C | Non-flow (instream mod) |
| D54B-05160 | Carnarvonleegte | C | Non-flow (instream mod) |
| D54B-05217 | Unnamed | B | Largely Natural |
| D54B-05230 | Unnamed | C | Non-flow (instream/riparian/wetland) |
| D54B-05247 | Boesak | Not assessed | Episodic |
| D54B-05266 | Bitterpoortloop | B | Largely Natural |
| D54B-05278 | Carnarvonleegte | B | Largely Natural |
| D54B-05293 | Carnarvonleegte | B | Largely Natural |
| D54B-05316 | Boesak | C | Non-flow (instream/riparian/wetland) |
| D54B-05341 | Unnamed | D | Flow, Non-flow (instream/riparian/wetland) |
| D54B-05381 | Unnamed | C | Non-flow (instream mod) |
| D54B-05384 | Boesak | C | Non-flow (instream mod) |
| D54B-05429 | Renosterpoort se Leegte | Not assessed | Episodic |
| D54B-05431 | Unnamed | C | Non-flow (instream/riparian/wetland) |
| D54B-05436 | Carnarvonleegte | C | Non-flow (instream mod) |
| D54B-05482 | Boesak | Not assessed | Episodic |
| D54B-05484 | Unnamed | Not assessed | Episodic |
| D54B-05533 | Unnamed | Not assessed | Episodic |
| D54B-05548 | Unnamed | C | Non-flow (instream mod) |
| D54B-05549 | Unnamed | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D54B-05556 | Unnamed | Not assessed | Episodic |
| D54B-05558 | Unnamed | Not assessed | Episodic |
| D54B-05618 | Unnamed | Not assessed | Episodic |
| D54B-05621 | Unnamed | C | Flow, Non-flow (riparian/wetland) |
| D54B-05661 | Carnarvonleegte | B | Largely Natural |
| D54B-05662 | Unnamed | Not assessed | Episodic |
| D54B-05690 | Unnamed | C | Non-flow (instream/riparian/wetland) |
| D54B-05693 | Unnamed | Not assessed | Endorheic |
| D54B-05779 | Carnarvonleegte | C | Non-flow (instream mod) |
| D54B-05792 | Carnarvonleegte | C | Non-flow (riparian/wetland), water quality |
| D54B-05814 | Bloudrif | Not assessed | Episodic |
| D54C-05087 | Unnamed | Not assessed | Endorheic |
| D54C-05147 | Unnamed | C | Non-flow (instream cont) |
| D54C-05162 | Unnamed | Not assessed | Dam |
| D54C-05185 | Unnamed | Not assessed | Endorheic |
| D54D-04544 | Unnamed | Not assessed | Endorheic |
| D54D-04630 | Carnarvonleegte | B | Largely Natural |
| D54D-04767 | Sand | Not assessed | Not a river |
| D54D-04810 | Unnamed | Not assessed | Episodic |
| D54D-04896 | Carnarvonleegte | C | Non-flow (instream cont) |
| D54E-05143 | Unnamed | Not assessed | Episodic |
| D54E-05146 | Unnamed | Not assessed | Episodic |
| D54E-05173 | Unnamed | Not assessed | Episodic |
| D54E-05180 | Unnamed | Not assessed | Episodic |
| D54E-05188 | Ysterdoringspan | B | Largely Natural |
| D54E-05199 | Ysterdoringspan | B | Largely Natural |
| D54E-05200 | Unnamed | Not assessed | Episodic |
| D54E-05220 | Jacoblinks se Laagte | Not assessed | Episodic |
| D54E-05240 | Jacoblinks se Laagte | Not assessed | Episodic |
| D54E-05261 | Unnamed | Not assessed | Episodic |
| D54E-05283 | Ysterdoringspan | B | Largely Natural |
| D54E-05298 | Unnamed | C | Flow, non-flow (riparian/instream) |
| D54E-05310 | Ysterdoringspan | B | Largely Natural |
| D54E-05330 | Unnamed | C | Non-flow (instream continuity) |
| D54E-05334 | Unnamed | Not assessed | Episodic |
| D54E-05342 | Botterslaagte | Not assessed | Episodic |
| D54E-05380 | Unnamed | Not assessed | Episodic |
| D54E-05383 | Unnamed | B | Largely Natural |
| D54E-05399 | Unnamed | Not assessed | Not a river |
| D54E-05406 | Unnamed | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D54E-05410 | Unnamed | Not assessed | Episodic |
| D54E-05428 | Unnamed | Not assessed | Episodic |
| D54E-05432 | Unnamed | Not assessed | Episodic |
| D54E-05465 | Unnamed | Not assessed | Episodic |
| D54E-05466 | Botterslaagte | Not assessed | Episodic |
| D54E-05477 | Unnamed | Not assessed | Episodic |
| D54E-05479 | Unnamed | Not assessed | Episodic |
| D54E-05492 | Unnamed | Not assessed | Episodic |
| D54E-05494 | Unnamed | Not assessed | Episodic |
| D54E-05525 | Unnamed | Not assessed | Not a river |
| D54E-05532 | Unnamed | Not assessed | Episodic |
| D54E-05538 | Unnamed | Not assessed | Endorheic |
| D54E-05555 | Unnamed | B | Largely Natural |
| D54E-05559 | Unnamed | Not assessed | Episodic |
| D54E-05561 | Unnamed | Not assessed | Endorheic |
| D54E-05568 | Unnamed | Not assessed | Episodic |
| D54E-05594 | Unnamed | Not assessed | Endorheic |
| D54E-05597 | Unnamed | Not assessed | Endorheic |
| D54E-05632 | Unnamed | Not assessed | Episodic |
| D54E-05633 | Unnamed | Not assessed | Endorheic |
| D54E-05635 | Unnamed | Not assessed | Episodic |
| D54E-05637 | Unnamed | Not assessed | Endorheic |
| D54E-05711 | Unnamed | Not assessed | Endorheic |
| D54E-05727 | Unnamed | Not assessed | Episodic |
| D54E-05731 | Unnamed | Not assessed | Endorheic |
| D54E-05734 | Unnamed | Not assessed | Episodic |
| D54F-04592 | Bloubosleegte | Not assessed | Episodic |
| D54F-04645 | Verneukpan | Not assessed | Episodic |
| D54F-04730 | Unnamed | Not assessed | Endorheic |
| D54F-04776 | Hartogskloof | B | Largely Natural |
| D54F-04850 | Unnamed | Not assessed | Endorheic |
| D54F-04862 | Unnamed | Not assessed | Endorheic |
| D54F-04863 | Unnamed | Not assessed | Endorheic |
| D54F-04934 | Bloubosleegte | Not assessed | Episodic |
| D54F-04953 | Unnamed | Not assessed | Episodic |
| D54F-04964 | Unnamed | Not assessed | Episodic |
| D54F-04967 | Bloubosleegte | Not assessed | Episodic |
| D54F-04996 | Unnamed | Not assessed | Episodic |
| D54F-04997 | Unnamed | Not assessed | Episodic |
| D54F-05003 | Unnamed | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D54F-05004 | Hartogskloof | B | Largely Natural |
| D54F-05036 | Unnamed | Not assessed | Endorheic |
| D54F-05048 | Unnamed | Not assessed | Endorheic |
| D54G-04242 | Keelafsnyleegte | Not assessed | Episodic |
| D54G-04282 | Unnamed | Not assessed | Episodic |
| D54G-04307 | Brandholteloop | B | Largely Natural |
| D54G-04325 | Unnamed | Not assessed | Episodic |
| D54G-04356 | Unnamed | Not assessed | Episodic |
| D54G-04365 | Unnamed | Not assessed | Episodic |
| D54G-04383 | Unnamed | Not assessed | Episodic |
| D54G-04407 | Hartbees | B | Largely Natural |
| D54G-04412 | Unnamed | Not assessed | Episodic |
| D54G-04462 | Unnamed | Not assessed | Episodic |
| D54G-04468 | Unnamed | Not assessed | Episodic |
| D54G-04474 | Keelafsnyleegte | B | Largely Natural |
| D54G-04491 | Unnamed | Not assessed | Episodic |
| D54G-04504 | Lekkerleleegte | Not assessed | Episodic |
| D54G-04505 | Unnamed | Not assessed | Episodic |
| D54G-04519 | Unnamed | Not assessed | Episodic |
| D54G-04527 | Hartbees | B | Largely Natural |
| D54G-04529 | Bastersput se Leegte | Not assessed | Episodic |
| D54G-04538 | Unnamed | Not assessed | Episodic |
| D54G-04542 | Unnamed | Not assessed | Episodic |
| D54G-04575 | Unnamed | Not assessed | Episodic |
| D54G-04577 | Unnamed | Not assessed | Episodic |
| D54G-04607 | Hartbees | B | Largely Natural |
| D54G-04623 | Bastersput se Leegte | Not assessed | Episodic |
| D54G-04628 | Unnamed | Not assessed | Episodic |
| D54G-04709 | Unnamed | Not assessed | Episodic |
| D55A-06617 | Elandsfontein se | C | Flow, non-flow (riparian/instream) |
| D55A-06714 | Unnamed | C | Non-flow (instream cont) |
| D55A-06734 | Sak | D | Flow, non-flow (riparian/instream) |
| D55A-06766 | Sak | C | Non-flow (instream cont) |
| D55A-06774 | Sak | C | Non-flow (instream cont) |
| D55A-06785 | Sak | C | Non-flow (instream cont) |
| D55A-06797 | Rietfontein | D | Flow, non-flow (riparian/instream) |
| D55A-06845 | Unnamed | Not assessed | Episodic |
| D55A-07039 | Sak | D | Flow, non-flow (riparian/instream) |
| D55A-07097 | Unnamed | C | Non-flow (riparian/instream cont) |
| D55A-07147 | Unnamed | C | Non-flow (instream cont) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D55A-07176 | Sak | C | Non-flow (riparian/instream cont) |
| D55A-07190 | Unnamed | C | Flow, non-flow (riparian/instream) |
| D55A-07234 | Sak | B | Largely Natural |
| D55B-06615 | Sak | B | Largely Natural |
| D55B-06678 | Unnamed | Not assessed | Episodic |
| D55B-06684 | Sak | C | Non-flow (riparian/wetland) |
| D55B-06689 | Sak | C | Non-flow (riparian/instream cont) |
| D55B-06697 | Unnamed | B | Largely Natural |
| D55B-06707 | Sak | D | Non-flow (riparian/instream cont) |
| D55B-06750 | Damfontein se | C | Non-flow (instream cont) |
| D55B-06847 | Damfontein se | Not assessed | Episodic |
| D55B-06860 | Unnamed | C | Non-flow (riparian/instream cont) |
| D55B-06938 | Unnamed | Not assessed | Episodic |
| D55B-06952 | Damfontein se | Not assessed | Episodic |
| D55B-07043 | Damfontein se | Not assessed | Episodic |
| D55B-07076 | Unnamed | Not assessed | Episodic |
| D55C-06421 | Brak | C | Non-flow (instream cont) |
| D55C-06500 | Brak | C | Non-flow (instream cont) |
| D55C-06505 | Slangfontein se | C | Flow, non-flow (riparian/instream) |
| D55C-06507 | Klein-Brak | C | Non-flow (instream cont) |
| D55C-06584 | Slangfontein se | C | Non-flow (instream cont) |
| D55C-06596 | Unnamed | B | Largely Natural |
| D55D-06116 | Soutpoort | C | Non-flow (instream cont) |
| D55D-06194 | Brak | C | Non-flow (instream cont) |
| D55D-06235 | Unnamed | C | Non-flow (riparian-wetland mod/instream cont) |
| D55D-06309 | Unnamed | Not assessed | Episodic |
| D55D-06378 | Brak | C | Non-flow (instream cont) |
| D55D-06395 | Unnamed | Not assessed | Episodic |
| D55D-06429 | Brak | C | Non-flow (instream cont) |
| D55D-06524 | Brak | C | Non-flow (riparian/instream); flow |
| D55D-06547 | Unnamed | Not assessed | Episodic |
| D55D-06570 | Unnamed | Not assessed | Episodic |
| D55D-06593 | Unnamed | Not assessed | Episodic |
| D55E-06496 | Sak | B | Largely Natural |
| D55E-06502 | Sak | B | Largely Natural |
| D55E-06529 | Sout | C | Non-flow (riparian-wetland mod/instream cont) |
| D55E-06582 | Sak | B | Largely Natural |
| D55E-06610 | Unnamed | Not assessed | Episodic |
| D55E-06614 | Unnamed | Not assessed | Episodic |
| D55E-06663 | Sout | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D55E-06711 | Unnamed | Not assessed | Episodic |
| D55E-06713 | Sout | B | Largely Natural |
| D55E-06728 | Unnamed | Not assessed | Episodic |
| D55E-06729 | Sout | B | Largely Natural |
| D55E-06768 | Unnamed | Not assessed | Episodic |
| D55E-06786 | Unnamed | Not assessed | Episodic |
| D55E-06823 | Unnamed | Not assessed | Episodic |
| D55E-06825 | Sout | B | Largely Natural |
| D55E-06854 | Sout | B | Largely Natural |
| D55E-06865 | Unnamed | C | Non-flow (instream cont) |
| D55E-06910 | Unnamed | C | Non-flow (riparian-wetland mod/instream cont) |
| D55E-06944 | Unnamed | Not assessed | Episodic |
| D55E-06946 | Sout | C | Non-flow (instream cont) |
| D55E-06961 | Unnamed | Not assessed | Episodic |
| D55E-06967 | Unnamed | C | Non-flow (instream cont) |
| D55E-06968 | Unnamed | Not assessed | Episodic |
| D55F-05685 | Unnamed | Not assessed | Episodic |
| D55F-05692 | Unnamed | Not assessed | Episodic |
| D55F-05742 | Unnamed | Not assessed | Episodic |
| D55F-05753 | Unnamed | D | Non-flow (instream/riparian-wetland) |
| D55F-05762 | Unnamed | Not assessed | Episodic |
| D55F-05763 | Unnamed | C | Non-flow (instream cont) |
| D55F-05800 | Unnamed | Not assessed | Episodic |
| D55F-05822 | Reitzvilleleegte | Not assessed | Episodic |
| D55F-05830 | Unnamed | Not assessed | Episodic |
| D55F-05850 | Kareebergleegte | C | Non-flow (instream cont) |
| D55F-05893 | Alarmleegte | Not assessed | Episodic |
| D55F-05911 | Kareebergleegte | B | Largely Natural |
| D55F-05936 | Alarmleegte | C | Flow, non-flow (riparian/instream) |
| D55F-05946 | Stofkraalleegte | Not assessed | Episodic |
| D55F-05958 | Brak | D | Non-flow (riparian-wetland mod/instream cont) |
| D55F-05969 | Reitzvilleleegte | B | Largely Natural |
| D55F-05983 | Stofkraalleegte | Not assessed | Episodic |
| D55F-06003 | Unnamed | Not assessed | Episodic |
| D55F-06004 | Platkuil | C | Non-flow (instream cont) |
| D55F-06055 | Kareebergleegte | C | Non-flow (instream cont) |
| D55F-06065 | Kareebergleegte | C | Non-flow (instream cont) |
| D55F-06081 | Unnamed | Not assessed | Episodic |
| D55F-06209 | Kareebergleegte | B | Largely Natural |
| D55G-06031 | Gansvlei | D | Non-flow (riparian/instream) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D55G-06300 | Gansvlei | C | Non-flow (instream cont) |
| D55G-06308 | Gansvlei | C | Non-flow (instream cont) |
| D55G-06406 | Unnamed | Not assessed | Episodic |
| D55H-06087 | Unnamed | C | Non-flow (riparian-wetland mod/instream cont) |
| D55H-06176 | Unnamed | Not assessed | Episodic |
| D55H-06234 | Droe | C | Non-flow (instream cont) |
| D55H-06259 | Sak | B | Largely Natural |
| D55H-06358 | Sak | B | Largely Natural |
| D55H-06381 | Sak | B | Largely Natural |
| D55H-06401 | Sak | B | Largely Natural |
| D55H-06404 | Sak | C | Non-flow (riparian-wetland), water quality |
| D55H-06423 | Unnamed | Not assessed | Episodic |
| D55H-06481 | Palmietfontein se Loop | Not assessed | Episodic |
| D55J-05539 | Unnamed | Not assessed | Episodic |
| D55J-05652 | Unnamed | Not assessed | Episodic |
| D55J-05855 | Sout | Not assessed | Episodic |
| D55J-05876 | Beeswaterleegte | Not assessed | Episodic |
| D55J-05900 | Unnamed | B | Largely Natural |
| D55J-05922 | Unnamed | Not assessed | Episodic |
| D55J-05980 | Draaiwal se Leegte | Not assessed | Episodic |
| D55J-06117 | Beeswaterleegte | Not assessed | Episodic |
| D55J-06120 | Sak | B | Largely Natural |
| D55J-06178 | Sout | Not assessed | Episodic |
| D55J-06180 | Sak | C | Non-flow (instream cont) |
| D55J-06212 | Beeswaterleegte | B | Largely Natural |
| D55J-06243 | Sak | D | Non-flow (riparian/instream) |
| D55J-06284 | Sak | B | Largely Natural |
| D55J-06297 | Unnamed | Not assessed | Episodic |
| D55K-06347 | Klein-Sak | B | Largely Natural |
| D55K-06357 | Klein-Sak | B | Largely Natural |
| D55K-06382 | Unnamed | Not assessed | Episodic |
| D55K-06417 | Unnamed | Not assessed | Episodic |
| D55K-06469 | Klein-Sak | C | flow, non-flow (riparian-wetland) |
| D55K-06532 | Klein-Sak | C | Non-flow (riparian/instream) |
| D55K-06537 | Unnamed | Not assessed | Episodic |
| D55K-06572 | Hongerkloof se Leegte | B | Largely Natural |
| D55K-06618 | Ploegfontein se Leegte | Not assessed | Episodic |
| D55K-06631 | Ploegfontein se Leegte | Not assessed | Episodic |
| D55K-06632 | Klein Sak | C | Non-flow (instream cont) |
| D55L-06115 | Sak | C | flow, non-flow (rparian/instream) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D55L-06175 | Unnamed | Not assessed | Episodic |
| D55L-06185 | Unnamed | Not assessed | Episodic |
| D55L-06204 | Sak | C | Non-flow (riparian-wetland mod/instream cont) |
| D55L-06269 | Sak | C | flow, non-flow (rparian-wetland) |
| D55L-06270 | Sak | C | flow, non-flow (rparian/instream) |
| D55L-06278 | Sak | C | Non-flow (instream cont) |
| D55L-06299 | Witleegte | Not assessed | Episodic |
| D55L-06301 | Sak | D | flow, non-flow (rparian/instream) |
| D55L-06307 | Unnamed | Not assessed | Episodic |
| D55L-06321 | Rietfonteinleegte | Not assessed | Episodic |
| D55L-06351 | Witleegte | Not assessed | Episodic |
| D55L-06370 | Unnamed | Not assessed | Episodic |
| D55L-06374 | Sak | C | Flow |
| D55L-06375 | Unnamed | Not assessed | Episodic |
| D55L-06418 | Unnamed | Not assessed | Episodic |
| D55L-06434 | Unnamed | Not assessed | Episodic |
| D55M-05697 | Sak | C | Non-flow (ripraian-wetland) |
| D55M-05801 | Tulbaghlaagte | Not assessed | Episodic |
| D55M-05851 | Sak | B | Largely Natural |
| D55M-05862 | Wielkolkslaagte | Not assessed | Episodic |
| D55M-05864 | Sak | C | Non-flow (riparian-wetland mod/instream cont) |
| D55M-05877 | Unnamed | Not assessed | Episodic |
| D55M-05898 | Unnamed | Not assessed | Episodic |
| D55M-05906 | Unnamed | Not assessed | Episodic |
| D55M-05940 | Wielkolkslaagte | Not assessed | Episodic |
| D55M-05955 | Unnamed | Not assessed | Episodic |
| D55M-06018 | Unnamed | Not assessed | Episodic |
| D55M-06022 | Sak | B | Largely Natural |
| D55M-06054 | Sak | B | Largely Natural |
| D55M-06060 | Unnamed | Not assessed | Episodic |
| D56A-07453 | Portugals | C | Non-flow (instream cont) |
| D56A-07624 | Unnamed | B | Largely Natural |
| D56A-07650 | Unnamed | B | Largely Natural |
| D56A-07652 | Portugals | B | Largely Natural |
| D56B-07416 | Unnamed | Not assessed | Ephemeral |
| D56B-07428 | Riet | B | Largely Natural |
| D56B-07486 | Riet | C | Non-flow (instream cont) |
| D56B-07731 | Unnamed | Not assessed | Ephemeral |
| D56B-07733 | Riet | C | Non-flow (riparian-wetland mod/instream cont) |
| D56C-07248 | Unnamed | Not assessed | Ephemeral |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D56C-07254 | Riet | B | Largely Natural |
| D56C-07273 | Unnamed | Not assessed | Ephemeral |
| D56C-07304 | Unnamed | B | Largely Natural |
| D56C-07325 | Riet | B | Largely Natural |
| D56C-07342 | Unnamed | B | Largely Natural |
| D56C-07389 | Unnamed | B | Largely Natural |
| D56C-07420 | Unnamed | C | Non-flow (riparian/instream) |
| D56D-06822 | Riet | B | Largely Natural |
| D56D-07055 | Unnamed | Not assessed | Ephemeral |
| D56D-07081 | Riet | B | Largely Natural |
| D56D-07091 | Riet | B | Largely Natural |
| D56D-07121 | Wolwe | Not assessed | Ephemeral |
| D56E-07285 | Klein-Riet | C | Non-flow (riparian/instream) |
| D56E-07308 | Klein-Riet | B | Largely Natural |
| D56E-07320 | Spinnekopkraal se | B | Largely Natural |
| D56E-07337 | Unnamed | Not assessed | Ephemeral |
| D56E-07456 | Unnamed | Not assessed | Ephemeral |
| D56E-07461 | Unnamed | Not assessed | Ephemeral |
| D56F-06883 | Klein | Not assessed | Ephemeral |
| D56F-06969 | Nuweveld | Not assessed | Ephemeral |
| D56F-07000 | Nuweveld | Not assessed | Ephemeral |
| D56F-07018 | Klein-Riet | B | Largely Natural |
| D56F-07034 | Unnamed | Not assessed | Ephemeral |
| D56F-07048 | Unnamed | Not assessed | Ephemeral |
| D56F-07049 | Klein-Riet | B | Largely Natural |
| D56F-07050 | Klein-Riet | B | Largely Natural |
| D56F-07067 | Karee | Not assessed | Ephemeral |
| D56F-07074 | Klein-Riet | B | Largely Natural |
| D56F-07144 | Klein-Riet | B | Largely Natural |
| D56F-07151 | Unnamed | Not assessed | Ephemeral |
| D56G-06753 | Klein-Riet | C | Non-flow riparian-wetland |
| D56G-06780 | Unnamed | Not assessed | Ephemeral |
| D56G-06815 | Unnamed | Not assessed | Ephemeral |
| D56G-06857 | Klein-Riet | C | Non-flow (riparian-wetland mod/instream cont) |
| D56G-06917 | Klein-Riet | B | Largely Natural |
| D56G-06932 | Klein-Riet | B | Largely Natural |
| D56G-06940 | Unnamed | Not assessed | Ephemeral |
| D56H-06719 | Riet | B | Largely Natural |
| D56H-06773 | Elands | Not assessed | Episodic |
| D56H-06776 | Unnamed | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D56H-06779 | Elands | Not assessed | Episodic |
| D56H-06882 | Elands | Not assessed | Episodic |
| D56H-06887 | Valslaagte | Not assessed | Episodic |
| D56J-06520 | Unnamed | Not assessed | Episodic |
| D56J-06522 | Riet | C | Non-flow (instream/riparian mod) |
| D56J-06555 | Leenderts | D | Non-flow (instream cont/riparian mod) |
| D56J-06597 | Riet | B | Largely Natural |
| D56J-06649 | Riet | C | Non-flow (instream/riparian) |
| D57A-05387 | Sak | C | Non flow (riparian-wetland), water quality |
| D57A-05452 | Unnamed | Not assessed | Episodic |
| D57A-05497 | Sak | B | Largely Natural |
| D57A-05517 | Unnamed | Not assessed | Episodic |
| D57A-05552 | Sak | C | Non flow (riparian-wetland), water quality |
| D57B-05197 | Unnamed | Not assessed | Endorheic |
| D57B-05305 | Swartbosleegte | Not assessed | Episodic |
| D57B-05309 | Rooidam se Laagte | C | Non flow (riparian-wetland) |
| D57B-05325 | Rooidam se Laagte | C | Non flow (riparian-wetland), water quality |
| D57B-05365 | Unnamed | Not assessed | Episodic |
| D57B-05457 | Soutsloot | Not assessed | Episodic |
| D57B-05567 | Unnamed | Not assessed | Episodic |
| D57B-05571 | Unnamed | Not assessed | Episodic |
| D57B-05665 | Unnamed | Not assessed | Episodic |
| D57B-05687 | Unnamed | Not assessed | Episodic |
| D57B-05691 | Unnamed | Not assessed | Episodic |
| D57B-05695 | Unnamed | Not assessed | Episodic |
| D57B-05754 | Unnamed | Not assessed | Episodic |
| D57B-05757 | Unnamed | Not assessed | Episodic |
| D57B-05805 | Unnamed | Not assessed | Episodic |
| D57B-05828 | Unnamed | Not assessed | Endorheic |
| D57B-05882 | Unnamed | Not assessed | Episodic |
| D57C-05215 | Sak | B | Largely Natural |
| D57C-05254 | Sak | B | Largely Natural |
| D57C-05267 | Unnamed | Not assessed | Episodic |
| D57C-05321 | Unnamed | Not assessed | Episodic |
| D57C-05323 | Rooidam se Laagte | C | Non flow (riparian-wetland), water quality |
| D57C-05333 | Unnamed | Not assessed | Episodic |
| D57C-05363 | Sak | C | Non flow (riparian-wetland), water quality |
| D57C-05396 | Unnamed | Not assessed | Episodic |
| D57D-04419 | Unnamed | Not assessed | Episodic |
| D57D-04512 | Unnamed | Not assessed | Endorheic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D57D-04526 | Unnamed | Not assessed | Episodic |
| D57D-04694 | Sak | C | Non flow (riparian-wetland), water quality |
| D57D-04815 | Sak | C | Non flow (riparian-wetland), water quality |
| D57D-04877 | Unnamed | Not assessed | Episodic |
| D57D-04897 | Unnamed | Not assessed | Episodic |
| D57D-04927 | Unnamed | Not assessed | Episodic |
| D57D-04962 | Unnamed | Not assessed | Endorheic |
| D57D-04972 | Sak | B | Largely Natural |
| D57D-05037 | Kettingkop se Laagte | Not assessed | Episodic |
| D57D-05050 | Sak | B | Largely Natural |
| D57D-05064 | Unnamed | Not assessed | Endorheic |
| D57D-05090 | Sak | B | Largely Natural |
| D57D-05092 | Unnamed | Not assessed | Episodic |
| D57D-05098 | Unnamed | Not assessed | Episodic |
| D57D-05127 | Sak | B | Largely Natural |
| D57D-05128 | Unnamed | Not assessed | Episodic |
| D57D-05166 | Unnamed | Not assessed | Episodic |
| D57D-05249 | Unnamed | Not assessed | Episodic |
| D57D-05250 | Unnamed | Not assessed | Episodic |
| D57D-05289 | Unnamed | Not assessed | Episodic |
| D57E-04304 | Knapsaklaagte | Not assessed | Episodic |
| D57E-04338 | Bosduiflaagte | B | Largely Natural |
| D57E-04351 | Unnamed | Not assessed | Episodic |
| D57E-04374 | Sak | B | Largely Natural |
| D57E-04423 | Sak | B | Largely Natural |
| D57E-04534 | Sak | B | Largely Natural |
| D57E-04535 | Sak | B | Largely Natural |
| D58A-06302 | Renoster | D | Non flow (riparian-wetland), water quality |
| D58B-06059 | Dassiesstraatlaagte | Not assessed | Episodic |
| D58B-06102 | Vis | C | Non flow (riparian-wetland mod), water quality |
| D58B-06170 | Vis | D | Non flow (riparian-wetland), water quality |
| D58B-06183 | Klein-Vis | Not assessed | Episodic |
| D58C-05390 | Vis | D | Non flow (riparian-wetland), water quality |
| D58C-05720 | Unnamed | Not assessed | Not connected |
| D58C-05818 | Unnamed | Not assessed | Not connected |
| D58C-05832 | Unnamed | Not assessed | Episodic |
| D58C-05848 | Unnamed | Not assessed | Not connected |
| D58C-05889 | Unnamed | Not assessed | Episodic |
| D58C-05932 | Vis | C | Non flow (riparian-wetland/instream), water quality |
| D58C-05945 | Unnamed | Not assessed | Episodic |

#### 4.2.3.5. D6 Secondary catchment: Ongers and Brak

Secondary catchment D6 comprises the Ongers River with the Brak River as the main tributary. The rivers in the sub-catchment are in a good ecological condition, falling within an B or C PES ecological category, with the exception of the upper reaches of the Brak and Ongers, the Ongers at the confluence of the Brak, short reaches of the Klein Brak and Elandsfontein which are the only D category river reaches (Table 20). This is due to non- flow impacts related land use and erosion.

**Table 20: PES and condition or PES Drivers for D6 catchment**

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D61A-06062 | Ongers | C | Non-flow (instream cont) |
| D61A-06083 | Ongers | C | Non-flow (instream cont) |
| D61A-06094 | Unnamed | Not assessed | Ephemeral |
| D61A-06128 | Unnamed | Not assessed | Ephemeral |
| D61A-06166 | Ongers | B | Largely Natural |
| D61A-06213 | Ongers | C | Flow, water quality, non-flow |
| D61A-06244 | Ongers | D | Non-flow (instream cont/riparian mod) |
| D61A-06245 | Ongers | B | Largely Natural |
| D61A-06246 | Unnamed | Not assessed | Ephemeral |
| D61A-06277 | Unnamed | Not assessed | Ephemeral |
| D61A-06368 | Unnamed | C | Non-flow (instream cont/riparian mod) |
| D61B-05795 | Unnamed | Not assessed | Episodic |
| D61B-05841 | Lakenrivier | C | Non-flow (instream/riparian-wetland) |
| D61B-05891 | Laken | C | Non-flow (instream cont/riparian mod) |
| D61B-05926 | Unnamed | C | Flow, Non-flow (instream cont) |
| D61B-05957 | Unnamed | Not assessed | Episodic |
| D61B-06028 | Laken | C | Non-flow (instream cont) |
| D61B-06050 | Unnamed | Not assessed | Episodic |
| D61B-06058 | Unnamed | Not assessed | Episodic |
| D61B-06066 | Unnamed | Not assessed | Episodic |
| D61C-05765 | Unnamed | Not assessed | Episodic |
| D61C-05771 | Unnamed | Not assessed | Episodic |
| D61C-05836 | Unnamed | Not assessed | Episodic |
| D61C-05840 | Unnamed | Not assessed | Episodic |
| D61C-05866 | Ongers | B | Largely Natural |
| D61C-05885 | Ongers | C | Non-flow (instream cont) |
| D61C-05905 | Ongers | C | Non flow (riparian-wetland zone mod) |
| D61C-05912 | Ongers | B | Largely Natural |
| D61C-05947 | Ongers | C | Non flow (riparian-wetland zone mod) |
| D61C-05991 | Unnamed | Not assessed | Episodic |
| D61C-06056 | Unnamed | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D61D-06156 | Brakpoort | B | Largely Natural |
| D61D-06215 | Brakpoort | C | Non-flow (instream/riparian-wetland), water quality |
| D61D-06256 | Unnamed | Not assessed | Episodic |
| D61D-06298 | Unnamed | Not assessed | Episodic |
| D61D-06352 | Brakpoort | B | Largely Natural |
| D61D-06353 | Brakpoort | C | Non-flow (instream cont) |
| D61D-06355 | Pretoriuskuil se Leegte | Not assessed | Episodic |
| D61E-06164 | Brak | C | Non-flow (instream cont) |
| D61E-06230 | Brak | D | Non-flow (instream cont), flow, water quality |
| D61E-06262 | Visgatspruit | Not assessed | Episodic |
| D61E-06276 | Unnamed | B | Largely Natural |
| D61E-06332 | Unnamed | Not assessed | Episodic |
| D61E-06362 | Visgatspruit | Not assessed | Episodic |
| D61E-06379 | Unnamed | Not assessed | Episodic |
| D61E-06410 | Unnamed | Not assessed | Episodic |
| D61E-06413 | Visgatspruit | Not assessed | Episodic |
| D61E-06466 | Unnamed | Not assessed | Episodic |
| D61E-06470 | Unnamed | Not assessed | Episodic |
| D61F-06130 | Unnamed | Not assessed | Ephemeral |
| D61F-06222 | Unnamed | B | Largely Natural |
| D61F-06258 | Klein Brak | D | Non-flow (instream/riparian-wetland), flow |
| D61F-06261 | Unnamed | B | Largely Natural |
| D61F-06271 | Unnamed | C | Non-flow (instream cont), flow |
| D61F-06294 | Unnamed | Not assessed | Ephemeral |
| D61F-06338 | Unnamed | C | Non-flow (instream cont) |
| D61F-06342 | Unnamed | Not assessed | Ephemeral |
| D61F-06348 | Unnamed | C | Non-flow (instream cont), flow |
| D61F-06371 | Unnamed | C | Non-flow (instream cont) |
| D61G-06077 | Unnamed | Not assessed | Episodic |
| D61G-06089 | Unnamed | Not assessed | Episodic |
| D61G-06109 | Klein Brak | C | Non-flow (instream cont) |
| D61G-06153 | Klein Brak | B | Largely Natural |
| D61G-06181 | Unnamed | Not assessed | Episodic |
| D61G-06223 | Klein Brak | C | Non-flow (instream/riparian-wetland), flow |
| D61H-05824 | Unnamed | Not assessed | Episodic |
| D61H-05854 | Unnamed | Not assessed | Episodic |
| D61H-05865 | Brak | C | Non flow (riparian-wetland zone) |
| D61H-05878 | Brak | B | Largely Natural |
| D61H-05960 | Klein Brak | Not assessed | Episodic |
| D61H-05963 | Brak | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D61H-05974 | Brak | B | Largely Natural |
| D61H-05984 | Visgat | Not assessed | Episodic |
| D61H-05998 | Brak | B | Largely Natural |
| D61H-06014 | Unnamed | Not assessed | Episodic |
| D61H-06032 | Unnamed | Not assessed | Episodic |
| D61H-06070 | Visgat | Not assessed | Episodic |
| D61H-06079 | Unnamed | Not assessed | Episodic |
| D61H-06191 | Unnamed | Not assessed | Endorheic |
| D61J-05622 | Unnamed | Not assessed | Episodic |
| D61J-05628 | Unnamed | Not assessed | Episodic |
| D61J-05649 | Unnamed | Not assessed | Episodic |
| D61J-05654 | Groen | B | Largely Natural |
| D61J-05669 | Unnamed | C | Non-flow (instream cont) |
| D61J-05671 | Unnamed | Not assessed | Episodic |
| D61J-05705 | Unnamed | Not assessed | Episodic |
| D61J-05740 | Unnamed | Not assessed | Episodic |
| D61J-05758 | Groen | B | Largely Natural |
| D61J-05761 | Unnamed | Not assessed | Episodic |
| D61J-05816 | Unnamed | Not assessed | Episodic |
| D61J-05849 | Groen | C | Non-flow (instream cont) |
| D61J-05860 | Groen | C | Non-flow (instream cont) |
| D61J-05883 | Unnamed | B | Largely Natural |
| D61J-05895 | Unnamed | Not assessed | Episodic |
| D61J-05921 | Unnamed | B | Largely Natural |
| D61J-05924 | Groen | B | Largely Natural |
| D61J-05939 | Groen | B | Largely Natural |
| D61J-05951 | Unnamed | Not assessed | Episodic |
| D61J-05961 | Unnamed | Not assessed | Episodic |
| D61J-05965 | Groen | C | Non-flow (instream cont) |
| D61J-05966 | Unnamed | Not assessed | Episodic |
| D61J-05972 | Unnamed | Not assessed | Episodic |
| D61K-05388 | Groen | C | Non-flow (instream cont) |
| D61K-05505 | Unnamed | Not assessed | Episodic |
| D61K-05639 | Groen | B | Largely Natural |
| D61K-05655 | Biesiekuilleegte | Not assessed | Episodic |
| D61K-05678 | Unnamed | Not assessed | Episodic |
| D61K-05681 | Biesiekuilleegte | Not assessed | Episodic |
| D61K-05833 | Unnamed | Not assessed | Episodic |
| D61K-05846 | Unnamed | Not assessed | Episodic |
| D61L-05453 | Graafwaterspruit | C | Non-flow (instream cont) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D61L-05546 | Unnamed | Not assessed | Episodic |
| D61L-05624 | Unnamed | Not assessed | Episodic |
| D61L-05689 | Unnamed | Not assessed | Episodic |
| D61L-05710 | Unnamed | Not assessed | Episodic |
| D61M-05343 | Ongers | D | Non-flow (instream/riparian-wetland) |
| D61M-05417 | Ongers | B | Largely Natural |
| D61M-05469 | Ongers | B | Largely Natural |
| D61M-05660 | Unnamed | Not assessed | Episodic |
| D61M-05749 | Ongers | B | Largely Natural |
| D62A-04951 | Unnamed | Not assessed | Episodic |
| D62A-05078 | Ongers | C | Non-flow (riparian-wetland mod.) |
| D62A-05138 | Unnamed | Not assessed | Episodic |
| D62A-05205 | Ongers | D | Water quality, flow, Non-flow (riparian-wetland zone) |
| D62A-05235 | Unnamed | Not assessed | Endorheic |
| D62A-05252 | Unnamed | Not assessed | Endorheic |
| D62A-05306 | Unnamed | D | Non-flow (instream/riparian-wetland), flow |
| D62A-05339 | Unnamed | Not assessed | Episodic |
| D62A-05344 | Unnamed | Not assessed | Episodic |
| D62B-04701 | Ongers | C | Non-flow (riparian-wetland mod.) |
| D62B-04987 | Unnamed | Not assessed | Episodic |
| D62B-05002 | Unnamed | Not assessed | Episodic |
| D62B-05057 | Sand | Not assessed | Episodic |
| D62B-05070 | Unnamed | Not assessed | Episodic |
| D62B-05075 | Unnamed | Not assessed | Episodic |
| D62B-05081 | Unnamed | Not assessed | Episodic |
| D62B-05082 | Unnamed | Not assessed | Episodic |
| D62B-05095 | Unnamed | Not assessed | Episodic |
| D62B-05105 | Unnamed | Not assessed | Episodic |
| D62B-05149 | Unnamed | Not assessed | Episodic |
| D62B-05153 | Unnamed | Not assessed | Episodic |
| D62B-05158 | Unnamed | Not assessed | Episodic |
| D62B-05209 | Unnamed | Not assessed | Episodic |
| D62B-05308 | Unnamed | Not assessed | Episodic |
| D62B-05357 | Unnamed | Not assessed | Episodic |
| D62B-05379 | Unnamed | Not assessed | Episodic |
| D62B-05400 | Unnamed | Not assessed | Episodic |
| D62C-05303 | Elandsfontein | C | Non-flow (instream/riparian-wetland) |
| D62C-05419 | Unnamed | Not assessed | Episodic |
| D62C-05422 | Elandsfontein | C | Non-flow (instream cont) |
| D62C-05523 | Unnamed | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D62C-05526 | Unnamed | Not assessed | Episodic |
| D62C-05528 | Unnamed | Not assessed | Episodic |
| D62C-05550 | Unnamed | Not assessed | Episodic |
| D62C-05564 | Unnamed | Not assessed | Episodic |
| D62C-05576 | Elandsfontein | C | Non-flow (instream cont) |
| D62C-05581 | Unnamed | Not assessed | Episodic |
| D62C-05583 | Unnamed | Not assessed | Episodic |
| D62C-05656 | Unnamed | Not assessed | Endorheic |
| D62C-05658 | Unnamed | Not assessed | Episodic |
| D62C-05663 | Unnamed | Not assessed | Episodic |
| D62C-05694 | Unnamed | Not assessed | Episodic |
| D62C-05696 | Unnamed | Not assessed | Episodic |
| D62C-05774 | Unnamed | Not assessed | Episodic |
| D62C-05847 | Elandsfontein | C | Non-flow (instream/riparian-wetland) |
| D62C-05852 | Unnamed | Not assessed | Episodic |
| D62C-05872 | Elandsfontein | D | Non-flow (instream/riparian-wetland) |
| D62C-05927 | Elandsfontein | C | Non-flow (instream/riparian-wetland) |
| D62C-05929 | Unnamed | Not assessed | Episodic |
| D62D-05175 | Unnamed | Not assessed | Episodic |
| D62D-05183 | Brak | B | Largely Natural |
| D62D-05194 | Unnamed | Not assessed | Episodic |
| D62D-05227 | Brak | B | Largely Natural |
| D62D-05245 | Unnamed | Not assessed | Episodic |
| D62D-05255 | Unnamed | Not assessed | Episodic |
| D62D-05332 | Brak | B | Largely Natural |
| D62D-05391 | Brak | C | Non-flow (instream cont.) |
| D62D-05392 | Unnamed | Not assessed | Episodic |
| D62D-05416 | Unnamed | Not assessed | Episodic |
| D62D-05486 | Brak | C | Non-flow (instream cont.) |
| D62D-05508 | Unnamed | Not assessed | Episodic |
| D62D-05553 | Brak | C | Non-flow (instream cont.) |
| D62D-05569 | Unnamed | Not assessed | Endorheic |
| D62D-05610 | Unnamed | Not assessed | Episodic |
| D62D-05613 | Brak | D | Non-flow (instream/riparian-wetland) |
| D62E-04834 | Unnamed | Not assessed | Episodic |
| D62E-04867 | Renostervleispruit | D | Non-flow (riparian-wetland mod.) |
| D62E-04914 | Brak | C | Non-flow (instream/riparian-wetland) |
| D62E-04938 | Hondeblafspruit | Not assessed | Episodic |
| D62E-05114 | Unnamed | Not assessed | Episodic |
| D62E-05118 | Brak | C | Non-flow (instream/riparian-wetland) |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| D62E-05169 | Unnamed | Not assessed | Episodic |
| D62E-05176 | Unnamed | C | Non-flow (instream cont.) |
| D62F-04509 | Unnamed | Not assessed | Endorheic |
| D62G-04397 | Unnamed | Not assessed | Endorheic |
| D62G-04703 | Unnamed | Not assessed | Episodic |
| D62G-04755 | Brak | B | Largely Natural |
| D62G-04811 | Unnamed | Not assessed | Episodic |
| D62J-04231 | Brak | B | Largely Natural |
| D62J-04379 | Unnamed | Not assessed | Episodic |
| D62J-04430 | Brak | B | Largely Natural |

#### 4.2.3.6. Coastal Areas Secondary catchments: F1 to F5, F60A

The coastal area catchment, F1 to F5 and F60A comprises the Holgat, Kamma, Buffels, Spoeg, Swartlintjies, Bitter, Groen and Brak as the main rivers. The rivers in the sub-catchment are in a good ecological condition, falling predominantly within a B PES ecological category (almost 77% of the reaches assessed) (Table 22). A small number of river reaches with a C PES category are found throughout the catchment. This is driven largely by non-flow impacts to the instream and riparian -wetland habitats and some related water quality impacts. Two reaches have PES category of D, located on the Buffels and Bitter rivers.

**Table 21: PES and condition or PES Drivers for the coastal area catchment**

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| F10A-03321 | Gaigas | B | Largely Natural |
| F10A-03345 | unnamed | B | Largely Natural |
| F10A-03402 | Kook | B | Largely Natural |
| F10A-03414 | unnamed | B | Largely Natural |
| F10A-03454 | Gaigas | B | Largely Natural |
| F10A-03456 | Kook | B | Largely Natural |
| F10A-03520 | Gaigas | B | Largely Natural |
| F10A-03534 | Holgat | B | Largely Natural |
| F10A-03573 | Modderfontein | B | Largely Natural |
| F10A-03578 | Holgat | B | Largely Natural |
| F10B-03391 | Holgat | B | Largely Natural |
| F10B-03605 | unnamed | Not assessed | Endorheic |
| F10B-03618 | unnamed | Not assessed | Endorheic |
| F10B-03756 | unnamed | Not assessed | Endorheic |
| F10C-03476 | unnamed | Not assessed | Episodic |
| F20A-03743 | unnamed | Not assessed | Not a river |
| F20A-03818 | unnamed | Not assessed | Not a river |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| F20A-03824 | unnamed | Not assessed | Episodic |
| F20A-03912 | unnamed | Not assessed | Episodic |
| F20A-03983 | unnamed | B | Largely Natural |
| F20A-04038 | unnamed | B | Largely Natural |
| F20A-04090 | unnamed | B | Largely Natural |
| F20A-04112 | unnamed | Not assessed | Episodic |
| F20B-04001 | unnamed | Not assessed | Not a river |
| F20B-04053 | unnamed | B | Largely Natural |
| F20B-04092 | unnamed | Not assessed | Episodic |
| F20B-04160 | unnamed | B | Largely Natural |
| F20B-04183 | unnamed | B | Largely Natural |
| F20B-04200 | unnamed | Not assessed | Endorheic |
| F20C-03777 | unnamed | B | Largely Natural |
| F20C-03863 | unnamed | Not assessed | Episodic |
| F20C-03866 | unnamed | B | Largely Natural |
| F20C-03902 | Kamma | B | Largely Natural |
| F20C-04012 | Kamma | B | Largely Natural |
| F20D-03937 | Kamma | C | Water quality, flow, non-flow (riparian/wetland zone) |
| F20E-04290 | Kwaganap | C | Non-flow (instream habitat modification) |
| F30A-04774 | unnamed | Not assessed | Episodic |
| F30A-04782 | Buffels | B | Largely Natural |
| F30A-04803 | Buffels | B | Largely Natural |
| F30A-04839 | Buffels | B | Largely Natural |
| F30A-04851 | unnamed | Not assessed | Episodic |
| F30A-04852 | Gasab | Not assessed | Episodic |
| F30A-04858 | unnamed | B | Largely Natural |
| F30A-04894 | Buffels | B | Largely Natural |
| F30A-04921 | Gasab | Not assessed | Episodic |
| F30A-04943 | Buffels | B | Largely Natural |
| F30A-04957 | unnamed | Not assessed | Episodic |
| F30A-05001 | Buffels | D | Flow, non-flow (riparian-wetland mod/instream habitat) |
| F30A-05047 | Buffels | B | Largely Natural |
| F30A-05054 | Buffels | B | Largely Natural |
| F30A-05069 | Papkuils | B | Largely Natural |
| F30A-05077 | Buffels | B | Largely Natural |
| F30A-05084 | Klein-Nou | C | Non-flow (instream continuity modification) |
| F30A-05099 | unnamed | Not assessed | Episodic |
| F30A-05101 | unnamed | Not assessed | Episodic |
| F30B-04496 | Jaagleegte | Not assessed | Episodic |
| F30B-04500 | unnamed | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| F30B-04507 | Kourkamma se Holte | Not assessed | Episodic |
| F30B-04525 | unnamed | Not assessed | Episodic |
| F30B-04570 | unnamed | Not assessed | Episodic |
| F30B-04578 | Brak | B | Largely Natural |
| F30B-04595 | Jaagleegte | Not assessed | Episodic |
| F30B-04610 | Brak | A | Natural/Close to natural |
| F30B-04650 | Brak | B | Largely Natural |
| F30B-04741 | Brak | B | Largely Natural |
| F30B-04742 | Brak | B | Largely Natural |
| F30C-04521 | Drodab | C | Non-flow (instream habitat modification), Water quality |
| F30C-04634 | Buffels | B | Largely Natural |
| F30C-04687 | Melk | Not assessed | Episodic |
| F30C-04705 | Brand | B | Largely Natural |
| F30C-04737 | Drodab | Not assessed | Episodic |
| F30C-04771 | Buffels | B | Largely Natural |
| F30C-04822 | Buffels | B | Largely Natural |
| F30C-04823 | Buffels | B | Largely Natural |
| F30C-04825 | Rooiplatklip | Not assessed | Episodic |
| F30C-04829 | Buffels | A | Natural/Close to natural |
| F30C-04855 | Ybeep | B | Largely Natural |
| F30C-04900 | Wolwepoort | B | Largely Natural |
| F30C-04963 | Haas | C | Flow, Water quality, non-flow (riparian-wetland) |
| F30C-05008 | Wolwepoort | B | Largely Natural |
| F30D-04502 | Eselsfontein | C | Water quality, non-flow (riparian-wetland) |
| F30D-04598 | Buffels | B | Largely Natural |
| F30D-04684 | Buffels | A | Natural/Close to natural |
| F30D-04781 | Koringhuis | Not assessed | Episodic |
| F30D-04891 | Buffels | A | Natural/Close to natural |
| F30E-04042 | Doring | C | Non-flow (instream continuity modification) |
| F30E-04230 | unnamed | Not assessed | Episodic |
| F30E-04314 | Skaap | B | Largely Natural |
| F30E-04317 | Doring | B | Largely Natural |
| F30E-04381 | Skaap | A | Natural/Close to natural |
| F30E-04417 | unnamed | Not assessed | Episodic |
| F30E-04444 | Skaap | B | Largely Natural |
| F30F-04163 | unnamed | Not assessed | Episodic |
| F30F-04166 | Stry | Not assessed | Episodic |
| F30F-04179 | unnamed | Not assessed | Episodic |
| F30F-04252 | Stry | Not assessed | Episodic |
| F30F-04255 | Stry | Not assessed | Episodic |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| F30F-04348 | Buffels | B | Largely Natural |
| F30F-04406 | unnamed | Not assessed | Episodic |
| F30F-04436 | Buffels | B | Largely Natural |
| F30G-04318 | Buffels | B | Largely Natural |
| F30G-04371 | unnamed | Not assessed | Episodic |
| F30G-04409 | Buffels | B | Largely Natural |
| F30G-04517 | Komaggas | B | Largely Natural |
| F30G-04539 | Buffels | C | Non-flow (instream habitat modification), Water quality |
| F40B-04698 | Wildeperdehoek se Brak | B | Largely Natural |
| F40B-04758 | Kourkam se Brak | Not assessed | Episodic |
| F40B-04917 | Wildeperdehoek se Brak | B | Largely Natural |
| F40C-04882 | Swartlintjies | B | Largely Natural |
| F40C-05007 | Swartlintjies | A | Natural/Close to natural |
| F40C-05012 | unnamed | Not assessed | Episodic |
| F40D-04789 | Swartlintjies | B | Largely Natural |
| F40D-05029 | Swartlintjies | A | Natural/Close to natural |
| F40D-05032 | unnamed | Not assessed | Episodic |
| F40E-05132 | Horees | B | Largely Natural |
| F40E-05135 | Spoeg | B | Largely Natural |
| F40E-05208 | unnamed | B | Largely Natural |
| F40E-05223 | Brand | Not assessed | Episodic |
| F40E-05318 | Spoeg | B | Largely Natural |
| F40E-05331 | Spoeg | B | Largely Natural |
| F40F-05159 | Spoeg | B | Largely Natural |
| F40G-05320 | Bitter | C | Non-flow (instream habitat/riparian-wetland), Water quality |
| F40H-05480 | Bitter | D | Flow, non-flow (riparian-wetland/instream habitat) |
| F40H-05531 | Outeep | Not assessed | Episodic |
| F50A-05191 | Hartbees | C | Non-flow (instream continuity modification) |
| F50A-05242 | unnamed | Not assessed | Ephemeral |
| F50A-05402 | Sout se | Not assessed | Ephemeral |
| F50A-05426 | Hartbees | C | Non-flow (instream habitat/riparian-wetland), Water quality |
| F50A-05586 | Hartbees | B | Largely Natural |
| F50A-05626 | Hartbees | B | Largely Natural |
| F50A-05702 | unnamed | Not assessed | Ephemeral |
| F50B-05307 | Swart-Doring | B | Largely Natural |
| F50B-05335 | Dabi | Not assessed | Ephemeral |
| F50B-05397 | unnamed | B | Largely Natural |
| F50B-05473 | unnamed | Not assessed | Ephemeral |
| F50B-05502 | Swart-Doring | B | Largely Natural |
| F50B-05515 | Swart-Doring | B | Largely Natural |

| SQ Reach | River | PES | Condition or PES Driver (if below a B category) |
|---|---|---|---|
| F50B-05636 | Swart-Doring | B | Largely Natural |
| F50C-05557 | Ondertuins | Not assessed | Ephemeral |
| F50C-05612 | Swart-Doring | B | Largely Natural |
| F50C-05735 | Swart-Doring | B | Largely Natural |
| F50C-05764 | Swart-Doring | B | Largely Natural |
| F50C-05783 | unnamed | Not assessed | Ephemeral |
| F50D-05726 | Swart-Doring | B | Largely Natural |
| F50D-05729 | Groen | A | Natural/Close to natural |
| F50D-05784 | unnamed | B | Largely Natural |
| F50D-05812 | unnamed | Not assessed | Ephemeral |
| F50E-05142 | Kys | C | Non-flow (instream habitat continuity modification) |
| F50E-05260 | Wilgerhouts | B | Largely Natural |
| F50F-05447 | Groen | C | Non-flow (instream habitat/riparian-wetland), Water quality |
| F50F-05560 | Groen | B | Largely Natural |
| F50F-05562 | unnamed | B | Largely Natural |
| F50G-05578 | unnamed | Not assessed | Ephemeral |
| F50G-05620 | Groen | B | Largely Natural |
| F50G-05755 | Groen | A | Natural/Close to natural |
| F60A-05886 | Brak | B | Largely Natural |

#### 4.2.3.7. Conclusion

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

### 4.2.4. EWR Site information

The Reserve (quantity and quality) is defined in terms of the Ecological Water Requirements (EWR), ensuring the water required to protect aquatic systems (flow, water quality, habitat and biota) of the water resource are provided for; and Basic Human Needs (BHN), ensuring that the essential needs of individuals served by the water resource in question are provided for. These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources, while allowing economic development. The Reserve forms a basis to the water resource classification process by ensuring that the ecological requirements and basic human needs of the significant water resources are accounted for in the analysis. In addition, they define the quantity component of the resource quality objectives. In terms of the IUA delineation the EWR sites form a key node at the outlet of each unit and the requirements drive the scenario analysis for different ecological configurations to be assessed for the setting of the class.

In the Lower Orange catchment, an Intermediate Environmental Flow Requirements (EFR) study was undertaken for ORASECOM in 2010 and included three sites on the lower Orange River at

Boegoeberg (EFR 02), Augrabies (EFR O3) and Vioolsdrift (EFR O4). A Reserve study undertaken for DWS for the Lower Orange River catchment in 2016 used the same sites and included an additional site on the Lower Orange at Sendelingsdrift (EFR O5). No sites were selected on the main tributaries (Sak, Hartbees, Ongers) presumably due to the arid nature of these rivers. EWRs were only determined for the main Orange River within the study area.

The river EWR sites are set out in Table 22 and shown in Figure 25. Although EWR site 01 in the Upper Orange River catchment was selected, the setting of flow requirements was not undertaken due to the present operation of Vanderkloof Dam and the strategic use for hydro-power generation that results in this operation (DWS, 2015). Additional release in this upper reach will need to be investigated as part of this study. As part of the high confidence Reserve study that is currently being completed for the Upper Orange River catchment, a site was selected at Marksdrift just upstream of the Upper Orange River and Vaal River confluence at Douglas.

**Table 22: Ecological Water Requirements (EWR) sites (intermediate)**

| EWR site code | Site description/ Location | River | Quaternary catchment | Co-ordinates | |
|---|---|---|---|---|---|
| **COMPREHENSIVE EWR SITES** | | | | | |
| EWR01 | HopeTown | Upper Orange | D33G | -29.516 | 24.00927 |
| UO_EWR10_I* | Marksdrift | Upper Orange | D33K | -29.14485 | 23.691403 |
| EWR02 | Boegoeberg | Orange | D73 | -29.0055 | 22.16225 |
| EWR03 | Augrabies | Orange | D81 | -28.4287 | 19.9983 |
| EWR04 | Vioolsdrif | Orange | D82F | -28.7553 | 17.71696 |
| EWR05 | | Orange | D82L | -28.0718 | 16.95951 |

** Part of the Upper Orange Reserve study*

There are no EWR sites for the ephemeral systems /episodic rivers in the Lower Orange catchment. The team with the DWS will need to confirm the approach for these systems. From a biotic perspective, the presence of the inverts will be related to the hydrological phase (*i.e.* pool, onset of flow or flow). If the river is dry though, no invertebrates are present, and keeping in mind they take between 4 and 6 weeks to re-colonise. For these systems flow is also not available for a solid period of time, thus there is a high level of unpredictability of surface flow in these systems. The fish usually move to the lower reaches into the pools if there are still pools or stay in the main stem. A technical workshop on addressing ephemeral systems will be required if biological components cannot be assessed. It will highly unlikely that it will be possible to address vegetation as the rivers are mostly sandy. It is recommended that the approach will need to focus on the land use/activities assessment - if there is an increase in land use, what it is and how it alter/impact the river system. Socio-economics will need to possibly be considered if ecological character cannot be determined.

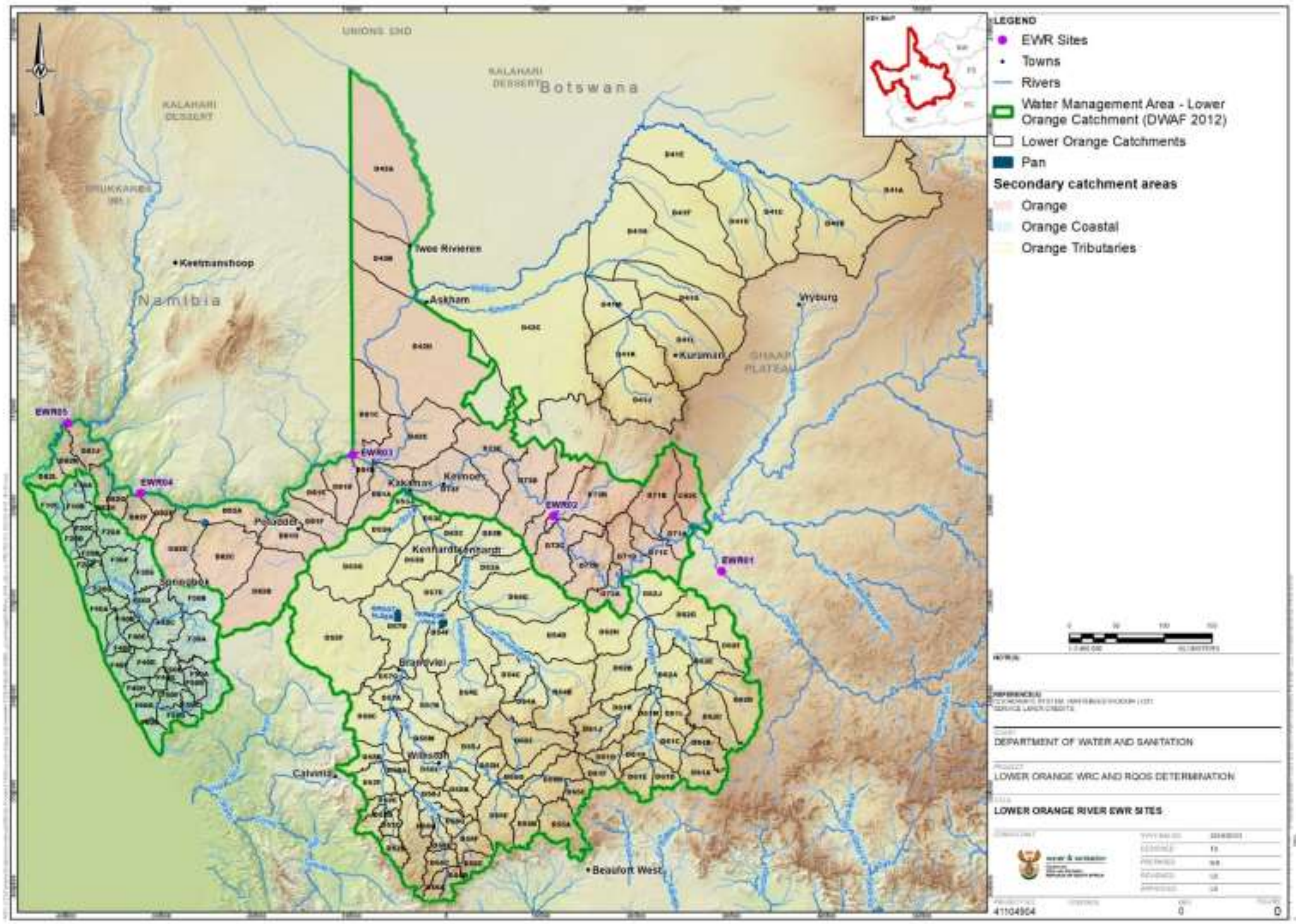



**Figure 25: Lower Orange River EWR sites**

#### 4.2.5. Hydrological Character

Hydrological Index values determined by Hughes and Hannart (2003) are used to characterise hydrological variability at a quaternary catchment level throughout South Africa. The hydrological index is based on an input time series of natural monthly flow volumes using a combination of monthly coefficients of variation (CV) and an index of baseflow contribution to total flow (BFI) (Table 23). Higher values imply rivers with variable and unreliable flow regimes. The CV Index is based on the sum of the average coefficient of variation for the three main wet season months and the three main dry season months.

The CV index is mainly a reflection of climatic variability (cycles of wet and dry periods), while the BFI is more closely associated with the runoff generation processes that dominate in the catchment of the river. The CV index varies from less than 1 to greater than 10 for South African rivers, while BFI is clearly constrained to be less than 1 (Hughes and Hannart, 2003). The CV index represents a quantitative descriptor of long-term flow variability.

**Table 23: Hydrological Index**

| Class | Coefficient of Variation Index | Hydrological character |
|---|---|---|
| Class 1 | CV_Index 1-4 | Perennial |
| Class 2 | CV_Index 5 | Seasonal |
| Class 3 | CV_Index 6- >10 | Ephemeral |

Qualitative descriptors of the hydrological character of rivers in South Africa usually include references to as perennial or ephemeral (flowing only in response to specific rainfall events) and those that are seasonally flowing.

For semi-arid to arid regions such as the Lower Orange catchment there is a high degree of variability of the CV index. The Orange River is a perennial river, with its tributaries being predominantly ephemeral (CV_ Index for rivers ranging from 5 to > 10). The ephemeral character of the sub-catchments is due to arid climate where the evaporation exceeds the precipitation. The Fish River (in Namibia) is the only other perennial river in the catchment. Perennial rivers flow throughout the year and are a characteristic of most rivers in southern Africa, particularly as main rivers in large river basins such as the Orange-Senqu basin.

Ephemeral rivers are characterised by highly variable flow regimes at all time scales caused by the intermittent occurrence of short duration events with steeply rising and falling hydrographs. Ephemeral rivers flow when there is rainfall and cease almost immediately afterwards (episodic). These include the Molopo, Kuruman, Hartbees, Sak, Brak and Ongers Rivers.

Seasonal rivers will have characteristics during the wet season that are similar to perennial rivers but will experience zero flow conditions during most dry seasons. Moderately seasonal rivers flow continuously during the rainy season and cease sometime after the end of the rains and dry up completely during the dry period. (https://www.dws.gov.za/iwqs/rhp/reports/report14/2_flow.pdf).

The ephemeral/episodic rivers require an adjusted approach to the setting of the water resource classes and specification of the ecological configuration, as EWRs cannot be determined with the absence of flow in these reaches/rivers.

### 4.2.6. Protected Areas

There are large extents of protected landscapes within the catchment especially those along the western side. Among the more valued natural resources in the river basin is a transboundary Ramsar protected wetland at the mouth of the Orange River. Important nature conservation areas include the Kgalagadi Transfrontier Park, the Ai-Ais-Richtersveld Transfrontier Park, and the Augrabies Falls National Park, Reimvasmaak Conservancy and Namaqua National Park. Various nature reserves are also found scattered within the catchment (Figure 26).

The estuary of the Orange River has been proclaimed a Ramsar site by both South Africa and Namibia, it is one of very few areas of sheltered shallow water along southern Africa's arid Atlantic coastline, and is a site considered important primarily for sustaining substantial numbers of water birds, including an appreciable number of Red Data-listed species such as the Cape Cormorant, Damara Tern and Hartlaub's Gull. The Orange River Mouth is regarded as the 2$^{nd}$ most important estuary in South Africa in terms of its ecological and conservation importance.

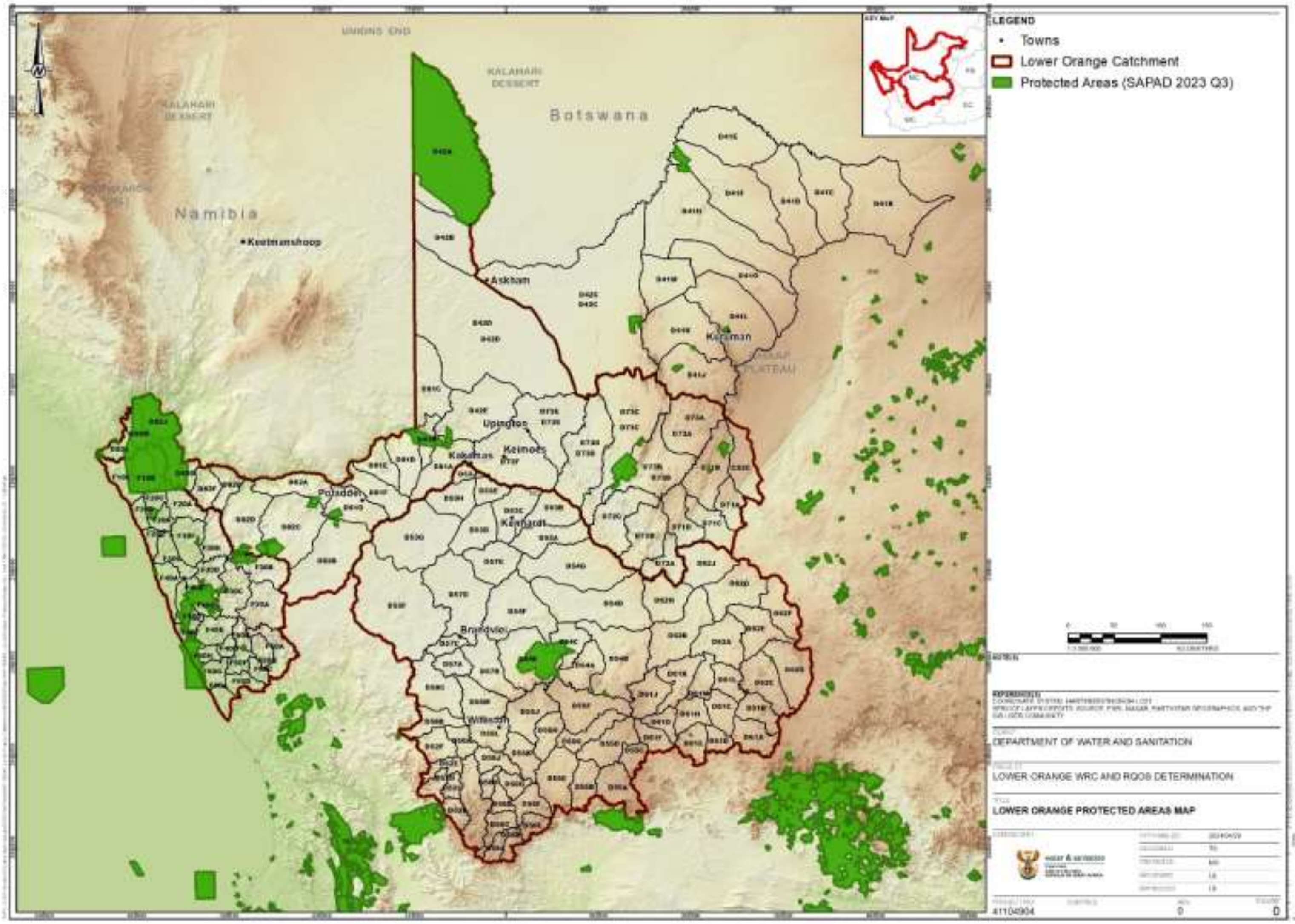



**Figure 26: Lower Orange Catchment Protected Areas**

# 5 STATUS QUO: GROUNDWATER

## 5.1. Overview

The Lower Orange and Lower Vaal catchments are situated in the arid and semi-arid northwestern region of South Africa – the climate conditions in the combined catchment are regarded as semi-arid (eastern part) to arid (western part). The use of groundwater is high as many water supply schemes have been developed for sole water supplies – one or 10 boreholes per water user/property to one or more well fields per water use entity (*viz*., municipalities, mines, or irrigation scheme).

Water users are merely (i) towns (population <30 000), (ii) mines (use and dewatering) and (iii) irrigation schemes[2], plus several thousand individual boreholes used on a daily interval for domestic and stock water supplies.

The groundwater Reserve determination for the Lower Orange catchment was conducted in 2013 as part of a study determining the EWRs in the catchment, and in 2008 preliminary determination of the rapid groundwater Reserve for the Lower Vaal catchment. The 2024 groundwater use figures for the Lower Orange catchment have been adopted from the 2016 study and indicate that ±50 million $m^3$/a are used. An annual water use appreciation of 1.6% was used to extrapolate the respective use figures to 2024 water use figures.

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

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

Groundwater use, i.e., abstraction from the aquifer system varies significantly over the water management areas due to diverse water use applications and availability thereoff. Critical cases where groundwater is pumped for large irrigations water supplies, municipal water supplies and dewatering of underground mine workings results in depletion (lowering) of the aquifer saturation levels triggering unsustainable aquifer conditions and in some cases deterioration of the groundwater qualities, *i.e.*, merely related to irrigation and mining activities.

## 5.2. Description

The groundwater resources in the Lower Orange-Lower Molopo River Catchment are found in all four specified aquifer types in South Africa. Aquifer formation types vary from Tertiary-Quaternary

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

sediments (*i.e.*, Kalahari Group and West Coast Group sediments of the Cenozoic Era) to early Archean acidic lavas (*i.e.*, The Venterdorp Supergroup Lavas) and the early Vaalian carbonates (dolomites and cherts) of the [well-known] Ghaap (Plateau) Groups. The lithologies towards the western parts of the Catchment includes the rock formations of the Namaqua-Natal Mobile Belt and various intrusive suites – these formations represents broad spectrum of intrusive and extrusive igneous rocks, sedimentary & meta-sedimentary and metamorphic rocks.

### 5.2.1. Geology

The geology in the catchment area consists of a wide range of different rock formations and can be grouped according to the following features:

- Geological Age;
- Similar lithologies;
- Specific structural terrains/terranes

The following geological units were recognized (extended and adjusted from DWS, 2016):

- **Kraaipan Group:** These formations are grouped under the Swazian Era (>3,100 Ma) consisting of a range of [rather diverse] rock formations of which the Kraaipan Greenstone Belt occurs in the upper reaches of the Molopo River. The succession consists mainly of mafic volcanic rocks with subordinate banded iron-formation and schist – three Formations have been mapped and exploratory drilling in the past has revealed moderate yields (b2-BYC) especially in the banded iron and limestone formations.
- **Marydale Group**: This greenstone belt is 2,910 – 3,000 Mega-annum (Ma) in age and is located from 20 km south-south west of Prieska up to the vicinity of Copperton and Marydale. They form part of the Namaqualand Metamorphic Province and occur as a compound syncline that is steeply folded and highly metamorphosed to greenstone level.
- **Randian intrusive rocks and volcanics**: This grouping consists of 2,700 – 2,900 Ma age granites and granitic gneisses outcropping near the Marydale Group.
- **Ventersdorp Supergroup**: The Sodium Group outcrops southeast of Prieska and consists of volcanic grits and tuffs, lavas, arkose, porphyry, limestone, chert. The Zeekoebaart Formation is exposed south of Boegoeberg dam and consists almost entirely of volcanic andesite and dacite, with some porphyry, tuff, and breccia. It has limited exposure related to extensive erosion. The Allanridge and Bothaville Formations is 2,600 Ma and outcrop near Vryburg and west of Kimberley to the northeast of the catchment.
- **Ghaap Dolomite Group**: These rocks form the Ghaap plateau and are 2,600 – 2,500 Ma in age. They are a significant aquifer hence have been separated from the remainder of the Transvaal Group ironstones and other sedimentary rocks. The bulk of the dolomitic outcrop occurs over quaternary catchment D71A, D71B, C92B, C92C, and D41L. A further narrow strip of dolomite, approximately 50 km long and less than 5km wide outcrops in a roughly north-west to south-east orientation along the Doringberg Fault, west of Peiring. The main body of the outcrop is present on quaternary catchment D72B.

- **Olifantshoek Supergroup**: The lower part of this grouping consists of clastic sediments and volcanic rocks, which grade upward to rudaceous (*i.e.*, coarse fragments) sediments. These rocks are encountered west of Postmasburg and east of Olifantshoek and build the foothills of the Langeberg, Korannaberg and Eselberg. They form a prominent north trending mountain range from Boegoeberg northward to the Korannaberg and is significantly folded and are almost vertical at places. They overlie Transvaal Supergroup rocks with a regional unconformity and are about 1,900 Ma in age.
- **Namaqua-Natal Province:** The region consists of metamorphic rocks formed or metamorphosed between 2,000 – 1,000 Ma. These rocks range from an assembly of compact sedimentary and volcanic rocks to extrusive and intrusive rocks including homogenous granites to migmatites and gneisses. The area underlain by the Namaqualand-Natal Province is situated near the Orange River between Prieska to Upington and Springbok. It consists of three phases of geological processes, *i.e.*, (i) metamorphism (±2,000 Ma), (ii) rifting/subduction – intrusive and extrusive rocks formed (1,600-1,200 Ma) and (iii) tectonic granitoids formed (1,000 – 1,000 ma).

  The Namaqua-Natal Province rock formations are grouped into six (6) sub-terranes based on marked changes in lithology across structural discontinuities (DWS, 2016), however, the successions consist of basement gneisses, metamorphosed rocks, sedimentary/volcanic metasediments, granitic intrusions with sporadic isolated undeformed unmetamorphosed cap rocks (Koras Group) and were deposited/reformed between 2,000 to 1,180 Ma ago. Several regional fault zones and shear zones, and thrust zones are present, *i.e.*, Hartbees River Thrust, Boven Rugseer Shear Zone, Brakbosch Shear Zone, and the Dabep Thrust – the rock formations should, therefore, be significantly fractures/jointed at specific terrains.
- **Namibian Successions**: These rocks are grouped into the Richtersveld Suite, the Gariep Supergroup and the Nama and Vanrhynsdorp Groups, and are intruded by granites. The Richtersveld Suite consists of felsic rocks intruded into rocks of the Vioolsdrift Suite and Orange River Group. The Gariep Supergroup are a meta-volcanic and sedimentary succession that fill a tectonic belt running from Kleinsee to Namibia. They have been extensively deformed and are about 700 Ma in age. The Nama and Vanrhynsdorp Groups were deposited in foreland basins and are separated from The Gariep Belt geographically.

- **The Karoo Supergroup**: Largest cover rocks in the catchment and occupy the southern lobe of the Lower Orange catchment and comprise thick successions of sedimentary rocks ranging from (i) basal diamictites and rhythmites, (ii) mudrock and siltstone, and (iii) coarser varieties (sandstones, conglomerates). They have been subdivided based on the following considerations:
  - Dwyka Tillite: This massive tillite consists of highly compacted diamictite with mudrock higher up in the sequence.
  - Carbonaceous Ecca Group shales (I): the Prince Albert and Whitehill Formations form thick sequences of black carbonaceous shale with the highest fracking potential where

they underlie other Karoo formations. They have been separated from the remainder of the overlying Ecca Group formations due to their poor water quality.

- Argillaceous Ecca Group shales and sandstones (II): These formations are of marine origin and are often more saline (up to 2.5x) than the overlying younger Karoo rocks.
- Beaufort Group rocks: Are of fluviatile and generally of continental origin. Their salinity is related to low recharge rather than connate marine salts like in the Ecca.

- **Karoo or Jurassic dolerite (magma) intrusions:** Hundreds of dolerite dykes and sills are commonly found throughout the Karoo Supergroup sequence and frequently intruded older rocks, ±200 – 140 Ma. There are, however, cases where Karoo Dolerite intrusions were mapped in even much older rock formations, *i.e.*, Mokolian gneiss-pegmatites in the Bushmanland. During the Karoo magma intrusions so-called dolerite contact-zone aquifer systems developed and these zones represent many of the (higher yielding) water bearing zones intercepted by water drilling exploration. The yields of these water bearing zones can be significantly higher than water bearing zones in the surrounding “host-rock formations”.

- **Sutherland Suite**: This 66 Ma aged Cretaceous dome structure consisting of several isolated intrusions lies ± 19 km east-southeast from the Northern Cape town Sutherland (quaternary catchment D56A) consisting of volcanic breccia, carbonatite, trachyte (alkali feldspar) and rare olivine-melilite rock types. Since the intrusion occur in the Beaufort Group, it is grouped with the Beaufort Group – the area around the feature is highly fractured.

- **Kalahari Group sediments:** A relative thick (<~130 m) sedimentary sequence consisting of merely (i) basal clayey gravels, (ii) sand(stone) to clay(stone) formations overlain by a thick layer of (iii) continental limestone (calcrete) occurs in the northern part of the catchment. These deposits were formed post-Cretaceous times (<64 Ma) and forms part of the much larger Central Kalahari Basin that covers large parts of Botswana, the eastern part of Namibia and the southern parts of Angola, Zambia and Zimbabwe. Theses deposits are overlain by large areas of thick (up to 30 m) of quaternary fine aeolian sand. The topography of the Kalahari Floor has several deep paleo drainage features where the initial gravels were deposited during the early Tertiary Period.

The simplified geological background is illustrated in Figure 27 – as noted above the rock formations varies from (i) some of the youngest rock formations (*i.e.*, The Gordonia Sand Formation – Quaternary Period <2Ma[3]) to (ii) rock formations of the Vaalian Era (<2,650 Ma), including the Namaqua-Natal metamorphic events (±1,200 Ma to 1,000 Ma).

[3] Ma = Million years.

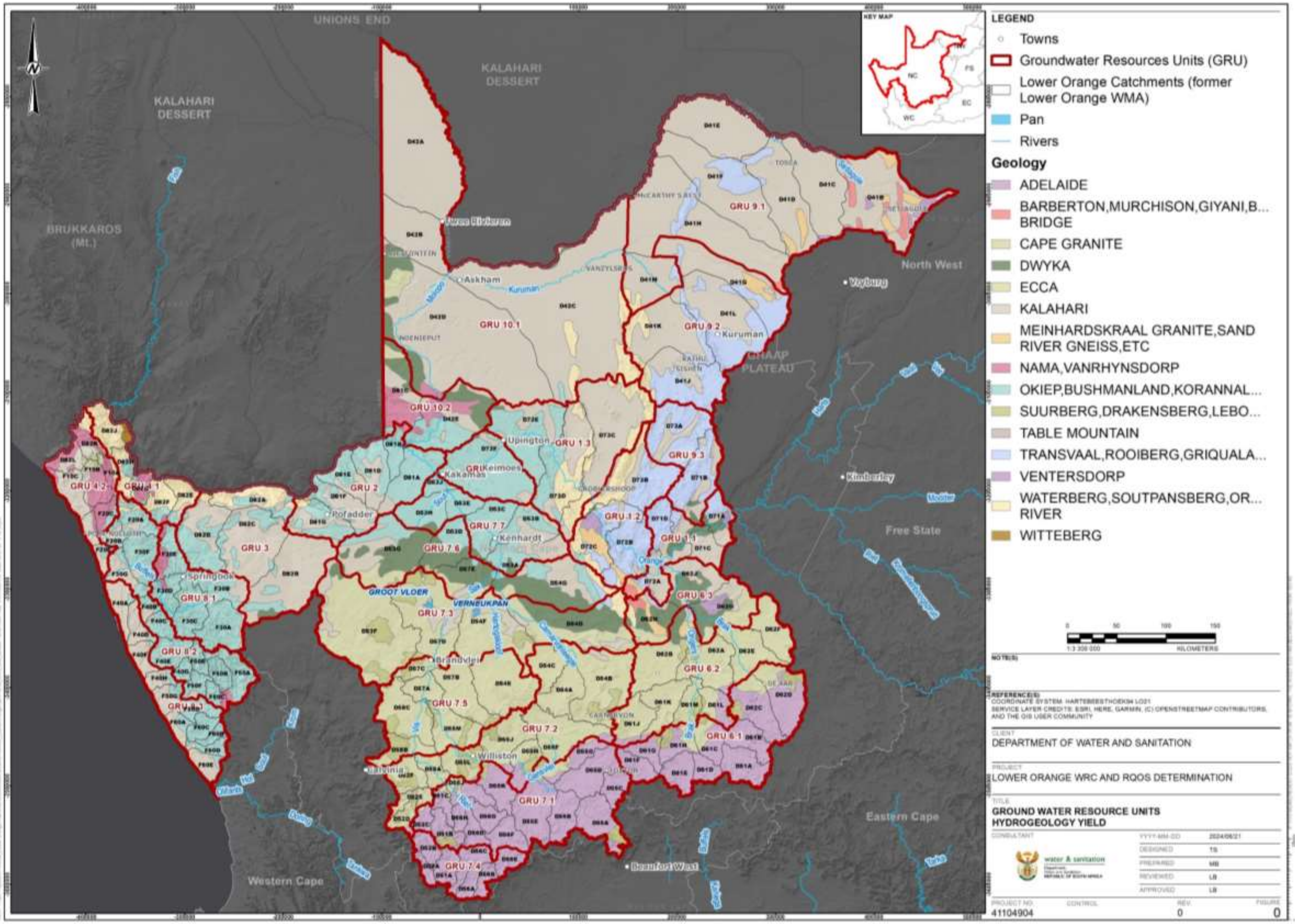



**Figure 27: Lower Orange and Lower Molopo Catchment (simplified) geological formations**

### 5.2.2. Hydrogeology, Aquifer Types and Vulnerability

Groundwater occurs in a wide range of aquifer systems and includes the four major Aquifer Types specified under the Geohydrological Map Series of South Africa. They are as follows:

- Intergranular aquifer type – unconsolidated to semi-consolidated sediments of the Kalahari Group sediments consisting of gravels, overlain by sandy to clayey sand(stones) and clay(stones). The West Coast Group consists of calcrete, dune sands, aeolianites, gravels and ancient shoreline sand/gravel terraces. In both cases the saturated basal gravels represent the aquifer system.
- Fractured aquifer type – virtually all types of the hard rock formations, (*i.e.*, meta- arenaceous rock, sandstone and mudrock) fall into this category and represents the bulk of the aquifer types present in the WMAs.
- Karst aquifer types – mainly present on specific sites on the Ghaap Plateau and further West and SW, *i.e.*, below the Banded Ironstone Formation (BIF) in the Gamagara River valley near Kathu, Northern Cape.
- Fractured and Intergranular type – merely applicable to the western part of the Lower Orange catchment consisting of quartzite, volcanics, andesitic lava, various granite-gneiss, and schist/phyllite formations.

The simplified hydrogeological background is shown in Figure 28 illustrating the borehole yield class(ification). The borehole yield class in this Catchment are highly diverse and fall between Insignificant (<0.1 L/s, d1 BYC) – merely along the West Coast-Namaqualand Region (*i.e.*, Intergranular and Fractured aquifer type) to Low-Moderate (0.1-0.5 & 0.5-2.0 L/s, b2-b3 BYCs) in the central and eastern part of the Catchment (*i.e.*, Fracture aquifer type). Moderate to Significant BYCs (0.5 to >5.0 L/s, b3-b5, d3-d5 and c3-c5 BYCs) – occur in the northeastern part of the Catchment (the Lower Molopo Catchment).

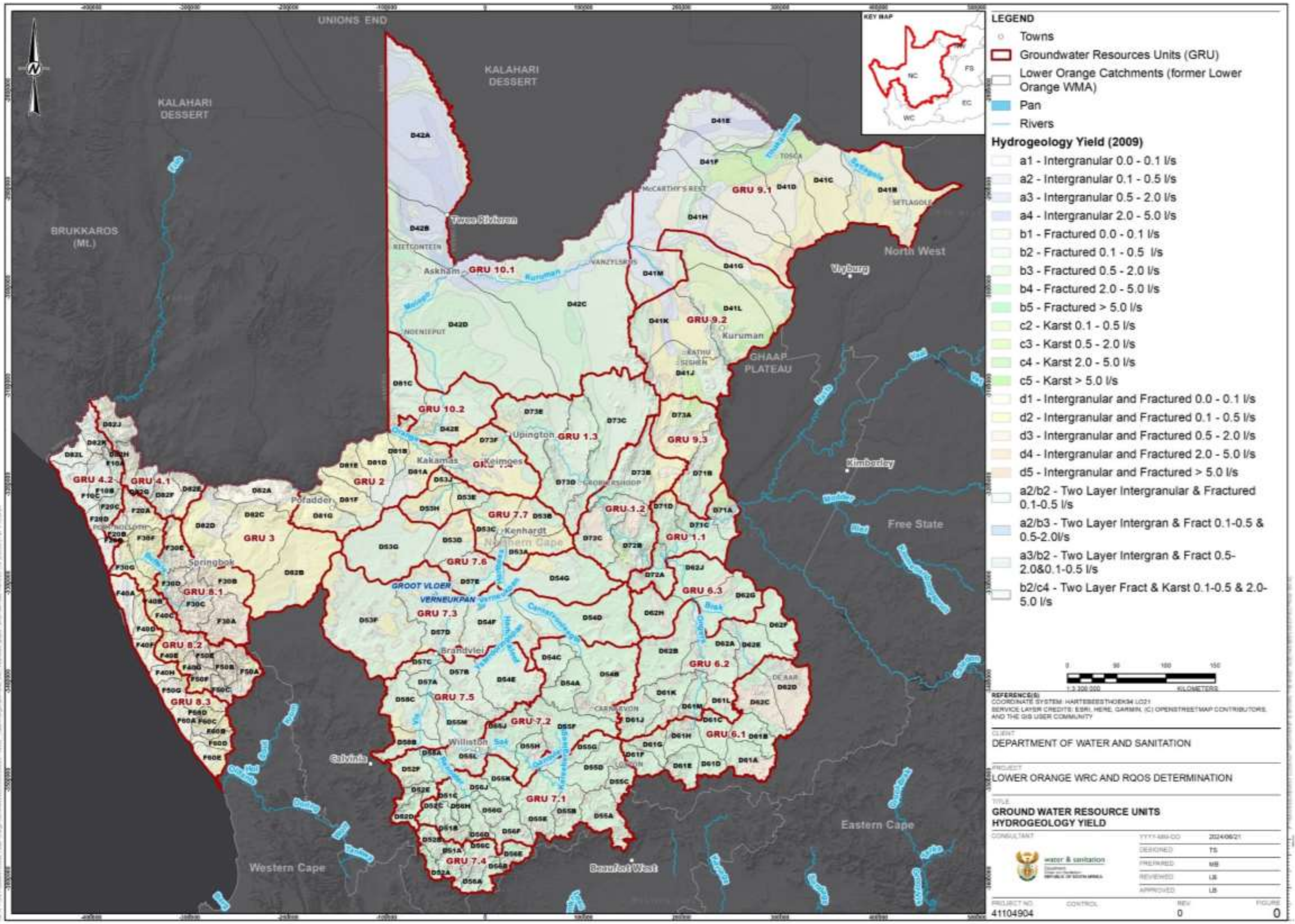



**Figure 28: Lower Orange and Lower Molopo Catchment geohydrological map**

## 5.3. Status

Two aspects are important to specify the status of the groundwater conditions, *i.e.*: water levels and water quality.

- Water levels/Aquifer saturation levels:

  Groundwater levels is a function of groundwater use (abstraction) and recharge. A good measure to assess the water level status of a groundwater resource is to calculate the so-called Stress Factor which is based on the groundwater Reserve (EWR) study that was conducted in 2016 (DWS, 2016). It is therefore expected that those quaternary catchments with high Stress Indices (SI), *i.e.*, >1.00, requires dedicated measures to reduce the high groundwater use, especially considering the recent deteriorating trend of climate variation in the Northern Cape Province. There are a total of 13 quaternary catchments that have SIs >1.00, and as high as 5.63 – this needs to be addressed in this study as these specific quaternary catchments are those with the larger towns in the catchment.

  Water levels in the Lower Orange catchment (as per the 2016 Groundwater EWR) indicates Shallow (<30 mbgl), Moderate (+30 to 60 mbgl) and Deep (+60 to 90 m) levels. According to the information assessed in the 2016 EWR study, the following were noted:

  - The upper parts of the Lower Orange catchment, *viz*. mainstem Orange River (from Vaal confluence), Ongers and Hartbees catchments have water levels falling in the Shallow Depth range;
  - The western parts of the catchment, viz. lower reach of the Orange River below Kakamas and coastal area have water falling in the Moderate Depth range: and
  - Towards the northern part of the catchment, in the Molopo and Kuruman catchments the groundwater levels drop from Moderate Depths to Ultra Deep (+90 mbgl).

  Groundwater levels are much shallower, *i.e.,* <20 mbgl in elevated areas such as the Namaqualand Highlands (*viz*. Kammiesberg Mountains) and the topographical higher southern parts of Ongers and Hartbees catchments have potentially more frequent rainfall events. On the contrary, areas (i) covered by thick (>6.0 m) Kalahari Sand cover, and (ii) elevated areas with highly fractured hard rock types, such as the banded ironstones of the Kuruman Hills, have Deep to Ultra Deep-water levels, *i.e*. >100 mbgl.

- Aquifer quality

  The groundwater quality of the Lower Orange catchment varies significantly and could be elucidated by the following baseline conditions in the said areas:

  - Sedimentary rock types: (i) the Dwyka Group diamictites /mudrocks (deep marine sedimentary conditions) and the Ecca Group mudrocks (marine-fluvial conditions) – the groundwater found in these formations are saline due to elevated sodium and chloride concentrations.

  - These rock formations have less saline water quality signatures towards the east due to high rainfall input.
- Crystalline rock types: Specifically, formation consisting of intrusive granites and gneisses in the Western Bushmanland terrain have elevated uranium and fluoride concentrations that needs to be acknowledged for domestic water supplies.
  - Water quality in the Eastern Bushmanland terrain is less saline (viz. 70-95% are potable).
- Coastal aquifer systems have a strong saline signature (*i.e.*, sodium chloride, NaCl) due to saline seaborne aerosol deposits on the land surfaces.
- Groundwater in the Kalahari Group Aquifers varies from hyper saline (TDS >35,000 mgTDS/L) for fresh (TDS<70 mgTDS/L) – phenomenon is (i) due to the complex differentiation of water quality in the basal Kalahari formations associated with the underlying Karoo Dwyka mudrocks, and (ii) water found in paleo-drainages frequently recharged by flush flooding of the Auob, Nossob, Kuruman and Molopo Rivers.
- Groundwater in the far eastern hard rock formations, *i.e.*, section of the Ghaap Plateau dolomites, the overlying banded ironstone formations (BIF) and andesitic lava/massive quartzites/schist of the Campbell-Griquatown-Olifantshoek-Volop Groups have ideal to marginal water quality types.

The long-term (5-10-years) groundwater quality in the Catchments shows the following long-term trend patterns varies between the following patterns:

- Fairly stable trends with occasional high/low oscillations – normal annual rainfall recharge, or
- Long-term decreasing water quality trend(s) – indicating refreshing conditions probably after a period of draught with limited rainwater recharge; or
- Long-term increasing water quality trend(s) – indicating deterioration of the groundwater qualities probably due to poor [refreshing] rainwater recharge and/or pollution of the local aquifer system.

An example of long-term groundwater quality trends is illustrated in Figure 29 below. The example is from the Kuruman A-Eye. This eye has been observed for several decades and provides water for the Kuruman Town and villages further downstream of the townlands.

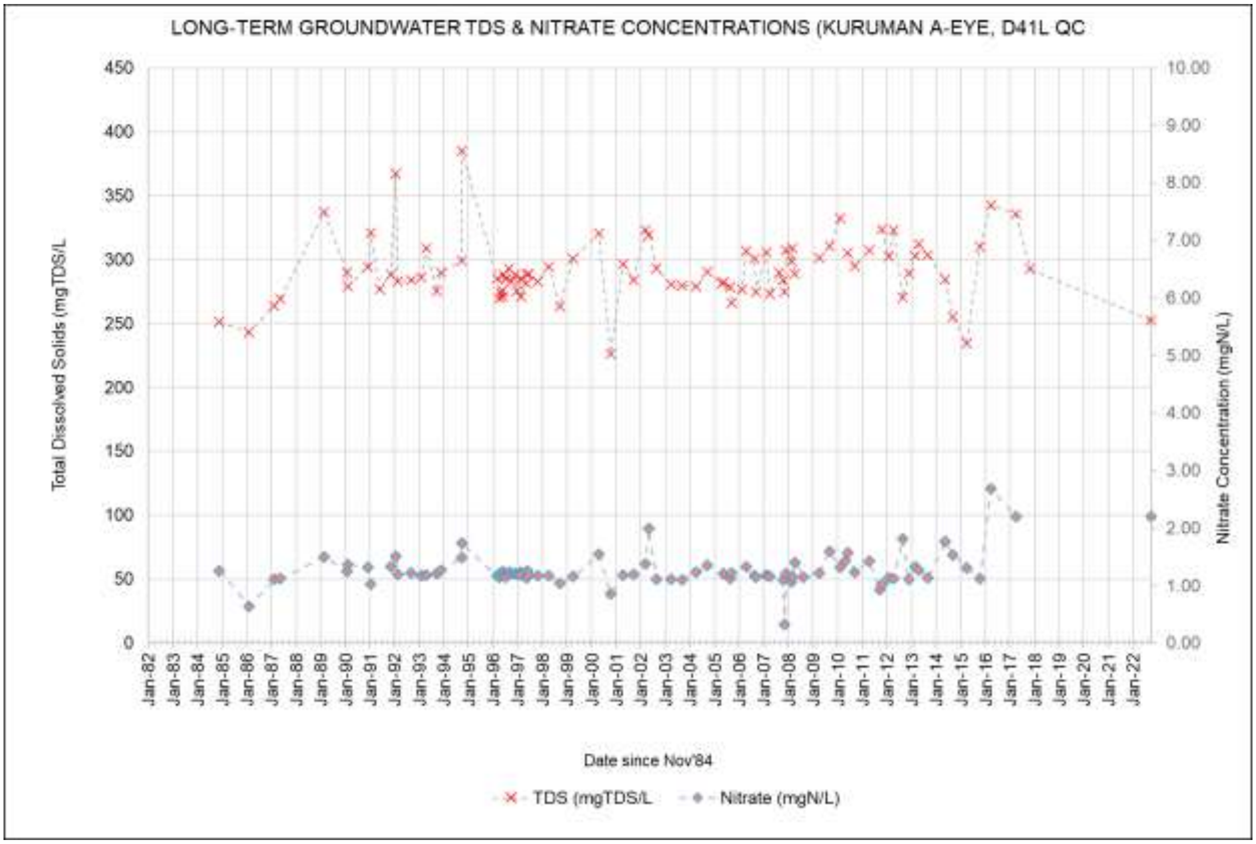



**Figure 29: Long-term groundwater quality trends in the D41L Quaternary Catchment (Kuruman A-Eye at origin of the Kuruman River)**

Sporadic nitrate pollution seems to become a concern in the groundwater of the catchment. An example of significant nitrate pollution at a monitoring site in the D54B quaternary catchment (ZQMCAR1, Carnarvon) is illustrated in Figure 30 – the concentration has decreased to a level <6.7 mgN/L since 2009, was at ±50 mgN/L between January 2000 and April 2004.

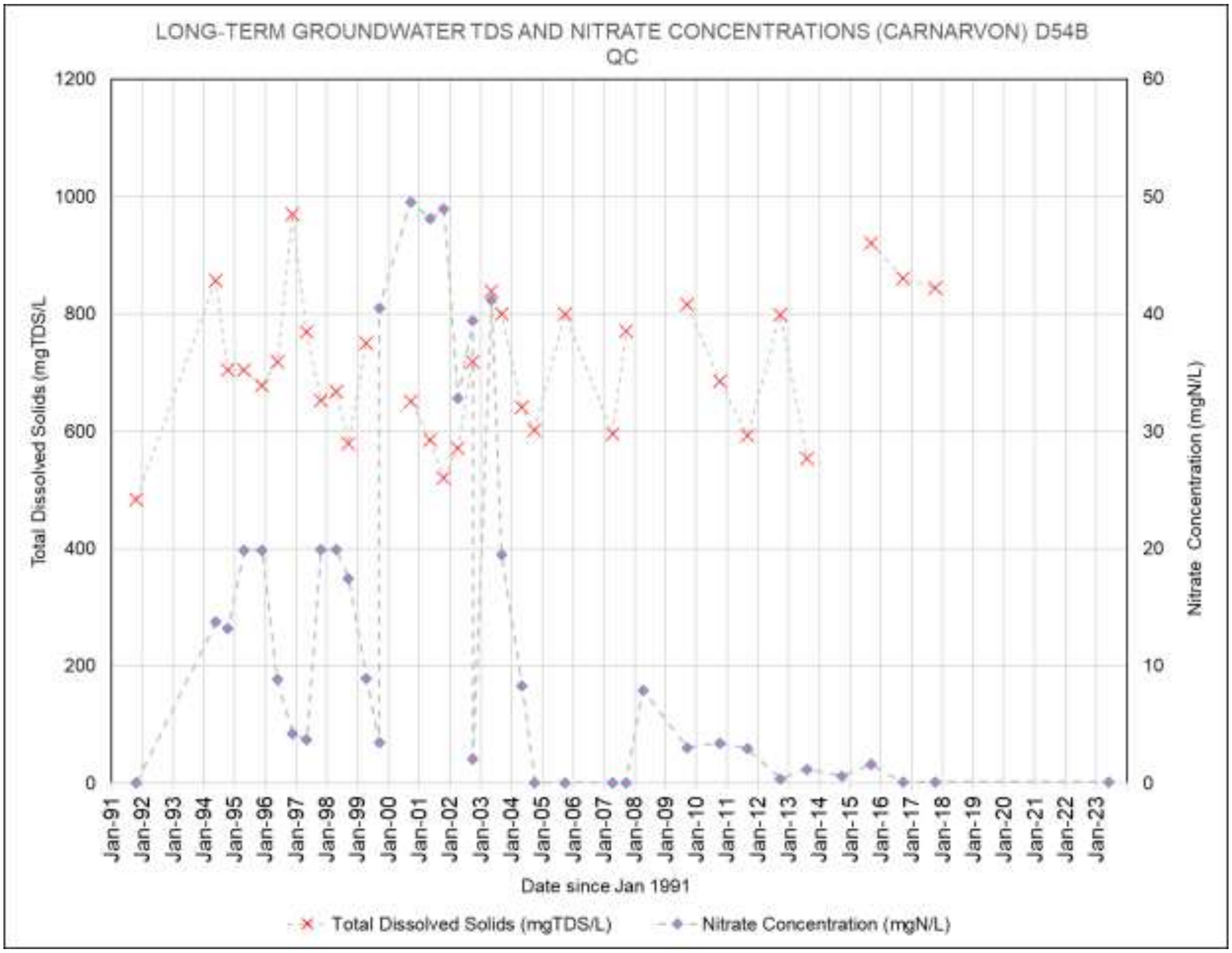



**Figure 30: Long-term groundwater quality trends in the D54B Quaternary Catchment (upstream Carnarvonleegte)**

Groundwater quality towards the western part of the catchment changes due to the impact of the West Coast aerosols and a “slight saline” quality signature of the rainfall driven by [cold] frontal systems from the Atlantic Ocean. The hydrochemical signatures of the groundwater are dominated by elevated sodium-chloride concentrations and is typical characteristic of the groundwater quality type. An illustration of the groundwater TDS concentrations and trend is shown in Figure 31**Error! Reference source not found.**.

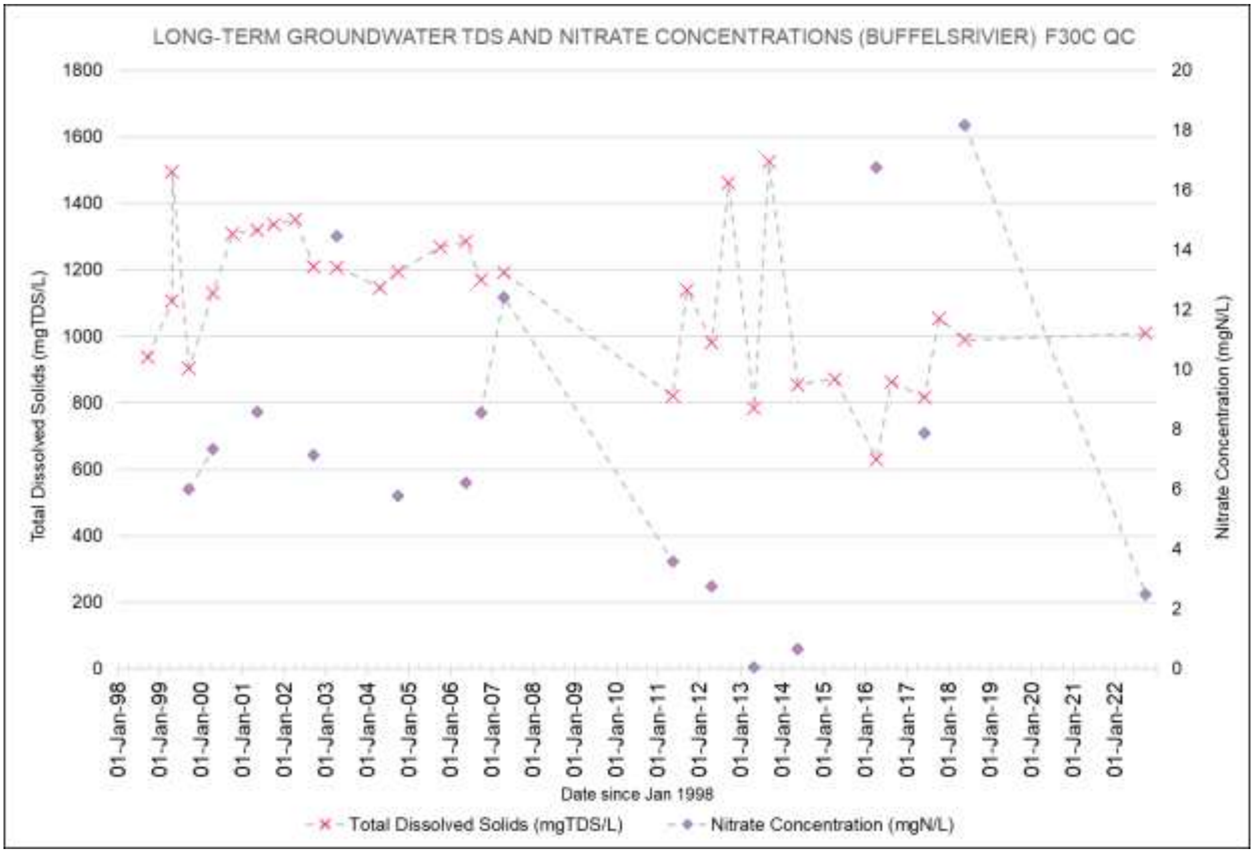



**Figure 31: Long-term groundwater quality trends in the F30C Quaternary Catchment (upstream Buffels River).**

### 5.3.1. Recharge

Groundwater recharge to the aquifer systems in the Lower Orange catchment is driven mainly by rainfall – frequency, rainfall intensity, terrain conditions, vegetation, ground slope, plays an important role on the effective recharge of the underlying aquifer systems.

Rainfall falling on hard rock formations will percolate via small/micro fractures/joints in the upper fractured (and weathered) rock face down to the saturation zone (direct recharging). Once an aquifer has reached a specific capacity (*i.e.*, water table is rising) it will start to drain sideways (according to the gradient of the terrain) and create additional recharge to lower laying aquifer systems (*i.e.*, lateral recharge/flux).

In general recharge across the catchment varies from close to 0.5 mm/a to 12 mm/a (DWS, 2016). In the Kalahari Region, groundwater recharge is very limited, *i.e.*, with >6 m Kalahari sand cover the effective recharge is very low, *i.e.*, <1.0 mm/a. High, episodic rainfall events can, however, generate local flush flooding of low laying terrains, such as the dry beds of the drainage systems and enhance local groundwater recharge significantly.

Groundwater recharge has been assessed for mostly the Karoo Supergroup aquifer systems and varies between 1.5 mm/a to 3.5 mm/a – based on Water Research Commission (WRC, 2002), Department of Water Affairs (DWA, 1995) and specialist studies (2010). Rainfall recharge in the eastern hard rock terrains, *viz*. the Griqualand East Sequence (dolomite, BIF and quartzites-lava), are much higher and could be as high as 12 mm/a.

To conclude, groundwater recharge is highly depending on (i) the rainfall depths (mm/event), (ii) rainfall ratio (mm/hour), (ii) ground surface conditions (hard rock-weathered rock surfaces), (iii) water ponding in depressions/or not), and (iv) frequency of exceedance of wet cycles.

Based on re-assessment of recharge in groundwater regions (Vegter, 2001 for specific areas where the recharge estimations included zero values, the groundwater recharge figure for the Lower Orange catchment was ±480 Mm$^3$/a (DWS, 2016). Recharge studies conducted for the Molopo-Kuruman catchment area was estimated at ±340 Mm$^3$/a (DWS, 2008).

It should be noted that these recharge figures are based on long-term MAP. With regards to the recent impact of climate variations, and ultimate change, it has become time to specify a “modern” mean annual precipitation (MAP) value for each quaternary catchment in the study area. This would probably look at rainfall estimated from post-1974 times only.

### 5.3.2. Groundwater use

According to the 2016 EWR study (DWS, 2016), borehole yields (NGA) were grouped per quaternary catchment to derive the geometric mean borehole yield. Borehole yields were below 1 l/s in Bushmanland, the Western Kalahari and Namaqualand. In these groundwater regions, more than 80% of boreholes generally yield less than 2 l/s. Across the Upper Karoo and the Ghaap Plateau, yields exceed 0.8 l/s and reach over 2 l/s and more than 40% of boreholes yield over 2 l/s.  Individual borehole yields could be much higher depending on local aquifer hydraulic conditions, borehole design/construction and land surface conditions (*viz*. hard rock formations, weathered hard rock terrains, and Kalahari sand cover).

Groundwater use in the Lower Orange catchment is in the order of 44 Mm$^3$/a (DWS, 2016). This figure is based on the basic human needs (BHN) estimation and the Reserve determination. Requirements for the EWR (*i.e.*, baseflow generated from local groundwater system(s)) are limited to only two quaternary catchments in the Lower Orange catchments. These figures should be correlated with the calculated SI for each quaternary catchment.  A SI of >40% (or 0.40) is regarded as the upper limit before an aquifer system becomes a risk for sustainable yield in terms of water use supplies. There are 28 quaternary catchments in the Lower Orange catchment classified with a PSC D and D+ – indicating that the allocatable groundwater volume are already over-allocated (*i.e.,* negative water balance), or very close to the 1:1 water balance in the aquifer system.

Groundwater use in the upper Molopo and upper Kuruman River systems draining towards the Molopo River and further downstream to the Kuruman-Molopo River confluence near Askham are only based on estimations of EWR and BHN. No information on groundwater uses for (i) mining, (ii) stock watering, and (iii) irrigation water schemes such as the Tosca-Vergeleë Groundwater

Scheme are not included in the Lower Vaal water use balance. These shortages will have to addressed in the current study to finalise the WRC and RQOs for the Lower Orange study area.

# 6 STATUS QUO: WETLANDS

## 6.1. Overview

The National Wetland Map 5 (Van Deventer *et al*., 2018) and the National Freshwater Ecosystem Priority Areas (NFEPA) wetland layer (Nel *et al*., 2011) were used to identify and map the significant wetland resources in the Lower Orange River catchment. The resulting map of the wetlands was used to support the delineations of the IUAs in the Lower Orange catchment. An indication of preliminary Priority Wetlands is provided in Figure 32 with a summary of the extent of wetlands per type, and a list of the preliminary Priority Wetlands and the priority wetlands mapped per IUA, is indicated in Section 9.2. This preliminary Priority Wetland list was supported by information gathered from Begg (1989) and www.Ramsar.org – Annotated List of Wetlands of International Importance – South Africa. The list of preliminary priority wetlands may be updated as more information on the wetlands within each IUA is collected during the course of the study.

While wetlands have been mapped to occur across the Lower Orange River catchment, only 4.28% of the catchment makes up wetland habitat (including rivers and estuaries). Forming part of the wetlands is the Orange River Mouth Ramsar Site (see www.Ramsar.org – Annotated List of Wetlands of International Importance – South Africa). Although large in size (approx. 33,267,470), the Lower Orange River catchment is located in an arid area with few wetland systems.

## 6.2. General Description of Wetlands

Based on the National Wetland Map 5 (Van Deventer *et al*., 2018) and the NFEPA wetland attribute data (Nel *et al*., 2011), five different hydro-geomorphic (HGM) wetland types have been described as occurring in the Lower Orange River WMA. These include:

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

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

Typically depression/pan wetlands were found to be the most extensive wetland type within the Lower Orange River Catchment, making up 1.31% of the total wetland habitat mapped (Table 30), with the largest number recorded within the Hartbees/Sak catchment and the Coastal area catchment. Channeled Valley Bottom wetlands make up the second most extensive wetland type in the catchment with 0.52%. River systems covered an area of approximately 1.97% of the catchment based on NWM5 dataset.

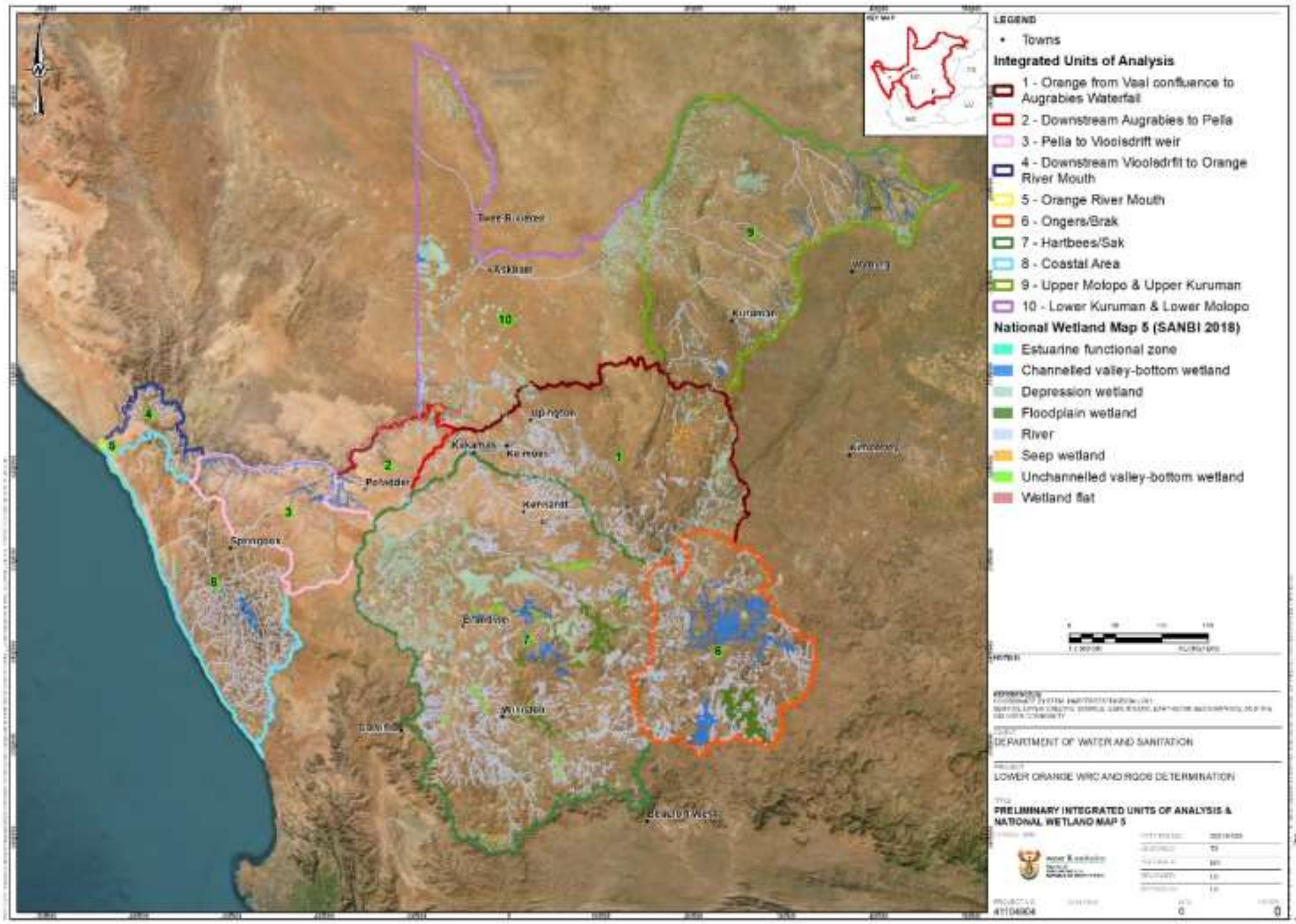
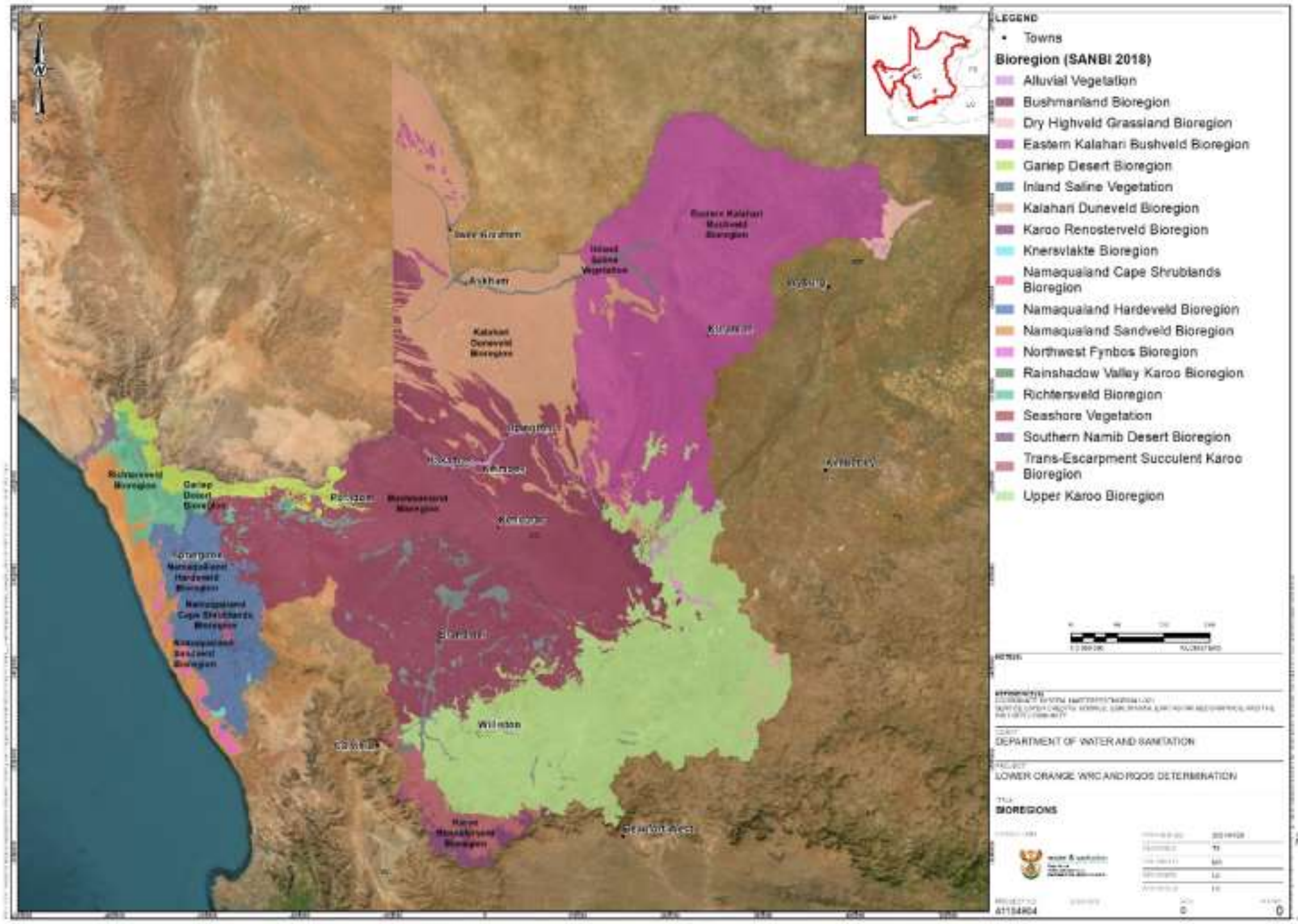



**Figure 32: Map showing the extent of wetlands mapped per IUA and the location of the preliminary Priority Wetlands (compiled from GIS coverage of Van Deventer *et al*., 2018 and Nel *et al*., 2011)**

Typically depression/pan wetlands were found to be the most extensive wetland type within the Lower Orange River Catchment, making up 1.31% of the total wetland habitat mapped, with the largest number recorded within the Hartbees/Sak catchment and the Coastal area sub-catchment. Channelled Valley Bottom wetlands make up the second most extensive wetland type in the catchment with 0.52%. River systems covered an area of approximately 1.97% of the catchment based on the NWM5 dataset.

The wetlands within the Lower Orange River Catchment occur across nine ecoregions and nineteen (19) different Bioregions as seen in Figure 33. The largest bioregion in the catchment is the Eastern Kalahari Bushveld bioregion followed by the Bushmanland bioregion and the Upper Karoo bioregion. The bulk of the wetlands straddle the Bushman bioregion and the Upper Karoo bioregion.

The general description of wetland condition is provided in Section 9.2.




## Figure 33: Bioregions in the Lower Orange Catchment

# 7 STATUS QUO: ESTUARIES

The main river system draining the Lower Orange River catchment is the Orange River. At the confluence with the Vaal River, the Orange River flows in a westerly direction to the west coast entering the Atlantic Ocean through the Orange River Estuary (CSIR, 2011).

The Orange River Estuary is the largest estuary in the catchment, however the catchment also includes adjacent coastal areas. Other than the Orange River estuary, five smaller estuarine systems are also located within the Lower Orange catchment. These systems include the Buffels, Swartlintjies, Groen, Spoeg and Sout (North) estuaries.

## 7.1. Orange River Estuary

### 7.1.1. Location and setting

The Orange (Gariep) River Estuary (28°38'30” S; 16°27'45” E) is situated just north of the coastal town of Port Nolloth in the Northern Cape and forms the border between South Africa and Namibia. The Orange River Estuary is a delta type river mouth and is classified as a Cool Temperate Large Fluvially Dominated system (Van Niekerk, *et.al*, 2019a). The Orange River Estuary comprises a channel system between sand banks, a tidal basin, the river mouth and the salt marsh on the south bank.

The Orange River Estuary has a wide range of habitats that consist of a series of braided troughs interspersed with sandbanks, channel bars and small islands, with a tidal basin and a salt marsh on the southern bank (Bornman 2008, Bornman, Adams and Bezuidenhout 2004). The vegetation on the braided system of islands within the lower reaches of the river are ephemeral due to periodic flooding.

The Orange River Mouth Wetland was designated a Ramsar status in 1991, however, in September 1995 this Ramsar site was placed on the Montreux Record as a result of a belated recognition of the severely degraded state of the salt marsh on the south bank.

The Orange River Estuary falls within quaternary catchment D82L. The PES of the catchment has been assigned as category C, moderately modified, while the ecological importance and sensitivity (EIS) is low to marginal. According to the Water Resources of South Africa, 2012 (WR2012) study database, the quaternary catchment has a gross catchment area size of 754 $km^2$. The Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAE) on the catchment is 42mm and 2200mm, respectively. The Mean Annual Runoff (MAR) in the catchment amounts to 0.02 million $m^3$ per annum.

During the 2018 National Biodiversity Assessment (NBA 2018), the Estuarine Functional Zone (EFZ) was defined for all estuaries in South Africa. The definition of the EFZ was defined as follow:

*In South Africa, the EFZ is defined as the area that not only encapsulates the estuary waterbody, but also the supporting physical and biological processes and habitats necessary for estuarine function and health. It includes all dynamic areas influenced by long-term estuarine sedimentary* *processes, i.e. sediment stored or eroded during floods, changes in channel configuration, aeolian transport processes, and changes due to coastal storms. It also encompasses all the multiple ecotones of floodplain and estuarine vegetation that contribute detritus (food source) and provide refuge from strong currents during high flow events* (Van Niekerk, et.al, 2019a).

The EFZ of the Orange River estuary spans an area of approximately 3095 ha. The estimated geographical boundaries of the Orange River Estuary set during confirmation of the EFZ (Van Niekerk, et.al, 2019a) are as follows:

- Downstream boundary: The estuary mouth (28°38'00.00"S, 16º27'09.40"E)
- Upstream boundary: Head of tidal influence is about 2 km above the Sir Ernest Oppenheimer bridge, approximately 13 km from mouth (28°33'44.51"S, 16°31'23.48"E).
- Lateral boundaries: 5 m contour above mean sea level (MSL) along the banks.

### 7.1.2. Ecological Status

The ecological flow requirements for the Orange River estuary were determined during the EWR 2017 study to have a PES and recommended ecological category (REC) of D and C, respectively. The EIS was assigned as very high (DWS, 2016). The reassessment of the PES and REC during the NBA 2018 assessment confirmed the PES to be category D, however, the REC was adjusted downward also to a category D (Van Niekerk*, et.al*, 2019a), see Table 24 below.

**Table 24: Orange River Estuary PES, REC and PES of individual estuarine components (Van Niekerk, *et.al*, 2019b)**

| NBA 2018 Condition Status | Heavily Transformed |
|---|---|
| Present Ecological State (PES), 2018 | D |
| Hydrology | D |
| Hydrodynamics | C |
| Water Quality | D |
| Physical habitat | B |
| Microalgae | E |
| Macrophytes | D |
| Invertebrates | D |
| Fish | D |
| Birds | E |
| **Recommended Ecological Category (REC)** | **D** |

The NBA 2018 assigned the hydrology and water quality components of the estuary a category D, while the hydrodynamics was assigned to a PES of category C. The biotic components of the Orange River Estuary were largely assigned to category D, besides microalgae and birds that was assigned to a heavily transformed state of a category E (Van Niekerk, *et.al*, 2019b).

The Department of Forestry Fisheries and Environment is currently underway with a project to update the Orange River Mouth Estuarine Management Plan. The outcomes of the study will be considered and incorporated as necessary.

### 7.1.3. Abiotic components

#### Hydrology

The natural runoff of the Orange-Senqu catchment is estimated at 11 600 million $m^3$/a of which approximately 4 000 million $m^3$/a originates in the Lesotho Highlands and approximately 6 700 million $m^3$/a originates from the areas contributing to the Vaal, Caledon, Kraai and Middle Orange rivers (Maré 2007). The remaining 900 million $m^3$/a arises from the catchment downstream of the Orange/Vaal confluence, including part of Namibia and a small portion in Botswana feeding the Nossob and Molopo rivers, however, whether these two rivers directly contribute to the Orange River remains to be confirmed (CSIR, 2011).

Water demand in the catchment is very high with more than 50% of the natural mean annual runoff being utilised by domestic and industrial purposes (extensive dam development), extensive irrigation and mining demands (Maré 2007).

River inflows to the Orange River Estuary have been markedly reduced from reference, with only an estimated 44% of natural flows still reaching the system (DWAF 2003). Despite the drastic reduction in flows and flow regulations, the estuary is still river-dominated with marine interchange limited to the middle and lower section of the estuary (CSIR, 2011).

The occurrence and magnitude of large floods has also significantly reduced. Floods in the Orange system normally occur during the summer months. The occurrence and magnitude of smaller floods with return periods of 1:1 year to 1:10 years during the summer months has further been greatly reduced. This results in a considerable reduction in the occurrence of flooding of the salt marsh near the mouth during the summer months. Such floods would probably have lasted for periods of a few weeks at a time.

The occurrence of periods of very low flow during the winter months which historically caused mouth closure and back flooding in the past has been significantly reduced under present conditions. This is the result of almost continuous releases from the dams upstream of the Orange River estuary, which are undertaken for the generation of electricity and for irrigation purposes. This lack of backflooding has had a pronounced impact on the salt march communities within the estuary.

#### Hydrodynamics

Hydrodynamics was assessed by Van Niekerk *et al.* (2003) and CSIR (2011). Mouth conditions in the Orange River Estuary are highly variable and range between various open positions between the north and south bank over time (Van Niekerk *et al*. 2003). The location of the open mouth is strongly influenced by the position where the mouth breachings occur over time.

Based on available data, three abiotic states are considered typical for the Orange River Estuary, each associated with a specific river inflow range (Van Niekerk *et al*. 2003), and include:

- Open, river dominated – Flow range > 50 $m^3$/s
- Predominantly Open, with marine influence - Flow range between 10 and 50 $m^3$/s

- Closed, for extended period - Flow range < 10 $m^3/s$

Using simulated river inflow patterns, the shift in the distribution of abiotic states from the reference conditions (natural state) and present state (at the time of the 2003 study was undertaken) suggests a shift in state distribution between reference and present states. This has been attributed largely to major dam development in the catchment (DWAF 2003). Under reference conditions, the Orange River Estuary was in an open river-dominated state between September to June which changed to an open marine-dominated state between June and August. Under present day conditions, however, the system is generally in an open river-dominated state between February and April, and June and July, with the estuary reverting to an open marine-dominated state during the other months of the year (CSIR, 2011).

The location of the mouth is believed to have a major influence on the salinity of the water reaching the salt marsh on the south bank near the mouth. When the location of the mouth is at the southern position, considerable amounts of seawater enter the area at spring tides (CSIR, 2011). The mouth of the Orange River Estuary is maintained by fluvial discharges and additional fluvial sediment passing through the estuary and deposited in the sea, where it is dispersed. Fluvial sediment extends from the upper estuary to close to the bar, and tidal deltas are absent or poorly developed (Cooper 2002, Van Heerden 1986 as referenced in CSIR, 2011).

Sediment distribution and organic content in sediments of the estuary were recorded in August 2004 and February 2005 by Wooldridge and Deyzel (2008). Results from these two surveys reveal large variability in sediment composition both spatially and temporally. Organic content in sediments also display marked variability between surveys, but on both occasions, results showed a decreasing trend moving upstream of the mouth where the highest organic content was recorded in the lower reaches of the estuary (Wooldridge and Deyzel, 2008).

The available information indicates that, in general, the depth and bed morphology over most of the estuary are similar to that of the reference condition, although under the present state the braided/meandering channels in the upper estuary are more stable and probably slightly narrower and/or shallower due to reduced intermediate river flows (Van Niekerk *et al.* 2003).

**Water Quality**

The status of the water quality in the lower Orange River is generally assessed to be moderately modified to strongly affected because of fragmentation and flow regulation (DEA, 2015). Water quality information and data, however, has been labelled as being fragmented between countries and institutions and inconsistent (CSIR, 2011). Salinity data collected in 2005 confirmed the existence of a more estuarine state under low flow conditions. Under natural conditions the Lower Orange would have an approximately neutral pH, low TDS, low concentrations of dissolved nutrients (nitrogen and phosphorous) and high turbidity. Although water quality as a whole still remains good, increased nutrients, specifically from irrigation return flows, and the fact that the upstream impoundments act as growth nurseries for algal development means that algal populations have increased (CSIR, 2011).

Temperature variation in the Orange River Estuary is seasonal, with lower temperatures (around 15°C) recorded in winter and early spring and higher temperatures (around 25°C) in summer (Van Niekerk *et al.* 2003; Wooldridge & Deyzel 2008). However, under strong marine influence, temperatures in the lower estuary can become low (<16°C) during summer as a result of upwelling (*i.e*. surfacing of colder seawater), a common feature along South Africa's west coast (DWAF 1995 as cited in CSIR, 2011).

pH levels in the estuary were recorded on four occasions, in January 1979 and September 1993 (Eagle & Bartlett 1984; Harrison 1997) and in August 2004 and February 2005 (Wooldridge & Deyzel 2008). No marked trend was evident in the pH with average levels measured around 8.5 (CSIR, 2011).

Turbidity in the estuary is generally high during most states (Secchi depth <0.25 m) with high turbidity levels expected during major floods. However, seawater intrusion can introduce clearer conditions into the lower part of the estuary near the mouth (CSIR, 2011).

The UNDP-GEF Orange Senqu Strategic Action Programme assessed available information on water quality variables during the Estuary and Marine Ecological Flow Requirements assessment as collected by Department of Water and Sanitation at the Ernst Oppenheimer Bridge. It was found that median dissolved inorganic nitrogen (DIN) concentrations (mainly comprising nitrate-N) correlate well with median monthly flow, where highest concentrations are measured during months of high river inflow. DIN concentration averaged about 100 µg/ℓ, peaking at 400 µg/ℓ in April. De Villiers and Thiart (2007) estimated DIN concentrations in river flow in the lower Orange catchment under reference condition to be <50 µg/ℓ. Higher concentration under the present state was mostly associated with runoff agricultural land-use in the catchment.

Dissolved inorganic phosphorus (DIP) concentrations in river flow did not show a strong correlation with flows. DIP concentrations averaged 30 µg/ℓ with a slight peak in April (50 µg/ℓ). De Villiers and Thiart (2007) estimated DIP concentrations in river flow from the lower Orange catchment under reference condition to be <10 µg/ℓ. Higher concentration under the present state was mostly associated with runoff from agricultural land-use in the catchment.

Water quality of the closest riverine monitoring station to the Orange River estuary was measured at monitoring station D8H012Q01 in the Orange River at Alexander Bay. Results were reported in the Development of Reconciliation Strategies for Large Bulk Water Supply Systems Orange River: Water Quality and Effluent Re-Use report (DWA, 2013). It was reported that at the monitoring station at Alexander Bay nitrate, orthophosphate and pH were in non-compliance with the Resource Water Quality Objectives set for the river reach and was of potential concern. The higher pH values in the middle and lower part of the Orange River are primarily ascribed to higher algal concentrations. (DWA, 2013).

### 7.2.3 Biota components

#### Estuarine vegetation

According to the NBA 2018, the Orange River estuary support approximately 144 ha and 626.9 ha of intertidal and supratidal salt march, respectively. Only about 1 ha of submerged macrophytes are supported, while 316.8 ha of reeds and sedges are also present in the estuary. The Orange River Estuary has a wide range of habitats that consists of a series of braided troughs interspersed with sandbanks, channel bars and small islands, with a tidal basin and a saltmarsh on the southern bank (Bornman 2008, Bornman, Adams and Bezuidenhout 2004).

The submerged macrophyte *Potamogeton pectinatus* was associated with *Phragmites australis*. This plant grows best at salinity < 10. The submerged macrophyte *Ruppia cirrhosa* was also reported but its abundance was said to be limited because of low salinity and high turbidity of the water. The following species comprised the salt marsh vegetation: *Cotula coronopifolia*, *Triglochin* spp., *Juncellus laevigatus*, *Sporobolus virginicus* and *Sarcocornia pillansii*. *Sarcocornia perennis* formed a salt marsh on the right bank of the Orange River estuary near the mouth. This species usually occurs in the intertidal zone of permanently open estuaries. *S. pillansii* was dominant in the salinized lower floodplains. On the south bank of the river a large area of desertified saltmarsh exists.

#### Invertebrates

Data on invertebrates of the Orange River Estuary were collected during two field surveys in August 2004 (winter) and February 2005 (summer) (Wooldridge & Deysel 2008) from nine station along the estuary, moving from the mouth to just downstream of the Oppenheimer Bridge.

Zooplankton species richness was greater in winter compared to summer, with about 25 and 16 species, respectively. Identification was not always taken to species level, particularly in the case of copepoda. Fish eggs and copepoda were the most important contributors to total abundance in August (43% and 53% respectively), while copepods dominated the zooplankton in February 2005 (95%) (Wooldridge & Deysel 2008).

The hyperbenthic community was dominated by the mysid shrimp, *Mesopodopsis wooldridgei* on both sampling occasions. In August 2004, the species was distributed throughout the estuary, with maximum abundance in the upper reaches. In February 2005, no mysids were recorded in the freshwater dominated upper estuary. The macrozoobenthic community was poorly represented, with only four species present in August and seven in February 2005 (Table). Polychaetes were the dominant group (Wooldridge & Deysel 2008).

#### Fish

The estuary supports a high diversity and abundance of estuarine dependant and marine fish species and being one of very few estuaries along this coastline is believed to provide an important role in linking fish populations among Angola, Namibia and South Africa.

The most recent fish data on the Orange River Estuary were collected during four surveys in February 2004 and 2005 (summer) and August 2004 and 2005 (both low flow winter periods) Fish were sampled using seine and gillnets at 18 sites from the mouth to Brandkaros 35 km upstream. A total of 33 fish species from 17 families have been captured from the Orange Estuary

Thirty four percent of the fish species caught show some degree of estuarine dependence, 24 % are marine and the remaining 42 % are freshwater species. The numbers, biomass and diversity of fish sampled during 2004 and 2005 were orders of magnitude greater than all the previous studies conducted over the last 50 years combined. The high diversity and abundance of estuarine dependant and marine species suggests that the Orange is an extremely important estuarine nursery area and not just a freshwater conduit as previously thought (Van Niekerk *et al*. 2008).

**Birds**

The Orange River Mouth supports more than 1% of the world population of three species of waterbirds that are endemic to southern Africa, namely the Cape Cormorant, Hartlaub's Gull and Damara Tern, and more than 1% of the southern African populations of six species of waterbirds, namely the Black-necked Grebe, Lesser Flamingo, Chestnut-banded Plover, Curlew Sandpiper, Swift Tern and Caspian Tern.

The Department of Tourism, Environment & Conservation, Northern Cape Province conducts bi-annual waterbird surveys of the Orange River estuary with the following aims: (a) to monitor waterbird numbers and diversity at a regionally important wetland, (b) to monitor the populations of various threatened waterbird species, (c) to fulfil the obligations in terms of the Ramsar Convention and (d) to use birds as an indicator of improvements in the wetland ecosystem, especially in the light of various rehabilitation measured which are currently being implemented (CSIR, 2011).

From January 1980 to August 2005 a total of 28 waterbird surveys have been conducted at the Orange River estuary. An analysis of most of these survey data shows how waterbird numbers have declined significantly since the first surveys, with the reason mainly being the present absence of large numbers of Common Terns and Cape Cormorants (Anderson *et al*. 2003). This decline was initially believed to be linked to food shortages, which resulted in poor recruitment to Cape Cormorant colonies, although some young birds have immigrated to other colonies to the north and south. The food shortage was linked to a range of environmental perturbations including the 1995 warm-water event or 'Benguela Niño' in Namibian waters, fluctuations in anchovy abundance, and the eastward displacement of sardine in South African waters. Cape Cormorant colonies in South Africa were also reduced by outbreaks of avian cholera. This species subsequently began breeding in large numbers at Sandwich Harbour in Namibia, some 600 kilometres north of the Orange River mouth which implies that disturbance by humans and availability of roost sites might have played a role in their abandonment of the Orange River estuary (Matthews, 2012).

### 7.1.4. Impacts on the Estuary

The Orange River has become highly regulated by virtue of more than 20 major dams and numerous weirs within its catchment. As a consequence, river inflows to the Orange River Estuary have been markedly reduced from reference, with only an estimated 44% of natural flows still reaching the system (DWAF, 2003). Abstraction and regulation have also resulted in a marked reduction in the variability in river inflows from a pronounced seasonal flow to a nearly even flow distribution throughout the year. Surplus water releases for the generation of hydropower has resulted in the elimination of water deficits in the lower reaches of the river and the mouth now remains open almost permanently. The lack of mouth closure and associated backflooding is regarded as particularly problematic as it is during such occurrences that flows into the saltmarsh area typically occur (CSIR, 2011a, DEA, 2015). It was further highlighted in the Draft Orange River Mouth Site Strategic Estuarine Management Plan, October 2015, that existing operating rules of dams are not conducive to improved estuary conditions, while future dam developments in the catchment pose risk and opportunities for the Ramsar site (DEA, 2015).

A causeway through the salt marsh was constructed to provide easy access to the beach from Alexander Bay. The causeway had a number of effects, which should be looked at in combination with other developments. These included the cutting off of the river channels through the salt marsh next to the Dunvlei Farm and the sewage oxidation ponds. The situation improved marginally in June 1995, when a channel through the causeway was opened near the mouth. Despite this, flow to the salt marsh is still restricted. This restriction has probably contributed to the significant die-back of marsh vegetation.

Alexkor have constructed a slimes dam to the east of the salt marsh. Fine material (from the slimes dam and overburden removal in the region) is transported by wind into the salt marsh, and saline seepage water has discharged into the peripheral salt marsh (resulting in hypersalinity). The excess of fine material and influences on salinity have also contributed to the die-back of marsh vegetation (CSIR, 2011).

Mouth breachings were undertaken on the north and south sides of the river by Namdeb and Alexcor respectively. The objective of these breachings was to protect low-lying infrastructure from being flooded. The location of the mouth could have a major influence on the salinity of the water reaching the salt marsh on the south bank near the mouth. When the location of the mouth at the southern position, considerable amounts of seawater enter the area at spring tides (CSIR, 2011).

Waterbird numbers have declined significantly since the first surveys, with the reason mainly being the present absence of large numbers of Common Terns and Cape Cormorants (Anderson *et al*. 2003).

The biggest threat for the Orange River Mouth in terms of alien invasive species are alien invader plants. A number of exotic plants with invasive potential have been recorded in the Ramsar site and include wild tobacco (Nicotiona glauca), Port Jackson (Acacia saligna), rooikrans (Acacia cyclops), and bluegum (Eucalyptus camaldulensis). Wild tobacco is arguably the most significant threat having established along large sections of the floodplain. Pampas grass (Cortaderia selloana) has also been identified as a concern, occurring along riverbanks as well as in the old channels now cut off from the river by the dyke around the town (DEA, 2015).

Access control is another issue of concern that will need to be addressed. This is of particular concern on the South African side where the lack of fencing or formal access control affects the ability to monitor and control access to the site. Formal protection of the South African side of the Ramsar site is required to better secure management of the area.

Agricultural activities in the catchment can be diffuse sources inorganic nutrients (nitrogen and phosphate) to the river. However, it is expected that river vegetation will largely acts as a ‘filter’ for nutrients resulting in water reaching the estuary not being that enriched. Occasional algal blooms occur, for example in the Spitskop Dam further upstream due to excessive nutrient loading from urban and agricultural development along the river. These blooms make its way downstream, resulting in almost anoxic waters reaching the Orange River Estuary during these blooms. Wastewater discharges from the mining activities at Alexander Bay also tend to modify interstitial/groundwater salinity levels in the saltmarsh areas (DWAF 2003).

## 7.2. Smaller Coastal Estuaries

### 7.2.1. Location and Setting

Other than the Orange River estuary, five smaller estuarine systems are also located within the Lower Orange catchment. These systems include the Buffels, Swartlintjies, Groen, Spoeg and Sout (North) estuaries. In terms of the revised estuarine classification system proposed in the NBA 2018, all five of these smaller estuarine systems are classified as Arid Predominantly Closed Estuaries (Van Niekerk, *et.al*, 2019a). In terms of the classification, these systems generally have a number of characteristics in common, which include:

- These systems are generally linear or funnel shaped and closed on annual to decadal scales.
- Salinities tend to be high to hypersaline (>35) as a result of low fluvial input and high evaporation rates. Thus, mixing processes tend to occur over long time periods and are dominated by the effects of evaporation, winds and seepage.
- Occasional breaching and over-washing during high sea conditions provide for marine input and connectivity in these systems.
- Sediment processes are generally stable on decadal time scales and are reset by large intermittent flash floods.
- Water levels are determined by the interplay between sand berm level, evaporation rates and seepage losses. Groundwater and inflows from local fountains replenish these losses and influence the salinity regimes of these estuaries.

Details related to the quaternary catchments in which each of the estuaries are located are provided in Table 25.

**Table 25: Details related to Quaternary Catchments and EFZ size**

| | Buffels | Swartlintjies | Spoeg | Groen | Sout (Noord) |
|---|---|---|---|---|---|
| Quaternary catchment | F30G | F40D | F40F | F50G | F60D |
| Gross area ($km^2$) | 980 | 741 | 682 | 775 | - |
| MAP (mm) | 102 | 123 | 118 | 96 | - |
| MAE (WR2005, mm) | 2201 | 1899 | 1899 | 1899 | - |
| MAR (million $m^3$) | 12.18 | 3.28 | 3.28 | 5.49 | - |
| Catchment PES | C | C | C | C | C |
| Catchment EIS | *Low* | *Moderate* | *Moderate* | *Moderate* | *Moderate* |
| **Estuary Functional Zone (EFZ) size** | 89.2 ha | 134.6 ha | 88.2 ha | 88.2 ha | 532.8 ha |

The health condition (the PES) of an estuary is typically defined on the basis of current condition (*i.e.*, the extent to which it differs from its reference or natural condition). Based on the above, estuary condition is described using six Ecological Categories (EC), ranging from natural (A) to critically modified (F). The PES for each estuarine component, including overall system PES and REC were recalculated during the NBA 2018 assessment (Van Niekerk, *et.al,* 2019b), and are included in Table 26.

**Table 26: PES, REC and PES of individual components of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries (Van Niekerk, *et.al,* 2019b)**

| | Buffels | Swartlintjies | Spoeg | Groen | Sout (Noord) |
|---|---|---|---|---|---|
| **NBA 2018 Condition Status** | **Heavily Transformed** | **Near Natural** | **Near Natural** | **Near Natural** | **Severely/ Critical Transformed** |
| **Present Ecological State (PES), 2018** | **D** | **B** | **A/B** | **B** | **E** |
| *Hydrology* | *E* | *B* | *C* | *C* | *E* |
| *Hydrodynamics* | *D* | *B* | *B* | *C* | *F* |
| *Water Quality* | *D* | *B* | *B* | *B* | *D* |
| *Physical habitat* | *D* | *B* | *B* | *A* | *E* |
| *Microalgae* | *D* | *B* | *B* | *B* | *E* |
| *Macrophytes* | *E* | *C* | *A* | *B* | *F* |
| *Invertebrates* | *D* | *D* | *A* | *C* | *E* |
| *Fish* | *E* | *B* | *A* | *B* | *F* |

| | Buffels | Swartlintjies | Spoeg | Groen | Sout (Noord) |
|---|---|---|---|---|---|
| **NBA 2018 Condition Status** | **Heavily Transformed** | **Near Natural** | **Near Natural** | **Near Natural** | **Severely/ Critical Transformed** |
| *Birds* | *D* | *B* | *A* | *B* | *E* |
| **Recommended Ecological Category (REC)** | **D** | **B** | **A/B** | **B** | **E** |

The Estuary Importance Score for an estuary takes size, the rarity of the estuary type within its biographical zone, habitat diversity and biodiversity importance of the estuary into account (DWAF, 2008). Biodiversity importance, in turn, is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its natural condition. The functional importance of an estuary, on the other hand, provides a measure of the role a specific estuary plays in the greater landscape. The functional importance of these systems was relatively high as collectively they contribute to a very rare and limited “wetland habitat type” for estuarine and coastal birds along the dry Namaqualand Coast (Table 27).

**Table 27: Functional Importance of the Buffels, Swartlintjies, Spoeg, Groen and South estuaries**

| Calculation of the functional importance score | Buffels | Swartlintjies | Spoeg | Groen | Sout |
|---|---|---|---|---|---|
| a) Estuary derived detritus and nutrients to the sea | 20 | 20 | 20 | 20 | 20 |
| b) Nursery function for marine-living fish | 20 | 0 | 20 | 20 | 0 |
| c) Movement corridor for river invertebrates and fish breeding in sea | 0 | 0 | 0 | 20 | 0 |
| d) Contribute to a very limited wetland type habitat for estuarine and coastal birds along arid coast | 80 | 60 | 80 | 60 | 60 |
| e) Catchment sediments provided to the sea | 40 | 40 | 40 | 40 | 20 |
| f) Coastal connectivity (way point) for fish | 40 | 10 | 40 | 10 | 0 |
| g) Movement corridor for mammals (mongoose and otters) | 40 | 40 | 40 | 40 | 20 |
| **Functional importance score - Max (a) to (g)** | **80** | **60** | **80** | **60** | **60** |
| **Functional importance rating** | **Very important** | **Important** | **Very important** | **Important** | **Important** |

In terms of estuary functional importance, the Buffels and Spoeg estuaries were rated as very important based on their important contribution to a very limited wetland type habitat for estuarine and coastal birds along an arid coast and for their function as a coastal connectivity way point for fish (Table 28). In terms of estuarine importance, all of these Arid Predominantly Closed Estuaries scored very low in terms of biodiversity importance, resulting in their estuarine importance being rated only as average importance (Table 29) (DWS, 2017a).

**Table 28: Estuarine Importance of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries**

| Estuarine Importance | Buffels | Swartlintjies | Spoeg | Groen | Sout |
|---|---|---|---|---|---|
| Size | 50 | 70 | 70 | 70 | 100 |
| Zonal Type Rarity | 30 | 30 | 30 | 30 | 30 |
| Habitat diversity | 60 | 50 | 60 | 60 | 30 |
| Biodiversity Importance | 13 | 10 | 15 | 10 | 10 |
| **Functional importance** | **80** | **60** | **80** | **60** | **60** |
| **Estuarine Importance Score** | **49** | **44** | **52** | **46** | **43** |
| **Estuarine Importance** | **Average Importance** | **Average Importance** | **Average Importance** | **Average Importance** | **Average Importance** |

Data and information on these smaller estuarine systems is, however, limited. The first notable assessment of the Buffels, Swartlintjies, Spoeg and Groen estuaries were undertaken in 1980 as part of the Estuaries of the Cape Programme, Part II (Bickerton, 1981a, Heinecken, 1981a, Bickerton, 1981b, Heinecken, 1981b). In these reports, basic information related to abiotic and biotic characteristics were reported for each of these systems. Since these reports, limited information, studies and assessments were undertaken on these smaller estuarine systems, except for the Sout (North) estuary.

A summary of the data available for the Buffels, Swartlintjies, Groen, Spoeg and Sout (North) estuaries are provided in Table 29.

**Table 29: Summary of data and information available for the Buffels, Swartlintjies, Groen, Spoeg and Sout (North) estuaries**

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| **Location and Setting** | • Located in the Northern Cape Province at the town of Kleinzee.<br>• Buffels Estuary consists of a dry sandy/rocky riverbed with shallow pans and channels in the lower reaches.<br>• Upstream limit of EFZ is marked by a road bridge that connects the diamond mining areas with Kleinzee (29°40'18.21"S, 17° 4'3.30"E)<br>• Downstream boundary: 29°40'37.01"S, 17° 03'4.41"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank | • Situated approximately 6.5 km south of Hondeklip Bay within a strict security area of the Koignaas mining concession.<br>• Upstream limit: 30°15'45.73"S, 17°17'8.36"E.<br>• Downstream boundary: 30°15'44.33"S, 17°15'36.39"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank | • Spoeg Estuary is situated 230 km south of the Orange Estuary.<br>• No urban development situated at, near or close to estuary.<br>• Upstream limit: 30°28'17.92"S, 17°22'32.83"E.<br>• Downstream boundary: 30°28'20.54"S, 17°21'34.07"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank | • Very little is known about the estuary because of its small size and remote location.<br>• No urban development situated at, near or close to Groen estuary.<br>• Upstream limit: 30°49'38.26"S, 17°34'40.18"E<br>• Downstream boundary: 30°50'49.05"S, 17°34'35.72"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank | • The Sout Estuary is situated 60 km north of the Olifants Estuary.<br>• Situated in between the small towns of Strandfontein to the south and Hondeklip Bay to the north.<br>• Very little is known about the estuary because of its small size and remote location.<br>• Saltworks located at the Sout estuary with numerous artificial channels and access roads dissecting the estuary.<br>• Upstream limit: 31°12'38.88"S, 17°53'24.41"E<br>• Downstream boundary: 31°14'37.66"S, 17°50'52.55"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank |
| **Hydrology:**<br>Estimated that floods reaching the estuaries were significantly reduced in frequency and magnitude because | • Monthly flows between 1920 and 2004 available.<br>• Reference MAR ($Mm^3/a$): 11.2<br>• Reference and present groundwater | • Monthly flows between 1920 and 2004 available.<br>• Reference MAR ($Mm^3/a$): 1.2<br>• Reference groundwater | • Monthly flows between 1920 and 2004 available.<br>• Reference MAR ($Mm^3/a$): 1.3<br>• Present surface hydrology estimated | • Monthly flows between 1920 and 2004 available.<br>• Reference MAR ($Mm^3/a$): 5.5<br>• Very little change has occurred in the | • Monthly flows between 1920 and 2004 available.<br>• Reference MAR ($Mm^3/a$): 0.7<br>• Very little information is available on the |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| of poorly designed local infrastructure | discharge os 0.23 and 0.84 ($Mm^3/a$), respectively<br>• Groundwater significantly modified with groundwater use far exceeding the recharge of the aquafer.<br>• No additional freshwater required to maintain/achieve the REC | discharge ($Mm^3/a$): 0.63<br>• Flow into the estuary severely reduced as a result of construction of roads through the riverbed.<br>• 30% reduction in the magnitudes of floods reaching the estuary assumed as a result of local structures.<br>• Present groundwater discharge ($Mm^3/a$): 0.59 and estimated to be similar to reference condition.<br>• No additional freshwater required to maintain/achieve the REC | at about 90% of reference condition.<br>• Reference groundwater discharge ($Mm^3/a$): 0.36<br>• Present groundwater discharge ($Mm^3/a$): 0.22<br>• Groundwater estimated to be moderately modified with groundwater use estimated at about 37%.<br>• System requires additional groundwater to achieve REC | surface water from an utilisation perfective.<br>• Reference groundwater discharge ($Mm^3/a$): 0.13<br>• Present groundwater discharge ($Mm^3/a$): 0.08<br>• Groundwater is estimated to be moderately modified with groundwater use estimated at about 40%.<br>• No additional freshwater required to maintain/achieve the REC | hydrology and desktop estimates indicate there is very little surface flow reduction.<br>• Reference groundwater discharge ($Mm^3/a$): 1.24<br>• Present groundwater discharge ($Mm^3/a$): 1.13<br>• No additional freshwater required to maintain/achieve the REC |
| **Hydrodynamics and Mouth condition:** Overall, the estuaries' connectivity to the marine environment was generally disrupted as a result of the reduced floods. However, very little information is available on the hydrodynamics of these systems. | • Hydrodynamics modified by mining road over the mouth, causeways in the lower and middle reaches, a road with culverts in the upper reaches, and a golf course.<br>• Natural breaching by flood waters estimated to have occurred every 3 to 7 years.<br>• Open mouth conditions would only prevail for short periods (days to a week or two) | • Lower reaches characterised by two extended meanders that widen out into the floodplain that was created by an extensive network of braided flood channels.<br>• System is very seldom connected to the sea through an open mouth.<br>• Natural breaching by flood waters is estimated to have occurred every 3 to 10 years during floods. | • The system is still relatively undisturbed.<br>• The open water area has also changed little over time.<br>• The mouth of the estuary is predominantly closed with a high berm that does not allow for regular overwash | • Very little is known about the estuary because of its small size and remote location.<br>• The Estuary Functional Zone of the Groen Estuary is largely untransformed.<br>• Estuary remains closed for long periods, with reports from farmers in the 1980s indicating that flow only occurs during heavy flooding roughly every 5 years<br>• During low or no flow conditions the estuary | • Very little is known about the estuary because of its small size and remote location.<br>• Saltworks is located in the upper reaches of the estuary.<br>• Historical imaginaries indicate that the estuary is nearly always closed to the sea. The limited runoff simulated for this catchment confirms that breaching is likely to occur at very low return periods, e.g. 1:100 years. |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| | | • Seawater regularly penetrates the system at spring tide through overtopping over the low sandbar.<br>• Overall, the system hydrodynamics shows a moderate level change overtime | | becomes highly saline with readings of 125 PSU recorded in the lower reaches.<br>• Springs at the head of the estuary maintain a lower salinity in the upper reaches.<br>• Little change in the surface water feeding the system, however likely that fluctuations in the open water area and associated water levels driven by the decline in groundwater to the system. | • |
| **Water Quality:** Water quality in the estuaries showed elevated salinities as a result of the impact of reduced surface and groundwater input. | • Water quality data very limited<br>• Salinity, dissolved oxygen, turbidity and inorganic nutrient were measured in 1980, 1993, 2015 and 2016.<br>• Estuary generally show elevated salinities, turbidity dissolved oxygen and DIP.<br>• Nutrient loading high as a result of diffuse run-off from adjacent golf course irrigated with sewage water | • Water quality data very limited<br>• Salinity, dissolved oxygen, turbidity and inorganic nutrient were measured in 2016 only through once off sampling event.<br>• Extreme hyper salinity characterises the system.<br>• However, water quality still in a fairly good condition compared with reference. | • Very little information is available on the salinity of the estuary, however historical information suggests that the system has always been a brackish system.<br>• Salinity and dissolved oxygen were measured in 1980, 1994, 2015 and 2016.<br>• System characterised by elevated salinities.<br>• However, water quality still in a fairly good condition compared with reference | • Water quality data very limited<br>• Salinity and dissolved oxygen were measured in 1979, 1980, 1993, 2015 and 2016.<br>• Extreme hyper salinity<br>• However, water quality still in a fairly good condition compared with reference.<br>• EHI scores were provided with low confidence. | • Water quality data very limited<br>• Salinity, dissolved oxygen and turbidity were measured in 1993 and 2016.<br>• Estuary remain in extreme hyper saline state.<br>• The EWR 2017 study assumed that hyper salinity values of up to 60 is representative of near natural conditions, while elevated values of 101 is seen as the possible result of sea water pumping.<br>• EHI scores were provided with low confidence. |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| **Sediment processes and habitat:**<br>In general, infilling of estuarine systems due to road infrastructure crossing these systems has resulted in loss / degradation of habitat, and changes in circulation patters leading to localised disruption of scour and deposition processes. | • Most of the area around the mouth consists of low scrub-covered dunes of windblown sand.<br>• The lower reaches consist of flat dune slacks between well-formed barchan dunes.<br>• Significant infilling and shallowing throughout the estuarine system | • From reference to present, there is little to moderate level of change in the physical habitat and associated sediment structure.<br>• Most changes are associated with poor land use practises in the catchment increasing the sediment load and a reduction in the flood peaks due to road infrastructure leading to reduce scouring and infilling in the lower reaches. | • The system consists of a long straight floodplain bounded by rocks and cliffs on the southern side.<br>• The mouth is generally closed forming a low flat berm.<br>• Generally, the estuary has a fine-grained muddy bottom.<br>• The physical habitat is very similar to that of the Reference Condition<br>• However there has been some loss of Supratidal areas due to road infrastructure, change in the sediment structure of the intertidal and subtidal due to loss of floods and poor farming practises | • Physical habitat and sediment process data very limited<br>• Bickerton (1981), described the substrate in the lower estuary as sandy, with anoxic conditions prevailing a short distance away from the water's edge.<br>• The sediment in the upper estuary was described as fine anoxic silt.<br>• EHI scores were provided with low confidence. | • The estuary is a highly transformed system. Road infrastructure has severely modified the lower reaches, filling in some of the supratidal and intertidal areas.<br>• The subtidal areas also significantly transformed with channel diversions and infilling.<br>• The upper reaches severely degraded by the presence of a salt works that have diverted some of the main channels modifying the intertidal and subtidal areas significantly.<br>• EHI scores were provided with low confidence. |
| **Microalgae:**<br>In general, because of the discontinuous nature of the estuaries, microalgae did not show typical distribution patterns in biomass. | • Sampled four sites in October 2016<br>• Phytoplankton biomass was extremely low except for Site 3 which showed bloom conditions,<br>• The results indicate signs of a highly transformed system | • System sampled only in October 2016<br>• The 2016 survey showed that microalgal biomass was less than 5 µg/l which is indicative of oligotrophic conditions. | • System sampled at 4 sites only in October 2016<br>• Phytoplankton biomass at Sites 1 - 3 were low (<20 µg/l)<br>• Hypereutrophic conditions in upper reaches (>60 µg/l chlorophyll-a).<br>• Phytoplankton composition was indicative of the brackish conditions. | • Hypereutrophic conditions in lower reaches (>60 µg/l chlorophyll-a).<br>• Groundwater abstraction, an increase in salinity and decrease in open water surface area over time have influenced the present state of the microalgae | • Hypereutrophic conditions in middle reaches (>60 µg/l chlorophyll-a).<br>• Little resemblance to the natural state which would be reflected in the microalgal condition.<br>• EHI scores were provided with low confidence. |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| **Macrophytes:** Arid conditions promote the growth of unique vegetation such as salt tolerant, succulent *Sarcocornia* spp. and *Salicornia* spp. that can occur kilometres inland making it difficult to distinguish between arid estuarine salt marsh vegetation and upstream Namaqualand riverine vegetation. These vegetated areas can be stable despite open water salinities reaching above 200. | • Sampling took place on 05 October 2016<br>• Macrophytes were mapped across the estuary, although macroalgae were not mapped.<br>• Submerged macrophytes only occurred in the fresher sections of the estuary.<br>• Disturbance in the floodplain and modification of the estuary has led to the loss of habitat and species richness. | • Sampling took place on 06 October 2016<br>• Macrophytes were mapped across the estuary.<br>• Disturbance to the EFZ at the time of the site visit appeared minimal.<br>• Aerial photos suggest that vegetation cover has changed little over time.<br>. | • Sampling took place on 06 October 2016<br>• Patches of reeds in the upper and riverine reaches indicating seepage sites<br>• This was one of the few estuaries to have submerged macrophytes *i.e. Ruppia cirrhosa*.<br>• The vegetation of however remains relatively unchanged and in a good condition.<br>• EHI scores were assigned with medium confidence | • The Groen Estuary was mapped in February 2015 (Adams *et al*., 2015).<br>• Stretch of reeds in the upper reaches indicating an important groundwater fed area.<br>• The dominant habitat was supratidal salt marsh while intertidal salt marsh occurred along the banks of the estuary mostly along the lower reaches of the northern bank.<br>• EHI scores were assigned with medium confidence | • No prior information exists on the vegetation of the estuary. The system was mapped on 9 October 2016 and checked to approximately 1.2 km upstream.<br>• Arid Estuarine Salt Marsh is the predominant vegetation type in the EFZ.<br>• In the middle reaches of the estuary large open sand flats devoid of vegetation are common due to the hypersaline conditions.<br>• EHI scores were provided with low confidence. |
| **Invertebrates:** Invertebrate diversity, abundance and community structure were generally a function of changes in groundwater inflow causing changes in salinity gradients, frequency and magnitude of floods, frequency and duration of breaching events and cycles within long periods of hypersalinity. | • The EWR Study 2017 stated that no directed invertebrate surveys of the Buffels Estuary have been done up until conclusion of the study in 2017,<br>• Never been any records of sandprawn or other large macroinvertebrates in the estuary.<br>• Sampling took place in October 2016, | • Two previous reports on invertebrates in the estuary, *i.e* ECRU Survey in 1980 (Heinecken, 1981b) and the recent EIA in 2016 (Massie and Clark, 2016)<br>• 1980 ECRU Survey saw very little water with most invertebrates recorded in hypersaline pools. | • A list of estuarine, sandy beach and rocky shore invertebrates adjacent to the mouth were reported in the 1980 ECRU survey.<br>• Fine-mesh seine samples taken in October 2016, but results were not available at the time of finalising the report.<br>• Estimated that reference conditions | • Historical data on the estuary invertebrate fauna is limited to Grindley (1979), the ECRU assessment by Heinecken 1981 and more recently Adams *et al*. (2015).<br>• No macro-invertebrates or zooplankton were present in samples collected at seven sites in February | • No available historical information on the fish or invertebrates of the Sout Estuary.<br>• Invertebrates are mostly brine shrimp with lower abundance of Harpacticoid copepods and Hydrophilid beetles in the younger pans that have not yet evaporated. |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| | however results unavailable at the time of finalisation of the report.<br>• Information thus very limited on invertebrates | • Massie and Clark (2016) sampled but found no benthic invertebrates but do mention a high biomass of *Artemia* throughout the system. | would have been similar to the present day with prolonged periods of closure (8-10 years) punctuated by flood and overwash resetting events.<br>• EHI scores assigned with medium confidence | 2015 (Adams *et al*., 2015).<br>• Invertebrate diversity, abundance and community structure in the estuary is a function of changes in groundwater inflow, frequency and magnitude of floods, frequency and duration of breaching and overwash events and salinity gradients<br>• EHI scores assigned with low confidence | • EHI scores were provided with low confidence. |
| **Fish:**<br>Fish diversity, abundance and community structure in all five estuarine systems relies on recruitment that is largely a function of connectivity with the sea and driven by the frequency and duration of floods and breaching events and the degree of overwash during high seas.<br><br>Fish survival depends largely on groundwater inflow maintaining a salinity gradient and at least some areas with | • Information limited on fish abundance and EHI scores were done with low confidence<br>• Reference conditions in the estuary are likely to have been dominated by *M. cephalus* and *L. richardsonii* but in much greater abundance than reported in 2017<br>• Fish mortalities a “regular” occurrence arising from eutrophication and low oxygen events or from suffocation in floodwaters backed up against poorly | • Information limited on fish abundance and EHI scores were done with low confidence<br>• Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 PSU<br>• Most recruitment is “suicidal” via overwash with survival depending on wave size and the height and width of the berm | • Information limited on fish abundance and EHI scores were done with low confidence<br>• Sampling conducted during 1980 ECRU survey, and more recently in August 2015 and October 2016<br>• Fish diversity, abundance and community structure in the Spoeg relies on recruitment through connectivity with the sea<br>• Fish survival depends mostly on groundwater inflow maintaining a salinity | • Information limited on fish abundance and EHI scores were done with low confidence<br>• Fish survival depends mostly on groundwater inflow maintaining a salinity gradient and at least some areas with hypersalinity not exceeding 40 PSU<br>• Most recruitment is “suicidal” via overwash with survival depending on wave size and the height and width of the berm<br>• Fish absent due to hypersaline state | • No previous records of fish in the estuary.<br>• Reference conditions are likely to have seen rare suicidal overwash recruitment and short-term survival of larval and juvenile fish that were in the surf-zone at the time.<br>• EHI scores were provided with low confidence. |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| hypersalinity not exceeding a salinity of 40. Safe return to the sea is usually during flood events and depends on a quick breach and fish not suffocating in sediment-laden water backing up against the berm. | planned roads and causeways | | gradient and at least some areas with hypersalinity not exceeding 40 PSU | | |
| **Birds:** | • Information on the birds of the Buffels Estuary is limited<br>• Three counts since 1980 to the present have recorded 48 bird species at the Buffels Estuary<br>• Overall, bird abundance and species composition has not changed much from reference and is mostly a function of salinity, water volume, surface area and available food, foraging and nesting habitat in this and adjacent systems.<br>• EHI scores were provided with low confidence. | • Very little information is available on the birds of the Swartlintjies.<br>• Three bird-counts exist for the estuary, *i.e*. the October 1980 ECRU survey, June 2016 and October.<br>• A total of 28 bird species have been recorded at the Swartlintjies Estuary and on the floodplain at the time of the EWR 2017 study<br>• EHI scores were provided with low confidence. | • Very little information is available on the birds of the Spoeg<br>• Three bird-counts exist for the estuary, *i.e*. the October 1980 ECRU survey, June 2016 and October 2016.<br>• Present-day conditions are close to reference and the relative lack of disturbance probably sees birds persist for longer than in adjacent systems<br>• EHI scores were provided with low confidence. | • Six bird-counts available for estuary, *i.e*. counts in January 1979, January 1980, October 1980 (Grindley, Cooper and ECRU), February 2015, August 2015 and October 2016 respectively (Adams *et al*. Smith EWT & CSIR)<br>• Bird diversity and abundance in the Groen Estuary vary mostly according to salinity and the availability of brine shrimp on which they feed.<br>• The dominant state of the Groen Estuary is hypersaline with a limited salinity gradient maintained by the freshwater spring in the upper reaches. | • No historical bird-counts exist for the estuary so this study is limited to the 15 species and 120 individuals recorded during the site visit in October 2016<br>• Available biomass of Artemia in the Sout is cyclic according to salinity as is the diversity and abundance of flamingos and other birds that feed upon them.<br>• Unlike the other estuarine systems discussed here, overwash and connectivity between the sea and estuary no longer occurs<br>• EHI scores were provided with low confidence. |

| Component | Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|---|
| **Pressures:** Major pressures on the estuarine systems were identified, confirmed and noted in the EWR study, 2017. Overfall confidence level in the observations on pressures were considered high. | • Loss of freshwater from groundwater abstraction<br>• Road infrastructure and damming of flood waters<br>• Mining activities<br>• Diffuse sewage runoff<br>• Human disturbances<br>• Alien invasives<br>• Artificial breaching/ mouth manipulation practiced<br>• Grazing in catchment changing sediment structure | • Road infrastructure and damming of flood waters and resulting in destruction of habitat<br>• Mining activities<br>• Alien vegetation<br>• Grazing in catchment changing sediment structure | • Loss of freshwater from groundwater abstraction<br>• Road infrastructure and damming of flood waters<br>• Future Mining activities<br>• Diffuse sewage runoff<br>• Human disturbances<br>• Grazing in catchment changing sediment structure | • Loss of freshwater from groundwater abstraction<br>• Road infrastructure and damming of flood waters<br>• Future Mining activities<br>• Grazing in catchment changing sediment structure | • Road infrastructure and damming of flood waters<br>• Grazing in catchment changing sediment structure<br>• Human disturbances<br>• Saltworks |

# 8 STATUS QUO WATER QUALITY

## 8.1. Background

As part of the status quo assessment task an overview water quality assessment was undertaken to provide a snapshot of the water quality in the Lower Orange River catchment based existing information (DWS water quality data). The aim of the assessment was to obtain an understanding of the current situation and in doing so identify the water quality “hot spots” that have a potential influence on the delineation of IUAs and for the future analyses of water resource classification scenario. Areas of concern that would most likely also inform the development of RQOs for the catchment area.

Assessment of the present water quality status quo was based on assessing the fitness for use of the water for key water user, namely irrigation water use, domestic water use, and aquatic ecosystems. Fitness for use is a scientific judgement, involving objective evaluation of available evidence, of how suitable the quality of the water is for its intended use. Water quality can therefore only be expressed in terms of fitness for use. Water quality assessment to determine fitness for use is based on assessment water quality objectives/planning limits that have been set for the water resource.

The degree to which water quality objectives/limits are met include three elements: the designated users of the water resource (e.g., recreational, aquatic ecosystem, industrial use, domestic), the criteria, guidelines or thresholds that the aquatic ecosystem, animals and humans from exposure to levels of pollution that may cause adverse effects, and the anti-degradation policy intended to prevent waters from deteriorating from their current condition (discharge standards).

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

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

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

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

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

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

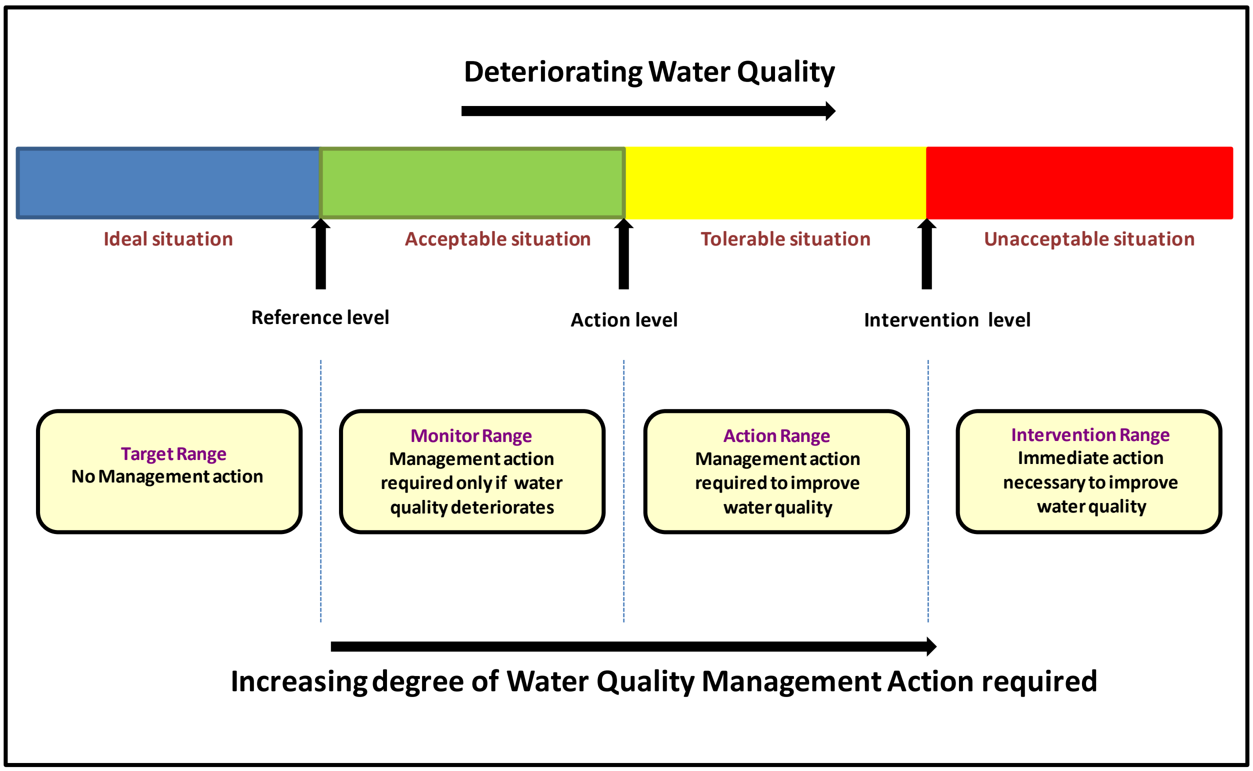



**Figure 34: Relationship between assessment rating and degree of water quality management action required**

In the Orange River the major water user is agriculture (principally irrigation) with on average about 89.8 %, followed by domestic use and industrial use - 9.6 %, while mining uses the remainder 0.6 % (DWS, 2013). Afforestation is negligible in the Orange River catchment. The pressure on the water supply from dry-land crop production, as well as stock and game farming, is insignificant compared with the demand for irrigation water. The irrigation industry is the biggest single water user in the Orange River.

The water quality planning limits used for the assessment (Table 30) were derived using the Resource Water Quality Objectives (RWQOs) Model (Version 4.0) (DWAF, 2006) which uses as its basis the South African Water Quality Guidelines (DWAF, 1996), Quality of Domestic Water Supplies: Assessment Guide, Volume 1 (WRC, 1998) and Methods for determining the Water Quality Component of the Reserve (DWAF, 2008) and are based on the strictest water user criteria (thus represent fairly conservative limits). With respect to ionised ammonia, the General and Special Standard Effluent limit was applied due to the absence of an available water quality limit value.

**Table 30: Water quality criteria used to assess the present water quality status**

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

The fitness for use is described using four water quality categories: Ideal (blue), Acceptable (green), Tolerable (yellow), and Unacceptable (red) for concentrations greater than the upper boundary of the Tolerable range.

## 8.2. Data sources

The Department's Resource Quality Information Services (RQIS) water quality database, the Water Management System (WMS) has been used as the primary source of the water quality data for the analysis. In terms of water quality data assessment, the water quality monitoring stations and related information are largely concentrated on main stem river and tributaries. Data gaps exist for the smaller tributary catchments.

Historical data for water quality monitoring points in the study area were obtained from the National Chemical Monitoring Programme (NCMP) on WMS for the period 2013 to 2023. Microbial data and algal data were source from 2014-2024 from the National Microbiological Monitoring (NMMP) and National Eutrophication Monitoring Programmes (NEMP) respectively. The monitoring points within the Lower Orange Catchment are primarily located on the main stem Orange River and some in the upper reaches of the major tributaries (Riet, Hartbees and Brak rivers). 38 registered points on the WMS have monitoring data available since 2000, however the frequency and extent of monitoring varies considerably. The routine DWS river and dam water quality monitoring points locations for the study area are shown in Figure 35 and listed in Table 31. A challenge posed for the classification study is the determination of the current water quality status in the tributary catchments of the Brak, Ongers, Sak, Hartbees and Molopo rivers where limited or no monitoring is currently undertaken – this however can be largely attributed to the non-perennial nature of the rivers.

The WMS database primarily includes monitoring data for Electrical Conductivity, Total Dissolved Salts (TDS), pH, Sodium, Magnesium, Calcium, Hardness, Potassium, Fluoride, Chloride, Sulphate, Phosphate as P, Total Alkalinity as $CaCO_3$, Ammonium as N, Nitrate + Nitrite as N, and Chemical Oxygen Demand. Total suspended solids and turbidity are also not monitored. For the purposes of this study, the certain indicator variables have been used to assess *status quo*.

Very limited microbiological and algal data was available on the DWS database to assess status. It should be noted, however, that the nature of national sampling of microbiology has been limited by the fact that a bacteriology sample must be analysed within 12 hours (more or less of sampling) and so there have to be accredited labs close enough to the sampling point. The basis for site selection of microbial sampling within the NMMP is also that hot spot sites are selected - those where there is a high likelihood of their being a microbial problem rather than an unbiased status and trends type of monitoring programme.

Chemical water quality monitoring data for the period of assessment (2013 to 2023) is limited for most of the study area. The quaternary catchments with data that could be assessed are the following:

- Lower Orange mainstem
  - D71A – catchment downstream of Maselsfontein
  - D71C – catchment at Higg's Hope
  - D72A – catchment up to Prieska
  - D72C – catchment between Koegas and Boegoeberg Dam
  - D73B – catchment downstream of Boegoeberg Dam
  - D73D - catchment between Groblershoop and Grootdrink
  - D73E - Catchment between Karos settlement and Upington
  - D73F - catchment between Upington and Kakamas
  - D81A – incremental catchment between Kakamas and Augrabies Falls
  - D81B - catchment between Vredensvlei and Brak river confluence
  - D81F - catchment downstream of Brak / Orange River confluence and Skuit Drfit
  - D81G - catchment between Velloorsdrif and Cammasfontein
  - D82D – catchment on Brak River downstream of Henkries
  - D82L - catchment from Sanddfrift to the river mouth at the Atlantic Ocean
- Tributary catchment: Brak River
  - D61E – Upstream of Brak River before confluence with Brakport River
  - D61M – Ongers River downstream of confluence with Brak River to Smartt Syndicate Dam

- Tributary catchment: Hartbees River
  - D51B – Renoster River from Sutherland to Bonekraal
  - D52F – Vis River downstream of Hottentotsfotein se Laagte
  - D53A – Hartbees River from De Kruis to Rooiberg Dam
  - D55E - Sak River at Tabaks Fontein
  - D55L - Sak River at de Kruis/Williston
  - D57C – Sak River downstream of confluence with Rooidam se Laagte at Brandvlei
  - D58A - Renoster River at Leeuwenkuil downstream of Riet/Renoster confluence to the Vis River.

To assess microbiological and eutrophication quality, and determine the extent of data available, the last 10 years' worth of data, spanning 2014 to 2024 was requested from the RQIS. Table 32 shows the extent of available data received and the number of samples at the currently active monitoring sites.  Very limited data is available, with some sites being outdated.

## Table 31: Chemical Water quality monitoring sites assessed in the Lower Orange Catchment

| Station ID | Tertiary Drainage | Site Name | River Name | Latitude | Longitude | Total Number of Samples in record | Total Number of Samples assessed in | Start Date | End Date |
|---|---|---|---|---|---|---|---|---|---|
| 1000261715 | D73D | Orange River At Groblershoop Bridge | Orange River | -28.87947778 | 21.98653889 | 32 | 13 | 2013/02/07 | 2023/01/24 |
| 1000261716 | D73D | Orange River At Gariep Bridge | Orange River | -28.56356944 | 21.76476389 | 43 | 17 | 2013/03/14 | 2023/06/19 |
| 1000261717 | D73F | Ikaia River Lodge - @ Keimoes Bridge Over Orange River Near Ikaia | Orange River | -28.727375 | 20.98497222 | 53 | 20 | 2011/06/03 | 2023/06/19 |
| 1000261718 | D73F | Orange River At Kanoneiland @ Bridge Near Grape Farms | Orange River | -28.63539167 | 21.08921667 | 51 | 18 | 2013/03/14 | 2023/06/19 |
| 1000265470 | D81B | Blouputs - @ Blouputs Bridge On Orange River , Near A Weir A Grape | Orange River | -28.51302778 | 20.18572222 | 34 | 17 | 2022/06/07 | 2023/06/20 |
| 1000265471 | D71A | Mazelsfontein - @ Douglas Confluence Of Orange River And Vaal River | Orange River | -29.07233333 | 23.63347222 | 34 | 17 | 2021/12/17 | 2023/05/19 |
| 1000265472 | D82D | Henkries @ Henkries Sedibeng Water Pump Station Near Sedibeng Water Treatment Plants Water Abstract | Orange River | -28.90155556 | 18.16608333 | 26 | 12 | 2022/06/09 | 2023/06/22 |
| 1000265473 | D73F | Neusberg - @ Neusberg Weir | Orange River | -28.77452778 | 20.74552778 | 40 | 19 | 2021/12/14 | 2023/06/20 |
| 1000265474 | D82L | Orangerivermouth - Orange River Mouth - @ Orange River Estuary @ | Orange River | -28.6345 | 16.46172222 | 36 | 17 | 2021/12/13 | 2023/05/18 |
| 1000265476 | D81F | Pella - @ Pumpstation/Abstraction Site For Sedibeng Water Treatment | Orange River | -28.96416667 | 19.15427778 | 26 | 12 | 2022/06/07 | 2023/06/20 |
| 1000265477 | D72A | Prieska - @ Prieska Bridge Near Farms | Orange River | -29.65958333 | 22.745 | 32 | 15 | 2022/02/25 | 2023/06/23 |
| 1000265478 | D71C | Rockwell - @ Rockwell Diamond Mine Pumpstation @ Orange River | Orange River | -29.29655556 | 23.2335 | 36 | 17 | 2022/01/26 | 2023/06/23 |
| 1000265479 | D81A | Witklip Farms - @ Bridge Over Brabees River , A Tributary Of Orange | Brabees River | -28.63763889 | 20.35394444 | 39 | 19 | 2021/12/14 | 2023/06/20 |
| 182750 | D73D | Volgraafsig Balancing Dam | Boegoeberg Canal (Boegoe River) | -28.7378 | 21.8267 | 837 | 18 | 2000/06/06 | 2018/06/19 |
| 182752 | D82D | Orange River At Henkries Namaqua Water Board Abstraction | Orange River | -28.8958 | 18.1511 | 369 | 6 | 2000/08/01 | 2023/02/24 |
| 182756 | D73F | Balancing Dam On Bloemsmond Kanoneiland | Orange River (North Bank Canal at | -28.6406 | 21.0644 | 458 | 10 | 2000/03/08 | 2016/12/13 |
| 184055 | D73E | Sun River Lodge - At Intake Of Upington Water Works On Orange River | Orange River | -28.4519 | 21.2604 | 1083 | 17 | 2001/07/03 | 2023/06/19 |
| 194551 | D81B | Orange River- At Blouputs Weir At Orange River | Orange River | -28.47717778 | 20.11683333 | 12 | 6 | 2021/12/14 | 2022/05/10 |
| D5H011Q01 | D51B | Renoster River At Bonekraal | Renoster River | -31.815278 | 20.578611 | 79 | 42 | 1995/12/21 | 2023/07/25 |
| D5H016Q01 | D57C | Sak River At Hol Pads Leegte | Sak River | -30.474444 | 20.519722 | 22 | 2 | 1973/03/21 | 2016/05/18 |
| D5H017Q01 | D58A | Renoster River At Leeuwenkuil | Renoster River | -31.436944 | 20.474722 | 95 | 40 | 1972/07/05 | 2023/05/30 |
| D5H019Q01 | D55E | Sak River At Tabaks Fontein | Sak River | -31.652222 | 21.768889 | 83 | 39 | 1976/03/11 | 2023/01/19 |
| D5H021Q01 | D55L | Sak River At De Kruis/Williston | Sak River | -31.394444 | 20.947222 | 149 | 25 | 1991/09/28 | 2023/02/23 |
| D5H022Q01 | D52F | Moutonsdrift | Vis River | -31.437778 | 20.279167 | 2 | 1 | 2023/01/19 | 2023/01/19 |
| D5R001Q01 | D53A | Rooiberg Dam On Hartbees River: Near Dam Wall | Hartbees River | -29.4 | 21.206111 | 75 | 4 | 1979/01/05 | 2023/01/16 |
| D6R001Q01 | D61E | Victoria West - Victoria West Dam On Dorpspruit: Near Dam Wall | Dorpspruit River | -31.4012 | 23.0984 | 19 | 6 | 1979/10/15 | 2023/06/01 |
| D6R002Q01 | D61M | Huisfontein 103 - Smartt Syndicate Dam On Ongersrivier: Near Dam | Ongers River | -30.6124 | 23.2992 | 42 | 2 | 1968/07/02 | 2023/01/20 |
| D7H002Q01 | D72B | At Prieska On Orange | Orange River | -29.651389 | 22.746389 | 1675 | 48 | 1952/10/24 | 2023/05/18 |
| D7H005Q01 | D73F | Orange River At Upington | Orange River | -28.460833 | 21.248889 | 4902 | 6 | 1952/10/03 | 2022/05/13 |
| D7H008Q01 | D73B | Orange River At Boegoeberg Reserve/Zeekoebaart | Orange River | -29.029722 | 22.187778 | 2333 | 3 | 1966/04/01 | 2017/04/18 |
| D7H012Q01 | D71A | At Irene On Orange | Orange River | -29.1825 | 23.575556 | 235 | 63 | 1989/02/27 | 2023/04/24 |
| D7H014Q01 | D73F | Orange River At Kakamas South/Neusberg Left Side | Orange River | -28.768056 | 20.720556 | 764 | 44 | 1995/01/02 | 2015/08/13 |
| D7H015Q01 | D73F | South Canal From Orange River At Kakamas/Neusberg | Orange River (South Bank Canal at Kakamas) | -28.769167 | 20.719722 | 1854 | 13 | 1994/08/01 | 2022/11/14 |
| D7H016Q01 | D73F | North Canal From Orange River At Kakamas/Neusberg | Orange River North Bank Canal at Kakamas) | -28.766667 | 20.72 | 1879 | 85 | 1995/08/25 | 2015/05/29 |
| D7R001Q01 | D72C | Boegoeberg Dam On Orange River: Near Dam Wall | Boegoeberg Dam Wall | -29.042222 | 22.201944 | 1320 | 5 | 1976/04/01 | 2016/12/12 |
| D8H007Q01 | D82L | Orange River At Korridor Brand Kaross | Orange River | -28.486111 | 16.695556 | 464 | 1 | 1971/08/08 | 2022/12/06 |
| D8H008Q01 | D81G | Orange River At Pella Mission | Orange River | -28.96362 | 19.15486 | 3274 | 42 | 1980/04/28 | 2022/12/08 |

## Table 32: Microbiological and Eutrophication water quality monitoring sites assessed in the Lower Orange Catchment

| Station ID | Quaternary Catchment | Monitoring Point Name | Microbial Samples | | | Chlorophyll *a* Samples | | |
|---|---|---|---|---|---|---|---|---|
| | | | Start Date | End date | Number of samples | Start Date | End date | Number of samples |
| D7R001Q01 | D72C | Boegoeberg Dam On Orange River: Near Dam Wall | | | | 2016/04/11 | 2016/12/12 | 3 |
| D7H005Q01 | D73F | Orange River At Upington | | | | 2016/02/26 | 2016/02/26 | 1 |
| D8H008Q01 | D81G | Orange River At Pella Mission | | | | 2014/03/22 | 2015/05/16 | 13 |
| 184055 | D73E | Sun River Lodge - At Intake of Upington Water Works On Oran | 2021/12/16 | 2022/05/12 | 6 | | | |
| 1000261715 | D73D | Orange River At Groblershoop Bridge | 2024/04/08 | 2024/04/08 | 1 | | | |
| 1000261717 | D73F | Ikaia River Lodge - @ Keimoes Bridge Over Orange River | 2014/06/12 | 2014/08/27 | 2 | | | |
| 1000261718 | D73F | Orange River At Kanoneiland @ Bridge Near Grape Farms | 2014/04/16 | 2015/07/21 | 3 | | | |
| 182752 | D82D | Orange River At Henkries Namaqua Water Board Abstraction | 2023/02/24 | 2023/02/24 | 1 | | | |

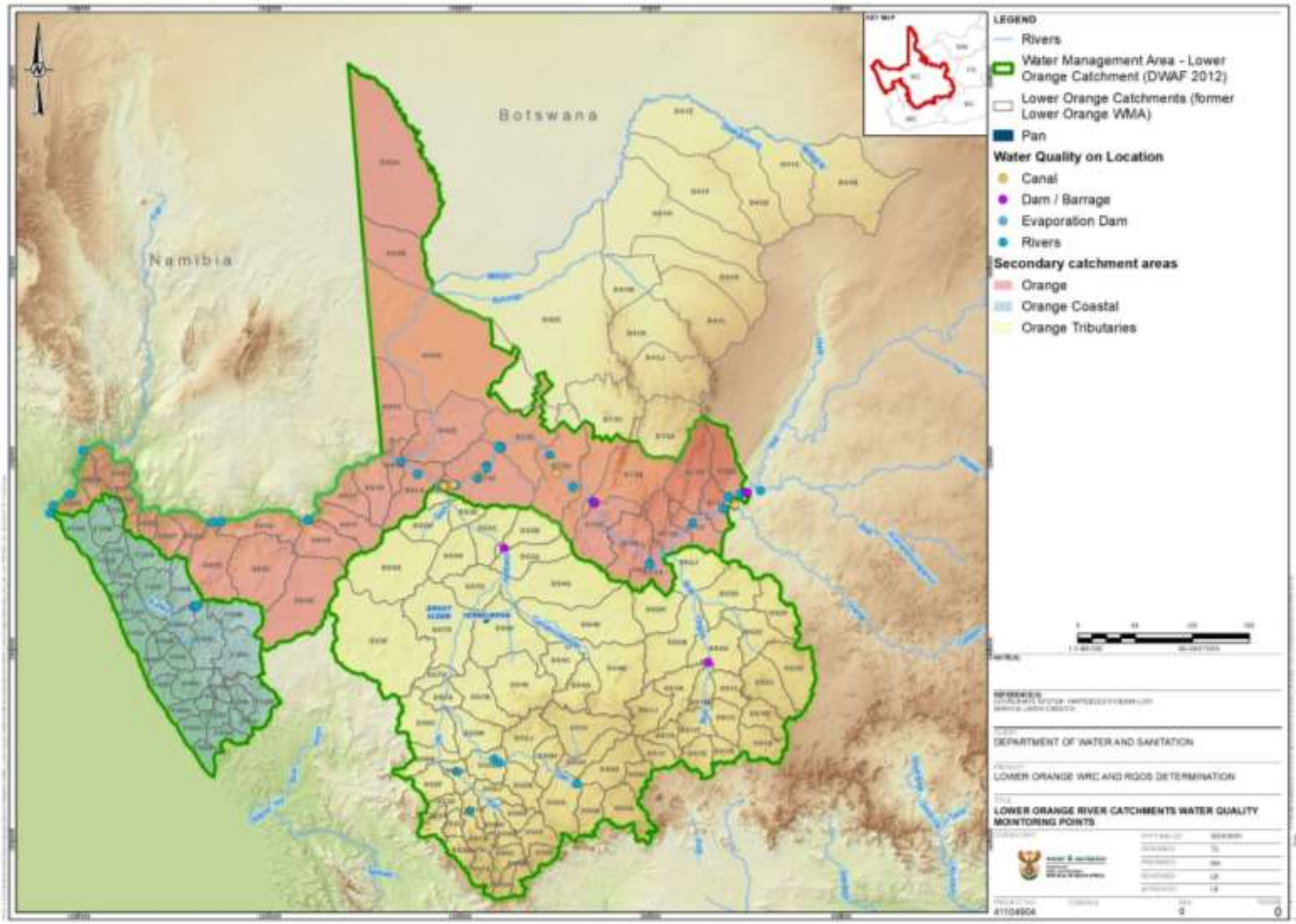



**Figure 35: Location of water quality monitoring sites in the Lower Orange**

## 8.3. Compliance Assessment

The water quality compliance assessment has been based on available data from the routine monitoring collected by the DWS in the Lower Orange catchment over the past 10 years. Water quality status at monitored points for the period 2013 to 2023 was assessed by categorising the current water quality state using the fitness for use criteria (Table 30). For the sampling points, the 50th percentile (median), 5th and 95th percentile statistics were calculated and assessed against the criteria to determine compliance. Percentiles are descriptive statistics. The median statistic is representative of typical water quality conditions (as opposed to average which may be skewed by spikes in water quality values), the 5th percentile statistic means that 5 percent of the concentrations were lower or equal to the statistic, and the 95th percentile represents the high concentrations observed at the sampling point, while excluding possible outliers that may be reflected if the maximum value was selected for assessment. It should be noted that microbial and nutrient data, due to their conservative speciation nature and decaying properties can only be relied upon for the most recent period using the $50^{th}$ percentile or average values.

The suite of water quality variables assessed serve as indicators of salinity, nutrient enrichment (eutrophication), agricultural impacts, aquatic toxicity, as well as natural variability of the water resources, the key water quality issues of relevance.

The variables assessed included:

- ***Physico-chemical***: pH, Total Dissolved Salts/ Solids (TDS), Electrical Conductivity (EC)
- ***Major Ions***: Calcium (Ca), Magnesium (Mg), Sodium (Na), Fluoride (F), Sulphate ($SO_4$) and Chloride (Cl)
- ***Nutrients:*** Ortho-phosphate ($PO_4$), Nitrate as N ($NO_3$-N) and Ionised Ammonia as N ($NH_4$-N), Chlorophyll *a*
- ***Microbiological***: *Escherichia Coli* (*E.Coli*); Faecal Coliforms and Total Coliforms.

The historical monitoring data for the Lower Orange Catchment for the 10-year period 2012-2014 to 2023/4 was found to be limited at some sites and with infrequent and inconsistent monitoring. In some sub-catchments such as the coastal tributaries and the lower reaches of the Orange River tributaries (Hartbees and Brak River), very little monitoring occurs. Microbiological and algal data for recent years is also lacking and limited, restricted to only the upper reach of the Lower Orange River. The water quality status of some catchment areas is thus represented by the analysis of data at a minimum of one monitoring site for a tributary catchment while up to 20 sites for the main stem Orange River. This variation may thus skew the perspective of the water quality situation dependent on the location of the monitoring site relative to the area of impacts (specifically were only one or two sites are present in a secondary catchment).

## 8.4. Overview Status

Water user requirements and water quality impacts need to be understood. A number of localised water quality issues around the towns, industrial areas, mining and related to agricultural practices are highlighted. This is key to understanding the hotspot areas with respect to driving ecological condition and to the development of RQOs and numerical limits in the catchment. Lack of recent monitoring information and/or infrequent monitoring has impacted on the assessment in some sub-catchments, while in other sub-catchment areas the absence of any baseline water quality monitoring data is a key gap.

An overview water quality assessment perspective of the Lower Orange Catchment is provided here. The summary of the water quality compliance observed per secondary catchment with respect to the number of monitoring sites assessed is provided in Table 33. The summary of 95$^{th}$ percentile compliance value is presented for TDS, EC, Ca, Mg, Na, F, $SO_4$, Cl and ionised ammonia; the 50$^{th}$ percentile compliance value for nitrate and orthophosphate, and the 5$^{th}$ and 95$^{th}$ percentile for pH per site. The identified water quality issues that are of concern within the Lower Orange Catchment are discussed.

The assessment indicates that overall, the water quality of the Lower Orange Catchment is relatively good with localised areas of impact related to land use. The key issues of concern are related to salinity and nutrient impacts prevalent in all secondary catchments, indicated by the non-compliance to the electrical conductivity, orthophosphate criteria and ionised ammonia.

### 8.4.1. Orange River Main Stem

***D7 - Orange River System Main Stem (Upstream)***

The water quality in the upper reaches of the Orange River catchment is generally good with impacts of nutrients from agricultural return flows and by wastewater treatment works (WWTWs). The Orange River within D71A exhibits acceptable to tolerable levels of total dissolved solids (TDS), but unacceptable concentrations of ammonia and orthophosphates. At the confluence with the Brak River in D72A the TDS levels along the Orange River increase by about 30% however, salinity concentrations improve after the Boegoeberg weir. Nutrient impacts, increased chloride concentration further downstream within catchment D73F at Neusberg weir are observed within the unacceptable range.

The section of the Lower Orange from the confluence with the Brak River is characterised with ideal salinity levels, however unacceptable concentrations of ammonia and phosphate are observed in this reach. Phosphate concentrations recover towards the acceptable range around Kakamas in D73F.

## Table 33: Summary of water quality compliance to the water quality criteria per secondary catchment for the monitoring sites assessed

| Sub-catchment | Calcium (mg/l) | Chloride (mg/l) | Total Dissolved Salts (mg/l) | Electrical Conductivity (mS/m) | Flouride (mg/l) |
|---|---|---|---|---|---|
| D5 - Hartbees River | 100% | 71% 29% | 33% 50% 17% | 83% 17% | 57% 29% 14% |
| D6 - Brak River | 100% | 50% 50% | 50% 50% | 50% 50% | 50% 50% |
| D7 - Oranger River Main Stem (Upstream) | 100% | 53% 37% 5% 5% | 53% 47% | 5% 68% 21% 5% | 84% 16% |
| D8 - Orange River main Stem (Downstream) | 88% 13% | 33% 56% 11% | 83% 17% | 25% 63% 13% | 100% |
| | | | | | |
| Ideal | 10 | 40 | 200 | 30 | 0.7 |
| Acceptable | 80 | 120 | 350 | 50 | 1 |
| Tolerable | 80 | 175 | 800 | 85 | 1.5 |
| Unacceptable | >80 | >175 | >800 | >85 | >1.5 |

| Sub-catchment | K (mg/l) | Magnesium (mg/l) | Sodium (mg/l) | Ionised Ammonia (mg/l) | Nitrate (mg/l) |
|---|---|---|---|---|---|
| D5 - Hartbees River | 100% | 86% 14% | 17% 17% 50% | 14% 14% 71% | Very limited data |
| D6 - Brak River | 100% | 100% | 50% 50% | 100% | Very limited data |
| D7 - Oranger River Main Stem (Upstream) | 100% | 100% | 100% | 32% 68% | 100% |
| D8 - Orange River main Stem (Downstream) | 83% 17% | 89% 11% | 75% 13% 13% | 11% 89% | Very limited data |
| | | | | | |
| Ideal | 25 | 70 | 70 | 0.015 | 6 |
| Acceptable | 50 | 100 | 92.5 | 0.044 | 10 |
| Tolerable | 100 | 100 | 115 | 0.073 | 20 |
| Unacceptable | <100 | >100 | >115 | >0.073 | >20 |

| Sub-catchment | pH | Orthophospate (mg/l) | Sulphate (mg/l) |
|---|---|---|---|
| D5 - Hartbees River | 17% 67% | 29% 71% | 14% 43% 14% 29% |
| D6 - Brak River | 50% 50% | 100% | 50% 50% |
| D7 - Oranger River Main Stem (Upstream) | 5% 21% 74% | 21% 53% 26% | 84% 16% |
| D8 - Orange River main Stem (Downstream) | 38% 38% 25% | 71% 29% | 71% 14% 14% |
| | | | |
| Ideal | ≤8 and ≥ 6.5 | 0.025 | 80 |
| Acceptable | ≤8.4 and ≥ 6.5 | 0.075 | 165 |
| Tolerable | ≤8.4 and ≥ 6.5 | 0.125 | 250 |
| Unacceptable | | >0.125 | >250 |

*Water Quality Hotspot Areas*

| Quaternary Catchment | River | Impact | Water Quality Issue/impact |
|---|---|---|---|
| D71A | Orange | Moderate | Elevated nutrients from irrigation |
| D72B | Orange | Moderate | Elevated nutrients from irrigation, salinity; mining and quarrying |
| D72C | Orange | Moderate | Elevated nutrients from irrigation and WWTW discharge at Marydale, |
| D73D | Orange | Large | Elevated nutrients from irrigation and WWTW discharges from Groblershoop to Grootdrink |
| D73F | Orange | Large | Elevated nutrients from extensive farming and irrigation; WWTW discharges near Upington |

| Drainage Region | Monitoring Point ID | Ca | Cl | DMS (TDS) | EC | F | K | Mg | Na | NH4-N | pH | PO4-P | SO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/l) | (mg/l) | (mg/l) | (mS/m) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (pH units) | (mg/l) | (mg/l) |
| | | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 |
| | | | | | | | | | | | | | |
| D7 sub-catchment | | | | | | | | | | | | | |
| **D71A** | 1000265471 | 47.0 | 38.3 | 289.6 | 54.3 | 0.3 | 4.4 | 22.0 | 42.7 | 1.50 | 8.1 | 0.04 | 56.4 |
| | D7H012Q01 | 39.9 | 168.1 | 386.4 | 102.6 | 0.6 | 6.7 | 39.5 | 44.3 | 0.15 | 8.6 | 0.29 | 154.9 |
| **D71C** | 1000265478 | 30.9 | 32.4 | 300.1 | 39.3 | 0.2 | 4.5 | 16.6 | 28.8 | 1.50 | 8.2 | 0.07 | 40.5 |
| **D72A** | 1000265477 | 36.4 | 43.3 | 321.4 | 44.1 | 0.2 | 4.9 | 20.3 | 33.6 | 1.50 | 8.1 | 0.06 | 48.2 |
| **D72B** | D7H002Q01 | 44.1 | 61.4 | 478.0 | 68.0 | 0.5 | 9.3 | 25.8 | 66.6 | 1.50 | 8.6 | 0.42 | 105.2 |
| **D72C** | D7R001Q01 | 33.8 | 32.5 | 334.6 | 42.5 | 0.9 | 2.9 | 20.5 | 28.9 | 0.05 | 8.5 | 0.03 | 41.0 |
| **D73B** | D7H008Q01 | 25.8 | 12.7 | 201.5 | 26.1 | 0.2 | 2.4 | 10.5 | 13.8 | 0.05 | 8.3 | 0.01 | 17.1 |
| **D73D** | 1000261715 | 32.6 | 39.6 | 364.3 | 46.7 | 0.2 | 3.8 | 18.1 | 31.7 | 1.50 | 8.6 | 0.07 | 53.0 |
| | 1000261716 | 33.8 | 39.2 | 377.2 | 46.9 | 0.2 | 3.9 | 20.0 | 34.6 | 1.50 | 8.6 | 0.13 | 53.7 |
| | 182750 | 28.2 | 37.6 | 305.7 | 46.5 | 0.4 | 3.3 | 16.4 | 29.5 | 0.07 | 8.6 | 0.01 | 60.8 |
| **D73E** | 184055 | 35.3 | 41.5 | 382.3 | 48.8 | 0.3 | 4.1 | 21.4 | 37.6 | 1.50 | 8.7 | 0.92 | 57.0 |
| **D73F** | 1000261717 | 37.7 | 40.3 | 337.5 | 51.0 | 0.3 | 3.3 | 19.2 | 34.6 | 1.50 | 8.7 | 0.20 | 52.0 |
| | 1000261718 | 38.8 | 44.9 | 375.4 | 48.2 | 0.2 | 3.9 | 19.8 | 36.2 | 1.50 | 8.6 | 0.05 | 53.5 |
| | 1000265473 | 38.0 | 190.1 | 404.0 | 47.9 | 0.3 | 4.3 | 44.1 | 41.8 | 1.50 | 8.0 | 0.05 | 100.6 |
| | 182756 | 31.1 | 27.8 | 269.1 | 38.5 | 0.8 | 2.7 | 14.9 | 24.2 | 0.05 | 8.5 | 0.01 | 31.2 |
| | D7H005Q01 | 30.2 | 28.5 | 268.6 | 40.5 | 0.4 | 2.8 | 19.2 | 24.0 | 1.14 | 8.5 | 0.01 | 33.7 |
| | D7H014Q01 | 33.7 | 42.3 | 368.0 | 49.8 | 0.5 | 3.4 | 20.2 | 40.4 | 0.07 | 8.6 | 0.03 | 49.1 |
| | D7H015Q01 | 34.6 | 38.1 | 339.1 | 44.6 | 0.8 | 3.2 | 18.8 | 37.3 | 0.05 | 8.6 | 0.07 | 39.5 |
| | D7H016Q01 | 38.3 | 45.0 | 409.5 | 54.7 | 0.5 | 3.8 | 24.0 | 44.6 | 0.08 | 8.6 | 0.03 | 51.2 |
| **D81A** | 1000265479 | 46.3 | 77.7 | 584.3 | 73.9 | 0.4 | 4.5 | 25.7 | 72.1 | 1.50 | 8.2 | 0.06 | 93.5 |

### D8 - Orange River System Main Stem (downstream)

The water quality downstream of the confluence of the Orange River and the Hartbees River is similar to the upstream portion of the river apart from acceptable levels of phosphate concentrations and generally more elevated total dissolved solids being in the tolerable range. Total dissolved solids increase in catchment D81A and recovers slightly flowing further downstream towards the river mouth. As the Orange River flows towards the river mouth (D82L at Korridor Brand Kaross), all parameters for which data is available are within ideal to acceptable ranges.

The water quality within the estuary, as expected, is highly saline as evidenced by the high TDS and accompanying chloride levels. pH and fluoride levels within this Orange River Mouth Ramsar site are within the ideal range. A threat to this portion of the river being loss of inflow of water and sediment, the water quality trend is likely to be an increase in salinity levels during low flow conditions caused by upstream activities and scattered alluvial diamond mining in Alexander Bay area.

*Water Quality Hotspot Areas*

| Quaternary Catchment | River | Impact | Water Quality Issue/impact |
|---|---|---|---|
| D81A | Orange | Large | Elevated nutrients and TDS from extensive farming and irrigation, Salinity and WWTW discharges near Augrabies |
| D81G | Orange | Moderate | Sediment and elevated nutrients from upstream irrigation at Vioolsdrift |

| Drainage Region | Monitoring Point ID | Ca | Cl | DMS (TDS) | EC | F | K | Mg | Na | NH4-N | pH | PO4-P | SO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/l) | (mg/l) | (mg/l) | (mS/m) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (pH units) | (mg/l) | (mg/l) |
| | | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 50 | 95 |
| **D8 sub catchment** | | | | | | | | | | | | | |
| **D81B** | 1000265470 | 39.4 | 59.2 | 508.5 | 70.1 | 0.3 | 4.0 | 26.0 | 62.2 | 0.19 | 8.4 | 0.05 | 65.1 |
| | 194551 | 26.5 | 19.3 | | 36.3 | 0.2 | | 13.3 | 25.5 | 1.50 | 8.0 | | |
| **D81F** | 1000265476 | 39.4 | 49.2 | 436.5 | 54.0 | 0.2 | 4.0 | 21.9 | 46.8 | 0.10 | 8.3 | 0.06 | 59.0 |
| **D81G** | D8H008Q01 | 37.4 | 47.4 | 418.3 | 58.0 | 0.6 | 3.6 | 21.3 | 49.5 | 1.50 | 8.6 | 0.24 | 59.1 |
| **D82D** | 1000265472 | 40.5 | 55.0 | 477.1 | 60.0 | 0.3 | 4.2 | 24.9 | 55.4 | 0.10 | 8.5 | 0.06 | 65.6 |
| | 182752 | 31.3 | 31.6 | | 48.3 | 0.6 | | 15.6 | 40.0 | 1.50 | 8.0 | | |
| **D82L** | D8H007Q01 | | 29.8 | | | 0.0 | | 12.2 | | 0.03 | | 0.05 | 24.1 |
| **D82L** | 1000265474 | 430.8 | 13483.2 | 19917 | 3076 | 0.6 | 175.5 | 1180.3 | 4439.4 | 1.51 | 8.0 | 0.15 | 1976 |

### 8.4.2. Orange River Tributaries

#### *D5 – Tributaries (Hartbees)*

The water quality in the headwaters of the Hartbees catchment is generally poor, with fair water quality exhibited within quaternary catchments D51A (Renoster River) and D57C (Sak River) which both show unacceptable levels of ammonia and phosphates, respectively. Catchments D53A, D55E and D55L all exhibit a similar water quality profile with elevated unacceptable calcium, total dissolved solids, electrical conductivity and sodium concentrations. TDS concentrations ranging between 1205 and 1700 mg/l are observed in quaternary catchments D53A, D55E and D55L, with the other macro-ions presenting a similar trend. An increase in sulphate levels from acceptable levels in the upper reaches of the Sak River (D55E) to unacceptable in the lower of the Sak just downstream of Willston Town are observed.

*Water Quality Hotspot Areas*

| Quaternary Catchment | River | Impact | Water Quality Issue/impact |
|---|---|---|---|
| D55E | Sout | Large | Elevated nutrients, high pH, TDS, high salinity and from upstream |
| D55L | Sak | Large | Cumulative impact from upstream, but with additional sulphate impact likely from mining upstream on Kareebergleegte catchment |
| D58A | Renoster | Moderate | Cumulative impacts from upstream. Elevated salinity, and WWTW discharges from upstream. SWSA potentially impacted by WWTW discharge |

| Drainage Region | Monitoring Point ID | Ca | Cl | DMS (TDS) | EC | F | K | Mg | Na | NH4-N | pH | PO4-P | SO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/l) | (mg/l) | (mg/l) | (mS/m) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (pH units) | (mg/l) | (mg/l) |
| | | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 |
| **Hartbees/Sak D5 sub-catchment** | | | | | | | | | | | | | |
| **D51B** | D5H011Q01 | 40.7 | 93.6 | 687.1 | 100.1 | 0.7 | 6.2 | 38.3 | 109.2 | 0.20 | 8.7 | 0.12 | 101.8 |
| **D58A** | D5H017Q01 | 51.2 | 386.1 | 519.5 | 238.6 | 0.5 | 7.7 | 57.8 | 387.6 | 0.11 | 8.6 | 0.38 | 221.8 |
| **D52F** | D5H022Q01 | | 336.2 | | | 1.6 | | 107.5 | | 0.03 | | 0.08 | 254.7 |
| **D55E** | D5H019Q01 | 42.9 | 182.9 | 1205.2 | 111.3 | 0.7 | 9.3 | 34.9 | 259.0 | 0.15 | 8.6 | 0.13 | 162.8 |
| **D55L** | D5H021Q01 | 47.1 | 609.3 | 1484.8 | 239.6 | 0.8 | 11.8 | 59.7 | 346.7 | 0.10 | 8.6 | 0.13 | 773.0 |
| **D57C** | D5H016Q01 | 26.7 | 77.0 | 383.8 | 53.8 | 0.4 | 7.0 | 8.4 | 72.8 | 0.05 | 8.4 | 0.13 | 34.6 |
| **D53A** | D5R001Q01 | 14.1 | 376.1 | 1702.2 | 230.8 | 0.5 | 15.7 | 9.8 | 504.0 | 0.07 | 8.4 | 0.23 | 139.6 |

***D6 – Tributaries (Brak)***

The water quality in the Brak River catchment for the monitoring sites assessed (dam and river) suggests nutrient pollution upstream of the two dams within catchments D61E and D61M, while Victoria West Dam within the upper reaches of the catchment indicate water quality impacts with all parameters within unacceptable levels except calcium, fluoride and potassium. High pH levels are also observed. Water quality is driven by the natural geology and the saline soil characteristics in this part of the catchment. An improvement in water quality occurs further downstream (Smartt Syndicate Dam) for all major parameters except for nutrients which are within the unacceptable range. The water quality data for the downstream site on the Brak River, which is downstream of the Ongers and Brak River confluence is currently very limited. The lack of monitoring data upstream on the Brak near De Aar is also a major concern due to potential impacts of the town area and associated activities. De Aar is home to the largest abattoir in the country and no routine quality water data was available for this part of the catchment.

*Water Quality Hotspot Areas*

| Quaternary Catchment | River | Impact | Water Quality Issue/impact |
|---|---|---|---|
| D61E | Brak tributary of Visgat | Moderate | High eutrophication at Victoria West Dam |
| D61M | Ongers | Moderate | High pH, Elevated TDS, sediment and high nutrients at Smartt Syndicate Dam |

| Drainage Region | Monitoring Point ID | Ca | Cl | DMS (TDS) | EC | F | K | Mg | Na | NH4-N | pH | PO4-P | SO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mg/l) | (mg/l) | (mg/l) | (mS/m) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (mg/l) | (pH units) | (mg/l) | (mg/l) |
| | | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 | 95 |
| **Brak – D6 sub-catchment** | | | | | | | | | | | | | |
| **D61E** | D6R001Q01 | 43.3 | 537.9 | 7154.1 | 754.4 | 0.9 | 35.2 | 236.7 | 1485.5 | 1.36 | 9.5 | 0.53 | 4029.7 |
| **D61M** | D6R002Q01 | 47.0 | 71.4 | 518.0 | 75.5 | 0.3 | 10.0 | 17.8 | 82.9 | 1.37 | 7.7 | 0.35 | 123.4 |

### 8.4.3. Orange River Coastal Catchment

There is no water quality data for the period of assessment for all quaternary catchments within coastal catchments, F1 (Holgat River), F2 (Kamma), F3 (Buffels River), F4 (Swartlintjies, Spoeg, Bitter River), F5 (Groen Rivers) and F6 (Sout River). Hotspot areas may be localised; however, alluvial diamond mining and sand and mineral mining remain a high activity, the water quality impacts of which need to be understood. This is of relevance to the Buffels River catchment. The presence of the WWTW within the Buffels catchment also suggests also localised impact. Apart from the scattered towns, the Swartlitjies, Spoeg, Bitter and Groen River catchments do not have high anthropogenic activities and as such, the water quality drivers might include increased sediments, natural geologic influences and saline backwater effects at the river mouths.

#### 8.4.4. Microbiological and Eutrophication Status

Table 34 and

Table 35 indicate the water quality statistics of the data received for the microbiological and eutrophic parameters assessed, respectively.

With limited data available, not much inference can be made into the prevailing microbiological and eutrophic quality status of the Lower Orange catchment. Nonetheless, it is evident that the few times where samples were collected, there was bacterial contamination occurring within the Orange River. The presence of the coliforms at the sites assessed is indicative of pollution from wastewater treatment works along the main stem Orange River.

The concentration of Chlorophyll *a* is generally used as a measure of the amount of algae growing in a water body. At the monitoring stations assessed the concentrations are less than 10 ug/l, which were indicative of an oligotrophic status (DWAF, 2008a). This data is however outdated (older than 5 years), and the eutrophic status of the Orange River has deteriorated since this monitoring was undertaken.

**Table 34: Average microbial concentration (count/100ml) per microbial parameter at selected sites within the Lower Orange River**

| Station ID | Monitoring Point Name | Quat | *n* | *E.Coli* | *n* | *E.Coli* (MPN* Method) | *n* | Faecal Coliform | *n* | Total Coliform | *n* | Total Coliform (MPN* method) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000261715 | Orange River At Groblershoop Bridge | D73D | | | | | 1 | 36 | | | | |
| 184055 | Sun River Lodge - At Intake of Upington Water Works on Orange River | D73E | 2 | 70 | | | 6 | 45 | 2 | 1348 | | |
| 1000261718 | Orange River At Kanoneiland @ Bridge Near Grape Farms | D73F | 1 | 16 | 1 | 22 | | | 1 | 210 | 1 | 649 |
| 1000261717 | Ikaia River Lodge - @ Keimoes Bridge Over Orange River | | 2 | 22 | 1 | 29 | | | 2 | 1428 | 1 | 921 |
| 182752 | Orange River At Henkries Namaqua Water Board Abstraction | D82D | | | 1 | 115 | | | | | 1 | 6 |

* - Most Probable Number method
*n* – Number of samples

**Table 35: Chlorophyll a concentration at selected sites within the Lower Orange River (2014-1016)**

| Station ID | Monitoring Point Name | Quat | n | Chlorophyll *a* (ug/L) (50th percentile) |
|---|---|---|---|---|
| D7R001Q01 | Boegoeberg Dam on Orange River: Near Dam Wall | D72C | 3 | 2.95 |
| D7H005Q01 | Orange River At Upington | D73F | 1 | 3.10 |
| D8H008Q01 | Orange River At Pella Mission | D81G | 13 | 2.35 |

*n* – Number of samples

Improved and consistent monitoring of eutrophic and microbial status is required, especially along the main stem of the Orange River system where the majority of land base activities and sources of pollution reside. This includes nutrients (fertilizers) from agricultural runoff due intense irrigation, wastewater treatment plant discharges and urban runoff. It is however noted that there is a challenge of the availability of laboratories within the study area that makes it impractical to adhere to sample holding times between sample collection and eventual analysis, especially for microbial parameters. Strategic sites for monitoring status should however be selected.

## 8.5. Green Drop Report

The DWS Greendrop Report (DWS, 2022) was reviewed to obtain an assessment of the status of wastewater services in the Northern Cape Province which fall within the Lower Orange Catchment. The Greendrop audit scores indicate poor performance by almost all wastewater treatment works in the catchment, with low scores and high cumulative risk (Table 36).

The cumulative risk rating is catchment for each system as follows:

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

*A = Hydraulic design capacity of the treatment plant in Ml/day*

*B = Operational flow as % of the installed design capacity*

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

*D = Number of technical skills gaps (supervision, operation, maintenance) in terms of Reg. 2834 & Draft Reg. 813.*

The Greendrop scores provide an indication of potential water quality impact of the wastewater treatment works on the receiving water resources. The results indicate that the WWTWs in the Lower Orange catchment are a threat to water quality.

**Table 36: Greendrop Performance for WWTWs in the Northern Cape Province (Lower Orange Catchment) (DWS, 2022)**

| Province | District Municipality Name | Local Municipality Name | Name | WWTW Type | System Design capacity (ML/d) | Resource discharged to | Green Drop score - 2021 | Cumulative Risk Rating - 2021 |
|---|---|---|---|---|---|---|---|---|
| Northern Cape | Namakwa | Karoo Hoogland | Sutherland | Oxidation ponds unlined | 0.5 | Dorps River | 9% | 100% |
| Northern Cape | Namakwa | Hantam | Middelpos | Oxidation ponds unlined | | | to be confirmed | |
| Northern Cape | Namakwa | Karoo Hoogland | Fraserburg | Oxidation ponds | 0.5 | Sout River | 11% | 100% |
| Northern Cape | Pixley ka Seme | Ubuntu | Loxton | Oxidation ponds unlined | 2.5 | No discharge | 24% | 100% |
| Northern Cape | Pixley ka Seme | Ubuntu | Richmond | Oxidation ponds unlined | 2.5 | No information | 24% | 100% |
| Northern Cape | Pixley ka Seme | Ubuntu | Victoria West | Oxidation ponds unlined | 2.5 | No discharge | 21% | 94.10% |
| Northern Cape | Namakwa | Karoo Hoogland | Williston | Oxidation ponds | 0.5 | Sak River | 9% | 100% |
| Northern Cape | Pixley ka Seme | Kareeberg | Carnarvon | Oxidation ponds | 0.52 | Land discharge | 45% | 70.60% |
| Northern Cape | Pixley ka Seme | Emthanjeni | De Aar | Activated sludge | 4 | Orange River | 11% | 88.20% |
| Northern Cape | Pixley ka Seme | Umsobomvu | Norvalspont | Oxidation ponds unlined | 0.14 | No information | 17% | 94.10% |
| Northern Cape | Pixley ka Seme | Kareeberg | Vosburg | Oxidation ponds unlined | 0 | No discharge | 29% | 94.10% |
| Northern Cape | Namakwa | Kamiesberg | Garies | Oxidation ponds unlined | 0 | Evaporation | 0% | 100% |
| Northern Cape | Pixley ka Seme | Emthanjeni | Britstown | Oxidation ponds unlined | 3 | No discharge | 20% | 94% |
| Northern Cape | Namakwa | Hantam | Brandvlei | Oxidation ponds unlined | 0.06 | Sak River | 27% | 76.50% |
| Northern Cape | Namakwa | Kamiesberg | Kamieskroon | Oxidation ponds unlined | 8.5 | Evaporation | 2% | 100% |
| Northern Cape | Pixley ka Seme | Thembelihle | Strydenburg | Oxidation ponds | 0.48 | Orange River | 35% | 82.40% |
| Northern Cape | Pixley ka Seme | Thembelihle | Orania | | 0 | | | |
| Northern Cape | Namakwa | Nama Khoi | Komaggas | Oxidation ponds unlined | 0.5 | Orange River | 28% | 94% |
| Northern Cape | Namakwa | Nama Khoi | Springbok | Oxidation ponds unlined | 1 | Orange River | 29% | 88.20% |
| Northern Cape | Namakwa | Nama Khoi | Kleinsee | Activated sludge | 1.2 | | | |
| Northern Cape | Pixley ka Seme | Siyathemba | Prieska | Bio-filter | 2.2 | Vaal River | 50% | 70.60% |
| Northern Cape | Namakwa | Nama Khoi | Carolusberg | Oxidation ponds unlined | 0.5 | Orange River | 28% | 88.20% |
| Northern Cape | Namakwa | Nama Khoi | Nababeep | Bio-filter | 2 | Orange River | 19% | 94% |
| Northern Cape | Namakwa | Nama Khoi | Okiep | Oxidation ponds unlined | 0.5 | Orange River | 29% | 88.20% |
| Northern Cape | Namakwa | Nama Khoi | Concordia | Oxidation ponds unlined | 0.5 | Orange River | 28% | 94% |

| Province | District Municipality Name | Local Municipality Name | Name | WWTW Type | System Design capacity (ML/d) | Resource discharged to | Green Drop score - 2021 | Cumulative Risk Rating - 2021 |
|---|---|---|---|---|---|---|---|---|
| Northern Cape | Pixley ka Seme | Siyathemba | Marydale | Oxidation ponds unlined | 0.94 | Vaal River | 50% | 64.70% |
| Northern Cape | Pixley ka Seme | Siyathemba | Niekerkshoop | Oxidation ponds unlined | 0.12 | Vaal River | 37% | 70.60% |
| Northern Cape | Siyanda | Kai !Garib | Kenhardt | Oxidation ponds unlined | 2 | Hartbees River | 10% | 94% |
| Northern Cape | Namakwa | Nama Khoi | Steinkopf | Oxidation ponds unlined | 0.5 | Orange River | 35% | 82.40% |
| Northern Cape | Namakwa | Khâi-Ma | Aggeneys | Oxidation ponds unlined | | | to be confirmed | |
| Northern Cape | Namakwa | Richtersveld | Port Nolloth | Oxidation ponds unlined | 0.3 | Irrigation | 2% | 82.40% |
| Northern Cape | Namakwa | Khâi-Ma | Pofadder | Oxidation ponds unlined | 0.38 | Evaporation | 0% | 88.20% |
| Northern Cape | Namakwa | Khâi-Ma | Pella | Oxidation ponds unlined | 0.063 | Orange River | 3% | 100% |
| Northern Cape | ZF Mgcawu | !Kheis | Brandboom | Oxidation ponds unlined | 1 | No information | 25% | 82.40% |
| Northern Cape | ZF Mgcawu | !Kheis | Groblershoop | Oxidation ponds unlined | 0.6 | No information | 2% | 88.20% |
| Northern Cape | Pixley ka Seme | Siyancuma | Griekwastad | Oxidation ponds unlined | 0.68 | Vaal River | 22% | 82.40% |
| Northern Cape | ZF Mgcawu | Kai !Garib | Kakamas | Oxidation ponds unlined | 2 | Orange River | 18% | 88.20% |
| Northern Cape | Frances Baard | Sol Plaatjie | Kimberley | Activated sludge | 30 | | to be confirmed | |
| Northern Cape | Namakwa | Khâi-Ma | Onseepkans | Oxidation ponds unlined | 0.063 | Orange River | 0% | 100% |
| Northern Cape | ZF Mgcawu | !Kheis | Topline | | 0.2 | No information | 0% | 100% |
| Northern Cape | ZF Mgcawu | Kai !Garib | Keimoes | Oxidation ponds unlined | 2 | Orange River | 14% | 94% |
| Northern Cape | Namakwa | Richtersveld | Alexander Bay | Oxidation ponds unlined | 0 | | to be confirmed | |
| Northern Cape | ZF Mgcawu | Dawid Kruiper | Upington | Bio-filter | 16 | | | |
| Northern Cape | ZF Mgcawu | Dawid Kruiper | Upington | Bio-filter | 16 | | | |
| Northern Cape | ZF Mgcawu | Tsantsabane | Postmasburg | Activated sludge | 2.8 | Groenwaterspruit and mining | 40% | 82.40% |
| Northern Cape | ZF Mgcawu | Tsantsabane | Jen Haven | Oxidation ponds unlined | 0 | Groenwaterspruit and mining | 28% | 94% |
| Northern Cape | ZF Mgcawu | Tsantsabane | Olifantshoek | Oxidation ponds unlined | 0.3768 | Farmer | 14% | 94% |
| Northern Cape | John Taolo Gaetsewe | Gamagara | Dingleton | Activated sludge | 0.11 | | to be confirmed | |
| Northern Cape | John Taolo Gaetsewe | Gamagara | Kathu | Activated sludge | 10 | Outflow onto pond | 28% | 72.20% |

| Province | District Municipality Name | Local Municipality Name | Name | WWTW Type | System Design capacity (ML/d) | Resource discharged to | Green Drop score - 2021 | Cumulative Risk Rating - 2021 |
|---|---|---|---|---|---|---|---|---|
| Northern Cape | John Taolo Gaetsewe | Gamagara | Dibeng | Oxidation ponds unlined | 0.6 | Gamagara River | 19% | 76.50% |
| Northern Cape | John Taolo Gaetsewe | Ga-Segonyana | Kuruman | Activated sludge | 4 | Wetland | 11% | 94% |
| Northern Cape | John Taolo Gaetsewe | Ga-Segonyana | Mothibistad | Oxidation ponds unlined | 2.4 | Orange River | 7% | 94% |
| Northern Cape | John Taolo Gaetsewe | Ga-Segonyana | Batlharos | Oxidation ponds unlined | | | to be confirmed | |
| Northern Cape | John Taolo Gaetsewe | Joe Morolong | Hotazel | Activated sludge | 0.35 | Irrigation | 3% | 94% |
| Northern Cape | John Taolo Gaetsewe | Joe Morolong | Van Zylsrust | Oxidation ponds unlined | 0.03 | No discharge | 0% | 94% |
| Northern Cape | ZF Mgcawu | Mier | Rietfontein | Oxidation ponds unlined | 0.16 | Evaporation | 36% | 76.50% |
| North West | Dr Ruth Segomotsi Mompati | Molopo/Kagisano | Pomfret | Activated sludge | 1.5 | | | |
| North West | Dr Ruth Segomotsi Mompati | Molopo/Kagisano | Ganyesa Hospital | Package Plant | 0.15 | | to be confirmed | |
| North West | Ngaka Modiri Molema | Mafikeng | Gelukspan Hospital | Package Plant | 0.15 | | | |
| North West | Ngaka Modiri Molema | Tswaing | Atamelang | Oxidation ponds unlined | 1 | Ponds | 0% | 100% |
| Western Cape | West Coast | West Coast DMA | Bitterfontein | Oxidation ponds | | | to be confirmed | |
| Western Cape | West Coast | West Coast DMA | Rietpoort | Oxidation ponds | | | | |

# 9 INTEGRATED UNITS OF ANALYSIS

## 9.1. Delineation of IUAs

An Integrated Unit of Analysis (IUA) is a broad scale unit (or catchment area) that contains several biophysical nodes. These nodes define, at a detailed scale, specific attributes that together describe the catchment configuration of the IUA. Scenarios are assessed within the IUA and relevant implications in terms of the socio-economics and different catchment configurations on the ecological conditions are provided for each IUA (DWA, 2007a).

### 9.1.1. Approach

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

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

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

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

### 9.1.2. Delineation

The following suite of characteristics was analysed, assessed and reviewed for delineation of IUAs within the Lower /orange River catchment:

- Socio-economic zones (SEZs)
- Catchment area boundaries (drainage regions and water resource systems)
- The resolution of the hydrological analysis and available water resource network configurations within the water resource models.
- Location of significant water resource infrastructure.

- Land use characteristics.
- Distinctive functions of the catchments in context of the larger system.
- The Present Ecological State (PES) of each biophysical node was considered, the type of impacts and the homogeneity of the status and impacts.
- The practicalities of the existing model setup and network in terms of the scenario evaluation of each IUA.
- Present status of water resources.
- Stakeholder input.

Based on the SEZs determined and the assessment of the information and considerations outlined in Sections 2 to 8 expert input and previous studies, ten IUAs have been delineated for the Lower Orange River catchment. The availability of representative EWR sites within each IUA, catchment boundaries and modelling catchments were also considered. Overlaying these aspects and data has resulted in the delineation of the IUAs which are similar from all the various components perspective and which can be managed as an entity, in addition comprising a logical unit for which scenarios can be designed and evaluated.

The ten IUAs delineated are listed in Table 37 and shown in Figure 36. The identified IUAs are to be have been discussed with the DWS and stakeholders within the Lower Orange catchment for adoption.

**Table 37: Integrated Units of Analysis (IUAs) in the Lower Orange River catchment**

| IUA | Delineation | Quaternary Catchment |
|---|---|---|
| **1** | Orange from Vaal confluence to Augrabies Waterfall | C92C, D71A, D71B, B71C, D71D, D72A, D72B, C72C, D73B, D73C, D73D, D73E, D73F, ~80% of D81A |
| **2** | Downstream Augrabies to Pella | Portion of D81A – D81G |
| **3** | Pella to Vioolsdrift weir | D82A – D82G |
| **4** | Downstream Vioolsdrift to Orange River Mouth | D82H, D85J, D82K, D82L |
| **5** | Orange River Mouth | Estuarine Functional Zone boundary in D82L |
| **6** | Ongers/Brak | D61A, D61B, D61C, D61D, D61E, D61F, D61G, D61H, D61J, D61K, D61L, D61M, D62A, D62B, D62C, D62D, D62E, D62F, D62G, D62H, D62J |
| **7** | Hartbees/Sak | D52 - D58 |
| **8** | Coastal Area | F10A to F60A |
| **9** | Upper Molopo and Upper Kuruman | D41B, D41C, D41D, D41E, D41F, D41H, D41K, D41G, D41M |
| **10** | Lower Kuruman and Lower Molopo | D42A, D42B, D42C, D42D, D42E, D81C |

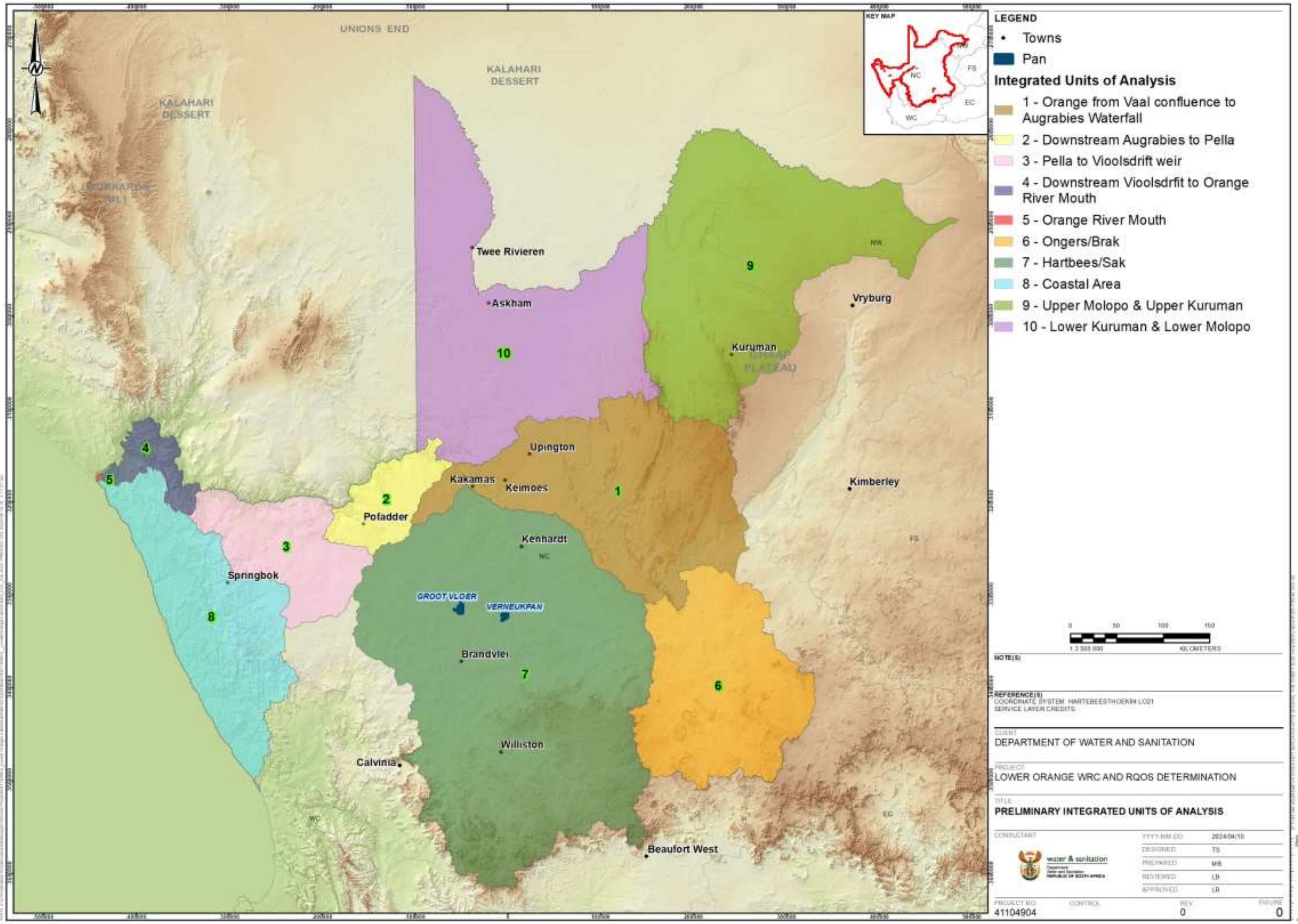



**Figure 36: Map of IUAs Delineated**

## 9.2. Priority Wetlands per IUA

A summary of the extent of wetlands per type, and a list of the preliminary Priority Wetlands per IUA, indicated in Table 38. Based on the IUA delineation, the IUA with the largest number of wetlands is IUA 7- Hartbees/Sak with 7% of wetland habitat relative to the size of the IUA. The Hartbees/Sak is also home to the high priority Pan wetlands highlighted in the 2016 EWR report (DWS, 2016), these include inter alia Verneuk Pan, Grootvloer, Boesmankop, and Bitterputs. Based on the EWR (2016) report, the majority of high priority wetlands in the catchment were mostly confined to the main stem of the Orange River. High and very high priority wetlands formed three distinct groupings of wetland HGM types, which include floodplain wetlands associated with the main stem of the Orange River, depression wetlands (some large but mostly small pans) towards the southern part of the catchment (Hartbees/Sak IUA) and high density channelled and unchanneled valley bottom wetlands along the Elandsfontein, Brak, Sak and Sout River which are within the Ongers/Brak and Hartbees/Sak respectively.

Thus, the IUAs with the largest number of wetlands are the Hartbees/Sak and the Ongers/Brak IUAs. One very important wetland system is the Orange River Mouth wetland situated within the smallest IUA, IUA 5- Orange River Mouth. Estuaries (11%) make up the bulk of the wetland habitat in this IUA, followed by River (the Orange River) and depression wetlands.

Based on the EWR study (DWS, 2016) study (Figure 37), priority wetlands are spread across all IUAs with the exception of IUA 8 and 9, of which IUA 9 was not part of the previous prioritization study.

### 9.2.1. General Conditions of Wetlands

The National Wetland Map 5 (Van Deventer *et al*., 2018) and the NFEPA wetland attribute data (Nel *et al*., 2011) as well as the 2016 EWR study (DWS, 2016) was used to provide a general description of the condition of the wetlands in each of the delineated IUAs. A summary of wetland condition per IUA is provided in Table 39. It is important to point out that as there is limited to no recent field verification of the ecological categorization of most the wetland systems in the Lower Orange River catchment, the general description of the condition of the wetlands taken from the datasets above may not be an accurate representation of the actual current ecological state of the wetlands. It should thus be seen as indicative and only provides a broad-scale perspective of the likely condition of the wetland systems in each IUA.

Based on the NWM5 (Van Deventer *et al*., 2018), majority of the wetlands in the catchment are considered to be in a relatively natural or near natural (PES A/B) state, which infers that little to no changes to the original wetland condition has occurred in the wetland. The dominant land use in the catchment supports the current PES category assigned to these wetlands, as the area is dominated by agricultural activities and game farming. Approximately 6% of the wetlands in the catchment are considered moderately modified (PES C), while only 3.5% of the wetlands considered to be in a largely to seriously modified state (PES E/F). The modified state of some of the wetlands infers that the wetlands have incurred some loss of natural habitat while the seriously modified means that the losses to wetland habitat and ecosystem functions are extensive.

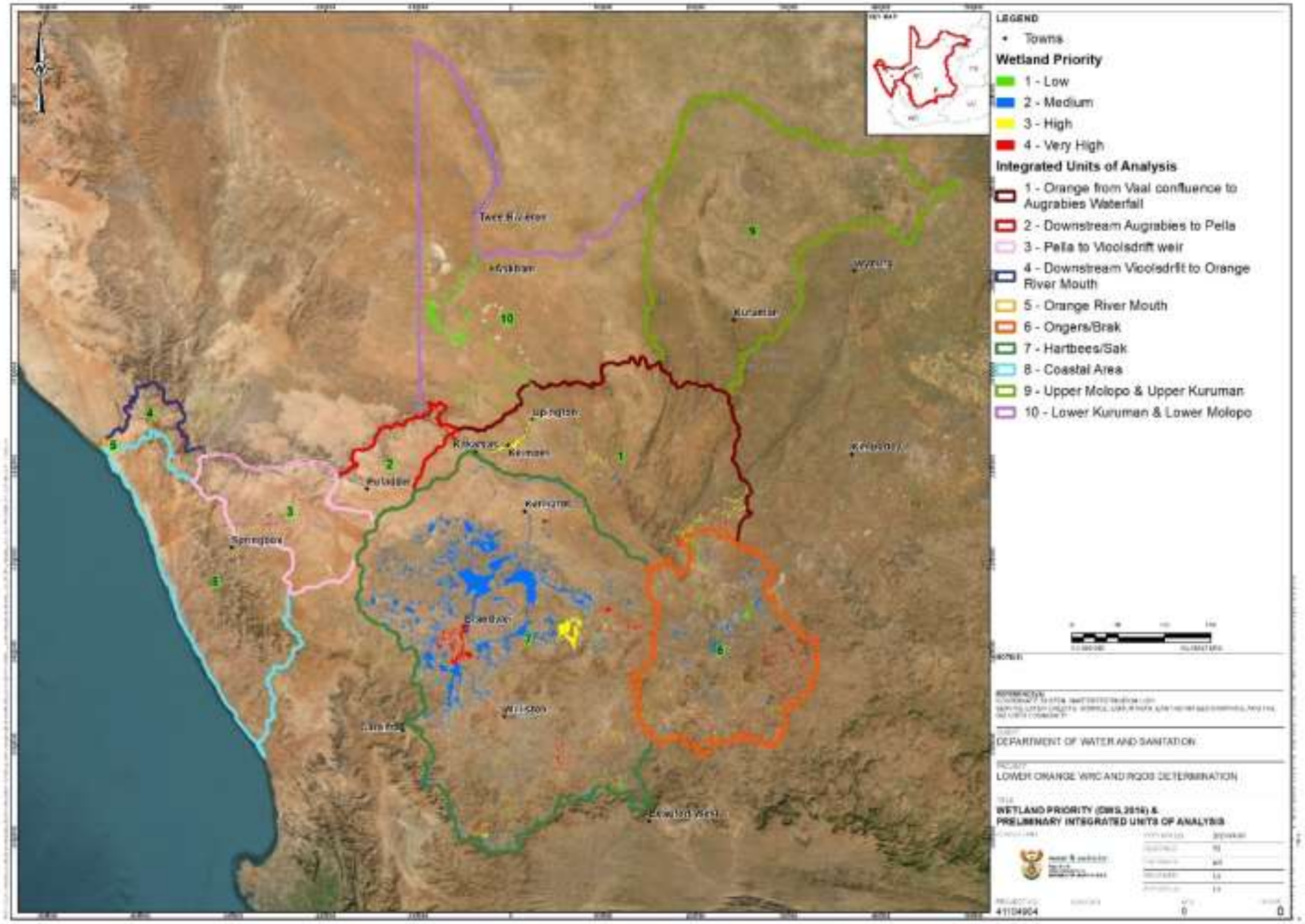



**Figure 37: Priority wetlands mapped per IUA (DWS, 2016)**

**Table 38: Wetland extent (area) and percentage of area per IUA (source: GIS coverage of Van Deventer *et al.*, 2018 ) Also indicated is a preliminary list of Priority Wetlands per IUA verified from DWS, 2016 and www.Ramsar.org – Annotated List of Wetlands of International Importance – South Africa.**

### IUA 1: Vaal Confluence to Augrabies Waterfall

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 4,209,737 | 100631.05 | 2% | 1176.045 | 0.28% | - | - | 8560 31 | 0.20% | - | - | 41.16 | 0.05% | | | Orange River (main stem) |

### IUA 2: Downstream Augrabies to Pella

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 809,011 | 19237.83 | 2% | 376. 94 | 0.05% | - | - | 978.58 | 0.12% | 7522.754 | 0.93% | - | - | | | Orange River (main stem) |

### IUA 3: Pella to Vioolsdrift weir

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 1,572,838 | 21380.73 | 1% | 5057.80 | 0.32% | 64.49 | 0.0% | 193.82 | 0.01% | 10250.68 | 0.65% | - | - | | | Orange River (main stem) |

### IUA 4: Downstream Vioolsdrift to Orange River Mouth

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 441,947 | 5767.91 | 1% | 77.42 | 0.000175% | - | - | - | - | 3567.08 | 0.008071% | - | - | | | Orange River (main stem) |

### IUA 5: Orange River Mouth

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Estuary | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 3,827 | 550.74 | 14% | 2.94 | 0.08% | - | - | - | - | - | - | - | - | 113.47 | 2.97 | 434.13 | 11.34 | Orange River Mouth |

### IUA 6: Ongers/Brak

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 3,200,827 | 341615.17 | 11% | 11608.15 | 0.36% | 55964.59 | 1.75% | 1699.13 | 0.05% | 108988.2 | 3.41% | 564.69 | 0.02% | 160614.7 | 5.02 | Valley bottoms associated with the Ongers, Brakpoort, Brak, Visgat and Klein Brak Rivers |

### IUA 7: Haartbees/Sak

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 9,296,791 | 668272.8 | 7% | 264493.4 | 2.84% | 54071.84 | 0.58% | 3328.702 | 0.04 % | 25114.42 | 0.27% | 20007.25 | 0.22% | 301461.3 | 3.24% | Valley bottoms associated with Hartbess, Sak, Klein Sak Hongerkloof se Leegte, Mottels and the High priority Pans- Verneuk Pan, Grootvloer, Boesmankop, and Bitterputs. |

### IUA 8: Coastal Area

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Estuary | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 2,858,155 | 61849.82 | 2% | 15794.7 | 0.55% | 1.51 | 0% | 1465.04 | 0.05% | 1524.43 | 0.05% | - | - | 42156.4 | 1.48 | 895.40 | 0.031 % | |

### IUA 9: Upper Molopo & Upper Kuruman

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 5,410,145 | 66514.36 | 1% | 22953.98 | 0.42 | 1231.66 | 0.02% | 3997.92 | 0.07% | 16059.38 | 0.30 | 12.44 | 0.0% | 22217.96 | 0.41% | |

### IUA 10: Kuruman & Lower Molopo

| Area (ha) | Area of wetlands in IUA (ha) | %Wetland area in IUA | Depression | | Floodplain | | Seep | | Channelled VB | | Unchanneled VB | | River | | Preliminary List of Priority Wetlands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % | ha | % | ha | % | ha | % | |
| 5,464,194 | 138024.61 | 3% | 103750.4 | 1.90% | - | - | 1276.98 | 0.023% | 1303.45 | 0.024% | - | - | 31692.15 | 0.58% | Wetlands along the Molopo main stem |

IUA 9- Upper Molopo and Upper Kuruman, was not part of the EWR, 2016 prioritization study and therefore no priority wetlands were mapped in this IUA.

**Table 39: Wetland condition summary per IUA (source: GIS coverage of Van Deventer *et al.*, 2018)**

| IUA | Area (ha) | Extent of wetlands (ha) in IUA | Wetland Condition A/B | | Wetland Condition C | | Wetland Condition D/E/F | |
|---|---|---|---|---|---|---|---|---|
| | | | ha | % | ha | % | ha | % |
| **Orange from Vaal Confluence to Augrabies Waterfall (1)** | 4,209,737 | 100,631.05 | 8756 | 0.21% | 4637 | 0.11% | 6935 | 0.16% |
| **Downstream Augrabies to Pella (2)** | 809,011 | 19,237.83 | 385 | 0.05% | 7 | 0.0% | 8487 | 1.05% |
| **Pella to Vioolsdrift weir (3)** | 1,572,838 | 21,380.73 | 2654 | 0.17% | 2340 | 0.15% | 10573 | 0.67% |
| **Downstream Vioolsdrift to Orange River Mouth (4)** | 441,947 | 5,767.91 | 77 | 0.02% | - | - | 3567 | 0.81% |
| **Orange River Mouth (5)** | 3,827 | 550.74 | - | - | - | - | 3 | 0.08% |
| **Ongers/Brak (6)** | 3,200,827 | 341,615.17 | 10019 | 0.31% | 40318 | 1.26% | 128581 | 4.02% |
| **Haartbees/Sak (7)** | 9,296,791 | 668,272.80 | 45791 | 0.49% | 141183 | 1.52% | 181912 | 1.96% |
| **Coastal Area (8)** | 2,858,155 | 61,849.82 | 4144 | 0.14% | 9501 | 0.33% | 5141 | 0.18% |
| **Upper Molopo & Upper Kuruman (9)** | 5,410,145 | 66,514.36 | 18130 | 0.34% | 7110 | 0.13 | 19016 | 0.35% |
| **Lower Kuruman & Lower Molopo (10)** | 5,464,194 | 138,024.61 | 32451 | 0.59% | 30601 | 0.56% | 43279 | 0.79% |
| | **33 267 470** | **1 423 845** | **122 407** | **811.63** | **2359 697** | **6.04** | **407 494** | **3.49** |

## 9.3. Groundwater Resource Units

### 9.3.1. Previous hydrogeological delineations

For the 2016 EWR study the following criteria were used to group areas into a set of unique groundwater resource units (GRUs):

- Importance of the RU to users (degree of groundwater dependence).
- Threat posed to water resource quality for users (aquifer vulnerability).
- Threat posed to water resource quality for the environment (baseflow).
- Degree of use (stress index).

The 2016 GRU demarcations were also based on the actual aquifer types which does not specifically falls on the surface water resource units (RUs, and subsequently the respective IUAs) thus, some quaternary catchments were spatially divided into two or three polygons that is difficult for the final gazetting of the WRC and RQOs of this catchment. The existing GRUs were reviewed with the focus of having a clearer demarcation correlating to the surface water integrated units of analysis (IUAs). A total of 25 GRUs, including the Lower Molopo River catchment consisting of 3 GRUs are therefore included in the Lower Orange Catchment area. The demarcations of these GRUs overlaid on the surface water IUAs are illustrated in Figure 38. The are, however, a few cases where specific hydrogeological characteristics of a quaternary catchment necessitated this specific quaternary catchment were translated from one IUA to a neighbouring IUA.

### 9.3.2. 2024 Groundwater Resource Unit Delineations

A total of 21 GRUs were mapped for the Lower Orange catchment for the 2016 EWR study but this has been reviewed and increased to 25 GRUs that correlates spatially with the surface water IUAs. The detail of the GRUs is listed in Table 40. This catchment consists of eleven (11) quaternary catchments where water supplies are solely from local groundwater resources varying from Insignificant BYC (*i.e.*, <0.1 L/s BYC) to Significant BYC (>5.0 L/s).

The main difference between the 2016 GRU demarcations (*i.e.*, these are merely demarcated by geohydrological differentiations) and the 2024 GRU demarcations is merely to align the latter GRUs into the proposed surface water IUAs for ease of final water resource classes and setting of resource quality objectives that is based on actual quaternary catchment demarcations. The 2016 GRU demarcations would for example required specific GIS applications during the interpretation of the Lower Orange catchment RDM results. Secondly, the RDM attributes (as per the 2016 EWR Study) are not that significantly different than those based on the 2024 hydrogeological differentiations.

To conclude, where the hydrogeological characteristics are playing a significant role, these areas will be highlighted “specific groundwater sites of importance” in the water resource classes and RQOs determined.

### 9.3.3. Delineation Approach and results

The following aspects were considered for the demarcation of the groundwater resources units, however, most of these aspects were found to be merely isolated cases resulting from individual land use activities where the number of boreholes used in the assessment were high, *i.e.,* smaller farming areas with stock kraals, municipal areas where several boreholes were used and mining areas (limited numbers).

#### 9.3.3.1. Groundwater Resource Category

As indicated above, the 2016 EWR GRU assessment used the hydrogeological characteristics as the dominant criteria to demarcate the 21 GRUs in specific polygons (using a “once-off” a high-level GIS translation); this, 2024 demarcation methodology focused on correlation with the surface water IUAs and the major hydrogeological characteristics to group the quaternary catchments into the IUA demarcations for the ease of the final gazetting of groundwater classes and RQOs.

#### 9.3.3.2. Groundwater Reserve

The 2016 EWR assessment included an estimated groundwater Reserve estimated for each quaternary catchment – these values fluctuate from quaternary catchment to quaternary catchment and was not considered as a criterion for demarcating the GRUs. A review of the groundwater Reserve values will be conducted in this assessment to adjust the figures (i) for the higher basic human need requirements (*i.e.*, updated population numbers) and (ii) for the effect of rainfall variations since 1980 (due to climate variations/changes). Groundwater reserves for the catchment will have to reviewed in the light of the changing parameters, *i.e.*, rainfall depths/patterns, population figures and water use figures since 2016. The required baseline information for the Lower Molopo River Catchment will have to be re-assessed for this project's objectives, *i.e.*, WRC and RQOs.

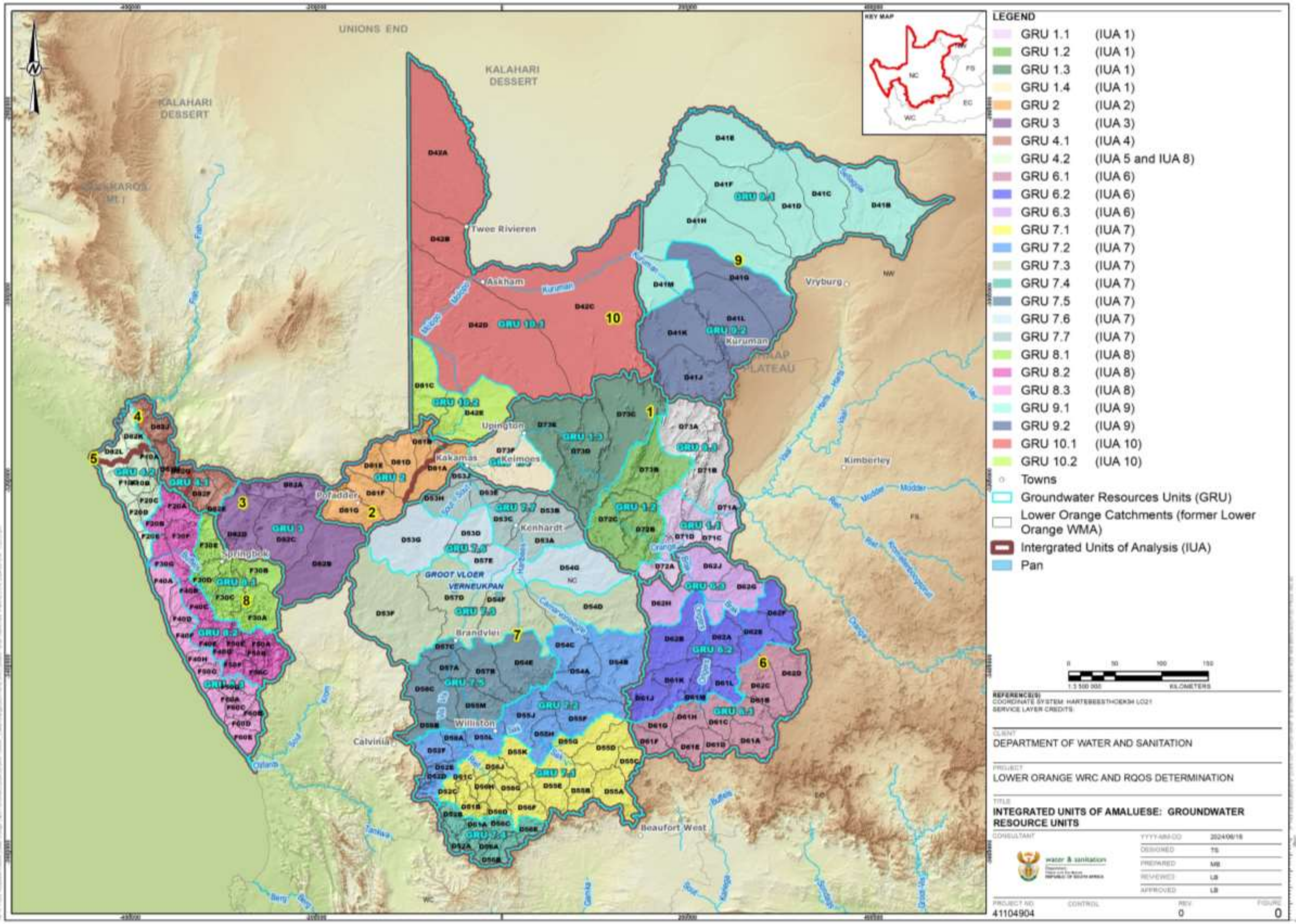



Figure 38: Map showing the demarcations of the surface water IUAs (colour) and the groundwater resource units (numbered 1 to 19)

**Table 40: 2024 Demarcated Groundwater Resource Units based on the 2016 EWR demarcations – reviewed for this study**

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area ($km^2$) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| **IUA 1:** GRU 1.1 | Taung-Prieska Belt-West Griqualand. | Hard rock formation incl. BIF, Ghaap Plateau DLMT and Karoo Dwyka Tillites | D71A, D71C, D71D & D72A. | 5,907 | 0.36 | A |
| **IUA 1:** GRU 1.2 | Bushmanland east - West Griqualand. | Hard rock formations incl. BIF and quartzites (folded/fractured strata) | D72B, D73B & D72C*. | 8,865 | 0.055 | A |
| **IUA 1:** GRU 1.3 | Western Kalahari - Bushmanland east. | Thin Kalahari Beds on hard rock formations consisting of meta-quartzites and granite-gneiss. | D73C, D73D & D73E | 9,592 | 0.052 | B |
| **IUA 1:** GRU 1.4 | Bushmanland east. | Hard rock formations consisting of granite-gneiss. | D73F. | 4,630 | 0.17 | B |
| **IUA 2:** GRU 2 | Bushmanland West. | Shallow Kalahari Beds overlying metamorphic terrane of poor groundwater quality. Hard rock formation consisting of various metamorphic rocks, *i.e.*, meta quartzites and granite-gneiss. | D81A[1], D81B, D81D, D81E, D81F, & D81G. | 10,115 | 1.02 | F [1]Outlier (D) |

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area ($km^2$) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| **IUA 3:** GRU 3 | Bushmanland west-Richtersveld. | Shallow Kalahari Beds overlying metamorphic terrane of <u>poor groundwater quality</u>. | D82A[1], D82B, D82C & D82D[2]. | 13,734 | 2.56 | ~F [1] Outlier (E) |
| **IUA 3:** GRU 4.1 | | Hard rock formation consisting of various metamorphic rocks, *i.e.*, meta quartzites and granite-gneiss. | D82E & D82F. | 939 | 0.15 | B |
| **IUA 4:** GRU 4.1 | Richtersveld. | Hard rock formation consisting of various metamorphic rocks, *i.e.*, meta quartzites and granite-gneiss. | D82G, D82H, & D82J, | 2,787 | 0.36 | ~D |
| **IUA 4:** GRU 4.2 | Far Northwestern Coastal Hinterland. | Coastal metamorphic terrane. | D82K[1] & D82L. | 1,661 | ~1.5 | D [1] Outlier (F) |
| **IUA 6** GRU 6.1 | Karoo Beaufort sandstone and shale East. | Higher recharge than the western region and moderately yielding. | D61A, D61B, D61C, D61D, D61E, D61F, D61G, D61H, D62C & D62D. | 13,878 | 9 | B |
| **IUA 6:** GRU 6.2 | Eastern Ecca Grp. (SNDS & SHLE). | Higher recharge than the western region. | D61J, D61K, D61L, D61M, D62A, D62B, D62E & D62F. | 18,222 | 3 | A/B |
| **IUA 6:** GRU 6.3 | Moderate thickness Ecca Grp, (SNDS) on Bushmanland (GNGS) | Higher recharge in the eastern region ⇨ better groundwater quality type. | D62G, D62J & D62H. | 6,804 | 0.05 | ~A |

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area ($km^2$) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| | and Taung-Prieska Belt (ANDE, TILL &SHLE). | | | | | |
| **IUA 7:** GRU 7.1 | Karoo Beaufort sandstone and shale West | Lower recharge towards the western part of GRU. | D51B, D51C, D52C[1], D55A, D55B, D55C, D55D, D55E, D55G, D55K, D56D, D56F, D56G, D56H & D56J. | 16,108 | 7 | A/B<br>[1] Outlier (E) |
| **IUA 7:** GRU 7.2 | Ecca Group sandstone and shale South and Central. | Typical Karoo sediment aquifers:(fractured/jointed). Numerous Karoo Dolerite (Jd) intrusions (dykes and sills, representing contact zone aquifer systems. | D54A, D54B, D54C, D55F, D55H, D55J, D55L, D52D, D52E, D52F & D58A. | 17,089 | 6 | B<br>(A-B-C-E) |
| **IUA 7:** GRU 7.3 | Ecca Group Carbonaceous shales west. | Typical Karoo sediment aquifers: (fractured/jointed).<br>Poor groundwater quality from marine sediments. | D53F[1], D54D[2], D54F, & D57D. | 21,359 | 0.42 | ~B<br>[1] Outlier (F) |
| **IUA 7:** GRU 7.4 | Karoo sandstone and shale southwest. | Typical Karoo sediment aquifers (fractured/jointed). Numerous Karoo Dolerite (Jd) intrusions (dykes and sills, representing contact zone aquifer systems.<br>Groundwater quality fresher due to slightly higher rainfall. | D51A, D52A, D52B, D56A, D56B, D56C & D56E. | 4,450 | 6 | B |

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area ($km^2$) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| | | Baseflow present (D51A) | | | | |
| **IUA 7:**<br>GRU 7.5 | Ecca Group sandstone and shale west. | Better water quality than other Ecca shales.<br>Pan present. | D54E, D55M, D57A, D57B, D57C, D58B & D58C. | 12,554 | 0.10 | B |
| **IUA 7:**<br>GRU 7.6 | Ecca Group shale west plus Dwyka Tillite, | Poor yield and groundwater quality. | D53D[1], D53G[2], D54G & D57E. | 13,048 | 0.27 | BC<br>[1] Outlier (C)<br>[2] Outlier (D) |
| **IUA 7:**<br>GRU 7.7 | Bushmanland Central Terrane: Gneiss, amphibolite, metaquartzite, schists, calc-silicates. | Metamorphic terrane of poor groundwater quality Poor water quality | D53A, D53B, D53C[1], D53E[2], D53H, & D53J. | 8,421 | 0.45 | ~C<br>[1] Outlier (F); &<br>[2] Outlier (B) |
| **IUA 8:**<br>GRU 4.2 | Far Northwestern Coastal Hinterland | Coastal metamorphic terrane. | F10A, F10B, F10C, F20C, F20D[1] & F20E | 4,211 | 0.61 | ~B<br>[1] Outlier (F) |
| **IUA 8:**<br>GRU 8.1 | Namaqualand west | Metamorphic terrane – Fresher water quality. | F30A, F30B, F30C, F30D[1] & F30E. | 7,293 | 0.49 | B/C<br>[1] Outlier (F) |
| **IUA 8:**<br>GRU 8.2 | Namaqualand west | Metamorphic terrane – Poor water quality (marine aerosol salinity). | F20A, F20B, F30F – F30G[1], F40B, F40C, F40E, F40G, F50A, F50B, F50C, F50E, & F50F. | 9,895 | 0.45 | ~B<br>[1] Outlier (F) |

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area (km²) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| **IUA 8:**<br>GRU 8.3 | Namaqualand coastal | Sediment cover over Nama (SNDS, LMST &QRTZ) and<br>Vanrhynsdorp Group (SNDS, SLTS, SHLE & LMST). | F40A, F40D, F40F, F40H, F50G, F50G,<br>F60A, [F60B, F60C, F60D & F60E]. | 6,568<br>[excl. QCs] | 0.19<br>[excl. QCs] | ~B<br>[excl. QCs] |
| **IUA 9:**<br>GRU 9.1 | Eastern Kalahari overlying various types of basement formations:<br>Greenstone Belts in Basement Granites;<br>Ghaap Plateau DLMT + BIF<br>Karoo SG Dwyka TILL. | Kalahari Group Aquifers with partly saturated paleo-drainage channels (upper ½ of GRU)<br>Thick (+6 m) Kalahari Sand on fractured & fractured & weathered aquifers (lower half of quaternary catchment)<br>Water quality and borehole yield class highly variable. | D41B[1], D41C, D41D[1], D41E, D41F, D41H, & D41M. | 57,540 | Na♦. | C/D<br>(B-C-D=E-F)<br>[1] Outlier (E+) |
| **IUA 9:**<br>GRU 9.2 | Eastern Kalahari overlying massive Ghaap Plateau DLMT + Asbesberge BIFs and Olifantshoek Grp LAVA & QRTZ. | Eastern Kalahari: Deep Kalahari Beds on Karoo Dwyka (N) and Basement Granites (S) with lava, BIF and dolomite outcrops.<br>Draining towards Lower Molopo River. | D41G[1], D41L[1], D41K & D41J[1]. | Na♦. | Na♦. | Na♦. |
| **IUA 9:** | Kuruman Hills (BIF) + Ghaap Plateau (DLMT) | Eastern Kalahari: Moderate thick Kalahari | D73A & D71B. | Na♦. | Na♦. | Na♦. |

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area ($km^2$) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| GRU 9.3 | & Olifantshoek Grp (QRTZ). | Beds on DLMT, BIF & QRTZ. | | | | |
| **IUA 10:** GRU 10.1 | Western Kalahari: (partial saturated Kalahari Beds). | Kalahari Group Aquifers with paleo-drainage channels (upper half of quaternary catchment) Thick (+6 m) Kalahari Sand on fractured & fractured & weathered aquifers (lower half of quaternary catchment) Water quality and borehole yield class highly variable. | D42A, D42B, D42C & D42D. | 29,146 | 8 | A/B |
| **IUA 10:** GRU 10.2 | Western Kalahari: (limited saturated Kalahari Beds). | Thin Kalahari Beds overlying Karoo Dwyka Grp (TILL) and Nama Grp. (QRTZ, SHLE & SNDS) all underlain by various Mokolian Era metamorphic rock formations (GRGS & QRTZ). Salinity due to primary (geological) conditions. | D42E[1] & D81C[2]. | 6,890 | ~0.53 | [1]=E [2]=C |

[1 or 2] One or more of the Quaternary Catchments in these GRUs are heavily over-utilised (Category E & F).

~ Based on statistical averages.

| GRU | Primary Name | Main Characteristics | Quaternary Catchments | Area (km²) | Stress Index (%) | Present Status Category (Qt) |
|---|---|---|---|---|---|---|
| * Geological formations are highly variable due to geological processes, *i.e.*, folding, fracturing, over thrusting and complex erosion and decomposition.<br>♦Only historic groundwater data available – not consistent, needs to be reviewed/upgraded to 2024 status. | | | | | | |

#### 9.3.3.3. Localised pollution

Quaternary catchments with elevated nitrate pollution are probably the result of localized pollution of groundwater sources due to anthropogenic activities, *i.e.*, sewage pollution and agricultural sites (*i.e.*, stock kraals). The nitrate concentrations at these sites are significantly high. Deep groundwater in the Kalahari West (GRU 16) have nitrate concentrations of >60 mg/l).

Elevated nitrate concentrations (>20 mg/l, up to 50% of boreholes) were noted in a few quaternary catchments in the Lower Orange catchment, *i.e.*,

- D62F (GRU 7);
- D58C (GRU 5);
- F40D (GRU 18);
- D82L (GRU 8);
- D82G (GRU 17);
- F30B (GRU 12);
- D52E (GRU 6);
- D56G (GRU 10; and
- D55F (GRU 6).

The results showing localized pollution could not be used as a criterion for GRU-IUA demarcation as the results show that these elevated cases are based on anthropogenic activities.

Fluoride concentrations are generally elevated in the Lower Orange catchment and is mainly contributed by the geological nature of the rock formations present. Practically all the quaternary catchments falling in the southwestern half of the Lower Orange catchment falls in the +50% of boreholes with fluoride concentrations >1.5 mg/l. The quaternary catchments along the northeastern perimeter of the catchment have also elevated fluoride concentrations (*i.e.*, ±55% of boreholes have fluoride concentrations >1.5 mg/l – except quaternary catchment D62F (GRU 7) and quaternary catchment D73E (GRU 1) for unknown reasons.

#### 9.3.3.4. Stress Index/Hotspots

An assessment of the Lower Orange catchment aquifer Classification (DWS, 2016) indicates that large portions of GRU 8, GRU 2, GRU 1, GRU 15 and GRU 4 are classified as having a Poor Aquifer Class.

According to Wentzel and Parsons (2006), groundwater resources can be classified by the significance of the aquifer (as specified in DWS, 2016):

- **Sole-source aquifer**: An aquifer used to supply >50% or more of water for a given area and for which there are no reasonably available alternative sources of water.
- **Major aquifer**: A high-yield aquifer system of good quality water with a Harvest Potential greater than 50 000 $m^3/km^2/a$ or average borehole yield greater than 2 l/s.
- **Minor aquifer**: A moderate-yield aquifer system of variable water quality with a Harvest Potential between 10 000 and 50 000 $m^3/km^2/a$, or average borehole yield between 1 and 2 l/s.

- **Poor aquifer**: A low- to negligible-yield aquifer system of moderate to poor water quality with a Harvest Potential less than 10 000 $m^3/km^2/a$, or average borehole yield less than 1 l/s.

This aspect has been included in the groundwater resource unit demarcations and will be regarded as important for the integrated units of analyses in the 2024 GDRM assessment specifically incorporation reviewed mean annual precipitation figures.

#### 9.3.3.5. Aquifer Vulnerability

An aquifer vulnerability rate formula (DRASTIC) was applied for the 2016 EWR study. The following criteria was used and weighing factor applied:

- D - Depth to groundwater;
- R - Recharge rate (net recharge);
- A - Aquifer media;
- S - Soil media;
- T – Topography; I - Impact on vadose zone; and
- C – Conductivity (Hydraulic Conductivity).

On scale of 0 to 110, (scaled from 60 to 170 points), only the following areas can be considered of moderately (to highly) vulnerable, *viz*.,

- The dolomite aquifers in the upper portion of quaternary catchment D71A (IUA 1, GRU 1.1):
    - Due to (i) high recharge index and (ii) potentially high abstraction rates possible.
- Quaternary catchment D62F (IUA 6, GRU 6.2) and quaternary D62D (IUA 6, GRU 6.1):
    - High abstraction rate for bulk municipal water supply scheme.

#### 9.3.3.6. Contribution to baseflow (as applicable)

Assessment of the groundwater contribution(s) to river baseflow in the 2016 EWR assessment, only two quaternary catchments were identified having “a minimal” baseflow. This report also quoted that “Consequently, groundwater plays a minimal role in maintaining baseflow in rivers”.

The surface water drainages along the coastal region (UIA 8, GRU 8.3 - Namaqualand Coastal) shows the following perennial baseflow (percentage of years): F50A (Groen River) - 32%, F50B - 5%, F50C - 2%, F50D - 9%, F50E - 4%, F50F - 4%, F50G - 4%, F60A (Sout River) - 55%, F60B - 55%, F60C - 55% and F60D - 55%. The typical rainfall pattern in the Namaqualand Coastal terrain does not create heavy downpours such as the continental rainfall pattern – the only times when sufficient surface runoff is generated to create effective drainage flows is during period of higher (e.g., 1½ x MAP).

The study team of the 2016 EWR study made an important comment regarding base flow support from groundwater: “the base flows found in these catchments therefore is not necessarily due to groundwater surface water interaction, but rather due to the rainfall occurring throughout the year” and further “no gauging weirs exist to calibrate these volumes, so the flows are uncertain” (DWS, 2016).

In important characteristic of the groundwater conditions in the Lower Orange catchment, is that the water level depths are most of the time several meters deeper than the base of the drainage systems. For example, in the Kalahari West and East GRUs, the groundwater levels are ±15 to 60 m below the valley bottom elevation.

Surface-groundwater interaction is merely classified as "a gaining groundwater" condition, but could be regarded as episodic events, only taking place during significant flooding of specific non-perennial river systems, *i.e.*:

- Molopo River (IUAs 9 & -10, GRUs 9.1 & -10.1);
- Kuruman River (IUA 9 & -10, GRU 9 & -10.1 &-10.2);
- Nossob River (IUA 10, GRU 10.1);
- Auob River (IUA 10, GRU 10.1);
- Hartbees River (IUA 7, GRU 7.7) and
- Buffels (IUA 8, GRU 8.1 &-8.2).

Thick(er) alluvial deposits along the upper Carnarvonleegte (UIA 7, GRU 7.2) and upper Brak River (UIA 6, GRU 6.1) are saturated and represents a significant (intergranular) aquifer system that is recharged by flooding of the local drainages. In some cases, "local groundwater driven baseflow" sections are present driven by the intergranular aquifer system for long-periods.

### 9.3.4. Conclusion

In addition to the aquifer characteristics (*viz.,* rock types, salinity and hydraulic status), the high variation in the rainfall depths over the catchment, and water use, the 2024 GRUs its will be treated as individual IUAs. However, based on estimated groundwater dependence values per quaternary catchment demarcations, the following GRUs will have a higher priority index during the water resource classification process and (crucial estimation(s) of) resource quality objectives:

- GRU 3 (IUA 3);
- GRU 7.5 (IUA 7);
- GRU 6.1, 6.2 & 6.3 (IUA 6);
- GRU 7.1 & 7.4 (IUA 7); and
- GRU 8.1, 8.2 & 8.3 (IUA 8).

In GRU 9.2 and GRU 9.3, *i.e.,* quaternary catchment D41J (Sishen-Kathu Area) and quaternary catchments D71B and D41J (Postmasburg and Lime Acres-Douglas) are highly impacted by mining operations and already depending on external water supply support (Vaal Gamagara Pipeline Scheme, now close to superfluous). In terms of long-term aquifer saturation level management, these quaternary catchments will have to be classified as highly impacted with specific classes and resource quality objectives.

## 9.4. Surface Water Resource Units

Based on the consideration on IUAs delineated and integration of the status quo components discussed above, as well as using expert knowledge including discussions with specialists, catchment water resource managers and the DWS study team, 27 surface resource units have been delineated in the Lower Orange Catchment. The RUs are shown in Figure 39 and are listed and described in Table 41. The resource units will form the basis of the RQO determination process once the water resource classes are set.

**Table 41: Surface Water Resource Units Delineated within IUAs**

| RU Number | Resource Unit (Description) | Catchment/s |
|---|---|---|
| **IUA 1: Upper Orange confluence to Augrabies** | | |
| **1.1** | Orange River to the Brak River confluence | D71A-D |
| **1.2** | Orange River from Brak River to Boegeberg weir | D72A-B; D73A-B |
| **1.3** | Orange River from Boegeberg weir to Upington | D73D-E |
| **1.4** | Orange River from Upington to Hartbees confluence | D73E-F |
| **1.5** | Kakamas to Augrabies Waterfall | Upper portion of 81A |
| **IUA 2: Downstream Augrabies to Pella** | | |
| **2.1** | Augrabies Gorge | 81A remaining |
| **2.2** | From below Augrabies Gorge to Pella | D81A-D81G |
| **IUA 3: Pella to Vioolsdrift weir** | | |
| **3.1** | As IUA delineation | D82A – D82G |
| **IUA: 4: Downstream Vioolsdrift to Orange River Estuary** | | |
| **4.1** | Vioolsdrift weir to D82H | D82H |
| **4.2** | Richtersveld National Park | D82J, D82K |
| **4.3** | Upper portion of D82L up to EFZ | D82L |
| **IUA 5: Orange River Estuary** | | |
| **5.1** | From EFZ (2km upstream (Ernest Oppenheimer Bridge) to ocean | D82L remaining portion |
| **IUA 6: Brak** | | |
| **6.1** | Upper Ongers River to confluence with Groen River | D61A – D61M |
| **6.2** | Upper reach of Brak River | D62C and D62D |
| **6.3** | Middle and lower reaches of Ongers Brak Rivers | D62A, B, D62E to D62J |
| **IUA 7: Hartbees/Sak** | | |
| **7.1** | Upper reaches of Catchment area | D54 to D58 |
| **7.2** | Hartbees | D53 |
| **IUA 8: Coastal Areas** | | |
| **8.1** | Holgat and Kamma catchments | F10-F20 |
| **8.2** | Buffels catchment area | F30 |
| **8.3** | Swartlintjies sub-catchment | F40A-40D |
| **8.4** | Spoeg, Bitter sub-catchment | F40E – F40G |
| **8.5** | Groen and Hartbees sub-catchments | F50A-G |
| **8.6** | Brak sub-catchment | F60A |
| **IUA 9: Upper Molopo and Upper Kuruman** | | |
| **9.1** | Kuruman tributaries | D41J, K, L, M, J, G |
| **9.2** | Upper Molopo | D41B to D41H |
| **IUA 10: Lower Molopo and Kuruman to confluence with the Orange River** | | |
| **10.1** | Middle Kuruman River to confluence with the Molopo River (includes middle reach of Molopo on catchment boundary) | D42C |
| **10.2** | Molopo River catchments to confluence with the Orange River | D42A, D42B, D42D, D42E, D81C |

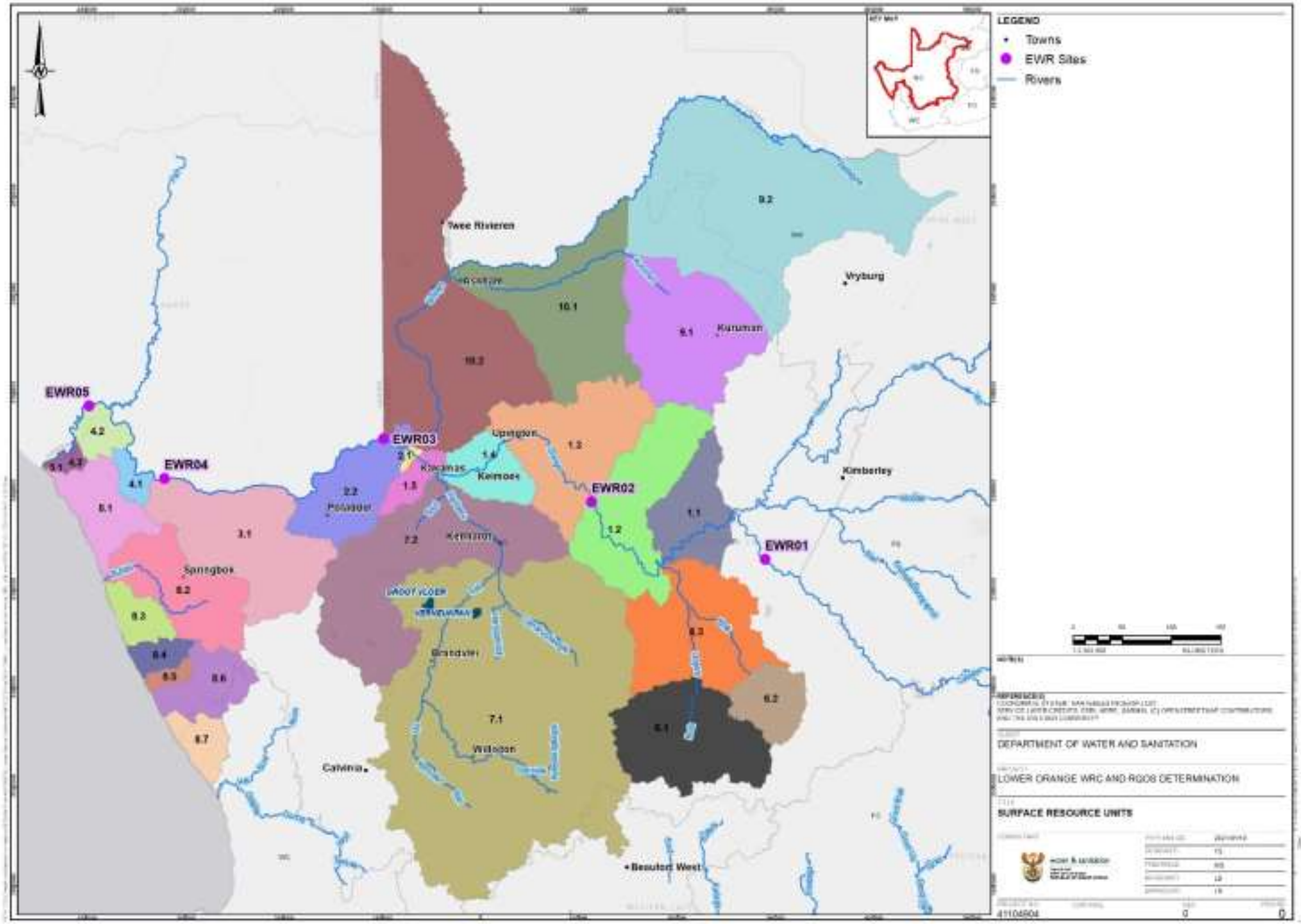



**Figure 39: Delineated Resource Units within the Preliminary IUAs**

# 10 DESCRIPTIONS OF INTEGRATED UNITS OF ANALYSIS (IUA)

## 10.1. IUA 1: Orange from Vaal confluence to Augrabies Waterfall

IUA 1 delineates the mainstem Orange River from the Orange-Vaal River confluence to the Augrabies Waterfall. It includes catchments D71A, D71B, B71C, D71D, D72A, D72B, C72C, D73B, D73C, D73D, D73E, D73F, ~80% D81A.

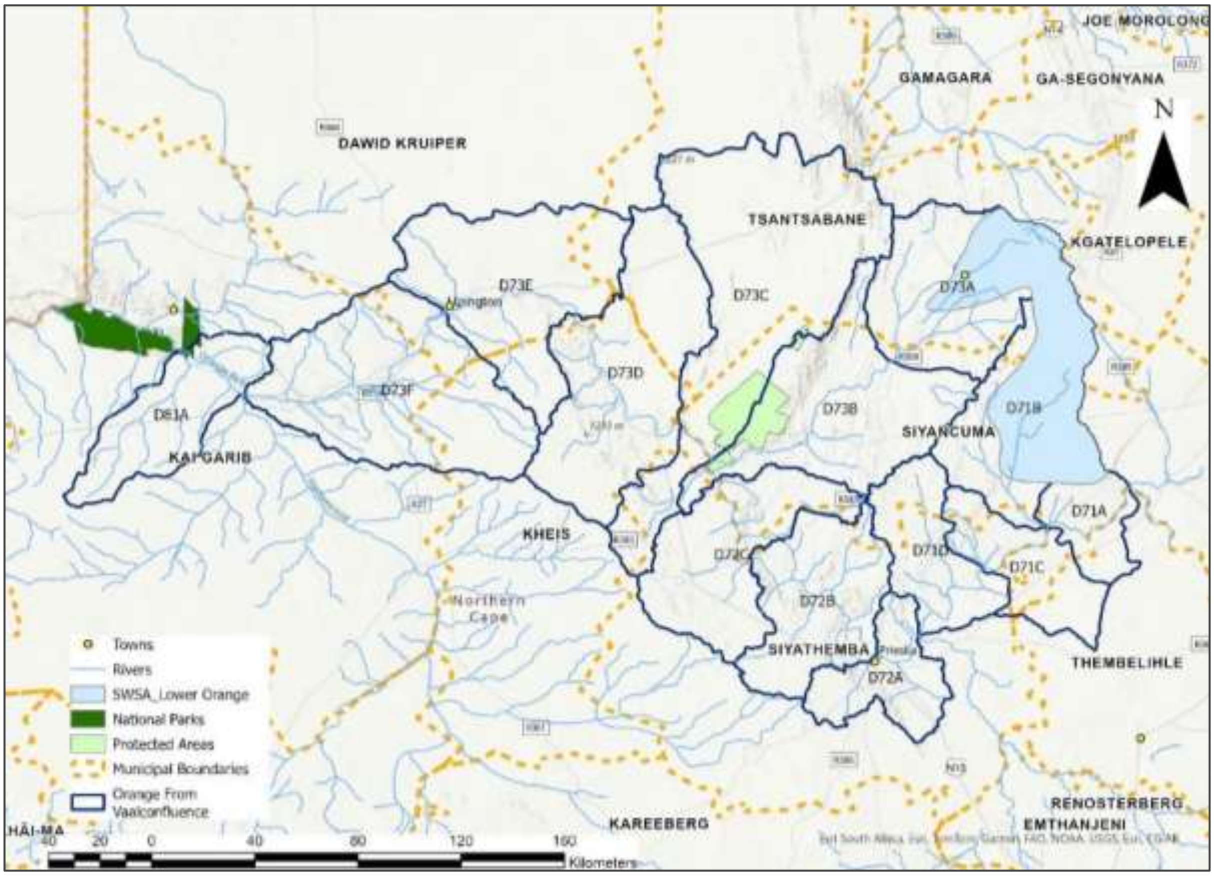



**Figure 40: Overview of boundaries and features in IUA 1 of the Lower Orange River Catchment**

### 10.1.1. Rationale

This region is very diverse with lowlands, hills and mountains with moderate and high relief, as well as closed hills and mountains with moderate and high relief, being the defining characteristics. The IUA delineation is based on the land use and associated impacts in the catchment area. The Orange River is the mainstem river with no major tributaries in the IUA. The IUA is dominated by intensive abstraction and irrigation along the mainstem river. The IUA boundary ends where the Augrabies waterfall begins, marking a natural and logical break in the system.

### 10.1.2. Overview

IUA 1 comprises 15 quaternary catchments straddling the Orange River from its confluence up to the Augrabies waterfall in quaternary catchment D81A which lies within the protected area of the Augrabies Falls National Park. Other protected areas within this IUA include Tierberg Nature Reserve, Glen Lyon Nature Reserve, Witsand Provincial Nature Reserve, Klaarwater Nature reserve and Rockwood Nature reserve. The area lies within parts of the municipalities of Kai !Garib, Dawid Kruiper, !Kheis, Siyancuma, Siyathemba and Tsantsabane in the Northern Cape province. Several towns, villages and settlements occur within the IUA with the main towns being Griekwastad, Postmasburg, Prieska, Groblershoop, Upington, Keimoes and Kakamas.

### 10.1.3. Water Resources

The key water resource in the IUA includes the main stem of the Orange River. Most of the IUA falls into the Agricultural SEZ, with the main land transformation being for irrigated agriculture along the Orange River and residential urban areas around the settlements and towns of the IUA. Six quaternary catchments (D71A, D71B, D71C, D71D, D72A and D73A) fall into the Mining SEZ with the main land transformation being for mineral mining and semi-precious stone mining. The IUA includes the groundwater SWSA, the Southern Ghaap Plateau.

The reach includes large weirs, *viz*. Boegeberg and Neusberg as part of major abstraction schemes. The river is impacted by irrigation return flows and wastewater discharges from Upington, Keimoes, Kakamas and Prieska.

### 10.1.4. Demographics and Socio-Economic Profile

The population is estimated as 304,820 (Stats SA Census 2011 adjusted) with approximately 86,041 households. Approximately 5.1% of the population has a higher education and 6.6% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within is estimated at 23% (NT, 2021).

The majority of residents have access to formal water services (Figure 41), with 91.2% having access to piped water inside their dwelling or yard and 7.4% to piped water where the community tap is within 200m of the household. People are mainly dwelling in formal dwellings with the proportion ranging from 66.3% to 87.1% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022). A small portion, 1.4% have limited access to piped water as the source is greater than 200m from the household or is from a water vendor. The residents that rely on informal water sources access water from rivers or streams (46%), boreholes (29%) or from dams and pools (2%) or rain-water tanks (3%) or other water sources (20%).

#### Economic sectors

The key land use is commercial irrigated agriculture along the Orange River and the IUA includes the Boegoeberg, Upington, Kakamas and Keimoes irrigation scheme canals. Other commercial agricultural activities include livestock farming.

Another important land use in this IUA is mining activity occurring within the quaternary catchment D73A (iron ore mining) and mineral mining activity within D71 quaternary catchments which includes open cast alluvial diamonds and tigers eye mines.

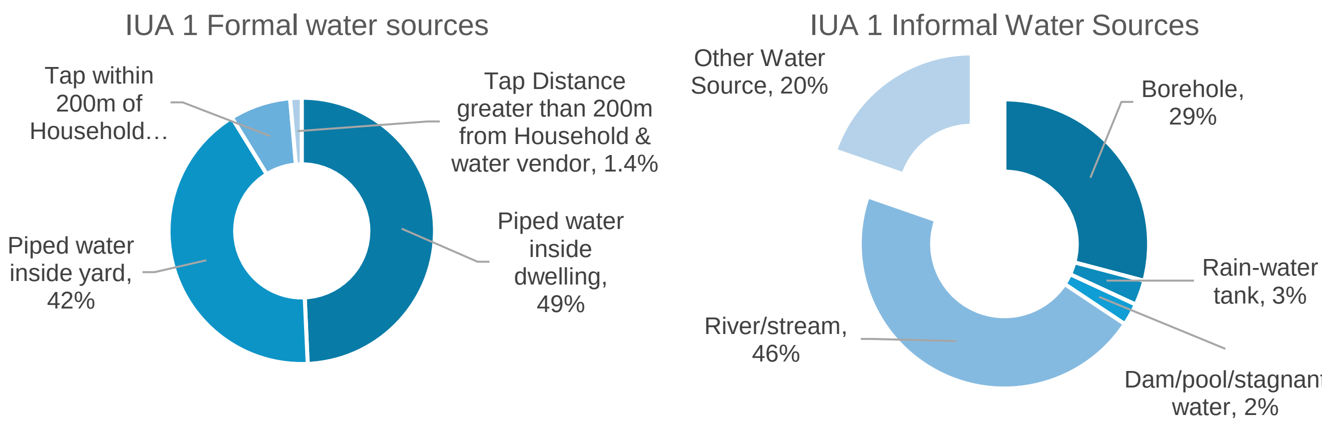



**Figure 41: Access to water services in IUA1**

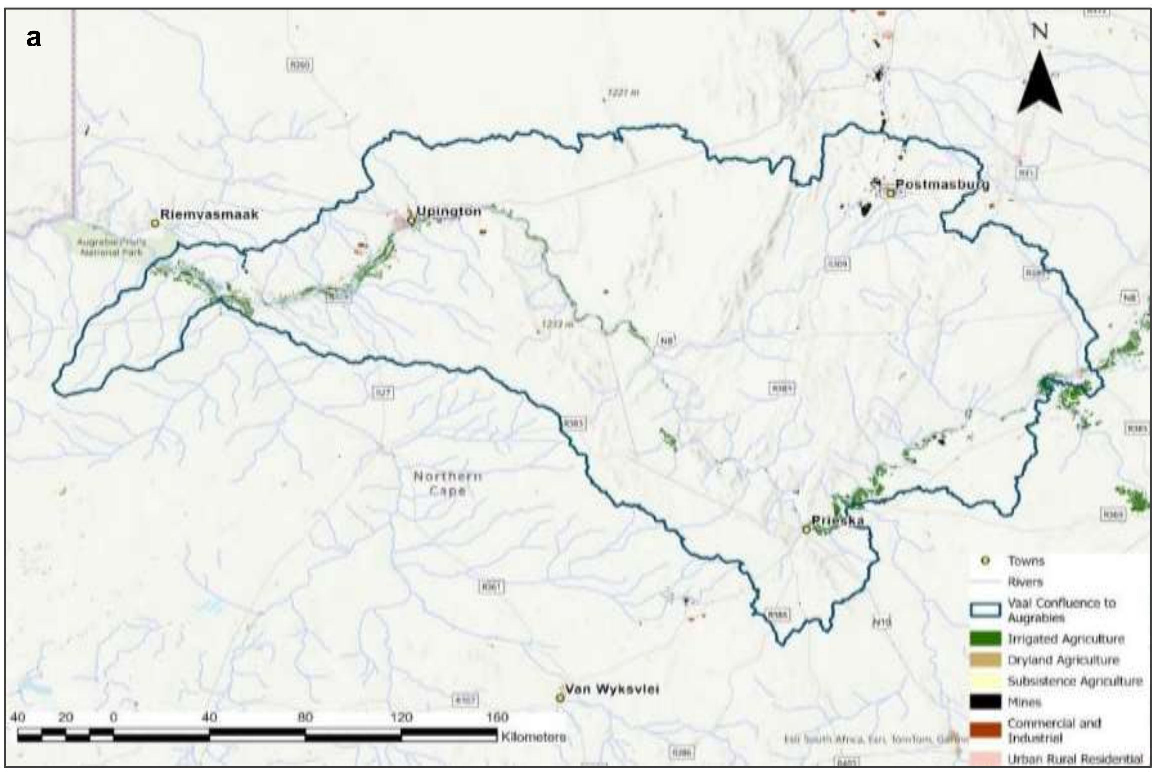



**Figure 42: Land Use by land cover in IUA 1 in the Lower Orange catchment (DFFE, 2020)**

The main economic drivers of municipalities falling within IUA 1 are set out in Table 42.

**Table 42: Economic drivers relevant to IUA 1**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 & 2023) |
|---|---|
| Kai !Garib | Kakamas and Keimoes are the main towns found within this IUA. The area in the IUA is characterised by irrigation agriculture along the Orange River including mainly vineyards (grapes - export (raisins), raisins, juice, table and wine), pecan nuts and citrus plantations. Other crops grown include grain and cotton.<br>Tourism is also an economic driver within this part of the IUA with activities along the Orange River and the Augrabies Falls National Park. The main water use is for agriculture and domestic use for the towns and settlements and farms within the IUA. |
| Dawid Kruiper | The main town in is Upington and there are several farming and residential settlements along the Orange river.<br>Prominent economic sectors and activities include agriculture, tourism and manufacturing. The manufacturing is focused on value adding of agricultural, mining, construction and renewable energy products.<br>Main water use is in agriculture for irrigation and domestic use. Manufacturers of wine and beverages are also water users in this IUA. |
| !Kheis | Grobblershoop and Grootdrink along the Orange River are the main towns in the IUA.<br>The largest economic sector is agriculture. Irrigation agriculture occurs adjacent to the Orange River with a large proportion of the area under grapes and in particular table grapes. Wine is produced at cellars in both main towns as well as grape juice. Other key crops include cotton, corn, wheat, tomatoes, peanuts, musk melons and pumpkins.<br>Agriculture activities in the IUA also include commercial livestock farming with sheep for meat production and the household farming in the IUA focuses on poultry, sheep and goats.<br>Water users include manufacturers in the food and beverages sector, domestic and for agriculture. |
| Siyancuma | Towns within the IUA include Prieksa, Marydale, Copperton and Niekerkshoop.<br>Economic sector activity includes agriculture and some mining activities. Irrigation agriculture of grains and vegetables along the Orange River mainly in and around Prieska. Commercial livestock farming of cattle, goats and sheet and game farming occurs in the IUA.<br>Mining activities include opencast semi-precious stone and alluvial diamond mining.<br>Water users include agriculture and domestic use. |
| Siyathemba | The main urban settlement is Griekwastad. This part of the IUA includes irrigation agriculture along the Orange River and mining activity includes alluvial diamond mines and one semi-precious stone mine. |

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 & 2023) |
|---|---|
| | Water users include agriculture and domestic use. |
| Tsantsabane | Postmasburg is the main town and there are several smaller settlements in the IUA. The key economic activity is mining followed by livestock farming. Mining is focused on iron ore and forms part of the Gamagara Corridor which is a mining belt focusing on iron and manganese. There are three iron ore mines within quaternary catchment D73A in this IUA.<br><br>Water users include livestock watering and domestic use. |

In IUA 1, the estimated contribution of the economic sectors to the Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 43 and Table 44.

**Table 43: Economic sectors in IUA 1 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R4,266 | 16% |
| Mining | R4,798 | 18% |
| Manufacturing | R1,705 | 7% |
| Electricity & water | R809 | 3% |
| Construction | R1,196 | 5% |
| Wholesale & retail trade; catering and accommodation | R2,875 | 11% |
| Transport & communication | R3,127 | 12% |
| Financial services | R3,271 | 13% |
| General government | R2,873 | 11% |
| Community, social & personal services | R1,216 | 5% |
| **Total GDP** | **R26,135** | |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA. | | |

**Table 44: The estimated employment by economic sector for IUA 1 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 30,648 | 35.0% |
| Mining | 1,875 | 2.1% |
| Manufacturing | 3,352 | 3.8% |
| Electricity & water | 293 | 0.3% |
| Construction | 4,229 | 4.8% |

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Wholesale & retail trade; catering and accommodation | 15,134 | 17.3% |
| Transport & communication | 2,971 | 3.4% |
| Financial services | 6,835 | 7.8% |
| General government | 11,852 | 13.5% |
| Community, social & personal services | 10,359 | 11.8% |
| **Total Employment** | **87,547** | |

### 10.1.5. Ecosystem Services

Notable locations include the towns of Upington and Prieska, as well as the Klaarwater Nature Reserve, Rockwood Nature Reserve, Witsand Provincial Nature Reserve, and Glen Lyon Nature Reserve. The primary water resource in this area is the Orange River, which runs from the Orange/Vaal confluence to the Augrabies Waterfall. The Orange River is accompanied by a range of aquatic and terrestrial ecological infrastructure.

There are several regionally significant aquatic resources, including the Orange River itself, its tributaries, wetlands, and strategic groundwater sources located in the western part of the region. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 45).

### 10.1.6. River Ecological information and PES

The ecological condition of the Orange River reach in the IUA ranges from moderately modified to largely modified (C and D category PES). A small reach in quaternary catchment D73F has a PES of an E category (in the vicinity of Upington, Keimoes and Kakamas. This is driven by flow and non-flow impacts. The IUA includes 1 EWR sites, EWR 02 (Orange at Boegoeberg in D73C), and a Joint Basin Survey site (JBS), JBS3-43 D72B also at Boegoeberg.

### 10.1.7. Wetlands

The wetland extent (area) and percentage of area within IUA 1 is presented in Table 38.  The IUA includes depression, seep and unchannelled valley bottom wetlands, covering 2% of the catchment area. The priority wetlands are associated with the mainstem Orange River.

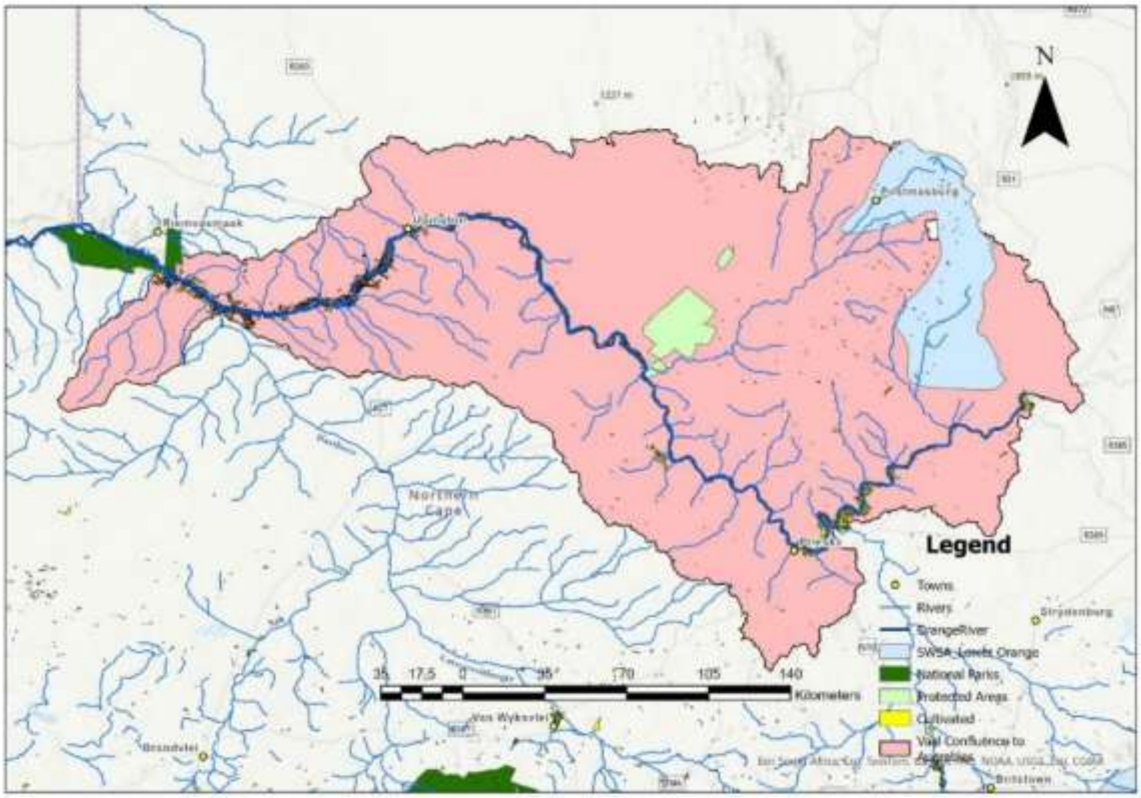



**Figure 43: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 1 in the Lower Orange Catchment**

**Table 45: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 1 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Food | Orange River and its tributaries; ephemeral Wetlands | Significant to Communities in the Upington, for fishing in the Upington canal | Households, Society |
| | Fresh Water | Orange River and its tributaries; ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities of Upington and Kakamas and Keimoes | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Raw materials | ephemeral Wetlands | Significance to Subsistence Farmers | Agriculture; Households, Society |
| | Medicinal resources | ephemeral Wetlands | Significance to Rural Communities | Households, Society |
| Regulating | Climate regulation | ephemeral Wetlands | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | ephemeral Wetlands; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities of Upington and Prieska. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | ephemeral Wetlands; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities of Upington and Prieska. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |

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

### 10.1.8. Groundwater

The GRUs included in this IUA are:

- GRU 1.1 (Taung-Prieska Belt – Various rock formation consisting of tillite, dolomite and banded ironstone overlain by surface calcrete and Kalahari Sand).
  - Stress Index = 3%, Moderate aquifer yield class; and
  - Fractured aquifer system with potential of ideal to good water quality types, except quaternary catchment D71C with primary saline water due to Karoo Dwyka tillite rock formation.
  - Proposed PSC: A/B.
- GRU 1.2 (West Griqualand/Bushmanland East – Various rock formations consisting of granite-gneiss (west), and meta-quartzites (east) – moderate-high deformed (folded).
  - Stress Index = ±6%, Moderate to Low aquifer yield class; and
  - Fractured aquifer system with potential of ideal to good water quality types.
  - Proposed PSC: A/B.
- GRUs 1.3 & 1.4 (Bushmanland East – Metamorphic Terrane consisting of QRTZ and GNGS):
  - Stress Index = ±5%, Moderate to Low aquifer yield class; and

  - Fractured and Intergranular & Fractured (GRU 1.4) aquifer system with potential of Good to Marginal water quality types.
  - Proposed Present Status Category (PSC): A/B
- GRU 9.3 (Kuruman Hills Formation (BIF) & Ghaap Plateau Subgroup (DLMT) & Olifantshoek Grp (LAWA & QRTZ):
  - Stress Index = <20%, Moderate to Significant yield class; and
  - Fractured aquifer systems (BIF, LAWA * QRTZ) and Karst aquifer system (DLMT).
  - Ideal to Good water quality types.
  - Proposed PSC: A/B.

*Summary:*

Groundwater resources not significantly affected by water use activities except in GRU 9.3 (mine dewatering).

## 10.2. IUA 2: Downstream Augrabies to Pella

The IUA is delineated from downstream the Augrabies waterfall to the town of Pella. It includes the lower portion of quaternary catchment D81A (10%) to the outlet of D81G.

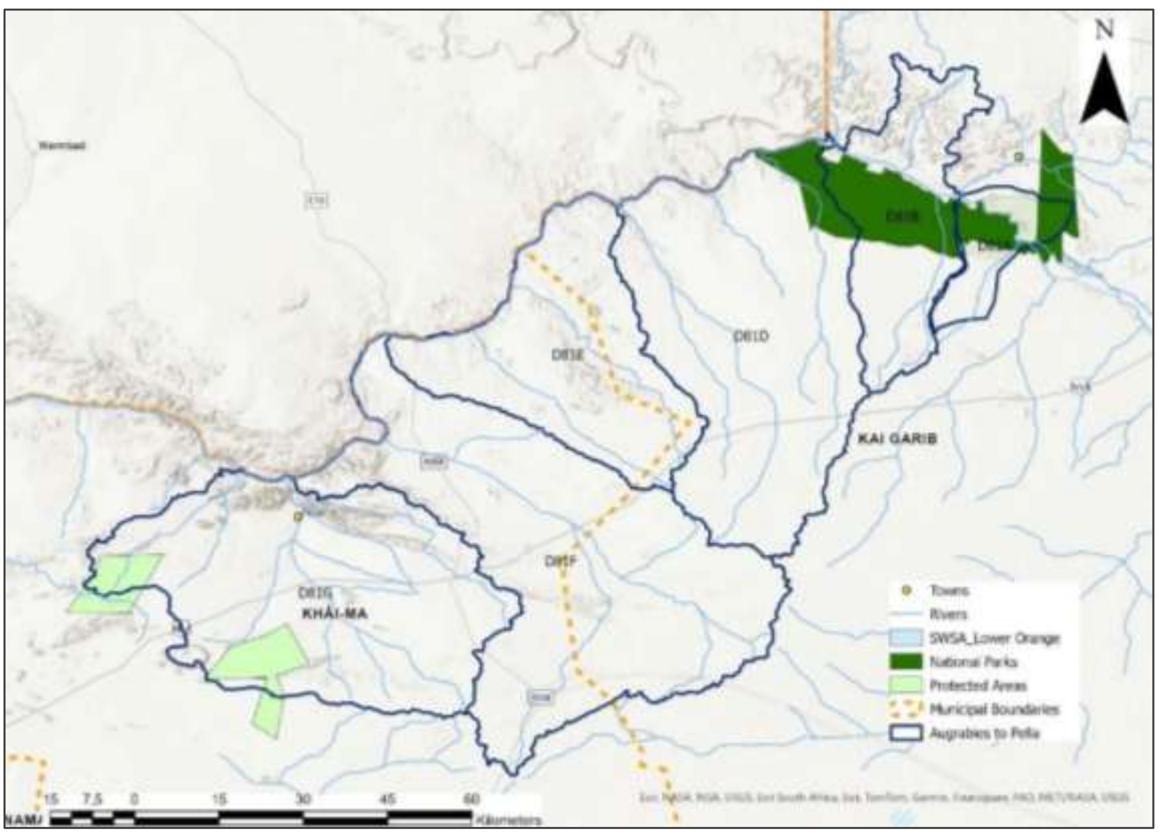



**Figure 44: Overview of boundaries and features in IUA 2 of the Lower Orange River Catchment**

### 10.2.1. Rationale

The IUA comprises part of the Orange River Gorge Ecoregion is characterized by closed hills, mountains, moderate and high relief. The IUA is defined from the natural and logical break at the base of the Augrabies waterfall downstream to Pella. Land use along this reach is similar, namely agricultural crops and extensive irrigation.

### 10.2.2. Overview

The IUA is situated downstream of Augrabies up to Pella. This IUA lies along the border of Namibia in the Northern Cape province where it shares the Orange River with Namibia. The IUA is composed of two partial sections of municipalities, Khâi-Ma LM and Kai Garib LM. The IUA composes of 6 quaternary catchments, D81A, D81B, D81D, D81E, D81F and D81G. The IUA includes the towns of Pofadder, Pella, Onseepkans and Vredesvallei.

### 10.2.3. Water Resources

The key water resource in the IUA includes the main stem of the Orange River in the north along the border and across the northeast of the IUA. There is some irrigation agricultural activity alongside the Orange River. There are the protected areas of the Gamsberg Nature Reserve in this IUA, part of the Augrabies Falls National Park area. The IUA lies within the Agricultural SEZ. The IUA includes the tributaries, Brabees, Bul, Kraalputs se Loop, Narries se Loop, Yas se Laagte, Samoep, Kaboep, T-Goob se Laagte, all largely ephemeral systems.

**Demographics and Socio-Economic Profile**

The population is estimated as 10,400 (Stats SA Census 2011 adjusted) with approximately 3,200 households. Approximately 30% completed secondary school. The unemployment rate was estimated as 17% (NT, 2021).

There is close to 100% of residents having access to formal water services. Approximately 4.1% of the population have access to piped water inside their dwelling and 3.6% of the population which have piped water in their yards. The remaining 92% of the population have access to a communal tap within 200m of their household (Figure 45).

**Economic Sectors**

The key land use is residential settlements in Pofadder, Pella, Onseepkans, and Vredesvallei. An important sector and land use is commercial irrigated agriculture along the Orange River. This IUA has some mining activity with quarrying for granite and sand mining, semi-precious stone mining and alluvial diamond mining. There are two mines in the western part (D81G) that mine zinc, lead and copper.

The main economic drivers and municipalities falling within IUA 2 are set out in Table 46.

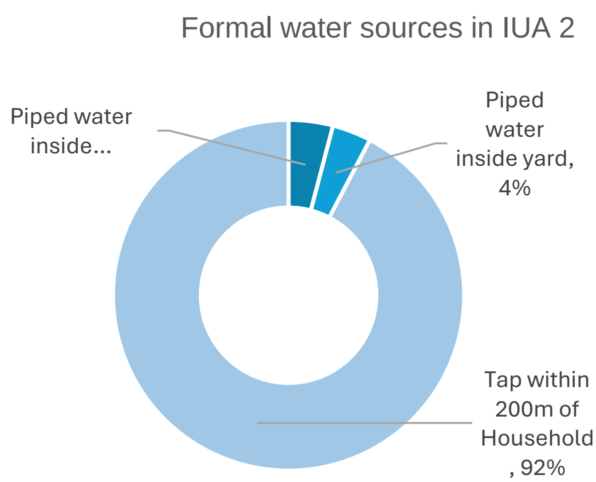



**Figure 45: Breakdown of the formal water sources within IUA 2**

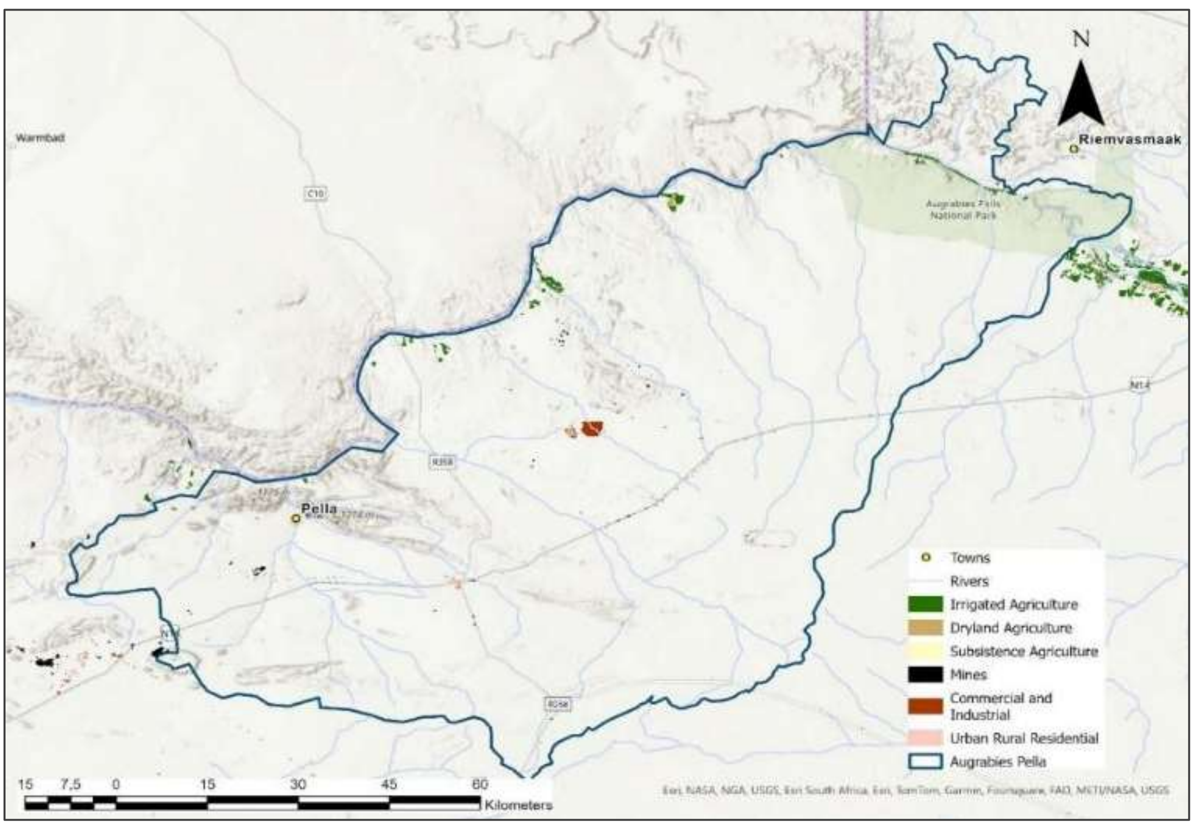



**Figure 46: Land Use by land cover in IUA 2 in the Lower Orange catchment (DFFE, 2020)**

**Table 46: Economic drivers relevant to IUA 2**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs) |
|---|---|
| Khâi Ma | Pofadder and Pella are the main economic areas of this part of the IUA. There is some irrigated agriculture in this section of the IUA along the Orange River consisting mainly of date plantations for local and export markets. Additionally, there is a large solar power plant (Xina Solar One Power Station) north of Pofadder.<br>Mining in this municipality within IUA 2 includes sand mining and mining of zinc, copper and lead.<br>Agriculture and domestic use are the main users of water in this section of the IUA. |
| Kai !Garib | Vredesvallei is the main town area in this IUA. There are large irrigation agriculture farms in this section of the IUA along the Orange River farming table grapes and dates. Southern Farms in this area has the largest date plantation farm in the Southern hemisphere.<br>There is an alluvial diamond mine north of the Orange River in quaternary catchment D81B.<br>Agriculture and domestic use are the main users of water in this section of the IUA. |

The contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 47 and Table 48.

**Table 47: Economic sectors in IUA 2 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R266 | 21.23% |
| Mining | R431 | 34.44% |
| Manufacturing | R108 | 8.66% |
| Electricity & water | R14 | 1.12% |
| Construction | R72 | 5.73% |
| Wholesale & retail trade; catering and accommodation | R78 | 6.26% |
| Transport & communication | R67 | 5.32% |
| Financial services | R50 | 4.01% |
| General government | R115 | 9.19% |
| Community, social & personal services | R51 | 4.05% |
| **Total GDP** | R1,253 | 100.00% |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA. | | |

**Table 48: The estimated employment by economic sector for IUA 2 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 2,131 | 49.11% |
| Mining | 204 | 4.69% |
| Manufacturing | 226 | 5.22% |
| Electricity & water | 5 | 0.12% |
| Construction | 126 | 2.91% |
| Wholesale & retail trade; catering and accommodation | 507 | 11.69% |
| Transport & communication | 70 | 1.62% |
| Financial services | 182 | 4.18% |
| General government | 527 | 12.14% |
| Community, social & personal services | 361 | 8.32% |
| **Total employment** | 4,339 | 100.00% |

### 10.2.4. Ecosystem Services

This region encompasses a diverse range of aquatic and terrestrial ecological infrastructure associated with the Orange River and its tributaries, such as Brabees, Bul, Kraalputs se Loop, Narries se Loop, Yas se Laagte, Samoep, Kaboep, and T-Goob Se Laagte. These natural features play a crucial role in providing a variety of ecosystem services that directly benefit the surrounding communities.

The region is home to protected areas such as the Augrabies National Park and Riemvasmaak Wetland. These protected areas are of utmost importance for conservation efforts, as they serve as vital habitats that safeguard the natural environment and biodiversity of the region. By preserving these unique ecosystems, they significantly contribute to maintaining the overall ecological balance and ensuring the long-term sustainability of IUA 2.

Significant aquatic resources in the region include the Orange River and its tributaries, as well as wetlands. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 49).

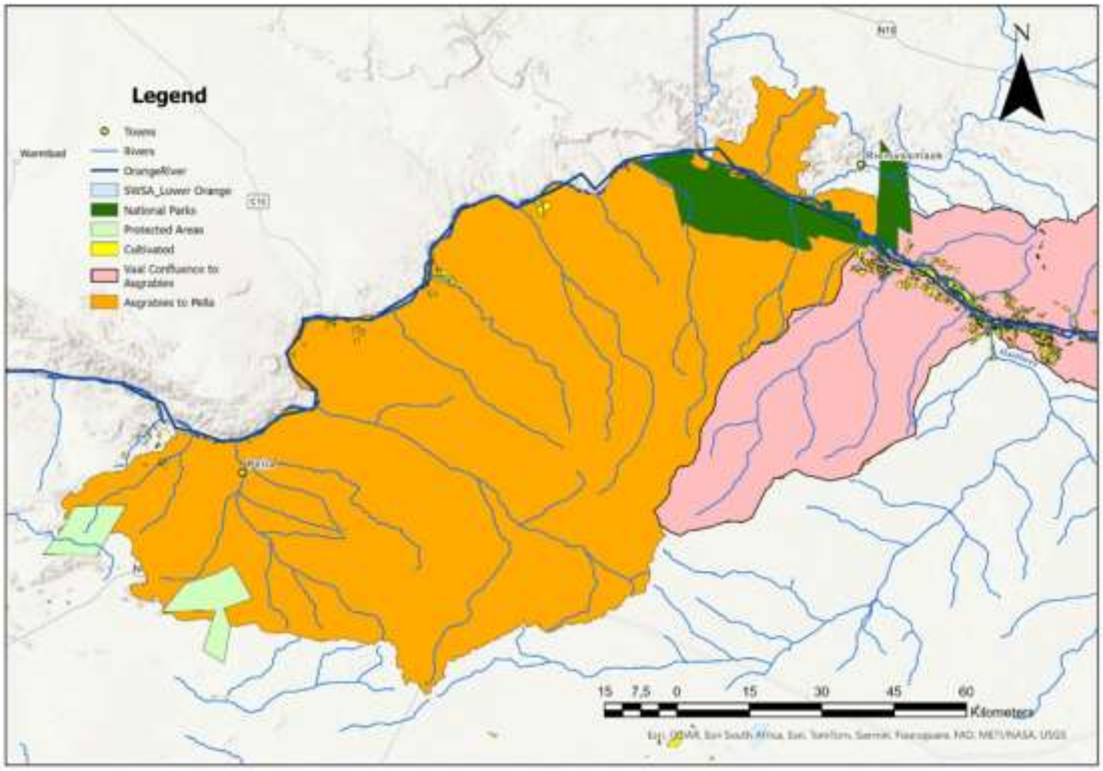



**Figure 47: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 2 in the Lower Orange Catchment**

**Table 49: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 2 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Food | Orange Rivers and its tributaries; Riemvasmaak Wetland; | The Orange River is significance to the Community of Pofadder for fishing. | Household |
| | Fresh Water | Orange Rivers and its tributaries; Riemvasmaak Wetland; ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA and to the Pofadder town for water supply. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Raw materials | Riemvasmaak Wetland; ephemeral Wetlands | Significance to Subsistence Farmers | |
| | Medicinal resources | Riemvasmaak Wetland; ephemeral Wetlands | Significance to Rural Communities | |

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Regulating | Climate regulation | Riemvasmaak Wetland; ephemeral Wetlands | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | Riemvasmaak Wetland; ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | Riemvasmaak Wetland; ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Riemvasmaak Wetland; ephemeral Wetlands; Orange Rivers and its tributaries | Major significance to commercial agriculture sector | Agriculture |
| | Biological control | Riemvasmaak Wetland; ephemeral Wetlands; Orange Rivers and its tributaries | Major significance to commercial agriculture sector | Agriculture; Households |
| Cultural | Landscape & amenity values | Protected Areas (Augrabies National Park); Orange Rivers and its tributaries | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | Riemvasmaak Wetland; ephemeral Wetlands; Orange Rivers and its tributaries | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Society; Tourism |
| | Maintenance of genetic diversity | Protected Areas (Augrabies National Park) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | Agriculture; Tourism; Society |

### 10.2.5. River Ecological information and PES

The Orange River is largely in a B and C PES ecological category. The river ecological condition is driven by flow and non-flow impacts. The IUA includes 1 EWR site, EWR 03 at Augrabies, and a JBS site, JBS3 (2021) -OSAEH48.

### 10.2.6. Wetlands

The wetland extent (area) and percentage of area within IUA 2 is presented in Table 38. The IUA includes depression, seeps and channelled valley bottom wetlands, covering 2% of the catchment area. The priority wetlands are associated with the mainstem Orange River.

### 10.2.7. Groundwater

The GRUs included in this IUA are:

- GRU2 (Bushmanland West - Metamorphic Terrane)
  - Stress Index = 74%, Poor to Seriously modified yield status; and
  - Fractured aquifer system with Poor groundwater quality type, viz., fluoride and salinity.
  - Good to Marginal water quality types, but Poor in quaternary catchment D81B.
  - Proposed PSC: D/E (varies from B to F)

*Summary:*

Groundwater quality is not good due to poor rainfall recharge (lack of periodic refreshing by rainwater recharge) and primary geological conditions (specific water-rock dissolution). Moderately/Low used, although borehole yield class are Insignificant to Low yield classes (<0.5 L/s).

## 10.3. IUA 3: Pella to Vioolsdrift Weir

The IUA is delineated from Pella to the Vioolsdrift weir at the outlet of D82G (D82A-D82G). The Orange River is the main river with all tributaries being ephemeral.

### 10.3.1. Rationale

The IUA comprises part of the Orange River Gorge Ecoregion characterized by closed hills, mountains, moderate and high relief. The IUA is delineated from Pella to Vioolsdrift weir which forms a logical break in the system. The area is dominated by intensive agricultural on both sides of the Orange River (South African and Namibian).


**Figure 48: Overview of boundaries and features in IUA 3 of the Lower Orange River Catchment**

### 10.3.2. Overview

Pella to Vioolsdrift Weir IUA comprises six quaternary catchments. The northern boundary of the quaternary catchments is alongside the Orange River. The are few protected areas in the southern part of quaternary D82C. The IUA lies within parts of the local municipalities of Nama Khoi, Khâi-Ma and Kamiesberg. Several towns, and settlements occur within the IUA including Goodhouse, Aggeneys, Concordia and Vioolsdrift.

### 10.3.3. Water Resources

The key water resource in the IUA includes Orange River, running along the border between South Africa and Namibia and several ephemeral river tributaries. The IUA falls into the Mixed Use SEZ 1 of the Lower Orange River catchment area. Land use in the IUA includes agriculture near the Orange River and mining activities which falls in part of the D82C quaternary, near the residential area Aggeneys and quarrying in D82A. The IUA includes the Vioolsdrift abstraction weir, part of a notable irrigation scheme known as the Vioolsdrift-Noordoewer Joint Irrigation Authority Scheme - into canals for irrigation along South Africa and Namibia.

### 10.3.4. Demographics and Socio-Economic Profile

The population is estimated as 10 970 (Stats SA Census 2011 adjusted) with approximately 3 443 households. Approximately 5.4% of the population has a higher education and 1.2% of the population have no schooling (Stats SA Census 2022 based on municipal data averaging for municipalities falling within the IUA). The unemployment rate within IUA 3 is estimated at 20% (NT, 2021).

The majority of the population have access to formal water services. Approximately 53% of the population have access to piped water inside their dwelling, 11% of the population have piped water in their yards, and the remaining 36% of the population have access to a communal tap within 200m of their household (Figure 49).

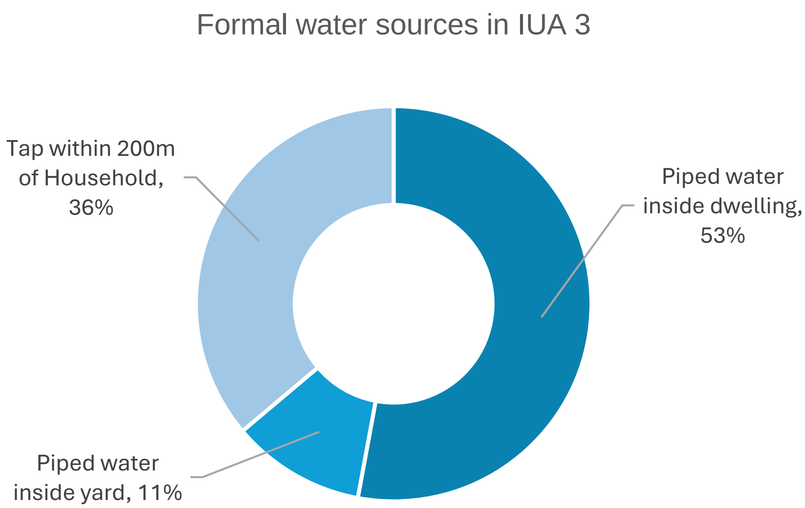



**Figure 49: Access to water services within IUA 3**

### Economic sectors

The main land use and economic activities for IUA 3 is from residential settlements and mining activity which occurs within the D82C quaternary catchment. The minerals which are mined from the underground mine are zinc, lead, copper and silver near Aggeneys mines. Additional mining activity from a granite mine near Goodhouse and a quarry (aggregate) in D82C also occurs within this IUA. There is minor agriculture in the D82A and the D82F quaternary catchments near the Orange River.

The main economic drivers and municipalities falling within IUA 3 are set out in Table 50.

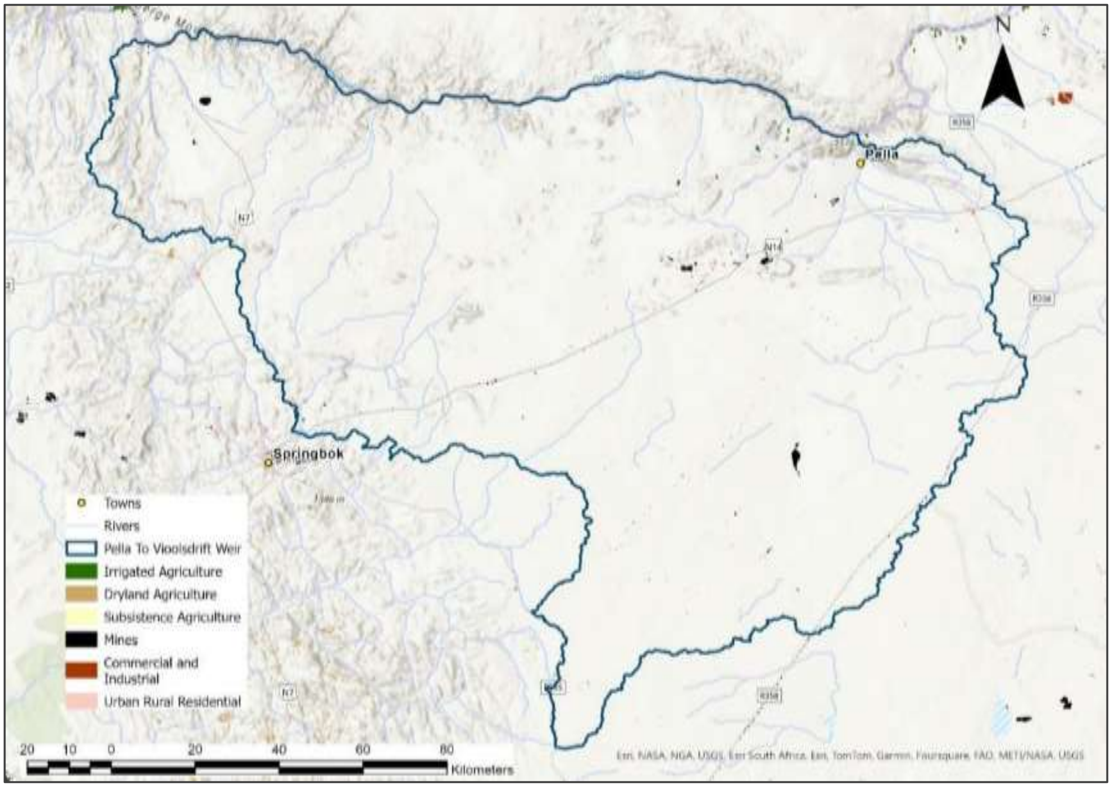



**Figure 50: Land Use by land cover in IUA 3 in the Lower Orange catchment (DFFE, 2020)**

**Table 50: Economic drivers relevant to IUA 3**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| Khai-Ma | Aggeneys is the main town found within this IUA. There are small agriculture areas near the Orange River.<br>An important land use and economic contribution is from the mineral mining of zinc, lead, copper and silver near Aggeneys.<br>The main water use is for agriculture and domestic use for the towns, settlements and farms within the IUA. |
| Nama Khoi | The main towns in IUA are Vioolsdrif, Goodhouse and Concordia which generate some economic activity.<br>Economic sectors and activities include agriculture along the Orange River and granite mining near Goodhouse. |

In IUA 3 the contribution of the economic sectors to the Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 51 and Table 52.

**Table 51: Economic sectors in IUA 3 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | 66 | 4.26% |
| Mining | 767 | 49.44% |
| Manufacturing | 88 | 5.66% |
| Electricity & water | 48 | 3.12% |
| Construction | 61 | 3.92% |
| Wholesale & retail trade; catering and accommodation | 114 | 7.38% |
| Transport & communication | 112 | 7.20% |
| Financial services | 115 | 7.39% |
| General government | 129 | 8.32% |
| Community, social & personal services | 51 | 3.32% |
| **Total GDP** | **1,551** | **100.00%** |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA. | | |

**Table 52: The estimated employment by economic sector for IUA 3 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 480 | 15.83% |
| Mining | 416 | 13.74% |
| Manufacturing | 143 | 4.72% |
| Electricity & water | 18 | 0.59% |
| Construction | 156 | 5.14% |
| Wholesale & retail trade; catering and accommodation | 640 | 21.11% |
| Transport & communication | 108 | 3.56% |
| Financial services | 252 | 8.32% |
| General government | 489 | 16.14% |
| Community, social & personal services | 329 | 10.85% |
| **Total employment** | **3,031** | |

### 10.3.5. Ecosystem Services

Situated in the western extent of the Lower Orange catchment, IUA 3 encompasses a diverse range of aquatic and terrestrial ecological infrastructure associated with the Orange River. These natural features are crucial in providing a variety of ecosystem services that benefit the communities in the area. The primary community in close proximity to IUA 3 is the Vioolsdrift small towns, located on opposite banks of the Lower Orange River.

Within the region, there is a notable irrigation scheme known as the Vioolsdrift-Noordoewer Joint Irrigation Authority Scheme. This scheme includes a weir in the Orange River that diverts water into main and sub-canals connected via siphons across the river. The water is then distributed to the Vioolsdrift community in South Africa and the Noordoewer community in Namibia. The purpose of this irrigation scheme is to support the agricultural sector and rural communities situated along the lower Orange River.

In terms of protected areas, the Richtersveld National Park, located on the western side near Kuboes, and the Helskloof/Nababiep Nature Reserve, near Vioolsdrift, are included within the boundaries of IUA 3. These protected areas play a vital role in conserving the natural environment and biodiversity of the region.

Regionally, the Orange River, its tributaries, and the wetlands are considered significant aquatic resources within IUA 3. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 53).

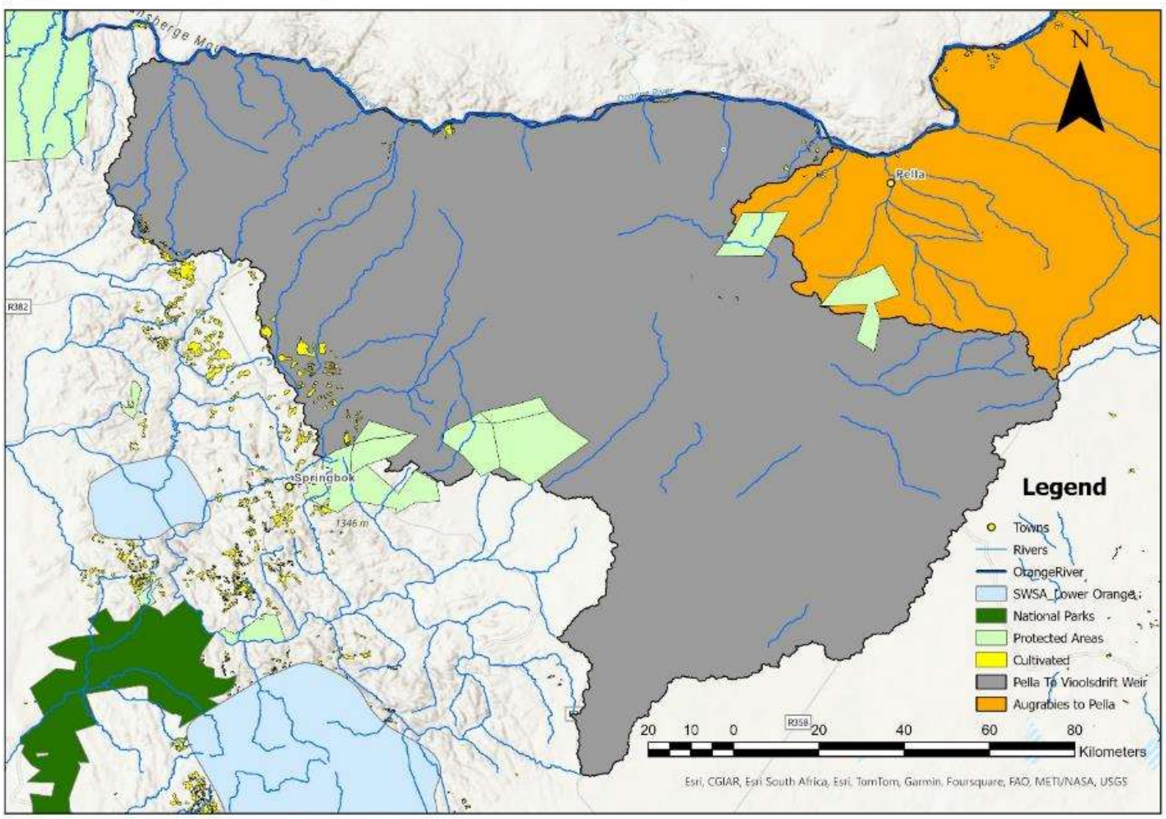



**Figure 51: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 3 in the Lower Orange Catchment**

**Table 53: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 3 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Food | Orange Rivers and its ephemeral tributaries; ephemeral Wetlands | The orange river is significance to the Vioolsdrift Community by providing fishes | Household, Society |
| | Fresh Water | Orange Rivers and its ephemeral tributaries; ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Vioolsdrift community in South Africa and the Noordoewer community in Namibia | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Raw materials | ephemeral Wetlands | Significance to Subsistence Farmers | Agriculture, Household, Society |
| | Medicinal resources | ephemeral Wetlands | Significance to Rural Communities | Household, Society |
| Regulating | Climate regulation | ephemeral Wetlands | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Vioolsdrift community in South Africa and the Noordoewer community in Namibia | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA, specifically for the Vioolsdrift community in South Africa and the Noordoewer community in Namibia | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | ephemeral Wetlands; Orange Rivers and its ephemeral tributaries | Major significance to commercial agriculture sector | Agriculture |
| | Biological control | ephemeral Wetlands; Orange Rivers and its ephemeral tributaries | Major significance to commercial agriculture sector | Agriculture; Households |
| Cultural | Landscape & amenity values | Protected Areas (Richtersveld National Park, and the Helskloof/Nababiep Nature Reserve); Orange Rivers and its ephemeral tributaries | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | ephemeral Wetlands; Orange Rivers and its ephemeral tributaries | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Society; Tourism |
| | Maintenance of genetic diversity | Protected Areas (Richtersveld National Park, and the Helskloof/Nababiep Nature Reserve) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity | Agriculture; Tourism; Society |

| Key Ecosystem Service | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|
| | | hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | |

### 10.3.6. River Ecological information and PES

The Orange River in the IUA is largely in a B and C PES ecological category, generally good ecological condition. The river ecological condition is driven by flow and non-flow impacts. The IUA includes 1 EWR site, EWR 04 at Vioolsdrift (C Category), and a JBS site, JBS3 (2021) - OSAEH49 (B/C category).

### 10.3.7. Wetlands

The wetland extent (area) and percentage of area within IUA 3 is presented in Table 38. The IUA includes depression, seep, floodplain and channelled valley bottom wetlands, covering 1% of the catchment area. The priority wetlands are associated with the mainstem Orange River.

### 10.3.8. Groundwater

The GRUs included in this IUA are:

- GRU 3 (Bushmanland West to Namaqualand East - Metamorphic Terrane)
  - Stress Index = 74%, poor to seriously modified yield class; and
  - Fractured aquifer system with poor groundwater quality type, *viz*., fluoride and/or salinity.
  - Proposed PSC: E/F.
- GRU 4.1 (only QCs D82E and D82F) (Richtersveld - Metamorphic Terrane: mostly highly various granite gneiss, meta-quartzites and amphibolite).
  - Stress Index = 15%, good to fair aquifer yield class; and
  - Fractured aquifer system with Marginal to Poor water quality types *viz*., fluoride and/or salinity.
  - Proposed PSC: B.

*Summary:*

Groundwater quality is not good due to poor rainfall recharge (lack of periodic refreshing). Water bearing zones are difficult to locate due to nature of metamorphic rock formations.

## 10.4. IUA 4: Downstream Vioolsdrift weir to Orange Estuary

IUA 4 is delineated from below Vioolsdrift weir to the estuarine functional zone (EFZ) at the Orange River Mouth, catchments D82H to D82L (upper portion).

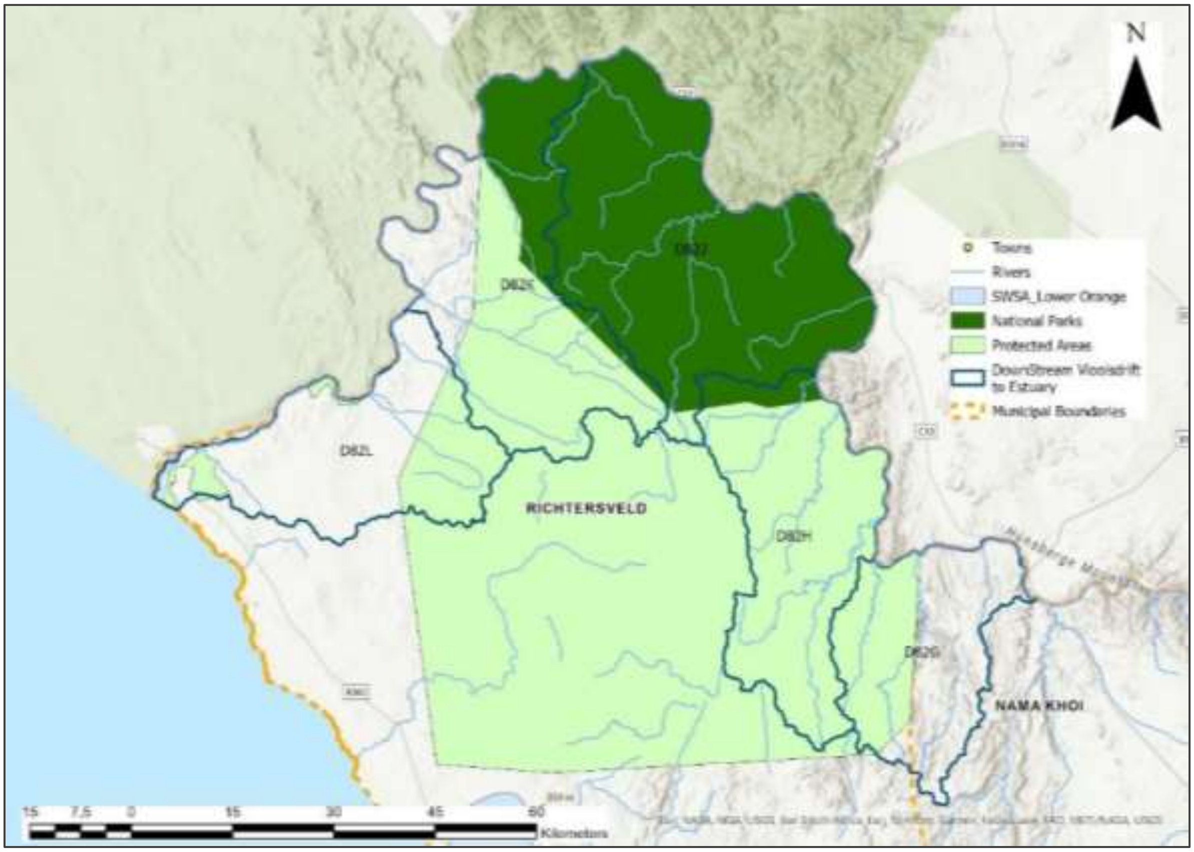



**Figure 52: Overview of boundaries and features in IUA 4 of the Lower Orange River Catchment**

### 10.4.1. Rationale

The IUA comprises part of the Orange River Gorge Ecoregion characterized by closed hills, mountains, moderate and high relief. The IUA extends from below the Vioolsdrift weir to the upper boundary of the Estuarine Functional Zone (EFZ) of the Orange River Mouth. Furthermore, extensive alluvial diamond mining operations take place along the main stem Orange River.

### 10.4.2. Overview

The IUA is situated downstream Vioolsdrift to Estuary, comprises five quaternary catchments. The northern boundary of the quaternary catchments is alongside the orange river. There are some protected areas within the IUA including the Nababiep Nature reserve and Richtersveld National Park. The IUA lies within parts of the municipalities of Richterveld and Nama Khoi. The settlements in this IUA include Eksteenfontein, Sanddrift, and Kuboes.

### 10.4.3. Water Resources

The key water resource in the IUA includes the main stem of the Orange River. There is agricultural activity which falls part of the D82G quaternary catchment situated on the northern side of Nama Khoi local municipality area. This IUA falls into Mixed Use SEZ 1 of the Lower Orange River catchment area. The tributaries include Stinkfontein se, Bak, Gannakouriep, Annis, Bloubos, Kook, Kouams, Khubus, predominantly ephemeral.

### 10.4.4. Demographics and Socio-Economic Profile

The population of IUA 4 is estimated as 1,871 (Stats SA Census 2011 adjusted) with approximately 663 households. Approximately 6.1% of the population has a higher education and 1.4% have no schooling (Stats SA Census 2022 based on municipal average data for municipalities falling within the IUA). The unemployment rate within IUA 4 is estimated at 20% (NT, 2021).

The majority of residents have access to formal water services. Approximately 80% of the population have access to piped water inside their dwelling, 18% of the population have access to piped water in their yards, and the remaining 2% have access to a communal tap water within 200m of their household (Figure 53).

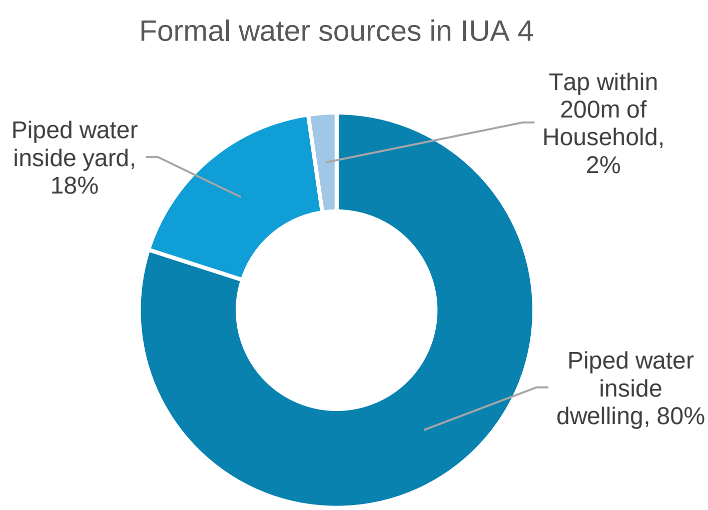



**Figure 53: Access to water services in IUA 4**

### Economic sectors

The key land use for IUA 4 is residential settlements and mining activity which occur along the northern sections of quaternary catchments D82C, D82L, and D82K. The mines within these quaternaries are usually surface mines mining for alluvial diamonds (mining areas can be seen Figure 54). The main economic drivers and municipalities falling within IUA 4 are set out in Table 54.

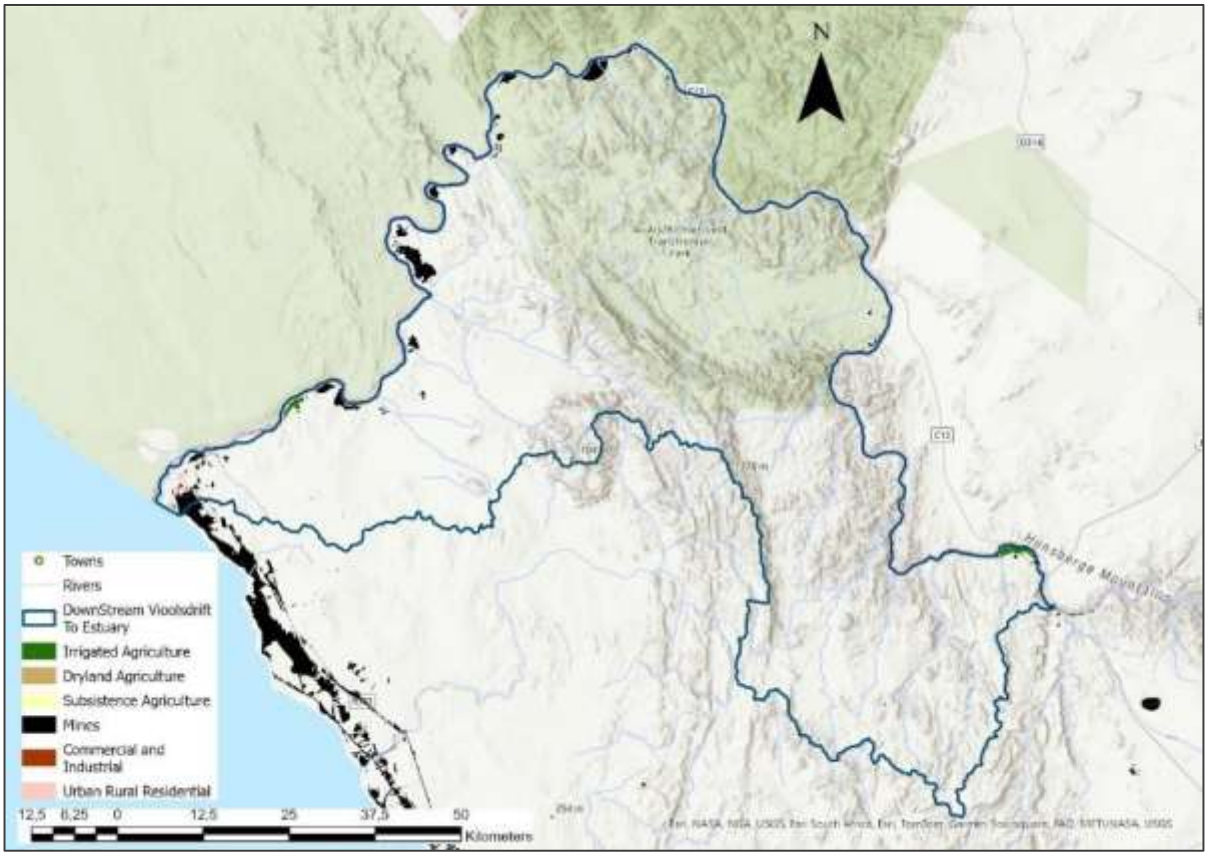



**Figure 54: Land Use by land cover in IUA 1 in the Lower Orange catchment (DFFE, 2020)**

**Table 54: Economic drivers relevant to IUA 4**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2023) |
|---|---|
| Nama Khoi | Goodhouse is the main town found within this IUA. The main settlement in this part of the IUA is the Rooiwal farming (irrigation agriculture) and residential settlements along the Orange river<br>The main water use is for agriculture and domestic use for the towns and settlements and farms within the IUA. |
| Richtersveld | The small towns include Sanddrift and Kuboes.<br>Economic sectors and activities include agriculture along the Orange River, mining (alluvial diamond mines) and tourism within the protected areas. |

In IUA 4, the contribution of the economic sectors to the Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 55 and Table 56.

**Table 55: Economic sectors in IUA 4 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | 8 | 2.13% |
| Mining | 173 | 47.59% |
| Manufacturing | 11 | 2.90% |
| Electricity & water | 6 | 1.71% |
| Construction | 18 | 4.97% |
| Wholesale & retail trade; catering and accommodation | 31 | 8.38% |
| Transport & communication | 41 | 11.22% |
| Financial services | 29 | 7.90% |
| General government | 32 | 8.86% |
| Community, social & personal services | 16 | 4.35% |
| **Total GDP** | **365** | **100.00%** |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA. | | |

**Table 56: The estimated employment by economic sector for IUA 4 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | IUA4 employment contribution |
|---|---|---|
| Agriculture, forestry and fishing | 66 | 8% |
| Mining | 92 | 12% |
| Manufacturing | 22 | 3% |
| Electricity & water | 3 | 0% |
| Construction | 51 | 6% |
| Wholesale & retail trade; catering and accommodation | 155 | 19% |
| Transport & communication | 33 | 4% |
| Financial services | 81 | 10% |
| General government | 144 | 18% |
| Community, social & personal services | 152 | 19% |
| **Total employment** | 800 | |

### 10.4.5. Ecosystem Services

IUA 4 is located in the eastern part of the Lower Orange catchment, encompassing a diverse range of aquatic and terrestrial ecological infrastructure associated with the Orange River and its tributaries. These include Stinkfontein se, Bak, Gannakouriep, Annis, Bloubos, Kook, Kouams, and Khubus. These natural features play a crucial role in providing a variety of ecosystem services that benefit communities such as Vioolsdrift, Sanddrift, and Kuboes.

The region is home to protected areas such as the Richtersveld National Park, which is located near Kuboes. These protected areas serve as critical conservation areas, safeguarding the natural environment and biodiversity of the region. They contribute to maintaining the ecological balance and preserving the unique ecosystems found within IUA 4.

Regionally, the Orange River, its tributaries, and the wetlands, including saltmarsh and floodplain areas, are considered significant aquatic resources within IUA 4. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 57).

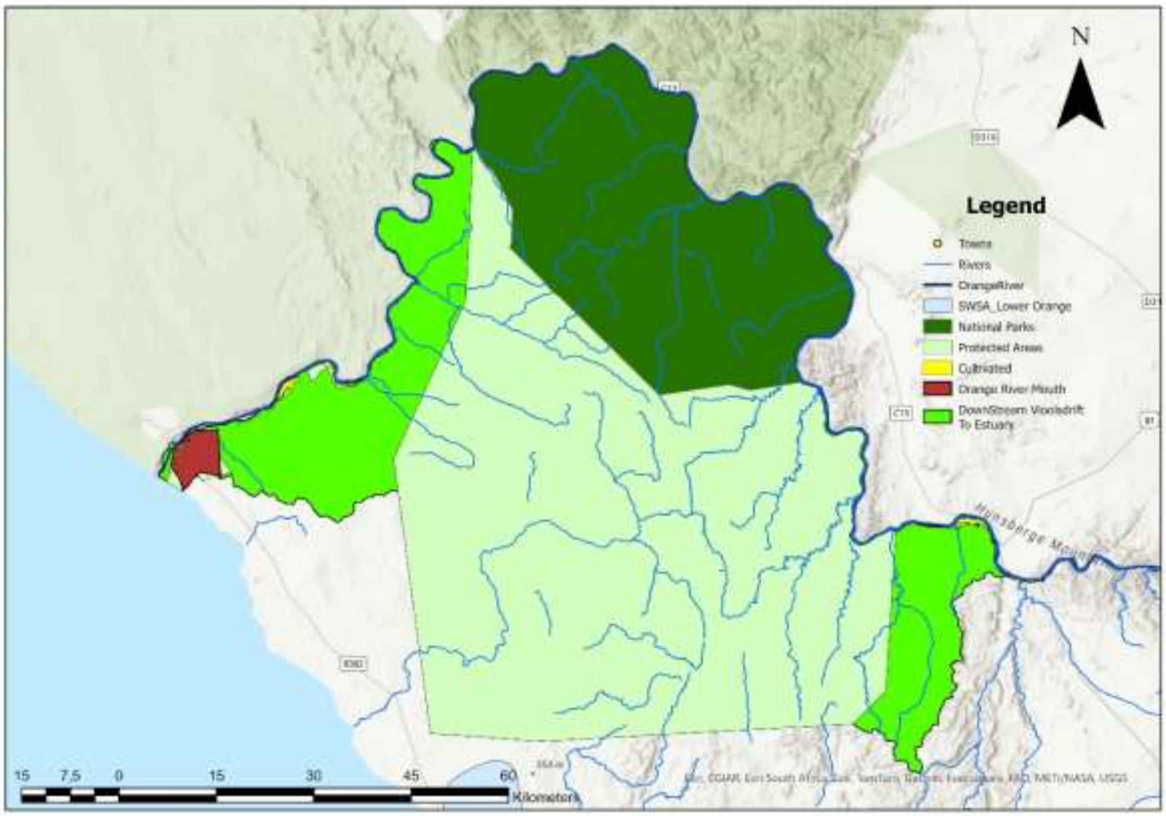



**Figure 55: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 4 in the Lower Orange Catchment**

**Table 57: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 4 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Food | Orange River and its tributaries; Wetlands (saltmarsh and floodplain) | Significance to Rural Communities in the east (Fishing, collection); Subsistence agriculture (livestock grazing) | Households; Society |
| | Fresh Water | Wetlands (saltmarsh and floodplain); | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| | | Strategic groundwater | communities such as Vioolsdrift, Sanddrift, and Kuboes. | |
| | Raw materials | Wetlands (saltmarsh and floodplain) | Significance to Subsistence Farmers | Agriculture; Households; Society |
| | Medicinal resources | Wetlands (saltmarsh and floodplain) | Significance to surrounding communities | Households; Society |
| Regulating | Climate regulation | Wetlands (saltmarsh and floodplain) | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | Wetlands (saltmarsh and floodplain) | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities such as Vioolsdrift, Sanddrift, and Kuboes. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | Wetlands (saltmarsh and floodplain) | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities such as Vioolsdrift, Sanddrift, and Kuboes. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Wetlands (saltmarsh and floodplain) | Major significance to commercial agriculture sector | Agriculture |
| | Biological control | Wetlands (saltmarsh and floodplain) | Major significance to commercial agriculture sector | Agriculture; Households |
| Cultural | Landscape & amenity values | Orange River and its tributaries; Wetlands; Protected Areas (Richtersveld National Park) | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | Orange River and its tributaries; Wetlands (saltmarsh and floodplain); Protected Areas (Richtersveld National Park) | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Society; Tourism |
| | Maintenance of genetic diversity | Protected Areas (Richtersveld National Park) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | Agriculture; Tourism; Society |

### 10.4.6. River Ecological information and PES

Rivers are in a B and C PES ecological category driven by flow and nonflow impacts, with localised water quality issues mainly around towns. There is 1 EWR site in the IUA, EWR 05 at Sendelingsdrif, and JBS site 52.

### 10.4.7. Wetlands

The wetland extent (area) and percentage of area within IUA 4 is presented in Table 38. The IUA includes depression and channelled valley bottom wetlands, covering 1% of the catchment area. The priority wetlands are associated with the mainstem Orange River.

### 10.4.8. Groundwater

The GRUs included in this IUA are:

- GRU 4.1 (quaternary catchments D82G, -H & J only) (Far Northwestern Coastal Hinterland – Coastal metamorphic terrane: granite-gneiss)
    - Stress Index = 36%, Insignificant aquifer yield class; and
    - Fractured & Weathered aquifer system with Marginal to Poor water quality type(s).
    - Proposed PSC: B
- GRU 4.2 (D82L & -K) only (Richtersveld - Metamorphic Terrane: Granite-gneiss and various meta-sedimentary formations and saturated unconsolidated marine alluvium.
    - Stress Index = 50%, Insignificant to Low aquifer yield class; and
    - Intergranular Aquifer systems represented by localized (paleo drainages) saturated Intergranular aquifer systems close to the Atlantic Ocean boundary.
    - Fractured & Weathered aquifer system depending on interception of specific water bearing zones.
    - Groundwater is Marginal to Poor water quality type.
    - Proposed PSC: C/D.

*Summary:*

Groundwater quality is not good due to poor rainfall recharge (lack of periodic refreshing) and the impact(s) of marine-innated aerosols. Hotspots are quaternary catchments D82K and F20D – however this needs to be confirmed.

## 10.5. IUA 5: Orange River Estuary

IUA 5 delineates the Orange River Estuary in the lower portion of catchment D82L. The IUA extends 13km from the mouth, up to 2km upstream of the Sir Ernest Oppenheimer bridge.

### 10.5.1. Rationale

The Orange River Mouth and EFZ presents a logical break for IUA delineation. The estuary is a management unit with requirements and ecological specifications that are different to river systems. The area is a RAMSAR site requiring additional protection and management. Land use impacts are different to the upper river reaches.

### 10.5.2. Overview

IUA 5, Orange River Mouth, comprises 1 quaternary catchment, D82L. The estuary is situated just north of the coastal town of Port Nolloth and forms the border between South Africa and

Namibia. This quaternary catchment comprises of an estuary which opens into the Atlantic Ocean. The northern boundary of the IUA is alongside the Orange River. The Orange River Mouth Ramsar site is within the IUA and the Orange River Mouth Nature Reserve adjacent to the town of Alexander Bay. The IUA lies within Richtersveld LM. This IUA has one town which is Alexander Bay.

### 10.5.3. Water Resources

The key water resource in the IUA includes the Orange River mouth and the estuary. There is some agricultural activity alongside the Orange River. This IUA is part of the Mixed Use SEZ 1. The estuary has an area of about 2 298 ha. The Orange River Estuary is a delta type river mouth, comprising a channel system between sand banks, a tidal basin, the river mouth and the salt marsh on the south bank. The extent of tidal exchange extends as far as the Ernest Oppenheimer Bridge, approximately 13 km upstream (CSIR, 2011).

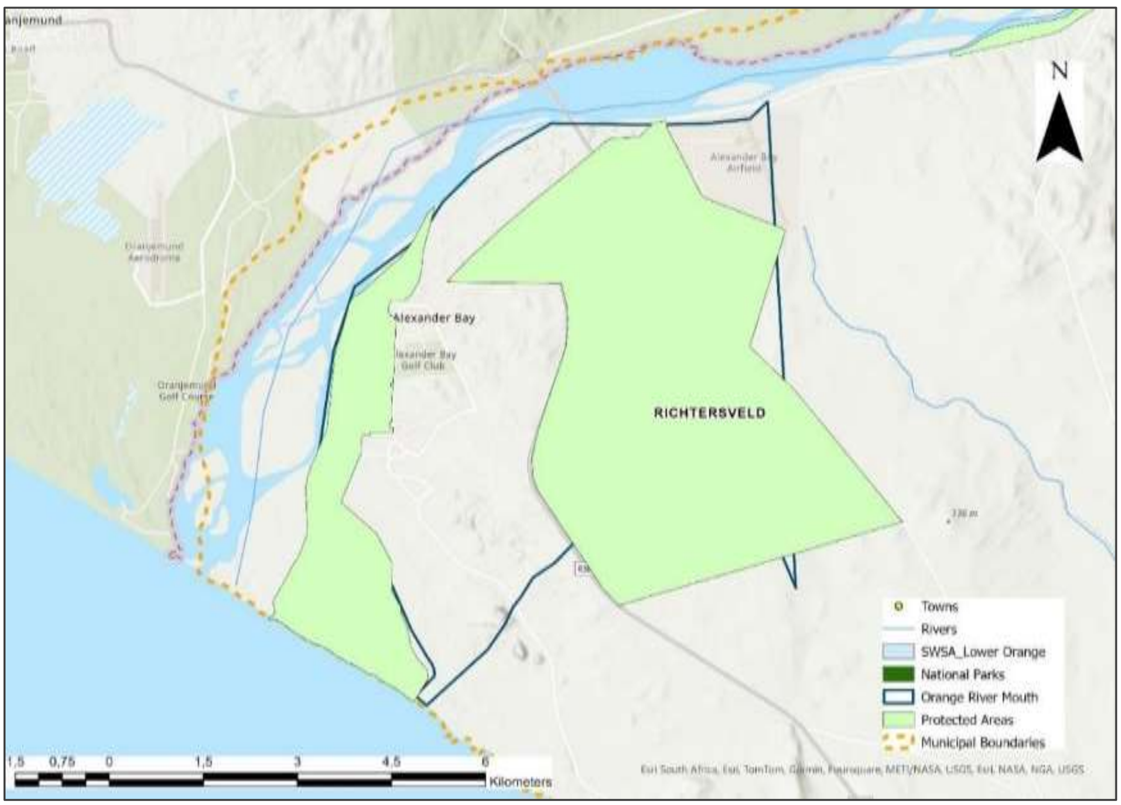



**Figure 56: Overview of boundaries and features in IUA5 of the Lower Orange River Catchment**

**Boundary and EFZ the Estuary**

The Orange River Estuary (28°38'30” S; 16°27'45” E) is situated just north of the coastal town of Port Nolloth in the Northern Cape and forms the border between South Africa and Namibia. The Orange River Estuary is classified as a Cool Temperate Large Fluvially Dominated system (Van

Niekerk, *et.al*, 2019a). The Orange River Estuary comprise a channel system between sand banks, a tidal basin, the river mouth and the salt marsh on the south bank.

The Orange River Estuary falls within quaternary catchment D82L. The PES of the catchment has been assigned as Class C: Moderately Modified, while the EIS is low to marginal.

During the NBA 2018, the EFZ was defined for all estuaries in South Africa. The EFZ of the Orange River estuary spans an area of approximately 3095 ha. The estimated geographical boundaries of the Orange River Estuary set during confirmation of the EFZ (Van Niekerk*, et.al*, 2019a) are as follow:

- Downstream boundary: The estuary mouth (28°38’00.00”S, 16º27’09.40”E)
- Upstream boundary: Head of tidal influence is about 2 km above the Sir Ernest Oppenheimer bridge, approximately 13 km for mouth (28°33’44.51”S, 16°31’23.48”E).
- Lateral boundaries: 5 m contour above MSL along the banks.

### 10.5.4. Demographics and Socio-Economic Profile

The population is estimated as 1736 (Stats SA Census 2011 adjusted) with approximately 511 households. Approximately 6% of the population has a higher education and 1.5% have no schooling (Stats SA Census 2022 based on Richtersveld local municipality data). The unemployment rate within IUA 5 is estimated as 21% if reflecting the municipal rate (NT, 2021).

All of the population have access to formal water services with approximately 75% of population having access to piped water inside their dwelling, 19% of the population have piped water in their yards, and 6% having tap water within 200m of the household (Figure 57).

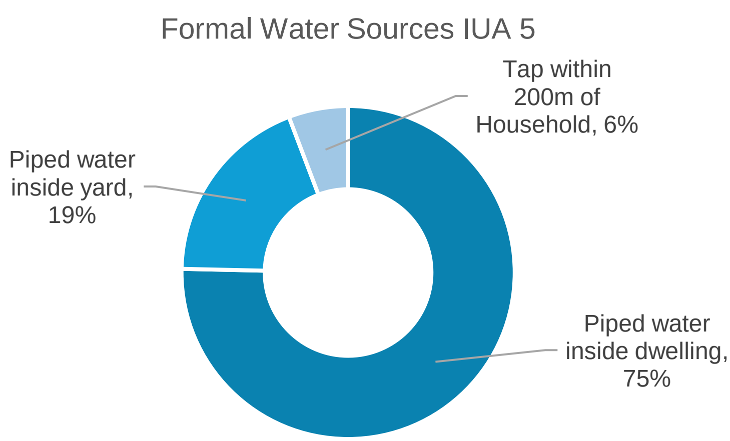



**Figure 57: Access to water services within IUA 5**

**Economic sectors**

The key land use for IUA 5 is residential settlements (Alexander Bay) and some agriculture alongside the Orange River. The other important land use is from mining (see Figure 58). The main economic drivers and municipalities falling within IUA 5 are set out in Table 58.

In IUA 5 the contribution of the economic sectors through Gross Dom (GDP) of the IUA and the employment within these sectors is summarised in Table 59 and Table 60.

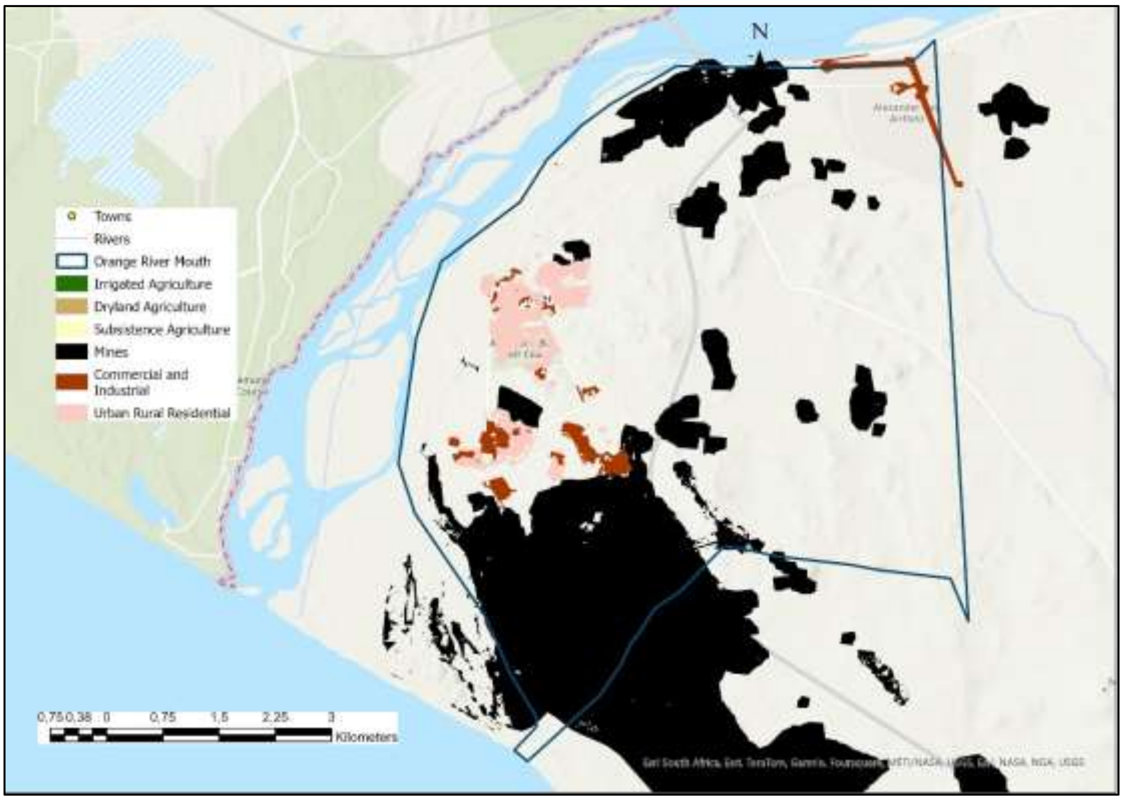



**Figure 58: Land Use by land cover in IUA 5 in the Lower Orange catchment (DFFE, 2020)**

**Table 58: Economic drivers relevant to IUA**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs) |
|---|---|
| Richtersveld | Alexander Bay is the only town within this IUA. The area in the IUA is characterised by irrigation agriculture along the Orange River.<br>This area has alluvial diamond mining activities towards north of Alexander Bay.<br>The main water use is for agriculture, mining and domestic use for Alexander Bay within the IUA. |

**Table 59: Economic sectors in IUA 5 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | 3 | 2.19% |
| Mining | 63 | 46.24% |
| Manufacturing | 3 | 2.09% |
| Electricity & water | 2 | 1.10% |
| Construction | 7 | 5.43% |
| Wholesale & retail trade; catering and accommodation | 12 | 8.67% |
| Transport & communication | 17 | 12.54% |
| Financial services | 11 | 7.89% |
| General government | 12 | 9.09% |
| Community, social & personal services | 7 | 4.75% |
| **Total GDP** | **137** | **100.00%** |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA | | |

**Table 60: The estimated employment by economic sector for IUA 5 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 27.58 | 8.55% |
| Mining | 33.24 | 10.30% |
| Manufacturing | 7.45 | 2.31% |
| Electricity & water | 0.72 | 0.22% |
| Construction | 21.06 | 6.53% |
| Wholesale & retail trade; catering and accommodation | 58.67 | 18.18% |
| Transport & communication | 13.54 | 4.20% |
| Financial services | 33.45 | 10.37% |
| General government | 59.02 | 18.29% |
| Community, social & personal services | 67.91 | 21.05% |
| **Total employment** | **322.63** | 100.00% |

### 10.5.5. Ecosystem Services

Like IUA 4, IUA 5 is situated in the eastern part of the Lower Orange catchment. This area is dominated by aquatic ecological infrastructures, which are associated with the Orange River Mouth. These natural features play a pivotal role in providing a wide range of ecosystem services that are beneficial to the nearby communities of Alexander Bay and Oranjemund Airport (in Namibia). The whole IUA harbours a Ramsar site, which has been designated as a wetland site of international importance under the Ramsar Convention.

This protected area serves as vital conservation zones, playing a crucial role in safeguarding the region's natural environment and biodiversity. They contribute significantly to maintaining the ecological balance and preserving the unique ecosystems found within IUA 5.

Regionally, the Orange River Mouth is considered significant aquatic resources. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem (Table 61).

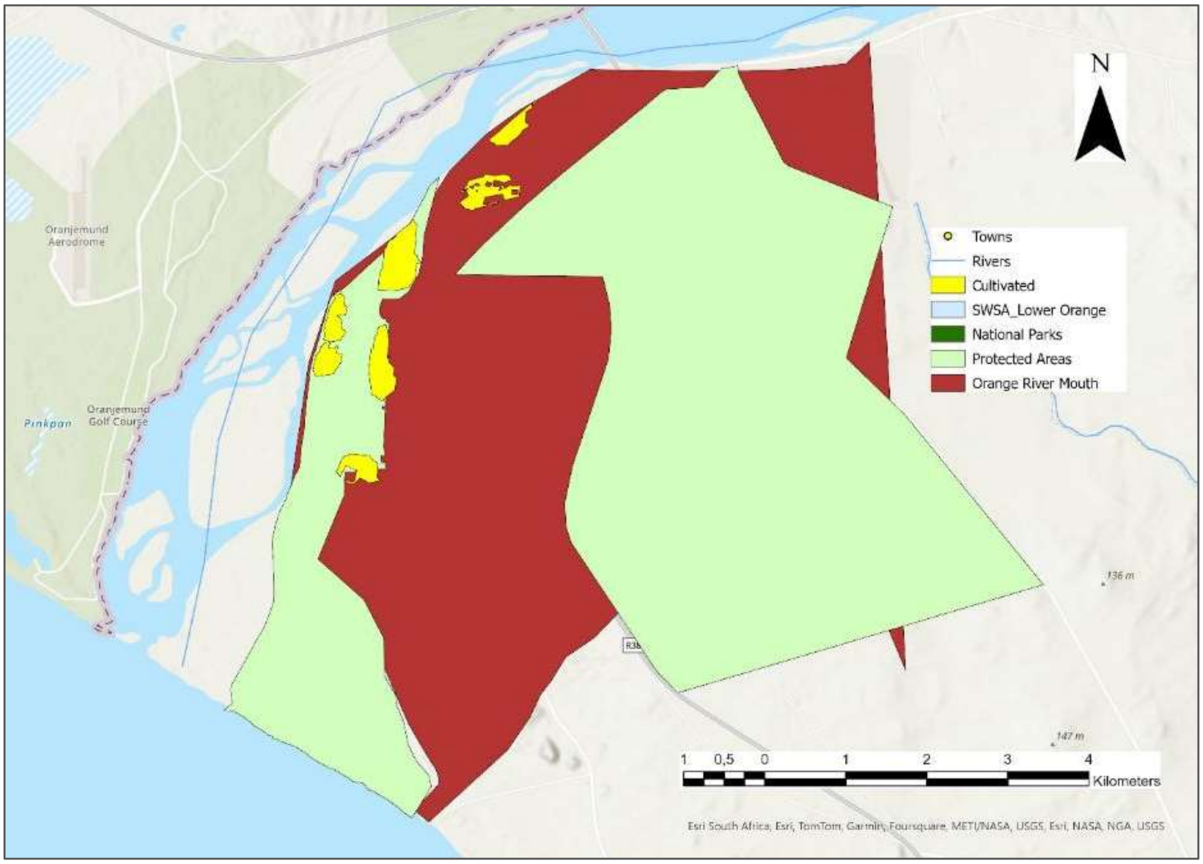



**Figure 59: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 5 in the Lower Orange Catchment**

**Table 61: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 5 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Fresh Water | Orange River Mouth Estuaries | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities such as Alexander Bay and Oranjemund Airport (in Namibia) | Households |
| Regulating | Climate regulation | Orange River Mouth Estuaries | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | Orange River Mouth Estuaries | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities such as Alexander Bay and Oranjemund Airport (in Namibia) | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | Orange River Mouth Estuaries | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities such as Alexander Bay and Oranjemund Airport (in Namibia) | Agriculture; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Orange River Mouth Estuaries | Major significance to coastal shoreline | Agriculture |
| | Biological control | Orange River Mouth Estuaries | Major significance to coastal shoreline native species | Agriculture; Households |
| Cultural | Landscape & amenity values | Orange River Mouth Estuaries & Ramsar site on Montreux Record) | Major Significance: To tourism industry and Alexander Bay and Oranjemund Airport communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | Orange River Mouth Estuaries & Ramsar site on Montreux Record) | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Society; Tourism |
| | Maintenance of genetic diversity | Protected Areas (Ramsar site on Montreux Record) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | Agriculture; Tourism; Society |

### 10.5.6. River Ecological information and PES

The ecological flow requirements for the Orange River estuary were determined during the EWR 2017 study to have a PES and REC of D and C, respectively. The EIS was assigned as very high

(DWS, 2016). The reassessment of the PES and REC during the NBA 2018 assessment confirmed the PES to be class D, however, the REC was adjusted downward also to a class D (Van Niekerk, et.al, 2019a), see Table 62.

The NBA 2018 assigned the hydrology and water quality components of the estuary a category D, while the hydrodynamics was assigned to a PES of category C. The biotic components of the Orange River Estuary were largely assigned to category D, besides microalgae and birds that was assigned to a heavily transformed state of a category E (Van Niekerk, *et.al,* 2019b).

**Table 62: Orange River Estuary PES, REC and PES of individual estuarine components (Van Niekerk, *et.al,* 2019b)**

| NBA 2018 Condition Status | Heavily Transformed |
|---|---|
| **Present Ecological State (PES), 2018** | **D** |
| *Hydrology* | *D* |
| *Hydrodynamics* | *C* |
| *Water Quality* | *D* |
| *Physical habitat* | *B* |
| *Microalgae* | *E* |
| *Macrophytes* | *D* |
| *Invertebrates* | *D* |
| *Fish* | *D* |
| *Birds* | *E* |
| **Recommended Ecological Category (REC)** | **D** |

### 10.5.7. Wetlands

The wetland extent (area) and percentage of area within IUA 5 is presented in Table 38. The IUA includes depression, and river wetlands, and the estuary, covering 14% of the catchment area. The priority wetlands include the Orange River Mouth.

### 10.5.8. Groundwater

Groundwater conditions found at this site are limited to sporadic saturated alluvial deposits related to the Orange River estuary and are regarded to fall in an Insignificant to Low yield class. Water quality is [significantly] impacted by local marine innated aerosol fall-out and primary rainwater quality (*i.e.*, frontal systems with a prominent saline quality signature).

## 10.6. IUA 6: Brak

The IUA comprises the Brak River and tributary catchments, comprising the D61A, D61B, D61C, D61D, D61E, D61F, D61G, D61H, D61J, D61K, D61L, D61M, D62A, D62B, D62C, D62D, D62E, D62F, D62G, D62H, D62J quaternary catchments.


**Figure 60: Overview of boundaries and features in IUA 6 of the Lower Orange River Catchment**

### 10.6.1. Rationale

This IUA is characterised by plains with closed hills, mountains, moderate and high relief. The IUA is delineated based on the D6secondary catchment boundary. The land use is similar and forming part of the mixed used zone SEZ, including commercial agriculture (livestock) and some mining. River systems are largely ephemeral.

### 10.6.2. Overview

IUA 6 consists of 21 quaternary catchments of D61 and D62 tertiary catchments which fall within parts of four local municipalities of Ubuntu, Emthanjeni, Thembelihle and Kareeberg in the Northern Cape province. A portion of quaternary catchment D62F falls within the boundaries of the Renosterberg municipality but has no significant sized towns and only the small settlement of

Potfontein. The main towns include Vosburg, Britstown, De Aar, Victoria West and Richmond. The towns of De Aar and Victoria West have small nature reserve protected areas adjacent to the towns.

### 10.6.3. Water Resources

In this IUA the main river is the ephemeral Brak river and numerous tributaries and there is a strategic groundwater resource area within quaternary catchment D62D on the eastern side of the IUA (De Aar Region). The main tributaries are the Ongers and Klein Brak. The catchment includes the Smart Syndicate Dam supporting irrigation use. The IUA forms part of the Mixed Use SEZ 2 with land use being for commercial livestock farming and industry use. The towns are highly dependent on groundwater sources.

### 10.6.4. Demographics and Socio-Economic Profile

The population is estimated as 69,328 (Stats SA Census 2011 adjusted) with approximately 18,569 households. Approximately 6.85% of the population has a higher education and 8.2% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within IUA 6 is estimated at 24.8% (NT, 2021).

There is a high reliance in this IUA on groundwater and the main river and its tributaries are ephemeral. The majority of the population (99%) has access to formal piped water sources (Figure 61) with 96.5% having access to piped water inside their dwelling or yard and the remaining 3.5% have access to a communal tap within 200m of the household. Informal water source in this IUA is from boreholes with 0.1% of the IUA population relying on their water from this source. People are mainly dwelling in formal dwellings with the proportion ranging from 68.1% to 95.2% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022).

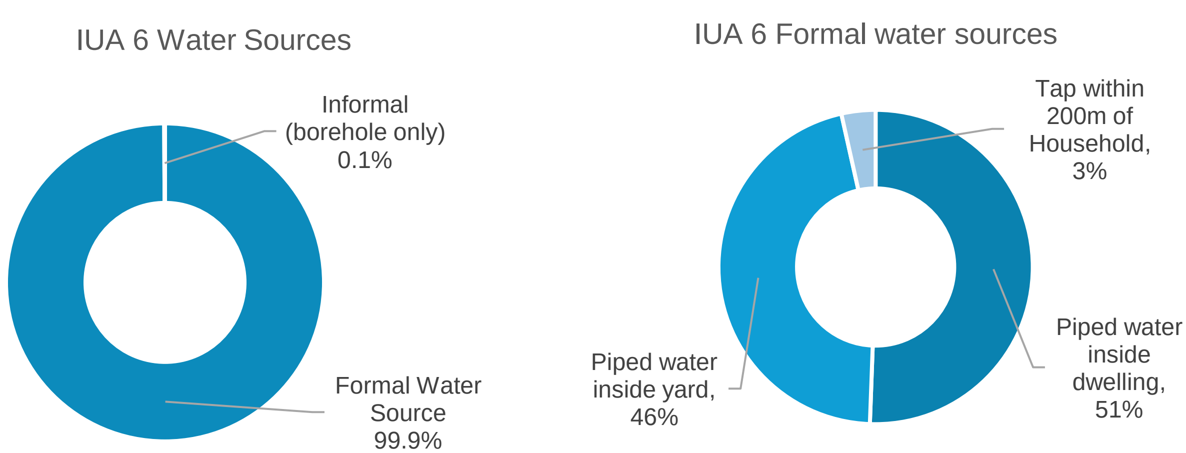



**Figure 61: Access to water services in IUA 6**

**Economic sectors**

Agricultural land use consists of extensive livestock farming in areas near the towns and includes sheep (for meat and wool), pig, cattle and goat farming. This IUA also includes areas where game farming takes place. Crop agriculture is also practiced to a lesser extent and particularly in the area near to Britstown.

The town of De Aar is an important railway junction in South Africa connecting Johannesburg, Cape Town, Qheberha and Namibia railway lines and it has the largest abattoir in the Southern Hemisphere supplying to all major centres in South Africa.

The main economic drivers of municipalities falling within IUA 1 are set out in Table 63.

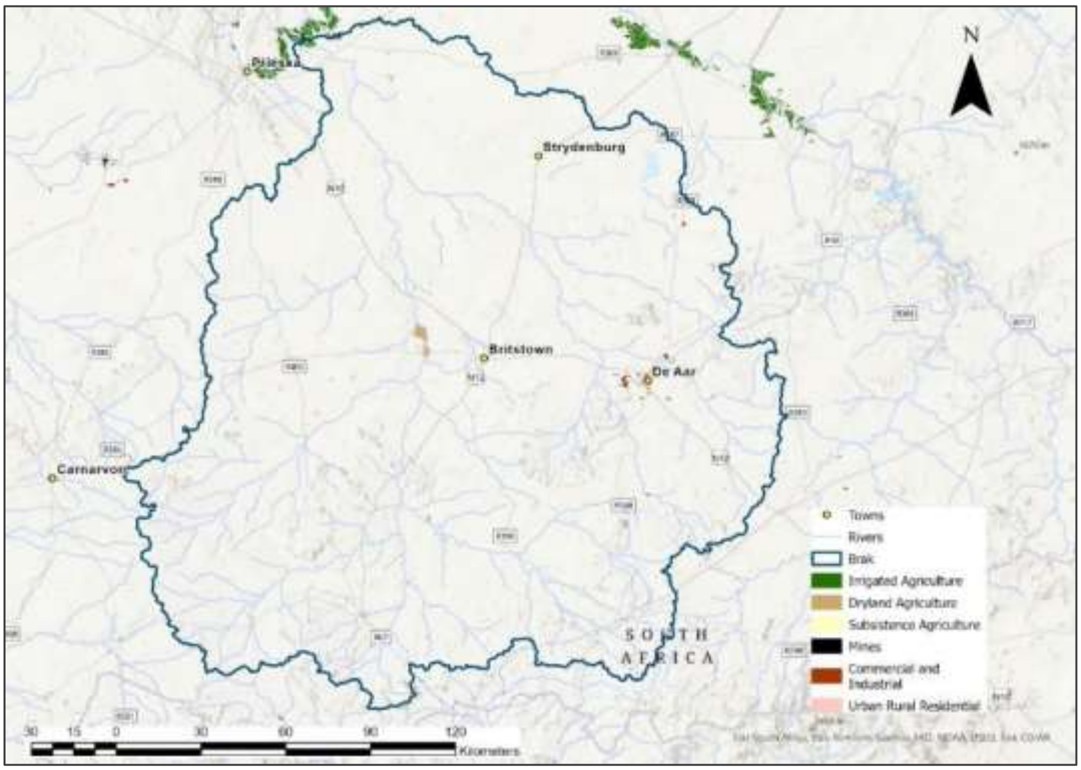



**Figure 62: Land Use by land cover in IUA 6 in the Lower Orange catchment (DAFF, 2020)**

**Table 63: Economic drivers relevant to IUA 6**

| **Local Municipality** | **Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2021, 2022 and 2023)** |
|---|---|
| Ubuntu | A large portion of IUA 6 lies in this municipality and the main towns include Victoria West, Richmond and smaller towns of Hutchinson and Merriman.<br>Economic activity is mainly agricultural with livestock (sheep, goats) and cattle. The area also supports game farms with antelope. |

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2021, 2022 and 2023) |
|---|---|
| | The groundwater in this part of the IUA has a high salt content making it unsuitable for irrigation purposes. |
| Emthanjeni | The main towns are Britstown and De Aar.<br>Key economic activities include extensive stock farming of sheep (mutton and wool farming of particularly Merino sheep), pigs, goats and cattle.<br>The IUA includes the Smartt Syndicate Irrigation Scheme approximately 25km west of Britstown along the Ongers river that supplies water to lucerne and wheat farmers in the area.<br>There is no significant mining however there is a small quarrying operation near De Aar.<br>The economy is supported by manufacturing and the largest abattoir in the Southern Hemisphere is located in De Aar which is also a railway and transport junction.<br>There are solar power plants in and near to the town of De Aar (Quat D62D) including the Mulilo Renewable Energy Solar PV plant, the large De Aar Solar Power plant and two Solar Capital solar project plants. |
| Kareeberg | The town of Vosburg is located in IUA 6 and the main economic activity is sheep farming for meat production. |
| Thembelihle | The town of Strydenburg is located in IUA 6. There is a small amount of manufacturing activity for meat processing in the town. |

In IUA 6 the estimated contribution of the economic sectors to the Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 64 and Table 65.

**Table 64: Economic sectors in IUA 6 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R502 | 13% |
| Mining | R14 | 0.4% |
| Manufacturing | R190 | 5% |
| Electricity & water | R151 | 4% |
| Construction | R273 | 7% |
| Wholesale & retail trade; catering and accommodation | R469 | 12% |
| Transport & communication | R560 | 14% |
| Financial services | R671 | 17% |
| General government | R775 | 20% |
| Community, social & personal services | R285 | 7% |
| **Total GDP** | **R3,890** | 100% |

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA | | |

**Table 65: The estimated employment by economic sector for IUA 6 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of jobs) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 3,072 | 21% |
| Mining | 7 | 0.05% |
| Manufacturing | 517 | 3% |
| Electricity & water | 61 | 0% |
| Construction | 943 | 6% |
| Wholesale & retail trade; catering and accommodation | 2,663 | 18% |
| Transport & communication | 504 | 3% |
| Financial services | 1,424 | 10% |
| General government | 3,158 | 21% |
| Community, social & personal services | 2,437 | 16% |
| **Total Employment** | **14,785** | 100% |

### 10.6.5. Ecosystem Services

Situated in the southeastern extent of the Lower Orange catchment, IUA 6 encompasses a diverse range of aquatic and terrestrial ecological infrastructure associated with the Brak River and its tributaries. These natural features play a vital role in providing a variety of ecosystem services that benefit the communities residing in urban areas (towns) and agricultural areas (livestock farming). It is worth noting that a significant strategic groundwater point has been observed in the eastern part of IUA 6.

Regionally, the Brak River, its tributaries, and the wetlands (including the channel, valley bottom, and floodplain) are considered significant aquatic resources within IUA 6. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 66).

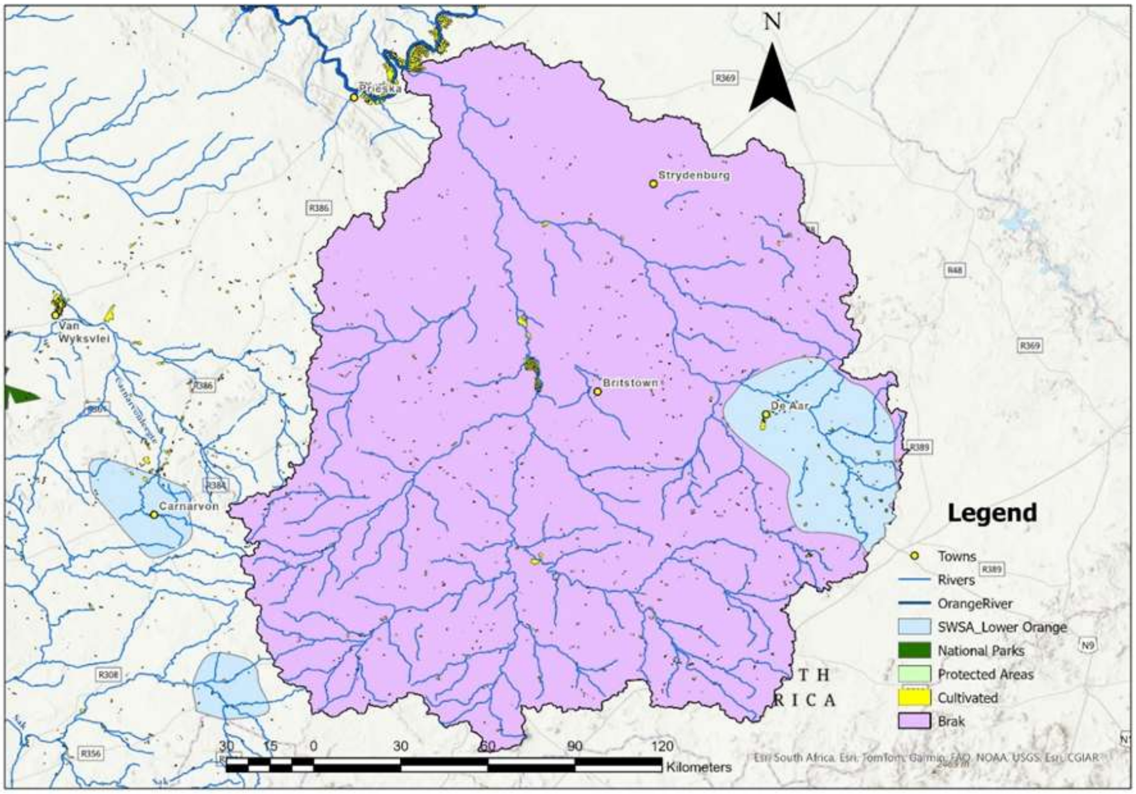



**Figure 63: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 6 in the Lower Orange Catchment**

**Table 66: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 6 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Fresh Water | Wetland; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and farms. Significant for the supply of water to De Aar, Britstown and Strydenburg | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Raw materials | Wetland | Significance to Subsistence Farmers | Agriculture; Households; Society |
| | Medicinal resources | Wetland | Significance to surrounding communities | Households; Society |
| Regulating | Climate regulation | Wetland systems | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | Wetlands; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and farms. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and farms. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil bility | Wetlands | Major significance to commercial agriculture sector | Agriculture |

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

### 10.6.6. River Ecological information and PES

The rivers in the sub-catchment are in a good ecological condition, falling within an B or C PES ecological category, with the exception of the upper reaches of the Brak and Ongers, the Ongers at the confluence of the Brak, short reaches of the Klein Brak and Elandsfontein which are the only D category river reaches. This is due to non- flow impacts related land use and erosion. There are no EWR sites or biological monitoring sites in this IUA.

### 10.6.7. Wetlands

The wetland extent (area) and percentage of area within IUA 6 is presented in Table 38. The IUA includes depression, floodplain, seep, channellled and unchannelled valley bottom, and river wetlands, covering 11% of the catchment area. The priority wetlands included the valley bottoms associated with the Ongers, Brakpoort, Brak, Visgat and Klein Brak Rivers.

### 10.6.8. Groundwater

The GRUs included in this IUA are:

- GRU 3 – Only GRU D62H (Ecca Group Carbonaceous shales West - Mudrock)
    - Stress Index = 5%, Natural yield status; and
    - Fractured and Weathered aquifer system with poor groundwater quality type, *viz.,* salinity due to marine type sedimentation.

  - Proposed PSC: A with 1x F+ (salinity).
- GRU 6.1 (Ecca Group (Beaufort) sandstone and shale East) - Typical Karoo sediment aquifers (fractured/jointed). Numerous Karoo Dolerite (Jd) intrusions (dolerite dykes and sills).
  - Stress Index = 10%, Moderate aquifer yield class (0.5-2.0 L/s); and
  - Fractured (merely arenaceous formations) aquifer systems with dolerite intrusive contact-aquifer (water bearing zones).
  - Groundwater is Ideal to Good water quality type.
  - Proposed PSC: A/B.
- GRU 6.2 (Karoo (Ecca) sandstone and shale East – higher recharge than the western region and moderately yielding.)
  - Stress Index = 3.4%, Moderate aquifer yield class (0.5-2.0 L/s, higher recharge than the western region); and
  - Fractured (±75%) and Fractured & Weathered aquifer systems with dolerite-contact zone water bearing zones.
  - Groundwater Ideal to Good water quality type, except quaternary catchment D62B has an average Poor water quality due to the Dwyka tillite rock formation.
  - Proposed PSC: A.
- GRU 6.3 – (Various rock formations varying from:
  - (i) quaternary catchments D62G & D62H: Karoo (Ecca) sandstone & mudrocks overlying Karoo Dwyka mudrock (carbonaceous shales); and
  - (ii) quaternary catchment D62J: Bushmanland East – Metamorphic Terrane consisting of meta-quartzite and granite-gneiss overlain by Karoo Dwyka mudrock & tillite (just a cover gapping).
  - Stress Index = 4%, Moderate aquifer yield class (0.5-2.0 L/s).
  - Fractured aquifer systems.
  - Groundwater Ideal to Good water quality types.
  - Proposed PSC: A/B.

*Summary:*

Groundwater quality is Ideal to Good due to more frequent recharging rainfall events, typical fractured hard rock type with limited water-rock interaction. Areas where the Karoo Dwyla tillite/mudrock formations are present could be saline due to the primary rock formation type (marine origen).

## 10.7. IUA 7: Hartbees/Sak

This IUA encompasses the Hartbees River and tributary catchments, comprising the D51 to D58 tertiary catchments.


**Figure 64: Overview of boundaries and features in IUA 7 of the Lower Orange River Catchment**

### 10.7.1. Rationale

This IUA is characterized by plains with closed hills, mountains, moderate and high relief. The IUA is delineated based on the D5 secondary catchment boundaries within the Lower Orange catchment. The catchment is largely rural lying within the mixed-use zone 2 SEZ.

### 10.7.2. Overview

IUA 7, Hatbees/Sak is the largest IUA within the Lower Orange catchment study area comprising 54 quaternary catchments within the tertiary catchments of D51, D52, D53, D54, D55, D56, D57 and D58. This IUA quaternary catchments fall within parts of eight local municipalities including Khai-Ma, Kai !Garib, !Kheis, Siyatemba, Kareeberg, Ubuntu, Karoo Hoogland and Hantam in the Northern Cape province. The population and economic activities are mainly within five of these local municipalities (Kai! Garib, Kareeberg, Ubuntu, Karoo Hoogland and Hantam). The main towns in the IUA include Sutherland, Williston, Kenhardt, Carnarvon, Van Wyksvlei, Copperton, Swartkop, Loxton, Fraserburg, and Brandvlei.

### 10.7.3. Water Resources

There are several ephemeral rivers within this IUA including (not limited to) Hartbees, Carnvarvonleegte, Sak, Vis, Sout and Hartogskloof. Three SWSA lie within the IUA (see Figure 64). Only two protected areas, The Meerkat National Park is located within this IUA covering parts of quaternary catchments D54C, D54E and D54F and a small Nature reserve (Dr Appie van Heerden Nature Reserve) south of the town of Carnarvon. IUA 7 falls predominantly into the mixed Socio-Economic Zone 2 with land use being for commercial livestock farming and industry use.

### 10.7.4. Demographics and Socio-Economic Profile

The population is estimated as 40,961 (Stats SA Census 2011 adjusted) with approximately 13,071 households. Approximately 6.4% of the population has a higher education and 8.3% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within IUA 7 is estimated at 17% (NT, 2021).

The rivers and tributaries are ephemeral and there is a reliance on groundwater sources in this IUA. Most of the population has access to a formal source of water (97.4%) and the remaining population (2.6%) rely on informal water sources. In relation to formal water sources 61% of the population have access to piped water inside their dwelling and 35% to piped water inside the yard, 4% of the population have access to a communal tap within 200m of the household and the remaining 1% have access through a water vendor (Figure 65). In IUA 7 people are mainly housed in formal dwellings with the proportion ranging from 85.2% to 96.2% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022). Informal water sources (Figure 65) in the IUA include boreholes (45.6%), Rivers or streams (20.6%), rainwater tanks (2.5%) and dams or pools (6.1%) or other unspecified sources (25.2%).

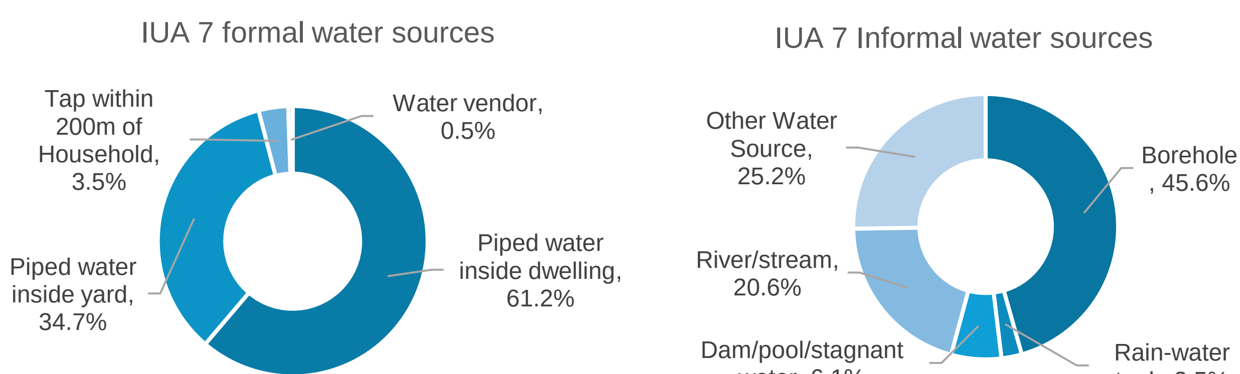



**Figure 65: Access to water services in IUA 7**

**Economic sectors**

The main land use and economic sectors in IUA 7 are agriculture and some tourism. Agriculture in IUA 7 includes of extensive livestock farming of sheep (for meat and wool), cattle and goat farming. This IUA includes areas where game farming takes place particularly in the surrounding areas of the town of Carnarvon. Crop agriculture is also practiced to a lesser extent.

A small amount of quarrying and salt mining takes place in the IUA and some contribution from the manufacturing sector mainly in agro-processing. There is a large abattoir in Carnarvon.

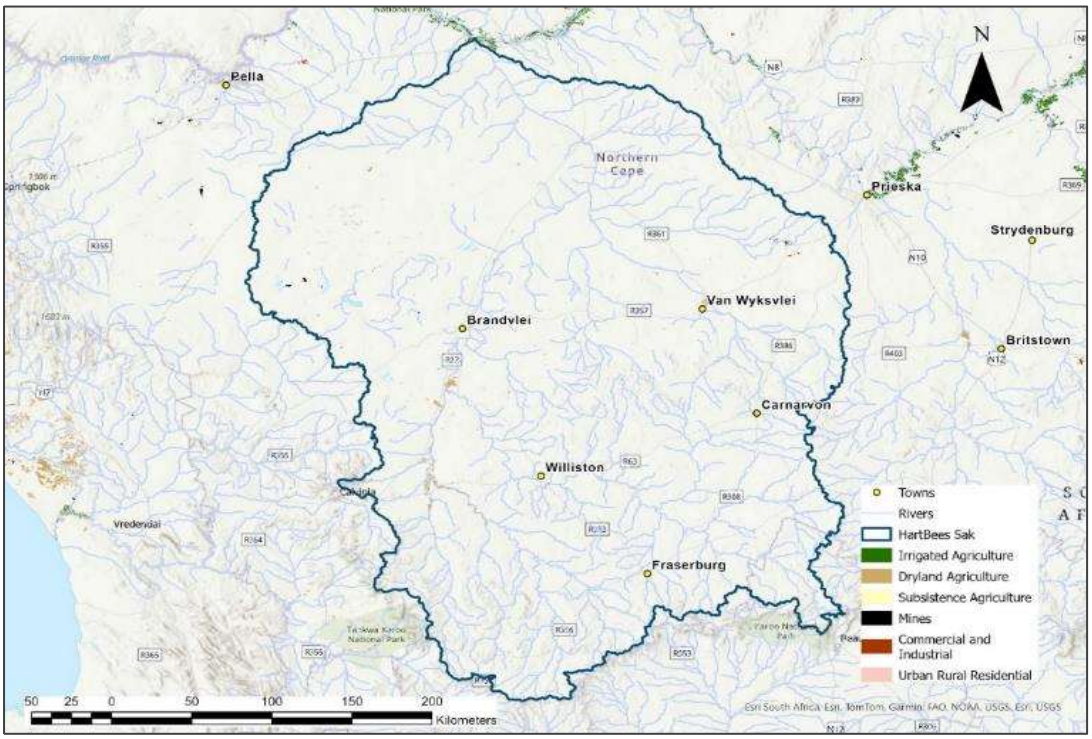



**Figure 66: Land Use by land cover in IUA 7 in the Lower Orange catchment (DFFE, 2020)**

The main economic drivers of municipalities falling within IUA 7 are set out in Table 67.

**Table 67: Economic drivers relevant to IUA 7**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| Hantam | The proportion of Hantam that lies within the Lower Orange catchment has the towns of Brandvlei and village of Middlepos.<br><br>Economic activity includes livestock farming of sheep and some crop farming of lucerne. |

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| | Manufacturing activity includes the production of salt for animal feeds from the salt pans within the area and Brandvlei is home to the large salt producing company of Saltcor. |
| Ubuntu | The small portion of Ubuntu within this IUA has the town of Loxton, the least populated town of the municipality.<br>The main land use and economic sector within IUA 7 is livestock farming of cattle. |
| Kareeberg | Towns within IUA 7 include Carnarvon and Van Wyksvlei.<br>Carnarvon supports a large sheep and game farming community, and this is the main economic sector within this IUA.<br>A small amount of tourism through the Meerkat National Park which has the Meerkat radio telescope and SKA (Square Kilometer Array) which hosts public open days for visits by the public to the site. |
| Karoo Hoogland | A large proportion of Karoo Hoogland falls within IUA 7 and has large rural areas. The main towns are Sutherland, Fraserburg and Williston.<br>The economy in this area is mainly supported by the agriculture sector and to a smaller extent tourism activities.<br>Some crop farming along the seasonal Sak river and dryland crop farming takes place in IUA 7 and there is extensive sheep farming.<br>Tourism attractions to the area are related to cultural and historical aspects with several heritage protection areas including a heritage house in Sutherland, unique houses and carved tombstones within Williston and the heritage town grid in Fraserburg. There is also the SALT (SA Large Telescope) Astronomy area north of Sutherland. |
| Kai !Garib | The main town in this IUA is Kenhardt and the main landuse and economic activity is small livestock farming of sheep. |

In IUA 7 the estimated contribution of the economic sectors to the Gross Domestic Product (GDP) of the IUA and the employment within these sectors is summarised in Table 68 and Table 69.

**Table 68: Economic sectors in IUA 7 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R767 | 33% |
| Mining | R4 | 0.2% |
| Manufacturing | R122 | 5% |
| Electricity & water | R32 | 1% |

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Construction | R124 | 5% |
| Wholesale & retail trade; catering and accommodation | R298 | 13% |
| Transport & communication | R222 | 10% |
| Financial services | R194 | 8% |
| General government | R372 | 16% |
| Community, social & personal services | R161 | 7% |
| **Total GDP** | **R2,297** | |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA | | |

**Table 69: The estimated employment by economic sector for IUA 7 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 4,713 | 43% |
| Mining | 3 | 0% |
| Manufacturing | 244 | 2% |
| Electricity & water | 13 | 0% |
| Construction | 420 | 4% |
| Wholesale & retail trade; catering and accommodation | 1,728 | 16% |
| Transport & communication | 189 | 2% |
| Financial services | 534 | 5% |
| General government | 1,571 | 14% |
| Community, social & personal services | 1,426 | 13% |
| **Total Employment** | **10,841** | |

### 10.7.5. Ecosystem Services

Situated in the southern extent of the Lower Orange catchment, specifically in the Hartbees/Sak rivers catchment, IUA 7 encompasses a diverse range of aquatic and terrestrial ecological infrastructure associated with the Hartbees River and its tributaries. These tributaries include Sout, Vis, Renoster, Sak, Carnarvonleegte, and Hartogskloof. These natural features play a vital role in providing a variety of ecosystem services that directly benefit the rural communities of Brandvlei, Kenhardt, Vanwyksvlei, Carnarvon, Swartkop, Copperton, Loxton, Fraserberg, Williston, and Sutherland.

Strategic water resource areas for groundwater have been observed in various areas within IUA 7. The region also boasts the presence of protected areas such as Meerkat National Park, further enhancing the ecological infrastructure and contributing to the provision of ecosystem services in the region.

Regionally, the Hartbees River, its tributaries, and the wetlands are considered significant aquatic resources within IUA 7. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 70).

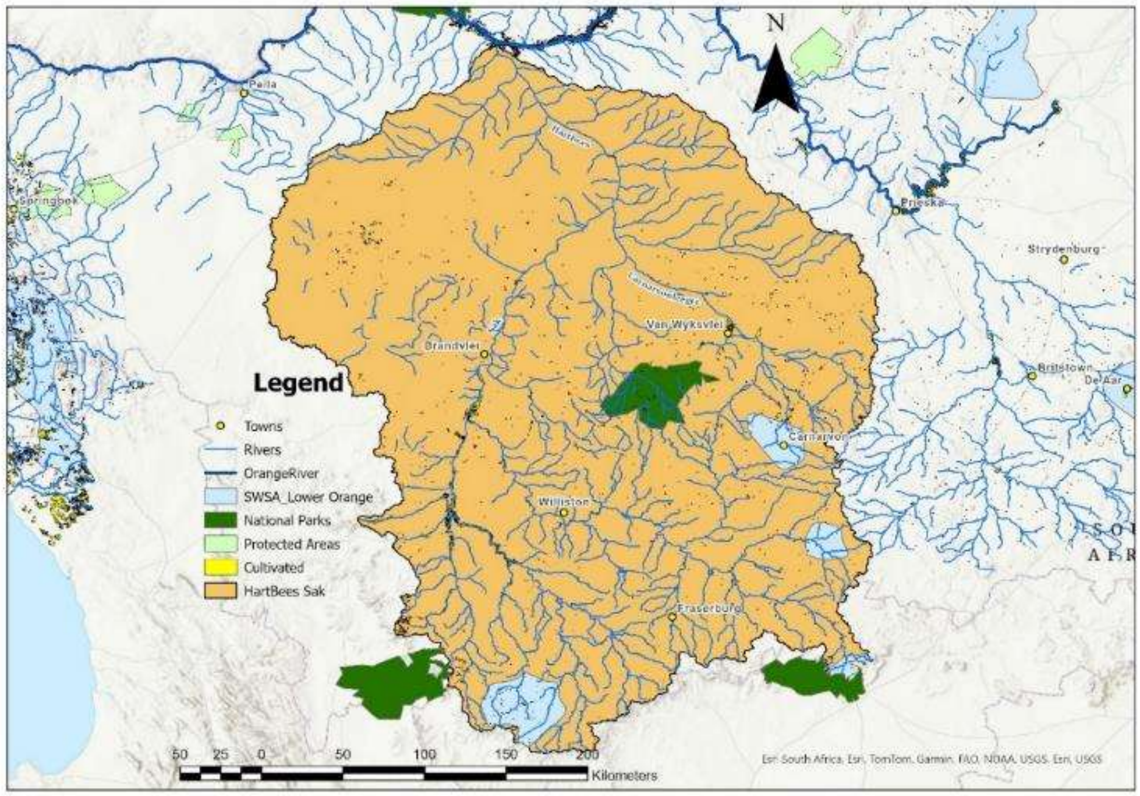



**Figure 67: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 7 in the Lower Orange Catchment**

**Table 70: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 7 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Fresh Water | Strategic groundwater, Sak river and Camarvonleegte river | Major significance: Tol crop farmers along the Vis river and smaller tributaries, Irrigation agriculture in the Williston area along the Sak river live-stock supply and household in Brandvlei, Kenhardt, Vanwyksvlei, Carnarvon, Swartkop, Copperton, Loxton, Fraserberg, Williston, and Sutherland communities. | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| | Raw materials | Wetlands | Significance to Subsistence Farmers | Agriculture; Households; Society |
| | Medicinal resources | Wetlands | Significance to Rural Communities | Households; Society |
| Regulating | Climate regulation | Wetlands | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | Wetlands; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities of Brandvlei, Kenhardt, Vanwyksvlei, Carnarvon, Swartkop, Copperton, Loxton, Fraserberg, Williston, and Sutherland | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | Wetlands; Dams; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA; Towns and communities of Brandvlei, Kenhardt, Vanwyksvlei, Carnarvon, Swartkop, Copperton, Loxton, Fraserberg, Williston, and Sutherland | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Wetlands; Hartbees River and tributaries | Major significance to commercial agriculture sector | Agriculture |
| | Biological control | Wetlands; Rivers | Major significance to commercial agriculture sector | Agriculture; Households |
| Cultural | Landscape & amenity values | Protected Areas (Meerkat National Park); Hartbees River and tributaries | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | Protected Areas (Meerkat National Park); Hartbees River and tributaries; Wetlands | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Tourism |
| | Maintenance of genetic diversity | Protected Areas (Meerkat National Park) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | Agriculture; Tourism; Society |

## 10.7.6. River Ecological information and PES

The sub-quaternary reaches are predominantly in a B and C ecological category, indicating basic ecosystem functions are still predominantly unchanged, with a good ecological condition. The ecological condition is largely related to non-flow impacts of riparian and instream zone modification or continuity or low flows. A small percentage of the reaches within the Sak sub-catchments (and Vis, Renoster and Gansvlei) are in a D category. There are no EWR sites, but JBS3 site, OSEAH45 on the Hartbees is located in D53J.

### 10.7.7. Wetlands

The wetland extent (area) and percentage of area within IUA 7 is presented in Table 38. The IUA includes depression, floodplain, seep, channellled and unchannelled valley bottom, and river wetlands, covering 7% of the catchment area. The priority wetlands included the valley bottoms associated with the Hartbees, Sak, Klein Sak, Hongerkloof se Leegte, and Mottels, and the high priority Pans- Verneuk Pan, Grootvloer, Boesmankop, and Bitterputs.

### 10.7.8. Groundwater

The GRUs included in this IUA are:

- GRU 7.1 (Karoo Beaufort sandstone and shale West – lower recharge towards the western part of GRU.)
  - Stress Index = 7%, Low aquifer yield class (0.1-0.5 L/s, lower recharge than the eastern region); and
  - Fractured (80%) and Fractured & Weathered aquifer system with potential of Ideal to Good water quality type(s).
  - Proposed PSC: B. Only 1x quaternary catchment with an E classification, *i.e*, D52C reason needs to be assessed).
- GRU 7.2 (Ecca Group sandstone and shale South and Central) - Typical Karoo sediment aquifers (fractured/jointed). Numerous Karoo Dolerite (Jd) intrusions (dolerite dykes and sills).
  - Stress Index = 6%, Moderate (east) to Low (west) aquifer yield class; and
  - Fractured (merely arenaceous) aquifer system.
  - Groundwater is a Good water quality type.
  - Proposed PSC: B, with some quaternary catchments having an A, B, and C classification with 1x an E.
- GRU 7.3 – (Ecca Group Carbonaceous shales West - Mudrock)
  - Stress Index = 5%, Low aquifer yield class (0.1-0.5 L/s); and
  - Fractured & Weathered aquifer system with poor groundwater quality type, viz., salinity due to marine type sedimentation.
  - Groundwater is a Marginal to Poor water quality type.
  - Proposed PSC: A with 1x F+ (salinity, QC D53F).
- GRU 7.4 (Karoo sandstone and shale Southwest - Typical Karoo sediment aquifers (fractured/jointed). Numerous Karoo Dolerite (Jd) intrusions (dykes and sills, representing contact zone aquifer systems.
  - Stress Index = 10%, Low aquifer yield class (0.1-0.5 L/s); and
  - Fractured aquifer system.
  - Groundwater quality is a, Ideal to Good water quality type.

  - Proposed PSC: B, but two quaternary catchments are classified with an E (seriously modified quantity).
- GRU 7.5 (Ecca Group sandstone and shale West) - Typical Karoo sediment aquifers (fractured/jointed). Numerous Karoo Dolerite (Jd) intrusions (dolerite dykes and sills).
  - Stress Index = 10%, natural to good aquifer yield status; and
  - Fractured (merely arenaceous) aquifer system with potential of ideal to good water quality types).
  - Proposed PSC: B, with some quaternary catchments having an A, and B classification with 2x an E (quaternary catchments D57A and D57C, seriously modified).
- GRU 7.6 – (Dwyka Tillite & mudrock – Basal diamictite and marine-type mudrock)
  - Stress Index = 30%, Low aquifer yield class (0.1-0.5 L/s); and
  - Fractured aquifer system.
  - Groundwater is Marginal to Poor groundwater quality type due to saline marine type sedimentation during deposition of rock formations.
  - Proposed PSC: C, although some quaternary catchments have an A, and C status.
- GRU 7.7 (Bushmanland West: Meta-sediments and meta-volcanics consisting of gneisses, schists, amphibolite, metaquartzite and older intrusive granites and gneisses.
  - Stress Index = 32%, Low aquifer yield class (0.1-0.5 L/s); and
  - Fractured & Weathered aquifer system.
  - Groundwater quality is a Poor water quality type, except quaternary catchment D53C is a Marginal water quality type.
  - Proposed PSC: C/D, but one quaternary catchment (D53C) are classified with an E (seriously modified quantity).

*Summary:*

Groundwater quality is good to Marginal to Poor due to (i) less frequent recharging rainfall events towards the west, (ii) primary salinity due to Karoo Dwyka and Ecca rock formations in a marine depositional environment, and (iii) rock type water-rock interaction.

## 10.8. IUA 8: Coastal Area

The IUA delineates the coastal catchments comprising the F10A to F60A quaternary catchments.

### 10.8.1. Rationale

The IUA encompasses a similar ecoregion (western coastal belt and Namaqua highlands). The IUA incorporates the coastal seasonal draining rivers and estuaries along the Atlantic Ocean from Papendorp north towards Visagiesfontein.

### 10.8.2. Overview

IUA 8 comprises 34 quaternary catchments. This IUA runs between two provinces, from the Northern Cape to the Western Cape. This IUA comprises of four local municipalities, including

Richterveld, Nama Khoi, Kamiesberg and a small portion of the Western Cape Matzikama municipality in the southern part of the IUA. The main towns are Port Nolloth and Springbok. There are numerous other smaller towns or villages scattered within the IUA. Port Nolloth is a fishing town and small to medium commercial sheep farming takes place in the surrounding area.

There are several protected areas including, Richtersveld protected area, the Skilpad and Namaqua National Park, part of Goegap Nature reserve in the Springbok area, Rooiklippies Nature reserve along the coast (in F40A quaternary catchment), Pleroma Nature reserve and Brakputs Nature reserve.

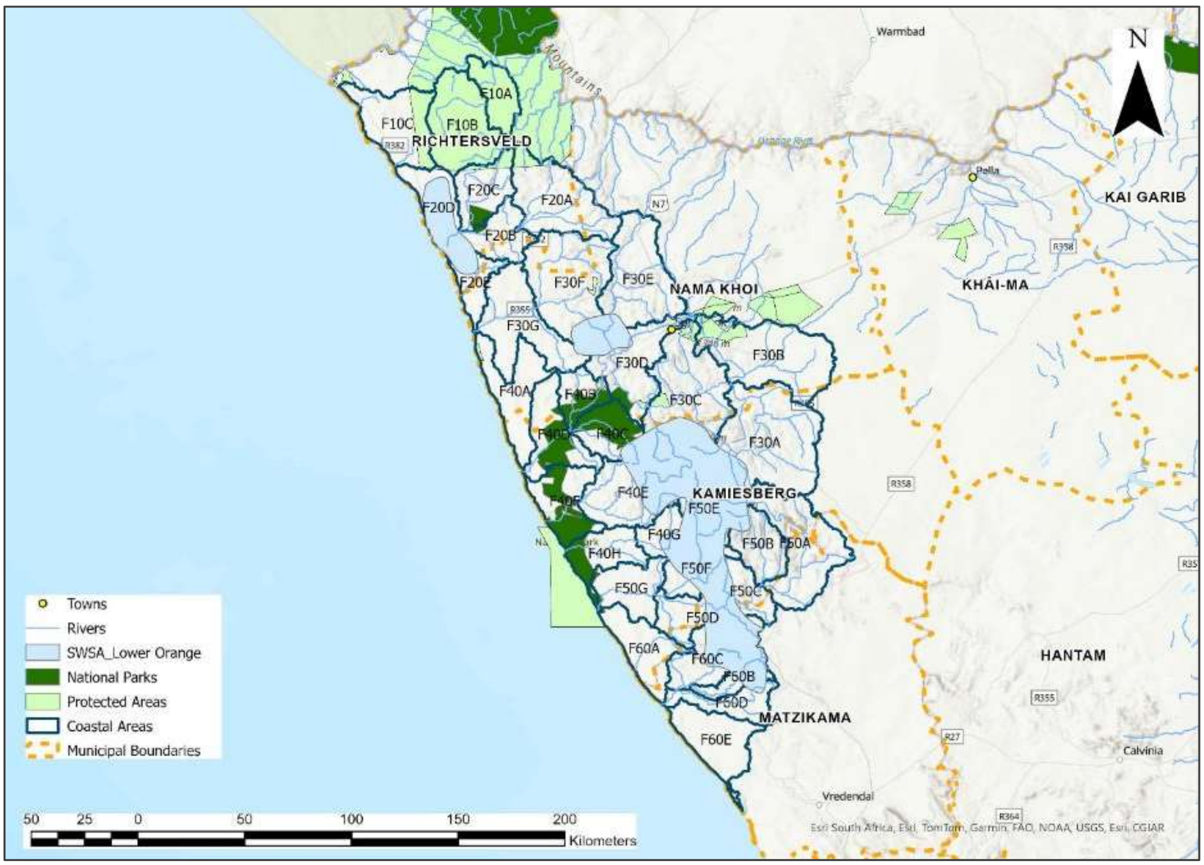



**Figure 68: Overview of boundaries and features in IUA8 of the Lower Orange River Catchment**

### 10.8.3. Water Resources

The IUA has several costal draining seasonal rivers and there are several river tributaries. The main rivers include Buffels, Holgat, Kamma, Swartintjies, Sout and Groen rivers. There is some agricultural activity along the Buffels river. There are three groundwater Strategic Water Sources areas within this IUA. IUA 8 falls within the mixed SEZ 1 with activities mainly from mixed mining, agriculture and tourism.

The IUA also includes the five smaller estuaries of national importance which are the Buffels, Sout, Swartlintjies, Spoeg and Groen estuaries. In terms of the revised estuarine classification system proposed in the NBA 2018, all five of these smaller estuarine systems are classified as Arid Predominantly Closed Estuaries (Van Niekerk, *et.al*, 2019a).

**Boundaries and EFZ of the Estuaries**

The estuarine systems include the Buffels, Swartlintjies, Groen, Spoeg and Sout (North). In terms of the classification, these systems generally have a number of characteristics in common, which include:

- These systems are generally linear or funnel shaped and closed on annual to decadal scales.
- Salinities tend to be high to hypersaline (>35) as a result of low fluvial input and high evaporation rates. Thus, mixing processes tend to occur over long time periods and are dominated by the effects of evaporation, winds and seepage.
- Occasional breaching and over-washing during high sea conditions provide for marine input and connectivity in these systems.
- Sediment processes are generally stable on decadal time scales and are reset by large intermittent flash floods.

Water levels are determined by the interplay between sand berm level, evaporation rates and seepage losses. Groundwater and inflows from local fountains replenish these losses and influence the salinity regimes of these estuaries.

The setting and boundaries of the Buffels, Swartlintjies, Groen, Spoeg and Sout (North) estuaries are summarised in Table 71.

**Table 71: Summary of data and information available for the Buffels, Swartlintjies, Groen, Spoeg and Sout (North) estuaries**

| Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|
| • Located in the Northern Cape Province at the town of Kleinzee.<br>• Buffels Estuary consists of a dry sandy/rocky river bed with shallow pans and channels in the lower reaches.<br>• Upstream limit of EFZ is marked by a road bridge that connects the diamond mining areas with Kleinzee (29°40'18.21"S, 17° 4'3.30"E) | • Situated approximately 6.5 km south of Hondeklip Bay within a strict security area of the Koignaas mining concession.<br>• Upstream limit: 30°15'45.73"S, 17°17'8.36"E.<br>• Downstream boundary: 30°15'44.33"S, 17°15'36.39"E (Estuary mouth).<br>• Lateral boundary: 5m contour above | • Spoeg Estuary is situated 230 km south of the Orange Estuary.<br>• No urban development situated at, near or close to estuary.<br>• Upstream limit: 30°28'17.92"S, 17°22'32.83"E.<br>• Downstream boundary: 30°28'20.54"S, 17°21'34.07"E (Estuary mouth).<br>• Lateral boundary: 5m contour above | • Very little is known about the estuary because of its small size and remote location.<br>• No urban development situated at, near or close to Groen estuary.<br>• Upstream limit: 30°49'38.26"S, 17°34'40.18"E<br>• Downstream boundary: 30°50'49.05"S, 17°34'35.72"E (Estuary mouth). | • The Sout Estuary is situated 60 km north of the Olifants Estuary.<br>• Situated in between the small towns of Strandfontein to the south and Hondeklip Bay to the north.<br>• Very little is known about the estuary because of its small size and remote location.<br>• Saltworks located at the Sout estuary with |

| Buffels estuary | Swartlintjies estuary | Spoeg Estuary | Groen estuary | Sout (north) estuary |
|---|---|---|---|---|
| • Downstream boundary: 29°40'37.01"S, 17° 03'4.41"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank | MSL along each bank | MSL along each bank | • Lateral boundary: 5m contour above MSL along each bank | numerous artificial channels and access roads dissecting the estuary.<br>• Upstream limit: 31°12'38.88"S, 17°53'24.41"E<br>• Downstream boundary: 31°14'37.66"S, 17°50'52.55"E (Estuary mouth).<br>• Lateral boundary: 5m contour above MSL along each bank |

### 10.8.4. Demographics and Socio-Economic Profile

The population is estimated as 65,587 (Stats SA Census 2011 adjusted) with approximately 20,354 households. In IUA 8 approximately 5.7% of the population has a higher education and 2.1% have no schooling (Stats SA Census 2022 based on the local municipalities data. The unemployment rate within IUA 8 is estimated at 22.8% (NT, 2021).

The majority of the population have access to formal water services with approximately 74% of the population have access to piped water inside their dwelling, 24% of the population have access to piped water in their yards, and the remaining 2% having access to a communal tap water within 200m of the household (Figure 69).

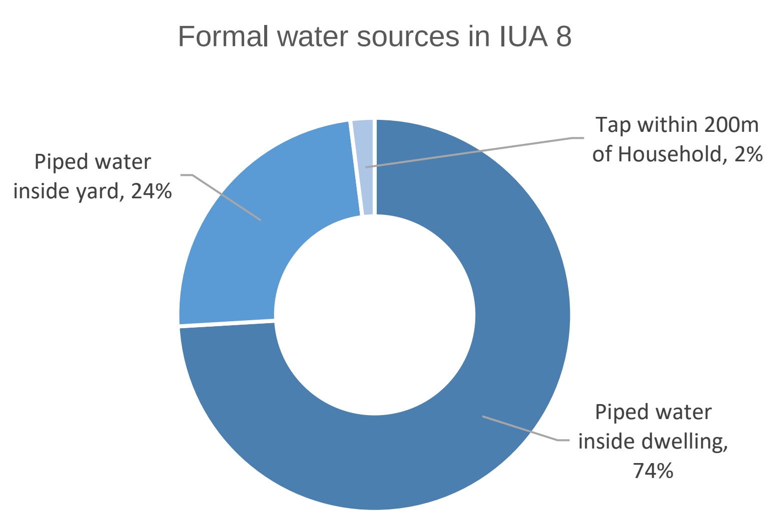



**Figure 69: Access to water services in IUA 8**

**Economic sectors**

The key land use for IUA 8 is residential settlements (Port Nolloth, Springbok and the numerous smaller towns) and some agriculture alongside the Buffels River. The other important land use is mining and this includes alluvial diamond mining, sand and kaolin clay mining, granite mining, minerals such as wollastonite and also copper mining.

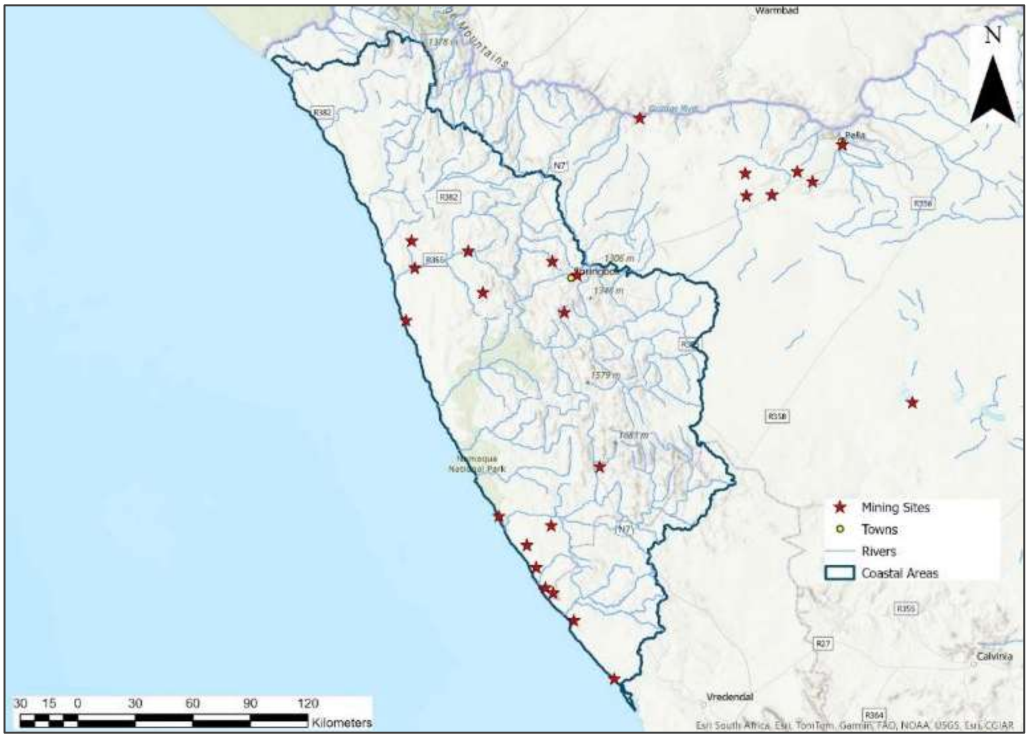



**Figure 70: Locality of mines in IUA 8 in the Lower Orange catchment**

The main economic drivers within the municipalities falling within IUA 8 are set out in Table 72.

**Table 72: Economic drivers relevant to IUA 8**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| Richtersveld | Port Nolloth is the main town within this IUA. The other small town is Lekkersing.<br>This part of the IUA is largely rural. The main economic activity includes small-scale fishing on the coast and tourism.<br>The main water use is for domestic use for the towns and other settlements in this part of the IUA |
| Nama Khoi | Towns in this part of the IUA are Springbok. Kleinsee, Steinkopf, Nababeep, Okiep.Bulletrap and Komaggas. Mining include Nama Copper mine (F30E), several sand mines and alluvial diamond mining. |

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| | The main water use is for the Diamond Coast Aquaculture, mines, and domestic use for the towns and other settlements in this part of the IUA. |
| Kamiesberg | Hondeklip Bay is the main town in this part of the IUA area. Other small towns include Kammieskroon, Koiingnaas, Soebatsfontein and Garies.<br>The main economic land use is mining and includes the mining of kaolin clay, sand mines, alluvial diamonds and mineral mining of wollastonite.<br>Another important economic activity is from tourism within the Namaqua National Park and coastal areas.<br>The main water use is for domestic use for the towns and other settlements in this part of the IUA |
| Matzikama | This part of the IUA also has a coastal area in the west of the IUA, there are various settlements like Bitterfontein and Rietport. This part of the IUA has large sands mining including Tronox Namakwa Sands which produces titanium dioxide feedstock (chloride and sulphate grades), zircon, rutile and high purity iron products and the Tormin mineral sands mine.<br>The Sere wind farm is located within quaternary catchment F60E.<br>The main water use is for mines, domestic use for the towns and other settlements in this part of the IUA. |

In IUA 8, the contribution of the economic sectors through Gross Value Added (GDP) of the IUA and the employment within these sectors is summarised in Table 73 and Table 74.

**Table 73: Economic sectors in IUA 8 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | 296 | 2.96% |
| Mining | 4,898 | 48.97% |
| Manufacturing | 427 | 4.27% |
| Electricity & water | 276 | 2.76% |
| Construction | 476 | 4.76% |
| Wholesale & retail trade; catering and accommodation | 772 | 7.72% |
| Transport & communication | 815 | 8.15% |
| Financial services | 812 | 8.12% |
| General government | 867 | 8.67% |
| Community, social & personal services | 362 | 3.62% |
| **Total GDP** | **10,002** | **100.00%** |

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA | | |

**Table 74: The estimated employment by economic sector for IUA 8 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 1,805 | 9.38% |
| Mining | 2,665 | 13.85% |
| Manufacturing | 685 | 3.56% |
| Electricity & water | 105 | 0.54% |
| Construction | 1,233 | 6.41% |
| Wholesale & retail trade; catering and accommodation | 4,166 | 21.65% |
| Transport & communication | 740 | 3.85% |
| Financial services | 1,858 | 9.65% |
| General government | 3,402 | 17.68% |
| Community, social & personal services | 2,586 | 13.44% |
| **Total employment** | **19,244** | **100.00%** |

### 10.8.5. Ecosystem Services

IUA 8 is situated in the western extent of the Lower Orange catchment, encompassing a diverse range of aquatic and terrestrial ecological infrastructure associated with the Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers and their tributaries. These tributaries include the Galgas, Stry, Doring, Skaap, Komagas, Brak, Jaagleegte, Koukamma se Holte, Wolwepoort, Klein Nou, Papkuils, Hartebees, Brand, Swart Doring, Bitter, Groen, and Klein Goerap rivers. Additionally, the region experiences seasonal draining of coastal rivers and estuaries along the Atlantic Ocean from Papendorp to Visagiesfontein. Scattered depressions and seeps near Kamieskroon and Leliefontein form wetland areas within IUA 8. These natural features play a vital role in providing a variety of ecosystem services that directly benefit the nearby communities.

Strategic water resource areas have been observed in various areas within IUA 8. The region is also home to protected areas such as Namaqua National Park and Goegap Nature Reserve, which further enhance the ecological infrastructure and contribute to the provision of ecosystem services in the region.

Regionally, the Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers, along with their tributaries and the wetlands, are considered significant aquatic resources within IUA 8. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 75).

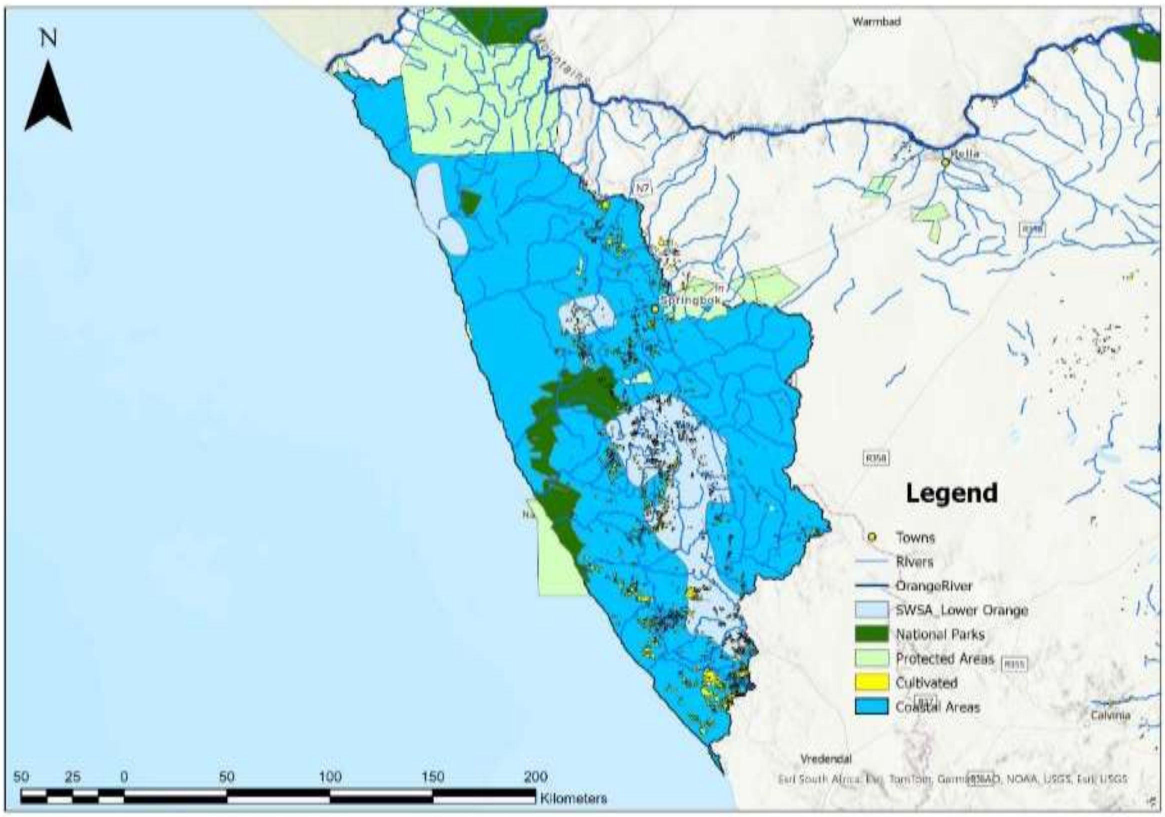



**Figure 71: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 8 in the Lower Orange Catchment**

**Table 75: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 8 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Fresh Water | Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers and their tributaries; Wetlands, Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA. Supplies water to the Springbok community. | Agriculture; Electricity and Water; Tourism; Households |
| | Raw materials | Wetlands | Significance to Subsistence Farmers | |
| | Medicinal resources | Wetlands | Significance to Rural Communities | |

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Regulating | Climate regulation | Wetlands | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | Wetlands; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | Wetlands; Strategic groundwater | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers and their tributaries; Wetlands | Major significance to commercial agriculture sector | Agriculture |
| | Biological control | Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers and their tributaries; Wetlands | Major significance to commercial agriculture sector | Agriculture; Households |
| Cultural | Landscape & amenity values | Protected Areas (Namaqua National Park and Goegap Nature Reserve); Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers and their tributaries; Wetlands | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | Protected Areas (Namaqua National Park and Goegap Nature Reserve); Buffels, Holgat, Kamma, Swartintjies Sout, and Groen Rivers and their tributaries; Wetlands | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Tourism |
| | Maintenance of genetic diversity | Protected Areas (Namaqua National Park and Goegap Nature Reserve) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | Agriculture; Tourism; Society |

### 10.8.6. River Ecological information and PES

The ecological condition of the rivers in the IUA are predominantly in the B PES category, indicating a largely natural state. The Buffels sub-catchment includes reaches with a PES of C and Bitter tributary with a D ecological category. These are related to localised impacts of water quality and flow. There are no river EWR sites in the IUA.

In the 2017b EWR study by DWS, an Estuarine Health Assessment, included limited field assessments and sampling of the 5 estuaries to support the determination of EWRs for the estuaries (DWS, 2017b). The estuaries in the IUA have been delineated as separate Estuarine Resource Units in the 2017 EWR study (DWS, 2017b). The PES for each estuarine component, including overall system PES and REC were recalculated during the NBA 2018 assessment (Van Niekerk, *et.al*, 2019b), and are included in Table 76.

**Table 76: PES, REC and PES of individual components of the Buffels, Swartlintjies, Spoeg, Groen and Sout estuaries (Van Niekerk, et.al, 2019b)**

| | **Buffels** | **Swartlintjies** | **Spoeg** | **Groen** | **Sout (Noord)** |
|---|---|---|---|---|---|
| **NBA 2018 Condition Status** | **Heavily Transformed** | **Near Natural** | **Near Natural** | **Near Natural** | **Severely/ Critical Transformed** |
| **Present Ecological State (PES), 2018** | **D** | **B** | **A/B** | **B** | **E** |
| Hydrology | E | B | C | C | E |
| Hydrodynamics | D | B | B | C | F |
| Water Quality | D | B | B | B | D |
| Physical habitat | D | B | B | A | E |
| Microalgae | D | B | B | B | E |
| Macrophytes | E | C | A | B | F |
| Invertebrates | D | D | A | C | E |
| Fish | E | B | A | B | F |
| Birds | D | B | A | B | E |
| **Recommended Ecological Category (REC)** | **D** | **B** | **A/B** | **B** | **E** |

### 10.8.7. Wetlands

The wetland extent (area) and percentage of area within IUA 8 is presented in Table 38. The IUA includes depression, floodplain, seep, channellled valley bottom, river wetlands and the estuary covering 2% of the catchment area. No priority wetlands have been preliminarily identified.

### 10.8.8. Groundwater

The GRUs included in this IUA are:

- GRU 8.1 (Namaqualand East - Metamorphic Terrane consisting of various meta-quartzites, shist-phyllitic formations and granite-gneiss suites – very complex geology!).
  - Stress Index = 16%, Insignificant to Low aquifer yield class; and
  - Fractured & Weathered aquifer system.
  - Groundwater is a Marginal to Poor water quality type due to marine aerosols in the recharging rainwater.
  - Proposed PSC: B, with one quaternary catchment having a F status.

- GRU 8.2 (Namaqualand West – Metamorphic Terrane, plus Nama Group meta-sediments).
  - Stress Index = 11%, Insignificant to Low aquifer yield class.
  - Fractured & Weathered aquifer.
  - Groundwater is a Marginal to Poor quality type.
  - Proposed PSC: A/B. Only one quaternary catchment with an F classification, *i.e.*, F20B; reason needs to be assessed).
- GRU 8.3 (Namaqualand coastal - Sediment cover over Nama (quartzite, lava & siltstone) and Vanrhynsdorp (phyllitic siltstones) Groups and various granite-gneiss suites.
  - Stress Index = 18%, Insignificant to Low (<0.5 L/s) aquifer yield class; and
  - Fractured aquifer system.
  - Groundwater is an ideal to good water quality types.
  - Proposed PSC: B.
  - The following quaternary catchment s were not assessed during the 2016 EWR assessment: F60B, -C, -D, and -E.

*Summary:*

Groundwater quality is Marginal to Poor due to typical frontal rainfall events driven by westerly cold fronts. Water quality, therefore, has a dominant (natural) saline signature due to the saline seafront aerosols.

## 10.9. IUA 9: Upper Molopo and Upper Kuruman

This IUA incorporates the upper reaches of the Molopo and Kuruman sub-catchment areas comprising the D41B, D41C, D41D, D41E, D41F, D41H, D41K, D41G and D41M quaternary catchments. It includes the town of Kuruman in D41L. The IUA includes Botswana as its western and northern boundary.

### 10.9.1. Rationale

The IUA terrain morphological types consist of plains with low to moderate relief in the east, and open hills, lowlands and mountains with moderate to high relief in the west. The IUA is delineated based on land use activities, high density and associated impacts in the region (mining, towns and agriculture). Rivers are largely ephemeral. High dependence on groundwater.

### 10.9.2. Overview

IUA 9 comprises 10 Quaternary catchments in tertiary catchment D41 (excludes D41A) and these fall within the Northern Cape province and the Northwest Province. The local municipalities that fall partly or completely within the IUA include Joe Morolong, Ga-Segonyana, Gamagara in Northern Cape and Kagisano/Molopo, Ratlou, and a very small portion of Mafikeng, Tswaiing, and Ditsobotla local municipalities in the Northwest province. The IUA includes the towns of Kathu, Sesheng, Olifantshoek, Dibeng, Hotazel, Glosum, Lohatlha army base and larger town of Kuruman in the Northern Cape. In the portion of the IUA that falls within the Northwest province it is more rural and is characterised by many townships and villages within the area but no major towns.

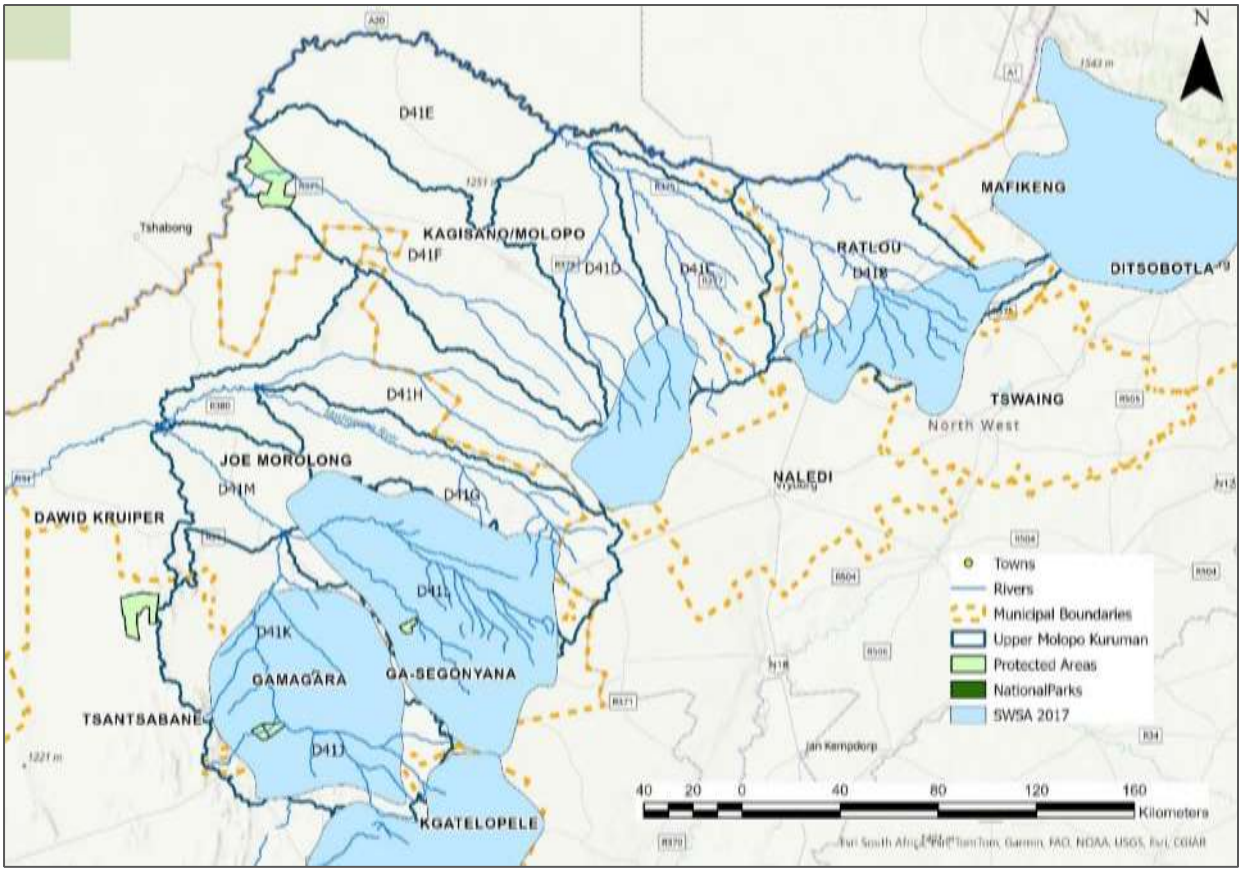



**Figure 72: Overview of boundaries and features in IUA 9 of the Lower Orange River Catchment**

### 10.9.3. Water Resources

The main rivers with this IUA include the Molopo River on the boundary with Botswana and several of its tributaries including Setlagole, Tlhakgameng, Phepane, and the Kuruman River and tributary Moshaweng River. The IUA area includes the protected area of the Molopo Game Reserve, Brooks Nature Reserve, Khathu Forest Nature Reserve and Billy Duvenage Nature reserve and three groundwater Strategic Water Resources Areas (*viz*. Sishen/Kathu, Northern Ghaap Plateau, Eastern Kalahari A and B) falling in parts of the IUA in D41L, D41D and D41B. The IUA falls within two SEZs. Quaternary catchments D41J, D41K and D41M fall into the Mining SEZ, and the remaining quaternary catchments fall into the Mixed SEZ 3 with the main land use being for mainly for subsistence and a small amount of commercial agriculture.

### 10.9.4. Demographics and Socio-Economic Profile

IUA 9 is the most densely populated IUA in the Lower Orange Catchment study area and the population is estimated as 527,241 (Stats SA Census 2011 adjusted) with approximately 196,490 households. In IUA 9 approximately 6.6% of the population has a higher education and 11.66% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within IUA 9 is estimated at 29.5% (NT, 2021).

Most of the population have access to a formal source of water (92%) and the remaining population (8%) rely on informal water sources (Figure 73). In relation to formal water sources 63% of the population rely on communal taps as the source of water with 49% having access to a tap that is within 200m of the household and 14% have more limited access with the tap more than 200m from the household. Only 32% of the population has access to piped water inside their dwelling or inside their yard (Figure 73). In IUA 9 people are mainly housed in formal dwellings with the proportion ranging from 82.4% to 96.8% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022). Informal water sources in the IUA include boreholes (88%), Rivers or streams (3%), rainwater tanks (2%) and dams or pools (1%) or other unspecified sources (6%).

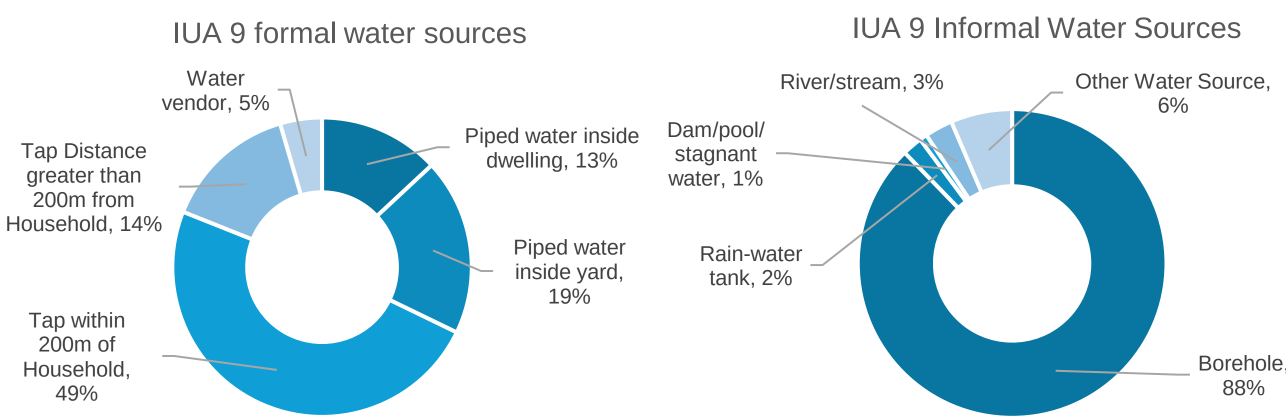



**Figure 73: Access to water services in IUA 9**

### Economic sectors

The key land use in IUA 9 providing the main economic contribution is from mining of iron ore and manganese in quaternary catchments D41J, D41K and D41M and this area is in the Gamagara Mining development corridor. Other land use and economic activity is from commercial agriculture including livestock, poultry and crop farming and a large area of subsistence farming (mixed farming of grains, vegetables, poultry and livestock) and some manufacturing particularly in the Kuruman area (furniture and metals, machinery and equipment manufacturing sectors).

The main economic drivers of the main economic contributing municipalities falling within IUA 9 are set out in Table 77.

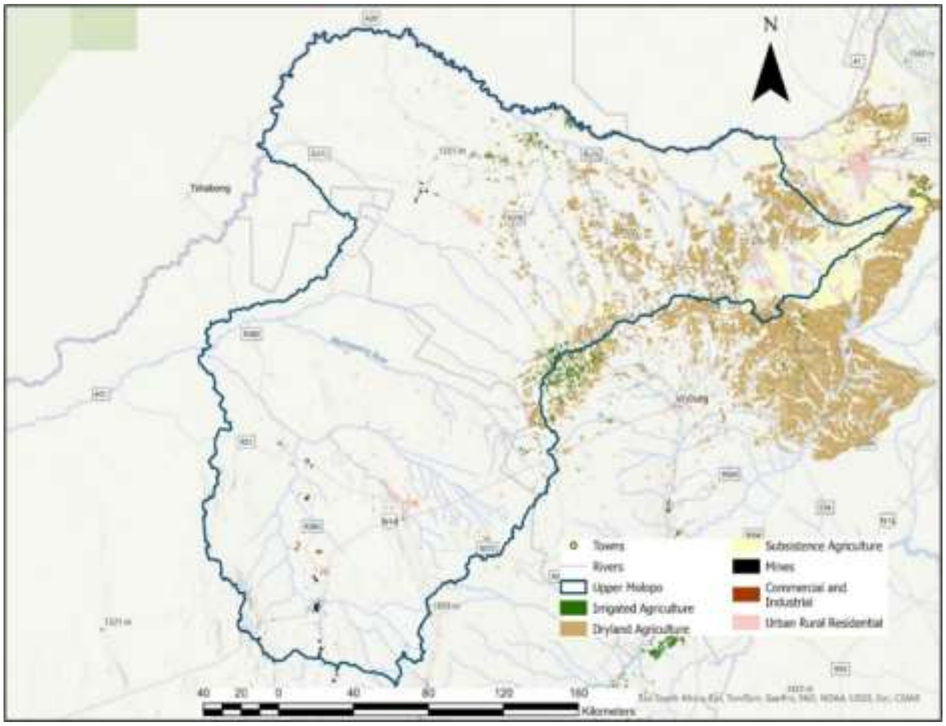



**Figure 74: Land Use by land cover in IUA 9 in the Lower Orange catchment (DFFE, 2020)**

**Table 77: Economic drivers relevant to IUA**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2021, 2022, 2023) |
|---|---|
| Joe Morolong | The small town of Hotazel is in IUA 9 and numerous rural residential settlements or townships are scattered within this municipality area of the IUA.<br><br>A key economic activity on the western part of the IUA is the extensive mining of iron ore and manganese.<br><br>Agriculture is also an important economic sector with mainly livestock farming.<br><br>Tourism activities also contribute to the economy of the IUA particularly from the Tswalu Kalahari Nature Reserve. |
| Ga-Segonyana | The main town is Kuruman and a large number of more rural residential settlements or townships. The main formal economic activities are in the town of Kuruman and include manufacturing (furniture and metals, machinery and equipment). Agriculture is also important in the municipal area and includes cattle farming, goat farming, poultry farming, game farming, meat processing, fruit and vegetable farming and there is a leather tannery.<br><br>The large rural community is involved in mixed farming activities. |

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2021, 2022, 2023) |
|---|---|
| | Other economic activity includes tourism with attractions including the Kuruman Eye (spring), Kuruman Moffat Mission and the Wonderwerk Caves. |
| Kagisano/Molopo | A large proportion of this municipality falls within IUA 9 and has numerous villages. The main economic activity is agriculture based and includes both livestock and crop farming. Main crops include potatoes, peanuts, cabbage, carrots and onions. Livestock includes sheep, goats and game.<br>The IUA is also characterised by areas of subsistence agriculture in and around the villages. |
| Gamagara | The main towns in the IUA include Kathu, Sesheng, Olifantshoek and Dibeng.<br>The key economic sector and land use is from mining and forms part of the Gamagara mining corridor with iron mines. There is also a shale brickmaking and bitumous coal mine in this IUA near Oilifantshoek.<br>Some tourism activities as the area have an endemic camel-thorn tree forest which has National Heritage status north of Kathu. |
| Ratlou | This part of the IUA is largely rural and has numerous villages. There are commercial farms within this IUA and it is for dryland agriculture. |

In IUA 9 the estimated contribution of the economic sectors to the Gross Domestic Product (GDP) of the IUA and the employment within these sectors is summarised in Table 78 and Table 79.

**Table 78: Economic sectors in IUA 9 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R1,585 | 4% |
| Mining | R17,659 | 49% |
| Manufacturing | R1,389 | 4% |
| Electricity & water | R606 | 2% |
| Construction | R1,367 | 4% |
| Wholesale & retail trade; catering and accommodation | R3,313 | 9% |
| Transport & communication | R2,230 | 6% |
| Financial services | R2,842 | 8% |
| General government | R2,855 | 8% |
| Community, social & personal services | R1,931 | 5% |
| **Total GDP** | **R35,777** | **100%** |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA | | |

**Table 79: The estimated employment by economic sector for IUA 9 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of jobs) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 14,138 | 18% |
| Mining | 8,733 | 11% |
| Manufacturing | 2,998 | 4% |
| Electricity & water | 243 | 0% |
| Construction | 3,536 | 4% |
| Wholesale & retail trade; catering and accommodation | 16,326 | 20% |
| Transport & communication | 2,516 | 3% |
| Financial services | 7,177 | 9% |
| General government | 11,714 | 15% |
| Community, social & personal services | 12,823 | 16% |
| **Total Employment** | **80,205** | **100%** |

### 10.9.5. Ecosystem Services

IUA 9 is situated in the northeastern part of the Lower Orange catchment and encompasses a diverse range of aquatic and terrestrial ecological infrastructure associated with the Molopo and Kuruman Rivers, as well as their tributaries, including Setlagole, Tlhakgameng, Phepane, and Moshaweng. These tributaries are likely to provide a variety of ecosystem services to the communities in the area. This IUA is also home to various small nature reserves including Molopo Game Reserve in D41F, Brooks Nature Reserve and Khathu Forest Nature Reserve in D41J and Billy Duvenage Nature reserve in D41L.

The Molopo and Kuruman Rivers, along with their tributaries and ephemeral wetlands, are considered significant aquatic resources within IUA 9 and strategic groundwater sources located in the southern and western part of the region. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 80).

### 10.9.6. River Ecological information and PES

The rivers in the IUA are in a moderate to largely modified ecological condition, falling largely within a C or D PES ecological category, with the exception of the upper reaches of the Kuruman and an unnamed tributary, which are the only river reaches in E PES category. This is due to flow and non-flow (riparian zone and instream modification or continuity) impacts related small weirs, instream dams, land use and erosion. Wate quality impacts are observed in the around the town on Kuruman. The reach of the Kuruman River in D41M is in a B PES category. A large part of the area includes ephemeral or episodic rivers which were not assessed. There are no EWR sites in the IUA as the rivers are predominantly ephemeral. A JBS3 site, site 54 is located in D41B.

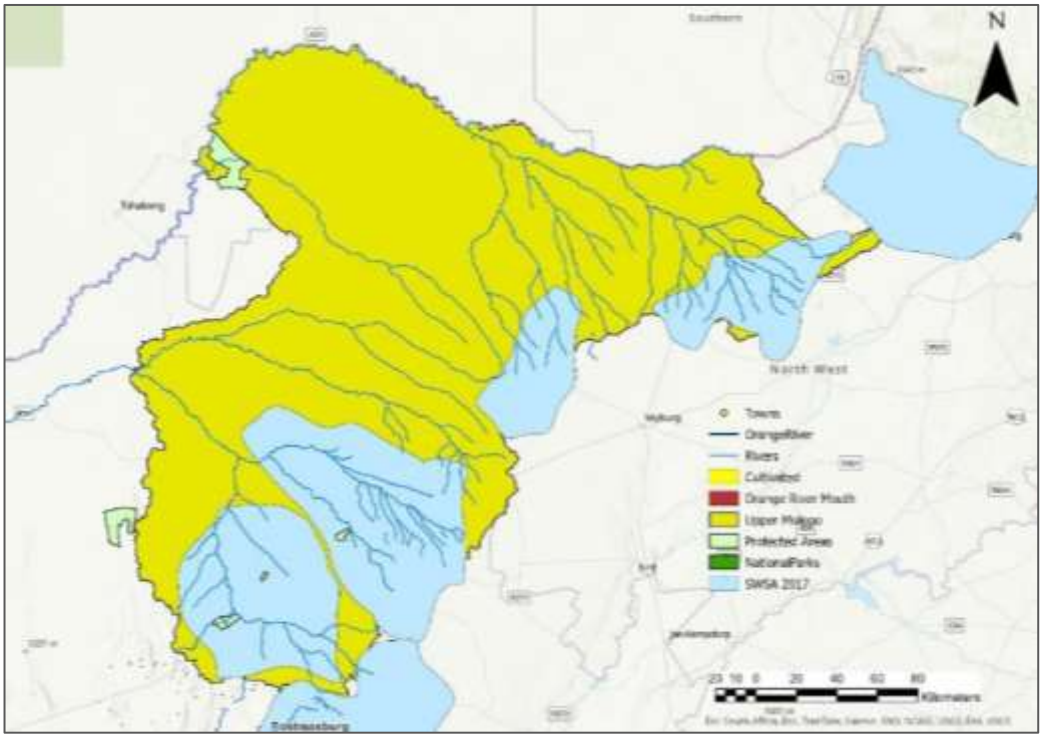



**Figure 75: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 9 in the Lower Orange Catchment**

**Table 80: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 9 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment)**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Fresh Water | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA and the supply of water to Kuruman community | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Raw materials | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | Significance to Subsistence Farmers | Agriculture; Households; Society |
| | Medicinal resources | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | Significance to Rural Communities | Households; Society |
| Regulating | Climate regulation | ephemeral Wetlands | Major Significance to Global Beneficiaries | Society |
| | Water quantity regulation | ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | ephemeral Wetlands | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | Major significance to commercial agriculture sector | Agriculture |

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| | Biological control | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | Major significance to commercial agriculture sector | Agriculture; Households |
| Cultural | Landscape & amenity values | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| Biodiversity | Critical habitat & range restricted species | Molopo River, Kuruman River, and tributaries; ephemeral Wetlands | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Tourism |

### 10.9.7. Wetlands

The wetland extent (area) and percentage of area within IUA 9 is presented in Table 38. The IUA includes depression, floodplain, seep, channellled and unchannelled valley bottom, and river wetlands, covering 1% of the catchment area. No preliminary priority wetlands are identified in this IUA.

### 10.9.8. Groundwater

The GRUs included in this IUA are:

- GRU 9.1 (Eastern Kalahari – Lower Molopo River - Kalahari Group Aquifers with paleo-drainage channels (upper half of quaternary catchment). Thick (+6 m) Kalahari Sand on fractured & fractured & weathered aquifers (lower half of quaternary catchment). Water quality and borehole yield highly variable.
  - Kalahari Beds overlying:
    - Basement Granite & Greenstone Belts;
    - Kalahari Beds on Ghaap Plateau & BIF;
    - Deep Kalahari Beds on Karoo Dwyka;
    - Deep Kalahari Beds on Karoo Dwyka (N) and Basement Granites (S) with lava, BIF and dolomite outcrops; and
    - Moderate Kalahari Beds on Karoo Dwyka Tillites.
  - Stress Index: not assessed; and
  - Fractured basement hard rock formation consisting of quartzites, banded ironstone and dolomites, overlain by Kalahari Group Sediments (gravels, sand(stone), clay(stone), silcrete, calcretes and aeolian sand)
  - Proposed PSC: not assessed yet.

- GRU 9.2 (Upper reaches of the Gamagara, Kuruman and Moshaweng Rivers draining towards the Molopo River) with the following hydrogeological characteristics:
  - Kalahari Beds overlying:
    - Ghaap Plateau (DLMT);
    - Thin Kalahari Beds overlying Olifantshoek Grp. (LAWA), Asbesberge Frm. (BIF), and Ghaap Plateau Frm. (DLMT); and
    - Moderate Kalahari Beds overlying Olifantshoek Grp (LAVA, East) and (QRTZ, West).
  - Fractured basement hard rock formation consisting of quartzites, banded ironstone and dolomites, overlain by Kalahari Group Sediments (gravels, sand(stone), clay(stone), silcrete, calcretes and aeolian sand)
  - Partial combination of Fractured & Weathered aquifer type with isolated, but saturated paleo drainages filled with basal Kalahari Group gravels.
  - Stress Index: not assessed.
  - Groundwater is an Ideal to Good water quality type.
  - Proposed PSC: not assessed yet.
- GRU 9.3 (Upper reaches of the Groenwaterspruit-Soutloop (quaternary catchment D73A) and “Unknown” spruit (quaternary catchment D71B) draining towards the Orange River.
  - Stress Index = 18%, Insignificant to Low (<0.5 L/s) aquifer yield class; and
  - Fractured aquifer system.
  - Groundwater is an Ideal to Good water quality type.
  - Proposed PSC: A, but QC D73A is not assessed yet.

*Summary:*

Groundwater quality in this GRU is highly variable due to the limiting rainfall recharge due to the overlying Kalahari (aeolian) sand and Kalahari Group sediments below. On the southern part of the GRU, where the Kalahari Group sediments are thinner higher yields and good water quality are present. Borehole yields are generally low to insignificant with good to marginal water quality type, however, where the paleo-drainage channels in the Kalahari floor are saturated (with good water quality type), these individual yields can be as high as 10 l/s.

## 10.10. IUA 10: Lower Molopo

IUA 10 incorporates the lower reaches of the Molopo and Kuruman rivers, comprising the D42A, D42B, D42C, D42D, D42E, D81C quaternary catchments. It includes the Lower Molopo and Kuruman to Orange River Confluence.

### 10.10.1. Rationale

Terrain morphological types consist of plains with low to moderate relief in the east, and open hills, lowlands and mountains with moderate to high relief in the west. IUA is largely rural, limited development. Rivers are largely ephemeral.

### 10.10.2. Overview

IUA 10 comprises five quaternary catchments of tertiary catchment D42 and one of D81 falling within the Dawid Kruiper, Kai !Garib, Joe Morolong and Tsantsabane local municipalities and the Northern Cape province bordering Namibia to the west and Botswana to the north-east of the IUA. The main towns within IUA 10 include Groot Mier, Klein Mier, Rietfontein, Welkom, Tweerivieren, Askham, Van Zylsrus, Noenieput and Riemvasmaak – most of these towns are solely supplied by local groundwater resources.

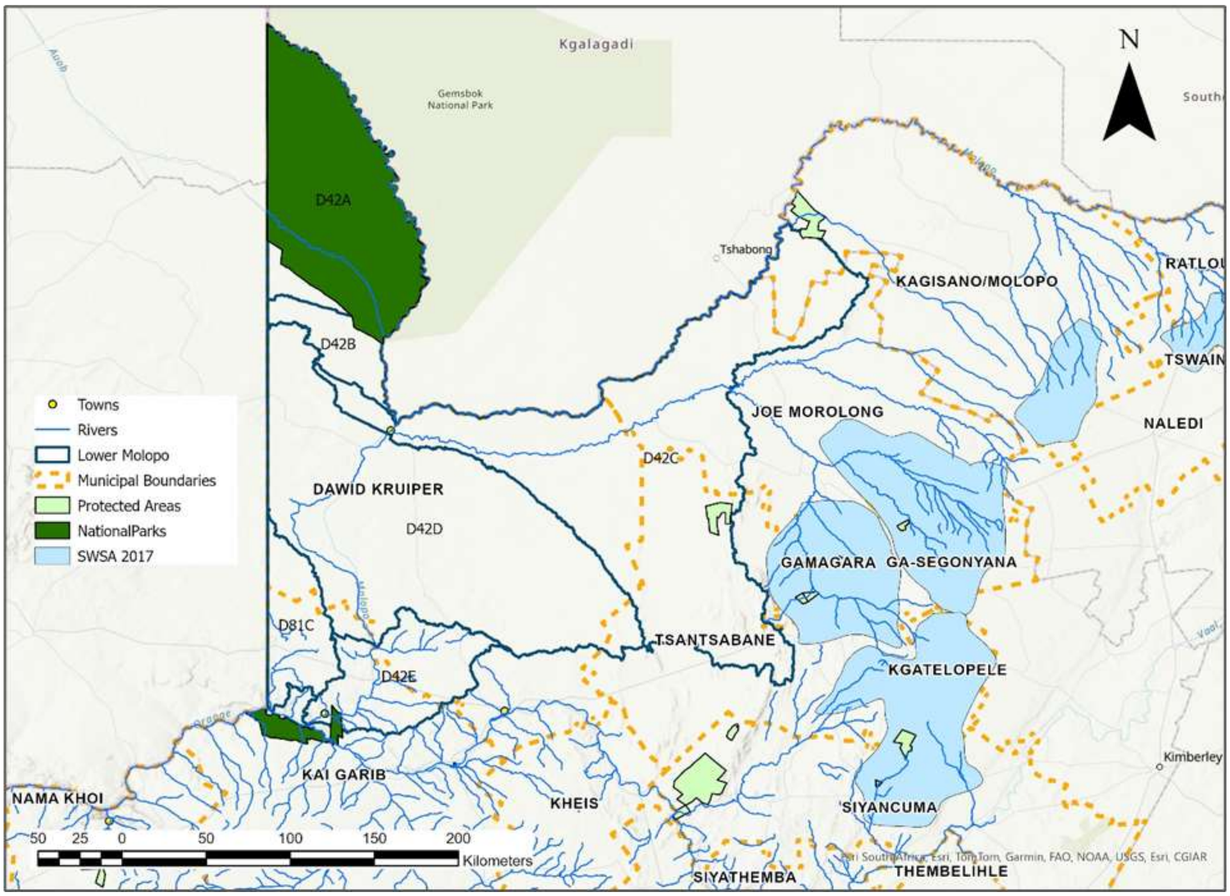



**Figure 76: Overview of boundaries and features in IUA 10 of the Lower Orange River Catchment**

### 10.10.3. Water Resources

The main river in this IUA is the Molopo River which confluences with the Orange River in D42E at the outlet of this IUA and then main tributary is the Kuruman River. Much of this IUA is dry and arid. Most of the northern most quaternary catchment of IUA 10 is part of the Kalahari Gemsbok Park which forms part of the cross-border Kgalagadi Transfrontier Park with Botswana. Other protected areas within IUA 10 include parts of the Augrabies Falls National Park near Riemvasmaak in quaternary catchment D42E and Tswalu Kalahari Nature Reserve in D42C. This IUA is part of mixed use SEZ 3 with land use including livestock and game farming and some salt mining use around the salt pans in quaternary catchment D42D and tourism in the National Park and nature reserves of the IUA.

### 10.10.4. Demographics and Socio-Economic Profile

The population of IUA 10 is estimated as 10,675 (Stats SA Census 2011 adjusted) with approximately 2,929 households. In IUA 10 approximately 5.4% of the population has a higher education and 4.3% have no schooling (Stats SA Census 2022 based on municipal data for municipalities falling within the IUA). The unemployment rate within IUA 10 is estimated at 26.1% (NT, 2021).

Access to water services is predominantly from formal water sources (98%) and 2% of the population rely on informal water sources (Figure 77). 84% of the population has access to piped water within their dwelling or yard and 15% rely on water from a communal tap. People are mainly housed in formal dwellings with the proportion ranging from 71.5% to 88.6% across the municipalities falling in the IUA in comparison to the National 88.5% of households residing in formal dwellings (Stats SA Census 2022). In terms of informal water sources most of the population relying on these water sources source water from boreholes (47%) or rivers and streams (34%) while approximately 19% rely on water from dams, pools or stagnant water.

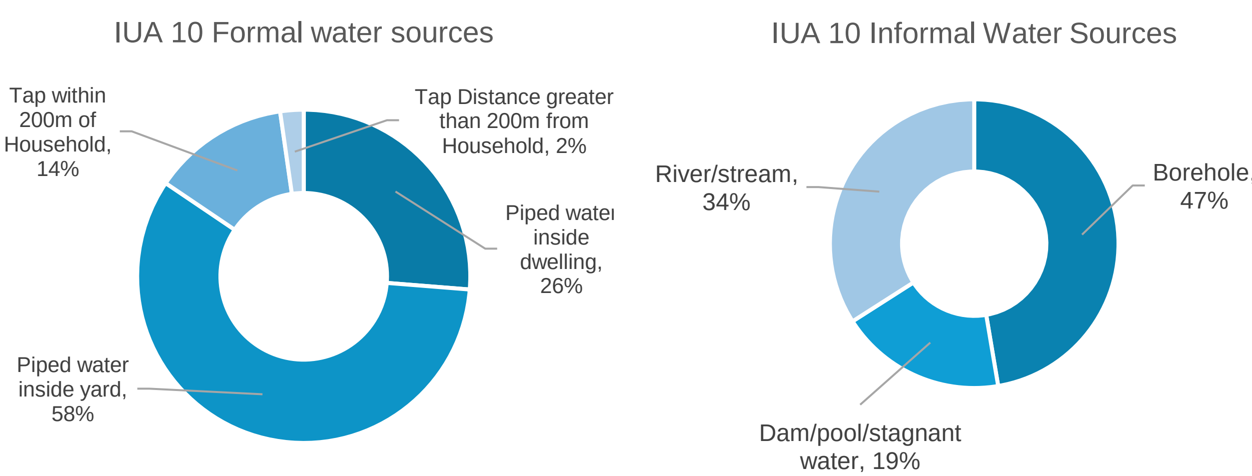



**Figure 77: Access to water services in IUA 10**

#### Economic sectors

The main economic sectors contributing to the economy of IUA 10 are in the tertiary sector. Agriculture is the larger primary sector contributor and is mainly from livestock and game farming. Tourism is an important economic sector within this IUA. Mining plays a minor role in comparison to the other IUAs within the Lower Orange catchment.

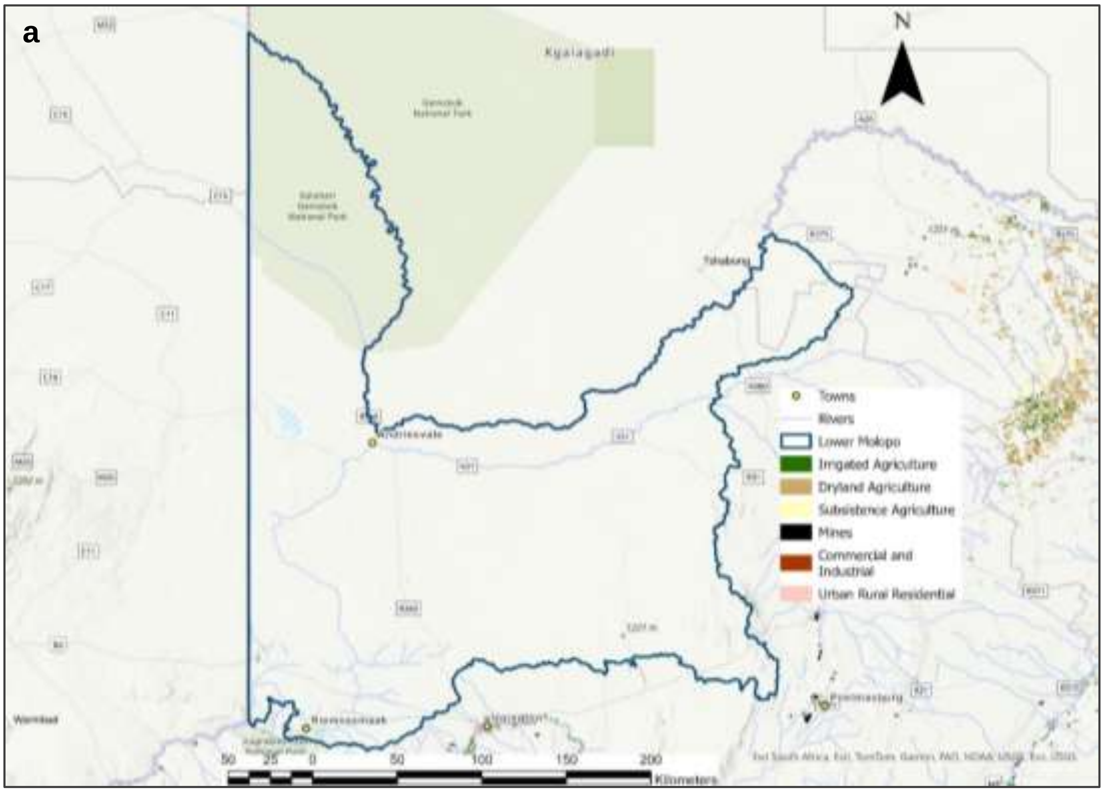



**Figure 78: Land Use by land cover in IUA 10 in the Lower Orange catchment (DFFE, 2020)**

The main economic drivers of the municipalities that contribute towards the main economic activity within IUA 10 are set out in Table 81.

**Table 81: Economic drivers relevant to IUA 10**

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| Dawid Kruiper | The main towns within this IUA are Groot Mier, Klein Mier, Rietfontein, Welkom, Tweerivieren, and Noenieput. The main economic activities include tourism with one of the main attractions being the Kalahari Gemsbok Park at the northern part of the IUA.<br>The area is in salt deposits and two salt mining companies operate in this IUA which are Eenzaamheid Salt mine and Upington Super Sout (EDMS) Ltd. |
| Kai !Garib | In this IUA the main settlement or town is Riemvasmaak and part of an area of land held by The Riemvasmaak Community Trust. The main land use here is subsistence livestock farming and a small area of crop farming of grapes. |

| Local Municipality | Description of economic sectors and activity of importance in the IUA (Municipal IDPs 2022 and 2023) |
|---|---|
| Joe Morolong | The town of this municipality that falls within IUA 10 is Van Zylsrus. The main activity within the area is rangeland type of livestock farming. |

In IUA 10 the estimated contribution of the economic sectors to the Gross Domestic Product (GDP) of the IUA and the employment within these sectors is summarised in Table 82 and Table 83.

**Table 82: Economic sectors in IUA 10 and the contribution to GDP (NT, 2021)**

| Economic Sector | GDP by economic sector (R million) | % GDP contribution |
|---|---|---|
| Agriculture, forestry and fishing | R104 | 12% |
| Mining | R5 | 1% |
| Manufacturing | R74 | 8% |
| Electricity & water | R33 | 4% |
| Construction | R32 | 4% |
| Wholesale & retail trade; catering and accommodation | R126 | 14% |
| Transport & communication | R150 | 17% |
| Financial services | R188 | 21% |
| General government | R131 | 15% |
| Community, social & personal services | R55 | 6% |
| **Total GDP** | **R897** | **100%** |
| * The values are estimated from the municipal socio-economic profiles (NT, 2021) and taking into account the proportion of the population and municipality that falls within the IUA | | |

**Table 83: The estimated employment by economic sector for IUA 10 (NT, 2021)**

| Economic Sector | Employment by economic sector (number of people) | % contribution |
|---|---|---|
| Agriculture, forestry and fishing | 723 | 23.6% |
| Mining | 3 | 0.1% |
| Manufacturing | 154 | 5.0% |
| Electricity & water | 12 | 0.4% |
| Construction | 138 | 4.5% |
| Wholesale & retail trade; catering and accommodation | 648 | 21.1% |
| Transport & communication | 128 | 4.2% |
| Financial services | 339 | 11.1% |
| General government | 527 | 17.2% |
| Community, social & personal services | 394 | 12.9% |
| **Total Employment** | **3,066** | **100%** |

### 10.10.5. Ecosystem Services

IUA 10 is located in the northern part of the Lower Orange catchment and encompasses a diverse range of aquatic and terrestrial ecological infrastructure associated with Molopo River tributaries, including Kuruman, which flow from IUA 9 to IUA 10. These tributaries likely provide a variety of ecosystem services to the communities in the area. Additionally, the Molopo River runs through IUA 10. The region is also home to the Kgalagadi Transfrontier National Park, a protected area and the protected area of the Tswalu Nature reserve.

Within IUA 10, the Molopo River, its tributaries, and the saltpans/wetlands are considered significant aquatic resources. Utilising the presence of ecological infrastructure, a mapping exercise was conducted utilising the presence of ecological infrastructure together with socio-economic status quo to identify likely flows of ecosystem services (Table 84).

### 10.10.6. River Ecological information and PES

The lower Molopo River and its tributaries the Kuruman, Nossob and Auob rivers are found within the IUA. The rivers in the sub-catchment are in a good to moderate ecological condition, falling largely within a B, C or D PES ecological category. This is due to flow and non-flow (riparian zone and instream modification or continuity) impacts related small weirs, instream dams, land use and erosion. A large part of the area includes ephemeral or episodic rivers which were not assessed. The lower reaches of the Molopo are in a largely natural or natural state (A and B category PES). There are no EWR sites in the IUA, but there are 2 JBS3 groundwater sites (GW4 &GW5)

### 10.10.7. Wetlands

The wetland extent (area) and percentage of area within IUA 10 is presented in Table 38. The IUA includes depression, seep, channelled valley bottom, and river wetlands, covering 3% of the catchment area. The priority wetlands include the wetlands along the Molopo main stem.

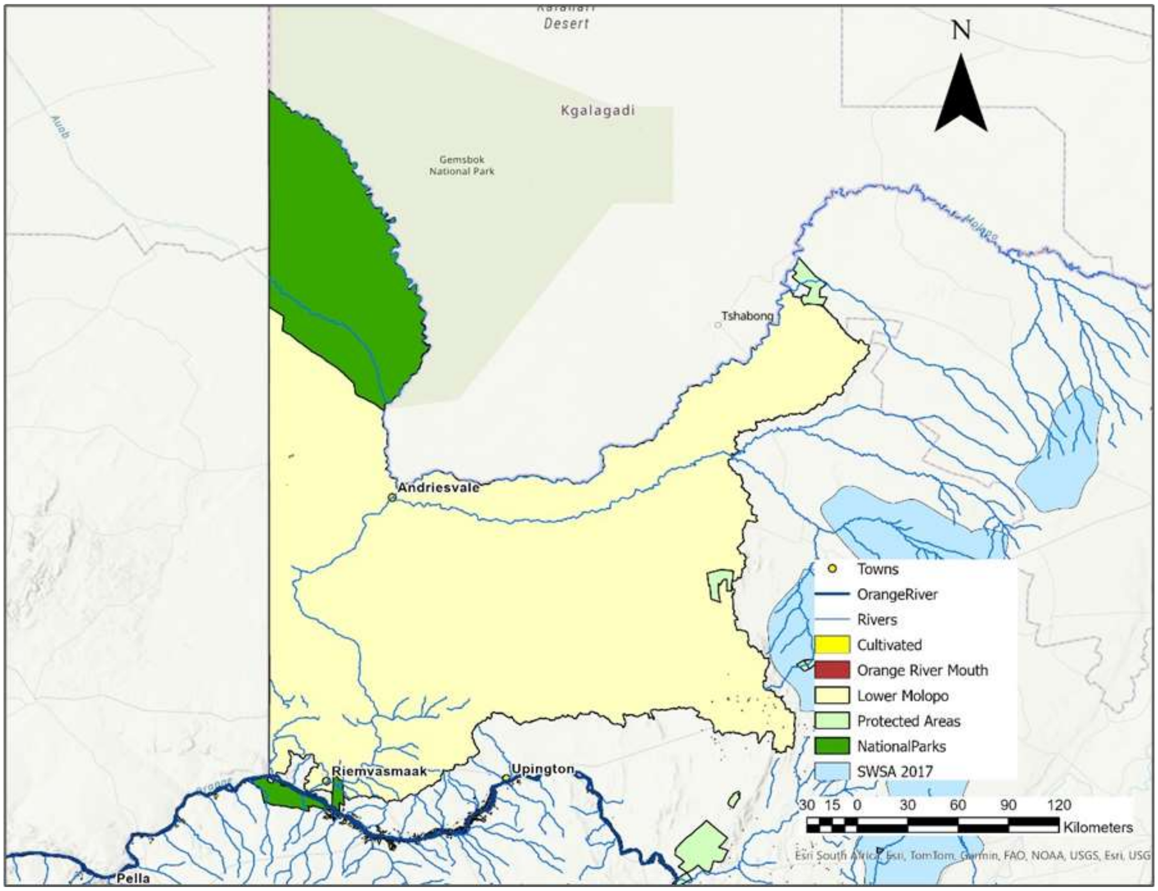



**Figure 79: Locality of ecological infrastructure, cultivation, national parks, and protected areas in IUA 10 in the Lower Orange Catchment**

**Table 84: Key ecosystem services with corresponding ecological infrastructure, beneficiaries and sector in IUA 10 in the Lower Orange Catchment (Note: the list is not exhaustive and only includes services with relatively high benefits for the catchment**

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| Provisioning | Fresh Water | Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Electricity and Water; Tourism; Households |
| | Raw materials | Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | Significance to Subsistence Farmers | Agriculture; Households; Society |
| | Medicinal resources | Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | Significance to Rural Communities | Households; Society |
| Reg ulati | Climate regulation | ephemeral Wetlands (Salt marsh) | Major Significance to Global Beneficiaries | Society |

| Key Ecosystem Service | | Key Ecological Infrastructure | General Beneficiaries | Sector (12 Sectors) |
|---|---|---|---|---|
| | Water quantity regulation | ephemeral Wetlands (Salt marsh) | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Water purification & waste management | ephemeral Wetlands (Salt marsh) | Major significance: Commercial agriculture and irrigation activity throughout the IUA | Agriculture; Mining; Manufacturing; Electricity and Water; Tourism; Households |
| | Erosion control/ Soil stability | Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | Major significance to commercial agriculture sector | Agriculture |
| | Biological control | Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | Major significance to commercial agriculture sector | Agriculture; Households |
| **Cultural** | Landscape & amenity values | Protected Areas (Kalahari Gemsbok National Park); Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | Major Significance: To tourism industry and rural communities through cultural value | Households; Tourism; Society |
| | Ecotourism & recreation | | | |
| | Educational values and inspirational services | | | |
| **Biodiversity** | Critical habitat & range restricted species | Protected Areas (Kalahari Gemsbok National Park); Molopo River; Kuruman tributary; ephemeral Wetlands (Salt marsh) | The area holds major significance for flora and fauna species, as it provides essential habitat for range-restricted species and supports the migration of various species. | Tourism |
| | Maintenance of genetic diversity | Protected Areas (Kalahari Gemsbok National Park) | The diverse ecological infrastructure plays a vital role in maintaining ecosystem services by preserving genetic diversity. This diversity is essential for the growth of locally adapted cultivars and the advancement of commercial crops and livestock. Some habitats, referred to as 'biodiversity hotspots', are exceptionally rich in species, thus exhibiting greater genetic diversity and requiring conservation. | Agriculture; Tourism; Society |

### 10.10.8. Groundwater

The GRUs included in this IUA are:

- GRU 10.1 (Western Kalahari – Lower Molopo River - Kalahari Group Aquifers with paleo-drainage channels. Thick Kalahari Group Sediments present in paleo drainage channels, up to 120 m with saturation thicknesses up to 40 m in places. Water quality and borehole yield classes highly variable due to underlying.
  - Basement soft rock formation consisting of Karoo Ecca and Dwyka Group mudrock and diamictites, overlain by Kalahari Group Sediments (gravels, sand(stone), clay(stone), silcrete, calcretes and aeolian sand)
  - Stress Index: not assessed.

  - Groundwater quality is highly variable due to the dual aquifer system geometry – shallower freshwater resources and deep, saline-hyper saline hard rock aquifers. Overall, from Ideal to Unacceptable groundwater types.
  - Aquifer yield class varies from Moderate to Insignificant.
  - Proposed PSC: not assessed yet.
- GRU 10.2 (Lower section of the Molopo River drainage (a solely non-perennial drainage system) with the following hydrogeological characteristics:
  - Kalahari Beds overlying:
    - Thin Kalahari Beds overlying Karoo Dwyka Grp (TILL) and Nama Grp. (QRTZ , SHLE & SNDS) all underlain by various Mokolian Era metamorphics (GRGS & QRTZ)Thin Kalahari Beds overlying Olifantshoek Grp. (LAWA), Asbesberge Frm. (BIF), and Ghaap Plateau Frm. (DLMT); and
    - Thin Kalahari Beds overlying Karoo Dwyka Grp. (TILL) and Nama Grp. ( SNDS)Fractured basement hard rock formation consisting of quartzites, banded ironstone and dolomites, overlain by Kalahari Group Sediments (gravels, sand(stone), clay(stone), silcrete, calcretes and aeolian sand).
  - Aquifer yield class varies from Moderate to Insignificant.
  - Stress Index: 53% (too high for this area – needs to be confirmed).
  - Groundwater is a Marginal to Poor water quality type.
  - Proposed PSC: C (quaternary catchment D42E) and E (quaternary catchment D81C) needs to be confirmed.

*Summary:*

Groundwater quality in this GRU is highly variable due to the limiting rainfall recharge due to the overlying Kalahari (aeolian) sand and Kalahari Group sediments below. The present Molopo and Kuruman River channels are acting as recharging system for the underlying Kalahari Group Sediments and boreholes with moderate yields and ideal to good water quality are found all along the river channels. Borehole yield classes are generally low to insignificant with good to marginal water quality type, however, where the paleo-drainage channels in the Kalahari floor are saturated (with good water quality type), these individual yields can be as high as 5 l/s.

Kalahari Pans (windblown depressions within pre-Kalahari basement) are present in the central part QC D42D, known historically as the “Kalahari Salt Block” containing hyper saline groundwater and several salt mines are present in this area. These pans operates as large “sub ponds”.

# 11 CONCLUSION

This report has presented the findings of the status quo assessment for the water resources of the Lower Orange catchment. Based on the available information and literature, data assessment and analysis, review of previous studies and discussions held with DWS personnel a perspective of the characteristics, nature, attributes, condition and key aspects of the Lower Orange water resources have been provided. This has formed a basis for the understanding of the catchment, the status and use of water resources and the assessment of the socio-economic profile that exists.

It can be concluded that the Lower Orange River is a hard-working, well-regulated river supporting numerous socio-economic activities, towns and livelihood within the catchment. It forms part of a larger integrated and complex system of water resource infrastructure and system operation inter-linked to other catchments, WMAs and countries. The catchment also includes a number of conservation and protected areas. The setting of water resource classes will require that all these considerations are accounted for.

The status quo indicates that overall, the water resources are generally in a good state, with localised areas of impacts related primarily to the land uses. Ecological condition is largely in a B to C PES category, with only a limited number of reaches in a D category (largely modified). There are flow and water quality impacts identified along the mainstem Orange River and on the major tributaries related to salinity and nutrients. The Orange River Estuary is significantly impacted, specifically with inadequate flows and surrounding land use activities. In addition, the water requirements indicate that the system is in deficit and will require further interventions to meet future needs. The process will have to consider how the balance within the larger integrated Orange-Senqu River System can be achieved in the estuary, as the flows are regulated through releases from the Upper Orange catchment. A large number of rivers are ephemeral/episodic which will require an adapted approach to setting of classes and RQOs. Strategic Water Source Areas (SWSAs) in the catchment are groundwater resources of national significance.

The wetlands in the catchment are not well mapped and characterised. This process has been reliant of previous studies to identify the priority systems. The information available for wetlands and estuaries is in many instances outdated and does not adequately support the information requirements for the setting of the RQOs. Water quality data were also found to be limited for many tributary catchments.

The groundwater resources in the Lower Orange catchment area are highly variable due to the following aspects:

- Highly variable rainfall depths and recharge mechanisms from east to west over the catchment area;
- Highly variable aquifer rock types – from semi-consolidated Kalahari Group sediments, various Karoo Sediment types (argillaceous-arenaceous), to complex metamorphic rock formations in the Bushmanland and Namaqualand areas;

- Water use varies significantly, and a few quaternary catchments are listed of highly over-pumped. These quaternary catchments will be regarded as "hotspots" in this assessment and specific attribute/narratives generated to comply for the water resource classification and quality objects parameters.
- The groundwater quality is also highly variable.

To conclude, estimations of rainfall depths should be reviewed considering the poor rainfall patterns noted in a large part of the catchment area since 1980, and specifically since 2009. Several seasons with very low total annual rainfall (*i.e*., <50 mm/a) were recorded. This phenomenon impacts on the applicable aquifer yield insurances, *i.e*, the groundwater stress indices, and resident water quality status in the medium (2-15 years) to long-term (15+-years).

Based on the detailed evaluations that underlie the above, Socio-Economic Zones, IUAs and resource units have been delineated as the basis for the determination of water resource classes.

The IUA delineation has been presented to and discussed with stakeholders through various engagement platforms and can be adopted for the process of quantifying the EWRs and setting water resource classes.

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