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water affairs
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Water Affairs
REPUBLIC OF SOUTH AFRICA
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DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

WATER QUALITY AND EFFLUENT RE-USE REPORT

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ORANGE RIVER

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Prepared by:

WRP Consulting Engineers, Aurecon, Golder Associates Africa, and Zitholele Consulting.

Report No. P RSA D000/00/18312/8

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Authors:	*Priya Moodley and Trevor Coleman*
Project Name:	***Development of Water of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River***
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LIST OF REPORTS

The following reports form part of this study:

Report Title	Report number
Inception Report	P RSA D000/00/18312/1
Literature Review Report	P RSA D000/00/18312/2
International obligations	P RSA D000/00/18312/3
Current and future Water Requirements	P RSA D000/00/18312/4
Urban Water Conservation and Water Demand Management	P RSA D000/00/18312/5
Irrigation Demands and Water Conservation/Water Demand Management	P RSA D000/00/18312/6
Surface Water Hydrology and System Analysis	P RSA D000/00/18312/7
Water Quality and Effluent Re-use	**P RSA D000/00/18312/8**
Review Schemes and Update Cost Estimates	P RSA D000/00/18312/9
Preliminary Reconciliation Strategy Report	P RSA D000/00/18312/10
Final Reconciliation Strategy Report	P RSA D000/00/18312/11
Executive Summary	P RSA D000/00/18312/12
Reserve Requirement Scenarios and Scheme Yield	P RSA D000/00/18312/13
Preliminary Screening Options Agreed: Workshop of February 2013	P RSA D000/00/18312/14

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER

Water Quality and Effluent Re-use Report

EXECUTIVE SUMMARY

The Department of Water Affairs (DWA) has identified the need for detailed water resource management strategies as part of their Internal Strategic Perspective (ISP) planning initiative, which recommended studies to identify and formulate intervention measures that will ensure enough water can be made available to supply the water requirements for the next three to four decades.

As part of this process the need for the Reconciliation Strategy Study for the Large Bulk Water Supply Systems in the Orange River was also defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries, various water resource planning and management initiatives compiled during the past few years as well as those currently in progress will form an integral part of the strategy development process.

Since 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the Liebenbergsvlei River into the Vaal Dam to augment the continuously growing water needs of the Gauteng Province. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is already in its planning stages. Polihali Dam is expected to be in place by around 2022. Flows that are currently still entering into Gariep and Vanderkloof dams will then be captured by Polohali Dam, thus reducing the inflow to Gariep and Vanderkloof dams. This will result in a reduction in yield of the Orange River Project (ORP) (Gariep and Vanderkloof dams) to such an extent that shortages will be experienced in the ORP system. Some sort of yield replacement is then required in the Orange River to correct the yield versus demand imbalance in the ORP system.

The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs for a 25 year planning horizon. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

Appropriate integration with other planning and management processes as well as cooperation among stakeholders will be key success factors in formulating coherent recommendations and action plans.

While the preliminary and final reconciliation strategies form the two main deliverables of the study, they are supported and based on a number of baseline investigations and assessments. One such assessment was that of water quality. This report presents the Report on water quality.

The purpose of this report

The main purposes of this report are the following:-

- *To understand the water quality profile and pollution sources in the study area to inform the interventions proposed in the reconciliation strategy;*
- *To compile a set of interim Resource Water Quality Objectives (RWQOs) which can be used to identify the water quality issues in the study area and can be used to assess the water quality impacts of the reconciliation interventions.*
- *Discuss the potential re-use of sewage effluent to meet the water requirements.*

An assessment of the water quality of the Orange River was undertaken in order to identify water quality "hot spots" and issues/aspects that may have an influence on the overarching planning and management of the system. The available water quality data in the study area was sourced from the Department of Water Affair's (DWA) Water Management System (WMS) database. The available Resource Water Quality Objectives (RWQOs) for the Upper and Lower Orange WMAs were collated and used to compare the instream water quality against. The results of the analysis were assessed and discussed and based on this, management actions for the water quality of the Orange River System are recommended. In addition based on an understanding of the water quality of the system, a high level qualitative assessment of the implications of the reconciliation options is presented.

Water quality analysis:

The water quality assessment highlighted the following:

- *The water quality and quantity in the uppermost reaches of the Orange River, above Gariep Dam, is still in a largely unimpacted state and show minor changes over the past 13 years.*
- *The water in these uppermost reaches is moderately soft, relatively low in salt concentrations, but generally high in suspended solids and turbidity.*
- *The water quality in the Lower Orange River occasionally exceeded the RWQO for irrigation especially the salt concentrations and high pH values.*
- *The nutrient (nitrate and orthophosphate) concentrations in the Orange River are in general non-compliant to the RWQOs.*
- *Some of the water withdrawn for irrigation is returned to the river environment for re-use, but its quality is degraded with considerably higher salt and nutrient concentrations which contributes significantly to the salt load in the Orange River.*
- *The mean chlorophyll-a concentrations (algal biomass) in the Gariep and Vanderkloof Dams were low (<13 µg/ℓ) and fall in the range of oligotrophic systems, but the Chl-a concentrations, were much higher at Upington and Pella (mean 30 µg/ℓ) corresponding to mesotrophic water bodies. More monitoring data is required to obtain a better understanding of the trophic status*

of these sites. Chl-a data is limited and more data is required to provide a conclusive understanding.

- *The general water quality in Kornetspruit and Kraai River was good. Orthophosphate levels are high which indicates contributions from urban areas such as wastewater discharges and urban runoff.*
- *The Seekoei River's salt and nutrient concentrations are high but are possibly considered to represent natural conditions.*
- *The analysis of the available Stormbergspruit water quality data indicates high salts and nutrient levels.*
- *The water quality in the Caledon River is highly variable but in general is in a fair condition when compared to the RWQO, however, nutrient levels were elevated and turbidity levels are high, indicating high sediment concentrations.*
- *Water quality at the Ash River tunnel outlet is very good (natural state) indicating the water quality at the headwaters of the Senqu River is ideal.*

Conclusions and recommendations:

In terms of the water quality analysis and assessment of water quality issues undertaken the following can be summarised in terms of the task conclusions and recommendations:

- *The water quality present state analysis indicates increasing salinity in the Orange River (temporal and spatial) and high nutrient concentrations that indicate the potential for eutrophic conditions throughout the catchment and a possibility of hypertrophic conditions. The evidence suggests that the high turbidity in the system is the limiting factor for algal growth.*
- *The high concentration of turbidity that is evident in the system specifically in the Upper Orange WMA does not appear to be a significant threat to the aquatic ecosystem based on ecological assessments that have been undertaken. However it is apparent that it must be taken into consideration in the design and management of water supply infrastructure.*
- *The development of an integrated water quality management strategy is required that addresess the nutrient and salinity management of the system, the refinement and adoption of the RWQOs, the quantification of the extent of the actual and emerging problems of water pollution/water quality deterioration and the actions required for land use management.*
- *It is recommended that:*
    - *Nutrient modelling of the system be undertaken, and*
    - *Irrigation return flows be assessed.*
- *Improved and consolidated water quality monitoring of the Orange River System (surface and groundwater) is required to support effective water resource management.*
- *The qualitative high level assessment undertaken of the water quality implications of the reconciliation options indicates that there will be no significant impacts on the current water quality of the Orange River System. However the potential for Vioolsdrift Dam to act as a*

sink for nutrients and sediment and for Verbeeldingskraal Dam to capture sediments does exist. These impacts must be investigated further should these options be implemented.

- *A desktop study was undertaken to identify the opportunities for re-use of treated sewage effluent from the urban areas. The current and future discharge volumes were obtained from the literature and from the municipalities. The water quality requirements for the re-use for irrigation, indirect re-use and direct re-use options are discussed. The water treatment requirements for the different re-use options are presented and the capital costs for the treatment determined. The assessment of the opportunities for re-use of treated effluent showed that currently the potential is limited. However effluent re-use could contribute to the suite reconciliation options in the future with the expected growth in the effluent volumes.*

Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River

WATER QUALITY AND RE-USE REPORT

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Development of a Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River

Water Quality and Effluent Re-use Report

INTRODUCTION

1.1 BACKGROUND

The Department of Water Affairs (DWA) has identified the need for detailed water resource management strategies as part of their Internal Strategic Perspective (ISP) planning initiative, which recommended studies to identify and formulate intervention measures that will ensure enough water of acceptable quality can be made available to supply the water requirements for the next three to four decades.

The DWA Directorate National Water Resource Planning (NWRP) therefore commenced with the strategy development process in 2004 by initially focusing on the water resources supporting the large metropolitan clusters, followed by the systems supplying the smaller urban areas to systematically cover all the municipalities in the country.

As part of this process the need for the Reconciliation Strategy Study for the Large Bulk Water Supply Systems in the Orange River was also defined. Given the location of the Orange River System and its interdependencies with other WMAs as well as other countries (see study area description in **Section 1.3**), various water resource planning and management initiatives compiled during the past few years as well as those currently in progress will form an integral part of the strategy development process.

Major water resource infrastructure in the study area are the Gariep and Vanderkloof dams with associated conveyance conduits supporting large irrigation farming in the provinces of the Free State, Northern Cape and the Eastern Cape - through the Orange-Fish Tunnel. This system is currently almost in balance.

The Caledon-Modder System supplies water to the Mangaung-Bloemfontein urban cluster (largest urban centre in the study area). The 2 200 km long Orange-Senqu River is the lifeline for various industries, mines, towns and communities located along the river until the river discharges into the Atlantic Ocean in the far west at Alexander Bay.

Since 1994, a significant driver of change in the water balance of the Orange River System was brought about by the storing of water in Katse Dam as the first component of the multi-phase Lesotho Highlands Water Project (LHWP). Currently Phase 1 of the LHWP (consisting of Katse, and Mohale dams, Matsoku Weir and associated conveyance tunnels) transfers 780 million cubic metres per annum via the Liebenbergsvlei River into the Vaal Dam to augment the continuously growing water needs of the Gauteng Province. Phase 2 of the LWHP comprising of Polihali Dam and connecting tunnel to Katse Dam is already in its planning stages and is expected to be in place by 2022. Flows that are currently still entering into Gariep and Vanderkloof dams will then be captured by Polohali Dam, thus reducing the inflow to Gariep and Vanderkloof dams. This will result in a reduction in yield of the Orange River Project (ORP)(Gariep and Vanderkloof dams) to such an extent that shortages will be experienced in the ORP system. Yield replacement is then required in the Orange River to correct the yield versus demand imbalance in the ORP system.

The above description illustrates the complex assortment of interdependent water resources and water uses which spans across various international and institutional boundaries that will be considered in the development of the Orange River Reconciliation Strategy.

1.2 MAIN OBJECTIVES OF THE STUDY

The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs of all the users up to the year 2040. This Strategy must be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

Appropriate integration with other planning and management processes, as well as cooperation among stakeholders, will be key success factors in formulating coherent recommendations and action plans.

The outcomes of the Strategy will be specific interventions with particular actions needed to balance the water needs with the availability through the implementation of regulations, demand management measures, as well as infrastructure development options.

1.3 STUDY AREA

As depicted in **Figure A-1** of **Appendix A** (Map of study area), the study will focus on the water resources of the Upper and Lower Orange River Water Management Areas (WMAs), while also considering all the tributary rivers and transfers affecting the water balance of the system. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa.

The focus area of the study comprises only the South African portion of the Orange River Basin, excluding the Vaal River Catchment. The Vaal River is an important tributary of the Orange River, but since the Vaal River Reconciliation Strategy has already been developed, the Vaal River Catchment will not form part of the study area. However, strategies developed for the Vaal River System that will have an impact on the Orange River, will be taken into account as well as the impacts of flows from the Vaal into the Orange for selected Integrated Vaal system scenarios.

The Orange River is an international resource, shared by four countries, i.e. Lesotho, South Africa, Botswana and Namibia. Any developments, strategies or decisions taken by any one of the countries that will impact on the water availability or quality in South Africa must be taken into account and will form part of this study. The opposite is also applicable. If this strategy plans anything in South Africa that will impact on any of the other countries, this impact must be considered as part of this study in terms of South Africa's international obligations.

The Orange River, the largest river in South Africa, has its origin in the high lying areas of Lesotho. The river drains a total catchment area of about 1 million km², runs generally in a westerly direction and finally discharges into the Atlantic Ocean at Alexander Bay.

The Caledon River, forming the north-western boundary of Lesotho with the Republic of South Africa (RSA), is the first major tributary of the Orange River. The Caledon and the Orange (called the Senqu River in Lesotho) rivers have their confluence in the upper reaches of the Gariep Dam.

Other major tributaries into the Orange River are:

- The Kraai River draining from the North Eastern Cape;
- The Vaal River joining the Orange River at Douglas;
- The Ongers and Sak Rivers draining from the northern parts of the Karoo;
- The Molopo and Nossob Rivers in Namibia, Botswana and the Northern Cape Province have not contributed to the Orange River in recorded history as the stream bed is impeded by sand dunes; and
- The Fish River draining the southern part of Namibia.

A separate study was also done for the Greater Bloemfontein Area, i.e. Water Reconciliation Strategy Study for Large Bulk Water Supply Systems: Greater Bloemfontein Area with it's follow up continuation study currently in process. The recommendations of this strategy and its continuation study will also be taken into account in this study.

Although the Senqu River Catchment in Lesotho does not form part of the focus study area, the development in this catchment impacts directly on the water availability in the study area.

The South African portion of the Orange River Basin has been divided in two Water Management Areas, *i.e.* the Upper and Lower Orange WMAs. The Upper WMA stretches from the headwaters of the Caledon River and Lesotho boundary down to the confluence of the Vaal River and the Lower Orange WMA from this point to the sea. (See **Figure A-1 in Appendix A**). It should be noted that the DWA by way of a Government Notice recently adopted that the two WMAs would be amalgamated into a single WMA, the Orange, to be managed as a unit. However for the purposes of this study, the discussions are done in terms of the Upper and Lower Orange catchment areas.

1.4 PURPOSE OF THIS REPORT

While the preliminary and final reconciliation strategies form the two main deliverables of the study, they are supported and based on a number of baseline investigations and assessments. One such assessment was that of water quality. This report presents the Report on water quality.

Quantity and quality water requirements of different users will not always be compatible, and the activities of one user may restrict the activities of another, either by requiring water of a quality outside the range required by the other user or by lowering quality during use of the water (e.g. discharges). Efforts to improve or maintain a certain water quality often require a compromise between the quality and quantity requirements of different users and management measures. The DWA recognises that, just as a quantity of water can be "used", so can water quality. For water to be regarded as "fit for use" for a number of different users in the same catchment, the water quality needs to satisfy the most beneficial of those users. The achievement of this desired resource water quality requires a combination of planning guidance and management actions that is integrated with the quantity aspect.

Thus in the development of the Reconciliation Strategy for Large Bulk Water Supply Systems in the Orange River an understanding of the water quality is required to determine the possible implications of the proposed options identified to balance the supply with the demand. A perspective of where the Orange River System is now and what interventions are required in terms of water quality management (issues and concerns) is necessary to determine how water quality will be changed or water use impacted upon by implementation of each of the identified intervention options. This will ensure that in planning for the bulk water supply reconciliation, the water quality requirements and implications are addressed through an integrated approach that will ensure long term sustainability of the Orange River.

In order to determine the water quality impacts and pollution sources that would feed into reconciliation option development, it was considered necessary to undertake an assessment of water quality of the Orange River and identify water quality “hot spots” and issues/aspects that may have an influence on the overarching planning and management of the system.

The outcome of this exercise was to contribute to a clearer understanding of the water quality status in the Orange River that will support the reconciliation of the water requirements with the water resource.

The re-use of effluents is becoming an option to achieve reconciliation in a number of the water management areas in South Africa. Re-use was identified in the Bloemfontein Reconciliation Strategy as a reconciliation option. In this task, the available current and future effluent data from urban wastewater treatment works was collated to assess the potential for reusing the effluent to help achieve reconciliation of water demand with water supply.

The analysis of the water quality of the Orange River will assist in prioritizing management actions that must be implemented as part of the Reconciliation Strategy.

The objectives of the water quality and effluent re-use task were:-

- To understand the water quality profile and pollution sources in the study area to inform the interventions proposed in the reconciliation strategy;
- To compile a set of interim Resource Water Quality Objectives (RWQOs) which can be used to identify the water quality issues in the study area and can be used to assess the water quality impacts of the reconciliation interventions.
- Discuss the potential re-use of sewage effluent to meet the water requirements.

The activities undertaken under this task include:-

- A perspective on the present state water quality;
- Collation of available Resource Water Quality Objectives (RWQOs) and water quality guidelines set in the study area to propose a set of guidelines/RWQOs for use in the study.
- Analysis of the available water quality data and comparison to RWQOs to identify water quality variables of concern and possible water quality issues;
- Identification of the potential sources of pollution, related to the measured water quality in the river system,
- Provision of inputs to the reconciliation interventions regarding water quality impacts that can be expected, and
- Assessment and discussion of the potential re-use of sewage effluent to meet the water requirements

1.5 REPORT STRUCTURE

The structure of the report is as follows:

- Section 1: This introduction, which introduces the study, and the context of the water quality task within the broader study.
- Section 2: Describes the catchment area;
- Section 3: Provides an overview of the state of water quality of the Orange River catchment;
- Section 4: Resource water quality objectives.
- Section 5: Describes the analysis of available water quality data and compliance to the resource quality objectives and provides a discussion of the results;

- Section 6: Highlights potential sources of pollution and recommends management actions related to the measured water quality in the river system,
- Section 7: Provides inputs on water quality with respect to the proposed reconciliation interventions,
- Section 8: Details the potential for effluent re-use.
- Section 9: Provides a summary and conclusion of the outcomes of water quality analysis undertaken

2 ORANGE RIVER CATCHMENT DESCRIPTION

The Orange is the largest river in South Africa and (with the Vaal River) drains almost two-thirds of the interior plateau of the country, which includes much of the densely populated Gauteng Province. The basin incorporates portions of six of the nine provinces in South Africa as well as three neighbouring states namely Namibia, Lesotho, and Botswana (**Figure 2-1**). It stretches 2 300 km from the source to the Orange River Mouth at Alexander Bay where it discharges into the Atlantic Ocean. The catchment population is estimated to be around 11 million. There are extensive areas of urbanisation and industrialisation which has altered the land significantly in these areas. Irrigation and dry-land crop production of cash crops such as maize, wheat and sunflower are extensive in many of the central areas.

Rain-fed commercial farming ranges from maize and wheat production on the grasslands of the east, to increasingly extensive dryland based livestock farming in the west. The Orange and Vaal rivers and some of their tributaries have significant areas of intensive, commercial, irrigated agriculture along their middle and lower reaches. The rest of the Orange River catchment is characterised by small towns and villages, widely scattered throughout the region, serving mainly mining and/or agricultural land uses. Gauteng's industrial, mining and residential area (Johannesburg, Soweto, Vereeniging, Vanderbijlpark areas) spans the northern watershed of the Vaal River System. There is extensive water utilisation in the Vaal River Basin, most of which is used for agriculture and urban requirements. Mining takes place most notably in the Vaal River catchment area and the lower Orange River.

The following four sectors dominate the economy in the region:

- agriculture, forestry and fishing
- mining and quarrying
- manufacturing and utilities, and
- services (which includes government).

The Upper Orange WMA stretches from the origin of the Orange River in Lesotho to its confluence with the Vaal River at Douglas. Major rivers include the Modder, Riet, Kraai, Caledon and Orange. The main storage dams in the Orange River are Gariep and Vanderkloof. Welbedacht Dam in the Caledon River, Rustfontein, Mockes, and Krugersdrift Dam in the Modder River with the Tierpoort and Kalkfontein Dams in the Riet River. The Lesotho Highland Water scheme (Phase 1A), that transfers water from the headwaters of the Orange River to the Vaal River.

Land use in the Upper Orange is mainly under natural vegetation with livestock farming (sheep, cattle and some game) as the main economic activity. Extensive areas are under dry land cultivation, mostly for the production of grains, are found in the north-eastern parts of the Upper Orange WMA. Large areas under irrigation for the growing of grain and fodder crops have been developed along the main rivers, mostly downstream of irrigation dams. Bloemfontein, Botshabelo and Thaba 'Nchu represent the main urban and industrial developments in the Upper Orange WMA.

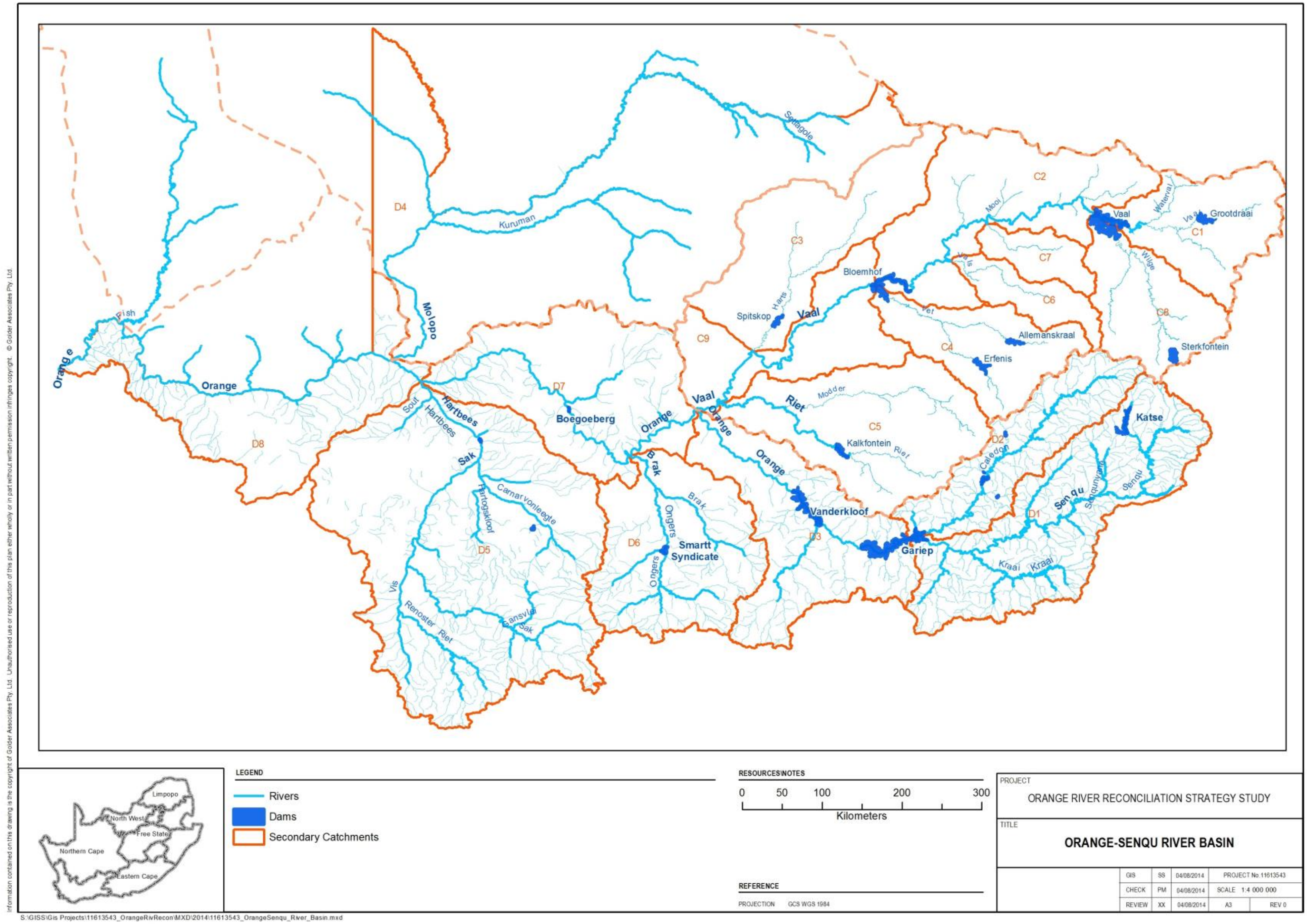

Figure 2-1: Orange-Senqu River Basin

Two large hydropower stations were constructed at Gariep and Vanderkloof Dams. Mining activities have significantly declined and currently mainly relate to salt works and small diamond mining operations.

The Lower Orange WMA forms the stretch of the Orange River between the Orange-Vaal confluence and Alexander Bay where the river meets the Atlantic Ocean which is a distance of approximately 1 200 km. The Orange River, which forms a green strip in an otherwise arid but beautiful landscape, also forms the border between South Africa and Namibia.

The Vaal River, the main tributary to the Orange River, has its confluence with the Orange River about 13 km west of Douglas. Other tributaries are the Ongers and Hartebeest rivers from the south, and the Molopo River (an endoreic tributary) and Fish River (Namibia) from the north. There are a number of highly intermittent water courses along the coast which drain directly to the ocean.

The Lower Orange catchment area is the driest and most sparsely populated in South Africa. The area experiences the lowest mean annual rainfall in the country, yet is one of the highest users of water. Potential evaporation can be as high as 3 000 mm per year and in general is several times more than the rainfall (DWAF, 2003b).

Minerals and water from the Orange River were the key elements for economic development in the region, and still remain so. Irrigation is by far the dominant water use sector in the Lower Orange catchment area, representing 94 % of the total water requirements.

The importance of the agriculture sector is attributable to the climate which is particularly suitable for the growing of some high value crops, together with the availability of water along the Orange River. Due to the climate, a window of opportunity exists for the provision of high quality table grapes to Europe early in the season when prices are at their highest. Other products include dates, raisins, wine, flowers, vegetables, grain and fodder crops. The wine grapes of Oranjerivier Wine Cellars originate from 930 producers all along the Orange River. These pockets of vineyard land stretch over a distance of more than 300 kilometres between Groblershoop and Blouputs. Five wineries have been established in Kakamas, Keimoes, Grootdrink and Groblershoop. The Oranjerivier Wine Cellars is one of the biggest wine cellars in South Africa (DWA, 2009)

The recreational use of the lower Orange River has gained in intensity over the past twenty years. The rafting and canoeing industry in this remote area has developed into an extremely popular experience for tourists (ARTP JMB, 2008).

The catchment area of the Orange River is shown in **Figure 2-2**.

2.1 DEVELOPMENT OF THE ORANGE RIVER

The Orange River is of great importance to South Africa since the natural flow represents more than 22% of the country's surface water resources. The natural water resources of the Orange River Basin are estimated to be in the order of 12 000 million m^3 /annum, although less than half of the available water is currently abstracted by various developments in the Orange and Vaal basins.

The Orange River Basin is one of the most developed of all the rivers in Southern Africa. The flow is regulated by numerous dams constructed in the Vaal and Orange Rivers. The construction of the Gariep and Vanderkloof dams made a great contribution towards the establishment and maintenance of irrigated crops throughout large sections of the Orange River, however, with a negative impact on the environment.

Large-scale infrastructural development (dams, etc.) and water abstraction in the catchment results a reduces annual runoff reaching the Orange River estuary. Until today most of the Orange's water is used for irrigation farming. Water is also used for the generation of hydropower at Gariep and Vanderkloof dams. In terms of surface water resources the two large sub-systems within the study basin, the Lesotho Highland Water Project and the Orange River Project (Gariep and Vanderkloof dams), are providing most of the available yield within the Orange/Senqu system.

Groundwater is an extremely valuable source in both WMAs and in particular in the Lower Orange WMA. It is assumed that there are adequate groundwater resources available in the basin to supply towns and communities not connected to the main surface water supply schemes, although the volume of groundwater available is significantly lower than that of surface water resources and often with elevated salinity.

2.2 ESTUARY AND CONSERVATION AREAS

Extensive activities with minimal rehabilitation or environmental considerations have degraded much of the habitat along the rivers, which have become susceptible to invasion by alien species. Important nature conservation areas include the Kgalagadi Transfrontier Park, the Ai-Ais-Richtersveld Transfrontier Park, and the Augrabies Falls National Park. Areas around major dams in the basin are protected as provincial nature reserves. These reserves, such as Rolfontein and the Gariep Dam Nature Reserve, are used for recreation and conservation, with wildlife having been introduced to restore populations to historic numbers and species and as part of provincial biodiversity conservation objectives. A review of biodiversity information shows that a total of 24 fish species are found in the basin, of which seven are endemic, two of which are threatened with extinction (DWA, 2009).

Among the more valued natural resources in the river basin is a transboundary Ramsar protected wetland at the mouth of the Orange River. The estuary of the Orange is proclaimed a Ramsar site by both South Africa and Namibia and is regarded as the sixth most important coastal wetland in Southern Africa in terms of the number of birds supported, at times as high as 26 000 individuals from up to 57 species (DWA, Website). However, in September 1995, the Orange River mouth wetland was placed on the Montreux Record (a record of Ramsar sites where changes in ecological character have occurred, are occurring or are likely to occur) following the collapse of the salt marsh component of the estuary (Earle *et al*., 2005).

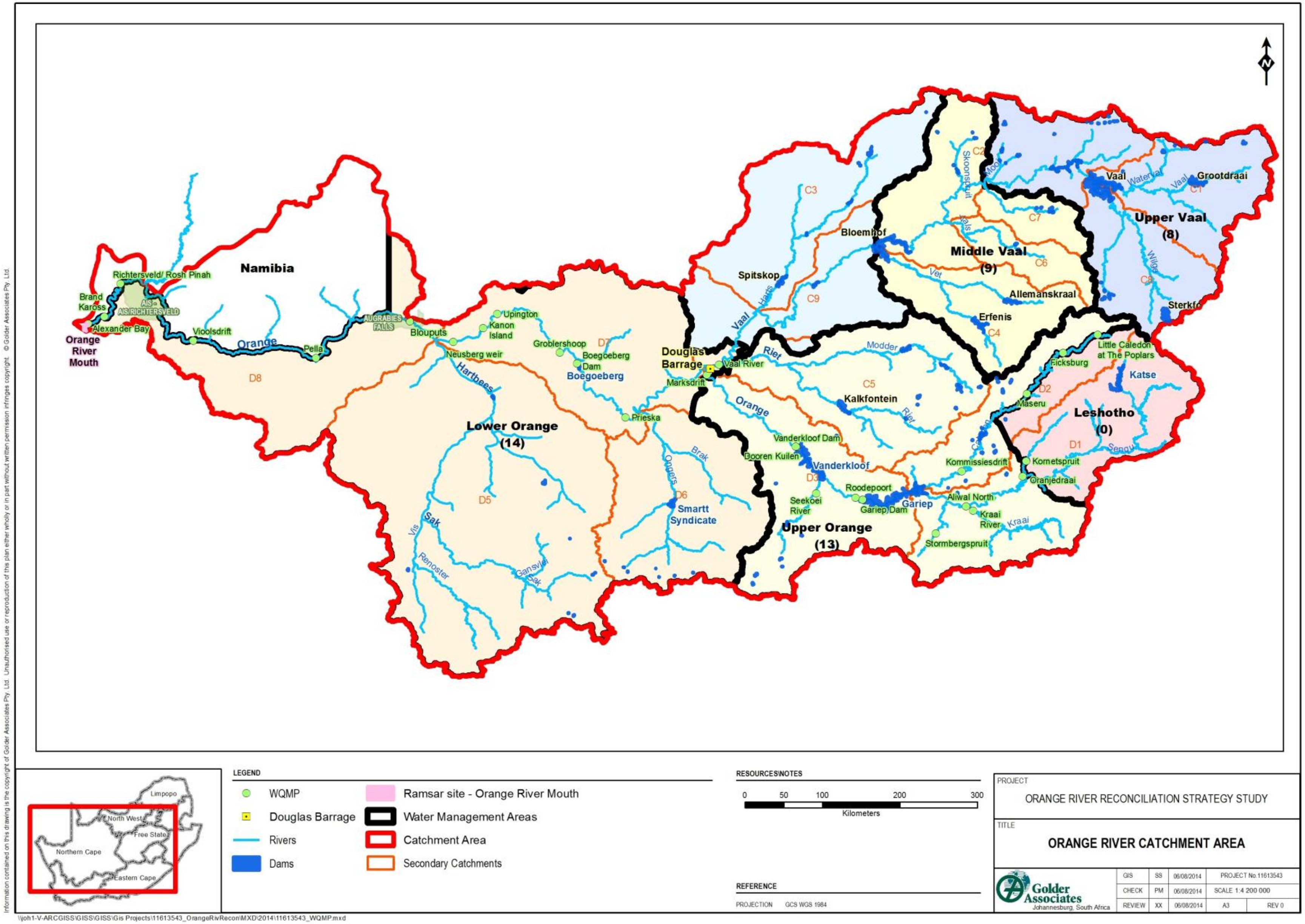

Figure 2-2: Upper and Lower Orange River catchment areas

3 STATE OF WATER QUALITY IN THE ORANGE RIVER

The water quality in the Orange River catchment is highly variable due to a combination of natural factors such as rainfall, evaporation, geology and soils, and anthropogenic factors which cause man-made changes to the chemistry of the rivers in the basin. In the case of the Orange River, natural factors play a major role in determining water quality due to the size and extent of the catchment, stretching across several topographical, geological and climatic zones.

Against this natural variability in water chemistry, there are significant anthropogenic sources of pollution in the basin, particularly in the Vaal catchment. This catchment includes the main urban and industrial conurbations of South Africa, the main gold mining areas of the country, parts of the Highveld coal fields, some of the country's power stations and significant areas of dryland and irrigation agriculture. The Orange River catchment as a whole is less developed, although irrigation agriculture occurs extensively along the river downstream of Vanderkloof Dam (UNDP/GEF, 2008).

Based on previous assessments undertaken and current understanding of the system the main threats to water quality in the Orange River have been identified as altered flow regime, nutrient enrichment; increased salinity from acid mine drainage and irrigation return flows; microbial contamination from urban settlements and poorly operated wastewater treatment works and elevated sediment concentrations. In addition trace metals and persistent organic pollutants, while they do not pose catchment-wide risk currently, do show high concentrations in certain localised areas. Other concerns include lack of adequate, co-ordinated and appropriate water quality monitoring and the implementation of resource water quality objectives to sustainably manage water quality in the catchment. Indications are that the water quality of the Orange River is declining.

The key issues that have been identified as potential threats are briefly discussed below:

- *Altered flow regime*: In the Orange River system, the controlled releases of water from the major storage reservoirs have improved the reliability of supply to water users along the lower reaches of the Orange-Senqu River in South Africa and Namibia with the result that the river no longer experiences periods of low flow. However, the construction of dams has also homogenized the flow regimes, chiefly through modification of the magnitude and timing of ecologically critical high and low flows. It also has greatly dampened the seasonal and inter-annual stream flow variability of the Orange River, thereby altering natural dynamics in ecologically important flows.

  Large volumes of water are diverted from the Orange River. The Lesotho Highlands Water Project has resulted in large volumes of low salinity water being diverted from the Senqu River into the Vaal River catchment. This has lead to an increase in salt levels in the Gariep and Vanderkloof dams.

  Regulated releases from the dams also resulted in a constant blackfly problem in the lower Orange. Blackflies breed in rivers in a constant flow of fast-moving water where they attached to rocks and plants and filter out suspended particles.

The total mean annual runoff of the lower Orange River has decreased significantly during the past 45 years. The recent flow volumes are about 46 % lower at Upington, about 68 % lower at Pella, and 60 % lower at Vioolsdrift compared to the natural flow. Therefore, the significant water abstractions from the lower Orange River (primarily for irrigation) are drastic having severe impacts on the aquatic environment (DWA, 2009).

- *Eutrophication*: Eutrophication is a severe problem in the Vaal catchment and in isolated pockets of the Orange River catchment. Localised eutrophication and microbial pollution is known along the Caledon River, along the Orange River downstream of Lesotho and downstream of the Upington irrigation area. However, there is insufficient information to determine the extent of this pollution. Gariep and Vanderkloof Dams are relatively low (<5 μg/ℓ) and fall in the range of oligotrophic systems. Algal blooms, including cyanobacteria, were recorded at Upington and Pella. Serious cyanobacterial blooms, aesthetic problems and toxic algal species in central and lower Orange have been recorded since 2000 and more recently in the Upper Orange.

A Joint Basin Survey-1 undertaken by ORASECOM to provide a snapshot of the quality of the water resources of the Orange-Senqu Basin in 2010 indicates that nutrient concentrations throughout most of the Basin are sufficiently high to cause algal blooms (ORASECOM, 2011).

- *Salinisation*: The increase in Total Dissolved Solids (TDS) in the Vaal and Lower Orange catchments and the concomitant increase in constituents such as chloride and sulphate has had major implications for domestic, industrial and agricultural water use. The increase in salinity has been ascribed to irrigation return flow and reduced flows. Of special concern, is the river reach between Boegoeberg Dam and Kakamas where TDS regularly exceeds 500 mg/L. Salinity problems in the Lower Riet River have also been observed. Impact on sustainability of agriculture is a concern. The salt load from the Vaal River needs to be taken into account in the siting of future dams.

Salinity modelling was undertaken on the Orange River as part of a recent DWA study (DWA, 2013) on the calibration of the WQT TDS Model. The annual average volumes and loads were calculated for the WQT model calibration period from 1970 to 2004.

The salinity modelling highlighted the following (DWA, 2013):-

- The majority of the TDS load and flow contribution is from the Senqu, Caledon and Kraai Rivers in the Upper Orange River. The water leaving these rivers into the Orange main stem is of a good quality with a flow weighted TDS concentration ranging from 107 mg/L to 124 mg/L.

- The majority of the land use development is agriculture with extensive irrigation areas particularly in the Lower and Middle Orange River reaches. There are abstractions for domestic use from the Caledon River and in rivers draining the Lesotho Lowlands area. The discharge volumes from the wastewater treatment works at the urban centres are small in comparison to the river flows. Their load contributions are therefore small. The major source of pollution from a TDS perspective is irrigation return flows.

- The Stormberg, Seekoei and Kraai catchments are developed with irrigation areas and farm dams. The flow weighted TDS concentrations from these tributaries are higher than the Senqu and Caledon Rivers. However the loads and volumes are small compared to flows and loads in the Orange River. The loads are assimilated with a small increase in the average concentration downstream of the confluences.

- The Gariep and Vanderkloof dams are large dams and attenuate the variation in TDS concentrations significantly.

- The Vaal River contributes 21% of the volume to the Orange River but 42% of the TDS load. The average concentration of the Vaal inflow is 353 mg/L which is higher than the 130 mg/L average concentration of the flow in the Orange at Marksdrift upstream of the Vaal and Orange confluence.

- The contribution from the Fish River (Namibia) is small. The flow from the Fish River occurs intermittently and discharges close to the estuary. The average concentration of the discharge is relatively high at 383 mg/L.

- The return flow volume from the irrigation areas was modelled to be an average of 16% for the middle and lower Orange Rivers. The 10% average irrigation return flow modelled in the hydrological models in the Upper Orange was maintained in the WQT modelling. The return flow TDS concentrations ranged from 850 mg/L to 1250 mg/L.

- The modelling showed that the majority of the volume and load in the system goes to the sea at Alexander Bay.

The acid mine drainage originating from the Vaal catchment has been identified as a potential threat. Critical problems are known to exist in the Eastern and Central Basins where, respectively, limited and no pumping is taking place. Decant has occurred in the Eastern Basin, while the Central Basin is currently flooding and will decant within two to three years. The Eastern Basin is also considered an AMD priority area, due to the lack of adequate measures to manage and control the problems related to AMD. The critical urgency in this basin is to implement intervention measures before the problems become more serious.

In April 2011, the Minister of Water Affairs in South Africa directed the Trans Caledon Tunnel Authority to undertake emergency works as part of short term interventions to deal with the problem of Acid Mine Drainage on the Witwatersrand. The short term management measures include the installation of pumping systems in the basins to manage the water level below the environmental crictical level and to neutralise the mine water before discharge. The South African Department of Water Affairs is in the process of investigating and recommending a feasible long-term solution to the AMD problem, in order to ensure long term water supply security and continuous fitness for use of Vaal River water.

Downstream of the Vaal Dam, the discharge of AMD has contributed to increased sulphate levels in the Vaal River – primarily through the Klip and Suikerbosrand rivers. The salinity of these rivers is frequently in the 'unacceptable' range. However, salinity in the Klip River has gradually improved since 1986 (largely because of the higher volumes of effluent from the wastewater treatment works and the reduction in the mine water discharge volumes over time) and now falls mainly in the 'tolerable' range. Historically, the Klip River contributed most of the salt load (about 80%) to the Vaal Barrage. The TDS concentration in the Vaal Barrage is managed through dilution releases from Vaal Dam to a concentration of 600 mg/L.

- *Suspended Solids and Turbidity:* The suspended solid loads in the lower Orange River have changed dramatically and reduced by up to 97 % from the 'natural' levels. The total suspended solids in the Orange River from the Gariep Dam and downstream have however decreased drastically after the construction of the dams particularly during the last 10 – 20 years (DWA, 2009). The growth of benthic algae and phytoplankton, which include important nuisance organisms, is limited by light availability, which is restricted by the turbidity. New dams, or an increase in the salinity of the water (with which flocculation and sedimentation of suspended solids is associated), or both factors acting together, could reduce the turbidity increasing the risk of blooms of algae and phytoplankton.
- *Microbiological Pollution:* There are concerns along all the rivers which flow through towns and villages throughout the catchment regarding localized microbiological pollution from untreated and partially treated sewage entering the rivers. Microbiological quality risks are also associated with the large urban areas but the available data shows that the risks are localised.
- *Heavy metals:* The impacts of heavy metals are unknown due to a lack of monitoring data and detailed studies, but some level level of prevalence of these pollutants is suspected. The available data highlighted that the concentrations of Aluminium, Cadmium, Copper and Lead were occasionally unacceptably high and could potentially be harmful to human health and the aquatic environment – the reason for the high metal concentrations measured at Upington, Neusberg, Pella, and Vioolsdrift are unknown and are a matter of concern especially in the Lower Orange River. The role of the numerous mineral mines along the river should be particularly investigated as possible sources of metals. High uranium concentrations have been recorded on the Vaal River at Schmidtsdrift. In addition higher than average levels of several elements have been recorded on the Caledon and Malibamatso rivers draining into the Orange River (ORASECOM, 2011).
- *Water Quality Monitoring*: An extensive monitoring system does exist for the Orange River as part of the DWA's monitoring programme, although there are a number of deficiencies in the data sets available, particularly along the Lower Orange River. The historical chemical data sets of DWA are good at several monitoring sites on the Orange River and tributaries, however, serious gaps and low frequency occurred and some critical parameters, like TSS and turbidity are not measured at most of the sites. Upgrading and expansion of the monitoring programme is required. Trace metals and microbiological pollutants need to be monitored. Lack of co-ordinated sampling and

inconsistent sampling as well as the selection of the most appropriate sites for water quality monitoring has presented problems.

- *Resource Water Quality Objectives:* The Orange River is currently managed without Resource Water Quality Objectives being formerly adopted or uniformally applied throughout the system. RWQOs provide the numeric or descriptive goals, within which the water quality component of the water resource must be managed. Preliminary RWQOs have been developed for the Orange River as part of a DWA study undertaken in 2009. These RWQOs need to be refined and implemented as part of a water quality management strategy for the Orange River.

From the above overview of the state of the water quality and relevant issues identified the key elements related to declining water quality can be summarised to include:

- Nutrient enrichment (and eutrophication in some areas),
- Increased salinity of the Vaal River and lower Orange River,
- Impacts from acid mine drainage originating from the Vaal River catchment should the short and long term strategies are not implemented,
- Inadequate monitoring of surface and groundwater quality to gain an understanding of trends and pollution sources to support required management action,
- Localised areas of heavy metals and microbiological pollution;
- Inadequate enforcement of compliance water quality discharge standards;
- Lack of implementation of Resource Water Quality Objectives,
- Increased costs related to water treatment, and
- Lack of knowledge, capacity and awareness related to pollutants and appropriate measures to deal with them.

4 RESOURCE WATER QUALITY OBJECTIVES (RWQOS)

The DWA's Water Quality Planning objective is to provide effective management strategies and policy guidance to address the current water quality management challenges facing South Africa. This is aimed at ensuring the sustainable fitness for use of water resources and the maintenance of the integrity of aquatic ecosystems. A key component of water quality planning is resource directed management which focuses on the sustainable management of the water resource specifically on how water quality in water resources should be managed, particularly in respect of use and protection.

Resource directed management of water quality includes the development and implementation of Resource Water Quality Objectives (RWQOs). RWQOs are a mechanism through which the balance between sustainable and optimal water use and protection of the water resource can be achieved. RWQOs are the water quality components of the Resource Quality Objectives (RQOs) which are defined by the National Water Act as "clear goals relating to the quality of the relevant water resources" (DWAF, 2006). RWQOs are typically set at a finer resolution than RQOs to provide greater detail upon which to base the management of water quality. RWQOs provide the basis for determining the allocatable water quality and water quality stress.

In setting RWQOs, the Department strives to achieve a balance between protecting the water resource for the downstream users and allowing use and development of the water resource upstream (**Figure 4-1**). For the downstream water users, the focus is on protecting the water quality in order to ensure a healthy functional aquatic ecosystem, while also meeting the water quality requirements of the other recognised water user groups (*viz*. domestic, agricultural, industrial and recreation) downstream of the RWQOs point. However, the selected RWQO might also restrict the type and extent of water use upstream of the point. Water uses refer to those described in Section 21 of the NWA and includes uses such as the discharge of water containing waste (using some of the allocatable water quality) or taking water from a water resource (using some of the dilution capacity) (DWAF, 2006). It may not always be possible to meet the ideal water quality requirements since impacts from land developments and water use may already exist. Thus management objectives may be set at levels which are achievable through sound management practices.

4.1 RESOURCE WATER QUALITY OBJECTIVES FOR THE ORANGE RIVER CATCHMENT

Preliminary RWQOs are currently available for the Orange River (Upper and Lower WMAs) (DWA, 2009). These recommended preliminary RWQOs were set through the DWA (2009) study ("Orange River: Assessment of Water Quality data requirements for WQP Purposes"). The needs of the water users and other stakeholders with respect to the in-stream water quality of the water resources in their catchments', and their needs with respect to the disposal of water that contains waste to the resource were formulated into objectives.

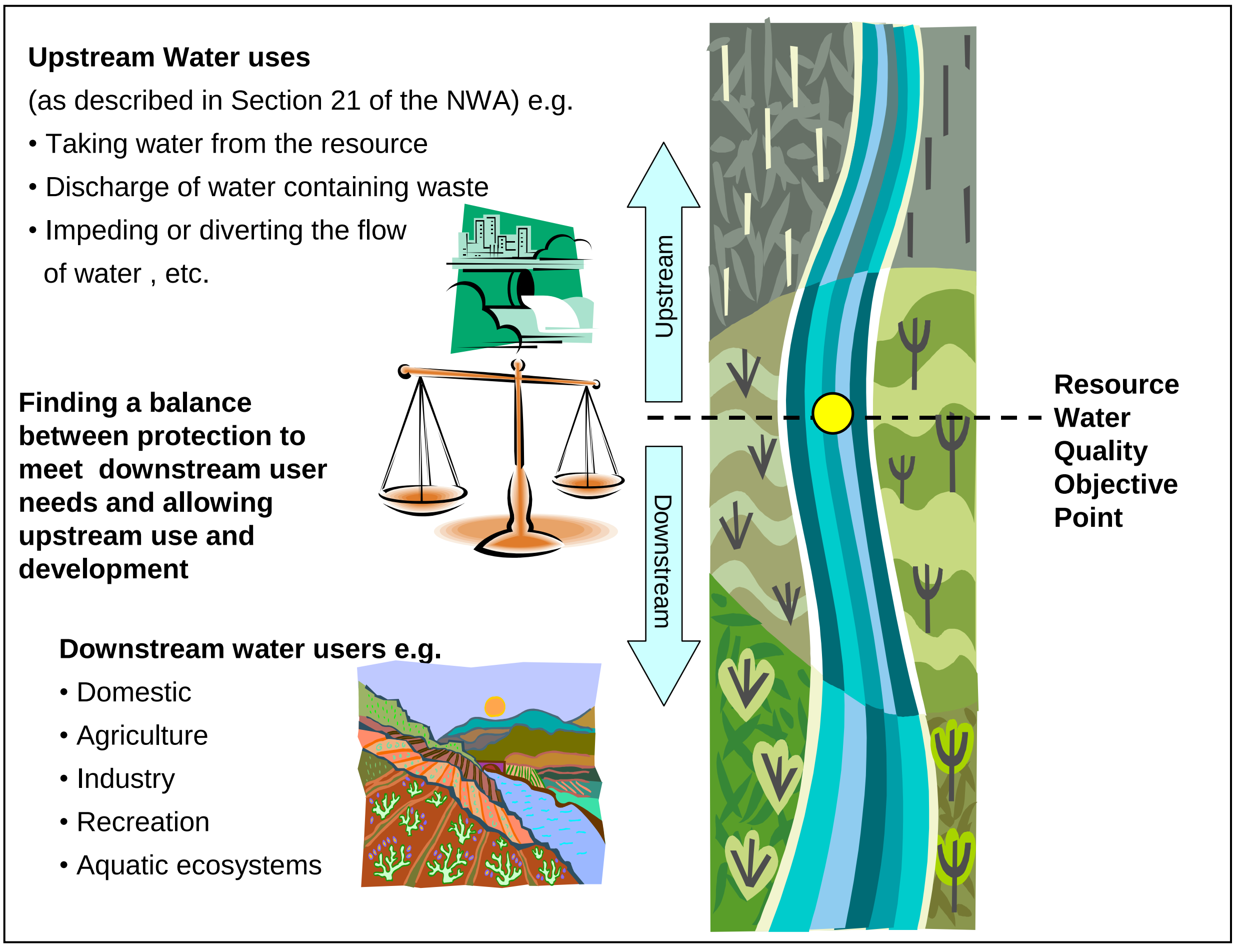

Figure 4-1: Balancing the needs of downstream water users with upstream water use and development (DWAF, 2006)

The catchment vision reports for the Upper and Lower Orange River have identified many of the current and future water user requirements and the desired state of the catchment through agreement with key stakeholders (DWAF, 2009a; 2009b). In these reports great emphasis is placed on water quality, *i.e.* "to ensure that water supplies are of an acceptable quality to all water users."

Major water user requirements include irrigation (mainly maize, wheat and lucern in upper Orange and mainly grapes in lower Orange), stock farming (mainly cattle sheep and goat farming) and supplying domestic water to towns and rural communities. In the Lower Orange area, producers of table grapes, dried fruit and wine grapes need to give proof of compliance with the SANS:241 requirements to the Perishable Products Export Control Board (PPECB).

In the Orange River, the major consumptive 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 % (**Figure 4-2**). Afforestation is negligible in the Orange River WMAs. 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 (see **Figure 4-3** to **Figure 4-6**).

The RWQOs for the Upper and Lower Orange River WMAs are shown in **Table 4-1**; **Table 4-2** and **Table 4-3** per monitoring station (river reach). The RWQOs for the Orange comprise Level 1 and that for the tributaries comprise Level 2. The RWQOs determined are primarily based on the DWA South African Water Quality Guidelines (DWAF, 1996) through application of the RWQOs Model 4.1 of DWAF (DWAF, 2006), and were guided by the catchment visions of the WMAs that describe the level of protection required by the water users and stakeholders in the area. The output RWQOs by the Model were adjusted based on the need for more stringent water quality requirements and expert knowledge to recommend the final RWQOs (DWA, 2009).

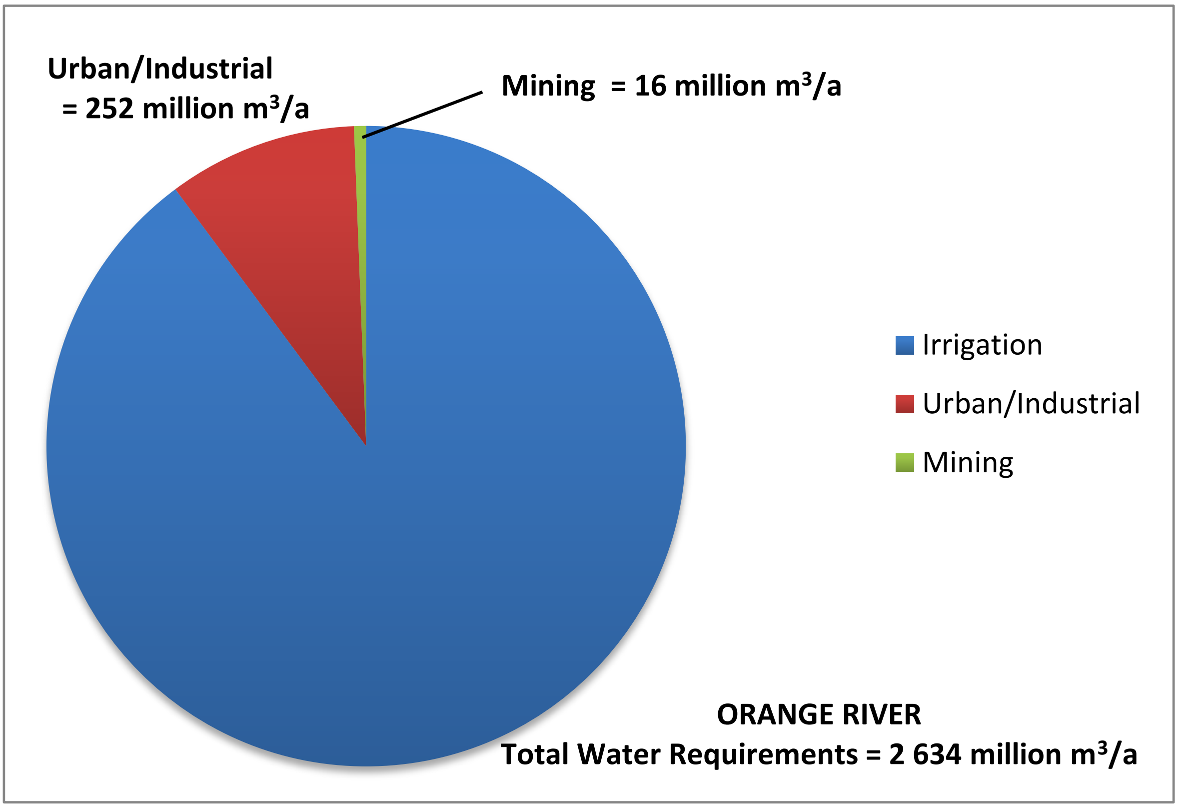

Figure 4-2: Pie chart of the average water requirements (for the year 2012) from the Upper and Lower Orange WMAs (DWA, 2013)

Table 4-1: Resource Water Quality Objectives (Level 1): Upper Orange River

Variable	Units	Bound	ASH RIVER TUNNEL	ORANJE--DRAAI	ALIWAL NORTH	GARIEP DAM	ROODE-POORT	VANDERKLOOF DAM	DOORIEN KUILEN	MARKSDRIFT
Algae (Chl-*a*)	ug/l	Upper	5	5	10	10	10	5	10	10
Alkalinity ($CaCO_3$)	mg/l	Upper	175	175	175	175	175	175	175	175
Ammonia (NH_3-N)	mg/l	Upper	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Calcium (Ca)	mg/l	Upper	60	60	80	60	60	60	60	80
Chloride (Cl)	mg/l	Upper	40	40	40	40	40	40	40	50
Fluoride (F)	mg/l	Upper	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.75
Magnesium (Mg)	mg/l	Upper	30	30	30	30	30	40	40	30
NO_3 (NO_3-N)	mg/l	Upper	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.5
pH	units	Upper	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
		Lower	6.9	6.9	6.9	6.9	7.3	7.1	7.1	7.1
Potassium (K)	mg/l	Upper	10	10	25	25	10	10	10	25
Ortho-phosphate (PO_4-P)	mg/l	Upper	0.045	0.045	0.045	0.040	0.04	0.043	0.040	0.030
SAR	mmol/l	Upper	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sodium (Na)	mg/l	Upper	30	30	40	40	40	40	40	70
Sulphate (SO_4)	mg/l	Upper	60	60	80	60	80	80	65	60
TDS	mg/l	Upper	260	260	260	260	260	260	260	360
Total Hardness	mg/l	Upper	175	175	175	175	175	175	175	175
Si	mg/l	Upper	20	20	20	20	20	20	20	20

Table 4-2: Resource Water Quality Objectives (Level 1): Lower Orange River

Variable	Units	Bound	BOEGE-BERG	NEUSBERG	UPINGTON	PELLA MISSION	VIOOLS-DRIFT	ALEXANDER BAY
Algae (Chl-*a*)	ug/l	Upper	10	10	15	15	15	30
Alkalinity ($CaCO_3$)	mg/l	Upper	300	300	300	300	300	300
Ammonia (NH_3-N)	mg/l	Upper	0.015	0.03	0.058	0.03	0.03	0.015
Calcium (Ca)	mg/l	Upper	80	80	80	80	80	80
Chloride (Cl)	mg/l	Upper	100	100	100	100	100	100
Fluoride (F)	mg/l	Upper	0.7	0.7	0.7	1	1	0.7
Magnesium (Mg)	mg/l	Upper	30	50	70	70	70	70
NO_3 (NO_3-N)	mg/l	Upper	0.4	0.2	0.2	0.15	0.15	0.25
pH	units	Upper	8.4	8.4	8.4	8.4	8.4	8.5
		Lower	7.1	7.6	7.2	7.4	7.0	7.5
Potassium (K)	mg/l	Upper	15	25	25	25	25	25
Ortho-phosphate (PO_4-P)	mg/l	Upper	0.03	0.025	0.025	0.03	0.03	0.03
SAR	mmol/l	Upper	1.5	2	3	3	3	3
Sodium (Na)	mg/l	Upper	70	70	92.5	92.5	92.5	92.5

Variable	Units	Bound	BOEGE-BERG	NEUSBERG	UPINGTON	PELLA MISSION	VIOOLS-DRIFT	ALEXANDER BAY
Sulphate (SO_4)	mg/l	Upper	**80**	**100**	**200**	**150**	**150**	**150**
TDS	mg/l	Upper	**400**	**450**	**450**	**550**	**550**	**550**
Total Hardness	mg/l	Upper	**200**	**200**	**250**	**250**	**250**	**250**
Si	mg/l	Upper	**20**	**20**	**20**	**20**	**20**	**20**

Table 4-3: Resource Water Quality Objectives (Level 2): Orange River Tributaries

Variable	Units	Bound	KORNET-SPRUIT	KRAAI	STORMBERG-SPRUIT	SEEKOEI	CALEDON			
							POPLARS	FICKSBURG	KOMMISSIE-DRIFT	TIENFONTEIN (WELBEDACHT DAM)
Algae (Chl-*a*)	ug/l	Upper	**10**	**10**	**20**	**10**	**15**	**15**	**15**	**10**
Alkalinity ($CaCO_3$)	mg/l	Upper	**175**	**175**	**450**	**450**	**300**	**300**	**300**	**300**
Ammonia (NH_3-N)	mg/l	Upper	**0.015**	**0.015**	**0.058**	**0.015**	**0.015**	**0.015**	**0.015**	**0.058**
Calcium (Ca)	mg/l	Upper	**80**	**60**	**150**	**80**	**80**	**80**	**80**	**80**
Chloride (Cl)	mg/l	Upper	**40**	**20**	**138**	**138**	**50**	**40**	**40**	**100**
Fluoride (F)	mg/l	Upper	**0.7**	**0.4**	**1.0**	**1**	**0.7**	**0.7**	**0.7**	**0.7**
Magnesium (Mg)	mg/l	Upper	**70**	**30**	**100**	**70**	**30**	**70**	**70**	**30**
NO_3 (NO_3-N)	mg/l	Upper	**0.2**	**0.15**	**0.75**	**0.2**	**0.4**	**0.2**	**0.25**	**0.8**
pH	units	Upper	**8.4**	**8.4**	**8.4**	**8.5**	**8.5**	**8.4**	**8.4**	**8.4**
		Lower	**7.0**	**7.1**	**7.4**	**7.6**	**7.1**	**7.1**	**7.1**	**7.1**
Potassium (K)	mg/l	Upper	**25**	**5**	**50**	**50**	**25**	**10**	**25**	**25**
Ortho-phosphate (PO_4-P)	mg/l	Upper	**0.04**	**0.03**	**0.13**	**0.05**	**0.05**	**0.04**	**0.05**	**0.1**
SAR	mmol/l	Upper	**1.5**	**1.0**	**3**	**6.0**	**1.5**	**1.5**	**1.5**	**1.5**
Sodium (Na)	mg/l	Upper	**45**	**20**	**92.5**	**115**	**70**	**50**	**70**	**70**
Sulphate (SO_4)	mg/l	Upper	**80**	**25**	**100**	**150**	**80**	**80**	**80**	**100**
TDS	mg/l	Upper	**260**	**260**	**550**	**1000**	**400**	**360**	**450**	**195**
Total Hardness	mg/l	Upper	**50**	**175**	**300**	**300**	**200**	**200**	**200**	**200**
Si	mg/l	Upper	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**

Figure 4-3: Satellite image (Google Earth) of irrigation fields along the Orange River downstream of Vanderkloof Dam – Upper Orange

Figure 4-4: Satellite image (Google Earth) of irrigation fields (pivots) along the Orange River close to Prieska – Lower Orange.

Figure 4-5: Satellite image (Google Earth) of irrigation fields along the Orange River at Louisvale, close to Upington – Lower Orange.

Figure 4-6: Satellite image (Google Earth) of irrigation fields along the Orange River at Upington – Lower Orange

5 WATER QUALITY COMPLIANCE TO RESOURCE WATER QUALITY OBJECTIVES

Analysis of the available water quality data and comparison to RWQOs listed above (in **Section 4.1**) was undertaken as part of this task in order to identify water quality variables of concern and possible water quality issues in the Orange River catchment, as well as assess how the results compare to the state of water quality as described in **Section 3**. Specifically to confirm the key issues and sources of the pollution which would then inform the required management actions and linkages to the Reconciliation Strategy.

5.1 WATER QUALITY DATA SOURCE

The historical data on physico-chemical parameters were obtained from the DWA Resource Quality Services (RQS) for the monitoring sites on the Orange and Caledon Rivers and some major tributaries. The DWA has a comprehensive monitoring system of water quality sites throughout the country as part of the National Chemical Monitoring Programme (NCMP). Monitoring data collected is stored on the Department's Water Management System (WMS). The current water quality status (2000 – 2013) was determined using the long-term chemical data collected at relevant water quality monitoring sites. The changes in the water quality over time (temporal) and the spatial (downstream) variability of salinity in the Orange River was also assessed.

The analysis included 22 water quality monitoring sites in the Upper and Lower Orange WMAs. See **Table 5-1** for a description of the sites on the Orange River, Caledon River and major tributaries and **Figure 5-1** for the location of the sites. Thirteen of the sites are on the Orange River main stem, including the two major dams, 4 on major tributaries of the Orange and 4 on the Caledon River. The additional site is at the Ash River Tunnel outfall from Katse Dam. This was included to obtain an indication of the water quality of the Senqu River.

The monitoring sites on the Upper Orange River main stem are at Oranjedraai, Aliwal North, Roodepoort, Dooren Kuilen and Marksdrift. The main tributaries are Kornetspruit, Kraai River, Stormbergspruit and Seekoei River. Sites on the Caledon River, main stem, are at confluence the with Little Caledon River, at Ficksburg, Kommissiedrift and the tributary Little Caledon River. There are 11 monitoring sites on the lower Orange River, from Zeekoeibaard to Alexander Bay.

Table 5-1: Water Quality Monitoring sites on the Orange River

WQ STATION	MONITORING SITE – DESCRIPTION	LOCATION: GPS CO-ORDINATES	ELEVATION/CATCHMENT
C8H036	Ash River Tunnel Outlet from Katse Dam (at Butterworth)	S28.43778; E 28.39806	Elevation: 1742 m; D83A
D1H001	Stormbergspruit at Burgersdorp (Wonderboomspruit at Diepkloof)	S31.00109; E26.35314	Elevation, 1 379 m; below weir; D14E
D1H003	Orange River at Aliwal North (Road bridge)	S30.68612; E26.70600	Elevation: 1 310 m; D14A
D1H006	Kornetspruit at Maghaleen	S30.16003; E27.40145	Elevation, 1 428 m; D15G

WQ STATION	MONITORING SITE – DESCRIPTION	LOCATION: GPS CO-ORDINATES	ELEVATION/CATCHMENT
D1H009	Orange River at Oranjedraai; at Lesotho border	S30.33772; E27.36277	Elevation, 1 392 m; D12A
D1H011	Kraai River at Roodewal	S30.73707; E26.78440	Elevation, 1 299 m; D13L
D2H012	Little Caledon River at The Poplars; confluence with Caledon River	S28.69477; E28.23486	Elevation: 1 603m; D21C
D2H035	Caledon River d/s from Ficksburg	S28.90409; E27.83084	Elevation, 1 536m; D22C
D2H036	Caledon River at Kommissiedrift at N6 crossing	S30.27994; E26.65427	Elevation: 1 323 m; D24G
D2R004	Welbedacht Dam	S29.90889; E26.86056	Elevation:1 388m; D24C
D3R002	Gariep Dam on Orange River: near dam wall	S30.60794; E25.50465	Elevation: 1 273 m, D34A
D3H013	Orange River at Roodepoort; ds of Gariep Dam	S30.58487; E25.42084 (S30.62062; E25.46511)	Elevation: 1 195 m D34A, 1976 – 2013 (1548)
D3H015	Seekoei River at De Eerste Poort	S30.53480; E24.96250	Elevation: 1 214 m, D32J
D3R003	Vanderkloof Dam, near dam wall	S29.99447; E24.73524	Elevation: 1 169 m, D31E
D3H012	Orange River at Dooren Kuilen; below Vanderkloof Dam	S29.99141; E24.72414	Elevation: 1 083 m, D31E
D3H008	Orange River at Marksdrift	S29.16201; E23.69447	Elevation: 980 m, D33K
D7H008	Orange River at Boegeberg Reserve/Zeekoebaard	S29.02625; E22.18608	Elevation: 973 m, D73BC
D7H016	Orange River at Neusberg weir (North canal)	S28.77481; E20.74558	Elevation: 678 m, D73F
D7H005	Orange River at Upington Water Works	S28.45259; E21.25994	Elevation: 791 m D73F
D8H008	Orange River at Pella Mission	S28.96443; E19.15276	Elevation: 301 m, D81G
D8H003	Orange River at Vioolsdrift	S28.76208; E17.72631	Elevation: 167 m; D82E
D8H012	Orange River at Alexander Bay/ Ernest Oppenheimer Bridge	S28.56689; E16.50728	Elevation: 9 m; D82L

5.2 WATER QUALITY VARIABLES AND DATA ANALYSIS

The key water quality variables for the assessment were based on the associated activities and impacts in the catchment and the typical water quality variables that are assessed in characterising the natural background state. Major sources of impact in the Orange River catchment area include irrigation return flows, intensive fertilizer use, discharges from wastewater treatment works, un-serviced dense settlements (sewage pollution), and erosion.

The water quality variables analysed at the sites included:

- Chemical water quality parameters, including total dissolved salts, alkalinity, mineral ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, F^{-}, Si & SO_4^{2-}), nutrients [nitrogen (NO_3^{2-} & NH_3) and phosphorus (PO_4^{3-})
- Physical parameters: Turbidity and total suspended solids (TSS) (where available).
- Biological parameters: Algal biomass (*Chl*-*a*), at selected sites.

Microsoft Office Excel software was used for data manipulation and for the statistical analyses. The water quality analysis was undertaken within the constraints of the available data on the WMS of the DWA.

5.3 WATER QUALITY ANALYSIS: RESULTS

Seventeen physico-chemical water quality variables and Chlorohyll-*a* of the National Chemical Monitoring (Priority) Programme were analysed by comparing the median, 75th and 95th percentile values to the RWQOs established. Other possible data sources such as regional monitoring programmes did not form part of this analysis. The results of the water quality analysis are presented in **Table 5-2** and **Table 5-3** below which indicate compliance in terms of the RWQOs as listed in **Section 4.1** (refer to **Table 4-1**; **Table 4-2** and **Table 4-3)**. **Table 5-5** provides an interpretation of the results of the fitness for use analysis. Turbidity data was only available for 16 of the 22 monitoring stations. The turbidity readings are sown in

Table 5-4 for information purposes. Compliance assessment of turbidity was not undertaken due to the fact that turbidity RWQOs are yet to be established. It is not possible to apply a generic RWQO for the entire system. A RWQO for turbidity is highly site specific, dependent on reference conditions and the species of aquatic biota present.

Seven of the eighteen water quality variables are depicted on a water quality map for the Orange River catchment. The variables include Total Dissolved Salts (TDS), Orthophosphate (PO_4-P), Chloride (Cl^{-}), Sodium Absorption Ratio (SAR), Turbidity, Alkalinity and pH. These seven variables were selected as they serve as a suitable indicator of the overview salinity, eutrophication and soil erosion status, the major concerns in the Orange River. These indicators also consider the requirements of the major water user in the Orange River catchment, being irrigation. In addition, these variables showed the greatest degree of non-compliance and potential for impact on the fitness of use of the water resources of the Orange River. **Figure 5-2** represents the water quality of selected variables at the water quality monitoring sites. Very limited water quality data was available for suspended solids and *E.coli*, thus these variables were not included in the analyses. This is a gap iidentified in the water quality monitoring programme.

The spatial (downstream) variability of Total Dissolved Salts (TDS) in the Orange River was assessed and is depicted in **Figure 5-7**. In the box and whiskers plot, the box represents 50 % of the data and the whiskers represent the 5th and 95th percentile. The median is represented by the solid line.

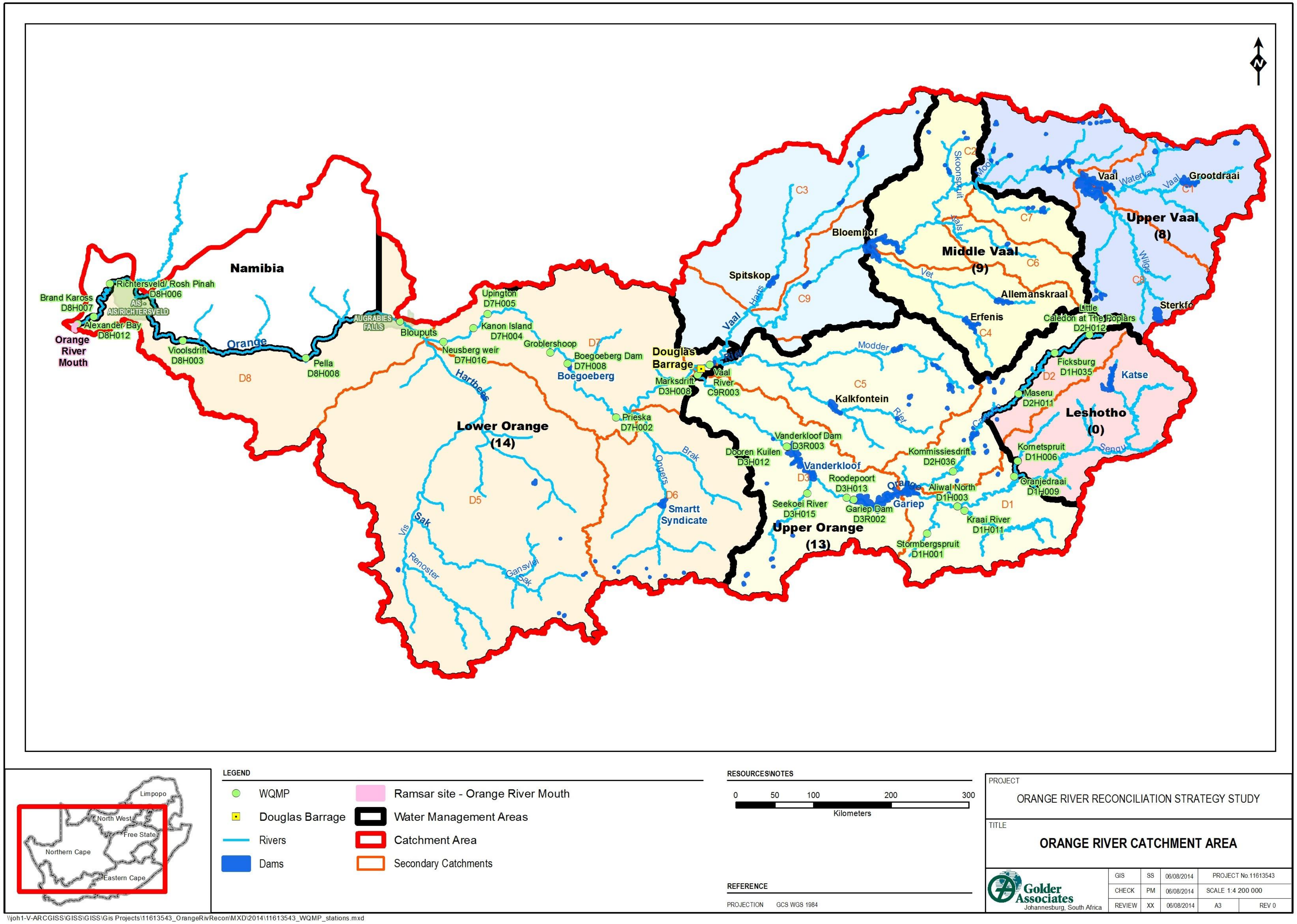

Figure 5-1: Location of water quality monitoring site on the Orange River

Table 5-2: Water quality compliance to RWQOs at the selected monitoring sites on the Orange River (1 of 6)

Compliant | Non-compliant | No data

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	10 mg/l	30 mg/l	0.015 mg/l	0.4 mg/l	30 mg/l	0.045 mg/l	1.5 mg/l	60 mg/l	20 mg/l	175 mg/l	≥ 6.9 - ≤ 8.4
C8H036Q01 AS RIVER TUNNEL OUTLET FROM KATSE AT BOTTERKLOOF	C83A	Median	9.647	4.844	70.207	0.100	37.815	0.497	3.321	0.001	0.202	2.534	0.017	0.179	5.44	6.92	35.25	7.66
		75%tile	10.223	5.000	73.965	0.122	39.663	0.599	3.534	0.001	0.240	2.804	0.024	0.197	6.90	7.27	37.66	7.81
		95%tile	11.201	5.337	80.147	0.183	42.984	1.690	4.033	0.003	0.302	3.874	0.049	0.264	10.20	7.79	41.81	8.01
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	150 mg/l	138 mg/l	550 mg/l	1 mg/l	300 mg/l	50 mg/l	100 mg/l	0.058 mg/l	0.75 mg/l	92.5 mg/l	0.13 mg/l	3 mg/l	100 mg/l	20 mg/l	450 mg/l	≥ 7.4 - ≤ 8.4
D1H001Q01 WONDERBOOM/STORM BERG SPRUIT AT DIEPKLOOF/ BURGERSDORP	D14E	Median	47.6	32.5	552.4	0.371	235.6	4.8	29.6	0.005	0.8	49.7	0.333	1.323	31.94	5.20	267.06	8.2
		75%	55.30	42.17	635.43	0.419	285.12	6.09	36.32	0.027	1.76	58.72	0.729	1.554	38.22	6.41	314.29	8.36
		95%	64.35	68.79	808.60	0.521	343.43	8.98	44.10	0.264	5.10	78.49	1.495	1.933	57.98	7.67	375.06	8.56
		Compliance to RWQO	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	25 mg/l	30 mg/l	0.015 mg/l	0.3 mg/l	40 mg/l	0.045 mg/l	1.5 mg/l	80 mg/l	20 mg/l	175 mg/l	≥ 6.9 - ≤ 8.4
D1H003Q01 ORANGE RIVER AT ALIWAL NORTH	**D14E**	Median	20.35	4.26	151.04	0.1	81.1	1.0	7.1	0.002	0.086	5.1	0.021	0.25	8.53	9.10	82.21	8.01
		75%tile	24.00	5.00	175.67	0.2	95.3	1.8	8.6	0.003	0.190	5.9	0.037	0.29	9.93	9.79	99.24	8.16
		95%tile	30.09	6.06	221.94	0.3	123.8	2.4	12.6	0.007	0.402	8.0	0.067	0.36	14.34	10.97	126.49	8.36
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant

Water quality compliance to RWQOs at the selected monitoring sites on the Orange River (2 of 6)

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	25 mg/l	30 mg/l	0.015 mg/l	0.3 mg/l	40 mg/l	0.045 mg/l	1.5 mg/l	80 mg/l	20 mg/l	175 mg/l	≥ 7.0 - ≤ 8.4
D1H006Q01 KORNET SPRUIT AT MAGHALEEN	D15G	Median	20.83	4.69	150.23	0.143	82.2	1.2	7.1	0.002	0.18	5.60	0.024	0.3	10.9	9.71	79.12	8.03
		75%tile	24.79	5.00	176.54	0.188	97.2	1.8	8.6	0.003	0.43	6.46	0.042	0.3	12.7	10.38	96.03	8.19
		95%tile	30.73	6.35	217.75	0.337	118.3	2.4	11.0	0.010	0.79	8.68	0.133	0.4	15.5	11.49	126.13	8.37
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	10 mg/l	30 mg/l	0.015 mg/l	0.4 mg/l	30 mg/l	0.045 mg/l	1.5 mg/l	60 mg/l	20 mg/l	175 mg/l	≥ 6.9 - ≤ 8.4
D1H009Q01 ORANGE RIVER AT ORANJEDRAAI	D12A	Median	18.3	4.5	129.8	0.140	71.6	1.0	6.3	0.001	0.16	4.56	0.027	0.24	8.67	8.9	71.0	7.95
		75%tile	22.2	5.0	152.1	0.174	86.4	1.5	7.8	0.002	0.31	5.42	0.042	0.27	10.01	9.5	85.8	8.11
		95%tile	28.0	6.2	187.4	0.330	109.2	2.2	10.1	0.006	0.46	6.98	0.172	0.34	12.90	10.6	109.6	8.27
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	10 mg/l	30 mg/l	0.015 mg/l	0.4 mg/l	30 mg/l	0.045 mg/l	1.5 mg/l	60 mg/l	20 mg/l	175 mg/l	≥ 7.1 - ≤ 8.4
D1H011Q01 KRAAI RIVER AT ROODEWAL	D13L	Median	24.94	5.00	194.28	0.14	103.62	1.2	10.2	0.002	0.03	6.43	0.017	0.27	8.85	9.73	106.9	8.2
		75%tile	31.36	5.39	237.84	0.18	131.59	1.7	13.3	0.003	0.06	7.79	0.035	0.32	10.72	10.76	135.9	8.3
		95%tile	37.86	7.73	285.43	0.36	155.43	2.3	15.9	0.007	0.14	10.51	0.084	0.38	13.49	11.78	168.0	8.5
		Compliance to RWQO	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	50 mg/l	400 mg/l	0.7 mg/l	200 mg/l	25 mg/l	30 mg/l	0.015 mg/l	0.4 mg/l	70 mg/l	0.05 mg/l	1.5 mg/l	80 mg/l	20 mg/l	300 mg/l	≥ 7.1 - ≤ 8.5
D2H012 CALEDONSPOORT 190 THE POPLARS 199 AT THE POPLARS ON LITTLE CALEDON RIVER	D21C	Median	33.73	5.42	250.40	0.16	139.96	2.025	13.576	0.003	0.05	10.85	0.025	0.406	13.87	9.201	140.90	8.27
		75%tile	41.38	8.13	328.02	0.22	176.46	2.564	17.518	0.004	0.12	14.12	0.044	0.486	16.29	11.023	185.95	8.40
		95%tile	46.42	11.07	389.86	0.32	211.98	3.131	22.477	0.010	0.28	18.65	0.078	0.612	21.89	12.654	227.80	8.53
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Water quality compliance to RWQOs at the selected monitoring sites on the Orange River (3 of 6)

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	40 mg/l	360 mg/l	0.7 mg/l	200 mg/l	10 mg/l	70 mg/l	0.015 mg/l	0.2 mg/l	50 mg/l	0.04 mg/l	1.5 mg/l	80 mg/l	20 mg/l	300 mg/l	≥ 7.1 - ≤ 8.4
D2H035Q01 CALEDON RIVER AT FICKSBURG/ FICKSBURG BRIDGE	D22C	Median	22.68	5.00	171.51	0.15	91.64	1.61	8.59	0.002	0.136	6.77	0.020	0.32	10.29	8.05	97.35	8.11
		75%tile	30.12	5.77	215.01	0.20	118.47	2.31	11.72	0.003	0.297	9.16	0.037	0.37	12.21	8.94	122.11	8.29
		95%tile	37.09	8.02	272.72	0.34	154.25	2.91	15.27	0.009	0.607	14.08	0.077	0.50	15.52	10.12	165.27	8.49
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	40 mg/l	450 mg/l	0.7 mg/l	200 mg/l	25 mg/l	70 mg/l	0.015 mg/l	0.25 mg/l	70 mg/l	0.05 mg/l	1.5 mg/l	80 mg/l	20 mg/l	300 mg/l	≥ 7.1 - ≤ 8.4
D2H036Q01 CALEDON RIVER AT KOMMISSIEDRIFT	D24G	Median	22.71	5.80	177.58	0.22	89.93	2.23	8.10	0.002	0.11	9.51	0.026	0.47	12.67	6.21	92.70	8.08
		75%tile	32.66	11.01	257.34	0.26	133.85	2.72	12.66	0.004	0.39	15.71	0.046	0.61	16.59	7.25	140.31	8.25
		95%tile	42.12	18.45	426.76	0.37	207.74	4.11	24.32	0.010	0.58	31.47	0.093	0.96	26.32	8.14	226.57	8.44
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	100 mg/l	195 mg/l	0.7 mg/l	200 mg/l	25 mg/l	30 mg/l	0.058 mg/l	0.8 mg/l	70 mg/l	0.1 mg/l	1.5 mg/l	100 mg/l	20 mg/l	300 mg/l	≥ 7.1 - ≤ 8.4
D2R004Q01 WELBEDACHT 285 - WELBEDACHT DAM ON CALEDON RIVER: NEAR DAM WALL	D24C	Median	22.22	7.18	185.50	0.21	89.80	2.506	8.2455	0.002	0.13	10.526	0.028	0.493	14.05	6.27	90.77	7.98
		75%tile	31.50	12.28	266.41	0.25	133.75	3.039	12.958	0.004	0.40	17.500	0.048	0.670	19.00	7.26	138.17	8.21
		95%tile	39.37	18.74	370.81	0.39	173.87	4.210	17.584	0.011	0.83	27.265	0.097	0.945	32.10	8.59	185.73	8.45
		Compliance to RWQO	Compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH	Chl-*a*
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	25 mg/l	30 mg/l	0,015 mg/l	0.4 mg/l	40 mg/l	0.04 mg/l	1.5 mg/l	60 mg/l	20 mg/l	175 mg/l	≥ 6.9 - ≤ 8.4	0.005 mg/l
D3R002Q01 OVISTON NATURE RESERVE - GARIEP DAM ON ORANGERIVIER: NEAR DAM WALL	D34A	Median	18.56	4.80	138.88	0.17	73.53	1.4165	6.6	0.002	0.319	5.844	0.023	0.297	9.124	7.456	73.8445	8.01	0.001
		75%tile	19.90	5.37	147.40	0.19	78.57	1.740	7.156	0.003	0.417	6.584	0.035	0.328	11.085	8.178	79.027	8.15	0.004
		95%tile	21.96	7.02	166.97	0.33	87.44	2.469	8.139	0.008	0.518	8.384	0.076	0.412	15.608	8.850	91.854	8.29	0.013
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Water quality compliance to RWQOs at the selected monitoring sites on the Orange River (4 of 6)

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	10 mg/l	30 mg/l	0.015 mg/l	0.4 mg/l	40 mg/l	0.04 mg/l	1.5 mg/l	80 mg/l	20 mg/l	175 mg/l	≥ 7.3 - ≤ 8.4
D3H013Q01 ROODEPOORT ON ORANGE RIVER	D34A	Median	17.86	4.8	135.64	0.168	71.41	1.446	6.369	0.002	0.350	5.697	0.025	0.294	8.67	7.84	71.99	8.00
		75%tile	19.29	5.0	147.34	0.196	77.77	1.949	7.28	0.004	0.437	6.678	0.039	0.326	11.00	8.24	78.80	8.15
		95%tile	21.83	6.9	168.17	0.328	87.52	2.475	8.238	0.007	0.551	8.593	0.081	0.422	14.98	8.80	92.04	8.28
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	138 mg/l	1000 mg/l	1 mg/l	300 mg/l	50 mg/l	70 mg/l	0.015 mg/l	0.2 mg/l	115 mg/l	0.05 mg/l	6,0 mg/l	150 mg/l	20 mg/l	450 mg/l	≥ 7.6 - ≤ 8.5
D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT	D32J	Median	37.49	49.24	655.41	0.57	249.60	3.91	41.06	0.004	0.025	73.92	0.018	1.93	41.54	4.3	308.2	8.46
		75%tile	44.27	70.77	801.72	0.72	327.47	4.52	51.51	0.006	0.082	101.63	0.048	2.39	52.43	5.5	372.6	8.56
		95%tile	57.60	90.87	894.30	0.92	379.60	6.31	61.03	0.019	0.602	129.57	0.159	3.05	75.65	8.1	428.6	8.74
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant (95th%tile)	Non-compliant (95th%tile)	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH	Chl-a
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	10 mg/l	40 mg/l	0.015 mg/l	0.4 mg/l	40 mg/l	0.043 mg/l	1.5 mg/l	80 mg/l	20 mg/l	175 mg/l	≥ 7.1 - ≤ 8.4	0.005 mg/l
D3R003Q01 KAREEKLOOF 1184 - VANDERKLOOF DAM ON ORANJERIVIER: NEAR DAM WALL	D31E	Median	20.58	5.00	151.19	0.18	79.34	1.56	7.47	0.002	0.204	6.70	0.016	0.323	9.54	6.86	80.09	7.98	0.001
		75%tile	21.60	5.98	160.54	0.20	84.17	1.82	7.95	0.003	0.277	7.82	0.027	0.369	11.23	7.60	85.83	8.14	0.002
		95%tile	23.68	7.78	177.51	0.40	91.39	2.57	8.98	0.007	0.484	9.28	0.054	0.436	14.79	8.26	100.22	8.32	0.004
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant

Site			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	60 mg/l	40 mg/l	260 mg/l	0.7 mg/l	175 mg/l	10 mg/l	40 mg/l	0.015 mg/l	0.4 mg/l	40 mg/l	0.04 mg/l	1.5 mg/l	65 mg/l	20 mg/l	175 mg/l	≥ 7.1 - ≤ 8.4
D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003)	D33A	Median	20.13	5.000	151.53	0.167	80.36	1.493	7.315	0.002	0.242	6.633	0.018	0.321	9.258	7.025	80.745	7.98
		75%tile	21.37	5.444	159.29	0.198	84.35	1.980	7.783	0.003	0.321	7.688	0.029	0.368	10.702	7.670	85.791	8.13
		95%tile	22.84	7.500	170.55	0.325	89.30	2.646	8.618	0.007	0.490	9.424	0.053	0.452	12.637	8.447	94.835	8.36
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant

Water quality compliance to RWQOs at the selected monitoring sites on the Orange River (5 of 6)

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	50 mg/l	360 mg/l	0.75 mg/l	175 mg/l	25 mg/l	30 mg/l	0.015 mg/l	0.5 mg/l	70 mg/l	0.03 mg/l	1.5 mg/l	60 mg/l	20 mg/l	175 mg/l	≥ 7.1 - ≤ 8.4
D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER	D33K	Median	21.51	7.37	167.54	0.18	87.72	1.48	8.10	0.002	0.3315	9.19	0.018	0.424	12.48	7.08	86.40	8.12
		75%tile	22.95	9.91	184.15	0.21	94.59	1.77	9.09	0.004	0.442	11.57	0.030	0.523	14.78	7.57	93.49	8.22
		95%tile	24.92	14.34	214.23	0.33	105.99	2.80	10.98	0.010	0.599	14.84	0.061	0.660	20.18	8.44	109.46	8.38
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	100 mg/l	400 mg/l	0.7 mg/l	200 mg/l	15 mg/l	30 mg/l	0.015 mg/l	0.4 mg/l	70 mg/l	0.03 mg/l	1.5 mg/l	80 mg/l	20 mg/l	300 mg/l	≥ 7.1 - ≤ 8.4
D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE/ ZEEKOEBAART	D73B	Median	25.13	15.98	207.48	0.196	105.80	1.89	10.55	0.003	0.18	14.90	0.022	0.63	22.10	6.51	97.31	8.12
		75%tile	28.00	24.51	247.61	0.215	123.13	2.30	13.11	0.005	0.39	21.52	0.033	0.85	36.54	7.31	105.41	8.28
		95%tile	34.05	46.23	341.44	0.263	159.80	3.98	17.99	0.011	0.56	35.35	0.066	1.27	63.86	8.01	117.12	8.60
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Complian t	Compliant	Non-compliant (95th%tile)

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH	Chl-a
		RWQO	80 mg/l	100 mg/l	450 mg/l	0.7 mg/l	200 mg/l	25 mg/l	50 mg/l	0.03 mg/l	0.2 mg/l	70 mg/l	0.025 mg/l	2 mg/l	100 mg/l	20 mg/l	300 mg/l	≥ 7.6 - ≤ 8.4	0.01 mg/l
D7H016Q01 NORTH CANAL FROM ORANGE RIVER AT KAKAMAS/ NEUSBERG	D73F	Median	27.86	21.12	256.34	0.25	122.78	2.28	12.91	0.002	0.055	21.2	0.020	0.86	28.32	6.44	114.25	8.23	0.007
		75%tile	30.64	32.11	312.83	0.28	139.90	2.80	15.38	0.005	0.173	29.4	0.032	1.08	42.94	7.61	134.46	8.35	0.014
		95%tile	35.90	47.99	389.15	0.41	169.17	3.90	20.06	0.012	0.557	44.4	0.067	1.48	60.68	8.98	156.13	8.53	0.04
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant

Site	Code		Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH	Chl-a
		RWQO	80 mg/l	100 mg/l	450 mg/l	0.7 mg/l	250 mg/l	25 mg/l	70 mg/l	0.058 mg/l	0.2 mg/l	92.5 mg/l	0.025 mg/l	3 mg/l	200 mg/l	20 mg/l	300 mg/l	≥ 7.2 - ≤ 8.4	0.015 mg/l
D7H005Q01 ORANGE RIVER AT UPINGTON	D73F	Median	27.76	21.42	245.64	0.23	120.5	2.33	12.81	0.002	0.116	21.49	0.020	0.85	28.70	6.19	110.94	8.18	0.007
		75%tile	31.76	34.35	312.74	0.26	146.0	3.08	16.16	0.005	0.387	31.25	0.031	1.15	45.46	7.50	123.08	8.30	0.02
		95%tile	37.30	52.44	392.56	0.35	179.0	4.30	21.91	0.011	0.596	46.79	0.074	1.56	71.58	8.44	142.30	8.43	0.03
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant

Water quality compliance to RWQOs at the selected monitoring sites on the Orange River (6 of 6)

			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH	Chl-*a*
		RWQO	80 mg/l	100 mg/l	550 mg/l	1 mg/l	250 mg/l	25 mg/l	70 mg/l	0.03 mg/l	0.15 mg/l	92.5 mg/l	0.03 mg/l	3 mg/l	150 mg/l	20 mg/l	300 mg/l	≥ 7.4 - ≤ 8.4	0.015 mg/l
D8H008Q01 ORANGE RIVER AT PELLA MISSION	D81G	Median	31.13	25.78	286.39	0.30	135.49	2.38	14.26	0.003	0.055	27.27	0.019	1.01	35.04	6.39	125.00	8.26	0.009
		75%tile	34.87	38.33	336.46	0.34	158.17	2.83	17.56	0.005	0.135	37.40	0.032	1.32	49.47	8.18	139.52	8.35	0.015
		95%tile	40.93	62.65	460.94	0.43	199.39	4.06	23.92	0.013	0.521	60.31	0.071	1.87	79.38	9.89	163.79	8.51	0.039
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant

			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	100 mg/l	550 mg/l	1 mg/l	250 mg/l	25 mg/l	70 mg/l	0.03 mg/l	0.15 mg/l	92.5 mg/l	0.03 mg/l	3 mg/l	150 mg/l	20 mg/l	300 mg/l	≥ 7.0 - ≤ 8.4
D8H003Q01 AT VIOOLSDRIFT ON ORANGE RIVER	D82E	Median	31.13	27.77	299.14	0.31	137.11	2.56	14.75	0.003	0.04	29.19	0.019	1.08	35.54	6.23	129.19	8.26
		75%tile	35.54	41.48	360.00	0.37	160.03	3.15	18.08	0.004	0.07	41.65	0.031	1.44	51.96	8.08	146.61	8.37
		95%tile	41.97	70.54	497.30	0.46	204.88	4.11	25.27	0.009	0.53	67.21	0.063	2.05	82.91	9.85	171.77	8.50
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

			Ca	Cl	TDS	F	Hardness as $CaCO_3$	K	Mg	NH_3 as N	Nitrate as N	Na	PO_4 as P	SAR	SO_4	Si	Alkalinity as $CaCO_3$	pH
		RWQO	80 mg/l	100 mg/l	550 mg/l	0.7 mg/l	250 mg/l	25 mg/l	70 mg/l	0.015 mg/l	0.25 mg/l	92.5 mg/l	0.03 mg/l	3 mg/l	150 mg/l	20 mg/l	300 mg/l	≥ 7.5 - ≤ 8.5
D8H012Q01 ORANGE RIVER AT ALEXANDER BAY	D82L	Median	34.65	29.79	332.58	0.271	146.52	3.61	14.97	0.003	0.09	31.42	0.024	1.16	54.75	4.60	124.78	8.34
		75%tile	38.41	40.21	362.98	0.323	163.66	4.15	16.63	0.004	0.23	41.20	0.045	1.42	63.99	5.63	140.78	8.41
		95%tile	42.11	63.03	497.34	0.487	207.86	5.51	23.54	0.007	0.79	63.76	0.085	2.09	85.50	8.54	182.56	8.57
		Compliance to RWQO	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Table 5-3: Summary of water quality compliance to RWQOs at the identified monitoring sites on the Orange River

Compliant	Non-compliant	No data

Monitoring Site	Chl-*a*	Calcium	Chloride	TDS	Flouride	Hardness	K	Mg	NH_3	Nitrate	Na	PO_4^-	SAR	SO_4	Si	Alkalinity	pH
C8H036Q01 AS RIVER TUNNEL OUTLET FROM KATSE AT BOTTERKLOOF		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D1H001Q01 WONDERBOOM/STORMBERG SPRUIT AT DIEPKLOOF/BURGERSDORP		Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D1H003Q01 ORANGE RIVER AT ALIWAL NORTH		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D1H006Q01 KORNET SPRUIT AT MAGHALEEN		Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant
D1H009Q01 ORANGE RIVER AT ORANJEDRAAI		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D1H011Q01 KRAAI RIVER AT ROODEWAL		Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D2H012 CALEDONSPOORT 190 THE POPLARS 199 AT THE POPLARS ON LITTLE CALEDON RIVER		Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D2H035Q01 CALEDON RIVER AT FICKSBURG/ FICKSBURG BRIDG		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D2H036Q01 CALEDON RIVER AT KOMMISSIEDRIFT		Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Non-compliant
D2R004Q01 WELBEDACHT 285 - WELBEDACHT DAM ON CALEDON RIVER: NEAR DAM WALL		Compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant
D3R002Q01 OVISTON NATURE RESERVE - GARIEP DAM ON ORANGERIVIER: NEAR DAM WALL	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D3H013Q01 ROODEPOORT ON ORANGE RIVER		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant
D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT		Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant (95th%tile)	Non-compliant (95th%tile)	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Non-compliant
D3R003Q01 VANDERKLOOF DAM ON ORANJERIVIER: NEAR DAM WALL	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003)		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant (95th%tile)	Compliant	Compliant	Compliant	Compliant	Compliant
D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE/ZEEKOEBAART		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D7H016Q01 NORTH CANAL FROM ORANGE RIVER AT KAKAMAS/NEUSBERG	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D7H005Q01 ORANGE RIVER AT UPINGTON	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D8H008Q01 ORANGE RIVER AT PELLA MISSION	Non-compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D8H003Q01 AT VIOOLSDRIFT ON ORANGE RIVER		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)
D8H012Q01 ORANGE RIVER AT ALEXANDER BAY		Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)	Compliant	Non-compliant	Compliant	Compliant	Compliant	Compliant	Non-compliant (95th%tile)

Table 5-4: Turbidity data for some water quality sites on the Orange River and tributaries (mg/l)

	D1H003Q01 ORANGE RIVER AT ALIWAL NORTH (D14E)	D1H006Q01 KORNET SPRUIT AT MAGHALEEN (D15G)	D1H009Q01 ORANGE RIVER AT ORANJEDRAAI (D12A)	D1H011Q01 KRAAI RIVER AT ROODEWAL (D13L)	D2H012 CALEDONSPOORT AT THE POPLARS ON LITTLE CALEDON RIVER (D21C)	D2H035Q01 CALEDON RIVER FICKSBURG BRIDGE (D22C)	D2H036Q01 CALEDON RIVER AT KOMMISSIE-DRIFT (D24G)	D2R004Q01 WELBEDACHT DAM ON CALEDON RIVER: NEAR DAM WALL (D24C)	D3R002Q01 OVISTON NATURE RESERVE - GARIEP DAM ON ORANGERIVIER (D34A)	D3H013Q01 ROODEPOORT ON ORANGE RIVER (D34A)	D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT (D32J)	D3R003Q01 VANDERKLOOF DAM ON ORANJERIVIER: NEAR DAM WALL (D31E)	D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003) (D33A)	D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER (D33K)	D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE / ZEEKOEBAART (D73B)	D8H003Q01 AT VIOOLSDRIFT ON ORANGE RIVER (D82E)
Median	37.1	15.4	19.3	4.3	2.8	13.3	38.8	26.6	6.3	12.0	1.8	2.2	3.2	5.5	3.2	4.0
75%tile	138.5	78.9	146.0	18.3	7.1	39.3	201.5	95.0	19.8	28.0	4.6	6.1	6.8	13.8	10.1	17.4
95%tile	553.0	525.8	623.8	145.1	28.3	266.1	960.5	547.2	53.4	86.6	53.7	31.6	32.3	48.4	30.5	90.8

Table 5-5: Summary of Fitness for use assessment

Monitoring Site	Non compliance/ potential concern	FITNESS FOR USE ASSESSMENT
C8H036Q01 AS RIVER TUNNEL OUTLET FROM KATSE AT BOTTERKLOOF	Orthophosphate	Water quality at this site is very good, primarily ideal water quality and fit for use. The levels of ortho-phosphate may have some effect on the aquatic ecosystem.
D1H001Q01 STORMBERG SPRUIT AT DIEPKLOOF/BURGERSDORP	TDS, Hardness, Ammonia, Nitrate, Orthophosphate, pH	Water quality at this site is impacted in terms of salinity and nutrients. The water quality may impact on irrigation and industrial water use. The orthophosphate concentration is unacceptably high (1.49mg/l – 95th %tile) which may affect biological activity and is a potential threat for algal blooms should suitable conditions arise. The ammonia levels are also non-compliant and may impact on the aquatic biota.
D1H003Q01 ORANGE RIVER AT ALIWAL NORTH	Orthophosphate, Nitrate	Water quality is generally fit for use. It is however high in turbidity and nutrient concentrations. Total hardness is also non-compliant (2.37X higher than RWQO) however there are no major industrial users in the area. The highly turbid water does indicate the extent of erosion in the catchment and may impact on domestic use. The Kraai River has high salinity concentrations with the RWQO for TDS being exceeded.
D1H006Q01 KORNET SPRUIT AT MAGHALEEN	Hardness, Nitrate, Orthophosphate	
D1H009Q01 ORANGE RIVER AT ORANJEDRAAI	Nitrate, Orthophosphate, Turbidity	
D1H011Q01 KRAAI RIVER AT ROODEWAL	TDS, Orthophosphate, Turbidity, pH	
D2H012 CALEDONSPOORT 190 THE POPLARS 199 AT THE POPLARS ON LITTLE CALEDON RIVER	Orthophosphate, Hardness, pH	Water quality in the Caledon River is of acceptable quality. Nutrients are again non-compliant which indicates high levels of nutrients. pH is slightly high in the Caledon River (95th %tile above 8.4). This may have some effect on irrigation use and the aquatic biota. The TDS concentrations at Kommissiedrift and at Poplars are at tolerable levels (approx. 400 mg/l). Total hardness and alkalinity is high and unacceptable for industrial use. Turbidity is very high at Welbedacht Dam. This is indicative of the sedimentation problems experienced at the dam. The dam storage capacity has been impacted due to sedimentation. This has impacted on the availability of water for downstream users (in the Bloemfontein area).
D2H035Q01 CALEDON RIVER AT FICKSBURG/ FICKSBURG BRIDG	Nitrate, Orthophosphate, pH	
D2H036Q01 CALEDON RIVER AT KOMMISSIEDRIFT	Orthophosphate, Hardness, Turbidity, Alkalinity	
D2R004Q01 WELBEDACHT 285 - WELBEDACHT DAM ON CALEDON RIVER: NEAR DAM WALL	Nitrate, Orthophosphate, Hardness, Turbidity, pH	
D3R002Q01 OVISTON NATURE RESERVE - GARIEP DAM ON ORANGERIVIER: NEAR DAM WALL	Nitrate, Orthophosphate, Turbidity, Chlorophyll-*a*	Water quality in Gariep Dam and just downstream at Roodepoort is generally good and fit for use. However, nitrate, orthophosphate and turbidity are high and are non-compliant. Again, the nitrate and orthophosphate may impact on biological activity in the river.
D3H013Q01 ROODEPOORT ON ORANGE RIVER	Nitrate, Orthophosphate, Turbidity	
D3H015Q01 SEEKOEI RIVER AT DE EERSTE POORT	Hardness, Sodium, Orthophosphate, Nitrate, Ammonia, Alkalinity, pH	Water quality in the Seekoei river is suitable for domestic and recreation use. TDS and sodium concentrations are high and may impact on irrigation and industrial water use. Nitrate and orthophosphate in the river is at unacceptable concentrations and has a potential impact on aquatic ecosystem health.
D3R003Q01 VANDERKLOOF DAM ON ORANJERIVIER: NEAR DAM WALL	Nitrate, Orthophosphate	Water quality in Vanderkloof Dam and just downstream is good and fit for use. However, nutrients and turbidity are high. The nutrients are at unacceptable levels as at most sites on the Orange River.
D3H012Q01 ORANGE RIVER AT DOOREN KUILEN (DOWNSTREAM OF D3R003)	Nitrate, Orthophosphate	
D3H008Q01 AT MARKSDRIFT ON ORANGE RIVER	Nitrate, Orthophosphate	Water quality is good and generally fit for domestic, irrigation and recreation use. Nutrient concentrations do not comply with the RWQOs.

Monitoring Site	Non compliance/ potential concern	FITNESS FOR USE ASSESSMENT
D7H008Q01 ORANGE RIVER AT BOEGOEBERG RESERVE/ZEEKOEBAART	Nitrate, Orthophosphate, pH	Water is generally good for domestic, irrigation and recreation and industrial use. Nitrate and orthophosphate are non-compliant to the RWQO and pose a threat to aquatic health (nutrient enrichment).
D7H016Q01 NORTH CANAL FROM ORANGE RIVER AT KAKAMAS/NEUSBERG	Nitrate, Orthophosphate, pH, Chlorophyll-*a*	Water quality in the Lower Orange is generally good. TDS is at tolerable concentrations (approx. – 400 - 500 mg/l). Orthophosphate, nitrate and *Chl-a* concentrations are non-compliant at Upington, Pella Mission and Neusberg and do indicate the potential for algal blooms should conditions be suitable. The water is slightly hard at the Upington, Pella Mission and Vioolsdrift site which may have some impact on industrial use. However industrial use is very limited in this area. The Orange River at Vioolsdrift does indicate slightly high levels of turbidity, however whether it is unclear as to whether this is due to natural conditions. The pH of the lower Orange River is slightly high – in the region of 8.5.
D7H005Q01 ORANGE RIVER AT UPINGTON	Nitrate, Orthophosphate, pH, Chlorophyll-*a*	
D8H008Q01 ORANGE RIVER AT PELLA MISSION	Nitrate, Orthophosphate, pH, Chlorophyll-*a*	
D8H003Q01 AT VIOOLSDRIFT ON ORANGE RIVER	Nitrate, Orthophosphate, pH	
D8H012Q01 ORANGE RIVER AT ALEXANDER BAY	Nitrate, Orthophosphate, pH	

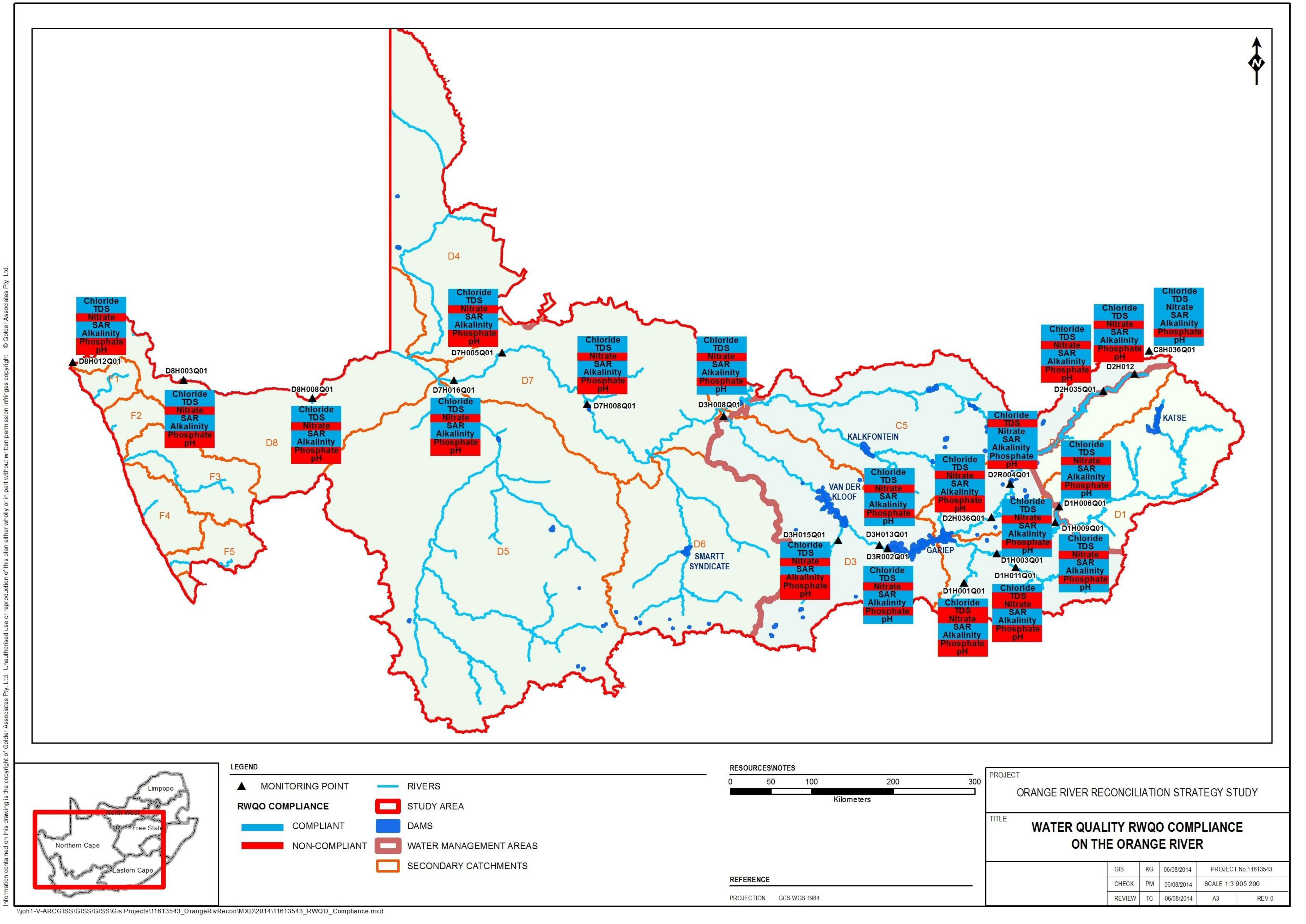

Figure 5-2: Water quality RWQO compliance of selected variables along the length of the Orange River

5.4 WATER QUALITY ANALYSIS: DISCUSSION

5.4.1 Fitness for use

Fitness for use of the Orange River water in terms of the key water users, *viz*. irrigation, livestock watering and domestic consumption are discussed below, based on the results of compliance analysis of the observed water quality (2000- 2013) of selected water quality variables compared to the RWQOs set.

- *Domestic Use*: The water quality in the upper and lower Orange River is generally suitable for domestic use. Water quality generally complied with the RWQOs set with the exception of turbidity. Domestic use could potentially be impacted by high turbidity concentrations in the Upper Orange however this is related primarily to direct water use from the water resource (mainly with respect to rural water use, where raw water is not properly treated). However for domestic use where the 'raw' water is treated before use, turbidity concentrations observed will not influence the household activities.

  The concentrations of metals and microbiological parameters and their impact on domestic use of water is still a gap to be assessed. The lack of data was a constraint in terms of this assessment.

- *Agriculture Use – Irrigation:* The water in the Upper and Lower Orange River was found to be suitable for irrigation in the WMAs. The water quality in the Upper Orange River can be characterised by low TDS and low SAR (sodium adsorption ratio). In the Lower Orange River, the salts concentrations were above 200 mg/ℓ for irrigation but still in the acceptable ranges (< 600 mg/ℓ). The pH generally increases downstream and occasionally exceeds the upper limit for irrigation of 8.4.

- *Recreational and Industrial use*: The water in the Upper and Lower Orange River was found to be suitable for recreational and industrial use. Unacceptable alkalinity concentration in the tributaries Stormbergspruit, Caledon and Seekoei exceed the RWQO. The high alkalinity implies that the water is unsuitable for direct industrial use, however direct abstractions for industrial use in the catchment are limited. In general most industries rely on treated water supplied through urban water supply systems. The bacteriological levels (*E. coli*) in the water resources need to be assessed to determine suitability for full contact recreational activities. The lack of available data was a constraint.

- *Aquatic Ecosystem:* Free (un-ionized) ammonia (NH_3) at high concentrations is toxic to fish and the percentage composition in water increases with temperature and higher pH values (DWAF, 1996). Fish kills have been reported in the Lower Orange River that was ascribed to water quality factors including high ammonia concentrations (DWA, 2009). However, the present status was relatively low at an average of 11 μg/ℓ. These recorded NH_3 concentrations (2000 – 2013) is still suitable for cold-water fish (aquaculture) at pH >8 (DWAF, 1996).

The orthophosphate (PO_4^-) RWQO used applies specifically for the requirements of the aquatic ecosystem. Phosphate is usually the limiting factor in algal growth and therefore, controls the primary productivity of a water body. The RWQO limits relate to the periphyton and phytoplankton response to nutrient enrichment of the water resource. Orthophosphate (PO_4^-) has no direct effect on the use of water, but is an indicator of contamination from activities in the catchment such as sewage discharges, industrial effluents and fertiliser mobilised in run-off which contribute to elevated levels of orthophosphate in surface waters. High concentrations of phosphates can indicate the presence of pollution and are largely responsible for eutrophic conditions. The general non-compliance of orthophosphate through the Orange River catchment indicates that the potential for nutrient enrichment does exist under suitable conditions.

5.4.2 Water quality analysis

- The water quality and quantity in the uppermost reaches of the Orange River, above Gariep Dam, is still in a largely unimpacted state and show minor changes over the past 13 years.
- The water in these uppermost reaches is moderately soft, relatively low in salt concentrations, but generally high in suspended solids and turbidity.
- The water quality in the Lower Orange River occasionally exceeded the RWQO for irrigation especially the salt concentrations and high pH values.
- The nutrient (nitrate and orthophosphate) concentrations in the Orange River are in general non-compliant to the RWQOs.
- Some of the water withdrawn for irrigation is returned to the river environment for re-use, but its quality is degraded with considerably higher salt and nutrient concentrations which contributes significantly to the salt load in the Orange River.
- The mean chlorophyll-*a* concentrations (algal biomass) in the Gariep and Vanderkloof Dams were low (<12 µg/ℓ) and fall in the range of oligotrophic systems, but the Chl-*a* concentrations, were much higher at Upington and Pella (mean 30 µg/ℓ) corresponding to mesotrophic water bodies. More monitoring data is required to obtain a better understanding of the trophic status of these sites. Chl-*a* data is limited and more data is required to provide a conclusive understanding.
- The general water quality in Kornetspruit and Kraai River was good. Orthophosphate levels are high which indicates contributions from urban areas such as wastewater discharges and urban runoff.
- The Seekoei River's salt and nutrient concentrations are high but are possibly considered to represent natural conditions.
- The analysis of the available Stormbergspruit water quality data indicates high salts and nutrient levels.
- The water quality in the Caledon River is highly variable but in general is in a fair condition when compared to the RWQO, however, nutrient levels were elevated and turbidity levels are high, indicating high sediment concentrations.

- Water quality at the Ash River tunnel outlet is very good (natural state) indicating the water quality at the headwaters of the Senqu River is ideal.

5.4.3 Key water quality variables of concern and related concerns

5.4.3.1 Turbidity

The concentration of turbidity in the upper Orange River is high and is primarily attributed to soil erosion. Turbidity refers to water clarity. The Orange River is known as a very turbid river. Most Orange River suspended sediment is produced upstream of the Caledon-Orange confluence. The majority of the Orange River suspended load is derived from erosion of Karoo sedimentary bedrock and soils (DWA, 2009). The high turbidity in the Upper Orange River and specifically in the Caledon will limit algal growth. Assessment of the temporal variation of turbidity between 1992 and 2007 at Oranjedraai, Dooren Kuilen and Boegeberg Dam in the Orange and at Kommissiedrift on the Caledon Rivers does not indicate any increasing trend in concentration (Refer to **Figure 5-3**; **Figure 5-4**; **Figure 5-5** and **Figure 5-6**) (DWA, 2009). The high concentration of turbidity that is evident in the system specifically in the Upper Orange WMA does not appear to be a significant threat to the aquatic ecosystem based on ecological assessments that have been undertaken. However it is apparent that it must be taken into consideration in the design and management of water supply infrastructure.

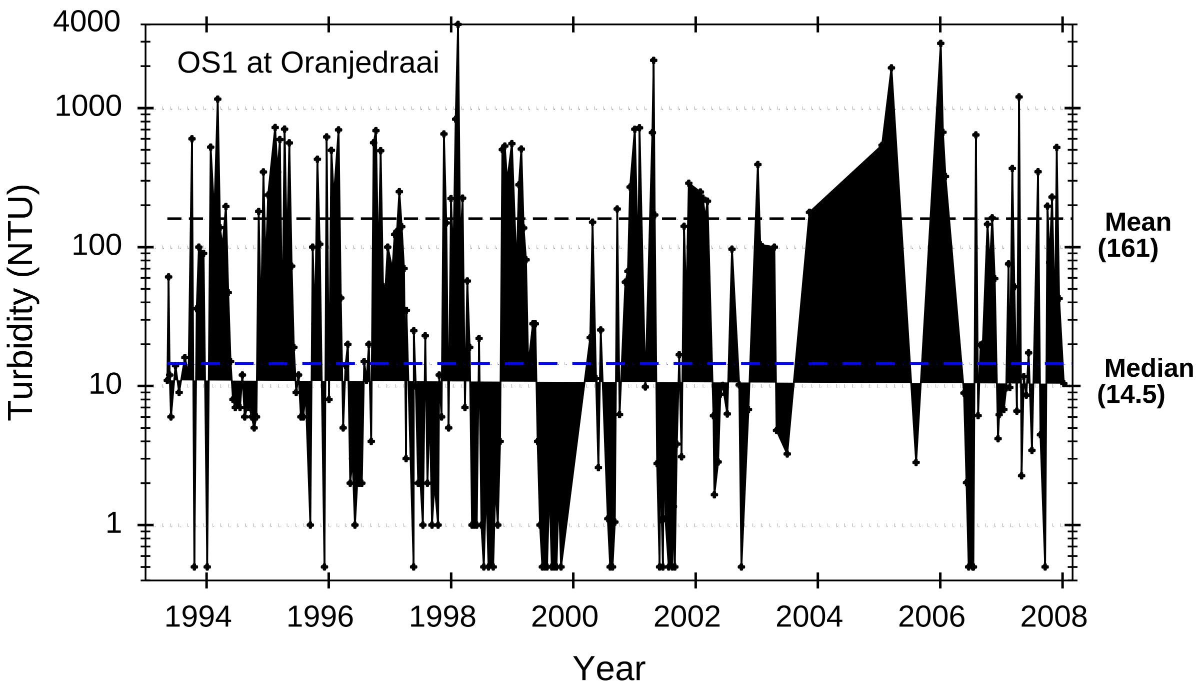

Figure 5-3: Temporal variation of turbidity (NTU) in the Orange River at Oranjedraai (1993 – 2007). Note the log scale on y-axis (DWA, 2009)

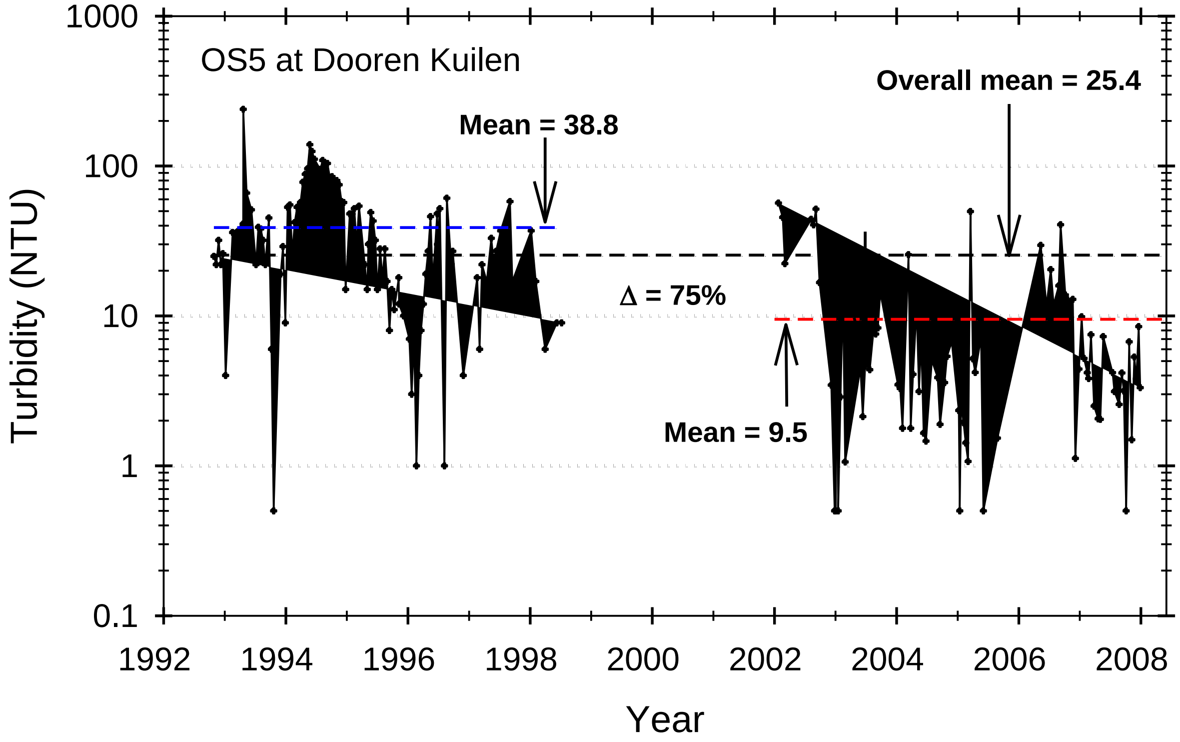

Figure 5-4: Temporal variation of turbidity (NTU) in the Orange River at Dooren Kuilen (1992 – 2007). Note the log scale on y-axis (DWA, 2009)

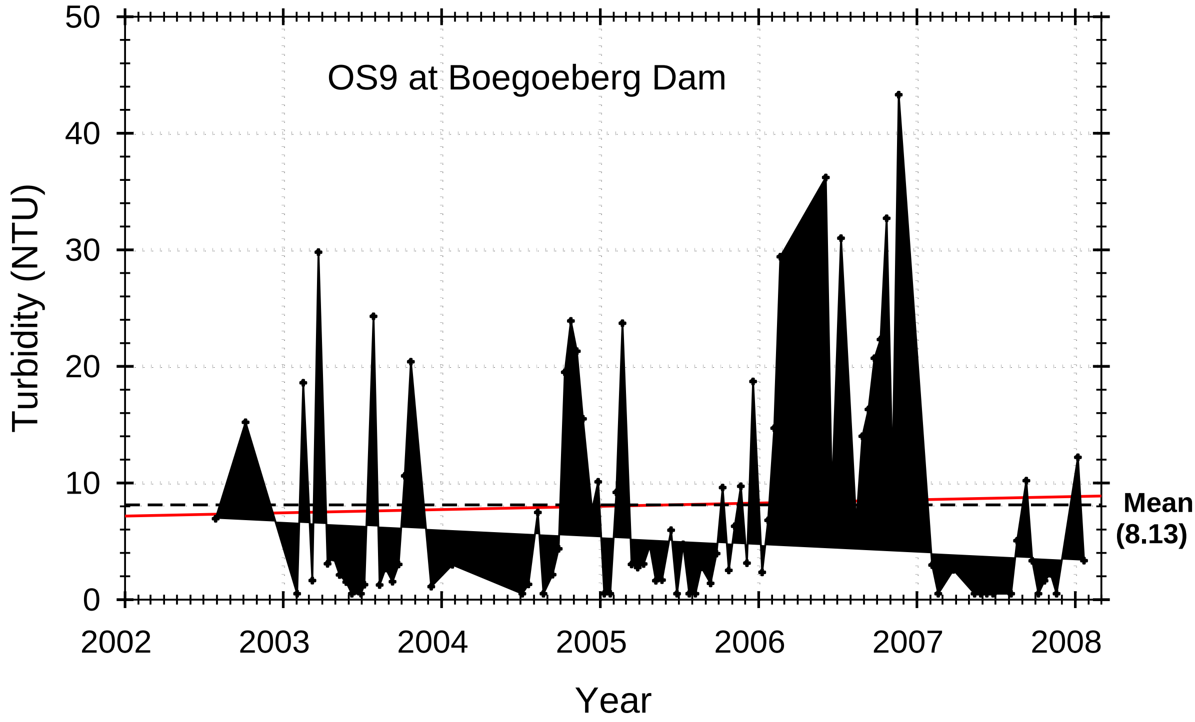

Figure 5-5: Temporal variation of turbidity (NTU) in the Orange River at Boegeberg Dam (2002 – 2007) (DWA, 2009)

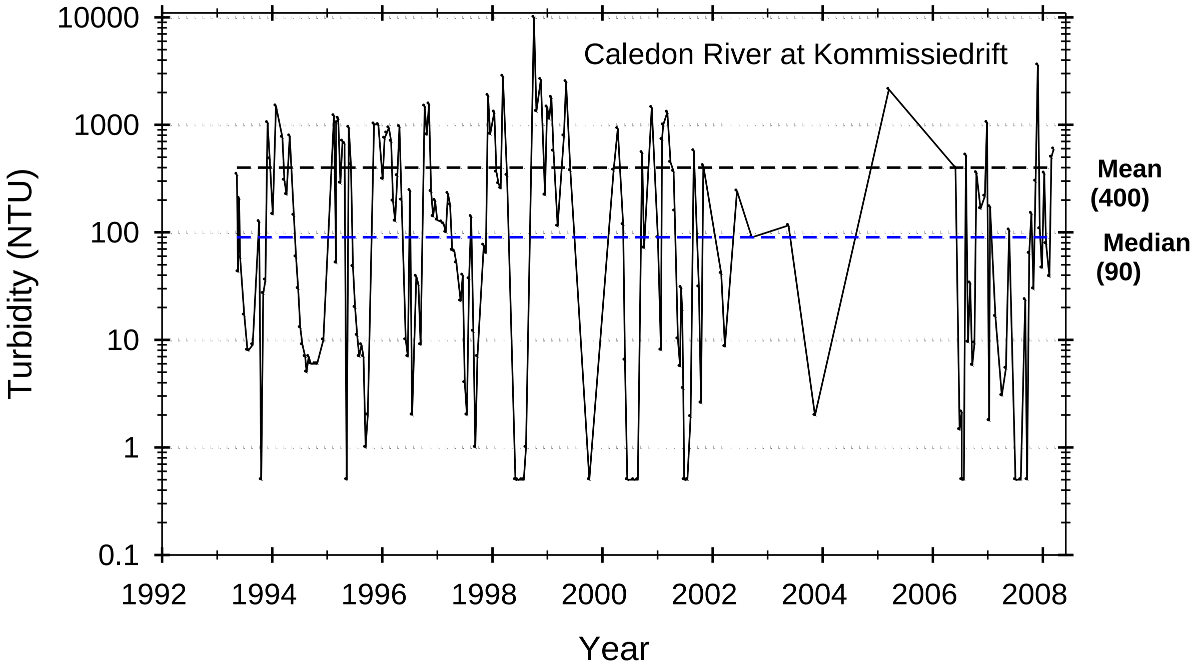

Figure 5-6: Temporal variation of turbidity (NTU) in the Caledon River at Kommissiedrift (1993 – 2007) (DWA, 2009)

5.4.3.2 pH

The pH values in the whole Orange River were high (alkaline, median, 8.3); generally increase downstream and occasionally exceeds the upper limit for irrigation of 8.4. The pH is an important variable in water quality assessment, as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. The pH values were relatively low in the upper part of the river (mean of 8.1). The higher pH values in the middle and lower part of the Orange River are primarily ascribed to higher algal concentrations.

Water having a pH in excess of 8.4 may cause foliar damage, decrease the visual quality of marketable products (if they are wetted during irrigation), affect the availability of several micro and macro-nutrients, and also increase problems with encrustation of irrigation pipes and clogging of drip irrigation systems (DWAF, 1996).

5.4.3.3 Nitrate and Orthophosphate ($PO4^{-}$)

The nitrate and orthophosphate concentrations in the Orange River show the largest non-compliance in terms of the water quality variables assessed. The analysis of the available data showed that the orthophosphate concentrations at the sites on the Orange River, except at Oranjedraai, similar (50 ± 30 µg/ℓ). However the tributaries of the Orange River, *viz*. Stormbergspruit, Kornetspruit, and Seekoei River indicate much higher levels of orthophosphate (> 100 µg/ℓ).

The present state nitrate concentrations are at an average concentration of 0.82mg/l in the Orange River and its tributaries. The concentrations are approximately 3 times higher than the RWQOs in the Lower Orange from Neusberg to Alexander Bay. The tributaries with the exception of the Kraai River also show non-compliance to the RWQOs.

The nutrient concentrations are indicating the potential for eutrophic conditions throughout the catchment and a possibility of hypertrophic conditions. There are a number of factors however that determines the extent of algal growth. These include the availability of adequate sunlight and suitable temperatures. The turbid waters experienced in the catchment is limiting sunlight penetration and limiting algal growth. The assessment results shown can only be considered indicative. However the indications are supported by observations of algal blooms in the lower reaches of the Orange River downstream of the confluence of the Orange and Vaal River confluences. The eutrophication effects in the Orange River need to be investigated further.

5.4.3.4 Salinity

Salinity is an indication of the concentration of dissolved salts in a body of water. The level of salinity in aquatic systems is important to aquatic plants and animals as species can survive only within certain salinity ranges. Salinisation is the process by which the concentration of total dissolved solids in inland waters is increased.

The total dissolved salt (TDS) concentrations in the Orange River show a clear downstream increase (**Figure 5-7**). The TDS concentrations in the upper section of the Orange River (*i.e.* from Oranjedraai to Dooren Kuilen, just downstream of Vanderkloof Dam), are relatively low (mean 182 mg/ℓ). From Marksdrift and downstream the dissolved salts increases continuously and reached concentrations (95^{th} percentile) of approximately 500 mg/ℓ from Vioolsdrift to Alexander Bay. These increasing concentrations of salinity may have negative consequences for the river's ecosystem as well as for crop production further downstream. Some of the water withdrawn for irrigation is returned to the river environment for re-use, but its quality is degraded with considerably higher salts and nutrient concentrations. The increased TDS concentration of the return flow contributes significantly to the salt load in the Orange River. There are also significant water losses in the lower reaches of the Orange River due to evaporation. The evaporation of water from the water body results in the increase in the downstream TDS concentrations.

The ionic composition in the Orange River changes downstream, with proportionally higher sulphate (SO_4), sodium (Na) and chloride (Cl) concentrations probably originating from the irrigation return flows. In the Orange River, the sulphate concentration has increased from 12.9 mg/ℓ at Oranjedraai (upper reaches) to 85.5 mg/ℓ at Alexander Bay (lower end), while sodium and chloride increase from approximately 7 mg/l to 64 mg/l. The increase in sulphate concentration is likely to be attributed to the impact of the Vaal River.

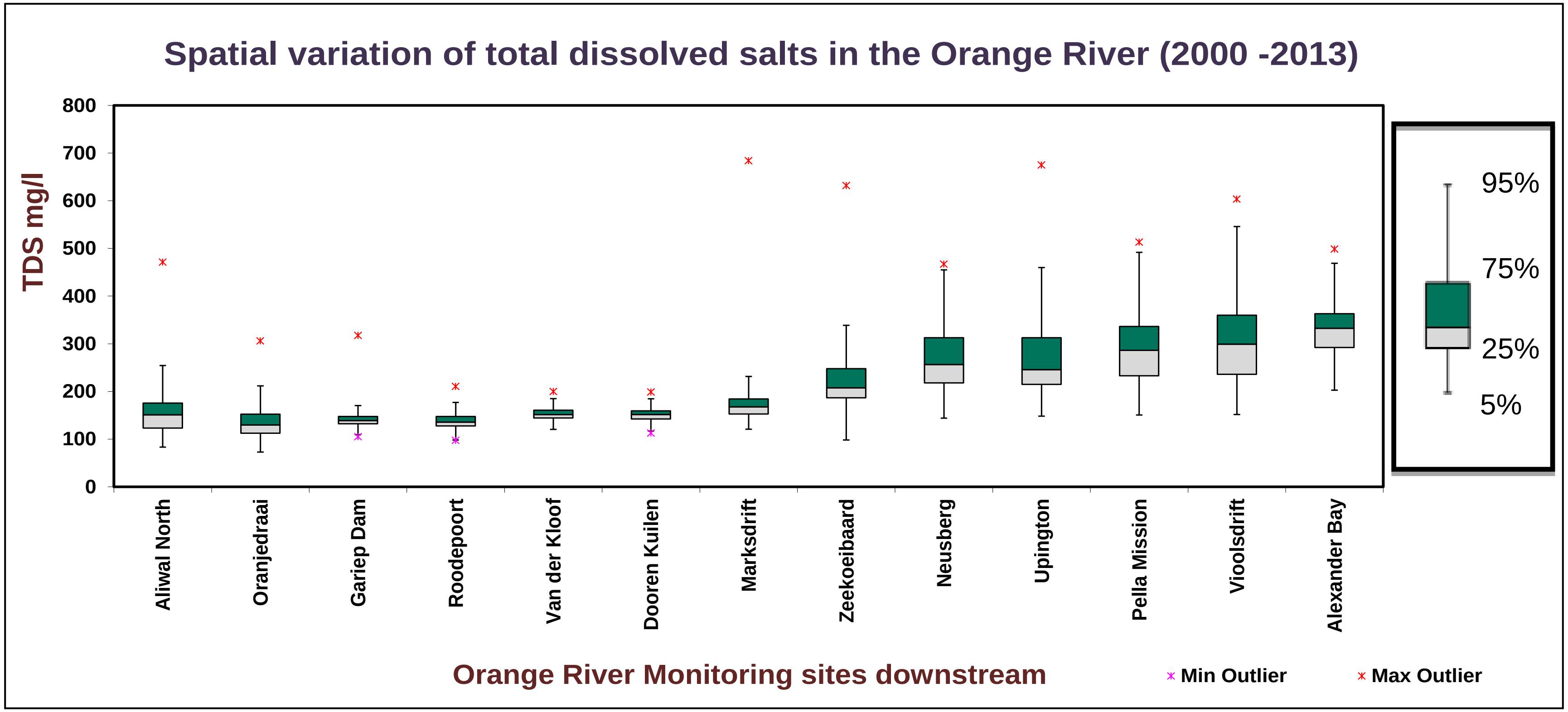

Figure 5-7: Spatial variation of Total dissolved salts (mg/ℓ) in the Orange River during 2000 - 2013

6 POTENTIAL SOURCES OF POLLUTION AND PROPOSED WATER QUALITY MANAGEMENT ACTIONS

As outlined in **Section 3**, the data analysis for the period 2000 -2013 confirms that the water quality threats to the Orange River include nutrient enrichment (increasing nitrate and phosphate levels); increased salinity specifically in the Lower Orange (potentially through the impact of the Vaal River and increased irrigation return flows) and elevated sediment concentrations. The altered flow regime is considered a contributing factor to the water quality situation.

The localised threats posed by microbiological contamination needs to be confirmed through improved monitoring and adequate data is required to understand the extent of the problem. Previous work also highlighted that heavy metals and persistent organic pollutants, pose a risk in certain localised areas however no specific trend could be identified. Again, improved monitoring data is required to understand the potential risk to the system.

.Again, improved monitoring data is required to understand the potential risk to the system.

6.1 SOURCES OF POLLUTION

Deterioration of the quality of the water resources in the Orange River catchment is mainly attributable to one or more of the following land-use impacts, occurring with the catchment:

- Irrigation return flow as the major impactor (originating from large irrigated areas within the system which carry fertilisers and high salt loads through leaching) (Upper and Lower Orange River). This is expected due to the large water use requirement by the agricultural sector;
- Mining pollution from point sources e.g. direct discharge from mine dewatering and effluent disposal; acid mine drainage and non-point or diffuse pollution from runoff and seepage from mining waste dumps. This has been identified in the Vaal River specifically. The increasing salinisation being observed is evidence of this.
- Discharges from waste water treatment works in the numerous small towns and urbanised areas within the catchment, many of which are not in compliance with the waste water discharge standards and licence conditions. This is prevalent both in the Upper and Lower Orange catchments, with the general elevated concentrations observed for nutrients.
- Runoff and seepage from developed and informal urban areas; contributing to the nutrient enrichment and possibly microbial contamination.
- Overgrazing and poor land management practices, especially on steep slopes and in marginal agricultural areas (Upper Orange and Caledon Rivers) increasing the sediment load reporting to the rivers.

6.2 PROPOSED MANAGEMENT ACTIONS

The assessment of the water quality of the water resources of the Orange River catchment indicate that water quality is declining and that management action and intervention is required. Elements of management will require inclusion of controlling of pollution and impacts, use of water and land use, as well as basin scale, catchment-wide interventions that relate to planning and resource directed water quality management. The state of water quality described and the water quality analysis undertaken as part of this assessment confirms that key actions and interventions are required to manage the water quality of the Orange River Basin, to limit further deterioration, ensure the maintenance of fitness for use, as well as the sustainability of the system to support ecosystem health.

Based on the analysis the following key actions are recommended for future work (includes actions adapted from ORASECOM, 2014):

- Development of an integrated water quality management strategy for the Orange River catchment area. The strategy should focus on:
    - A detailed assessment to quantify the extent of the actual and emerging problems of water pollution/water quality deterioration. This would need to confirm threats of microbiological pollution and heavy metal toxicity, in addition to quantifying the salinisation and increasing nutrient enrichment. Further to that the sedimentation needs to be understood specifically in the Upper Orange River.
    - Formulating plans and setting priorities for managing the water quality of the Orange River catchment;
    - Development of sub-strategies and implementation plans to address the water quality priorities.
    - Development of a programme of management action and associated timing to support implementation.
    - The strategy would need to link to basin wide water resource planning, resource protection and management.
- Adoption and implementation of the RWQOs and development of sectoral short- and medium-term targets to meet the objectives.
    - Confirmation of the proposed RWQOs is required, as well as inclusion of additional variables if identified. The RWQO targets should be confirmed to support the management strategy.
    - The final RWQOs must be adopted and implemented in the short term to manage the water resource and impacts to the system.
- Increasing salinity resulting from the effects of irrigated agriculture specifically in the Lower Orange and the impact of the Vaal River should be investigated further. Huge volumes of irrigation return flows enter the Orange River, particularly the Lower Orange. In assessing the water quality data in the Lower Orange River, an increasing trend in TDS concentrations was observed. In calibrating the WQT water quality model, there was limited water quality data against which to calibrate the models irrigation modules. These return flows have a major impact on the water quality of the river. The extent of the impact is not well understood and a monitoring program should be set up on selected irrigation schemes to understand the return flow volumes and water qualities.

- Improve the water quality monitoring network throughout the catchment to support the requirements of the water quality management strategy and RWQOs. The following aspects should be addressed:
    - Upgrading and expansion of the DWA chemical monitoring programme is required. There are gaps and low frequency of monitoring has occurred for some critical parameters. The water quality variables to be monitored and monitoring frequency needs to be confirmed and variables added if necessary. The inclusion of additional water quality monitoring sites specifically in the Lower Orange is required.
    - Currently very little information is available on pesticides and herbicides in the river system. Monitoring of these sources of pollution is required to determine the extent of their impact
    - An assessment of persistent organic pollutants and heavy metals in the Vaal and Lower Orange catchments is required.
    - Suspended solids and turbidity monitoring should be done at all the proposed monitoring sites on the Orange and Caledon River,
    - Chl-*a* measurements are currently undertaken at 7 sites on the Orange River however in order to support the usefulness of the data and its analysis, the frequency of measurement should be increased to at least biweekly.
    - The national microbiological monitoring programme must be expanded.

- A nutrient balance or nutrient modelling is necessary to determine the fate of nutrients in the Orange River system. A more detailed study on the effect of eutrophication on the Orange River should be undertaken, especially to understand the development of algal blooms in the Lower Orange. Improvement of compliance monitoring and enforcement is required. The sources of nutrients in the catchment have not been quantified. The management tools in terms nutrient models and eutrophication models are not available to assess nutrient management options. The framework for a basin wide nutrient model suitable to run with the Water Resource Planning Model was developed as part of the Phase 2 of the ORASECOM Study. The model needs to programmed and tested to see if it can be calibrated (ORASECOM, 2014).

  The following is proposed:
    - The development of the nutrient balance using the available instream flow and the development of the nutrient balance using the available instream flow and water quality data is required. The balance must include all the point sources and estimates of the washoff loads from urban and agricultural areas. The monitoring of the return flows of the irrigation schemes as part of the salinisation study will support the nutrient balance study.
    - The nutrient model framework developed in the ORASECOM Study needs to be reviewed and changed where necessary based on the nutrient balance. The phosphorus model should be programmed and calibrated against the available water quality data.

   - The calibrated nutrient model should be run with the WRPM to develop a nutrient management strategy. The strategy should indicate the discharge standards required for the wastewater treatment works and industrial discharges. The management of the phosphorus load from agricultural runoff and return flows should also be addressed. The results of the modelling will assist in setting the RWQO for nutrients.

- A Water Resource Classification study and development of RQOs should be undertaken to support basin wide planning and water quality management interventions.

- An understanding of groundwater quality is required. A consolidated groundwater water quality monitoring programme must be implemented.

7 THE PROPOSED RECONCILIATION INTERVENTIONS AND WATER QUALITY

The Reconciliation Strategy for Large Bulk Water Supply Systems in the Orange River proposes certain interventions for reconciling water requirements with water use. An understanding of the water quality is required to determine the possible implications of the proposed interventions identified on water quality as well as to determine how the state of water quality impacts on the reconciliation interventions if any.

In terms of the Reconciliation Strategy (DWA, 2014 *in publication*), the recommended scenario comprising a combination of options has been selected. The scenario comprises the following (DWA, 2014 *in publication*):

- Groundwater Development;
- Real time monitoring at Orange/Vaal confluence to optimise the releases from Vanderkloof Dam;
- Water Conservation and Demand Management;
- Minimum Operating Level – Vanderkloof Dam;
- Construction of Vioolsdrift Dam;
- Gariep Raising or construction of Verbeeldingskraal Dam

In terms of the suite of options listed above, the relevant aspects as they pertain to water quality are discussed below. The assessment is qualitative only and should be supported and confirmed using the appropriate water quality modelling.

- *Groundwater Development:* It is proposed that future water deficirts in small towns will be satisfied with groundwater. In terms of quality, it may not always be preferable to rely on the groundwater due to high salinity levels that exist naturally in parts of the Orange River catchment. Groundwater quality must be assessed to determine if the water can be exploited and support the water requirements of the users who rely on them. This option could have limitations should the quality be unsuitable. This would then require that these users be supplied from surface water resources or the appropriate treatment be provided.

- *Real time monitoring at Orange/Vaal confluence to optimise the releases from Vanderkloof Dam:* The optimisation of the releases from Vanderkloof Dam to save an estimated 80 million m^3/a as an intervention, may influence to some extent the diluting function that the Orange River water serves with respect to water quality. The increasing salinity originating from the Vaal River is masked by the good water quality of the Orange River. Reducing flow even further could potentially result in poorer water quality.

- *Water Conservation and Demand Management*: This savings achieved through this intervention in the domestic and irrigation sectors could be significant. The savings will be achieved to lining irrigation canals to limit seepage, fixing leaking pipe systems, pressure management and changing irrigation methods. In terms of the water quality implication, reduced water volumes in the return flows could increase the salt and nutrient concentrations in the return flows. This is particularly relevant to irrigation areas, where the fertiliser application rates are unlikely to be changed which will result in a build up of salts and nutrients in the soil profile which will result in increased concentrations in the soils. However coupled with the increase in soil concentrations will be a reduction in return flow volumes. The salt and nutrient load is therefore unlikely to change significantly. The impact on the TDS concentrations in the receiving water environment can be tested using the irrigation module in the WRPM.

- *Minimum Operating Level – Vanderkloof Dam*: The lowering of the minimum operating level of the Vanderkloof Dam will not have a significant effect of the water quality of the system or the supply to the users.
- *Construction of Vioolsdrift Dam:* Vioolsdrift Dam is being constructed at the lower end of the Orange River below the Vaal River confluence with the Orange and the majority of the water users. The dam will receive the return flows from the irrigation areas as well as the inflow from the Vaal River. The water quality issues experienced at Vioolsdrift currently are related to nutrients. The orthophosphate and the nitrate concentrations exceed the RWQO. The dam storage will generally attenuate the concentrations and reduce the variation in concentration of the water leaving the dam. Although stratification in the dam will influence the concentration and temperature of the water discharged depending on the dam level from which the water is released. The dam will act as a sink for the nutrients and sediments. Based on the current measured median nutrient concentrations, the dam is likely to be mesotrophic. Nitrate is currently the limiting nutrient for algal growth. Operating rules should be developed for releases from the dam depending on the water level in the dam and the time of the year.
- *Gariep Raising or construction of Verbeeldingskraal Dam*: The increase in Gariep Dam capacity due to the raising of the dam will provide greater retention time which will increase the potential to settle sediment in the dam basin. The dam capacity is currently significant and provides sufficient retention time to settle out the majority of the sediment leaving only the colloidal sized particles which will not easily settle. The increase in the dam capacity therefore will not significantly change the sediment concentrations downstream of the dam. With the dam turbidity not expected to change significantly, the trophic status of the dam is not likely change from the current status of mesotrophic.

  The construction of the Verbeeldingskraal Dam in the upper reaches of the Orange River upstream of Gariep Dam will capture sediment. The removal of sediment will result in increased scour of the Orange River downstream of the dam. Given the expected high turbidity of the water stored in the dam and the relatively low nutrient concentrations, the trophic status of the dam will be mesotrophic. Besides the impact on the sedimentation and erosion processes in the reaches of the upper Orange River and the temperature and water quality changes associated with discharges of water from the bottom layers of a dam, the construction of the Verbeeldingskraal Dam is not expected to significantly impact on the water quality of the Orange River.

- The implementation of the new Polihali Dam will influence (reduce) the flow of water into the Gariep and Vanderkloof dams, which in turn will have a negative effect on water quality and availability in the lower reaches of the Orange-Senqu River.

8 POTENTIAL FOR EFFLUENT RE-USE

8.1 INTRODUCTION

This part of the study was carried out to investigate the potential for re-use of sewage effluents in the catchment. The study included a desktop investigation of the Wastewater Treatment Works (WWTW) in the study area and discussions with relevant municipalities. The current and future effluent volumes were determined and the options for re-use of the treated effluent are discussed. The typical treatment processes required to achieve water of a suitable quality for the different uses are also described.

8.2 WASTE WATER TREATMENT WORKS IN STUDY AREA

Refer **to Figure 14.1** for an indication of the WWTW in the area. The location, capacity and Green Drop score for the WWTWs is presented in **Table 8-1**.

Table 8-1: WWTW in the Upper and Lower Orange River catchments

Wastewater Treatment works (WWTW)	Local Municipality	Capacity (Mℓ/d)	Green drop	Discussion
Dordrecht WWTW	Emalahleni	-	-	
Barkly East WWTW	Senqu	-	-	
Burgersdorp WWTW	Gariep	-	-	
Bethulie WWTW	Kopanong	0.5	0.6	Insufficient information
Jagersfontein WWTW	Kopanong	2.2	0.6	Insufficient information
Philippolis WWTW	Kopanong	0.47	0.6	Insufficient information
Aliwal North WWTW	Mohokare	1.5	64.5	
Smithfield WWTW	Mohokare	0.5	60.3	
Zastron WWTW	Mohokare	1	49	
Brandfort WWTW	Masilonyana	-	-	No information submitted
Ficksburg WWTW (Caledon River)	Setsoto	12.2	25.3	Improved monitoring required. Low flow through plant.
Bloemfontein (Botshabelo) WWTW	Mangaung	10.5	39.4	Poor record keeping.
Bloemfontein (Thabanchu)	Mangaung	4.5	20.4	Poor record keeping.
Bloemfontein (Bainsvlei)	Mangaung	4	43.5	Poor record keeping.
Bloemfontein (Northern works)	Mangaung	3	38.8	Poor record keeping.
Bloemfontein WWTW (Bloemspruit)	Mangaung	73	39.8	Improved to 49 % on site inspection. Inflow exceeds hydraulic capacity
Bloemfontein WWTW (Bloem Industria)	Mangaung	0.5	13.4	Poor record keeping.
Bloemfontein WWTW (Welwaart)	Mangaung	4	47.0	Poor record keeping.
Bloemfontein (Sterkwater – North East))	Mangaung	18.6	39.3	Improved to 66 % on site inspection. Inflow exceeds hydraulic capacity
North West Works - New	Mangaung	To be commissioned		
Alexanderbaai WWTW	Richtersveld	-		
Port Nolloth WWTW	Richtersveld	0.27	27.6	Dropped to 6 % on inspection. Poor operation and maintenance.
Kleinsee WWTW	Nama Khoi	-	-	
Garies WWTW	Kamiesberg	0.167	6.7	improved to 45 % on site inspection. Insufficient information supplied.
Fraserburg WWTW	Karoo Hoogland	-	13.7	Inadequate information supplied

Wastewater Treatment works (WWTW)	Local Municipality	Capacity (Mℓ/d)	Green drop	Discussion
Williston WWTW	Karoo Hoogland	-	11.7	improved to 64 % with site inspection
Sutherland	Karoo Hoogland	-	10.2	Inadequate information supplied
Loxton WWTW	Ubuntu	-	23.5	
Victoria West WWTW	Ubuntu	-	23.5	Inadequate monitoring, poor operation and maintenence
Noupoort WWTW	Umsobomvu	-	4	Inadequate data available
Britstown WWTW	Emthanjeni	0.5	19.4	Inadequate monitoring
De Aar WWTW	Emthanjeni	4	20.8	Inadequate monitoring
Hanover WWTW	Emthanjeni	1	22.4	Inadequate monitoring
Uilfontein WWTW (Hanover)	Emthanjeni	-		
Carnarvon WWTW	Kareeberg	0.52	44.5	Improved to 94 % on site inspection. Insufficient information supplied.
Niekerkshoop WWTW	Siyathemba	-	17	
Prieska WWTW	Siyathemba	22	21.9	
Douglas WWTW	Siyancuma	-	3.7	Information not supplied, poor operation and maintenance observed on site
Griquatown WWTW	Siyancuma	-	3.7	Information not supplied, poor operation and maintenance observed on site
Kakamas WWTW	Kai !Garib	0.5	10.5	Inadequate monitoring, poor operation and maintenance
Keimoes WWTW	Kai !Garib	0.5	7.5	Inadequate monitoring, poor operation and maintenance
Kenhardt WWTW	Kai !Garib	0.3	7.5	Inadequate monitoring, poor operation and maintenance
Upington WWTW	Kara Hails	1.6	47.8	Poor quality discharge, inflow exceeds design capacity, poor record keeping

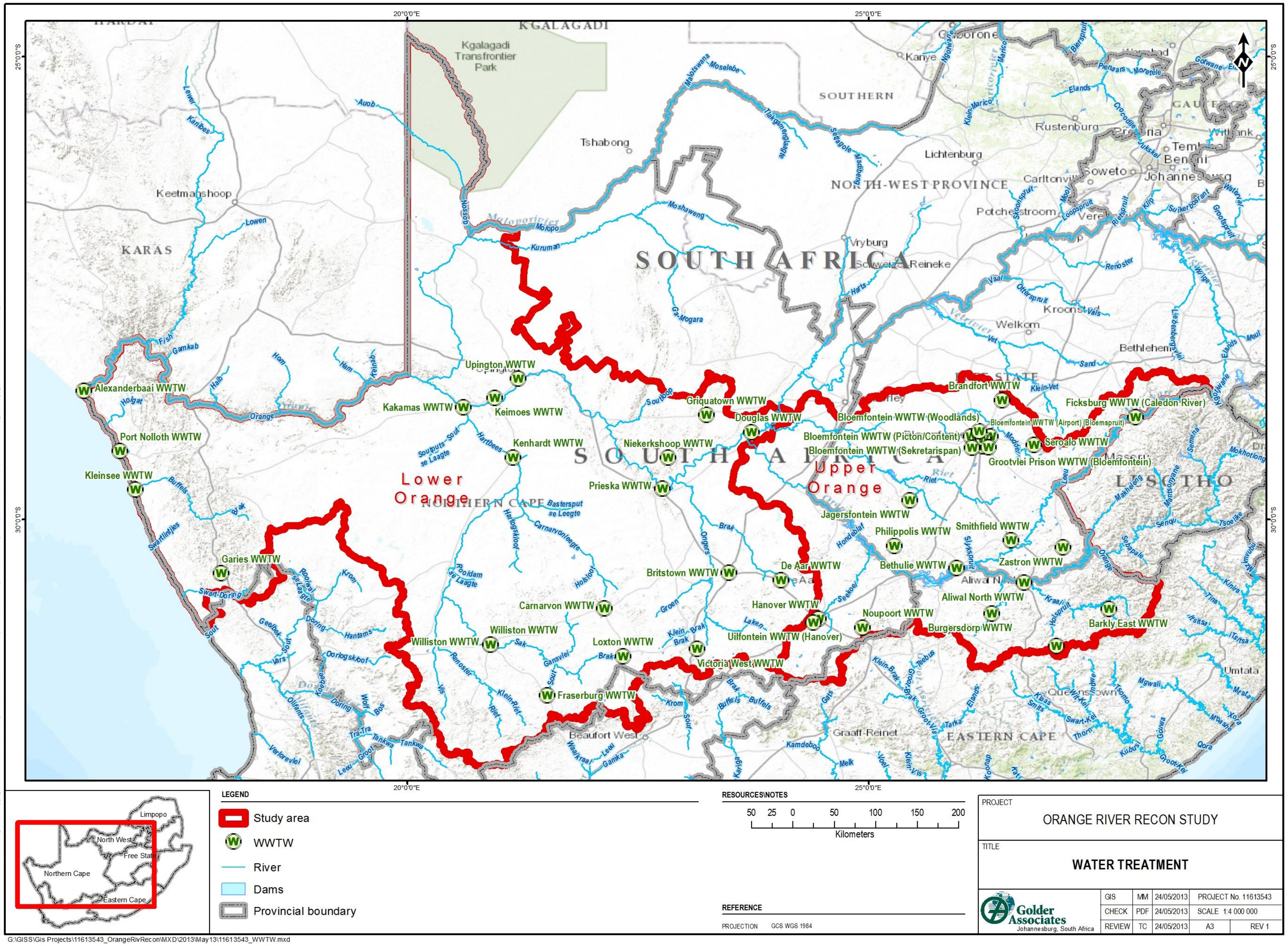

Figure 8-1: Map indicating WWTWs in the study area

Based on the information obtained from the Green drop reports, the Mangaung Municipality, which covers the great Bloemfontein area is well suited for investigating re-use options. Discussions were carried out with the Municipality to confirm the volumes of water being treated and current discharge points. The information obtained is presented in **Table 8-2**.

Table 8-2: Current WWTW in Manguang Municipality

Treatment plant	Design capacity (Mℓ/d)	Actual flow (Mℓ/d)	Current discharge
Botshabelo	20	15	Discharged into Moderspruit catchment upstream of the Rustfontein Dam – abstraction point for Bloemfontein drinking water supply.
Thabanchu	6.5	4.5 / 5	
Bainsvlei	5	4	Open evaporation dam
Northern works	6	2.5	Discharge to environment
Bloemspruit	56	65	Bloemspruit stream which reports to the Modderspruit downstream of the Krugersdrift Dam
BloemIndustria	1	0.2	
Welwaart	6	4.5	Upstream of Tierpoort Dam
Sterkwater (North East Works)	22	18	Rhinospruit which reports to Bloemspruit stream with water from Bloemspruit works
North West Works	15 (under construction)	0	Expected completion date – 2015 Bloemspruit

The municipality is currently working on increasing their treatment capacity by constructing a new WWTW, the North West Works. Upon completion, the Bloemspruit works will receive a much needed refurbishment and upgrade.

The Bloemspruit works and Sterkwater North East and North West works could potentially be considered for further treatment and re-use.

8.3 RE-USE OPTIONS

Three re-use options were considered. These include:

- Re-use for irrigation
- Indirect re-use
- Direct re-use

8.3.1 Re-use for irrigation

The treatment process selected in this case must ensure that the following specifications are met:

- Farmworkers and public users must be protected against infection by waterborne diseases.
- The water quality of the treated water adheres to the DWA water quality guidelines for irrigation.

The recommended treatment process consists of two steps. The first step is a dual media filtration of treated sewage effluent to remove residual suspended solids. This will allow for effective disinfection. The second step will involve disinfection, either through UV or the addition of chlorine.

The disinfected water will then be pumped to storage facilities for distribution to the various irrigation schemes.

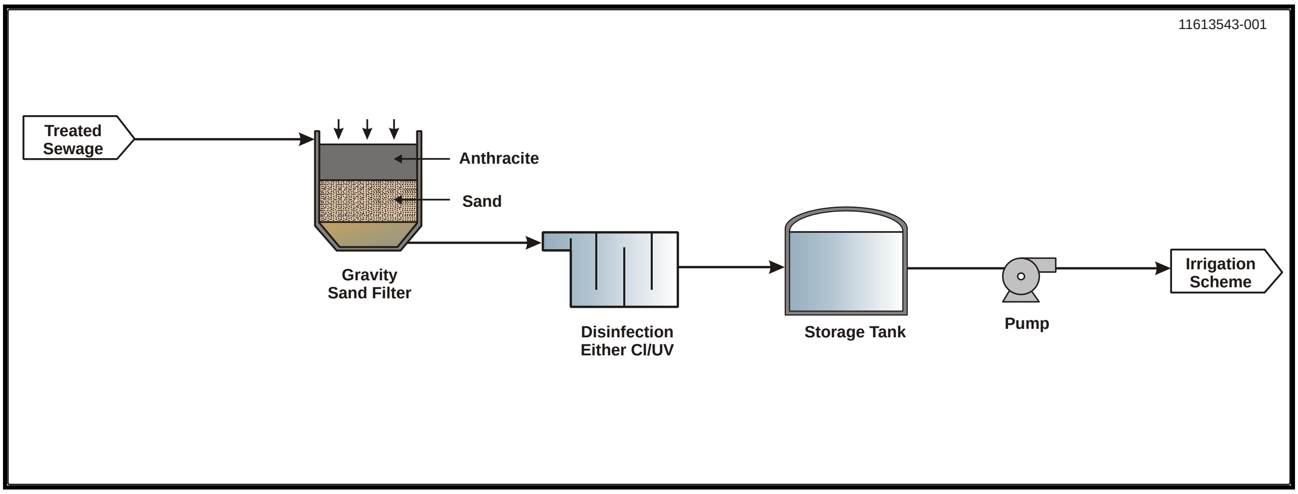

Figure 8-2: Proposed additional treatment of treated sewage effluent for Irrigation

8.3.2 Indirect re-use: Treatment for discharge into the Rustfontein Dam

The Rustfontein Dam is the main abstraction point for the potable water treatment plant for Bloemfontein. The flow to the dam can be supplemented by pumping treated effluent from the WWTW, making more water available for downstream users.

The treatment process in this case must meet the following criteria.

- Eutrophication (excessive growth of algae and water plants) in the dam must be avoided.
- The dam and downstream water users must be protected against infection by waterborne diseases.

Eutrophication can be prevented by the removal of phosphorous to levels below 0.1 mg/l. This can be achieved by adding Alum or Ferric to facilitate the precipitation of phosphorous. A clarifier will be required for the separation of the phosphorous rich sludge from the supernatant. The clarifier supernatant will pass through either a granular media filter or microfiltration membrane to remove residual suspended solids. The filtrate will then be disinfected either with the addition of chlorine or exposure to UV. Should chlorination be used, a de-chlorination step is recommended prior to discharge into the dam.

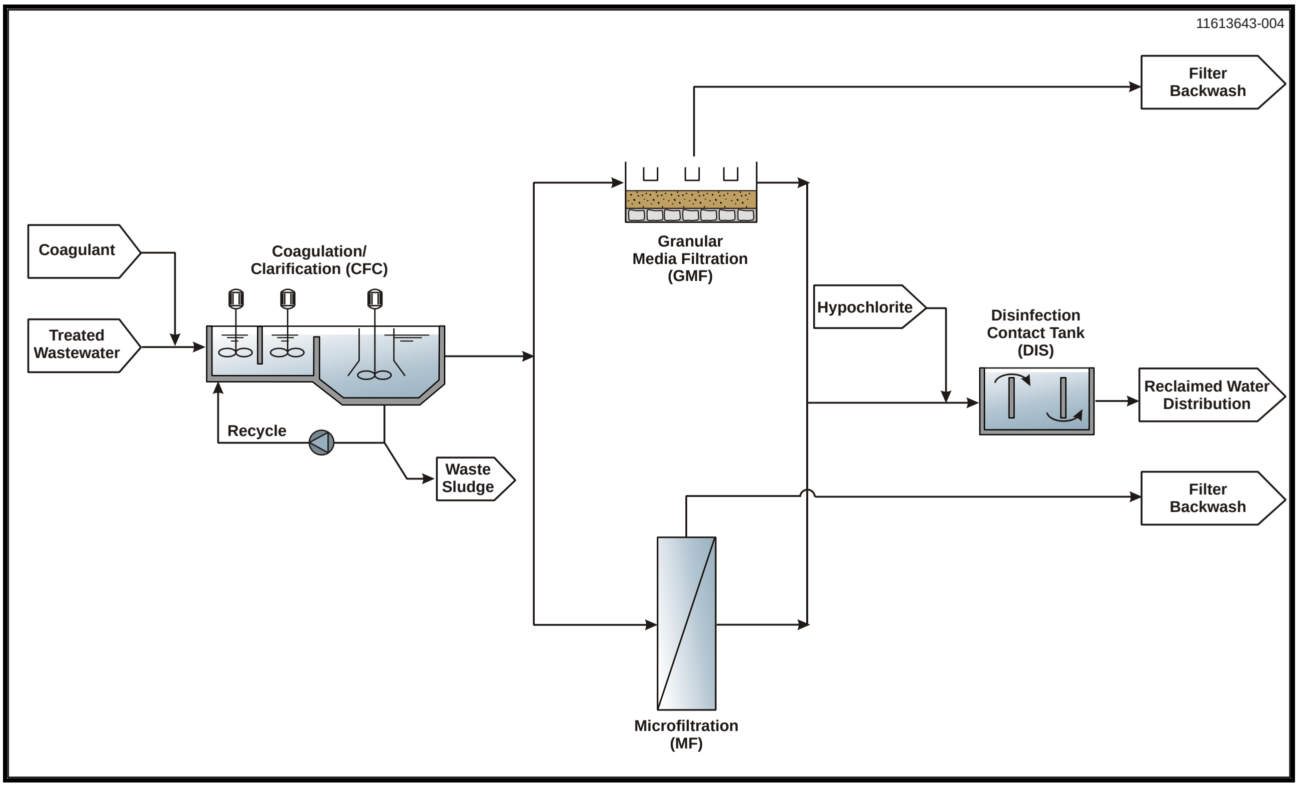

Figure 8-3: Proposed treatment process for indirect reuse

8.3.3 Direct re-use: Treating water to potable standard

The treatment process in this case must meet the following criteria:

- Risks of contacting waterborne illnesses from the water must be illuminated.
- The South African drinking water standards (SANS 241:2006, Ed 6) must be met.

The direct re-use of treated sewage effluent requires extensive treatment systems with multiple barriers of treatment to all categories of water quality variables. The re-use treatment technology train can be one of two generic options; Membrane Based Treatment or Ozone/Granular Activated Carbon (GAC) Treatment. Membrane processes are often selected for high salinity waters and these processes produce a waste brine stream which requires further management. One would not expect high salinity water in the Bloemfontein area. For these reasons, the Ozone/GAC process was proposed.

The treatment train would include a coagulant dosing and clarification step to remove any suspended solids carried over from the sewage treatment process. This will be followed by an ozone disinfection step. The ozonation process would have an added benefit of removing colour, odour and taste from the water if these problems do occur. This will be followed by a rigorous filtration process, using biologically activated carbon columns followed by granular activated carbon columns. Ultrafiltration membranes were added to remove any particulates carried over from the BAC and GAC. Disinfection would take place using UV or hydrogen peroxide. Hypochlorite would be dosed as a final step in order to ensure a residual chlorine concentration for the treated water which will be distributed.

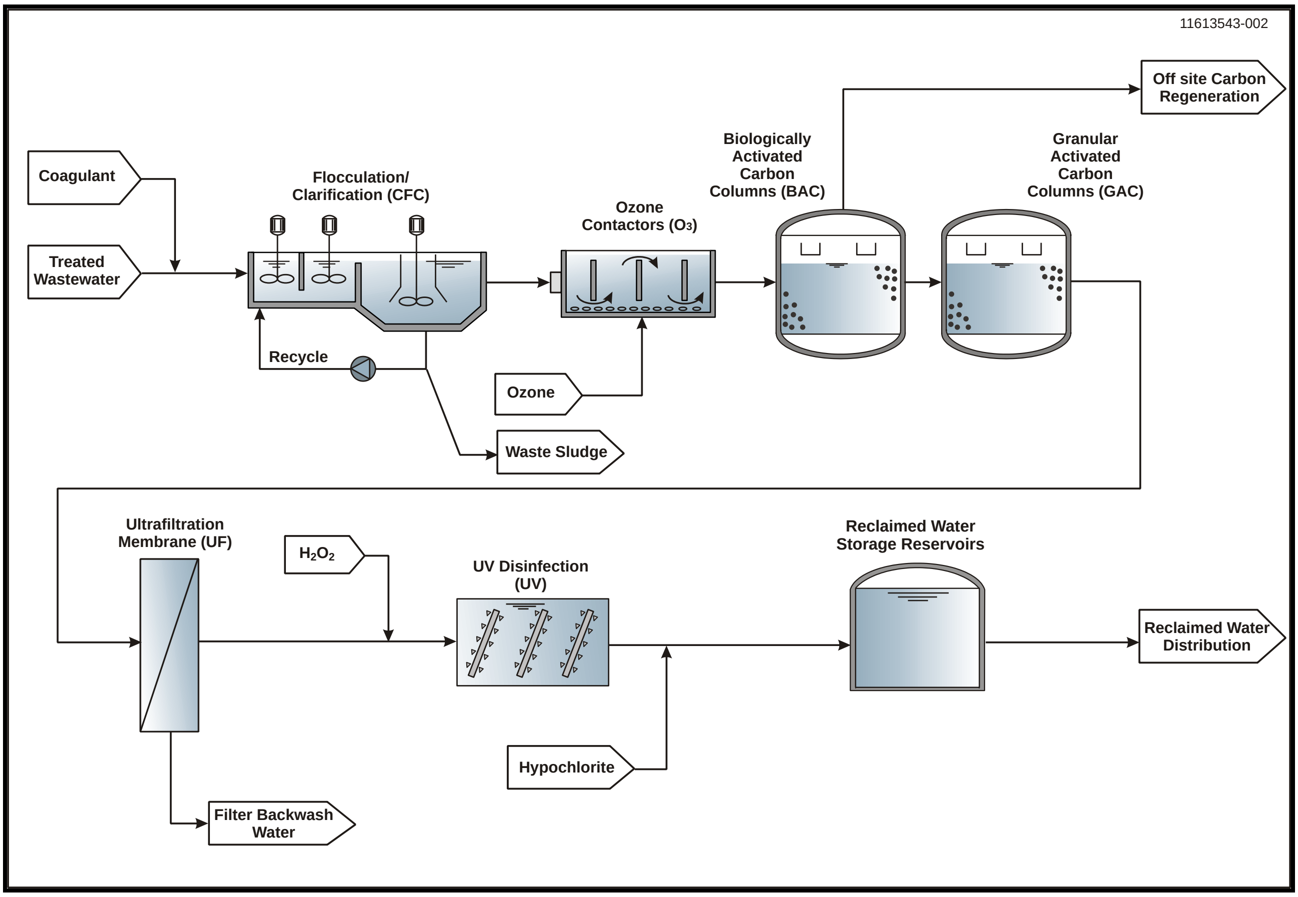

Figure 8-4: Proposed treatment process for direct reuse

8.4 COST IMPLICATIONS

A high level cost exercise was carried out to estimate the costs associated with the various options considered.

The following assumptions were made when determining the cost estimates:

- The treated water from the WWTW will meet their effluent discharge standards
- The cost exclude distribution costs
- Costs are presented in 2013 Rand value
- Repairs and maintenance to existing infrastructure has been excluded
- And additional purchase of land required has been excluded

The estimated CAPEX for additional treatment requirements on the existing WWTW in order to meet the reuse criteria proposed are presented in **Table 8-3**.

Table 8-3: CAPEX estimates for additional treatment requirements to WWTW effluents for reuse.

WWTW	Capacity (ML/d)	Irrigation	Indirect re-use	Direct re-use
Bloemspruit	65	R 78 000 000	R 109 000 000	R 318 000 000
Sterkwater (North East)	22	R 37 000 000	R 51 000 000	R 149 000 000
Sterkwater (North East)	15	R 32 000 000	R 44 000 000	R 130 000 000

8.5 CONCLUSIONS

The following conclusions can be made as a result of the high level assessment of the potential re-use of WWTW effluent:-

- There are a number of WWTW in the study area. The majority of the WWTW associated with the small towns are small with the discharges to the river system used by downstream water users. Groundwater has been identified as the future source of water for the majority of these smaller towns. The re-use of WWTW effluent is currently not feasible in these towns except for local irrigation of parks and golf courses.

- The larger WWTW in the Mangaung Municipality (Bloemfontein area) represent the most likely opportunity for re-use. The current Mangaung Municipality WWTW effluent discharges to the river system are used by the downstream water users. However there is opportunity in the future as the effluent volumes increase with the increasing water requirements to re-use either directly or indirectly, the growth in effluent volume over time. The re-use of the growth in effluent volume is therefore form part of the long term reconciliation strategy when the excess volumes become sufficiently large to warrant the costs associated with indirect or direct re-use. The estimated that re-use could be feasible after 2027.

9 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

In terms of the water quality analysis and assessment of water quality issues undertaken the following can be summarised in terms of the task conclusions and recommendations:

- The water quality present state analysis indicates increasing salinity in the Orange River (temporal and spatial) and high nutrient concentrations that indicate the potential for eutrophic conditions throughout the catchment and a possibility of hypertrophic conditions. The evidence suggests that the high turbidity in the system is the limiting factor for algal growth.
- The high concentration of turbidity that is evident in the system specifically in the Upper Orange WMA does not appear to be a significant threat to the aquatic ecosystem based on ecological assessments that have been undertaken. However it is apparent that it must be taken into consideration in the design and management of water supply infrastructure.
- The development of an integrated water quality management strategy is required that addresses the nutrient and salinity management of the system, the refinement and adoption of the RWQOs, the quantification of the extent of the actual and emerging problems of water pollution/water quality deterioration and the actions required for land use management.
- It is recommended that:
    - Nutrient modelling of the system be undertaken, and
    - Irrigation return flows be assessed.
- Improved water quality monitoring of the Orange River System (surface and groundwater) is required to support effective water resource management.
- The qualitative high level assessment undertaken of the water quality implications of the reconciliation options indicates that there will be no significant impacts on the current water quality of the Orange River System. However the potential for Vioolsdrift Dam to act as a sink for nutrients and sediment and for Verbeeldingskraal Dam to capture sediments does exist. These impacts must be investigated further should these options be implemented.
- Effluent re-use could contribute to the suite of reconciliation options in the future with the expected growth in the effluent volumes.

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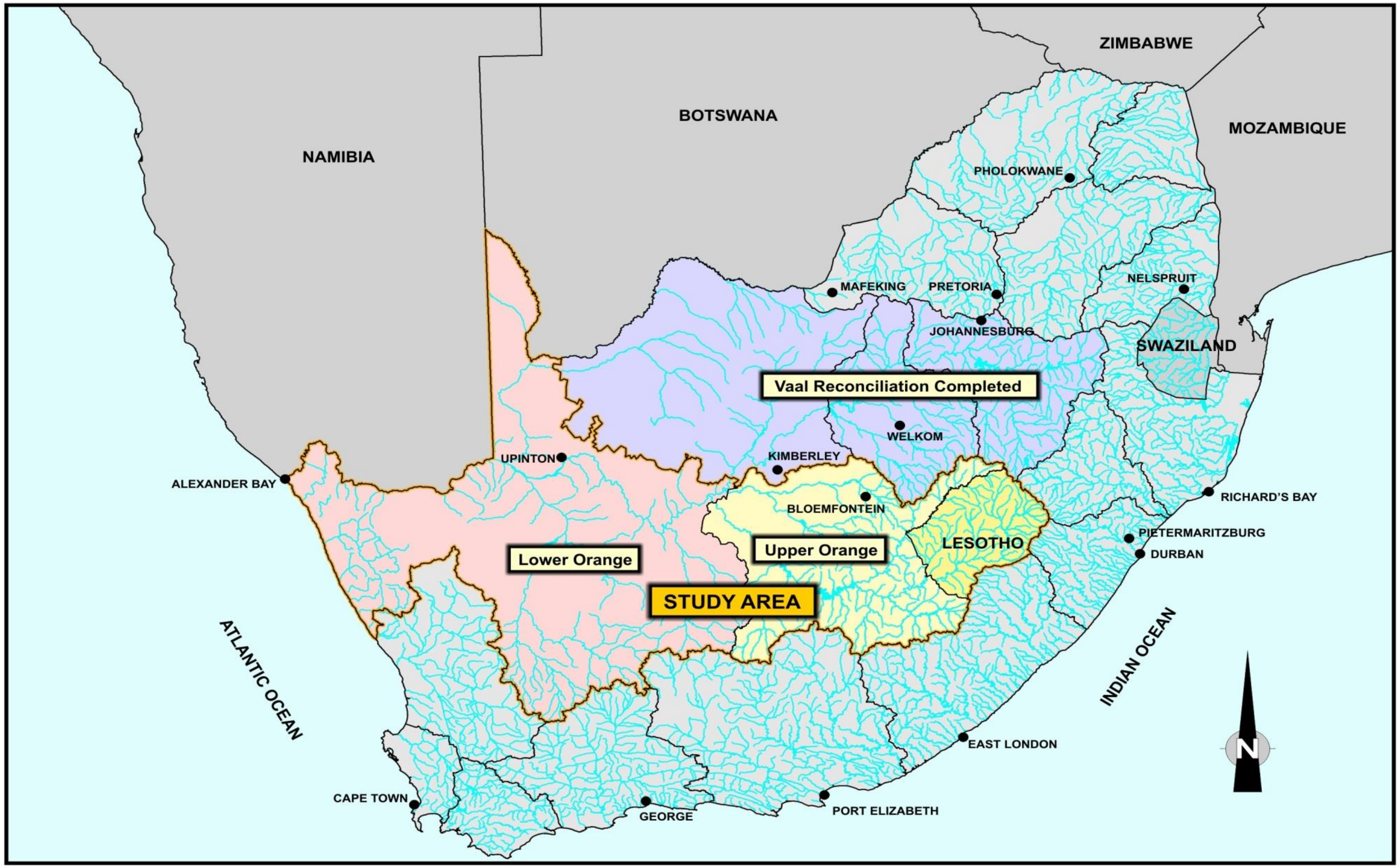
Appendix A

MAPS



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Last updated: 2011/09/02

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: ORANGE RIVER: PROPOSAL	**Study area locality map**