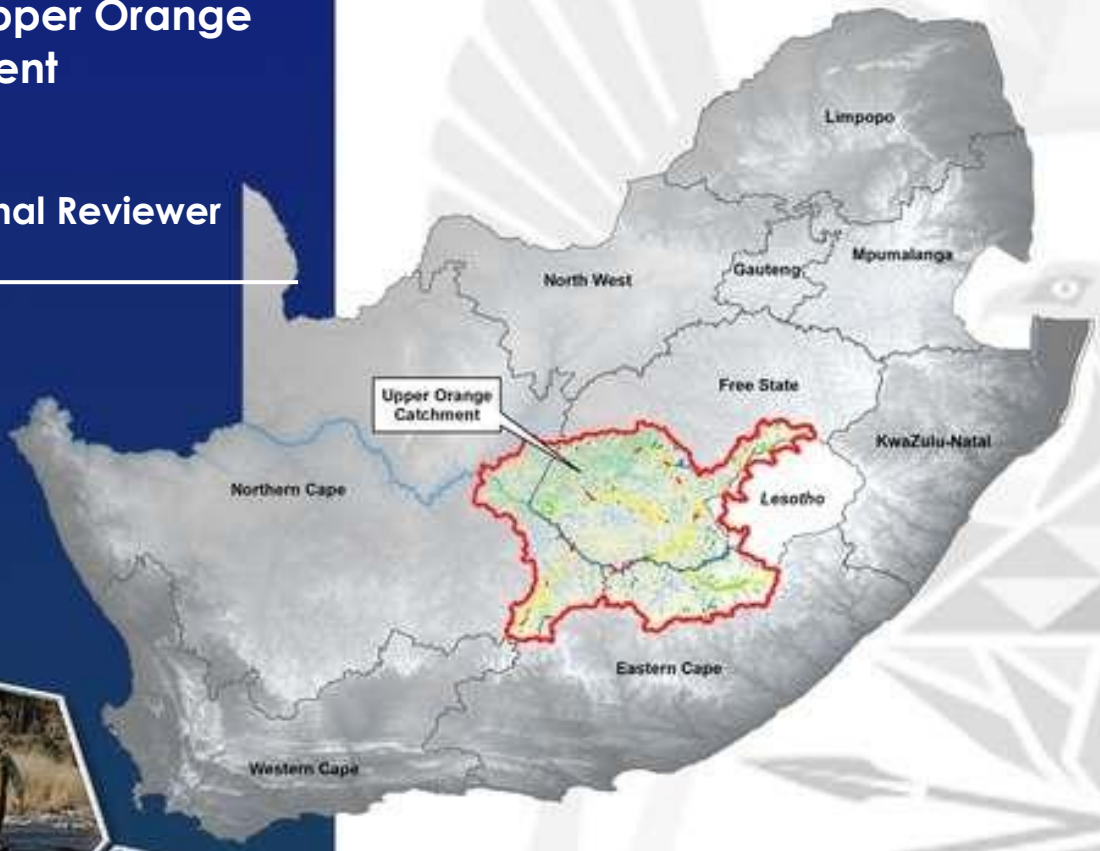
DEPARTMENT OF WATER AND SANITATION

A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange Catchment

WP11343

Close-out and External Reviewer Report



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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report

INDEX	REPORT NUMBER	REPORT TITLE
1.0	RDM/WMA13/00/CON/COMP/0121	Inception Report
2.0	RDM/WMA13/00/CON/COMP/0221	Stakeholder Engagement Plan
3.0	RDM/WMA13/00/CON/COMP/0321	Gaps Analysis Report
4.0	RDM/WMA13/00/CON/COMP/0422	Resource Units Report
5.0	RDM/WMA13/00/CON/COMP/0522	Wetland Field Survey Report
6.0	RDM/WMA13/00/CON/COMP/0622	Groundwater Survey Report
7.0	RDM/WMA13/00/CON/COMP/0722	River Survey Report 1
8.0	RDM/WMA13/00/CON/COMP/0822	Basic Human Needs Assessment Report
9.0	RDM/WMA13/00/CON/COMP/0922	Wetland Report
10.0	RDM/WMA13/00/CON/COMP/1022	Groundwater Report
11.0	RDM/WMA13/00/CON/COMP/1123	Socio-Economics Outline Report
12.0	RDM/WMA13/00/CON/COMP/1223 (a)	Eco-Categorisation Report – Volume 1
12.0	RDM/WMA13/00/CON/COMP/1223 (b)	Eco-Categorisation Report – Volume 2
13.0	RDM/WMA13/00/CON/COMP/1323	Quantification of Ecological Water Requirements Report
14.0	RDM/WMA13/00/CON/COMP/1423	Scenario and Consequences Report
15.0	RDM/WMA13/00/CON/COMP/1523	Ecological Specifications and Monitoring Plan Report
16.0	RDM/WMA13/00/CON/COMP/1623	Capacity Building Report
17.0	RDM/WMA13/00/CON/COMP/1723	Integrated Main Report
18.0	**RDM/WMA13/00/CON/COMP/1823**	**Close-out and External Reviewer Report**

LIST OF ACRONYMS

AEH	Aquatic Ecosystem Health
BHN	Basic Human Needs
BID	Background Information Document
CD: WEM	Chief Directorate: Water Ecosystems Management
CS	citizen science
DWS	Department of Water and Sanitation
EIS	Ecological Importance and Sensitivity
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FMP	Flow Management Plan
FIFHA	Fish Invertebrate Flow Habitat Assessment Model
GRDM	Groundwater Resource Directed Measures
I&APs	Interested and Affected Parties
JBS	Joint Basin Survey
NWA	National Water Act
PAI	Physical-chemical driver Assessment Index
PES	Present Ecological State
PMC	Project Management Committee
PSC	Project Steering Committee
RDM	Resource Directed Measures
RDRM	Revised Desktop Reserve Model
REMP	River Eco-status Monitoring Programme
RU	Resource Units
RQO	Resource Quality Objective
SANBI	South African National Biodiversity Institute
SDG	Sustainable Development Goals
WARMS	Water use Authorization & Registration Management System
WULA	water use license applications
WMA	Water Management Area
WR2012	Water Resources 2012
WRCS	Water Resources Classification System
WWTW	Wastewater Treatment Work

EXECUTIVE SUMMARY

In August 2021, the Department of Water and Sanitations (DWS's) Chief Directorate: Water Ecosystems Management initiated a high-confidence Reserve determination for the Upper Orange catchment area. The study aimed to coordinate this determination, design a Reserve template with ecological specifications and a monitoring program for presentation to the Minister. Following a comprehensive methodology aligned with regulations, the study excluded the gazetting of the Reserve due to the absence of initiated classification studies. Covering the Orange WMA6 in South Africa, the Upper Orange Catchment includes major tributaries. The study, delivered on time and within budget, identified Ecological Water Requirement (EWR) sites, faced challenges in water quality data, yet outlined EcoSpecs to maintain or enhance water quality. The EcoSpecs contribute to ongoing Classification study Resource Quality Objectives (RQOs), and the study proposed further development of a conceptual Flow Management Plan (FMP) and a novel concept focusing on synergy between surface and groundwater resources, suggesting integration into the ongoing Classification study for improved GIS data.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Background

The National Water Act (No. 36 of 1998) (NWA) is founded on the principle that the National Government has overall responsibility for and authority over water resource management for beneficial public use without seriously affecting the functioning and sustainability of water resources. Chapter 3 of the NWA enables the protection of water resources by the implementation of Resource Directed Measures (RDM). As part of the RDM process, an Ecological Reserve must be determined for a significant water resource to ensure a desired level of protection.

The Reserve (water quantity and quality) is defined in terms of (i) Ecological Water Requirements (EWR) based on, the quantity and quality of water needed to protect aquatic ecosystems; water quantity, quality, habitat and biota in the desired state and (ii) Basic Human Needs (BHN), ensuring that the essential needs of individuals dependant on the water resource is provided for. These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources while allowing economic development.

The Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS) is responsible for coordinating all Reserve Determination studies in terms of the Water Resource Classification System (WRCS). These studies include the surface water (rivers, wetlands and estuaries) and groundwater components of water resources.

The Reserve has priority over other water uses in terms of the NWA and should be determined before license applications are processed, particularly in stressed and over utilised catchments. Accordingly, the CD: WEM identified the need to determine the Reserve for the ecosystems (rivers, wetlands and groundwater) of the Upper Orange River catchment in the Orange Water Management Area (WMA 6). The aim is to provide adequate protection for (i) possible hydraulic fracturing activities, (ii) assessment of various water use license applications (WULA), and (iii) evaluation of impacts of current and proposed developments on the availability of water.

1.2 Study Overview

The need to undertake a detailed EWR and BHN study in the Upper Orange catchment was owing to possible hydraulic fracturing, various water use license applications, the conservation status of various resources, and the associated impacts of current and proposed developments on the availability of water. Due to these anticipated impacts that may occur because of hydraulic fracturing, the protection of groundwater resources will have to be prioritised such that the EWR and BHN components, as well as livelihoods are not adversely impacted. In the event of unavoidable adverse impacts, mitigation measures will need to be

set in anticipation of such impacts and where pollution of water resources would have occurred, remedial measures need to be undertaken.

Hence, the primary motivation of this study was to determine the EWR of all the significant water resources in the catchment thereby, providing high confidence results for the protection of these resources. This will ultimately assist the DWS in making informed decisions regarding the authorisation of future water use and the magnitude of the impacts of the proposed developments.

A number of studies have been conducted for the Upper Orange River catchment, mainly focussed on long-term planning of the water resources. Some of these studies were undertaken by DWS or in association with Lesotho, especially with the development of the Senqu River catchment for water transfers to the Upper Vaal system. Furthermore, and importantly, every 5 years, the Orange-Senqu River Basin is subject to the Joint Basin Survey (JBS) where the Aquatic Ecosystem Health (AEH) monitoring programme is conducted. Consequently, all information and data from previous studies was used for baseline for this study. These are summarised in **Table 1-1** below.

Table 1-1: Previous studies conducted in the Upper Orange catchment

Year	Study Name
Surface water resources and Aquatic Ecosystem Health	
2009	Department of Water Affairs (DWA), 2009. Development of an Integrated Water Quality Management Strategy for the Upper and Lower Orange River Water Management Areas, Desktop Catchment Assessment Study: Upper Orange Water Management Area (WMA 13). Report No. 2.1 (P RSA D000/00/7909/2).
	DWAF, Department of Water Affairs and Forestry, 2009. Directorate Water Resource Planning Systems: Water Quality Planning. Orange-Senqu River: Assessment of water quality data requirements for planning purposes. Water Quality Monitoring and Status Quo Assessment. Report No. 3 (P RSA D000/00/8009/1). ISBN No. 978-0-621-38690-5, Pretoria, South Africa.
	Seaman, M.T., Avenant, M.F., Watson, M., King. J., Armour, J.Barker, C.H., Dollar, E., du Preez, P.J., Hughes, D., Rossouw, L. and van Tonder, G. Developing a method for determining the environmental water requirements for non-perennial systems. WRC Report.
2010	Support to Phase 2 of the ORASECOM basin-wide Integrated Water Resources Management Plan: Environmental Flow Requirements.
	Orange-Senqu Water Resources Quality Joint Basin Survey 1 (JBS1). Final Report.
	ORASECOM, 2010. A Fitness for use Assessment of waters of the Orange-Senqu Basin. Pretoria.
	WRC, 2010. Developing a method for determining the environmental water requirements for non-perennial systems. (WRC Project No. K5/1587)

Year	Study Name
2011	Support to Phase 2 of the ORASECOM basin-wide integrated water resources management plan: Extension of hydrological records.
2012	ORASECOM. 2012. From Source to Sea: Interactions between the Orange-Senqu River Basin and the Benguela Current Large Marine Ecosystem. Orange-Senqu River Basin Commission, Pretoria.
2013	LHDA Contract 6001. Specialist consultants to undertake baseline studies (flow, water quality and geomorphology) and instream flow requirement (IFR) assessment. INR, 2013.
2014	A Desktop Assessment of the PES, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Compiled by RQIS-RDM.
	Department of Water Affairs, South Africa, 2013. Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River - Final Reconciliation Strategy (November 2014).
	ORASECOM, 2014. Integrated Water Resources Management Plan for the Orange-Senqu River Basin. Support to Phase 3 of the ORASECOM Basin-wide integrated Water Resources Management Plan. Consolidation of Knowledge of Water Quality. Report No. ORASECOM 017/2014.
	ORASECOM, 2014. National Action Plan for the Orange–Senqu River Basin in South. Pretoria: Orange–Senqu River Commission (ORASECOM).
	ORASECOM, 2014. Environmental flow requirements of the lower Orange–Senqu River: Determining the flows required to safeguard ecological health and human wellbeing. Report 008/2014, produced by the Orange–Senqu Strategic Action Programme for ORASECOM. Pretoria.
	ORASECOM. 2014. Strategic Action Programme for the Orange-Senqu River Basin. Orange-Senqu River Basin Commission, Pretoria.
	ORASECOM. 2014. Orange-Senqu River Basin Transboundary Diagnostic Assessment. Orange-Senqu River Basin Commission, Pretoria.
	ORASECOM. 2014. Orange-Senqu River Basin Transboundary Diagnostic Assessment. Orange-Senqu River Basin Commission, Pretoria.
	The Setting of Resource Water Quality Objectives for the Modder-Riet River
2015	Orange-Senqu Water Resources Quality Joint Basin Survey 2 (JBS2). Final Report. ORASECOM report: ORASECOM/001/2015.

Year	Study Name
2020	ORASECOM. 2020. Situation Analysis and Priority Action Plan for the Rehabilitation of the Orange-Senqu River mouth. Baseline Assessment of the Orange-Senqu River Mouth Rehabilitation Demonstration Project in South Africa and Namibia. Prepared by OneWorld.
2021	Orange-Senqu Water Resources Quality Joint Basin Survey 3 (JBS3) (currently being undertaken by Groundtruth).
Groundwater	
1954	Du Toit, A.L. (1954). The Geology of South Africa. 3rd Edition. Oliver and Boyd, London
1970	Truswell J.F. (1970). Historical Geology of South Africa. Purnell, Cape Town
1982	Tankard A.J., Jackson M.P.A., Eriksson K.A., Hobday D.K., Hunter D.R., Minter W.E.L. (1982). Crustal evolution of South Africa. Springer Verlag. New York
1998	Botha J.F., Verwey J.P., Van der Voort I., Vivier J.J.P., Buys J., Colliston W.P., Loock J.C. (1998). Karoo Aquifers – Their geology, geometry and physical properties. Water Research Commission Report No. 487/1/98. ISBN No. 1 86845 386 3. Pretoria
2003	DWS. Overview of water resources – Availability and Utilisation: Upper Orange Water Management Area
2004	DWS. Internal Strategic perspective Upper Orange Water Management Area
2004	A Functional Approach to Setting Resource Quality Objectives for Groundwater: Final Report. CSIR Report ENV-S-C 2003-120, Water Research Commission and CSIR, Pretoria, South Africa
2005	Groundwater Resources Assessment Phase II
2007	Groundwater Resource Directed Measures Manual. Setting Resource Directed Measures (Rdm) for Groundwater: A Pilot Study. WRC Report No TT 299/07
2011	Aarnes I., Svensen H., Polteau S., Planke S. (2011). Contact metamorphic devolatilization of shales in the Karoo Basin, South Africa, and the effects of multiple sill intrusions. Chemical Geology Vol. 281, no. 3–4: 181–194. Elsevier B.V. 2011
2012	Water Resources of South Africa – Resource Centre. Royal Haskoning DHV and Water Research Commission. Pretoria
2013	WRC. Groundwater Resource Directed Measures (2012 Edition). Ingrid Dennis, Kai Witthüsser, Koos Vivier, Rainer Dennis & Andrew Mavurayi. WRC Report No TT 506/12.
2012	All Towns Reconciliation Strategies

Year	Study Name
2021	Orange-Senqu Water Resources Quality Joint Basin Survey 3 (JBS3): groundwater component (currently being undertaken by Groundtruth)
Geomorphology	
1972	Kriel, JP. The role of tile Hendrik Verwoerd Dam in the Orange River Project. Civil Engineering, 1972(2), pp.51-61.
1993	De Wit, M.C. Cainozoic evolution of drainage systems in the North-western Cape. Unpublished PhD dissertation, University of Cape Town
1995	Dollar, E.S.J. and Rowntree, K.M. Hydroclimatic trends, sediment sources and geomorphic response in the Bell River catchment, Eastern Cape Drakensberg, South Africa. South African Geographical Journal, 77(1), pp.21-32.
1996	Rowntree, KM and Dollar, ESJ. Controls on channel form and channel change in the Bell River, Eastern Cape, South Africa. South African Geographical Journal, 78(1), pp.20-28.
2005	Dollar, E.S.J. Macro-reach analysis for Seekoei River. Prepared for Centre for Environmental Management, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein. Environmental water requirements in non-perennial systems. Water Research Contract No. 1587. Report No. ENV-S-C-2005-106. Project No. JNWA002. CSIR NRE, Stellenbosch.
2006	Partridge, T.C., Dollar, E.S.J., Moolman, J. and Dollar, L.H. Geomorphic provinces of South Africa, Lesotho and Swaziland: a physiographic subdivision for earth and environmental scientists, especially those concerned with the conservation of biodiversity within aquatic ecosystems. Council for Geoscience, Pretoria
2007	Compton, JS and Maake, L. Source of the suspended load of the upper Orange River, South Africa. South African Journal of Geology, 110(2-3), pp.339-348.
	De Villiers, JWL and Basson, GR. Modelling of long-term sedimentation at Welbedacht Reservoir, South Africa. Journal of the South African Institution of Civil Engineering, 49(4), pp.10-18.
	Slabbert, N. The potential impact of an inter-basin water transfer on the Modder and Caledon River systems (Doctoral dissertation, University of the Free State)
2008	Petersen, C.R. and Dollar, E.S.J. Report on the sediment surveys for four EWR sites on the Seekoei River, Northern Cape. Report prepared for the Centre for Environmental Management as part of the Water Research Commission Project No. 1587. University of the Free State, Bloemfontein.
2010	Compton, JS, Herbert, CT, Hoffman, MT, Schneider, RR and Stuut, JB. A tenfold increase in the Orange River mean Holocene mud flux: implications for soil erosion in South Africa. The Holocene, 20(1), pp.115-122.

Year	Study Name
2011	Bouwman, H, and Pieters, R. POPs, PAHs and elemental levels in sediment, fish and wild bird eggs in the Orange–Senqu River basin: Final report. [Published as ORASECOM Report 002/2013] Technical Report Number 15.
2014	George, MJ. Determination and correlation of herbicide residues in water and sediments in the streams flowing into the Caledon River using the bubble-in-drop single drop micro-extraction method. Eur Chem Bull, 3, pp.1098-1102.
2015	JBS 2 - Orange-Senqu Water Resources Quality Joint Basin Survey 2 (JBS 2) – final report persistent organic pollutants and metals survey in 2015
Wetlands	
2011	NFEPA Wetlands Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B., Mbona, N., Downsborough, L. and Nienaber, S. 2011. Technical report for the national freshwater ecosystem priority areas project. WRC Report No. 1801/2/11. Water Research Commission, Pretoria, South Africa
2018	National Wetland Map 5 South African National Biodiversity Assessment. Technical Report. Volume 2a: South African Inventory of Inland Aquatic Ecosystems (SAIIAE). Version 3, final released on 3 October 2019. Council for Scientific and Industrial Research (CSIR) and South African National Biodiversity Institute (SANBI): Pretoria, South Africa. Report Number: CSIR report number CSIR/NRE/ECOS/IR/2018/0001/A; SANBI report number http://hdl.handle.net/20.500.12143/5847.
2019	Department of Environmental Affairs (DEA). Environmental Programmes: Natural Resource Management. 2019. Working for Wetlands: Free State Provincial Strategic Plan: 2019-2024. Unpublished Report.
	DEA. Environmental Programmes: Natural Resource Management. 2019. Working for Wetlands: Eastern Cape Provincial Strategic Plan: 2019-2024. Unpublished Report.
	DEA. Environmental Programmes: Natural Resource Management. 2019. Working for Wetlands: Northern Cape Provincial Strategic Plan: 2019-2024. Unpublished Report.

Additionally, various Reserve studies were conducted for the Upper Orange catchment area, each at varying levels of detail, all of which were incorporated. Moreover, when choosing EWR sites within the prioritized river resource units, alignment was ensured with both JBS3 AEH sites and the pre-existing DWS River Eco-status Monitoring Programme (REMP) monitoring sites.

1.3 Study Area

The Upper Orange Catchment area, which forms part of the Orange Water Management Area (WMA6) in South Africa, encompasses the Orange River and its major tributaries. The study area consists of 129 quaternary catchments, covering an approximate area of 106 000 km^2. This includes secondary catchments D1, D2, D3 and C5. The sub-catchments, associated rivers, catchment areas and quaternary catchments are listed in **Table 1-2** and illustrated in **Figure 1-1.** The Gariep and Vanderkloof Dams, which the upper Orange River flows through, being two of the country's largest reservoirs, are used for hydropower, transfers of water and releases for irrigation before reaching its confluence with the Vaal River at Douglas in the Northern Cape.

Table 1-2: The sub-catchment areas within the study area

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
D12	Upper Orange	Orange, Hendrik Smitstroom, Kromspruit, Sterkspruit, Mpongo, Mhlangeni, Bamboesspruit, Gryskopspruit, Winnaarspruit, Knoffelspruit, Wilgespruit, Beeskraalspruit, Nuwejaarspruit	370.23	D12A
			386.25	D12B
			344.05	D12C
			356.49	D12D
			714.47	D12E
			806.27	D12F
D13	Kraai	Rifle Spruit, Bokspruit, Kraai, Sterkspruit Koffiehoekspruit, Bamboeshoekspruit, Langkloofspruit, Vrouenshoekspruit, Rytjiesvlaktespruit, Joggemspruit, Vlooikraalspruit, Three Drifts, Diepspruit, Klein-Wildebeesspruit, Saalboomspruit, Vaalhoek, Noodshulpspruit, Wasbankspruit, Wolwespruit, Rooihoogte se Loop, Holspruit, Kromspruit, Telemachusspruit, Skulpspruit, Braklaagtespruit, Leeuspruit, Karringmelkspruit, Bossielaagtespruit, Oslaagte, Rondefonteinspruit, Windvoelspruit, Elandspruit, Klipspruit	475.81	D13A
			534.04	D13B
			517.99	D13C
			636.66	D13D
			1033.54	D13E
			972.74	D13F
			1128.43	D13G
			1148.62	D13H
			1171.36	D13J
			398.40	D13K
			684.01	D13L
			680.71	D13M
D14	Upper Orange	Orange, Sanddrifspruit, Melkspruit, Stormbergspruit, Wilgespruit, Wonderhoekspruit, Bamboesbergspruit, Buitendagspruit, Klein-Buffelsvleispruit, Witkopspruit, Barnardspruit, Mooiplaasspruit, Kop-en-pootjiespruit, Modderbulrspruit, Palmietspruit	767.76	D14A
			325.52	D14B
			724.94	D14C
			683.34	D14D
			666.69	D14E
			543.46	D14F
			608.08	D14G
			700.44	D14H
			517.40	D14J

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
			637.24	D14K
D15 (SA only)	Makhaleng	Mantikoana, Deklerkspruit, Makhaleng (mainly in Lesotho), Worsfonteinspruit	486.22	D15G
			361.89	D15H
D18 (SA only)	Upper Orange	Tele (border between Lesotho and RSA), Blikana, Pelandaba, KwaSijoa, KwaNomlengaba, Sidwadwa , Orange	937.34	D18K
			611.26	D18L
D21	Caledon	Caledon, Little Caledon, Brandwater, Swartspruit	309.77	D21A
			211.94	D21C
			251.84	D21D
			268.79	D21E
			480.46	D21F
			278.63	D21G
			381.58	D21H
D22	Caledon	Caledon, Meulspruit, Moolmanspruit, Rantsho, Mopeli, Morakabi, McCabes Spruit, Beytelspruit, Modderpoortspruit, Tenniskopspruit, Tweelingspruit	636.91	D22A
			458.07	D22B
			486.51	D22C
			629.32	D22D
			972.07	D22G
			542.41	D22H
			377.50	D22L
D23	Caledon	Appledore Spruit Caledon, Klein-Leeu, Leeu, Mokopu, Bokpoortspruit, Sandspruit, Montsoane, Klipspruit, Rietspruit, Nuwejaarspruit, Bloemspruit	609.80	D23A
			863.98	D23C
			566.97	D23D
			704.61	D23E
			352.82	D23F
			513.33	D23G
			779.42	D23H
			535.69	D23J
D24	Caledon	Boesmanskopspruit, Witspruit, Klipspruit, Elandspruit, Witspruit, Blaasbalkspruit, Wilgeboomspruit, Vaalspruit, Caledon, Vinkelspruit,Grahamstadspruit,Leeuspruit, Eldoradospruit, Skulpspruit, Groenspruit, Slykspruit,	310.97	D24A
			472.13	D24B
			399.66	D24C
			601.03	D24D
			491.22	D24E
			569.31	D24F
			628.57	D24G
			739.25	D24H
			1037.34	D24J
			881.17	D24K
			513.36	D24L
D31	Middle Orange	Hondeblaf, Diepsloot, Berg, Orange, Kattegatspruit	1167.61	D31A
			1004.52	D31B
			682.38	D31C
			1116.49	D31D
			976.80	D31E
D32	Middle Orange		721.55	D32A
			586.23	D32B

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
		Seekoei, Klein-Seekoei, Elandskloof, Soetvlei se Loop, Noupoortspruit, Elands, Gansgatspruit	856.58	D32C
			858.40	D32D
			1166.88	D32E
			1454.84	D32F
			1052.82	D32G
			576.52	D32H
			1122.20	D32J
			830.52	D32K
D33	Middle Orange	Orange, Lemoenspruit	597.66	D33A
			1026.63	D33B
			811.59	D33C
			950.01	D33D
			1551.71	D33E
			870.56	D33 F
			1419.61	D33 G
			1052.19	D33 H
			873.70	D33 J
			493.06	D33 K
D34	Middle Orange	Oorlogspoort, Klipfonteinspruit, Rietkuilspruit, Orange, Vanderwaltsfonteinspruit, Paaiskloofspruit, Otterspoortspruit	798.76	D34A
			710.71	D34B
			765.62	D34C
			603.24	D34D
			522.64	D34E
			696.77	D34F
			956.17	D34G
D35	Upper Orange	Orange, Oudagspruit, Broekspruit, Winnaarsbakenspruit, Broekspruit, Bossiespruit, Brakspruit, Swarthoekspruit, Suurbergspruit, Orange	255.86	D35A
			261.53	D35B
			948.27	D35C
			589.76	D35D
			313.82	D35E
			560.73	D35F
			555.08	D35G
			501.14	D35H
			1007.80	D35J
			678.37	D35K
C51	Riet	Leeuspruit, Fouriespruit, Kroonspruit, Riet, Ruigtespruit, Ospoortspruit, Holspruit, Kromellenboogspruit, Prossesspruit, Vanzylspruit	678.73	C51A
			1700.14	C51B
			627.68	C51C
			926.16	C51D
			810.82	C51E
			882.08	C51F
			1846.09	C51G
			1793.32	C51H
			1058.71	C51J
			3659.64	C51K
			2049.75	C51L
			1534.38	C51M

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
C52	Modder	Kromspruit, Modder, Bo-Kromspruit, Gannaspruit, Klein-Modder, Sepane, Kgabanyane, Wildebeesspruit, Steynspruit, Korannaspruit Matjiespruit, Koringspruit, Klein-Osspruit, Osspruit, Renosterspruit, Bloemspruit, Dardoringspruit, Keeromspruit, Doringspruit, Rietspruit, Stinkhoutspuit, Kaalspruit, Klein-Kaalspruit	940.83	C52A
			953.30	C52B
			602.88	C52C
			473.51	C52D
			901.24	C52E
			691.29	C52F
			1797.99	C52G
			2386.92	C52H
			1933.89	C52K
			4362.20	C52L

The Upper Orange water resources plays a pivotal role in South Africa, as they are used to support requirements for water in other parts of the country with large transfer schemes both from and within this WMA. These include transfers out from the Senqu River (Lesotho Highlands Water Project) through the Katse and Mohale and planned Polihali Dams to the Upper Vaal WMA, the Orange Fish Transfer from Gariep Dam to the Fish / Tsitsikamma WMA) and the Orange-Vaal Transfer to the Lower Orange WMA. Transfer from Muela Dam in Lesotho to the Caledon River is used during droughts to supply water to Maseru and surrounding areas. Transfers within occur from the Orange and Caledon Rivers to the adjacent Modder / Riet catchment (DWA, 2009).

In terms of the catchment's wetlands, there are a total of 2,868 wetlands and covering 74,378ha, which are mainly associated with the Upper Karoo Bioregion. While most wetlands are categorized as Least Concern or Vulnerable, human activities like agriculture, mining, and urbanization continue to threaten their integrity within this catchment area. In terms of the groundwater, the Karoo Sedimentary Aquifer, a transboundary aquifer, underlies the area, with groundwater use estimated at 132Mm^3/a, predominantly for agriculture.

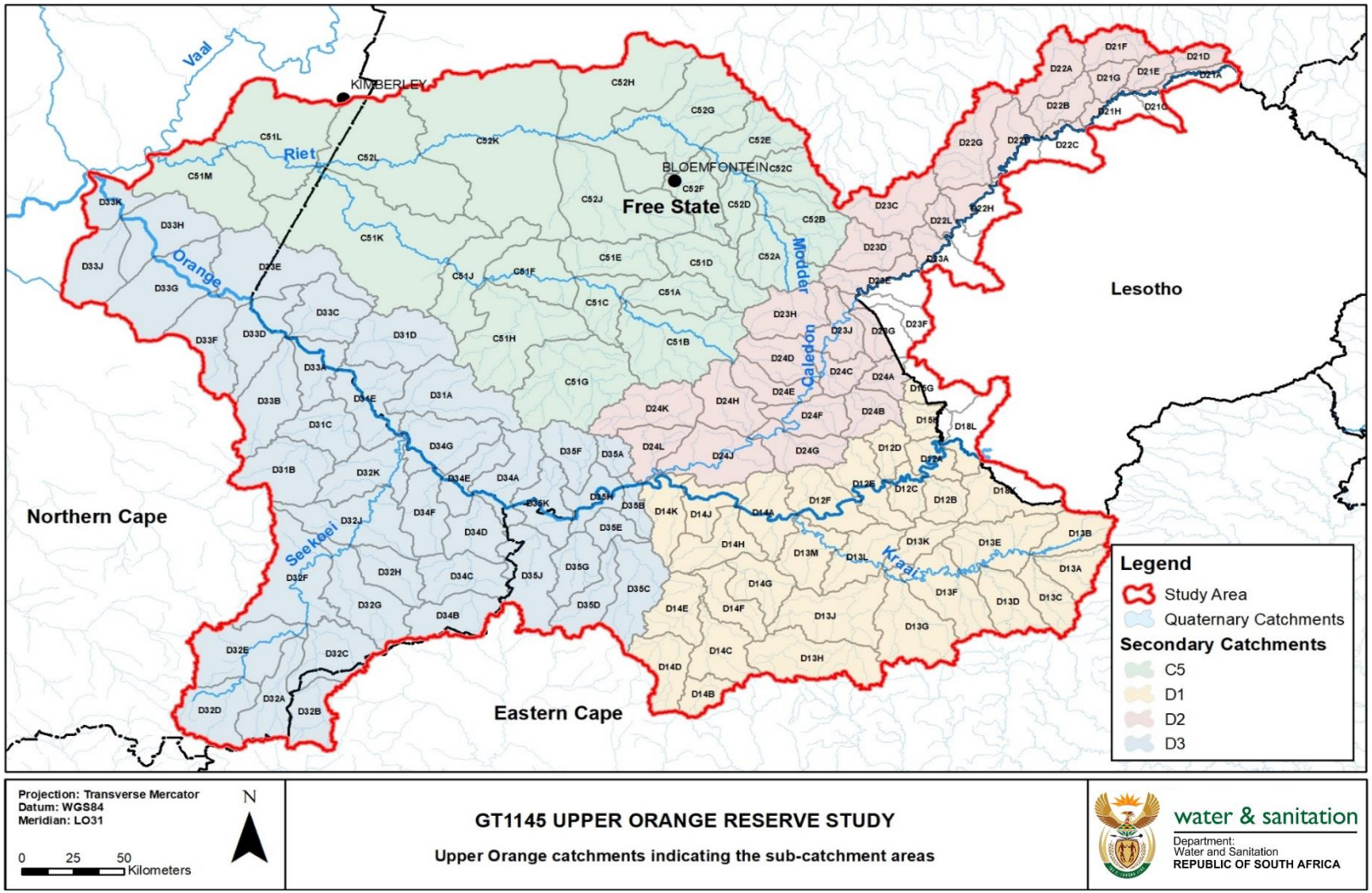

Figure 1-1: Upper Orange catchment: indicating the sub-catchment area

1.4 Purpose of this Report

This report forms the final deliverable of the study and serves as feedback on final deliverables, milestones, challenges and lessons learnt through the undertaking of the study, 'High Confidence Reserve Determination of the Upper Orange Catchment Area'. It comprises the reporting on these aspects and makes some recommendations for future studies. Furthermore, this report includes the opinion, recommendations and suggestions provided for by the external reviewer for this study, Dr Neels Kleynhans.

2. STUDY DELIVERABLES AND OUTPUTS

The study deliverables are summarised in **Table 2-1** below. All key deliverables were submitted within the timelines agreed, or within a week of the scheduled time.

Nevertheless, due to the flood events occurring in the Upper Orange catchment area throughout this study, numerous delays had to be accommodated from a river standpoint. This, in turn, led to the rescheduling of the anticipated study outcomes. Additional information can be found in Chapter 3 below. Despite these challenges, it is noteworthy that the study successfully adhered to the contractual end date of March 2024.

Table 2-1: Summary of deliverables for theUpper Orange Reserve determination study

INDEX	REPORT NUMBER	REPORT TITLE	Deliverable Summary	Expected Final Deliverable due date	Draft Report submitted	DWS Approval of Deliverable
1.0	RDM/WMA13/00/CON/COMP/0121	Inception Report (Deliverable 4.3.1)	The Inception Report was compiled to better define the scope of work and methodology that would be applied for this high confidence Reserve determination study for surface water, groundwater and wetlands in the Upper Orange catchment. Furthermore, to highlight related considerations that could influence the study and confirm the stakeholder engagement process, capacity building activities, the study programme and timeframes.	End-October 2021	15 September 2021	30 September 2021
2.0	RDM/WMA13/00/CON/COMP/0221	Stakeholder Engagement Plan (Deliverable 4.3.15)	Stakeholder involvement and communication is critical to any Reserve determination process, and thus an independent deliverable was based on the Stakeholder Engagement Plan (SEP). The objective of the SEP was to provide the approach to stakeholder engagement, identifying the various stakeholders in the Upper Orange catchment area and communication processes and tools. Importantly, it further included the understanding within the policy context i.e. protection of personal information Act No 4 of 2013 and compliance with COVID-19 policy (which was the case at the time of the commencement of this study).	End-December 2023	25 November 2021	15 December 2023
3.0	RDM/WMA13/00/CON/COMP/0321	Gaps Analysis Report (Deliverable 4.3.2)	This report documented the available data, information and water resources models available from previous studies and monitoring activities and to identify the gaps relevant to the determination of the Reserve for the rivers, wetlands and groundwater in the Upper Orange Catchment. This report further provided the context for the integration component between surface water, groundwater and wetlands, which was to be considered and evaluated with the use of available data. Knowledge of these interactions was essential in addressing the key gaps identified in this report.	End-December 2021	26 November 2021	13 January 2022

4.0	RDM/WMA13/00/CON/COMP/0422	Resource Units Report (Deliverable 4.3.3)	The Resource Units (RU) Report documented the data, information, approaches followed and the results of the selection and prioritisation of RUs for rivers, wetlands and groundwater in the Upper Orange Catchment. It was for these where the Ecological Water Requirements (EWR) were going to be determined for the priority river and groundwater RUs and ecological specifications provided for the priority wetlands. Integration between the various components, where applicable, was also assessed and the linkages between the components was defined. Cognisance was taken of the gaps that were identified for the study area in the previous deliverable, and where possible, additional data could be collected during the various field surveys.
			
			The above was supported by a technical RU prioritisation workshop held on 31 August 2021 with DWS, whereby the following was discussed:
			• Approaches per component to obtain approval from DWS:
			  • Surface water
			  • Groundwater
			  • Wetlands
			• Discussion on the identified river RUs and levels of determination; and
			Integration of rivers RUs with groundwater and wetlands.
				End-February 2022	31 January 2022	3 March 2022

5.0	RDM/WMA13/00/CON/COMP/0522	Wetland Field Survey Report (Deliverable 4.3.11)	The wetland field survey was conducted from 10 – 14 April 2022 to review the greater study area and the selected RUs within the study area. The infield survey of the RUs allowed for the condition of the wetlands to be reviewed, following on from the desktop analysis of the systems. The survey report included an overview of the field survey, limitations that were	End-May 2022	29 April 2022	6 June 2022

INDEX	REPORT NUMBER	REPORT TITLE	Deliverable Summary	Expected Final Deliverable due date	Draft Report submitted	DWS Approval of Deliverable
			faced while in the field, site photographs and co-ordinates, along with a brief description of the wetland that was surveyed. Lastly, a chapter on the capacity building event with DWS colleagues was included, whereby expert knowledge was shared whilst in the field along with any photos that were taken during the event.			
6.0	RDM/WMA13/00/CON/COMP/0622	Groundwater Survey Report (Deliverable 4.3.9)	The hydrocensus was conducted from 25 – 29 April 2022 to review the greater study area and the selected RUs within the study area. The survey report presented an overview of the groundwater hydrocensus, inclusive of preliminary results obtained during the survey. Lastly, a chapter on the capacity building event with DWS colleagues was included, whereby expert knowledge was shared whilst in the field along with any photos that were taken during the event.	End-June 2022	06 May 2022	11 July 2022
7.0	RDM/WMA13/00/CON/COMP/0722	River Survey Report 1 (Deliverable 4.3.4)	The first river survey was conducted from 4 – 15 July 2022 to conduct all three Reserve level assessments (intermediate, Rapid Level 3 EWR sites and field verification sites) at the identified priority RUs throughout the Upper Orange catchment. The survey report included upstream and downstream site photographs, site description, site impacts and preliminary results namely, *in situ* water quality (pH, Electrical Conductivity, Dissolved Oxygen, Oxygen Saturation, Total Dissolved Solids, temperature, clarity and salinity) and discharge. Lastly, a chapter on the capacity building event with DWS colleagues was included, whereby expert knowledge was shared whilst in the field along with photos that were taken during the event.	End-August 2022	30 July 2022	22 August 2022
8.0	RDM/WMA13/00/CON/COMP/0822	Basic Human Needs Assessment Report (Deliverable 4.3.13)	The Basic Human Needs (BHN) Report documented the approach and results of the BHN assessment to determine the BHN Reserve for this study. The BHN determination aimed to ensure that the essential needs of individuals served by the water resources in question, rivers and groundwater, were provided for and pertained specifically to those people not linked to a formal (municipal) water supply system and directly dependent on surface water (rivers) and groundwater abstraction to meet their basic needs. The assessment covered all the quaternary catchments of the study area and indicated the river/stream and groundwater BHN requirements separately.	End-November 2022	September 2022	24 October 2022
9.0	RDM/WMA13/00/CON/COMP/0922	Wetland Report (Deliverable 4.3.12)	Additional information gathered on wetlands, gaps throughout the study area, discussions on approaches, discussions on working for wetlands strategic planning and general discussions were had during a technical wetland workshop held on 9 December 2021. Following the above, coupled with the collection, collation and data analysis from the desktop and wetland infield survey, the wetland report was compiled. This report included the data, information, approaches followed and the results of the assessments for the selected wetland RUs for the Upper Orange River catchment area. Furthermore, recommendations for the quantification of the EWRs for specific priority wetlands and where integration between groundwater and/ or rivers and wetlands are crucial were made.	End-October 2022	12 October 2022	14 November 2022
10.0	RDM/WMA13/00/CON/COMP/1022	Groundwater Report (Deliverable 4.3.10)	The purpose of this report was to document the groundwater quantity and quality Reserve. The report included the approach taken for the groundwater component, following by providing information on the present state for each groundwater RU and sought to establish the volume of groundwater that contributed to sustaining the EWR and BHN and to establish	End-December 2022	5 December 2022	Initially: 20 February 2023 Further updates and approval: 9

INDEX	REPORT NUMBER	REPORT TITLE	Deliverable Summary	Expected Final Deliverable due date	Draft Report submitted	DWS Approval of Deliverable
			groundwater quality per groundwater RU and per quaternary catchment. This was a necessary pre-requisite to determine the quantity and quality of groundwater potentially available for allocation to users and potential users.			February 2024
11.0	RDM/WMA13/00/CON/COMP/1123	Socio-Economics Outline Report (Deliverable 4.3.14)	The objective of this report was to present an overview of the socio-economic context of the study area. The report profiled the socio-economic conditions and well-being of the communities, with a particular focus on socio-economic water use and cultural importance. The socio-economic profile provided the baseline for evaluating the social consequences of potential operational flow scenarios of the Reserve Determination process.	End-March 2023	23 February 2023	5 April 2023
12.0	RDM/WMA13/00/CON/COMP/1223	River Survey Report 2 (Deliverable 4.3.5)	The second river survey was conducted from 29 May – 4 June 2023 to re-survey all Intermediate EWR sites in the Upper Orange catchment. The survey report included updated upstream and downstream site photographs, site description, site impacts and additional preliminary results namely, *in situ* water quality (pH, Electrical Conductivity, Dissolved Oxygen, Oxygen Saturation, Total Dissolved Solids, temperature, clarity and salinity) and discharge. Lastly, the capacity building chapter was expanded with further DWS colleagues that attended the survey and photos that were taken during the event.	End-July 2023	6 June 2023	28 June 2023
12.0	RDM/WMA13/00/CON/COMP/1223 (a)	Eco-Categorisation Report – Volume 1 (Deliverable 4.3.6)	The purpose of this report was to document the results from the Ecological Categorisation (Eco-Categorisation), of all EWR sites, based on the information and data that was currently available through various previous studies and the two (2) river field surveys that were undertaken. The report provided summaries of the EcoStatus results, and the ultimate Recommended Ecological Category per site.	End-August 2023	28 July 2023	6 September 2023
12.0	RDM/WMA13/00/CON/COMP/1223 (b)	Eco-Categorisation Report – Volume 2 (Deliverable 4.3.6)	This included all the appendices to Volume 1 of the Eco-categorisation Report.	End-August 2023	28 July 2023	6 September 2023
13.0	RDM/WMA13/00/CON/COMP/1323	Quantification of Ecological Water Requirements Report (Deliverable 4.3.7)	A technical EWR workshop for all Intermediate EWR sites was held on 19 July 2023 with DWS, following the completion of the Eco-categorisation phase of the study. The following was discussed amongst DWS colleagues and specialists: • Quantification of the EWR for all Intermediate EWR river sites within the Upper Orange Catchment area; • Discussions on the hydraulic modelling and Habitat Flow (HABFLO) Model; • Discussion on the Flow-Stressor Response model; • Discussion around the responses form a geomorphological, riparian vegetation and instream biota perspective; • Illustration of the Desktop Reserve Model within SPATSIM which was used for the integration of data produced from the surveys and the eco-categorisation to quantify the EWRs; This above workshop supported the completion of the EWR Report. The report described the approaches, methods and models used to determine the EWRs for the priority river reaches at selected EWR sites. Ultimately, the quantification was based on information and data that was available through various previous studies and the surveys that were undertaken as part of this study. Further, the conceptual Flow Management Plan (FMP) proposed for the	End-September 2023	31 August 2023	2 October 2023

INDEX	REPORT NUMBER	REPORT TITLE	Deliverable Summary	Expected Final Deliverable due date	Draft Report submitted	DWS Approval of Deliverable
			Orange River downstream of Gariep and Vanderkloof Dams was presented in this report. Additionally, an initial approach for the integration/ interaction between rivers, wetlands and groundwater, which had been developed for the purpose of this study, was also included within this report.			
14.0	RDM/WMA13/00/CON/COMP/1423	Scenario and Consequences Report (Deliverable 4.3.8)	Seven (7) operational scenarios were taken forward in this study and the detail provided for in this report. The evaluation of both the ecological and socio-economic consequence were undertaken to finalise the EWRs that can be met. Furthermore, a more detailed outline of the conceptual FMP was provided with detailed action plans as for the way forward.	End-November 2023	7 November 2023	14 December 2023
15.0	RDM/WMA13/00/CON/COMP/1523	Ecological Specifications and Monitoring Plan Report (Deliverable 4.3.17)	Based on these results and the review of the eco-categorisation, the objectives for the protection of the ecosystem have been defined through the Ecological Specifications (EcoSpecs) and monitoring requirements for the maintenance/ improvement of the present state at each EWR site. The EcoSpecs were ensured to be quantifiable and enforceable descriptors of the quantity, quality, habitat and biotic integrity as they pertain to the ecological objectives for a particular water resource. These were the values of parameters that should not be exceeded to meet the REC specified for the water resource. Therefore, the aim of the EcoSpecs and monitoring requirements provided are to ensure the maintenance of the Reserve for the water resources of the Upper Orange catchment area, as they relate to hydrology, water quality, geomorphology, riparian vegetation, habitat and biota of rivers, groundwater and wetlands.	End-December 2023	4 December 2023	16 January 2024
16.0	RDM/WMA13/00/CON/COMP/1623	Capacity Building Report (Deliverable 4.3.19)	This report listed all the technical workshops and capacity building events that were held during the duration of this study. Each workshop/capacity building event included the list of DWS delegates that attended and what was covered during the session.	End-February 2024	30 January 2024	February 2024
-	-	Reserve Template (Deliverable 4.3.18)	The Reserve template was split between surface and groundwater. The surface water Reserve template included: • The locality of all EWR sites, including the field verification sites; • The PES, REC and quantified EWR results for REC for each EWR site; • Preliminary Ecological Reserve – Water Quantity; • Preliminary Ecological Reserve – Water Quality; • Preliminary Basic Human Needs; • Special conditions and limitations; and • Background and methodology. It further included the categorisation of wetlands. The groundwater template included: • Preliminary Groundwater Reserve – Water Quantity • Preliminary Groundwater Reserve – Water Quality • Recommended conditions during WULA • Background and Record of Decision • Methodology	End-February 2024	30 January 2024	February 2024
17.0	RDM/WMA13/00/CON/COMP/1723	Integrated Main Report (Deliverable 4.3.20)	The purpose of this report was to provide an integrated and holistic summary of the findings and recommendations of the Reserve determination for surface and groundwater in the Upper Orange Catchment Area.	End-Marc 2024	16 February 2024	March 2024
18.0	RDM/WMA13/00/CON/COMP/1823	Close-out and External	This report forms the final deliverable of the study and serves as feedback on final deliverables, milestones, challenges and	End-March 2024	20 February 2024	March 2024

INDEX	REPORT NUMBER	REPORT TITLE	Deliverable Summary	Expected Final Deliverable due date	Draft Report submitted	DWS Approval of Deliverable
		Reviewer Report (Deliverable 4.3.21)	lessons learnt through the undertaking of the study, 'High Confidence Reserve Determination of the Upper Orange Catchment Area'. It comprises the reporting on these aspects and makes some recommendations for future studies. Furthermore, this report includes the opinion, recommendations and suggestions provided for by the external reviewer for this study, Dr Neels Kleynhans.			

The following meetings were also seen as milestones in the project:

- Seven Project Management Committee meetings;
- Three Project Steering Committee meetings; and
- Eight specialist meetings relating to the:
    - Resource Unit prioritisation and delineation;
    - Eco-categorisation for the Rapid 3 EWR sites;
    - Eco-categorisation for the Intermediate EWR sites;
    - EWR quantification for the Rapid 3 EWR sites;
    - EWR quantification for the Intermediate EWR sites;
    - Wetland component;
    - Groundwater component; and
    - Approach to the evaluation of the ecological and socio-economic consequences to the operational scenarios.
- Wetland workshop with DWS and other government officials and NGOs.

2.1 Comments And Response Report

All comments received from DWS and the external reviewer, Dr Neels Kleynhans, were documented within the Comments and Response register, along with the responses from the PSP. Please refer to **Appendix A** for the register.

3. STAKEHOLDER CONSULTATION

Extensive stakeholder consultation was undertaken aligned to the technical steps of the study. An extensive stakeholder database for the Upper Orange catchment area was set up at the onset of the study and updated throughout the study as required.

In February 2022, the study was announced to the stakeholders by way of a letter of invitation addressed to all Interested and Affected Parties (I&APs) inviting them to the first stakeholder engagement hybrid meeting which was going to be held on 30 and 31 March 2022 at two venues, Aliwal North and Bloemfontein. The letter was accompanied by a Background Information Document (BID) and a reply sheet for I&APs to register as stakeholders and RSVP to the meeting. However, owing to the poor in-person attendance response, the meeting was converted to a virtual meeting held on 31 March 2022. All stakeholders were notified. It was during this first virtual stakeholder engagement meeting, that members for the Project Steering Committee (PSC) were also nominated.

The second stakeholder engagement meeting was held on the 13th March 2024 at the University of Free State, the Centre of Environmental Management in Bloemfontein. Table 3-1 summarises the two public meetings.

In addition to the formal stakeholder engagement meetings, notification letters were distributed several weeks prior to in-field surveys to inform all stakeholders, including landowners, farmers, and industrial owners, about priority river and wetland areas within their property boundaries, which required thorough verification of the water resource. The letters included survey programs and maps, enabling stakeholders to identify the specialists' locations on specific days and to give them the option to join the survey team for additional information. Stakeholders were also encouraged to share information, data, and knowledge to enhance

awareness of the significance of these systems. Additionally, they were requested to provide any relevant farm or landowner contact details to ensure timely communication when the survey team arrived on their property to monitor the river site.

3.1 Citizen Science

The feasibility of utilizing citizen science (CS) for in-field surveys in the selected river approach levels was considered for this study. This approach aimed to extend data collection across more sites, promote community participation in water resource management, complement existing data, and enhance the skills of community members. The initiative included defining appropriate CS tools and this approach enabled simple monitoring tasks for those interested in joining, such as measuring flow/discharge requirements, diatom samples and/or *in situ* water quality.

Both river surveys offered opportunities for CS to participate. Colleagues from the South African National Parks (SANParks) and the Directorate: Water Use and Irrigation Development under the Department of Agriculture Land Reform and Rural Development engaged in the surveys and participated in learning, assisting, and sharing their catchment knowledge with the PSP and DWS team. Ultimately, the importance of this lay in achieving some of the Sustainable Development Goals (SDG) targets, for example, Target 6.b – Stakeholder participation - “Supporting and strengthening the participation of local communities in improving water and sanitation management” - 2030 Agenda for Sustainable Development (see https://www.sdg6monitoring.org/indicators/target-6b/).

Table 3-1: Key stakeholder engagement meetings summary

Date	Platform / venue	Total attendees	Organisation represented	Information presented at the meeting
Stakeholder engagement meeting 1				

31 March 2022	Virtual
	(Teams Meeting)
		47	• DWS: Water Resource Development Planning
			• DWS: Reserve Determination
			• DWS: Water Resource Management Planning
			• DWS: Sources Directed Studies
			• DWS, Directorate: Mine and Industrial Water Quality Regulation
			• DWS: Water Resource Classification
			• DWS, Surface Water Reserve Determination
			• DWS, Directorate: Compliance Monitoring
			• DWS, Directorate: Sources Directed Studies
			• SANParks
			• SANParks - Water Resources
			• Agri Northern Cape
			• DFFE - Oceans and Coasts Research
			• South African National Biodiversity Institute (SANBI), Freshwater Biodiversity Programme
			• NCPT: Infrastructure Performance Management Directorate
				• Purpose of the meeting and stakeholder involvement;
				• Introduction to the project;
				• Project background and objectives;
				• Study area and impacts;
				• General approach and methodology for the Reserve determination study;
				• Information review and gap analysis;
				• Delineated and prioritisation of RU and level of Reserve determination ;
				• Stakeholder discussions, input, agreement;
				• Upcoming in-field surveys (rivers, wetlands and groundwater);
				• Rivers:
				  • Approach to the eco-categorisation, EWR quantification and ecological consequences of scenarios
				• Wetlands
				  • High level of the wetlands and the approach that would be followed, along with some preliminary desktop results on the current state of some of the wetlands.
				• Groundwater

Date	Platform / venue	Total attendees	Organisation represented	Information presented at the meeting
			• Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs • Thembelihle LM, Superintendent - Water & Sanitation • Sparta Baby Beef (Pty) Ltd • Orange Vaal Water Users Association in Douglas NC • Centre for Environmental Management, University of the Free State • Consulting Town Planner based in Welkom in FS, Company Kenosis Heights Town Planners. • Vanderkloof Water Users Association • Agreenco: biodiversity, rehabilitation and closure • Department of Correctional Services; Directorate Facilities Management • SAAFWUA • Control Environmental Officer: Estuaries management • Agri Northern Cape	• The approach taken for the groundwater component for setting the quality and quantity Reserve. • Socio-economics and Basic Human Needs • Approach to setting the ecological specifications for all components, monitoring plan and Reserve template preparation; and • The importance of stakeholder involvement throughout the study.
Stakeholder engagement meeting 2				
13 March 2024	Hybrid – University of Free State, Centre of	60	• SANBI • Department of Agriculture, Land Reform and Rural Development • LWO Employers organisation	• Study progress to date since the first stakeholder engagement meeting; • Summary of the river's Eco-categorisation and EWR Quantification results;

Date	Platform / venue	Total attendees	Organisation represented	Information presented at the meeting
	Environmental Management		• Department of Water and Sanitation • Eskom • Absa Bank • Orange Vaal Water Users Association • Agri Eastern Cape • SANParks • Arbor Acres • iWater Solutions • The Eastern Cape Socio-Economic Consultative Council • Department of Forestry, Fisheries and Environment • Department of Agriculture, Land Reform and Rural Development • Eskom • Fauré Enterprise Engineering • Nkanyi Holdings • FS DESTEA • Kenosis Heights Town Planners • WSP • Tokologo local municipality: dealesville • Lesotho DWA • STANTEC • Free State Agriculture / Vrystaat Landbou • "Lesotho Technologies for Economic Development - TED" • Sasol • Lesotho: Relilox Enterprise • Agri Eastern Cape • Lesotho: Relilox Enterprise	• Summary of the river's scenarios and consequences results; • Findings and results of the wetland component; • Findings and results of the groundwater component; • Summary of the Ecological Specifications and monitoring programme for all water resources; and • Next steps of the study before project closure.

Date	Platform / venue	Total attendees	Organisation represented	Information presented at the meeting
			• Lesotho: Department of Water Affairs • DWA -Lesotho (water Law) • Ministry of Environment and Forestry • National University of Lesotho • DWA -Lesotho • University of Free State	

4. ISSUES AND CHALLENGES

4.1 Lack of data

The major information gap for the water quality Reserve determination was the lack of historical and present-day water quality data which impacts the confidence of the Reserve results. The lack of water quality data (for both surface and groundwater) also made it challenging to determine reference conditions. Overall, this is a problem generically and systemically in this environment we are working in.

River's water quality

Reference and recent conditions of surface water quality at all river EWR sites, or the Sub-Quaternary (SQ) reach within which the sites are located, posed major gaps and concerns for this study area. Several data sources were used to collate information of the current and historical Physical-chemical state of the assessed river systems and associated catchments. The DWS Resource Quality Information Services (RQIS) website was the obvious first choice used to obtain data from the country wide DWS monitoring network. Most of data obtained from the RQIS did not show reference/baseline conditions as most of it was collected after major impacts had been introduced in the catchments. Additionally, the lack of consistent monitoring left years' worth of gaps in data. Further, there was no recent data, which posed a challenge when attempts were made to assess the current physical-chemical state. Furthermore, the porosity in data limited the ability to assess site reference conditions confidently and accurately.

Consequently, the inadequate data that would have been provided by one or two water quality samples, had they been collected, would not have been sufficient for conducting the Physical-chemical driver Assessment Index (PAI) or obtaining highly confident results. Thus, the inadequate data available was not enough to populate the PAI and it was therefore not used in this study. However, the decision was made to use diatoms as a surrogate. This approach aimed to deduce both the reference condition and the current status of the physical-chemical conditions of the river systems under consideration. The utilisation of diatoms in water quality monitoring is extensively documented and accounts for historical conditions as well.

Groundwater quality, level and borehole yield data

Multiple attempts were made to gather reference and current conditions for groundwater quality and groundwater level data during the study. However, that data too was very sparce and the major lack of data, posed a limitation in this catchment, and impacted the confidence of the groundwater Reserve. The lack of monthly rainfall and abstraction data to determine more detailed groundwater recharge calculations, as well as the lack of rainfall chemistry data for detailed groundwater recharge calculations contributed to the limitations and gaps. Although WR 2012 rainfall data was used, the data was only until end-2009. In the absence of rainfall chemistry data, default values were used as prescribed by the Recharge Toolkit.

Overall, the data for the Groundwater Reserve determination was obtained through various sources, which included:

- The WARMS database provided by DWS;
- Groundwater quality, levels data from DWS regional offices;
    - Specifically electrical conductivity and pH was the only data readily available that provided an indication of the groundwater quality for much of the study area. Detailed water quality data from laboratory testing analysis results were not freely available and difficult to obtain.
- SanParks - which officially commenced their groundwater monitoring programme two years ago, inclusive of Mokala Nature Reserve, located within our study area;
- Department of Agriculture, land reform and rural development, although only groundwater level and yield data were obtained.

Unfortunately, municipalities, entrusted with the responsibility of collecting groundwater quality data, did not furnish any data, despite several attempts in requesting such data for the purpose of this study.

Wetlands component

While there was existing information on the general extent and distribution of wetlands in the Upper Orange catchment area, it was all predominantly limited to desktop studies. However, owing to the vast numbers of wetlands located within this study area, a comprehensive field-verification survey was not practical. Thus, the identification of the priority wetlands and the development of an integrated Priority Wetland GIS layer, combined with updated desktop delineations and categorisations was an important supplement to the study results.

Furthermore, limited flow and water quality data (especially updated information and as described above) added to the limitations on the wetland component.

4.2 Flooding Events

The La Niña cycle took place during the duration of this study. Four events took place in South Africa between 2022 and 2023, of which on 15 February 2023, the government declared a National State of Disaster, in response to the floods currently devastating seven of the nine provinces in SA, which includes parts of the Upper Orange catchment area. Of relevance to this project, it was clear that the high flows indicative of floods and safety hazards were focused on the southern side of the study area, particularly the Kraai and along the Orange River main stem, moving further downstream, with both Gariep and Van Der Kloof Dams which were spilling at the time, and contributing to those high flow velocities. This was not only a major health and safety issue for staff sampling these rivers, but also have significant impacts on the biota, particularly the macroinvertebrates which were washed away, and limited access to fish refugia. The decision was made to postpone the river survey, and all related deliverables thereafter. The necessary motivational letters for all flood events and the requirement to postpone were submitted and approved by DWS, along with the revised timeframes for all deliverables.

4.3 Hydropower releases from Gariep Dam

The severely modified flow along the Orange River between Gariep and Vanderkloof Dam, and downstream of Vanderkloof Dam, primarily due to the hydropower releases from these dams, has a negative impact on the biodiversity of the river. Furthermore, there are limited options for changes to the flows as well. Therefore, one of the considerations was to consider this as part of the Reserve and aim to influence the release curve for the Gariep Dam developed annually for hydropower and downstream demands. However, it was rather suggested and approved by DWS that the most feasible option was to optimise releases by developing a conceptual Flow Management Plan (FMP) which will seek to achieve a sensitivity and setting of achievable EWRs. Information for this was drawn from and informed by the ORASECOM recently conducted Joint Basin Survey (JBS3) and accompanied Aquatic Ecosystem health (AEH) Report. The recommendations will be taken forward into the Classification process newly initiated. The ultimate goal will be for the FMP to be written into conditions once the Reserve is gazetted, to ensure the rules become compulsory.

4.4 Health hazard due to poor water quality

Dysfunctional WWTW was noted to be a systemic issue throughout this catchment area. This was even more so noted during the river surveys. The discharge of untreated sewage into certain river systems, notably the Upper Modder, Klein Modder, and Renosterspruit Rivers, presented substantial health risks to the specialist team and DWS colleagues whilst on site during the field surveys, not to mention the impacts this is having on the receiving aquatic ecosystem. Raw sewage carries a dangerous mix of pathogens, including bacteria, viruses, and parasites, which can lead to various waterborne illnesses such as cholera, typhoid fever, and gastroenteritis.

4.5 Approaches

Lastly, it is important to reiterate that the Groundwater Resource Directed Measures (GRDM) methodology is currently being updated and will only be available in 2024. As the project end date for this study is March 2024, the current groundwater assessment was therefore based on WRC (2012) methodology.

4.6 Meeting fatigue

To some extent, there seemed to be fatigue among the key stakeholders and DWS colleagues, especially noticeable during the online PSC3 meeting on 14 February 2024, a concern also noted by the Chief Director, Ms. Ndileka Mohapi. There were few questions and discussions. The constant stream of meetings may have caused attendees to feel overwhelmed. Finding a balance, prioritising essential meetings, ensuring the PMC meetings are more focused on project progress, next steps and financial management, and the PSC meetings focused on the technical feedback, can help prevent this fatigue and ensure that meetings are productive and meaningful.

5. INSIGHTS GAINED, CHALLENGES FACED AND STRATEGIES EMPLOYED TO OVERCOME THEM

The main challenges experienced during the study are summarised in **Table 5-1** below, coupled with strategies employed in order to overcome some of these challenges. In addition, some insighted gained/lessons learnt are further included within the table.

Table 5-1: Insights gained, challenges faced and strategies employed to overcome them

Challenges / Lessons Learnt	Interventions where feasible
Rivers	
Limited gauging stations linked to EWR sites	Data from gauging stations was used where available and the confidence was indicated within the results.
River surveys, floods and higher baseflows than natural (i.e. during the July 2022 survey)	Unfortunately, this was due to the La Niña cycle experienced throughout this study period (i.e. when southern African summer rainfall regions experienced a generally wetter and cooler than normal wet season. This is the typical impact of a La Niña event). Therefore, the prevailing conditions were duly acknowledged, and all results were approached with caution, ensuring thorough and appropriate interpretation.
Both river surveys were undertaken during the dry period, opposed to one post-wet and one dry season. It must be noted that the baseflows during the dry season surveys were extremely high due to late rainfall in the catchment.	The team ensured that two (2) river surveys were undertaken, keeping in mind they were scientifically sound and safe. Therefore, the prevailing conditions were duly acknowledged, and all results were approached with caution, ensuring thorough and appropriate interpretation.
DWS officials accompanying various water resource surveys and correct equipment.	Although DWS officials displayed enthusiasm by participating in all water resource surveys, their frustrations stemmed from the absence of a suitable vehicle, specifically a 4x4, for navigating rough gravel and muddy roads during site visits. This limitation constrained their ability to attend sites and hindered their ongoing learning experiences.
Limited or lack of water quality data (for all water resources) for prioritised RUs.	Information from other sources (namely, the JBS3 – Upper Orange catchment) was utilised to evaluate the present condition of water quality in the research area. Additionally, diatom samples were collected at EWR sites and strategically chosen field verification sites,

Challenges / Lessons Learnt	Interventions where feasible
	as they serve as effective bioindicators of water quality. The selection of field verification sites was carefully done to ensure that the obtained diatom samples could yield water quality insights for those systems and their impact on downstream systems.
Limitations around the Fish Invertebrate Flow Habitat Assessment Model (FIFHA) should be noted. The FIFHA model was developed to enable rapid monitoring of water levels related to critical habitats and instream biota requirements through the use of HABFLO and hydrology. The model does not account for increased flows or where water quality impacts are driving the system. However, the FIFHA was specifically prescribed in the Terms of Reference for this study and was consequently employed for modelling the scenarios for Intermediate EWR sites. Owing to the above, certain EWR sites such as the Seekoei (seasonal to ephemeral) , Upper Modder (very high baseflows, water quality driving the site), and Lower Orange River (constant baseflows), the FIFHA model did not yield accurate results.	For such sites where the FIFHA did not yield accurate results, the team reverted to fundamental principles and incorporated additional metrics into their interpretations, based on available data and expert knowledge integration, namely, taking into account increased flows, siltation, erosion, incision, and/or limited habitat availability. Thus, the FIFHA was used as a “stop-gap’ approach. Owing to these constraints, it is recommended that the model be reviewed, to continue its use in the future.
Wetlands	
Gaps in the national wetland coverage for the middle to southern reaches of the Free State.	The specialist team combined all existing and relevant wetland shapefiles into a consolidated and updated wetland shapefile. Furthermore, a specialist wetland workshop was held with SANBI, DWS, Northern Cape Wetland Forum, Working for Wetlands representatives and various other wetland specialists for further input/support to address this challenge in the wetland component gaps.

Challenges / Lessons Learnt	Interventions where feasible
A wetland Decision Support system (DSS) was developed for the purpose of this study to assess which wetlands within the prioritised wetland RUs would require EWR quantification. Following the assessment, none of the 12 wetland RUs were identified to require EWR quantification. As such, ecological specifications were set for all wetland RUs. Consequently, it will be these EcoSpecs which can be incorporated into Water Use License (WUL) conditions to allow for monitoring and auditing of the condition of the resources.	It will be important that the developed wetland DSS approach be revised during the Classification study of the Upper Orange catchment area, for validity of the results and where the determined EcoSpecs can support development the wetland Resource Quality Objectives.
Groundwater	
The Groundwater Resource Directed Measures (GRDM) methodology is currently being updated and will only be available in 2024.	The current assessment was based on WRC (2012) methodology and noted as such in the Groundwater Report.
Major gaps in any groundwater data.	DWS intervened and assisted the PSP in trying to contact the municipalities, etc. monthly feedback meetings were had with DWS. Unfortunately, it was accepted of this gap and thus this major limitation was listed in the report. It is recommended that during the Classification study for the Upper Orange catchment area, additional hydrocensus surveys be conducted in order to acquire the necessary data. This is prompted by this significant deficiency in groundwater data within this catchment area, compounded by the unreliable nature of municipalities in both collecting and sharing any relevant data for the purpose of these studies.

Challenges / Lessons Learnt	Interventions where feasible
Socio-economics	
The Basic Human Needs (BHN) component needed to make use of the StatsSA out-dated census data (i.e. 2011) as the update to the census data was being conducted during the course of this study, with the MetaData only being released in March/April 2024.	The BHN Report was finalised with the 2011 StatsSA census data.
Integration component	
The study area encompasses both surface and groundwater systems characterised by significant variability in quantity and quality, leading to intricate aquatic ecosystems. The distribution of surface water in these systems is fragmented, making it challenging to formulate straightforward Reserve recommendations or implement effective water resource management.	To address this complexity, the management of these water resources necessitated robust data collection to inform decision-making and the application of operational rules. Achieving this goal also required a cohesive integration of various disciplines.
No existing information or processed data available for the integration of the various components. Some partial integration between components has been undertaken as part of previous Reserve studies	A specific area was selected where the integration of rivers, wetlands and groundwater components were undertaken and where the focus would be on. From a specialist workshop, it was proposed that the Kraai River catchment was used as it also forms part of the Strategic Water Source Area. A proposed methodology was developed, which DWS approved and thus can further be adapted moving into the Classification phase of the Upper Orange catchment area. However, there is a need for better modelling of groundwater contribution to surface water flow. Better water resource protection methods and modelling of flow for groundwater-dependent ecosystems are required. The inability of hydrological models to include groundwater contributions in groundwater-dependent ecosystems is a major shortcoming, and should be assessed during the Classification study of the Upper Orange catchment area.

Challenges / Lessons Learnt	Interventions where feasible
Stakeholder Engagement	
Attendance of stakeholders in-person was poor.	The initial stakeholder engagement meeting was initially planned as an in-person/hybrid event however, stakeholders expressed a preference for the online platform. Similarly, the intention for the second Project Steering Committee Meeting was to have a hybrid format, but it had to be shifted to a virtual setting due to low attendance.
Water resource protection needs to be prioritised in this catchment area	
Water resource management in the area is still focused on water users. DWS must take a much stronger stance when it comes to water quality in this catchment area.	Please refer to the dedicated **Chapter 5.1** with a major focused on water quality, a major learning within this study for both the PSP and DWS.
Empowerment of local water resource management (water use, allocation and water quality).	Effective water use and resource protection in this area depend on leadership, champions, and robust communication within communities, fostering harmony. The localised management of water resources is crucial for effectiveness, but this relies on establishing trust in those overseeing the resources. The DWS must play a moderating role in collaboration with leaders and WUL applications. Strengthening communication of data outcomes is vital to enhance trust. The process of establishing a Catchment Management Agency and expediting WUL applications for the area is imperative.
Overall	
The enthusiasm of all DWS Head Office and Regional Offices who took part in the wetland, hydrocensus and both river surveys was outstanding and the PSP team thank DWS for their support, assistance and knowledge sharing through these events.	

Challenges / Lessons Learnt	Interventions where feasible
No health and safety incidents were reported following any of the field surveys. It is essential to continue good health and safety standards and procedures when conducting such projects going forward.	However, future sampling of the Upper Modder, Klein Modder or Renosterspruit Rivers, should be undertaken with caution due to the raw sewage in the systems.

5.1 WATER QUALITY IN THE UPPER ORANGE CATCHMENT: THE ULTIMATE DRIVER OF CATCHMENT

It is evident that deteriorated water quality was the driving factor affecting the ecological condition at the sites on most of the streams and rivers in the Upper Orange catchment area. The source of this problem is primarily related to nutrient overload, originating from the various Wastewater Treatment Works (WWTWs) and agricultural runoff associated with the towns and cultivation in the catchment. Most WWTW in the catchment are either unmaintained, dysfunctional, or run over-capacity; a problem across most of South Africa (with more detailed information and data within the Scenario and Consequences Report (Report No. RDM/WMA13/00/CON/COMP/1423).

Only 35 of the 73 WWTWs in the Upper Orange River catchment had data on the volume of wastewater treated per day. The total volume of wastewater according to these 35 was ~194 million L/day. Assuming the volume from the remaining 38 WWTW has a roughly similar value, one can broadly assume that the WWTW in the catchment are discharging ~390 million L/day into rivers in the catchment. As noted for several WWTW, this value does not account for the large volumes of wastewater not reaching WWTW where the volume they are processing has decreased between 2013 and 2021, or where they operate well-below capacity[1]. The volume of wastewater (including a huge portion that is only partially, or wholly untreated) entering the rivers can therefore be safely assumed to exceed ~400 million L/day in the Upper Orange River catchment. Considering the amount of missing data for discharge, it is problematic to calculate exactly how the sewage releases contribute to the baseflows at a given site. However, considering the wastewater discharge is equivalent to at least 160 Olympic sized swimming pools per day entering rivers in the catchment, one can be sure that there is a significant contribution of wastewater to baseflows, especially during the drier months. For reference, 400 million L/day is equivalent to a discharge rate of 4.63 cubic meters per second (m^3/s), a discharge rate approximately four times (~4x) higher than the modelled natural low flows in July for the Lower Riet site (UO_EWR09_I). This shows how much potential WWTW discharge in the catchment has for contributing to the baseflows in the dry months.

There were comparable data on WWTW discharge rates between 2013 and 2021 for 27 of the WWTW in the catchment. Of these, eight reported decreases in the volume of wastewater treated daily, totalling 5.44 million litres per day less than in 2013. As mentioned above, this is despite the fact that population, urbanisation, and water access trends are consistently upward in South Africa, suggesting that the amount of water being treated should steadily increase over time. Therefore, it is likely that this wastewater, and considerably more, is still being generated but not reaching the WWTW. Consequently, it can be assumed that it is discharging, untreated and unaccounted for, into freshwater systems throughout the catchment, thus compromising water quality throughout.

The GD scores in 2021 also illustrate the dire wastewater situation in the catchment, and by association the serious water quality issues within the catchment. A total of 26 WWTW, out of the 73, were critically failing and dysfunctional (GD score <31 %), with another 12 very close

[1] https://www.dailymaverick.co.za/article/2023-08-10-millions-of-litres-of-poo-a-day-never-even-reach-sas-failing-underserviced-sewage-plants/

(GD score < 36 %). The lack of data on discharge (or any data at all in some instances) is also concerning (38 WWTW (52 %) did not have data on the daily volume treated in 2021), since discharge rates from WWTW are a critical component of their performance and impact on the receiving system.

In support of the above, a letter notification to DWS was submitted, of which was included within the Scenario and Consequences Report (Report No. RDM/WMA13/00/CON/COMP/1423). This communication pertains to a non-operational WWTW and its connected infrastructure, which, in the past and potentially still today, has been discharging significant volumes of untreated sewage into the natural environment. This discharge has caused, and continues to cause, a considerable decline in the water quality of the receiving system. This degradation directly impacts the Caledon River, a vital tributary of the Orange River, which serves as a critical water source for agricultural, industrial, and domestic use, both for commercial and subsistence purposes. It is essential to recognise that this issue is systemic, extending throughout the Upper Orange catchment area, as elaborated above.

Overall, the degradation of water quality in this catchment area is alarming and ultimately, our river ecosystem is in danger of failing with a loss of biodiversity and ecosystem services, i.e. thus potentially moving into an E or E/F ecological category. It is the mandate and responsibility of DWS to ensure enforcement and accountability within the municipalities that are responsible for these WWTWs (National Water Act, 1998). DWS investigations into this issue are essential to improve and regulate the water quality issues this catchment faces. Management of the water quality status must be regarded as an urgent issue. The current conditions are disastrous for the environment, human needs, the functionality of ecosystem services, and from a health perspective. If not addressed effectively, the current conditions will continue and worsen, resulting in the non-attainment of the REC for the EWR sites.

6. BENEFIT TO THE CLIENT

- A better understanding of the problems and issues impacting on the water resources of the Upper Orange;
- The surface water and groundwater Reserve templates have been drafted and ready to be taken forward into the Classification study of the Upper Orange;
- Buy-in with sector and stakeholder groups have been achieved to the greater extent through the stakeholder engagement initiatives.
- Department personnel have derived benefit from the process and activities undertaken as part of this study and have a better understanding of the approaches and steps that need to be undertaken for a high confidence Reserve study;
- Linkages and alignment with other studies and initiatives have been and will continue to be achieved. For instance, linkages with the data collected from this study from a surface water perspective will contribute greatly to the current update to the PES-EIS study currently being undertaken);
- Letters addressing the deteriorating water quality in significant systems such as the Middle Caledon (Groot/Brandwater) and Sterkspruit, which were submitted to the DWS have raised awareness. It is incumbent upon the DWS to assert its mandate and ensure accountability within the municipalities overseeing these WWTWs. Conducting thorough investigations into this matter is imperative for the Department to enhance regulatory measures and address the water quality challenges in this catchment area. This will ultimately improve the state of the water resources in the Upper Orange catchment area.

Following last communications from DWS, a directive was issued to the municipality in question and further investigations will be undertaken; and
- Ongoing capacity building was undertaken as part of this study. Capacity building and knowledge transfer for DWS officials and stakeholders was done at key points in the study through forums namely specialist workshops, meetings and field surveys.

The nature of the capacity building was that of presentations, discussions of approaches and processes and interactive discussions. Capacity building milestones included:

- *Technical workshops*
  - Resource unit prioritisation workshop;
  - Wetland technical workshop / meeting; and
  - Ecological Water Requirements workshop.
- *Capacity building / Training*
  - Resource unit prioritisation approach for all water resources;
  - Wetland and groundwater resource units;
  - Site selection for all water resources;
  - River eco-categorisation (EcoStatus tools);
  - Scenario and consequences; and
  - Holistic overview of the Reserve determination process for the Upper Orange.
- *Mentorship*
  - Wetland survey;
  - Hydrocensus; and
  - 2 x river surveys.

7. EXTERNAL REVIEWER: OPINION, RECOMMENDATIONS AND SUGGESTIONS

This Report contains a complete and effective overview of the project. Dr Neels Kleynhans, the studies external reviewer, has provided a summary of his views and recommendations and which are listed in **Table 7-1** below.

Table 7-1: External reveiewer views and recommendations following the ocmpletion of the Upper Orange Reserve determination

Topic	External reviewers' views/recommendations
Project Management	The subject Reports reflect effective and professional management. Environmental conditions during the project (weather conditions and water quality conditions, etc.) seriously hampered field surveys throughout the course of the project. Nevertheless, by adaptive planning and communication with the client (DWS), the team were able to successfully negate these restrictions.
Historical physico-chemical data	A major problem was a scarcity of water quality data at the various sampling sites. This was compensated for using SASS5 data and by sampling diatoms and interpreting data according to established indices and the association of various taxa/species with water quality conditions. However, it is important that the DWS solve problems with sampling and analysis of water samples.

Topic	External reviewers' views/recommendations
River Ecostatus Monitoring Programme (REMP)sites	Similarly, monitoring of the REMP sites (previously RHP sites) could potentially also have added information on instream biota and riparian conditions if monitoring by DWS were done regularly. The utility of the various EcoStatus indices would also have vastly improved if REMP sites were sampled regularly. It follows that serious attention should be given by DWS to reviving the REMP and for sampling to happen regularly.
The Habitat Flow Stressor Response (HFSR) index	This index was successfully applied to the Intermediate EWR sites using hydrological data and hydraulic information (HABFLO model). The HFSR information is expected to provide an important basis for future monitoring and data interpretation, including the Classification System and Resource Quality Objectives (RQOs).
Fish Invertebrate Flow Habitat Assessment (FIFHA)	The FIFHA was used to obtain e-flow information and assess the consequences of the instream biota for all EWR sites. However, as was correctly pointed out in the Scenario and Consequence Report deliverable, this method was developed for monitoring at suitable sites, i.e., where habitats are available for rheophilic fish species and macroinvertebrate taxa, or where rheophilics require fast flowing water during certain life stages. The successful application of the FIFHA comes down to the presence of suitable velocity-depth classes for rheophilics or semi-rheophilic organisms. If these habitats and rheophilic or semi-rheophilics are scarce or absent, the FIFHA will not be very useful.
	Furthermore, the FIFHA was not designed to assess flow and physico-chemical interactions. The approach followed by the team to use available information and expert knowledge to derive the flow and physico-chemical interaction was justified given the situation. However, setting of RQOs and monitoring will eventually require more quantitative information. It follows that the comment of the team that the FIFHA needs more development to be applied under data limited conditions is supported and should receive consideration by DWS. Lastly, it can be useful to also focus on the Revised Desktop Reserve Model (RDRM) in data scarce situations (Tanner *et al.,* 2020).
EcoStatus indices	The results from Ecostatus Indices, viz, FRAI, MIRAI and VEGRAI must be considered as hypotheses that needs to be tested and refined when new information becomes available. This can only be achieved if monitoring is done regularly and by following an adaptive management approach. In this context, it also becomes necessary to consider adapted versions of the Indices that are shaped according to the capacity of resource management agencies; an adapted version of the FRAI was developed recently and needs consideration for future monitoring activities, and to further be used in the Classification study.

Topic	External reviewers' views/recommendations
Water quality concerns and mismanagement	A situation of extreme concern that came out of the study is the current mismanagement of the system due to disposal of raw sewage from dysfunctional and overloaded WWTWs. This is a key problem that must be addressed and rectified, before setting of EWRs, would make any sense. It defies all logic to develop sophisticated methods and models and try to implement EWRs if fundamental management of key issues is not happening. Currently, this problem poses an extreme danger to both human and river health and resource protection.
Conceptual Flow Management Plan (FMP)	Development of a conceptual FMP for the Orange River between Gariep and Vanderkloof Dam is an important starting point to deal with artificial flow releases and downstream environmental degradation.
Decision Support System (DSS) - wetlands	The development of a DSS for assess which priority wetlands require EWR quantification was very useful and an important step to properly manage the water resources and further development should be supported.
Integration tool	The approach and method defined and adapted from Serov *et al.* (2012) and Colvin *et al.* (2002) to assess the interactions between surface water (wetlands and rivers) and groundwater was a very important step to properly manage water resources and further development should be supported.

In conclusion, it is very evident from the Reports that was reviewed that all team members were very proficient and professional in their approach and presentation of information. The Reports attest to proper data preparation and presentation, i.e., the text, tables, figures, maps and photographs. Similarly, the management of the study and adaptation to unpredictable events was very professional. This is reflected by the fact that the study was done within the approved budget and time.

8. STUDY FINANCES

The total project budget was R 6 560 802.60 (inclusive of VAT). Please refer to the **Table 8-1** for the project cash flow that was followed through the study, along with the expenditure and **Figure 8-1** for the graphical illustration. This was illustrated in every monthly and/or quarterly progress report during the study.

The contract went through four (4) addendums, due to the continual flooding of the system and having to postpone the river surveys on two (2) occasions, which resulted in the revision of the rest of the project deliverables. This was initiated through motivational letters and meetings with DWS, which included the motivation and proposed revised timeframes. Once approved, the addendums were received and signed, for the project to continue.

Initially, the end date for this study was July 2023, however following the above, the due date was subsequently revised to March 2024, and successfully completed in that revised timeframe.

Table 8-1: Expenditure and cashflow for the Upper Orange Reserve determination for all water resources

WP11343: A High Confidence Reserve Determination Study for Surface Water, Groundwater and Wetlands in the Upper Orange										
CASHFLOW PROJECTION										
Contract No.	Deliverable	CASH FLOW PROJECTIONS					ACTUAL EXPENDITURE PER QUARTER (incl. VAT)			Invoice Status
		Invoice	Month	Month of approval	Proposed Projected Expenditure (incl. VAT)	Cumulative Projected Expenditure (incl. disbursements if applicable)	Invoiced (excl. VAT)	Invoiced (incl. VAT)	Culumulative invoiced	
4.3.1	Information and data gathering, Inception report	1	Sep-21	Oct-21	R500 974.14	R500 974.14	R403 415.00	R463 927.25	R463 927.25	PAID
4.3.2	Gap analysis and report	2	Nov-21	Dec-21	R444 031.14	R945 005.28	R365 303.24	R418 357.64	R882 284.89	PAID
4.3.15	Stakeholder database and plan	3	Nov-21	Dec-21	R102 326.40	R1 047 331.68	R88 979.48	R102 326.40	R984 611.29	PAID
4.3.3	Resource Units Report	4	Jan-22	Feb-22	R238 411.62	R1 285 743.30	R195 151.65	R224 424.40	R1 209 035.69	PAID
4.3.16	Stakeholders comments & response register (round 1)	17	May-22	Jun-22	R196 355.31	R1 482 098.61	R166 468.66	R191 438.96	R1 400 474.65	PAID
4.3.11	Wetland survey report	6	May-22	Jun-22	R178 626.60	R1 660 725.21	R155 327.48	R178 626.60	R1 579 101.25	PAID
4.3.9	Groundwater survey report	7	May-22	Jul-22	R155 040.00	R1 815 765.21	R134 817.39	R155 040.00	R1 734 141.25	PAID
4.3.4	River survey 1 report	8	Aug-22	Sep-22	R455 074.32	R2 270 839.53	R395 716.80	R455 074.32	R2 189 215.57	PAID
4.3.13	BHN report	12	Oct-22	Oct-22	R107 072.22	R2 377 911.75	R93 106.28	R107 072.22	R2 296 287.79	PAID
4.3.12	Wetland report	10	Oct-22	Nov-22	R222 142.68	R2 600 054.43	R193 167.55	R222 142.68	R2 518 430.47	PAID
4.3.10	Groundwater report	13	Jan-23	Feb-23	R470 960.22	R3 071 014.65	R409 530.63	R470 960.22	R2 989 390.69	PAID
4.3.14	Socio-economics report	15	Apr'23	May'23	R92 005.98	R3 163 020.63	R80 005.20	R92 005.98	R3 081 396.67	PAID
4.3.5	River survey 2 report	5	Jun'23	Jul'23	R658 443.48	R3 821 464.11	R572 559.55	R658 443.48	R3 739 840.15	PAID
4.3.6	Ecocategorisation report	9	Sep'23	Oct'23	R441 320.22	R4 262 784.33	R383 756.71	R441 320.22	R4 181 160.37	PAID
4.3.7	EWR quantification report	11	Oct'23	Nov'23	R648 230.22	R4 911 014.55	R563 678.45	R648 230.22	R4 829 390.59	PAID
4.3.8	Ecological consequences of scenarios Report	14	Dec'23	Jan'24	R702 494.22	R5 613 508.77	R610 864.54	R702 494.22	R5 531 884.81	PAID
4.3.17	Ecospecs and monitoring plan	16	Dec'23	Jan'24	R244 328.22	R5 857 836.99	R212 459.32	R244 328.22	R5 776 213.03	PAID
4.3.16	Stakeholders comments & response register (round 2)	22	Jan'24	Feb'24	R196 355.31	R6 054 192.30	R170 743.75	R196 355.31	R5 972 568.34	MID-MARCH 2024
4.3.18	Reserve template preparation	18	Feb'24	Mar'24	R102 098.40	R6 156 290.70	R88 781.22	R102 098.40	R6 074 666.74	SUBMITTED
4.3.19	Capacity building report	19	Feb'24	Mar'24	R65 244.48	R6 221 535.18	R56 734.33	R65 244.48	R6 139 911.22	SUBMITTED
4.3.20	Final Integrated Main report	20	Mar'24	Apr'24	R255 591.42	R6 477 126.60	R222 253.41	R255 591.42	R6 395 502.64	SUBMITTED
4.3.21	Close-out report, incl external reviewer report	21	Mar'24	Apr'24	R83 676.00	R6 560 802.60	R72 761.74	R83 676.00	R6 479 178.64	SUBMITTED
					R6 560 802.60					
	All components	Wetlands								
	Rivers	Socio-economics								
	Groundwater	Stakeholder engagement								

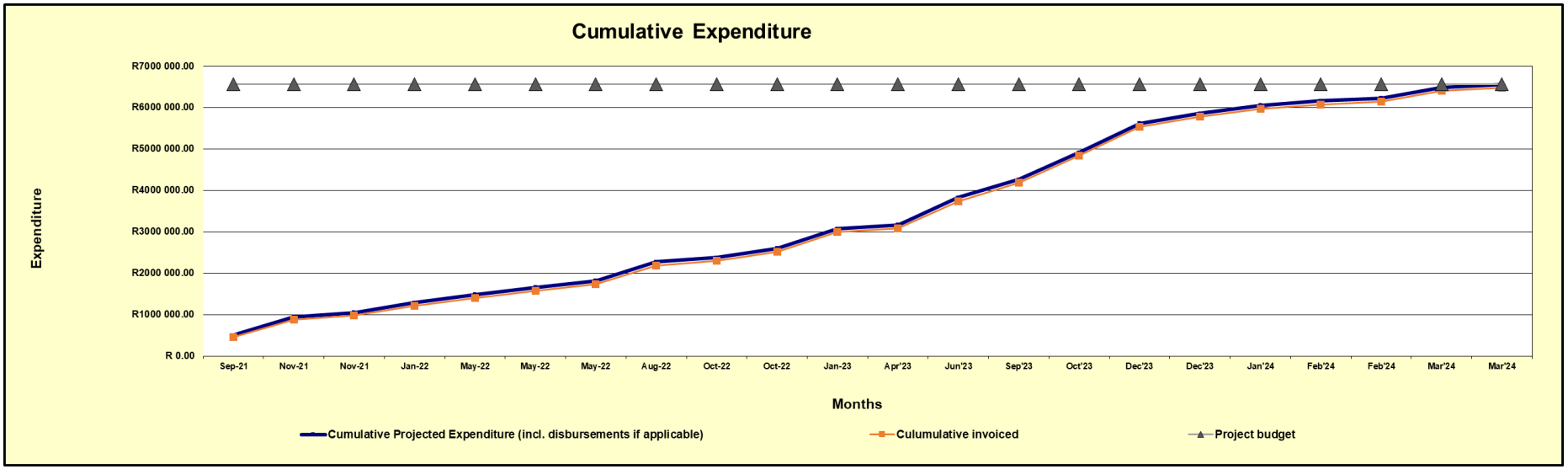

Figure 8-1 : Cash flow

9. CONCLUSION

In August 2021, the Chief Directorate: Water Ecosystems Management of the DWS initiated the high confidence Reserve determination for the Upper Orange catchment area.

The primary objective of this study was to coordinate the Reserve determination of the Upper Orange catchment and in so doing, design an appropriate Reserve template, with ecological specifications and a monitoring programme, for presentation to the Minister. The project approach and methodology that was applied was in accordance with the 8-step process as outlined in Regulation 810 (Government Gazette 33541) dated 17 September 2010, as well as The Reserve determination process as outlined in the study, 'Development of Procedures to operationalise Resource Directed Measures (DWS, 2017). However, it must be noted that this study excluded the gazetting of the Reserve (step 8), as the classification study had not been initiated at the time of this study and thus the water resource classes had not been determined.

The Upper Orange Catchment area, which forms part of the Orange WMA6 in South Africa, encompasses the Orange River and its major tributaries being the Caledon, Kraai, Seekoei and further included the Modder-Riet (main tributaries of the Vaal River system) in the north).

The milestones set as part of the contract were delivered on time and within budget. The study identified and surveyed 10 Intermediate and six Rapid level 3 EWR sites, along with 25 additional field verification sites. The assessment involved determining the PES, deriving the REC, quantifying EWRs, determining operational scenarios, and evaluating ecological and socio-economic consequences. Wetlands and groundwater were also prioritized, with EcoSpecs assigned for effective monitoring. However, the study faced challenges due to a lack of historical and current water quality data, affecting confidence levels in the results.

Despite limitations, the team is confident that the water quality EcoSpecs outlined for all water resources will maintain or enhance water quality. Monitoring programs aligned with adaptive management principles are recommended, ensuring adjustments to practices if EcoSpecs are not met. These EcoSpecs will contribute to RQOs in the ongoing Classification study, aiming to ensure the maintenance or improvement of the state of the water resources in the Upper Orange catchment area.

The study further incorporated two additional elements: a conceptual FMP for the areas between Gariep and Vanderkloof dams, and downstream of the latter dam, and a novel concept designed to evaluate the synergy between surface and groundwater resources, focusing on the Kraai River. This concept is suggested to be further developed and integrated into the ongoing Classification study, aiming for improvements and updates in GIS data to indicate the likelihood of groundwater or surface water dependency.

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11. APPENDICES

Appendix A: Comments and Response Register

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
DRAFT INCEPTION REPORT					
1	5.7, Table 5-1	The PSP should send a capacity building table to everyone involved in Capacity Building so that they can indicate which training/topic they are interested in attending.	Tinyiko Mpete	27 September 2021	Noted. The Capacity Building table 5.1 will be sent through to Ndivhuwo to circulate to the team to add their names for finalisation. Thank you.
2	5.7, Table 5-1	Table 5.1 Correct the spelling to Preliminary in the title of the table.	Netshiendeulu Ndivhuwo	27 September 2021	Done. Thank you.
3	1	Capitalize Resource Directed Measures in Paragraph 1, line 5.	Netshiendeulu Ndivhuwo	27 September 2021	Done. Thank you.
4	5.7, Table 5-1	May you please add my name on capacity building of rivers and wetlands.	Makhwedzha Rendani	27 September 2021	Included. Thank you.
5	2.4	Hopefully, in addition to the WR (2021) latest data on groundwater use sourced from either Head Office or Regional Office WARMS would be considered in the *"Gap Analysis Report"*	Nzama Stanley	30 September 2021	Noted. The GW component will reply on the latest WARMS data going forward.
6	2.4, Table 2-9	The analysis and the map were produced based on the data for **UGEP_wet**. However, if one wants to be conservative which is the approach that has been	Nzama Stanley	30 September 2021	Thank you and this is a valid point. The WR, 2012 does not have the UGEP_Dry data.

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
		followed in the GRDM studies, the **UGEP_dry** data would have been used, and a different picture could have been drawn.			Please may we request this from the Department. Upon receipt this will be updated and included into the Gap Analysis Report.
7		Please rectify Page numbering from the **Introduction** to the page with **Figure 2.3**; and then continue from there with the correct numbers in the rest of the pages.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
8	Section 2,1	(Rivers), the sentence "….three ecoregions, namely the Eastern Escarpment Mountains, Nama Karoo and Highveld (Figure 2-2)"is not accurate because Ecoregions are not indicated in this Figure. Rather move Figure Reference to the 4 sub-areas mentioned or include Ecoregions on the map.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
9	Figure 2.4	The Legend can be questionable as it includes **"Estuarine Functional Zone** and **Estuarine Microsystems"** which are not applicable for this area.	Kwazikwakhe Majola	15 October 2021	Map updated
10	first sentence below Figure 2.5	"The Upper Orange WMA…"; please refer to 'Upper Orange catchment' instead if 'Upper Orange WMA' because the latter no longer "exists".	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
11	Page 10, Lines 4, 5, and 6-7	water management area'; please rectify.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
12	Figures 2.6 – 2.10	Upper_Orange_WMA; please rephrase to Study area instead, just like other Figures prior.	Kwazikwakhe Majola	15 October 2021	Map updated
13	Figures 2.6 – 2.10	The yellow insert SA WMAs maps depicts the old version of WMAs. Please rectify to the current version.	Kwazikwakhe Majola	15 October 2021	Map updated
14	Figure 3.1	I suppose the word after AEH is 'monitoring'….and not 'monitoring'	Kwazikwakhe Majola	15 October 2021	Figure title updated
15	Figure 3.2	suppose the word after JBS3 is 'monitoring'...?	Kwazikwakhe Majola	15 October 2021	Figure title updated
16	Page 32, Chapter 4, 2nd Paragraph	The Referenced item indicates *'ERROR! Reference source not found'*; please rectify.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
17	Page 37, 1st line of the Paragraph below Bullet points	"Refer to Sections 5.4 and ? for the wetland and groundwater component….."; please include the missing word/number where there is a question mark.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
18	Page 45, Bullet #2	Sub-bullet #2, "Table 5-1Error! Reference source not found". Please rectify.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
19	Current Page 45, Bullet #3	"….which will be trained upon during the workshops (Error! Reference source not found.)", Please rectify.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
20	Page 47, Last sentence above Table 5.1	"Refer to Table 5-1Error! Reference source not found. for the c capacity building opportunities and preliminary schedule." Please rectify.	Kwazikwakhe Majola	15 October 2021	Done. Thank you.
STAKEHOLDER ENGAGEMENT PLAN					
21	No serious comments/amendments				
GAP ANALYSIS REPORT					
22	Throughout and reference section	Amend all references and include all references	Dr Neels Kleynhans	7 December 2021	Done. Thank you.
23	Section 1.2	Explain "priority" rivers	Dr Neels Kleynhans	7 December 2021	Priority rivers are selected through the process of assessing water use impacts (quantity and quality) to determine the integrated water use index (IWUI) or water stress and (ii) integrated ecological index (IEI) that considers the PES and the ecological importance (EI) and ecological sensitivity (ES) of each sub-quaternary reach. Through the process, priority resource units are identified where ecological water requirements (EWR) need to be quantified.

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
24	Section 1.2	Explain high confidence study	Dr Neels Kleynhans	7 December 2021	High confidence study referring to a combination of different river level assessments, from desktop extrapolation to intermediate river approach assessments. Furthermore, a wider coverage of the catchment will be undertaken, not only the main stem Orange River, but inclusive of the smaller tributaries within the catchment. In addition, groundwater and wetland priority resources throughout the catchment and their interactions will be assessed.
25	Edits throughout document	Throughout document	Dr Neels Kleynhans	7 December 2021	Done. Thank you.
26	Section 4.2, Table 4.1	How this Seekoei going to be verified since there is no Coordinates	Tinyiko Mpete	13 December 2021	These co-ordinates are still trying to be located. Once this information is received, it will be verified.
27	Section 4.2, Table 4.1	Is this correct: “Cal_EWR2 - Rapid 3: 2021|	Tinyiko Mpete	13 December 2021	A Rapid 3 survey was conducted at site Cal_EWR2 in the middle of 2021 as part of a Lesotho study undertaken by GroundTruth. We will be

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
					asking the client permission as to whether we can utilise the data collected from that site for the purpose of this study. Thus no error in terms of "Rapid 3 – 2021" as per Tinyiko's comment.
28	Section 3.3	It would add value to also use the latest groundwater use (allocation) data from the Department's WARMS, maybe it can bring a different dynamic to identifying stressed catchments. I believe this data was forwarded to the PSP by Ndivhuwo already.	Kwazikwakhe Majola	14 December 2021	Thank you. The PSP has recently received updated WARMs data. I have include the following into the Gap Report: "It is important to add continuing on this study is that the received latest groundwater use (allocation) data from the Department's WARMS database will further be assessed to identify further stressed catchments".
29	Section 4.3, Table 4-2	Please define the difference between the gross and the nett catchment areas in the text in terms of this sub-chapter.	Kwazikwakhe Majola	14 December 2021	Defined in the report. Thank you.
RESOURCE UNITS REPORT					
30	Throughout	Review was focus on general aspects, but especially tried to look at clarity etc.	Dr Neels Kleynhans	9 February 2022	All grammar, sentence amendments and

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
					clarifications expanded within the report.
31	Chapter 3, section 3.1	The approach does not come through very clearly. Neels submitted supporting documentation in order to help guide the process of revising this chapter and approach.			The entire section 3.1 was revised and updated to ensure further clarity. The matrixes used for further explained and interpreted.
32	Section 4.2	Co-ordinates to be consistent throughout all reports			Table updated and consistency ensured
33	Section 3.3	This Section is lean on details when it comes to explaining the criteria followed. More explanation can be included for the sake of non-groundwater reader.	Kwazikwakhe Majola	18 February 2022	Chapter updated with more detailed approach.
34		How about the latest (2012/3) version?			WRC (2012) included
35		Please expand on “Sole source”			Bullet point updated to state where groundwater is used as the sole source of supply to communities
36		Please expand on “subterranean Government control areas”			Bullet point updated to state that these are protected groundwater areas as promulgated in the Water Act 54 of 1956
37		“other physical, management and/or functional criteria” such as?			An example of functional criteria is groundwater

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
					dependent ecosystems where groundwater plays a major role in sustaining wetlands and/or riparian vegetation. This has been updated in the report.
38		(point 2) >2.0l/s and borehole yields <2.0l/s: why was 2.0 l/s selected as a threshold?			These are generally regarded as median values for borehole yields as per DWS hydrogeological map series.
39		(point 4) Are there threshold volumes to this? In other words, if e.g., Recharge is 10 mm and the sum for these other attributes is 12 mm in one catchment, would the 'stressed catchment' status be the same with a catchment where the sum of attributes is 20 mm at Recharge of 10 mm?			The values are from 0Mm3 to -38Mm3. It is possible to have different levels of stress from low to very high.
40		(point 5) What informed this choice of a threshold; i.e. 20 mm/a was selected based on what?			
41	Chapter 4.3 – table 4-6	It will be helpful to also indicate in the Table the Quaternary Catchment(s) wherein these RUs are located.			Table updated with the requested quaternary catchments.
42	Chapter 5	Please define Strategic Water Source Areas			These are the legislated SWSA as per Lötter & Maitre, 2021. The reference has been included into the sentence.

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
43	Chapter 5, table 5-1	Is this the same as GW_RU01 of Table 4.6? This question is applicable to the rest of the numbers in this Table as well.			That is correct. I have updated the table 5-1 to reflect the formal GW RU numbers.
					Please note, updated maps under Figure 5-1 and Figure 5-2 included into the Final Report.
BASIC HUMAN NEEDS REPORT					
44	Chapter 4, Tables 4.1 and 4.2	When we determine our Reserves we present data in the format of table 2 highlighted in grey, I will appreciate if the data be presented in this format for surface Water Reserves.	Tinyiko Mpete	18 October 2022	The BHN specialist has separated the surface and groundwater BHN requirements into two separate tables and used the template provided. Regarding the decimal points, she has used 5 decimals (instead of the suggested 3, otherwise most of the quaternaries would be 0.000) for the surface water BHN. Please advise you are happy with this.
45	Chapter 3, Table 3.1	DWS indicated MCM	Tinyiko Mpete	18 October 2022	Converted to million cubic metres throughout and used MCM

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
46	Chapter 3, Table 3.1	Dr Neels Kleynhans recommended cu m or m3 in place of CM.	Dr Neels Kleynhans	18 October 2022	Converted to million cubic metres throughout and used MCM
WETLAND REPORT					
Limited comments					
GROUNDWATER REPORT					
47	Authors	Regan Rose to confirm if MN was included in tender docs as part of the project team	Kwazikwakhe Majola	16 December 2022	Regan has amended the report to reflect Andile Gumede who is part of the team.
48	Section 1.2	Refer to additional sources and include all references in the reference section of this report	Neels Kleynhans	3 January 2023	All relevant references have already been included
49	Figure 1 to Figure 4	Increase font size in all maps	Kwazikwakhe Majola	16 December 2022	All maps have been updated accordingly
50	Section 2	Produce an additional map showing boundary of the UO Catchment, GRU's and Quaternary catchments	Kylie Farrell	16 December 2022	An additional map showing this information has been included in the report
51	Section 3.2	Comment on GW-SW interaction and the presence of deep and shallow aquifers and their hydraulic conductivity	Kwazikwakhe Majola	16 December 2022	Lack of references to support this statement. Information pertaining to this has been

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
					excluded during this assessment and will be included in the forthcoming report
52	Section 5	Include stress index and the presence of a groundwater dependant ecosystem in the GRU tables (Table 2- Table 15)	Kwazikwakhe Majola	16 December 2022	Information pertaining to this has been excluded during this assessment and will updated with the latest water use data in the forthcoming report. Stress index (WR,2012) has been reported in a previous version
53	Throughout	Include quaternary catchment per GW monitoring site in Tables 2-Table 15	Kwazikwakhe Majola	16 December 2022	All tables have been updated with the relevant information
54	Throughout	Include comment on the origin of the site name vs the alternate name	Kwazikwakhe Majola	16 December 2022	All alternate names have been removed from the report
55	Figure 5 to Figure 18	Increase font size, include quaternary catchment and aquifer type	Kwazikwakhe Majola	16 December 2022	All maps have been updated as per the comment
56	Section 6.1	Comment on how mean recharge was obtained	Kwazikwakhe Majola	16 December 2022	This section has been updated accordingly
57		Define "Available for Recharge" vs "Mean Recharge"	Kwazikwakhe Majola	16 December 2022	The "available for recharge" section has been removed from this report and therefore no comment has been made on this definition

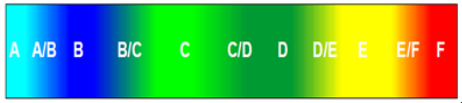
No.	Chapter No.	DWS comment	Contributor	Date	PSP response
58		Express the "Available for Recharge" and "Mean Recharge" in Mm3/a	Kylie Farrell	16 December 2022	A recharge table for each catchment has been included in Annexure B. Mean recharge has been expressed as required
59	Section 6.2	BHN section required detailed description	Kwazikwakhe Majola	16 December 2022	This section has been updated accordingly. Description of BHN provided as required
60	Section 6.3	Populate table showing groundwater contribution to baseflow per Quaternary Catchment	Kylie Farrell	16 December 2022	This section has been updated accordingly
61	Section 7	Various comments	Kwazikwakhe Majola	16 December 2022	This section has been updated accordingly
62	Section 8	Various comments	Kwazikwakhe Majola	16 December 2022	This section has been updated accordingly
63	Annexure A Graphs	Include on which river the surface water flow stations are located on maps	Kwazikwakhe Majola	16 December 2022	All maps have been updated to show on which rivers the flow stations are located
64	Annexure C	Clarify what population is listed on the table (Catchment or populations depending on BHN)	Kwazikwakhe Majola	16 December 2022	This section has been updated accordingly (Previous heading reworded)
65	Annexure E	1. Please also show Reserve estimation per GRU 2. Reserve consists of both groundwater quantity and quality:	Henry Maluleke	1 March 2023	

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
		• Please include the groundwater quality Reserve per quaternary catchment (Refer to the table below for an example of the DWS groundwater quality Reserve template including parameters and refer to the attached excel spreadsheet for example of groundwater quality Reserve estimation). • Please note that for quaternaries without water quality data, DWS usually extrapolates the data from the neighbouring a quaternary if the geology is similar. • Ambient Ground Water Quality is the Median value • Ground Water Quality Reserve is 10% of the Median Value • Basic Human Needs Reserve is the water quality standard for domestic use			
66	5.1	Include the groundwater quality Reserve per quaternary	Stanley Nzama	1 March 2023	This has been updated within the report.
67	Title of the study	Given the data limitations and the assumptions in this report can it be referred to as a high confidence or rather a high level	Luckson Machingambi	1 March 2023	According to the DWS ToR, this is a high confidence study.
68	General comment	Is the aquifer stress considered in the report, as an indication of which catchments are being over-used. This is usually shown by the decline in water level, reduced baseflow and deteriorating water quality.	Philani Khoza	1 March 2023	The aquifer stress and data from WR2012 was used to delineate the resource unit, this was mentioned in previous reports not in this report. However, the aquifer

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
					stress will be included into the Final Report.
69	1.1	GRDM Acronym to be stated in full	Luckson Machingambi	1 March 2023	Done
70	1.1	All 8 steps of GW Reserve determination to be listed	Luckson Machingambi	1 March 2023	Report updated with all 8 steps
71	1.1	BHN acronym to be added	Luckson Machingambi	1 March 2023	Insertion accepted
72	1.2	Information used should be under references	Luckson Machingambi	1 March 2023	Section has been left as is. This section does not need to be moved as the reports are listed in the references.
73	2	DEDTEA Acronym to be stated in full	Luckson Machingambi	1 March 2023	Acronym explained included
74	5	Heading does not inform the content	Luckson Machingambi	1 March 2023	Section updated with relevant information. Tables have not been moved as they show relevant information pertaining to the present status of each groundwater resource unit based on the monitoring point data.
75	6.1	ACRU Acronym to be stated in full	Luckson Machingambi	1 March 2023	Acronym explained included

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
76	6.1	Clarification on CMB Recharge method required	Luckson Machingambi	1 March 2023	Monthly data not required to determine reserve using CMB method
77	6.2	List the type of data that was used for Step 1 of the BHN assessment	Luckson Machingambi	1 March 2023	Updated noting that Census data was used
78	6.2	Reference to be included	Luckson Machingambi	1 March 2023	Reference removed
79	6.2	Review margins and pay attention to blank spaces	Luckson Machingambi	1 March 2023	Completed
80	6.3	Edit table reference error	Luckson Machingambi	1 March 2023	Updated with correct referencing.
81	7	Why wasn't SAWS data used	Luckson Machingambi	1 March 2023	SAWS data could not be obtained; Comes at a cost
82	Annexure A	Outliers on graphs during 1995/1996 are suspicious	Gonah Tichatonga	1 March 2023	Outliers are suspicious however this is as per the data that was received
83	Annexure B	How is the qualified guess value estimated	Gonah Tichatonga	1 March 2023	This has been explained in Section 6.1 of the report
WETLAND REPORT					

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
84	Report overall	Key consideration in overall water requirements, especially with reference to climate change and human requirements.	Dr Neels Kleynhans	6 March 2023	We will be doing a 'high' level climate change scenario as part of the ecological consequences, so will be able to interpret from a biotic perspective. In the SE baseline report, we have brought in anticipated climate change effects through the Arid Innovation Region, which identifies areas significantly vulnerable to future climate change trends (higher temperatures and less rainfall) - this could be overlaid with various water flow/quality scenarios to consider cumulative outcomes and possible consequences.
SOCIO-ECONOMIC REPORT					
85	Report overall	Is/could climate change be brought in as one of the scenarios? Are climate change impacts being considered in the hydrological modelling and ecosystem/biophysical assessments?	Dr Neels Kleynhans	6 March 2023	In the SE baseline report, we have brought in anticipated climate change effects through the Arid Innovation Region, which identifies areas significantly vulnerable to future climate change trends (higher temperatures and less rainfall) - this could be overlaid

No.	Chapter No.	DWS comment	Contributor	Date	PSP response
					with various water flow/quality scenarios to consider cumulative outcomes and possible consequences. Furthermore, the team will be doing a 'high' level climate change scenario as part of the ecological consequences, so will be able to interpret from a biotic perspective.
86	Table 3.1	Indicate working age?	Dr Neels Kleynhans	6 March 2023	Updated within the report
87	Table 4.8	Indicate the area of LMs	Dr Neels Kleynhans	6 March 2023	Updated within the report
ECOLOGICAL CATEGORISATION REPORT					
88	Throughout	"Change the colour for PES table, and use the colour code in the (RIVER ECOCLASSIFICATION: MANUAL FOR ECOSTATUS DETERMINATION (Version 2) Module A: EcoClassification and EcoStatus Determination, CJ Kleynhans & MD Louw TT 329/08)" 	Tinyiko Mpete	15 August 2023	Amended throughout the report

EWR QUANTIFICATION REPORT					
89	1.3	In the graphic on page it is referred to as Present Ecological Status. Is state and status interchangeable?	Luckson Machingambi	13 September 2023	It is Present Ecological State. We have ensured consistency.
90	Chapter 1.3	now Vaal-Orange?	Luckson Machingambi	13 September 2023	The WMA is formally Orange WMA. However, this study has brought in the Modder-Riet which forms part of the Vaal WMA.
91	Chapter 5.4	Clarity may be required here. This phrase may suggest that there is a bridge currently under construction. If it is an existing bridge (as Table 4-4 seems to suggest), it may have to be stated as such to remove unambiguity.	Luckson Machingambi	13 September 2023	Sentence amended to the following: *there is artificial substrate in the form of SIC which functions as a biotope for the macroinvertebrates. This artificial habitat is not natural, as this material was brought in for the purpose of a foundation for the existing bridge constructed many years ago.*
92	Chapter 5.4	What kind of specialists? Are these specifications or rather recommendations? S And should the specialists not be referenced?	Luckson Machingambi	13 September 2023	The flood requirements were specified by the specialist team (geomorphologist, riparian specialist) etc in a workshop forum for the study. Their names are included in the report upfront as contributors.

93	Throughout	Review consistency in spacing between digits and units when typing quantities in this report.	Luckson Machingambi	13 September 2023	Amended throughout.
94	Table 4-1	What is the name of site EWR 10. Please include the river name.	Tinyiko Mpete	13 September 2023	Lower Orange. Included in the report.
95	Table 4-1	What is the meaning of a dash?	Tinyiko Mpete	13 September 2023	The nomenclature of all EWR sites were UO_EWR (number)_I (for intermediate) or R (Rapid 3). We just used underscores as it was a neat and consistent.
96	Table 4-4	Please explain the meaning of dash. Does that mean there was no discharge?	Tinyiko Mpete	13 September 2023	The dashes are there for the Lower Riet as this site was not surveyed but rather data has been retrieved from the 2019 Vaal Comprehensive study (Vaal_EWR19) for this site for the purpose of this study.
97	Throughout the report	Various gramme amendments throughout	Dr Neels Kleynhans	14 September 2023	Amended throughout.
98	Table 4-1	Any information of how much Discharge (etc.) differs from the average for the season?	Dr Neels Kleynhans	14 September 2023	Report updated with the following: It should be noted that the discharges during both the surveys, especially the dry season surveys in July 2022 were much higher than expected (above average) due

					to increased baseflows as a result of continuous high rainfall throughout the previous summer and autumn.
99	Chapter 4.1	Hirschowitz PM, Birkhead AL, James CS – provide correct reference.	Dr Neels Kleynhans	14 September 2023	Corrected and included into references.
100	**Table 4-5**	Include catchment area sizes of EWR sites?	Dr Neels Kleynhans	14 September 2023	Updated in the report.
101	**Chapter 4.3**	Consider referring to an EWR assessment where DRIFT and BBM were combined in this way?)	Dr Neels Kleynhans	14 September 2023	Report updated with the following: The HFSR is based on the approach as developed by IWR S2S, 2004 and O'Keeffe et al., 2002 and is a modification of the Building Block Methodology (BBM) from King and Louw, 1998 and was used to determine the baseflows. The approach to set freshets and floods is a combination of the downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM and was used in a number of high confidence Reserve determination studies, including the intermediate

					study on the Mvoti, Umkomazi and Umngeni Rivers.
102	**Chapter 5.1 – 5.10**	Provide further motivation as the adjustments made to the DRM results in each chapter of the report.	Dr Neels Kleynhans	14 September 2023	A motivation was provided for those relevant sites as to the reasoning why the DRM results were adjusted from a biotic perspective (fish and macroinvertebrates).
103	**Chapter 7.4**	I think the geomorphic zone should also be looked at as supporting evidence for the extrapolating process.	Dr Neels Kleynhans	14 September 2023	This was assessed and included into the report where relevant.
104	**Chapter 8.2.4**	Are there any estimation of the life-expectancy of hydro-power generation from the two dams? Is it possible that in the (very) long term releases for irrigation may be the main purpose for the dams?	Dr Neels Kleynhans	14 September 2023	There is a large level of uncertainty here with respects to the long-term releases for irrigation and what that holds for the future. It is too uncertain to speculate.
SCENARIOS AND CONSEQUENCES REPORT					
105	**Chapter 1.1**	There is no estuary in the Upper Orange.	Tinyiko Mpete	23 November 2023	This sentence is relating to all Reserves throughout the country, not focused on the Upper Orange only. The subsequence paragraph relates to the Upper Orange and only mentions rivers, wetlands and groundwater.

106	**All hydrology graphs**	Colour for BF and SC4 is difficult to identify this colours, can you please use a different colour that will be visible/or change one colour between the two	Tinyiko Mpete	23 November 2023	The colour of the BF was changed to yellow. Thank you.
107	**Chapter 5**	Which one is Sc7 since figure 5-1, Table 5-2, 5-3 end at Sc6.	Tinyiko Mpete	23 November 2023	Scenario 7 is the present day with EWR for REC (Sc2) with progressive water quality decline. Those tables and figure 5-1 are only related to flow i.e. Sc1 – Sc6.
108	**Chapter 5.2.1.**	When running the HAI model, does riparian vegetation scoring taken into consideration? The reason for my question is that I see PES of HAI is C but riparian vegetation is E, please clarify.	Tinyiko Mpete	23 November 2023	The HAI model is for hydrology, while the VEGRAI is run for the riparian vegetation. The riparian vegetation takes into account flow/floods etc. Riparian vegetation came out as an E for this site owing to extensive alien invasive plants along the marginal riparian zone.
109	**Throughout**	Please re-reference all tables/figures as the document has become corrupted.	Tinyiko Mpete	23 November 2023	Thank you. This has been implemented throughout.
110	**Table 4-2**	Only a very general mention is made to information sources. This is not really proper literature references? Maybe only refer to the “reports indicated above”?	Dr Neels Kleynhans	22 November 2023	Amended.
111	**Chapter 5.1**	Provide context to the geomorphology	Dr Neels Kleynhans	22 November 2023	Sentence restricted and updated.

112	**Chapter 5.1.1.**	Simplify sentence “Refer to Appendix A for a reiteration as to the method in assessing the water quality in the Upper Orange catchment was undertaken, along with interpreting scenario 7 from a water quality perspective.”	Dr Neels Kleynhans	22 November 2023	Amended to “Refer to Appendix A for a summary of how the assessment of water quality in the Upper Orange catchment was conducted, including an analysis of scenario 7 from a water quality standpoint”.
113	**Chapter 5.1.4.**	See the short explanation attached to the email. If you revert to basic principles in problem cases, it is important to indicate how it was done, e.g., available data and knowledge integration (example).	Dr Neels Kleynhans	22 November 2023	FIFHA limitations amended following discussions with Neels.
114	**Chapter 5.1.6**	This whole approach needs to be elaborated on in an Appendix	Dr Neels Kleynhans	22 November 2023	We have tried to keep this approach (which is an adaptable approach) not to detailed as to not loose the readers/stakeholders. It was set in a way to be straight forward.
115	**Chapter 5.1.6. Step 4**	How? Diatoms, Inverts? Explain	Dr Neels Kleynhans	22 November 2023	Amended to “The category result for the biota with reference to Sc7 (water quality) was based on expert opinion through assessing the diatom results and the responses from the aquatic macroinvertebrate community, taking into consideration the PES of the overall water

					quality component. This will apply throughout the report“
116	**Chapter 5.1.6. Step 4**	Step 4 needs more explaining.	Dr Neels Kleynhans	22 November 2023	Amended to “The crucial factor determining the ranking of EWR sites in the ecosystem is their relative position and influence on simulated operations. This involves considering factors such as the location (upstream or downstream) in relation to WWTW or other developments, as well as the nature and extent of their influences on the EWR site. The hierarchy of these sites depends on their significance in the modelling context, which determines the primary driver EWR site for "releases" within the model. These key sites can either be the most downstream or have a higher REC (or PES) compared to others, resulting in a greater flow requirement and, consequently, higher ecological importance (DWS, 2014)”
117	**Chapter 5.2.2.**	Not entirely clear? Elaborate on the deficits.	Dr Neels Kleynhans	22 November 2023	Amended to “the deficits being the lower flows within the

					scenario compared to the quantified EWR flows to meet the REC)"
118	**Chapter 5.2.2.**	Too many ideas in one sentence. Restructure	Dr Neels Kleynhans	22 November 2023	Amended to "Since the aquatic macroinvertebrate community is already significantly altered due to poor water quality, it's logical to expect that any further decline and a severe compromise in water quality could lead to an increase in waterborne diseases. This would likely sustain the presence of highly tolerant macroinvertebrates thriving in conditions marked by very low water quality in this ecosystem in the future"
119	**Chapter 5.2.3.**	The dam expected to be filled by 2029 - This appears to be a fragment of a different thought?	Dr Neels Kleynhans	22 November 2023	The dam will take approximately 3 to 4 years to fill up, so predicted to be full by 2029. I have however restructured the sentence.
120	**Chapter 5.2.3.**	Very long sentence regarding Sc7 and macroinvertebrates	Dr Neels Kleynhans	22 November 2023	Amended to "Regarding Scenario 7, where a further decline in water quality is expected, it's pertinent to note that the existing state of the aquatic macroinvertebrate community is already

					moderately to largely modified and responsive to poor water quality. As mentioned earlier, it is logical to expect that the anticipated further deterioration and a critical compromise in water quality might lead to an increased prevalence of waterborne diseases. This, in turn, would perpetuate the presence of highly tolerant macroinvertebrates thriving in conditions characterized by very low water quality within this ecosystem in the future."
121	**Chapter 5.2.3.**	Due to impacts or naturally? – "restricted habitat availability"	Dr Neels Kleynhans	22 November 2023	Amended to "restricted habitat availability (not natural owing to dominance of alien invasive plants within the riparian zone and bank erosion/scouring)"
122	**Chapter 5.2.3.**	Scenario 7 - What about the resilience of the system to recover from extreme events; has it potentially been compromised?	Dr Neels Kleynhans	22 November 2023	This was the finding from the water quality specialists assessing the diatom data (2 rounds of data), inverts, location of the EWR site in relation to land use i.e. WWTW locations, agriculture etc. See approach and land use map in Appendix A.

123	**Throughout**	Restructuring sentences, making telegram style etc.	Dr Neels Kleynhans	22 November 2023	Amended where requested throughout.
124	**Chapter 5.2.10**	Why was a more appropriate taxon (or combination of flow-substrate (e.g., coarse fast) not selected)?	Dr Neels Kleynhans	22 November 2023	The FIFHA was rerun using the Leptophlebiidae. They are also a flow-dependent taxon, which show the greatest response for moderately-fast flowing water between 0.3 – 0.6m/s, over cobbles, but can tolerate >0.6m/s and in the habitats of gravel, sand, mud. Should flows fall below this target, this taxon will be absent from the macroinvertebrate community. They further have moderate requirement for unmodified physico-chemical conditions. The results however remain the same. This is due to the nature of this homogenous system and limited habitat. Also the cross-section was over only a sandy biotope.
125	**Chapter 6**	This is a very fine summary and conclusion. One could add that the river ecosystem is in danger of failing with a loss of biodiversity and ecosystem services, i.e. moving into an E or EF category	Dr Neels Kleynhans	22 November 2023	Thank you. This has been updated into the chapter.

126	**Appendix A**	Appendix A – Upper Modder beneath Wastewater: I think it is necessary that this misrepresentation be pointed out specifically to RDM.	Dr Neels Kleynhans	22 November 2023	Noted. DWS please take note.
127	**Throughout**	All percentile and flow tables – description on the orange/red highlights	Dr Neels Kleynhans	22 November 2023	This is stated upfront above the table "The 'red' highlighted areas in the tables indicate where the EWR could not be met (deficit – not enough water in the system to meet the EWR)."
128	All percentile and flow tables throughout	What about the baseflows	Dr Neels Kleynhans	22 November 2023	The following was included in the report: "It is crucial to note, and this applies across the report, that the tables below do not incorporate natural baseflows. Comparing them with other scenarios that encompass freshets/floods would be inappropriate. To gauge the baseflows, one can consider the 60th to 85th percentile as an indicative measure".
129	Chapter 7.4	I understand and agree with the concepts and principles indicated. However, I think it is worthwhile to also interpret the problem in terms sources and causes. A main part of the issue is about cheap energy generation necessary for the economy. Are there alternatives that could conceivably 'compete'	Dr Neels Kleynhans	22 November 2023	Please see update at the end of Chapter 7.

		with hydropower to at least reduce reliance on hydropower, e.g., solar etc.? and restrict releases to the more predictable requirements for agriculture in the medium-long term?			
ECOLOGICAL SPECIFICATIONS AND MONITORING PROGRAMME					
130	Chapter 5.1.6	Macroinvertebrate EcoSpecs and indicators?	Dr Neels Kleynhans	18 December November 2023	Each site has selected indicator taxa within the tables
131	Chapter 5.1.6	Restructure sentence	Dr Neels Kleynhans	18 December November 2023	Sentence has been restructured
132	Table 5-8	What does the grey 'ed out cells indicate	Dr Neels Kleynhans	18 December November 2023	It is indicated beneath Table 5-8 that the grey cells indicate the preferences of the macroinvertebrates to the velocity and substrate classes. This applies for all the matching tables throughout the report.
133	Chapter 7	A conceptual example of how this would look and how it would be applied would be useful? I am not sure if this License condition would be linked to streams and/ or groundwater impacts etc.	Dr Neels Kleynhans	18 December November 2023	The DSS will be assessed and outlined in more detail during the WRCS currently being undertaken, and which will further include management options for implementation.
	Table 6-1	It would be useful if reference is made within the report of the aquatic ecological monitoring done by DWS (e.g., REMP), other Departments and	Dr Neels Kleynhans	18 December November 2023	Chapter 3.3 has been updated and includes a paragraph of

		Provinces; the main objectives of this monitoring may differ but there are useful links that should be exploited for information, etc.			the NAEHMP and in particular the REMP. Furthermore, within the EcoSpecs tables for macroinvertebrates. It does mention whether the indicator taxa were recorded during these other monitoring events. Furthermore, an additional line item has been added to Table 6-1 including a table where the UO EWR sites align with the DWS REMP, JBS and SanParks to ensure data is shared.
134	Table 6-1	Different types of monitoring should be indicated, e.g., compliance monitoring, EcoSpec monitoring, etc.	Dr Neels Kleynhans	18 December November 2023	Monitoring and management measures have now been included into separate tables for rivers and wetlands.
135	Table 6-1	It is evident in the report that a clear distinction should be made between monitoring and management plans as well as the development of decision support systems (DSS; where actionable responses to monitoring results can be addressed). In some sections of the document, no distinction is made between a monitoring and management plan. Overall it would be useful if the sequence of events and links between these be pointed out to provide the correct context of the ecological monitoring. This principle that the EcoSpecs are "precursors" for	Dr Neels Kleynhans	18 December November 2023	Comment as above. Furthermore, an illustration (Figure 3-1) has been included in the approach in Chapter 3-3 which shows the eight steps of the Ecological Reserve process with links to those pertaining to Eco-categorisation and monitoring.

		RQOs is indicated to some degree but should be emphasized.			
136	Table 6-1	The RHAM should be considered for Rapid sites (it forms part of the remnants of the REMP/RHP.	Dr Neels Kleynhans	18 December November 2023	The RHAM has been included as a sperate line item in the monitoring programme for all Rapid 3 sites.
137	Monitoring programme	In my view it is not feasible to develop a full-scale monitoring programme within the context of the total project. However, it is realistic to develop the concepts on which the monitoring should be conducted. This should be indicated in the report.	Dr Neels Kleynhans	18 December November 2023	I have included an independent chapter to the monitoring (Chapter 6).
138		Essentially, the concepts proposed on which the monitoring programme is based, should be seen as testable hypotheses that should be confirmed, adapted or rejected following monitoring. This is an important requirement within the context of an adaptable management (and monitoring) approach and should be emphasised within the report to provide the relevant context (cf. the relevant literature).	Dr Neels Kleynhans	18 December November 2023	I have included an independent chapter to the monitoring (Chapter 6). Here I have included the following paragraph: *"Thus, it is essential to recognise that the concepts presented in Table 6.1, Table 10 1 and Table 14-1, for all components underlying the monitoring program, should be regarded as testable hypotheses. These hypotheses must be confirmed, adjusted, or rejected through ongoing monitoring efforts."*
ADDITIONAL COMMENTS ON THE GROUNDWATER REPORT					

139	Annexure D	Table 25, the first 3 columns under Baseflow – the Units should be % and not Mm3/m	Kwazikwakhe Majola	14 February 2024	Regan Rose To remain unchanged as we are referring to volume. A column for % is more applicable to the groundwater template and will be included
140	Annexure E and F	Tables 26 – 56, BHN Reserve column for Nitrate and Nitrite as N should be <10 and not <1.0	Kwazikwakhe Majola	14 February 2024	Regan Rose Kwazi assisted in contacting the laboratories and WRC with regards to this uncertainty. DWS will investigate further as there does appear to be an issue with the statement including both Nitrate and Nitrite as N which should be <1.0. Thus, Kwazi instructed the team to leave the nitrate and nitrite values as they are in the report.
141	Annexure G	there are cases where Stress Index is low (A) whilst the Allocable GW is negative e.g. G13B. Notably, this is because the ecological component of the Reserve is more than the Recharge, while GW use is negligible. To some audience, this Stress symbol indication can be confusing. So I'm wondering if perhaps a footnote (or any preferred format) alluding to the reason(s) for such a situation can be included	Kwazikwakhe Majola	14 February 2024	Regan Rose: This will remain unchanged
SW RESERVE TEMPLATE					

GW RESERVE TEMPLATE					
CAPACITY BUILDING REPORT					
No comments received					
INTEGRATED MAIN REPORT					
CLOSE-OUT REPORT					