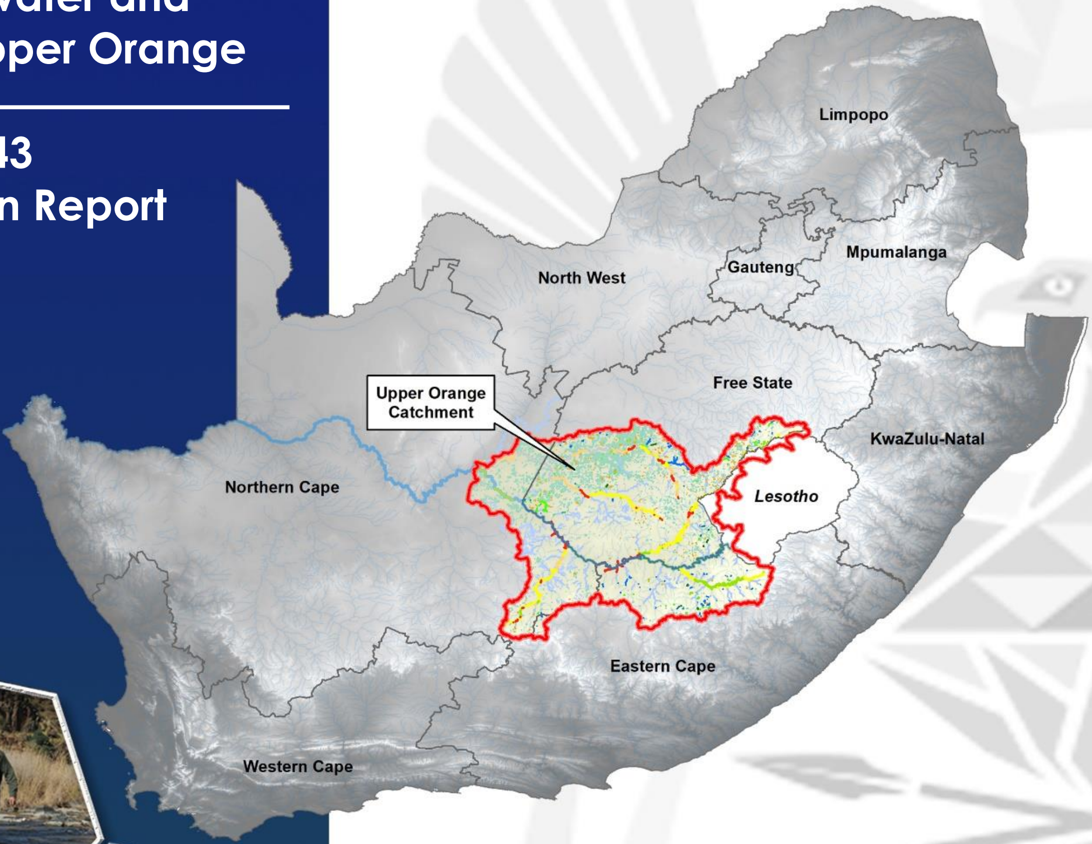
DEPARTMENT OF WATER AND SANITATION

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

WP11343
Final Inception Report



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AEH	Aquatic Ecosystem Health
AQC	Analytical Quality Control
BHN	Basic Human Needs
BID	Background Information Document
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CLiP	Commonwealth Litter Programme
CS	Citizen Science
DFFE	Department of Forestry, Fisheries and the Environment
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
eDNA	Environmental DNA
EC	Electrical Conductivity
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FPA	Fine Particle Application
FRAI	Fish Response Assessment Index
GIS	Geographic Information System
GSM	Gravel, sand and mud
GW	Groundwater
HFSR	Habitat Flow Stressor Response
IBA	Important Bird Areas
IFR	In-stream Flow Requirement
IHI	Index of Habitat Integrity
ILB	Inter Laboratory Benchmarking
ISO	International Organization for Standardization
JBS	Joint Basin Survey
LHDA	Lesotho Highlands Development Agency
MAP	Mean Annual Precipitation
MIRAI	Macroinvertebrate Response Assessment Index
NaDEET	Namib Desert Environmental Education Trust

NASS2	Namibian Scoring System Version 2
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act
ORASECOM	Orange-Senqu River Commission
PES	Present Ecological State
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RHP	River Health Programme
RQO	Resource Quality Objectives
RU	Resource Units
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SASS5	The South African Scoring System Version 5
SE	Stakeholder Engagement
SPI	Specific Pollution sensitivity Index
SWSA	Strategic Water Source Areas
TDS	Total Dissolved Solids
ToR	Terms of Reference
SST	Sustainable Sea Trust
UCT	University of Cape Town
VEGRAI	Vegetation Response Assessment Index
WMA	Water Management Area
WR2012	Water Resources 2012
WRC	Water Research Commission
WRCS	Water Resources Classification System
WWTW	Wastewater Treatment Works

1. INTRODUCTION

The National Water Act (No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of water resource systems. To achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of Resource Directed Measures (RDM). As part of the RDM, a Reserve must be determined for a significant water resource, as a means to ensure a desired level of protection.

The Reserve (quantity and quality) is defined in terms of the Ecological Water Requirements (EWR), ensuring the water required to protect aquatic systems (water quality, habitat and biota) of the water resource are provided for; and Basic Human Needs (BHN), ensuring that the essential needs of individuals served by the water resource in question are provided for. These measures collectively aim to ensure that a balance is reached between the need to protect and sustain water resources, while allowing economic development.

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) is tasked with the responsibility of co-ordinating 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 use in terms of the NWA, and should be determined before license applications are processed, particularly in stressed and over utilised catchments.

Consequently, the CD: WE have identified the need to determine the Reserve for the Upper Orange catchment (rivers, wetlands and groundwater) forming part of the Orange Water Management Area (WMA6) in accordance with the WRCS.

1.1 Study motivation

The need to undertake a detailed EWR and BHN study in the Upper Orange catchment is owing to possible hydraulic fracturing (HF), 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 HF, 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 proposed study will be 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.

1.2 Study objective

The primary objective of this study is 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 following targets will be followed to meet the above objective:

- Identify gaps to be addressed in the Upper Orange catchment;
- Determine the EWR (quantity/quality) and BHN for the rivers at various EWR sites;
- Determine the water quantity/quality component of the EWR and BHN for the priority wetlands/wetland clusters where applicable;
- Determine the groundwater quality/quantity component of the BHN and the groundwater quantity component of the EWR for each resource unit/quaternary catchment in the study area;
- Address priority water resources identified to be investigated;
- Assess and evaluate the operational scenarios, considering the various water transfers and proposed developments in Lesotho and in the Upper Orange basin;
- Determine ecological specifications/protection measures to support the Reserve requirements;
- Prepare the EWR and BHN templates for the Upper Orange Reserve;
- Continual communication and liaison; and
- Skills development and transfer.

1.3 Purpose of this study

The purpose of this study is to determine the Reserve (quantity and quality of the EWR and BHN) for priority rivers, wetlands and groundwater areas on a high level of confidence in the Upper Orange System. The results from the study will thereby guide the Department to meet the objectives of maintaining, and if possible, improving the state of the water resources within this catchment. The primary deliverable will be the preparation of the Reserve templates for the Upper Orange Catchment, specifying the ecological water requirements for the priority rivers, wetlands and groundwater areas.

1.4 Purpose of this report

The Inception Report has been compiled to better define the scope of work and methodology that will 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.

2. *STUDY AREA*

The study area of the Upper Orange catchment, forming part of the Orange Water Management Area (WMA6) is geographically illustrated in Figure 2-1 and Figure 2-2 in relation to the rest of the country.

The Upper Orange catchment further forms part of the Orange-Senqu River Basin and hence, is a shared water course, not only with Lesotho in the upper reaches, but also with Botswana and Namibia in the Lower Orange catchment area. Henceforth, a consideration of the international responsibilities/commitments and bilateral agreements is imperative.

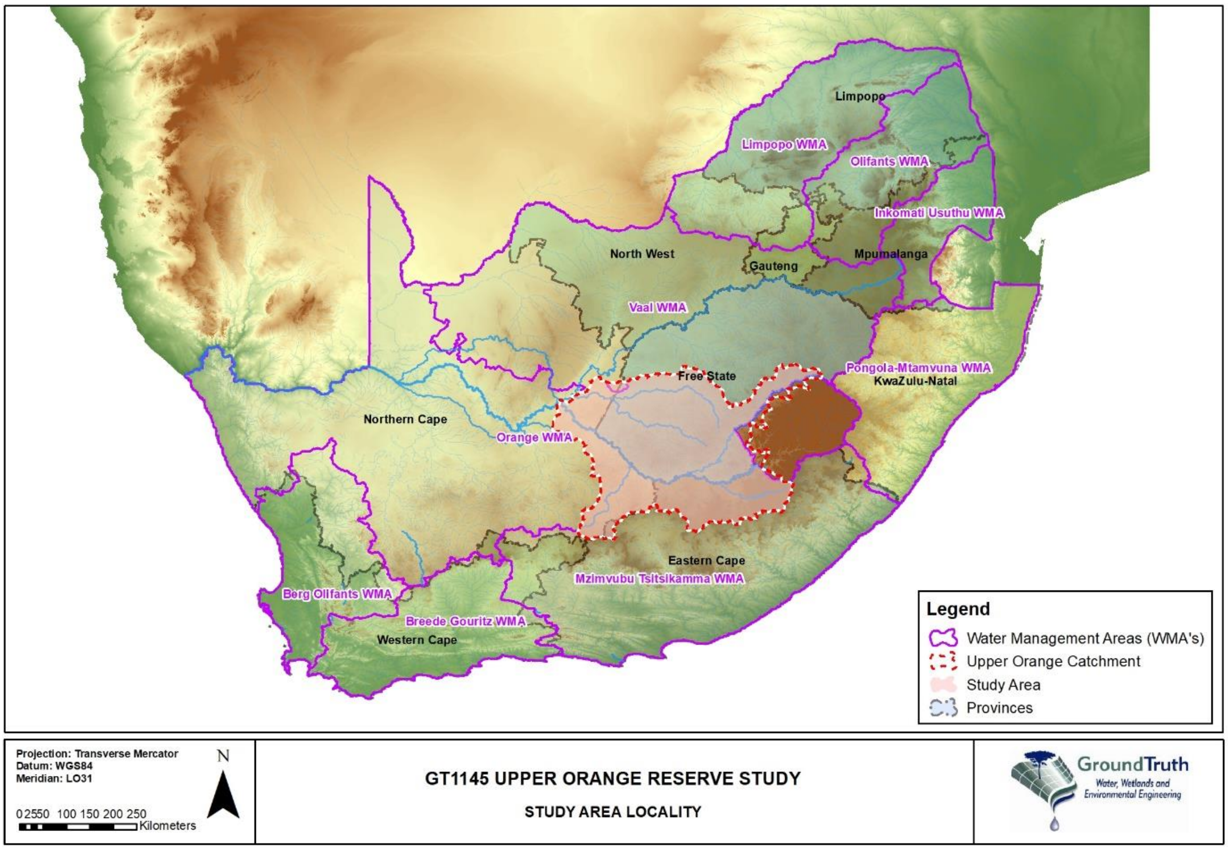

Figure 2-1: Location of the study area in relation to WMAs

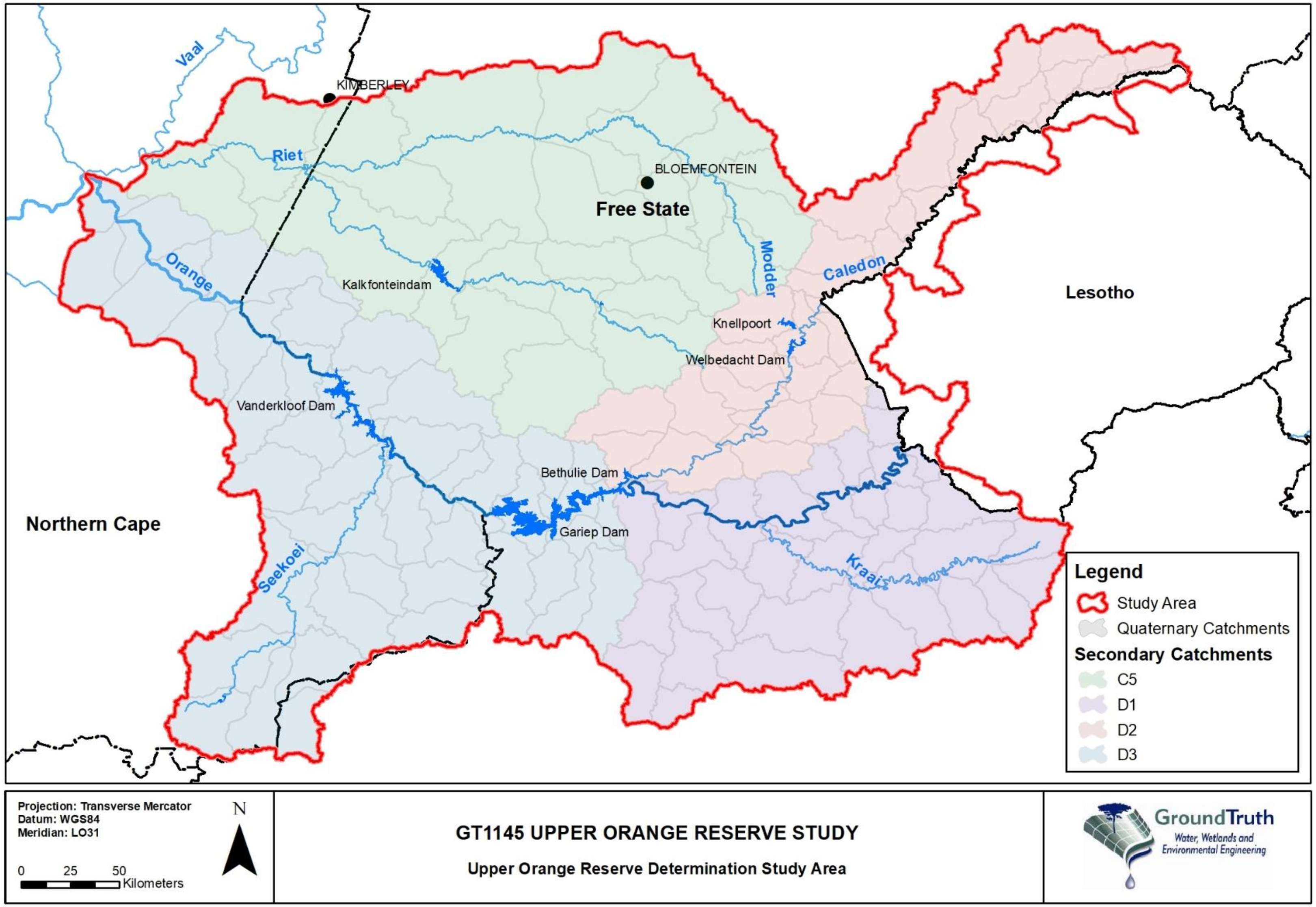

Figure 2-2: Quaternary catchments, rivers and dams occurring within the study area

2.1 Rivers

The Orange River (main stem) originates in the Eastern Highlands of Lesotho, where it is known as the Senqu River. The main stem flows west approximately 2 200 km, where it flows into the Orange River Mouth and into the Atlantic Ocean at Alexander Bay. The Orange-Senqu River Basin is made up of the Vaal, Upper Orange and Lower Orange catchments (Figure 2-2). However, for the purpose of this study, the study area only covers the South African Upper Orange catchment (the smaller of these three catchments areas). This catchment is divided into four distinct sub-areas, stretching across the Northern Cape, Free State and Eastern Cape provinces and further across three ecoregions, namely the Eastern Escarpment Mountains, Nama Karoo and Highveld:

- The Caledon River from its headwaters and its tributaries to the Gariep Dam;
- The Orange River from the Lesotho Border to the Gariep Dam, including the main tributaries namely Kornetspruit, Sterkspruit, Stormbergespruit and Brandwaterspruit;
- The Kraai River catchment; and
- The Orange River from the Gariep Dam, through Vanderfkloof Dam to Marksdrift weir, just before the confluence with the Vaal River, including the Seekoei River in the south, and the Modder-Riet River (main tributaries of the Vaal River system) in the north.

The study area consists of 129 quaternary catchments, covering an approximate area of 106 000 km2. This includes secondary catchments D1, D2, D3 and C5 (Figure 2-3). The sub-catchments, associated rivers, catchment areas and quaternary catchments are listed in Table 2-1 for further detail.

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 (Figure 2-2).

In accordance with DWS (2014) desktop PES/EI/ES, the data revealed that 64% of the sub-quaternary reaches assessed in the catchment were in a moderately to largely modified state (category C and D respectively), congruent with conditions seen in the catchment (Figure 2-4).

Table 2-1: 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,	767.76	D14A
			325.52	D14B
			724.94	D14C
			683.34	D14D

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
		Barnardspruit, Mooiplaasspruit, Kop-en-pootjiespruit, Modderbulrspruit, Palmietspruit	666.69	D14E
			543.46	D14F
			608.08	D14G
			700.44	D14H
			517.40	D14J
			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	609.80	D23A
			863.98	D23C

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
		Caledon, Klein-Leeu, Leeu, Mokopu, Bokpoortspruit, Sandspruit, Montsoane, Klipspruit, Rietspruit, Nuwejaarspruit, Bloemspruit	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	Seekoei, Klein-Seekoei, Elandskloof, Soetvlei se Loop, Noupoortspruit, Elands, Gansgatspruit	721.55	D32A
			586.23	D32B
			856.58	D32C
			858.40	D32D
			1166.88	D32E

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
			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

Sub-catchment	Main River	Associated Rivers	Catchment Area (km^2)	Quaternary catchments
			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
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

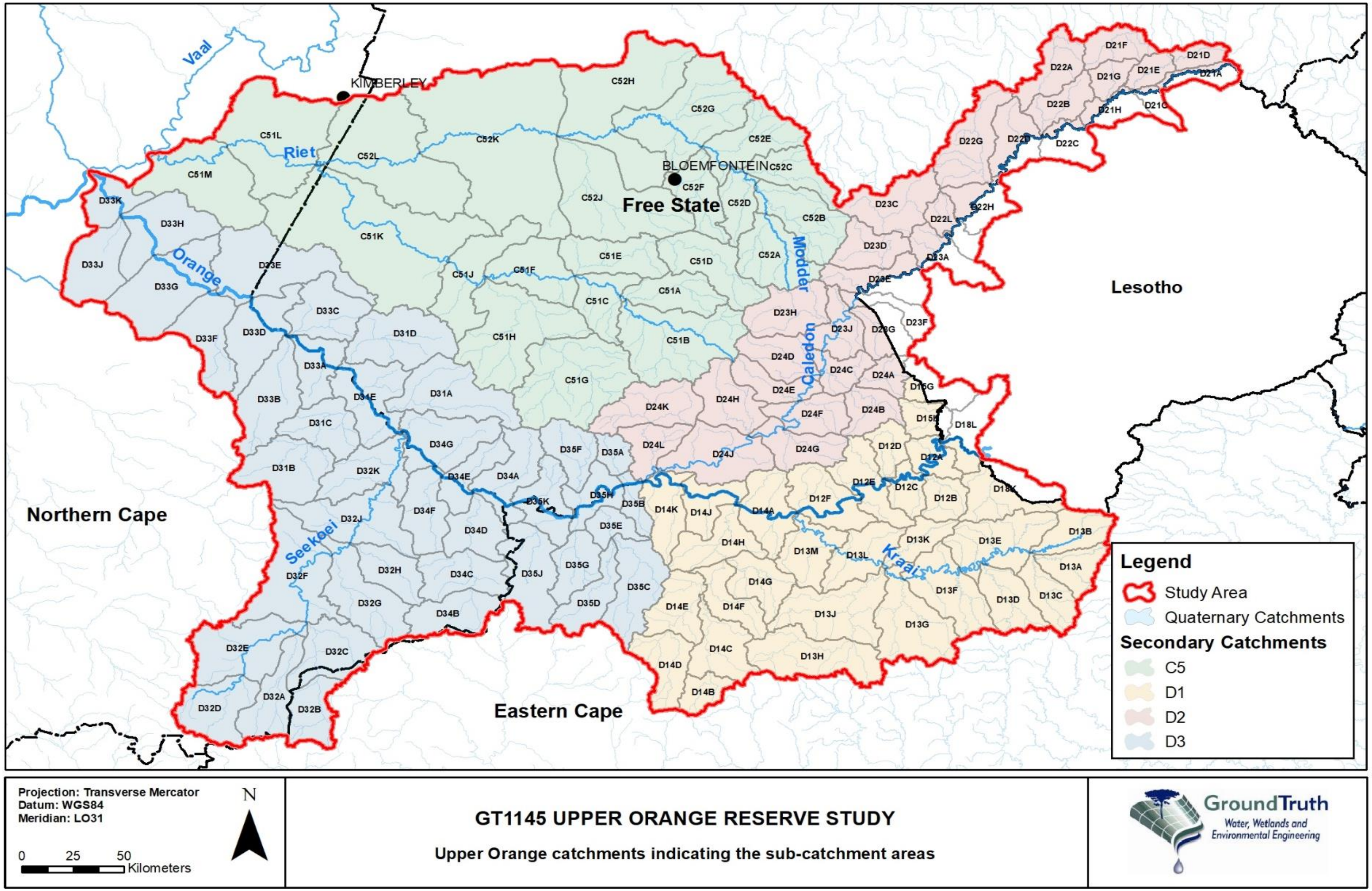

Figure 2-3: Upper Orange catchment: indicating the sub-catchment area

The main catchment developments, water users, as well as the impacts, primarily on the water availability and quality are summarised below per sub-catchment (DWA, 2009).

The Caledon system is mostly associated with agriculture. The main agricultural produce includes asparagus, cherries, maize, wheat, lucerne, other fruit and vegetables and pastures. Cattle farming is also a major activity in this sub-catchment. A number of dams have been constructed on tributaries to provide water for irrigation purposes, as well as for domestic use for Clarens, Fouriesburg, Ficksburg, Clocolan, Ladybrand and Wepener. Welbedacht Dam is the largest dam in this sub-catchment, however, has less than 10% storage due to sedimentation. Water is transferred from the Caledon River upstream of the Welbedacht Dam to the Knellpoort Dam (off-channel as situated on a small tributary of the Caledon River) to provide domestic water for the Bloemfontein area. Water can also be transferred into the Caledon River from Muela Dam in Lesotho during droughts.

The main impacts on the water quantity and quality include:

- *Localised nutrient enrichment from return flows of Wastewater Treatment Works (WWTW) from the towns, which are not being maintained or working effectively;*
- *Return flows from the irrigation;*
- *Large sediment export, primarily within the Caledon River, ultimately attributed to erosion from over-grazing, intensive agricultural activities and other land use practices within South Africa and Lesotho supporting these sediment loads. This sedimentation is having a detrimental effect on the full supply capacity within the Welbedacht Dam; and*
- *Transfers to the Modder River.*

The Upper Orange River system is relatively undeveloped with local sparse communicates. The main agricultural produce includes maize, wheat and pastures. Cattle and sheep farming contribute to the major activities in this sub-area, including some game farms. The Jozanna's Hoek Dam is located in the head waters of the Sterkspruit to supply water to the greater Hershell Area. The Gariep Dam is situated towards the lower end of this area after the confluence of the Orange and Caledon Rivers.

The main impacts on the water quantity and quality include:

- *Reduced flows due to Mohali and Katse Dams in Lesotho with large volumes of water being transferred to South Africa (Upper Vaal River) from these dams ;*
- *Nutrient enrichment, as well as microbiological issues, from return flows of Wastewater Treatment Works (WWTW) mainly from the Caledon catchment;*
- *Localised water quality impacts from the Sterkspruit catchment;*
- *Return flows from the irrigation, particularly adjacent to the main stem Orange River;*
- *Algal blooms within the Gariep Dam, thus a response to nutrient enrichment;*
- *Large sediment loads, primarily within the main stem Orange River, as a results of over-grazing and land use practices within South Africa and Lesotho;*
- *Transfer from Gariep Dam to the Fish River system in the Eastern Cape; and*
- *Impacts attributed to flow variations downstream of Gariep Dam due to hydropower and other releases.*

The Kraai River system is also undeveloped, in terms of major towns or industrial activities. Some irrigation occurs along the banks of the Kraai River and the major tributaries. The main agricultural produce includes cabbage, maize, wheat, lucerne, potatoes and pastures. There are no large dams in this system, although there is prospective for a dam to be constructed near the confluence of the Kraai and Orange River.

Although the water quality of the resources within this sub-area are still in a good condition, some of the *impacts identified on the water quality include:*

- *Nutrient enrichment from return flows of Wastewater Treatment Works (WWTW) from the towns i.e Barkly East; and*
- *Some return flows from the irrigation, although minimal.*

Similar to the Kraai River system**, the Middle Orange River system** continues to be undeveloped and sparsely populated, with no major towns or industrial activities. Vanderkloof Dam, one of the 2 largest dams in this catchment area, is located in this system and which supplies water for a number of irrigation schemes via releases into the Orange River as well as a canal to the Riet River catchment. The dam further releases water for hydro power generation. Agriculture (maize, wheat and lucerne, pecan nuts and soya) are the predominant land use activity in this system, mainly with water sourced from the Orange River. There is small scale alluvial diamond mining, including prospecting diamond mining, which occurs at Koffiefontein and along the banks of the Orange River from Hopetown to Douglas.

The main impacts on the water quantity and quality include:

- *Localised nutrient enrichment from return flows of Wastewater Treatment Works (WWTW) from the towns;*
- *Return flows from the irrigation impacts on the water quality of the Orange River with subsequent algal blooms in the river indicative of localised nutrient enrichment; and*
- *Some sediment loads, primarily owing to the alluvial diamond mining and prospecting on the banks of the Orange River. Although occurring in small pockets, these activities are evidently having an impact;*
- *Changed flow patterns due to transfers and movement of water for downstream irrigation; and;*
- *Impacts owing to flow fluctuations downstream of VanderKloof Dam due to hydropower releases.*

The Modder-Riet system is well developed with the main agricultural produce maize, wheat, lucerne, other fruit and vegetables and pastures. Cattle farming are also a major activity in this sub-catchment. Bloemfontein and surrounding areas are situated in the upper reaches of tributaries of the Modder River. A number of large dams have been constructed in the Modder and Riet Rivers for water supply to the various towns and irrigation.

The main impacts on the water quality include:

- *Nutrient enrichment from return flows of Wastewater Treatment Works (WWTW) from the towns;*
- *Irrigation and return flows which continue to highly impact the lower reaches of the Riet; and*
- *Transfers from the Caledon catchment, through the off-channel Knellpoort Dam, supplying water to Bloemfontein. Furthermore, transfers from Vanderkloof Dam to the Riet via a canal*

system and from Marksdrift weir on the Orange River just before the confluence with the Vaal River, to the lower Modder-Riet.

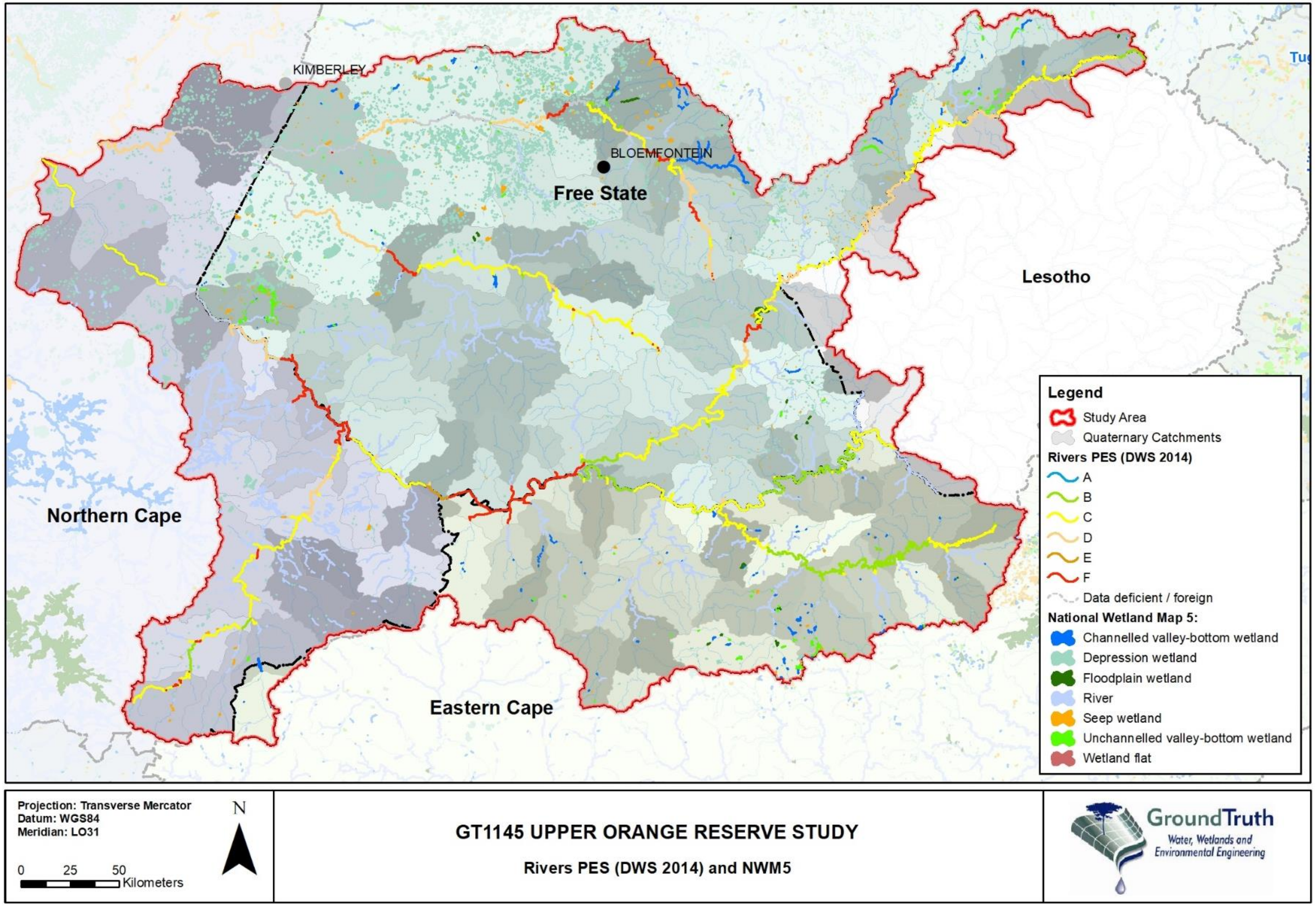

Figure 2-4: Overview of the DWS PES (2014) results and NWM5 for the Upper Orange catchment

2.2 Major dams and transfer schemes

The Upper Orange catchment is characterised by some of the country's largest dams, providing a pivotal role in supplying water to users in the catchment, as well as strategically important neighbouring catchments, namely the Upper Vaal WMA (DWA, 2009).

The major storage dams within this catchment are the Gariep and Vanderkloof Dams, two (2) of the largest reservoirs in South Africa and which further supply hydroelectric power. There are numerous other smaller dams within the catchment. The effects of the numerous dams on the Upper Orange River and tributaries have impacted the wellbeing of the water resources. These impacts have been exacerbated by the generation of power, particularly at Gariep Dam where the flows have become highly variable on a daily basis. The larger dams in the Upper Orange catchment are listed in Table 2-2 below.

Table 2-2: Storage dams characterising the Upper Orange catchment

Dam	Associated River	Volume (ML)	Surface area (km^2)
Major storage dams			
Gariep	Orange River	5 340 600	352.162
Vanderkloof		3 171 300	133.402
Smaller storage dams			
Armenia	Caledon River	13 000	3.933
Egmont		9 300	2.442
Welbedacht		10 200	10.185
Knellpoort	Off-channel storage dam supplementing water supply to Bloemfontein	130 000	9.854
Rustfontein	Modder River	72 200	11.585
Mockes		-	-
Krugersdrift		66 000	18.525

Dam	Associated River	Volume (ML)	Surface area (km^2)
Tierpoort	Riet River	34 000	9.11
Kalkfontein		325 100	37.697

The resources of the Upper Orange catchment are used to support requirements for water in other parts of the country with large transfer schemes both from and within this WMA. These include transfers 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).

2.3 Wetlands

Depression wetlands are some of the more common wetland types found within the Upper Orange catchment, which is largely associated with a combination of geology, rainfall and temperature. Overall, a total of 2,868 wetlands were identified by the National Wetlands Map (NWM5) spatial layer (Van Deventer *et al.,* 2018), covering a total area of 74,378ha.

Majority of the identified wetlands are located within the Upper Karoo Bioregion, followed by the Mesic Highveld Grassland Bioregion. Of the 2,868 wetlands, majority of the wetlands have been categorised as Least Concern followed by Vulnerable. These threat status ratings are based on the vulnerability of the wetland type and vegetation. 58% of the wetland systems have been categorised within the PES score of A/B, indicating that more than half of the identified wetlands are largely natural with limited modifications.

Furthermore, the Modder River, a tributary of the Riet River has a large density of high priority National Freshwater Ecosystem Priority Areas (NFEPA) systems, consisting largely of depression wetlands. Important wetlands also occur between the Orange and Riet Rivers.

With climate being one of the main drivers of the presence of wetlands within a landscape, it should be noted that, typically, areas with less than 300mm of mean annual precipitation (MAP) tend to have less wetlands within the landscape. In the Upper Orange River catchment, such areas are associated with those quaternary catchments within the upper north-western boundary of the study area and the south-western quaternary catchments. These include quaternary catchments D32E, D33D, D33E, D33F, D33G, D33H, D33J and D33K.

Some of the main impacts affecting the integrity of the wetlands within the Upper Orange catchment is associated with multiple land use impacts. Where portions of the Northern Cape cross over into the Upper Orange catchment, some of the main impacts include irrigated commercial croplands, bare areas associated with mining operations and small populated areas (hardened surfaces). Low shrubland areas dominated a large proportion of the landcover within the Northern Cape.

In the Eastern Cape, which is another of the three provinces that make up the Upper Orange catchment, some of the major impacts to surrounding wetlands includes commercial agriculture, highly dispersive (erodible) soils and urban settlements. The highly dispersive soils are a key consideration when selecting wetlands of importance for protection and maintenance, since many of these systems are already highly degraded and at risk of eroding beyond any rehabilitation opportunities. For these reasons, those wetlands that have degraded beyond a D category (at most) should be re-prioritised below those wetlands in better ecological conditions.

The Free State Province makes up majority of the Upper Orange catchment, with portions of the province also characterised by dispersive soils and increased risks of erosion within the natural systems. According to the Landcover map (2013/14), some of the main impacts to wetland integrity may include irrigated commercial farmlands, intensive commercial farming, subsistence cultivation, urban settlements and mining. Interestingly, in the Eastern Cape specifically, areas associated with subsistence farming and urban villages are surrounded by eroded areas (dongas). This relationship is something that will need to be considered and made note of during the final wetland prioritisation process. Additional impacts are likely to include poor land use management practises and over-grazing within all three provinces.

2.4 Groundwater

The regional geology is dominated by the Karoo Supergroup that was deposited in the Karoo Basin with a surface area of 200,000 km^2 (Aarnes *et al,* 2011). The Karoo Supergroup was formed through sedimentation within an intracratonic, foreland basin on Gondwanaland, during the Carboniferous, Permian, Triassic and early Jurassic ages, about 300 Ma to 160 Ma ago (Truswell, 1970). The main Karoo Basin covers a large part of the central and eastern parts of South Africa, and according to Du Toit (1954), the Karoo Basin has a maximum thickness in the southern parts of the Northern Cape Province and Lesotho. In accordance with Tankard *et al*., (1982), the succession of rocks comprising the Karoo Supergroup is shown in Figure 2-5.

Drakensberg Volcanics		Basalt	**Jurassic**
Stormberg Group	Clarens	Cross-bedded sandstone	**Triassic**
	Elliott	Red mudstone and sandstone	
	Molteno	Sandstone, conglomerate and mudstone	
Beaufort Group	Tarkastad Subgroup	Burgersdorp Formation	
		Katberg Sandstone	
	Adelaide Subgroup	Green, grey and purple mudstones	**Permian**
		Sandstone	
Ecca Group		Shale and sandstone	
Dwyka Group		Tillite and diamictite	**Carboniferous**

Figure 2-5: The Karoo Supergroup (Tankard *et al.,* 1982)

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

In accordance with WR (2012), the aquifer types associated with the Karoo Supergroup are mainly "fractured" and "fractured and intergranular" (Figure 2-6). The fractured nature of the Karoo Supergroup sediments is due to the brittle nature of the rocks in response to deformational processes. The intergranular and fractured aquifers are mainly represented in the area by the dolerite sills and dykes, which exhibit a dual porosity. Due to the in-situ weathering nature of dolerite it develops a dual porosity within the upper weathered and lower fractured zone respectively.

The Upper Orange-Senqu River basin coincides with a major transboundary aquifer, i.e. The Karoo Sedimentary Aquifer. The Stormberg Group of the Karoo Supergroup underlying the trans-boundary area comprises horizontal to sub-horizontal dipping sedimentary rocks of the Burgersdorp, Molteno, Elliot and Clarens Formations. These include fluvio-deltaic mudstones, siltstones and sandstones with dolerite ring dyke intrusions. Formation groundwater storage and flow are functions of porosity. Primary effective porosities are low due to sediment cementation and the fine-grained nature of the sediment, as well as compaction and high mudstone contents. Secondary porosities are enhanced by fracturing and dolerite dyke intrusion. The highest borehole yields are associated with the fractured dolerite and thick sandstone contacts and where these contacts are covered by alluvium. The alluvium plays an important role to enhance recharge to the subsurface lithologies. The borehole yields are variable in the catchment and range from 0.1 L/s to >5.0 L/s, dependent on the underlying geological group.

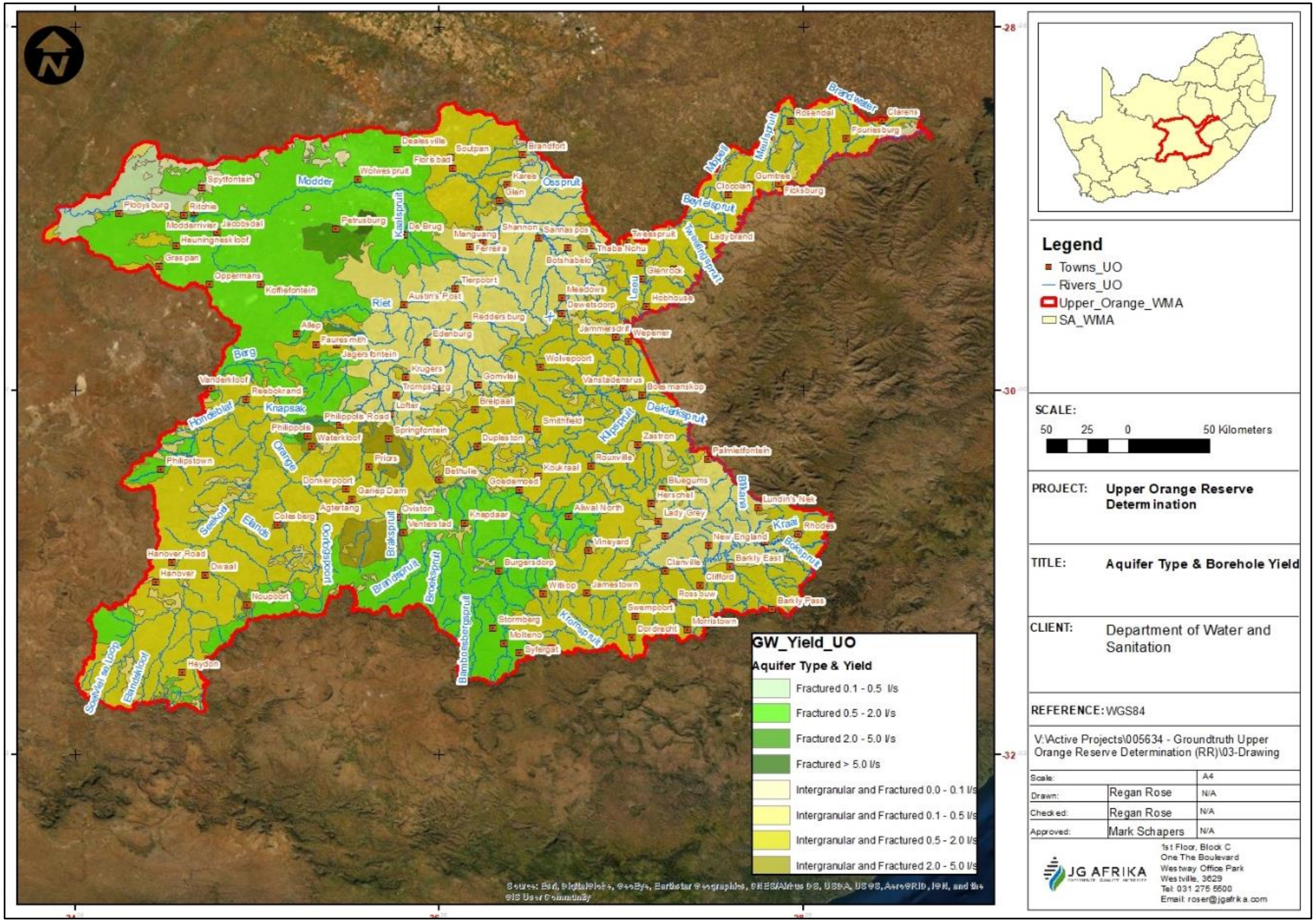

Figure 2-6: Aquifer Type and Borehole Yield

The groundwater quality varies over the catchment area (Figure 2-7). Using the Electrical Conductivity (EC) as overall groundwater quality indicator, groundwater quality is mainly good over the eastern parts of the catchment (0 – 70mS/m) but deteriorates slightly towards the western parts of the catchment (70 – 300mS/m) (WR, 2012). A similar spatial distribution is observed with groundwater recharge, which is highest along the Lesotho Highlands areas (maximum of 94mm/annum) and lowest to the west and southwest (minimum of 4mm/annum) (Figure 2-8).

The total available groundwater, known as the Utilisable Groundwater Exploitation Potential (UGEP), varies from about 26 000$m^3/km^2/a$ in the east to about 1900$m^3/km^2/a$ in the west (Figure 2-9). The UGEP is regarded as the sustainable potential yield that may be used for planning purposes in the rural, domestic, municipal, industrial, and agricultural water use sectors.

According to WR (2012), the total groundwater use in the catchment is estimated at about 132Mm^3/a of which 80% is being used for agriculture, 13% for agricultural livestock and 3% for municipal. Stressed catchments have been identified in several quaternary catchments in the south-eastern parts of the catchment (Figure 2-10). In these quaternaries the total abstraction and baseflow exceed the estimated recharge. The remainder of the catchment appears to have surplus groundwater available for development. In the drier western and southern parts of the catchment, groundwater constitutes the main source of water for rural domestic supplies and stock watering. According to DWS (2003), severe over-exploitation of groundwater is experienced in some peri-urban areas, i.e. Bainesvlei smallholdings near Bloemfontein, as well as Petrusburg in the Riet/Modder sub-area due to increasing irrigation from groundwater in the area.

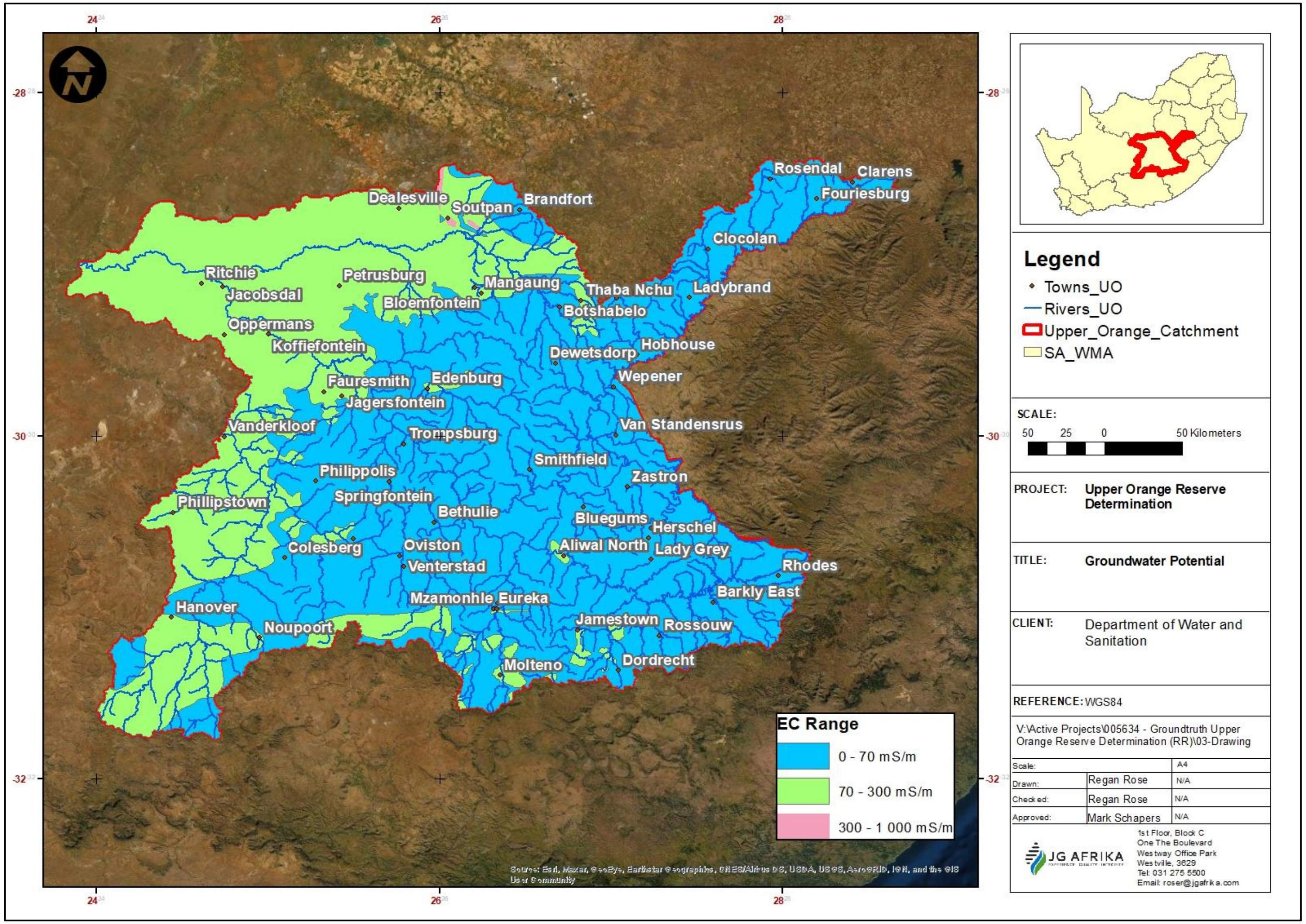

Figure 2-7: Groundwater quality

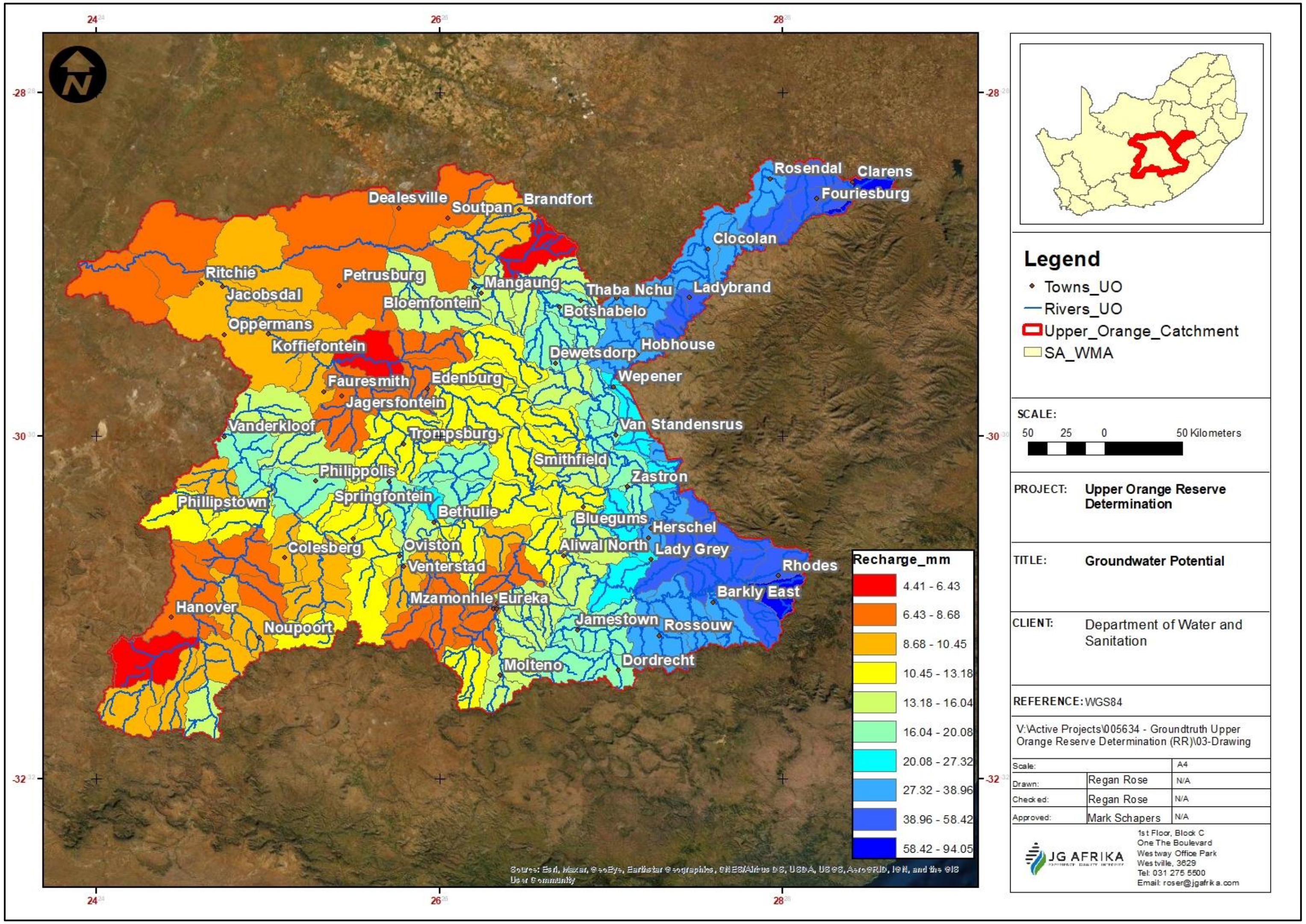

Figure 2-8: Groundwater recharge

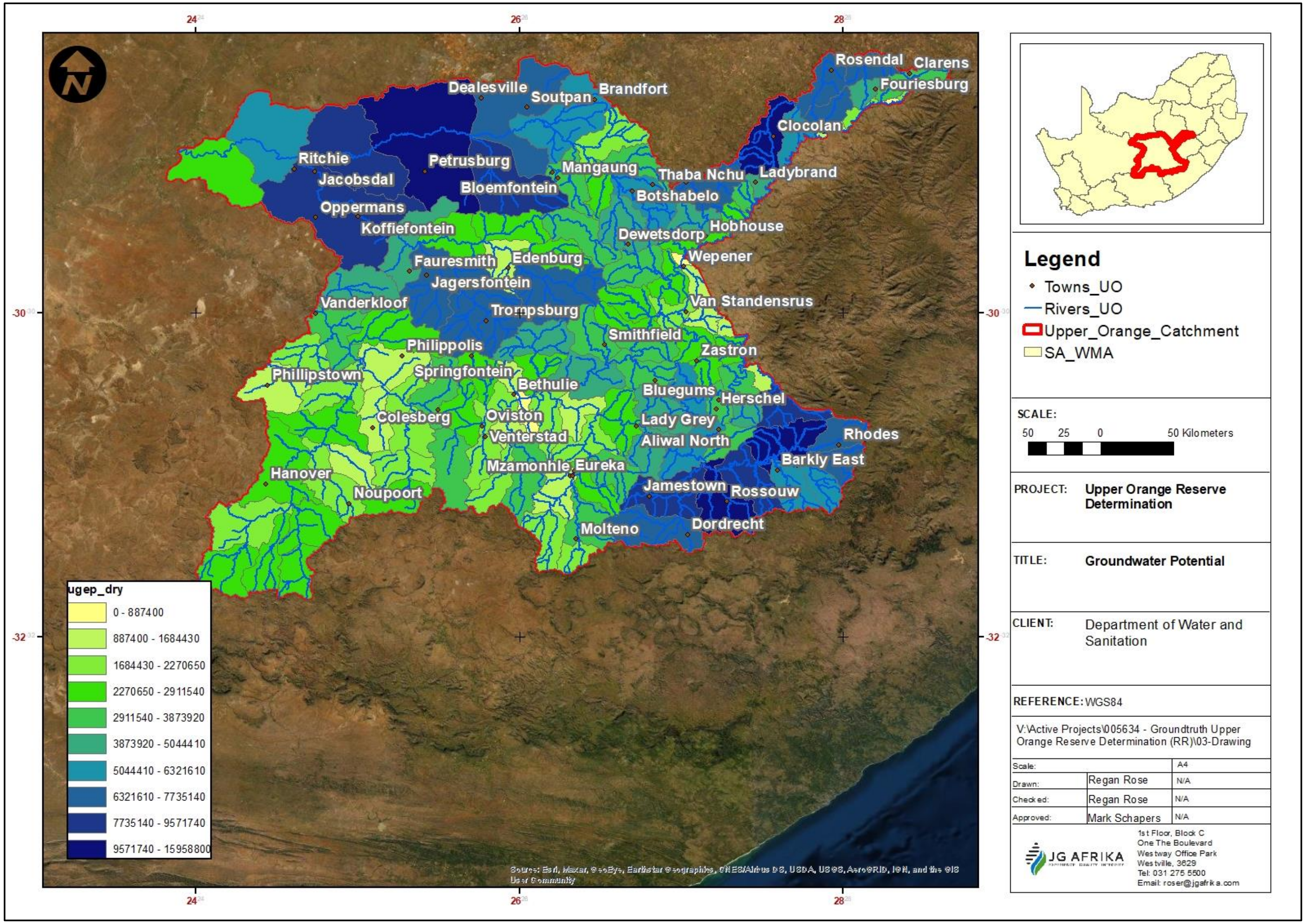

Figure 2-9: Groundwater potential

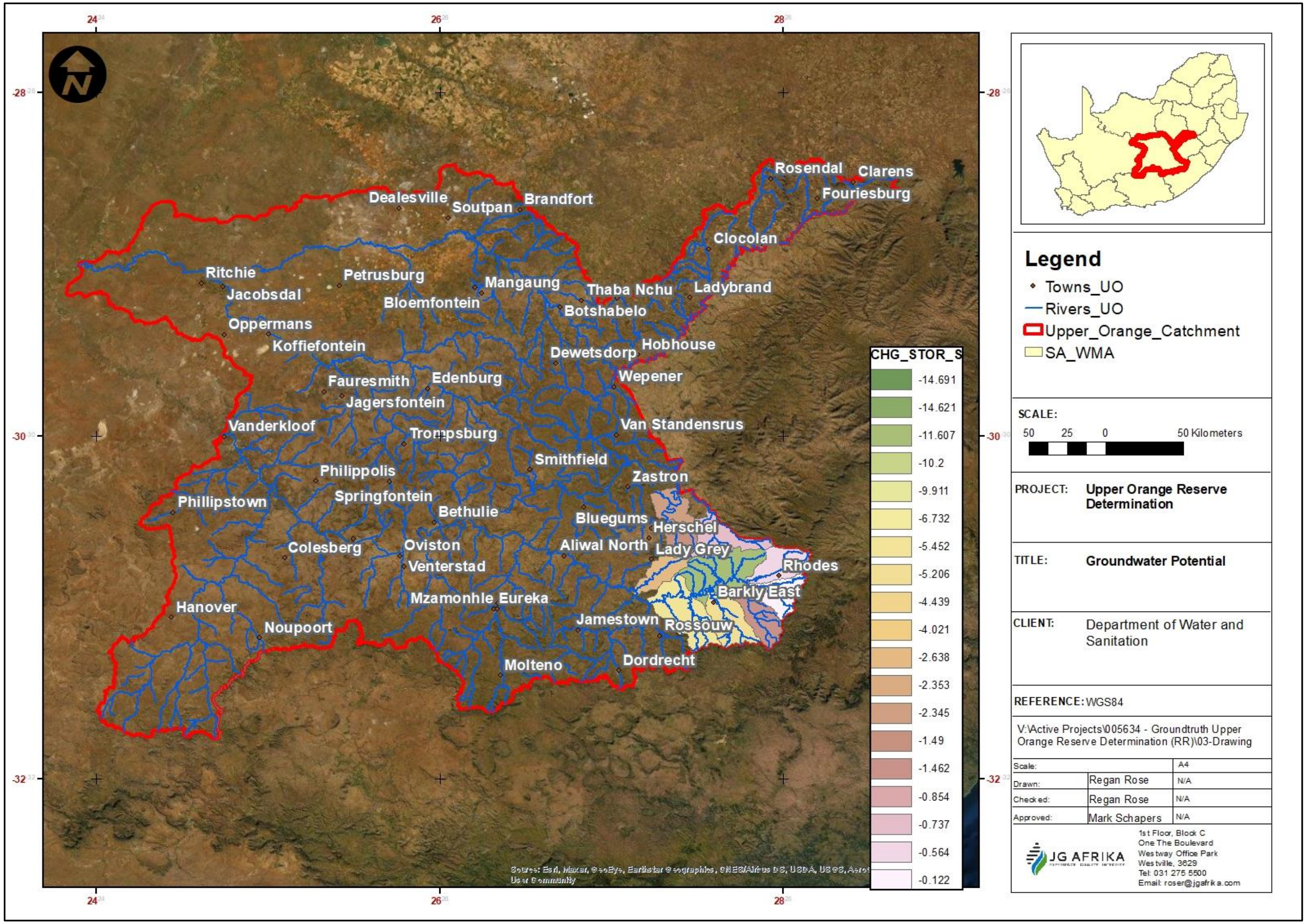

Figure 2-10: Stressed groundwater catchments

2.5 Ecological important areas

Several nature reserves and conservation and cultural important areas occur in the catchment area. Cultural Ecosystem Services are the non-material benefits people obtain from nature, and they include for example recreation, aesthetic benefits and cultural and spiritual experiences related to the natural environment. They contribute to a sense of place and are essential for human well-being. These include the Golden Gate National Park, near Clarens and the Tussen-2-Riviere Nature Reserve located between the Caledon and Orange River near Bethuli in the Free State Province, being the most renowned. The Mokala National Park is situated in the lower reaches of the Riet River and smaller conservation areas associated with the major dams. The famous Tiffendell Ski Resort also falls within the upper reaches of the Kraai River, located on the border with Lesotho (DWA, 2009).

Therefore, cognisance needs to be taken in relation to these ecological and cultural important areas.

3. INFORMATION REVIEW

3.1 Previous Studies

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.

While DWS is responsible for monitoring water volumes and water quality for rivers and groundwater as well as aquatic ecosystem monitoring, the South African National Biodiversity Institute (SANBI) manages the biomonitoring data, using the Freshwater Biodiversity Information System (FBIS). The Water Research Commission (WRC) is funding the development of a "Water Research Observatory" which collates water related data sources and applications in a single portal, for ease of access.

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, from a surface water and AEH perspective, the most-up-to-date data will be utilised for this study for the Upper Orange catchment, along with previous JBS data, where gaps may be identified. Refer to Table 3-1 which lists available key sources of information available to determining this Reserve.

Table 3-1: 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).

Year	Study Name
	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)
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

Year	Study Name
	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.
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

Year	Study Name
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 HaskoningDHV 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
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.

Year	Study Name
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.
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

Year	Study Name
	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.

3.2 Reserve Studies

Several Reserve studies have been undertaken for the Upper Orange River catchment, although at different levels of detail and not for the entire catchment. These include:

- Rapid level 3 studies were done pre 2005 on the main stem Caledon River and tributaries with very little information available for this study.
- An intermediate Environmental Flow Requirements (EFR) study was undertaken for ORASECOM in 2010 and included a site on the Kraai River, two sites on the Caledon River and one site on the Orange River at Hopetown. Information available from this study will improve the confidence of the results of this Reserve study and the same selected EWR sites will be used to undertake the various surveys to update the PES and verify the requirements.
- A study was undertaken for the Modder/ Riet system pre 2010 on a rapid level 3 at four EWR sites. Information from this study will be used and additional surveys undertaken to provide ecological input for the management of this highly regulated system.
- A high confidence study was undertaken at four sites on the Seekoei River from 2006 to 2010.
- A comprehensive site was selected on the lower reaches of the Riet River (originally part of the Modder/Riet study) as part of the Vaal comprehensive Reserve study in 2006 to 2010.
- Ad hoc rapid level 3 studies were undertaken for water resource developments, including tributaries of the Karringmelkspruit and Wilgespruit in D12E and D13K; and on the main stem Caledon River in D22D.

Additionally, a number of desktop studies have also been conducted to evaluate water use licenses. Where information from previous studies are available, (see Table 3-2), it will be used during this study to enhance the confidence in the final results.

Table 3-2: Locality of EWR sites from previous studies

Site no.	Site name	River	Latitude	Longitude	Level & Date
EFR 01	Hopetown	Orange	-29.516	24.00927	Intermediate, 2010
EFR C5	Upper Caledon	Caledon	-28.6508	28.3875	Intermediate, 2010
EFR C6	Lower Caledon	Caledon	-30.4523	26.27088	Intermediate, 2010
EFR K7	Lower Kraai	Kraai	-30.8306	26.92056	Intermediate, 2010
Vaal_EWR19	Lillydale Lodge	Riet	S29 02 18.3	E24 30 10.2	Comprehensive, 2008
Zach_EWR1	-	Tributary of Wilgespruit	S30.6957°	E27.1690°	Rapid 3, 2017
Karn_EWR1	-	Tributary of Karringmelkspruit	S30.7143°	E27.3086°	Rapid 3, 2017
Modder_EWR3	-	Modder	-28.901712°	25.925395°	Rapid 3, pre 2010
Riet_EWR2	-	Riet	-29.589286°	25.698148°	Rapid 3, pre 2010
Riet_EWR4	-	Riet	-29.489458°	25.196783°	Rapid 3, pre 2010
Cal_EWR2	-	Caledon	S28.908	E27.7850°	Rapid 3, 2021
EWR1	-	Seekoei	D32E		Intermediate, 2010
EWR2	-	Seekoei	D32F		Intermediate, 2010
EWR3	-	Seekoei	D32J		Intermediate, 2010

Site no.	Site name	River	Latitude	Longitude	Level & Date
EWR4	-	Seekoei	D32J		Intermediate, 2010
Site 1	-	Little Caledon	S28°31'37"	S28°28'53"	Rapid 3, 2003
Site 4	-	Little Caledon	S28°36'41"	S28°18'07"	Rapid 3, 2003
Site 2	-	Groot	S28°40'50"	S28°08'24"	Rapid 3, 2003
Site 6	-	Leeu	S29°31'19"	S27°08'08"	Rapid 3, 2003
Site 3	-	Caledon	S29°43'20"	S28°09'03"	Rapid 3, 2003
Site 5	-	Caledon	S29°06'50"	S27°38'00"	Rapid 3, 2003

3.3 Alignments with ORASECOM Basin-wide studies

The Orange-Senqu River Commission (ORASECOM) commissioned a study in 2009 to assess existing relevant environmental flow studies for the entire Orange River Basin. However, this previous study only focussed on the major rivers of the basin. A more detailed intermediate level study further commissioned in 2011, focussed on the portion of the Orange River, downstream of the confluence with the Fish River, up to the Orange River Estuary. This previous study covered both rivers and estuarine water resources.

ORASECOM further undertakes the Joint Basin Survey (JBS) every five (5) years, which commenced in 2010 (first of its iterations – JBS1). The JBS focusses on the aquatic ecosystem health (AEH) from source to sea through the Basin. The second survey was conducted in 2015 (JBS2), followed by the third iteration (JBS3), currently being conducted and the survey scheduled for October 2021. Information, data and knowledge gathered from these surveys will further add depth to this study within the Upper Orange catchment, thereby achieving the objective of ensuring a high confidence study, particularly from an ecological standpoint. Data relating to fish, aquatic macroinvertebrates, diatoms (algae), instream and riparian vegetation, water quality (including physico-chemical parameters and microbial), persistent organic pesticides (POPs), metals and other compounds and new innovative tools and data (2021) will include radionuclides, microplastics and environmental DNA (eDNA).

Monitoring sites were previously selected throughout the basin by Dickens (2009) which were surveyed in 2010 and 2015. The rationale for the sites selected during these assessments were as follows (Dickens, 2009):

- The monitoring sites were selected to reflect the AEH at the scale of the Orange-Senqu River Basin to ensure a full spatial coverage to assess water quality, and other stresses, driving the system and consequently aquatic biota responding to these stressors;

- Positioned at strategic points, located at the outlet of major tributaries, representing the contribution of that tributary to the system (note, the sample sites were not selected to manage localised water issues in the basin);
- Located on the mainstem river at regular intervals so that there are at least 3 mainstem sites within each Ecoregion including the upper, middle and lower sections of the ecoregion. This enabled (Dickens, 2009):
    - an appropriate choice of sampling sites as sites within an Ecoregion should manifest similar ecological characteristics; and
    - the use of Reference Sites or Reference Conditions, providing a benchmark against which to compare any other site which may be in an altered state.
- Not immediately adjacent to or downstream of point source impacts;
- Monitoring of the basin was to be conducted at a high level to assess the broader basin owing to the scale, and not to monitor minor streams and isolated parts;
- Existing member State priority sites (i.e. sites used by the River Health Programme and for Ecological Reserve monitoring (or Ecological Water Requirements (EWR)) in South Africa and also sites used by the Lesotho Highlands Development Authority in Lesotho; and
- Continuity is important. Thus sites were selected in terms of location, to ensure monitoring in the long term and comparative trend analysis.

These principles and the genesis of JBS1 and JBS2 were taken cognisance of when assessing the final monitoring sites for the JBS3. They were subsequently refined and optimised based on selecting the results from JBS1 and JBS2 ensuring sites covering the various components (e.g. AEH) were aligned as much as possible and to ensure continuity of historical sites. Some of these sites will be aligned with the sites selected, optimising the most up to date and seasonal data for this study.

In summary, the number of anticipated final sample sites for the JBS3, particularly for the Upper Orange catchment (South Africa), include 12 detailed AEH (where all indicators will be sampled as per above), 3 POPs (including potential sites for bird egg and fish tissue sampling), 5 macro and microplastic sampling sites, 1 radiological and 3 eDNA sites. Unfortunately, no groundwater sampling sites are included in this JBS3 for this catchment.

Refer to Table 3-4 and Figure 3-1 for further information regarding the ORASECOM JBS3 AEH monitoring sites, including the rationale. The site ID number within the table aligns with the site ID number in the map. These sites will either be aligned with the priority sites selected for this Reserve study, or alternatively, the biological data from the JBS3 surveys, with added hydraulic data, will significantly contribute to improve the confidence of the EWRs in this study.

In addition to the above, a summary of the EcoStatus Category scores for the separate AEH components obtained during both JBS1 and JBS2 surveys is provided in Table 3-5 below. Once the JBS3 results are obtained in October 2021, the data and these categories will be used within and to compare with when running the various EcoStatus4 models for this study. Colour coding of the sites is according to the EcoStatus classification.

3.4 Alignment with SANParks routine monitoring in the Upper Orange

SANParks conducts routine monitoring at locations within the Golden Gate Highlands National Park and Mokala National Park, from a water quality and aquatic macroinvertebrate perspective. Data from this routine monitoring will also be drawn upon to aid in this high confidence Reserve determination study. These sites are listed in Table 3-3 and illustrated in Figure 3-2 below.

Table 3-3: SANParks monitoring points within the Upper Orange catchment

Park/River	Site Name	Coordinates	
Golden Gate/Little Caledon	Site 1	-28.5268	28.58368
	Site 2	-28.5095	28.58344
	Site 3	-28.5085	28.58273
	Site 4	-28.5076	28.61612
	Site 5	-28.5015	28.58132
GoldenGate/Klerkspruit	Site 10	-28.5343	28.65206
	Site 11	-28.4627	28.681275
Mokala/Riet	Lylidale	-29.0375	24.50606
	De Kranze	-28.999	24.47951

Table 3-4 Sites selected for the ORASECOM Joint Basine Surevy (JBS) 3 covering the Upper Orange catchment, where various assessments will be performed at each site including AEH, water quality, POPs, metals, microplastics, radiological and eDNA

Site ID	Site Code	River	Latitude	Longitude	Detailed * AEH & WQ	POPs & Metals	Micro-plastics	Radio-logical	eDNA	Motivation for Selection
27	OSAEH_15_1	Caledon	-28.723127	28.155754	Y	Y				Ecological Reserve site (Dickens, 2009); AEH (JBS1 upstream, JBS2); POPs (JBS1, JBS2)
28	OSAEH_15_6	Caledon	-29.371059	27.405291	Y	Y	Y		Y	Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1 upstream, JBS2 upstream); added plastics and eDNA
29	OSAEH_11_20	Leeuspruit	-29.517692	27.129677	Y					Ecological Reserve site (Dickens, 2009); AEH (JBS2); POPs (JBS1)
33	OSAEH_11_22	Orange	-30.504720	27.213977	Y					Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1)
34	OSAEH_26_11	Kraai	-30.690069	26.741568	Y					Monitoring site (Dickens, 2009); AEH (JBS1 upstream, JBS2)
35	OSAEH_26_13	Stormbergspruit	-30.650172	26.465164	Y					Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1)
36	OSAEH_26_14	Orange	-30.571418	26.451660	Y		Y		Y	Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1); added plastics and eDNA
37	OSAEH_26_8	Caledon	-30.427571	26.305008	Y		Y			Monitoring site (Dickens, 2009); AEH (JBS1, JBS2); POPs (JBS1); added plastics

Site ID	Site Code	River	Latitude	Longitude	Detailed * AEH & WQ	POPs & Metals	Micro-plastics	Radio-logical	eDNA	Motivation for Selection
38	OSAEH_26_15	Orange	-30.503784	25.240033	Y		Y			Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1); added plastics
39	OSAEH_26_12	Seekoei	-30.373578	25.000950	Y					Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1 upstream)
40	OSAEH_26_2	Orange	-29.643565	24.215537	Y				Y	Reference site (Dickens, 2009); AEH (JBS1 downstream, JBS2); POPs (JBS1 at Hopetown); added eDNA
41	OSAEH_26_3	Orange	-29.142069	23.691907	Y	Y	Y	Y		Monitoring site (Dickens, 2009); AEH (JBS2); POPs (JBS1, JBS2); added plastics and radiological

* Detailed AEH includes: benthic diatoms, aquatic macroinvertebrates, fish, riparian vegetation, and instream/riparian habitat integrity

Table 3-5: Summary of the EcoStatus Category scores for each AEH component recorded in JBS1 and JBS2

Catchment	Site Number	River	Diatoms JBS1	Diatoms JBS2	Fish JBS1	Fish JBS2	Inverts JBS1	Inverts JBS2	Instream JBS1	Instream JBS2	Rip Veg JBS1	Rip Veg JBS2	Overall Ecostatus JBS1	Overall Ecostatus JBS2
Upper Orange	OSAEH_15_2	Matsoku		B		E	D	C/D		D		E	C	D
Upper Orange	OSAEH_15_3	Senqu		C		D		C		C		C/D		C
Upper Orange	OSAEH_15_5	Senqu		B		D		C		C/D		B		C
Upper Orange	OSAEH_11_22	Orange		C/D		D		D		D		D		D
Upper Orange	OSAEH_26_11	Kraai	C	B	C	D	C	B/C	C	C	C	D	C	C
Upper Orange	OSAEH_26_13	Stormbergspruit		C		C		C/D		C		C		C
Upper Orange	OSAEH_26_14	Orange		C		D		D		D		C/D		D
Upper Orange	OSAEH_15_1	Caledon	B	B/C	D	C/D	C	B/C	D	C	C	E	C	D
Upper Orange	OSAEH_15_6	Caledon		F		E		D		D		D		D
Upper Orange	OSAEH_11_20	Leeu	C	C/D	C	D	C	C	C	C/D	B	C	C	C
Upper Orange	OSAEH_26_8	Caledon	C	D	D	C	D	D	D	C/D	B	C/D	C	C/D
Upper Orange	OSAEH_26_15	Orange		C		C/D		C/D		C/D		D		C/D
Upper Orange	OSAEH_26_12	Seekoei		C		D		C/D		C/D		A		C
Upper Orange	OSAEH_26_2	Orange	B	B	C/D	D	C	D	C	D	B/C	D	C	D
Upper Orange	OSAEH_26_3	Orange		B/C		C		D		C/D		B/C		C

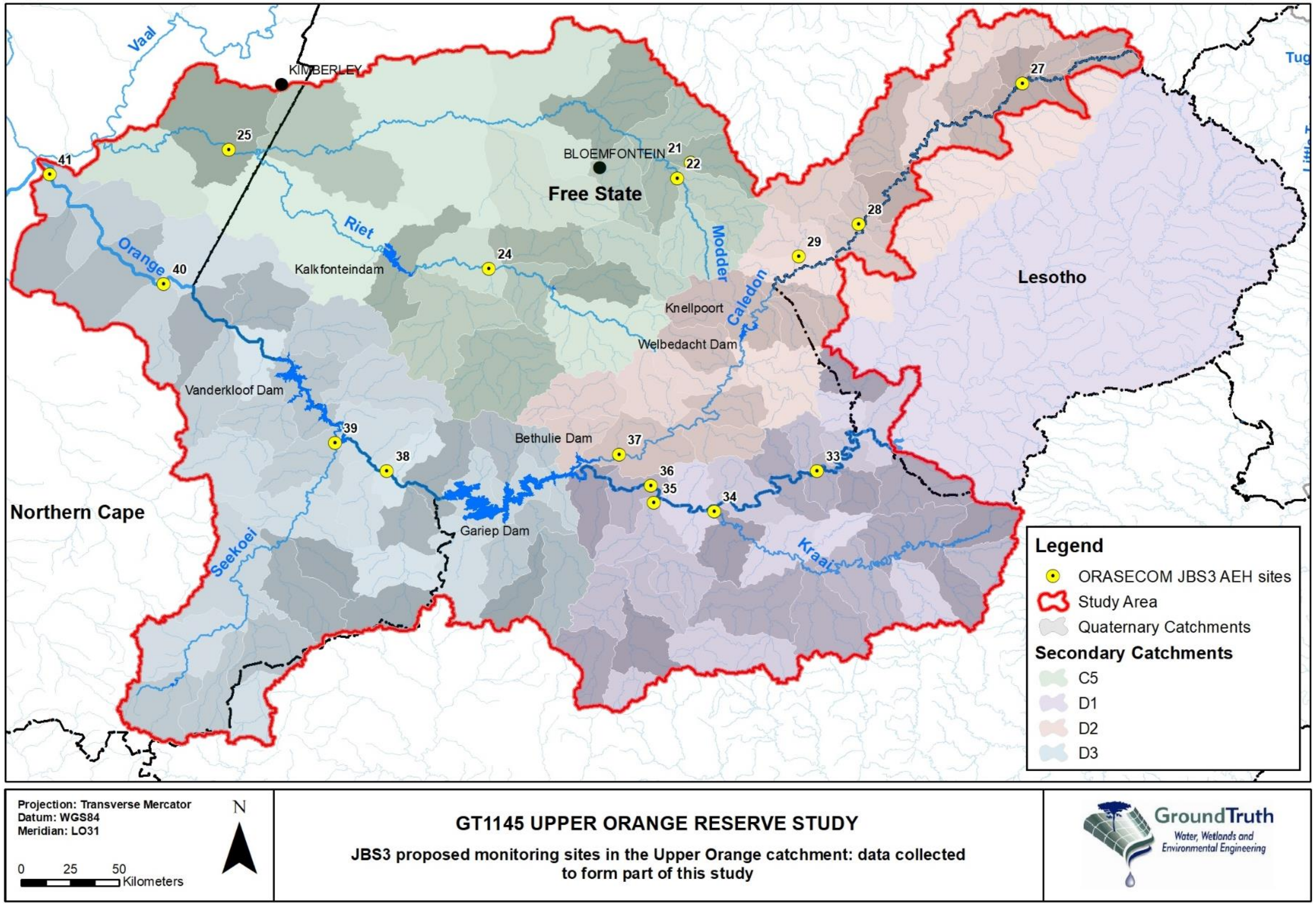

Figure 3-1: Potential alignment/additional data from ORASECOM JBS3 AEH monitoring sites for contribution to the Upper Orange Reserve determination study

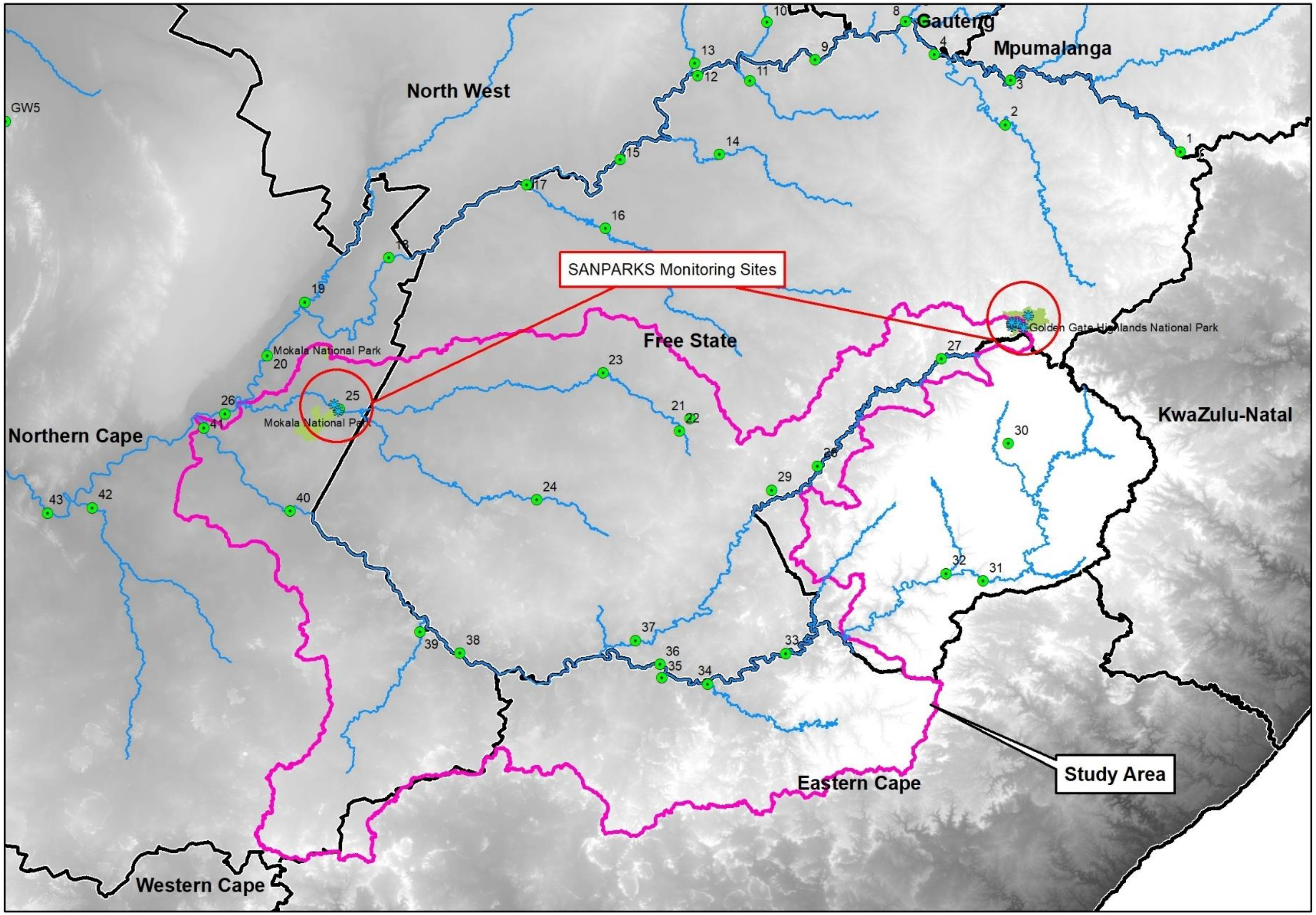

Figure 3-2: SANParks routine monitoring points - aligned with JBS3 monitoring points within the Upper Orange catchment

3.5 Hydrological Data and Modelling

The natural or reference hydrology of the Upper Orange River catchment has been extended for the period 1920 to 2004 as part of the study to support Phase 2 of the ORASECOM basin-wide integrated water resources management plan, 2011. This study also included the assessment of the existing gauging networks to provide recommendations for improvements.

The approach followed for the extension of the hydrology for the Upper Orange River (excluding Modder/ Riet system) was:

- Reconfiguration and recalibration of the WRSM2000 hydrological model;
- Extension of catchment rainfall time series to the period 1920 to 2004;
- Using selected gauging weirs for calibration of the flows and extrapolation to other non-gauged catchments; and
- Simulating new natural runoff time series for the period 1920 to 2004 per quaternary catchment

This hydrology and the model configurations were used during the WR2012 study when the hydrology was further extended to 2009. Thus, the natural flows that will be used for the determination of the EWRs will be based on the WR2012 hydrology for the period 1920 to 2009.

It is proposed to also use the WR2012 hydrology for the Modder/ Riet system as this will provide the most up to date information for this Reserve study and ensure the modelling of the transfers between the Orange/ Caledon and Modder/ Riet Rivers are based on the same record period.

The WR2012 hydrology that is based on a quaternary catchment level will be disaggregated to the selected EWR sites.

Below, Table 3-6 illustrates a full list of quaternary catchment numbers and catchment areas per major sub-catchment. The area for the Upper Orange only includes those quaternaries within South Africa. Where a quaternary catchment is shared between South Africa and Lesotho, the total catchment area has been included.

Table 3-6: Quaternary catchment numbers per major tributary and main stem Orange River within the Upper Orange catchment (ORASECOM, 2011)

Tertiary Catchment	Quaternary Catchments	Gross Tertiary Catchment Area (km^2)[1]	Gross Secondary Catchment Area (km^2)
Caledon (CA)	D21A-L, D22A-L, D23A- J, D24A-L	21 884	36 669
Kraai	D13A-M	9 354	
Seekoei	D32A-K	9 081	

Tertiary Catchment	Quaternary Catchments	Gross Tertiary Catchment Area (km^2)(1)	Gross Secondary Catchment Area (km^2)
Upper Orange (excluding Caledon, Seekoei and Kraai)*	D12A-F, D14A-K, D15G, H, D18K, L, D31A-E, D33A-K, D34A-G, D35A-K	31 251	
Modder/Riet	C51A-M, C52A-K	34 815	34 815

**Only include quaternaries within SA*

The results from the extension of the natural flows per major basin is shown in Table 3-7 below.

Table 3-7: Summary of the incremental natural runoff for the Upper Orange Basin (WR2012)

Tertiary Catchment	Catchment Area (km^2)		MAP (mm)	MAE (mm)	Natural Incremental Runoff (1920 -2009)
	Gross	Nett			$10^6 m^3/a$
Riet-Modder	34 815	20 738	443	1744	326.8
Caledon	21 884	21 884	677	1466	1405.9
Kraai	9 354	9 354	646	1583	684.2
Seekoei	9 081	9 081	313	1909	37.75
Orange Upper*	36 669	29 961	521	1670	710.4

*Only include quaternaries within SA

Management scenarios will be identified using the Reconciliation Strategy that was developed by DWA in 2014 for the Orange River. Any additional scenarios specifically relevant to the ecological function or well-being of the water resources, e.g. the operation of releases from the larger dams will be discussed with DWS before finalisation. Proposed dams, as identified in this strategy will be used to guide the selection of EWR sites on river reaches downstream of these dams. This will enable the assessment of the ecological consequences of altered flows from the dams and to optimise releases from the dams. The final set of selected scenarios for the evaluation of ecological consequences will be modelled using the existing WRYM configuration as used in the 2019 study that was undertaken to prepare a strategy and plan for climate resilient water resources in the basin.

3.6 Groundwater Studies

Available data and information from WR (2012) will mainly be used on a high level for the delineation of groundwater resource units. Additional reports on "Overview of water resources – Availability and Utilisation: Upper Orange Water Management Area", "Internal Strategic perspective Upper Orange Water Management Area" and "All Towns Reconciliation Strategies" are useful to gain knowledge of the overall catchment dynamics. However, additional specialist studies and local knowledge will be required to identify certain "hot spot" areas, notably where the groundwater potential is low and the demand is high.

3.7 Wetland Studies

At the inception phase of the project the prioritisation of wetland systems has largely been informed through a desktop screening process, making use of the various national spatial layers relating to wetlands, their importance and possible delivery of specific ecosystem services. Since majority of these spatial layers have been created at a national scale, the extent and associated attributes may not be accurate at a fine scale. As such, infield verification of these sites will be necessary to review the characteristics of the wetlands that have been prioritised and amend the final prioritisation accordingly.

The following information was sourced and utilised in the identification of priority wetlands for consideration in this study:

- National Wetland Map 5 spatial dataset;
- National Freshwater Ecosystem Priority Areas (NFEPAs) wetland shapefile;
- Important Bird Areas (IBAs);
- Crane sightings and nest sites;
- GIS coverage of important water supply dams;
- Wetlands which interacted with the surface and ground water strategic water source areas (SWSAs);
- Wetlands with a Present Ecological State (PES) of A/B;
- HGM unit type, which was used to determine the level to which each system may provide services associated with:
    - Flood attenuation;
    - Stream flow regulation;
    - Erosion control;
    - Sediment trapping; and
    - Water quality enhancements (assimilation of phosphates, nitrates and toxicants).
- Wetlands greater than 50ha (larger wetland systems, especially those which are relatively intact, provide greater opportunities for the provisioning of ecosystem services, benefitting those systems downstream and the surrounding water users);
- Those systems that were classified as *Critically Endangered or Endangered*;
- Wetlands located upstream of important water supply dams;
- Identified water-stressed catchments/basins from the river reserve process; and

- Top 5% of the quaternary catchments identified by Working for Wetlands for the Northern Cape, Free State and Eastern Cape provinces.

3.8 Stakeholder Engagement

Several stakeholders/ interest groups will be identified, with the assistance of the Department, which will be involved and invited to the two (2) proposed stakeholder engagement meetings proposed for 2022. These stakeholders should have a good understanding of the catchment and encouraged to share information, data and to even assist on the Reserve determination process.

4. APPROACH OVERVIEW

This study is of technical nature being supported by stakeholder engagement and consultation. The project approach and methodology that will be applied will be in accordance with the 8-step process as outlined in Regulation 810 (Government Gazette 33541) dated 17 September 2010 (Figure 4-1), as well as The Reserve determination process as outlined in the recently completed study, 'Development of Procedures to operationalise Resource Directed Measures (DWS, 2017). However, it must be noted that this study exludes the gazetting of the Reserve (step 8 illustrated in Figure 4-1), as the classification study has not been undertaken and thus the water resource classes have not been determined.

There are 8 main aspects that need to be addressed through the study which include:

- Review and analysis of existing information;
- Identifying and filling in of the ecological gaps identified (separate report);
- Identification of the priority resource units (RUs) (surface water, groundwater and wetlands) (separate report);
- Quantification of the EWRs for the priority RUs;
- Scenario analysis and operational considerations;
- Stakeholder engagement, co-operative governance and consultation processes to be followed;
- Preparation of the templates; and
- Study management and capacity building which will continue throughout the study period. The study management component will monitor performance, undertake client liaison, track expenditure and ensure the successful execution of the study tasks.

The study will further aim to provide a protection framework that will:

- Improve the detail and level of ecological specifications and management conditions; and
- Formulate practicable indicators for compliance monitoring and monitoring of the ecological health and integrity of the water resources in the said study area.

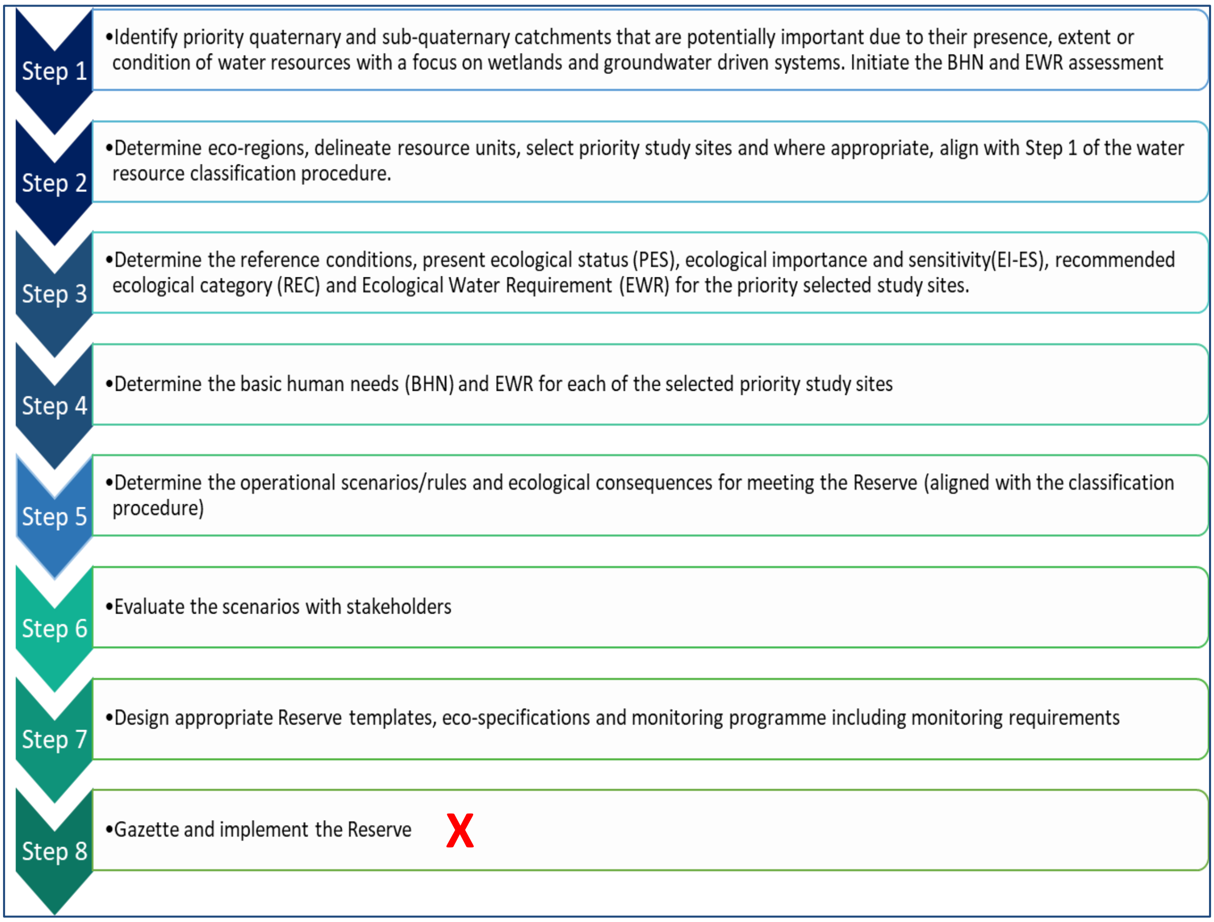

Figure 4-1: Integrated steps for the determination of the Reserve

The Study management, stakeholder engagement and capacity building task will continue throughout the study period (24 months) (Figure 4-2). Study tasks are for the most part not linear and will run concurrently over project timeframe.

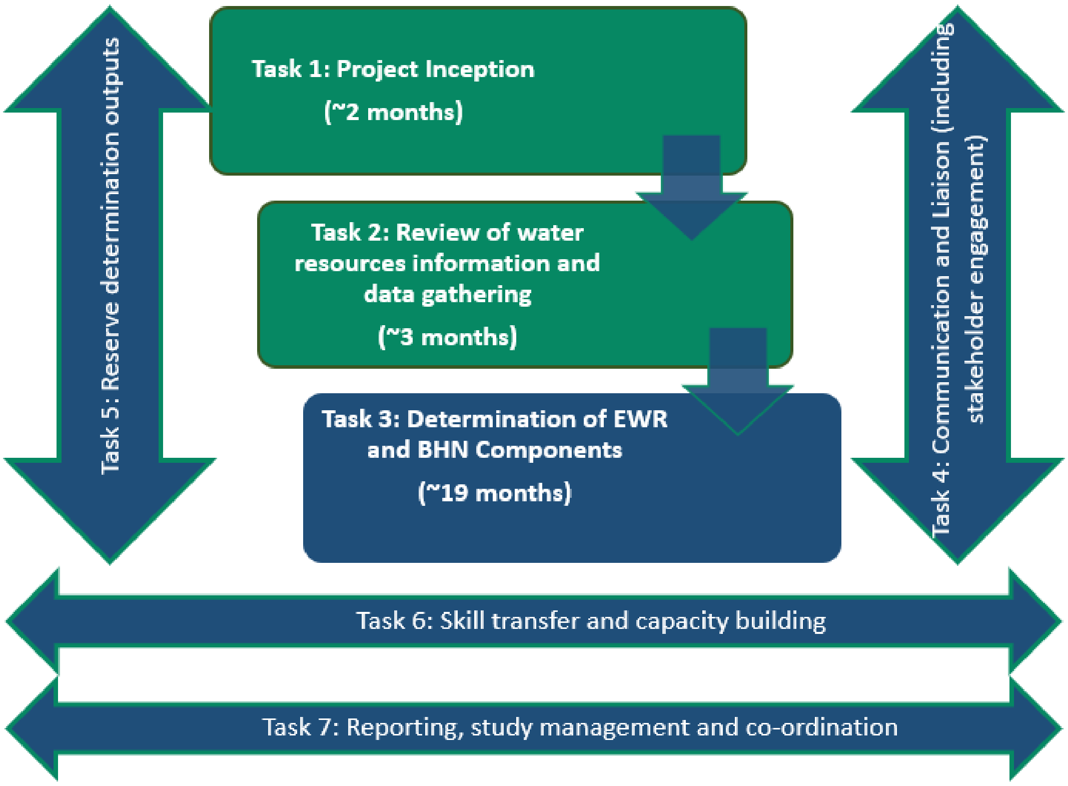

Figure 4-2: Proposed scope of work and approximate timelines

5. DETAILED SCOPE OF WORK / METHODOLGOY

5.1 Task 1: Project Inception

The study team views the inception phase as critical as it provides a platform for assessing and understanding the nature of the scope of the project to ensure alignment between DWS's expectations for the study and the actual product delivered by the study team.

The purpose of this phase was to clearly define the project scope, proposed approach, envisaged gaps and risks, to ensure the DWS and the study team are clear on the deliverables, timing, study programme and the budget. Project inception has included:

- A study team liasison and initiation meeting was held on 5 August 2021 whereby the team was mobilised and a presentation providing the study area, overview, proposed approach and deliverables were discussed;
- A team Initiation meeting with the client was held on 25 August 2021, to confirm the study terms of reference and client's specification in terms of study management, communication and liaison, stakeholder engagement and contractual aspects. Please refer to Appendix A for the meeting agenda, meeting minutes and presentation;
- Preliminary review of available information and data that will be used as base for this study;

- Key challenges were envisaged and identified;
- All approaches were outlined for the key components to be undertaken through the study process.

5.2 Task 2: Review of Water Resource Information and Data Gathering

This task ran concurrently with task 1, the inception phase, as the outcome of the information gap analysis would guide the rest of the project programme. The main focus for this task is to review all existing literature, reports, maps, models, aerial photographs and any other relevant information on the study area that is supportive and required for the Upper Orange Reserve Determination. The gap analysis will specifically put emphasis on the previous studies mentioned above, coupled with previous Reserve determination studies undertaken on the smaller tributaries of the Orange and Caledon Rivers and this will be documented separately within the Gap Analysis Report, to follow once the Inception Report (this Report) is finalised.

The gap analysis will further include information from water resource planning, other related Resource Directed Measures (RDM) studies, water quality studies, socio-economic, augmentation and reconciliation strategies and implementation and operational plans. All in support to the determination of the EWR and BHN components for this study. It will also include recommendations on the review of the Reserve results to include methods supported by the DWS that have been developed since previous studies. Furthermore, information from River Health Programme, Working for Wetlands studies and other related studies will also be assessed in performing a gap analysis to determine if there is any other additional work required.

The gap analysis will further place emphasis on the wetland types and their protection requirements based on their functionality in the landscape. This will mainly be informed by the NWM5 spacial layer results, coupled with previous wetland studies conducted in this catchment. Gaps in the water quality specifications/requirements will be addressed as part of the ecological Reserve and determined RQO for the various water resources, including priority groundwater areas. Areas where integration between the surface water (rivers and wetlands) and groundwater need to be considered will be highlighted to ensure relevant data is gathered during the field surveys.

This task will also include the sourcing of the applicable Water Resources Models and Water Quality models that have been used for the study area during previous studies. The models will be used to support the results obtained and improve the confidence level of the study results (implementation and achievability).

All of the above will be used to identify any data and information shortfalls. Specific recommendations will be made as to the collection of additional data and/or the extrapolation of existing data. This will be discussed with the client before finalization.

5.3 Task 3: Determination of the EWR and BHN for Rivers

This task will form the primary component of the study programme and result in the elements for the Reserve Determination, using appropriate methodology. As mentioned above, the eight-step procedure to determine the EWR and BHN components will be followed and adhered to Regulation 810 of Government Gazette 33541, 17 September 2010. Below is a detailed description of each step in determining the EWR and BHN component with the aim to determine the Reserve of the Upper Orange catchment.

5.3.1 Step 1: Priority resource units and level of assessment

The determination of the Reserve will follow the process as above, and will focus on the priority resource units (RUs) within the various quaternary and sub-quaternary catchments. Following the confirmation of the reference conditions, an assessment of all priority water resource sites (including selected existing EWR/ ORASECOM JBS3 sites), priority wetlands and groundwater-driven systems where the Reserve must be determined/re-assessed or where gaps need to be addressed will be undertaken. Preliminary sites have already been selected based on review of the area and exisiting information collected during previous studies (See Chapter 6).

A combination of the following three (3) river level approaches will be conducted at the selected priority sites within the identified RUs for the study which will include the following, along with descriptions:

(i) Biological level:
- Using the best available and updated biological data (MIRAI, FRAI) and Rapid Index of Habitat Integrity (IHI), 1996 model, to determine PES/EcoStatus, Ecological Importance (EI), Ecological Sensitivity (ES) and Recommended Ecological Category (REC). Furthermore, the Desktop Reserve Model (DRM) will be run to determine the EWR. Some biological sites will also include diatoms to assess the physico-chemical measurements/ecological water quality. Where information from EWR sites on rapid or higher level is available, the charcteristics of these will be used to extrapolate the EWRs for the biological sites. The use of the RDRM will be investigated to provide desktop hydraulic information to enhance the confidence in final extrapolated results.

(ii) Rapid level 3:
- Using the best available and updated biological data (MIRAI, FRAI) and Rapid IHI, 1996 model to determine PES/ EcoStstatus, EI-ES and REC, including the hydraulics surveyed data to verify the DRM results; and

(iii) Intermediate or higher level:
- The habitat-flow-stressor response (HFSR) approach will be followed in order to determine the EWR. The Fish Invertebrate Flow Habitat Assessment (FIFHA) will be run to assess fish and macroinvertebrate responses to the various ecological consequences and operational scenarios. These will be conducted on main tributaries in a very stressed state, as well as the main stem Orange River under high pressure.

5.3.2 Step 2: Quantification of BHN

Provides the context (water use areas, river reaches, priority wetlands and groundwater) to ensure protection of conservation and heavily impacted areas and to guarantee water for the BHN. The BHN will be quantified from surface and/or groundwater. The BHN will be quantified using the latest census or other data available for the Upper Orange catchment.

5.3.3 Step 3 and 4: Quantification of EWR

The quantification of the ecological requirements of the identified water resources (step 1) will be determined using the following:

- Results from previous studies and surveys undertaken in the Upper Orange catchment;
- Information collected during the field surveys (proposed to be post-wet and dry season surveys in order to provide high confidence results). Information from the JSB3 surveys will be used to increase the confidence in the final results;
- Results from the Eco-classification process (PES, EI-ES, REC and alternative categories where applicable);
- The DRM and the Flow Stressor Response model within SPATSIM for the integration of data produced from the surveys and Eco-classification to quantify the EWRs;
- Results from the hydraulic modelling (cross-sectional profile and discharge) to evaluate the DRM requirements; and
- Evaluation of the water quality at specific selected sites where quality was identified as an issue.

Refer to Sections 5.4 and 5.5 for the wetland and groundwater component approaches for the Reserve respectively. Ecological specifications will be identified. Where appropriate, specific protection measures will be specified to support biodiversity targets. Interaction of the various water resource components (river-groundwater, wetland-river and wetland-groundwater) will be taken into account to ensure that requirements are set to satisfy both the interaction requirements. Lastly, to ensure the integration of the ecological requirements between the rivers, wetlands and groundwater.

Socio-cultural importance will also be evaluated which will be informed by the Stats SA data on water use and other literature namely IDPs. No primary data will be collected for the socio-economic study.

5.3.4 Step 5 and 6: Scenario evaluation and consequences

An assessment of the operational flow scenarios will be conducted to evaluate the ecological consequences to finalise the EWRs that can be met. The primary aim of this task will be to determine any consequences of the EWR requirements through the running of the appropriate Water Resource Model (WRYM). The operational scenarios will take cognisance of any potential scenarios assessed previously for the Reconciliation Strategy or any other studies and taking into consideration water transfers from the rivers in the catchment to other catchments (e.g. transfer to Eastern Cape from Gariep Dam). These scenarios will be evaluated by the project team in terms of ecological and social consequences. A final set of scenarios will be presented to the department and stakeholders for discussion and decision as to the most appropriate scenario to implement. The final scenarios will form the basis for the finalisation of the Reserve as part of step 6.

Further as part of step 5 is an overview of the socio-economic water use in the area. This aspect of the study will be guided by the WRCS Socio-Economic Guidelines (DWAF, 2007), specifically the procedure to describe the present-day socio-economic status of the catchment and community well-being, with a focus on socio-economic water use and socio-cultural importance. The guidelines identify the following relevant aspects:

- Population density figures and related statistics (e.g., urban vs rural, demographics);
- Overview of the economy in terms of the relative contribution of different sectors (example data sources Statistics South Africa, Municipal documents such as Integrated Development Plans (IDPs));
- Land-use and related economic activities;
- The current wellbeing of the communities – a description of various aspects of each community that will gives a sense of the levels of financial, physical, human, social and natural

capital assets available to those communities (e.g., household characteristics - income category, services and infrastructure, education levels, community cohesion, etc.);

- Description of the way in which water is used currently, informed by a water users analysis based on registered water users information from the WARMS database;
- Description of the aquatic ecosystem goods and service of key importance, particularly those not reflected in the market economy – drawing on the study by Huggins *et al.* (2010) on the goods and services of the Orange River Catchment. The cultural value of catchments includes their contribution to education, scientific knowledge and the spiritual wellbeing of South Africans (Huggins *et al.,* 2010). Assessment of the socio-cultural value of the catchment reflects a qualitative assessment of how aquatic ecosystems contribute to community wellbeing in the target catchment.

Information and data to inform the description will be drawn largely from existing sources (reports, databases, statistics, municipal reports and plans (e.g., IDPs) etc.), supported by a review of existing studies of the Orange River catchment such as the goods and services report (Huggins *et al.,* 2010) as part of the previous assessment of environmental flow requirements for the Orange River Basin. The baseline assessment will provide an overall contextual background for the catchment; a more detailed consideration of the socio-economic context of specific parts of the catchment aligned with the EWR sites will be undertaken based on the availability of existing information.

5.3.5 Step 7: Ecospecs and monitoring programme

This step will assist the Department with the Water Use License Applications by developing the required templates, including the monitoring requirements for the selected priority water resources to ensure protection. Ecological specifications and the monitoring requirements will be presented in a way that the Department can develop indicators for compliance monitoring.

5.3.6 Step 8: Reserve template

Design and prepare the Reserve template for the Upper Orange Catchment Area.

5.4 Wetland Reserve Determination

Key priority wetland sites will be identified during the inception and gap analysis phase. The wetland EWR determination method will be applied to these priority wetlands. The protocol that have been developed for the rapid assessment of wetlands PES (i.e. the DSP) guides an assessor through the following prescribed steps:

- Step 1: the key wetlands will be classified in accordance with the Hydro-Geo-Morphic (HGM) classification system first described by Brinson (1993) and modified for application in South Africa by Marneweck and Batchelor (2002), Kotze, Marneweck, Batchelor, Lindley and Collins (2007) and SANBI (2009).
- Step 2a: Confirm that the aquatic ecosystem is an inland wetland.
- Step 2b: Delineate the wetland and type the wetland in terms of the Hydrogeomorphic (HGM) functions (i.e. classify the wetland type/s) and identify “assessment units”.
- Step 3a: Describe the perceived natural reference state of the (naturally occurring) wetland assessment unit.

- Step 3b: Select and fill in scoresheets to derive PES Scores and Ecological Categories for individual components of wetland PES.
- Step 3c: Select component weightings to derive an Overall PES Score and Ecological Category for the wetland assessment unit.
- Step 3d: Generate a summary of results.

A more detailed description of each of these steps is provided in the sections below.

5.4.1 Step 1: Collation of Existing Spatial Data

Given the extent of the Upper Orange catchment, and based on experience of the wetland databases available, it is expected that PES and Ecological Importance and Sensitivity (EIS) information will not be available for most systems. As such, numerous national wetland coverages that exist for the whole of South Africa, each differing in terms of scale and accuracy to which they were developed, will be considered. These coverages provide a good indication of the probable presence of wetland habitat within the landscape and will guide the identification of various wetland systems within the broader study area. These layers include the NFEPA and the National Wetland Database (SANBI). In addition to these national spatial coverages, existing projects and smaller scale spatial coverages will be reviewed to incorporate any relevant existing information into the database. Key drivers are essentially automatically derived as part of the HGM classification. This is the strength of the HGM system as each HGM wetland type has conceptually distinct hydrological drivers based on the input, throughput and output of flows or water (see Kotze *et al.,* 2020). This process will further be strengthened by taking a catchment-based approach and considering possible groundwater links.

Using surrogate information, such as land use datasets and the derived eco-classification of the priority wetlands and based on known threats or pressures for development within the catchment areas, the relationship between the threats/pressures and the expected change in condition of the priority wetlands identified will be determined. Wetland baseline condition or current PES will serve as the starting point. Expert judgement will be used to derive how the priority systems are likely to either stay the same or change depending on the pressures they are currently experiencing or based on additional threats or pressures going forward. By taking this approach, it is envisaged that the team will be able to provide information to the DWS which will assist with filling in the gaps in the current wetland Reserve dataset, predominantly in relation to the identification of additional priority wetlands that may be under threat and which should be considered for inclusion in the wetland Reserve for the three main river systems.

These wetlands will be identified for conservation prioritisation, especially in terms of protecting the water resource. The prioritisation of wetlands within the broader study area will be based on the following objectives:

- Encourage the protection of systems which are still fairly intact;
- Protect and maintain catchments upstream of water supply dams to secure the provisioning of water quality provision services;
- Protect those wetland systems that link to groundwater and major rivers;
- Encourage the inclusion of wetland systems associated with important NFEPAs; and
- Further prioritise those systems where rehabilitation has been undertaken in the catchment in the past.

Sustainable and achievable management recommendations will be provided for the prioritised wetland systems, relating specifically to the management of catchment impacts and the implementation of buffers to protect the systems from further degradation.

5.4.2 Step 2: Desktop Mapping

The desktop mapping of priority wetland systems or wetland complexes would be undertaken in accordance with the Guidelines for Mapping Wetlands in South Africa (SANBI 2018). Mapping would be undertaken in Quantum GIS (QGIS) to create a GIS spatial coverage of the priority wetlands. Desktop mapping encompasses the overlaying of numerous GIS coverages to determine the probability of wetland systems, which primarily includes aerial imagery, SPOT 5 satellite imagery, contour data, river coverages and existing wetland inventories. The combination of these layers assists in determining the probability of wetland habitat within the landscape; as wetland identification is normally based primarily on differences in vegetation patterns between wetland habitat and terrestrial areas, as well as landscape setting based on topography. In highly transformed landscapes, where natural vegetation and drainage lines have been entirely altered, the identification of various anthropogenic land use practices that could be seen as indicators of likely wetland habitat is undertaken. For example, features such as ridge and furrow drainage or herring-bone drainage systems in agricultural settings, are often visible in aerial imagery. The mapping of identified wetland areas will be undertaken at a scale of 1:5000 using GIS. This mapping will only be undertaken for those wetlands that have been prioritised for inclusion into the final list of prioritised systems.

5.4.3 Step 3: Desktop Assessment of Wetland Condition and Determination of HGM Unit Type

The state of the selected wetlands will be assessed at a desktop level using the land-cover type wetland assessment tool (Level 1B) included in the revised version of WET-Health (MacFarlane *et al*., 2020), which is considered appropriate in circumstances where a large number of wetlands need to be assessed across a variety of different landscapes. The land-cover assessment tool considers the impact of different land-cover types on wetland habitat, taking into account both catchment and within system impacts. Rapid application of the tool at a desktop level will provide an indication of the likely state of the surveyed wetland systems. The wetlands would be classified as either 'degraded', 'functional' or 'pristine'.

In addition to the desktop determination of the priority wetlands, the HGM unit types will be categorised where possible. Many of the existing inventories will provide the HGM Unit type classification, however where this is not possible, the HGM unit type will be defined based on topographical features.

5.4.4 Step 4: Infield Verification for Wetland Reserve Determination

One site visit, consisting of five full days in field will be undertaken to verify portions of the desktop mapping and assessment of wetland habitat. Given the extent of the study area, detailed delineation and assessment of all wetlands would be an expensive and time-consuming exercise. Therefore, infield verification of the desktop assessments would be undertaken at predetermined locations. The aim of the site visit would be to:

- Verify the presence of wetland habitat visually and, where necessary, in accordance with the DWS (2005) guideline document and best practice guidelines. The location and identified impacts to the wetlands will be recorded utilising a mapping grade Global Positioning System (GPS). The subsequent information will be used to adjust the desktop mapping if required;
- Verify the state of the priority wetland systems, with the site visit targeting a sample of wetlands within a variety of different land-cover types. This would provide an indication of the accuracy of the desktop assessment and the scores for wetlands' present ecological state and ecological sensitivity. The results of which will be tabulated;
- Verify the prioritisation of the wetland systems and determine whether the impacts identified at a desktop level are applicable; and
- Verify the wetland HGM unit type and describe the specific functions that each HGM unit type provides. This will also be provided in a table format.

5.5 Groundwater Reserve Determination

The Groundwater Reserve determination study has the following objectives:

- Execution of GRDM determinations for the set of groundwater resource units, including groundwater dependent ecosystems (GDEs), identified in the study.
- Address both the quantity and quality of the EWR and BHN components of groundwater resources.
- Integration of the GRDM determination results with those of the surface water Reserve determination studies in regard to rivers and wetlands following prioritisation of GRUs/GDEs in terms of current use, future potential use and degree impacted.
- Seek the protection of groundwater resources with due consideration to equitable and sustainable use thereof.
- Presentation the results in a manner that is supportive of the managerial and administrative procedures that inform implementation of the groundwater Reserve.

The study envisages to meet the requirements of a high level GRDM determination. This is informed by factors such as the significant degree of groundwater use, the measure of negative impact on and threat to groundwater quality, and the uncertainty regarding the importance and sensitivity of GDEs in the Upper Orange catchment.

The study will interrogate various literature sources and databases for groundwater information, including the National Groundwater Archive (NGA), the Water Authorisation and Registration Management System (WARMS), the Water Resources of South Africa 2012 Study (WR 2012), Reconciliation strategies, Water Resources Assessment documents, DWS and Water Research Commission (WRC) technical reports, Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) reports, Consultant reports and published scientific papers. The study will further utilise site-specific information where available and generate groundwater quality information for GRUs where data in this regard are poorly represented or absent. Data assessment methods will be tested during this study that may be reviewed and formalised in the on-going development of the GRDM methodology. The proposed methodology is described below.

5.5.1 Step 1: Review of water resources information and data

This phase will comprise a literature review task and may run concurrently with the inception phase. The detailed tasks include the following:

- Review of all previous studies in the WMA including water resources planning, EWR and BHN determinations, water quality, socio-economic, augmentation and reconciliation strategies specific to groundwater.
- List available water resources models and evaluate their applicability in the study.
- Undertake a gap analysis and compile recommendations on how to deal with information and data gaps.

5.5.2 Step 2: Determination of the EWR and BHN components

The study implementation phase will inform the essence of the study and will deliver the main product, i.e. a determination of the groundwater component of EWR and BHN (groundwater quantity and quality) in the Upper Orange catchment, through the sequential execution of an eight step procedure. The basic tasks for this phase are outlined below:

- ***Preparation***

The largely unknown relationship that exists between the groundwater regime and wetlands that might constitute groundwater (or aquifer) dependant ecosystems (GDEs) in the study area will be identified as a further challenge to the GRDM determination. Since uncertainty in this regard may also extend to riparian areas, it is envisaged that the level of detail and site-specific hydrogeological data available for such settings may be sparse or deficient.

- ***Description of study area***

This can be accomplished on the basis of existing available information obtained from various sources. Limited provision is made for the sourcing of new geohydrological data and information by means of focused field surveys and approaches to organizations such as mines and industries for localised data. This task facilitates a conceptual understanding of the groundwater environment that inform the subsequent tasks within the framework of a GRDM assessment, namely the delineation of GRUs and quantification of the Reserve.

- ***Defining the present status***

The present status category will be assessed for each GRU on the basis of factors such as the environmental impacts, level of stress, groundwater usage, groundwater contamination and land use. The present status category, in turn, inform the derivation of a water resource category for each GRU and the determining of the Reserve itself.

- ***Quantification of the Reserve***

This activity will seek to establish the volume of groundwater that contributes to sustaining the EWR and BHN. This is a necessary prerequisite to determining the quantity of groundwater potentially available for allocation to users and potential users.

- ***Compile a Monitoring Programme for GRUs***

This task will draw on the understanding of the groundwater resources gained from the study results to develop a multifunctional groundwater monitoring programme for the Upper Orange catchment that will meet different demands in terms of variables, frequency, etc. required to implement appropriate management and protection of the various GRUs.

- ***Data Sources and Software***

Significant groundwater and associated data exist for the study area in databases managed by the DWS, the WRC and the Council for Geoscience. Processed data and assessments of groundwater recharge and use such as are contained in the WR 2012 repository may prove to be invaluable to this study.

5.6 Task 4: Stakeholder Engagement Strategy

The stakeholder engagement strategy (SES) will form part of the study and stakeholders will be engaged through the process to ensure stakeholder input is incorporated into the determination of the Reserve process that is to follow. A robust and focused SES will be undertaken that is aligned to the technical steps of the study. Every effort will be made to link and align to existing structures and forums in the Upper Orange catchment. Stakeholder databases will be drawn upon, including the database GroundTruth has from the JSB2 and JBS3 ORASECOM studies and which will be built upon. The idea is not to try to consult with everybody, but rather with representatives of specific sectors of society.

The determination of the Reserve in the Upper Orange catchment will thus require the selection of appropriate points in the technical process that allow for optimisation of stakeholder involvement with required outcomes. The level of stakeholder engagement will range between technical involvement and consultation.

The Reserve determination will be followed as best suited to circumstances and conditions in the study area. This will be an iterative process and may have to be adapted according to the prevailing circumstances. The team will also strive to ensure that as much of the existing information will be used and the steps kept as simple as possible without comprising the validity of the process.

Overall, it is envisaged that the stakeholder outputs may include the following:

5.6.1 Consolidated stakeholder database

Stakeholder databases that have been compiled through earlier initiatives will be reviewed and expanded to include stakeholders relevant to the Upper Orange catchment. The format of the database will be maintained to ensure the reviewed database can be integrated with existing databases if required.

5.6.2 Consultation with the Client regarding project progress

An appropriate process will be developed, in consultation with the Client, to engage the representatives to assess and monitor the progress on the project.

5.6.3 Background Information Documents (BID):

Following the approval of the Inception Report, a BID will be compiled for distribution to all identified stakeholders. The purpose of this document will be to announce that the DWS is undertaking the Reserve determination of the Upper Orange catchment, the process to be followed, anticipated activities, proposed timelines as well as how stakeholders will be involved in the project. This document will also aim to explain the necessity of the project and the context of the study. At this early stage in the project, stakeholders will be requested to provide their comments and inputs and also to note if they are aware of any stakeholders who should become involved.

Stakeholders need to be given feedback towards the end of a project after the scenario evaluation and selection. A second BID will be prepared at this stage to communicate the outcomes of the study.

5.6.4 Stakeholder communication and sectoral workshops

Two (2) stakeholder engagement meetings will be undertaken for this study, and proposed to be hosted in the Gariep/Aliwal area for the upper part of the catchment and the Van der Kloof area for the lower part of the catchment, so that all stakeholders will have the opportunity to attend, for the presentation of the Reserve results.

The stakeholder engagement process will be based on a sectoral approach, i.e. ensuring communication and liaison with stakeholder representatives of the key sectors across the catchment. This will include:

- The results of the eco-classification of the priority river sites selected;
- Groundwater and wetland Reserve study results;
- Review of draft scenarios and explore gaps to establish scenarios representing stakeholders' vision for the catchment; and
- To ensure adequate detail has been provided by the local specialists and authorities to the stakeholders and environmental groups, for their understanding of the Reserve process and outcomes.

5.6.5 Issues and Response Report

The capturing of information from stakeholders is considered important to the Reserve determination process. An Issues and Responses Report will be compiled and updated throughout the study period of the project. This report will list all the comments from stakeholders (to be received at meetings, workshops, emails etc.) and the responses from the project team.

5.7 Task 5: Capacity Building

The study team is cognisant of the DWS's and specifically the CD: WE's imperative to build capacity and transfer skills in water resource management and protection. A capacity building programme has been developed and is included as Appendix C. This programme is based on a model well received by DWS officials on previous projects implemented by this team which includes introductory training before each key workshop, and mentoring of DWS officials by specialists during field surveys, EWR and scenario workshops etc. DWS officials are also encouraged to select specialist fields where they would like to learn more, and pair-up with that specialist during field surveys and workshops. This programme will be updated during the project and following each training session with final participants and comments from the Departmental participants.

Capacity building will be realised through the following mechanisms in this study, namely:

- **Mentorship:** Mentoring of the Upper Orange Reserve determination DWS team - which will involve dedicated, one-on-one guided sessions with the identified specialists on the team addressing rivers, wetlands and groundwater as the subject matter;
  Stakeholder Engagement/empowerment: stakeholder empowerment sessions will be linked to the stakeholder meetings. The team will capacitate stakeholders through the various meetings and consultation forums that are created over the duration of the project. Each presentation will run through the process, tools/ methods applied or applicable approaches followed so that stakeholders become familiar with the methodology applied. Where applicable supporting information will be made available to stakeholders;
- **Specialist workshops:** Various specialist workshops will be held during the course of this study, further providing a platform for identified DWS official, the DWS team and/or trainees.
  - Nine workshops are envisaged for this study, which will meet the needs to DWS members. Refer to:
  - Table 5-1 for the preliminary capacity building plan/schedule for these workshops/opportunities around rivers, groundwater and wetlands, that will be held through the duration of this study with more detail in Appendix C.
  - On 31 August 2021, the specialist team and DWS officials conducted the first specialist workshop (RU workshop), which was well attended by DWS. The approach followed for RU selection for rivers was discussed and trained upon. The department was then taken through the preliminary selected RUs (from a river perspective), with input from the specialists.
  - All workshops and training sessions will be held virtually, until such time the regulations around the Covid-19 pandemic are alleviated. However, should there become an opportunity for physical face-to-face workshops, whereby these are much more interactive and where the specialists can collaborate with the Department members, this will be done.
  - The various workshop platforms will be communicated to the Department well in advance.
  - During the initiation meeting held on 25 August 2021, GroundTruth requested the Department to submit the names of those officials who are interested to attend these initiatives and for which the various virtual invitations can be sent ahead of time for planning and preparation. These colleagues will be added to Table 5-1.
- **In-field capacity building:** Various surveys are envisaged for this study, particularly wet and dry season river surveys and wet season wetland and groundwater in-field verifications. It is encouraged that those members attend the field surveys, to obtain in-field insight, all which are incorporated into the below-mentioned tools and models, which will be trained upon during the workshops (Table 5-1); and
- **Training Workshop -** Participation of identified DWS officials – in a one-day dedicated workshop on water resource components and Reserve determination tools which will build their capacity and broaden their skills base with respect to the 8-step Reserve process, as well in terms of specific technical content. The following Reserve determination tools that the PSP will offer the officials will include the following:
  - Hydrological Driver Assessment Index (HAI);
  - Geomorphology Driver Assessment Index (GAI);

  - Physico-chemical Driver Assessment Index (PAI);
  - Fish Response Assessment Index (FRAI);
  - Macro Invertebrate Response Assessment Index (MIRAI);
  - Riparian Vegetation Response Assessment Index (VEGRAI);
  - Wetlands Reserve Determination Tools;
  - Groundwater modelling (conceptual, numerical etc);
  - Groundwater Resource Unit Delineation (GRU);
  - Recharge estimation per delineation (GRU);
  - Baseflow estimation per delineation (GRU); and
  - Determination of the groundwater component/contribution to baseflow.
- **Citizen science** – please refer to Section 5.7.1 below for further detail.

5.7.1 Citizen Science

The potential use of citizen science (CS) to assist during the various in-field verifications and monitoring using the selected river approach levels will be assessed. Beyond the lifespan of this project and its ToR, this will allow for more data to be collected at more sites, encourage community involvement in water resource management, complement data collected, and upskill community members. Where appropriate, CS tools will be defined and materials describing the implementation and their potential application will be provided. Ideally DWS staff with a specific mandate to monitor and/or engage with communities will be specifically identified to co-create the opportunities for the translation and then application of CS tools into longer term monitoring programmes to achieve and meet the Reserve monitoring requirements. For example, where a specific flow/discharge requirement might be defined and needed at a particular site, at a specified time of the year to meet the Reserve requirements, this could be simply monitored using a Transparent Velocity Head Rod (TVHR) or "plank" for routine monitoring purposes, and by a community or NGO member, and within the local area.

This negates the need for a skilled hydrologist/technician or gauging weir to measure attainment of the required Reserve requirement at that site. It also empowers local communities to engage with the Reserve process and the importance of these communities in achieving some of the Sustainable Development Gaols (SDG) targets, for example Target 6.b – Stakeholder participation - "Support and strengthen the participation of local communities in improving water and sanitation management" - 2030 Agenda for Sustainable Development (see https://www.sdg6monitoring.org/indicators/target-6b/)

Where possible, virtual training workshops and/or links to other training opportunities for these will be provided to empower community groups in and on these aspects.

The following DWS members will be invited to join the various capacity building opportunities:

- Kwazikwakhe Majola
- Ndivhuwo Netshiendeulu
- Adaora Okonkwo
- Fanus Fourie
- Jackie Jay
- Kgotso Mahlahlane

- Vernon Blair
- Mmaphefo Thwala
- Stanley Nzama
- Tichatonga Gonah
- Mkhevu Mnisi
- Maluleke Henry
- Philani Khoza
- Rendani Makhwedzha
- Mpete Tinyiko
- Nolu Jafta
- Elijah Mogakabe
- Ntuthuko Mthabela

Those members that attend will sign an attendance register, be included within the capacity building programme and requested for their comments, suggestions and recommendations following the capacity building initiative. This will in turn assist GroundTruth in ensuring experiences and expectations are met through the study. Refer to Table 5-1 for the capacity building opportunities and preliminary schedule.

Table 5-1: Capacity building preliminary schedule

Capacity Building opportunity		Proposed month
1	Approach for RU delineation and level of assessment	Aug-21
2	Selection of priority wetland and groundwater RUs	Jan-22
3	EWR site selection and river survey 1 (intermediate sites)	Mar-22
4	Wetland surveys	Feb-22
5	Groundwater surveys	Mar-22
6	River survey 2 (rapid 3 and biological sites)	Jun-22
7	Socio-economic outline and Socio-Cultural Importance (SCI)	Nov-21
8	River Ecoclassification (EcoStatus models)	Jul-22
9	River EWR quantification workshop (DRM, RDRM, HFSR)	Sep-22
10	Groundwater workshop (PES, quantification and setting RQOs)	Aug-22
11	Wetland's workshop (WET-Health, functioning, EIS)	Oct-22
12	Stakeholder workshop 1 (Citizen Science)	Aug-22
13	Scenarios and Water Resource Modelling	Nov-22
14	Ecological consequences, ecospecs and monitoring	Jan-23
15	Integration between components (rivers, wetlands & groundwater)	Feb-23

Capacity Building opportunity		Proposed month
16	Stakeholder workshop 2 (Citizen Science)	Jan-23
17	1-day Wrap-up training (all components)	Mar-23

5.8 Task 6: Communication, Liaison, Study Management and Co-ordination

A component to the Reserve determination for the Upper Orange catchment is the communication and liaison function. The study team will be responsible for the function and arrangement of various meetings and the specialist workshops, PSC meetings, sectoral workshops, review committee, ad-hoc technical liaison and stakeholder engagement meetings.

Technical workshops with the specialists on the team will be held at strategic phases throughout the project to ensure co-ordination and integration across the technical focus areas of the project. This collaboration will also feed the capacity building and mentoring/skills transfer objectives discussed within that section below.

It is proposed that nine (9) Project Management Committee (PMC) meetings will be undertaken over the two (2) year study period, with an additional six (6) ad-hoc technical meetings. These will include Project Steering Committee Meetings (PSC) and two (2) Stakeholder Engagement Meetings. Secretarial services namely agenda's, registers and the presentation will be provided by the PSP. **Meeting minutes of the PMC meetings will be provided by the Department.**

The reporting system will be instituted whereby progress reports, technical memoranda and other material necessary to inform the client and other stakeholders will be prepared. Monthly progress reports will be submitted to the Client to advice on progress and status, coupled with the actual expenditure against cash flow estimates, significant findings and outcomes and corrective actions taken in respect of work programme and cash flow estimates. These progress reports will be submitted monthly and more detailed ones quarterly.

A complete record of proceedings of all meetings will be maintained and appropriately archived.

Technical progress reports will be provided after each defined deliverable in the form of an interim milestone report. These reports shall describe the procedures and methodologies followed and the results achieved. The latter shall be prepared and submitted to the Client according to the milestone programme. These reports will be used as supporting documents for the final Main Report.

5.9 Project Closure

The purpose of this phase is to (i) consolidate the results of the project and to (ii) ensure that all documents, maps, data, etc. are transferred to the DWS for future reference and use. A close out report will be presented with the final main findings of the study, capacity building initiative and recommendations for future studies. As such a close out report will be submitted along with the final main report and external reviewer's report. This report will detail the completed deliverables, summary of work done, and skills transferred during the project.

An External reviewer has been included within this study and will assess and review various deliverables produced during the operational phase of the project.

6. PRELIMINARY RIVER RESOURCE UNITS AND LEVELS APPROACH

6.1 Rivers RU Approach

An approach has been developed through previous Reserve determination studies to assess a large number of river resource units (RUs) (sub-quaternary reaches) when basin-wide Reserve studies are undertaken. This approach includes the assessment of (i) 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. As a final step, the level of EWR determination is determined by integrating the IWUI and IEI.

The Upper Orange catchment consists of approximately 790 sub-quaternary reaches that were assessed as part of the Desktop PES/EI/ES study that was undertaken during the period 2012 to 2014 (DWS, 2014). The preliminary priority RUs that were identified for this study is based on the results from this 2014 study and the following steps were undertaken:

(i) Determine IWUI per sub-quaternary reach using the flow and quantity modification metric scores. These were scored from 0 (no modification) to 5 (critical modification). The highest score of the two metrics was used as the IWUI per sub-quaternary reach. If any water use developments between 2012 and 2021 were undertaken that changed the water use or quality in a specific area/ reach, these were included and the original score changed to reflect it.

(ii) Determine the Ecological Importance and Sensitivity (EIS – very low to very high) using the highest score of EI and ES.

(iii) Integrate the EIS with the PES, using the following matrix to determine the IEI (Figure 6-1).

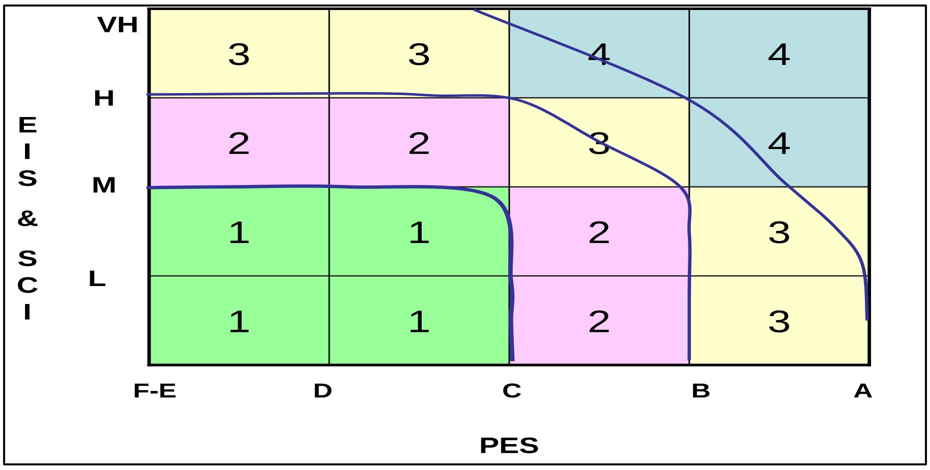

Figure 6-1: Matrix to integrate PES and EIS

(iv) The next step is to integrate the IEI and IWUI to determine the level of Reserve study (biological, rapid, intermediate or comprehensive) with the matrix below (Figure 6-2). Motivations and rationale for each of these selected RUs are provided and where future water developments are planned, these are included as part of the motivation.

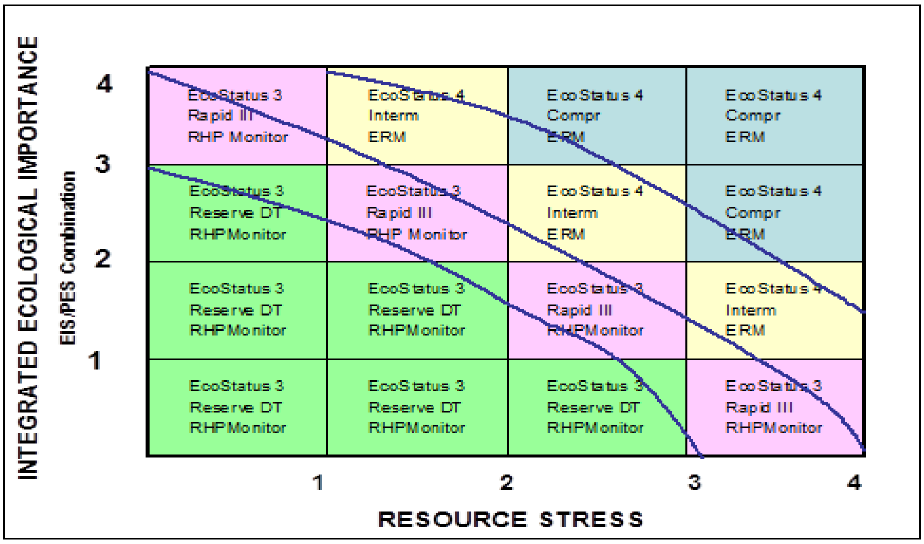

Figure 6-2: Matrix to integrate IEI and IWUI to determine level of assessment

(v) A final step is to check if any wetlands or groundwater areas, contributing to baseflows have been identified in specific sub-quaternary reaches that were not included as a priority RU. These are then included to ensure integration and to quantify the baseflows.

Further detail and final results from the above approach will be compiled within the RU Report due in January 2022.

6.2 Prioritised wetlands RU approach

Unfortunately, spatial wetland data is limited at a broad scale, especially when compared to the spatial data and information available for river systems. This will be one of the main limitations to the wetland component of the study, as gaps in data and limited additional information is available (this will be expanded upon within the Gap Assessment Report). However, through a combination of national data overlays, institutional knowledge and existing wetland work, the identification of important systems at a large scale is possible. With the project only at the inception phase of the process, broader national-scale wetland inventories have been utilised to inform the identification of potential wetland systems.

Using the available information in the NFEPAs wetland shapefile and the NWM5 spatial dataset, mapped wetlands were reviewed in terms of selected criteria within the basin area as follows:

- Wetlands with an A or B PES category;

- Wetlands classified a Critically Endangered and Endangered;
- Wetlands of conservation significance, considering;
- NFEPA identified systems;
- Wetlands coinciding with IBAs;
- Wetlands coinciding with crane habitat;
- Wetlands coinciding with ground and surface water strategic areas;
- Wetlands upstream of important water supply dams;
- Large (>50ha) wetland and/or wetland complexes;
- Wetland hydrogeomorphic (HGM) units recognised as supplying ecosystem services linked to water quantity;
- Wetland HGM units recognised as supplying ecosystem services linked to water quality; and
- Wetland HGM units providing the abovementioned ecosystem services that coincided with identified water-stressed catchments/basins.

Those areas where all/most of these attributes were recorded for identified wetlands were then flagged as potential wetland RU focus areas, some involving just one wetland system, whilst others involved larger wetland complexes. Areas flagged as important from a river perspective were also reviewed relative to the various wetland spatial layers overlapped, to identify where the protection of such wetlands upstream and/or along these areas could assist in supporting the river RUs. This was largely informed by the sub-quaternary catchments noted as water stressed areas in terms of water supply and water quality. These sub-quaternaries were overlayed with the wetland systems identified as providing one or more of the above-listed characteristics and those which intersected became a part of the possible candidate wetland list.

Using all the attributes gathered from the various spatial layers, a rating system was created to rank the most important wetland systems based on the various attributes. To simplify the process, a scoring system of 1-0 was utilised as part of a presence-absence approach (1=present, 0=absent). Wetland PES, *endangered or critically endangered* wetlands, wetlands with cranes, NFEPA wetlands verified by experts, wetland interacting with any SWSAs, wetlands upstream of water supply dams and wetlands greater than 50ha were all selected as the preliminary wetland site selection process. These wetlands were then further rated according to the HGM unit type and provisioning of ecosystem services and whether they were located within the sub-quaternaries identified through the river RU process of those areas under pressure in terms of water quality and/or quantity.

The preliminary wetlands were then rated out of a total of 17 points, and were then ranked highest to lowest. A total of 3 687 wetlands were prioritised, and it is anticipated that only the top 20% of these (737 wetlands) will be considered for further refinement for inclusion into the fieldwork component of the project. Due to the dearth of wetland data, however, it is recommended that interactions with relevant regional specialists be undertaken to identify if any priority systems may exist that had not been identified using the existing available coverages.

The results from the above approach will be compiled within the RU Report due in January 2022.

6.3 Groundwater RU approach

Colvin (*et al.,* 2004) outlines a functional approach to setting Resource Quality Objectives for groundwater. In addition to this, WRC (2007) and (2013) provides a Groundwater Resource Directed Measures (GRDM) manual to be used for the implementation of RQOs.

In accordance with WRC (2007), delineation of groundwater resource units is based on quaternary catchment boundaries, aquifer type (primary aquifer, secondary aquifer, karst aquifer) and other physical, management and/or functional criteria. Quaternary catchments form the basic unit for a GRDM assessment, however, these units can then be further subdivided (or grouped). Typically, areas of similar character can be mapped into distinct units using expert judgement and interpretation. A key outcome is a map showing the extent of the groundwater resource GRDM assessment data sheet, in which the name of each unit and its aerial extent are recorded.

RQOs are set for each resource unit using rules for selected classes (WRC, 2007). Based on the conceptual understanding of the area, key measurable indicators as RQOs are selected (e.g. water levels, total dissolved solids (TDS), faecal coliforms, etc) and the level at which they should be maintained (natural, slightly modified, etc.). A key outcome is a list of RQOs to guide management and monitoring activities.

The RU delineation procedure for groundwater will involve an evaluation process where available data including the WR2012 spatial data on geology, geohydrology (aquifer type and yield, groundwater quality) and groundwater regions will be considered to identify significant groundwater resources within the project area.

The results from the above approach will be compiled within the RU Report due in January 2022.

7. STUDY LIMITATIONS AND CONSIDERATIONS

7.1 D15 (Makhaleng) and D18 (Tele)

Table 7-1 illustrates the catchments D15 (Makhaleng) and D18 (Tele). These tributaries are higher up in the Upper Orange catchment along the border between South Africa and Lesotho. They have high salt and sediment loads, thus impacting the upper reaches of the Orange River. Following conducting the resource stress scoring in terms of water use, quality and the Integrated Water Use Index (IWUI), coupled with the Integrated Ecological Index (IEI) (Section 6.1), most of these rivers (tributaries) came out with a biological river level approach. This limitation was brought up with the Department during the Initiation Meeting held on 25 August 2021, as to whether D15 and D18 be included within the scope of work for this study. These reaches are very remote to the rest of the catchment, and thus there could be a lot of time wasted trying to reach some of these sites, when in fact we could be placing more focus on other prioritised rivers.

The Department responded in writing on 30 August 2021, that they agreed with GroundTruth (PSP) that these areas are not easily accessible, and should be a challenge from a monitoring perspective. However, it was confirmed that these catchments will be included within the Final EWR report (along with these said limitations) on a desktop level. The PSP will visit these two rivers (mainstem Tele and Makhaleng) to collect diatoms and undertake a habitat integrity assessment to determine the PES.

Table 7-1: D15 (Makhaleng) and D18 (Tele)

Sub-quaternary catchment	Quaternary catchment	River
D15G-04784	D15G	Mantikoana
D15H-04878	D15H	Deklerkspruit
D15H-04889	D15H	Makhaleng
D15H-04944	D15H	Makhaleng
D15H-04945	D15H	Worsfonteinspruit
D15H-04995	D15H	Makhaleng
D18K-05157	D18K	Tele
D18K-05187	D18K	Tele
D18K-05201	D18K	Tele
D18K-05203	D18K	Un-named tributary
D18K-05265	D18K	Tele
D18K-05268	D18K	Blikana
D18K-05359	D18K	Tele
D18K-05368	D18K	Pelandaba
D18K-05371	D18K	Blikana
D18K-05376	D18K	Tele
D18K-05393	D18K	KwaSijora
D18K-05407	D18K	KwaNomlengaba
D18K-05413	D18K	Sidwadwa
D18L-05017	D18L	Orange
D18L-05067	D18L	Orange

7.2 Sub-reaches within the study

Owing to approximately 790 sub-reaches identified within the Upper Orange catchment, we would like to aim to optimise assessing the whole catchment – although realistically and within budget. There are a large number of "unnamed tributaries" in this list, many with a Present Ecological State (PES) of a C or below. Following conducting the resource stress scoring in terms of water use, quality and the Integrated Water Use Index (IWUI), coupled with the Integrated Ecological Index (IEI), some of these unnamed tributaries came out with a biological river level approach. This limitation was brought up with the Department during the Initiation Meeting held on 25 August 2021, as to consider eliminating these unnamed tributaries and rather retain those reaches which are associated with a water use (high IWUI score) and which were identified to require a Rapid 3 or higher-level approach.

The Department responded in writing on 30 August 2021, that this limitation of eliminating some river reaches will be considered during the review of the Draft Resource Unit Report and confirmed with the PSP whether the areas selected represent a true reflection of the Upper Orange catchment.

7.3 Hydropower releases from Gariep Dam

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

We aim to move forward and optimise our time and efforts in achieving a high confidence Reserve. Consequently, the most feasible option will be to optimise releases by developing a Flow Management Plan (FMP) which will seek to achieve a sensitivity and setting of achievable EWRs. Information for this will be used from the JBS3 survey (being conducted in October 2021) to inform the FMP.

Further discussions will be had going forward in relation to this when the yield model is conducted during the scenario component of the study with the WRP and the relevant directorates. Through this platform, we shall see how we can influence the future development of that release curve for the next round to assess whether this can be implemented.

It is proposed that the FMP will be written into conditions once the Reserve is gazetted, to ensure the rules become compulsory.

7.4 Covid-19 and Riots

The current COVID-19 pandemic poses a significant risk to achieving some of the objectives of this study, particularly virtual platforms when requiring PMC, PSC, SE and the capacity building training component of the project. However, this risk will somewhat be alleviated as time goes by and the vaccination programme continues and improves. Either way, COVID-19 restrictions in place or not, GroundTruth plan to continue this study to the best of their ability in conducting the field surveys and improving SE and training opportunities.

As COVID-19 is the greatest current risk to the project, GroundTruth have an established and robust COVID-19 Health and Risk Workplace Policy under relevant SA legislation which will be adhered to. For this study, we have integrated this risk and designed suitable mitigation strategies (first aid kits, mobile contactless IR thermometers, face masks, PPE, sanitising etc.) to allow work and field-teams to operate safely, and limiting the risk to vulnerable communities. We also have suitable backstopping options with back-up field teams if needed, should any team member fall ill. These risks and mitigation strategies are continuously updated to industry best practise.

With the recent riot and lootings that occurred within South Africa, should such situations arise while the teams are on-site, the surveys will stopped immediately and postponed and continued until safe to do so.

7.5 Aquatic Monitoring

SASS5 sampling will only be carried out in available and accessible habitats, as per the standard SASS5 protocol (e.g. must be flowing water, ideally all substrate types/biotopes present, no flood conditions, wadeable water depth, etc.), and according to health and safety protocols. Elevated flows, lack of habitat etc. may impact on results and the ability to sample.

Diatoms can only be collected when suitable substrate exists in-stream – this is generally not such an issue as there is generally always some available.

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

8. SUMMARY OF STUDY DELIVERABLES AND TIMEFRAME SCHEDULE

The summary of deliverables for the study is included in Table 8-1 below.

Table 8-1: Summary of the study deliverables

Number	Deliverables	Expected Date
All components		
1	Information and data gathering, Inception report	September 2021
2	Gap analysis and report	November 2021
3	Resource Units Report	January 2022
Rivers		
4	River survey 1 report	March 2022
5	River survey 2 report	June/ July 2022
6	Ecoclassification report	August 2022
7	EWR quantification report	October 2022
8	Ecological consequences of scenarios Report	February 2023
Groundwater		
9	Groundwater survey report	April 2022
10	Groundwater report	November 2022
Wetlands		
11	Wetland survey report	March 2022

Number	Deliverables	Expected Date
12	Wetland report	September 2022
Socio-economics		
13	BHN report	October 2022
14	Socio-economics report	February 2023
Stakeholder engagement		
15	Stakeholder database and plan	November 2021
16	Stakeholders' comments & response register	April 2023
All components		
17	Ecological specifications and monitoring plan	March 2023
18	Reserve template preparation	April 2023
19	Capacity building report	April 2023
20	Final Integrated Main report	May 2023
21	Close-out report, including external reviewer report	July 2023

9. STUDY PROGRAMME

The study programme of the study tasks is provided in Appendix B. The study will be completed within the 24-month time frame as specified in the contract. In terms of the programme the study is expected to terminate in July 2023.

10. STUDY TEAM

The study team participating in the study are indicated in Table 10-1 and Figure 10-1.

Table 10-1: Study team members

Name	Company	Proposed project role
Dr Mark Graham	GroundTruth	Project Director/Water Quality Specialist
Kylie Farrell	Independent Specialist	Project co-ordinator/Invertebrate Specialist

Name	Company	Proposed project role
Juan Tedder	GroundTruth	Fish Specialist
Dr Bennie Van der Waal	Independent Specialist	Geomorphologist
Gary de Winnaar	GroundTruth	Riparian Specialist
Trevor Pike	GroundTruth	Hydraulics Specialist
Khwezi Mncwabe	GroundTruth	Hydraulics
Retha Stassen	Independent Specialist	Technical Lead/ Hydrology Specialist
Bennie Haasbroek	Independent Specialist	Systems Analysis Specialist
Keanu Singh	GroundTruth	Systems Analysis – capacity building
Regan Rose	JG Afrika	Groundwater/Geohydrology Specialist
Andile Gumede	JG Afrika	Groundwater/Geohydrology
Fonda Lewis	Independent Specialist	Socioeconomics/BHN Specialist
Michelle Browne	Independent Specialist	Socioeconomics/BHN Specialist
Craig Cowden	GroundTruth	Wetland Specialist
Fiona Eggers	GroundTruth	Wetland Specialist
Steven Ellery	GroundTruth	Wetland
Carla Hardman	GroundTruth	GIS
Neels Kleynhans	Independent Specialist	External Reviewer

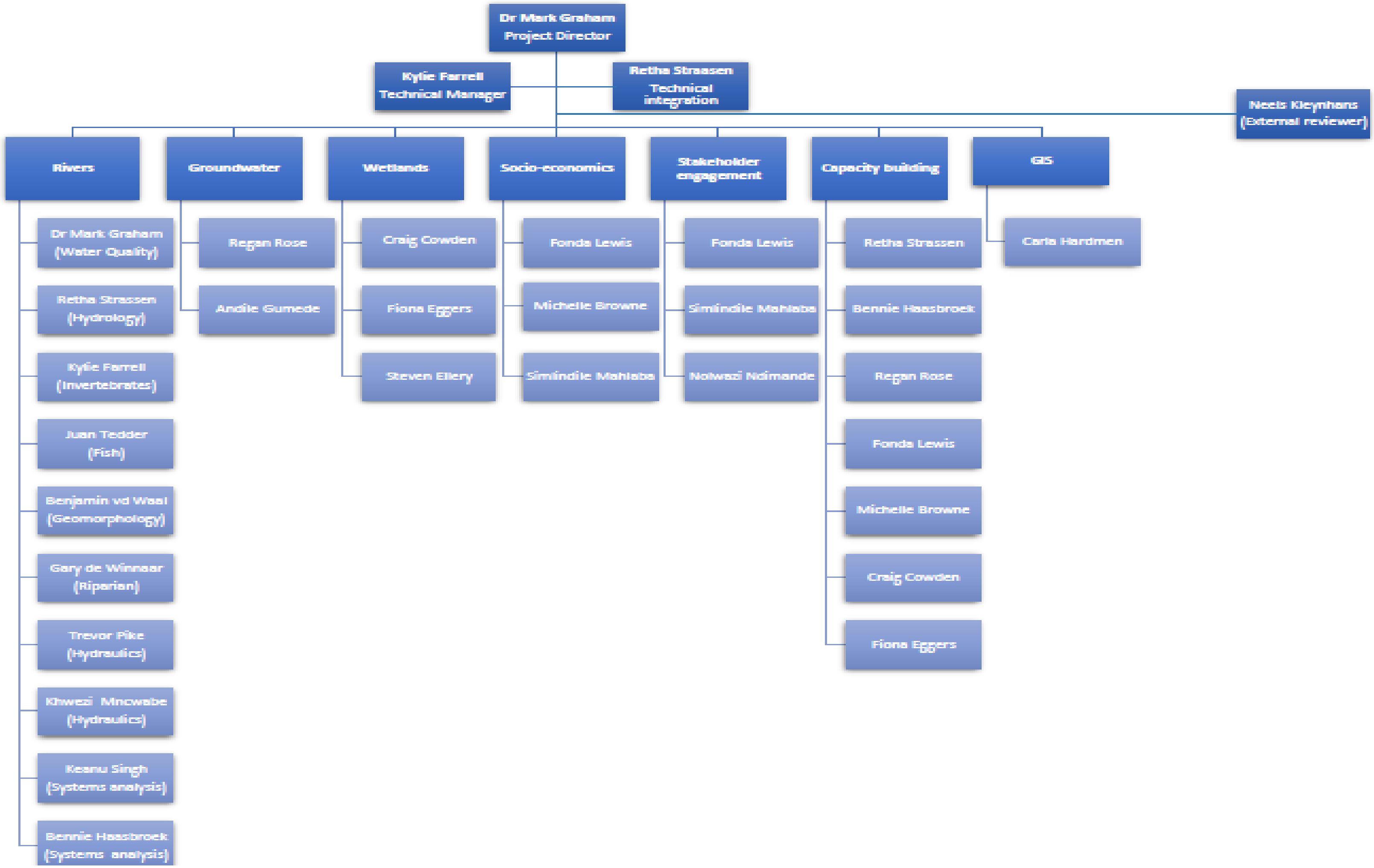

Figure 10-1: Organogram of the project team and their key roles and areas of expertise

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12. APPENDICES

Appendix A: Initiation Meeting: 25 August 2021 agenda, meeting minutes and presentation

Appendix B: Study programme

WP:11343HIGH CONFIDENCE RESERVE DETERMINATION STUDY FOR SURFACE WATER, GROUNDWATER AND WETLANDS IN THE UPPER ORANGE CATCHMENT

study tasks	YEAR																							
	2021					2022												2023						
	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
Project management																								
Contract finalisation and sign off																								
Project management																								
Attendance of Project team meetings (2)																								
Attendance and preparation for PMC meetings with DWA (9)																								
Monthly progress reports and quarterly progress reports																								
Attendance of ad hoc meetings (6)																								
Project Inception																								
Inception meeting with DWA (PTA)																								
Data gathering and collation of background information and mode																								
Preparation of Inception Report (incl Integrated Work & Capacity E																								
Gap analysis workshop																								
Preparation of Gap Analysis Report																								
Adressing gaps identified (reserves, WQ etc)																								
Determination of EWR and BHN																								
1. Rivers																								
Define resource units, prioritise and site selection																								
Survey 1 (post-wet season)																								
Field survey report, inclu RUs, site selection																								
Survey 2 (dry season)																								
Data preparation for workshops																								
Workshop 1 (ecostatus, alternative categories, EIS)																								
Ecoclassification report																								
Workshop 2 (EWR determination)																								
Extrapolation, scaling to other areas																								
EWR quantification report																								
Define scenarios																								
Water resources model adjustments and testing																								
Scenario modelling																								
Workshop 3 (scenario evaluation and ecological consequences)																								
Ecological consequences report																								
Workshop 4 (Integration with other components - wetlands, grour																								
Ecospecs and monitoring programme																								

Study tasks	YEAR																							
	2021					2022												2023						
	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
2. Groundwater																								
Preparation and re-assessment of TOR	■																							
Description of study area		■																						
Groundwater RUs		■				■																		
Groundwater surveys									■															
Groundwater workshop (PES, quantification, RQOs)											■	■												
Groundwater report																■			■	■				
3. Wetlands																								
Collation of existing data	■	■																						
Desktop Mapping, prioritisation, assessments			■	■																				
Field surveys							■	■																
Wetland assessment workshop										■	■													
Wetlands report														■										
4. Socio-economics and BHN																								
Outline of socio-economic water use & determination of socio-cult							■	■	■															
Basic Human Needs assessment													■	■										
Socio-economics report															■									
5. Stakeholder engagement																								
Develop stakeholder database and engagement plan				■							■				■									
General awareness creation (BID, invitations)					■	■											■	■						
Stakeholder meetings x 2									■											■				
Register of stakeholder comments and responses																					■			
Capacity building																								
Rivers - Resource units and site selection		■																	■					
Rivers - ecostatus, EWR determination						■													■					
Rivers - scenario evaluation and ecospecs																	■		■					
Groundwater																			■					
Wetlands																			■					
Socio-economics																			■					
Reporting																								
Main integrated report																						■		
Ecospecs and monitoring report																				■				
Preparation of templates																				■	■			
Capacity building report																					■			
Close-out report, external reviewer and final report																								■

Appendix C: Detailed capacity building programme

INTEGRATED VAAL RIVER COMPREHENSIVE RESERVE DETERMINATION STUDY: PROJECT MANAGEMENT UPDATED PROGRAMME

	Activities	Final Participants	Comments from trainees	2021					2022												2023						
				AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
1	Approach for RU delineation and level of assessment			◆																							
2	Selection of priority wetland and groundwater RUs								◆																		
3	EWR site selection and river survey 1 (intermediate sites)										◆																
4	Wetland surveys									◆																	
5	Groundwater surveys										◆																
6	River survey 2 (rapid 3 and biological sites)													◆													
7	Socio-economic outline and Socio-Cultural Importance (SCI)						◆																				
8	River ecoclassification (ecostatus models)														◆												
9	River EWR quantification workshop (DRM, RDRM, HFSR)																◆										
10	Groundwater workshop (PES, quantification and setting RQOs)															◆											
11	Wetlands workshop (WET-Health, functioning, EIS)																	◆									
12	Stakeholder workshop 1 (Citizen Science)															●											
13	Scenarios and Water Resource Modelling																		◆								
14	Ecological consequences, ecospecs and monitoring																				◆						
15	Integration between components (rivers, wetlands & groundwater)																					◆					
16	Stakeholder workshop 2 (Citizen Science)																				●						
17	1-day Wrap-up training (all components)																						◆				

◆ = Training workshop

▲ = Individual training

● = Awareness creation/ Citizen science