WSM LESHIKA CONSULTING (PTY) LTD

PROJECT NUMBER: WK21047

INVESTIGATION OF GROUNDWATER AND SURFACE WATER INTERACTION FOR THE PROTECTION OF WATER RESOURCES IN THE LOWER VAAL CATCHMENT. LITERATURE REVIEW AND DATA GATHERING REPORT

DATE: May 2022

REPORT VERSION: V1.2

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

WP11380

DWS REPORT NUMBER: RDM/WMA05/00/GW/SW/0222

Published by

Department of Water and Sanitation
Private Bag X313
PRETORIA, 0001
Republic of South Africa

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This report should be cited as:

Department of Water and Sanitation (DWS), South Africa. 2022. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Literature Review and Data Gathering Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0222

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Main Report on Surface-Subsurface Interaction	RDM/WMA05/00/GWSW/0523
Close-out Report	RDM/WMA05/00/GWSW/0623

Bold indicates this report

APPROVAL

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REPORT NO:	RDM/WMA05/00/GWSW/0222
FORMAT:	MSWord and PDF
WEB ADDRESS:	http://www.dws.gov.za

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REPORT SCHEDULE

Version	Date
First draft	April 2022
Final	May 2022

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BHNR	Basic Human Needs Reserve
CD: WE	Chief Directorate: Water Ecosystems
CV	Coefficient of Variability
Dir: NWRP	Directorate National Water Resource Planning
DM	District Municipality
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
GRAII	Groundwater Resource Assessment Phase II
GRIP	Groundwater Resource Information Project
GRUs	Groundwater Resource Units
IUA	Integrated Unit of Analysis
ISP	Internal Strategic Perspective
MAP	Mean annual precipitation
MAR	Mean Annual Runoff
MCA	Multi-Criteria Analysis
MRU	Management Resource Units
NGA	National Groundwater Archive
NGI	National Geo-spatial Information
NWA	National Water Act
OCSD	Off-Channel Storage Dam
PES	Present Ecological State
PES/EI/ES	Present Ecological State/Ecological Importance/Ecological Sensitivity
PM	Project Manager
PMC	Project Management Committee
PSC	Project Steering Committee
PSP	Professional Service Provider
RDRM	Revised Desktop Reserve Model
REC	Recommended Ecological Category
RO	Regional Office
RPO	Red Meat Producers Organisation
RQO(s)	Resource Quality Objective(s)
RU(s)	Resource Unit(s)
SALGA	South African Local Government Association

SAM	Social Accounting Matrix
ToR	Terms of Reference
TPC(s)	Threshold(s) of Probable Concern
WARMS	Water Authorisation and Management System
WIM	Water Impact Model
WMA	Water Management Area
WR2012	Water Resources of South Africa 2012
WRC	Water Resource Classes
WRCS	Water Resource Classification System
WRSM2000/Pitman	Water Resources Simulation Model 2000 – Pitman Model
WRUI	Water Resource Use Importance
WRYM	Water Resources Yield Model
ZQM	National Groundwater Quality Monitoring Network

1 INTRODUCTION

1.1 Study Context and Motivation

The Lower Vaal catchment area extends across three of South Africa's provinces (Free State, Northern Cape and North West), and constitutes the lower catchment area of the Vaal River, a major tributary of the Orange River. The area is of major national strategic and economic importance.

The Vaal River is one of the most highly utilised rivers in the country and this has resulted in a moderate to severe degradation of the ecological state in most sections of the main river and its tributaries. Isolated important ecological areas do occur however centred around, for example, reserves, wetlands and less disturbed areas. The Vaal River is one of South Africa's largest rivers, and due to the scarceness of such river types in SA, this makes it important in its own right, irrespective of its state. Protection of these resources in some acceptable form, even as a heavily utilised river, is important.

This study intends to determine and quantify groundwater and surface water interactions and identify protection zoning to prevent the disturbance of the ecological integrity of ecosystems where such interactions occur. A feasibility study undertaken by the Department of Water and Sanitation (DWS) in 2007 and the National Water Resource Strategy II identified the need for surface-subsurface interaction studies in the Lower Vaal. The purpose of such studies would be understanding subsurface processes when determining the Reserve.

The Lower Vaal catchment (former WMA 10) lies in the north-eastern part of the Northern Cape Province, the western part of Northwest Province, and a part of the northern Free State Province. It contains the Molopo, Harts and Vaal (below Bloemhof dam) catchments. Included in these basins are the Dry Harts, and Kuruman catchments. The Molopo River forms an international boundary and contains transboundary aquifers. These catchments include Tertiary catchments C31-C33, C91-92, D41 (excluding Quaternary catchment D41A), and Quaternary catchments D73A, D42C-D, D73B-E. Some of the catchments include dolomites, where interaction can be significant.

The main rivers are perennial and most of their tributaries are ephemeral. The main source of surface water is the Vaal River, which flows into the study area below Bloemhof Dam, until its confluence with the Orange River. The main dams are Wentzel, Taung, Spitskop, Vaalharts weir, Douglas weir and Bloemhof. The only pan is Barbaspan, located in the Harts sub-catchment.

Major towns include Kimberley, Lichtenburg, Kuruman, Vryburg and Postmasburg.

1.2 Aims and Objectives of the Project

The need to undertake significant groundwater-surface water interaction studies became apparent to the DWS due to the need to understand groundwater flow, water levels, and water quantity and quality when determining the Reserve. Groundwater can make significant contributions to the ecological reserve, as well as meet Basic Human Needs for future water supply.

It is the Consultant's understanding that the main objectives of the study are:

- Review existing water resource information (this report)

- Conduct a hydrocensus on an institutional level
- Conduct a groundwater resource assessment of recharge, baseflow, abstraction, groundwater balance, present status category
- Quantify aquifer parameters and describe aquifer types
- Determine groundwater-surface water interactions both in terms of quality and quantity to determine protection zones
- Capacity building and skills transfer to DWS staff
- The project timeframe is 24 months, starting from November 2021-November 2023.

1.3 Purpose and Layout of the Report

This report describes the review of information carried out by the appointed Professional Service Provider (PSP) for undertaking the quantification of surface-subsurface interactions in the Lower Vaal catchment of the Vaal Water Management Area (WMA), as well as the identification of information gaps, and proposals of how to address these gaps.

The findings of the Literature and data gathering report will be utilised to subsequently compile the Gap analysis report.

Chapter 1 outlines the objectives of the study and the report, **Chapter 2** provides a description of the study area; **Chapter 3** summarises information from existing literature and **Chapter 4** summarises existing data obtained and applied to the study area. **Chapter 5** covers the progress with data gathering.

2 REVIEW OF STUDY AREA

2.1 Location and Description

The study area consists of former Lower Vaal WMA (**Figure 2-1),** which consists of parts of the C and D drainage regions. It is important to note that the Riet-Modder catchment (secondary catchment C5), forms part of the Orange River WMA, and is not included in the study area. Although the Riet-Modder Catchment forms part of the Vaal River Basin, it is included as part of the Upper Orange River sub-system, mainly due to the fact that there are several transfers from the Orange River to support water requirements in the Riet-Modder catchment. The only connection between the Vaal and Riet-Modder rivers is the spills from the Riet-Modder catchment into the Vaal River just upstream of Douglas Weir.

The Lower Vaal is located between the Middle Vaal drainage region and the Lower Orange drainage region, with the Upper Orange basin to the south and Botswana to the north. The Lower Vaal has an area of approximately 136 146 km^2.

The Lower-Vaal Sub-system comprises of the Harts River catchment (C3), the Lower Vaal River incremental catchment downstream of Bloemhof Dam and upstream of Douglas weir (i.e., excluding the Riet-Modder

River catchment) (C91), the Molopo River system above its confluence with the Nossob (D4) and portions of the Vaal river catchment below the confluence with the Harts and Douglas weir (C92 and D73).

The basin is located in a semi-arid to arid region of South Africa. Most of the surface water resources originate upstream of Bloemhof dam. Groundwater is an important water resource, especially in areas located away from surface water bodies.

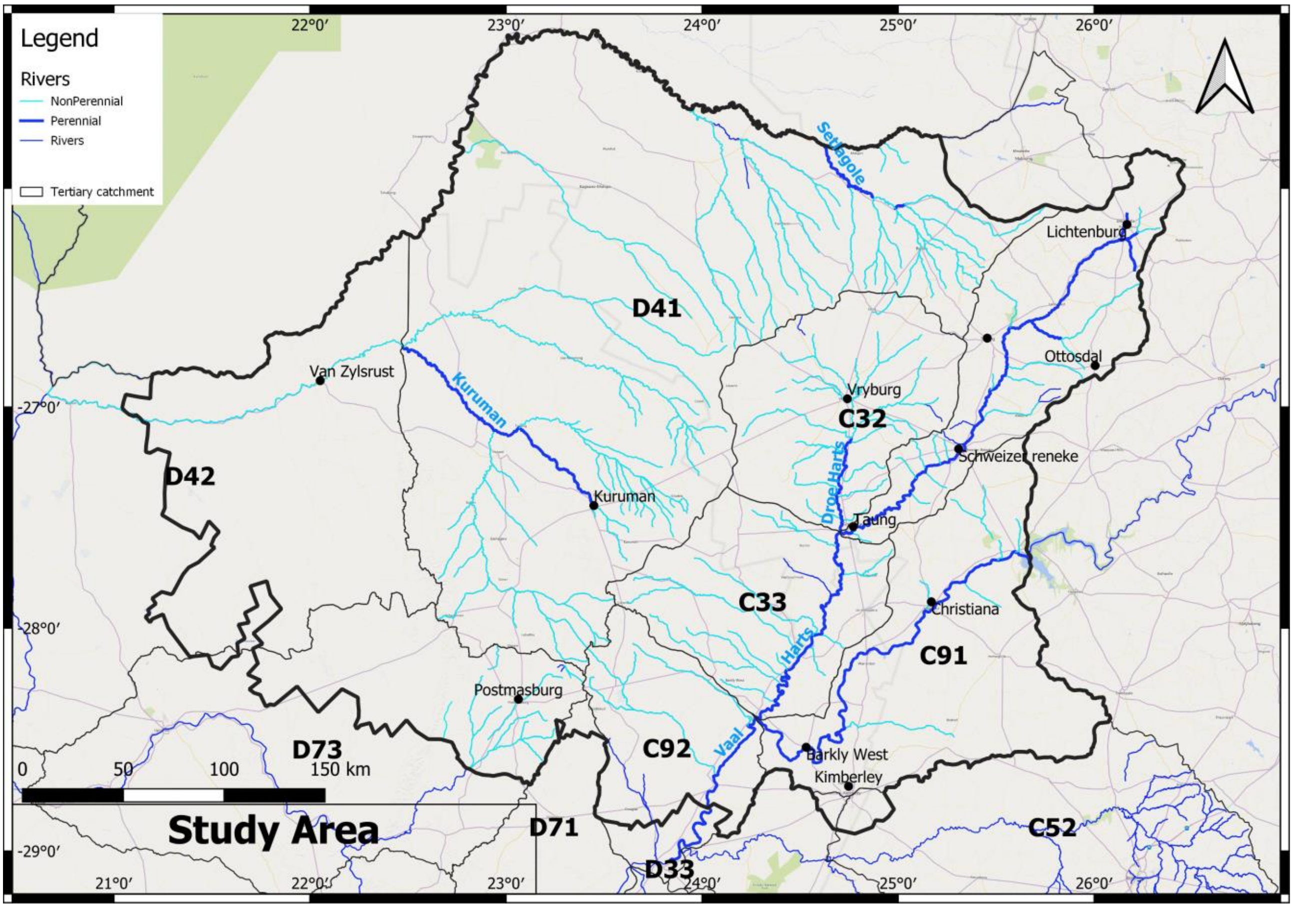

Figure 2-1 Lower Vaal drainage Region

2.2 Municipalities

The following District Municipalities are located within the Lower Vaal (**Figure 2-2**):

- Dr Ruth Segomotsi Mompati
- John Taolo Gaetsewe
- Siyanda
- Frances Baard
- Lejweleputswa
- Ngaka Modiri Molema

Small portions of

- Pixley ka Seme
- Dr Kenneth Kaunda
- Xhariep

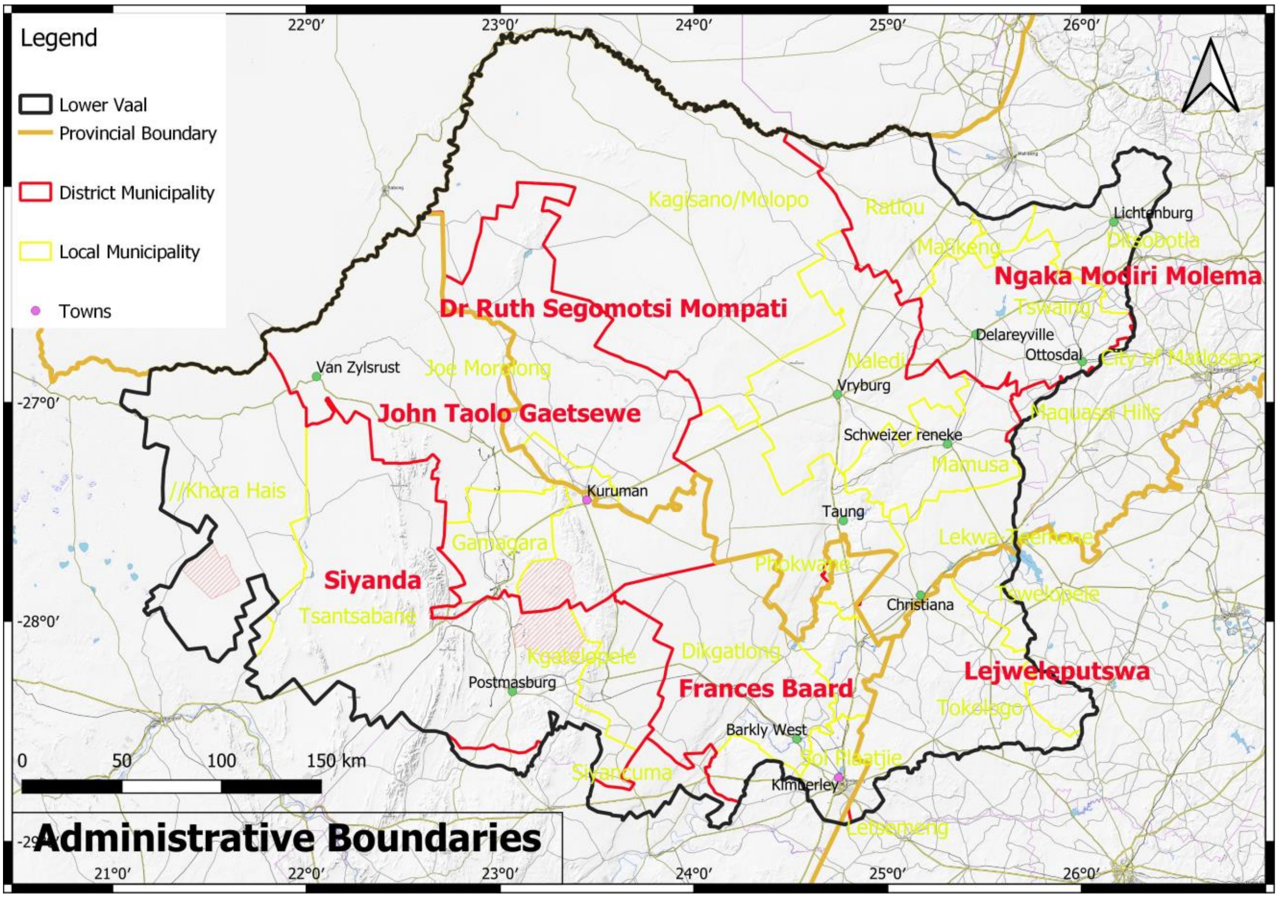

Figure 2-2 Administrative boundaries

2.3 Topography

The water in the Lower Vaal region drains to the Lower Orange drainage region before reaching the Atlantic Ocean near the town of Alexander Bay in the western corner of the country. There are no distinct topographic features with most of the terrain being relatively flat except for low hills west of Kuruman and around Postmasburg (**Figure 2-3)**. As a result of the generally arid climate, vegetation over the flat topography is sparse, consisting mainly of grassland and some thorn trees.

The elevation declines from east to west from approximately 1374 m above mean sea level in the east in the Sannieshof /Lichtenburg area to 936 m above mean sea level in the west in the Vanzylsrus area. The highest peak is south of Kuruman at 1854 m above mean sea level.

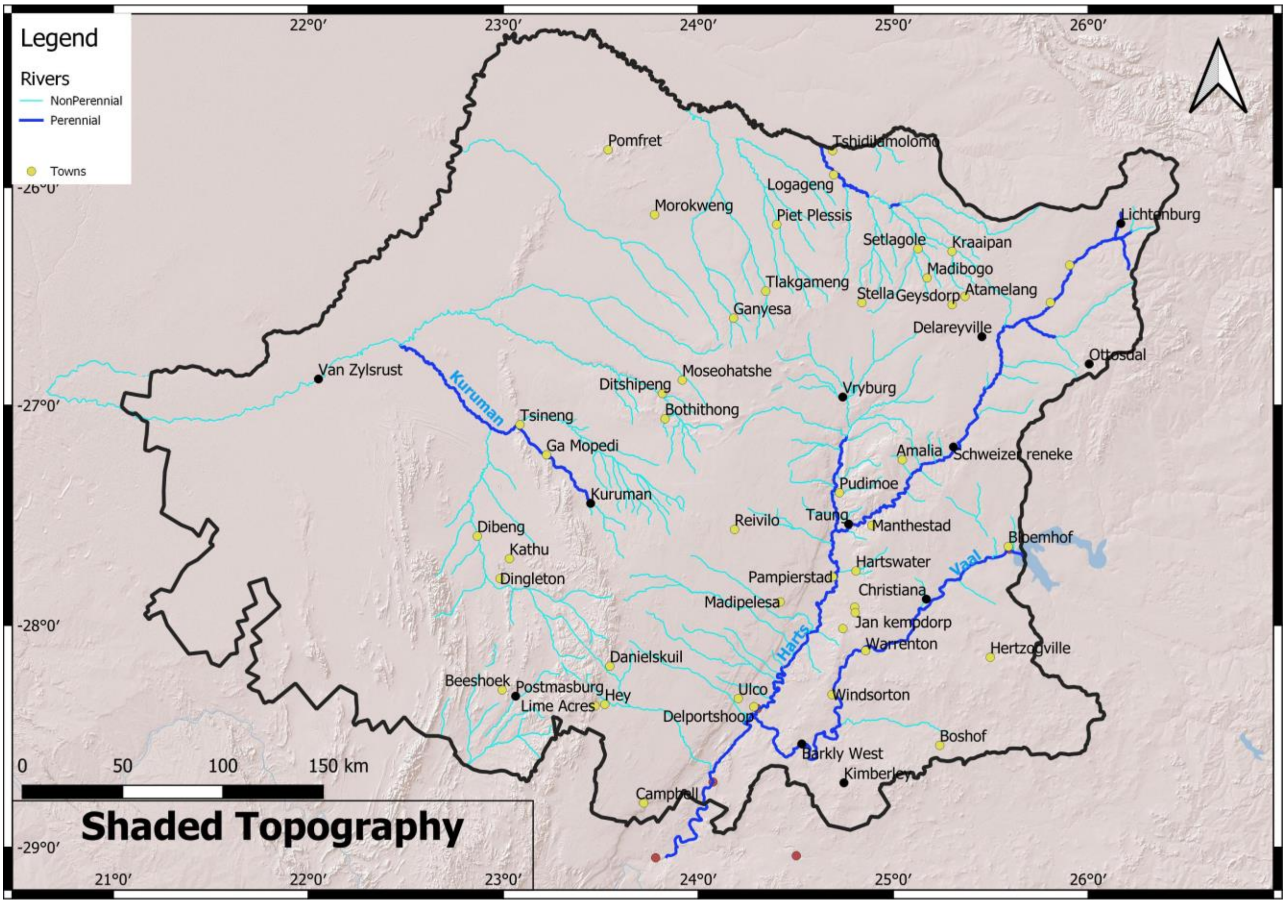

Figure 2-3 Topography

2.4 Climate

Climatic conditions are fairly uniform from east to west across the study area. The mean annual temperature ranges between 18.3° C in the east to 17.4° C in the west. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. Frost occurs throughout the study area in winter, typically over the period mid-May to late August.

Precipitation is strongly seasonal with most rain occurring mainly in the summer months (October to April) with the peak of the rainy season in December and January. Rainfall occurs generally as convective thunderstorms, therefore rainfall events are of short. Maximum development of the storms occurs in the afternoon and early evenings. The overall range of the Mean Annual Precipitation (MAP) is 100 mm to 500 mm.

Humidity is generally highest in February (the daily mean over the study area ranges from 66 % in the east to 62 % in the west) and lowest in August (the daily mean over the study area ranges from 53 % in the east to 57 % in the west). Average gross potential mean annual evaporation (as measured by Class S-pan) ranges from 1800 mm to 2 690 mm, increasing from east to west.

2.4.1 Rainfall

Minute by minute gridded rainfall shows that rainfall ranges from 150 to over 600 mm/a, with the highest rainfall in the northeast, declining to the west. (**Figure 2-4**). The monthly distribution of rainfall is available from WR2012 dataset.

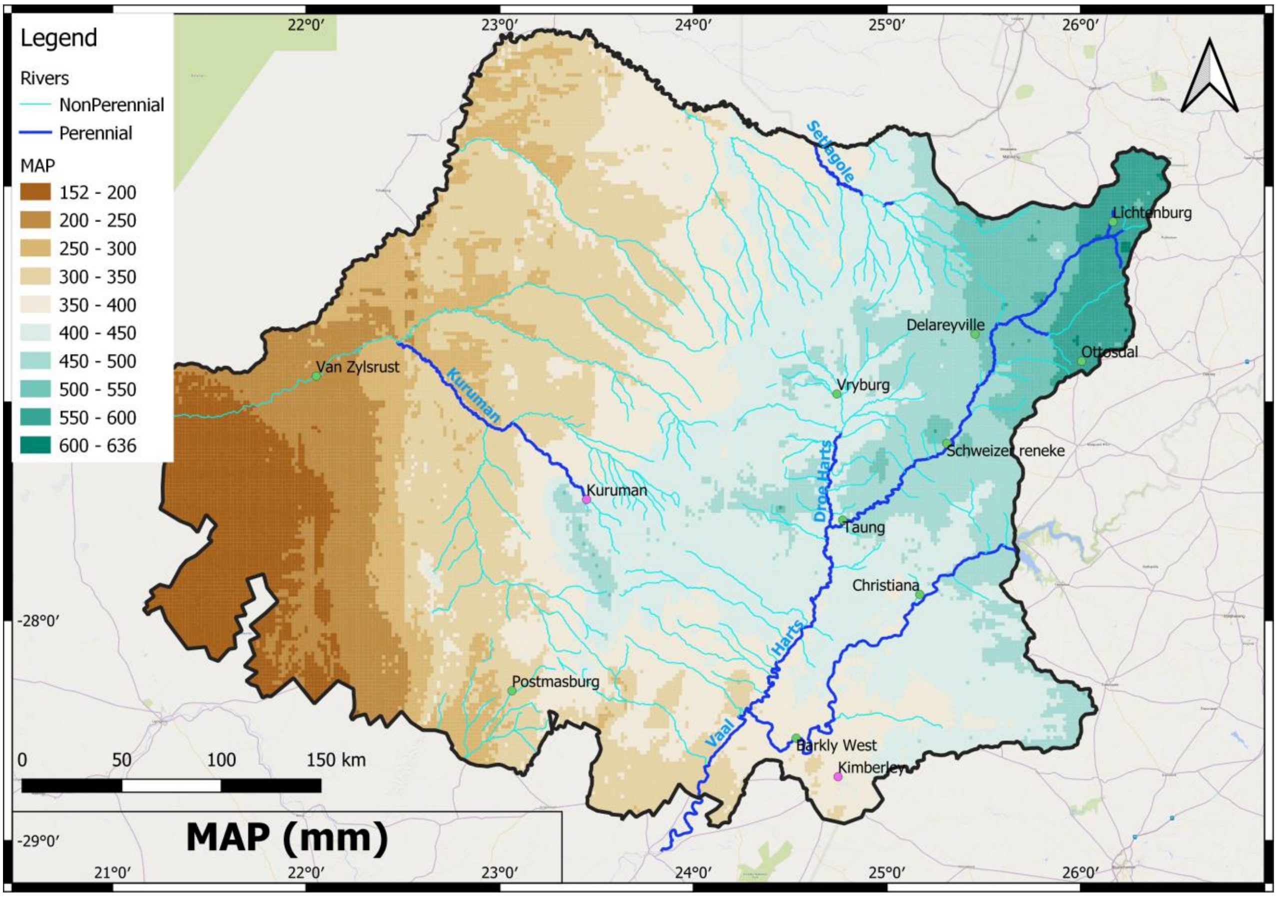

Figure 2-4 MAP in the lower Vaal

2.4.2 Evaporation

S-pan evaporation increases from 1800 mm/a in the east to 2690 mm/a in the west (**Figure 2-5).** The monthly distribution of evaporation is available from WR2012. Net evaporation losses from open water surfaces can be significant.

Significant evaporation and operational losses occur in the Vaal River downstream of Bloemhof Dam. Evaporation losses from the Vaal River reach between Bloemhof Dam and Vaalharts weir were estimated to be in the order of 78 million m^3/a (WRP, 2010). Operational losses below De Hoop weir are estimated to be about of 115 million m^3/a.

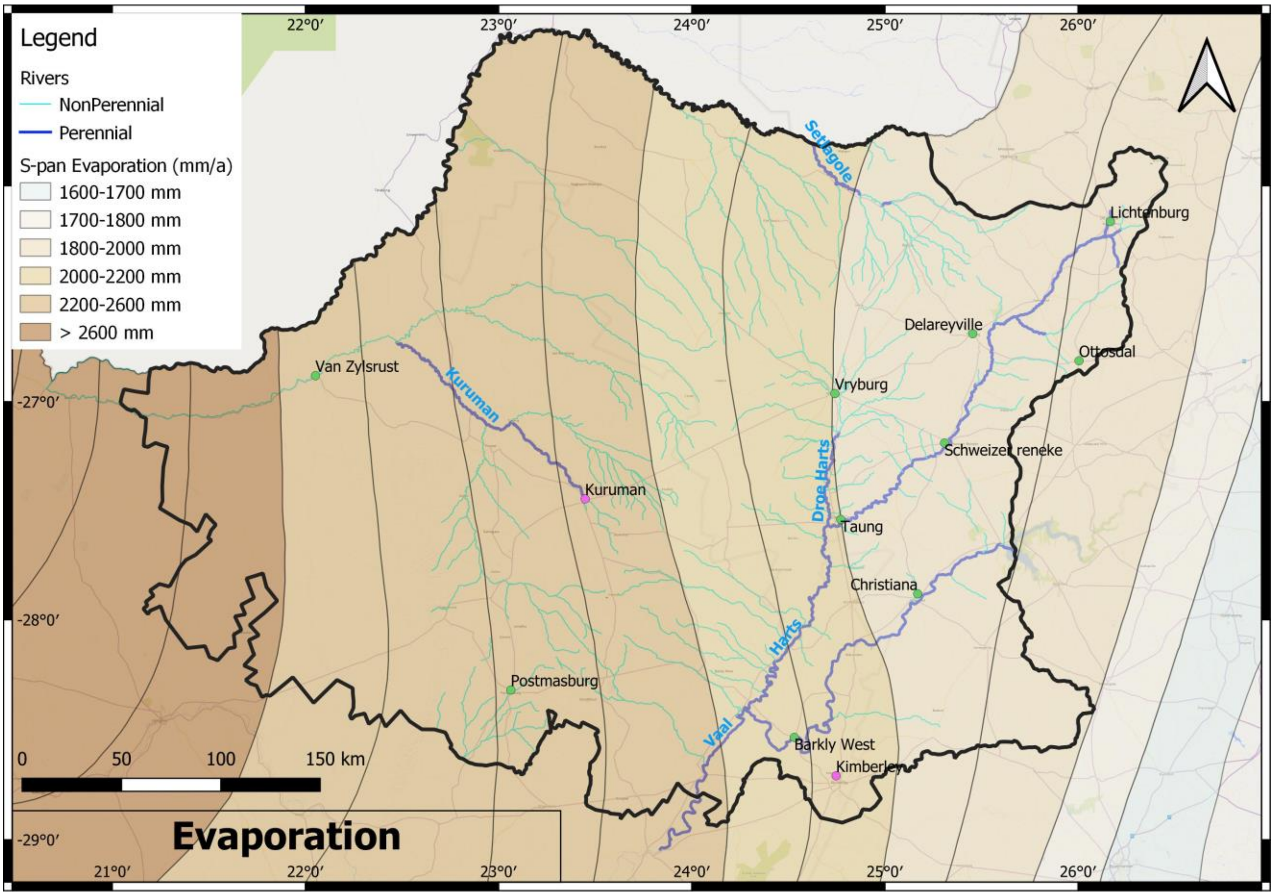

Figure 2-5 Mean annual S-pan evaporation

2.5 Drainage

Major rivers in the Lower Vaal include the Molopo, Harts, Dry Harts, Kuruman and Vaal rivers. The tertiary drainage areas comprise of C31, C32, C33, C91, C92, D41 (excl. D41A), parts of D42C and D42D, parts of D73A and D73C (**Figure 2-6).** The Lower Vaal consists of 34 quaternary catchments. In the C drainage region, it consists of the catchment area downstream of Bloemhof Dam and upstream of Douglas Weir. It extends to the headwaters of the Harts River. The D drainage region consists of the Molopo and Kuruman Rivers (D41 and D42) in the north and some tributaries of the Orange River in the south (D73).

The Molopo River forms the border between South Africa and Botswana and together with its tributaries it drains much of the northern part of the Lower Vaal catchment. The Molopo River flows from approximately 35 km north-east of Mafikeng along the border with Botswana to the west where it joins the Nossob River approximately 70 km from the Namibian border. The Kuruman River together with its tributaries mainly drains the southern part of the Lower Vaal catchment. The Kuruman River originates approximately 35 km southeast of Kuruman and joins its tributaries approximately 120 km north-west of Kuruman.

The Kuruman and Molopo Rivers, which drain the Kalahari and northern Lower Orange regions, do not make a meaningful contribution to the surface water resources nor to interactions with groundwater. However, dolomitic springs form distinct groundwater ecosystems and are a form of surface-groundwater interaction.

Drainage regions C31, C32, C33, C91 and C92 are divided into the Harts River catchment and the Vaal River catchment. The Harts River drains a catchment area of approximately 31 000 km^2 and has one major tributary, the Dry Harts River which joins the Harts River just downstream of Taung.

The stretch of Vaal River considered here is the reach between Bloemhof Dam and the Orange and Vaal River confluence. The total catchment area is almost 22 500 km^2.

2.6 Geology

The Lower Vaal WMA is underlain by diverse lithologies. Several broad lithostratigraphic units fall within the boundaries. A simplified geological map of the study area is presented in **Figure 2-7** and the legend is shown in **Table 2-1** from oldest to youngest lithologies.

Table 2-1 Stratigraphy of the study area

Age	Map label (Figure 2-7)	Group	Lithostratigraphy	LIthology
	N-Qg		ALLUVIUM, COLLUVIUM, ELUVIUM, GRAVEL, SCREE, SAND, SOIL, DEBRIS	Alluvium, colluvium, eluvium, boulder gravel, gravel, scree, sand, soil, debris
Neocene	N-Ql		CALCRETE, SURFACE LIMESTONE, HARDPAN	Calcrete, surface limestone, hardpan
Cretaceous	K-Qk	Kalahari	KALAHARI GROUP	Pebbly and calc-conglomerate, mudstone, gritstone, siliceous/calcareous sandstone, silcrete, diatomaceous limestone, calcrete
Jurassic	Jd		KAROO DOLERITE SUITE	Dolerite, minor ultrabasic rocks
	Pbf	Adelaide	BALFOUR FORMATION	Greenish- to bluish-grey and greyish-red mudstone, siltstone, subordinate sandstone
	Pt		TIERBERG FORMATION	Grey shale with interbedded siltstones in the upper part
	Pw		COLLINGHAM AND WHITEHILL FORMATIONS	Grey shale, tuff, minor sandstone, chert, black (white-weathering) carbonaceous shale
	Ppw		PRINCE ALBERT, WHITEHILL AND COLLINGHAM FORMATIONS	Green to grey shale, rapidly alternating grey shale (and subordinate sandstone/siltstone), thin yellow-weathering tuff (K-bentonite) layers
Permian	Pe	Ecca	ECCA GROUP	Shale, carbonaceous shale, siltstone, tuff, chert, phosphatic nodules, sandstone
Carboniferous	C-Pd	Dwyka	DWYKA GROUP	Diamictite, varved shale, siltstone, mudstone with dropstones, fluvioglacial gravel and sandstone
	ECz		ZONDERHUIS FORMATION	Reddish/purplish quartzite, phyllite, schist, dolomite, conglomerate
	ORpy		PRYNNSBERG FORMATION	Muscovite quartzite, schist
	ORbs		BRULSAND SUBGROUP	Fine- to medium-grained, white and grey quartzite
	ORma	Volop	MATSAP SUBGROUP	Coarse-grained, reddish-brown to grey and purple quartzite/subgreywacke, minor conglomerate
	ORha		HARTLEY FORMATION	Basalt, basaltic andesite, tuff, quartzite, minor conglomerate
	ORlm	Olifantshoek	LUCKNOW AND MAPEDI FORMATIONS	Quartzite, flagstone, shale, dolomitic limestone, andesite

Age	Map label (Figure 2-7)	Group	Lithostratigraphy	LIthology
Mokolian	Rvw		VO ├ïLWATER SUBGROUP	Dolomite, jasper, iron-formation, chert, minor volcanic rocks
	Rd		DIABASE	Magnesium-rich tholeiite, melanorite
	Rog	Cox	ONGELUK FORMATION	Biotite-muscovite metapelite
	Rmg		MAKGANYENE FORMATION	Diamictite, subordinate sandstone, carbonate rock, jaspilite, mudrock, chert and conglomerate
	ORgm		GAMAGARA FORMATION	Conglomerate and shale
	SDko		KOEGAS SUBGROUP	Jaspilite, banded iron-formation (minnesotaite lutite, minor riebeckite lutite), jaspilite, mudrock, claystone, siltstone, quartzite, quartz wacke, stromatolitic dolomite, chert
	SDda		DANI ├ïLSKUIL FORMATION	Iron-formation ("jaspilite"), mudrock (towards top), minor crocidolite, riebeckite and minnesotaite
	ANrv		REIVILO FORMATION	Chert-poor dolomite characterized by giant stromatolite domes, laminated, iron-rich dolomite, ferruginous chert
	ANpa		PAPKUIL FORMATION	Dolomite, limestone, banded iron-formation, quartzite, shale, jaspilite, chert
	SDku	Griquatown	KURUMAN FORMATION	Banded iron-formation, riebeckite-amphibolite, chert, minor minnesotaite and crocidolite, finely laminated brown to red-brown shale
	SDwo		WOLHAARKOP FORMATION	Ferruginised brecciated banded ironstone
	ANkf		KLIPFONTEINHEUWEL FORMATION	Dolomite, prominent chert at base
	ANko		KOGELBEEN FORMATION	Dolomite/limestone, banded iron-formation, quartzite, shale, jaspilite, chert
	ANkl		KLIPPAN FORMATION	Conglomerate, talus breccia, quartz arenite, shale, andesite, limestone
	ANga		GAMOHAAN FORMATION	Dolomite, limestone, banded iron-formation, quartzite, shale, jaspilite, chert
	ANff		FAIRFIELD FORMATION	Stromatolitic dolomite
	ANmo		MONTEVILLE FORMATION	Dolomite and subordinate shale, siltstone and quartzite
	ANcw		CLEARWATER FORMATION	Shale, minor dolomite
	ANbp	Campbell	BOOMPLAAS FORMATION	Dolomite/limestone, mudrock
	ANvb		VRYBURG FORMATION	Quartzitic sandstone, mudrock, andesite, basalt, siltstone, dolomite, limestone, minor conglomerate, tuff and chert
	Rtr	Pretoria	TIMEBALL HILL AND ROOIHOOGTE FORMATIONS	Mudrock, quartzite (ferruginous in places), wacke, chert breccia, minor diamictite, conglomerate, shale, magnetic ironstone
	ANml	Chuniespoort	MALMANI SUBGROUP	Dolomite, stromatolitic, interbedded chert, minor carbonaceous shale, limestone and quartzite
Vaalian	ANbr		BLACK REEF FORMATION	Quartzite, subordinate conglomerate and shale
Randian	ANmt	Intrusive	MOSITA GRANITE	Pinkish, coarse-grained, porphyritic granite

Age	Map label (Figure 2-7)	Group	Lithostratigraphy	LIthology
	ANbo		BOTHAVILLE FORMATION	Conglomerate, gritstone, quartzite, subgreywacke, shale lenses
	ANal		ALLANRIDGE FORMATION	Andesite, tuff
	ANrg		RIETGAT FORMATION	Andesite to dacitic volcanic rocks, minor conglomerate, greywacke and shale
	ANmk		MAKWASSIE FORMATION	Acid volcanic rocks (mainly quartz porphyry), ash flows, subordinate sedimentary rocks
	ANgg		GOEDGENOEG FORMATION	Greenish grey porphyritic and subordinate non-porphyritic mafic volcanic rocks
	ANka	Platberg	KAMEELDOORNS FORMATION	Shale, conglomerate, greywacke
	ANkb	Klipriviersberg	KLIPRIVIERSBERG GROUP	Tholeiitic basalt, andesite, basalt, tuff and agglomerate
	AMhh	West Rand	HOSPITAL HILL SUBGROUP	Fine- to medium-grained quartzite, shale, magnetic shale
	AMdo	Dominion	DOMINION GROUP	Basaltic andesite, quartz-feldspar porphyry, amygdaloidal andesite, tuff, conglomerate, quartzite
	AMlv		LINDEN GNEISS, MIDRAND GNEISS, VICTORY PARK GRANODIORITE, HONEYDEW GRANODIORITE	Ultramafic rocks, granitic rocks, dioritic gneiss, hornblende gneiss, biotite gneiss, hybrid mafic rocks, migmatite, porphyritic granodiorite
	AM-APg	Intrusive	UNDIFFERENTIATED TONALITE, GRANITE AND GNEISS	Potassic gneiss and migmatite, strongly porphyroblastic
	APzu	Intrusive	MULDERSDRIF, ROODEKRANS, CRESTA-ROBINDALE, EDENVALE-MODDERFONTEIN, ZANDSPRUIT COMPLEXES, UNDIFFERENTIATED MAFICS AND ULTRAMAFICS	Serpentinised dunite, harzburgite, lherzolite, pyroxenite and gabbro
	AMkh		KHUNWANA FORMATION	Banded chert/jaspilite, minor metavolcanic rocks and amphibolite
	AMfr		FERNDALE FORMATION	Variegated, banded jaspilite
	AMgg		GOLD RIDGE FORMATION	Mica, pyrophyllitic and quartz-chlorite schists, magnetite quartzite, dolomite, banded iron-formation and amphibole-rich zones
Swazian	AMkr	Kraaipan	KRAAIPAN GROUP	Banded iron-formation, jaspilite, metavolcanic rocks (amphibolite)

A large portion of the central and north-east corner of Lower Vaal is underlain by the Transvaal Supergroup consisting of the dolomite, chert, and subordinate limestone (DWAF, 2004). This area is characterised by a high potential for groundwater with a 50 to 75% probability and accessibility throughout the dolomitic area. The groundwater level is between 8 to 20 metres below ground level on average. Water is found mainly in fractures; dissolution features are not prominent. Interactions occur where these compartments drain via dolomitic eyes.

The Olifantshoek Supergroup lies to the west of this area in the vicinity of Vanzylsrus, Hotazel, Sishen and Postmasburg. Here the Geology presents very low-to-low grade metamorphic rocks of schist, quartzite, lava, sub greywacke and conglomerates. Tillite with sandstone, mudstone and shale is also found in the area (DWAF,2004).

Unlike the central dolomitic area, the geology of the western part of the catchment does not lend itself to groundwater resources. Boreholes tend to be less successful and much deeper, up to 125 metres below ground level. Water is also often saline. It is this very limited and unreliable groundwater resource that necessitated the implementation of the Kalahari East and West rural water supply schemes. There is no connection between surface and groundwater.

The Ventersdorp Supergroup lies to the east and north of the Transvaal Supergroup and is composed mainly of volcanic rocks, andesite, quartz porphyry, sedimentary rocks, conglomerate, and sandstone. This area also represents a low-grade metamorphism and water is found in weathered fractures. Probability of a successful borehole yielding >2l/s is 10-20% with and average groundwater level of between 8 to 20 metres below ground level.

The main minerals in this area are iron, manganese (associated with the Kalahari Manganese Field) and asbestos mines in the southwest. This has a major impact on the water situation of the region since there are a number of Manganese mines in the area which are situated in the region where ground water is extremely limited. Alluvial diamonds are associated with the central and east area and Kimberlite diamonds in the west near Kimberley. There are also a few copper, zinc and gold mines throughout the catchment area.

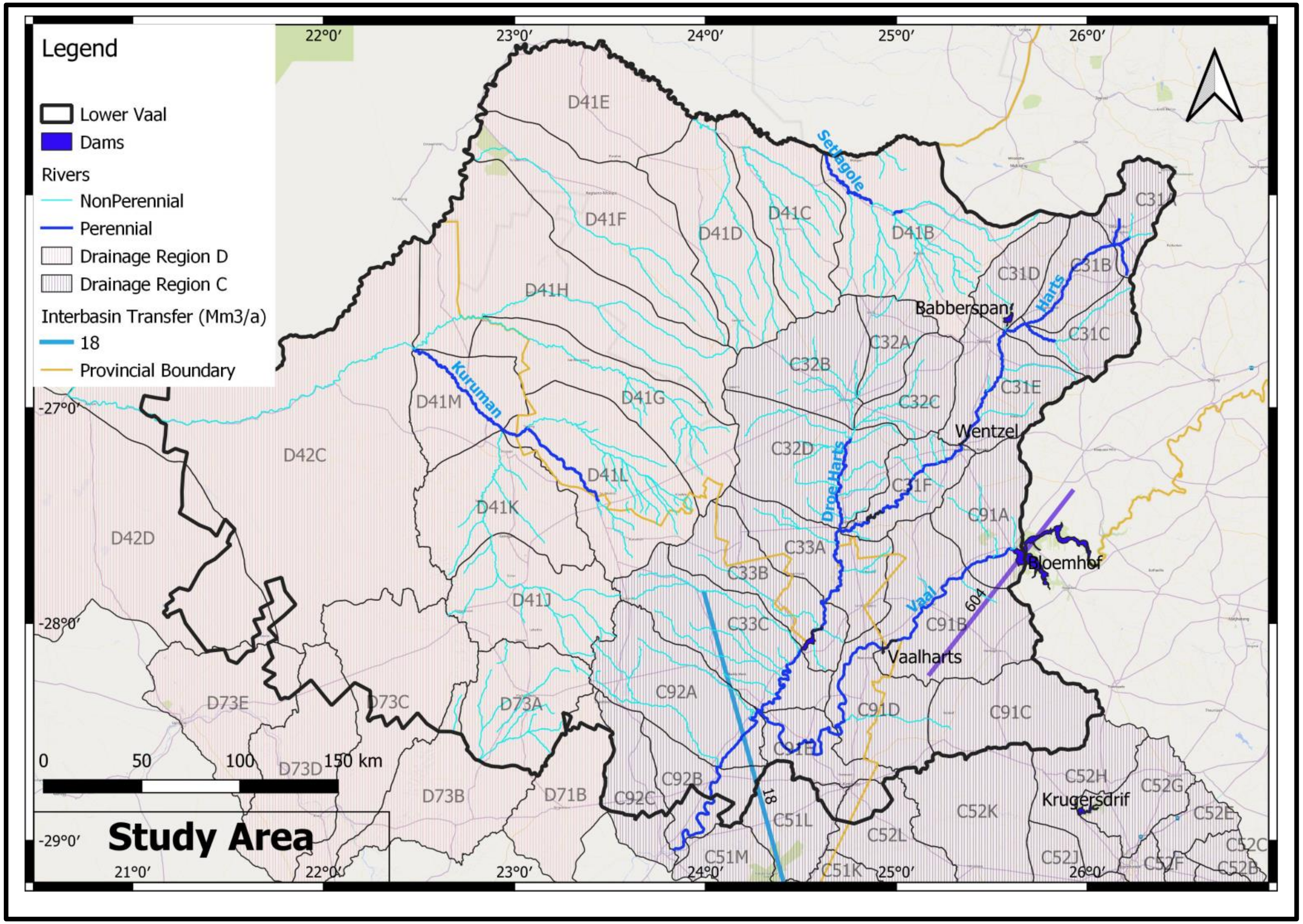

Figure 2-6 Catchments in the study area

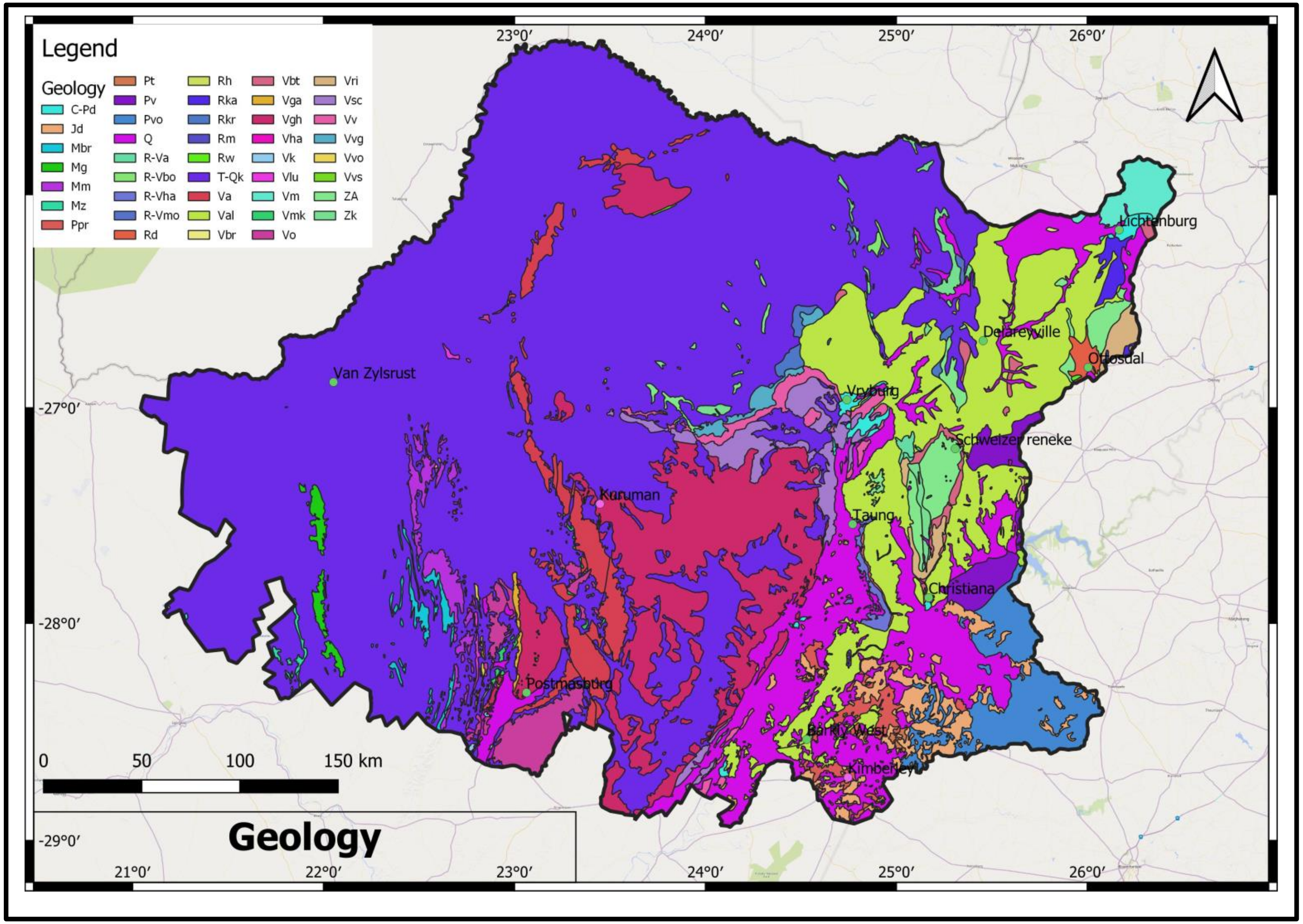

Figure 2-7 Geology. See Table 2-1 for lithologies of Geology codes

3 LITERATURE REVIEW

3.1 Existing Reports

Table 3-1 lists the reports that have been obtained and reviewed.

Table 3-1 Existing Reports

Report	Prepared by
Department of Water Affairs, South Africa, March 2011. Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8, 9, 10 Water Resource Analysis Report	WRP Consulting Engineers (Pty) Ltd
Lower Vaal Water Management Area: Water Resources Situation Assessment Report Main Report P 10000/00/0301	BKS Group (Pty) Ltd
Determination of the Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10). WP10535 Resource Unit Delineation Report. Report Number: RDM/WMA10/00/CON/RQO/0113	the Institute of Natural Resources (INR) NPC.
Development of Internal Strategic Perspectives. Groundwater Overview for Lower Vaal Catchment Management Area	Darcy Groundwater Scientists and Consultants
Department of Water and Sanitation (DWS). 2014. Determination of Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10): Resource Quality Objectives and Numerical Limits Report. Report No.: RDM/WMA10/00/CON/RQO/0214.	Institute of Natural Resources (INR) NPC.
Department of Water Affairs and Forestry, South Africa. 2004. Internal Strategic Perspective: Vaal River System Overarching Report. Report No.: P RSA C000/00/0103	PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 (Pty) Ltd
Preparation of Climate Resilient Water Resources Investment Strategy & Plan and Lesotho-Botswana Water Transfer Multipurpose Transboundary Project. Components i and ii. Groundwater report ORASECOM 006/2019	WRP Consulting Engineers (Pty) Ltd

Department of Water and Environmental Affairs (DWEA), 2009. Resource Directed Measures: Intermediate Reserve Determination Study for the Integrated Vaal River System: Lower Vaal Water Management Area. Groundwater Component: Groundwater Report.	Compiled by Raath, CJD (AGES),

3.2 Hydrology

The current hydrology generated for the study area was generated as part of the ORASECOM Phase 2 Study completed in 2011. Most of the hydrology from this study was only extended to 2004 using previous calibrations, which was also the case with the hydrology then generated for the Lower Vaal. At that time ORASECOM had just completed a hydrology study on the Molopo/Nossob River basins. This hydrology already covered the period 1920 to 2004 and was accepted without changes for the ORASECOM Phase 2 study.

From the ORASECOM Phase 2 Study it, was found that the number of open and useful flow gauges in the Lower Vaal catchment had already reduced from 5 to 4 since the previous calibrations done as part of the Vaal River System Analysis Update Study. In the Molopo/Nossob basin the open and useful flow gauges reduced from 8 to 6. The decline in the available flow gauges is thus a concern.

The point rainfall gauges in the Lower Vaal over the same period reduced by 53% from 74 to only 35 rainfall stations in 2004. In the Molopo a similar reduction in available rainfall station was evident reducing by almost 50% from 99 to only 49 stations. This is a major concern as rainfall is the primary and most important input required in the generation of surface runoff.

The runoff produced from the Lower Vaal and Molopo catchments is very low and the ORASECOM Phase 2 Study indicate that only 0.8% and 0.1% respectively of the rainfall that will eventually appear as surface runoff.

In the Molopo basin there are relatively few gauging stations available to verify the generated data. High losses are experienced from the natural runoff. It is however not mentioned in the ORASECOM study how these losses were determined.

Rainfall and runoff for each Quaternary catchment based on WRSM Pitman simulations is shown in **Table 3-2**. The WR2012 configuration was used to develop the ORASECOM hydrology. It can be noted that very large discrepancies exist from the previous WSR2005 configuration for D41 and D42.

Total runoff generated by WRSM Pitman simulation is 226 Mm^3/a. Of the total catchment area of 125 114 km^2, only 83 788 km^2 contributes directly to the river network. The remainder drains into the many pans and enclosed drainage basins and is evaporated. As a result of these endoreic areas (**Figure 3-1)**, the low rainfall and high potential evaporation, the MAR (Mean annual runoff) from the catchment is only about 1 mm/a.

During extreme high rainfall years some of the pans in these endoreic areas fill up and start to spill into the non endoreic areas, resulting in excessive floods.

Table 3-2 Hydrology of the lower Vaal

BASIC INFORMATION								NATURALISED FLOW MARs			
Quaternary	Catchment area			S-pan evaporation		Rainfall		MAR (WR90)	MAR (WR2005)	MAR (WR2012)	Change in MAR
	Gross	Net	evap		MAE	Rainfall	MAP	Net	Net	Net	WR2005 to WR2012
	(km^2)	(km^2)	zone		(mm)	zone	(mm)	(mcm)	(mcm)	(mcm)	(percent)
C31A	1402	851	8A		1860	C3A	577	9.10	8.39	8.11	-3.3
C31B	1743	1358	8A		1900	C3A	553	11.00	10.00	9.68	-3.2
C31C	1635	1635	8A		1900	C3A	566	15.10	13.32	13.26	-0.5
C31D	1494	780	8A		1925	C3A	530	4.80	4.26	4.30	0.9
C31E	2960	1941	8A		1930	C3B	506	15.10	11.04	13.22	19.7
C31F	1789	1789	8A		1960	C3B	477	10.20	5.49	8.16	48.6
Tertiary	***11023***	***8354***			***1918***		***529***	***65.30***	***52.50***	***56.73***	**8.1**
C32A	1405	681	8A		1970	C3C	449	5.60	3.91	4.09	4.6
C32B	3002	1587	8A		2000	C3C	434	11.20	8.06	8.22	2.0
C32C	1658	916	8A		1960	C3C	460	8.30	5.74	6.16	7.3
C32D	4140	2732	8A		2050	C3C	442	20.40	14.83	15.29	3.1
Tertiary	***10205***	***5916***			***2013***		***443***	***45.50***	***32.54***	***33.76***	**3.7**
C33A	2859	1806	8A		2070	C3D	432	15.40	15.27	11.93	-21.9
C33B	2835	1483	8A		2100	C3D	422	11.50	9.78	8.57	-12.4
C33C	4149	1691	8A		2150	C3D	397	10.20	9.88	7.34	-25.7
Tertiary	***4980***	***9843***			***1066***		***211***	***37.10***	***34.93***	***27.84***	**-20.3**
C91A	2546	868	9B		1940	C9A	464	4.40	4.04	4.03	-0.2
C91B	4679	1640	9B		1950	C9A	433	6.10	5.57	5.65	1.4
C91C	3135	3135	9B		1880	C9B	430	13.10	11.07	10.93	-1.3
C91D	2697	1466	9B		2050	C9B	397	4.40	3.86	3.75	-2.8
C91E	1509	1066	9B		2140	C9B	371	2.40	2.16	2.06	-4.6
Tertiary	***14566***	***8175***			***1965***		***421***	***30.40***	***26.70***	***26.42***	**-1.0**
C92A	3923	1612	7A		2250	C9C	367	12.60	11.45	10.76	-6.0
C92B	1979	889	7A		2225	C9C	331	5.00	4.75	4.11	-13.5
C92C	1959	435	7A		2300	C9C	326	2.30	2.35	1.74	-26.0
Tertiary	***7861***	***2936***			***2250***		***350***	***19.90***	***18.55***	***16.61***	**-10.5**
D41A	4322	1544	8A		1952	D4A	509	9.70	6.24	5.03	-19.4
D41B	6164	971	8A		1952	D4A	443	1.90	2.16	1.76	-18.5
D41C	3919	924	8A		2050	D4B	396	1.10	1.19	2.09	75.6
D41D	4380	1636	8A		2050	D4B	380	1.60	1.69	3.13	85.2
D41E	4497	4030	8A		2250	D4B	334	2.00	2.07	4.02	94.2
D41F	6011	4513	8A		2250	D4B	332	2.20	2.39	4.52	89.1
D41G	4312	1904	8A		2199	D4C	366	2.60	1.92	4.18	117.7
D41H	8657	6419	8A		2250	D4C	324	2.70	2.85	7.89	176.8
D41J	3878	2518	8A		2351	D4D	358	3.20	1.75	7.26	314.9
D41K	4216	2664	8A		2351	D4D	344	2.80	1.92	6.53	240.1
D41L	5383	2437	8A		2250	D4D	391	4.40	3.36	10.78	220.8
D41M	2628	2157	8A		2399	D4C	305	1.30	0.62	2.05	230.6
Tertiary	***58367***	***31717***			***2234***		***355***	***35.50***	***28.16***	***59.24***	**110.4**
D42A		Lower Orange									
D42B		Lower Orange									

D42C1	10102	9999	6B		2700	D4E	216	7.20	7.95	3.38	
D42C2	8010	6848	6B		2700	D4E	216			2.32	
D42C total										5.70	-28.3
D42D	Lower Orange										
D42E	Lower Orange										
Tertiary	***18112***	***16847***	***0***		***2700***		***216***	***7.20***	***7.95***	***5.70***	
Study Area	**125114**	**83788**			**2241**		**354**	**240.90**	**201.33**	**226.30**	**16**

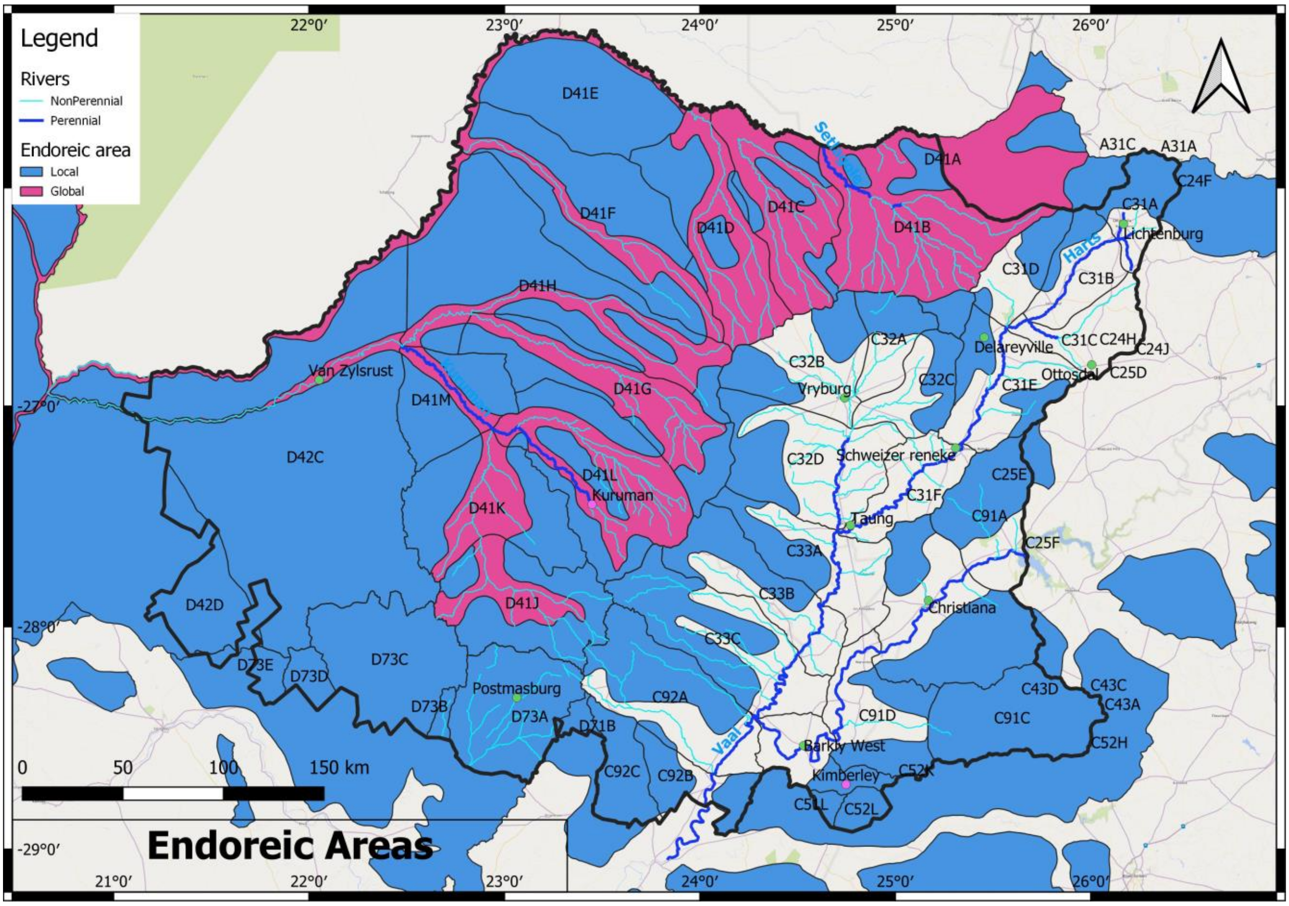

Figure 3-1 Endoreic areas

3.3 The Reserve

As part of the Comprehensive Reserve Determination Study, (DWA, 2010) natural runoff time series data for each quaternary catchment were derived. During the scenario phase and final decision making of the Comprehensive Reserve Study it was recommended that the present flow regime and operation of the system should be signed off as the reserve. The current flow regime will maintain the Recommended Ecological Classification (REC) which in all cases is also the Present Ecological State (PES).

The Reserves for these three EWR sites have been gazetted in 2020 (**Table 3-3).**

Table 3-3 Surface water Reserve

EWR Site	Site Name	River	Latitude	Longitude	Quaternary	%MAR
EWR16	Downstream Bloemhof dam	Vaal	-27.65541	25.59565	C91A	13.02
EWR17	Lloyd's weir	Harts	-28.376.94	24.30305	C33C	51.60
EWR18	Schmidtsdrift	Vaal	-28.70758	24.07578	C92B	21.87

The intermediate Groundwater Reserve for the Lower Vaal was undertaken in 2009 (AGES. 2009). The groundwater reserve determination was undertaken with the GYMR model. It was compared with the results obtained using GRDM methodology to demonstrate the differences in terms of groundwater flow balances and management of groundwater resources. The report states that the existing GRDM methodology based on stress index should not be used. The existing GRDM system classifies the groundwater units based on "stress indexes". It was found that this classification cannot and should not be used as it is not based on actual, but estimated groundwater volumes. It could lead to incorrect perceptions that the groundwater systems are actually stressed.

Based on the GRDM methodology, the report suggests recharge would be estimated at 1871 Mm_3/a, which is 47% higher than the recharge determined at a 95% assurance level by the GYMR model. The groundwater component of base flow would be 1254 Mm^3/a. This figure is 2.3 times the base flow values obtained from the GYMR method. It was concluded from that study that the GRDM methodology will consistently produce groundwater base flows groundwater allocations that are unrealistically high.

The PSP is in accordance with this conclusion as the GRDM methodology cannot account for how groundwater abstraction can impact on baseflow, nor is the suggested recharge estimation methodology linked to baseflow to derive an integrated surface and groundwater balance.

Groundwater RQOs and numerical limits were set in (DWS, 2014). These are based on maximum water level fluctuations, but do not consider borehole location. Water level fluctuations can be mitigated by boreholes tapping aquifers hydraulically connected to perennial water courses. The investigation focussed on catchments with perennial surface water and ephemeral catchments were excluded. Six IUAs were identified and utilised for developing RQOs for the Lower Vaal. The D catchments of the western portion feeding the Kuruman and Molopo rivers were excluded.

The groundwater reserve for Drainage Region C was gazetted in 2020 (**Table 3-4).** There was no corresponding calibration against gauging stations to confirm baseflow and recharge, but this would require integrated modelling of the whole Vaal system.

Table 3-4 Groundwater Reserve

Quaternary	Area km^2	MAP (mm)	Recharge (Mm^3/a)	Recharge %	BHN (Mm3)	Baseflow (Mm3/a)	Reserve (Mm3/a)	Groundwater Use (Mm3/a)	Allocable groundwater (Mm3/a)
C31A	1402	330	32.68	7	0.71	5.55	6.26	0.77	25.65
C31B	1743	230	20.59	5	0.11	11.07	11.18	1.15	8.26
C31C	1635	280	21.79	5	0.02	9.33	9.35	1.45	10.99
C31D	1493	300	22.95	5	0.76	5.55	6.31	0.57	16.07
C31E	2958	270	37.91	5	1.64	20.31	21.95	2.33	13.64
C31F	1787	205	12.92	3	1.59	9.92	11.51	1.41	0
C32A	1403	165	8.62	3.5	0.63	6.91	7.54	1.08	0
C32B	2997	225	31.22	5	3.08	25.63	28.71	2.52	0
C32C	1657	245	15.24	3.5	0	9.69	9.69	0.79	4.76
C32D	4134	240	60.26	6	1	16.63	17.63	3.26	39.37
C33A	2855	245	35.29	5	1.44	10.69	12.13	1.06	22.1
C33B	2830	230	36.55	5	0.44	6.58	7.02	0.83	28.7
C33C	4141	190	35.06	4.5	0.06	11.44	11.5	0.97	22.59
C91A	2545	170	16.81	3.5	0.28	7.86	8.14	0.77	7.9
C91B	4675	270	59.66	4.5	0.07	21.89	21.96	1.11	36.59
C91C	3133	240	33.55	4	0.26	7.18	7.44	0.18	25.93
C91D	2694	265	27.83	4	0.55	3.55	4.1	0.46	23.27
C91E	1506	190	9.32	3	0.91	3.16	4.07	0.42	4.83
C92A	3913	180	27.5	4	0.6	9.8	10.4	0.88	16.22
C92B (68%)	1341	190	9	3.5	0	5.63	5.63	0.32	3.15
C92C (67%)	1332	185	10	4	0.17	5.38	5.55	0.65	3.9
Total	52174		564.75		14.32	213.75	228.07	22.98	313.92

3.4 Integrated Units of Analysis

The area has been divided into 6 IUAs (**Figure 3-2 and Table 3-5**). The Molopo River Catchment was not part of the Vaal River Comprehensive Reserve Determination Study (DWS, 2010).

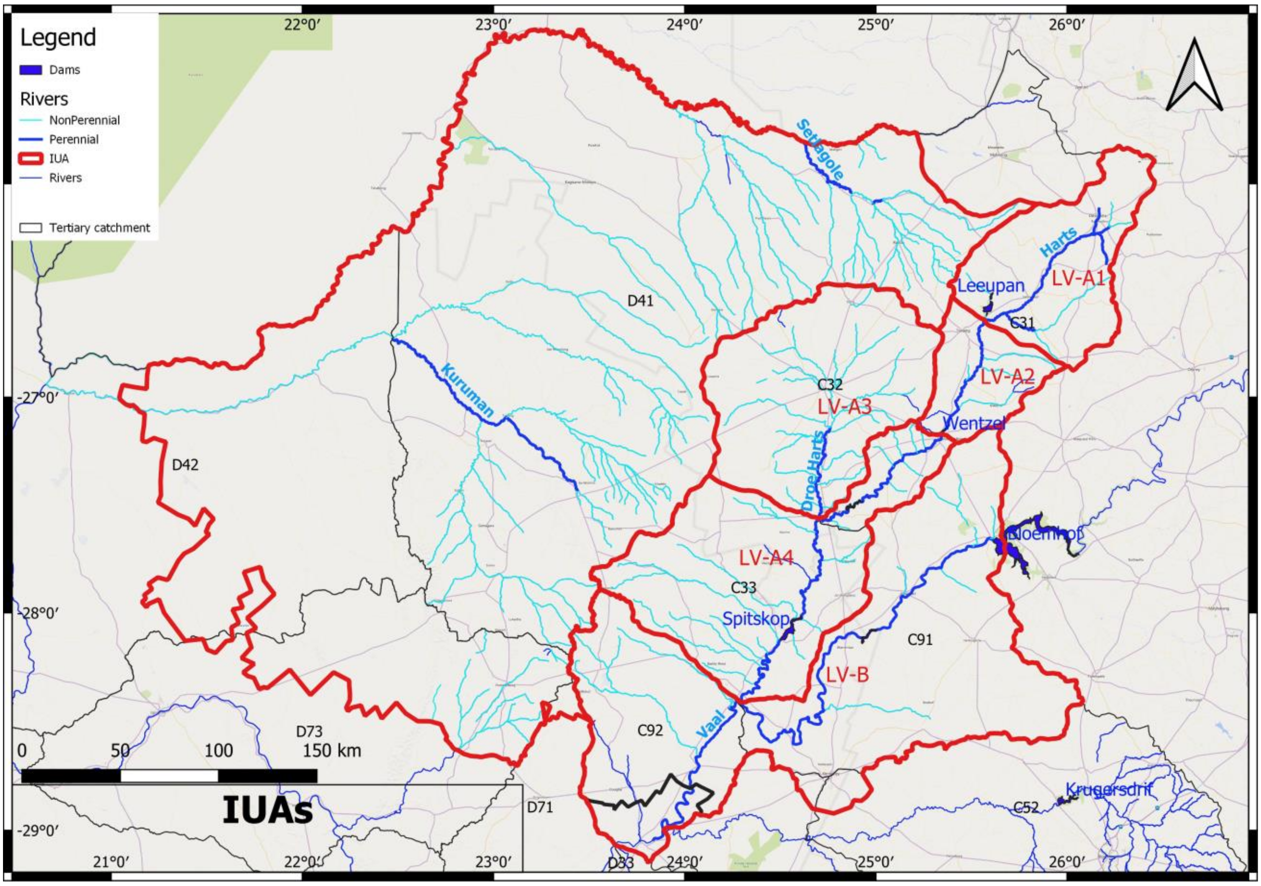

Figure 3-2 IUAs in the lower Vaal

Table 3-5 Summary of IUAs in Lower Vaal

IUA Reference	Description of resources	Major impoundments	Quaternary catchments
LV-A1	Upper Harts River	Barberspan	C31A – C31D
LV-A2	Middle Harts River	Wentzel Dam	C31E
LV-A3	Dry Harts River	-	C32A – C32D
LV-A4	Lower Harts River	Taung and Spitskop dams	C31F, C33A – C33C
LV-B	Vaal River from downstream of Bloemhof Dam to Douglas Weir	Vaalharts Weir	C91A– C91E, C92A – C92C
LV-C	Groundwater: dolomite aquifer in the Lichtenburg area	-	-

3.4.1 lv-a1: upper Harts River

This river reach has no upstream regulating storage and there are substantial irrigation abstractions that are already experiencing low assurance of supply. Water is also diverted from the Harts River (approximately from the outlet of C31B) into Barberspan (located in quaternary C31D). This diversion will result in most of the baseflow being removed from the river reach. **Barberspan Nature Reserve** is positioned 16 km northeast of Delareyville. It has been identified as a RAMSAR site and is a sanctuary for waterfowl.

3.4.2 lv-a2: middle Harts River

Wentzel Dam is located at the outlet of quaternary C31E and has limited release capability. The dam supplies water to Schweizer-Reneke for domestic purposes. The available yield of Wentzel Dam is fully utilised and EWR releases will result in a deficit in supply.

3.4.3 lv-a3: Dry Harts River

No regulation storage is present in this catchment and the flow is largely natural. The river is non-perennial.

3.4.4 lv-a4: Lower Harts River

Taung Dam is not utilised, and an investigation was undertaken to determine the feasibility of using the dam to supply domestic and/or irrigation water requirements from the dam.

Significant flows occur in the Harts River upstream of Spitskop Dam from the return flows of the Vaalharts Irrigation Scheme. The return flows have substantially changed the flow regime compared to natural conditions. This river reach receives flows from the Dry Harts River (upstream of and including quaternary C32D), which has no regulating storage structure as well as from Taung Dam located in quaternary C31F.

The water available in Spitskop Dam is more than the water requirements supplied from the dam. This is due to the large volume of return flows generated by the Vaalharts Irrigation Scheme located upstream of the dam. Water is released from Spitskop Dam from where it is abstracted for irrigation along the downstream river reach. Spitskop Dam has the capability to regulate flow releases in this river reach. Investigations were done to identify potential further users of the excess water available in the dam with the purpose of improving the water quality in the Vaal.

3.4.5 lv-b: Vaal River reach downstream of Bloemhof Dam

The flow in the river reach between Bloemhof Dam and Vaalharts weir is dominated by the releases made from Bloemhof Dam for the Vaalharts Irrigation Scheme. Evaporation losses along this river reach is relatively high. Vaalharts weir serves as the structure from where the irrigation water is diverted into the canal that feeds the Vaalharts Irrigation Scheme. Vaalharts weir is generally operated at 90% of its Full Supply Capacity (FSC). Significant operational losses have also been identified and recommendations have been made in the past to improve on the operation of the system in order to minimise losses. Bloemhof Dam has substantial flow regulation capability.

There are a number of abstractions along the main stem of the Vaal River to supply water for irrigation and urban use (Kimberley, Christiana, Warrenton, Windsorton, Barkly West and Delportshoop). The Vaal-Gamagara Government Water Scheme also abstracts water from the Vaal River upstream of the Riet-Modder confluence with the Vaal and has an allocation of about 13 million m^3/a. The confluence of the Riet- and Vaal rivers is downstream of Schmidtsdrift and upstream of Douglas Weir. Douglas weir is the most downstream storage structure, which has limited flow-regulating capability.

The Douglas Irrigation Scheme is supplied from the Douglas weir and, in addition to the runoff entering Douglas weir from the upstream incremental catchments, water is transferred (pumped) from the Orange River into Douglas weir. No releases are made from storage structures in the Vaal, Harts or Riet-Modder river systems to support the water requirements in Douglas weir.

3.4.6 lv-c: Dolomitic area near Lichtenburg

The Lichtenburg compartment consists of 10 sub-compartments covering an area of 698 km^2 and is largely underlain by the chert poor Lytellton formation. It is separated from the Schoonspruit compartment to the east by the Doornkop dyke and from the Grootpan compartment to the north by the Blaauwbank dyke.

Recharge to the aquifer is about 37 million m^3/a, which approximately equals the abstraction. Consequently, spring flow from the aquifer at Aaslaagte eye has dried up. Lichtenburg obtains water from boreholes, as do the communities of Itsoseng, Sheila and Bodibe, as well as several cement plants. There is also extensive irrigation in the area, which accounts for 28 million m^3/a of the abstraction. The aquifer is highly stressed and forms part of the Bo-Molopo Groundwater Control Area.

3.4.7 Molopo Catchment

Groundwater resources play an important part in the Molopo catchment. Some hydrology work was carried out in this area for 2011 ORASECOM study regarding ecological water requirements. WRSM Pitman model setups are available for this area however, no groundwater surface water interaction was modelled at the time.

3.5 Water Supply Infrastructure

3.5.1 Dams

The major dams are Wentzel Dam, Taung Dam and Spitskop Dam, all located on the Harts River, with Vaalharts Weir on the Vaal River and Douglas Weir located at the outlet of the Vaal River catchment.

Harts River Catchment: The major dams in this sub-catchment are Wentzel Dam, Taung Dam and Spitskop Dam, all located on the Harts River, with Vaalharts Weir on the Vaal River. Wentzel Dam is the most upstream dam on the Harts River and relies totally on the natural flow from the Harts. The only existing abstraction from the dam is the Schweizer Reneke town demand, reaching 1.02 million m^3/a at 2006 development level. Taung Dam is located downstream of Wentzel Dam not far upstream of the town of Taung. The Taung Dam was built in the Harts River in 1993 to augment irrigation supplies to the Taung irrigation area and possibly support new irrigation areas in the Pudimoe area. Currently the dam is not utilised at all. The DWA completed a Feasibility study in 2008 investigating the utilisation of Taung Dam. It seems as if the recommended utilisation of Taung Dam might only start to be implemented in 2023.

Spitskop Dam was constructed in 1975 in order to supply irrigators along the lower Harts upstream of the Vaal confluence. The dam was reconstructed in 1989 due to damage incurred by floods in 1988. The dam is positioned downstream of the Vaalharts Irrigation Scheme and therefore substantial volumes of return flows seep into the dam. The dam is currently only utilised to supply irrigation along the Harts River downstream of the dam.

Douglas Weir (Orange-Vaal Transfer Scheme): Douglas Weir is the most downstream storage structure in the Vaal River situated just upstream of the confluence with the Orange River. Douglas Weir has limited flow-regulating capability. The Douglas Irrigation Scheme, as well as Douglas Town, is supplied from the Douglas Weir and, in addition to the runoff entering Douglas Weir from the upstream incremental catchments, water is transferred (pumped) from the Orange River into Douglas Weir. No releases are made from storage structures in the Vaal, Harts or Riet/Modder river systems to support the water requirements in Douglas Weir. Since these two user groups do not have allocations from the Vaal River Sub-system, they only have access to the outflow from the Vaal. During periods of insufficient flow from the Vaal, the supply to these users is augmented with transfers from the Orange River System by means of the Orange-Vaal Transfer Scheme as mentioned above.

3.5.2 Water Supply schemes

Kimberley Municipality and the Vaal-Gamagara Government Regional Water Supply Scheme, as well as small towns, abstract water for urban/industrial use from the Vaal River downstream of Bloemhof Dam. The larger water related schemes which are in place are linked to either irrigation or abstractions from the Vaal River, which is the only abundant source of water within the sub-system.

Riverton-Kimberley Scheme: Water is abstracted from the Vaal River at Riverton and purified at the Riverton water treatment plant before being pumped to Kimberley. Projected abstractions for the 2009 planning year were estimated at 19.7 million m^3/a for Kimberley and 21.2 million m^3/a for other towns in the region.

Vaal-Gamagara Government Water Scheme: The Vaal-Gamagara Regional Water Supply Scheme was initiated in 1964 to supply water mainly to the mines in the Gamagara Valley in the vicinity of Postmasburg and further north of this town. An abstraction works and low lift pumping station are located on the Vaal River near Delportshoop, just below the confluence with the Harts River, from where water is pumped to the water purification works situated next to the Vaal River. Purified water is then pumped to reservoirs on the watershed of the Vaal River Catchment near Clifton. From the reservoirs at Clifton, water is gravity fed over a distance of 182 km along the route via Postmasburg – Sishen - Hotazel - Black Rock. The scheme has an allocation of 13.7 million m^3/a from the Vaal River.

Several local municipalities are dependent on groundwater as a source of bulk water supply. The water is supplied from boreholes within the municipal grounds. Some of the towns water supply is augmented by surface water supply e.g., Vryburg. The towns dependent on groundwater include:

- Bankara Bodulong
- Danielskuil
- Dibeng
- Groenwater
- Holpan
- Jennhaven
- Kathu
- Kono
- Kuruman
- Majeng
- Postmasburg
- Schmidtsdrift
- Amalia
- Schweizer Reneke

- Gamotlatla
- Lichtenburg
- Itsoseng
- Ottosdal
- Sannieshof
- Stella
- Vryburg
- Delarey
- Reivilo
- Setla-Kgobi North
- Setla-Kgobi South
- Ganyesa/Kudumane

3.5.3 Vaal Harts scheme

The Vaalharts Irrigation Scheme, situated in the Harts River catchment, is the largest irrigation scheme in the country and supports widespread irriagtion south of Taung (**Figure 3-3)**. Water is released from Bloemhof Dam to the Vaalharts Weir, situated on the Vaal River between Christiana and Warrenton, from where it is diverted into a canal. The incremental yield of Bloemhof Dam is less than the water requirements of the Vaalharts Scheme and other irrigators along the Lower Vaal. Bloemhof Dam is consequently supplemented by releases from Vaal Dam in times of shortages. The Vaalharts Scheme therefore forms part of the greater Vaal System.

Naledi and Greater Taung Municipalities also source their water from the Vaalharts Scheme, and water is purified at Pudimoe treatment works. Pokwane Municipality also obtain water directly from the Vaalharts canal system to supply Jan Kempdorp, Hartswater, and Pampierstad, with water purified at the Jan Kempdorp, Hartswater and Pampierstad treatment works.

Average transfers to the Vaalharts Irrigation Scheme (including distribution losses) are estimated at 450 million m^3/a. The Vaalharts canal system is reasonably old and in need of refurbishment. Distribution losses are therefore high and estimated to be in the order of 127 million m^3/a.

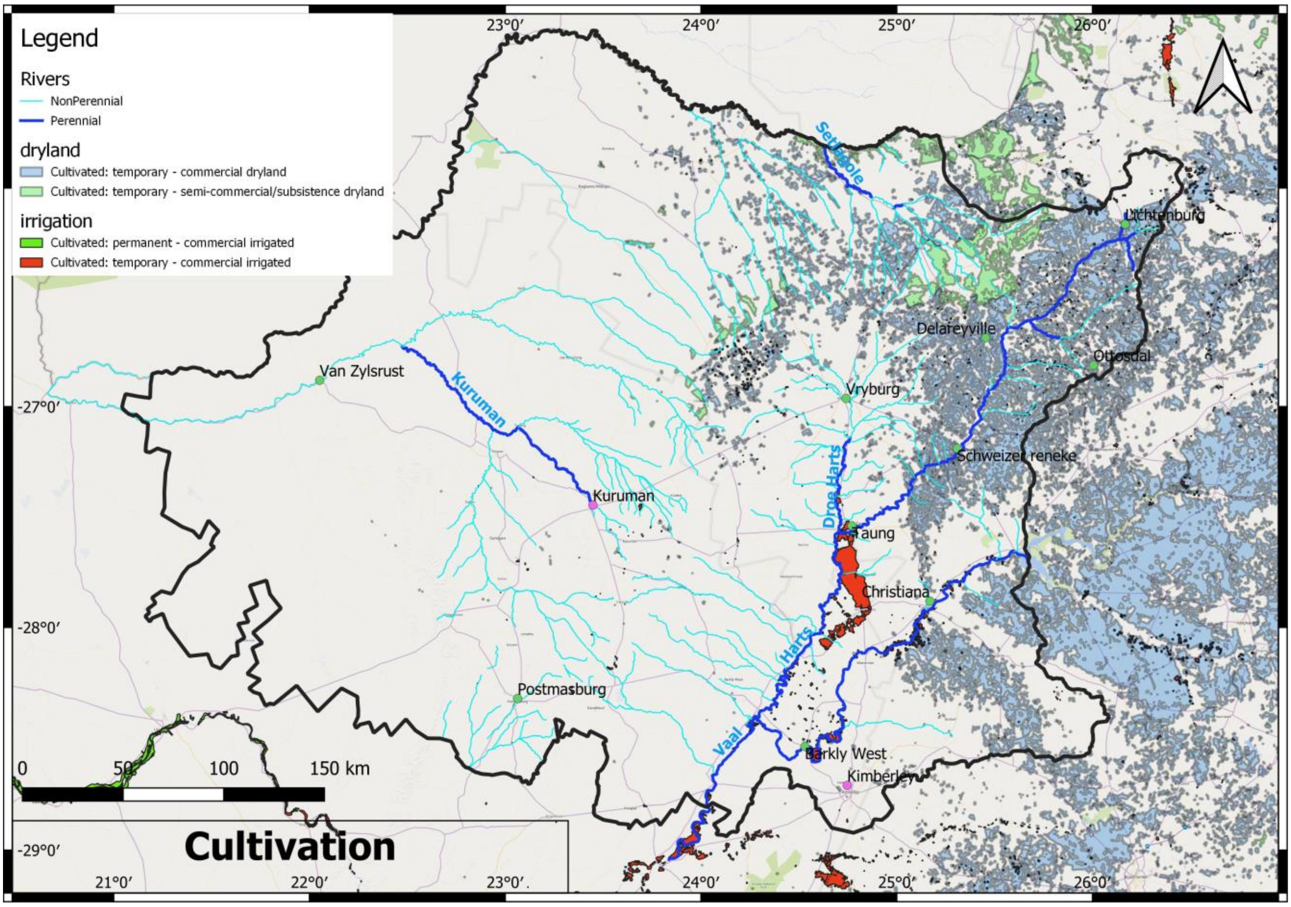

Figure 3-3 Cultivation in the lower Vaal

3.5.4 Other irrigation schemes

There are a number of abstractions along the main stem of the Vaal River to supply water for irrigation (**Figure 3-3).** Other irrigation scattered throughout the region away from the main rivers is groundwater based.

3.5.5 Industrial and mining

There are quite a number of mining operations in the Lower Vaal. These activities vary from base metal mining; diamond mining and even limited gold mining in the Kalahari greenstone belt.

The North Cape manganese deposits lie to the north and west of Kuruman. They are known to cover an area of at least 1 100 km^2 and are the largest manganese deposits in the world. It is estimated that more than 80% of the worlds known manganese reserves are situated in the north Cape Deposits. They stretch from Black Rock in the north to Postmasburg in the south and effectively form two distinct ore bodies namely the Kalahari Manganese Field and the Postmasburg Manganese Field.

Groundwater use at most of these sites is limited and should any seepage occur into opencast pits or underground workings, the water is usually pumped and utilized in processes to minimize use of other water sources. This pumping often causes localized dewatering. The only mine where this effect is pronounced is Anglo-American's Sishen Mine near Kathu.

Sishen is one of the seven largest open cast mines in the world with an open pit of approximately 11 km long, 1.5 km wide and almost 400 m deep. Although the Sishen Mine can utilise Vaal River water via the 700mm diameter Vaal-Gamagara pipeline, it currently makes use of groundwater abstracted directly from the mining area. Approximately 1.5 million m^3 of water is abstracted monthly from the mine of which approximately 0.9 million m^3 is used for the mining operations or for the towns housing the mine employees and their families (Dingleton, Kathu and Sesheng). The remainder is distributed to other mines in the area including Hotazel and Olifantshoek via the Vaal-Gamagara pipeline. It is anticipated that the groundwater will gradually be depleted and that Sishen Mine will eventually have to import water.

Assmang operate the Beeshoek iron ore operations, located near Sishen. Both Beeshoek North and South mines are opencast operations. Pering Mine is a lead (Galena) and zinc (Sphalerite) mine that is located in the southwestern portion of the North West Province close to the border with the Northern Cape Province. The nearest town, Reivilo is 20 km southwest of the mine. Vryburg is 70 km northeast of the mine. The Pering Mine ore body is rapidly approaching depletion after being in operation since late 1986. It is estimated that 8 million m^3/a of groundwater is abstracted at Pering.

The Finsch diamond mine, located 160 km northwest of Kimberley, is one of De Beers' seven South African operations. Pumping controls groundwater seepage from the overlying strata of dolomite and limestone. No abstraction volumes are available.

Smaller mining operations include a limestone quarry at LimeAcres, Kalahari Goldridge Mine (opencast mine with heap leach extraction) near Mmabatho and several diamond diggings in alluvial deposits along the Vaal and smaller tributaries. The diamond diggings have little impact on water quality; huge amounts of water are abstracted locally during the processing of the diggings and surface environment and drainage patterns are altered. Currently the Kalahari Goldridge mine supply its own water by circulating water from the pit and sludge lagoons as well as from boreholes (Total 120 Ml/year).

3.5.6 Schedule 1 and livestock water use

Agriculture plays a major role in terms of economic development. Almost every farm unit is dependent on groundwater for domestic use and stock watering.

3.6 Point and diffusive pollution

Water quality status in the Upper Vaal catchment is impacted on by discharges from gold mines, seepages from tailings dams, discharges from industry directly to the river, urban runoff and discharges from the large number of sewage treatment plants located in the urban areas. The return flows from sewage treatment plants have resulted in the flows in many of the river systems exceeding the natural flows. Although the Middle Vaal is less urbanized, discharges from mining operations and sewage treatment facilities have a notable influence on the water balance.

The predominant land use in the Lower Vaal is agriculture, with extensive irrigation schemes located on the Vaal River and along the Harts River. The following points summarize water quality status of the Vaal River (Scherman, 2010):

- The usage of water in the Vaal River is impacted by high levels of salinity and related macro-ions particularly downstream of Vaal Dam.

- Eutrophication due to high nutrient levels is a key issue in the Vaal River, resulting in algal blooms and growth of water hyacinth. The algae resulting from eutrophication has led to odour and colour problems in the intake water to water treatment plants which are not geared for dealing with eutrophic waters.
- Microbiological pollution is an emerging concern.
- While sections of the upper part of the Vaal catchment have water of a good quality, the areas of concern include the Vaal Barrage and Lower Vaal River downstream of Harts River confluence.
- Discharges from coal and gold mining, industrial discharges and decant from mines post closure, cause water quality problems in the Vaal system.
- Along the main stem of the Vaal organics has been raised as an issue by the water boards, with monitoring programmes identifying increases in Dissolved Organic Carbon (DOC) in raw intake water to the water treatment plants.

Agricultural activities are a source of diffuse water contamination. The contribution of each farm on a local scale is often fairly small but the contribution on a catchment scale needs to be included in assessing any pollution situation. Most findings regarding this issue can only be assessed in a generic way due to the lack of data. Nitrates are the contaminant of most concern, since they are very soluble and do not bind to soils, nitrates have a high potential to migrate to groundwater. Because they do not evaporate, nitrates/nitrites are likely to remain in water until consumed by plants or other organisms. Generally, on a local scale the areas of intense cultivation are the major contributors in terms of inorganic nitrates. The primary inorganic nitrates, which may contaminate drinking water, are potassium nitrate and ammonium nitrate both of which are widely used as fertilizers. Feedlots contribute to the organic nitrates in groundwater and can be far more problematic.

Other contaminants of concern are pesticides and herbicides. The contribution of these to groundwater contamination is very difficult to quantify on catchment scale.

During 2003, a study was funded by the WRC (Ellington, 2003), which investigated the effects of the high-density cultivation at the Vaalharts surface water irrigation scheme on the underlying aquifer. The irrigated area is 32000ha, comprising of the North and West Canal areas. It was found that the TDS of the groundwater has increased at a rate of 13 mg/l/annum. The leaching addition of approximately 100000 t/annum was found to be the main source of this TDS increase. Simultaneously, the main contributor to the salt load within the Vaalharts Irrigation Scheme was found to be the incoming canal water from the Vaal River at Warrenton. Whereas fertilizers contribute only 50000 t/annum, the incoming Vaal River water contributes 130000 t/annum of salts. These salts are moving towards the Harts River at a rate of approximately 5Mm^3/a. The path towards the Harts River, however, sees the rainfall having a dilution effect on the concentration, and thereby reducing the groundwater TDS concentrations on its path towards the Harts River, and therefore too on the concentration of salts entering the Harts river.

4 REVIEW OF DATA

4.1 Groundwater Regions

The study area is divided into several groundwater regions, based on physiography and geology (**Figure 4-1**).

- The eastern and western Kalari regions cover the lithologies overlain by Kalahari sands covering a host of lithologies
- The Ghaap Plateau is underlain by Campbell Group and Schmidtsdrift Group dolomites with Vryburg Formation shales and sandstones
- The Zeerust-Delmas Karts Belt consists of dolomites and chert
- The Western Highveld is underlain by Ventersdorp Supergroup volcanics and the Dominion group volcanics
- The North-eastern and Central Pan Belts consist of Ecca group shales and dolerite

4.2 Aquifer types

The aquifer types found in the area **Figure 4-2** can be subdivided as follows:

- Karst aquifers: these are present in the dolomite in the vicinity of Kuruman and Lichtenburg in the Zeerust-Delmas Karst Belt and Ghaap Plateau. They cover large part of the central part of the basin and yields can be over 5 l/s.
- High yielding (>5 l/s) fractured aquifers are found along the margins of the dolomites in the banded ironstones.
- Low yielding (<0.5 l/s) Fractured aquifers are found in the western part of the basin in the Western Kalahari
- Moderately yielding fractured aquifers are found in in the Western Kalahari and North-eastern and Central Pan Belts
- Fractured and weathered aquifers are found widely in the east. The most significant are in the Western Highveld. The lowest yielding are found in the Eastern Kalahari and North-eastern Pan Belt.
- Intergranular aquifers are found the Eastern Kalahari

Secondary fractured and weathered aquifers are of highly variable yield and are related to the lithology and structures present. Weathering gives rise to low to moderately yielding aquifers where groundwater is stored in the interstices in the weathered saturated zone and in joints and fractures of competent rocks. Groundwater in these aquifers often occurs in leaky type aquifers, where water is stored in the overlying weathered horizon, and the underlying fractures are the main transmissive zone. Pumping from the transmissive zone results in a vertical gradient inducing leakage from the overlying weathered zone. The upper and lower zones are hydraulically linked. The deeper fractures often have a high transmissivity but lower storativity than the shallow zone fractures and the yields of boreholes varies with the depth of weathering.

The main variations in hydrogeology occur due to variations in degree of fracturing and weathering, depth of water level relative to the depth of weathering, the distribution and nature of dolerite and diabase intrusions.

In the Louwna area the weathered pegmatitic granite yields are generally greater than 5 l/s as well as at the contact zone of the Kraaipan Group and the granite (Stella area). In the Delareyville area the contact between the Allanridge formation and the granites can be targeted for exploitable water. In the Schweizer Reneke area yields of up to 2l/s can be drilled in weathered ones of the granite.

Groundwater yields of 2 l/s – 5 l/s is found in fractured and weathered lavas of the Klipriviersberg formation (Sannieshof area). The andesitic lava of the Allanridge formation can yield groundwater in excess of 2 l/s in fractures associated with faults or intrusions.

Solution cavities in dolomitic rocks of the Ghaap Group and Chuniespoort group often develop in association with diabase dykes and faults, contain large quantities of exploitable groundwater (yields > 5 l/s). Some dykes isolate compartments, which may be dewatered during overexploitation (e.g., Tosca). The contact between the banded iron formation and the dolomite is transitional with alternating shale and dolomite bands. This zone is a well-developed aquifer in association with faults and dykes.

Joints and fractures in the Volop quartzite and the whole of the Postmasburg Group can be targeted for boreholes with yields of up to 2 l/s. Yields in the Dwyka and Ecca sediments associated with fractures and intrusions, are not very high (0.1-0.5 l/s) and often the groundwater is associated with poor quality.

4.3 Water Level data

Groundwater level data is available from 233 open stations (**Table 4-1)**. There are 17 stations with more than 40 years of record, 52 with more than 30 years of record and 113 with more than 20 years of record. This provides much valuable data for assessing water level trends. Their distribution is shown in **Figure 4-3.** The monitoring stations cover all of the catchments with high levels of abstraction except C91B in the vicinity of Christiana and C31F near Schweizer Reneke.

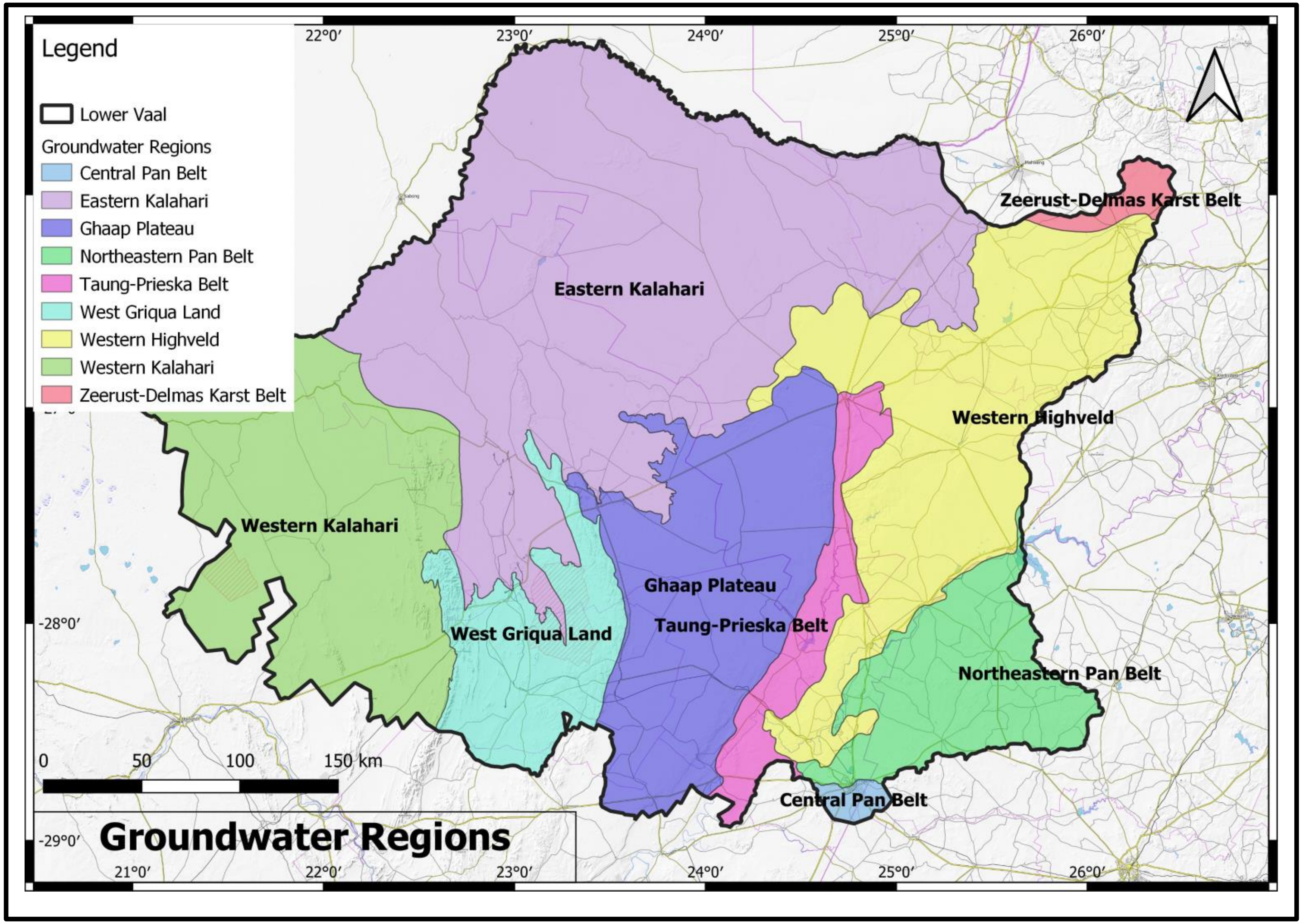

Figure 4-1 Groundwater regions

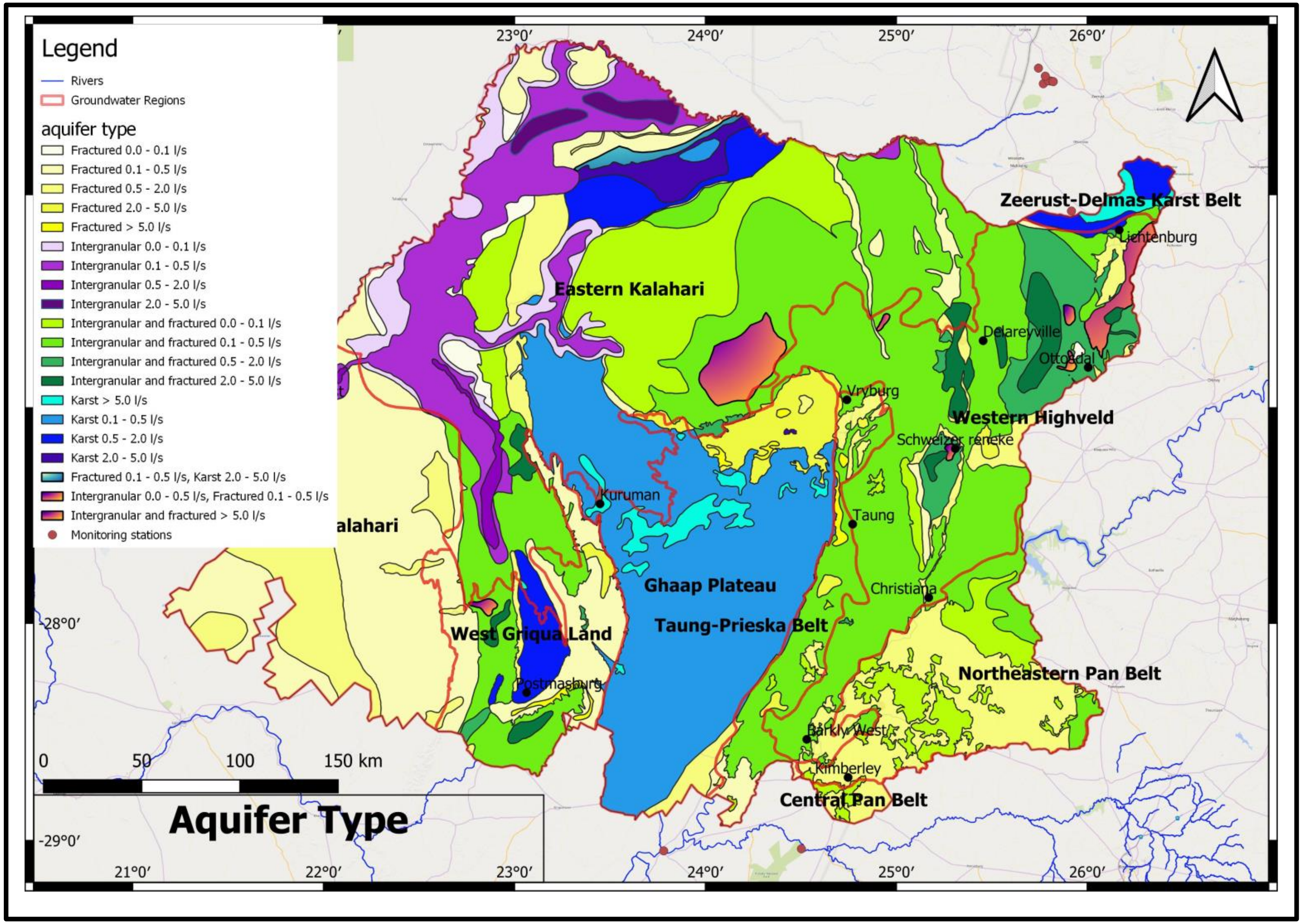

Figure 4-2 Aquifer type

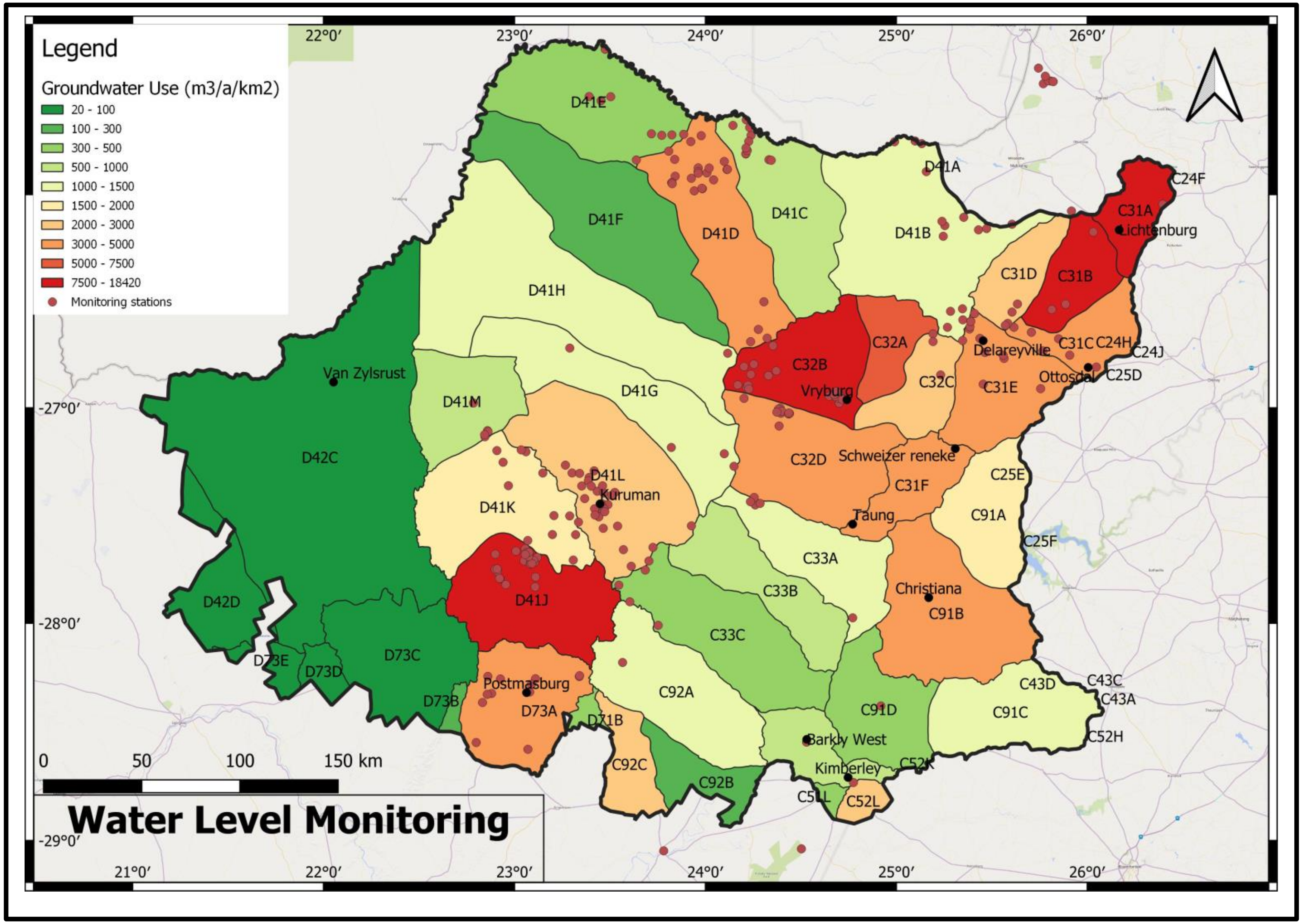

Figure 4-3 Open Groundwater monitoring stations

Table 4-1 Open Groundwater level monitoring stations

Station Number	Quaternary	Begin Date	Monitoring Frequency
C3N0030	C31B	1975/08/15	Quarterly
C3N0050	C32B	1980/10/03	Quarterly
C3N0054	C32B	1980/07/28	Quarterly
C3N0060	C32B	1982/11/07	Quarterly
C3N0062	C32B	1980/05/30	Quarterly
C3N0064	C32B	1981/10/31	Quarterly
C3N0069	C32B	1980/09/06	Quarterly
C3N0071	C32B	1979/09/01	Quarterly
C3N0072	C32B	1980/09/09	Quarterly
C3N0075	C32B	1981/10/17	Quarterly
C3N0078	C32B	1979/06/09	Quarterly
C3N0098	C32D	1985/02/21	Quarterly
C3N0099	C32D	1984/10/31	Quarterly
C3N0107	C31B	1987/04/01	Quarterly
C3N0500	C31C	1987/08/13	Quarterly
C3N0511	C32B	1958/05/12	Quarterly
C3N0527	C33A	1987/07/25	Quarterly
C3N0530	C33A	1987/01/22	Quarterly
C3N0553	C31A	1990/08/23	Quarterly
C3N0555	C33A	1992/12/22	Quarterly
C3N0556	C33A	1994/07/08	Quarterly
C3N0561	C32D	1995/03/15	Quarterly
C3N0605	C33A	2003/04/07	Quarterly
C3N0621	D41L	2002/09/25	Quarterly
C3N0655	C32A	2013/06/05	Quarterly
C3N0656	C32C	2013/06/05	Quarterly
C3N0657	C31C	2013/06/03	Quarterly
C3N0661	C31E	2013/06/05	Quarterly
C3N0662	C31E	2013/06/05	Quarterly
C3N0665	C33C	2013/09/17	Quarterly
C3N0666	C33C	2013/09/17	Quarterly
C3N0668	C31C	2017/08/21	Quarterly
C9N0549	C92A	2002/09/17	Quarterly
C9N0559	C91E	2006/12/18	Quarterly
C9N0616	C91E	2012/06/27	Quarterly
D3N0561	C32D	2002/04/15	Quarterly
D3N0562	C32D	2002/04/15	Quarterly
D3N0564	C32D	2002/04/15	Quarterly
D3N0565	C32D	2002/04/15	Quarterly
D3N0566	C32D	2002/04/15	Quarterly
D3N0569	C32D	2002/04/15	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N0143	D41B	1977/02/11	Quarterly
D4N0706	D41J	1981/11/23	Quarterly
D4N1533	D41L	1998/01/17	Quarterly
D4N1535	D41B	1997/08/27	Quarterly
D4N1536	D41B	1997/08/27	Quarterly
D4N1538	D41G	1997/03/04	Quarterly
D4N1539	D41L	2001/08/01	Quarterly
D4N1544	D41L	1973/01/23	Quarterly
D4N1546	C33C	1970/01/01	Quarterly
D4N1548	D41L	1985/12/05	Quarterly
D4N1550	D41L	1970/07/11	Quarterly
D4N1556	D41L	2001/01/24	Quarterly
D4N1557	C33C	1995/03/03	Quarterly
D4N1560	D41J	1996/09/04	Quarterly
D4N1564	D41J	1996/06/01	Quarterly
D4N1566	D41J	1996/06/01	Quarterly
D4N1568	D41J	1996/06/01	Quarterly
D4N1569	D41J	1998/07/27	Quarterly
D4N1572	D41J	1996/06/01	Quarterly
D4N1580	D41L	1987/11/24	Quarterly
D4N1581	D41L	1988/05/10	Quarterly
D4N1583	D41L	1992/12/31	Quarterly
D4N1585	D41L	1988/01/26	Quarterly
D4N1614	D41J	1996/06/01	Quarterly
D4N1616	D41J	1996/09/04	Quarterly
D4N1654	D41B	1998/12/14	Quarterly
D4N1660	D41E	1998/09/15	Quarterly
D4N1662	D41E	1997/10/30	Quarterly
D4N1665	D41E	1998/09/04	Quarterly
D4N1671	D41H	1985/08/20	Quarterly
D4N1685	C32D	1985/01/08	Quarterly
D4N1694	C32D	1987/09/01	Quarterly
D4N1700	D41E	1992/07/29	Quarterly
D4N1721	D41D	1985/01/11	Quarterly
D4N1789	D41L	1992/03/12	Quarterly
D4N1791	D41L	1992/03/12	Quarterly
D4N1792	D41L	1992/03/12	Quarterly
D4N1799	D41L	1994/06/07	Quarterly
D4N1861	D41K	2005/05/09	Quarterly
D4N1866	D41L	1991/05/01	Quarterly
D4N1867	D41L	1991/05/01	Quarterly
D4N1868	D41L	1994/09/28	Quarterly
D4N1869	D41L	1991/01/02	Quarterly
D4N1871	D41L	1991/01/02	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N1872	D41L	1991/01/02	Quarterly
D4N1876	D41L	1991/01/02	Quarterly
D4N1878	D41L	1995/03/03	Quarterly
D4N1882	D41L	2002/10/22	Quarterly
D4N1885	D41L	2006/05/26	Quarterly
D4N1894	D41L	2004/08/25	Quarterly
D4N1956	D41D	1998/04/01	Quarterly
D4N1977	C32D	1998/04/01	Quarterly
D4N1988	D41D	1998/04/01	Quarterly
D4N1989	C32D	1998/04/01	Quarterly
D4N1993	C32D	1998/04/01	Quarterly
D4N1998	C32B	1998/04/01	Quarterly
D4N2000	C32D	1998/04/01	Quarterly
D4N2009	D41D	1998/04/01	Quarterly
D4N2024	C32D	1998/04/01	Quarterly
D4N2031	C31E	2008/11/09	Quarterly
D4N2034	C31D	2010/03/25	Quarterly
D4N2038	C31D	2008/11/09	Quarterly
D4N2050	C31E	2011/11/01	Quarterly
D4N2051	C31E	2008/11/05	Quarterly
D4N2060	C31C	2008/11/04	Quarterly
D4N2068	C31C	2008/11/04	Quarterly
D4N2070	C31E	2008/11/05	Quarterly
D4N2082	C31C	2008/11/04	Quarterly
D4N2085	C31B	2008/11/04	Quarterly
D4N2097	C31D	2008/11/06	Quarterly
D4N2108	C31E	2008/11/04	Quarterly
D4N2113	C31E	2008/11/06	Quarterly
D4N2125	C31E	2008/11/07	Quarterly
D4N2143	C31E	2008/11/07	Quarterly
D4N2174	C31E	2008/11/06	Quarterly
D4N2175	C31D	2008/11/06	Quarterly
D4N2178	C31E	2008/11/07	Quarterly
D4N2186	C31E	2008/11/06	Quarterly
D4N2187	C31E	2011/11/04	Quarterly
D4N2225	C31E	2008/11/08	Quarterly
D4N2264	C32C	2008/11/07	Quarterly
D4N2274	C32D	2002/04/15	Quarterly
D4N2277	C32B	2001/04/15	Quarterly
D4N2279	C32D	2002/04/15	Quarterly
D4N2280	C32D	2002/04/15	Quarterly
D4N2281	C32D	2002/04/15	Quarterly
D4N2286	D41D	2003/09/23	Quarterly
D4N2287	D41D	2003/09/16	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N2288	D41D	2003/09/12	Quarterly
D4N2289	D41D	2003/10/23	Quarterly
D4N2290	D41D	2003/10/22	Quarterly
D4N2291	D41D	2004/03/29	Quarterly
D4N2296	D41D	1991/07/09	Quarterly
D4N2297	D41D	1991/06/14	Quarterly
D4N2298	D41C	2004/06/18	Quarterly
D4N2302	D41D	1991/06/27	Quarterly
D4N2305	D41D	1991/06/19	Quarterly
D4N2309	D41D	2001/04/01	Quarterly
D4N2310	D41D	2001/04/01	Quarterly
D4N2311	D41C	2004/09/02	Quarterly
D4N2314	D41D	1991/02/21	Quarterly
D4N2315	D41D	1991/02/27	Quarterly
D4N2316	D41D	1991/02/08	Quarterly
D4N2317	D41D	1991/02/08	Quarterly
D4N2320	D41D	1991/03/22	Quarterly
D4N2322	D41D	1991/03/15	Quarterly
D4N2323	D41D	1991/03/13	Quarterly
D4N2325	D41D	1991/02/16	Quarterly
D4N2326	D41D	1991/02/16	Quarterly
D4N2344	D41D	1991/02/26	Quarterly
D4N2370	D41J	2006/05/22	Quarterly
D4N2371	D41J	2006/08/16	Quarterly
D4N2373	D41J	2006/02/09	Quarterly
D4N2375	D41J	2006/02/09	Quarterly
D4N2377	D41J	2007/05/16	Quarterly
D4N2378	D41L	2006/09/07	Quarterly
D4N2382	D41K	2006/09/08	Quarterly
D4N2383	D41K	2006/09/08	Quarterly
D4N2384	D41K	2009/03/04	Quarterly
D4N2385	D41K	2006/05/25	Quarterly
D4N2386	D41K	2006/05/25	Quarterly
D4N2458	D41L	2006/05/23	Quarterly
D4N2459	D41K	2006/08/17	Quarterly
D4N2461	D41K	2008/05/20	Quarterly
D4N2463	D41K	2006/08/21	Quarterly
D4N2464	D41K	2006/12/11	Quarterly
D4N2466	D41K	2006/08/19	Quarterly
D4N2467	D41K	2006/08/19	Quarterly
D4N2470	D41J	2007/11/26	Quarterly
D4N2488	D41E	2002/08/21	Quarterly
D4N2490	D41E	2002/08/22	Quarterly
D4N2498	D41B	2010/07/20	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N2499	D41B	2013/06/19	Quarterly
D4N2503	D41B	2010/08/02	Quarterly
D4N2519	D41E	2011/06/21	Quarterly
D4N2523	D41M	2014/05/20	Quarterly
D4N2524	D41M	2014/05/20	Quarterly
D4N2525	D41K	2014/05/19	Quarterly
D4N2528	D41M	2014/05/20	Quarterly
D4N2529	D41M	2014/05/20	Quarterly
D4N2537	D41L	2006/05/23	Quarterly
D4N2539	C31E	2013/06/04	Quarterly
D4N2545	D41G	2006/05/22	Quarterly
D4N2548	D41J	2013/06/03	Quarterly
D4N2549	D41J	2013/06/03	Quarterly
D4N2558	D41K	2013/08/15	Quarterly
D4N2559	D41L	2014/05/21	Quarterly
D4N2560	D41L	2014/05/21	Quarterly
D4N2561	D41L	2014/05/21	Quarterly
D4N2563	D41G	2014/09/17	Quarterly
D4N2565	D41M	2014/09/12	Quarterly
D4N2567	D41K	2014/03/18	Quarterly
D4N2568	D41K	2014/03/18	Quarterly
D4N2573	D41E	2015/03/18	Quarterly
D4N2576	D41E	2015/03/20	Quarterly
D4N2578	D41E	2015/08/24	Quarterly
D4N2580	D41E	2015/03/20	Quarterly
D4N2582	D41D	2015/03/20	Quarterly
D4N2583	D41E	2015/03/20	Quarterly
D4N2592	D41D	2015/03/20	Quarterly
D4N2593	D41L	2015/03/20	Quarterly
D4N2603	D41D	2015/03/26	Quarterly
D4N2604	D41D	2015/03/26	Quarterly
D4N2605	D41C	2015/03/26	Quarterly
D4N2608	D41C	2015/03/26	Quarterly
D4N2609	D41C	2015/03/26	Quarterly
D4N2616	D41C	2015/03/26	Quarterly
D4N2617	D41C	2015/03/26	Quarterly
D4N2622	D41L	2006/05/25	Twice yearly
D4N2623	D41J	2015/03/04	Twice yearly
D4N2627	D41E	2010/06/08	Quarterly
D4N2636	D41B	2016/08/25	Quarterly
D4N2637	D41B	2016/12/03	Quarterly
D4N2638	D41B	2016/11/03	Quarterly
D4N2639	D41B	2016/11/03	Quarterly
D4N2642	D41E	2015/08/25	Quarterly

Station Number	Quaternary	Begin Date	Monitoring Frequency
D4N2643	C31D	2015/09/08	Quarterly
D4N2644	D41E	2015/08/24	Quarterly
D4N2649	D41J	2014/06/24	Quarterly
D6N0645	C91D	2012/03/22	Quarterly
D7N0525	D73A	2002/05/07	Quarterly
D7N0527	D73A	2002/05/07	Quarterly
D7N0531	D73A	2004/09/28	Quarterly
D7N0533	D73A	2004/09/28	Quarterly
D7N0534	D73A	2004/09/28	Quarterly
D7N0536	D73A	2004/09/28	Quarterly
D7N0537	D73A	2004/09/28	Quarterly
D7N0539	D73A	2004/09/28	Quarterly
D7N0540	D73A	2004/09/28	Quarterly
D7N0580	D73A	2007/10/08	Quarterly
D7N0723	D73A	2000/01/26	Quarterly
D7N0728	D73A	1994/12/01	Quarterly

4.4 Population

The population was calculated from StatsSA 2021 population estimates for each LM, and scaled by the proportion of the LM in the Lower Vaal (**Table 4-2).** The population is 1.9 million. The largest concentration of urban population is in Kimberley. Nearly 8% of the population is registered on Stats SA as being dependent on groundwater sources which are not regional schemes. These are Schedule 1 water users.

Table 4-2 Population

Local Municipality	Total Area (m^2)	% in lower Vaal	Population	Population in Lower Vaal	% Dependent on boreholes and springs
Letsemeng	9 828 574 156	0.27	43 057	116	13.76
Tokologo	9 325 860 055	66.52	31 285	20 812	23.55
Tswelopele	6 524 073 123	27.42	50 809	13 930	17.11
Ratlou	4 883 647 387	91.55	125 314	114 722	7.46
Tswaing	5 966 249 820	99.65	473 985	472 345	11.89
Mafikeng	3 698 444 551	15.57	200 516	31 229	10.13
Ditsobotla	6 464 870 937	43.63	201 641	87 979	5.19
Naledi	6 941 194 598	100.00	73 552	73 552	4.51
Mamusa	3 614 838 572	99.85	64 689	64 589	4.73
Greater Taung	5 635 470 804	100.00	204 744	204 744	4.61
Lekwa-Teemane	3 681 201 030	85.30	60 490	51 598	1.29
Kagisano/Molopo	23 827 264 140	99.98	111 858	111 835	17.19
City of Matlosana	3 561 460 574	1.37	469 765	6 423	4.62
Maquassi Hills	4 643 048 752	5.86	92 360	5 414	20.39
Siyancuma	16 752 682 162	11.17	37 406	4 177	18.23

//Khara Hais	21 779 779 792	42.36	93 494	39 602	0.77
Tsantsabane	18 332 777 517	88.14	41 314	36 416	11.82
Kgatelopele	2 477 925 756	100.00	21 709	21 709	9.25
Sol Plaatjie	3 145 390 920	58.84	266 341	156 718	0.90
Dikgatlong	7 314 725 964	100.00	50 630	50 630	9.53
Magareng	1 541 671 017	100.00	25 072	25 072	6.83
Phokwane	833 876 466	100.00	62 538	62 538	7.08
Joe Morolong	20 172 046 183	99.98	87 402	87 387	15.89
Ga-Segonyana	4 491 641 561	100.00	109 572	109 572	3.37
Gamagara	2 619 424 597	100.00	56 815	56 815	5.78
TOTAL	198 058 140 434		3 056 359	1 909 926	7.75

The population density is shown in **Figure 4-4**. There are large rural populations in the Lower Vaal, especially in the areas southwest of Mafikeng, around Kuruman, Pampierstad and Lichtenberg. The central and western portions are sparsely populated.

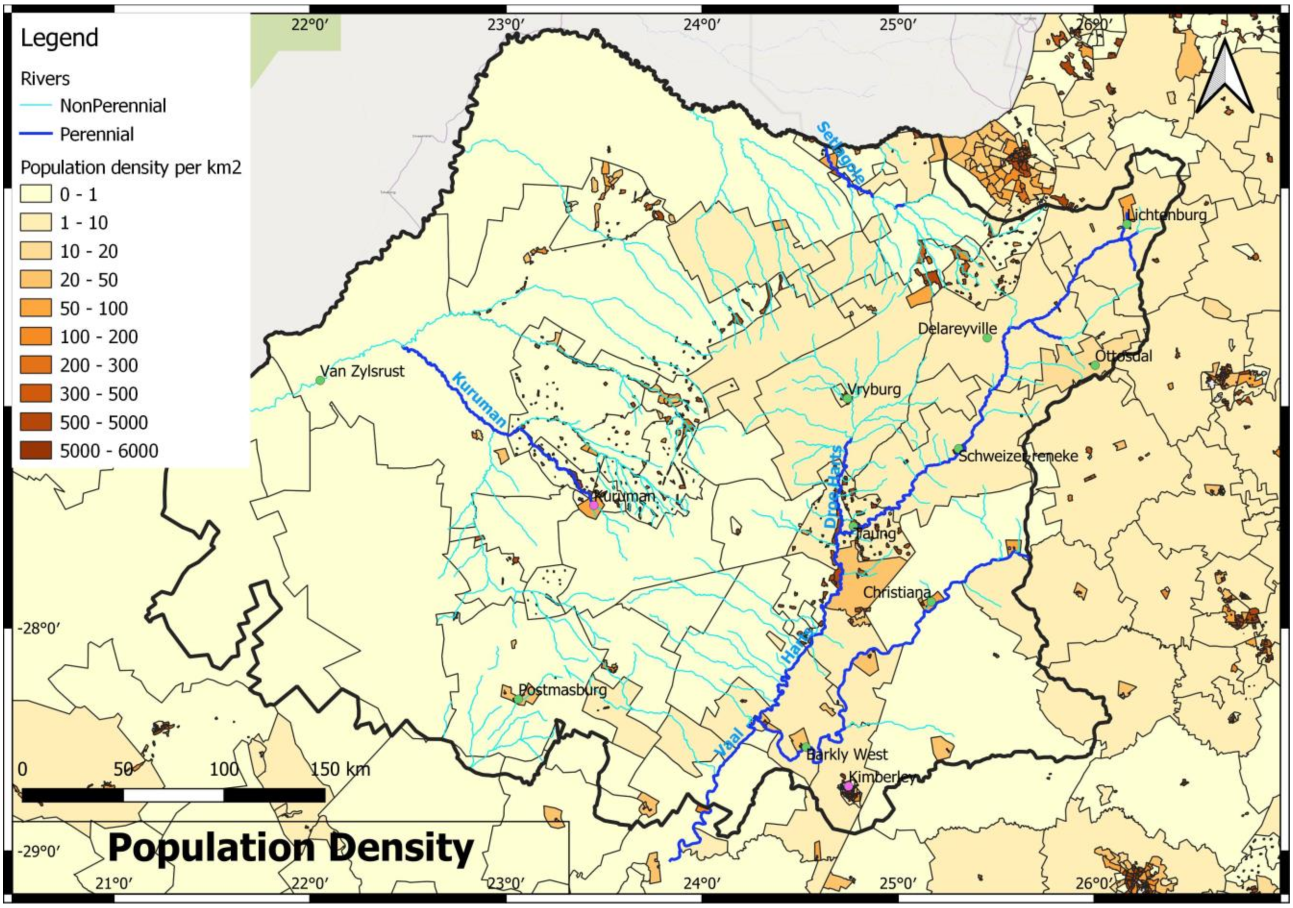

Figure 4-4 Population density

4.5 Surface Water Use

Surface water use is shown in **Table 4-3.** The largest registered use is for the Vaal-Harts irrigation scheme at 270 Mm^3/a, whose coordinates are not registered correctly on WARMS. The use occurs in C33C but plots in C92A (**Figure 4-5)**. Total use is 569.49 Mm^3/a. It is concentrated on the Vaal and Harts rivers.

Table 4-3 Surface water registered use

Quaternary	Registered Use (Mm^3/a)
C31A	0.0462
C31C	1.044757
C31E	1.10625325
C32A	0.363
C32C	0.1675
C32D	0.122498
C33A	0.982252
C33B	0.20094
C33C	363.929887
C51L	0.05505
C91A	36.312944
C91B	44.64669855
C91C	0.254393
C91D	13.66204175
C91E	79.08902265
C92A	17.5543003
C92B	5.0624713
C92C	0.18867
D41K	0.0073
D41L	0.680112
D73A	0.01824
Total	565.49

Water use by sector is shown in **Table 4-4.** Irrigation utilises 86% of the surface water use.

Table 4-4 Surface water use by sector

Sector	Use (Mm^3/a)	Percent
AGRICULTURE: IRRIGATION	486.34	86.00
AGRICULTURE: WATERING LIVESTOCK	0.01	0.00
INDUSTRY (NON-URBAN)	0.40	0.07
INDUSTRY (URBAN)	30.33	5.36
MINING	14.83	2.62
WATER SUPPLY SERVICE	33.58	5.94

4.6 Groundwater Use

Registered groundwater use amounts to 338 Mm^3/a, excluding Schedule 1 domestic and livestock water use. 59% of this use is for irrigation (**Table 4-5).** Groundwater use is dispersed in the study area, which the largest use near Vryburg and Postmasburg (**Figure 4-6).**

Table 4-5 Registered groundwater use by sector

Sector	Use (Mm^3/a)	Percent
AGRICULTURE: AQUACULTURE	0.01	0.00
AGRICULTURE: IRRIGATION	199.53	58.95
AGRICULTURE: WATERING LIVESTOCK	0.56	0.17
INDUSTRY (NON-URBAN)	0.99	0.29
INDUSTRY (URBAN)	8.54	2.52
MINING	82.95	24.51
POWER GENERATION	0.03	0.01
SCHEDULE 1	0.00	0.00
WATER SUPPLY SERVICE	45.87	13.55
Total	338.49	

The Groundwater Reserve study AGES (2009) utilised a borehole abstraction of 49.6 Mm^3/a for water supply. Livestock water use was estimated at of 5.3 Mm^3/a. The BHN community water allocation was calculated at of 13.4 Mm^3/a (represents 1.4 % of recharge) for a total of 1 012 833 people in the catchment. The water was allocated at 25 L/person/day where there was no WARMS data available. Farm irrigation volumes from groundwater resources amount to 172 Mm^3/a (17.5 % of recharge), according to the WARMS data (registered volumes from boreholes). Spring flow is one of the lowest users of groundwater at 1.3 Mm^3/a from 224 springs.

The volumes in the Reserve study are significantly lower than what is recorded in WARMS.

4.6.1 Irrigation

In addition to the controlled irrigation there is a significant amount of diffuse irrigation which is supported by groundwater abstractions. Irrigation schemes making use of groundwater from the dolomite and fault zones are numerous and the water supply is very reliable if well managed. Ground water use for irrigation is concentrated in the north-eastern part of the Lower Vaal, diminishing towards the west (**Figure 4-7)**.

4.6.2 Mining Water Use

There are several mines in operation in the Lower Vaal. Large diamond mines are concentrated in the Kimberley area, but numerous alluvial diamond operations can be found along many of the rivers or along paleo-river channels filled with diamondiferous gravels. The largest open cast mine in South Africa, the Sishen iron ore mine is situated near Kathu where large volumes of water are pumped from the pit each day. The water pumped from the pit originates from the dolomitic aquifer in which the mine is situated. Mining groundwater use is shown in **(Figure 4-8).**

4.6.3 Industrial water use

Industrial water use is relatively small, with the largest registered use between Postmasburg and Kuruman in Kathu (**Figure 4-9).**

4.6.4 Water Supply

Groundwater use for water supply is concentrated in the central part of the Lower Vaal from the Ghaap Plateau dolomites in the vicinity of Kuruman, and from the dolomites near Lichtenburg (**Figure 4-10)**.

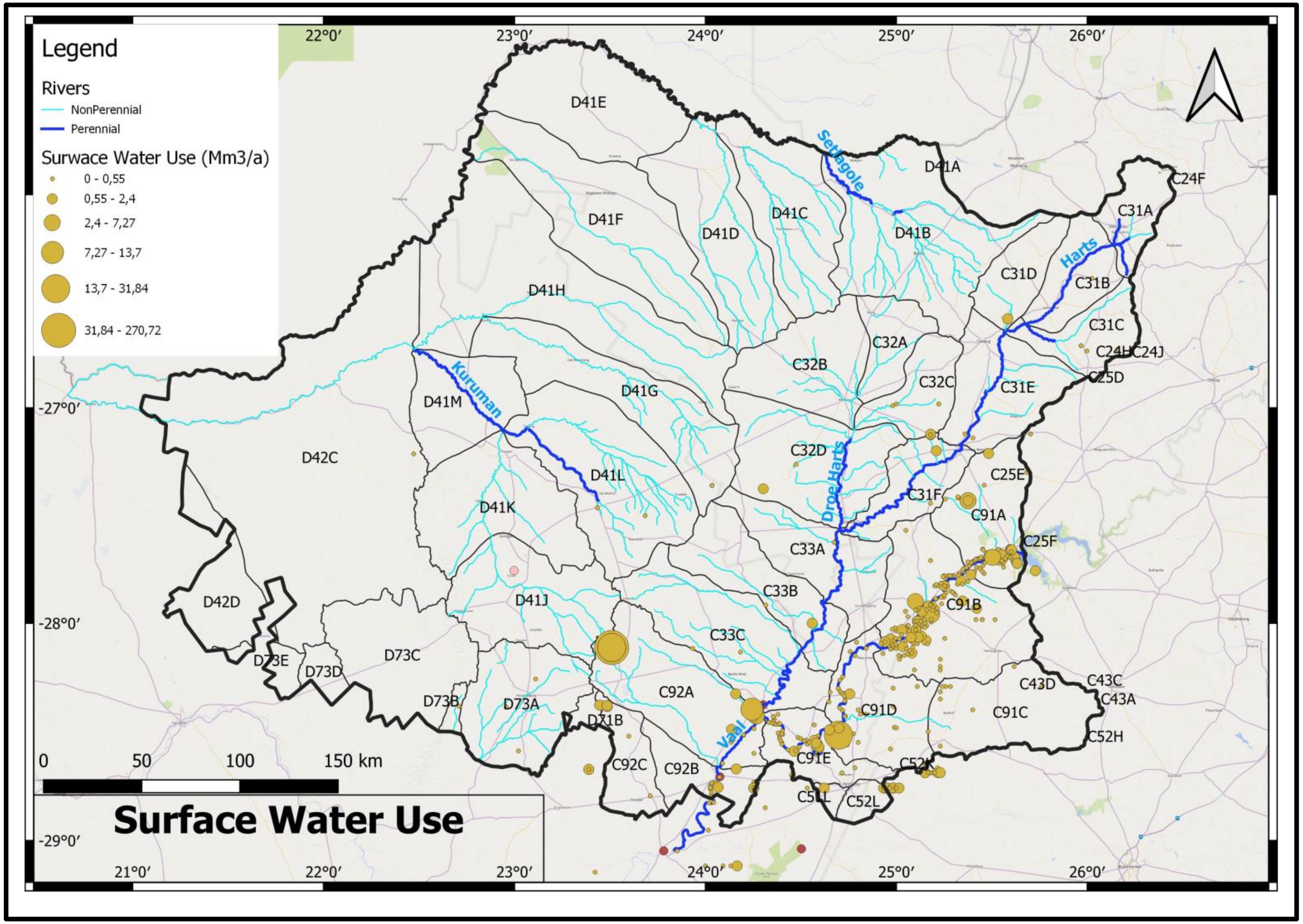

Figure 4-5 Surface water use

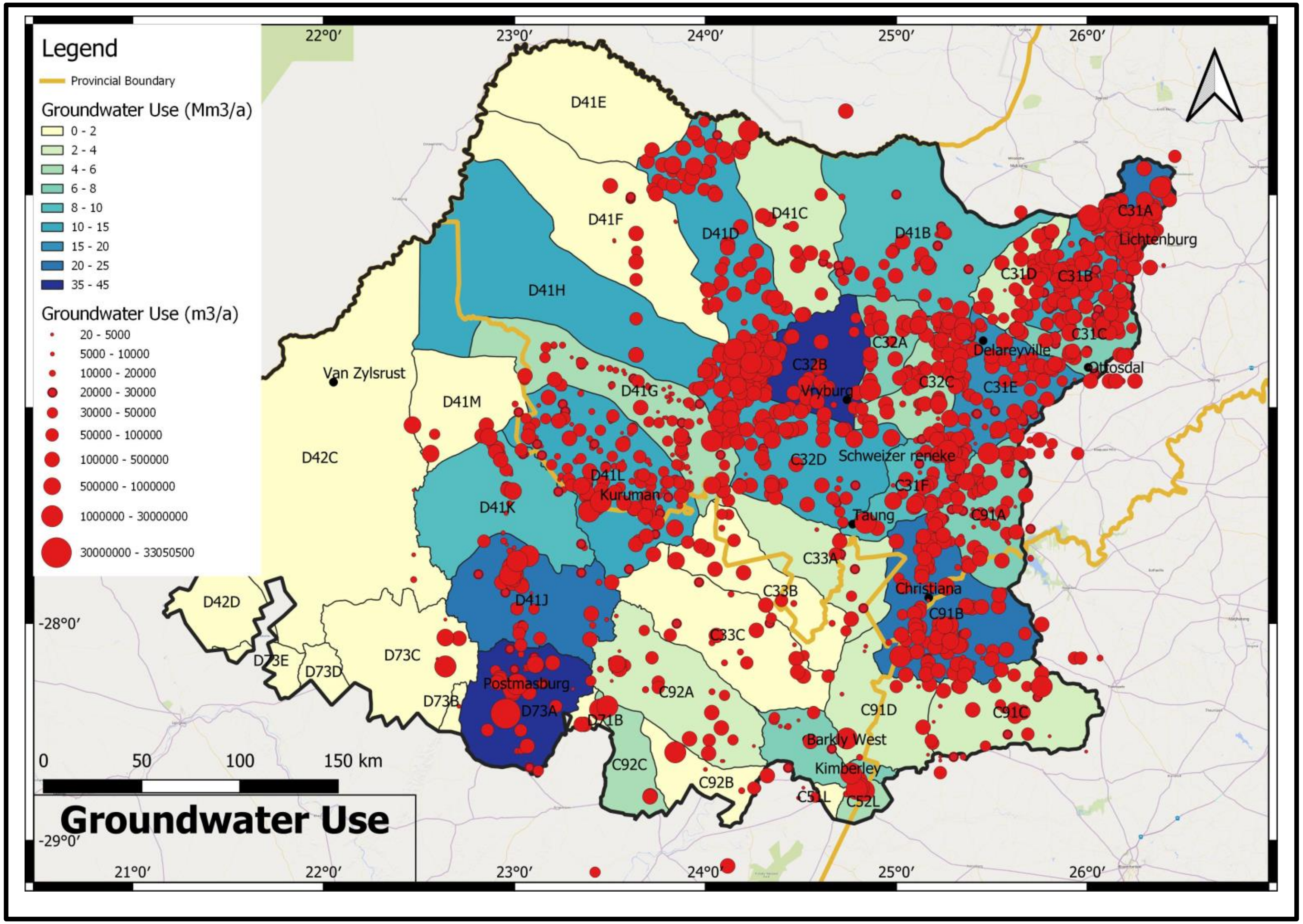

Figure 4-6 Groundwater use

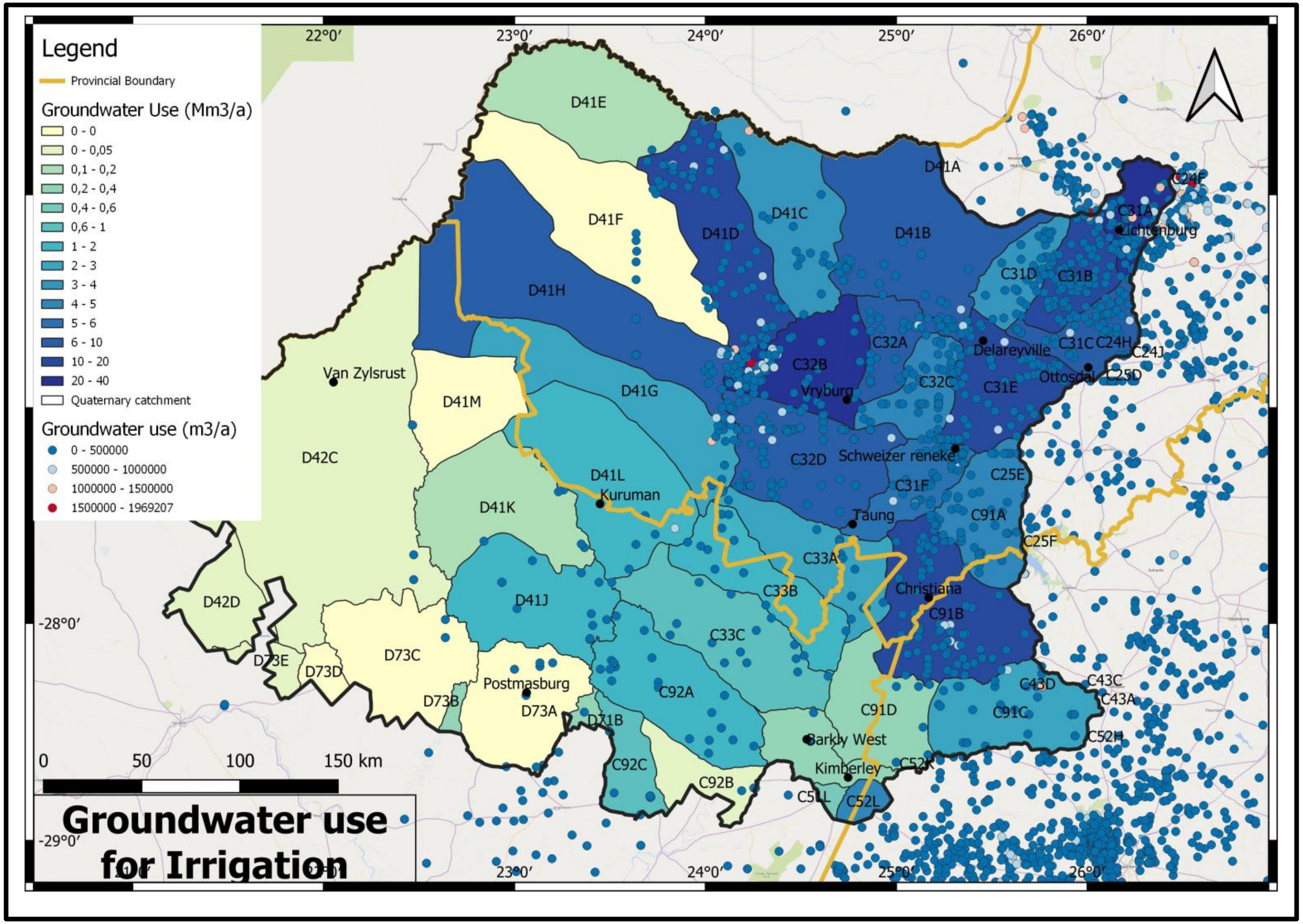

Figure 4-7 Groundwater use for irrigation

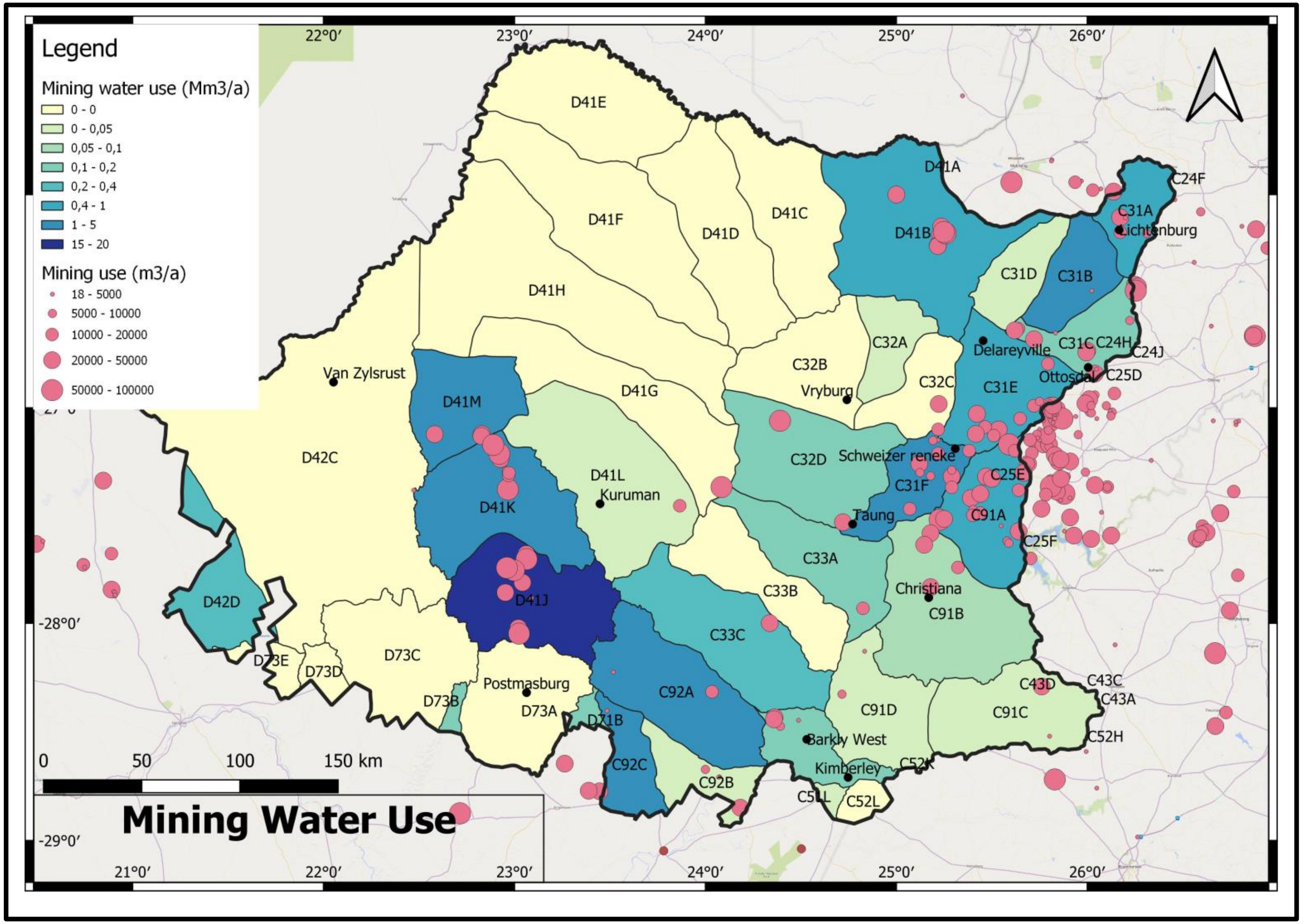

Figure 4-8 Groundwater use for mining

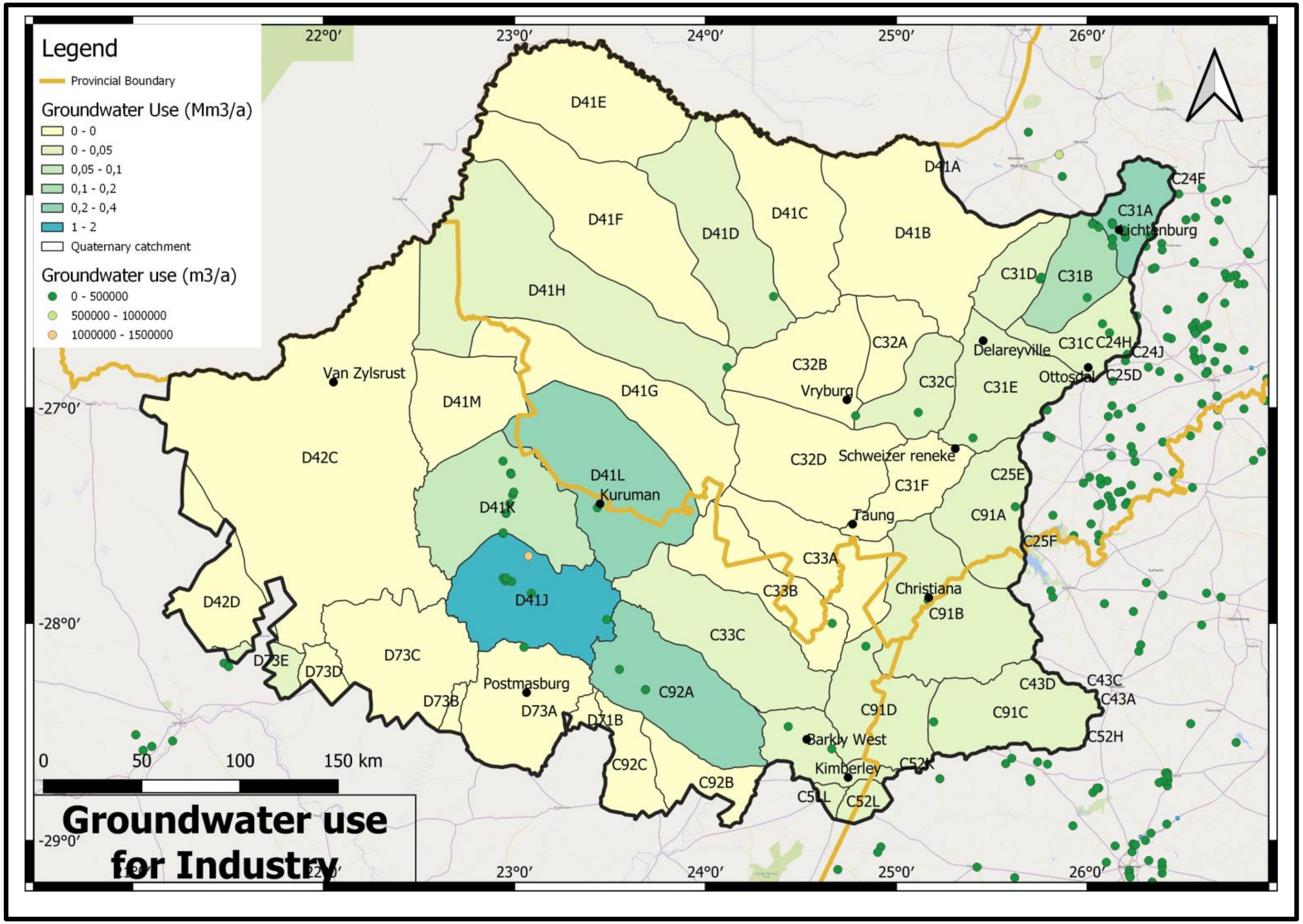

Figure 4-9 Groundwater use for Industry

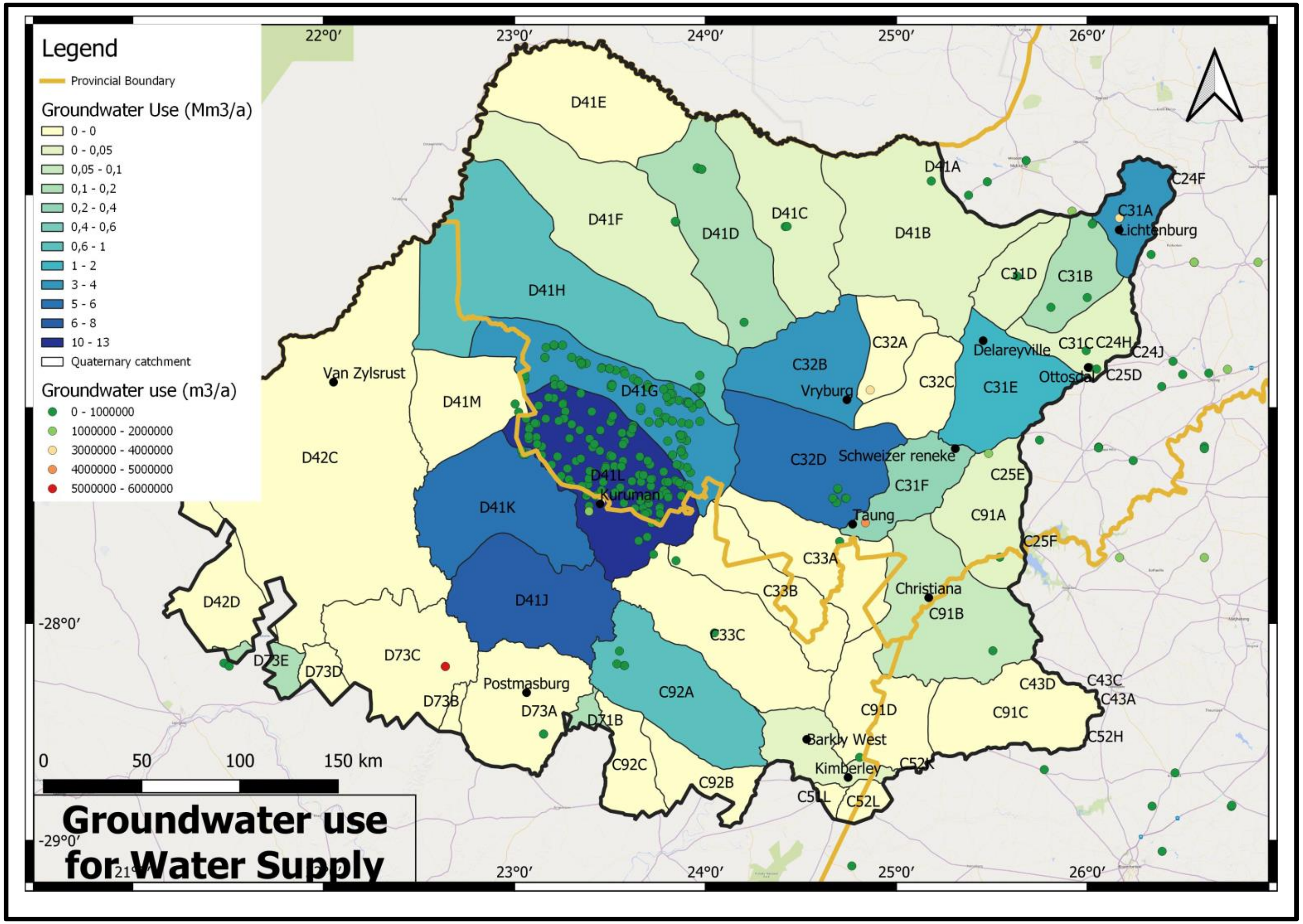

Figure 4-10 Groundwater use for water supply

4.7 Groundwater Resources

4.7.1 Borehole Yields

Borehole blow yields as listed in the NGA were grouped by lithology and per Quaternary catchment to derive the mean and median borehole yield, and the percentage of boreholes yielding more than a specified yield (**Figures 4-11 to Figure 4-13**). Yields above 2 l/s are considered economical for motorised and reticulated water supply, while yields greater than 1 l/s are suitable for local water supply or wellfields. Yields below 0.5 l/s do not warrant exploitation for water supply at greater than a household level.

Large parts of the study area have median yields of below 0.8 l/s (**Figure 4-12**). The highest median yields are found in the Dolomites of the Ghaap Plateau and in the dolomites in the vicinity of Lichtenburg.

Over most of the study area the probability of drilling a borehole of over 2 l/s is less than 40%, with the exception of the dolomites around Kuruman (**Figure 4-13)**. In the dolomites, 22% of the boreholes can yield > 5 l/s **(Table 4-6).**

Table 4-6 Borehole yields by lithology

Lithology	Average (l/s)	Median (l/s)	% > 2 l/s	% > 0.5 l/s	% > 5 l/s
Acid and intermediate extrusives	1.88	0.68	22.8	61	7.7
Basic / Mafic lavas	1.49	0.64	18.3	57.8	5.8
Compact sedimentary strata	1.22	0.60	10.7	56.7	1.7
Dolomite and limestone	4.14	1.37	43	74.3	22.3
Intercalated arenaceous and argillaceous strata	0.82	0.40	10.3	48.1	1
Intercalated assemblage of compact sedimentary and extrusive rocks	1.42	0.75	20.8	65.3	4.6
Porous unconsolidated and consolidated sedimentary strata	1.65	0.68	20.9	61.3	5.7
Principally arenaceous strata	1.37	0.58	11.9	57.3	1.7
Principally argillaceous strata	1.29	0.69	21.9	60.1	4.2
Tillite	2.13	0.60	21.7	54.7	6.5

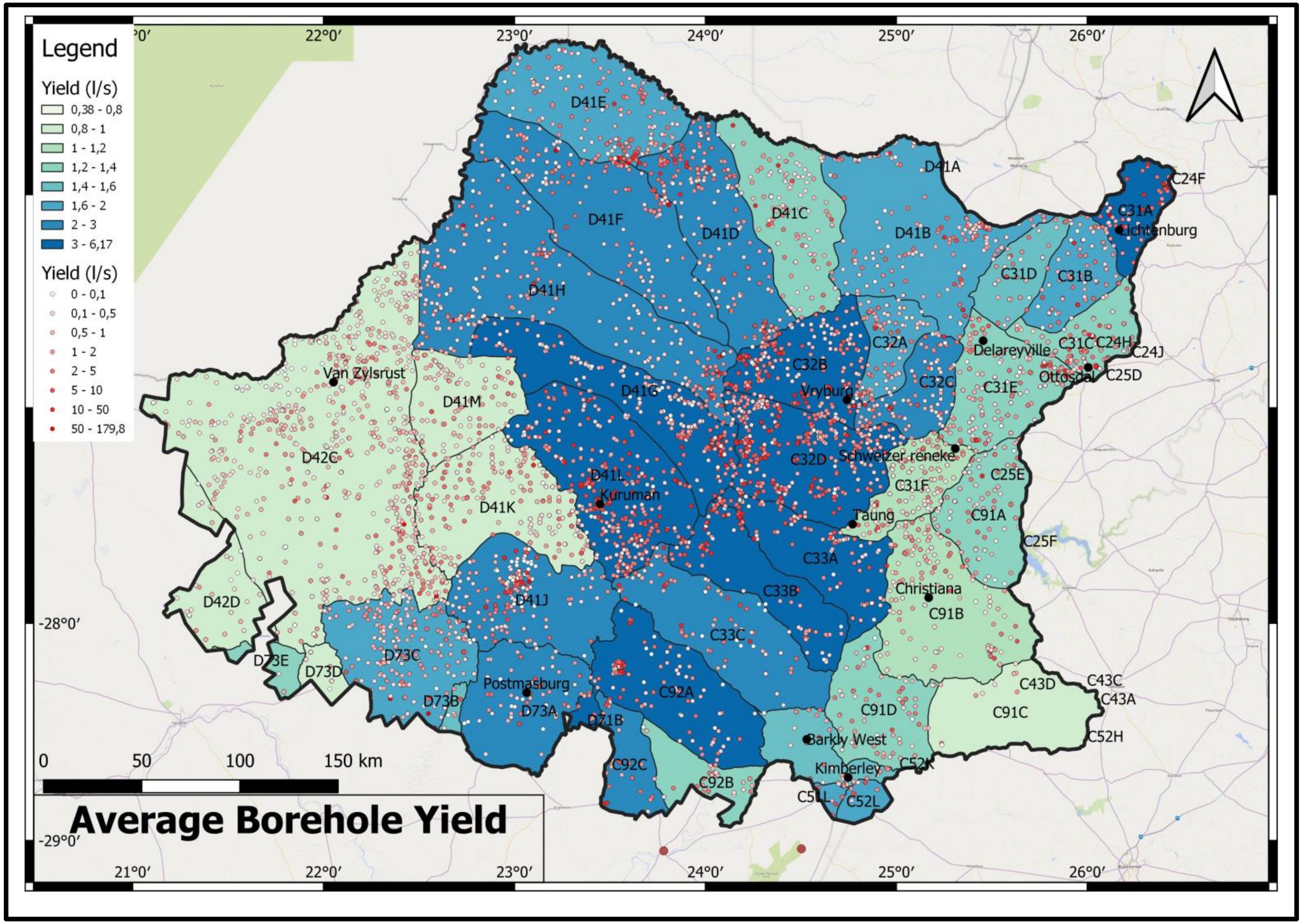

Figure 4-11 Average borehole yield

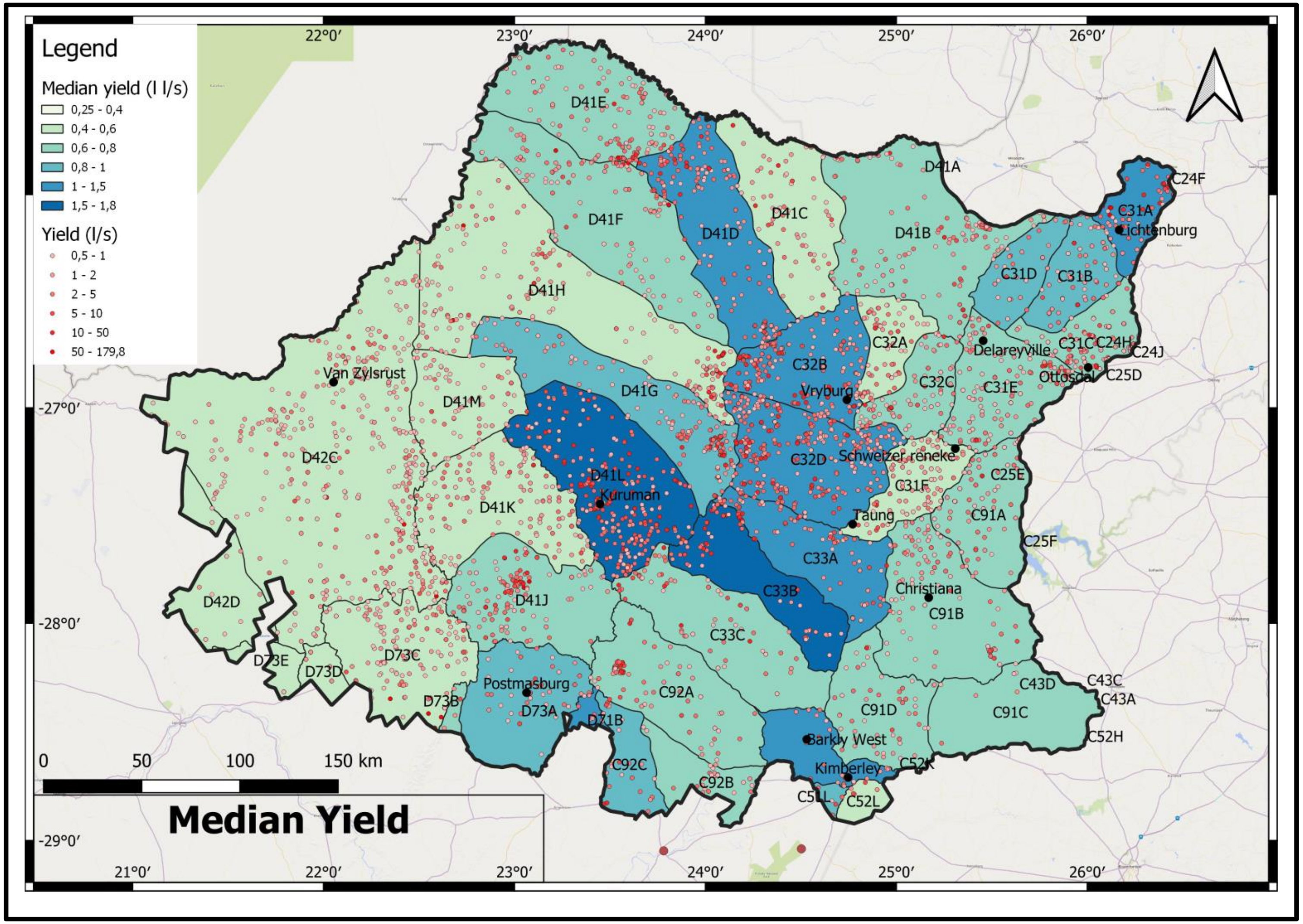

Figure 4-12 Median borehole yield

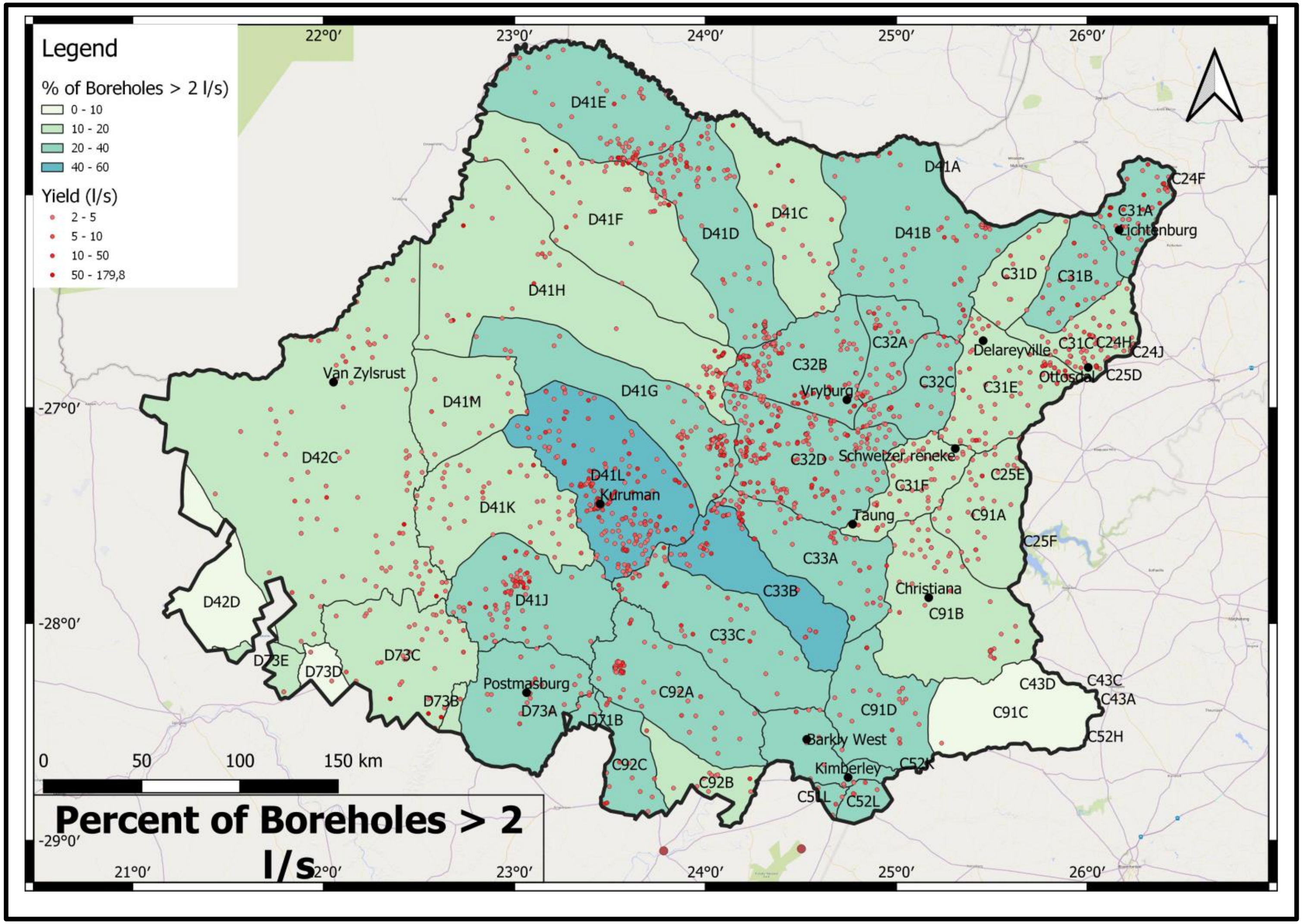

Figure 4-13 Percent of boreholes yielding > 2 l/s

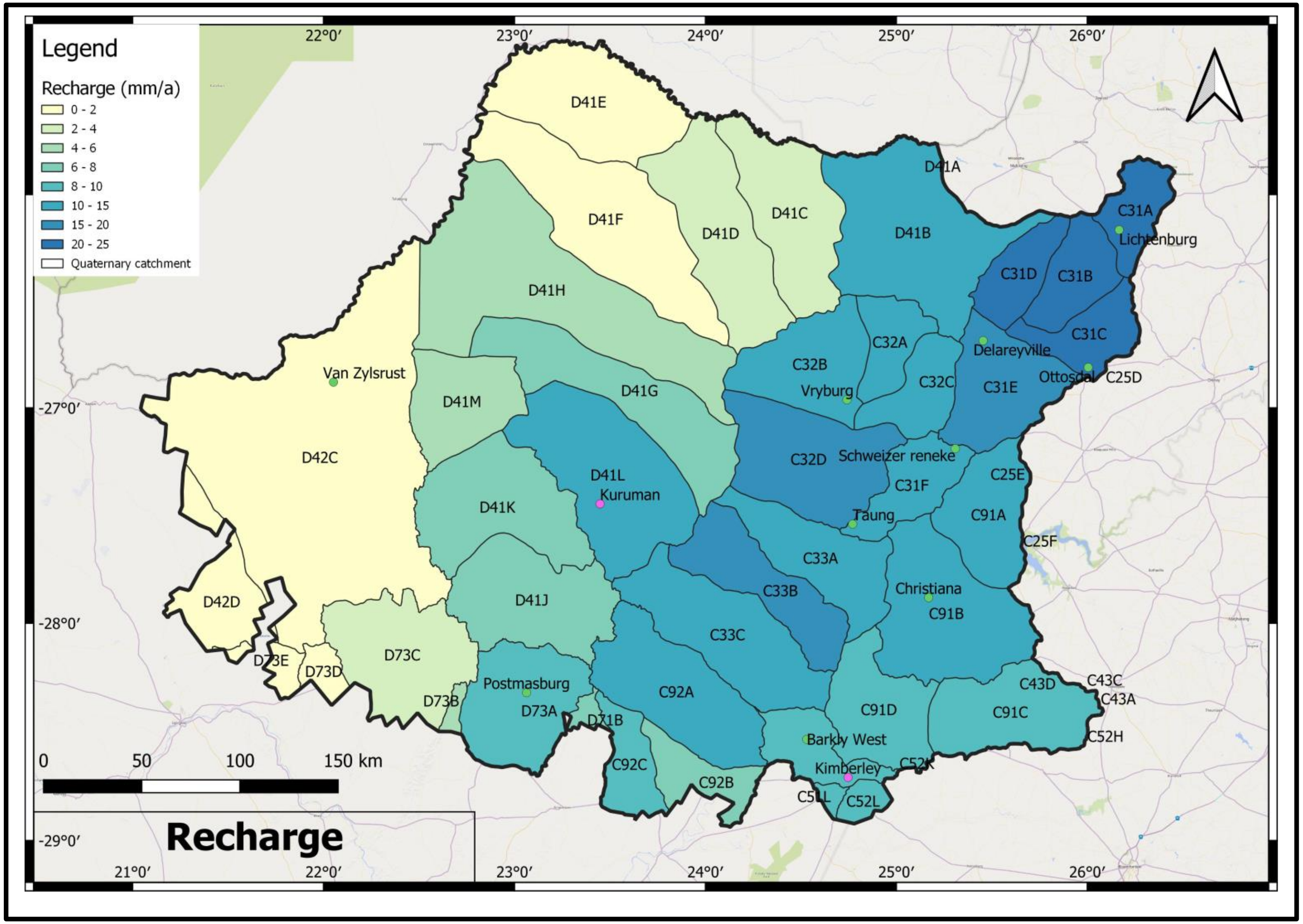

Figure 4-14 recharge

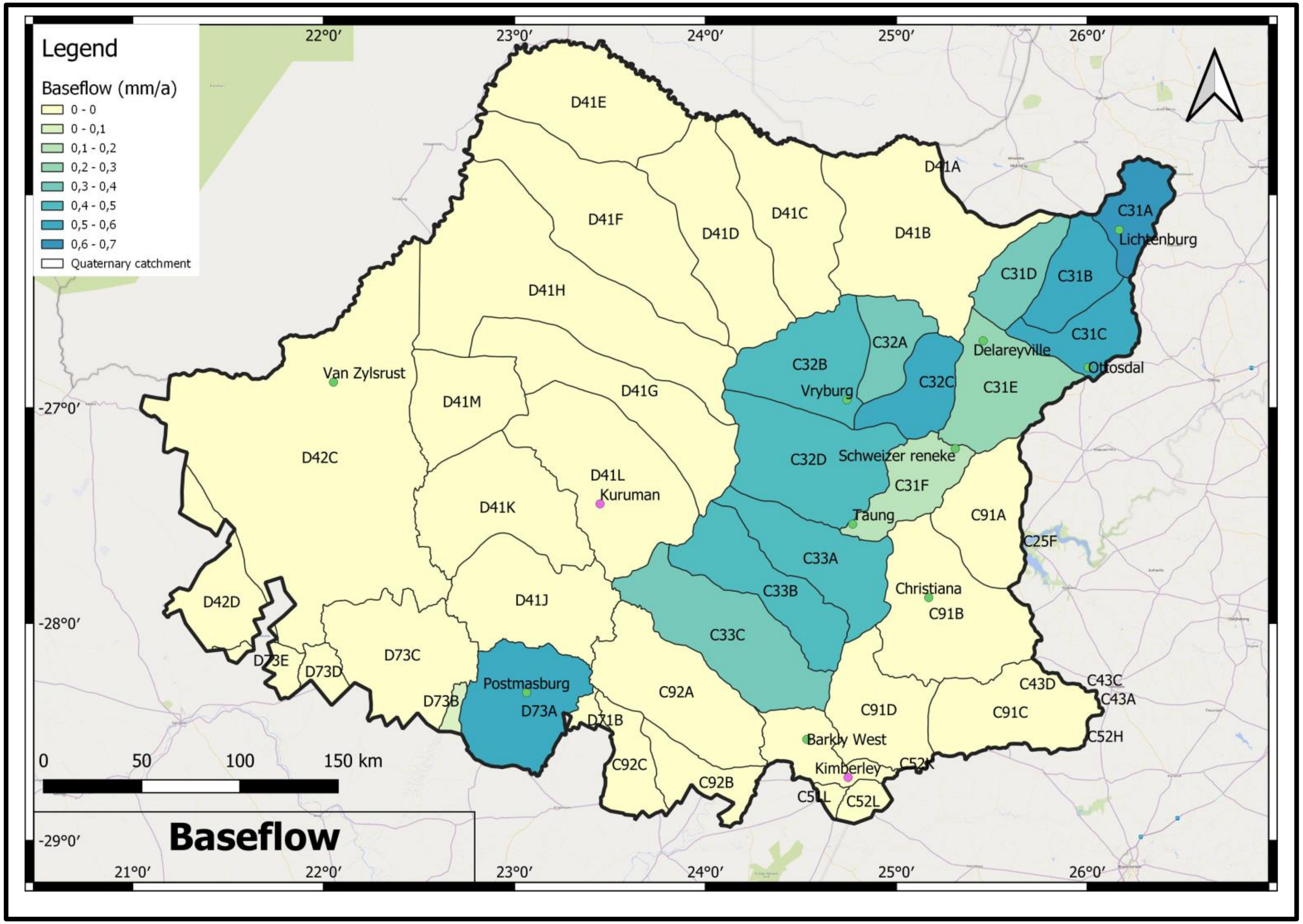

Figure 4-15 Baseflow

4.8 Groundwater Resources Assessment

4.8.1 Recharge and Baseflow

Surface water resources are well documented and commonly assessed through simulation models like WRSM Pitman, calibrated against observed flows and reservoir records. These flow simulations are also used to calculate the Reserve.

The standard methodology for assessing groundwater resources, the groundwater Reserve and allocable groundwater requires assessing recharge and baseflow. These are commonly sourced from GRAII. Recharge in GRAII was derived using the Chloride method, and not incorporated into a full surface and groundwater balance. Potentially there are large volumes of recharge whose fate is not accounted for, or insufficient recharge to meet observed baseflow and such water balance discrepancies should be investigated before calculating the Reserve. The Surface-groundwater interaction project of GRAII calibrated baseflow against simulated WR90 baseflow on a regional scale, which is a coarse calibration against observed flow. Recharge and baseflow in GRAII are shown in **Figure 4-14 and Figure4-15.**

Not all Groundwater Reserve studies attempt a water balance of recharge and baseflow against observed flow records. For the Lower Vaal the suggested and Gazetted Recharge and baseflow volumes are tabulated in **Table 4-7.** It did not cover catchments of Region D of the Lower Vaal. The Groundwater Reserve report calculates natural baseflow as 834 Mm^3/a, and the Gazetted volume, presumably the minimum required baseflow, is 202 Mm^3/a. Values calculated by Pitman, Hughes, and in GRAII project 3b, are calibrated against observed flows, calculate baseflow as 0-13 Mm^3/a. There is over an order of magnitude discrepancy between these volumes and the gazetted volumes greatly exceed observed flows. This implies they cannot be utilised for any water allocation as even natural flows cannot meet the Reserve.

The error in baseflow cannot solely be attributed to an error in recharge as the Gazetted recharge, based on AGES (2009), is lower than that in GRAII. However, the recharge volumes in GRAII can also be questioned as the discrepancy in a recharge of 1161 Mm^3/a and a natural baseflow of only 13 Mm^3/a need to be accounted for. The importance of deriving a water balance between recharge and baseflow with an integrated surface and groundwater balance is therefore highlighted in order to quantify interactions.

Table 4-7 Baseflow and recharge data in Mm^3

	Baseflow					**Recharge**	
	Groundwater Component of Reserve	**Pitman**	**Hughes**	**GRAII Project 3b**	**Gazetted Baseflow (2020)**	**Recharge (Gazetted)**	**Recharge GRAII**
C31A	31.18	0	0.64	0.95	5.55	32.49	34.90
C31B	19.16	0	0.58	0.90	11.07	20.59	38.37
C31C	20.7	0	0.64	0.95	9.33	21.79	35.29
C31D	22.59	0	0.28	0.56	5.55	22.95	32.72
C31E	32.39	0	0.56	0.79	20.31	37.33	50.67
C31F	8.28	0	0.02	0.35	9.92	12.46	22.50
C32A	4.9	0	0.51	0.53	6.91	8.62	17.33

C32B	27.57	0	1.17	1.26	25.63	31.22	40.81
C32C	12.69	0	0.78	0.87	9.69	15.30	22.76
C32D	53.08	0	1.82	1.84	16.63	60.26	70.69
C33A	30.9	0	1.12	1.36	10.69	35.29	40.01
C33B	30.64	0	0.94	1.23	6.58	34.06	44.27
C33C	26.98	0	1.08	1.41	11.44	35.06	50.07
C91A	12.93	0	0.00		7.86	15.41	32.41
C91B	54.94	0	0.00		21.89	57.52	58.74
C91C	33.3	0	0.00		7.18	33.31	26.98
C91D	25.34	0	0.00		3.55	27.83	24.09
C91E	6	0	0.00		3.16	8.32	12.62
C92A	21.25	0	1.02		9.8	27.50	40.29
C92B	11.97	0	0.00		0	13.60	15.15
D41B	17.5	0	0.00			29.58	63.92
D41C	20.4	0	0.00			28.38	24.51
D41D	27.15	0	0.00			34.39	34.53
D41E	20.53	0	0.00			20.57	20.77
D41F	13.63	0	0.00			18.80	30.38
D41G	34.48	0	0.00			41.91	34.03
D41H	41.6	0	0.00			48.68	38.17
D41J	13.25	0	0.00			20.62	27.61
D41K	13.49	0	0.00			18.13	29.14
D41L	36.33	0	0.00			49.12	61.79
D41M	2.09	0	0.00			3.92	12.34
D42C	67.44	0	0.00			72.22	23.89
D73A	12.16	0	0.00			18.57	27.82
D73C	27.37	0	0.00			27.37	21.77
Total	834.21	0	11.15	12.98	202.74	983.17	1161.35

4.9 Springs

Springs are an important baseflow component in dolomites. The dolomite aquifers are compartmentalised by dolerite dykes. Groundwater decants at the lowermost boundary of dolerite dyke compartments from where a downstream spring and wetland zone forms that eventually seeps into the next compartment and evaporates 1 to 3 km from the decant point. These compartment boundaries do not always correspond to catchment boundaries, requiring that each compartment be treated separately in terms of a water balance. The subcompartments in the Ghaap plateau dolomites have not been subdivided and most have no gauging station.

The main compartments are shown in **Table 4-8.** Not all of them have gauging stations for calibration of recharge and springflow. Springs are very vulnerable to flow reduction resulting from groundwater abstraction. These flow records will be utilised to calibrate the WRSM pitman model.

Table 4-8 Groundwater management units and springs

Dolomite Compartment	GMU	Quaternary	Gauging Station
Lichtenburg	C31A-01	C31A	
	C31A-02		
	C31A-03		C3H011
	C31A-04		
Dudfield	C31B-01		
Itsoseng	C31D-01		
Upper Ghaap Plateau		C32D, C33A-B	C3H009, C3H010
Moshaweng		D41G	
Matlhwaring		D41L	D47007, D4H010, D4H011
Reivilo		C33B	C3H012
Upper Kuruman		D41L	D4H005, D4H006, D4H008, D4H009
Klein Boetsap		C33C	
Danielskuil		C33C C92A	C9H013
Upper Gamagara		D41J	
Prieska		D73A	
Griquatown		C92B, C92C	

4.10 Rainfall

The stations listed in **Table 4-9** were open in 2011 and are available from WR2012. To extend the modelling to present will require data from these stations to present.

Table 4-9 Open rainfall stations

Number	Name	Start	End
0252005 W	VOORDEELSPAN	1973	2011
0253174 W	MARYDALE - POL	1915	2011
0253363 W	BOEGOEBERGDAM - IRR	1919	2011

Number	Name	Start	End
0254589 W	NIEKERKSHOOP - POL	1913	2011
0254871 W	WITWATER	1960	2011
0255202 W	NUWEJAARSKRAAL	1900	2011
0255552 W	ORANJEOORD	1936	2011
0256381 W	GERTSPAN	1935	2011
0256453 W	DOUGLAS - POL	1883	2011
0256631 W	MALABAR	1971	2011
0258182 W	MODDERRIVIER - POL	1914	2011
0284008 W	THORNLEA	1899	2011
0284832 W	GROBLERSHOOP - POL	1937	2011
0286209 W	DINGLE	1993	2011
0287441 W	GRIQUATOWN - TNK	1883	2011
0287885 W	POPLARS	1935	2011
0288054 W	KOEKAMA	1957	2011
0288528 W	TWEEFONTEIN	1919	2011
0290032 W	BARKLY WEST - TNK	1885	2011
0290468AW	KIMBERLEY	1931	2011
0290560 W	BENFONTEIN	1917	2011
0291313 W	WATERPASLAAGTE	1955	2011
0291392 W	BOSHOF - TNK	1879	2011
0291570 W		2001	2011
0292461 W	DEALESVILLE - MAG	1908	2011
0293045 W	SOUTPAN SOUTWERKE	1994	2011
0316294 W	LUTZPUTS	1956	2011
0317447AW	UPINGTON - AGR	1939	2011
0317475AW	UPINGTON - WK	1919	2011
0319869 W	WELTEVREDE	1960	2011
0320348 W	DUNMURRAY	1892	2011

Number	Name	Start	End
0320654 W	WOLHAARKOP	1929	2011
0320828 W	AUCAMPSRUS	1940	2011
0320843 W	FOUROSS	1928	2011
0321110 W	POSTMASBURG - POL	1916	2011
0321116 W	MOOIDRAAI	1969	2011
0321441 W	TIERKOP	1939	2011
0322071AW	DANIELSKUIL	1984	2011
0323535 W	DELPORTSHOOP - POL	1966	2011
0324202 W	ROCKLANDS	1929	2011
0324379 W	WINDSORTON - POL	1912	2011
0324607 W	WARRENTON - MUN	1910	2011
0325304 W	LEEUHEUWEL	1988	2011
0325877 W	HERTZOGVILLE - POL	1923	2011
0326073 W	KOUTER	1949	2011
0326668 W	GELUK	1931	2011
0327258 W	BULTFONTEIN - MUN	1988	2011
0327784 W	NELSDRIFT	1907	2011
0327883 W	GROOTKUIL	1910	2011
0356285 W	HOPKINS	1918	2011
0356417 W	OLIFANTSHOEK - POL	1918	2011
0356636 W	DEBEN - POL	1924	2011
0356712 W	SMYTHE	1911	2011
0356733 W	BISHOPS WOOD	1972	2011
0356880 W	KATHU E	1992	2011
0358049 W	WONDERWERK	1951	2011
0358216 W	DIPPENAARSHOOP	1978	2011
0358268 W	MOUNT CARMEL	1933	2011
0359808 W	BOETSAP - POL	1886	2011

Number	Name	Start	End
0360375 W	PAMPIERSTAD	1978	2011
0360400 W	MAGAGONG	1989	2011
0360453AW	TAUNG E	1995	2011
0360595 W	JAN KEMPDORP - IRR	1934	2011
0360597 W	VAALHARTS - AGR	1919	2011
0360663 W	MANTHESTAD	1959	2011
0361277 W	WELKOM	1952	2011
0361285 W	DE HOOP	1971	2011
0361295 W	CHRISTIANA - TNK	1903	2011
0361762 W	HOLFONTEIN	1973	2011
0361846 W	S A LOMBARD NATUURRESERV	1951	2011
0362159 W	BLOEMHOF - POL	1930	2011
0362189 W	BLOEMHOF E	1992	2011
0363571 W	HENDRIK THERON	1931	2011
0391834 W	WHYENBAH	1937	2011
0391857 W	DEDEBEN - POL	1930	2011
0392148 W	WINTON	1925	2011
0393083 W	MILNER	1930	2011
0393126 W	TSINENG - POL	1966	2011
0393806 W	KURUMAN - TNK	1987	2011
0393864 W	MOTHIBISTAD	1983	2011
0396813 W	LELIEFONTEIN	1912	2011
0397075AW	AMALIA - POL	1971	2011
0397581 W	SCHWEIZER-RENEKE - POL	1931	2011
0397784 W	KOPPIESVLEI	1933	2011
0398479 W	KINGSWOOD	1985	2011
0399404 W	LEEUDORINGSTAD - SKL	1931	2011
0399894 D	C2E010 Balkfontein	1968	2011

Number	Name	Start	End
0399894 W	BOTHAVILLE - BALKFONTEIN	1919	2011
0424354 W	GEMSBOK - POL	1967	2011
0424357 W	WITDRAAI - POL	1939	2011
0427083BW	VAN ZYLSRUS E	1992	2011
0428635 W	SEVERN - POL	1960	2011
0431306 W	GENESA - POL	1966	2011
0431723 W	TIPPERARY	1985	2011
0432237 W	ARMOEDSVLAKTE - AGR	1919	2011
0432633AW	STELLA	1985	2011
0433115 W	RIETPAN	1925	2011
0433791 W	DELAREYVILLE - MUN	1921	2011
0433858 W	RIETPAN 1	1923	2011
0434020 W	RIETPAN 11	1926	2011
0434359 W	BRAKPAN	1922	2011
0434512 W	SANNIESHOF - POL	1969	2011
0434888 W	OTTOSDAL - POL	1911	2011
0435019AW	OTTOSDAL - MUN	1919	2011
0435400 W	WERK - MET - LUST	1928	2011
0435608 W	MON REPOS	1952	2011
0435735 W	HARTBEESFONTEIN - SKL	1903	2011
0468318 W	PALMYRA	1912	2011
0471269 W	KLIPPAN	1936	2011
0472278 W	LICHTENBURG E	1992	2011
0472279 W	LICHTENBURG - TNK	1939	2011
0472279AW	LICHTENBURG - DORP	1983	2011
0472455 W	MANANA	1953	2011
0472560 W	COLIGNY - POL	1966	2011
0473025 W	KAFFERSKRAAL	1961	2011

Number	Name	Start	End
0473204 W	MAKOKSKRAAL - WITKLIP	1985	2011
0473352 W	VENTERSDORP-RATZEGAAI	1919	2011
0473471 D	C2E016 Elandskuil @ Elandskuil Dam	1975	2011
0508047 W	MMABATHO - AER	1983	2011
0508422 W		1999	2011
0508649 W	SLURRY	1915	2011
0508825 W	OTTOSHOOP - POL	1903	2011
0509123 W	ZEERUST - TNK	1904	2011
0509211 D	A3E003 Kalk Dam @ Li-Maricopoort Dam	1959	2011
0509283 W	DOORNHOEK	1927	2011
0509759 W	TWYFELSPOORT	1909	2011
0510306 W	WINKELHAAK	1934	2011
0510308 W	SWARTRUGGENS - POL	1906	2011
0510712 W	KOSTER - POL	1911	2011
0512702 D	A2E015 Waterval @ Koster River Dam	1965	2011
0539861 W	MOKOPONG GRENSPOS	1981	2011
0541297 W	BRAY - POL	1946	2011

4.11 Existing WRSM Pitman Network

The hydrology for the entire Vaal and Orange river catchments were extended to 2004 as part of the ORASECOM Phase 2 Study (Support to Phase 2 of the ORASECOM basin-wide Integrated Water Resources management Plan Work Package 2: Extension and Expansion of the Hydrology of the Orange -Senqu Basin.) The ORASECOM study used as basis the hydrology carried out for the Vaal River Systen Analysis Update Study (VRSAU) for the Lower Vaal, covering the period 1920 to 1994.

The surface groundwater interaction modules were not included in the Pitman Modelling carried out for the Lower Vaal, Molopo and Kuruman rivers and need to be added for the purpose of the current study.

4.11.1 Rainfall

The application for SAWS rainfall is being made by the Directorate: Strategic Water Resource Planning under the project: Support in Development: Updating and review of Strategies to Reconcile Water Availability and Requirements in North, Central, East and South Planning Areas. Although available to this project team, it may not be in time for this project. And CHIRPS data will be compared to pre-2012 rainfall, before being used for extension of the hydrology.

4.11.2 Lower Vaal Hydrology

Calibrations for the Lower Vaal system was carried out at the following flow gauging stations:

- C3R001 – Wentzel Dam
- C3R002 – Spitskop Dam
- C3H003 – Taung Dam
- C9R001 – Vaalharts Weir
- C9H009 – De Hoop gauging weir
- C9R003 - Douglas Weir

The WRSM Pitman networks for the Lower Vaal were set up with runoff units representative of each quaternary catchment upstream of the calibration point and in some cases a portion of a quaternary catchment. It is however a concern that no irrigation modules are included in the Lower Vaal Pitman networks as this catchment includes the large Vaalharts Irrigation Scheme. The return flows from this scheme should at least in some way impact on the flows to Spitskop Dam and one would expect that is should have been included in the modelling setup prepared for the ORASECOM study. In the VRSAU study these return flows were however included in the calibration setups. The WRSM2012 Pitman Model setups also include the details of the irrigation return flows similar to those evident from the VRSAU study. For the purpose of this study it thus seems that either the VRSAU study or the WRSM2012 Pitman Model setups should rather be used than those prepared for the ORASECOM study.

The existing networks in WRSM2012 are shown in appendix 1. Releases and spills from Bloemhof dam function as upstream inflows into the Lower Vaal system.

The Pitman model setups for the Lower Vaal as used in the ORASECOM study includes very little present detail of the water use in this area which is a serious concern. It is thus recommended that both the VRSAU study and the WRSM2012 Pitman Model setups be compared and the most suitable data set be used for the purpose of the current study.

4.11.3 Molopo Catchment Hydrology

For the Molopo and Kuruman rivers the ORASECOM study used as basis work done in another ORASECOM study (Feasibility Study of the Potential for Sustainable Water Resources Development in the Molopo-Nossob Watercource: Hydrology Report of February 2009) covering the period 1920 to 2004. No further extension of the simulated records from this study was thus required by the ORASECOM Phase 2 study.

For the Molopo catchment calibrations were carried out at:

D4H013 – Molopo River Rietvallei

D4H037 – Molopo River Lotlamoreng Dam

D4H002 – Mareetsane River Neverset gauge

Due to the poor availability of accurate and reliable streamflow records within the Molopo catchment area a conventional calibration approach was only possible in the upper Molopo catchment. Due to the high river losses in this catchment, channel losses were included as a calibration parameter. Calibrated Pitman parameters were transferred to similar sub-catchments that could not be calibrated. A larger-scale Pitman Model calibration was then carried out based on historical extreme events and anecdotal evidence of flows along certain parts of the lower river reaches.

The model sub-catchments for the Molopo and Kuruman Rivers were initially based on existing quaternary catchments but to facilitate scheme development options at a finer resolution they were further delineated. Flow sequences were developed for at least each of the Quaternary catchments.

The Pitman model setups for the Molopo and Kuruman Rivers included the modelling of small and large dams, irrigation as well as urban water use. Mines used groundwater as resource including water transferred from other surface water resources outside of the catchments and were thus not included in the Pitman Model setups. The main discharge points included in the Molopo and Kuruman River system includes the inflows from the many dolomitic eyes in the basin based on the observed gauged flows as well as return flows from irrigation areas.

The Feasibility Study simulation period was from 1920 to 2004. These were extended in ORASECOM (20111). The existing networks for the Lower Vaal are shown in Appendix 1.

Groundwater was not included and discharge from dolomitic springs was treated as in inflow into the surface water network rather than being simulated.

Catchment D41A has been simulated until 2020 for the Northern Reconciliation Strategy, and includes groundwater, with each dolomitic compartment being a runoff unit. This network will be utilised as upstream inflow to the lower Vaal system. Including Groundwater resulted in a significant improvement to the simulated hydrology, since runoff largely originates from groundwater discharge from dolomitic compartments. Due to large scale development of groundwater and several dams, very little discharge currently enters the Lower Vaal, except during large storm events.

5 DATA GATHERING

5.1 Hydrocensus

Contact has been made with municipalities regarding the itinerary for visits**. Table 5-1** lists the contacts that have been made. The hydrocensus is planned for May or June 2022.

Table 5-1 Hydrcocensus contacts

NAME	CONTACT PERSON	Email Address
Sedibeng Water (Vaal Gamagara)	Mr. Obby Masia	omasia@sedibengwater.co.za
Sedibeng Water (North West Region)	Mr. Moses Lebitso	mlebitso@sedibengwater.co.za
Botshelo Water	Mr. Solomon Mathebula	tmahlakoleng@nwpg.gov.za / bsmmolutsi@nwpg.gpv.za
Frances Baard District Municipality	Ms. Mamikie Bogatsu	mamikie.bogatsu@fbdm.co.za natasha.april@fbdm.co.za
John Taolo Gaetsewe District Municipality	Ms. M Bokgwathile	bokgwathilem@taologaetsewe.gov.za
Dr. Ruth Segomotsi Mompati District Municipality	Mr. Zebo Tshetlo	keoalogileo@bophirima.co.za
Lejweleputswa District Municipality	Ms Palesa Kaota	jane@lejwe.co.za
Vaalharts Water User Association	Mr. Neil Van Eeden	ceo@vhwater.co.za / afutcher@vhwater.co.za
Kalahari East Water User Association	Mr. Jakobus Nel	rita@nelenvennote.co.za / kobus@nelenvennote.co.za
Agri SA	Dr Jack Armour	
Department Of Environmental Affairs	Ms Sammy Ntsuku	
Sedibeng Water	Mr Danie Traut	
Vaalharts Water	Mr Pieter Burger	
Dikgatlong Municipality	Mr Desmond Makaleni (Acting Technical Director)	desmond.makaleni@dikgatlong.co.za
Sol Plaatje Municipality	Mr Zughdi Adikary And Mr Sabelo Mkhizen (Both In The Water And Sanitation Unit)	zadikary@solplaatje.org.za smkhize@solplaatje.org.za
Phokwane Municipality	Mr Lubabalo Jange (Acting Technical Director) Cell: 078 109 9906	jange.lubabalo@gmail.com
Magareng Municipality	Mr Tumelo Thage (Technical Director)	tumelo.thage@gmail.com

5.2 Data collection

Table 5-2 lists the information and data sourced for the execution of the work.

Table 5-2 Data sources

Type of Data	Data	Source	Status
Catchment delineation	Quaternary catchment boundaries	WR2012 DWS redefined	Obtained
Population	Population	Stats SA	Obtained and utilised to calculate Schedule 1 use
Climatic data	Rainfall and evaporation	SAWS/CHIRPS	Permission has been obtained to source CHIRPS data to extend the rainfall record DWS is in the process of compiling a formal request to SAWS for all the Recon studies of which Central Region is one. The list of stations Activity has not begun
Geology	Lithology and structures	CGS geological maps	Obtained
Hydrology	WRSM2000 /Pitman Network for WR2012 and ORASECOM Observed flow files	project team DWS	Obtained Dolomite springs are treated as an observed inflow to the model and not modelled due to Groundwater not being incorporated ORASECOM Pitman Model setups for Lower Vaal excludes the large irrigation developments in this area.
Geohydrology	Harvest Potential	ORASECOM ORASECOM	Obtained

	Exploitation Potential Recharge Hydrochemistry Water levels Borehole yields	ORASECOM WMS database and hydrocensus data NGA HYDSTRA NGA	
Water use	Registered water use Municipal water use Schedule 1 water use Livestock water use	WARMS Hydrocensus StatsSA GRA II (DWAF, 2006a)	Obtained Planned for May To be calculated Obtained
Wetlands	location	NFEPA	Obtained
Dolomitic eyes	Location and flow	DWS hydrological services and dolomite maps	Obtained

6 REFERENCES

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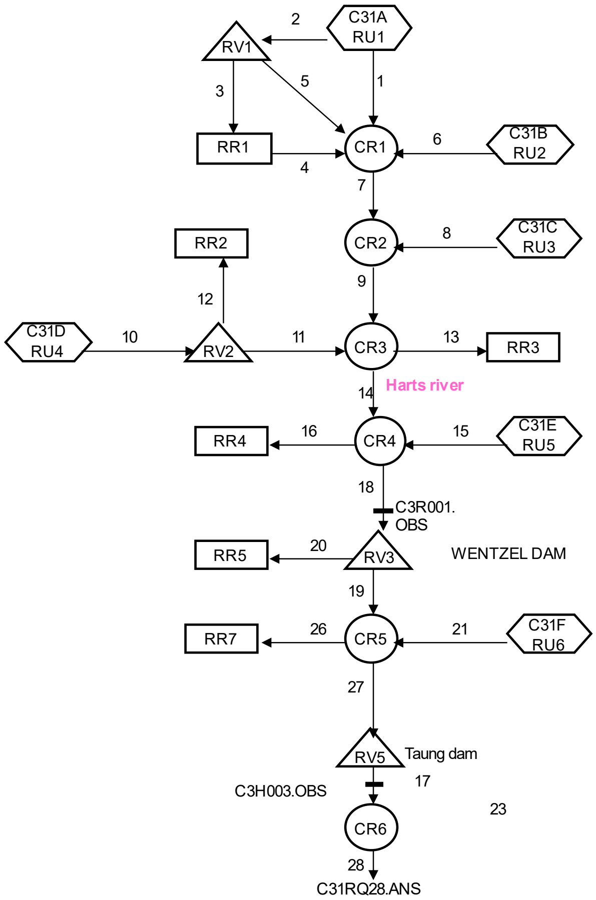
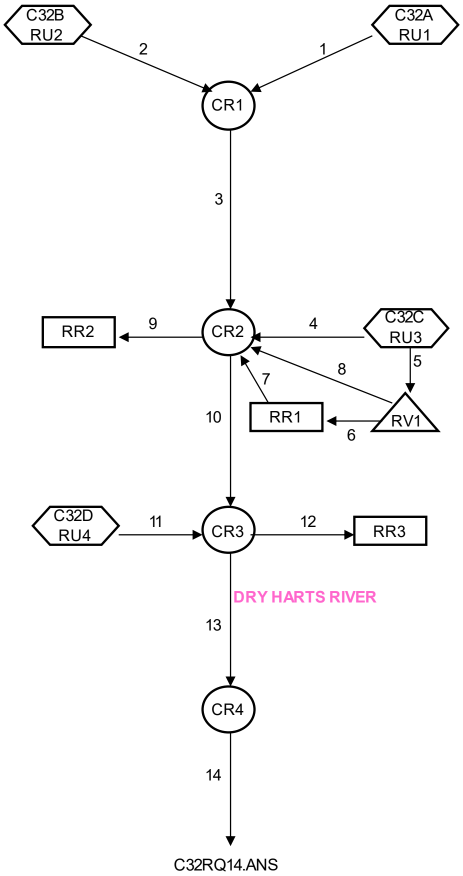
7 APPENDIX – HYDROLOGY NETWORKS

Drainage region C

C31

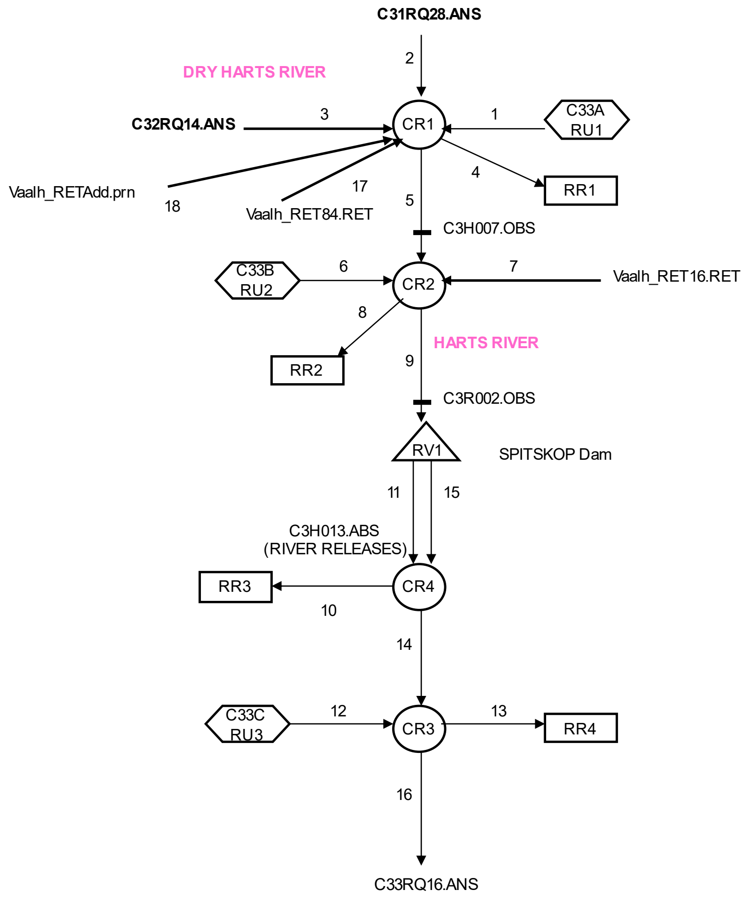


C32

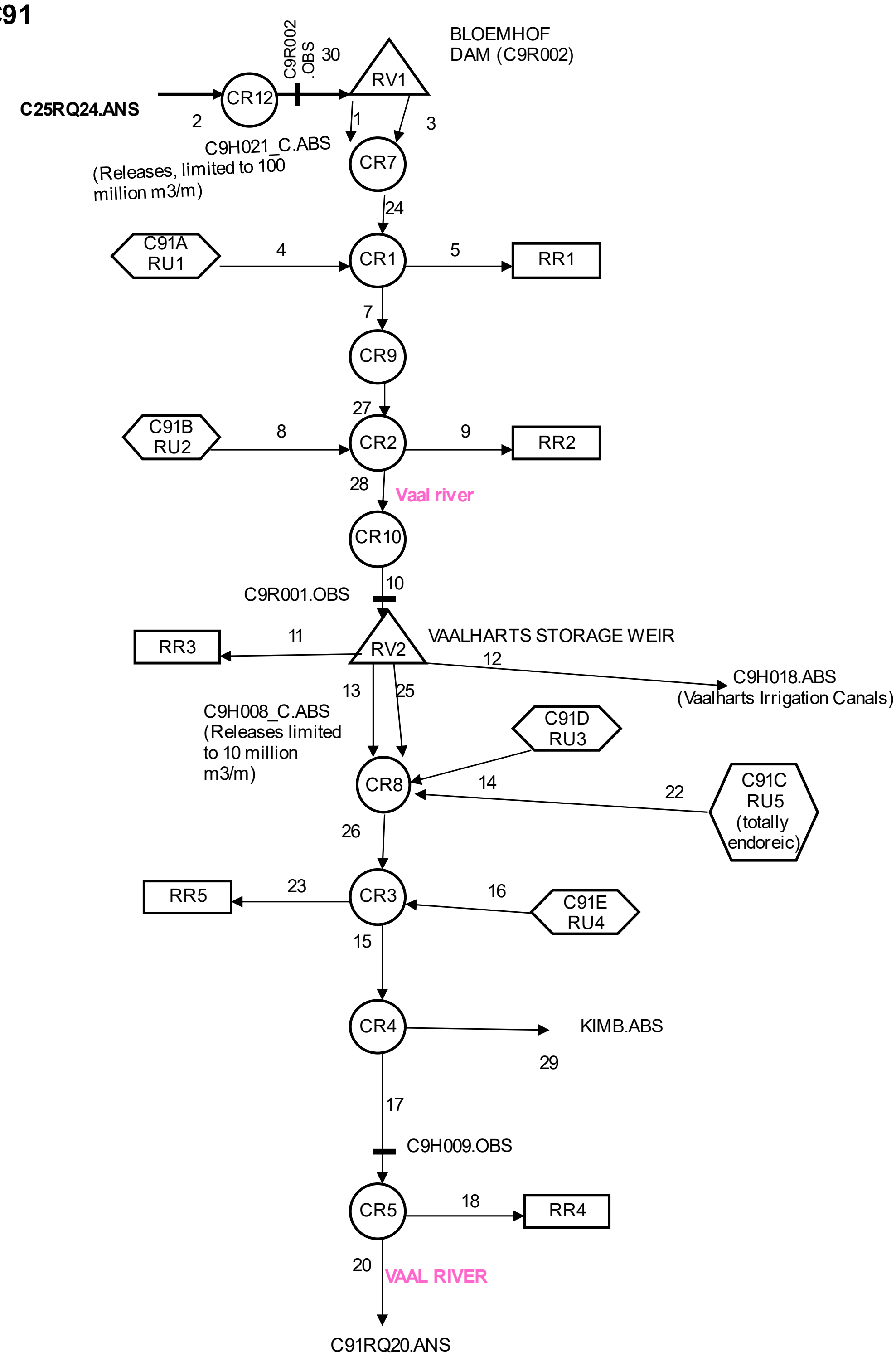


C32B
RU2
C32A
RU1
2
1
CR1
3
RR2
9
CR2
4
C32C
RU3
5
8
7
10
RR1
RV1
6
C32D
RU4
11
CR3
12
RR3
DRY HARTS RIVER
13
CR4
14
C32RQ14.ANS

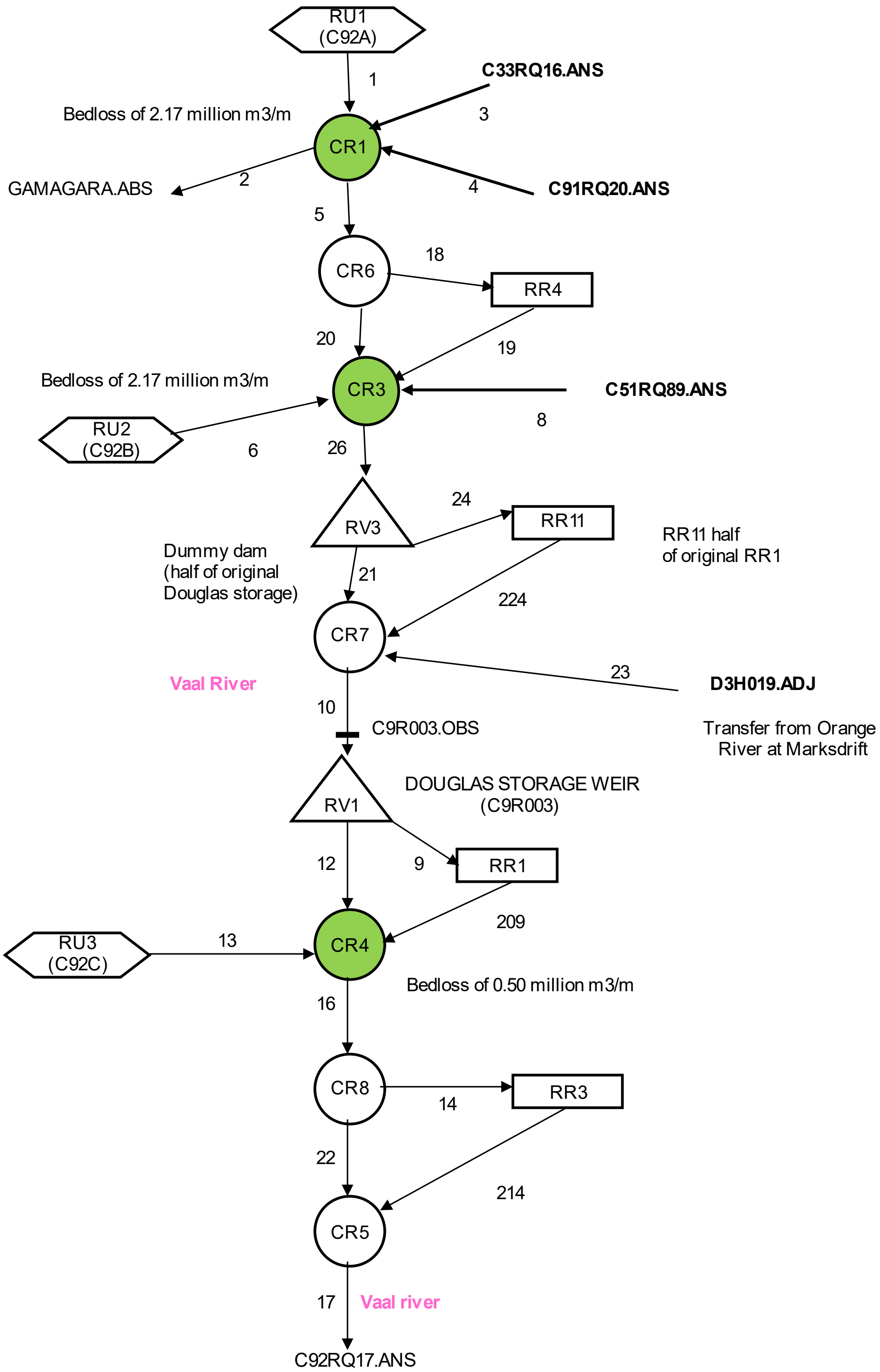
C33


C31RQ28.ANS
2
DRY HARTS RIVER
C32RQ14.ANS
3
CR1
1
C33A
RU1
4
RR1
Vaalh_RETAdd.prn
18
17
Vaalh_RET84.RET
5
C3H007.OBS
C33B
RU2
6
CR2
7
Vaalh_RET16.RET
8
HARTS RIVER
RR2
9
C3R002.OBS
RV1
SPITSKOP Dam
11
15
C3H013.ABS
(RIVER RELEASES)
RR3
CR4
10
14
C33C
RU3
12
CR3
13
RR4
16
C33RQ16.ANS

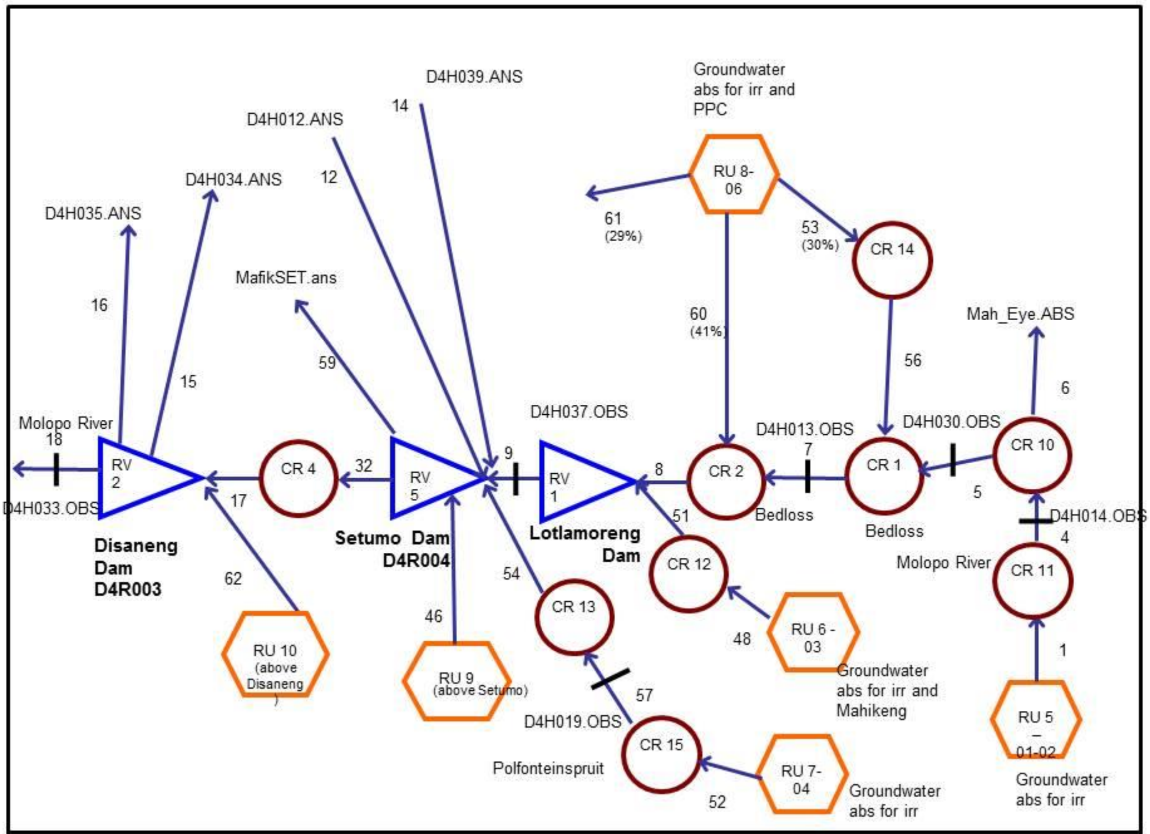
C91


C25RQ24.ANS
2
CR12
C9R002
.OBS
30
RV1
BLOEMHOF
DAM (C9R002)
1
3
C9H021_C.ABS
(Releases, limited to 100
million m3/m)
CR7
24
C91A
RU1
4
CR1
5
RR1
7
CR9
27
C91B
RU2
8
CR2
9
RR2
28
Vaal river
CR10
10
C9R001.OBS
RR3
11
RV2
VAALHARTS STORAGE WEIR
12
C9H018.ABS
(Vaalharts Irrigation Canals)
13
25
C9H008_C.ABS
(Releases limited
to 10 million
m3/m)
C91D
RU3
CR8
14
22
C91C
RU5
(totally
endoreic)
26
RR5
23
CR3
16
C91E
RU4
15
CR4
KIMB.ABS
29
17
C9H009.OBS
CR5
18
RR4
20
VAAL RIVER
C91RQ20.ANS

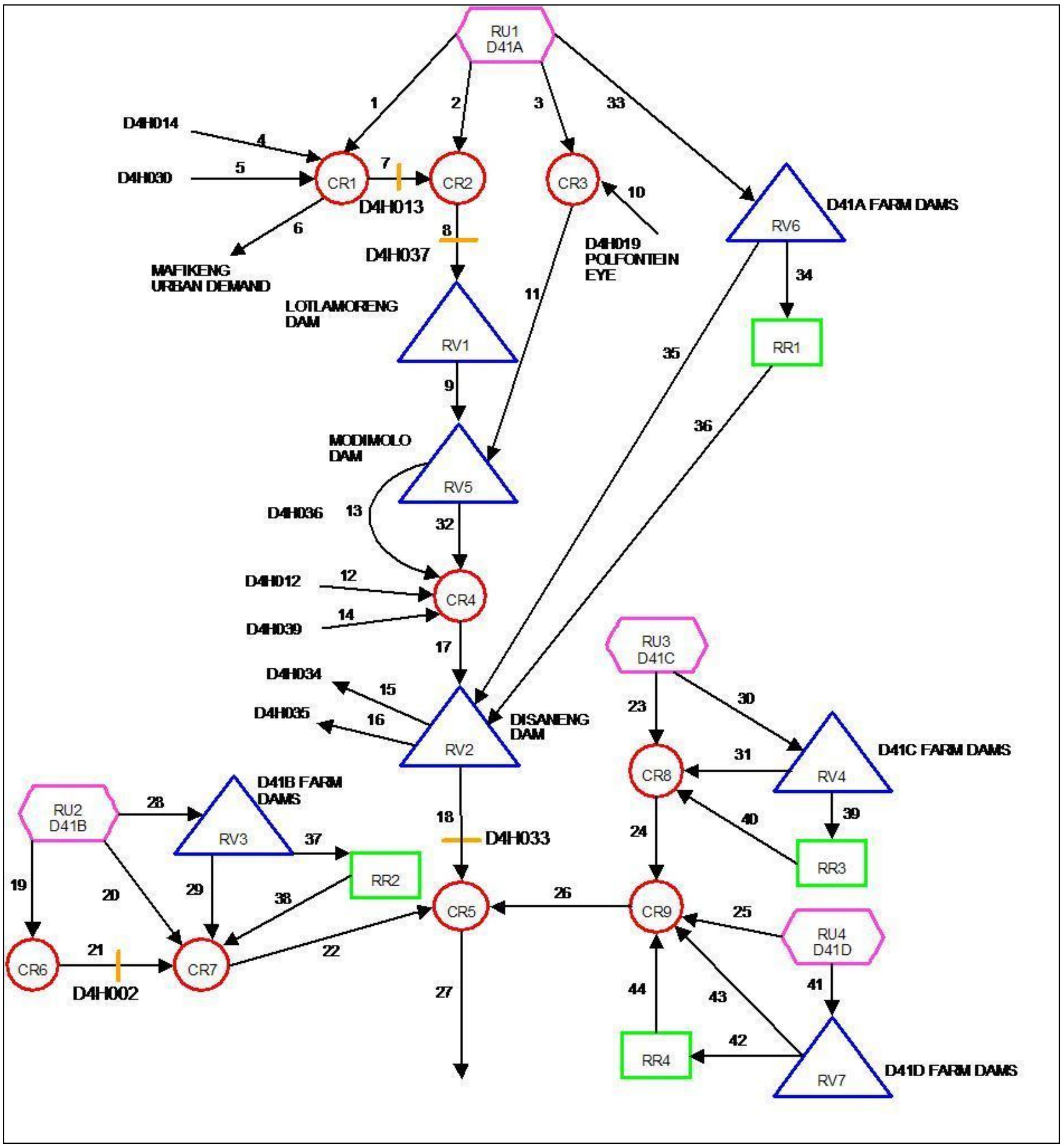
C92



Drainage region D



Network Diagram for WRSM/Pitman Model : Mahikeng Catchment D41A



RU1
D41A
1
2
3
33
D4H014
4
D4H030
5
CR1
7
CR2
CR3
10
D4H013
6
8
MAFIKENG
URBAN DEMAND
D4H037
D4H019
POLFONTEIN
EYE
D41A FARM DAMS
RV6
34
LOTLAMORENG
DAM
11
RV1
RR1
35
9
36
MODIMOLO
DAM
RV5
D4H036
13
32
D4H012
12
CR4
D4H039
14
17
RU3
D41C
D4H034
15
23
30
D4H035
16
DISANENG
DAM
RV2
CR8
31
RV4
D41C FARM DAMS
RU2
D41B
28
D41B FARM
DAMS
18
24
40
39
RV3
37
D4H033
RR3
19
20
29
38
RR2
CR5
26
CR9
25
RU4
D41D
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21
CR7
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D4H002
27
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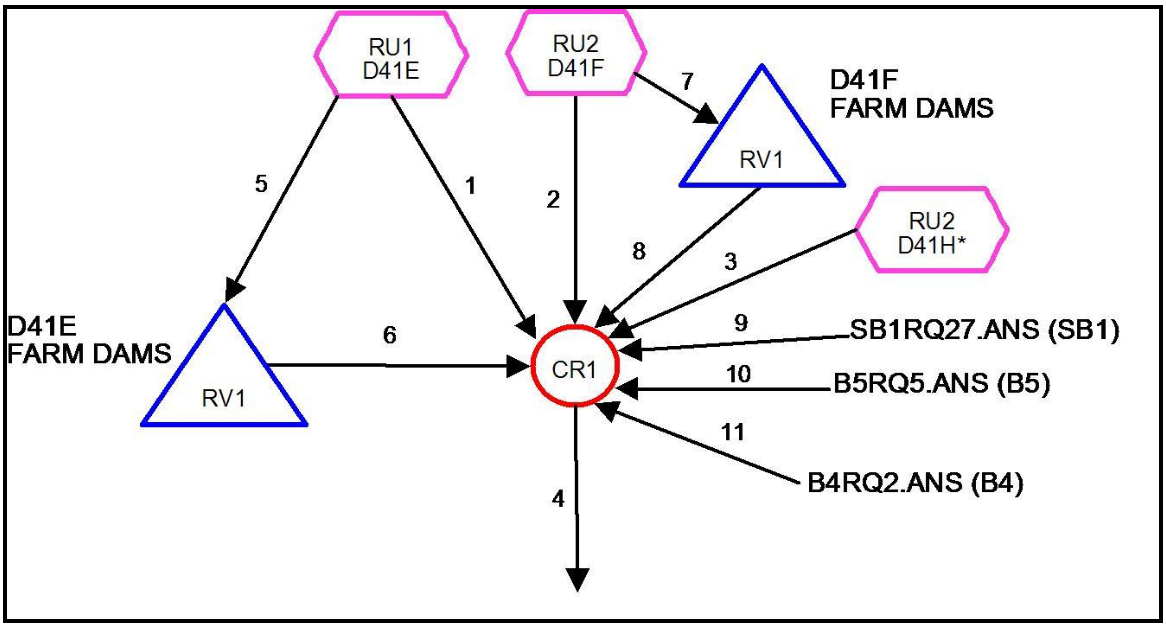
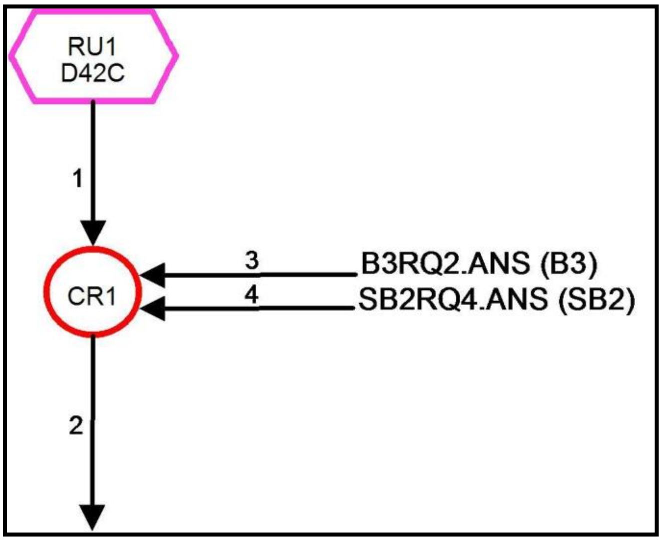
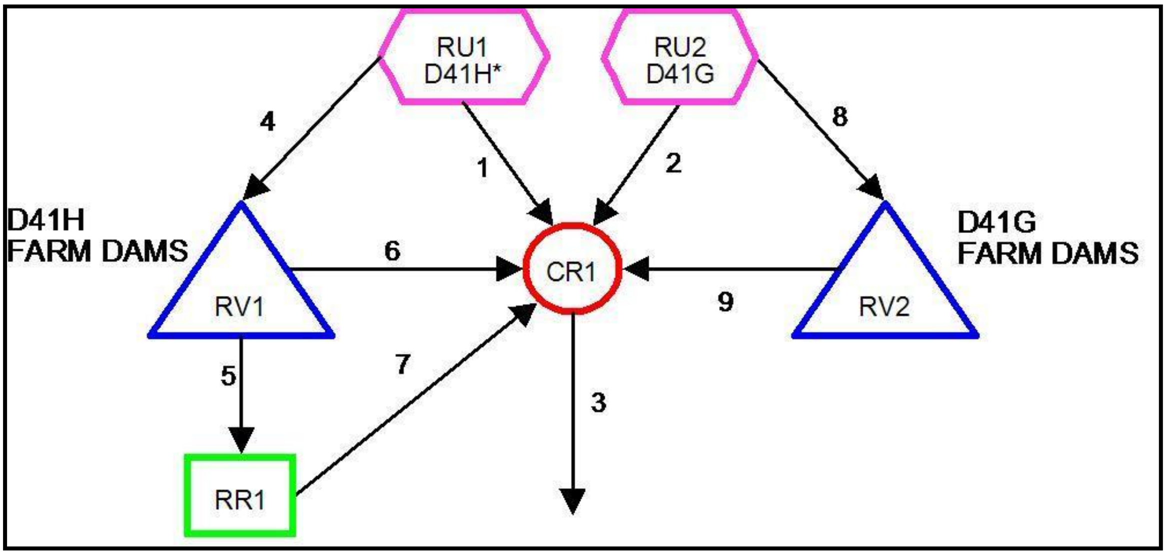
42
RR4
RV7
D41D FARM DAMS



RU1
D41E
RU2
D41F
D41F
FARM DAMS
RV1
RU2
D41H*
D41E
FARM DAMS
RV1
CR1
SB1RQ27.ANS (SB1)
B5RQ5.ANS (B5)
B4RQ2.ANS (B4)
1
2
3
4
5
6
7
8
9
10
11



RU1
D42C
CR1
B3RQ2.ANS (B3)
SB2RQ4.ANS (SB2)
1
2
3
4



RU1
D41H*
RU2
D41G
D41H
FARM DAMS
RV1
CR1
D41G
FARM DAMS
RV2
RR1
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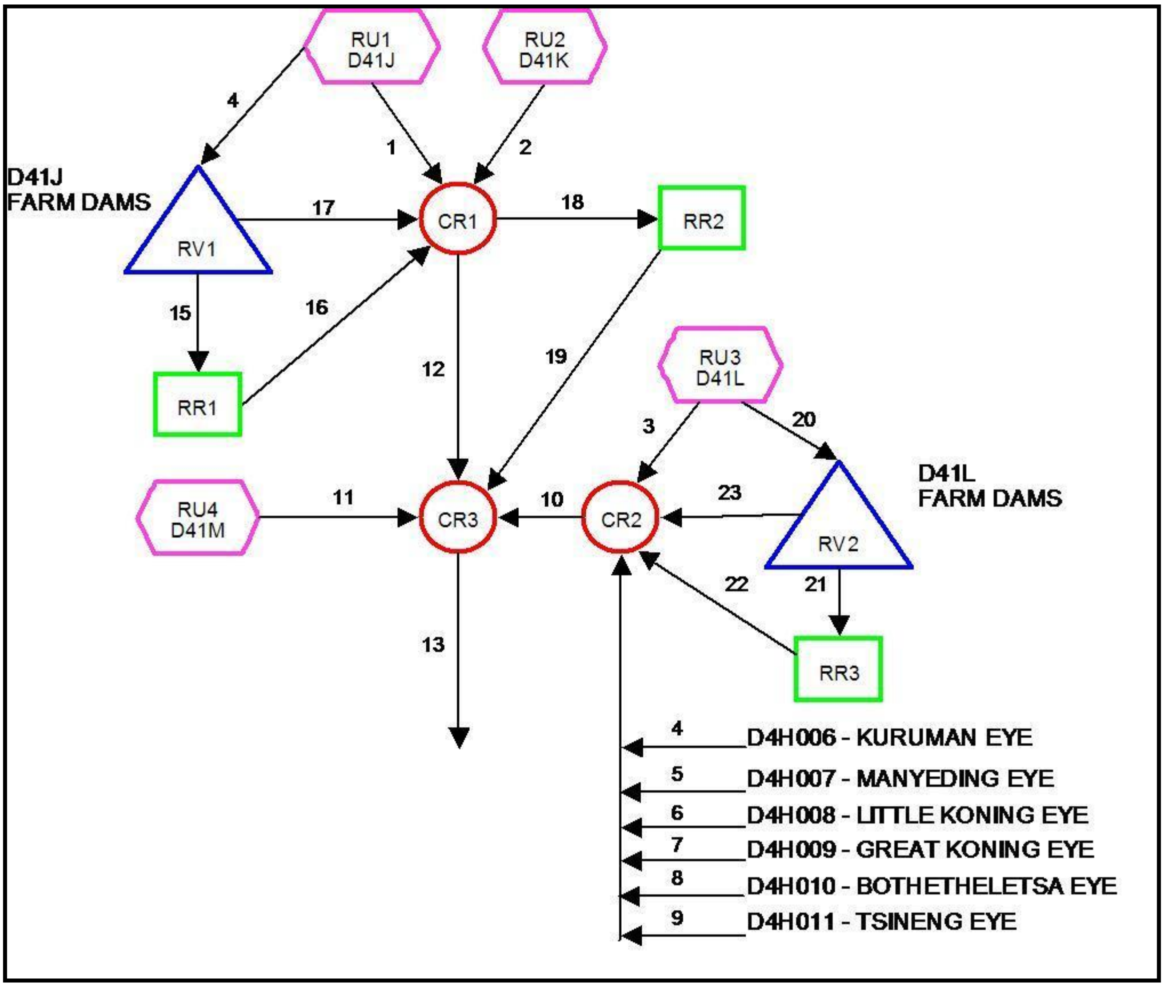
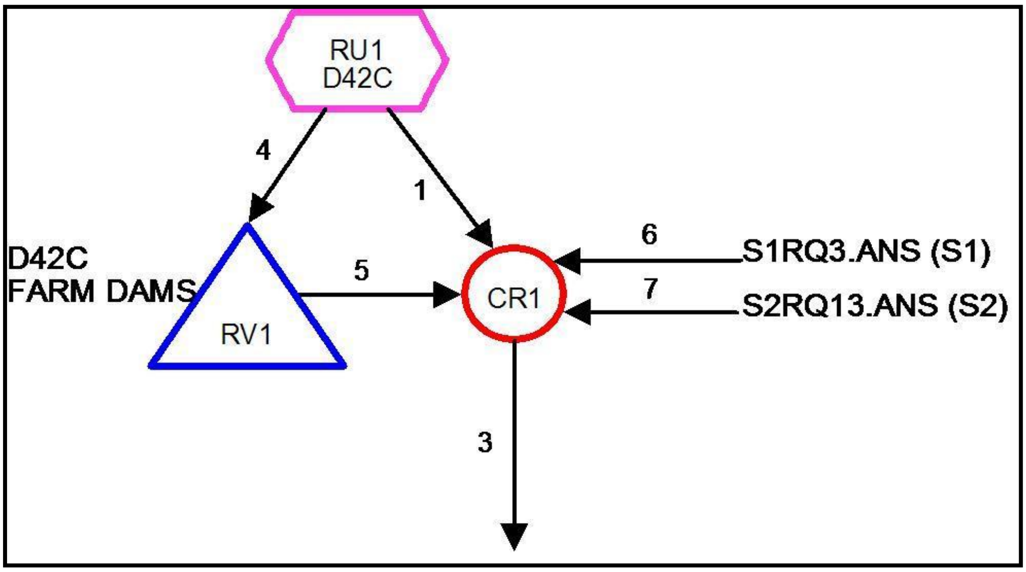
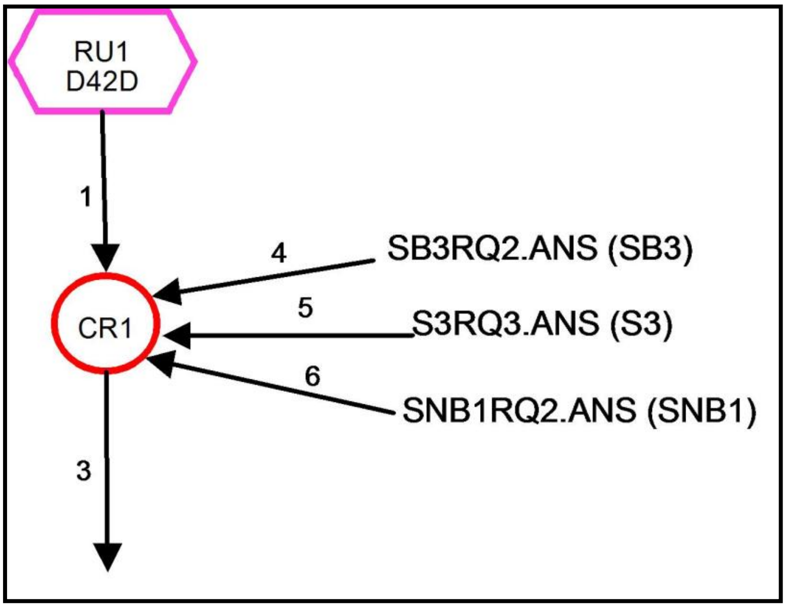
5
6
7
8
9


RU1
D41J
RU2
D41K
D41J
FARM DAMS
RV1
CR1
RR2
RR1
RU3
D41L
RU4
D41M
CR3
CR2
D41L
FARM DAMS
RV2
RR3
D4H006 - KURUMAN EYE
D4H007 - MANYEDING EYE
D4H008 - LITTLE KONING EYE
D4H009 - GREAT KONING EYE
D4H010 - BOTHETHELETSA EYE
D4H011 - TSINENG EYE


RU1
D42C
D42C
FARM DAMS
RV1
CR1
S1RQ3.ANS (S1)
S2RQ13.ANS (S2)


RU1
D42D
1
4
SB3RQ2.ANS (SB3)
5
CR1
S3RQ3.ANS (S3)
6
SNB1RQ2.ANS (SNB1)
3