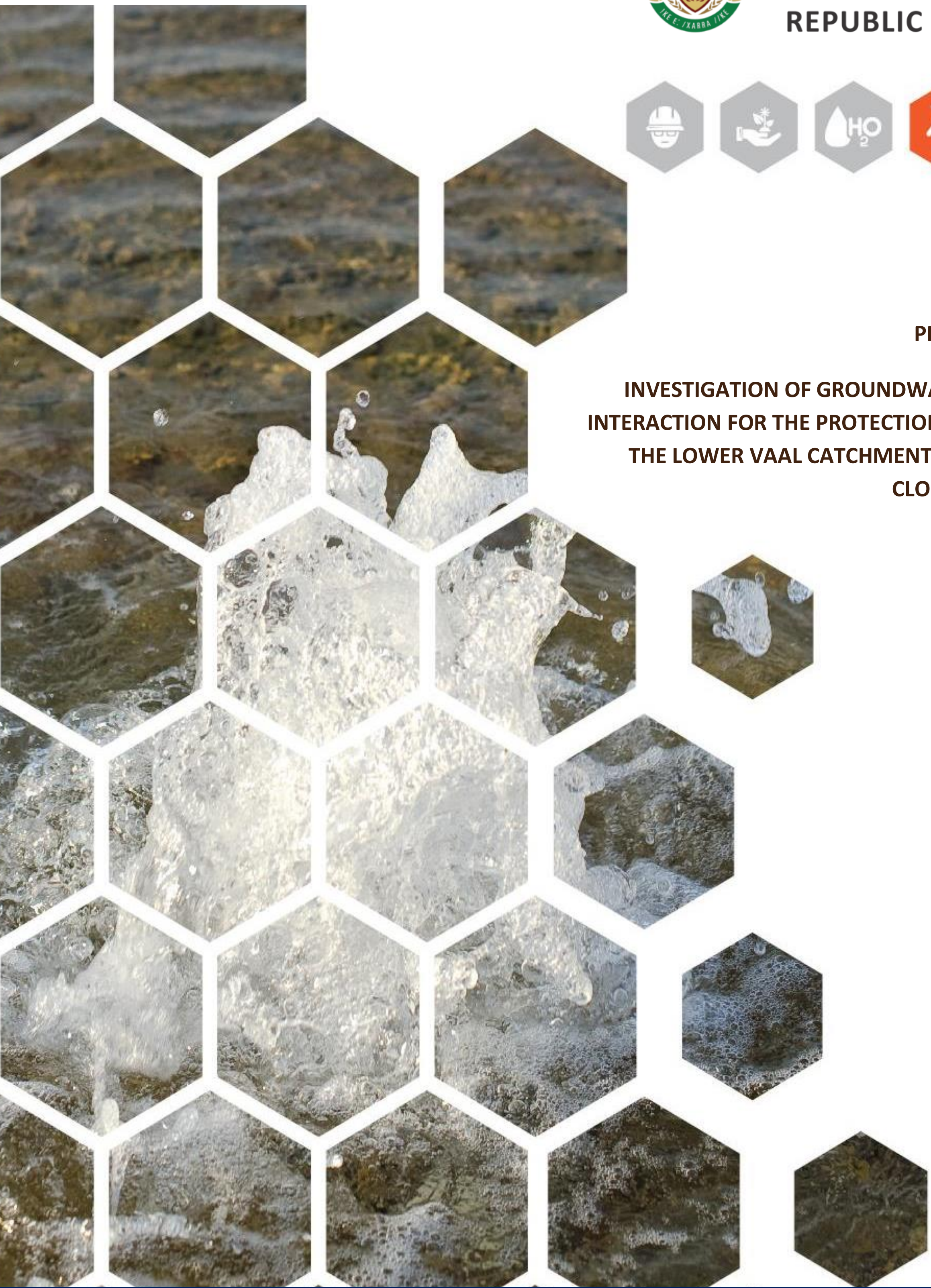
water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA



PROJECT NUMBER: WK21047

INVESTIGATION OF GROUNDWATER AND SURFACE WATER INTERACTION FOR THE PROTECTION OF WATER RESOURCES IN THE LOWER VAAL CATCHMENT. SURFACE GROUNDWATER CLOSE-OUT REPORT (WP11380)

DATE: September 2023

REPORT VERSION: V1.0

WP11380

DWS REPORT NUMBER: RDM/WMA05/00/GWSW/0823

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

INVESTIGATION OF GROUNDWATER AND SURFACE WATER INTERACTION FOR THE PROTECTION OF WATER RESOURCES IN THE LOWER VAAL CATCHMENT WP11380

CLOSE-OUT REPORT

SEPTEMBER 2023
DRAFT

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

Published by

Department of Water and Sanitation

Private Bag X313

PRETORIA, 0001

Republic of South Africa

Tel: +27 (12) 336 7500

Fax: +27 (12) 323 0321

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: Close Out-Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0823

Compiled by:

WSM Leshika Consulting

Postnet Suite No.8

Private Bag X9676

Polokwane 0700

DOCUMENT INDEX

Report name	**Report number**
Inception Report	RDM/WMA05/00/GWSW/0122
Literature Review and Data Gathering Report	RDM/WMA05/00/GWSW/0222
Gap Analysis Report	RDM/WMA05/00/GWSW/0322
Hydrocensus Report	RDM/WMA05/00/GWSW/0422
Water Resources Assessment Report	RDM/WMA05/00/GWSW/0522
Quantified Recharge and Baseflow Report	RDM/WMA05/00/GWSW/0123
Groundwater Quality Categorization Report	RDM/WMA05/00/GWSW/0223
Protection Zones Report	RDM/WMA05/00/GWSW/0323
Surface-Groundwater Interaction Report	RDM/WMA05/00/GWSW/0423
External Reviewer Report	RDM/WMA05/00/GWSW/0523
Capacity Building and Training Report	RDM/WMA05/00/GWSW/0623
Main Report on Surface-Subsurface Interactions	RDM/WMA05/00/GWSW/0723
Close-out Report	**RDM/WMA05/00/GWSW/0823**

Bold indicates this report

APPROVAL

TITLE:	Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Close Out-Report
DATE:	September 2023
AUTHORS:	Project Team
EDITOR:	Fourie I.
REVIEWERS:	Project Management Team
LEAD CONSULTANT:	WSM Leshika Consulting
REPORT NO:	RDM/WMA05/00/GWSW/0823
FORMAT:	MSWord and PDF
WEB ADDRESS:	http://www.dws.gov.za

Approved for WSM Leshika Consulting by:

____

Mr. K. Sami

Study Leader

Approved for the Department of Water and Sanitation by:

___________________________________	---------------------------------------
Ms L. Molokomme	Mr K. Majola
Project Manager	Scientific Manager: Groundwater Reserve Determination

____

Mr Y. Atwaru

Director: Reserve Determination

ACKNOWLEDGEMENTS

The following persons contributed to this project.

Project Management Committee

Atwaru, Yakeen	DWS
Baloyi, Lucky.	DWS
Biyela, Mfundi.	DWS
Boniwe, Nobubele.	DWS
Fourie, Fanus.	DWS
Khoza, Philani.	DWS
Mahlahlane, Kgotso.	DWS
Majola, Kwazikwakhe	DWS
Mazibuko, Molefe Jacob.	DWS
Mokgatle, Tumelo.	DWS
Mokoena, Portia.	DWS
Molokomme, Lerato.	DWS – Project Manager
Mulangaphuma, Lawrence.	DWS
Ngilande, Terrence.	DWS
Okonkwo, Adaora.	DWS
Thebe, Olebogeng.	DWS
Sami, Karim.	WSM Leshika (Pty) Ltd – Study Leader
Mare, Manie	WRP Consulting Engineers (Pty) Ltd
Leshika, Danny	WSM Leshika (Pty) Ltd

AUTHORS

The following persons contributed to this report:

Author	Company
Sami, K	WSM Leshika (Pty) Ltd
Mare, M	WRP Consulting Engineers (Pty) Ltd

REPORT SCHEDULE

Version	Date
First draft	September 2023
Second draft	
Final	

TABLE OF CONTENTS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

BHNR	Basic Human Needs Reserve
CD: WEM	Chief Directorate: Water Ecosystems Management
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

The purpose of the NWA (1998) is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors: promoting equitable access to water; redressing the results of past racial and gender discrimination; promoting the efficient, sustainable and beneficial use of water in the public interest; facilitating social and economic development; protecting aquatic and associated ecosystems and their biological diversity and; meeting international obligations (NWA, 1998). Chapter 3 introduces a series of measures which together are intended to protect all water resources.

The Chief Directorate: Water Ecosystems Management (CD: WEM) is tasked with the responsibility to coordinate all Reserve determination studies which have priority over other uses in terms of the NWA.

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.

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 the groundwater balance when determining the Reserve. Groundwater not only provides for dispersed water supply needs, but also make significant contributions to the ecological reserve, as well as to Basic Human Needs for future water supply. The main objectives of the study are:

- Review existing water resource information;
- Conduct a hydrocensus on an institutional level;
- Conduct a water resource assessment of surface water, groundwater, baseflow, abstraction, surface and 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.

1.3 Purpose and Outline of Report

This report forms the final deliverable of the study and serves as feedback on final deliverables, milestones, stakeholder participation, training, challenges, and lessons learnt through the undertaking of the project.

Chapter 1: Introduction: provides a general background to the project, study area and purpose of the project.

Chapter 2: Milestones: Deliverables and Reports provides a summary of the Study tasks as well as the deliverables and reports produced during the study.

Chapter 3: Stakeholder Participation is a brief description of the stakeholder programme.

Chapter 4: Issues, Challenges and Lessons Learnt: The chapter provides a summary of challenges experienced during the execution of the study and encapsulate the lessons learnt during the process.

Chapter 5: Information Repository: An outline of the data generated during the study is provided.

Chapter 6: Recommendations: Recommendations made during the study, are summarised.

Chapter 7: References

1.4 Study Area

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 (**Figure 1-1**). It contains the Molopo, Harts, and Vaal (below Bloemhof dam) catchments. The basins are 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. Groundwater use depletes the already meagre surface water resources by inducing losses from river channels or depleting flow from dolomitic eyes and as baseflow. 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.

Included in these basins are the Lower Vaal (C9) River, the incremental catchment downstream of Bloemhof Dam and upstream of Douglas weir, the Harts (C3), and Kuruman/Molopo catchments (D4). These catchments include Tertiary catchments C31-C33, C91-92, D41, and Quaternary catchments D73A, D42C-D, D73B-E. These catchments also contain dolomite aquifers, where interaction with surface water can be significant.

The Lower Vaal is located between the Middle Vaal drainage region and the Lower Orange drainage region, with the Upper Orange basin to the southeast, and Botswana to the north. The Lower Vaal has an area of approximately 136 146 km^2. It excludes the Riet-Modder River catchment) (C5), the Molopo River system above its confluence with the Nossob (parts of D42) and portions of the Vaal River catchment below the confluence with the Harts and Douglas weir (parts of C92B and C, and D71B). It is important to note that 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 because 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 main rivers of the Lower Vaal catchment, the Vaal, and Harts, 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, before its confluence with the Orange River. The main dams are Wentzel, Taung, Spitskop, Vaalharts Weir, Douglas weir and Bloemhof. The largest pan is Barberspan, located in the Harts sub-catchment.

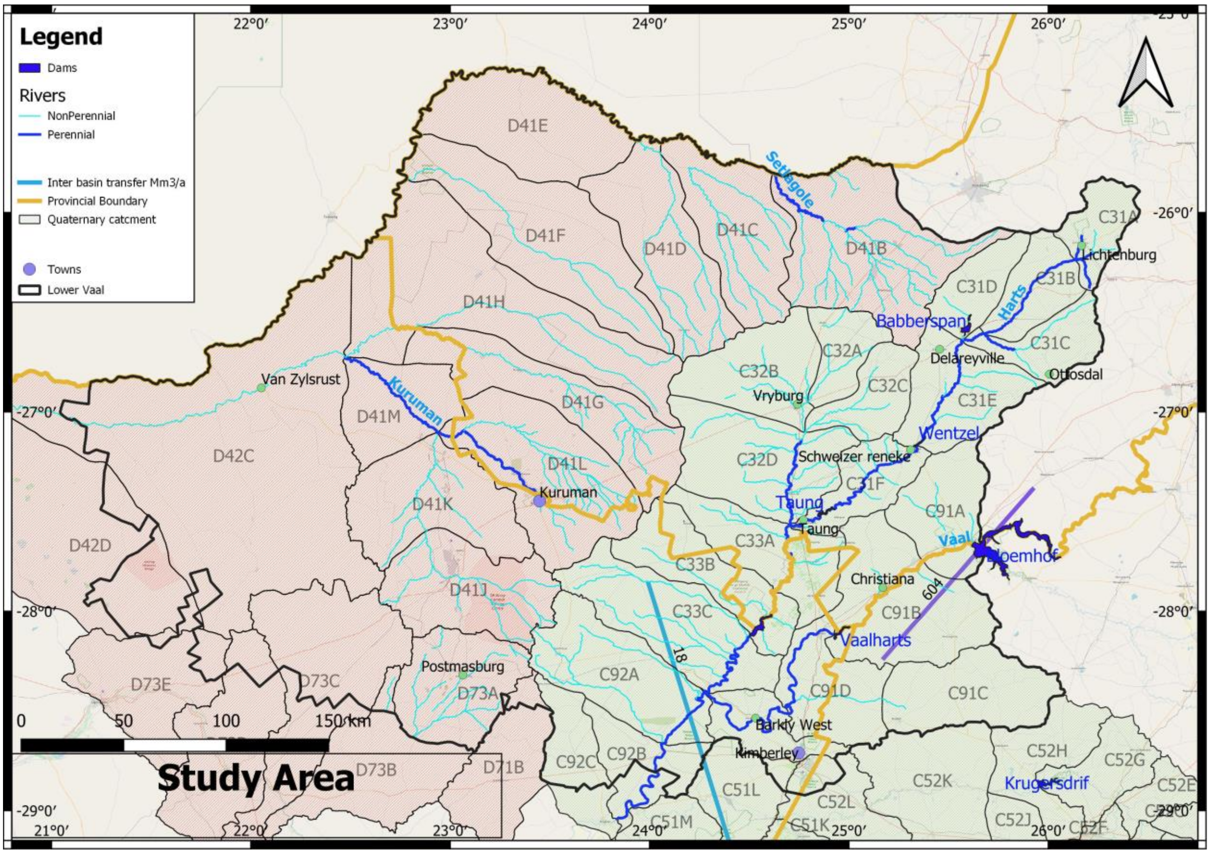


Figure 1-1 Lower Vaal drainage Region

The Kuruman and Molopo Rivers, which drain the Kalahari and northern Lower Orange regions of Drainage region D, do not make a meaningful contribution to the surface water resources of the Orange River, and only interact with groundwater via evapotranspiration and losses of flow generated by upstream springs into dry river channels. These dolomitic springs form distinct groundwater ecosystems and are themselves a form of surface-groundwater interaction.

The Molopo and its tributary the Kuruman River together drain the western part of the Lower Vaal catchment. The Kuruman River originates approximately 35 km southeast of Kuruman and becomes ephemeral approximately 120 km north-west of Kuruman, east of Van Zylrust.

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

2 MILESTONES, DELIVERABLES AND REPORTS

2.1 Deliverables

The study was structured and broken down into various tasks and sub-tasks (**Table 2-1**) with associated deliverables and reports which were the milestones of the study project (**Table 2--2**).

Table 2-1 Tasks and sub-tasks of the study

Section	Task description	Deliverables
2,2	Study Inception	
	Identification of existing reports	**Inception report** Work programme Capacity building plan Expenditure projections
	Refine scope of work	
	Identify role players	
	Identify Capacity building objectives	
2.3	Review of Water Resource Information	
2.3.1	Literature Review and data gathering	**Literature Review and Data Gathering Report** **Gap Analysis Report** **Hydrocensus Report** **Water Resources Assessment Report**
2.3.2	Hydrocensus	
2.3.3	Resource Assessment	
2.4	Surface-Groundwater Interactions	
2.4.1	Quantity groundwater recharge and baseflow	**Quantified Recharge and Baseflow Report** **Surface-Groundwater Interaction Report** **Groundwater Quality Categorisation Report** In protection zones report:
2.4.2	Categorise groundwater quality	
2.4.3	Groundwater levels and their fluctuations	
2.4.4	Determination relevance of groundwater contribution to surface water and identify protection zones	**Surface-Groundwater Interaction Report** **Protection Zones Report**
2.4.5	Groundwater conceptual model and maps	
2.4.6	Present status of groundwater	
2.4.7	Compilation of a monitoring programme	**Main Report**
3	Communication and Liaison	
3.1	Coordination of meetings	Meeting documentation Secretarial services Project file of correspondence
3.2	Study Management	Study Management Committee meetings (6) Project steering Committee Meetings (3) **Close out report** **External reviewer Report**
4	Capacity Building	Training workshop Refresher course Task assigned on self-learning and group feed back

Section	Task description	Deliverables
		Task assigned on WULA assessment and group feed back **Capacity Building Report** WRSM Pitman handover, manuals, and logins to Water Resources South Africa 2012 database

Table 2-2 Milestones and deliverables

Deliverables	Date	Links to tasks
Draft Inception report	December 2021	2.2
Final Inception Report	January 2022	2.2
PSC 1	March 2022	3.2
Draft Literature review & data gathering Report	April 2022	2..3.1
Final Literature review & data gathering Report	May 2022	2.3.1
Draft gap analysis report	June 2022	2.3.1
Final Gap analysis report	July 2022	2.3.1
Draft Hydro census report	August 2022	2.3.2
Final Hydro census report	September 2022	2.3.2
Draft Water Resources assessment report	October 2022	2.3.3
Capacity Building Workshop	November 2022	4
Final Water resources assessment report	December 2022	2.3.3
Draft Recharge and Baseflow quantification Report	January 2023	2.4.1
Final Recharge and baseflow quantification report	February 2023	2.4.1
Draft groundwater quality categorization report	March 2023	2.4.2
PSC 2	March 2023	3.2
Final groundwater quality categorization report	April 2023	2.4.2
Draft protection zones report	May 2023	2.4.3, 2.4.4
Final protection zones report	June 2023	2.4.3, 2.4.4
Draft Surface-groundwater interaction report	July 2023	2.4.5, 2.4.6
Draft Main Report	August 2023	2.4.7
Final Surface-groundwater interaction report Main Report Capacity Building Report Close-Out Report PSC 3	Sep 2023	2.4.5, 2.4.6 2.4.7 4. 3.2 3.2
External Reviewer Report Electronic data transfer	Oct 2023	

2.2 Study Reports

2.2.1 Inception Report

Report Reference: 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: Inception Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0122.

Report Purpose: The Inception Report describes the proposed work to be undertaken by the appointed Professional Service Provider (PSP). The work description in the report is based on the data available for the Lower Vaal catchment and covers the data needs for the application of the proposed methods. During the execution of the activities and tasks of the study, the data and information will be evaluated for consistency and any irresolvable anomalies and deficiencies will be brought under the attention of the Client for clarification by the data and information originators.

The purpose of the Inception Report is to define the extend of work and associated costs based on the proposed methodology and availability of information, existing data as well as initial evaluations carried out after the submission of the Proposal.

Key Information:

- Data requirements
- Scope of work
- Study procedure and methods
- Management and project structure
- Financial summary

2.2.2 Literature Review and Data Gathering Report

Report Reference: 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

Report Purpose: This report describes the review of information carried out, 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.

Key Information:

- Review of study area
- Existing reports
- Water related infrastructure
- Existing Reserve and RQOs
- Review of existing data on water use, water level, population, borehole yields, geology, recharge and baseflow, rainfall, WRSM Pitman model networks

2.2.3 Gap Analysis Report

Report Reference: 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: Gap Analysis Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0322

Report Purpose: This report summarises the review of information carried out for undertaking the quantification of surface-subsurface interactions in the Lower Vaal catchment of the Vaal Water

Management Area for the purpose of the identification of information gaps, and proposals of how to address these gaps.

2.2.4 Hydrocensus Report

Report Reference: 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: Hydrocensus Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0422

Report Purpose: This report provides an interim report on hydrocensus results. This report and details the following aspects of the work carried out including first consultation meetings and data collection.

Key Information:

- Institutions for water supply
- Registered water use
- Estimated water use
- Water quality
- Wetland identification

2.2.5 Water Resources Assessment Report

Report Reference: 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: Water Resources Assessment Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0522

Report Purpose: This report summarises the water resources information in terms of:

- Groundwater resources including Exploitation Potential, Recharge, Baseflow and groundwater use
- Conceptual model of aquifers and aquifer types
- Water balance and stress index
- Identification of interaction zones
- Existing surface water resources and use

  Key Information:

  - Surface water resources data on rainfall, observed flows, water requirements and simulated flows
  - Groundwater resources based on existing data
  - Discharge from dolomitic eyes

2.2.6 Recharge and Baseflow Report

Report Reference: 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: Recharge and Baseflow Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0123

Report Purpose: This report quantifies recharge and baseflow in terms of:

- Existing data on recharge and baseflow
- Existing surface water hydrology data
- Revisions to the WRSM Pitman network
- Calibration of WRSM Pitman
- Revised surface water discharge, recharge and baseflow

Key Information:

- Simulated surface water flows and calibrations
- Calibrated Recharge and baseflow

2.2.7 Groundwater Quality Categorisation Report

Report Reference: Department of Water and Sanitation (DWS), South Africa. 2023. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Groundwater Quality Categorisation Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0223

Report Purpose: This report categorises groundwater quality for macro and microconstituents in terms of:

- Quaternary catchment
- Processes and Catchment characteristics that impact on groundwater quality

Key Information:

- Groundwater quality including metals
- Surface water quality
- Interaction processes affecting quality

2.2.8 Protection Zones Report

Report Reference: Department of Water and Sanitation (DWS), South Africa. 2023. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Groundwater Protection Zones Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0323

Report Purpose: This report identifies priority areas where groundwater-surface interaction is important and zones which need to be protected.

Key Information:

- Local water supply protection zones
- Aquifer vulnerability
- Baseflow vulnerability
- Groundwater stress and water levels

2.2.9 Surface-groundwater Interaction Report

Report Reference: 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: Surface-Groundwater Interaction Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report No. RDM/WMA05/00/GWSW/0423

Report Purpose: This report categorises surface-groundwater interactions in terms of simulated channel losses, recharge and baseflow from revisions to the WRSM Pitman network and subsequent calibration.

Key Information:

- Modelling of natural and present-day flows
- Impacts of present-day water use on hydrology and interactions

2.2.10 Capacity Building and Training Report

Report Reference: 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: Capacity Building and Training Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0623

Report Purpose: This report forms the final deliverable of the study and serves as feedback on the capacity building undertaken during the project and the skills transferred.

Key Information:

- Description of training provided

2.2.11 Main Summary Report

Report Reference: 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: Main-Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0723

Report Purpose: This report summarises the work undertaken during the project and presented in a series of reports.

Key Information:

- Description of study area

- Background and Status Quo of hydrology, the reserve, population. Water supply and water use, monitoring
- Surface and groundwater resources
- WRSM Pitman modelling of surface water, recharge and baseflow
- Surface groundwater interactions
- Impacts of abstraction on surface and groundwater resources
- Water quality
- Protection zones
- Recommendations

2.2.12 Close Out Report

Report Reference: 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: Close Out-Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0823

Report Purpose: This report forms the final deliverable of the study and serves as feedback on final deliverables, milestones, stakeholder participation, training, challenges, and lessons learnt through the undertaking of the project.

3 STAKE HOLDER PARTICIPATION

3.1 Purpose and Objectives

The objectives of stakeholder engagement in this process were to a) provide sufficient and accessible information to stakeholders in an objective manner to assist them to contribute relevant local information and knowledge to the study, and b) to comment on the recommendations of the study. Taking into consideration the objectives of stakeholder engagement, the following section provides a summary of the process deliverables and opportunities provided to stakeholders.

3.2 Project Development

The Work Plan was submitted by WSM Leshika Consulting for the adaptation of the generic guideline for the implementation of the project and the requirements of the communication strategy – comprised the Stakeholder Engagement Plan (**Table 3-1**) which was discussed and agreed on. A virtual meeting was held in this regard – 20th April 2022. At this meeting agreement was also reached upon the time frames for deliverables, as well as the list of stakeholder groupings to be included in the consultation process. The inception and development meeting served the following purposes:

- Introduce the Professional Service Provider (PSP)
- Establish common ground amongst role-players; and

- Development of a Project Execution Plan.

Table 3-1 Stakeholder engagement plan

Item No:	Main Activity	Outcome	Target Output	Key Performance Indicator
1.1	First Consultation with Stakeholders	All Stakeholders give the Project a Buy-In	Roles and Responsibilities of all Stakeholders are clearly defined in terms of Project Implementation.	The Stakeholders approval of the Project. Identification of all relevant water users to form part of the Project Steering Committee (PSC) - inclusive of all stakeholders. Notes and/or Minutes of First Consultation Meetings and Engagements.
1.2	One-on-One Sessions with affected Stakeholders	Department, Municipality, Water Boards, Irrigation Boars, etc. form part of the Project Steering Committee and assist WSM Leshika Consulting as the Project Agent to work smoothly in conducting a hydrocensus.	The PSC is Established and Terms of Reference for the PSC signed off – explaining each member's roles and responsibilities.	Composition of the PSC representatives of the municipality, Water Boards, Irrigation Boards, etc. for the "Project Programme".
1.3	Conducting a Hydrocensus	The site has a clear, approved framework within which project implementation can proceed and against which performance can be measured. The actions include: Obtain WARMS data Hydrocensus of relevant institutions Identification of wetlands and protected areas Identification of contaminant sources Analysis of water quality status	Data obtained from stakeholders Concerns of stakeholders identified .	Compilation of hydrocensus report

3.3 Stakeholder Identification and Database

The identification of stakeholders was done at the beginning of the project in collaboration with the DWS and other stakeholders in the study area. Stakeholders were also identified by using existing databases. Telephonic, email inquiries and stakeholder referrals also supported the establishment of a comprehensive database. Stakeholders who were identified and invited to participate in the process were representative of all relevant interests and sectors of society in the study area.

Stakeholder details were captured electronically, and the database is shown in **Table 3-2 and Table 3-3.**

Table 3-2 Sectors of society represented by Interested and Affected Parties (I&APs) on the direct mailing list

Sectors of Society
Local Government (local and district municipalities)
Water Service Authorities
Mining Sectors

Stakeholders received all project documentation and special efforts were made to encourage their attendance at the meetings, as well as submission of their comments in writing. In addition to capturing stakeholder details, the database was also used to record stakeholder interactions, including what and when information was distributed to or received from stakeholders and which stakeholders attended each meeting.

Table 3-3 Stakeholder database

Name	Contact Person	Email Address	Invites/Email		Contacted via Phone call	PSC No 1		Invite/Email		Contacted via Phone call	PSC No 2		Contacted via Phone call	PSC No 3	
			Date Sent	Date Follow Up	Yes/No	Accepted	Attended	Date Sent	Date Follow Up	Yes/No	Accepted	Attended	Yes/No	Accepted	Attended
Sedibeng Water (Vaal Gamagara)	Mr. Obby Masia	Omasia@Sedibengwater.Co.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	No	No	Yes		
Sedibeng Water (North West Region)	Mr. Moses Lebitso	Mlebitso@Sedibengwater.Co.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	No	No	Yes		
Dikgatlong Municipality	Mr Desmond Makaleni	Desmond.Makaleni@Dikgatlong.Co.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	Yes	Yes	Yes		
Frances Baard District Municipality	Mr Rorisang Setshogoe	marisa.ridgard@fbdm.co.za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	Yes	Yes	Yes		
Sol Plaatjies	Mr Zughdi Adikary And Mr Sabelo Mkhizen	Zadikary@Solplaatje.Org.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	Yes	Yes	Yes		
Kgatelopele Local Municipality (Lime Acres)	Irene Williams, Cllr	Mayor@Kgatelopele.Gov.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	No	No	Yes		
Lejweleputswa District Municipality	Ms Palesa Kaota	Jane@Lejwe.Co.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	No	No	Yes		
Magareng Municipality	Mr Tumelo Thage	Tumelo.Thage@Gmail.Com	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	No	No	Yes		
Vaalharts Water	Mr Kobus Harbon	Kobus@Vhwater.Co.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	Yes	Yes	Yes		
Polokwane Municipality	Mr Lubabalo Jange	Jange.Lubabalo@Gmail.Com	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	Yes	Yes	Yes		
Kalahari East Water User Association	Mr. Jakobus Nel	Rita@Nelenvennote.Co.Za / Kobus@Nelenvennote.Co.Za	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	No	No	Yes		
Naledi Municipality	Mr Leon Pretorius	Gdlpretorius@Gmail.Com	10/02/2022	4/03/2022	Yes	No	No	31/03/2023	02/05/2023	Yes	Yes	Yes	Yes		
Sedibeng Water	Mr Frans De Vos	Fdevos@Sedibeng.Gov.Za	10/02/2022	4/03/2022	Yes	Yes	Yes	31/03/2023	02/05/2023	Yes	No	No	Yes		
Sishen Iron Ore Company	Thenius Kotzee	JACO.LAMBRECHTS@ANGLOAMERICAN.COM											Yes		
Finsch Diamond Mine	Clyde Garth Johnson	ELRINA.CILLIERS@PETRADIAMONDS.COM											Yes		
Assmang	Aluwani Kangala/Doranne Odendaal	aluwani.kangala@assmang.co.za											Yes		

Crown Resources	Didi De Abreu	DIDI.DEABREU@PETRADIAMONDS.COM											Yes		
Sedibeng Iron Ore	Tau Khwau	tauk@seio.co.za											Yes		
Kudumane Manganese Resources	Tshekedi Montshusi	montshusi.tshekedi@kmr.co.za											Yes		
Idwala Industrial Holdings	Ireen Huyssteen	VHS@IDWALA.CO.ZA											Yes		
Good Hope Diamonds & Estates	Petrus Johannes Keeve	PJKEEVE@IAFRICA.COM											Yes		
Nelesco Mining	Wikus De Winnaar	wikusdw.wdw@gmail.com											Yes		
Kalahari Goldridge Mining Company Ltd	Irene Nadunga	IRENE.NADUNGA@HARMONY.CO.ZA											Yes		
Sedibeng Mining	Gamza Gool	GAMZAGOOL@GMAIL.COM											Yes		

3.4 Project Announcement

The study was announced with an invitation to interested parties to register and to actively participate in the study. The following methodology was applied in announcing the study:

No	General Public and Key Stakeholders
a	Key Stakeholders were contacted telephonically and informed of the study and the process.
b	A Background Information Document (BID) and invitation letter to participate was distributed.
c	Stakeholders were informed of the establishment of the Project Steering Committee (PSC).
d	A PSC nomination form was circulated to stakeholders who expressed interest or were keen to make a nomination on behalf of their organisation and/or sector.
e	A letter inviting identified stakeholders and nominees to serve in the PSC was circulated to relevant and interested sectors within the study area.
f	To ensure that stakeholders fully understood the role of the PSC, a TOR for the PSC was provided to all organisations who expressed interest in participating.
g	Stakeholders who expressed interest in the PSC were then invited to the inaugural PSC meeting held on 10 March 2022.

3.5 Preparations for the Establishment of the Project Steering Committee (PSC)

This process ran parallel with the project announcement phase. Communication with stakeholders to prepare for the establishment of the PSC was undertaken through the following activities:

- Distribution of an introductory letter which explained the need for the project, the context of the study which illustrated the extent of the study area. In addition, information was provided on aspects such as where additional information can be obtained and the contact details of the Public Participation team. This letter also invited nominees to the first PSC meeting.

The letter was accompanied by a comment sheet which enabled interested people and organisations to:

- Register as a stakeholder.
- Express interest in participating in the PSC.
- Provide comments, and/or
- Nominate additional stakeholders.
- BID 1 was compiled and distributed to all stakeholders on the database. This BID contained the description of the project, an explanation of all the components of the study, the need for Public Participation and the contact details of both the Public Participation and technical teams, for ongoing communication during the study.

3.6 Project Steering Committee Meetings

3.6.1 Establishment of PSC

The PSC was established at the first virtual meeting held on 10 March 2022. The PSC was established as a result of a process of nomination which started during the project announcement phase. A list of stakeholder groupings to be consulted as part of the stakeholder engagement process was provided by the Department of Water and Sanitation.

The purpose of establishing the PSC was to provide a structured platform for the public to give inputs into the study and share information with other stakeholders in the study area. The PSC consisted of members from various organisations and sectors, striving for balanced representation to achieve balanced view points and inputs from stakeholders within the study area.

3.6.2 Format of PSC meetings

A focused stakeholder engagement process was undertaken throughout, as such, all PSC meetings were aligned to specific deliverables and technical steps of the study. The role of the PSC was to guide the study during all stages as it unfolded and to provide sectoral inputs and review technical reports.

Table 3-4 provides detail of all PSC meetings that were held during the course of the study. All three meetings were held online.

Table 3-4 Details of PSC Meetings

Meeting	Date	Objectives of the Meeting
PSC 1	10-Mar-22	To introduce, recap and report on the progress of the study. To present the following: • Objectives, tasks, and reports • Existing infrastructure • Previous work • Other planned projects (e.g., Reconciliation strategy) • Data requirements • An overview of finalized Inception Report • Study structure • Discussion of targeted hydrocensus
PSC 2	10-May-23	To introduce, recap and report on the progress of the study. To present the following: • Summary of progress and reports compiled • Hydrocensus Report • Water Resources Assessment Report • Recharge and Baseflow Quantification Report • Capacity Building course provided
PSC 3	27-Sep-23	To recap and report on the progress of the study. To present the following: • Summary of progress and reports compiled • Groundwater Quality Categorization Report • Protection Zones Report • Surface Groundwater Interaction Report • Capacity Building

3.6.3 Information made available to Stakeholders

Stakeholders were regularly updated on the status of the project *via* distribution of BIDs, which took form of a newsletter (**Table 3-5**). The purpose of information documents was to communicate progress made on the study and to provide them with a summary overview of study information. BIDs were circulated electronically prior to PSC meetings and assisted PSC members to engage meaningfully during the discussions.

Table 3-5 Summary of information distributed in relation to each PSC meeting

No	Circulation Date	Information Document
1	10/02/2022	BID 1
		Meeting Agenda
		Invitation Email
		Stakeholder Reply Sheet
2	31/03/2023	BID 2
		Meeting Agenda
		Stakeholder Reply Sheet
		PSC Meeting 1 Minutes
3	04/09/2023	BID 3
		PSC Meeting 2 Minutes
		Stakeholder Reply Sheet
		Meeting Agenda

3.7 Consultation Meetings

A series of one-on-one meetings (site visits) and interactions were held between the dates – 13th June 2022 and 15th June 2022 with the following stakeholders: (1) Francis Baard Municipality, (2) Phokoane Municipality, (3) Magareng Municipality, (4) Dikgatlong Municipality, (5) Sol-Plaatjie Municipality, (6) Naledi Municipality, (7) Vaalhaarts Water and (8) Sedibeng Water.

The meetings were arranged to formally introduce WSM Leshika Consulting to representatives of various stakeholders as beneficiary stakeholders. At these meetings, the scope of work was discussed, and agreement was reached in terms of the data required as part of the Hydrocensus.

Details of consultation meetings and interactions with various stakeholders are shown in **Table 3-6.**

Table 3-6 Consultation meetings

Stakeholder Name	Stakeholder Representative	Meeting Date
Francis Baard Municipality	Rorisang Setshogoe	13th June 2022
Magareng Municipality	Tumelo Thage	13th June 2022
Dikgatlong Municipality	Desmond Makaleni	13th June 2022
Sol-Plaatjie Municipality	Sabelo Mkhize Boy Dhluwayo	14th June 2022
Phokoane Municipality	Lubabalo Jange	13th June 2022
Vaalhaarts Water	Anita Kooverjee Niel Van Eeden	13th June 2022
Sedibeng Water	Frans De Vos	13th June 2022
Naledi Municipality	Leon Pretorius	14th June 2022

N.B. In addition, other stakeholders i.e., mainly Mining Houses were invited to be part of the PSC and attend its meetings with no success. However, it is worth mentioning that a few mining houses have confirmed their attendance of the last PSC meeting.

3.8 Website

All technical reports and supporting documentation made available to the I&APs during the course of the study were uploaded on http://www.dws.gov.za/rdm/currentstudies/default.aspx

3.9 Recordkeeping

An important part of the stakeholder engagement process is record keeping. The following information has been kept on record both as hard and electronic copies:

- Minutes of meetings.
- Attendance registers.
- Comment sheets.
- Letters, e-mails
- Stakeholder Engagement Report (this section), which summarises stakeholder engagement activities up to the submission of the project close-out report.

4 ISSUES, CHALLENGES AND LESSONS LEARNT

4.1 Water Resources Information, Uncertainties and Solutions

The flow in the Lower Vaal system is to a high degree dependent on the flows generated in the Upper and Middle Vaal River. No flow now enters the system from the D41A Upper Molopo except during high rainfall events. The hydrological data, updated and extended as part of the Orange-Senqu River Commission (ORASECOM) Integrated Water Resources Management Plan (IWRMP) Phase 2 study (ORASECOM, 2014), applied for all the areas upstream of the Orange-Vaal confluence covers an 85-year period from 1920 to 2004 hydrological years. The hydrology information in the upstream catchments is generally of high to very high confidence.

A summary of the identified data gaps is shown in **Table 4-1.**

Table 4-1 Data gap and resolution

Information	Data Gap	Resolution	Comment
Hydrology	Few flow gauging stations in the Molopo catchment (D41 and D42)	Cannot be resolved	
	Large discrepancies in MAR for D41 and D42 between WR2005 and WR2012	Hydrology will be revised	Since a large part of the discharge originates from dolomitic springs, revising the hydrology to include groundwater should address this issue
	No high confidence Reserve study was undertaken for Region D	Cannot be resolved	Recommendations can be made for the Reserve based on the revised hydrology
	ORASECOM hydrology does not include detail on abstractions or irrigation for Vaal-Harts	Utilise WR2012 Network which includes irrigation modules	
	Dolomitic discharge was not simulated and observed flows were input as an inflow route to the model	Dolomite compartments will be simulated	Observed flows and are not linear in time due to the impacts of groundwater abstraction. Many springs are not gauged, thereby baseflow is underestimated
Groundwater	WRSM Pitman model not configured with groundwater	Include groundwater and revise runoff units to include dolomitic compartment boundaries	
	Delineation of dolomitic compartments in hydrology	Dolomitic compartment maps to be used to delineate dolomite runoff units	Compartments do not follow topography and may require assessment outside the Lower Vaal boundary

	Not all abstractions are monitored or available	Assume abstraction based on WARMS Attempt to get data during hydrocensus	
	Large discrepancies between recharge and baseflow in GRAII	To be resolved by integrated modelling in WRSM Pitman	
	Current Groundwater level data not available in the vicinity of Schweizer Reneke and Christiana	Stress index to be assessed and compared to historical data	
Rainfall	Large reduction in number of rainfall stations since the 1990s	Cannot be resolved	
	Rainfall data not publicly available after 2010	Use of CHIRPS or use of SAWS data if obtained by Directorate: Strategic Water Resource Planning	
Dolomitic springs	Not all dolomitic springs are gauged to calibrate recharge-discharge	Transfer parameters from gauged compartments	

4.1.1 Rainfall

A list of the stations listed open in 2011 and that are available from Water Resources of South Africa, 2012 (WR2012) was compiled. The SAWS 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.

Good-quality observed rainfall data is always the best option to use when generating hydrology for a catchment. Unfortunately, the DWS initiatives to obtain the required rainfall data up to and including the hydrological year 2019 from SAWS were not successful at the beginning of the project. The Study Team thus resort to satellite-based rainfall data. The CHIRPS satellite-based database was utilised for this purpose. CHIRPS consists of satellite observations like gridded satellite-based precipitation estimates from NASA and NOAA have been leveraged to build high-resolution (0.05°) gridded precipitation (https://www.chc.ucsb.edu/data/chirps). Daily rainfall records from October 1981 to July 2022 were downloaded and then converted to monthly rainfall records per quaternary catchment.

Observed rainfall data from the previous Pitman Model calibration covered the period 1920 to 2009 hydrological years. It was thus possible to compare the observed rainfall data with the CHIRPS rainfall data for the 1981 to 2009 overlapping period. The rainfall trends from the observed versus CHIRPS rainfall data sets for the same sub-catchment in general compared well. The observed rainfall however in most cases showed higher peaks and lower dry years, which also led to a higher coefficient of variance (CV) for the observed rainfall data. The average rainfall over the overlapping period in general compared reasonably well. In some cases, the average from the CHIRPS rainfall was slightly higher, some slightly lower and some almost the same over the overlapping period. The CHIRPS rainfall was in all cases adjusted to provide the same average as obtained from the observed rainfall data.

The lower coefficient of variance (CV) as applicable to the CHIRPS rainfall data was initially a bit of a concern as it might lead to simulated runoff with a lower variance than would have been the case when observed rainfall was used. To improve the CHIRPS mass plot an adjusting factor was determined for each of the quaternary catchments. This improved the MAR and Std Dev of the CHIRPS rainfall record. The difference in the MAR between the adjusted CHIRPS and the observed rainfall record was only 2%. The difference in the Std Dev decreased from the initial 21% to 14% and the CV from 15% to 11%.

The Pitman model (rainfall-runoff model) was used to simulate the runoff from the sub-catchments within the study area. In most cases, the flows simulated by the Pitman model are calibrated against observed flows from existing flow gauging stations in the study area. The Pitman model makes use of different so-called regional parameters which can be adjusted depending on the catchment characteristics to enable the modeler to calibrate the simulated flows against the observed flows. By doing this the modeller can increase the CV of the simulated flows to fit that of the observed flows and thereby overcome the problem of the lower CV as found in the CHIRPS rainfall data sets.

An advantage of the CHIRPS rainfall data is that no patching of the data is required, while it always needs to be done with observed data. In general, using the CHIRPS rainfall data worked well in combination with the observed rainfall data. With available current observed rainfall stations becoming less over time it will be very useful to fill these gaps by using CHIRPS rainfall or similar satellite-based rainfall. It is however recommended to always check the satellite-based rainfall against observed rainfall data.

The use of CHIRPS rainfall for monthly data is a useful tool to patch and extend rainfall records, particularly given the declining rainfall records. It also provides areal rainfall rather than point data, not always located in the most representative locations. The use of CHIRPS requires comparisons to SAWS data not just in terms of annual rainfall, but monthly distribution and standard deviation.

4.1.2 Hydrology Networks

The hydrology for the entire Vaal and Orange River catchments was extended to 2004 as part of the ORASECOM Phase 2 Study. The ORASECOM study used as its basis the Vaal River System Analysis Update Study (VRSAU) for the Lower Vaal, covering the period 1920 to 1994. 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 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 concluded that the WRSM2012 Pitman Model setups should rather be used than those prepared for the ORASECOM study.

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 a 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. Groundwater was not included and discharge from dolomitic springs was treated as in inflow into the surface water network rather than being simulated. This was not deemed acceptable as not all dolomites are gauged, and flows have been declining over time, hence these inflows were removed, and the dolomites simulated as runoff units.

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. 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, and catchments with dolomites were subdivided by dolomite compartments and non-dolomitic areas.

Endoreic areas were normally excluded from the gross catchment area when simulating rainfall-runoff in surface water hydrology, since they don't contribute runoff to main river stems. However, recharge occurs over the gross catchment area, and baseflow is generated from dolomitic eyes and to pans, even if it does not reach the main stem. In order to derive a groundwater balance of all recharge and baseflow, gross catchment area must be utilised and runoff which does not reach the main stem lost via transmission losses (reality) or evaporation losses or reservoir/wetland modules. These transmission losses sustain the multitude of wetlands, hence the volumes of baseflow generated from endoreic areas is of significance to the water balance. Ruoff units were modified to include endoreic areas, and their runoff was lost using transmission losses for surface water, and evaporation for groundwater. A challenge remains in that in WRSM Pitman channel losses are 'lost' and do not currently recharge groundwater units. This can only be accounted for at present by increasing recharge in the receiving unit based on the simulated channel loss volume.

4.1.3 Streamflow Gauges

The number of open and useful flow gauges in the Lower Vaal catchment has reduced 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, and these are in D41A. The decline in the available flow gauges is thus a concern. In the Molopo basin there are relatively few gauging stations available to verify the generated data. High losses are experienced from the natural runoff.

Calibrations for the Lower Vaal system was carried out at 6 flow gauging stations and all the dolomitic flow gauging stations.

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.

4.1.4 Water Use

The WRSM Pitman model requires data on actual use for calibration purposes. WARMS data was found to under account for water use as many water supply schemes are not registered. The hydrocensus data was used in preference.

4.1.5 Rainfall-runoff simulation

The rainfall-runoff simulations in the semi-arid areas of the Lower Vaal and Harts rivers seemed to provide good results using the Pitman Model. In the more arid area of the Molopo and Kuruman rivers, it is difficult to tell whether good simulations could be obtained by using the Pitman Model as there were no observed flow gauges that could be used for calibration purposes.

Although good calibrations were obtained at the streamflow gauges located on the main Vaal River downstream of Bloemhof Dam it is important to take note that these calibrations are mainly influenced by the flows in the main Vaal River as the flow from the incremental catchment in the Lower Vaal only contributes in the order of between 1% to 2 % of the flow in the Lower Vaal River. Changing any of the Pitman Model catchment calibration factors to obtain an improved calibration at any of the key sites along the Lower Vaal River mainstream will thus be meaningless as the impact on these flows is minute.

The Harts River a tributary of the Lower Vaal River originates in the Lower Vaal River and thus did not pose the same problem with calibrations as in the case of the Vaal River where high inflows in the Vaal River from upstream of the study area enter the Lower Vaal. Within the Harts River, good calibrations were also obtained although there were several issues regarding inaccuracies of the observed flows at several gauging stations and storage dams.

The Taung Flow gauge (C3H003) seemed to be the best flow gauge to use for calibration purposes in the Upper Harts River catchment, although checks were also carried out at Wentzel Dam (C3R001) and flow gauge C3H017 (Harts at Tlapeng). Unfortunately, there were no observed records available for Taung Dam located between C3H003 and C3H017. The Taung Flow gauge (C3H003) has a long record period of available data from 1938 to 2021 which is ideal for calibration purposes. A very good calibration was obtained at the Taung Gauge (C3H003).

The only flow gauge capturing the flows from the Dry-Harts is the one at Espagsdrif gauge (C3H007) located just downstream of the confluence of the Upper Harts and Dry-Harts Rivers with a relatively long record period of record period from 1964 to 2021. This gauge is thus ideal for calibration purposes and formed in combination with the Spitskop Dam the two main calibration points on the Lower Harts River. Although the flow record as obtained from DWS indicated that the flow data is reliable except for a few flagged monthly values, it was later revealed that this flow gauge is overestimating flows.

This was clearly indicated by the high unit runoffs obtained from the initial calibration at the Espagsdrif gauge (C3H007). Observed data from Spitskop Dam was not up to date and only a record period from 1990 to 2005 of monthly data was available which contained several unreliable values as flagged by DWS. This gauge was initially used as the secondary calibration point on the Lower Harts but due to the overestimation of flows at the Espagsdrif gauge (C3H007) that were only later discovered, it was changed to the primary calibration point to obtain more realistic unit runoff values that compared with the surrounding areas.

The only surface water flow gauge in the Molopo and Kuruman catchment that could be used for calibration purposes is D4H002 in D41B located in a small tributary of the Setlagole River. The observed flow however did not correspond well to the simulated flow, and it was thus not used for calibration. One could then use the normal regional Pitman Model parameters to simulate the flows in the arid Molopo and Kuruman catchments. This however provided an unrealistic high flow that does not occur in reality.

As part of a previous detailed ORASECOM study on the Molopo basin, calibrated Pitman parameters were transferred to similar sub-catchments that could not be calibrated. This was followed by a larger-scale Pitman Model calibration based on historical extreme events and anecdotal evidence of flows along certain parts of the lower river reaches. Riverbed losses were used as part of this calibration process. These findings were accepted for the purpose of the current study. These calibrations were improved through the groundwater calibrations to be carried out for quite a number of the dolomitic eyes in this area where some observed data is available. The groundwater-surface water interaction modelling was not part of the ORASECOM Study.

The large difference between the total natural flow of 86.3 million m^3/a and the total Molopo/Kuruman outflow from the study area of 23.7 million m^3/a is mainly due to river bed and evaporation losses, with a small contribution due to surface water usage.

4.1.6 Groundwater level Data

Groundwater level data is available from 233 open stations. 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. 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.

4.1.7 Groundwater Resources

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.

According to GRAII, baseflow generation is largely restricted to the C31-C33 catchments. This is not actually the case as dolomitic compartments generate baseflow, however it is lost down channel. Hence a full surface and groundwater balance is not possible from GRAII and Wr2012 alone.

Simulated recharge is significantly higher than GRAII in dolomites, and significantly lower in non-dolomitic sub-areas. The rainfall recharge relationship shows a distinct difference between dolomitic and non-dolomitic aquifers, with a variation between dolomitic aquifers overlain by Kalahari sand and those not.

4.2 Linkage to Other RDM studies

The use of an integrated calibrated approach surface and groundwater methodology, with endoreic areas and dolomitic discharges included, provides a coherent water balance for surface and groundwater that can be used for setting realistic Reserve values at based on selected surface water points or groundwater Reserves at compartment level. This avoids situations where recharge cannot be accounted for in observed baseflow volumes, or reserve volumes exceeding actual baseflow. The derived networks can also be used to assess the impacts of future proposed surface and groundwater abstractions on flows at selected IFR points.

4.3 Stakeholder Participation

The stakeholder engagement process followed has provided sufficient opportunities for stakeholders to become involved in the process. Stakeholders received information through a variety of avenues. The process has allowed sufficient time for stakeholders to contribute. The stakeholder process was transparent; stakeholders had access to all technical documents and project team members to clarify matters of concern.

Based on the inputs received during the stakeholder engagement process, the following conclusions may be drawn:

- Stakeholder engagement and participation was central and effective throughout the whole project process and as such, improving the credibility of this report and also consensus in the findings.
- There was a strong desire and participation by mostly the municipalities as stakeholders in the work being undertaken.
- Project Sterring Committee meetings were a vital initiative in maintaining dialogue amongst stakeholders.
- The department should view the trust, ownership and confidence that this stakeholder engagement has built as an investment towards achieving the overall goals envisaged in this report.
- Consensus and transparency were of utmost importance when the issues and concerns of stakeholders were being discussed.
- Overall, stakeholders played a key role in the determination of project findings and outcomes. For this reason, stakeholder engagement served as a vital tool for the whole project process

and gave an indication of whose interests should be considered and why they should be included in the decision-making process.

- Ensuring attendance at meetings remains difficult and requires rigorous follow-up.

5 INFORMATION REPOSITORY

All the reports and relevant information utilised and generated were provided electronically on a flash drive.

Data have been indexed according to the directory structure given in **Table 6-1.**

Data	Directory	Format
Final Reports	Reports	pdf
GIS coverages	GIS	shp
Training	Training	Word, ppt, WRSM networks
WRSM Pitman networks	WRSM	WRSM networks
Meeting Minutes, agendas, BIDs, presentations, stakeholder list	Management	Word, ppt, xls

6 RECOMMENDATIONS

Recommendations are summarised below, and further detail is available from the Main Summary Report.

- Existing water use licences need to be verified against actual use.
- The groundwater Reserve for the Lower Vaal needs to be revised in light of the calibrated recharge and baseflow volumes derived and data on existing use.
- The use of CHIRPS rainfall for monthly data is a useful tool to patch and extend rainfall records, particularly given the declining number of rainfall records, missing data and availability of rainfall data. It also provides areal rainfall rather than point data, not always located in the most representative locations. In future, the CHIRPS data can be used with confidence in combination with observed rainfall data to provide reliable runoff. It is however always important to compare and evaluate the CHIRPS data against observed data as the CHIRPS data might require some adjustments.
- DWS should obtain an agreement with SAWS to obtain rainfall data from them for DWS hydrology and related studies at a reasonable cost for all DWS studies.
- DWS should start with dam balances for Taung Dam to build up inflow and outflow records at this key point for future use.
- DWS need to check the flow record for gauge C3H017 (Harts at Tlapeng) as there seem to be some glitches in the data. If this can be corrected it might be a good flow record to be used in future.

- A new flow duration curve is required for the Espagsdrif gauge (C3H007) as it is overestimating the actual flows at this site. DWS should add a note to this record to warn users about this overestimation of observed flows.
- Spitskop Dam is a key point on the Lower Harts River, and it is very important that the dam balance for this dam is up to date and accurate
- Observed flow records cannot be used for baseflow separations to estimate recharge where non-stationarity and declining discharge, or where increasing groundwater abstraction, large point source discharges or abstractions and streamflow reduction activities exist. Naturalised flows are required.
- A significant problem with recharge estimation in isolation from surface water investigation is the potential for estimating large volumes of recharge whose fate is not accounted for, or possibly insufficient recharge to meet observed baseflow and spring discharge. Such water balance discrepancies should be investigated before calculating the Reserve.
- Endoreic areas are normally excluded from the gross catchment area when simulating rainfall-runoff in surface water hydrology, since they don't contribute runoff to main river stems. However, recharge occurs over the gross catchment area, and baseflow is generated from dolomitic eyes and to pans, even if it does not reach the main stem. In order to derive a groundwater balance of all recharge and baseflow, gross catchment area must be utilised and runoff which does not reach the main stem lost via transmission losses (reality) or evaporation losses or reservoir/wetland modules. These transmission losses sustain the multitude of wetlands, hence the volumes of baseflow generated from endoreic areas is of significance to the water balance.
- It is highly recommended to have reconciliation and integrated surface/subsurface hydrology in parallel with classification and Reserve studies.
- Validated water use data is a prerequisite for high confidence classification outcomes, and water use is a challenge for both model calibration and determining Allocable groundwater
- Long term monitoring is critical. Without the necessary investment before the study high confidence results cannot be provided regardless of how much time and effort goes into field investigations.
- Operationalisation and monitoring in order to implement all recommendations and exercise compliance control.
- It is recommended that the members of the PSC be valued as stakeholders of the department who have already been capacitated to a certain degree. They have already received and have participated in the process and should be kept informed of the next steps following the completion of the project.
- For the outcomes to be used for licensing or setting RQOs, it is recommended that the integrated water balance be understood buy officials so that the impacts of further allocations are understood. This can be achieved by maintaining a lice WRSM Pitman model set up, where

new allocations are added to the model and impacts assessed relative to RQOs and impacts on other users. Comprehension of model results enhances confidence in the results.

- Specialist scientists within DWS need to play a much stronger role in verifying results provided by PSPs to ensure surface and groundwater resources provide a reasonable water balance. The project has shown that the right candidates can quickly learn the basics of integrated modelling and come up with acceptable water balances.

7 REFERENCES

Department of Water and Sanitation (DWS), South Africa. 2023. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Groundwater Protection Zones Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0323

Department of Water and Sanitation (DWS), South Africa. 2023. Investigation of Groundwater and Surface Water Interaction for the Protection of Water Resources in the Lower Vaal Catchment: Groundwater Quality Categorisation Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0223

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: Recharge and Baseflow Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0123.

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: Water Resources Assessment Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0522

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: Hydrocensus Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0422

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: Gap Analysis Report. Prepared by WSM Leshika Consulting (Pty) Ltd. Report no. RDM/WMA05/00/GWSW/0322

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

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. Prepared by: WRP Consulting Engineers (Pty) Ltd

Department of Water and Sanitation (DWS) 2014. Determination Of Resource Quality Objectives in The Lower Vaal Water Management Area (WMA10) WP10535 Resource Unit Delineation Report. Report Number: RDM/WMA10/00/Con/RQO/0113. Prepared by: the Institute of Natural Resources (INR) NPC.

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. Prepared by: Institute of Natural Resources (INR) NPC. INR.

Department of Water Affairs, South Africa, February 2012. 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. Prepared by: WRP Consulting Engineers (Pty) Ltd.

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. Prepared by: 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. Prepared by: Raath, CJD (AGES).

Department of Water Affairs and Forestry 2008. Vaal River System: Feasibility Study for Utilisation of Taung Dam Water. Main Report. P WMA 10/C31/00/0408. Prepared by Kwezi V3 Engineers.

Department of Water Affairs and Forestry, South Africa, March 2004. Development Of Internal Strategic Perspectives Groundwater Overview for Lower Vaal Catchment Management Area. Prepared by: Darcy Groundwater Scientists and Consultants.

Department of Water Affairs and Forestry, South Africa. 2004. Internal Strategic Perspective: Vaal River System Overarching. Report No P RSA C000/00/0103. Prepared by: PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3.

Sami, K & Druzynski, AL (2003). Predicted Spatial Distribution of naturally Occurring Arsenic, Selenium and Uranium in groundwater in South Africa-Reconnaissance Survey. WRC Report 1236/1/03.

Department of Water Affairs and Forestry 2002. Lower Vaal Water Management Area: Water Resources Situation Assessment Report Main Report P 10000/00/0301. Prepared by: BKS.

Department of Water Affairs. (1998). WRC Report Nr. TT 101/98: Quality of Domestic Water Supplies. Volume 1: Assessment Guide. The Department of Water Affairs and Forestry, Pretoria.

Lynch, S.D., Reynders, A.G., and Schulze, R.E. (1997). A DRASTIC approach to groundwater vulnerability in South Africa. South African Journal of Science, vol.93, February 1997.