

Mine Water Sharing for Sustainable Water Security - A Strategy for a Water-Scarce Region

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Abstract

The study investigated mine water sharing as a strategy to address water scarcity in Rustenburg, South Africa. Active and abandoned mines store water creating subsurface reservoirs that supplement municipal, agricultural, and mining demands thereby supporting economic development. The research developed a legally aligned, implementation framework supported by stakeholder engagement, hydrochemical analyses and hydrogeological modelling. Results show most mine water requires minimal treatment, with hardness and nitrates as primary concerns. Numerical models estimated sustainable yields and a prioritisation tool identified high-potential areas. A case study and financial analysis will confirm feasibility and then support replication across other mining regions.

Keywords: Water scarcity, mine water sharing, underground reservoirs, water-scarce region, modelling

Introduction

South Africa has a rich heritage of over 150 years of deep mining across all provinces. The Rustenburg area, northwest and west of the main industrial areas of Johannesburg and Pretoria, has been mined for Chrome and Platinum since the 1950's. Mining creates underground and surface voids, which then fill with water, creating new underground reservoirs, aka aquifers and surface storage.

The Rustenburg region of South Africa is water-scarce with a fast-growing population, and numerous socio-economic and infrastructural challenges undermine equitable, reliable access to high-quality water. Seasonal rainfall variability and aging infrastructure (RLM 2022) exacerbate these issues. Within the region, active Chrome and Platinum mines generate excess water that requires safe management or disposal. Moreover, closed underground workings create underground mine voids and storage zones that are not depleted by evaporation. These mine voids present an untapped opportunity to augment supplies for nearby communities and water-stressed sectors such as agriculture and other mining operations. Their incorporation into the

regional water supply will reduce demand on an overstretched municipal supply system. This study, funded by the Water Research Commission of South Africa, is investigating how this unused asset can be integrated in a regional water supply and conservation strategy.

Figure 1 shows the area of the study, comprising parts of four quaternary catchments in the Rustenburg and Madibeng Local Municipalities, and the geology. Figure 2 shows the mines in the area and their proximity to villages and towns, all of which require reliable water supply to enable them to support economic growth and generate income for the area.

Methods

This study is developing a step-by-step, implementable mine water sharing strategy aligned with local legislation. Adoption by stakeholders, including mining companies, municipalities, water authorities, and government will facilitate the sustainable distribution of excess mine water stored in abandoned workings. Successful implementation of the mine water sharing strategy requires evaluating the quality and quantity

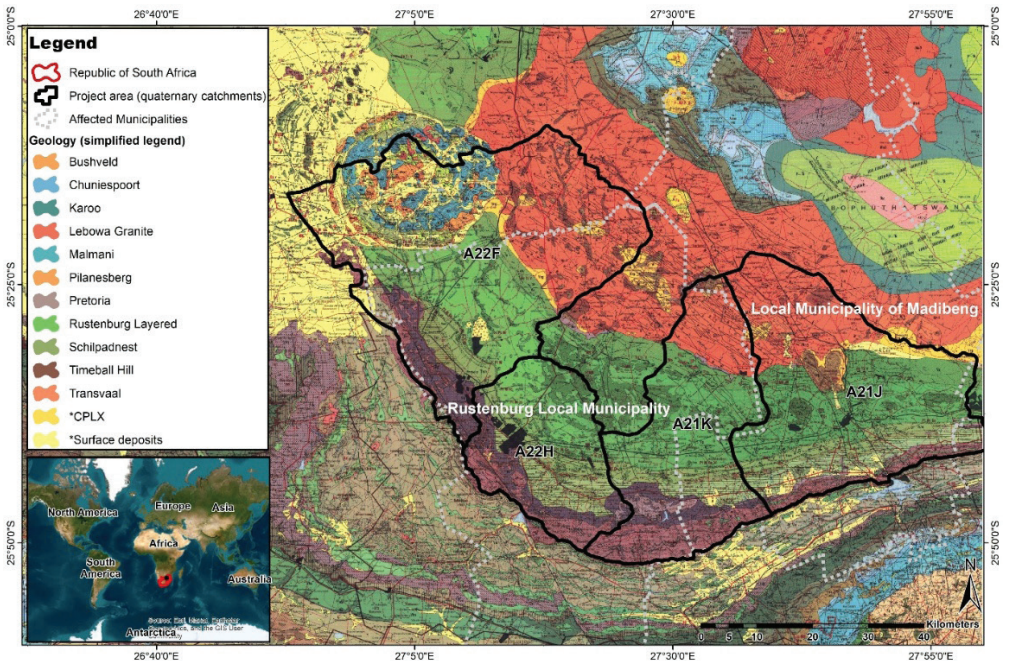


Figure 1 Location of the study area and its geology, Rustenburg, South Africa (GSSA 1981).

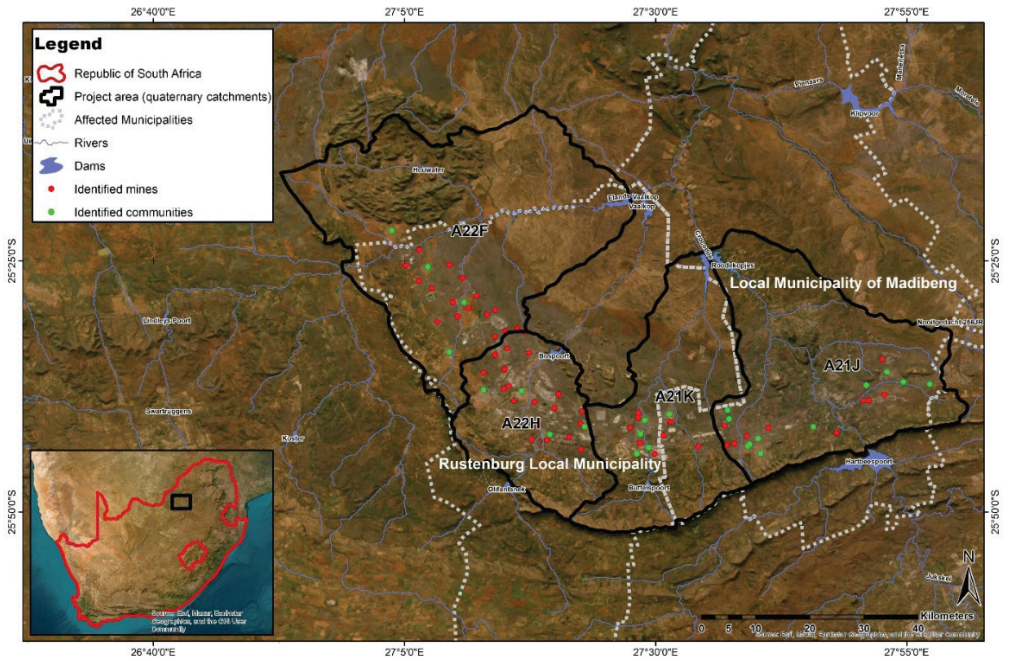


Figure 2 Mines in the study area and their proximity to villages.



of mine water, identifying potential treatment and reticulation options, and assessing local demand.

The scope of work comprised: a desk top study, stakeholder engagement, geochemical analysis, and numerical hydrogeological modelling followed by prioritisation of an area for use in a case study.

Desktop assessment

Information was collected and reviewed to support a mine water sharing strategy, understand the legal compliance requirements, and to collate the geological, hydrogeological, and other relevant environmental factors. Key national and spatial datasets were obtained including long-term meteorological records from the South African Weather Service (SAWS), topographic data, borehole records from the National Groundwater Archive, surface-water quality and quantity data from the Department of Water and Sanitation's (DWS) National Integrated Water Information System. The DWS also provided water use data and spatial data from the 2012 Water Resources of South Africa study. Literature on the geology and hydrogeology, as well as open-source data about mine water quantity and quality were also reviewed

A legislative review was done to identify statutory constraints and institutional roles for implementation. This included water needs evaluation and a review of historic augmentation efforts. The desk study also compiled an inventory and assessment of legacy, active and planned underground mine workings and their inflows, water balances and post-closure scenarios. Finally, the desk top study characterised and summarised the climate, topography, drainage, land cover, geology and hydrogeology to establish preliminary recharge estimates and hydrogeological parameters for the area.

Stakeholder engagement

A structured, top-down approach guided the stakeholder engagement process, beginning by engaging the water use authorities then municipalities, water services providers, and mining companies. On-line and in person consultations were used to introduce the

project, gather feedback and sentiment, receive suggestions, and request data for the overall study.

Geochemical analysis

Mine water chemistry determines the methods used for treatment to ensure the water is fit for purpose. Open-source mine water quality data was collected and compiled into a consolidated water quality database. Water quality data was also provided by Tharisa Minerals from their active Chrome mine. Low-flow verification sampling was done at the Tharisa Mine. The quality of water being used by villages and townships was assessed through spot sampling within selected communities to identify background usage.

Piper trilinear diagrams were used to characterise and group different water types at each mine, while Stiff diagrams were used to map the water quality variations across the project area. Results were benchmarked against the South African National Standards (SANS) 241-1 2015 (drinking water) and DWS Target Water Quality Guidelines (agricultural use), to identify the need for treatment. Time-series graphs and regression models were used to identify long-term trends and to identify parameters of concern. Hardness and Nitrate were the main parameters identified as requiring reduction.

Numerical hydrogeological modelling and prioritisation

High-level numerical hydrogeological models for each catchment have been developed in a FEFLOW™ to estimate the volume of groundwater inflow and storage within the reservoirs created by mining. An Excel-based analytical water balance model was used to estimate preliminary groundwater inflows and outflows as input to the numerical models. The groundwater models included all relevant flow boundaries as translated from the desktop conceptualisation.

An Excel-based prioritisation tool was developed to weight and rate criteria to identify areas for potential sharing of water. The criteria included: proximity of source to potential water users, water quality and treatment requirements, reticulation options,



accessibility of the resources, groundwater inflow and volume stored in the potential sources, and the needs of potential recipients. The results will be used to select a high-priority area for use as a case study. The next phase will draft a step-by-step implementable water sharing strategy, apply it to a prioritised area, and then conduct an economic evaluation for the case study area to determine the financial feasibility.

Results and Discussion

Desktop assessment

The Rustenburg area is characterised by a semi-arid climate, with low, variable rainfall and high evaporation rates (SAWS 2024). The topography is diverse, with several notable drainage systems and runoff patterns that influence water availability. Geologically, the area has key structural features such as faults and dykes that influence groundwater flow. The rocks consist of a diverse set of lithologies belonging to the Pretoria Group (Transvaal Supergroup), the Bushveld Igneous Complex, and the Pilanesberg Complex. There have also been multiple phases of dyke and sill emplacement. Four main sets of faults have been identified. The most noteworthy fault set is NNW-oriented faults that parallel the Brits Graben, probably formed in an extensional regime, and can be substantial carriers of groundwater. The major natural aquifers include alluvial, shallow intergranular, and fractured systems.

The desktop assessment established the need for additional water sources. The Rustenburg (RLM) and Madibeng (MLM) Local Municipalities suffer severe water scarcity, driven by increasing demand from rapidly growing urban and rural populations. Table 1 and 2 show the population's access to water infrastructure and the reliability of the water supply in the RLM and MLM, respectively.

52% to 60% of both rural and urban populations (about 500 000 people in both areas) in the Rustenburg and Madibeng areas have reliable access to water infrastructure and reliable supplies. This water is primarily supplied by the municipality from some boreholes and three supply systems:

1. Magalies Water (Vaalkop System): This is a primary source, providing approximately 80 Mℓ (megalitres) per day to the towns and mines.
2. Rand Water (Barnardsvlei System): Supplies approximately 120 Mℓ per day to the municipality and mining sector.
3. Bospoort Dam (via Bospoort Water Purification Works): Managed by the Rustenburg Local Municipality, this source provides approximately 12 Mℓ per day.

The population is growing rapidly meaning that additional sources of water are required. Old and new mines, mainly Platinum Group Metals (PGM's) and Chrome, may provide additional storage and can be used as supplementary water supplies.

Table 1 Population with access to water infrastructure and reliable supply in the RLM (DWS n.d.).

Area Type	Population	Population with Water Access	Population with Reliable Supply	% Population with Water Access	% Population with Reliable Access
Rural	191 996	183 653	99 773	96	52
Urban	372 167	351 367	191 842	94	52

Table 2 Population with access to water infrastructure and reliable supply in the MLM (DWS n.d.).

Area Type	Population	Population with Water Access	Population with Reliable Supply	% Population with Water Access	% Population with Reliable Access
Rural	341 921	257 307	204 004	75	60
Urban	187 739	141 200	111 971	75	60

An inventory of 53 mines and mine shafts was created and their potential contribution calculated. Inflows into mines across quaternary catchments A22F, A22H, A21K, and A21J range from 100 to 4 000 m³/d which can be used to meet domestic and industrial demand.

Several key pieces of legislation that affect the implementation of a bulk water-sharing strategy were reviewed, notably the National Water Act (1995). No legal obstacles for the implementation of this mine water sharing strategy were identified, and the mine water sharing strategy will be further developed to detail the specific legislative requirements.

Stakeholder engagement

The most complex aspect of this study is getting all the different water authorities and suppliers to contribute. The DWS provided guidance as the Competent and National Water Use Authority. RLM and MLM (local Water Services Authorities) highlighted water scarcity and infrastructure challenges. Mining companies, including Sibanye Stillwater and Implats (combined they own 75% of operations in the study area), provided operational insights. Concerns were raised

regarding liability and community trust when sharing water. The Royal Bafokeng Nation (RBN), Magalies Water (a local Water Service Provider), and the South African Minerals Council offered to facilitate connections with relevant departments. Overall, these entities emphasised the need to confirm the scientific feasibility for the area to develop a mine water sharing project, before engaging farmers and communities to prevent raising false hope. The approaches to the Department of Mineral and Petroleum Resources and Rand Water (the largest bulk water supplier in Africa) have yet to yield a response.

Geochemical analysis

Hydrochemical data show that minimal treatment of mine water will be required to meet the SANS for domestic use (SABS 2015). Hardness and nitrate concentrations are the principal concerns, while trace metals were detected only sporadically. Mine water quality in the Rustenburg region can typically be classified as magnesium-bicarbonate dominant or mixed (Fig. 3). At numerous sites, samples had to be taken from pre-filled buckets, as water was not available from the taps 24 hrs a day. In communities, nitrate was

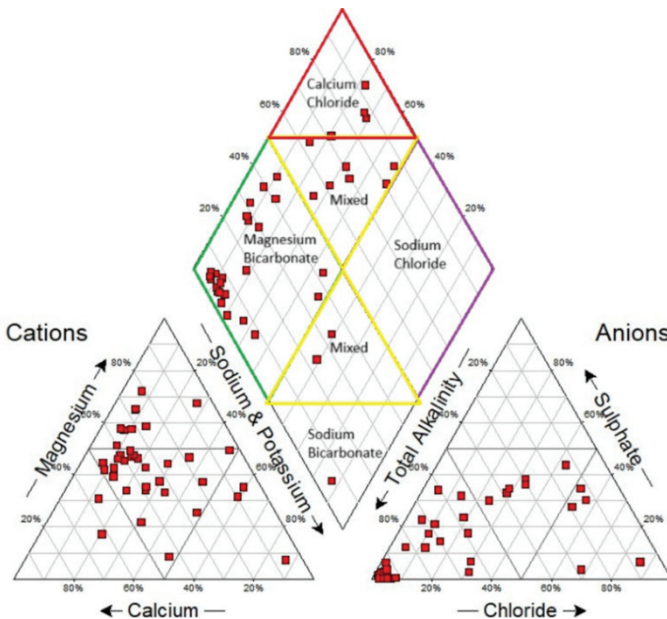


Figure 3 Typical water quality from mines in the Rustenburg project area.



identified as a parameter of concern at 71% of the sites and poses chronic health risks to domestic users. E. coli, manganese, fluoride, and turbidity posed localised risks.

Numerical hydrogeological modelling and prioritisation

The analytical water balance showed that all catchments exhibit a positive net water balance, confirming the presence of usable groundwater resources. Recharge through rainfall dominates the inflow component of the water budget, mine sites such as pits, backfilled areas, and waste rock dumps have enhanced recharge and increase water storage. The numerical model indicated a reliable and stable regional groundwater system, with a balanced water error of only 0.1%. The numerical model results show:

- Quaternary catchment A21K indicated the highest cumulative pit inflows, typically ranging between 10 000 to 30 000 m³/day with distinct sharp peaks during high-recharge periods
- Quaternary catchment A22H indicated the highest cumulative underground reservoir inflows, stabilising at 12 000 to 13 000 m³/day

This data will be fed into the prioritisation tool to select an area for a detailed case study.

Further Work

In the next phase, a comprehensive, step-by-step implementable mine water-sharing strategy will be developed. This will be supported by a detailed case study that conceptualises the implementation of mine water sharing within a prioritised zone. The case study will include financial models quantifying the costs and benefits over defined timeframes. Insights from the case study will be used to refine the overall strategy, promoting its implementation and potential replication across other South African mining regions.

Conclusions

Early findings conclude that it will be feasible to use water stored in old underground workings of PGM and Chrome mines to supplement the water supply to the Rustenburg area. The hydrochemistry indicates that it will require minimal treatment to meet the SANS for domestic use. Hardness and nitrate concentrations represent the principal concerns, while trace metals were detected only sporadically. Numerical modelling indicated high daily inflows into underground voids and increased storage.

We are confident that the financial modelling will show that it will be cost-effective to use mine storage water to contribute to the long-term planning for the development of the Rustenburg area. The strategy can then be applied to other mining regions world wide taking into account the hydrochemistry of each different metal mined.

Acknowledgements

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References

- Department of Water and Sanitation (DWS n.d.) National Integrated Water Information System. <https://niwis.dws.gov.za/niwis2/>
- Geological Survey of South Africa (GSSA 1981) Geological Sheet Rustenburg 2526. GSSA, Pretoria, Gauteng, RSA
- Rustenburg Local Municipality (RLM 2022) Rustenburg Local Municipality 5-Year IDP 2022/2027. <https://www.rustenburg.gov.za/wp-content/uploads/2022/07/IDP-2022-2027-FINAL.pdf>
- South African Bureau of Standards (SABS 2015) SANS 241-1:2015 Drinking water - Part 1: Microbiological, physical, aesthetic and chemical determinants. Pretoria, South Africa: SABS
- South African Weather Service (SAWS 2024) Daily and Hourly Weather Data. <https://www.weathersa.co.za/>
- Water Resources of South Africa study <https://waterresourceswr2012.co.za/>