



FACULTY OF ENGINEERING

DEPARTMENT OF WATER RESOURCES ENGINEERING

FINAL YEAR PROJECT REPORT

**ASSESSMENT OF GROUNDWATER VULNERABILITY TO
IMPACTS OF UNDERGROUND MINING:**

CASE STUDY: GREENSTONE RESOURCES LTD, TIIRA TOWN COUNCIL

BY

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*This final year report is submitted to the Department of Water Resources Engineering
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ABSTRACT

Underground mining posed significant risks to groundwater systems, particularly in geologically complex regions. This study assessed the vulnerability of groundwater resources to the impacts of underground mining at Greenstone Resources Ltd., located in Tiira Town Council, Busia District, Uganda. The research aimed to (i) identify and categorize the geological and hydrological features of underground mining tunnels and their surrounding groundwater systems, (ii) develop a numerical model to determine groundwater flow behavior, and (iii) simulate the extent of directional changes in groundwater flow due to tunneling.

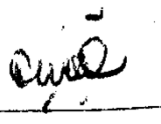
A combination of field data, borehole logs, and spatial analysis using GIS and MODFLOW 6 was employed. The study area exhibited a shallow water table (12–20 m), with dominant geological features including shear zones, quartz veins, and weathered regolith influencing water movement. A three-layered aquifer system was defined and modeled, incorporating weathered regolith, weathered rock, and fractured rock, each with distinct hydraulic properties. Simulation results revealed flow redirection, particularly around highly fractured and faulted regions. The modeling confirmed that mining activities disrupted natural groundwater gradients, intensified hydraulic head loss, and increased vulnerability in adjacent aquifer units.

The study underscored the importance of hydrogeological characterization and numerical modeling in assessing and mitigating groundwater risks in mining-impacted areas. The findings provided critical input for groundwater management, policy development, and the design of environmentally responsible mining practices, contributing to the achievement of Sustainable Development Goals 6 (Clean Water and Sanitation) and 12 (Responsible Consumption and Production).

DECLARATION

I Olwa Alan, hereby declare that the work presented in this research report is entirely my own, except where appropriate references have been cited. This work has not been previously submitted for any academic award at any institution of higher learning.

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SUPERVISOR'S APPROVAL

This is to certify that this report has been under my supervision and is ready for submission to the Department of Water Resources Engineering of Busitema University.

SIGN:

A handwritten signature in black ink, consisting of stylized, overlapping loops and a long horizontal stroke at the bottom.

DATE: 19th-MAY-2025

NAME: Mr. Oketcho Yoronimo

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LIST OF ABBREVIATIONS

DISV	Discretization by Vertices
DRN	Drain
GIS	Geographic Information System
GSI	Geological Strength Index
HFB	Horizontal Flow Barrier
MODFLOW	Modular Finite-Difference Groundwater Flow Model
NDP III	National Development Plan III
SDG	Sustainable Development Goals
SGS	United States Geological Survey

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5. Conclusion and Recommendations

This study confirmed that underground mining at Greenstone Resources Ltd significantly alters groundwater flow, increasing vulnerability in fractured zones. The MODFLOW 6 model provided robust predictions, highlighting the role of faults and shear zones in flow disruption.

To mitigate impacts, I recommend:

- a) Regular monitoring of piezometric levels and pumping rates should be institutionalized around mining shafts and community boreholes to detect early signs of aquifer stress.
- b) Establish threshold pumping limits, particularly in highly fractured or weathered zones, to prevent irreversible and aquifer collapse.
- c) Conduct a comparative analysis of groundwater depths over time to assess the extent of changes caused by mining activities.
- d) Based on vulnerability assessments, invest in alternative sources such as rainwater harvesting or piped surface water supply systems, particularly in affected areas like Buteba and Salama villages.

These measures support sustainable mining and SDG 6 and 12 objectives.

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References

Adadzi, P., Allwright, A., & Fourie, F. (2022). Multivariate and geostatistical analyses of groundwater quality for acid rock drainage at waste rock and tailings storage site. *Journal of Ecological Engineering*, 23(12), 1–15.

- Akurugu, B. A., et al. (2022). Groundwater resources assessment in the Densu Basin: A review. *Journal of Hydrology: Regional Studies*, 40, 101017.
- Chen, S., et al. (2021). Investigation of the impacts of tunnel excavation on karst groundwater and dependent geo-environment. *Environmental Science and Pollution Research*, 28(30), 40203–40216.
- Liu, R., et al. (2022). Analysis of groundwater changes (2003–2020) in the North China Plain using geodetic measurements. *Journal of Hydrology: Regional Studies*, 41, 101085.
- Ma, C., et al. (2021). Numerical investigations of the tunnel environment effect on the performance of energy tunnels. *Renewable Energy*, 172, 1279–1292.
- Mukisa, G. (2022). Water crisis hits Buteba sub-county. *Uganda Radio Network*. Retrieved from <https://ugandaradionetwork.net/story/water-crisis-hits-buteba-sub-county->
- Patel, V. K., & Raja, B. D. (2021). Comparative performance of recent advanced optimization algorithms for minimum energy requirement solutions in water pump switching network. *Archives of Computational Methods in Engineering*, 28, 1545–1559.
- Wang, C., et al. (2023). Hydrogeochemical evolution induced by long-term mining activities in a multi-aquifer system in the mining area. *Science of the Total Environment*, 854, 158806.