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Analogy of the mineral systems approach with the new proposed groundwater vulnerability approach: Case study of Highveld-Ermelo-Witbank coalfields, South Africa

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South Africa has nineteen coal provinces, of which the current mining activities are largely focused in the Highveld, Ermelo and Witbank coalfields of Mpumalanga province, South Africa. Several areas have been mined out and some areas are still to be mined, hence appropriate tools to avoid and mitigate impacts of mining on groundwater need to be developed. This can be done by doing a groundwater vulnerability assessment and advising policy and decision makers, miners on groundwater vulnerability status of the coalfield with regard to effects of surface introduced pollution sources.

The minerals system approach for mineral exploration involves the understanding of geological processes that are required to form and preserve an ore deposit. It gives emphasises on those processes critical to the formation of a mineral deposit i.e. driving energy – ligands / metal source – transport – trap and outflow, where all processes must occur for a deposit to be formed. This approach can be translated into an approach for assessment of groundwater vulnerability. The mineral systems approach components can be translated to: driving energy being water, ligands / metal sources translated to pollutant sources, transport - trap translated to soil and unsaturated zone properties and the outflow translated to the aquifer properties. This translation was illustrated using a case study of Witbank-Ermelo-Highveld coalfields. Predictor layers for water sources (rainfall, dams, rivers and irrigation), pollutant sources (agricultural area, mines and landfills), transport – traps (soil, vadose properties) and outflow (aquifer properties) were produced. The predictor layers were generated for each catchment and results combined to form predictor layer for the entire coalfield. Knowledge based GIS - fuzzy inference system (FIS) was build were predictor layers were transformed into fuzzy memberships based on expert knowledge of the relative importance of each layer to groundwater vulnerability. Fuzzy membership functions for each layer were combined using a series of AND, OR and GAMMA fuzzy operators to generate a fuzzy model for groundwater vulnerability of the study area.

US EPA developed DRASTIC model for groundwater vulnerability assessment was also produced for the study area and the results compared very well with the fuzzy results using the mineral system analogue approach. Vulnerability was done per catchment and results combined showing areas with high, moderate and low vulnerability. Highly vulnerable areas were identified on the northern corner of the study area where dolomites were mapped and high pollutant loads. Results from the correlation analysis indicate a significant association between high groundwater nitrate and sulphate concentration with high groundwater vulnerability areas. Correlation coefficient of 0.72 between nitrate and groundwater vulnerability were obtained from the FIS as compared to 0.58 of the DRSTIC method. This shows that the new approach can be used as another approach for groundwater vulnerability assessment. The approach accounts for surface water – groundwater interaction but only valid for water soluble pollutants as water acts as the driving energy for pollutant transport. It only accounts for pollution migration until groundwater and does not account for travel thereafter. Further research to refine the approach includes incorporation of the transport mechanisms and regional groundwater flow into the predictor layers.