Regolith importance in groundwater development

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SUSTAINABILITY OF WATER AND SANITATION SYSTEMS

Regolith importance in groundwater development

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THROUGHOUT UGANDA, CRYSTALLINE basement rocks are extensively concealed by a regolith which is the result of intense chemical weathering. The extent of chemical weathering and hence development of the regolith depends on the nature of the basement rock including its age structure and lithology as well as the climate and relief. Its saturated thickness is variable and the aquifer can be dry in areas of low rainfall and or steeply sloping topography.

Interest in the regolith has gained considerable momentum in recent years with the recognition that it may provide a more sustainable and less costly source for rural water supplies that the bedrock fractures.

Hydrogeological investigations aimed at determining the regolith characteristics and nature of the relationship between regolith and bedrock aquifers have been undertaken under Hydrogeology Uganda phase II research project.

The work was carried out through geophysical surveys, exploratory drilling, core sampling, grain size analysis, piezometer testing and pumping tests.

Description of the methods

Geophysical surveys

These were carried out to determine regolith thickness and provide an indication of regolith lithology which in most cases have an effect on yields of shallow wells. The surveys involved carrying out Electromagnetic (EM) and Surface resistivity Studies. Surveys were mostly carried out on sites adjacent to existing boreholes where test holes were drilled. This made it possible to compare these results with those obtained during drilling.

Exploratory drilling

A number of wells were drilled in the study areas in an effort to:

- determine regional hydraulic gradient
- allow monitoring of water levels during extended pumping tests of production wells
- carry out both water and sediment sampling
- carry out geological logging
- carry out piezometer tests

Core sampling

This was carried out during drilling of the test holes to obtained sediment samples for analysis. Sampling was done whenever there was a change in colour and or lithology.

Grain size analysis

This was used to estimate the regolith hydraulic conductivity and the distribution of minerals in the vertical section of the regolith. A number of methods of calculating hydraulic conductivities of the regolith from grain size data are available but most of these relationships are derived from well sorted material. Since the regolith demonstrates considerable heterogeneity in its grain size distribution a method which takes care of that was adopted in the study. This method was developed by Masch and Denny (1966) and its an empirical relationship between a formation's mean grain - size (d50) and its hydraulic conductivity that incorporates a measure of a material's heterogeneity in grain size (6).

$$6 = (d84 - d16) / 4 + (d95 - d5) / 6.6$$

where the d % s represent the grain diameter by which that % mass of sample is finer.

Grain size analysis was performed by standard wet-sieving procedures.

Piezometer testing

This was carried out to determine in situ values of hydraulic conductivity. Two kinds of tests namely bail tests and slug tests were performed. Bail tests involve the removal of the cylinder to cause an instantaneous decline of water level, slug test involve the addition of the cylinder to cause a water level rise. The two tests were performed in sequence, the cylinder first being inserted and later removed. A series of water level measurements were taken at 20 second intervals.

Pumping tests

Long pumping tests were carried out to determine whether there is any hydraulic interaction between the regolith and bedrock aquifer. Pumping of a production well lasted for 24 hours or more and measurements of drawdown were made in the pumped well and in an observation well located in the regolith, 5m from the pumped well.

Results

Geophysical Surveys

Combined use of Electromagnetic and Resistivity surveys made it possible to determine regolith thickness and lithology. The results obtained were verified by drilling data and were found to be almost similar. Results obtained using Electromagnetic methods along a transect sometimes vary as they are affected by varying depths to

Table 1. Shows relationship between regolith thickness determined by resistivity sounding and the regolith thickness as indicated by the length of the casing installed

Borehole Number	Regolith Thickness Resistivity (m)	Casing depth (m)
CD3651	20	27
CD78	36	39.5
WDD312	30	31
CD722	12	19
WDD53	45	33.7
CD2253	48	37

N.B It should be recognized that casing length is not an ideal measure of regolith depth as casing usually penetrates a metre or two beyond the weathered zone to permit a good grout seal to be obtained in solid bedrock.

bedrock and lithological changes. The results of the method have therefore to be used with borehole control otherwise they may be difficult to interpret. In most cases they were found to be far different from those obtained by both resistivity method and drilling and were therefore not always reliable.

However, a generally favourable relationship is shown. Resistivity surveys gave an indication of regolith lithology since each soil type has characteristic resistivity values.

Exploratory drilling

Water levels measured in the drilled holes were used to determine the regional hydraulic gradient and therefore flow direction. Water and soil sampling plus piezometer testing of the regolith were made possible by drilling of test holes. In addition to the above, it was possible to monitor water levels in the test holes during extended pumping tests of adjacent production wells.

Grain size analysis

Soil samples obtained during core sampling were analyzed for grain sizes in order to determine the hydraulic conductivity of the regolith. From the analysis it was found that the numerical values of 6 range from 0 for very well sorted material to 4 for very poorly sorted.

Piezometer testing

The observation of the recovery of water level with time gave an indication of the permeability of the formation. A rapid water level recovery indicated a permeable medium while a slow recovery occurred in low permeability materials. The results were analyzed and interpreted using AQTESOLV software.

An order of magnitude difference exists between the hydraulic conductivity of the muddy sand aquifer in the regolith predicted by the field piezometer tests and laboratory grain size analyses. In situ field experiments are usually more reliable than empirical data gained in the laboratory. This stems largely from the problem of extracting a representative sample of the aquifer medium in the field for examination in the laboratory. Nevertheless, the tests suggests that the hydraulic conductivity of the regolith aquifer rests somewhere in the range of 0.5 and 5 m / d.

Table 2. Estimates of hydraulic conductivity based on regolith grain size analyses.

Site	Catchment	d_{50} (µm)	K (m/d)
Gradient Hole 1	Aroca	125	3
Gradient Hole 5	Aroca	100	3
CD 78	Aroca	70	3
GS1943	Aroca	110	4
DS714	Nyabisheki	1100	4

Table 3. Gives AQTESOLV solutions of regolith piezometer tests.

Site	Catchment	Bail Test Hydraulic Conductivity m/day	Slug Test Hydraulic Conductivity m/day
Gradient Hole 2	Aroca	0.6	0.4
Gradient Hole 6	Aroca	0.7	1.3
CD 360	Nyabisheki	0.05	0.09
CD 2253	Aroca	0.3	0.4

Table 4. Shows summary of long term pumping tests results.

Borehole	Total Drawdown in borehole (m)	Total Drawdown in regolith (m)	Length of Drawdown phase (hours)
GS 1943	11.05	0.03	24
CD 2253	23.09	0.10	24
CD 722	27.52	0.12	24
CD 78	4.32	0.03	24
CD 360	7.91	0.07	42

Pumping tests

During the long pumping tests a lowering of the water table in the regolith was observed. Although measured drawdowns were slight, averaging just 7 cm, it was an indication that the regolith aquifer is able to replenish the weaker bedrock aquifer. This would make development of the bedrock aquifer sustainable on a long term basis in cases where values of vertical hydraulic conductivity at the bedrock / regolith interface are reasonable.

Conclusion

Quantitative hydrogeological studies of the regolith reveal that the unit is considerably more permeable than the underlying bedrock and where a substantial thickness exists, is likely to provide a significantly better aquifer.

Hydraulic conductivities are variable but are typically in the range of 0.5 to 5 m / d. As a result, the aquifer in the regolith tends to be between one and two orders of magnitude more transmissive than the underlying bedrock aquifer.

In Uganda, where the practice has until recently been development of only the bedrock aquifer, the above findings stress the need to develop the regolith aquifer which is likely to provide a more sustainable and less costly source for rural water supplies than the bedrock fractures. This would be possible through construction of shallow wells (augered and or dug) in areas where the conditions are favourable. In areas where the regolith aquifers so thick to provide enough water, deep wells exploiting the bedrock aquifer and screened in the regolith would be more sustainable. All in all, the regolith is very important in groundwater development as it is able to provide a cheap and more sustainable source of water supply and can recharge the weaker bedrock aquifer through vertical leakage.

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