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ACCESS TO SANITATION AND SAFE WATER: GLOBAL PARTNERSHIPS AND LOCAL ACTIONS

Viability of marginal yield boreholes in selected geological formations in Ghana

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The Community Water and Sanitation Agency (CWSA) has adopted standards for borehole provision in rural communities in Ghana. One of such standards is declaring as marginal or unsuccessful, borehole with yield less than 0.81m³/hr. This has resulted in most marginal yield boreholes in fractured zone aquifers either being abandoned for insufficient water, or are possibly ear marked for hydro fracturing to enhance their viability. The study reviewed the use of marginal yield boreholes (0.30-0.78m³/hr) in order to specify criteria for their sustainable use. Out of 3,025 boreholes drilled between 1995 & 2005 in the Voltaian, Granite and Birimian, 438 were marginal yield boreholes which were viably used, each serving a population ranging from 90 to 400. The results have shown that the viability of these boreholes depend on aquifer characteristics such as the Specific Capacity, Transmissivity and Recovery rate and the population using the marginal yield borehole. The paper specified the required ranges of the aquifer parameters and community sizes for viable use of such boreholes.

Introduction

As part of Ghana's policy objectives for achieving the Millennium Development Goal (MDG) based on economic growth and Poverty Reduction Strategy, the Government has embarked on water supply in terms of borehole provision in the rural communities.

The overall coverage for water supply in Ghana is still low. It is about 51.9% for rural communities which constitute about 70% of the population in Ghana, and 70% for urban areas (CWSA, 2003). This does not put the country in a firm position towards meeting the targets of the MDG. Therefore to increase the rate of potable water supply for rural communities especially underlain by low yield aquifers, it has become necessary to utilize marginal yield boreholes.

Geological formations in Ghana have groundwater potentials that range from poor to good and have borehole yields between 0.41-48m³/hr (Dapaah et al. 2002; WRRI,1996). In view of the astronomical cost of drilling boreholes, various combinations of modern geophysical techniques have been employed to enhance the success rate. The techniques have been effective in the location of water-bearing zones, but the discharge characteristics are not guaranteed in fractured zone aquifers, although the analysis of geological logs may indicate poor to highly developed fractures. Thus many of these boreholes turn out to have marginal yields (less than 0.81m³/hr). By Community Water and Sanitation Agency (CWSA) standard, boreholes need to be declared successful when the yield is equal to or greater than 0.81m³/hr, otherwise it is declared marginal (CWSA, 2003). Marginal yield boreholes are normally abandoned for insufficient water, or are earmarked for hydro fracturing to enhance their viability. Depending on the geological formation and other related factors the hydro fracturing may or may not be successful. If unsuccessful, additional cost is incurred and the borehole will still be rejected.

The study reviewed the use of marginal yield boreholes (0.30-0.78m³/hr) in order to specify criteria for their viability.

Description of study area

The study area covers 33 districts in five administrative regions of Ghana having a total area of 19,490km² and lies between latitudes 50 00'N and 100 30' N. The mean monthly temperature ranges from 26°C in the South to 36°C in the North and the mean annual rainfall varies from 1000mm in the North to 1900mm in the South. The vegetation varies from Guinea Savannah woodland in the North to Rainforest zone in the South (Dickson & Benneh, 1988).

Research methodology



Data for the study was collected from the (CWSA) offices in Tamale, Koforidua, Kumasi, Water Research Institute (WRI) in Accra, and World Vision Ghana Rural Water Project (WV-GRWP), Tamale. All data collected were screened and crossed checked for accuracy and reliability with the help of the officials from CWSA, WRI and WV-GRWP.

Aquifer and borehole characteristics, including specific capacity, transmissivity, recovery rate, static water level and population were given major consideration in data collection.

Data for 3,025 boreholes drilled in three major geological formations within a 10-year period (1995-2005) covering five (5) regions of Ghana, namely, Northern, Western, Ashanti, Eastern and Brong-Ahafo regions were collected and studied. The study areas are as shown in Figure 1.

CWSA Standard for successful Boreholes was utilized to classify the boreholes. According to CWSA, boreholes are declared as successful when the yield is 0.81m³/hr (13.51/min.) or more. This criterion is based on the following considerations:

Average demand per person per day in a rural Ghanaian community with population of 300 is fixed at 20 litres. The quantity of water required per day for 300 people (300*20 litres) is 6,000 litres. The required yield of a borehole to satisfy the demand is estimated based on 8- hours pumping time. A borehole with yield of 13.5 l/min will produce (13.5 l/min.*60min/hr*8hrs) 6,480 litres of water which is considered sufficient to meet community water demand.

Data analysis

Hydro-geological data including pumping test results, specific capacities, transmissivities and recovery rates of the boreholes were compiled and analyzed. Successful marginal yield boreholes were categorized according to rock type, borehole depth, aquifer zone, borehole yield, specific capacity, transmissivity, recovery rates and geological formation. Pumping Tests were carried out for six-hour periods and recovery rates monitored for three hours.

The Specific Capacities and Transmissivities of the boreholes were calculated using the relations shown in Equations 1 and 2 (MacDonald and Davies, 2000).

SP = Q/Dd

Where SP= Specific Capacity (m²/day) Q= Discharge (m³/day) Dd= Drawdown (m) = Dynamic Water Level (DWL) – Static Water Level (SWL) T =15.3 (Q/Dd)^{0.67}

Where $T = Transmissivity (m^2/day)$

Q= Discharge (m³/day) Dd= Draw down (m) = DWL - SWL

Discharge depth variation of aquifer system

The study of the marginal-yield borehole logs in the Granite, Voltaian and Birimian formations revealed six (6) aquifer trends depicted by these boreholes as follows;

Trend 1: A steady or constant flow rate after strike of water to the depth of the borehole. This implies that the aquifer may be a confined type. This trend is common in the Granite aquifers.

Trend 2: An alternating increase and decrease in flow rate that is, either from above marginal yield to end at marginal yield or from marginal yield to end within marginal yield at the depth of the borehole. This trend possibly depicts a multi-layered confined aquifer, which contributes to the increase in flow rate when borehole depth is within the aquifer thickness and a decrease in flow rate when borehole depth is within the impermeable layer of the aquifer. Based on percentages recorded in Table 1, Trend 2 characterizes most of the aquifers analyzed from the borehole logs in the three (3) geological formations.

Trend 3: Discharge commences from high yield and reduces gradually to marginal yield until the end of the borehole. This trend may depict an aquifer with the leaky confining layer type where significant flow is generated from leakage into the aquifer through overlying or underlying confining layers. However, only one borehole depicted this trend.

Trend 4: Increasing discharge all within marginal yields become steady at the end depth of borehole. This trend depicts semi-confined aquifer type where the overlying layer is semi-permeable, contributing significant amounts of water to the aquifer. A constant flow rate at the depth of the borehole possibly indicates a non-permeable layer of the aquifer reached, which equalizes the significant contribution of water from the semi-permeable layer of the aquifer. This type of aquifer dominates the Voltaian sandstone (see Table 1).

Trend 5: Discharge commences from above marginal yield and reduces to marginal yield. The aquifer depicted in this trend may be the confined type where borehole depth is in the impermeable layer of shallow thickness. There could be the possibility of entering another layer of aquifer to contribute to the water flow, or continuing the depth of drilling in the impermeable layer.

Trend 6: Initial constant yield from strike of water and then increases to end close to the upper limit of the marginal yield. The aquifer type depicted by this trend may be the multi-layered confined type. This means the first aquifer layer reached could produce a minimal quantity of water at a constant flow rate before entering another aquifer with a higher groundwater flow potential.





equation 1

equation 2

These Discharge-depth variations in the various geological formations are shown in Figures 2 and 3. A summary of the percentages revealing the trends in Discharge-depth variations depicted by the various rock types presented in the Table 1 below indicate that Trend 2 is the predominant discharge-depth variation in the geological formations in the study area. This is followed by trends 3 and 5 respectively.

Results and discussions

Four hundred and ninety-nine (499) of the boreholes studied had marginal yields and four hundred and thirty-eight (438) of the marginal yield boreholes have been successfully used, representing 88%. The viable boreholes serve a population range between 90 and 400. The characteristics of marginal and non-marginal boreholes summarized in Tables 2 and 3 respectively have shown that the salient aquifer yield characteristics which make them viable include: Specific Capacity, Transmissivity and Recovery rate.

Table 1. Summary of percentages in the flow trends exhibited by the rock types in the discharge
depth variations

Geological formation	Rock type	Trend 1	Trend 2	Trend 3	Trend 4	Trend 5	Trend 6
Voltaian	Sandstone		20%	-	70%	10%	-
	Siltstone	-					
	Mudstone		75%	-	10%	15%	-
	Shale						
Granite	Granite	15%	65%	-	15%	-	5%
Birimian	Phyllite	-	750/	-	200/	5%	-
	Schist	-	73%	-	20%		

Table 2. Summary of aquifer characteristics of marginal yield boreholes in three (3) geological formations and population range served

Geological formation	No. of boreholes sampled	No. of successful boreholes	Specific capacity (m²/day)	Transmissivity (m²/day)	Recovery rate (%)	Population range served
Voltaian	291	256	0.32 -4.30	0.13 -3.70	70 -100	90 - 400
Granite	136	113	0.24 -1.96	0.37 -38.70	60 -100	90 - 400
Birimian	72	69	0.37 -13.96	0.76 -26.96	70 -100	90 - 400
Total	499	438				

Table 3. Summary of aquifer characteristics of non- marginal yield boreholes in three (3)geological formations and population range served

Geological formation	No. of boreholes	Specific capacity (m²/ day)	Transmissivity (m²/day)	Recovery rate (%)	Population range served
Voltaian	256	1.96 -49.54	24.02 -214.39	80 -100	≥300
Granite	113	0.69 -33.93	11.93 -162.87	90 -100	≥300
Birimian	69	1.29 -21.60	18.15 -121.52	95 -100	≥300
Total	438				

Although the Specific Capacities and Transmissivities of the marginal yield boreholes computed are relatively low, indicating low groundwater potential, the recovery rate range of 60-100% of the marginal yield boreholes compared to the non-marginal yield recovery rate of 80-100% indicates that recovery rate is an indicator of viability.

Conclusions

Based on the research work, the results and the analysis, the following conclusions were made;

- 1. Out of the 3,025 boreholes drilled in the study area between 1995 and 2005, 16.5% were marginal yield boreholes.
- 2.88% of the marginal yield boreholes are viable
- 3. A viable marginal yield boreholes have the following characteristics: Voltaian Specific Capacity range of 0.32 4.30m²/day, Transmissivity range of 0.13 3.70 m²/day and recovery rate range of 70 100%; Granite Specific Capacity range of 0.24 -1.96m²/day, Transmissivity range of 0.37 -38.70 m²/day and recovery rate range of 60 100%; Birimian Specific Capacity range of 0.37 13.96m²/day, Transmissivity range of 0.76 -26.96 m²/day and recovery rate range of 70 -100 %.
- 4. The dependable yield of a marginal yield borehole is the constant yield obtained during standard pumping test.
- 5. Recovery rate is one the salient parameters for borehole viability.

Recommendations

Based on the findings of the viability of some marginal yield boreholes developed, the following recommendations are made:

1. Viable marginal yield boreholes should be developed to serve a population range of 90 to 400.

- 2. It is recommended that CWSA adopt these results as standards for development of viable marginal yield boreholes.
- 3. Viable marginal yield boreholes need to be pump tested until a constant yield is obtained, which must be considered as the sustainable yield.
- 4. It is recommended that viable marginal yield boreholes should be redeveloped after 3 to 5 years of use to enhance viability.

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