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COOU Journal of Physical Sciences 5 (1), 2022

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EVALUATION OF GROUNDWATER LEVEL TIME-DEPENDENT VARIATION AND AQUIFER CHARACTERISTICS WITHIN SHEET 223, ILORIN NORTH-WEST, SOUTH-WESTERN NIGERIA.

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ABSTRACT

The assessment of groundwater level time-dependent variation and aquifer characteristics has been carried out, aimed at knowing the variation in groundwater elevation at the end of the rainy season and at the peak of the dry season. The time-dependent variation was done by direct in situ groundwater level measurement from eighty existing wells. Aquifer characteristics were determined by using pumping test data of the available boreholes in the area, using modified Jacob's method. Configuration of groundwater level contours shows that the highest groundwater elevation in the area is 445 m and the lowest is 295 m above sea level. Also, areas with water levels ranging between 1 and 2 m are areas of low water level while areas with water levels ranging between 9.5 m and 11 m are areas of high water level. Transmissivity is estimated to range between 3.49 and 8.50 m^2 /day with an average value of 5.61 m^2 /day, Hydraulic conductivity range between 2.18 × 10^{-1} and 7.64× 10^{-2} m /day with an average value of 1.65 × 10^{-1} m /day and Storativity range from 3.45 to 9.15 with an average value of 5.04. Areas with the shallow water level, depicting high potential, are in the southern part while the northern part is an area of low groundwater potential. The average value for Storativity is higher than the assigned limit (0.005-0.00005) for most confined aquifers, indicating that the storage potential of the boreholes is high; hence their recharge potential is high.

Keywords: Groundwater, Time-dependent variation, Aquifer characteristics,

1. INTRODUCTION

Hydrogeology is concerned with the distribution and movement of groundwater in the soil and rocks of the earth's crust. It's worthy of note that groundwater currently supplies approximately 40 % of the world's irrigated area. It enables 13 % of total food production and groundwater contributes to about 44 % of irrigated food production [K.G. Villholth et.al, 2013]. Although groundwater may also be susceptible to drought, e.g. where groundwater storage is limited, meteorological drought risk is high and where population density is high, groundwater dependency is relatively high for both domestic and productive purposes.

A good-quality and sustainable groundwater can be guaranteed if the aquifer parameters determined from the pumping test and bore-hole loggings are integrated. A pumping test involves pumping water from a test well at a constant rate and measuring the water depth over a given time (Mele, M. et al, 2010). The difference between the measured depth and the static

water level gives the drawdown values used in estimating transmissivity. The borehole loggings are used to evaluate the character and thickness of the different geologic materials penetrated by wells and test holes. Various pumping methods have been used to estimate aquifer parameters, among which are the Sushil K. Singh method, Jacob method, and Theis method. Jacob's method has been the most popular method for calculating aquifer parameters due to its simplicity was the method adopted in the study.

The study area is a sub-urban settlement within the Basement Complex of southwestern Nigeria. The area was bounded between latitude 8^0 15' and 8^0 25' and between longitude 4^0 30' and $4^0$37.5'covering an area of 72 km^2 (Figure 1) However, groundwater occurrence in such Basement Complex is held in porous formations which are rocks containing a relatively large portion of void spaces (Deming, 2002). The study area is underlain by crystalline rocks and generally, crystalline rocks have porosities of less than 3% (Bouwer, 1978). As such rocks of the Basement Complex, when not weathered are practically impermeable and have no storage capacity. However, appreciable porosity and permeability might have been developed in the rocks through fracturing and weathering processes (Davis and De Wiest, 1966), depending on the lithology and texture of the original rock. The local geology of the area consists of gneissic rocks of different varieties (migmatite gneiss, Porphyroclastic gneiss, banded gneiss, augen gneiss, and granite gneiss), quartz mica schist, and fine-grained granite. The area is of a dissected topography, lies within the humid tropical climate with a total annual rainfall of about 1200 mm, and has a dendritic drainage pattern (Figure 1).

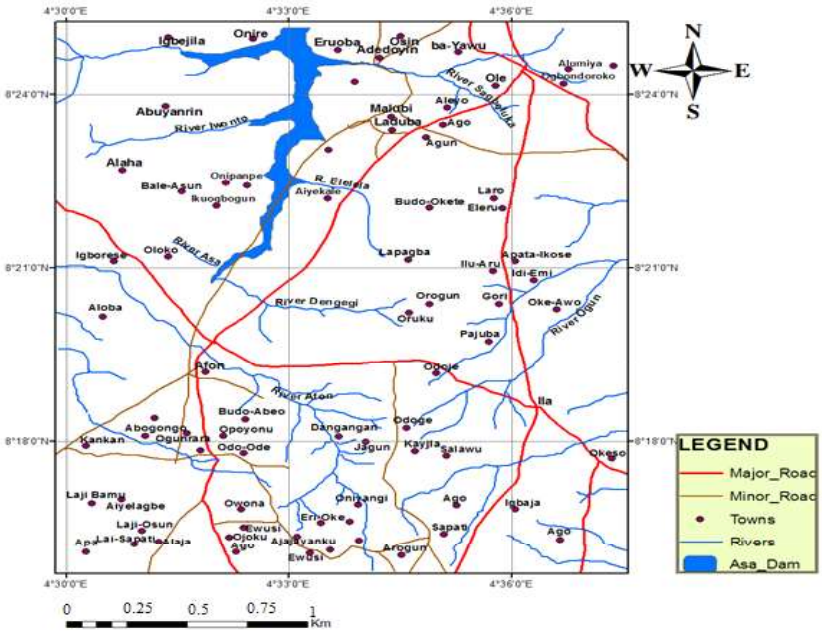


Figure 1: Topographical map showing the Drainage pattern of the study area

The dwellers of the area depend solely on shallow hand-dug wells which are vulnerable to contamination because of their shallowness and surface water sources which are far and polluted by various sources. The available boreholes in the area were drilled by individuals who could afford that. This paper, therefore, aims at evaluating groundwater level elevation in both seasons and assessing its aquifer parameters.

2. Materials and methods

A weighted surveyor's tape was used to measure the groundwater level of the area. The groundwater level contour map is a hydrogeological map that shows the configuration of the phreatic surface and the regional direction of groundwater flow in the study area. It was prepared by plotting the altitudes of water levels measured in dug-wells on a topographical map. The water levels were measured by inserting into the wells a weighted surveyor's tape at the base to touch the surface of the water in the wells. The altitude of the water level in each of the wells was calculated by deducting the measured water levels below the ground surface (depth to water level) from the altitude of the well locations. Lines were then drawn to join points of equal water level elevation. The map was prepared for both the end of raining season and the peak of the dry season. Map of the depth to water level (map of the unsaturated zone) is a map that shows the depth to water level from the ground surface. It was also prepared by plotting values of measured water levels from the ground surface on a topographical map using a suffer software. Lines were then drawn to join points of equal values of the unsaturated zone of thicknesses. This map was prepared for the end of raining season and at the peak of the dry season.

Aquifer parameters which are Transmissivity, Hydraulic conductivity, and Storativity were determined using pumping test data available in the area. The transmissivity (T) was estimated by plotting the drawdown values (m) of water level in wells against time in minutes since pumping started on a semi-logarithmic co-ordinate paper. Hence, the transmissivity was calculated using Jacob's modified formula which is given as $T= 2.30Q/4\pi\ \Delta s \times \log_{10}(t_2/t_1)$, where T = transmissivity (m^2/day), Q= discharge rate, Δs = change in drawdown, t_2 and t_1 = time (days) since pumping started. Hydraulic conductivity was calculated using the formula K= T/b, where K= hydraulic conductivity (m/day), T= transmissivity (m^2/day), b= aquifer thickness (m). Storativity or storage co-efficient of groundwater in the area was calculated by extrapolating the straight line of the semi-log curve to a point at which it intersects with the zero draw-down axes which permit the computation of 'S' as $S = 2.25Tt_0/r^2$ Where S= storage coefficient, T = transmissivity (m^2/day), t_o = time intercept on zero draw-down axis, r = distance of the borehole.

3. Results

3.1 Groundwater level configuration

Groundwater level configuration shows that the highest groundwater elevation in the study area is 445 m above sea level while the lowest elevation is 295 m above sea level and groundwater flows from the highest elevation to the lowest elevation. Areas of low water level are areas with water levels ranging from 1 m to 2 m while those areas of high water level are areas with water level values ranging from 9.5 m to 11 m.

3.2 Hydraulic parameters

Evaluation of aquifer characteristics in the area shows that the values of Transmissivity estimated for the available boreholes in the area range between 3.49 and 8.50 m^2 /day with an average value of 5.61 m^2 /day, Hydraulic conductivity values range between 2.18 × 10^{-1} and 7.64× 10^{-2} m /day with an average value of 1.65 × 10^{-1} m /day and Storativity values range from 3.45 to 9.15 with an average value of 5.04. The result of the aquifer characteristics in the area is summarized in Table 1.

Table 1: Calculated Values of Hydraulic Conductivity, Transmissivity and Storage coefficient obtained from six boreholes in the area

Names of the boreholes	Hydraulic Conductivity(m/day)	Transmissivity (m^2/day)	Storage coefficient	Bedrock types
Reke Village	2.99×10^{-1}	6.19	3.45	Porphyroblasic gneiss
Ita –Elepa	3.23×10^{-2}	3.68	3.57	Augen gneiss
Ganmo	2.84×10^{-1}	8.50	4.28	Porphyroblasic gneiss
Osin Aremu	8.10×10^{-2}	5.91	5.72	Augen gneiss
Budo- Ojoku	7.64×10^{-2}	3.49	4.06	Fine grained granite
Amoyo	2.18×10^{-1}	5.90	9.15	Porphyroblasic gneiss

4.0 Discussion

Groundwater level configuration maps were prepared for both the end of raining season (October) and the peak of the dry season (March). Figures 2 and 3 show the groundwater configurations. The direction of groundwater flow also known as the direction of groundwater movement which is indicated in the map of the study area by the arrows drawn perpendicular to the groundwater level contours (equipotential lines). Groundwater in the study area flows from the higher groundwater elevation contour (445 m above sea level [a.s.l]) to lower groundwater elevation contour (295 m a.s.l) and the flow is largely towards the north-western direction (Figure 4)

Evaluation of the map of the thickness of the vadose zone shows that the highest contour of thickness is 11.5 m while the lowest is 1m. For the end of the rainy season, areas with water levels range between 1 and 2 m are areas with low water levels which include Okeso and Gbaija villages while areas with water levels range between 9.5 and 11 m are areas with high water levels which include Eri-Eru, Alomilaya, and Ba-Yawu (Figure 5). At the peak of the dry season, areas with water levels range between 2.5 and 3.5 m are areas with low water levels which include Okeso and Gbaija villages while areas with water levels range between 10 and 11.5 m are areas with high water levels which include Eri-Eru, Alomilaya, and Laji villages. The water level during this season has receded to about 1.5 m below the ground surface (Figure 6). There are two major aquiferous units in the study area and these are overburden and

fractured crystalline aquifers. These two aquifers are of different groundwater potentials and characteristics. The depth to the weathered zone varies and depends largely on the composition and texture of the parent rock together with the density of the regional fracture field.

The aquifer characteristics calculated for the available boreholes in the area include hydraulic conductivity, transmissivity, and Storativity and cut across Reke, Ita-Elepa, Ganmo, Osin-Aremu, Amayo, and Budo-Ojoku villages. The hydraulic conductivity values of the aquifers range from 3.23×10^{-2} m /day to 2.99×10^{-1}m/day with a mean of 2.83×10^{-1}m/day, Transmissivity values of the aquifers range between 3.49 m^2/day and 8.50 m^2/day with an average value of 5.61.m^2/day and Storage coefficient values vary from 3.45 to 9.15 with a mean of 5.03. It was observed that the storage coefficients of Reke, Ita-Elepa, Ganmo, Osin-Aremu, and Amayo boreholes (3.45, 3.57, 4.28, 5.72, and 9.15 respectively) are of metamorphic origin with thicker overburden than that of Budo-Ojoku (4.06) which is of granitic origin. Figure 7 - 12 shows the graph of the plot of drawdown against time for the Reke waterside and the other villages.

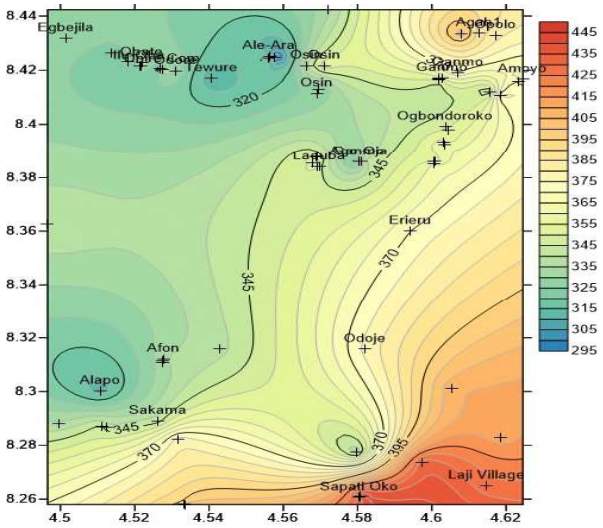


Figure 2: Groundwater contour map at the end of the rainy season

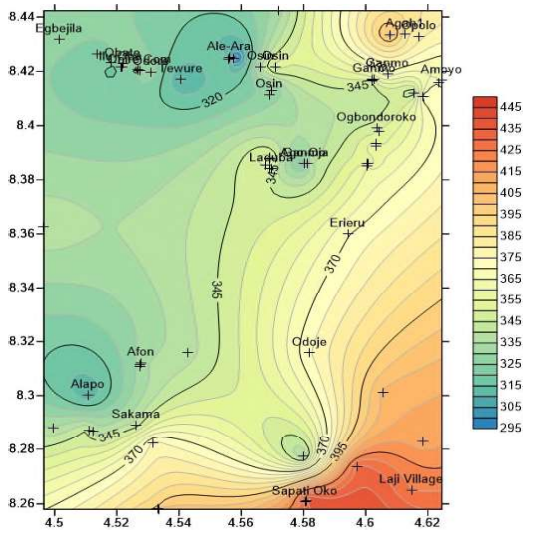


Figure 3: Groundwater contour map at the peak of the dry season

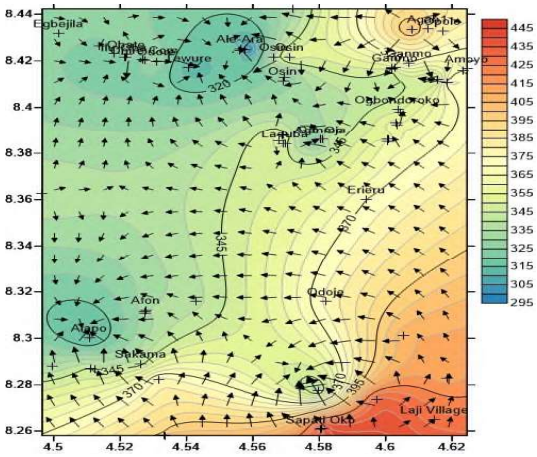


Figure 4: Groundwater flow net

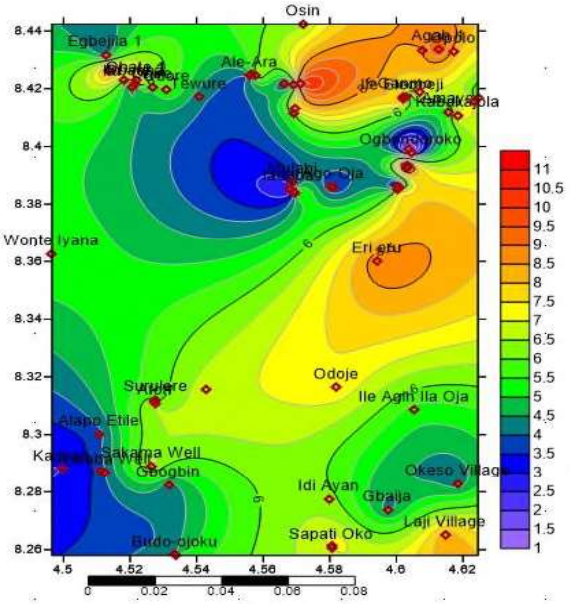


Figure 5: Groundwater level map at the end of the rainy season

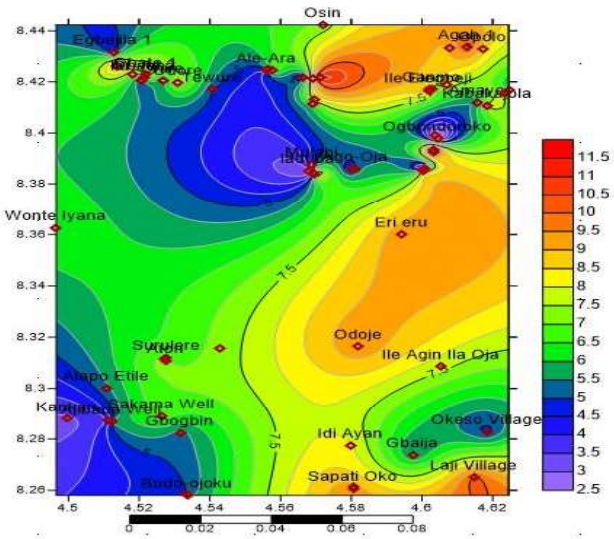
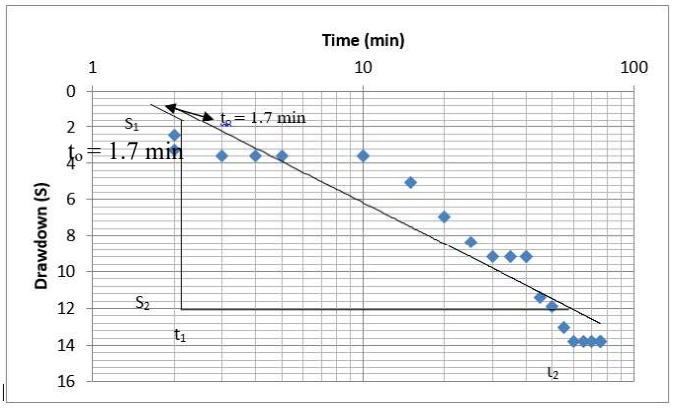


Figure 6: Groundwater level map at the peak of the dry season



S1

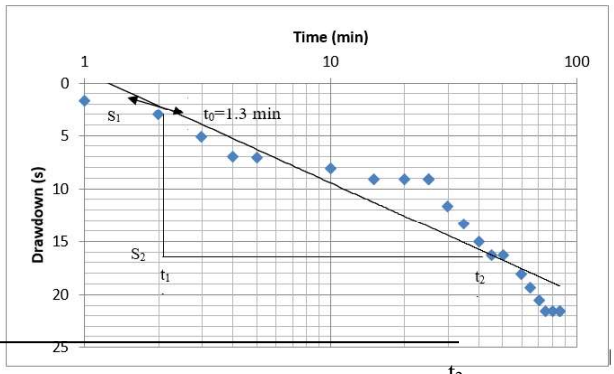
t_o = 1.7 min

Figure 7: Plot of drawdown versus time for Reke waterside

$$Transmissivity\ T = \frac{2.30Q log\frac{t_2}{t_1}}{4\pi\Delta S} = \frac{2.3X0.25X10^3 log30}{4X3.142X10.9} = 6.19\ m^2/day$$

$$Hydraulic\ conductivity\ K = \frac{T}{b} = \frac{6.19}{20.7} = 2.99X10^{-1}\ m/day$$

$$Storativity\ S = \frac{2.25Tt_0}{r^2} = \frac{2.25X6.19X0.001}{(0.635)^2} = 3.45\ units$$



S2

t1 t2

Figure 8: Plot of drawdown versus time for Ganmo waterside

$$Transmissivity\ T = \frac{2.30Q log\frac{t_2}{t_1}}{4\pi\Delta S} = \frac{2.3X0.5X10^3 log20}{4X3.142X14.0} = 8.57\ m^2/day$$

$$Hydraulic\ conductivity\ K = \frac{T}{b} = \frac{8.50}{29.9} = 2.84X10^{-1}\ m/day$$

$$Storativity\ S = \frac{2.25Tt_0}{r^2} = \frac{2.25X8.50X9.0277X10^{-4}}{(0.635)^2} = 4.28\ units$$

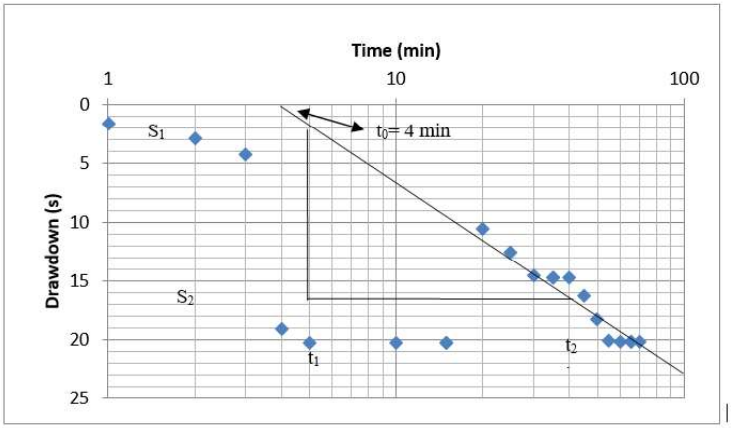


Figure 9: Plot of drawdown versus time for Amayo waterside

$$Transmissivity\ T = \frac{2.30Qlog\frac{t_2}{t_1}}{4\pi\Delta S} = \frac{2.3X0.5X10^{-3}log8}{4X3.142X14.0} = 5.90\ m^2/day$$

$$Hydraulic\ conductivity\ K = \frac{T}{b} = \frac{5.90}{27.1} = 2.18X10^{-1}\ m/day$$

$$Storativity\ S = \frac{2.25Tt_0}{r^2} = \frac{2.25X5.90X2.778X10^{-3}}{(0.635)^2} = 9.15\ units$$

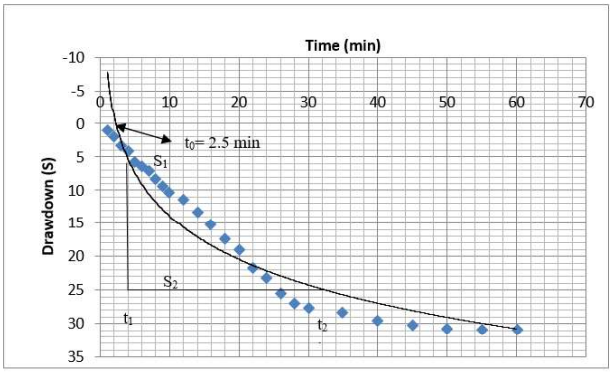
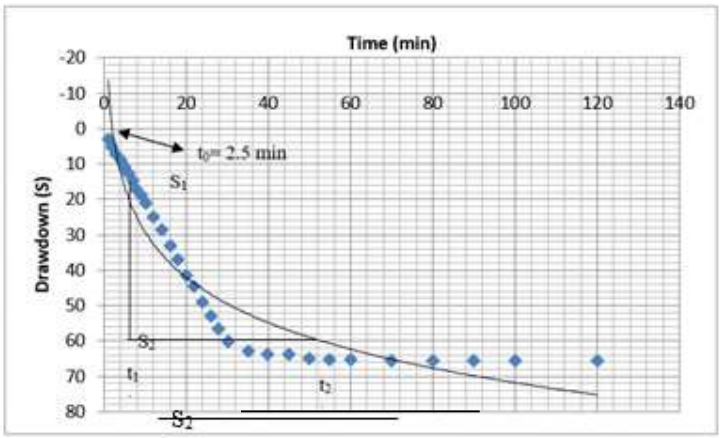


Figure 10: Plot of drawdown versus time for Osin- Aremu waterside

$$Transmissivity\ T = \frac{2.30Qlog\frac{t_2}{t_1}}{4\pi\Delta S} = \frac{2.3X0.68X10^{-3}log8}{4X3.142X19.0} = 5.91\ m^2/day$$

$$Hydraulic\ conductivity\ K = \frac{T}{b} = \frac{5.91}{72.93} = 8.10X10^{-2}\ m/day$$

$$Storativity\ S = \frac{2.25Tt_0}{r^2} = \frac{2.25X5.91X1.736X10^{-3}}{(0.635)^2} = 5.72\ units$$



S_2

t_1 t_1 t_2 t_2

Figure 11: Plot of drawdown versus time for Ita - Elepa waterside

$$Transmissivity\ T = \frac{2.30Qlog\frac{t_2}{t_1}}{4\pi\Delta S} = \frac{2.3X0.83X10^{-3}log13}{4X3.142X19.0} = 3.68\ m^2/day$$

$$Hydraulic\ conductivity\ K = \frac{T}{b} = \frac{3.68}{114.01} = 3.23X10^{-2}\frac{m}{day}$$

$$Storativity\ S = \frac{2.25Tt_0}{r^2} = \frac{2.25X3.68X1.736X10^{-3}}{(0.635)^2} = 3.57\ units$$

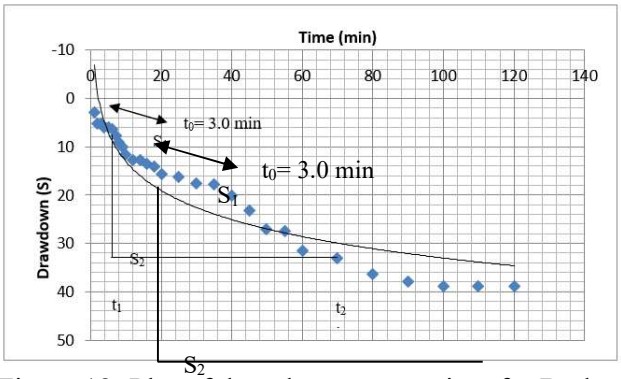


Figure 12: Plot of drawdown versus time for Budo-Ojoku waterside

$$Transmissivity\ T = \frac{2.30Qlog\frac{t_2}{t_1}}{4\pi\Delta S} = \frac{2.3X0.38X10^{-3}log16}{4X3.142X24} = 3.49\ m^2/day$$

$$Hydraulic\ conductivity\ K = \frac{T}{b} = \frac{3.49}{45.69} = 7.64X10^{-2}\ m/day$$

$$Storativity\ S = \frac{2.25Tt_0}{r^2} = \frac{2.25X3.49X2.083X10^{-3}}{(0.635)^2} = 4.06\ units$$

t_2

5. Conclusion

The elevation of groundwater in the area at the end of the rainy season was higher than that of the peak of the dry season. Areas in the southern part of the study area were areas of low water level with high groundwater potential while areas in the northern and western parts were areas of high water level with low groundwater potential. The average value for Storativity of the boreholes is higher than the assigned limit for most confined aquifers, indicating that the storage potential of the boreholes is high; hence their recharge potential is high and drawdown is high.

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