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Well Performance Analysis based on Pumping Test

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Abstract: Water is a renewable resource that is perpetually replenished. The necessity of water for the existence of all species, including humans, is well acknowledged. A number of the countries that make up Malaysia suffered from water shortages a few years ago, which almost certainly led to the implementation of predetermined water limitations. In light of the concerns raised, this study objective is to identify the characteristics of the groundwater obtain at RECESS, UTHM and to evaluate the well performance acquired from the groundwater pumping activities. The procedure is carried out as a single well pumping test, and as part of the data gathering process, a constant rate pumping test method is utilized as the analytical tool. Five characteristics of groundwater were analyzed; transmissivity (T), storativity (S), hydraulic conductivity (K), flow rate (Q) and specific yield (Sy) gathered from the pumping test activities. A recharge well (REWES) is a device used to regulate the amount of water pumped into a groundwater reservoir. The result from this study are the Q = 59.46 (m^3/day) , T = 3.628 (m^3/day) S = 0.027, K = 0.087 (m/day), and lastly S_y = 0.971. The feasibility of the well was evaluated based on its parameters and quantity of groundwater and for the result for the well performance, the performance of flow rate of well was increasing by 27 %. The well's water supply is still sufficient, but the water level and volume have declined. Although smaller, the well can nevertheless provide water over the long term. If the well is not pumped excessively, it can be utilised for over a decade longer.

Keywords: Groundwater, Groundwater quantity, Well performance

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1. Introduction

Water is a renewable resource that is never depleted. Water is widely acknowledged to be essential for the survival of all organisms, including humans. As a result, ensuring enough water supply is critical for human well-being. As the world's population and consumption grow, so does the need for domestic, industrial, and agricultural water [1]. Population and prosperity, as well as other global pressures, will have a direct and significant impact on water quality and quantity. Irrigated agriculture's expansion into semiarid regions with minimal precipitation and surface water has significantly increased irrigated crops' reliance on groundwater withdrawal [2].

Groundwater contains significantly more freshwater than surface water and is becoming increasingly important for water security in many countries and regions; yet, many aquifers are vulnerable to unsustainable abstraction levels and pollution. According to the United Nations [3], groundwater provides drinking water to at least half of the world's population and accounts for 43 percent of all water utilized for irrigation. It is estimated that 20% of the world's aquifers are overexploited. Groundwater use is most common in water-stressed areas, where aquifers are used as an additional source of surface water [4] but it also occurs in areas where there is no water scarcity and the supply of water from other sources is plentiful and secure, such as urban settings in developed countries. The quantity of groundwater in an unconfined aquifer at the well was the subject of this study. This study analyzed groundwater characteristics and assessed the performance of test wells.

2. Water Well Pumping Test

A pumping test was carried out in the field to learn more about the hydraulic properties of aquifers. As water is pumped from a well at a set or variable rate, the drawdown in the well and nearby observation wells is observed. As a result, the hydraulic characteristics of the aquifer can be calculated using appropriate equations based on time and distance drawdown observations.

There are two kinds of pumping tests: single wells and multiple wells. A single well pumping test measures the water level in the pumped well and surrounding observation wells or piezometers, whereas multiple well pumping tests pump and measure several wells. It is not commonplace for pumps to operate at variable discharge rates, either intentionally or as a result of pump qualities [5], [6].

Testing the hydraulic conductivity, transmissivity, and storage capacity of an aquifer and a well with pumping experiments is a relatively reliable method of acquiring information for these investigations. Pumping can also be used to test the impact of pumping or a decline in groundwater level on other water supplies. The groundwater extraction was assessed in this investigation utilizing a single well pumping test. There is no ability to view or monitor anything other than the single well during a single well pumping test. Following groundwater extraction, observations of the recovery session at the test were made. As a result of this discovery, the well's performance is being monitored.

2.1 Constant rate pumping test

A constant rate pump test involves pumping a well at the same rate while monitoring the drawdown in the well and other observation wells chosen based on aquifer properties and site-specific factors. After pumping, water levels in pumping wells and observation wells are examined. Many analytical solutions exist to compute transmissivity, particular yield (under unconfined conditions), and specific storage capacity [7]. This test can be run at various rates, but the most common is to use a constant rate.

2.2 Daily and weekly water abstraction

Water is extracted over the course of five days and three weeks. To obtain a more exact and consistent result, the excellent test required five days of daily testing and three weeks of weekly testing.

3.0 Methodology

3.1 Well performance

The first groundwater model in Malaysian studies was the Recharge Well System (REWES) in Parit Raja, Johor. Based on the sorts of ground layers, this trial model can forecast the recharge volume. The site-implemented Recharge Well System was built on a deep clay deposit with limited penetration rates (REWES). The chosen site in Parit Raja, Johor Malaysia, was constructed in a physical model for both wet and dry concerns [8].

As a recharging point for the chosen area, a single 150 mm diameter well tube was used. According to investigation records, the top layer is composed of clay layers that extend more than 30 meters deep, with a little quantity of fine sand and organic detritus mixed in [9].

The performance of the well is being determined for the purposes of this research by performing a pumping test and assessing the properties of the groundwater. One of the parameters used to evaluate the functioning of the well after a number of years is the transmissivity and storativity of the discovered groundwater. Furthermore, the well's performance can be assessed by comparing the flow rate from the previous year to the flow rate from the current year.

3.2 Cooper Jacob’s method

Single-well aquifer testing can provide the value of transmissivity without the cost and accessibility of multi-well aquifer testing, the test data is typically analyzed using CooperJacob's (1946) straight line approach because to its simplicity.

Cooper and Jacob (1946) reduced Theis's (1935) equation by noticing that for large values of time t and tiny values of r (0.01), the series expansion of Theis's (1935) equation after the first two terms is negligible.

3.3 Equations

a. Transmissivity

The transmissivity is measured by fitting a straight line on semi-logarithmic paper between log time and drawdown.

$$T = \left(\frac{(2.3Q)}{4\pi}\right)\left(\frac{\Delta(logt)}{\Delta s}\right) Eq. 1$$

Where Q is the flow rate in (m^3/day), $\Delta(logt)$ is a change in time per 1 log cycle in (min) and Δs is a change of drawdown in (m).

b. Storativity

The storativity obtained by fitting a straight line on semi-logarithmic paper between log time and drawdown to the transmissivity value

$$S = \frac{2.25Tt_o}{r^2} \; Eq. 2$$

Where T is the transmissivity in (m), t_o is the intercept of the straight line with zero drawdown in (min) and r is the distance in (m) to the nearest well.

C. Flow Rate

$$Q = qA \; Eq.3$$

$$q = \frac{Q}{2\pi r_1 b} \; Eq.4$$

$$A = \frac{\pi d}{4} \; Eq.5$$

Where Q is the average of the flow rate data collected in (m^3/day), r_1 is the radial distance to the nearest well in (m), b is the aquifer thickness in (m) and d is the diameter of well in (m).

4.0 Results and Discussion

This chapter presents the findings of the fieldwork as well as a discussion of those findings. The study was conducted at the Research Centre of Soft Soil, popularly known as RECESS, which is part of Universiti Tun Hussein Onn Malaysia, or UTHM. Pumping test procedures were carried out in order to acquire all of the data required for the following investigation of groundwater properties.

4.1 Flow rate

The volume flow rate (Q), also known as capacity, is the amount of liquid that flows through the pump in a given amount of time (meter cube per day). It specifies the speed at which a pump may move fluid across a system.

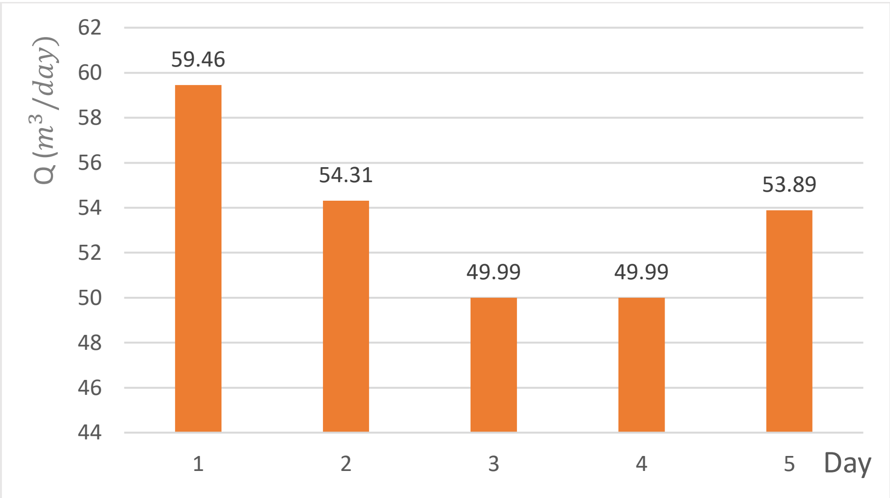

Figure 1: Daily flowrate, Q (m^3/day) for 5 days

Figure 1 shows the groundwater flow rate appears to be decreasing, demonstrating that the pressure is increasing over the first four days of pumping. As a fluid's speed increases, its pressure falls, according the Bernoulli principle. Considering the pump's size, the pump pipe may be too narrow for water pumping. Smaller pipe restricts water flow. Reduced flow reduces pipe pressure loss, increasing pressure. The more volume, the lower the flow rate, as the daily pumping time is about the same. On the last day of pumping, sample 5, the volume decreases since the well hasn't entirely recovered due to delayed soil infiltration. This causes sample 5's last-day flow rate increase.

4.2 Storativity and transmissivity

Storativity, also known as storage coefficient, is defined as the amount of water released from storage per unit drop in hydraulic head in the aquifer, per unit area of the aquifer. Meanwhile, Transmissivity, T, is the rate at which water with the current kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Table 1 shows that storativity is between 0.02 and 0.03. Rock and fluid compressibilities are ignored in unconfined aquifers. The storativity of an unconfined aquifer is determined by its specific yield (Sy), which is the volume of water that drains under gravity from a unit bulk volume.

Table 4.1 shows that the well in RECESS has a low potential of transmissivity. Great transmissivity indicates a well's high water-transmission potential. Transmissivity increases would boost oil storage. Based on the clay soil strata in RECESS, which has weak permeability relative to low fluid viscosity, wells create a considerable volumetric flow. Low reservoir permeability and heavy oil reduce rock transmissibility, limiting production.

Table 1: Transmissivity And Storativity Data Result For Daily And Weekly

	Sample	S	T (m^2/day)	Transmissivity potential
day	1	0.027	3.628	Low potential
	2	0.027	3.725	Low potential
	3	0.024	3.294	Low potential
	4	0.032	3.431	Low potential
	5	0.025	3.414	Low potential
week	1	0.027	3.628	Low potential
	2	0.032	3.474	Low potential
	3	0.024	3.294	Low potential

4.3 Data comparison from previous data

The data performance analysis displays the well's performance based on the volume of water extracted from the well and the flow rate of the collected groundwater. Table 4.2 depicts the well's performance between 2011 and 2022. Table 4.2 is used as a comparison for the volume and flow rate performance.

Table 2 shows that flow rate performance rose by 27% from 2011 to 2022 without a drop. After several years, volume performance drops. Soil infiltration is slower. Even though the well hasn't been utilised for 10 years, it still generates enough water. According to daily and weekly pumping analyses, the volume receiver is similar, but recovery is low. After 10 years, the well still produces enough water. More flow means less well volume pushed. The lesser the pumping time, the higher the flow rate. This means aquifer water is depleting.

Table 2: Volume Performance Percentage By Year

Sample	Flowrate, Q (m^3/day)	Flow rate performance percentage %
21/04/2011	43.00	27
20/03/2022	59.46	

4.4 Data comparison from previous study

The data comparison in this analysis is based on a prior study that explored the aquifer reflection on deep clay conditions for water quantity evaluations. Data from the preceding study are from 2011.

Table 3 displays the results of the previous study's aquifer reflection study from 2011, while in 2022 it displays the effect of analysis parameters from a single well. The approach utilised comes from the Neuman equation, which incorporates Jacob's correction for partial dewatering of water-table aquifers, permitting the application of the Cooper and Jacob solution for unconfined aquifers, according to Table 4.3. The table shows a method that used Cooper Jacob's equation on a single well. It is demonstrated that the value of transmissivity from the previous year reduced from 1440 to 3.628 to sluggish potential to transmit water in 11 years. The research area's soil condition causes the potential to convey water into the well to be slow. Because the pores of clay are so small, the water infiltration becomes low as the year goes on. This explains why the storativity of 2011 will increase by 2022. The specific yield value indicates that the water table of the well is falling as the specific yield correlates to the depth of the well. According to Table 4.3, as the transmissivity volume decreases, the hydraulic conductivity increases. As the value of hydraulic conductivity increases, it shows that the pores of a saturated soil are expanding to allow water circulation, hence keeping storativity low.

To summarise, based on the data from 2011 to the current year in 2022, the value and parameters of groundwater in RECESS are dropping throughout the year.

Table 3: Data Analysis 0f 2011 And 2022

	2011	**2022**
Well name	RW	RW
method	Neuman	Cooper Jacob
Aquifer model	Unconfined	Unconfined
T	1440 m^2/day	3.628 m^2/day
S	0.001	0.027
Sy	0.119	0.971
K	2.222 x 10^{-5}	0.087 m/day

5.0 Conclusion

The major purpose is to characterise the RECESS, UTHM groundwater. The flow rate, transmissivity, storativity, hydraulic conductivity, and specific groundwater yield may be determined. In this study, the transmissivity achieved was 3.628 (m^2/day), the storativity was 0.027, the flowrate was 53.53 (m^3/day), the average hydraulic conductivity was 0.087 (m/day), and the specific yield was 0.971. The groundwater quality determined by daily and weekly pumping tests at RECESS, UTHM.

According to this study, the well's performance is falling by up to 27% while still generating an appropriate amount of water. It has been demonstrated that the well can still be used if it produces enough water for the next ten years. Because the study area is exclusively within UTHM, the amount of data that may be collected is significantly limited. The pumping test equipment is manually examined, data inaccuracies in volume and drawdown measurements are possible. In future research, more time and better equipment may be available for data collecting, resulting in greater precision and a broader range of work.

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