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# Relationship Between Safe Discharge and Groundwater Zoning in Production Wells at PT Monokem Surya Rengasdengklok District, Karawang Regency West Java Province

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**Abstract.** PT Monokem Surya utilizes water to process zircon ore which is entirely sourced from groundwater with a minimum requirement of 550 m3/day. The source of groundwater comes from 7 drilled wells, all of which extracted a water from the confined aquifer layer. A study is needed to determine the potential of groundwater and aquifer parameters from wells with a pumping test. After discovering the aquifer parameters and optimum discharge, simultaneous pumping simulations were carried out for all wells and resulted in drawdowns that were generally not classified as safe criteria. Furthermore, a trial and error re-simulation is carried out by changing the discharge and pumping duration to make drawdown that fall within the safe criteria with a well efficiency limit of not less than 70%. The simulation resulted in drawdown classified as safe criteria (<40%) and the amount of groundwater produced was 513.68 m3/day. These results do not meet the minimum water needs, so other water sources are needed to cover these needs. Based on the values of several aquifer parameters, the groundwater potential at the research location can be classified into the moderate class.

**Keywords:** *aquifer parameter; confined aquifer; drawdown; optimum discharge; pumping test.*

## 1 Introduction

The impact of developing the region into a center for industry, settlements, services and manufacturing has led to high population growth and also increased demand for natural resources, one of which is water. Until now, this demand for water has not been fulfilled by surface water sources, and still relies heavily on sources from groundwater. Karawang Regency has now grown into an industrial area, in this case including the textile industry, manufacturing, services etc. Where the distribution is almost evenly distributed in all regions, it can even be said that Karawang Regency is currently the national industrial center area. Along with this, the availability of groundwater and its utilization by various industries is very important as the supporting factors of the sustainability of its business.

PT Monokem Surya is a company engaged in the manufacturing industry, especially as a supplier of ceramic raw materials derived from zircon ore which utilizes groundwater to processing zircon ore into ceramic raw materials. The source of groundwater comes from 7 drilled wells, all of which extracted a water from the confined aquifer layer. The minimum groundwater requirement is 550 $m^3$/day to process zircon ore, it is necessary to conduct a study regarding the optimum and safe pumping discharge and its relation to groundwater zoning.

## 2 Research Methods

Administratively, the research location is at Jl. Proklamasi Km. 12 Amansari Village, Rengasdengklok District, Karawang Regency, West Java Province with an elevation of 8-10 meters above sea level. Geologically, the research location is included in the Flood Plain Sediment (Qaf) formation which consists of clayey sand, sandy clay, humus/peat clay, according to Achdan and Sudana in [1]. The regional hydrogeology of the location from the results were given by Soetrisno in [2] is included in the aquifer group in which flow is mainly intergranular with moderate productivity and wide distribution. In general, these aquifers has moderate transmissivity where the water table or groundwater piezometry is near or above the ground surface. Well discharge are generally less than 5 liters/second.

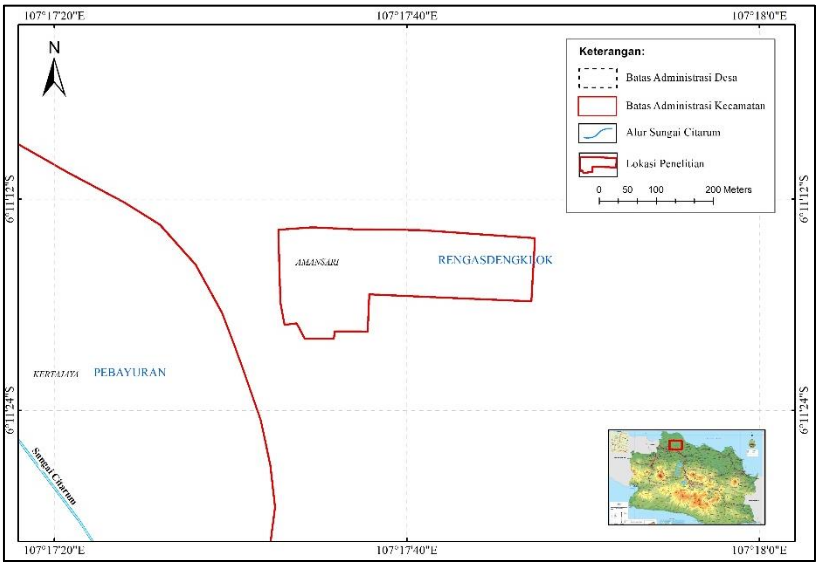


**Figure 1** Administrative map of the research location

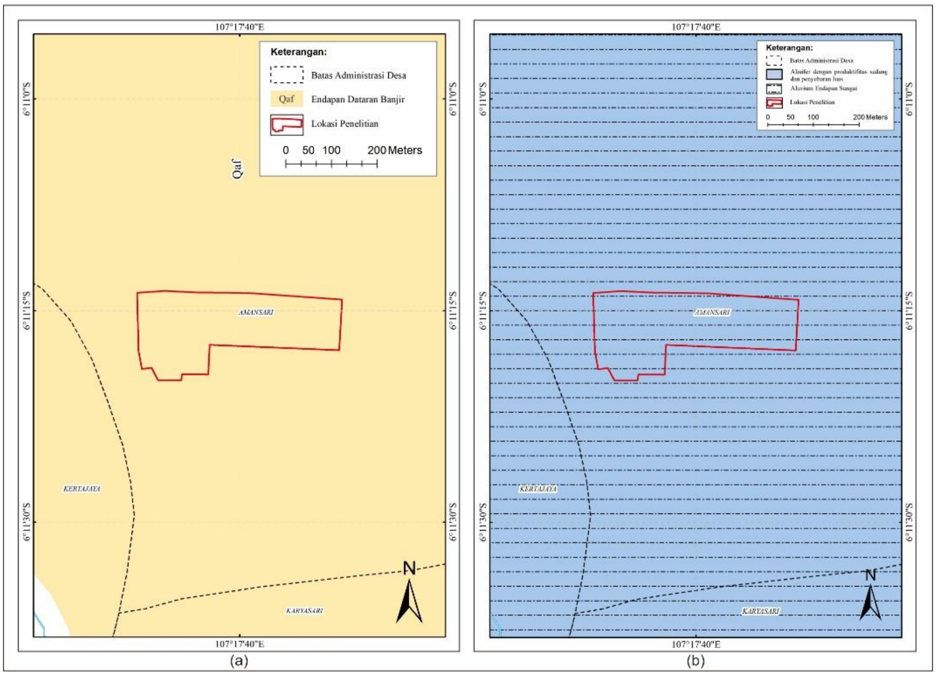


**Figure 2** (a) Regional geological map, modified from Achdan and Sudana (1992) and (b) Regional hydrogeological map, modified from Soetrisno (1985)

The research stages consisted of collecting primary data in the form of pumping test data and secondary data in the form of drilling and geoelectric reports. After all the data were collected, calculations are carried out to analyze optimum pumping discharge and aquifer parameters in every single well at research location. And then, a pumping simulation is carried out to discover how the drawdown condition of each well based on the simulation model and determine the drawdown criteria.

In this study, two kinds of pumping test were carried out. First is a step drawdown test which is carried out on all wells and the second is a constant rate test which is conducted only on 3 wells that are considered representative of the distribution of wells in the research location. Determination of the optimum pumping discharge was carried out using a step drawdown test based on the Hantush-Bierschenk method according to Kruseman and de Ridder in [3] and BSN Standard SNI 8061:2015 in [4], where the duration of the test was 2 hours with 3 stages in every well. Well parameters in the form of aquifer loss coefficient (B), well loss coefficient (C), aquifer loss (BQ), and well loss ($CQ^2$) can be known from this method.

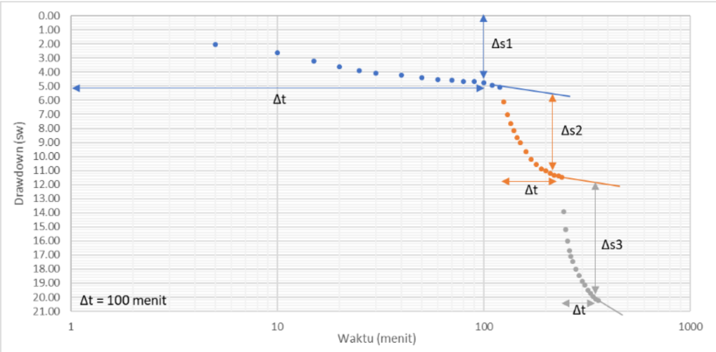


**Figure 3** Determination of drawdown differences for each stage, modified from Kruseman and de Ridder (2000)

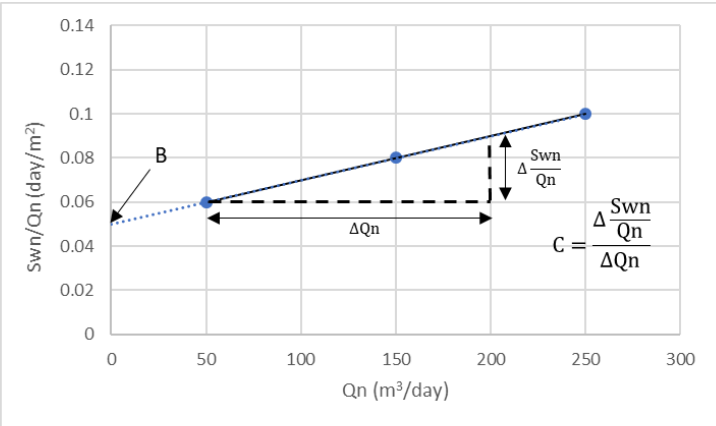


**Figure 4** Determination of parameters B and C, modified from Kruseman and de Ridder (2000)

Then, the value of well efficiency (Ew) can be calculated using the following equation.

$$E_w = \left( \frac{BQ}{BQ + CQ^2} \right) \times 100\% \quad (1)$$

The aquifer parameters were obtained by carrying out a constant rate test on 3 wells which were considered representative and field conditions allowed for this test to be carried out. The test was carried out for 72 hours in each well, to then calculate the aquifer parameter in the form of transmissivity based on the Cooper-Jacob method according to Kruseman and de Ridder in [3]. Besides transmissivity, other aquifer parameters that can be calculated are hydraulic conductivity and specific capacity.

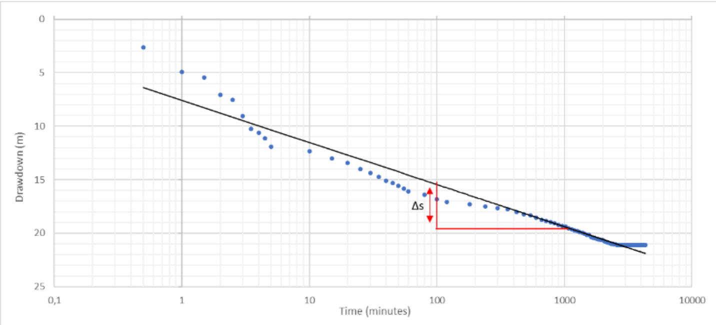


**Figure 5** Determination of Δs value from constant rate test, modification from Kruseman and de Ridder (2000)

The aquifer parameter values (transmissivity, hydraulic conductivity, and specific capacity) can be calculated using the following equations.

$$T = \frac{2{,}3.Q}{4\pi.\Delta s} \tag{2}$$

$$K = \frac{T}{b} \tag{3}$$

$$Sc = \frac{Q}{Sw} \tag{4}$$

The notation T is the transmissivity, Q is the pumping discharge, Δs is the drawdown due to pumping in one logarithmic cycle, K is the hydraulic conductivity, b is the length of the screen in the well, Sc is the specific capacity, and Sw is the drawdown due to pumping during testing.

The transmissivity value obtained was only found in 3 out of 7 wells in the research location. For pumping simulation purposes, the estimated transmissivity values for the other 4 wells are calculated using the Logan equation in [5] which is based on the relationship between specific capacity and transmissivity as follows.

$$T = 1{,}22 \times Sc \tag{5}$$

Some of the assumptions in this pumping test is: the pumped confined aquifer has unlimited lateral distribution, is homogeneous, and has a relatively uniform thickness.

Next is the creation of a pumping simulation model for 7 wells simultaneously which includes data such as initial groundwater level, pumping discharge, well radius, transmissivity, screen length of each well, and pumping duration. The pumping discharge used is the value of optimum discharge from each well in the form of a discharge at a condition of 70% well efficiency. The result of this simulation is drawdown from each well and the distance of the pumping effect.

According to the Minister of Energy and Mineral Resources Regulation No. 31 of 2018 in [6] it is noted that drawdown that is categorized as safe is <40% of the initial condition, so if in the initial simulation the resulting drawdown exceeds the safe limit, then a re-simulation is carried out in trial and error by changing the discharge and pumping duration until a drawdown < 40% is obtained while maintaining a well efficiency value of not less than 70%.

## 3 Results dan Discussion

Knowledge of the subsurface geological and hydrogeological conditions of the research location was obtained from drilling data and also geoelectrical interpretation. Based on the results of the correlation between cutting analysis and geoelectrical interpretation, three types of rock were obtained that is clay, sandy clay, and sand where the three layers were covered by soil which generally has thickness of 3 meters. While the hydrogeological units at the research location are aquicludes, aquitars, semi-confined aquifers, and confined aquifers. The results of the reconstruction of the geological and hydrostratigraphic conditions at the research location are presented in a fence diagram. All wells in the research location are extracted a water from confined aquifer layer at a depth of 50-100 meters with a screen length that varied from 6-12 meters from each well.

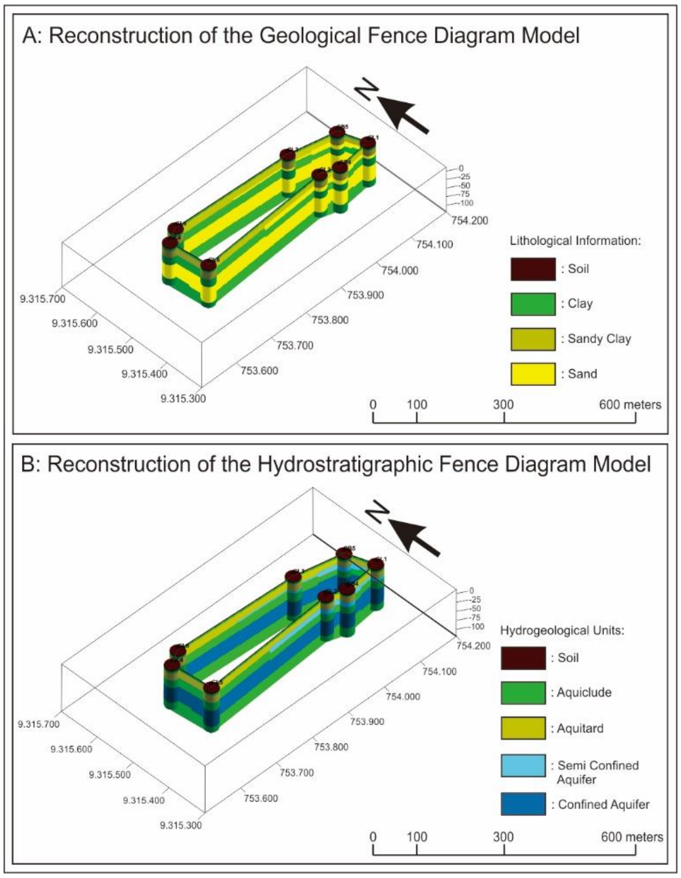


**Figure 6** (a) Reconstruction of the fence diagram model for geological conditions and (b) Reconstruction of the fence diagram model for hydrostratigraphic conditions

From the results of data processing of step drawdown test using the Hantush-Bierschenk method, the optimum discharge amount from each well is ± 2 liters/second, assuming a well efficiency value of 70% is the lowest value that the pumping of the well is said to be still efficient, and well efficiency that is less than 70% is classified as inefficient pumping condition.

**Table 1** Data Processing Results of Step Drawdown Test

| Well Code | Step | Δs (meter) | $S_{w(n)}$ (meter) | $Q_n$ | | $S_{w(n)}/Q_n$ | C | B | BQ | $CQ^2$ | Well Eff (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | l/sec | $m^3$/day | | | | | | |
| SB-1 | 1 | 4,76 | 4,76 | 1,00 | 86,40 | 0,0551 | $9{,}9x10^{-5}$ | 0,045 | 3,867 | 0,741 | 83,910 |
| | 2 | 5,,2 | 10,68 | 2,10 | 181,44 | 0,0589 | | | 8,120 | 3,270 | 71,291 |
| | Qopt | - | - | 2,23 | 193,00 | - | | | 8,637 | 3,700 | 70,011 |
| | 3 | 8,15 | 18,83 | 3,00 | 259,20 | 0,0726 | | | 11,600 | 6,673 | 63,481 |

| Well Code | Step | Δs (meter) | $S_{w(n)}$ (meter) | $Q_n$ | | $S_{w(n)}/Q_n$ | C | B | BQ | $CQ^2$ | Well Eff (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | l/sec | $m^3$/day | | | | | | |
| SB-2 | 1 | 4,76 | 4,76 | 0,87 | 75,17 | 0,0633 | $9,2x10^{-5}$ | 0,053 | 4,003 | 0,522 | 88,458 |
| | 2 | 5,63 | 10,39 | 1,95 | 168,48 | 0,0617 | | | 8,973 | 2,624 | 77,372 |
| | 3 | 8,71 | 19,10 | 2,78 | 240,19 | 0,0795 | | | 12,793 | 5,334 | 70,575 |
| SB-3 | 1 | 5,16 | 5,16 | 0,92 | 79,49 | 0,0649 | $1,2x10^{-4}$ | 0,054 | 4,294 | 0,767 | 84,837 |
| | 2 | 7,40 | 12,56 | 2,02 | 174,53 | 0,0719 | | | 9,428 | 3,700 | 71,817 |
| | Qopt | - | - | 2,20 | 190,00 | - | | | 10,264 | 4,385 | 70,067 |
| | 3 | 7,12 | 19,68 | 2,70 | 233,28 | 0,0844 | | | 12,602 | 6,610 | 65,594 |
| SB-4 | 1 | 4,93 | 4,93 | 0,87 | 75,17 | 0,0656 | $1,1x10^{-4}$ | 0,054 | 4,045 | 0,648 | 86,201 |
| | 2 | 6,13 | 11,06 | 1,97 | 170,21 | 0,0649 | | | 9,160 | 3,320 | 73,395 |
| | Qopt | - | - | 2,31 | 200,00 | - | | | 10,763 | 4,584 | 70,129 |
| | 3 | 8,36 | 19,42 | 2,64 | 228,10 | 0,0851 | | | 12,275 | 5,963 | 67,305 |
| SB-5 | 1 | 5,00 | 5,00 | 0,89 | 76,90 | 0,0650 | $1,1x10^{-4}$ | 0,054 | 4,183 | 0,652 | 86,524 |
| | 2 | 6,70 | 11,70 | 1,99 | 171,94 | 0,0680 | | | 9,354 | 3,257 | 74,171 |
| | Qopt | - | - | 2,43 | 210,00 | - | | | 11,424 | 4,859 | 70,159 |
| | 3 | 8,10 | 19,80 | 2,74 | 236,74 | 0,0836 | | | 12,879 | 6,175 | 67,591 |
| SB-6 | 1 | 4,97 | 4,97 | 1,00 | 86,40 | 0,0575 | $10^{-4}$ | 0,046 | 3,958 | 0,798 | 83,215 |
| | Qopt | - | - | 2,08 | 180,00 | - | | | 8,247 | 3,465 | 70,411 |
| | 2 | 6,54 | 11,51 | 2,23 | 192,67 | 0,0597 | | | 8,827 | 3,971 | 68,975 |
| | 3 | 8,19 | 19,70 | 2,95 | 254,88 | 0,0773 | | | 11,677 | 6,948 | 62,694 |
| SB-7 | 1 | 4,89 | 4,89 | 0,85 | 73,44 | 0,0666 | $1,1x10^{-4}$ | 0,055 | 4,036 | 0,607 | 86,917 |
| | 2 | 6,07 | 10,96 | 1,95 | 168,48 | 0,0650 | | | 9,258 | 3,197 | 74,332 |
| | Qopt | - | - | 2,37 | 205,00 | - | | | 11,265 | 4,733 | 70,414 |
| | 3 | 8,50 | 19,46 | 2,62 | 226,37 | 0,0859 | | | 12,440 | 5,772 | 68,308 |

Processing of constant rate test data using the Cooper-Jacob method resulted transmissivity values ranging from 9,93-11,57 $m^2$/day. While the estimated value of transmissivity for wells that were not subjected to a constant rate test, using the Logan equation resulted in an estimated transmissivity ranging from 13,47-15,46 $m^2$/day.

**Table 2** Data Processing Results of Constant Rate Test

| Well Code | Pumping Discharge (Q) | | Δs (m) | Transmissivity (T) | | b (m) | Hydraulic Conductivity (K) | |
|---|---|---|---|---|---|---|---|---|
| | l/sec | $m^3$/sec | | $m^2$/sec | $m^2$/day | | m/sec | m/day |
| SB-1 | 3,00 | 0,00300 | 4,10 | 0,00013399 | 11,5768215 | 6 | 0,000022332 | 1,92947 |
| SB-2 | 2,78 | 0,00278 | 3,10 | 0,00013397 | 11,57479048 | 6 | 0,000022328 | 1,92913 |
| SB-3 | 2,70 | 0,00270 | 4,30 | 0,00011498 | 9,93452822 | 9 | 0,000012776 | 1,10384 |

**Table 3** Transmissivity Estimation Value Using the Logan Equation (1964)

| Well Code | Pumping Discharge (Q) | | Sw (m) | Specific Capacity (Sc) | | Transmissivity (T) | | b (m) | Hydraulic Conductivity (K) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | l/sec | $m^3$/sec | | l/sec/m | $m^3$/sec/m | $m^2$/sec | $m^2$/day | | m/sec | m/day |
| SB-4 | 2,64 | 0,00264 | 20,44 | 0,1292 | 0,000129 | 0,000158 | 13,6143 | 9 | 0,0000175 | 1,5127 |
| SB-5 | 2,74 | 0,00274 | 20,07 | 0,1365 | 0,000137 | 0,000167 | 14,3905 | 12 | 0,0000139 | 1,1992 |
| SB-6 | 2,95 | 0,00295 | 20,11 | 0,1467 | 0,000147 | 0,000179 | 15,4626 | 9 | 0,0000199 | 1,7181 |
| SB-7 | 2,62 | 0,00262 | 20,50 | 0,1278 | 0,000128 | 0,000156 | 13,4717 | 6 | 0,0000260 | 2,2453 |

Baumle in [7] modify the groundwater classification potential created by Struckmeyer and Margat in [8] into 4 categories, that is high, moderate, limited, and essentially none based on several aquifer parameters, that is transmissivity, hydraulic conductivity, and specific capacity. In addition, the discharge that can be generated from each of these categories are also estimated. Based on the aquifer parameters obtained from the processing of step drawdown test and constant rate test, as well the optimum discharge in each well, the groundwater potential at the research location is classified into the moderate class. This is corresponding with a regional hydrogeological study conducted by Soetrisno (1985) which stated that the research location belongs to the aquifer group with moderate productivity with a well discharge of less than 5 liters/second.

**Table 4** Groundwater potential at the research location, modified from baumle (2011)

| Specific Capacity (l/sec/m) | Transmissivity ($m^2$/day) | Hydraulic Conductivity (m/day) | Estimated Discharge (l/sec) | Groundwater Potential |
|---|---|---|---|---|
| > 1 | > 75 | > 3 | > 10 | High |
| 0,1 - 1 | 5 - 75 | 0,2 - 3 | 1 - 10 | Moderate |
| 0,001 – 0,1 | 0,05 - 5 | 0,002 – 0,2 | 0,01 - 1 | Limited |
| < 0,001 | < 0,05 | < 0,002 | < 0,01 | Essentially None |

After a number of aquifer parameters are known, pumping simulations are then carried out on 7 wells at the research location simultaneously to determine the simulation model and also the drawdown of each well. From the simulation results with the pumping discharge used which is the optimum discharge from each well and the pumping duration of 10 hours/day shows that the drawdown is generally not included in the safe category. SB-2 and SB-3 even fall into the critical category (60%-80%) while the safe category is only found in SB-5 and SB-6, and the other three wells are included in the vulnerable category.

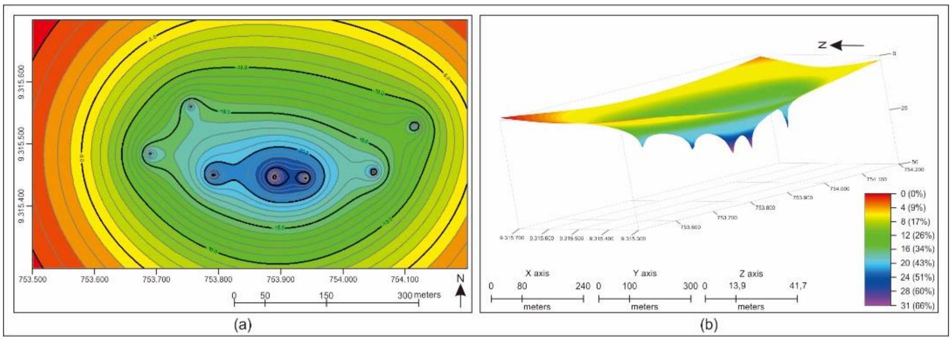

**Figure 7** (a) Drawdown contour map resulting from the optimum discharge pumping simulation and (b) 3-dimensional drawdown model resulting from the optimum discharge pumping simulation

**Table 5** Pumping Simulation Results Based on Optimum Discharge

| Well Code | Top of Aquifer Layer (m) | Water Table (m) | Water Column Height (m) | Pumping Discharge (l/sec) | Transmissivity ($m^2$/day) | Pumping Duration (hours/day) | Drawdown (m) | Drawdown Percentage | Category |
|---|---|---|---|---|---|---|---|---|---|
| SB1 | 51,35 | 6,85 | 44,50 | 2,23 | 11,5768 | | 25 | 56,18% | Vulnerable |
| SB2 | 52,87 | 6,10 | 46,77 | 2,78 | 11,5748 | | 31 | 66,28% | Critical |
| SB3 | 53,62 | 6,70 | 46,92 | 2,20 | 9,9345 | | 31 | 66,07% | Critical |
| SB4 | 55,00 | 6,89 | 48,11 | 2,31 | 13,6143 | 10 | 27 | 56,12% | Vulnerable |
| SB5 | 54,00 | 6,92 | 47,08 | 2,43 | 14,3905 | | 18 | 38,23% | Safe |
| SB6 | 57,72 | 7,03 | 50,69 | 2,08 | 15,4626 | | 20 | 39,46% | Safe |
| SB7 | 50,16 | 6,87 | 43,29 | 2,37 | 13,4717 | | 20 | 46,20% | Vulnerable |

The pumping simulation with the pumping discharge used is the optimum discharge from each well and the pumping duration is 10 hours/day shows a drawdown which is generally not included in the safe category. Therefore a re-simulation was carried out in trial and error by changing the discharge and pumping duration of each well. In SB-5, SB-6 and SB-7, the pumping rate was not changed from the initial simulation, but only the pumping duration was set to be longer, namely 18 hours/day. This is done in order to maintain the efficiency of the well so that it is not less than 70%. The duration of pumping in SB-1, SB-2 and SB-3 is reduced to 2 hours/day with a pumping discharge of 2,13 liters/second in SB-1, 1,75 liters/second in SB-2, and 1,58 liters/second in SB-3.

Meanwhile, the duration of pumping in the SB-4 was reduced to 3,80 hours/day with a pumping discharge of 2,08 liters/second. This pumping simulation resulted a safe drawdown (<40%) in all wells with the lowest drawdown in SB-5 of 13 meters and the highest drawdown in SB-4 of 19 meters. The quantity of produced groundwater from this simulation is 513,68 $m^3$/day.

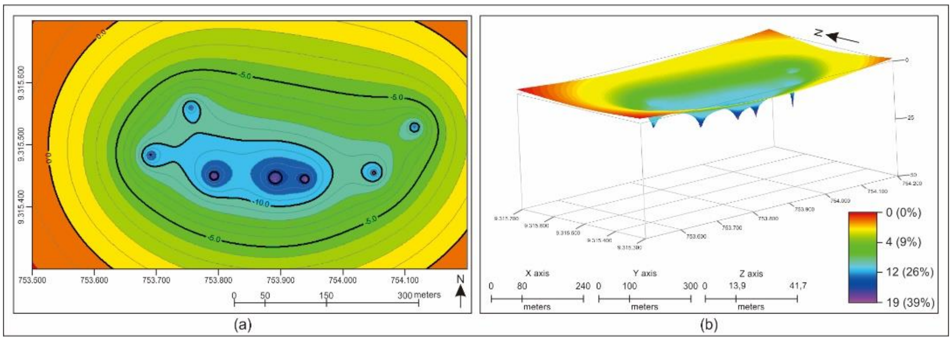


**Figure 8** (a) Contour map of safe drawdown from pumping simulation results and (b) 3-dimensional model of safe drawdown from pumping simulation results

**Table 6** Pumping Simulation Results of a Safe Limit Drawdown

| Well Code | Pumping Discharge (l/sec) | Pumping Duration (hours/day) | Drawdown (meters) | Drawdown Percentage | Water Production | | Category |
|---|---|---|---|---|---|---|---|
| | | | | | l/day | $m^3$/day | |
| SB1 | 2,13 | 2,00 | 17 | 38,20% | 15.360 | 15,36 | Safe |
| SB2 | 1,75 | 2,00 | 18 | 38,49% | 12.600 | 12,60 | Safe |
| SB3 | 1,58 | 2,00 | 18 | 38,36% | 11.400 | 11,40 | Safe |
| SB4 | 2,08 | 3,80 | 19 | 39,49% | 28.500 | 28,50 | Safe |
| SB5 | 2,43 | 18,00 | 13 | 27,61% | 157.464 | 157,46 | Safe |
| SB6 | 2,08 | 18,00 | 14 | 27,62% | 134.784 | 134,78 | Safe |
| SB7 | 2,37 | 18,00 | 15 | 34,65% | 153.576 | 153,58 | Safe |
| Total Water Production | | | | | 513.684 | 513,68 | |

## 4 Conclusion

The aquifer parameters and the optimum discharge resulting from the pumping test show that the research location is included in the moderate groundwater potential. The results of the pumping simulation using the optimum discharge and pumping duration of 10 hours/day generally do not meet the safe drawdown criteria in several wells, so a re-simulation is carried out by changing the discharge and pumping duration so that the safe drawdown criteria are met. This condition is possible due to the distance between the wells that are too close, so that there is a significant pumping effect between one well and another. Based on this condition, the distance between the wells is considered not ideal, while for the other three wells it shows an ideal distance. The safe drawdown criterion is reached after the pumping discharge is lowered from the optimum discharge and the pumping duration is reduced in SB-1, SB-2, SB-3 and SB-4.

## Acknowledgement

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