EFFECT OF PUMPING AND HYDRAULIC PROPERTIES ON UNSATURATED GROUNDWATER FLOW IN YANGON AREA

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ABSTRACT: Recent groundwater resources development in Yangon area may bring out severe environmental problems such as land subsidence, groundwater pollution and drought. The final goal of this research project is to construct the ground water management for Yangon area to avoid such problems that will be induced by the excess pumping in a near future. Groundwater flow in the center part of Yangon was 3- dimensionally simulated with changing pumping rates, locations and pumping time. The area of this model is 25 km^2 and the depth is considered for 30 m where the groundwater can meet as much as possible. The hydraulic conductivity values were estimated by using the data from grain size distribution. The usage of groundwater resource will be much more increased in near future for the development of industrial work in Yangon area. It was found that the effect of pumping rate and hydraulic properties on groundwater flow in Yangon area could be roughly clarified.

INTRODUCTION

It was well known that groundwater is an important water resource. However, groundwater decline, land subsidence and salinization of groundwater in costal areas due to excessive groundwater usage will bring out a big social problem. Such problems can be occurred in developing countries as a result of a rapid increase of water resource utilization. Groundwater as well as river water has been used in the Yangon area for domestic and industrial use. The daily amount of water supplied from the groundwater sources is approximately 15 million gallons for all purposes. During the rainy season (mid May to mid October), the replenishment of groundwater is very significant because rainfall exceeds the water demand and evapotranspiration. After the rainy season, the groundwater level start to decline and the lowest level is reached at the end of dry season (mid May).The usage of groundwater will be much more increased in near future due to the development of industrial work. A proper management system of groundwater resource is desired to be constructed to avoid the environmental problems due to excess pumping. The final goal of this study was focused on the development of a proper groundwater management system by controlling the pumping rate according to the groundwater demand of the considered area. As a first step to construct the system, groundwater flow in the center part of Yangon was 3-dimensionally simulated with changing pumping locations and its rates.

GEOLOGY OF YANGON AREA

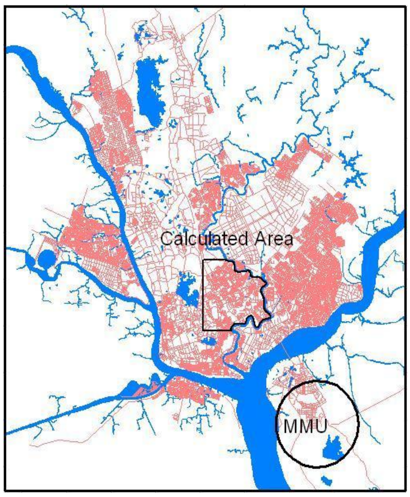
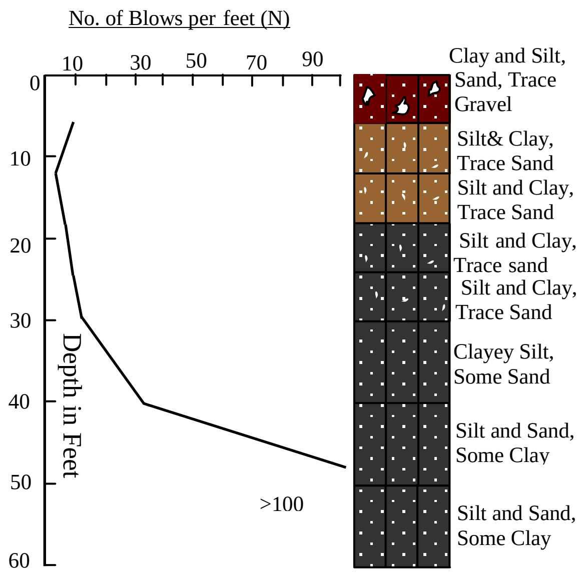
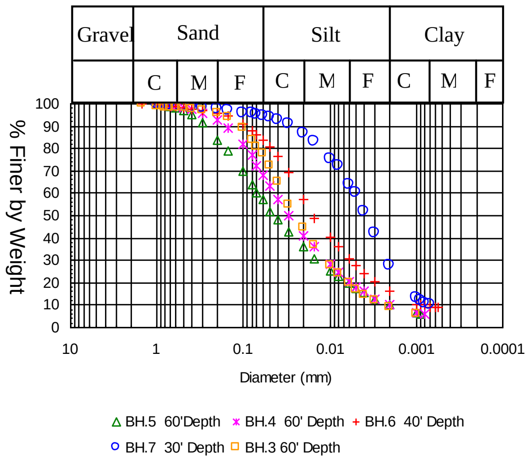


Fig-1 Yangon area map

Figure 1 illustrates the calculated area and also shows the location of Myanmar Maritime University (MMU) at which geological study was conducted. In recent geological research works were performed in MMU campus and Figure 2 shows the geological condition obtained from one of the bore hole results. The geological of this area is mostly composed of sand, silt and clay layer. Grain size distribution of typical soil was also shown in this figure. The geological condition of the calculated data was assumed as the same as MMU campus.



Ground Profile
(Location: MMU Campus)



C- Coarse M- Medium F- Fine

Grain size distribution curve

Fig-2 Geological condition in MMU area

HYDRAULIC PROPERTIES ESTIMATION

Estimation of hydraulic properties is indispensable for the calculation. Unfortunately, hydraulic test was not performed, so that, the hydraulic conductivity was estimated from grain size distributions. Four predictive empirical equations for hydraulic conductivity are used in this study. These empirical equations are mainly based on effective grain size, relative density of soil grain, porosity and void ratio of the soil sample. Table-1 indicates these empirical equations with their estimated hydraulic conductivity values of different bore hole locations. Based on these results and the characteristics of soil sample, the saturated hydraulic conductivity value was estimated as $5x10^{-6}$ m/sec in this study.

Table 1: Empirical equations for saturated hydraulic conductivity and their estimated values

Hydraulic Conductivity Equations	Hydraulic conductivity values				
	$BH-3$ $60'$ Depth	$BH-4$ $60'$ Depth	$BH-5$ $60'$ Depth	$BH-6$ $40'$ Depth	$BH-7$ $30'$ Depth
Kozeny Carman(Bear,1972) $k=\left[\frac{\rho g}{\mu}\right]\left[\frac{\eta^3}{(1-\eta)^2}\right]\left[\frac{d_m^2}{180}\right]$	7.07 $x10^{-6}$	8.33 $x10^{-6}$	6.6 $x10^{-6}$	2.67 $x10^{-6}$	3.13 $x10^{-6}$
Chapuis & Mantour (1992) $k_s=C\frac{g}{\mu_w\rho_w}\frac{e^3}{s^2D_r^{\,2}(1+e)}$	1.15 $x10^{-6}$	1.07 $x10^{-6}$	5.63 $x10^{-7}$	2.16 $x10^{-6}$	7.37 $x10^{-6}$
Aubertin et al. (1996) $K_s=\frac{c\gamma_w}{\mu_w 10^3}C_u^{1/3}D_{10}^2\frac{e^{3-x}}{1+e}$	2.65 $x10^{-5}$	2.68 $x10^{-6}$	3.56 $x10^{-6}$	6.26 $x10^{-7}$	1.08 $x10^{-7}$
Krubein and Monk equation $k=760(Gm_e)^2e^{(-1.31\sigma_\phi)}$	5.85 $x10^{-6}$	9.54 $x10^{-6}$	7.22 $x10^{-5}$	1.73 $x10^{-6}$	1.96 $x10^{-7}$

To predict the unsaturated hydraulic conductivity, Van Genuchten Model was adopted for presenting the soil hydraulic function k (θ) and h (θ). This model can be expressed as follows:

$$Se=\frac{\theta-\theta_r}{\theta_s-\theta_r} \qquad (0\le Se\le 1) \qquad (1)$$

$$Se=\left\{1+\left|\alpha\psi\right|^n\right\}^{-m} \qquad (\alpha>0) \qquad (2)$$

$$n=\frac{1}{1-m} \qquad (0<m<1, n>1) \qquad (3)$$

$$r(\theta)=Se^{1/2}\left\{1-\left(1-Se^{1/m}\right)^m\right\}^2 \qquad (4)$$

$$k(h)=k_s r(\theta) \qquad (5)$$

Where , *k(h)* is the unsaturated hydraulic conductivity (m/sec), k_s is the saturated hydraulic conductivity (m/sec), *r(θ)* is the relative hydraulic conductivity, S_e is the effective saturation, θ_r (L^3/ L^3) and θ_s (L^3/ L^3) are the residual and saturated volumetric water content and $\alpha(L^{-1})$, n and m are empirical parameters. These values are not easy to be measured. In this study, Van Genuchten parameter values of θ_s, θ_r, α (cm^{-1}) and n are roughly assumed as 0.45, 0.2, 0.11 and 6.67 respectively.

CONSIDERATION DOMAIN OF NUMERICAL MODEL

Figure 3 illustrates the area conducted and the mesh division. 3D FEM was used for the groundwater analysis. The area is about 25 km^2 and it covers about 1/4 of the whole Yangon area. The requirement of groundwater supply is mainly for domestic and groundwater demand of this area is higher than the other part. The effect of groundwater pumping is analyzed to manage the groundwater resource.

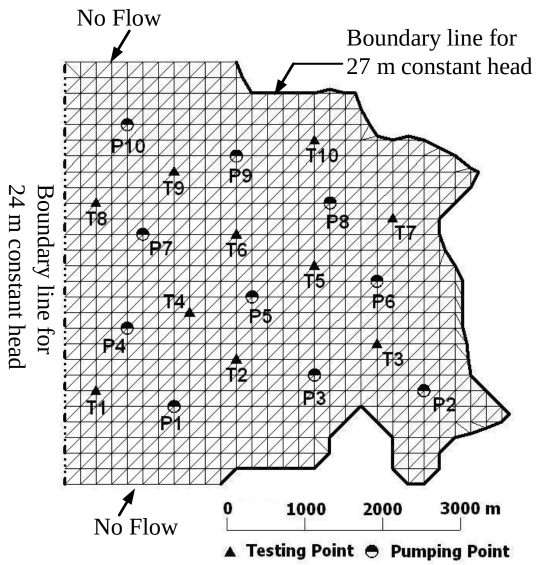


Fig-3 Schematic of domain area with finite element grid

The depth of this modal was fixed as 30 m and under this layer was assumed as impervious layer. To analyze in detail, the model was divided into 11 layers of each 3 m depth. There are 680 node points in each layer and totally 7480 node points. The boundary condition of the flow on the right hand side was fixed as 27 m and for the left hand side was 24 m, as shown in Figure 3. No flow boundaries were adopted in the top and bottom side of the domain. The initial condition of piezometric head was set as 27 m and the modal was run for various pumping rate from different locations. No rain fall condition was treated with considering the dry season. In this study, groundwater was pumped out from 10 pumping wells under various condition of pumping location, pumping rates and pumping duration. In this study, 10 testing points were selected near pumping points to analyze how can influence the pumping effect on these points. Location of pumping points and testing points are also illustrated in Figure 3. To analyze the pumping effect on groundwater flow, the piezometric head values under four conditions of pumping were calculated. Two of these are the cases of which groundwater pumping from the different layers of (-30 m depth and -15 m depth) with same pumping rate and pumping time. The other two calculations are groundwater pumping from the layer of (-15m) depth with different pumping rates and the last one was based on long time period of groundwater pumping from the layer of (-30m depth). Of course these conditions are not real ones. However, the groundwater behavior can be roughly evaluated.

RESULT AND DISCUSSION

Figure 4 presents the results obtained by pumping from (-30m) depth with pumping rate 0.0025 m^3/sec of each well. Calculated piezometric head curves for pumping points and testing points are shown in this figure. Pumping lasts 14 days from 10 pumping well. The results are mostly the same at pumping points. The lowest piezometric head reached to around 21.75 m at pumping points and around 25 m at testing points. The results from Figure 5 are obtained by pumping from (-15 m) depth with the same pumping rate 0.0025 m^3/sec per each well and pumping lasts for 14 days. In this case, the lowest piezometric value approached to 21 m at pumping points and below 25 m at testing points. By comparing these two pumping conditions, it can be evident that deeper pumping location can keep the piezometric head in high level.

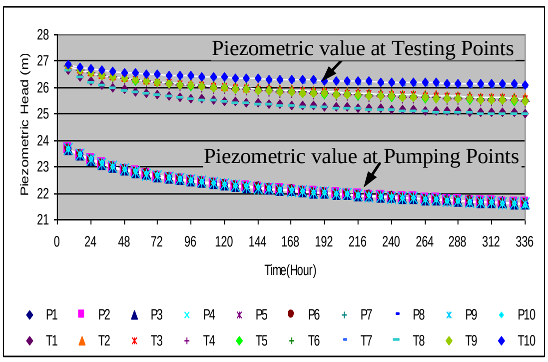


Fig-4 Piezometric Head Distribution of Groundwater Flow at (-30 m) Depth with Pumping Rate 0.0025 m^3/sec in each well

To analyze the relation between pumping rate and piezometric head distribution, various pumping rates are also considered in this study. Figure 6 displays the drawdown of the ground water table under the various pumping rate ($0.0015m^3$/sec~$0.0025m^3$/sec)in each pumping well. Pumping from (-30 m) depth and pumping lasts for 14 days. Although the piezometric head values of each pumping points are changed, the curves feature are similar and almost parallel to each other. Pumping rate is directly proportional to the piezometric head difference for defined pumping duration. Also the results of piezometric head at testing points are not so much changed although the pumping rates are changed. It may be the effect of unsaturated hydraulic conductivity of soil and the ground water pumping rate.

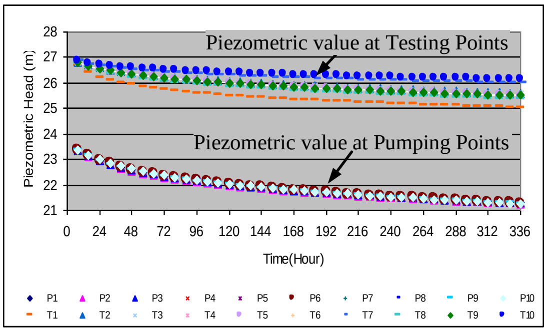


Fig-5 Piezometric Head Distribution of Groundwater Flow at (-15 m) Depth with Pumping Rate 0.0025 m^3/sec in each well

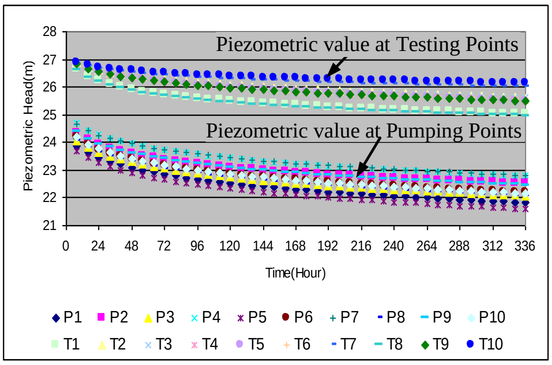


Fig-6 Piezometric Head Distribution of Groundwater Flow at (-30 m) Depth with Different Pumping Rate in each well

In this study, long time pumping condition is also taken into consideration for the pumping effect on groundwater level. Pumping time was 60 days from all wells at the rate of 0.01 m^3/ sec and the pumping was reduced to zero. These results are illustrated in Figure 7 and it can be seen that how much groundwater level can be decreased during 60 days and also how fast the water table starts to rise after pumping has been stopped.

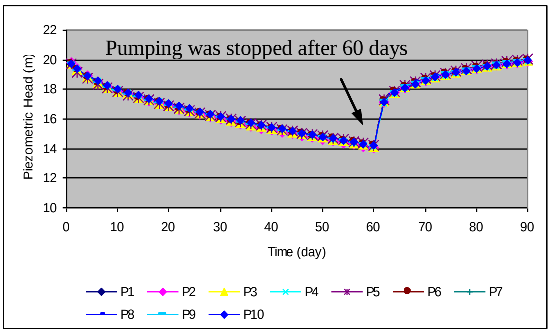


Fig-7 Piezometric Head Distribution of Groundwater Flow at (-30 m) Depth with Pumping Rate 0.01 m^3/sec in each well

CONCLUSION

Now the pumping rate and the groundwater table depth is not regulated in the Yangon City area. However, proper regulation system of groundwater should be constructed on the basis of hydrological investigation and groundwater simulation. Groundwater management is essential for sustainable extraction and to minimize the related socio-environmental problems such as land subsidence, groundwater pollution and drought. As the first step to construct groundwater management system for the Yangon, Myanmar, the effect of pumping rates on piezometric head was analyzed. The relation between groundwater pumping operation and the variation of groundwater table was evaluated in this study.

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