STOCHASTIC GROUNDWATER TRANSPORT FLOW MODEL IN PONTIAN, JOHOR

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To my beloved

Mum, Dad, and Roger

Thank you for always being there for me.

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ABSTRACT

Groundwater is the fresh water contained in aquifers buried below the earth's surface and is becoming vital natural resources for the nation nowadays. The demand of groundwater development in many countries is increases due to the limitation supplies of the fresh water on earth. However, due to the presence of rivers and abundance of rainfall in Malaysia, groundwater is given less priority as a source of water supply. This research studied on the hydraulic conductivity, *K* which is an important variable in groundwater transport flow. The data used in this study are two sets of secondary data collected by using auger-hole method with 2 different diameter measuring auger-hole near Jalan Sawah, Pekan Nanas, Pontian, Johor. The values of soil hydraulic conductivity were obtained by using Ernst and Hooghoudt formula. From the calculation, the range of hydraulic conductivity is between $0.3457\ x\ 10^{-3}$ cm/s to $4.8135\ x\ 10^{-3}$ cm/s and it agrees that the hydraulic conductivity of peat soil that is between 1×10^{-4} cm/s to 1×10^{-3} cm/s. Besides that, this research also studies the effect of depth of water table and radius of auger hole toward hydraulic conductivity. The result obtained from multiple linear regressions shows that the depth of water table and radius of auger hole affect the hydraulic conductivity significantly. Lastly, stochastic approach was used to model the one dimensional, steady state and saturated groundwater flow and the exact solution is the expected function of the gradient of the head potential.

ABSTRAK

Air bawah tanah merupakan air segar dikebumikan dalam akuifer di bawah permukaan bumi. Ia adalah sumber semula jadi yang amat penting untuk negara pada masa kini. Oleh kerana bekalan air tawar di bumi yang terhad , ia meningkatkan permintaan pembangunan air bawah tanah di banyak negara. Walau bagaimanapun, air bawah tanah di Malaysia agak kurang diberi keutamaan sebagai sumber bekalan air disebabkan oleh kehadiran sungai dan hujan di Malaysia. Kajian ini mengkaji tentang konduktiviti hidraulik, *K* yang merupakan satu parameter yang penting dalam aliran pengangkutan air bawah tanah. Data yang digunakan dalam kajian ini adalah dua set data sekunder yang dikumpulkan dengan menggunakan kaedah gerimit lubang yang berbeza diameternya di Jalan Sawah , Pekan Nanas, Pontian, Johor. Nilai konduktiviti hidraulik tanah telah diperolehi dengan menggunakan Ernst dan Hooghoudt formula. Dari pengiraan, julat konduktiviti hidraulik adalah di antara $0.3457\ x\ 10^{-3}$ cm/s hingga $4.8135\ x\ 10^{-3}$ cm/s dan ia bersetuju bahawa konduktiviti hidraulik tanah gambut adalah antara 1×10^{-4} cm/s to 1×10^{-3} cm/s. Selain itu, kajian ini juga mengkaji kesan kedalaman aras air dan jejari lubang auger terhadap konduktiviti. Model yang diperolehi daripada model regresi linear berganda menunjukkan bahawa kedalaman aras air dan jejari lubang auger mempengaruhi konduktiviti hidraulik dengan ketara. Akhir sekali , penyelesaian stokastik telah digunakan untuk membentuk air bawah tanah bagi satu dimensi yang berada dalam keadaan tepu dan mantap. Penyelesaian tepat telah diperoleh dalam bentuk fungsi jangkaan kecuranan kepala hidraulik.

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LIST OF SYMBOLS/ABBREVIATIONS

T	-	Time
Q	-	Quantity of water
K	-	Hydraulic conductivity
A	-	Cross-sectional area
$\frac{dh}{dl}$	-	Hydraulic gradient
K_s	-	Saturated hydraulic conductivity
Δy	-	Average water level
Δt	-	Time interval
r	-	Radius of the hole
S	-	Depth of the impermeable layer
y	-	Depth of the water level in the hole
d	-	Depth of water table
m	-	Slope line
c	-	*Y*-intercept
X	-	Predictor
α	-	Significance level of hypothesis test
β_j	-	Coefficients
β_i	-	Best set parameter
$W(t)$	-	Stochastic process
$x(t)$	-	Stochastic parameter
dw	-	Differential form of the Brownian motion
D'	-	Depth of auger-hole
D_1	-	Depth of water table
H_0	-	Null hypothesis
H_1	-	Alternative hypothesis

b_1	-	Estimated slope coefficient
$F(s)$	-	Stochastic random fields
$f(s)$	-	Stochastic random fields
$h(s)$	-	Stochastic random fields
σ_g^2	-	Variance of g
σ_f	-	Standard deviation of f
$p(g)$	-	Probability distribution of g

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water is crucial for all life on earth. It plays an important role in our health, environment and even world economy. However, there is limiting supplies for the fresh water on earth due to pollution, contamination and so on. Therefore, this increases the demand of underground water development in many countries. It also has been fully used in many other countries mainly to supply water to various needs of industry, domestic, agriculture and social development. In Malaysia, due to the presence of rivers and abundance of rainfall, groundwater is given less priority as a source of water supply.

However, according to Yahya and Suratman (2009), the utilization of groundwater is an increasing trend due to high water demand, viability of supply and costs-saving for industrial operators. In Malaysia, rural areas use groundwater for domestic purposes because there is lack of piped water supply. However, there exist several large capacity municipal wells in Kelantan, which provide 70% of the public water supply for the state in the form of groundwater. While, other states such as Pahang, Selangor, Perlis and Sarawak have developed groundwater on a limited scale for public water supply. Besides for domestic purposes, Selangor Darul Ehsan uses this resource of water especially for industrial purpose.

Therefore, proper management of these groundwater resources requires detailed knowledge of the groundwater system. However, it has never been found in the literature so far on the application of stochastic model of groundwater flow in Malaysia using real data. This application could be used to develop rational groundwater management practices and policies as well as a robust modeling and analysis tool for groundwater in Malaysia. However, there is uncertainty associated with the undefined input parameters in such models such as hydraulic conductivity which vary stochastically. Hence, deterministic method is no longer suitable to model the groundwater. Therefore, the main purpose of this research is to model the groundwater transport flow in Pontian, Johor by using multiple linear regression and stochastic approach. This finding will give some general information on the groundwater transport flow in the district of Johor, Pontian which is needed by environmental engineers to manage the groundwater.

1.2 Problem Statement

Groundwater is one of the natural clean water sources. However, surface water resources from river, lakes and rainfall are more exploited and used rather than groundwater in Malaysia. In recent decades, there are a lot of problems related to surface water resource such as degradation in water quality and quantity that had been addressed by Ibrahim, *et al*. (2012). Therefore, groundwater could become an important alternatives source of clean water for various uses such as drinking purpose, residential water supply and industrial use. Hence, this reinforces the demand for developing groundwater flow model to obtain better understanding of this environmental problem so that the current supply of water would be in tandem with population and industrial production growth.

The gap between stochastic theories and application in studying fluid flow had been addressed by Li *et al*. (2003). They agree that the reason for this gap is due mainly to the excessive computational demands of available numerical methods for solving stochastic problems. Besides that, according to Illangasekare and Saenton (2004), the uncertainties associated with the undefined input parameters such as hydraulic conductivity and porosity that vary in space results in groundwater flow model prediction errors. Hence, it is necessary to incorporate parameter uncertainty into the groundwater flow models to increase confidence in predictions. Thus, stochastic approaches are needed to deal with these parameter and prediction uncertainties. However, it has never been found in the literature so far on the application of stochastic model of groundwater flow in Malaysia using real data. So, we wish to model the soil hydraulic conductivity of groundwater in Pontian using real data and solve the groundwater transport flow model by stochastic approach.

1.3 Objectives of Study

Thus this research will embark on the following objectives:

i- To determine the hydraulic conductivity of the peat soil in Pontian.

ii- To model the hydraulic conductivity of groundwater in Pontian using multiple linear regressions.

iii- To model the groundwater transport flow using stochastic approach.

1.4 Scope of Study

This study emphasize on the groundwater transport flow in the district of Johor Bahru, Pontian. The hydraulic conductivity of the peat soil in Pekan Nanas, Pontian was calculated by using Ernst and Hooghoudt formula. Furthermore, the observed and calculated hydraulic conductivity for both data sets were modeled by using linear regression and multiple linear regressions (MLR). The models obtained from MLR were compared using mean square error (MSE). Lastly, the one dimensional, steady state, and saturated groundwater transport flow model in Pontian was modeled by using a stochastic approach. The data used in this research is a secondary data which is collected by Abdullah (2007).

1.5 Significance of Study

By the end of this study, we can have a better understanding on the hydraulic conductivity of groundwater in Pontian. The model of hydraulic conductivity is usually needed by environmental engineers to manage the groundwater and to improve the groundwater system in Malaysia. Furthermore, this study further enriches the knowledge of exact stochastic solution of groundwater transport flow in Pontian which gave a better estimation on the groundwater that will help environment scientist to manage groundwater resources more efficiently

1.6 Thesis Organization

This thesis is organized into five chapters. Chapter 1 is the introduction of this thesis. It highlights the background of the study and the problem statement. Objectives and scopes of this study are also mentioned in this chapter. The significant of study is also defined in this chapter.

On the other hand, Chapter 2 outlines literature review of this study. It starts with an introduction of Pekan Nanas, Pontian which is the scope of this study. The structures and review of groundwater are described in this chapter. Besides, some basic concept such as hydraulic head, Darcy's law and hydraulic conductivity are presented. Some review of groundwater, transport flow and hydraulic conductivity are also highlighted in this chapter. Moreover, this chapter has included knowledge about multiple linear regressions, Brownian motion, stochastic differential equation (SDE) and Gaussian probability distribution.

Furthermore, Chapter 3 includes the methodology used to solve the groundwater transport flow model and to model the hydraulic conductivity of groundwater in this thesis. All the steps that are considered and discussed in this chapter were summarized in the research framework in section 3.3. For the parameter estimation part, the hydraulic conductivity, *K* value is introduced and calculated. It further was modeled by using linear regression and multiple linear regressions. This chapter also discusses the properties of Brownian motion and stochastic differential equation. Lastly, groundwater flow model was presented.

Chapter 4 presents the data analysis of the peat soil's hydraulic conductivity in Pontian. Next, the field of hydraulic conductivity value, *K* is determined. The data used in this study was the experimental data collected by Abdullah (2007) using auger-hole method. The data obtained were analyzed based on Ernst and Hooghoudt formula which is non-linear. Besides that, the result obtained was analyzed and correlations between the parameters were drawn. A linear model obtained from multiple linear regressions was used to find the estimated field of hydraulic conductivity value, K_e. Then, a comparison of mean square error (MSE) for the observed log-conductivity and calculated log-conductivity with their linear model was done for Data 1 and Data 2 respectively. Finally, the groundwater transport flow in Pontian was modeled by using stochastic approach in order to help authority to make future planning for the groundwater in Pontian.

Lastly, Chapter 5 discusses the conclusion of this thesis. Furthermore, few recommendations for the future studies are also been presented at the end of this chapter.

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