UNIVERSITI PUTRA MALAYSIA

UTILIZATION OF ARTIFICIAL AQUIFER PHYSICAL MODEL TO AID TECHNICAL LEARNING OF GROUNDWATER HYDROLOGY

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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A study of hydrogeological process involves movement of water beneath the ground surface. Water content in the aquifer influences the quantitative determination of aquifer hydraulic parameters. The limited opportunity to explore and demonstrate groundwater processes is the reason why students have inappropriate understanding of groundwater concept. The visualisation of groundwater flow is quite difficult as it deals with subsurface condition which cannot be seen. In research, field experiments on groundwater are difficult to carry out because time consuming and involves uncertainty in aquifer conditions. Physical models have been used in classroom as a tool for teaching hydrogeology. Further understanding was developed by demonstration and observation of groundwater flow using simple sand tank. Previous research implemented sand tank under controlled conditions to investigate the mechanism and flow process of groundwater. A large artificial physical aquifer model was developed in this study as an alternative to show the students the real aquifer condition and hydrogeology processes. The model consisted of three different layers of soils, in which water table level was controlled using water tank at both sides of the physical model structure. Hydraulic parameters of the artificial aquifer and performance of production well were evaluated by pumping tests. The groundwater flow in the artificial aquifer model was simulated accordingly to Darcy's law. Analysis of pumping test was computed by an Aquifer Test software. Well performance measurement provided by a step drawdown pumping test estimated the efficiency of well as 99%. The artificial aquifer model was verified by constant rate discharge pumping test and found to be a leaky aquifer. The pumping test analyzed the aquifer with transmissivity of 78.50m^2/day and hydraulic conductivity of 7.37m/day while recovery test analyzed the transmissivity to be 8.22m^2/day and hydraulic conductivity of 7.34m/day. Both test analyzed the storage coefficient as 0.5. This artificial aquifer physical model was designed and developed to enhance student's understanding of groundwater theory. Through hands-on pumping test on the aquifer model, students would be able to visualize clearer the groundwater processes.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PENGGUNAAN MODEL AKUIFER BUATAN FIZIKAL UNTUK MEMBANTU PEMBELAJARAN TEKNIKAL HIDROLOGI AIR BAWAH TANAH

Oleh

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Kajian mengenai proses hidrogeologi melibatkan pergerakan air di bawah permukaan tanah. Kandungan air di dalam akuifer mempengaruhi penentuan parameter hidraulik bagi akuifer secara kuantitatif. Peluang yang terhad untuk meneroka dan menunjukkan proses air bawah tanah menjadi sebab mengapa pelajar mempunyai kefahaman yang kurang tepat mengenai konsep air bawah tanah. Visualisasi aliran air bawah tanah adalah agak sukar kerana ia berkaitan dengan permukaan bawahan yang tidak dapat dilihat sepanjang kajian. Dalam penyelidikan kajian lapangan tentang air bawah tanah kadang-kala sukar untuk dijalankan kerana memakan masa dan melibatkan ketidaktentuan keadaan akuifer. Model fizikal pernah digunakan di dalam kelas sebagai alat untuk pengajaran hidrogeologi. Pemahaman lebih lanjut dapat dikembangkan melalui demonstrasi dan pemerhatian aliran air bawah tanah menggunakan tangki pasir yang ringkas. Kajian terdahulu menggunakan tangki pasir di bawah keadaan terkawal untuk menyiasat mekasnime dan proses aliran air bawah tanah.Model akuifer buatan yang besar telah dibangunkan dalam kajian ini sebagai alternatif untuk menunjukkan keadaan akuifer sebenar dan proses hidrogeologi kepada pelajar. Model ini terdiri daripada tiga lapisan tanah yang berbeza, di mana paras air dikawal menggunakan tangki air pada kedua-dua belah struktur model. Parameter hidraulik akuifer buatan dan prestasi telaga pengeluaranjuga telah dinilai oleh ujian pengepaman.Aliran air bawah tanah di dalammodel akuifer buatan disimulasi mengikut kaedah undang-undang Darcy. Analisis ujian pengepaman telah dikira dengan perisian *Aquifer Test*. Pengukuran prestasi telaga yang dilakukan oleh ujian pengepaman surutan berperingkat pengeluaran menganggarkan kecekapan sebanyak 99%. Model akuifer buatan dibuktikan sebagai akuifer bocor dengan ujian pengepaman luahan tetap. Ujian pengepaman juga menganalisis akuifer dengan nilai keterusan sebanyak 78.50m^2/hari dan kekonduksian bernilai 7.37m/hari. Manakala ujian pemulihan menganalisis akuifer dengan nilai keterusan 8.22m^2/hari dan kekonduksian bernilai 8.22m^2/hari. Pekali simpanan pula bagi

kedua-dua ujian adalah 0.5. Model fizikal akuifer buatan telah direka dan dibangunkan untuk meningkatkan kefahaman pelajar tentang teori air bawah tanah. Melalui amali ujian pengepamanpada model akuifer ini, pelajar akan dapat gambaran lebih jelas tentang proses air bawah tanah.

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APPROVAL SHEET

I certify that a Thesis Examination Committee has met on 13 February 2015 to conduct the final examination of Shazelia Ashikin binti Sulaiman on her thesis entitled “Utilization of Arificial Aquifer Physical Model to Aid Technical Learning of Graoundwater Hydrology” in accordance with the Universities and University CollegesAct 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS AND SYMBOLS

m	: Meter
mm	: Millimeter
m/day	: Meter per day
m^2	: Meter square
m^3/hr	: Meter cubic per hour
m^2/day	: Meter square per day
L/hr	: Litre per hour
m3/day	: Meter cubic per day
S	: Storage coefficient
A	: Area
K	: Hydraulic conductivity
T	: Transmissivity
D	: Diameter
BQ	:Aquifer loss
CQ^2	:Well loss
Q	: Discharge

CHAPTER 1

INTRODUCTION

1.1. Background

Hydrogeology is a study of water movement in the soil of the earth's surface. This water movement known as groundwater flow is an integral part of the water cycle. Water evaporates from the earth's surface such as ocean, lake or through transpiration from plants, condenses to form clouds and return to the earth's surface as precipitation. The precipitation in a form of snow or rain will infiltrate into the subsurface to become groundwater. Possessing appropriate understanding of the water cycle, including groundwater formation and movement is a fundamental component of scientific literacy (Dickerson et al., 2006).

Groundwater moves from locations of higher pressure to lower pressure and completely fills the void spaces beneath the earth surface. This geologic water-bearing formation, known as aquifer can yield significant amounts of water through pumping which can be used for domestic or agricultural uses (Harter, 2003). Groundwater recharge is a process where excess water infiltrates throughout porous spaces in the aquifer. The groundwater moves in a constant motion either vertically or horizontally and emerges as discharge from various sources and locations.

Dickerson et al. (2006) made a survey and highlighted in the report that the term groundwater was seldom mentioned in the context of water cycle in the standard teaching document. Thus students are unable to imagine such abstract phenomena directly and misunderstanding of groundwater concepts occurs due to the lack of exposure about groundwater in teaching and learning process.

The limited opportunity to explore the process of groundwater movement in classroom is the reason why student unable to visualize what exists and occurs inside the structure of the earth. Hilton(2008) reported students should be provided with hands-on learning activities to improve their imagination ability regarding groundwater concepts.

The rise of the environmental awareness concerning water resources does increase the importance of an appropriate perception on groundwater. The history of public misconceptions provided by Meyer (1987), which describe most groundwater occurs in very small pore spaces in unconsolidated materials lead to further study on how to enhance teaching and learning of groundwater among students.

It is necessary to create clear picture of what happened to the water underground, where it cannot be seen to develop understanding of groundwater concepts (Dickerson et al., 2006). Thus artificial physical aquifer model is used to demonstrate the conceptual of groundwater study. Physical models have served important functions in engineering research, practice, and education for hundreds of years (Ferguson, 1992).

Models play an important role in determining the quantifying process in the field(Singha and Loheide II, 2011). Students will estimate rates, mechanisms and the magnitude of parameters controlling groundwater flow and contaminant transport better by testing the hypothesis made on the models. Groundwater model is used as a tool for further understanding about the flow of water in the aquifer. Singha (2011)used 2-D ant farm sand tank to provide undergraduate students visual processes of hydrogeological concept. The concept is demonstrated through the observation of groundwater flow as well as the effects of pumping on the aquifer.

Physical model is also utilized in the laboratory as an alternative for studying flow and transport in the subsurface (Close et al., 2008). Some field experiments are difficult to carry out because time consuming and involves uncertainty of aquifer conditions. Researchers run the experiment on artificial aquifer under controlled laboratory conditions to investigate the mechanism and flow process of groundwater.

There is a need to utilize similar laboratory scale aquifer model and to be evaluated in the same way as a real aquifer. Its ability to demonstrate groundwater concepts such as simulation of natural groundwater flow condition, hydraulic gradient and observing the effects of well pumping to the aquifer would be able to enhance the comprehension of students and also to overcome researcher's problem in groundwater study. Data collected from the model can be used either for advance investigation or to relate it with real site case.

1.2. Research gap

Aquifer physical model has been used to provide visual processes of hydrogeological in teaching and also as an alternative to study groundwater under certain conditions in the laboratory. All the aquifer physical models described in the previous research and studies are consisted of homogenous type of aquifer and small in size which can be mobilized to any place required.

The artificial aquifer in this study though, reproduced according to a real aquifer condition respectively. The condition in groundwater research area in Jenderam Hilir, Selangor, was referred and thus a heterogenous and anistropic layer of aquifer was developed and utilized as an artificial aquifer model. The model is larger than the common size of the aquifer model in previous research and has complex functions which enhance its ability to show the hydrogeological processes.

1.3. Objectives

The hydrologic cycle is often illustrated simply as water transfer between land and ocean. However, hydrologic cycle needs to be viewed at a wide range for better understanding and water resources management. The water cycle illustration often lack of its integral part, which is known as groundwater process. The groundwater cycle should be emphasized during class by addressing appropriate information of the groundwater mechanism in water cycle. However, assessment and practice to assist students to study the groundwater occurrence are limited due to the difficulties in observing the groundwater movement.

Physical model is one of the teaching techniques to enhance student's understanding of groundwater theory. It provides students, quick understanding of groundwater concepts through demonstration for clearer visual of groundwater process. The use of the simulation technique is a strategic approach to ensure understanding in complex mechanism of groundwater flow. By observing the groundwater system directly and implementing the real-world activities on this physical aquifer model, students will be able to relate this mechanism on the real aquifer condition.

The objective of this study was to analyze and evaluate the actual subsurface structure of an aquifer by utilizing artificial aquifer model in order to improve teaching and learning of groundwater concepts. The artificial aquifer model demonstrates processes involved in groundwater theory, including groundwater flow, well hydraulics and also hydraulic parameters of the aquifer. The specific objectives of this research were:

i. To utilize an artificial aquifer model resembling the real aquifer, related to aquifer condition of groundwater research area in Jenderam Hilir, Selangor.
ii. To demonstrate natural groundwater flow using artificial aquifer model based on Darcy's law.
iii. To analyze the performance of pumping well developed in the physical model using step drawdown pumping technique.
iv. To evaluate the hydraulic parameters of the artificial aquifer developed using constant rate discharge pumping technique.

1.4. Scope and Limitation

The scope of the research covered only on the development of the artificial aquifer model which included the study of the hydraulic parameters and the properties of well. The study was carried out to an extent this artificial aquifer model would work and represents the real aquifer condition. Errors are expected due to the limited confined structure of the aquifer model and artificial structure of the soil. Thus the observation performed on this model might be slightly different with the theoretical observation.

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