UNIVERSITI PUTRA MALAYSIA

KNOWLEDGE- AND DATA-DRIVEN APPROACH TO GIS MODELLING TECHNIQUE FOR GROUNDWATER POTENTIAL MAPPING AT THE UPPER LANGAT BASIN, MALAYSIA

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By

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Thesis Submitted to the School of Graduates, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Wan Nor Azmin Sulaiman, PhD

Faculty: Environmental Studies

The traditional way of groundwater assessment for alluvial and fractured rock aquifers in Malaysia was found to be not so systematic and sometimes improper. In some circumstances groundwater exploration within hard rock aquifer had been carried out using wild cat methods. The study area is the Upper Langat Basin which is located in the south eastern part of Selangor State, Malaysia. The area coverage is about 492 km^2 and approximately 27 km from the city center of Kuala Lumpur. In this study, nine groundwater controlling factors that affect groundwater occurrences are derived from remotely sensed imagery, available maps, and associated databases. Those factors are: lithology, slope, lineament, land use, soil, rainfall, drainage density, elevation, and geomorphology. Next the parameter layers were integrated and modeled by using a knowledge-driven Geographical Information System (GIS)

technique. The generation of groundwater potential map was performed using four different types of GIS modelling techniques. The models were weighted linear combination (WLC), weighted aggregation method (WAM), weighted index overlay analysis (WIOA) and pairwise comparison of Analytical Hierarchical Process (AHP). The weightage and score for each parameter and their classes are based on the surveys of Malaysian groundwater expert opinion. The predicted groundwater potential map was classified into four distinct zones based on the classification scheme designed by Department of Minerals and Geoscience Malaysia (JMG). The analysis and comparison of these results show that: (1) the weightage values for groundwater controlling factors based on groundwater expert opinion indicated that the lineament length density is the most important controlling factor, followed by lithology, geomorphology, rainfall, slope, elevation, soil, drainage density, and land use, (2) the WLC classification method is considered as the best result for the knowledge-driven GIS approach with prediction accuracy of 76%, (3) the frequency ratio approach indicated that slopes between 0 and 5 degree, river density less than 0.0010 km/km^2, geomorphology of floodplain and land use type of rubber have the high probability of groundwater occurrences, and (4) The WLC model also had a slightly better prediction accuracy compared to the probability approach of frequency ratio (75%) and a much better prediction accuracy compare to the existing groundwater potential map which have only 25% accurate precision. Therefore the map based on the WLC method is selected as the final map of this study. The final groundwater potential map of the study area showed that about 85.11 km^2 (14.78%) of the study area falls under low potential zone, with 327.13 km^2 (67.68%) on moderate potential zone, 78.37 km^2 (16.90%) with high potential zone, and only 2.16 km^2 (0.62%) falls under very high potential zone. The high and very high

groundwater potential zones are characterized by: (1) Slope degree ranging from 0 to 5, (2) Low density of drainage systems, (3) High density of lineament, and (4) The geomorphology unit is floodplain. In addition statistical analysis indicated that the hard rock aquifer dominant of the study area is better controlled by fracture system rather than well depth. Proximity analysis of the groundwater borehole wells indicated that higher yields are located near to the lineament. Further evaluation revealed a low correlation (correlation coefficient = -0.36 and R^2 = 0.13) between well yield and well depth. However there is high correlations (correlation coefficient = 0.755) between area percentage for groundwater potential zones of the final map and groundwater well yield. Results obtained from this study can be use for future planning of groundwater exploration, planning and development by related agencies in Malaysia which provide a rapid method and reduce cost as well as less time consuming. The modeling technique may also be used in other areas of similar hydrological characteristics and climate conditions.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENDEKATAN PENGETAHUAN DAN DATA BERPANDU BAGI PEMODELAN GIS UNTUK PEMETAAN POTENSI AIR BAWAH TANAH DI BAHAGIAN HULU LEMBANGAN LANGAT, SELANGOR, MALAYSIA

Oleh

MOHAMAD BIN ABD MANAP

April 2013

Pengerusi: Wan Nor Azmin Sulaiman, PhD

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Kaedah tradisi penilaian air bawah tanah untuk akuifer alluvium dan batuan keras di Malaysia, adalah tidak begitu sistematik dan teratur. Lebih-lebih lagi eksplorasi air bawah tanah pada akuifer batuan keras yang menggunakan kaedah rawak. Kawasan kajian adalah di Bahagian Hulu Lembangan Langat yang terletak di bahagian tenggara negeri Selangor, Malaysia. Ianya meliputi kawasan seluas 492 km^2 dan terletak lebih kurang 27 km daripada pusat bandar Kuala Lumpur. Dalam kajian ini, sembilan faktor mengawal simpanan air bawah tanah yang mempunyai pengaruh keatas kewujudan air bawah tanah dihasilkan daripada imej penderiaan jauh, peta sedia ada dan pangkalan data yang berkaitan. Faktor tersebut adalah litologi, cerun, tanih, lineamen, guna tanah, hujan, kepadatan saliran, ketinggian dan geomorfologi. Seterusnya lapisan parameter ditindan dan dimodelkan menggunakan teknik

pengetahuan berpandu Sistem Maklumat Geografi (GIS). Penghasilan peta potensi air bawah tanah dilakukan dengan menggunakan empat jenis teknik permodelan GIS yang berbeza. Jenis pemodelan tersebut adalah *weighted linear combination* (WLC), *weighted aggregation method* (WAM), *weighted index overlay analysis* (WIOA) dan *pairwise comparison of Analytical Hierarchical Process* (AHP). Pemberat dan skor bagi setiap parameter dan kelas masing-masing adalah berdasarkan kepada survei pendapat pakar air bawah tanah di Malaysia. Peta ramalan potensi air bawah tanah dikelaskan kepada empat zon berbeza berasaskan kepada skim pengkelasan yang telah dibangunkan oleh Jabatan Mineral dan Geosains Malaysia (JMG). Analisis dan hasil perbandingan menunjukkan: (1) nilai pemberat bagi faktor mengawal air bawah tanah berdasarkan kepada pendapat pakar air bawah tanah menunjukkan kepadatan lineamen merupakan faktor pengawal yang paling penting, diikuti oleh litologi, geomorfologi, hujan, cerun, ketinggian, tanih, kepadatan saliran, dan guna tanah, (2) Kaedah pengkelasan WLC dianggap sebagai hasil terbaik bagi pendekatan pengetahuan berpandu GIS dengan ketepatan ramalan sebanyak 76%, (3) pendekatan *frequency ratio* menunjukkan cerun yang bersudut di antara 0 hingga 5, kepadatan saliran kurang daripada 0.0010 km/km^2, geomorfologi jenis *floodplain* dan guna tanah jenis getah mempunyai kebarangkalian yang tinggi terhadap kewujudan air bawah tanah, dan (4) model WLC juga mempunyai ketepatan ramalan sedikit berbeza dan jauh lebih baik berbanding dengan pendekatan kebarangkalian *frequency ratio* (75%) dan peta terdahulu potensi kawasan air bawah tanah yang mempunyai ketepatan sekadar 25%. Justeru itu peta berasaskan kaedah WLC dipilih sebagai peta akhir untuk kajian. Peta akhir potensi air bawah tanah untuk kawasan kajian menunjukkan bahawa sebanyak 85.11 km^2 (14.78%) mewakili zon potensi rendah, 327.13 km^2 (67.68%) untuk zon potensi sederhana, 78.37 km^2 (16.90%) dengan zon

potensi tinggi, dan hanya 2.16 km^2 (0.62%) termasuk dalam zon potensi sangat tinggi. Kawasan zon potensi tinggi dan sangat tinggi dicirikan oleh: (1) Darjah kecerunan di antara 0 hingga 5, (2) Kepadatan rendah sistem saliran, (3) Kepadatan tinggi lineamen, dan (4) geomorfologi jenis *floodplain*. Sebagai tambahan analisis statistik menunjukkan kawasan kajian yang didominasi oleh batuan keras yang dikawal oleh *secondary porosity* seperti sistem rekahan berbanding dengan kedalaman telaga. Analisis *proximity* telaga gerudian air bawah tanah menunjukkan luahan yang tinggi di kawasan yang berdekatan dengan lineamen. Penilaian seterusnya mendedahkan korelasi yang rendah (*correlation coefficient* = -0.36 dan R^2 = 0.13) di antara luahan dan kedalaman telaga. Bagaimanapun, terdapat korelasi yang tinggi (*correlation coefficient* = 0.755) di antara peratusan kawasan zon potensi air bawah tanah bagi peta akhir dengan luahan telaga air bawah tanah. Hasil yang diperoleh daripada kajian ini sangat berguna bagi tujuan ekplorasi perancangan dan pembangunan air bawah tanah oleh agensi berkaitan di Malaysia yang mana ianya menyediakan kaedah cepat, mengurangkan kos serta menjimatkan masa. Kaedah ini juga boleh digunakan di kawasan yang mempunyai kesamaan dari segi ciri hidrogeologi dan iklim.

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I certify that a Thesis Examination Committee has met on 2 April 2013 to conduct the final examination of Mohamad bin Abd Manap on his thesis entitled "Knowledge- and data-driven approach to GIS modelling technique for groundwater potential mapping at the Upper Langat Basin, Malaysia" in accordance with the Universities and University Colleges Act 1971 and Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the degree of Doctor of Philosophy

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

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MOHAMAD BIN ABD MANAP

Date: 2 April 2013

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