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Remote sensing and geographic information system (GIS) approach in groundwater potential zone mapping in hardrock terrain: A case study of the Langat Basin, Selangor

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Abstract: The advantages of remote sensing images in projecting ground surface features of a wide area and the ability of the geographic information system (GIS) to integrate several layers of data of certain area are used in producing the groundwater potential map of the Langat Basin. By using the GIS technique, all groundwater related data in hardrock terrain, consisting of lineaments and land use information depicted from remote sensing images are integrated with other auxiliary data such as topographic elevation, topographic gradient, annual rainfall, soil type, drainage density and lithology of the area. As a result, a derived map which demarcate the study area into very high, high, moderate, low or very low groundwater potential zones is produced. The map indicates that hardrock terrain that was previously mapped as low to very low potential actually possess moderate to high groundwater potential. Since the derived groundwater potential zone map is very useful, and can be produced quickly, it is suggested that this method be applied in the early stages of groundwater exploration to locate target areas in hardrock terrain, before further detailed investigation.

Abstrak: Kelebihan imej penderiaan jauh memaparkan fitur-fitur permukaan bumi kawasan yang luas dan kemampuan sistem maklumat geografi (GIS) mengintegrasikan beberapa lapisan data suatu kawasan telah digunakan dalam menghasilkan peta potensi air tanah terrain berbatuan di Lembangan Langat. Dengan menggunakan teknik GIS, semua data yang berkaitan dengan air tanah kawasan terrain batuan keras, terdiri daripada maklumat lineamen dan guna tanah yang diperolehi daripada imej penderiaan jauh diintegrasikan dengan data tambahan lain seperti elevasi topografi, kecerunan topografi, curahan hujan, jenis tanah, ketumpatan saliran dan litologi kawasan kajian. Hasilnya, satu peta terbitan yang membahagikan kawasan kajian kepada sama ada sangat tinggi, tinggi, sederhana, rendah atau sangat rendah daripada segi potensi air tanah diperolehi. Peta ini menunjukkan terrain batuan keras yang dahulunya dipetakan sebagai rendah hingga sangat rendah sesungguhnya juga mempunyai potensi yang tinggi hingga sederhana daripada segi potensi air tanah. Oleh kerana peta potensi zon air tanah mengandungi sumber maklumat yang berguna dan ianya boleh dihasilkan dalam masa agak cepat maka dicadangkan agar kaedah ini digunakan diperingkat awal dalam eksplorasi air tanah terrain batuan keras bagi mementukan kawasan sasaran sebelum penyiasatan lanjut dan terperinci dijalankan.

INTRODUCTION

Generally, it is well understood that groundwater cannot be directly seen on the surface of the earth. To test the presence or the ground water potential of a certain area, several surveys need to be conducted, among these are geological mapping and interpretation which involve field study and geophysical method particularly the resistivity technique. Geological investigation, in general requires a long period of time and is very 'tiring', while geophysical investigation is very costly especially when dealing with a large area. In the last decade, the availability of remote sensing images have become one of the important tool in understanding the nature of the groundwater system in term of hydrostructures and hydrogeomorphology (Todd, 1980).

Siddiqui and Parizek (1971) have shown the relationship between the interpreted lineaments from aerial photograph and groundwater, while Waters (1989) clearly explained the method of lineament analysis in hydrogeologic studies using satellite image. Information extracted from satellite image, especially lineaments and several other parameters or information which are expected to be related with groundwater could be integrated by using geographic information system (GIS) in order to predict groundwater potential zones of a selected area.

This study makes use of the advantages and ability of satellite data to project surface features especially lineaments and the ability of the GIS in integrating a numbers of data layers. The integration will produce a derived map which shows potential zones in term of the availability of groundwater in the area. Langat Basin is selected in this study since it is located next to the developed Klang Valley, which depends very much on surface water collected in the Langat Basin. The water crises in 1998 triggered awareness in many part of the society about the necessity to investigate and find alternative sources of water in order to make sure that water supply in the Klang Valley is sufficient and continuous for the future.

The main objective of this study is to predict and map the groundwater potential zone in a selected hardrock terrain by integrating a number of thematic maps, using geographic information system (GIS). Apart from that, this study is also intended to show the ability of the remote sensing and GIS integration method in predicting groundwater potential zone in the area. This regional scale map is useful to locate the target area for further detailed groundwater investigation in a larger scale.

AREA OF STUDY

The study area is situated in the southern part of Selangor and northern part of Negeri Sembilan, covering the upstream part of the Langat Basin with an area of about 1600 km^2 (Figure 1). Generally, the topography of the study area is moderately high and the slope gradient is approximately between 19 and 30 degrees. About 60% of the area is underlain by igneous rocks (mainly granite), about 30% by metamorphic rocks mainly schist and phyllite and the rest of the area consists of limestone, volcanic rocks and alluvium. Most of the hilly part of the area is covered by tropical forest and the rest has been cleared for agriculture, residential or other development purposes. At present, the information provided by the available hydrogeology (groundwater) map of the area is still very general and is not very useful for further detailed groundwater exploration work although the need for such information is increasing.

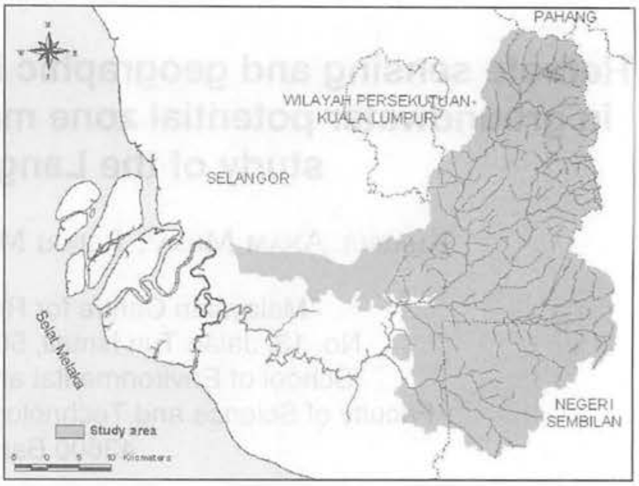

Figure 1. Study area.

METHOD OF STUDY

In order to map the groundwater potential zone in the area, related information extracted from remote sensing image and the auxiliary available data were used in GIS modeling. The study can be classified into five main stages; basic data collection and derived map preparation, satellite data analysis, spatial database building, spatial data analysis and spatial integration and modeling (Figure 2).

Basic Data Collection and Derived Map Preparation

Apart from satellite data, other groundwater related data and maps were collected and utilized. The LANDSAT TM data were obtained from the Malaysian Centre for Remote Sensing (MACRES) with index series 127/58, dated 6 March 1996. Presently available maps used in this study include topographic map on 1:50,000 scale, published by the Land Survey Department 1990, geological map on scale 1:63,360 published by the Geological Survey Department 1976, soil series map on scale 1:150,000 published by the Agriculture Department 1966. Rainfall data for the years 1982-96 were obtained from the Drainage and Irrigation Department, the Meteorology Department and the Climatology Lab of Universiti Kebangsaan Malaysia (UKM). A hydrogeology map on scale 1:500,000 published by the Geological Survey Department was also utilized as a general guide. From the basic data and maps, a number of derived maps covering the study area were produced. LANDSAT TM data were analyzed to produce a lineament density map and a land use map. The available data and maps used in this study and their corresponding derived maps are listed in Table 1.

Satellite Data Analysis

This analysis was done in order to get a reliable LANDSAT TM image, which could later be used for special purposes, in this case to interpret lineaments and land use of the area. The data is digitally processed, involving geometric and radiometric correction, contrast enhancement, colour display and filtering before it is used for lineament interpretation and land use classification.

Spatial Database Building

All information from derived maps were transformed into digital form and accurately registered according to the Malayan Rectification Skew Orthomorphic (RSO Malaya) coordinate system in order to ensure that the information from all derived maps could be overlapped correctly. Following this, all the digitized maps were converted into a new form by several processes such as transformation, conversion from raster to vector, gridding, density calculation, interpolation and reformatting. By doing that, new set of thematic maps were produced and grouped together within the geographic information system (GIS) spatial database.

Spatial Data Analysis

This stage involves attribute analysis, polygonal classification and weightage assignment. Every polygon (following a certain class of data) will be given suitable weightage value (in term of percentage) depending on the groundwater recharge characteristic or the contribution of that data class towards the formation or accumulation of groundwater, as discussed by Khairul *et al.* (2000).

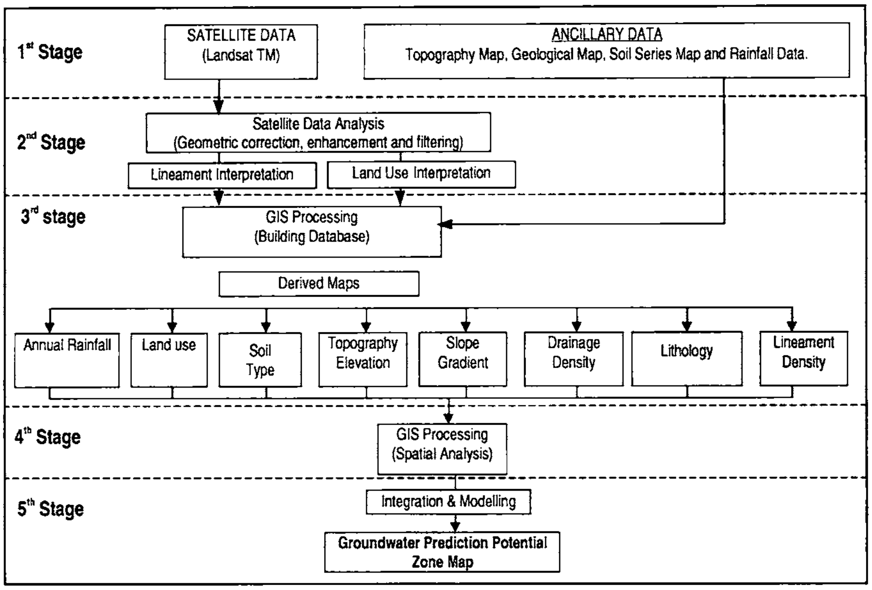

Figure 2. Methodology flowchart for groundwater potential zone mapping.

Spatial Integration and Modeling

At this stage, the thematic layers consisting of lithology, lineament density, drainage density, topographic elevation, slope gradient, soil type, land use and rain fall are combined or integrated using GIS modeling. Each thematic layer consists of several polygons which represent different features, depending on the information provided by the map. Each polygon is categorized according to the suitability or its relevance to the groundwater potential. Then, suitable weightage value for the polygons were assigned following the value proposed by Krishnamurthy *et al.* (1996, 1997). In cases where the proposed values are not available, logical values were assigned based on available knowledge. Finally all the layers are integrated using a groundwater potential model which is a modified DRASTIC model (Aller, 1985). The formula used in this study is as follows:

$$GW= RF+LT+LD+LU+TE+SS+ST$$

where GW is groundwater, RF is annual rainfall, LT is lithology, LD is Lineament density, LU is landuse, TE is topographic elevation, SS is slope steepness, DD is drainage density and ST is soil type.

The result of the integration in the form of cumulative weightage values of polygons (Table 2) are grouped together in the final thematic map layer (representing groundwater potential map) and then categorized or classified into either very high, high, moderate, low or very low potential zones. This predicted groundwater potential zone is superimposed with main streams, lithologic boundaries and boreholes in the study area for quick reference of the locations and to test the accuracy of this prediction map compared to the actual groundwater discharge rate from the result of pumping test.

RESULTS AND DISCUSSION

The groundwater potential map of hardrock terrain in the Langat Basin is shown in Figure 3. The result is summarized in Figure 4. The groundwater potential map indicates that some of the hardrock terrain, which was previously classified as very low to low potential (Jabatan Penyiasatan Kajibumi Malaysia, 1975), actually has higher potential. Borehole data collected by the Minerals and Geoscience Department were used to compare the potential map with the actual field data. Since the estimation and classification of discharge rate was based on an alluvium terrain which has very high value (Jabatan Penyiasatan Kajibumi Malaysia, 1975), it is proposed that a different value be used for hardrock terrain, i.e. very high (>7.0 m^5/hour/well), high (6.0 -7.5 m^3/hour/well), moderate (4.5 - 6.0 m^3/hour/well), low (3.0 - 4.5 m^3/hour/well) and very low potential (<3.0 m^3/hour/well). As a result, the classes of groundwater zones in the potential map show very good correlation with the discharge rate of the boreholes. The high potential zones in the hardrock terrain coincide with high lineament density. The result also indicates that metamorphic terrain with lower elevations and gentler slopes have higher potential compared to granite terrain. In future it is believed that hardrock terrain will become more important as a target area for groundwater exploration. Since there are a lot of useful information that could be provided by this derived groundwater potential zone map of hardrock terrain, it is suggested that this method be applied in the early stages of groundwater exploration before any further investigation to locate target areas are conducted.

CONCLUSIONS

Based on the results of this study, a number of conclusions can be made and among these are:

1. This study has successfully produced a ground water potential map in hardrock terrain. The variety of ground water potential zones shown in this map indicate that hardrock terrain also has areas with high potential for ground water.
2. Satellite images which cover a wide area and has been

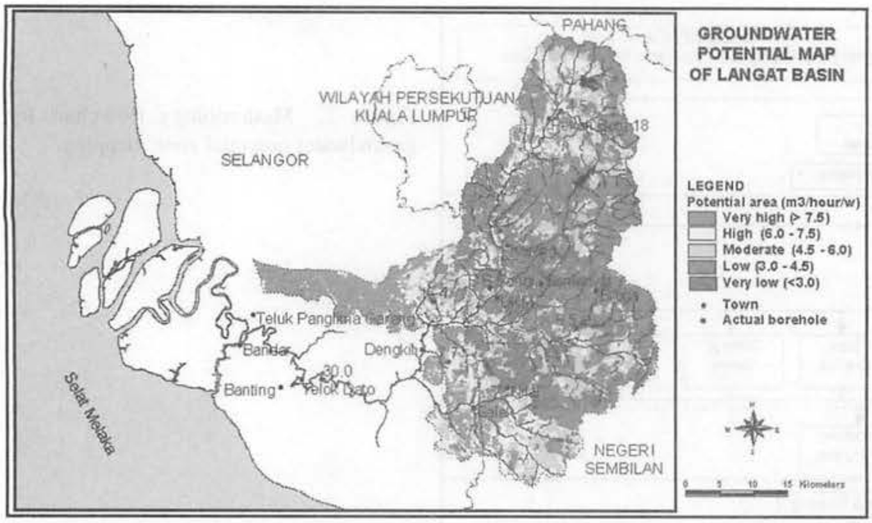

Figure 3. The groundwater potential map of hardrock terrain in the Langat Basin.

Table 1. Basic data and maps used in this study and their corresponding derived maps.

Number	Basic data and maps	Derived maps
1	Topographic map	Topographic elevation map
		Slope gradient (steepness) map
		Drainage density map
2.	Soil series map	Soil series map
3.	Geology map	Lithologic map
4.	Rain fall	Rain fall map
5.	LANDSAT TM	Lineament density map
		Land use map

Table 2: Cumulative weightage values of the area polygons in the final map.

Score/value	Class of groundwater zone	Estimate of discharge rate
270 - 360	Very High	> 7.5 m^3/hour/well
250 - 270	High	6.0 – 7.5 m^3/hour/well
240 - 250	Moderate	4.5 – 6.0 m^3/hour/well
225 - 240	Low	3.0 – 4.5 m^3/hour/well
175 - 225	Very Low	< 3.0 m^3/hour/well

recorded in infrared wavelength is very useful and effective in providing and displaying surface information such as lineaments and landuse which are related to the existence of groundwater in certain areas. It is proven that remote sensing data and GIS integration method can be successfully used to produce a ground water potential map of a selected area.

3. Data and basic information which are related to the occurrence of ground water such as lithology, lineament, soil type, topographic relief, slope gradient, drainage, landuse and rainfall were identified and found to be useful in producing a ground water potential map of the study area.

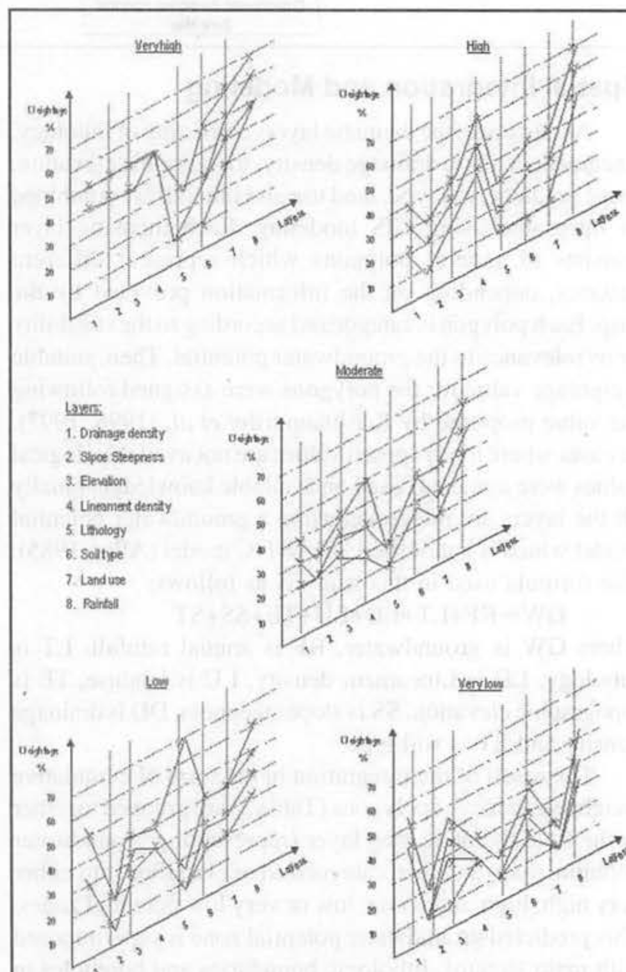

Figure 4. Summary the result of spatial analysis.

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