The effect of major faults and folds in hard rock groundwater potential mapping: an example from Langat Basin, Selangor

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Abstract: Together with other factors, geological factors such as lithology, bedding, fractures (lineaments), faults and folds play a very significant role in the movement and accumulation of groundwater in hard rock terrain. However, in most cases of groundwater potential mapping, only the role of lithology and lineaments are considered together with other non-geological factors. This paper will demonstrate the effect of faults and folds in groundwater potential mapping by using remote sensing and the geographic information system integration method. By incorporating faults and folds in the study, zones of groundwater potential become more focussed and well defined as compared to the result when only lithology and lineaments are considered. It is hoped that the derived ground water potential zonation map will be useful for further work in groundwater exploration of a selected area.

Abstrak: Di samping faktor lain, faktor geologi seperti jenis litologi, perlapisan batuan, retakan (lineamen), sesar dan lipatan berperanan daripada segi pergerakan serta pengumpulan air tanah dalam terain berbatuan. Walau bagaimanapun, kebanyakan kajian tentang pemetaan potensi air tanah hanya mengambil kira faktor litologi dan juga lineamen di samping faktor bukan geologi yang lain. Kertas ini mempamerkan kesan atau pengaruh faktor sesar dan lipatan dalam pemetaan potensi air tanah menggunakan kaedah integrasi penderiaan jauh dan sistem maklumat geografi. Kajian ini mendapati bahawa penzonan kawasan berpotensi air tanah lebih jelas dan terfokus jika dibandingkan dengan kajian yang hanya mengambil kira faktor litologi dan lineamen. Peta penzonan potensi air tanah yang terhasil diharapkan akan lebih membantu serta memudahkan kerja-kerja eksplorasi air tanah selanjutnya.

INTRODUCTION

Water is one of the basic needs for all life on the earth including humans, animals and plants. In most areas, surface water is used as the main source of water. However, climatic changes such as a long dry season or drought and pollution of surface water in rivers or lakes have reduced the availability or sources of clean surface water in certain areas (Zainudin Isa, 1998). Due to the water crisis which hit the Klang Valley, as a result of the El Nino phenomenon in 1998 there is a need to use groundwater as an alternative source to surface water to guarantee clean and permanent water supply.

Although groundwater cannot be directly seen on the earth's surface, many indirect information such as land use, rainfall distribution, topographic height, slope gradient, lithologic type, soil type, drainage density and lineament density can be used to identify the groundwater potential of an area. Apart from the available information, remote sensing technology can also be used to generate information, which can be used together with the other data. By applying the geographic information system (GIS) method all these data can be processed to produce a thematic map, which shows the potential areas for groundwater. Among the studies which have used the above information and methods are Krisnamurthy *et al.* (1996, 1997, 2000), Kararaju *et al.* (1996), Saraf & Choudhury (1998), Murthy (2000) and Khairul *et al.* (2000, 2001).

This study is a continuation of previous work to identify the effect of faults and folds in the groundwater potential mapping of the Langat Basin, Selangor (Fig. 1).

DATA AND METHODS

Data and methods used in this study are very similar to those used in a pervious study (Khairul *et al.*, 2000, 2001) which involved five main stages, i.e., a) basic data collection and derived map preparation; b) satellite data analysis; c) spatial database building; d) spatial data analysis and e) spatial integration and modelling. The only difference is that in this study, faults and folds were incorporated to the previously used eight parameters in stage (e) (Fig. 2). Faults were traced from published geological maps of the area (1:63,360) as well as from major lineaments (greater than 5 km in length) traced from Landsat images (Fig. 3). Folds (anticlines and synclines) were interpreted based on strike and dip data plotted on published and unpublished geological maps of the area. Topographic maps (1:50,000) were also used to interpret the strike and dip directions, from strike ridges in areas where such strike and dip data were not available. For faults, a higher weightage (value) were assigned to zones close to the faults, while for folds,

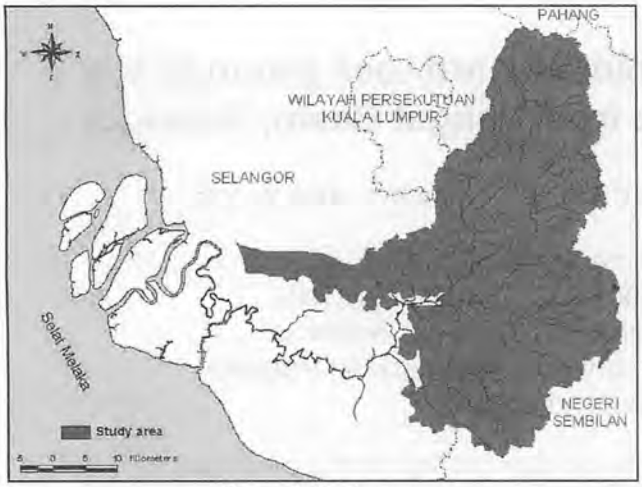

Figure 1. Study area.

Table 1: Major fault zone.

Major Fault Zone (m)	Weightage
< 500	50
500 – 1,500	40
1,500 – 3,000	30
> 3,000	20

Table 2. Folds zone.

Folds Zone	Weightage
Syncline Zone	50
Middle Zone	30
Anticline Zone	10
Outside Folds Zone	0

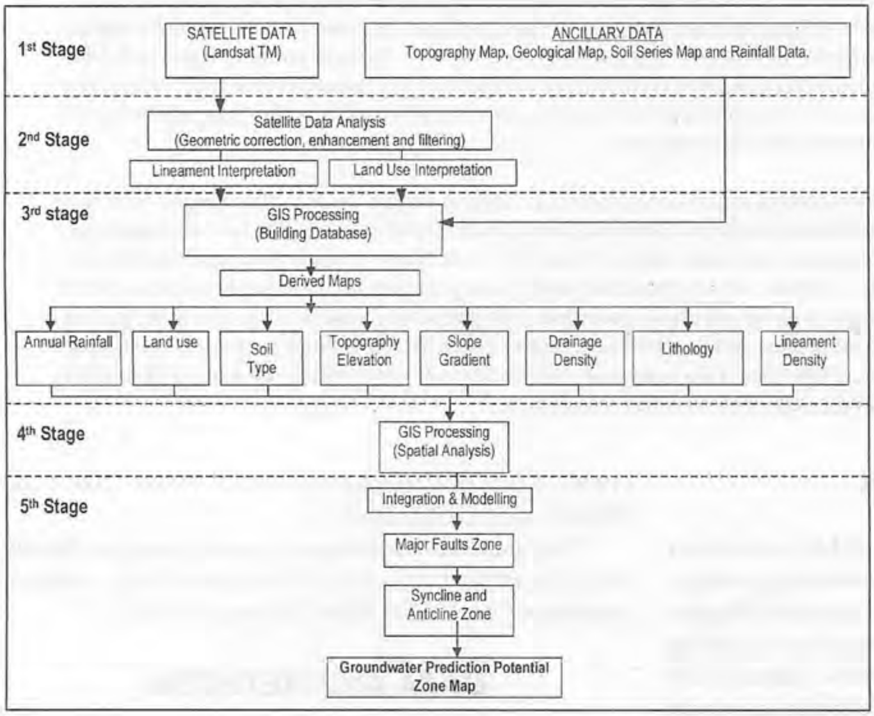

Figure 2. Methodology flowchart for groundwater potential zone mapping.

synclinal zones were assigned higher value and anticlinal zones, are given minimum value (Table 1 and Table 2).

RESULTS AND DISCUSSION

The groundwater potential map in hard rock terrain of the Langat Basin based on eight parameters (or eight layers) (Khairul *et al.*, 2001) is shown in Figure 4. Figure 5 shows the groundwater potential of the same area with the fault parameter added (nine layers) and Figure 6 with the fault and fold parameters (ten layers) incorporated in spatial integration and modelling stage. Table 3 summarizes the result of the spatial integration and modelling using eight, nine and ten parameters (layers).

All three groundwater potential maps (Figs. 4, 5 and 6) show a variety of the groundwater potential in hard rock terrain, from very high to very low. All maps generally show a reasonably good correlation with borehole discharge data of the boreholes. This indicates that the data and the method used in this study is suitable and could produce good groundwater potential maps.

However, if we look in more detail, by applying the fault parameter in this analysis as shown by Figure 5, a more systematic and focused groundwater potential is different in certain zones. This map is considered as more realistic since groundwater is generally not evenly distributed but is controlled by certain factors. In the case of Langat Basin, it is very clear that fault is a main factor controlling a groundwater potential in the area. As a result, almost all areas, which are mapped as having high to very high groundwater potential, are situated within the fault zones. Further more, the fault intersection areas are mapped as very high potential. However, the correlation between the map and boreholes data is not very good, possibly

Table 3. Summary the result of the spatial integration and modelling using eight, nine and ten parameters (layers).

Borehole	Longitude (X)	Latitude (Y)	Depth (m)	Discharge (m^3/hour/well)	Prediction discharge		
					8 layers	9 layers	10 layers
1 (Sg Sai)	429850	351150	110	4.5	High	Very high	Very high
2 (Kajang)	421000	333700	60	3.3	High	High	Moderate
3 (Putrajaya)	411200	323500	15.3	16.4	Moderate	High	Low
4 (Dengkil)	413400	314800	1.2	7.7	Very high	High	Moderate
5 (Beranang)	432200	319600	200	5.5	High	Moderate	Moderate

Note:

Class of groundwater zone	Estimate of discharge rate
Very High	> 7.5 m^3/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
Very Low	< 3.0 m^3/hour/well

because of the number of borehole data are very limited and not well distributed.

On other hand, the effect of the folds to the groundwater potential map is not as clear as the effect of faults. There are several possible reasons for this. Firstly, the terrain under study consists of metamorphic rock whereby the existence of fold is not well defined as compared to the sedimentary terrain. Secondly, the strike and dip data collected in the field and published geological map of the area which are used to interpret the major folds (anticlines and synclines) are very limited. Some of the data may not represent the bedding plane but foliation. In this case topographic maps of the area are used to interpret the strike and dip direction that are later used together with field and published data to interpret major folds in the area. The result as shown in Figure 6 probably indicates that for the metamorphic terrain, fold parameter or factor is not or only gives minor effect in groundwater potential mapping. If the study is done in sedimentary terrain whereby a lot of field data could be collected, the fold parameter could be used to produce more detail analysis.

CONCLUSIONS

Based on the result of this study as discussed above, a number of conclusions are arrived;

1. Groundwater potential in hard rock terrain varies from very high to very low. This indicates than in this type of terrain, there is a great possibility to find groundwater.
2. The advantages of satellite data (images) which cover a wide area and show very clear lineaments that could representing faults are very useful in this study. It is proven that the combination of the remote sensing data and GIS methods are capable of producing a reasonably good groundwater potential map.
3. The use of fault parameter in the stage of spatial integration and modelling has resulted in a more systematic and focused groundwater potential map.
4. In metamorphic terrain where folds are not well defined, the effect of fold parameter is not very clear. If this parameter is to be used, a sufficient field data should be acquired in order to interpret major fold in the area.
5. This study indicates that fault parameter plays a more important role compared to the fold in controlling the distribution and existence of the groundwater.

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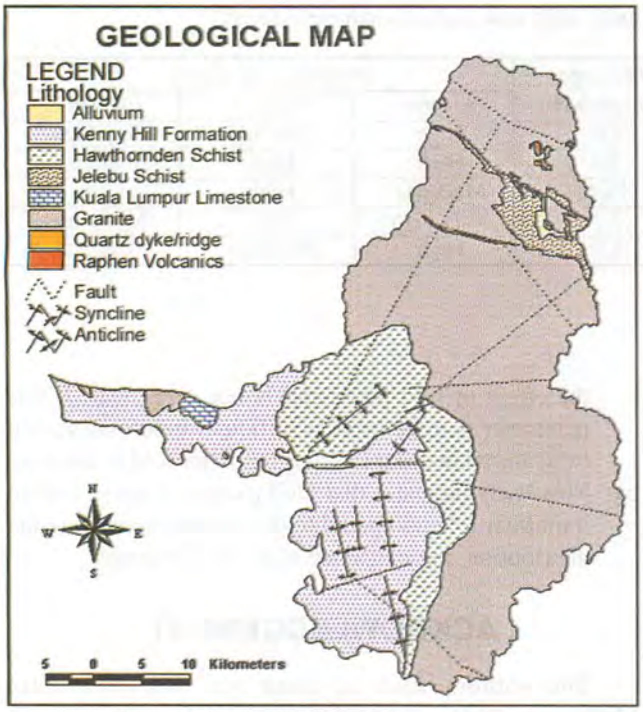

Figure 3. Geological Map of the study area.

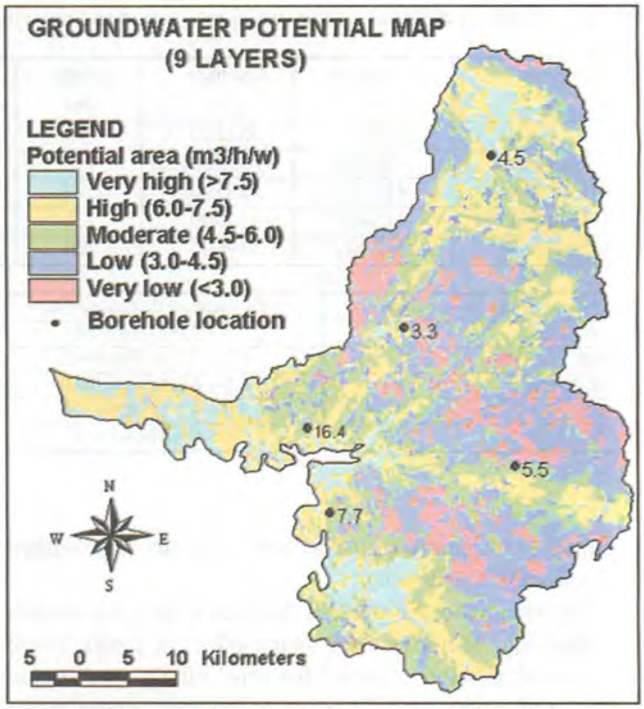

Figure 5. The groundwater potential map in hard rock terrain of Langat Basin (nine Layers).

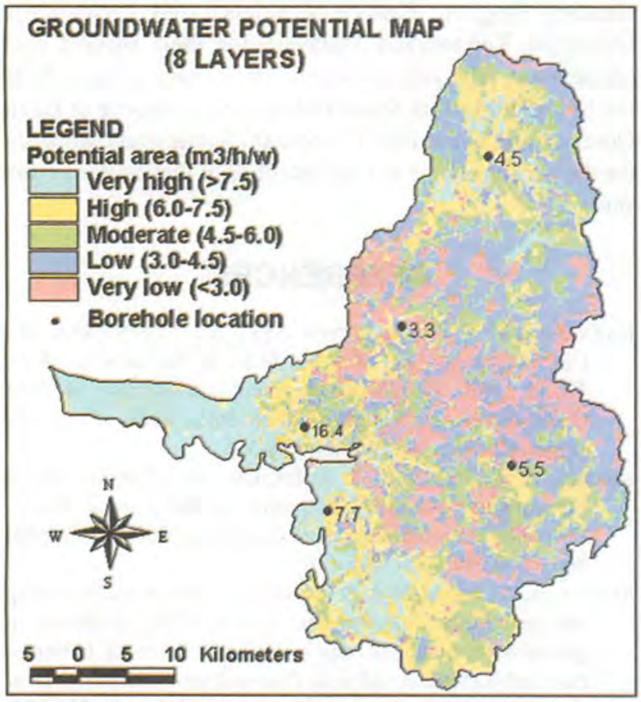

Figure 4. The groundwater potential map in hard rock terrain of Langat Basin (eight layers).

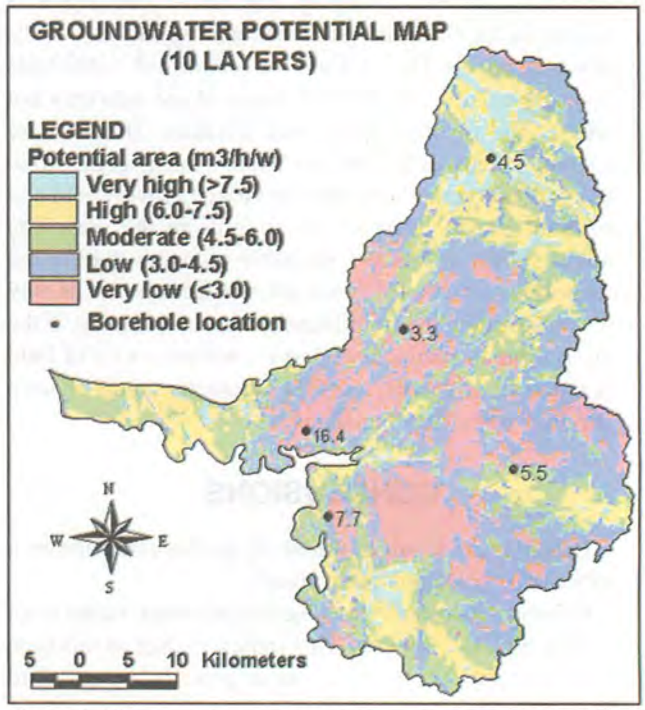

Figure 6. The groundwater potential map in hard rock terrain of Langat Basin (ten layers).

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