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Groundwater resources in Johor, Malaysia: resource potential and information management

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Abstract: Based on data from the exploration and development work of groundwater undertaken in Johore, Malaysia, the potential of groundwater resources in most rock types in the state can be evaluated. Variations of well-yield depend on the lithology, thickness and fracture intensity of the aquifers. The water quality also varies with aquifer materials and proximity to the sea.

Raw data including borehole locations, aquifer properties and results of water analysis are compiled in hardcopy forms. However, with these data, including spatially-related data, there is a restriction to some extent on data presentation. With the Geographical Information System (GIS) approach, these data can be easily accessed for retrieval, query and presentation of information. This system is to be customised to enable users to search for any information related to groundwater.

INTRODUCTION

In Johor, systematic hydrogeological investigation and development started since GSD's Groundwater Development Project in RM6 (1991–1995). Meanwhile, the private drillers were also developing groundwater production wells since 1980's. To date the department has compiled more than 220 wells drilled in Johor by the government bodies and the private sectors.

Presently all the groundwater data are stored in Department's HYDAT database with some restriction on data handling and presentation. Lately an improved Customised Groundwater Information Management (CGIM) has been developed to produce thematic maps and specific reports.

RESOURCE POTENTIAL AND GROUNDWATER QUALITY

There are two main categories of resource potential based on types of aquifer and their hydrogeological properties.

Aquifers in alluvium

The most productive aquifers are the alluvial aquifers which are located along the coastal region of Johor. There are deposited in two different environments namely the Quaternary continental deposit and the Quaternary marine deposit. They consist of gravel, sand, silt and clay. Where sand and gravel predominate and where the aquifers are extensive, the yields can reach up to 150 m^3/h.

The quality of water is generally acceptable with some having high iron and manganese. Aquifer close to the sea will experience some elevated values of salinity.

Aquifers in hardrock

Hardrock aquifers occur within cracks, fractures, joints, solution cavities and weathered zone. These aquifers are seldom extensive and normally only locally important. The hardrock aquifers can be divided into three major types based on lithology namely sedimentary/metamorphic rocks, volcanic rocks and plutonic igneous rocks.

a) Sedimentary/metamorphic rocks

This type of aquifer is made up of shale and sandstone (and their metamorphic equivalents). Fractured aquifer may yield up to 25 m^3/h. The aquifer has good quality water but has moderate to high total dissolved solids.

b) Volcanic rocks

This type of aquifer is made up of tuff and tuffaceous varieties. Fractured aquifer may yield up to 70 m^3/h. The quality of water is generally medium to good quality. Figure 1 shows the quality of water from volcanics based on average Total Dissolved Solids as compared to other rock types.

c) Plutonic igneous rocks

Fractured igneous rocks which cover large areas of Johor, may give yield up to 10 m^3/h. The quality of water is generally good to excellent with low total dissolved solids.

GROUNDWATER DATABASE

The aim of having a database is to be able to store large amount of groundwater data in tables which allow easy and consistent retrievals to be done. The system is also meant to validate data that is entered into it. The database should help towards achieving and setting standards within the Geological Survey Department. The database must also allow better use of existing groundwater data and must be able to support complex queries run frequently by the users.

The groundwater database is presently being stored in hardcopy form and most of it has been entered in the HYDAT, the Department's present database system. However the system has some restrictions on data presentation and usually not easily tailored to the customers' needs.

INFORMATION MANAGEMENT SYSTEM

Lately, a much improved groundwater information management package has been

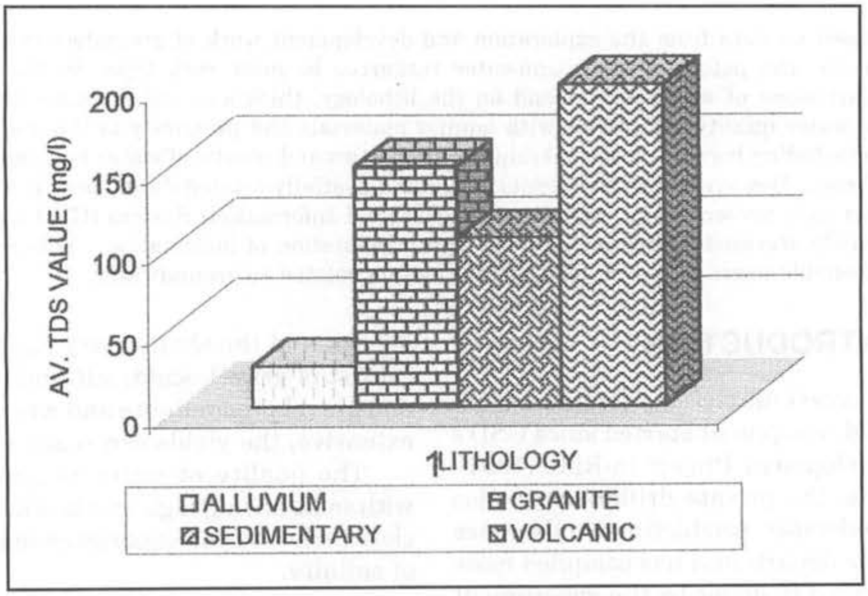

Figure 1. Lithology vs average TDS.

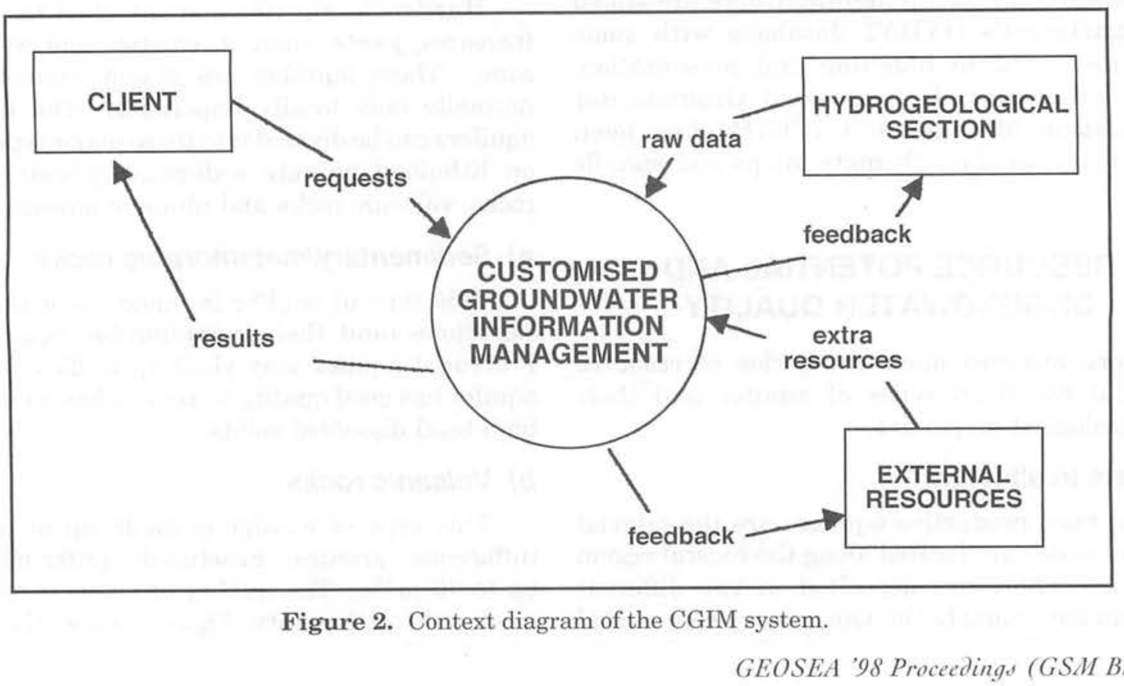

Figure 2. Context diagram of the CGIM system.

developed for the state of Johore. This system named CGIM (Customised Groundwater Information Management) is making use of database and GIS softwares to produce thematic maps and specific reports for the customers.

Context diagram

The context diagram for this new system is shown in Figure 2, with the client referring to the personnel or agencies that request the system. The client gets results from the system that may in the form of reports, processed map or screen displays. The Hydrogeological Section is referred to the section who submit raw data to the system. The environment is made up of the clients and the external resources where extra resources may be obtained. External resources are usually universities or other sections of the Geological Survey that will also get some feedback from the system.

Figure 3 shows a decomposition diagram from the context with three processes, the data capturing phase, statistical analyses and GIS analyses all of which can produce results.

The diagram in the following section in Figure 4 is the decomposition of the data capturing phase. The first process involved receiving raw data and classifying the data into borehole or well data from companies and field data from data collectors. Field data is entered into form in the second process and the third process is changing the borehole records into the databases. All the data is stored in the database which has Open Data Base Connectivity (ODBC) links with the GIS. The forth process is for data retrieval which received requests from the client and returns retrieved data.

The GIS analyses involved three processes (Fig. 5). The first process is for retrieving data via ODBC tables and the second process is for data analyses. Visualised information or processed map is the third process with obtains extra resources from external sources. Results are mainly in the form of thematic maps. Feedback may be in terms of advice or reports to the source that would have provided the extra resources.

Figure 6 shows the three processes in the statistics part of the CGIM system which involved reporting platforms, plotting graphs and producing summary statistics reports.

The Entity-Relationship (ER)

An analysis on the design of the CGIM System was done for the Johor State. The system was designed to be used by the geologist for storing and processing groundwater data. A database model was designed using the entity relationship approach as shown in Figure 7. There are six attribute tables in the system.

The enterprise rules required for the ER diagram are:

i. A borehole only to have one location
ii. A borehole can only have one property
iii. A borehole can be made up by one or more lithological layers

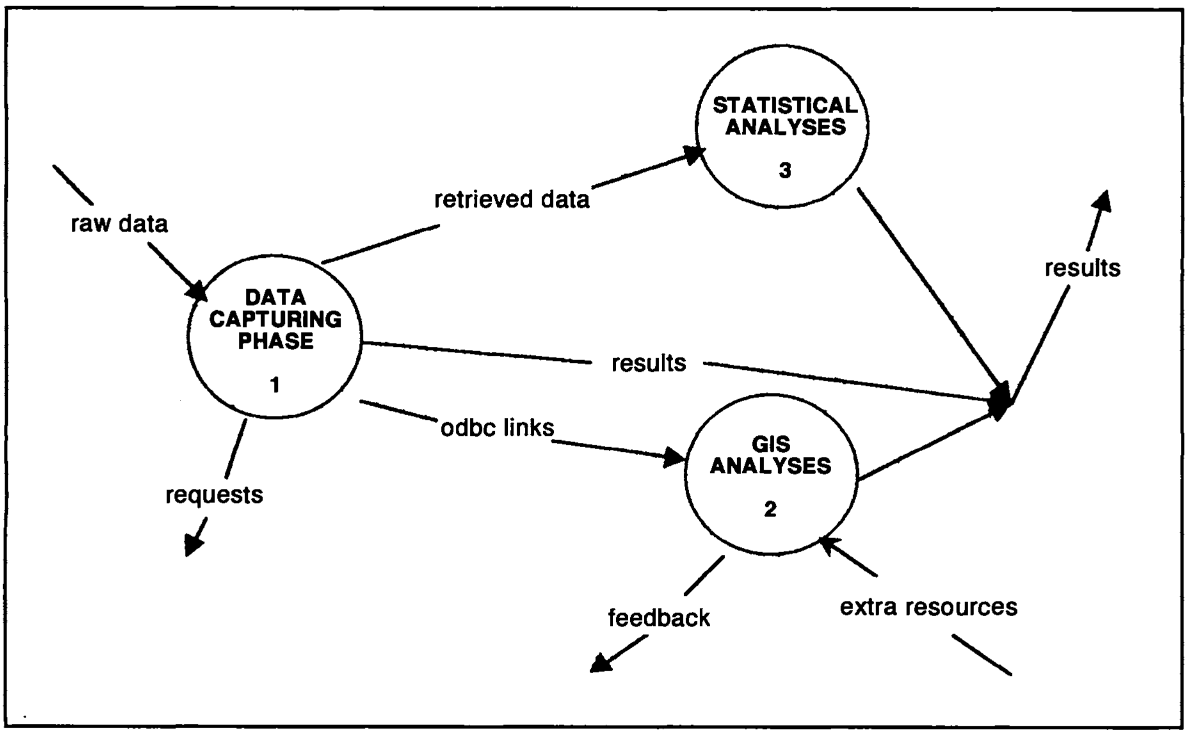

Figure 3. The three processes in the CGIM System.

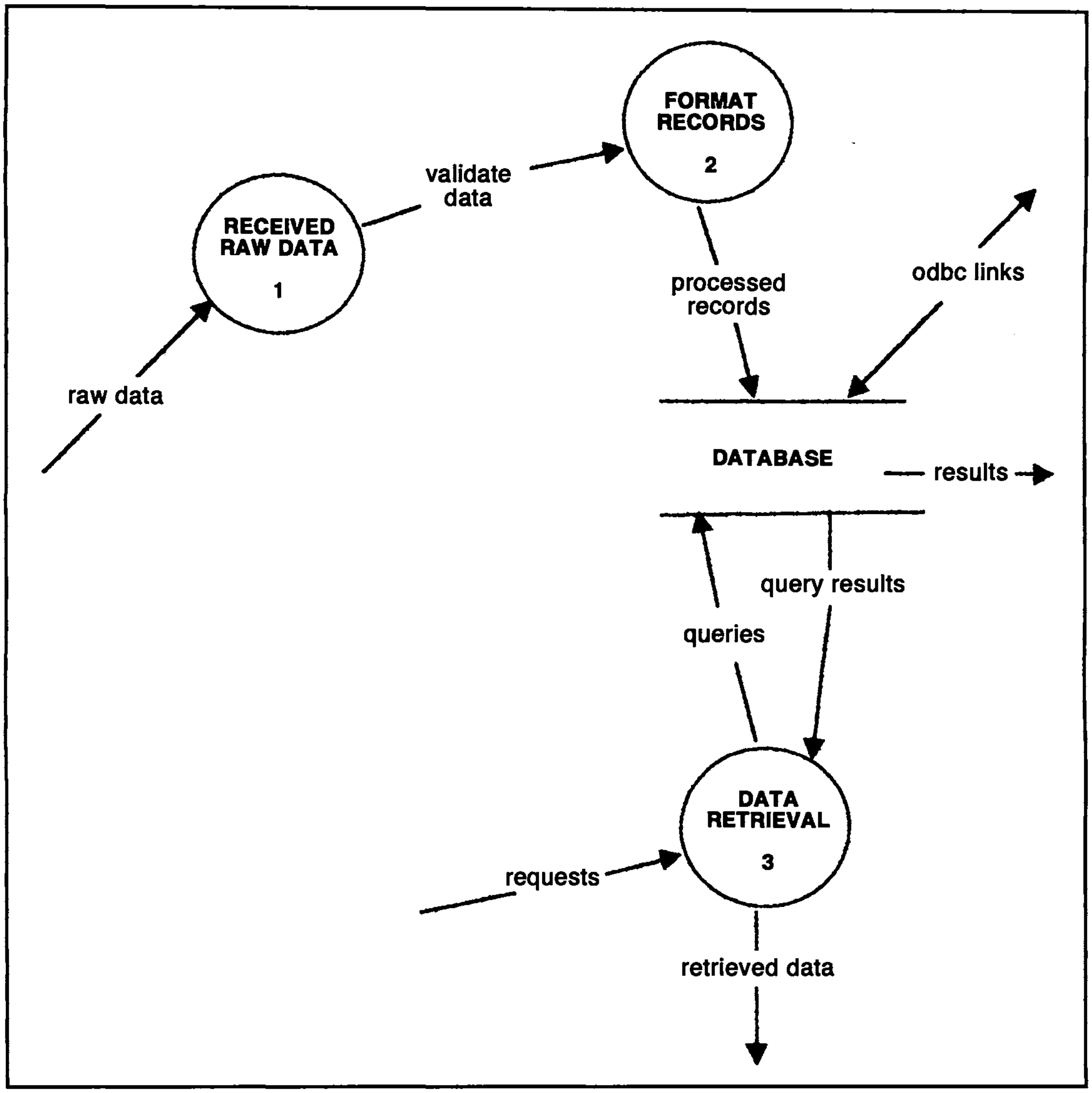

Figure 4. Data capturing process.

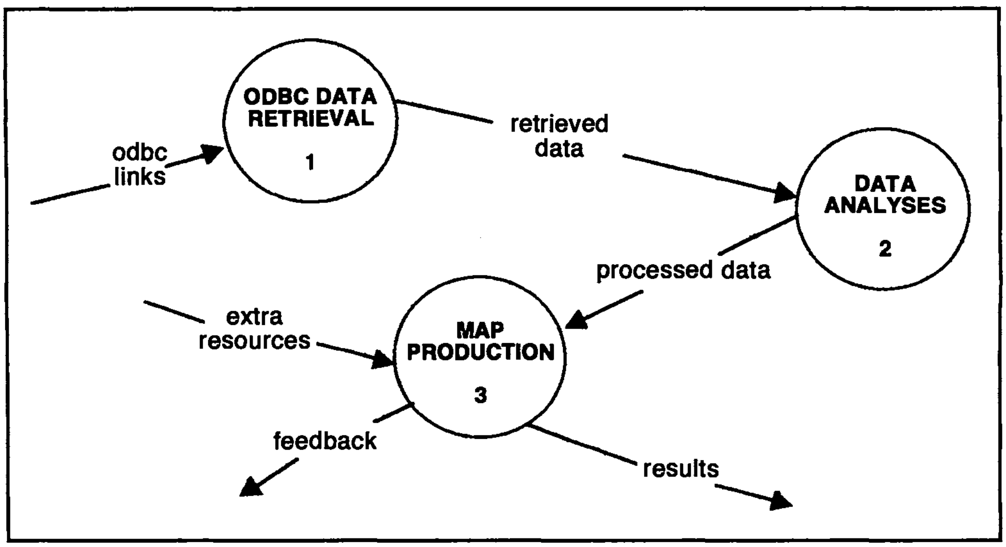

Figure 5. The three processes on GIS part of the CGIM System.

iv. There are can be one or more water samples at a single borehole

v. A sample can only have one water analysis

The database was implemented using Microsoft Access/Visual DBase with a total of six entities. Six entities identified are borehole, location, layer, property, sample and chemical analysis. A borehole is defined to refer to all types of boreholes. Location refers to the geographic position where the borehole is situated. Water analysis refers to laboratory

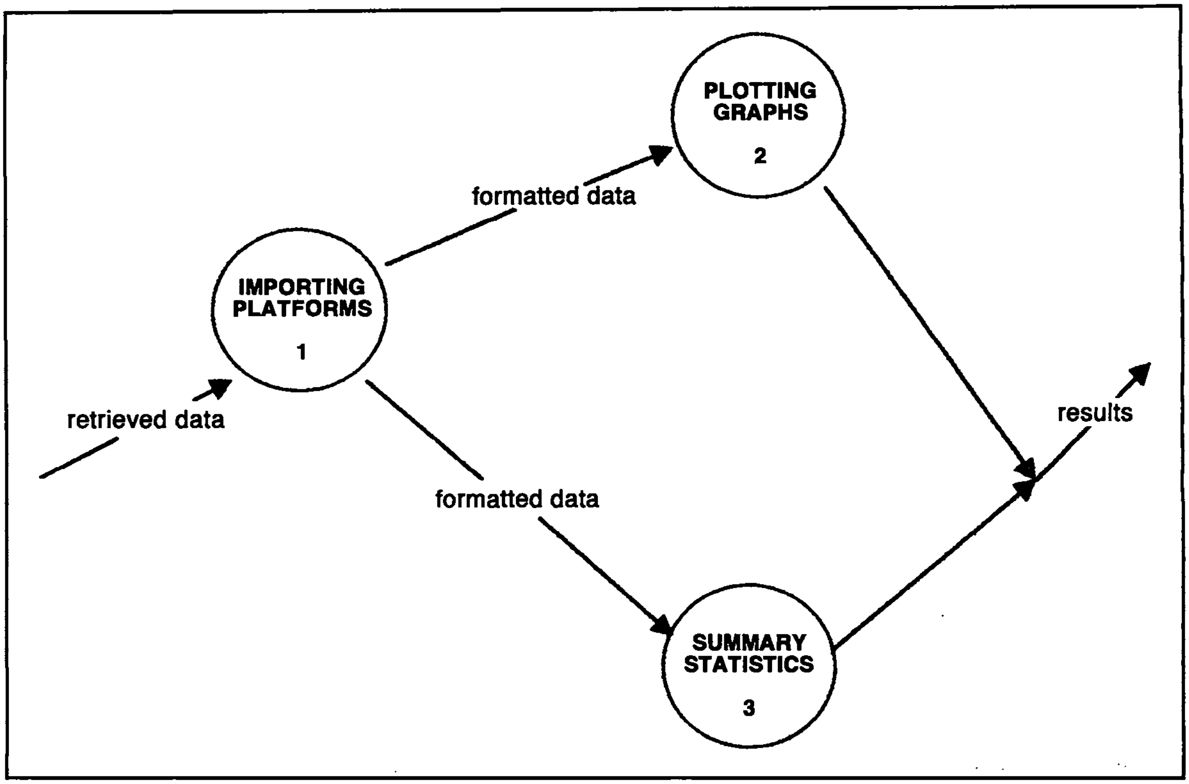

Figure 6. The three processes in the statistics part of the CGIM System.

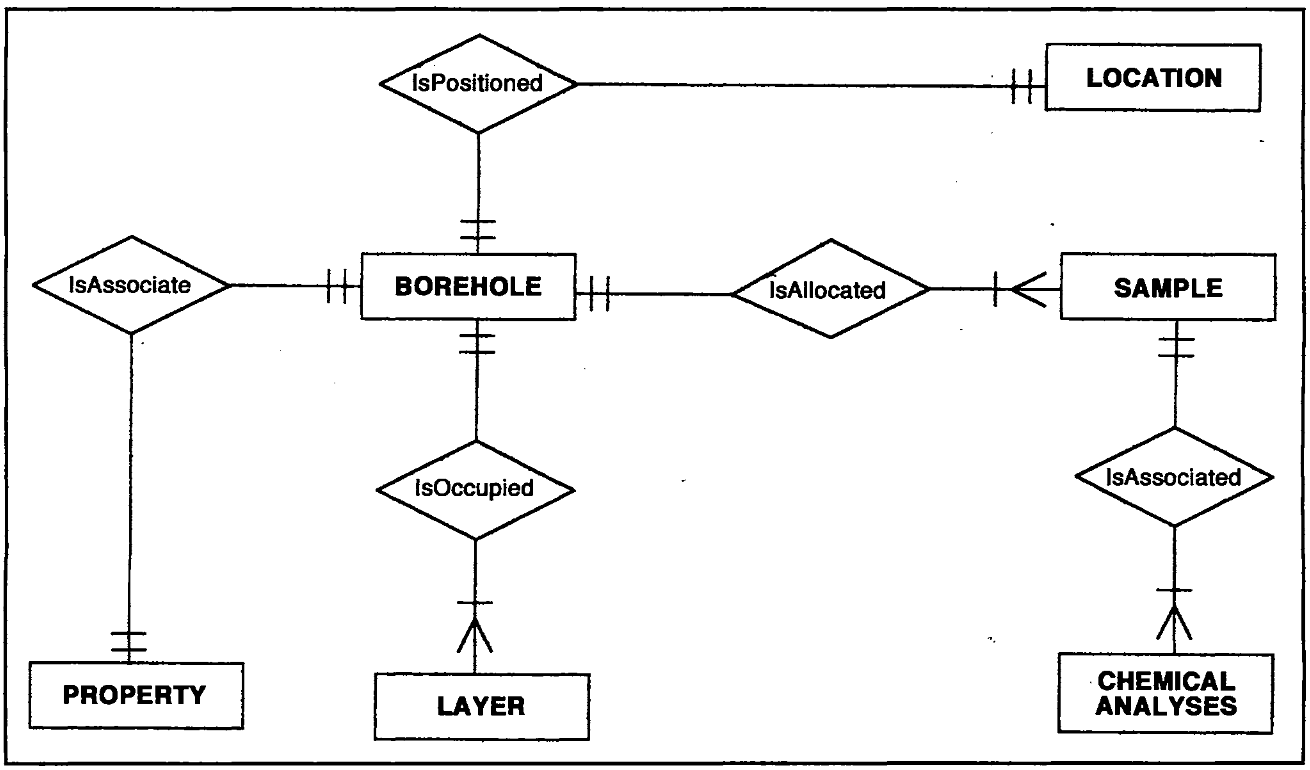

Figure 7. Entity relationship model of the CGIM System.

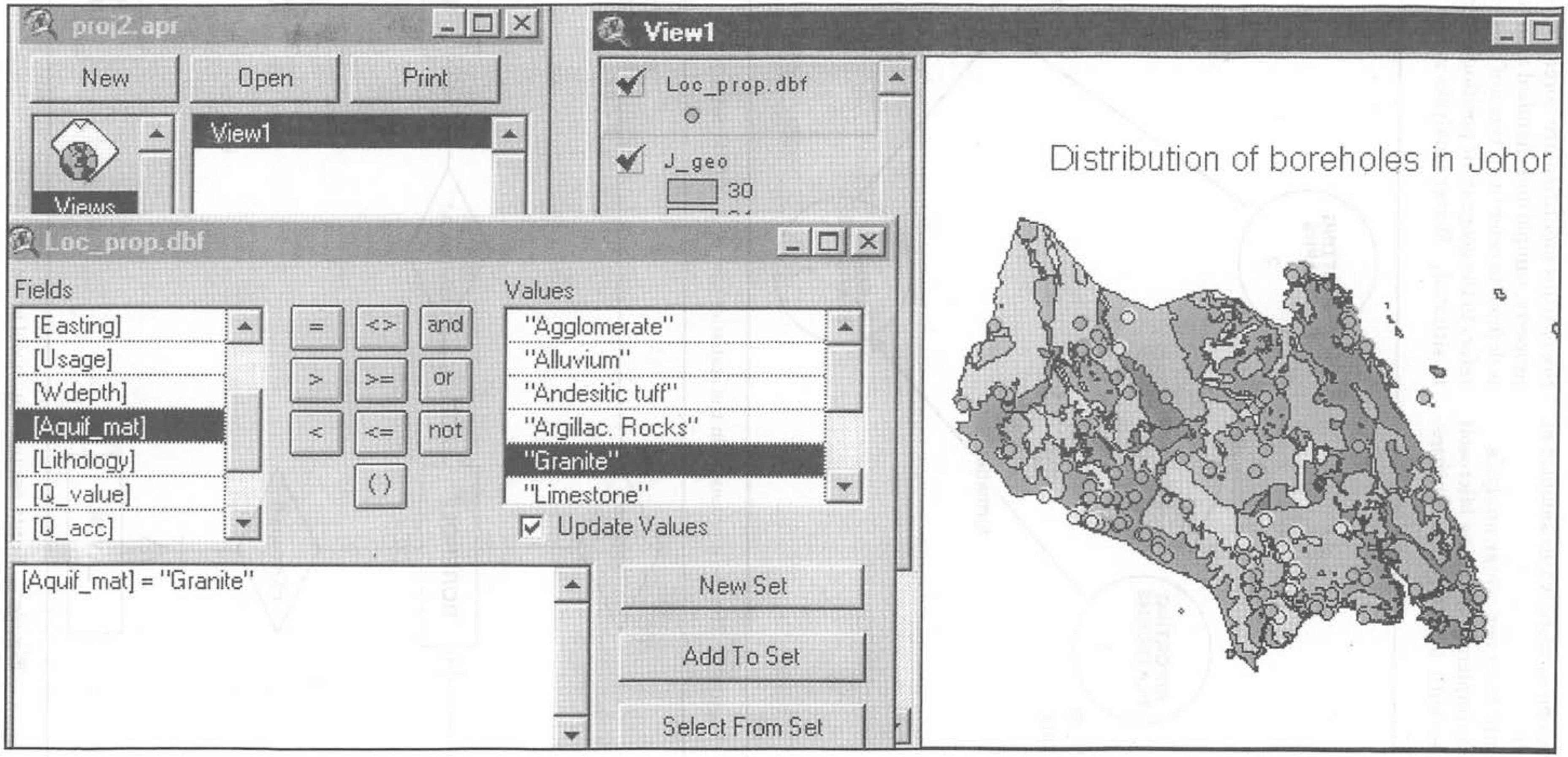

Figure 8. A query map showing the distribution of wells in granitic area.

results of water samples. Sample entity is defined as water sample which is collected from a borehole. Layer is referred to the lithological strata which is encountered during drilling. Property is defined to refer to the well aquifer properties.

A data dictionary in the form of a table was built to explain all the terms in the database.

The database was populated with groundwater data of the State of Johor, Malaysia which has about two hundred records in six tables. Several representative query systems were designed and extended to see how the systems work. These queries use dynamic views of the data such that new data entered into the database will appear in the query tables. These typical query tables were linked to the GIS using ODBC drivers.

Geographic Information System

The expression GIS can be defined as geographic coverages, implies that the data is stored in location coordinates. Information refers to the useful knowledge often expressed as coloured maps and images, statistical graphs and tables. Systems implies that there are numerous interelated functionalities such as data capture, input, manipulation, transformation, visualisation, combination, query, analyses, and output.

In GIS, data can be stored as attribute tabular data like in conventional databases as graphical map data if the data has X and Y coordinates. Each map object is linked to attributes such as numerical, coded and textual data describing each object. There are four types of map objects namely point, line, area and text. These are two main geo-relational models used in GIS namely vector and raster. A vector model represent objects in the real world by points, lines and polygons defining boundaries. A raster model represent objects in space with regular subdivisions called cell. This model is typically used in picture and image storage.

In GIS, data is stored in tabular form with specific coordinates columns which allow data to be processed according to their spatial distribution. Data models in a GIS organise data by both spatial and non-spatial attributes. Visualisation of data is achieved by the ability of GIS to display data in graphical form. In a geoscience environment data shown on a map is usually more readily understood than the same data represented in tabular form. Spatial queries enable the user to find information where spatial relationship may exist such as occurrence of a borehole or well site with another being favourable for the existence of a certain groundwater resources.

Connectivity

Open Data Base Connectivity (ODBC) provides reliable connectivity between the database and the GIS. An advantage of ODBC is that it had to be set up only once for the database. ODBC is convenient as it does not require any coding and opening of an ODBC table (which resides in the database). ODBC ensures a dynamic link between the database and GIS. The best way to unlink the connectivity is to save the file in ArcInfo/ArcView as a separate file with a different name from the original file.

APPLICATION OF GIS TOOLS

In GIS, data retrieved from CGIM in Microsoft Access/Visual DBase tables were viewed. Points were created in Arc View using easting and the northing coordinates. Thematic maps were then created using different attributes for the same area.

A geo-referenced map of Johor was obtained from Arc Info catalogue. The well data was imported into ArcView as a DBF file to be used as point in the thematic layers. Most queried information can be extracted from the database. Figure 8 shows an example of a query map showing the distribution of wells in granitic area.

Some of the elementary statistics can be done in the database and/or in the Arc View. Microsoft Excel application was also used for plotting some plots comparing different elements. In ArcView Ver. 3.0, Summary Statistics in the theme table window is only generate the 'click' operation from the statistics option under the main menu option. The 'click' operation also can plot the charts under the theme chart menu interface. An example of statistical results is shown as in Figure 1.

CONCLUSIONS

Based on the work done using Johore Groundwater Database (CGIM) and GIS applications much work can be accomplished that will satisfy the customer within a short period of time. The resource potential and water quality of various rock types can be evaluated with much confidence. CGIM and GIS approaches have made the retrieval, query and presentation of information easier and more meaningful to the users.

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