GIS in Groundwater Modeling

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In the United State, groundwater in aquifers plays an important role for water supply. An estimated 100 million persons in the United States get their water from community water systems that rely on groundwater. Approximately 15 percent of Americans rely on their own private drinking water supplies. Unfortunately, numerous contaminants threaten the quality of groundwater in aquifers, such as application of fertilizer, leaking storage tank, and discharge form industrial areas. So Environmental concerns related to groundwater generally focus on the impact of pollution and quality degradation in relation to human uses. Thus, groundwater quantity modeling became important. However, this task is extremely time consuming when the modeler is required to analyze complex heterogeneous aquifers and manipulate large amounts of input and output data. The GIS technology provides suitable alternatives for efficient management of large and complex databases.

GIS is a powerful tool and has great promise for use in environmental problem solving. Most environmental problems have an obvious spatial dimension and spatially distributed models can interact with GIS. GIS has been found to be very effective to assess the groundwater quality. GIS are designed to manage, analyze and display all types of spatial data. It provides a visualization platform in which layered, spatially distributed databases can be manipulated with ease. This capability makes GIS a powerful tool in conducting groundwater modeling. The application of traditional data processing methods for groundwater modeling is very difficult and time consuming, because the data is massive and usually needs to be integrated. GIS is capable of developing information in different thematic layers and integrating them with sufficient accuracy and within a short period of time.

Contamination of groundwater has become a major concern in recent years. Since testing of water quality of all domestic and irrigation wells within large watersheds is not economically feasible, one frequently used monitoring strategy is to develop contour maps based on the data from sampled wells. One of the common applications is using GIS as a tool to illustrate groundwater characters. Below are some examples of these maps.

**Groundwater Table Map:** The groundwater table map, which is prepared, based on the spatial data analysis shows that the water tables in the study area. The groundwater table map can further indicate a regional groundwater flow direction.

**Depth to Groundwater Level Map:** Depth to groundwater can range from shallow groundwater levels close to the ground surface to a depth of over hundreds meters.

**Water Quality Maps:** Different water quality maps can be produced using point data spatial analysis of GIS and the maps are believed to indicate the water quality conditions of the aquifer. The following water quality parameters have been found often applied by the paper review: Total Dissolved Solids (TDS) Map, Hardness Map, Nitrate Map, pH Map, and Sodium/Chloride Map. Below is an example of how to using GIS great a groundwater quality map.

In order to generate the total dissolved solid (TDS) and the ground-water classification maps, using GIS contouring methods within the ArcGIS software, the TDS map can be created using available TDS values (measured in mg/L) from sampled water wells. Contours were generated from a point shape file, using a fixed interval. A polygon coverage outlining the TDS class boundaries was then manually created in
ArcGIS using the contoured shape as a guide. The land-surface-area percentage of each groundwater class category can also be calculated by building the polygon coverage in ArcGIS and calculating the corresponding areas. Land-use planners can now use these maps as a basis for enacting regulations to protect water resources in the studying areas.

The most common application of GIS found during the literature review is creating groundwater contamination vulnerability maps. The map can reveal the areas of extreme and high groundwater vulnerability. Modeling groundwater contamination vulnerability can be divided into a handful of steps. The first step is to construct a spatial database of the area of interest containing information that will affect the vulnerability to groundwater contamination. Information layers such as land use, soil characteristic, bedrock geology, topography, recharge, hydraulic conductivity, groundwater levels, well locations and climate were common data layers have been used. The combination of these layers enables the vulnerability of an area to be assessed for specific pollutants. Once the groundwater contamination vulnerability map is created a classification of the model into vulnerability classes can be created. This is done by ranking the input layers according to their impact on groundwater vulnerability. Some cases using low numbers represent high vulnerability and high numbers represent low vulnerability. Finally, the vulnerability score of each of the layers are combined to create a vulnerability index. Vulnerability index can be represented in either a numerical value or a comparison value such as very high, high, low, etc. Another useful technique is to create a number of models of an area. In each of the models one of the variables is weighted more than the other depending on the degree of impact on the system. The different models are then compared to find common trends and patterns. A graphical representation of vulnerable aquifers, combined with graphical representations of potential sources of contamination and public water supplies would allow decision makers to evaluate current land use practices and make recommendations for changes in land use regulations which would better prevent the groundwater from contamination. For example, it may not be considered responsible to build a new chemical plant in the contributing area of a particularly vulnerable aquifer or area of an aquifer. Additionally, such a representation would provide a quick tool for determining possible responsible parties if contamination is found, thereby expediting the remediation process.

The third application of GIS in groundwater quality modeling is running groundwater modeling like DRASTIC and MODFLOW in a GIS environment. In these models, groundwater models play a role of analysis, and GIS play the role of displaying the map and find out the areas that are mostly concerned. Like from one of my reviewed paper, the DRASTIC model was used for vulnerability assessment in studying area using hydro-geological parameters, aquifer recharge, and the final map of DRASTIC aquifer vulnerability for the area was developed in ARCGIS software.

GIS modeling of groundwater contamination has many advantages but it also has a number of drawbacks. Many of the GIS modeling approaches are simplified and do not take into consideration processes such as preferential flow, hydrodynamic dispersion or absorption-desorption reactions. In some cases the influence of these processes can not be ignored which would make the simple GIS layer method unusable. Errors inherent in GIS include errors in source map, digitization, rasterization, and overlay procedures.

The ease with which a GIS can integrate multiple layers is invaluable in modeling groundwater pollution and pollution potential. Using a GIS to model groundwater contamination is quickly becoming a standard for groundwater modeling. The future of GIS and groundwater contamination is optimistic, as groundwater models become more sophisticated GIS will increasingly be a useful resource. It can also be
imagine that combination of other groundwater modeling methods with GIS would be widely used to generate more effective and accurate analysis of groundwater.

Annotated Bibliography


In this paper, Rahman found out the groundwater vulnerable zones in shallow aquifers in Aligarh and its surrounding areas, which is one of the fastest growing big cities of north India, using the DRASTIC model in a GIS environment. This model is based on the seven data layers that provide the input to the modeling. It corresponds to the initial seven layers i.e. Depth of water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone and hydraulic Conductivity. ILWIS 3.0 (Integrated Land and Water Information System) and Arcview 3.2a GIS software were used to find out the water vulnerable zones in shallow aquifers. The GIS technique has provided an efficient tool for assessing and analyzing the vulnerability to groundwater pollution. This study suggested that this model can be an effective tool for local authorities who are responsible for managing groundwater resources. The good point of this paper is that it presents how GIS combined with other software to do groundwater modeling.


This paper talked about the spatial distributions of nitrate concentrations in the studying area. In order to study the fact of nitrate contamination, water quality samples were taken from 139 wells in 1998 and from 156 wells in 2001 within the study area of 427.5 km². A vector-based GIS software package ArcView GIS 3.2 was used to map, query, and analyze the data in this study. A hardcopy map of the city was digitized in the UTM projection system. The well locations were obtained for 198 wells spreading all over the region by using a Magellan Spor Trak hand held Global Positioning System (GPS) receiver. In the conclusion part, authors suggested that an enhanced database can be created including more detailed analysis of land use maps using GIS, soil characteristics, sewer lines and well construction information. It means that enhanced database could improve the results of studies.


In this study factors to determine the areas most suitable for groundwater recharge via recharge basins in a coastal aquifer in the Gavbandi Drainage Basin in the southern part of Iran. The paper talked about that there are many factors to be considered when determining if a particular site will be receptive to artificial recharge. Then the authors discussed the differences between GIS method compare with traditional data modeling methods. Thematic layers for the parameters such as: slope, infiltration rate, depth to groundwater, quality of alluvial sediments and land use are considered, were prepared, classified, weighted and integrated in a GIS environment by the means of Boolean and Fuzzy logic. Thematic layers for these parameters were prepared, classified, weighted and integrated in a GIS environment by the means of Boolean and Fuzzy logic. In this research Boolean logic, in which only satisfactory and unsatisfactory conditions are considered (zero and unit values), and fuzzy logic in which
a range of zero to one is considered for different satisfactory levels were used. This paper present an example which is not be often talked about. But by assigning different layers to represent different parameters, and using right methods, GIS is powerful in doing various tasks.


The hypothesis of this research stated that an integrated study including factors of geology, hydrology, topography and geochemistry and technical factors is necessary to characterize the major variables influencing the concentration of radon in drinking water. This study investigated how the concentration of radon in drinking water is correlated to altitude, land use, geology, fracture zone and occurrence of uranium. The study investigated radon (222Rn) in 1460 drilled wells in Stockholm County, taking into consideration a number of factors that were originally considered to be independent sources of information. A combined approach of GIS and multivariate statistical analyses were used. The results show that the following factors clearly affect the radon content: bedrock, distance to fracture, topography and the use of the well. The spatial analyst function of ArcGIS was used to derive the spatial pattern of each well from each factor map.


This article presents results of a long-term investigation surveying VOC and VC groundwater contamination upstream of a large groundwater works in Cologne, Germany. For spatial analysis and display, all test results additional hydrogeological attribute data were transferred to a geographical information system (ArcGIS 8.0s). For this purpose, all sample sites were geo-referenced. The test readings as well as further information about the sample points (diameter, depth, position of filter segments and depth of the tertiary, impervious horizon) were added to the attribute data. The kriging method was used as interpolation procedure for the spatial estimation of the concentrations in the study, as it delivers the best linear unbiased estimator and takes into account the variogram as well as the sample point pattern. By applying this methodology to an extended VOC contamination, it could be shown that GIS, including geo-statistical interpolation tools, is a valuable support for dealing with this task. The point information could be mapped for comparison purposes, and kriging being implemented into the GIS made a method available which has proved itself in order to derive area-wide estimations of pollution from point information. This study showed that GIS can substantially support public health authorities in identifying and assessing health risks from chemical groundwater contaminations, in moderating communication processes and when taking decisions. It also offered a good example of using Kriging in GIS for small area before the developed method being used into widely used in large area.

This paper demonstrated that the usefulness of simple, commercially available GIS technology as a supporting tool for groundwater exploration in large regions in developing countries with poorly mapped baseline information and low digital data availability. Locating additional long-term groundwater resources in semi-arid regions of developing countries with growing populations is an expensive undertaking. Simple GIS techniques can be utilized to facilitate efficient application of expensive geophysical techniques and test-drilling by functioning as an interdisciplinary integration and decision-making tool, especially in data-poor and poorly mapped environments where more sophisticated GIS techniques are not applicable. This paper demonstrated this in the context of the search for groundwater alternatives to the dwindling river water supply in the Boteti area of the Kalahari region in Botswana. The paper showed that simple GIS applications can assist significantly toward the location of regional groundwater resources in developing countries primarily by using integrated data derived from a variety of sources – including digital satellite imagery, GPS-data collected during field explorations and ‘on-screen’ geomorphological interpretations – for multi-disciplinary decision making during exploration work.


This research examined the relationship between the Conservation Reserve Program (CRP) and the changes in the groundwater levels within Texas County in the Oklahoma Panhandle region. The paper talked about how the spatial data were projected. AVSWAT (ArcViewSWAT), a hydrologic/watershed modeling extension for ArcViewGIS, was used in this study to delineate the watershed and calculate groundwater recharge for each HRU (Hydrologic Response Unit) in the Beaver watershed which covers Texas County. The paper showed how data pertaining to soil, land use/cover data, weather and land management information were imported into AVSWAT, and how to calibrate the model by adjusting sensitive parameters including Curve Number (CN), Soil Available Water capacity Adjustment (%), Soil Evaporation Compensation and Factor (ESCO), until acceptable fit to measured surface flow at the basin outlet was obtained. This GIS-based modeling study indicated that there is a significant relationship between CRP percentage in each sub-basin and difference in groundwater level between 1990 and 2000. The novel application of GIS as demonstrated in this study is not only useful to understand spatial dynamics through visual analysis, but also to understand spatial linkages between land use and environmental impacts.

Other References:


