Improving the Odds

Preliminary hydrogeologic assessment is key to cost-effective groundwater exploration.

By David S. Hume, Mike Plante, and Roscoe Sopiwnik

Like any large municipality that relies on groundwater resources to supply its customers, large rural water systems and smaller rural water utilities generally undertake groundwater exploration and well field development projects for several reasons: to meet increases in water demand, improve water quality, and comply with regulations that protect the resource.

Many factors must be taken into consideration during the initial stage of identifying areas for possible groundwater source development: the location of future service areas, current distribution pipelines, existing and proposed water treatment plants, and the costs associated with these. More important, areas selected for well field consideration must be located where an aquifer can provide a sustainable, long-term supply under the stress of pumping while minimizing impact to other users and resources. However, not all rural water systems have the luxury of extensive aquifers with high-quality water, as many are established in regions where these resources are limited. This can result in challenging and costly groundwater exploration projects, particularly for larger systems, where the areas of interest may cover hundreds of square miles.

When a rural water system is faced with this dilemma, and a groundwater exploration project is necessary, they are advised to have the consultant complete a preliminary hydrogeologic assessment to identify those areas where the aquifers have the greatest potential to provide the necessary water source. This assessment should be completed before costly infrastructure work and hydrogeologic field investigation activities such as geophysics, test-hole drilling, and aquifer pumping tests.

Finding Scarce Water in Minnesota

Recently, a large rural water system in Minnesota retained Leggette, Brashears & Graham, Inc. (LBG, www.lbgweb.com) to help identify areas where potential groundwater resources could be developed to meet an increase in their peak demand of about three mgd.

This water system has steadily grown since 1979, serving agricultural producers, other rural customers, and small communities over a nine-county area. The water system obtains its water supply from three well fields that are separated from each other by about ten miles to 40 miles. The wells are completed in buried sand and gravel aquifers that range in depth from about 30 ft to 450 ft. While these are reliable long-term water sources, they are at or near their production capacity.

The nature of the hydrogeology in southwestern Minnesota is such that it is difficult to find water as the geology consists primarily of buried glacial outwash sand and gravel channel deposits that can be difficult to delineate. Moreover, the areas of interest covered about 1,000 sq miles and included a tremendous amount of stratigraphic, water level, and specific capacity data. An aggressive timeline and large data sets required the project team to implement an efficient and effective data analysis workflow and site-selection process. The project team's use of GIS software and spatial analysis was invaluable in enabling it to cost-effectively meet the challenges of identifying target zones for exploration.

GIS Identifies Target Zones

Completing a preliminary assessment reduces the time and cost associated with groundwater exploration, and mitigates the risk of developing infrastructure based on false assumptions. This assessment began by gathering readily available hydrogeologic data from various sources, including the Minnesota Department of Natural Resources, Minnesota Department of Health (MDH), Minnesota Geological Survey, U.S. Geological Survey, and discussions with the owner and their engineer about groundwater quality and potential water treatment issues. The most useful information included hydrogeologic reports, maps, and well and boring logs. These sources provided data about the thickness and extent of the aquifers, water quality, and estimated well yields. Approximately 700 well logs were downloaded from the MDH database and evaluated. The data was organized into a logical workflow and incorporated into the GIS for further processing and analysis with subsequent spatial models.

Using Microsoft's Visual Basic programming language, LBG wrote a script that enabled the GIS tool to automatically post data from the well and boring logs to labels beside each well symbol on the GIS map. These data included the well identification number, aquifer elevation, aquifer thickness, total depth, and specific capacity. This allowed rapid development of a preliminary site conceptual model and aided in selecting hydrogeologic cross-section transects. Visual representations from this preliminary assessment included contour maps of total aquifer thickness and specific capacity that qualitatively emphasized target areas with the greatest potential for a high-capacity water supply.

The project team evaluated five areas of interest to identify specific target zones that appeared to have the highest potential to meet the demand based on the hydrogeologic characteristics of the buried aquifers. The team refined the selection process through evaluation of various hydrogeologic criteria, narrowing the list of possible options. Hydrogeologic cross sections were constructed to evaluate the extent of shallow, intermediate, and deep aquifers. The team identified 24 sites with hydrogeologic characteristics that warranted further evaluation. Each of the 24 sites was ranked, considering available drawdown, estimated yield, water quality, and potential regulatory issues. Finally, the three best aquifer zones were identified and recommended for further exploration.

Refining the Site-Selection Process

Following completion of the preliminary assessment, the owner selected one of the five areas of interest for test drilling. The project team developed an exploration work plan that outlined the strategy and scope of work to address the data gaps in the target zones. This phase included sampling groundwater from existing wells, drilling test holes, installing test wells, and conducting short-term aquifer pumping tests.

Implementing the work plan provided the project team with site-specific data that were needed to narrow down the target zones and identify those areas with the greatest potential for a possible well-field site. Criteria included aquifer material and grain size, groundwater quality, aquifer thickness and extent, available hydraulic head above the top of the confined aquifer, and estimated yield. In addition to aquifer characteristics, potential regulatory issues were considered, such as interference with other wells, safe-yield thresholds, and impact to surface waters or other sensitive environments.

The project team incorporated these field data into a GIS-based spatial modeling application that is capable of estimating aquifer yield based on hydrogeologic data, additional site-specific boring information, aquifer pumping test results, and regulatory guidelines. This model, written using ESRI's (www.esri.com) ModelBuilder and Python open-source programming language, solves for pumping rate, which was one of the owner's criteria for selecting potential well sites. Using the model, it took only minutes to run multiple scenarios; compared with conventional methods, this resulted in significant savings for the owner. Also, the ability to visualize the hydrogeologic setting gave the owner greater confidence when selecting locations for potential production well sites.

Based on the project team's and owner's review of all site data, along with output from the model, the owner selected a single 100-sq mile area with five to six specific locations for the installation of high-capacity production wells—the culmination of a process that narrowed the field from 1,000 sq miles to just 100 sq miles. This information, along with confirmation test borings at the specific locations, provided the owner with the confidence to now move forward, knowing that these locations have the capacity to meet the system's demand of three mgd.

It is always a challenge to identify groundwater resources that have the potential to be developed into high-capacity, long-term water sources across large, rural areas with hydrogeologic characteristics such as those found in southwestern Minnesota. This is why it is critical to begin an exploration project with a preliminary assessment to narrow the field and to use the tools—in particular, GIS—that can help pinpoint areas with the greatest potential for high-yielding wells. GE

Mr. Hume, P.G., is a Senior Associate, Mr. Plante, P.G., is a Senior Hydrogeologist, and Mr. Sopiwnik is an Environmental Scientist in the St. Paul, MN, office of Leggette, Brashears & Graham, Inc.

Test-hole drilling starts at a target site.