DEVELOPING WATER RESOURCE BASELINE CONDITIONS FOR PLANNING

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Abstract

The Barrington Area Council of Governments (BACOG) is studying groundwater resources in the region for the purpose of establishing groundwater conditions and baseline data and to develop policy recommendations for sustainable development. By analyzing data layers using geographic information systems (GIS) including subsurface bedrock, groundwater wells, wetlands, watersheds, soils, land use, zoning, water consumption and population, BACOG will describe existing groundwater resources, posit the relationship of groundwater to surface waters, project the development and population growth that will occur in the region to build-out, analyze the sustainability of that development by existing groundwater resources, and provide recommendations to governments for protecting sensitive environments and aquifer recharge areas along with public education/conservation programs. The paper will focus on the local planning framework for conducting this research and strategies and methodologies for data collection and analysis.

Background

The BACOG geographic area is located approximately 40 miles northwest of downtown Chicago in northeastern Illinois. BACOG is a regional planning organization comprised of seven member municipalities:

- Barrington
- Barrington Hills
- Deer Park
- Lake Barrington
- North Barrington
- South Barrington
- Tower Lakes

Politically, BACOG's jurisdiction covers portions of four counties:

- Cook
- Kane
- Lake
- McHenry

It also includes multiple townships and the seven villages, all of which have independent governing bodies. The area is a unique regional community with a central business district and village atmosphere surrounded by semi-rural countryside residential areas and extensive acreage in wetlands, forest preserves, parks, agriculture, and horse farms. As a regional planning organization, BACOG's primary functions are to promote the regional comprehensive land use plan and protect environmental resources, for the greater good and preservation of the community.

Over 30 years ago, community and municipal leaders joined together to develop the first regional comprehensive plan for BACOG. The plan was based on the relationship of land uses to natural resources, and the resources available to support development were to limit development. This plan has been implemented substantially, but there is still much development to occur within BACOG until complete build-out. The concept of development being limited to naturally sustainable levels has been steadfastly maintained since 1970 through the BACOG comprehensive plan, the municipal comprehensive plans, and other planning policies.

Groundwater is the lifeblood of the BACOG area. Residents are dependent primarily on the shallow aquifer, and within that, primarily the shallower layers of the shallow aquifer, for all water needs. Only the central "hub" village of Barrington, Tower Lakes, and small sections of the other communities offer public water or sewer, again with the water supply coming primarily from the shallow aquifers. The countryside communities require well and septic systems that utilize the shallow aquifer and large lot zoning (one or more acres) that are necessary for proper functioning of those systems. With very few exceptions, public water is not offered or planned for the area, and only those areas currently served contain the infrastructure required for public utilities. Publicly provided water is metered, but most other water consumption is not measured or estimated. Any threat to the quantity or quality of water in the aquifers would threaten the community structure, the public health, safety and welfare, and the ability of families and businesses to survive.

As more development occurs throughout and surrounding the BACOG area and the BACOG municipalities experience increasing pressures for higher density development and higher intensity uses, development sometimes attempts to break zoning and planning by threatening lawsuits and land disconnection in order to negotiate higher densities and secure water and sewers from other towns. BACOG towns find it more and more difficult to fend off development that could negatively affect the wetlands, natural areas, and aquifers of the area.

High density and commercial/industrial development in villages and areas adjacent to BACOG also could affect water resources locally. Peaker power plants, users of extremely high amounts of water, have attempted to locate in nearby communities. Water resources do not respect political boundaries, and the water that is available today to residents and to sustain sensitive natural areas could be compromised by intense development in surrounding communities or by mining and other industrial uses nearby.

Concerns about groundwater supply and quality have been prominent for some time because of the dependence of BACOG's more than 35,000 residents on groundwater. There is virtually no possibility of obtaining water from Lake Michigan. Other northeastern Illinois communities are using the maximum allocation, governed by a Supreme Court ruling and international treaty. Regardless, the cost of providing infrastructure from so far away would be very high, and the cost of providing new infrastructure to serve homes in the countryside communities would be exorbitant. Available allocation and infrastructure costs would also be impediments to obtaining water from the Fox River, where there also are restrictions on diversion of water. As water quality and quantity in the deep aquifer have declined over past decades, fewer deep wells have been developed, and in fact, numerous municipalities have abandoned their deep wells. Areas within and adjacent to BACOG have been identified by the Northeastern Illinois Planning Commission's (NIPC's) water management plan (NIPC, 2001) as having the potential for water shortages in the future. Developing trends towards higher usage of the shallow aquifer, the vulnerability of the shallow aquifer to contamination, and constraints on alternative water supplies have resulted in concern for the sustainability of groundwater in the BACOG area.

Recognizing these concerns, in early January 2001 BACOG proposed to the member villages a study of groundwater resources. The Executive Board agreed and authorized the formation of a committee to begin a study. The Committee is entirely staffed by volunteers and includes advisory members from the Illinois State Water Survey, the Lake County Health Department, and a private environmental consulting firm. In addition to representatives from all the BACOG villages and a number of county boards and townships, members also include representatives of conservation and community organizations. Under the direction of the BACOG Executive Director, the Water Resources Committee conducted its first meeting in April 2001, providing educational materials and presentations for its members for the first few months. The Committee began identification of local groundwater issues, data collection, research, and structuring of the project later that year. Since then work has continued through regular meetings of the committee and its five subcommittees. Project progress has been reported on a regular basis (Peters, Agnoletti, and Thomsen, 2003; and Agnoletti and Thomsen, 2003)

Other governmental entities have recognized the importance and vulnerability of groundwater resources. Although vetoed by the Governor due to cost, the State Legislature in 2003 approved a statewide study and mapping of groundwater resources. Local governments are also involved in groundwater research. For example, McHenry County completed an aquifer-mapping project in conjunction with the Illinois State Water Survey and is currently developing a management plan, and Kane County has begun a similar project. The BACOG Water Resources project will complement and build upon these and other efforts by creating a detailed database with accompanying planning recommendations and education programs for a specific geographical area within the larger regions of county, metropolitan area and state.

The BACOG project will offer practical applications and solutions relating to development. Although final reports have not yet been issued, enough data has been collected and analyzed to bring some facts to bear on several local situations. One of the BACOG villages became concerned about a proposed expansion of a wastewater treatment facility in a neighboring municipality. The effect the consequent increased effluent discharge into a small waterway that passes through portions of the BACOG village would have on the shallow aquifer in the area were of concern. Project data were analyzed for the small geographic area of the creek receiving the discharge and adjacent wetlands. Stratigraphy, well depths, soil characteristics, topography and watershed data were used to evaluate the potential for the waters of the creek and wetlands to interact with groundwater. Several areas containing wells were identified as moderate recharge areas that therefore would possibly be vulnerable to contamination. Findings were used by the BACOG village in testimony to the Illinois Environmental Agency regarding the permit expansion and the need for the plant effluent to meet clean water standards. A similar small-scale study and analysis was done for an unincorporated area near the Village of Barrington.

Through the initiative, BACOG will expand its base of knowledge, technical capacity, and data on water resources. Specific data on water conditions and water availability, rough mapping of the aquifers, estimates of current and projected water consumption, the potential for groundwater contamination, a network of private monitoring wells, and future monitoring against current conditions are all critical to the desired goals of sustainability of natural resources and balance with development. Geographic Information System (GIS) technology, a computer mapping and data management tool, will be utilized for data collection and analysis for the entire project.

Since the footprint of the communities that comprise the BACOG area is irregular, a boundary was drawn around the extent of the seven communities to establish the BACOG area for the purposes of this study. The extent of the BACOG area for the water project is approximately 175 square miles (Figure 1). A six-mile wide buffer was established around the BACOG area to identify the entire BACOG study area. This buffer zone was included to insure that the system characteristics at the border of the BACOG area can be established. The complete BACOG study area contains about 600 square miles.

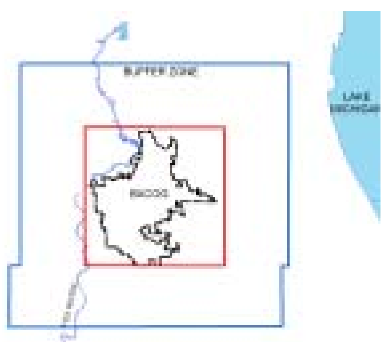

Figure 1 BACOG Study Area

The groundwater system in this study area includes the unconsolidated sand and gravel water-bearing units (aquifers) located in the glacial drift (material deposited by glaciers) as well as the uppermost bedrock immediately underlying the glacial drift. The bedrock unit is a Silurian dolomite/limestone and is located at 150 to 350 feet below the ground surface. One to five aquifers may be present at any given location within this study area (Meyer, 1998). These units may be interconnected or they may be separated by impermeable (aquicludes) or semi-permeable units (aquitards) of glacial till (fine materials deposited by glaciers). Therefore, these units may exhibit unconfined, semi-confined or confined hydraulic conditions.

Water Balance

A water balance approach is being used to characterize the groundwater system in the study area. The water balance approach develops a conceptual model of the study area indicating that the change in groundwater storage is equal to the sum of the groundwater inflows minus the sum of the groundwater outflows. Inflows to the groundwater system include the groundwater that flows across the site boundary into the study area, groundwater recharge, and upward seepage from the underlying bedrock. Outflows include the groundwater that flows across the site boundary out of the study area, the groundwater that is withdrawn for consumption, seepage to the underlying bedrock, and groundwater discharging to the surface system (Figure 2).

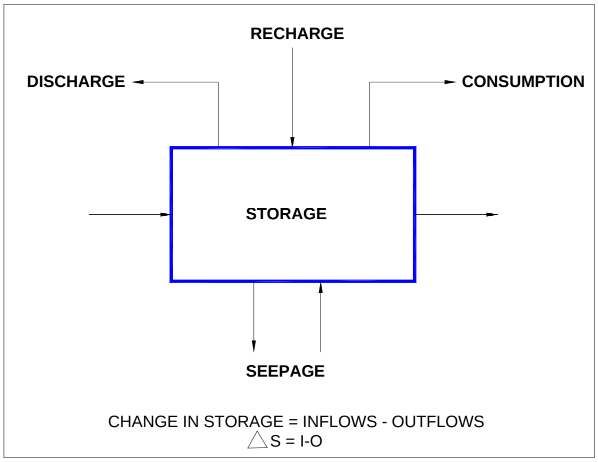

FIGURE 2: CONCEPTUAL MODEL OF THE GROUNDWATER SYSTEM

Figure 1 BACOG Study Area

Storage

The volume of groundwater that is stored within the study area is determined by establishing the volume of the water-bearing units and then using the porosity of the units along with groundwater water levels to determine the actual volume of water contained in these units. Since not all the water contained in an aquifer is available for removal, an estimate will be made of the amount of water that aquifers within the study area will yield.

Inflows

Inflows into the study area include, groundwater flow into the study area through the study area boundaries, recharge through the surface of precipitation, and ground water seepage from the bedrock underlying the study area.

Groundwater Flow into Study Area

Inflow rates are determined by developing a picture of the distribution of hydrogeologic units (aquifers, aquitards, and aquicludes) in vertical sections that coincide with the study area borders. The area of aquifers where groundwater flow is into the study area is determined. Combining this information with ground water levels and soil characteristics that include hydraulic conductivity and effective porosity, groundwater flow rates into the study area through the site boundaries are established.

Recharge

Potential recharge areas are determined by establishing the water transmission characteristics of the topsoil and the underlying materials to a depth equal to the location of the uppermost aquifer. This information is used to develop a map that depicts the distribution of relative water transmission rates into the soil to the first aquifer throughout the study area. These transmission rates are then ranked to indicate the areas that have high potential for recharge and those that have lesser potential for recharge.

Several methods have been identified to estimate the recharge flow rate required by the water balance approach. First, soil maps and water transmission rates through soils combined with annual precipitation data could be used to determine the portion of annual precipitation that enters the ground as recharge. A second method is to determine the base flow of the Fox and Des Plaines Rivers that flow through the study area from stream flow records and use this information to determine a recharge rate. A third method to determine recharge is to estimate runoff from the small watersheds located in the study area during annual precipitation events using the Rational Method (USDA, 1986) and subtracting this value from the precipitation amount leaving the amount available for recharge. A fourth method is to search the literature for recharge values. At the time of this writing, the method that will be used in this study has not been selected.

Seepage from Bedrock

Groundwater flow is driven by differences in groundwater levels (head), and therefore, some of the groundwater in the shallow aquifer system may infiltrate into the bedrock as well as some bedrock groundwater may flow upward into the shallow aquifer system. The amount of flow seeping into the shallow aquifer system from the bedrock is a function of the flow characteristics of the bedrock and the difference in elevation of the bedrock and shallow aquifer head. If the bedrock groundwater level is higher than that of the shallow aquifer, then the seepage of the bedrock groundwater is upward into the shallow aquifer.

Outflows

Flows out of the study area include, groundwater outward through the study area boundaries, groundwater withdrawals for consumption, ground water seepage into the bedrock underlying the study area, and natural groundwater discharge to the surface.

Groundwater Flow from Study Area

Outflow rates are determined by developing a picture of the distribution of hydrogeologic units (aquifers, aquitards, and aquicludes) in vertical sections that coincide with the study area borders. The area of aquifers where groundwater flow is out of the study area is determined. Combining this information with groundwater levels and soil characteristics that include hydraulic conductivity and effective porosity, groundwater flow rates out of the study area through the site boundaries are established.

Consumption

The annual water consumption rate is determined by multiplying the per capita water consumption rate for Lake County Illinois (NIPC, 2001) by the U.S. 2000 Census population figures. Commercial, industrial and other water consumption will be accounted for in this figure. This gives total water consumption from all sources for the entire study area. The population of municipalities and areas that are supplied by deep aquifer water, surface waters (e.g., rivers), or Lake Michigan water are then subtracted from the total. The final figure represents shallow groundwater consumption.

Seepage into Bedrock

The amount of flow seeping into the bedrock from the shallow aquifer is a function of the flow characteristics of the bedrock and the difference in elevation of the bedrock and shallow aquifer head. If the bedrock groundwater level is lower than that of the shallow aquifer, then the seepage of the shallow aquifer groundwater is downward into the bedrock.

Groundwater Discharge

The value for groundwater discharge is determined using stream flow records of the Fox and Des Plaines Rivers that are available from the U.S. Geological Survey (USGS). Stream flow characteristics are analyzed to establish the base flow. The base flow is a function of groundwater discharge. The base flow value is manipulated to provide a value for the annual groundwater discharge rate.

DATA PREPARATION AND BEDROCK TOPOGRAPHY

The first task in characterization is to develop a bedrock topography map. There are approximately 15,000 well logs available in the BACOG study area. Data contained in the well logs are fairly general, not consistent, and loaded with errors. Fortunately, the coverage is good; the data are generally adequate to broadly define major stratigraphic units as well as being ideal for developing baseline conditions. Unfortunately, the disadvantages of the well log data make it difficult but not impossible to conduct GIS queries.

The database of well logs contained a wealth of information, chief among which are a unique identification number, stratigraphic information, and location. Missing on most of the well logs was the ground surface elevation at the well location.

The first task to characterize the 600 square-mile study area was to develop a map of the bedrock surface. The well log information acquired from the ISGS contained about 80,000 lines of data for the approximately 15,000 wells within the study area. Very few of the wells had surface elevations associated with them, which are required to establish the elevation of the bedrock surface as well as other stratigraphic features. Using GIS techniques, the water well data were joined to an Illinois topographic reference file (Lumin, Smith, and Goldsmith, 2003) resulting in surface elevations for each well in the database.

The first step in developing the bedrock topographic map was to identify all the wells in the database that were drilled to bedrock or beyond. To accomplish this, GIS techniques were set up to query the database using descriptors for bedrock such as rock, limestone, shale, sandstone, lime, and stone. The database was queried and the wells containing bedrock terms were set-aside in a new file. At this time, quality assurance/quality control (QA/QC) procedures were instituted to ensure that all wells penetrating bedrock were found. About 3,000 bedrock wells were identified during the first pass.

QA/QC was begun by reviewing each line of the database by hand to identify wells missed by the first query. When a missed bedrock well was identified, the descriptor identifying bedrock was added to the query list, and a query using that descriptor was conducted. The list of descriptors included other terms such as unique nouns and adjectives, misspelled words and abbreviations. The newly found bedrock wells were added to the bedrock well file.

Next, the original database was entered at the point where the last descriptor was found. Again the database was reviewed line by line until another bedrock well was found. The new descriptor was added to the list and a query was conducted. This process continued until all the bedrock wells in the database were identified and added to the bedrock well file. When all bedrock wells were identified, the descriptor list contained more than 20 descriptors and almost 7,000 bedrock wells were identified.

The surface of bedrock in the study area may be weathered. This means the bedrock may be broken and not competent. The weathered portion of the bedrock may range from a thickness of a foot or two to 10 or 15 feet. In this study, the weathered portion of the bedrock is considered part of the shallow aquifer system. The bedrock surface is the surface of the competent bedrock.

The next step in establishing the bedrock topography map was to query the file using the descriptors "weathered" and "broken". Lines of data containing these descriptors were removed, and QA/QC procedures were applied to determine if there were other descriptors of weathered bedrock. Other descriptors were added to the list and queries using these descriptors were conducted. All additional lines containing weathered bedrock information were removed.

The 7,000 bedrock wells were then queried to establish the depth of the actual surface of the bedrock. Any wells with lines of information containing the descriptor "bedrock" above or below this surface were eliminated. At this point the depth to bedrock for each location was subtracted from the surface elevation, previously established, to determine the elevation of bedrock in AMSL.

Querying a database is a tedious process as evidenced by the effort involved in developing a bedrock surface map using the complete database. Because of the effort involved in this first querying effort, it was decided to develop a protocol for analyzing and querying the data to arrive at the components of the water balance using a small section of the study area whose data could reasonably be analyzed by hand and then used to develop querying techniques.

A 10 square mile area was selected measuring 2.5 by 4 miles for developing the analytical protocol for the study. The same area selected to determine the effects of the proposed expansion of the wastewater treatment facility mentioned in Section 2.0 was to be again used. This sub-area contains just fewer than 400 bedrock wells and is a microcosm of the study area. All work on the protocol completed to date has been conducted on the data from this sub-area. This sub-area will be used to complete the protocol and the analytical and querying techniques developed will be applied to the entire study area database. The following sections describe the data analytical approach developed using the protocol and provides an example of how the magnitude of the water balance components are determined.

DATA ANALYSIS

In the previous section, site characterization methods and data manipulation techniques were described. Outcomes of these activities are used to establish values for the components of the water balance. This section describes data analytical procedures that will be used to determine these values. The procedures described will initially be used to analyze the data. Some of these procedures will be revised based on the results of the first attempt at data analysis. In some cases, there may several data analytical iterations before a successful outcome is achieved.

Storage

Storage capacity of the shallow aquifer system is the amount of water that is held in the pore spaces of the permeable material within the system. The semi-permeable and impermeable materials within the system also store water in their pore spaces (voids), but this water is not available for use. As mentioned before, not all the water in the permeable units is actually available for use. For purposes of the water balance, the storage capacity of the system will be the amount that is available for use.

Before the available storage capacity is obtained, the total capacity of the permeable units (aquifers) must be established. This will be accomplished by analyzing the layers of the stack-unit map. The stack-unit map is composed of layers that describe the distribution of aquifers, aquitards, and aquicludes in 20-foot intervals. This distribution is presented using contours. As mentioned before, a grid map is generated when contouring. The grid map data will be queried and all grid points having hydraulic conductivity values of less than or equal to -3.0 will be eliminated and the number of the remaining grid points will be established. Each grid point is associated with a known area that was established when the grid map was created. The total area of the remaining grid points will be calculated and multiplied by 20 feet to establish the volume of the aquifer material.

The volumes of each layer of the system will be added together to give the total volume of the aquifer material in cubic feet. This volume includes the volume of the soil material as well as the volume of pore spaces. Typically, an aquifer has a porosity of 25 percent meaning that 25 percent of the total volume is the volume of the pore spaces. One cubic-foot of pore space contains 7.48 gallons of water. Multiplying the pore space volume times 7.48 will yield the number of gallons of water held in storage. A conservative estimate of the amount of water that is available for use is about 50 percent; the amount available could be less. Therefore, the storage capacity of the system is about half the amount of water in the pore spaces. This value is reported in gallons. A preliminary evaluation of the total volume of water in the aquifers of the sub-area is 34 billion gallons, making the available amount about 17 billion gallons.

Discharge

All the groundwater discharge within the study area eventually finds its way to the major rivers in the study area and flows out of the area. There are three major river watersheds in the BACOG study area. These are the Fox, Des Plaines, and the Kishwaukee River watersheds.

Base flow is the portion of stream flow that is contributed by groundwater discharge. During dry periods, base flow is the entire stream flow. Since all the groundwater discharge in the study area would eventually find its way to the major rivers draining the study area, the base flow of these rivers will contain the groundwater discharge from the area.

The U.S. Geological Survey (USGS) has a software package that separates base flow from stream flow records (USGS, 1996). This package will be used to determine the base flows of the Fox, Des Plaines, and Kishwaukee rivers. The base flows will be related to the area of the watershed from which the base flow occurs and converted to a flow per unit area figure. This figure will be used in conjunction with the area of the watershed that is in the study area to arrive at a groundwater discharge contribution from that portion of the watershed. The flows from the various watershed portions within the study area will be added together to yield a value for the whole study area. This value will be in gallons/year.

Records from five stream flow gauging stations will be used for base flow separation. Conveniently, gauging stations are located at the north and south ends of the study area on both the fox and Des Plaines Rivers. The headwaters of the Kishwaukee River and its watershed lie partially in the western portion of the study area. Records from the first downstream gauging station located on the Kishwaukee River will also be used.

There are no streams in the sub-area; therefore, groundwater discharge for the sub-area is equal to 0 billion gallons/year.

Recharge

The recharge component of the water balance will be determined by analyzing precipitation data for a recent year. Data will be taken from recording stations that are nearest to or within the study area. The precipitation data will detail events occurring during a year by providing precipitation intensity and duration data. This information will supply a rate at which precipitation falls for each event. Analyzing the available soil data will yield the rate at which water is absorbed by the various soil types encountered in the study area. Precipitation rates, for most events, are significantly higher than the rates for soil entry. Using the difference between the two rates results in an estimate of the portion of each precipitation event that enters the soil. These amounts are added for the course of a year to yield a recharge per year value for the study area.

At this time, recharge data have not been analyzed. At a recent presentation, (Mehnert, 2003) of the ISGS provided a value of recharge applicable to the study area of 21.5 inches per year. This translates to 3.74 billion gallons of recharge in a year. This figure will be used in the water balance example. Stratigraphic information used to establish recharge characteristics are described by Thomsen and Agnoletti (2004).

Consumption

A per capita consumption rate will be determined that will be representative of conditions in the study area. The portion of the population to be served by the shallow groundwater system will be calculated from U.S. 2000 Census data and projections from the Northeastern Illinois Planning Commission (NIPC). NIPC also provided information on the use of Lake Michigan water within the study area. Other sources of water in the study area include deep aquifer groundwater and surface water. The total consumption minus Lake Michigan, deep aquifer and surface water consumption represents water consumption in the study area. At this time, the population served by the shallow groundwater system has not been determined

The population of the sub-area is about 10,400. At 162 gallons per day per person, the annual consumption of water is 0.615 billion gallons. This value will be used in the example.

Bedrock Seepage

The bedrock in the study area is composed of limestone, dolomite and to a lesser extent shale. All of these materials have a low hydraulic conductivity; therefore, seepage in or out of the bedrock will be low.

Groundwater level data for all the wells drawing water from the shallow aquifer system and also for all the wells drawing from the bedrock aquifer will be obtained from the ISGS. Two contour (potentiometric) maps will be generated. One map will represent the groundwater levels in the shallow aquifer system and the other will represent the water levels in the bedrock aquifer. As mentioned, grid maps are generated when contour maps are produced. The grid point values of the bedrock aquifer map will be subtracted from the grid point values of the shallow groundwater system map creating a new grid map. The areas on this resultant map that have negative grid point values represent areas having seepage into the system. The areas having positive grid point values represent areas having seepage out of the system. The total area of the areas having negative and positive flows will be determined and the flow characteristics of the bedrock aquifer will be applied to estimate the annual flow into and out of the bedrock aquifer.

It is assumed that seepage into and out of the bedrock aquifer is approximately equal and small. Seepage in and out of the bedrock aquifer in the sub-area is estimated to be about 0.00253 billion gallons per year.

Through Flow

As mentioned, the study area is represented by a three-dimensional box having areal extent as well as depth. Through flow is the flow of groundwater that flows in and out of the walls of the box. The sides of the box would be represented by the distribution of aquifer, aquitard, and aquiclude material shown in a cross section. The 20-foot interval maps generated as part of stack-unit mapping are used to create the cross-section. The vertical axis is the elevation and the horizontal axis is distance or the length of the side of the box. Using the individual layers of the stack-unit map, the contacts between the hydrogeologic units (aquifers, aquitards, and aquicudes) are projected through the interval on the cross-section coinciding with the map interval, i.e., 680 to 700 feet. When completed, the cross-section will have a series of straight vertical lines each 20 feet long that do not match from interval to interval. The next step is to vertically connect comparable contact lines to show the vertical distribution of the hydrogeologic units. Once complete, the area of the aquifer material will be determined.

Finally, the potentiometric map for the shallow aquifer system will be used to determine the direction of ground water flow and the gradient at the border of the box. The direction of the flow will be used to assign inward or outward groundwater flow to the appropriate portions of the cross-section. The gradient will be used with the hydraulic conductivity and effective porosity of the aquifer materials to calculate groundwater velocity. Combining velocity with area information yields the flow into or out of the system through the border. Stratigraphic information used to establish groundwater through flow characteristics are described by Thomsen and Agnoletti (2004).

These calculations have not yet been done for the sub-area. It is assumed that through flow in and out of the system is about equal. The value for through flow in and out of the system is estimated to be approximately 7.18 billion gallons per year.

EXAMPLE OF WATER BALANCE APPLIED TO TEST AREA

The preceding sections are a preliminary overview of the approach being used to establish the water resource characteristics in the BACOG area. Baseline characteristics are being established using a water balance approach. The water balance is defined as: the change in groundwater storage is equal to the groundwater inflows minus the groundwater outflows. The mathematical definition is:

$$\Delta S = Gw_i + R + S_i - Gw_o - D - S_o - C$$

where:

S = Storage

Gw_i = Groundwater Inflow
R = Recharge
S_i = Seepage Inflow
Gw_o = Groundwater Outflow
D = Discharge
S_o = Seepage Outflow
C = Consumption

Estimated values for the water balance components in billions of gallons are:

S = 17.0
Gw_i = 7.18
R = 3.74
S_i = 0.00253
Gw_o = 7.18
D = 0
S_o = 0.00253
C = 0.615

then,

$$\Delta S = 7.18 + 3.74 + 0.00253 - 7.18 - 0 - 0.00253 - 0.615 = 3.13$$

The results indicate that the shallow groundwater system within the sub-area has an increase in groundwater of 3.13 billion gallons per year. This means that public water consumption from the groundwater system in the sub-area is about 16 percent of the water entering the system.

CONCLUSION

The study of water resources for BACOG is an ongoing process. By using GIS to analyze both the surface and subsurface water activity in the study area, BACOG will provide quality scientific data and sound policy recommendations to the community in order to preserve natural resources and quality of life. Critical elements to the success of the study thus far include the cooperation of local, regional and state governments in supporting and guiding the project; the use of GIS to accumulate and analyze data; and the donation by volunteers of hundreds of hours of time -- professionals and laypersons alike -- to achieve the project's goals. With continued work of the committee and investment in GIS, BACOG's efforts will enhance the region's capabilities to respond to development and plan appropriately for the future.

REFERENCES

Agnoletti, J.L. and K.O. Thomsen, 2003. Sustainable Development and Groundwater. Presentation, Illinois GIS Association, 13^{th} Annual Fall Conference 2003, Lisle, IL, November 17 – 18.

Lumin, D.L., L.R. Smith, and C.C. Goldsmith, 2003. Illinois State Topography: Champaign, Illinois. Illinois State Geological Survey, Illinois Map 11, Scale 1:500,000.

Mehnert, E., 2003. Presentation Notes. ISGS Hydrogeologist, Lake Barrington Village Hall, Public Meeting, Lake Barrington, IL.

Meyer, Scott C., 1998. Ground-Water Studies for Environmental Planning, McHenry County, Illinois. McHenry County Board of Health and Illinois Department of Natural Resources, prepared by Illinois State Water Survey, June.

NIPC, 2001. Strategic Plan for water Resource Management. Northeastern Illinois Planning Commission and Harza Environmental Services, Chicago, IL.

Peters, J.D., J.L. Agnoletti, and K.O. Thomsen, 2003. Water Resources for BACOG: Looking Below to Plan for Above. Proceedings of the 23rd Annual ESRI International User's Conference, San Diego, CA, July 7 – 11.

Thomsen, K.O. and J.L Agnoletti, 2004. Stratigraphic Mapping for Establishing A Groundwater Resource Baseline. Proceedings of the 24th Annual ESRI International User's Conference, San Diego, CA, August 9 - 13.

U.S. Department of Agriculture (USDA), 1986. Urban Hydrology for Small Watersheds. Technical Release 55, National Resource Conservation Service, Conservation Engineering Division, Washington, DC, June.

U.S. Geological Survey (USGS), 1996. HYSEP: A Computer Program for Stream flow Hydrograph Separation and Analysis. U.S Geological Survey, Water-Resources Investigations Report 96-4040, Washington, DC.

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