Ground Water

About half the Nation and nearly all the rural population obtain drinking water from ground-water sources. As development spreads and people move beyond traditional urban centers, demands for ground water increase dramatically as water managers and planners grapple to find sustainable, safe water supplies for the growing suburban population.

The USGS Ohio Water Science Center (WSC) has been involved in ground-water investigations since 1938. At that time, an alarming decline in ground-water levels prompted Butler and Hamilton Counties to ask the USGS to evaluate the safe yield of aquifers in the area. The USGS was also asked to determine methods of sustainably increasing the ground-water withdrawals around Cincinnati and nearby urban areas. Since this beginning almost 70 years ago, the USGS ground-water program in Ohio has constantly evolved, and the USGS Ohio WSC staff has applied the most recent techniques and technology toward understanding and solving ground-water problems in Ohio.

Hydrologists recognize that ground water and surface water are really a single resource; ground water sustains the flow of streams during dry weather, and this sustaining flow is the critical factor for maintaining riparian and wetland ecosystems. To address all the human and environmental ground-water issues, USGS hydrologists approach problems in the following systematic ways.

Assessing Potential Ground-Water Supplies

To assist water-resources management in areas that rely on ground water for drinking-water supply, USGS hydrologists characterize the geologic framework of the aquifers and confining units in the region. USGS hydrologists determine long-term productivity of an aquifer by measuring recharge rates and hydraulic properties of the aquifer, and they determine suitability of an aquifer as a drinking-water source by collecting and analyzing ground-water samples. Assessments of ground-water supplies have been completed in several Ohio counties. Recent investigations include an estimate of aquifer hydraulic properties in the lower part of the Great Miami River Buried Valley Aquifer System in southwestern Ohio and an ongoing assessment of water availability in aquifers of the Great Lakes Basin.

Determining Ground-Water Flow Directions

Is your water supply upgradient or downgradient from a contamination source? Where does water recharge the aquifer? Is ground water discharging to a local stream, or is the stream losing water that is recharging the aquifer? Are two aquifers hydraulically connected? The USGS can provide evidence to answer such questions by analyzing the results of relatively simple measurements, such as depth to water in wells and flow in streams. Synoptic water levels (levels measured over a broad area in a short time span) have been used in numerous USGS studies to determine ground-water flow directions and depth to ground water. For example, when the U.S. Environmental Protection Agency (USEPA) began investigating the Tremont City Landfill Site in western Ohio in summer 2000, they found that multiple directions of ground-water flow had been described at the landfill site. Also, offsite ground-water levels and flow directions were poorly defined because they were based on scattered water-level reports from well drillers over many years. The USGS aided the USEPA investigation by helping measure synoptic water levels near Tremont City and then using the water-level data to create a map of the potentiometric surface. From this map, directions of regional ground-water flow could be determined in the area surrounding the

Tremont City Landfill. The study found that, near the landfill, ground-water-flow directions diverge in a semiradial pattern. Where flow directions indicated that ground water discharged to a local creek, the interpretation was confirmed by measuring volume of flow in the creek at successive downstream locations between tributaries.

Measuring Effects of Drought, Climate Change, and Increased Water Use

Long-term monitoring of ground-water levels in conjunction with local precipitation and population data can be used to assess whether water-level fluctuations are a function of short-term changes in precipitation, long-term climate change, or increased water use due to urbanization or agricultural use. The USGS and Ohio Department of Natural Resources created a statewide observation well network in the 1940s that is still operating today. This network currently consists of 122 sites where ground-water levels are continuously monitored and 4 sites that are periodically measured. Eleven Ohio ground-water sites transmit real-time data. Ground-water level data are made available to the public at *http://waterdata.usgs.gov/oh/nwis/gw*. The USGS also operates a county-level observation well network for Geauga County, which relies heavily upon ground-water as a drinking-water source. County planners are concerned that, as the county population grows, water levels will decline in the more densely populated areas.

Understanding Regional Ground-Water Flow and Influence of Human Activities

Since the advent of computer models for ground-water simulations, the USGS Ohio WSC has been using such models to better understand regional ground-water systems and impacts of human activities. Computer models can be used to determine areas contributing recharge to water-supply wells, determine ground-water flow paths, predict effects of increased pumping, and simulate geochemical reactions along a flow path and movement of contaminants in an aquifer. Such models can also be used to test specific water-resource management plans. In recent years, ground-water simulation models such as MODFLOW have been linked with parameter-estimation techniques (to help calibrate the models to measured data), surface-water models (to more accurately assess surface/ground-water interaction), and optimization-modeling techniques (to determine best management strategies from among many possible strategies). Optimization modeling can integrate management requirements such as minimum streamflow and maximum allowed ground-water-level decline, along with a set of possible management options (such as several possible locations and pumping rates for a new water-supply well). From this information, the model can help determine the single management strategy that best meets the specified requirements.

Using Ground-Water Age Dating To Explain Contaminants in Public-Supply Wells

The screened or open intervals of public-supply wells are commonly tens to hundreds of feet long; therefore, water from these wells is generally a mixture of waters that recharged the aquifer at different times, enter the well screen at different depths, and are associated with different potential sources of contamination. To ascertain where and how contaminants from different sources enter public-supply wells, USGS scientists with the National Water-Quality

Assessment (NAWQA) Program are using a special downhole sampler to collect well-bore flow information and water-quality samples at multiple depths in pumping public-supply wells. Depth-interval samples are analyzed for multiple tracers such as sulfur hexafluoride, chlorofluorocarbons, tritium/helium-3, and tritium, whose concentrations yield clues to the age of the ground water. In a recent nationwide NAWQA study, some public-supply wells were found to contain predominantly young water (less than 50 years old)—a result that was consistent with the area contributing recharge as determined by numerical simulation models; however, other public-supply wells, which were expected to contain only old water (greater than 50 years old), contained young water drawn down locally by short-circuiting through natural conduits (such as sinkholes) or other features (such as abandoned wells). Further information about the NAWQA national-scale study of public-supply wells can be found at *http://oh.water.usgs.gov/tanc/NAWQATANC.htm.* Locally, the USGS is analyzing ground water for age-dating tracers and other chemical constituents to help define sources of water to wells in the Tuscarawas River watershed and at the City of Columbus.

Understanding the Distribution of Arsenic in Ground Water

Arsenic concentrations greater than the USEPA maximum contaminant level (MCL) for drinking water (10 micrograms per liter) have been detected in aquifers in southwestern Ohio. The distribution of arsenic concentrations is sporadic and difficult to predict. A current USGS study involving ground-water-quality sampling and geochemical modeling will provide some insight into the occurrence of arsenic. In northern Preble County, arsenic concentrations were measured in ground water in three aquifer types: Silurian-age bedrock, glacial buried-valley deposits, and glacial till with interbedded sand and gravel. Nested monitor wells were installed to sample water at multiple depths in a recharge area and a discharge area. In addition, solid-phase (rock and sediment) analysis was done on 110 core samples. Water-quality and solid-phase analyses are being compared to lithology using graphical methods, statistical analyses, and geochemical modeling. A better understanding of the relation between arsenic in the solid phase and arsenic in the ground water of southwestern Ohio will help water managers and planners avoid installing water-supply wells in areas with a high risk of arsenic contamination.

Assessing Effectiveness of a Novel Acid-Mine-Drainage Reclamation Method

An abandoned coal mine in eastern Ohio was reclaimed with a coal-combustion byproduct. To evaluate the effectiveness of the combustion byproduct as a mine-spoil reclamation amendment and determine the fate of elements of concern in the byproduct, the USGS monitored water quality at the site for 7 years after reclamation. Samples included water from the unsaturated zone, ground water, and springs. Reclamation of the site was successful in that vegetation was re-established, erosion was reduced, and pH in the unsaturated zone was raised (thus helping to neutralize infiltrating rain water). However, the USGS study found that quality of ground water and spring water was unchanged. Sulfur isotopes and ratios of magnesium to calcium ions were used to trace leachate from the coal-combustion byproduct. These ratios showed that, although notable changes in water quality were observed in unsaturated zone waters during the study period, little, if any, leachate reached ground water or springs. Geochemical modeling indicated that precipitation of secondary minerals in the unsaturated zone may have reduced the concentrations of major and trace elements derived from the byproduct before byproduct leachate reached the ground water. More likely, the application rate of coal combustion byproduct at the site was so small that dilution by rainwater and the overwhelming influence of acid mine drainage obscured detection of leachate in ground water by the methods used in this study.

Understanding Stream-Aquifer Interaction

Knowledge of the physical characteristics controlling stream-aquifer interaction is important to the managers of public-supply well fields located adjacent to the Great Miami River. The well-field managers are concerned that surface-water contaminants could possibly enter the aquifer near wellheads where induced infiltration of surface water is occurring. Although it is understood that streambed hydraulic parameters, such as vertical hydraulic conductivity of the streambed (Ksb), largely control the amount of infiltration from the river to the underlying aquifer, such parameters are inherently difficult to measure because of the large volume of water flowing in the Great Miami River. An ongoing study by Miami University is measuring Ksb directly in five areas along the lower Great Miami River using various types of seepage meters. Miami University also plans to install and monitor temperature sensors in piezometers in the stream for later temperature modeling to calculate Ksb. For both types of measurements, instrumentation can be installed only in certain sections of the stream—typically shallow and slow velocity waters. To transfer the results of Miami University's data-collection program to other parts of the stream where it may not be possible to maintain direct contact with the stream bottom, the USGS is testing two geophysical methods to determine whether they can produce continuous geological information about the streambed. Both geophysical methods (continuous seismic profiling and continuous resistivity profiling) utilize equipment that is towed behind a boat; both methods image the stratigraphy to depths of more than 5 feet below the streambed. After collection of geophysical data and interpretation, spatial patterns of Ksb as interpreted by Miami University researchers will be compared to geologic interpretations of the geophysical data from near the seepage meters. Any patterns in sub-bottom stratigraphy may indicate spatial variability in riverbed hydraulic conductivity.

Managing Water-Resources Data With GIS Databases

Because the quantity of data generated during management of a large water-resources program can be overwhelming, the USGS has created Geographic Information System (GIS) databases for several entities (including the U.S. Air Force and USEPA) that spatially reference hydrologic data such as stream locations, well locations, geologic data, and water-quality sampling locations and results. In the Tuscarawas River watershed, increased population and changes in water use have prompted a need to better understand the water resources and water quality in the watershed and provide a foundation for policymakers to make decisions regarding future land and water uses. Land-use issues—including agriculture, mining, and landfills—could threaten the long-term viability and sustainability of the region's water resources. Recently, the USGS created a GIS database for the Tuscarawas River Watershed as part of a project that will advance the knowledge and understanding of the regional hydrologic system and to provide data useful to multiple parties for planning and operational purposes.

For Further Information

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