NATIONAL BRACKISH GROUNDWATER ASSESSMENT

The amount of fresh or potable groundwater in storage has declined for many areas in the United States and has led to concerns about the future availability of water for drinking-water, agricultural, industrial, and environmental needs. Use of brackish groundwater could supplement or, in some places, replace the use of freshwater sources and enhance our Nation's water security. However, a better understanding of the location and character of brackish groundwater is needed to expand development of the resource and provide a scientific basis for making policy decisions. To address this need, the U.S. Department of Interior's WaterSMART initiative, through the USGS Groundwater Resources Program, is conducting a national assessment of brackish aquifers.

Why study brackish groundwater?

In many parts of the country, groundwater withdrawals exceed recharge rates and have caused groundwater-level declines, reductions to the volume of groundwater in storage, lower streamflow and lake levels, or land subsidence. It is expected that the demand for groundwater will continue to increase because of population growth, especially in the arid West. Further, surface-water resources are fully appropriated in many parts of the country, creating additional groundwater demand. Development of brackish groundwater as an alternative water source can help address concerns about the future availability of water and contribute to the water security of the Nation.

Brackish groundwater is potentially abundant. Early studies indicated that mineralized groundwater underlies most of the country (fig. 1). Further, advances in desalination technologies are making treatment and use of brackish groundwater for potable water supply more feasible.

Despite the need for alternative water sources and the potential availability of brackish groundwater, the most recent national map showing the distribution of mineralized groundwater was published in 1965. An updated evaluation is needed to take advantage of newer data that have been collected over the past 50 years. In addition, consistent information about chemical characteristics (such as major-ion concentrations) and hydrogeologic characteristics (such as aquifer material, depth, residence time, thickness, flow patterns, recharge rates, and hydraulic properties) of brackish groundwater has not been compiled at the national scale. Improved characterization is important for understanding and predicting occurrences in areas with few data and for assessing limitations imposed by different uses and (or) treatment options. This information is needed to understand the potential to expand development of the brackish groundwater resource and to provide reliable science for making policy decisions.

Groundwater in basin-fill aquifers of the Southwest often increases in dissolved-solids content as it travels along its flow path as a result of geochemical interactions with the aquifer matrix and through evaporative processes. At the end of its flow path, groundwater may be brackish or saline and discharges to the surface through springs such as this one in Death Valley. Photo by USGS hydrologist David Anning.

What is brackish groundwater?

All water naturally contains dissolved solids that, if present in sufficient concentration, can make a surface-water or groundwater resource "brackish," typically defined as distastefully salty. Although quantitative definitions of this term vary, it is generally understood that brackish groundwater is water that has a greater dissolved-solids content than occurs in freshwater, but not as much as seawater (35,000 milligrams per liter). It is considered by many investigators to have dissolved-solids concentration between 1,000 and 10,000 milligrams per liter (mg/L). The term "saline" commonly refers to any water having dissolved-solids concentration greater than 1,000 mg/L and includes the brackish concentration range.

About the Study

The objectives of the study are to identify and characterize significant brackish aquifers in the United States. Brackish aquifers are defined for purposes of this study as aquifers that have groundwater within 3,000 ft of land surface, contain dissolved-solids concentrations between 1,000 and 10,000 milligrams per liter, and can yield usable quantities of water. The study is intended to provide information about brackish aquifers at national and regional scales and is not for defining site-specific or localized conditions. Study results can be used to identify areas where further evaluation of the brackish aquifers will be most productive for potential users of the resource.

Salt deposits, such as halite or gypsum, are found in many sedimentary basins in the United States and are highly soluble. Other deposits are less soluble but can contribute dissolved solids when in contact with groundwater over longer periods of time. Source: Siim Sepp, http://www.sandatlas.org/.

Major components of the study

• Compiling existing information that can be used to assess brackish aquifers
• Describing, to the extent that available data permit, dissolved-solids concentrations, other chemical characteristics, horizontal and vertical extents of aquifers containing brackish groundwater, ability of the aquifers to yield water, and current brackish groundwater use
• Generating national maps of dissolved-solids concentrations
• Identifying data gaps that limit full characterization of brackish aquifers

Groundwater discharge and rainfall-runoff collect and evaporate from this brackish playa lake in Saline Valley, CA. Photo by USGS hydrologist David Anning.

Improvements upon previous work

• An updated national inventory of brackish groundwater: Previous national assessments of the distribution of brackish groundwater used only a limited amount of the dissolved-solids data that currently are available. A more complete set of information will be assembled from a wide variety of sources and will include more recently collected data.
• Publication of digital datasets: The national inventory and selected results will be published as digital datasets so that other scientists can conduct assessments tailored to their specific needs. Published digital data relating to brackish groundwater currently are limited to a small number of state and regional studies.
• Enhanced characterization: The updated dissolved-solids inventory will be used to characterize brackish aquifers at a higher spatial resolution than previous national work. In addition to dissolved-solids distribution, other chemical characteristics (such as major-ion concentrations) and hydrogeologic characteristics (such as aquifer material, depth, residence time, thickness, flow patterns, recharge rates, and hydraulic properties) will be assessed to determine brackish groundwater availability. Improved characterization is important for understanding and predicting occurrences in areas with few data, and also for assessing limitations imposed by different uses and (or) treatment options.
• Consistent approach: Although several detailed assessments of brackish aquifers have been conducted at state and regional scales, the methods differed among the studies. This work will describe brackish aquifers using consistent data analysis and assessment methods across the country.

Previous Work

A national compilation of data on mineralized (brackish) groundwater was completed in the 1960s (Feth and others, 1965). That study provided maps showing depth to the shallowest groundwater containing more than 1,000 mg/L of dissolved solids and chemical types of groundwater, serving as the primary source of information for subsequent assessments of the national distribution of brackish groundwater. Feth (1965b) also compiled a reference list of approximately 500 reports documenting saline groundwater conditions that "is by no means exhaustive, but it is representative of the types of information available and will serve to lead the reader into the literature." In addition, Feth (1981) and Richter and Kreitler (1991) summarized various models and mechanisms used to explain the spatial and temporal variability of dissolved solids in groundwater. Feth (1981) provided a national synthesis of chloride in natural waters, noting that the ratio of various other anions to chloride can be used to identify the source of brackish groundwater. Richter and Kreitler (1991) supplemented work by Feth and others (1965) with a map by Dunrud and Nevins (1981) showing the approximate extent of halite (sodium chloride salt) deposits, mapped locations of oil fields, estimates of the extent of seawater intrusion to coastal aquifers, and mapped saline springs and seeps to identify areas where brackish groundwater naturally occurs. Richter and Kreitler (1991) also provided a state-by-state summary of the occurrence of each source of groundwater salinization.

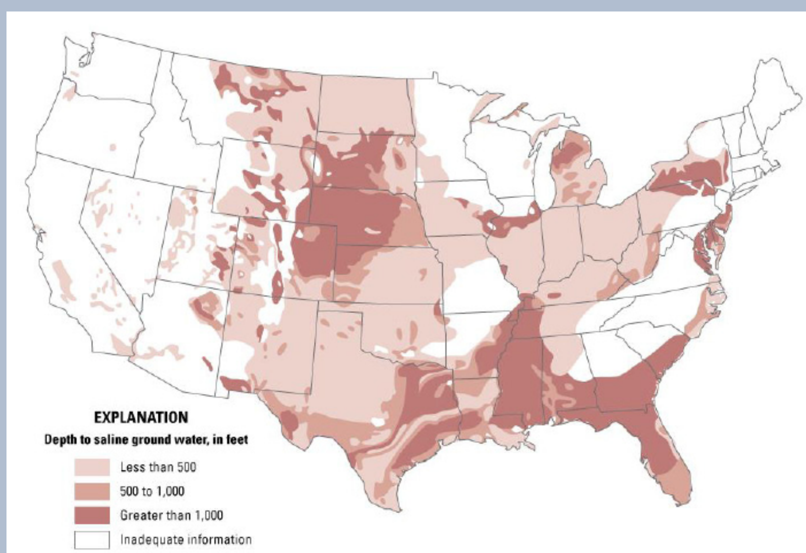

Figure 1. Depth to groundwater with total dissolved-solids concentration greater than 1,000 milligrams per liter in the United States (modified from Feth and others, 1965).

USGS Regional Aquifer-System Analysis (RASA) studies were conducted between 1978 and 1995 to define the regional geohydrology of the Nation's important aquifer systems. Maps showing dissolved-solids concentrations were published for many of these aquifer systems and compiled for the USGS Ground Water Atlas of the United States (U.S. Geological Survey, 2000). In some cases, regional RASA studies included geochemical characterization and modeling, which assisted with understanding, interpolating, and extrapolating brackish-water occurrence (for example, Busby and others, 1995).

More recently, Androwski and others (2011) used previously published USGS reports to conduct a national assessment of the total volume of the saline (dissolved-solids concentration between 1,000 and 35,000 mg/L) component of the principal aquifers of the conterminous United States that could be available for desalination. The primary sources of dissolved-solids and aquifer-dimension information for that study were digital maps from the USGS Ground Water Atlas of the United States (U.S. Geological Survey, 2000). No recently collected dissolved-solids data were used for the study, and depths to saline groundwater were estimated using simplistic assumptions and methods.

Examples of Regional Assessments of Brackish Aquifers

- The USGS, through the Groundwater Resources Program, is completing three pilot studies that use geochemical, geophysical, and geostatistical methods and previously published work to describe saline aquifers for the southern midcontinent, Mississippi embayment, and the southeastern United States. These "Challenge Area" studies were conducted from 2010 through 2012 to supplement the Groundwater Resources Program's freshwater regional groundwater availability assessments already underway in order to achieve a more complete picture of the Nation's groundwater availability.
- Sandia National Laboratories is assessing the relative availability and cost of using shallow (less than 2,500 feet (ft) below land surface) brackish groundwater as a water source for thermoelectric power generation in 17 western states (Vince Tidwell, Sandia National Laboratories, written commun., 2013). Sources of information for estimating the availability of brackish groundwater include volumetric estimates of brackish groundwater in Texas and Arizona, USGS water-use information (Kenny and others, 2009), and data for wells in the USGS National Water Information System (NWIS) that contain brackish groundwater.
- The Texas Water Development board is conducting the Brackish Resources Aquifer Characterization System (BRACS) study to provide a detailed characterization of brackish aquifers in Texas using geophysical bore-hole logs and available aquifer data (Meyer and others, 2011).

Top: Nuclear power plant cooled with brackish groundwater. Source: U.S. Nuclear Regulatory Commission. Right: Brackish water desalination facility in Harlingen, Texas. The plant was built in 2007 and has a capacity of 2.25 million gallons per day. Source: North Cameron Regional Water Supply Corporation.

How is Brackish Groundwater Being Used?

Brackish groundwater is directly used for purposes such as cooling water for power generation, aquaculture, and for a variety of uses in the oil and gas industry such as drilling, enhancing recovery, and hydraulic fracturing. For purposes requiring lower dissolved-solids content, especially drinking water, brackish water is treated through reverse osmosis or other desalination processes. In 2010, there were 649 active desalination plants in the United States with a capacity to treat 402 million gallons per day (Shea, 2010). Of the desalination plant capacity in the United States, 67 percent was for municipal purposes, 18 percent for industry, 9 percent for power, and the remaining 6 percent for other uses (Mickley, 2010). A total of 314 desalination facilities are used for municipal purposes, 49 percent of which were in Florida, 16 percent in California, 12 percent in Texas, and the remaining 23 percent dispersed among other states. More than 95 percent of the desalination facilities in the United States are inland (Mickley, 2010), and most facilities are designed to treat groundwater with dissolved-solids concentrations in the brackish range (Shea, 2010). Recent advances in technology have reduced the cost and energy requirements of desalination, making treatment of brackish groundwater a more viable option for drinking-water supplies (National Research Council, 2008).

References

Androwski, James, Springer, Abraham, Acker, Thomas, and Manone, Mark, 2011, Wind-Powered Desalination: An Estimate of Saline Groundwater in the United States: Journal of the American Water Resources Association, v. 47, no. 1, p. 93-102.

Busby, J.F., Kimball, B.A., Downey, J.S., and Peter, K.D., 1995, Geochemistry of water in aquifers and confining units of the Northern Great Plains in parts of Montana, North Dakota, South Dakota, and Wyoming: U.S. Geological Survey Professional Paper 1402-F, 146 p.

Dunrud, C.R., and Nevins, B.B., 1981, Solution mining and subsidence in evaporite rocks in the United States: U.S. Geological Survey Miscellaneous Investigations Series Map 1298, scale 1:5,000,000.

Feth, J. H., and others, 1965, Preliminary map of the conterminous United States showing depth to and quality of shallowest ground water containing more than 1,000 parts per million dissolved solids: U.S. Geological Survey Hydrologic Investigations Atlas, HA-199, 31 p., 2 plates, scale 1:3,000,000.

Feth, J. H., 1965b, Selected references on saline ground-water resources of the United States; U.S. Geological Survey Circular 499, 30 p.

Feth, J. H., 1981, Chloride in Natural Continental Water-A Review: U.S. Geological Survey Water-Supply Paper 2176, 30 p.

Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.

Meyer, J.E., Wise, M.R., Kalaswad, Sanjeev, 2011, Pecos Valley Aquifer, West Texas—Structure and Brackish Groundwater: Texas Water Development Board Report, 85 p. (PDF)

Mickley, Mike, 2010, Inland desalination—Current status and challenges, in Annual WateReuse Symposium, 25th, Washington, D.C., 2010, Conference Presentations: Alexandria, Va., WateReuse Assoc., 31 p., accessed September 5, 2012, at http://www.watereuse.org/information-resources/about-desalination/presentations.

National Research Council, 2008, Desalination—a national perspective: Washington D.C., The National Academies Press., 316 p.

Richter, B.C., and Kreitler, C.W., 1993, Identification of sources of groundwater salinization using geochemical techniques: Ada, Okla., U.S. Environmental Protection Agency Report EPA/600/2-91/064, 272 p.

Shea, A.L., 2010, Status and challenges for desalination in the United States, in Reuse & Desalination—Water Scarcity Solutions for the 21st Century Conference, Sydney, Australia, 2010, Conference Presentations: Alexandria, Va., WateReuse Assoc., 36 p., accessed September 5, 2012, at http://www.watereuse.org/information-resources/about-desalination/presentations.

U.S. Geological Survey, 2000, Ground-water atlas of the United States: U.S. Geological Survey Hydrologic Investigations Atlas, HA-730, 13 chapters, scale 1:1,000,000.