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Water Availability—The Connection Between Water Use and Quality

Water availability has become a high priority in the U.S., in large part because competition for water is becoming more intense across the Nation. Population growth in many areas competes with demands for water to support irrigation and power production. Cities, farms, and power plants compete for water needed by aquatic ecosystems to support their minimum flow requirements. At the same time, naturally occurring and human-related contaminants from chemical use, land use, and wastewater and industrial discharge, are introduced into our waters and diminish its quality.

The fact that degraded water quality limits its availability and suitability for critical uses is a well-known reality in many communities. What may be less understood, but equally true is that our everyday use of water can significantly affect water quality, and thus its availability. Inherent in this assertion is that natural features (such as geology, soils, and vegetation) along with water-use practices (such as ground-water withdrawals and irrigation) govern water availability because, together, they affect the movement of chemical compounds over the land and in the subsurface. Understanding the interactions of human activities with natural sources and the landscape is critical to effective water management and sustaining water availability in the future.

Understanding the Connection Through Examples

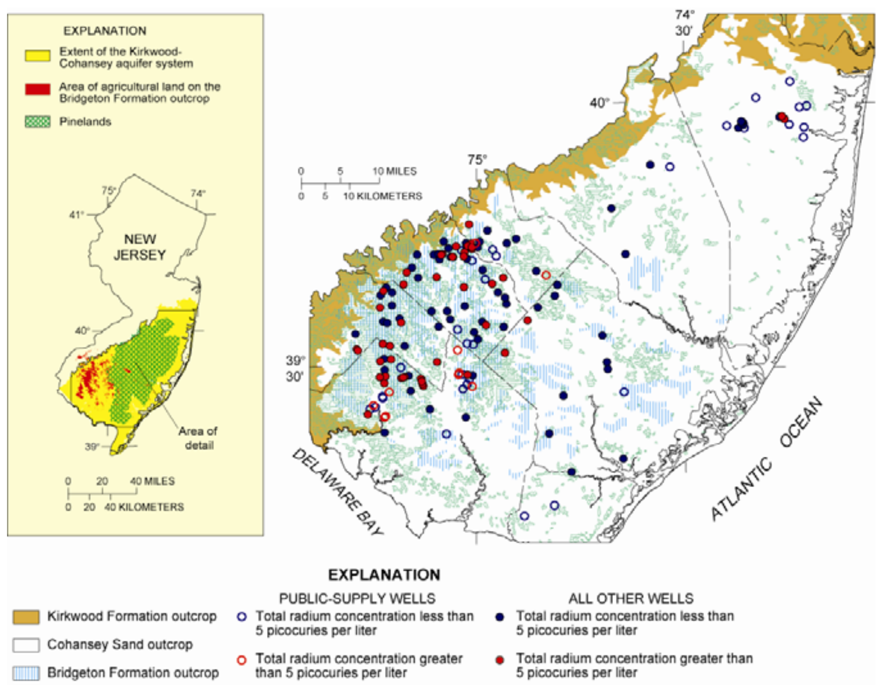
This document highlights several case examples and presents selected recommendations for increasing our understanding of the connections between water use and management, water quality, and availability.

Agricultural Practices Enhance Ground-Water Concentrations of Naturally Occurring Radium in Southern New Jersey –

Concentrations of total radium in the Kirkwood-Cohansey aquifer system underlying southern New Jersey exceeded the U.S. Environmental Protection Agency (EPA) drinking-water standard of 5 picocuries per liter in water from about one-third of the 170 wells sampled by USGS in the late 1990s (Szabo and DePaul, 1998) (The standard also is referred to as the Maximum Contaminant Level, or MCL, which is EPA's maximum permissible level of a contaminant in water delivered to any user of a public water system.) Some of the highest concentrations were in or near agricultural areas overlying the Bridgeton Formation where the ground water is acidic (pH less than 5). USGS findings suggest that agricultural practices, including liming and fertilizer use, have modified ground-water chemistry and created an environment that increased the mobility of the naturally occurring radium within the aquifer. The MCL was exceeded more frequently in water from domestic wells than in public-supply wells sampled in the USGS study, in large part because public-supply wells typically are distant from agricultural areas, tap deeper parts of the aquifer not as affected by activities on the land surface, and draw water from a larger radius associated with large pumping volumes.

Naturally occurring chemicals that are considered contaminants in domestic well waters are not limited to New Jersey. For example, USGS studies show that radon exceeded the proposed EPA alternative MCL of 4,000 picocuries per liter in water from about one third of the domestic wells sampled in crystalline aquifers throughout New England (Ayotte and others, 2007). Arsenic, also naturally occurring, is elevated in water from domestic wells in selected areas across the U.S., exceeding the MCL of 10 parts per billion in about 7 percent of wells sampled by the USGS. Some of the highest concentrations – a maximum of about 240 parts per billion—were found in the High Plains aquifers in Nebraska and Texas and in the Basin and Range aquifers in Arizona (McMahon and others, 2007; L.A. Desimone, USGS, written commun., 2008). Concentrations differed across the country, owing to a combination of natural features, such as presence of pyrite and other sulfide minerals, iron oxides, thermal water, and evapotranspiration (Welch and others, 2001).

Radium concentrations commonly exceeded the U.S. Environmental Protection Agency drinking-water standard (5 picocuries per liter) in or near agricultural areas overlying the Bridgeton Formation in southern New Jersey, in large part because liming and fertilizers have modified natural ground-water chemistry and increased the mobility of radium within the aquifer (Szabo and DePaul, 1998).



Ground-Water Development Mobilizes Naturally Occurring Uranium to Public-Supply Wells in the San Joaquin Valley, California - In the past 10 years, elevated concentrations of dissolved uranium, exceeding the EPA MCL of 30 parts per billion, have necessitated the removal of at least 14 public-supply wells from service in the eastern San Joaquin Valley of California. Uranium occurs naturally in soils and aquifer sediment derived from Sierra Nevada granitic rocks. USGS studies show that agricultural and urban development has increased pumping, as well as modified the natural ground-water chemistry by enriching the ground water with dissolved oxygen and increasing alkalinity. Together, an environment was created that promotes the leaching of uranium from sediments as water recharges the land surface and moves to the aquifer system, ultimately affecting the deeper parts of the aquifer used for public supply (Jurgens and others, 2005).

Withdrawals Enhance Saltwater Intrusion in Coastal Areas in the U.S.—In numerous coastal areas, large drawdowns in pumping wells cause adjacent or underlying saltwater to move into the freshwater system and affect the salinity of water supplies. Examples include Los Angeles and Orange Counties in California; Jacksonville, Tampa, and Miami, Florida; and coastal counties of New York and New Jersey. For example, as pumping in the Old Bridge aquifer underlying Union Beach Borough, New Jersey, caused ground-water levels to decline below sea level, saline water moved landward and concentrations of chloride and dissolved solids increased. As a result, pumping was curtailed in the 1980s, and the wells were abandoned in the early 1990s, replaced by wells farther inland (Alley and others, 1999; Barlow, 2003).

Pumping Induces Movement of Pesticides from Streams to Public-Supply Wells in the Midwest—In midwestern communities, high-capacity water-supply wells commonly are completed in the relatively permeable, unconsolidated sediments called alluvial deposits adjacent to large streams and rivers. Pumping can affect the movement of water between the alluvial aquifer and streams, and chemicals that are applied to farmland and transported in runoff can ultimately affect the quality of ground water used for drinking. In the Great Miami and Little Miami River basins in southwest Ohio, for example, USGS studies show that at least one pesticide was detected in 60 percent of samples from public-supply wells (about 80 feet deep). In this case, high pumping rates, as well as permeable streambed sediments and aquifer materials, have caused stream water to move into the ground-water system, sometimes reaching the wells in weeks or even days (Rowe and others, 2004).

Near Cedar Rapids, Iowa, pumping from public-supply wells has induced infiltration from the Cedar River, allowing contaminants to enter ground water. These contaminants often include pesticide breakdown products, which are forms of parent chemicals after transformation through natural processes. On average, nearly 85 percent of the total pesticide concentration in stream samples was composed of 10 breakdown products of agricultural herbicides, including acetochlor, alachlor, atrazine, cyanazine, and metolachlor. As a result, Cedar Rapids officials are pursuing additional research and monitoring of breakdown products and parent pesticide compounds in ground water used for city water supplies (Kalkhoff and others, 2000).

Re-use of River Water Affects Ground-Water Quality Underlying Coastal Basins of Southern California—The Santa Ana River is an example of a highly engineered system in which water re-use affects the movement of water over the land and in the subsurface, ultimately affecting the quality of water used for public supply. In this basin, surface and ground water are cycled twice before being discharged to the ocean. In the first cycle, tributaries exiting the San Gabriel and San Bernandino Mountains are diverted to ground-water recharge facilities in the Inland Basin, where ground water is later extracted for use and then discharged as treated wastewater to the Santa Ana River. In the second cycle, flow in the Santa Ana River is recharged to coastal aquifers. The artificially recharged water accounts for about three quarters of the water pumped from the coastal aquifer system (about 270 million gallons per day), and contributes water used for public supply for nearly 5 million people living in the Santa Ana Basin.

The large-scale pumping and recharge in the coastal basins have accelerated the flow of ground water and increased the transport of man-made compounds in ground water. The presence of tritium, an indicator of ground water recharged since the early 1950s, was common in USGS water samples, indicating widespread replacement of older, native ground water with water recharged during the past 50 years. Other man-made compounds, including chloroform, which is a byproduct of water treatment for disinfection, also was widely distributed in the aquifer system (although remaining below EPA drinking-water standards). The findings indicate that highly engineered systems in which water is reused and exchanged between surface and ground-water systems can influence water in the future – in this case, today's surface water affecting tomorrow's ground water (Belitz and others, 2004).

Water managers utilize the flow of the Santa Ana River for recharging coastal aquifers. An inflatable rubber dam across the Santa Ana River impounds water to facilitate diversion into recharge ponds (Belitz and others, 2004).

Natural Factors and Human Activities Affect Salinity in the Southwest—USGS findings document the variability of salinity (dissolved solids) in streams throughout the Southwest—from 22 to 13,800 milligrams per liter. The study, using geostatistical modeling, shows that both natural factors and human activities affect the degree of salinity in streams. Specifically, land-use practices and irrigation associated with pasture and cultivated land contribute more than half (56 percent) of the salinity to streams, whereas natural geologic materials provide the remaining 44 percent. The study also shows that the amount of dissolved solids that is transported and reaches streams varies considerably throughout the area, controlled in large part by water-use and agricultural activities, hydrology, and geology (Anning and others, 2007).

Understanding where salinity transport and accumulation occurs is critical to identifying watersheds primarily responsible for delivering salts to the Colorado River and its tributaries. Water managers, policy makers, drinking-water suppliers, and scientists throughout the region are using the results of USGS studies to implement and evaluate various salinity-control and water-management strategies throughout the Colorado River Basin. For example, the Colorado River Basin Salinity Control Program, a successful cooperation among local, State and Federal agencies, set an overall goal to cost-effectively reduce the amount of salinity in the Colorado River Basin. Salinity control projects, which involve low water-use irrigation systems and re-direction of saline water from streams, have been implemented since the mid-1970s by the Bureau of Reclamation (BOR), U.S. Department of Agriculture, and the Bureau of Land Management to control salinity of water per the 1974 Colorado River Basin Salinity Control Act (http://www.usbr.gov/uc/progact/salinity/).

USGS findings show that salinity decreased from 1989 through 2003 at all sites downstream from salinity-control projects, mostly located in the upper parts of the Colorado River Basin. For example, estimated annual loads of dissolved solids decreased by about 160,000 tons per year (or 14 percent of the annual load) downstream from the salinity-control unit on the Gunnison River. Decreases downstream from other projects ranged from about 4 to 11 percent of the annual loads. The continued, long-term decreases in salinity in the upper parts of the Colorado River Basin have resulted in salinity levels well below established goals at sites in or adjacent to the Lower Colorado River, including below Hoover and Parker Dams, and above Imperial Dam. On the basis of a BOR salinity damage model, the economic benefit of the decreases are estimated to be about $230M per year, in large part related to diminished damages to crops and crop yields (U.S. Department of Interior, 2005).

Recommended Actions

The examples herein illustrate how our use of water and management practices, together with natural features and the landscape, can affect water quality, and thus its availability. As addressed by the Subcommittee of Water Availability and Quality (SWAQ), under the National Science and Technology Council, strategic investments in water science and technology can move the Nation forward in addressing some of these water availability challenges (National Science and Technology Council, 2007). SWAQ, which is made up of 25 Federal agencies responsible for Federal water research and (or) water-resource management, report on a "coordinated, multi-year plan to improve research to understand the processes that control water availability and quality, and to collect and make available the data needed to ensure an adequate water supply for the Nation's future." Selected recommendations include:

- Continue to devise a national strategy, in partnership with State, regional, and local water agencies, for conducting a periodic inventory of the quantity and quality of the Nation's water resources, water use, and water infrastructure.
- Continue to develop water monitoring technology, including, for example, sensors and systems to measure water volumes and water quality inexpensively in real time; and data standards and protocols for data collection, management, and communication.
- Develop innovative technologies to use water more efficiently in the agricultural, energy, and industry sectors.
- Continue to improve understanding of water-related ecosystem needs by expanding monitoring, modeling, and research in ecosystem-based studies.
- Improve hydrologic models and their applications for decision-making at watershed scales. Inherent in model refinement are improved ancillary data, such as that on hydrology, geology, soils, climate, aquatic habitats, land-use changes, and chemical use.
- Support long-term data collection to provide the empirical basis for models and research needed to predict impacts of land-use change, water-use change, and climate change on the availability of water suitable for its intended uses.

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