Enhanced Ground Water Storage

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NGWA Information Brief

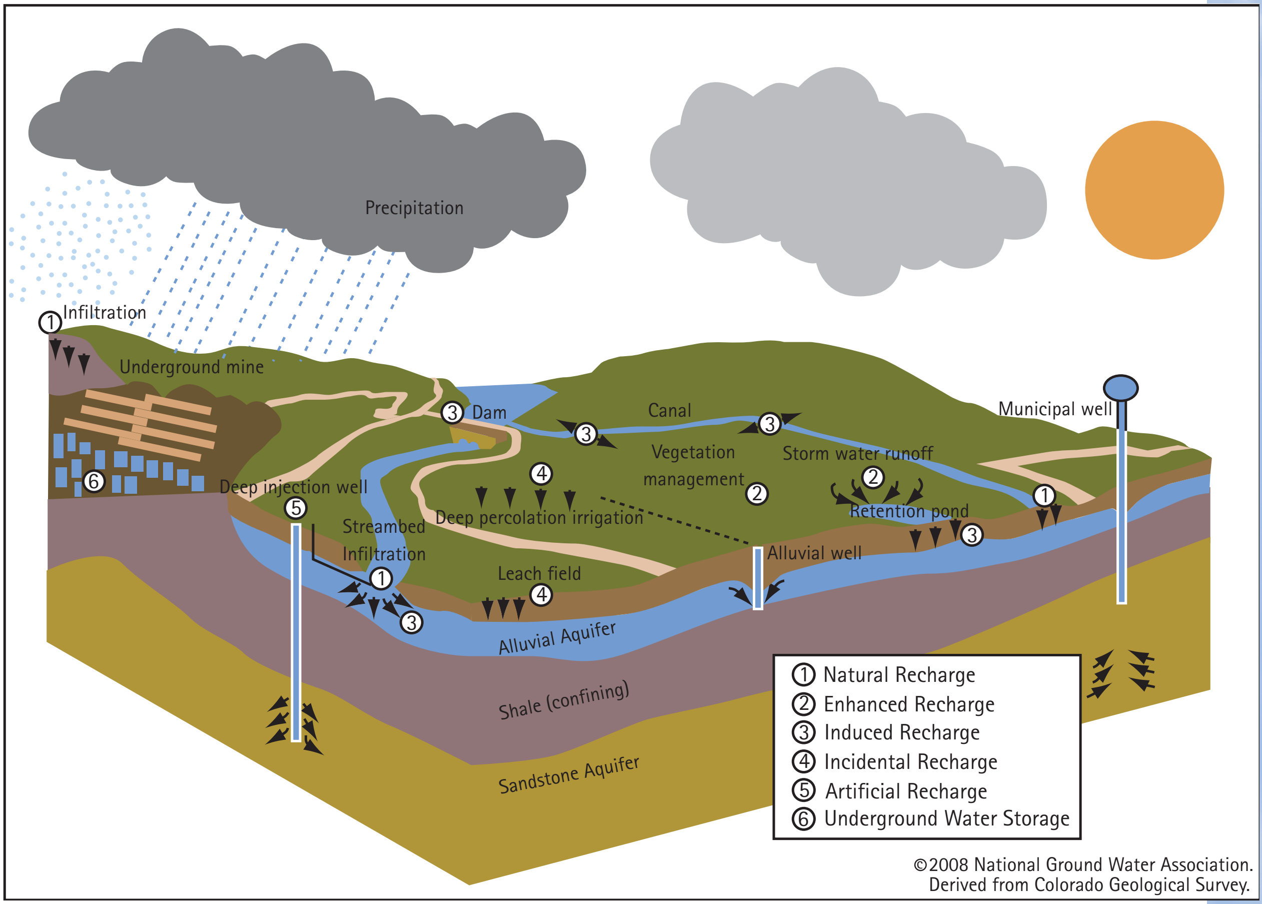

Figure 1[1]

Introduction

Information briefs are intended to provide non-technical readers a broad background on a ground water-related topic.

Developing scientifically based strategies for sustainable use of our ground water resources is essential to the need to address growing demands of an increasing population and to prepare for the effects of climate change. Ground water, the world's subsurface water reservoir, will be relied on more in the future to help balance the larger swings in precipitation and associated increased demands caused by heat and drought. Ground water will also be used to increase water supply reliability through periods of climate fluctuations. There will be more emphasis on conjunctive use, which involves the coordinated and planned operation of both surface water and ground water resources for conservation and optimal use. There will be an increased focus on efforts to manage aquifer recharge and there should be a greater emphasis on protecting our valuable ground water supplies.

The expanding emphasis on the need and usage of ground water resources will require improved management, planning, and policy tools based on sound science to provide the nation with safe, reliable water supplies.

There are a variety of options to assist man in managing supplies of ground water. This information brief discusses those options, their use, as well as the advantages and challenges to their use.

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What is enhanced ground water storage?

Enhanced ground water storage is a broad and general term more commonly recognized in the scientific and technical community as artificial storage and recover or aquifer storage and recovery. In the face of the concern about the depletion of natural ground water reserves and the potential reduction in surface water flows that result, artificially created ground water storage projects are being implemented throughout the United States. These ground water storage projects may employ wells to pump water underground for storage and later recovery. Ground water supplies are also recharged through the use of spreading basins and other recycling and reuse programs (see Figure 1). These augmentation strategies are generally employed to counteract saltwater intrusion and land subsidence, help maintain base flow in streams, and at the times when wetlands are covered by water, and store excess water to sustain adequate water supplies during periods of peak demand, or to address seasonal and drought cycles.

Important Enhanced Ground Water Storage Terms

- **Acre-Foot**: an acre-foot is the volume of water that would cover an acre of land to a depth of one foot (43,560 cubic feet, approximately 325,851 U.S. gallons, or approximately 1,233.48 cubic meters).
- **Aquifer Storage Recovery (ASR)**: injection of water into a well for storage and recovery from the same well.[2]
- **Aquifer Storage, Transfer, and Recovery (ASTR)**: injection of water into a well for storage and recovery from a different well, generally to provide additional water treatment.[3]
- **Artificial Recharge (AR)**: intentional banking and treatment of water in aquifers.[4]
- **Artificial Recharge and Recovery (ARR)**: recharge to and recovery of water from an aquifer, that is, both artificial recharge of the aquifer and recovery of the water for subsequent use.[5]
- **Conjunctive Use**: the operation of a ground water basin in combination with a surface water storage and conveyance system to maximize water supply. Water is stored in the ground water basin for later use by intentionally recharging a basin when a water supply is available (Bachman et al. 1997).[6]
- **Dry Well (also sometimes referred to as a vadose well or as a drainage well)**: a well constructed in the interval between the land surface and the top of the static water level and designed to optimize infiltration of water.
- **Ground Water Banking (also known as "mitigation banking"):** using available storage capacity within ground water basins to store surface water that is recharged during periods when it is available (e.g., during peak flood flows).[7]
- **Managed (or Management of) Aquifer Recharge (MAR)**: intentional banking and treatment of water in aquifers (synonymous with AR).[8]
- **Managed Underground Storage (MUS)**: the purposeful recharge of water into an aquifer system for intended recovery and use as a component of long-term water resource management.[9]
- **Sustainable Underground Storage (SUS)**: refers to underground storage projects in which technical and institutional challenges are overcome, resulting in the long-term viability and success of the projects.[10]
- **Underground Storage and Recovery (USR)**: similar to MUS; any type of project whose purpose is the artificial recharge, underground storage, and recovery of project water.[11]

How widespread is the use of enhanced or managed ground water storage?

Communities throughout the world are developing underground storage capacity to meet their growing water demands. In 2004, Topper et al. reported that artificial recharge was being "used in at least 32 states in the U.S., and at least 26 countries worldwide."[12] Many of these projects are implemented by state and local jurisdictions.

According to U.S. EPA fact sheets, there are 1,185 aquifer recharge and aquifer storage and recovery (ASR) wells in the United States. This number includes 807 aquifer recharge wells, 130 ASR wells, and 248 wells (in California and Idaho) that cannot be distinguished as aquifer recharge or ASR wells. The EPA says the actual number of aquifer recharge and aquifer storage and recovery wells could be "greater than 1,695 but unlikely to be higher than 2,000." More than 90 percent of the aquifer recharge and ASR wells known to EPA are located in 11 states (see table).[13]

State	Number of Aquifer Recharge and/or ASR Wells
California	200
Colorado	9
Florida	<488
Idaho	48
Nevada	110
Oklahoma	44
Oregon	16
South Carolina	55
Texas	67
Washington	12
Wisconsin	1
TOTAL	1,050 (96% of estimated national total)

Can its use be significantly expanded?

The capacity to store excess water in the subsurface is significant. However, ground water systems are complex. Development of these augmentation strategies needs to be based on sound science. Ground water storage can be significantly expanded; and as mentioned previously, many water providers are moving forward with plans to increase water supplies by developing local ground water storage programs.

While there is currently no comprehensive, nationwide assessment of ground water storage potential, there is some state-specific information. In 2004, the Colorado Geological Survey published a statewide assessment that included an estimate of storage capacity in all of Colorado's major aquifers. The survey concluded that from a "regional perspective large storage capacities (greater than 100,000 acre feet) are available in both unconsolidated alluvial and consolidated bedrock aquifers." Additionally, they found opportunities for local, smaller aquifer storage projects are "tremendous, and potential source waters exist even in over-appropriated surface water drainages."[14]

Conservative estimates in California indicate the potential to increase average annual water deliveries throughout the state by 500,000 acre-feet with nine million acre-feet of "new" ground water storage. New storage includes both re-operation of existing ground water storage and recharging water into de-watered aquifer space. More aggressive estimates from screening level studies indicate the potential to increase average annual water deliveries by two million acre-feet with about 20 million acre-feet of new storage.[15]

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What are some of the obstacles and challenges to implementing a ground water storage system?

Increasing the availability and capacity of ground water use and storage to augment and sustain water supplies and ecosystem services is a complex challenge. The obstacles to widespread implementation of ground water supply augmentation are numerous and include a broad range of scientific, economic, legal, and institutional issues that will need to be addressed. They include:

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Hydrogeologic System Characterization

- There may not be sufficient source water (or recycled water) to provide the total water storage (or yield) to fill the potential volume.
- The subsurface geologic and hydrogeologic systems are complex and as a consequence expensive to adequately characterize.
- The density and sufficiency of ground water level and ground water quality monitoring information to properly characterize the ground water storage receiving zone(s) is limited both spatially and temporally.
- There is insufficient geologic mapping identifying appropriate geologic, hydrologic, and hydrogeochemical characteristics of aquifer storage.
- Currently, the scale and density of data collected to characterize hydrogeologic systems may not be appropriate for evaluation and selection of sites, locally.
- The impact of global climate change on ground water reservoirs is only now being investigated.
- Surface and ground water interaction, in light of global climate change and land development practices, is not well understood.

Water Quality Characterization and Interaction

- Both ground water quality and the hydrogeochemical characteristics of aquifers and potential receiving zones will require additional assessment.
- The potential interaction of the water injected or otherwise used to augment ground water supplies will need to be carefully studied. The mixing of often chemically and microbiologically different waters may lead to potentially harmful reactions with each other and with materials comprising the aquifer matrix.

Economics and Finance

- The cost to adequately characterize and evaluate aquifer systems is high.
- The level of funding for characterization is variable from state to state and may not be adequate to assess risks of ground water recharge.
- Funding for basic research on the federal level is fragmented throughout several agencies with appropriately different missions.
- The price of water is typically undervalued and obtaining the capital funds for planning and constructing a ground water storage project is a challenge.
- Capital funds for planning and constructing a ground water storage project must compete with funds and obligations for other more traditional water and wastewater treatment projects.

Legal and Institutional

- Water laws and ownership rights to the water stored in the subsurface are being debated in the courts.
- Allocation of water rights is markedly different in the eastern and western United States, along with the ability to transfer water and water rights.
- Subsurface aquifers may cross multiple political subdivisions/boundaries and their management may be subject to multiple jurisdictions.

- Institutional control questions may arise where multiple local agencies have responsibility for water and ground water. Cooperative agreements may be required to develop ground water storage projects in a region.
- Regulatory issues are complex with overlapping federal and state laws and regulations. Water quality regulations are typically based on protection from pollution and not based on sustainability of water supplies or ecosystem services.
- Property rights issues may arise for easements and right-of-ways to transfer water to be stored to appropriate injection well locations.

What are the tradeoffs of ground water storage versus surface water storage?

Storing surface water underground may seem counterintuitive to the public, who cannot see the water and its impact on water availability. Some recharged water will not be recovered at all, although the same is true of surface water stored in reservoirs. Storing water below the ground is slower than surface water storage. You cannot capture storm flows as efficiently as with surface reservoirs, and extracting the water from the subsurface reservoir is slower, being dependent upon the number of wells and pumping rates. There needs to be in place sound ground water management practices for ground water storage to be a viable option.[16]

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Advantages of ground water storage versus surface water storage include:

- Ground water storage systems are, by design, more secure and less vulnerable to accidental contamination, acts of sabotage, or terrorism.
- Little, if any, water is lost through evaporation.
- Usually, there are fewer and less significant environmental impacts associated with ground water storage projects. Impacts to threatened or endangered species are greatly minimized, if not avoided altogether.
- Dams and surface water flows associated with surface storage reservoirs can cause damage to riparian habitat and otherwise impact fish and wildlife.
- Ground water storage and recovery well systems allow for the continued use of overlying land and reduce or eliminate the potential for displacements of humans and wildlife. Acreage that would be consumed or covered by water within surface storage reservoirs remains available for other use and provides continuing economic and environmental benefits.
- While moderately expensive, it may be the least expensive option.[17]
- Over time, surface water reservoirs fill up with sediment, reducing overall storage capacity.

“In addition to enhanced ground water storage, we must also promote actions such as sound ground water management, ground water protection and treatment, water conservation and recycling, and support innovative technologies . . .

What is the role of enhanced ground water storage and availability?

The role of enhanced ground water storage is but one element of a balanced water management portfolio that will be needed to sustain our resources into the distant future. Continued investment in existing facilities and carefully planned new water developments will also be required to provide a strong foundation to meet future demands from continued growth. In addition to enhanced ground water storage, we must also promote actions such as sound ground water management, ground water protection and treatment, water conservation and recycling, and support innovative technologies such as desalination of seawater and brackish water to meet our future water needs.

Are there successful enhanced ground water storage projects involving the coordinated and planned operation of both surface and ground water resources for conservation and optimal use?

The following highlight examples of the successful operation of both surface and ground water resources for conservation and optimal use.

Arizona

Arizona Water Bank: Ground water may be withdrawn from underground storage and used during dry periods. This will result in a short-term reduction in ground water levels. If this short-term reduction is balanced in the long term with replenishment, ground water can be used much like an above-ground reservoir to store water for use when other sources are in short supply. The Arizona Water Bank is an example of this strategy. Nevada and California store excess Colorado River water underground in Arizona. During drought periods, Nevada and California divert surface water flow from the Colorado River while Arizona recovers the underground stored water for its uses.

California

Orange County Water District: In the early years of the 20th century, with a largely agricultural economy, including substantial orange groves siphoning more than 200,000 acre-feet of the ground water out of the Coastal Santa Ana basin annually, ground water levels dropped more than 65 feet. The Orange County Water District (OCWD) was formed in 1933 by a special act of the California Legislature, and was empowered to protect the water supply and the rights of those who depended upon it, which at that time was 60,000 people with 86 percent agricultural water use. This type of institution, with significant powers to manage, regulate, control, purchase, acquire, transport, exchange water and ground water within the basin, is not often found outside of California. Over time, dams were constructed on the Santa Ana River, which limited the flow into the basin, and a growing practice of importation of large quantities of water to recharge the basin began to occur. Ground water extraction continued to outpace recharge and by the mid-1950s seawater intrusion was evidenced more than three miles inland. Today's OCWD covers well over 300 square miles, serves 20 cities and water agencies and a population in excess of two million. In the area known as the forebay, managed aquifer recharge facilities consisting of spreading basins along the Santa Ana River receive a combination of treated wastewater, Santa Ana River water, and imported water. These recharge facilities provide the majority of recharge to the ground water basin, or approximately 250,000 to 275,000 acre-feet per year. Seawater intrusion is mitigated by pumping a blend of recycled water and deep well water into a series of injection wells near the coast. The recycled water treatment train includes chemical clarification, re-carbonation, multi-media filtration, granular activated carbon, reverse osmosis, chlorination, and blending of waters of varying qualities to obtain a larger supply of acceptable quality water.[18]

Florida

Peace River/Manasota Regional Water Supply Authority: Operating as a regional partnership with its members—Charlotte, DeSoto, Manatee, and Sarasota counties—the Authority works collectively to ensure adequate water supplies for an ever-growing population of more than 750,000 people in the region. The Authority supplies an average of 18 million gallons of water to its members. This water, skimmed from the Peace River, is treated at the main facility located on the Peace River in DeSoto County near Fort Ogden. This facility treats up to 24 million gallons per day and has been withdrawing water from the river since 1980. Treated water is then injected into an aquifer and recovered as needed. This ASR process is an ideal method for meeting seasonal water demands. This allows the Authority to withdraw water during "wet" months and then store it for use during "dry" periods when river levels are low. A regional reservoir expansion, slated to be completed by 2010, will provide an additional 24 million gallons per day of treatment capacity. The Peace River, as are other surface water supplies, is susceptible to drought conditions. The addition of a ground water supply through the Authority itself or its members would add a significant degree of reliability to the public supply system.[19]

Texas

San Antonio: San Antonio Water System's Twin Oaks Aquifer Storage and Recovery Facility (ASR) currently stores about 40,000 acre-feet of potable water, which equals about 12 billion gallons of water. The ASR's technology and science has been successfully proven as an economical and environmentally sensitive alternative in helping to meet the city's future water needs, especially if faced with environmental change issues resulting in reductions in rainfall.

The ASR withdraws water from the Edwards Aquifer—a karst-based limestone aquifer—in wet weather when water is abundant, and stores it in the Carrizo sandstone-based aquifer south of the city. Since the water tends to stay in place in the sandstone of the Carrizo Aquifer, the transferred Edwards water remains near the injection site.

The facility proved itself to the community in 2006 when the region experienced extreme drought. San Antonio Water System placed the ASR in recovery mode. San Antonio was in drought restrictions during much of that year, but retrieval of water from the ASR reduced the city's pumping from the Edwards Aquifer while providing much-needed water.

San Antonio Water System's Aquifer Storage and Recovery Facility opened in 2004, and has the capacity to pump more than 30 million gallons per day. It features 16 wells, a high-service pump station, and 30 miles of large-diameter transmission main to convey water to ground storage tanks. While there is currently about 40,000 acre-feet of storage at the site, San Antonio Water System is expanding the ASR system and studying what the maximum potential of the facility may be.[20]

Summary

As water resources are utilized, it is critical they be managed for long-term benefit to man and his environment. Enhanced ground water storage methodologies contribute to that intended outcome. Legislative and regulatory awareness of these water management options is increasing.

[1] Derived from graphic courtesy of Ralf Topper, Colorado Geological Survey. *Artificial Recharge of Ground Water in Colorado—A Statewide Assessment*, p. 6.

[2] Catherine Shrier, Ph.D., P.G., "Economic and Financial Issues and Conjunctive Water Use in a Systems Context," Managed Underground Storage of Water Policy Forum, Washington, D.C., March 18, 2008.

[3] Shrier.

[4] *NGWA's Illustrated Glossary of Ground Water Industry Terms*, 2003.

[5] Shrier.

[6] *NGWA's Illustrated Glossary of Ground Water Industry Terms*, 2003.

[7] From http://www.iep.ca.gov/cmarp/groups/scwt/combined.doc.

[8] Shrier.

[9] *Prospects for Managed Underground Storage of Recoverable Water*, Committee on Sustainable Underground Storage of Recoverable Water, Water Science and Technology Board, Division on Earth and Life Studies, National Research Council of the National Academies, The National Acadamies Press, 2008.

[10] From www.niph.go.jp/soshiki/suido/pdf/h19JPUS/abstract/r28.pdf.

[11] Shrier.

[12] Topper, R. et al. *Artificial Recharge of Ground Water in Colorado—A Statewide Assessment.* 2004, p. ii.

[13] From http://www.epa.gov/safewater/uic/class5/pdf/study_uic-class5_classvstudy_fsaq_rechrg_wells.pdf.

[14] Topper, R. "Nature's Underground Reservoir: Aquifer Storage" (abstract). *21st Century Ground Water Systems Conference Abstracts.* National Ground Water Association. October 2006.

[15] *California Water Plan Update 2005*. California Department of Water Resources Bulletin 160-05, December 2005, Volume 2, Chapter 4.

[16] Hanak, Ellen. *Water for Growth: California's New Frontier.* Public Policy Institute of California, San Francisco, California. 2005.

[17] Committee on Sustainable Underground Storage of Recoverable Water, National Research Council. "Prospects for Managed Underground Storage of Recoverable Water." Prepublication Copy, 2007. p. 215.

[18] Fox, Peter, editor. *Management of Aquifer Recharge for Sustainability.* Proceedings of the 6th International Symposium on Managed Aquifer Recharge of Ground Water, ISMAR6, Phoenix, Arizona, USA, October 28-November 2, 2007. Acacia Publishing Inc., Phoenix, Arizona.

[19] Personal communication, Jennifer Steadman Ryan, Sarasota County Water Resources. 2008.

[20] Personal communication, Anne Hayden, San Antonio Water Systems. 2008.