# The Federal Role in Groundwater Supply: Overview and Legislation in the 115th Congress

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# Summary

Groundwater, the water in aquifers accessible by wells, is a critical component of the U.S. water supply. It is important for both domestic and agricultural water needs, among other uses. Nearly half of the nation's population uses groundwater to meet daily needs; in 2015, about 149 million people (46% of the nation's population) relied on groundwater for their domestic indoor and outdoor water supply. The greatest volume of groundwater used every day is for agriculture, specifically for irrigation. In 2015, irrigation accounted for 69% of the total fresh groundwater withdrawals in the United States. For that year, California pumped the most groundwater for irrigation, followed by Arkansas, Nebraska, Idaho, Texas, and Kansas, in that order. Groundwater also is used as a supply for mining, oil and gas development, industrial processes, livestock, and thermoelectric power, among other uses.

Congress generally has deferred management of U.S. groundwater resources to the states, and there is little indication that this practice will change. For example, several bills introduced in the 115th Congress contain provisions that would direct that the federal government recognizes that aspects of groundwater, such as the connection between surface water and groundwater, be consistent with state water laws (surface water includes streams, rivers, lakes, ponds, and is not groundwater or atmospheric water, such as rain or snow). Those same bills also would prohibit the federal government from requiring the transfer of water rights to the United States or obtaining a water right in the name of the United States as a condition for receiving, renewing, amending, or extending "any permit, approval, license, lease, allotment, easement, right-of-way, or other land use or occupancy agreement." In addition, these bills contain language asserting that the legislation would not alter certain reserved rights associated with federal and tribal lands.

Congress, various states, and other stakeholders recently have focused on the potential for using surface water to recharge aquifers and the ability to recover stored groundwater when needed. Some see aquifer recharge, storage, and recovery as a replacement or complement to surface water reservoirs, and there is interest in how federal agencies can support these efforts. In the congressional context, there is interest in the potential for federal efforts to facilitate state, local, and private groundwater management efforts (e.g., management of federal reservoir releases to allow for groundwater recharge by local utilities). The two primary federal water resources agencies are the U.S. Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (USACE). No significant federal restrictions apply to Reclamation's authorities to deliver water for purposes of aquifer recharge, storage, and recovery. USACE authorities also do not contain restrictions on the nonfederal use for groundwater recharge of water stored or released from USACE reservoirs. Both agencies acknowledge that some state restrictions affect the use of the delivered or stored waters for groundwater activities. Some legislative proposals would provide the agencies with additional directives and mechanisms regarding their authority to support nonfederal groundwater recharge.

Other federal agencies support activities that inform groundwater management. For example, the U.S. Geological Survey monitors and reports groundwater conditions across the country, develops groundwater models and software tools for characterizing aquifers, and provides long- and short-term forecasts of changing groundwater conditions as part of local and regional groundwater studies. The National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration also make observations and collect data that are relevant to groundwater monitoring and assessment. The U.S. Department of Agriculture collects groundwater data related to irrigation.

Long-term changes to the climate affecting the United States, particularly rising temperatures and changes in the patterns, quantities, and type of precipitation (i.e., rain versus snow), could affect

the availability of groundwater in the future. Other factors, such as changes to land use, irrigation practices, and patterns of water consumption, also may influence groundwater supplies.

# Contents

Overview ... 2
Who Relies on Groundwater? ... 2
Groundwater and Irrigation ... 2
The Federal Role in Groundwater Supply ... 3
Groundwater Supply Issues and Legislation ... 3
Groundwater Recharge, Storage, and Recovery ... 6
Background ... 6
Legislation ... 7
Groundwater Rights ... 8
Background ... 8
Legislation ... 10
Groundwater Monitoring ... 10
Background ... 10
Legislation ... 11
Primer on Groundwater ... 11
Types of Aquifers ... 12
Federal Activities and Authorities ... 16
Groundwater Monitoring and Assessment ... 17
U.S. Geological Survey ... 17
NASA ... 19
NOAA ... 20
USDA ... 20
Federal Authority Related to Groundwater Recharge, Storage, and Recovery ... 21
Bureau of Reclamation ... 22
U.S. Army Corps of Engineers ... 24
USDA ... 25
Federal Reserved Rights to Groundwater ... 26
Climate Change and Other Long-Term Influences on Groundwater Supply ... 27
Climate Change and Groundwater Recharge ... 27
Other Factors ... 30
Summary and Conclusions ... 31

## Figures

Figure 1. Groundwater Withdrawals for Irrigation (2010) ... 3
Figure 2. Unconfined, or Water Table, Aquifer ... 12
Figure 3. Different Types of Aquifers and Wells ... 13
Figure 4. Unconfined Aquifer Without Pumping (top) and With Pumping (bottom) ... 14
Figure 5. Water Level Changes in the High Plains Aquifer, Predevelopment to 2007 ... 15
Figure 6. Land Subsidence in the San Joaquin Valley Southwest of Mendota Between 1925 and 1977 ... 16
Figure 7. Below-Normal Groundwater Levels for Actively Monitored Wells ... 18
Figure 8. Shallow Groundwater and Soil Moisture Comparison from NASA Satellite Data ... 19

Figure 9. Groundwater Recharge, Storage, and Recovery ... 22
Figure 10. Conceptual Illustration of Recharge Mechanisms Under Two Different Climate Scenarios ... 30

## Tables

Table 1. Selected Bills That Address Groundwater in the 115th Congress ... 4

## Contacts

Author Contact Information ... 32

Groundwater, the water in aquifers accessible by wells, is a critical component of the U.S. water supply. It serves as a water source for domestic use and as irrigation water for agriculture, and it is used in mining, oil and gas development, industrial processes, livestock, and thermoelectric power, among other uses. Managing groundwater resources largely has been the purview of states rather than the federal government. How each state manages its groundwater resources differs and depends on a mix of common law emerging from the 19th century, state law, court decisions, water settlements, and, to a lesser extent, federal law. The federal role in managing groundwater includes activities under federal trust responsibilities to Indian tribes and reservations.[1] It also includes management responsibilities for certain federal reservations if the purposes of those reservations require water, such as some national monuments, national forests, military bases, and other federal land holdings. In addition, the federal government is involved in groundwater monitoring and assessment and in aspects of groundwater recharge, storage, and recovery. Much of the recent congressional interest in groundwater has been broadly related to policies for increasing water supplies generally, as a response to recent droughts, and in preparation for future droughts.

In recent Congresses, some Members have introduced legislation that could affect how groundwater resources may be managed to better ensure a sufficient and reliable supply, and several such bills (or portions of such bills) have been enacted into law. Drought conditions and constrained supplies of surface water have helped to spur legislative action.[2] These conditions continue to affect many regions in western states, although droughts can occur anywhere in the nation.[3] Congress could continue to explore its authority to affect policy, conduct oversight, and provide appropriations for federal activities that influence groundwater supply management in the United States. This report is intended to provide context and a broad summary of federal authorities and activities affecting the supply and use of groundwater resources.

Whereas the states primarily manage groundwater *supply*, the federal government plays a more direct role in managing the nation's groundwater *quality*. For example, the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. §§9601 et seq.) authorizes federal cleanup and enforcement actions to respond to releases of hazardous substances to the environment, including groundwater. In addition, the Safe Drinking Water Act (42 U.S.C. §§300f et seq.) authorizes the U.S. Environmental Protection Agency (EPA) to regulate underground injection activities to protect underground sources of drinking water, including injection wells used for aquifer recharge. This report focuses on issues related to groundwater supply, not groundwater quality.[4]

This report is divided into two parts. The first part discusses general background related to groundwater supply and management, including selected major issues before Congress. The second part provides a more detailed primer on groundwater resources, including relevant federal activities and authorities.

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[1] Unless otherwise noted, the terms *Indian*, *Indian tribes*, and *tribal reservations* refer to the approximately 1.9 million American Indians and Alaska Natives, the more than 570 federally recognized Indian tribes, and tribal land within reservation boundaries.

[2] Surface water includes streams, rivers, lakes, ponds, and is not groundwater or atmospheric water like rain or snow.

[3] For a general overview of drought in the United States, see CRS Report R43407, *Drought in the United States: Causes and Current Understanding*, by Peter Folger.

[4] Many CRS resources address issues of groundwater quality, including CRS Report R41039, *Comprehensive Environmental Response, Compensation, and Liability Act: A Summary of Superfund Cleanup Authorities and Related Provisions of the Act*, by David M. Bearden; and CRS Report RL31243, *Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements*, by Mary Tiemann.

# Overview

## Who Relies on Groundwater?

Nearly half of the U.S. population relies on groundwater to meet their everyday needs. Groundwater makes up a portion of the water supplied to about 149 million people (46% of the U.S. population in 2015) for their domestic indoor and outdoor water uses.[5] Most U.S. citizens (approximately 282 million people, or 87%) depended on public water supplies in 2015.[6] Because about 38% of public supply water is groundwater, that translates into about 107 million people using groundwater from public water supplies.[7] The remaining 13% (approximately 42.5 million people) supplied their own water, and nearly all of these citizens (98%, or about 42 million) pumped the water from their private wells. The 107 million people using groundwater from public water supplies plus the 42 million people pumping groundwater from their private wells equal 149 million people total using groundwater in 2015.

## Groundwater and Irrigation

The greatest *volume* of groundwater used is for agriculture, nearly entirely for irrigation. In 2015, irrigation accounted for over 69% of all fresh groundwater withdrawals in the United States,[8] which corresponded to about 57.2 billion gallons per day (bgpd) in irrigation withdrawals as compared to 18.4 bgpd in withdrawals for domestic use (both public supply and self-supplied groundwater).[9] Among all states, California uses the most groundwater for irrigation, withdrawing 13.9 bgpd in 2015. Arkansas was second, withdrawing 9.28 bgpd in the same year, followed by Nebraska (5.42 bgpd), Idaho (4.9 bgpd), Texas (4.48 bgpd), and Kansas (2.56 bgpd).[10] Overall, groundwater withdrawals for irrigation in 2015 accounted for 48% of the total water withdrawn for irrigation, an increase of 16% compared to 2010.[11] In comparison, surface water sources supplied 52% of total irrigation withdrawals, a decrease of about 8% from 2010.[12]

**Figure 1** illustrates the amount of groundwater withdrawn for irrigation by state. Generally speaking, western states tend to use the most groundwater, due in part to hydrology and other surface water supply constraints.

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[5] Cheryl A. Dieter and Molly A. Maupin, *Public Supply and Domestic Water Use in the United States, 2015*, U.S. Geological Survey (USGS), Open-File Report 2017-1131, 2017, at https://doi.org/10.3133/ofr20171131. (Hereinafter, Dieter and Maupin, 2017.) 2015 is the most recent year for which data are available.

[6] *Public water supply*, as used in USGS reports and herein, refers to water withdrawn by public and private water suppliers that provide water to at least 25 people or have a minimum of 15 connections. It excludes self-supplied domestic withdrawals.

[7] Dieter and Maupin, 2017.

[8] Cheryl A. Dieter et al., *Estimated Use of Water in the United States in 2015*, USGS, Circular 1441, 2018, at https://pubs.er.usgs.gov/publication/cir1441. (Hereinafter, Dieter et al., 2018.) 2015 is the most recent year for which data are available. Nearly all groundwater withdrawals in 2015 were freshwater (about 97%); the remainder (3%) were saline water withdrawals.

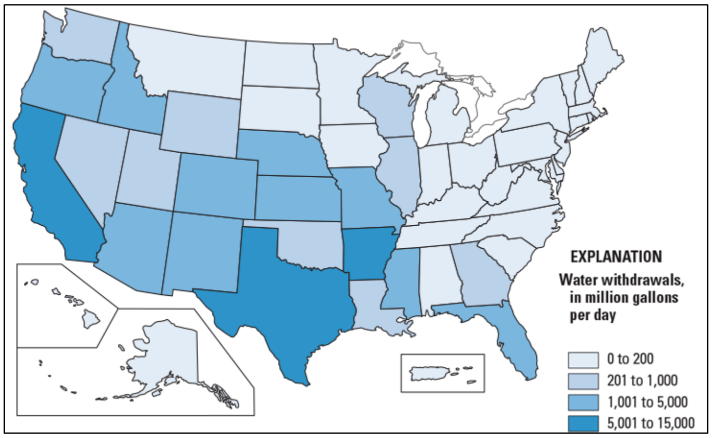
[9] Irrigation, public supply, and self-supplied groundwater withdrawals accounted for about 92% of the total fresh groundwater pumped in 2015. The remaining 8% included uses for livestock, aquaculture, industrial, mining, and thermoelectric power. Dieter et al., 2018, Table 4a.

[10] Dieter et al., 2018, Table 7.

[11] Dieter et al., 2018, p. 28.

[12] Dieter et al., 2018, p. 28.

**Figure 1. Groundwater Withdrawals for Irrigation (2010)**




**Source:** Molly A. Maupin et al., *Estimated Use of Water in the United States in 2010*, U.S. Geological Survey (USGS), Circular 1405, 2014, at https://pubs.usgs.gov/circ/1405/, p. 27, figure 7. (Modified by CRS.)

## The Federal Role in Groundwater Supply

The federal government directly and indirectly influences how groundwater is managed in the United States. Several federal agencies monitor groundwater directly or with partners—through measurements at wells and springs—and remotely using satellites or other remote sensing devices to provide information on groundwater flow, storage, depletion, and other characteristics that help inform state and local groundwater management. This includes the U.S. Geological Survey (USGS), the National Aeronautics and Space Agency (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA).[13] Congress has provided other federal agencies with the authority to make available some water delivered from or stored at federal water resource projects for groundwater recharge, storage, and recovery. This includes the two principal federal water resources agencies: the U.S. Army Corps of Engineers (USACE, which operates nationwide) and the U.S. Bureau of Reclamation (Reclamation, which operates in the 17 coterminous states west of the Mississippi River). Additionally, courts have found that when the federal government reserves lands for a particular purpose (such as for a tribal reservation or national monument), it impliedly reserves a right to water necessary to accomplish the purposes for which the reservation was created. Thus, federal land management agencies and the Bureau of Indian Affairs often are involved in water rights issues. Federal reserved water rights doctrine has long been recognized for surface water; more recently, it is also being considered for groundwater.

# Groundwater Supply Issues and Legislation

In recent years, congressional interest in groundwater has generally been in three major areas:

- aquifer storage, recharge, and recovery;
- groundwater rights (including among other things, groundwater/surface water interaction and federal reserved water rights); and
- groundwater supply monitoring and assessment.

[13] For more information on the roles of the agencies, see the below section, "Federal Activities and Authorities."

In some cases, these issues overlap.

Numerous bills introduced in the 115th Congress would address several groundwater-related topics. **Table 1** includes bills that would affect, in some manner, groundwater topics discussed in this report, including aquifer storage and recharge, groundwater-surface water interaction, treatment of groundwater rights by the federal government, aspects of tribal water rights, Reclamation water recycling and reuse programs, drought relief, groundwater studies, and groundwater monitoring and assessment. **Table 1** does not include all bills introduced in the 115th Congress that touch on the topic of groundwater; some of the bills omitted, for example, provide definitions for groundwater but do not affect the policy issues introduced above. Other omitted bills pertain to groundwater quality (i.e., bills addressing groundwater protection or remediation), which is not addressed in this report.

**Table 1. Selected Bills That Address Groundwater in the 115th Congress**

| Bill Number | Short Title | Topics Addressed | Reference Location |
|---|---|---|---|
| S. 32 | California Desert Protection and Recreation Act of 2017 | Groundwater recharge, storage, and recovery; treatment of groundwater rights by the federal government | Title I, Section 105(d) |
| S. 714 | Yakima River Basin Water Enhancement Project Phase III Act of 2017 | Groundwater studies; groundwater recharge, storage, and recovery | Section 4(d)(3); Section 5 |
| S. 1012 | New Mexico Drought Preparedness Act of 2017 | Drought relief | Sections 7 and 11 |
| S. 1230 | Water Rights Protection Act of 2017 | Treatment of groundwater rights by the federal government; groundwater-surface water interaction; tribal water rights | Sections 2, 3, 4, 5 |
| S. 1460 | Energy and Natural Resources Act of 2017 | Groundwater recharge, storage, and recovery; tribal water rights | Division B, Title IX, Subtitle C, Sections 9204 and 9205 |
| S. 2563 | Water Supply Infrastructure and Drought Resilience Act of 2018 | Groundwater recharge, storage, and recovery; treatment of groundwater rights by the federal government; groundwater-surface water interaction; drought relief; tribal water rights | Title II, Subtitle B, Sections 211-214; Title III, Subtitle A, Sections 301, 302, 303, 304 |
| S. 2800 | America's Water Infrastructure Act of 2018 | Groundwater recharge, storage, and recovery | Title V, Section 5016 |
| H.R. 2[a] | Agricultural Improvement Act of 2018 | Groundwater recharge, storage, and recovery | Title II, Sections 2303(5), 2411(g)(2) |

| Bill Number | Short Title | Topics Addressed | Reference Location |
|---|---|---|---|
| H.R. 23 | Gaining Responsibility on Water Act of 2017 | Groundwater recharge, storage, and recovery; groundwater studies; treatment of groundwater rights by the federal government; groundwater-surface water interaction; tribal water rights | Title I, Section 106; Title II, Section 204; Title VII, Sections 702, 703, 704, 705 |
| H.R. 2939 | Water Rights Protection Act of 2017 | Treatment of groundwater rights by the federal government; groundwater-surface water interaction; tribal water rights | Sections 2, 3, 4, 5 |
| H.R. 3275 | Water and Energy Sustainability Through Technology Act | Groundwater recharge, storage, and recovery; groundwater monitoring and assessment; groundwater studies | Title I, Subtitle B, Section 1221; Title II, Sections 2005, 2006, 2007, 2008 |
| H.R. 4425 | Food and Farm Act | Groundwater recharge, storage, and recovery | Title II, Subtitle B, Section 213(f)(1) |
| H.R. 4723 | Hualapai Tribe Water Rights Settlement Act of 2017 | Groundwater recharge, storage, and recovery; treatment of groundwater rights by the federal government; tribal water rights | Section 5 |
| H.R. 5127 | Water Recycling Investment and Improvement Act | Reclamation water recycling and reuse | Section 2 |
| H.R. 5487 | Regional Conservation Partnership Program Improvement Act of 2018 | Groundwater recharge, storage, and recovery | Section 5(a) |
| H.R. 5596 | Water Infrastructure Resiliency and Sustainability Act of 2018 | Groundwater recharge, storage, and recovery | Section 2 |
| H.R. 5895[b] | Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019 | Groundwater recharge, storage, and recovery | Title II, Section 203 |

**Source:** Congressional Research Service (CRS).

a. At the time of publication, H.R. 2 has passed and agreed to in both the House and Senate and is awaiting conference. The engrossed in House (EH) version, however is different from the engrossed amendment Senate (EAS) version. The Senate-passed bill (EAS) includes provisions related to groundwater recharge, storage, and recovery and therefore is the version referenced in this table and discussed further below.

b. Refers to the provision in the version of H.R. 5895 as reported in the House, May 21, 2018.

Background on selected topics of interest in the 115th Congress, including relevant legislation, is discussed in more detail below.

## Groundwater Recharge, Storage, and Recovery

### Background

Historically, the federal government, through USACE and Reclamation, has played a prominent role in creating infrastructure related to surface water resource management (e.g., storage, control, or delivery). At the same time, the federal government has played a comparatively smaller role in creating infrastructure to develop groundwater storage, which is commonly conducted as aquifer storage, recovery, and/or recharge.[14] The reasons for the differing levels of federal involvement are complex, tied to the long and complicated history of common law water rights, state water law, legal adjudication, federal deference to states on water supply issues, and a historically cruder understanding of how groundwater occurs and moves underground compared to surface water.

Both public and congressional focus on groundwater storage has sharpened in recent years, particularly in reaction to recent major drought events. Congressional interest has increased in the potential to assist with state, local, and private groundwater management efforts, including efforts to use surface water to recharge and/or store water in aquifers and to recover (i.e., pump to the surface) the stored groundwater when needed. Some see aquifer recharge, storage, and recovery as potentially complementary to existing storage; some also see these projects as possible alternatives to building new surface water reservoirs that may prove less costly and/or pose fewer environmental issues.[15]

Authorities to provide water for irrigation (Reclamation) and store water for various purposes (USACE) exist and are one way for the federal government to promote aquifer recharge, storage, and recovery (see below section, "Federal Authority Related to Groundwater Recharge, Storage, and Recovery"). Currently, there are no general federal restrictions on the nonfederal use of water delivered by Reclamation or stored by USACE for aquifer recharge, storage, and recovery purposes; however, some state restrictions and federal environmental protection laws may affect the use of these waters for groundwater recharge.[16] Although Congress has authorized aquifer storage, recharge, and/or recover for some individual projects, general congressional guidance in this area has been limited to date. Under the Water Infrastructure Improvements for the Nation Act (WIIN Act; P.L. 114-322), Congress provided general authority for Reclamation to support new and enhanced federal and state surface and groundwater storage projects under certain, limited circumstances.[17]

[14] For more background on this concept, see the below section, "Federal Authority Related to Groundwater Recharge, Storage, and Recovery."

[15] An example of a major aquifer storage project currently operating within a larger water storage framework is the Kern Water Bank, a water storage bank that operates on about 20,000 acres southwest of Bakersfield, California. As of 2018, the bank could store about 1.5 million acre-feet of readily available water underground, with the ability to recover approximately 240,000 acre-feet within a 10-month period. Since its construction in 1996, the bank has formed an important component of California's water storage network. For more information, see http://www.kwb.org/index.cfm/fuseaction/Pages.Page/id/330.

[16] For example, injection wells used for aquifer recharge or aquifer storage and recovery require a permit under the federal Safe Drinking Water Act (42 U.S.C. §300h). For further information, see https://www.epa.gov/uic/aquifer-recharge-and-aquifer-storage-and-recovery.

[17] For more information, see below section, "Reclamation Authority to Provide Financial Support for Groundwater Storage."

## Legislation

### Proposals Affecting Groundwater Recharge and Storage in General

Thirteen bills listed in **Table 1** address groundwater recharge, storage, and recovery in various ways. Whereas some bills address the concept broadly, others attempt to facilitate and, in some cases, add requirements for groundwater storage projects in specific locations. S. 2563 would provide detailed authorities to Reclamation for augmenting aquifer recharge activities, and would broadly establish that the use of water for aquifer recharge shall be considered an authorized purpose for a Reclamation project under reclamation laws. The bill also contains a sense of Congress that the Secretary of the Interior should give priority to use of Bureau of Land Management lands for aquifer recharge.

Two bills (S. 714, S. 1760) would expand the Secretary of the Interior's authority (through Reclamation) to provide technical assistance and to participate in recharge, storage, and recovery projects. Similarly, H.R. 2 and H.R. 4425 would expand the Secretary of Agriculture's authority under the Environmental Quality Incentives Program (EQIP) to improve water storage through water banking, aquifer recovery, and groundwater recharge. H.R. 3275 would address activities and authorities for groundwater recharge in both in DOI and USDA. H.R. 2. and H.R. 5487 would amend the Regional Conservation Partnership Program to USDA to make grants available for projects that promote groundwater replenishment and storage. S. 2800 and H.R. 5596 would authorize the Administrator of the Environmental Protection Agency to award grants for groundwater recharge, storage, and conjunctive use projects.[18] Also, S. 2800 would amend the Water Infrastructure Finance and Innovation Act (WIFIA) to authorize Reclamation to recommend aquifer recharge and certain other projects to EPA for WIFIA loan assistance.

Other legislation would attempt to facilitate groundwater storage as a means to mitigate drought. S. 2563 would augment aquifer recharge activities broadly to provide resilience and relief from drought. The legislation would enable activities that provide a net water storage benefit, meaning an increase in the volume of water stored in a reservoir or aquifer that is available for use within the area of a Reclamation project.

Under S. 1012, financial assistance would be made available under the authority of the Reclamation States Emergency Drought Relief Act of 1991 (43 U.S.C. 2201 et seq.) and Title XII of the Food Security Act of 1985 (16 U.S.C. 3801 et seq.) for "activities reducing or preventing groundwater depletion or promoting groundwater recharge" as a response to drought. The bill also would make available financial assistance for investigations and pilot projects involving brackish groundwater development and aquifer storage and recovery.

H.R. 5127 would amend title XVI of P.L. 102-575 (the Reclamation Wastewater and Groundwater Study and Facilities Act; 43 U.S.C. 390h et. seq.) to give funding priority to projects that meet certain criteria, including "groundwater management and enhancements." The bill also would increase authorization of appropriations for Title XVI from $50 million to $500 million.

### Proposals Affecting Groundwater Storage at Specific Locations

Other legislative proposals would add authorities for individual groundwater storage projects. H.R. 4723 would affect water rights of the Hualapai Tribe in Arizona, providing authority for the

[18] Conjunctive use or conjunctive management describes the process whereby groundwater and surface water are managed together for water supply.

tribe to store Colorado River water underground. The bill also would address the tribe's ability to transfer or lease its entitlement to Colorado River water stored underground or to exchange the entitlement for water that the tribe will use. In addition, the bill would specify authorities for the tribe to store Central Arizona Project water underground.[19] A provision in H.R. 5895 would allow the use of Reclamation water diversion structures for recharging the Eastern Snake Plain Aquifer with water available in excess of existing storage and hydropower rights.[20]

Some legislation would attempt to clarify standards applying to specific nonfederal aquifer storage projects. For example, language in S. 32 would amend the California Desert Protection Act of 1994 (16 U.S.C. 410aaa–41 et seq.), which addresses groundwater supplies in the Mojave National Preserve. The provision would restrict the federal government's rights to "authorize, permit, or allow the use of any right-of-way or lease to extract, consume, export, transfer, or distribute groundwater for municipal, commercial, or industrial use from aquifers ... in quantities that collectively exceed the perennial safe yield or annual recharge rate, as determined by the U.S. Geological Survey." The term *safe yield* is often used interchangeably with *sustainable yield*, as in, for example, the 2014 California Sustainable Groundwater Management Act (SGMA).[21] Generally, *sustainable* or *safe yield* means the amount of groundwater that can be withdrawn annually without causing permanent harm to the aquifer. The groundwater provisions in S. 32 relate centrally to a proposed, privately-funded groundwater capture project in southern California, the Cadiz Project, which would require federal permitting to move forward.[22]

# Groundwater Rights

## Background

### *Groundwater and Surface Water Interaction*

One reason often cited for the evolution of different legal frameworks for groundwater and surface water in most states is the relative lack of understanding of groundwater occurrence and movement in the 19th and early 20th centuries, when states and courts first established laws and rules allocating groundwater. Surface water was more readily understood, being in plain view, but groundwater was considered different and mysterious, being largely unobservable except at the bottom of a well. One commentator noted that the development of groundwater common law in England and the United States in the 19th century was "steeped in ignorance,"[23] as groundwater hydrology and hydraulics were virtually unknown compared to surface water. Citing a legal case from 1861 referring to groundwater, the commentator said,

> the existence, origin, movement and course of such waters, and the causes which govern and direct their movements, are so secret, occult and concealed, that an attempt to

[19] For a brief history of the Central Arizona Project, see http://www.cap-az.com/about-us/history.

[20] This provision is included in the version of H.R. 2895 as reported in the House, May 21, 2018.

[21] See California Department of Water Resources, "SGMA Groundwater Management," at https://www.water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management. The SGMA defines *sustainable yield* as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result."

[22] Background on the proposed project is available from the developer at http://www.cadizinc.com/water-project/.

[23] Joseph W. Dellapenna, "A Primer on Groundwater Law," *Idaho Law Review*, vol. 49, no. 265 (2013), p. 267. Hereinafter Dellapenna, 2013.

> administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible.[24]

Groundwater science has made significant strides in the interim, particularly in establishing the interconnected nature of surface water and groundwater in many instances, especially for shallow aquifers. Some observers argue that groundwater law has not kept pace in some cases, in part because of the courts' reluctance to unsettle a system of common law established under the principle of property rights; observers note that a disruption of this system could result in legal chaos.[25]

The complicated nature of groundwater laws and practices is noteworthy because any new executive branch action or federal legislation authorizing action that affects groundwater resources may perturb long-established state and local groundwater management regimes. The practice of managing groundwater and surface water together, termed *conjunctive management*, better reflects the intertwined nature of groundwater and surface water in many situations and is recognized as an effective management approach, especially for shallow aquifers. Yet, groundwater law sometimes does not reflect or address that surface-groundwater interconnection.

### Federal Reserved Water Rights

In the federal realm, federal reserved water rights doctrine is an important concept in groundwater law. This doctrine holds that when the federal government reserves lands for a particular purpose (such as for a tribal reservation or national monument), the government impliedly reserves a right to water necessary to accomplish the primary purpose for which the reservation was created.[26] Since 1908, when the Supreme Court established the doctrine in *Winters v. United States*, courts have applied this doctrine to surface waters.[27] A March 2017 decision of the U.S. Court of Appeals for the Ninth Circuit (Ninth Circuit) held, for the first time, that the doctrine can encompass groundwater as well.[28]

Congress has recently been involved in Indian water rights settlements, chiefly regarding tribal rights to surface water supplies and the appropriation of funds for enacted settlement agreements. The importance of groundwater to tribal water supplies is increasingly being discussed, and tribal rights to groundwater are the subject of ongoing litigation.[29]

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[24] Dellapenna, 2013, citing Frazier v. Brown, 12 Ohio St. 294, 311 (1861).

[25] Dellapenna, 2013, p. 268.

[26] See, for example, the U.S. Department of Justice, "Federal Reserved Water Rights and State Law Claims," at https://www.justice.gov/enrd/federal-reserved-water-rights-and-state-law-claims. The nature of the water right for a specific federal reservation depends on various aspects of the reservation, such as its purpose and the mechanism for the reservation; the discussion herein is intended to introduce the topic of groundwater rights related to federal reservations generally and is not intended to clarify how the specific rights related to a reservation are determined. For example, in some cases, Congress has expressly not reserved water rights.

[27] Winters v. United States, 207 U.S. 564, 575-77 (1908).

[28] Agua Caliente Band of Cahuilla Indians v. Coachella Valley Water District, No. 15-55896 (9th Cir. 2017). For a legal summary of the case, see CRS Legal Sidebar LSB10048, *Supreme Court Declines to Review Ninth Circuit Decision Applying Federal Reserved Water Rights Doctrine to Groundwater*, by Alexandra M. Wyatt.

[29] CRS Legal Sidebar LSB10048, *Supreme Court Declines to Review Ninth Circuit Decision Applying Federal Reserved Water Rights Doctrine to Groundwater*, by Alexandra M. Wyatt.

### Legislation

Six bills in **Table 1** address groundwater rights. Four of these bills (S. 1230, S. 2563, H.R. 23, and H.R. 2939) would prohibit the federal government from requiring the transfer of water rights to the United States, or obtaining a water right in the name of the United States, as a condition for receiving, renewing, amending, or extending "any permit, approval, license, lease, allotment, easement, right-of-way, or other land use or occupancy agreement." These bills also would address the groundwater-surface water connection, directing that the Secretaries of the Interior and Agriculture not "assert any connection between surface and groundwater that is inconsistent with such a connection recognized by State water laws." That provision would preserve, for example, the California state law that recognizes "subterranean streams flowing through known and definite channels" as subject to the prior appropriation doctrine; as distinguished from "underground water supply," which California law expressly excludes from prior appropriation water law.[30] Underground water supplies so characterized would be subject to a different state water law scheme of overlying and correlative rights to use groundwater, meaning the overlying land owner(s) would have priority.[31] The correlative rights principle means that multiple overlying land owners "each may only use his reasonable share when water is insufficient to meet the needs of all."[32]

## Groundwater Monitoring

### Background

Although the states have assumed primary responsibility for groundwater management, several federal agencies monitor, forecast, and assess groundwater conditions in the United States.[33] One agency, the U.S. Geological Survey (USGS), within the Department of the Interior (DOI), is a science agency with no regulatory or management responsibilities for water resources. For decades, USGS has monitored and reported groundwater conditions across the country; developed groundwater models and software tools for characterizing aquifers; and provided long- and short-term forecasts of changing groundwater conditions as part of local and regional groundwater studies.[34] The information is used to support federal, state, and local decisionmakers, and it is often conducted in collaboration with federal, state, and local partners. For example, USGS makes data from its distributed water database available to stakeholders. The database is a locally managed network of stations that monitor surface-water flow, groundwater levels, and

[30] Cal. Water Code §§ 1200-1201. http://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=1200.&lawCode=WAT. For further discussion, see Gary Bryner and Elizabeth Purcell, *Groundwater Law Sourcebook of the Western United States*, Natural Resources Law Center, University of Colorado School of Law, September 2003, p. 17, at http://www2.cde.state.co.us/artemis/ucbmonos/UCB6582G892003INTERNET/. *Prior appropriation water law* holds that the first party to put the water to beneficial use has a right to continue to do so, and those who appropriate water afterward have junior rights (also known as *first in time, first in right* water law).

[31] In 2014, California enacted three bills addressing groundwater, collectively termed the Sustainable Groundwater Management Act (SGMA). Language in the SGMA appears to preserve existing groundwater rights within the goal of sustainable management of groundwater. For example, §1(b)(4) of AB 1739 (one of the three bills within SGMA) notes that it is the intent of the legislature to "respect overlying and other proprietary rights to groundwater, consistent with section 1200 of the Water Code."

[32] Gary Bryner and Elizabeth Purcell, *Groundwater Law Sourcebook of the Western United States*, Natural Resources Law Center, University of Colorado School of Law, September 2003, p. 15.

[33] For more information on the roles of the agencies, see the below section, "Federal Activities and Authorities."

[34] USGS, "USGS Groundwater Information: USGS Groundwater Science for a Changing World," at https://water.usgs.gov/ogw/about/.

water quality across the nation. The database includes long- and short-term records from more than 850,000 groundwater measurement sites.[35]

Other agencies, such as the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), make observations and collect data that also are relevant to groundwater monitoring and assessment. Earth-observing satellites that detect changes in gravity, for example, can help link those changes to losses or gains in the volume of groundwater due to pumping or recharge. NOAA's estimation of drought severity throughout the country, as expressed in the U.S. Drought Monitor,[36] includes the estimation of the effects of drought on groundwater supplies. The U.S. Department of Agriculture (USDA) also collects irrigation data, including information on wells, characteristics of aquifers used for irrigation supply, and quantities of water applied from wells.[37]

### Legislation

Three bills listed in **Table 1** contain some provisions regarding groundwater monitoring or groundwater studies. S. 714 includes a provision to authorize feasibility analyses and environmental reviews of water supply, including groundwater, as part of the Yakima River Basin Enhancement Project. H.R. 23 would authorize a geophysical survey by Reclamation, in cooperation with the USGS, the state of California, and local and state water agencies to characterize aquifer systems and groundwater vulnerability in California. H.R. 3275 would require the Secretary of the Interior to conduct a study on the potential impacts of Reclamation projects on groundwater resources. The legislation would also require the Secretary to determine groundwater levels at Reclamation projects currently and going back 10 years, and to require the USGS to establish a groundwater information program based on those data "for the purpose of advancing the availability, timely distribution, and widespread use of groundwater data for groundwater management, education, research, assessment, and monitoring purposes."

## Primer on Groundwater

Groundwater science has advanced markedly in the last century; this primer presents an introduction to fundamental concepts relevant to groundwater use, management, and recharge.

Groundwater is found in aquifers. An aquifer is composed of (1) solid materials, such as rocks and mineral grains; (2) interconnected spaces or openings (*pore space*); and (3) groundwater, which completely fills the pore space (**Figure 2**). Strictly speaking, an aquifer is sufficiently permeable (i.e., groundwater can move readily through the interconnected pores) to transmit economic quantities of water to wells or springs.[38] In other words, if a farmer drills a well into a water-bearing layer of rock or sediments (sometimes called a *formation*) and can pump sufficient quantities of groundwater to irrigate crops, water livestock, or use for drinking water and washing, then that formation can be considered an aquifer. If the same farmer drilled a well but could not pump enough water to satisfy any needs, then the formation would not be considered an aquifer.

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[35] See, for example, USGS, "USGS Groundwater Watch," at https://groundwaterwatch.usgs.gov/.

[36] See United States Drought Monitor at http://droughtmonitor.unl.edu/.

[37] The U.S. Environmental Protection Agency (EPA) plays a significant role in matters related to groundwater quality. EPA activities in that area are beyond the scope of this report.

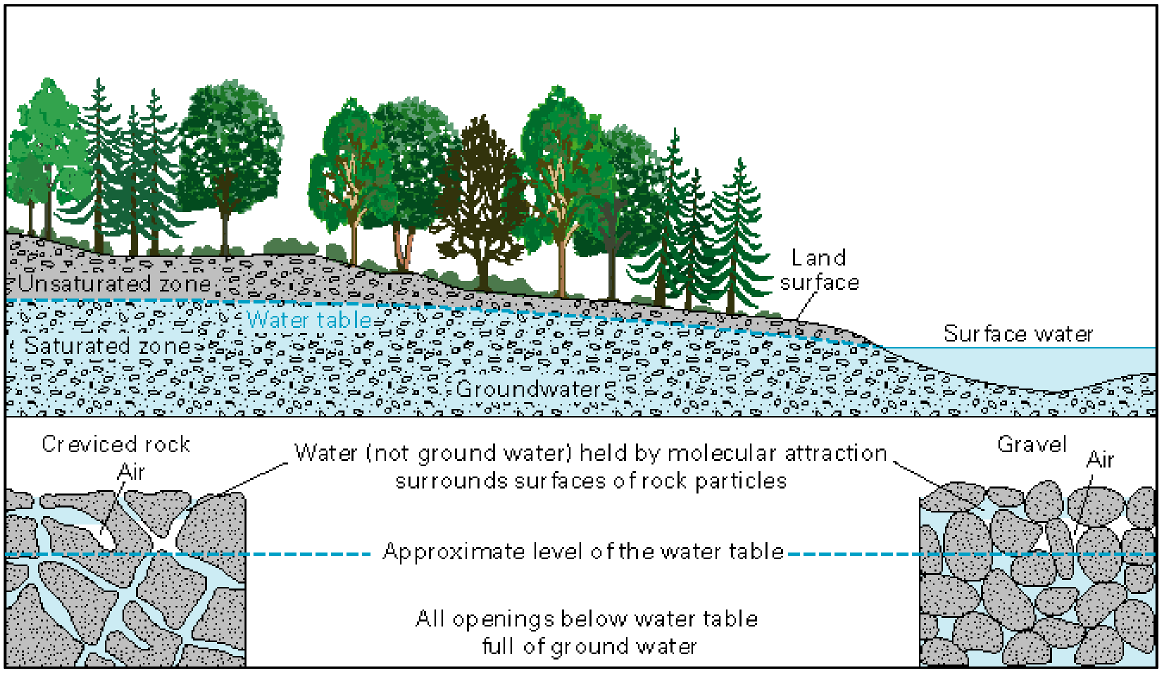
[38] C. W. Fetter, "Glossary," in *Applied Hydrogeology*, 2nd ed. (Columbus, OH: Merrill Publishing Company, 1988), p. 565.

## Types of Aquifers

There are two principal types of aquifers: unconfined and confined. An *unconfined aquifer* is one in which the water table moves up and down freely without an overlying confining layer (see **Figure 2**).[39]

**Figure 2. Unconfined, or Water Table, Aquifer**

(illustrating two types of pore space)



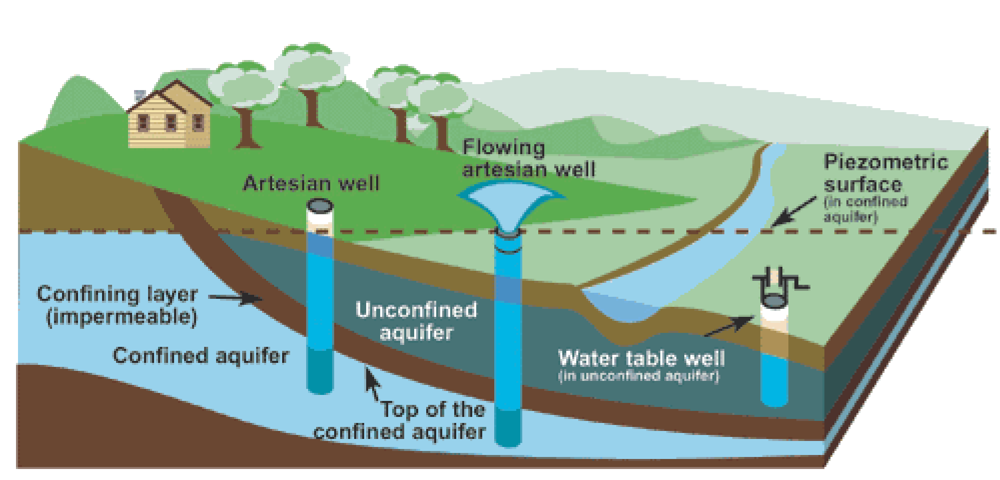

**Source:** USGS, USGS Water Science School, "Aquifers and Groundwater," at https://water.usgs.gov/edu/earthgwaquifer.html. (Modified by CRS.)

**Notes:** Above the water table, the pores may contain water but are not completely full. Only the saturated zone below the water table is considered the aquifer.

A *confined aquifer*, in contrast, is an aquifer overlain (and sometimes underlain) by an impermeable or confining layer that the water does not freely move above. The confining beds cause the aquifer to be under pressure. As a result, when a well penetrates a confined aquifer, the water will rise above the top of the aquifer, sometimes all the way to the land surface (the latter case is referred to as an *artesian aquifer*), as shown in **Figure 3**.

39 A *confining layer* is a bed or strata composed of relatively impermeable materials, such as clay, so that groundwater flow through the layer is impeded or significantly restricted. The ability of a bed or strata to conduct groundwater flow is referred to as *hydraulic conductivity*. A confining layer would have a low hydraulic conductivity compared to an aquifer.

**Figure 3. Different Types of Aquifers and Wells**




**Source:** Government of Canada, Environment and Natural Resources, "Water Sources: Groundwater," at https://www.canada.ca/en/environment-climate-change/services/water-overview/sources/groundwater.html.

**Notes:** The piezometric surface in the figure refers to an imaginary line that corresponds to where the water level in the confined aquifer would rise if not for the impermeable confining layer. It also corresponds to the water level in the artesian wells shown in the figure.

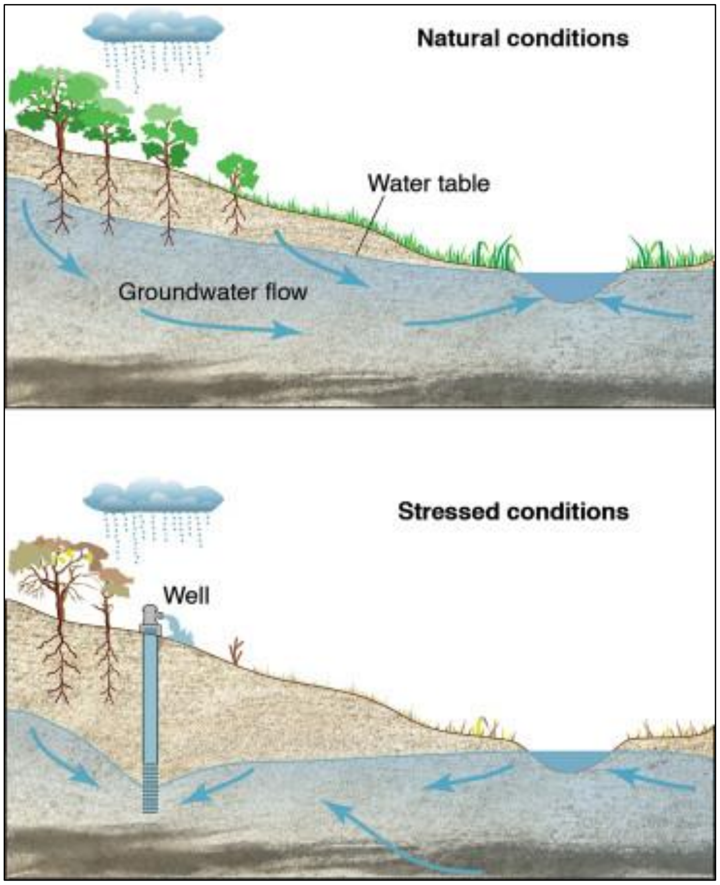
The distinction between unconfined and confined aquifers is important for this discussion, as the technique of groundwater recharge, storage, and recovery differs depending on what kind of aquifer is involved. Because a confining layer or layers separates a confined aquifer from surface water bodies, the degree of connection between surface water and groundwater is not as direct or distinct as it is for unconfined aquifers.[40] Groundwater recharge can occur naturally in confined and unconfined aquifers as water moves downward from the land surface into the aquifer from rain and melting snow, lakes, river, and streams. For unconfined aquifers, other sources of recharge water can include built impoundments, such as reservoirs; unlined irrigation ditches and canals; and applied irrigation water not consumed by crops. In a system of managed *artificial recharge*, water can be added deliberately to a confined or unconfined aquifer by using an injection well; by spreading water across the land surface, where it can trickle down into an unconfined aquifer; or by building an impoundment to temporarily store water and allow it to leak through the bottom down to an unconfined aquifer.

The distinction between an unconfined and a confined aquifer also is important for understanding the connection between surface water and groundwater. In **Figure 3**, the confined aquifer is separated from the river by a confining layer, so that changes in river flow will not directly affect groundwater in the confined aquifer and flow from the artesian wells will not directly affect flow in the river. In **Figure 4**, by contrast, the unconfined aquifer is connected directly to the stream. Under natural conditions, the groundwater will flow toward and feed the stream (top panel) because the slope of the water table is toward the top of the stream level. However, sometimes when aquifers are subject to excessive pumping—during drought conditions, for example, or because of a lack of surface water availability—they are said to be under stress. Under stressed conditions (bottom panel of **Figure 4**), pumping from a well will cause the water table to slope

[40] Decades of groundwater development involving hundreds or thousands of wells in some agricultural regions of the United States, such as California's Central Valley, sometimes has led to interconnections between the unconfined and confined aquifers. Wells penetrating the confining layer above the confined aquifers can serve as conduits for groundwater to flow up or down. See, for example, Claudia C. Faunt et al., *Groundwater Availability of the Central Valley Aquifer, California*, USGS, Professional Paper 1766, 2009, pp. 85-86.

away from the top of the stream. In that case, the water in the stream will leak through the stream bottom and flow into the aquifer, toward the pumping well.

**Figure 4. Unconfined Aquifer Without Pumping (top) and With Pumping (bottom)**

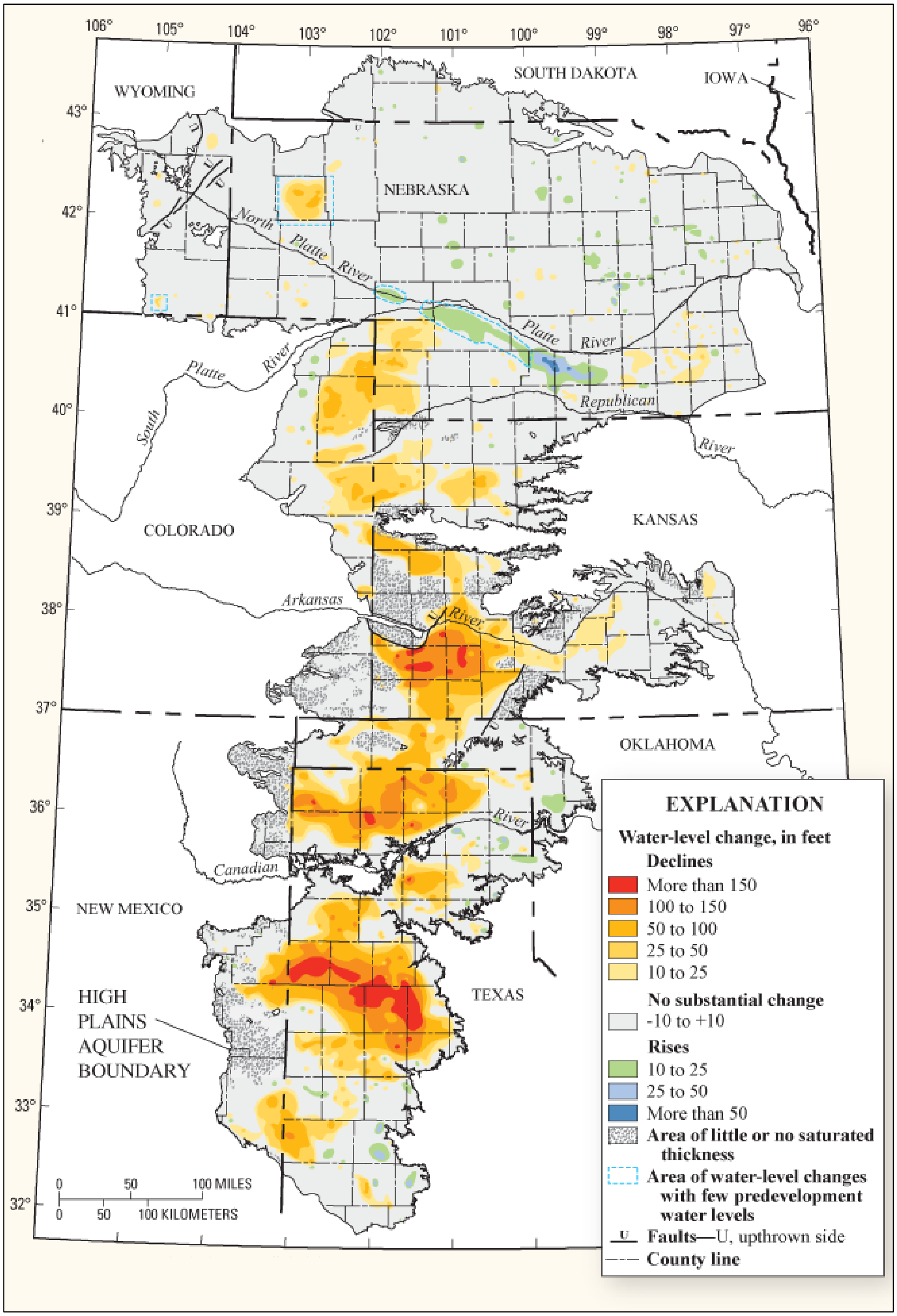



**Source:** Steven M. Gorelick and Chunmiao Zheng, "Global Change and the Groundwater Management Challenge," Water Resources Research, vol. 51, March 28, 2015 (with permission).

**Notes:** Under natural conditions in this particular case, groundwater flows toward the stream (arrows indicate direction of groundwater flow) and the water table is high enough to be accessible to trees and plants. During pumping, when the aquifer is stressed, water flows from the stream into the aquifer and toward the well. Also, the water table under stressed conditions drops below the roots of trees and plants depicted in the figure, affecting their growth.

Consistently stressed conditions can have dramatic long-term effects on groundwater. If pumping continues in excess of recharge, increasing stress on the aquifer, the water table may drop tens to hundreds of feet (**Figure 5**). This situation has occurred in many regions of the United States, including the Ogallala aquifer (also called the High Plains aquifer) in the Midwest and in California's Central Valley. In the Central Valley, historical levels of pumping caused the water table to drop so far in some areas that it caused the land surface to drop, or subside, nearly 30 feet (**Figure 6**). Excessive land subsidence can harm surface structures, such as canals and levees.

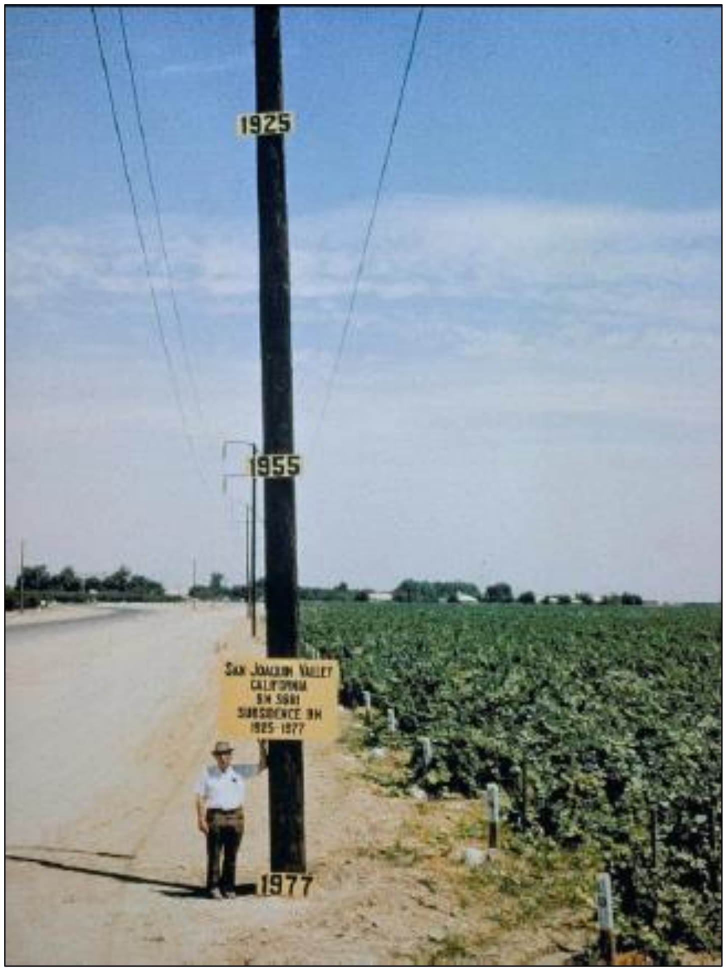
**Figure 5. Water Level Changes in the High Plains Aquifer, Predevelopment to 2007**




**Source:** V. L. McGuire, "Changes in Water Levels and Storage in the High Plains Aquifer, Predevelopment to 2007," USGS, Fact Sheet 2009-3005, February 2009. (Modified by CRS.)

**Note:** *Predevelopment* refers to approximately 1950.

**Figure 6. Land Subsidence in the San Joaquin Valley Southwest of Mendota Between 1925 and 1977**




**Source:** Devin Galloway et al., "Land Subsidence in the United States," USGS Circular 1182, 1999, p. 23, at http://pubs.usgs.gov/circ/circ1182/pdf/06SanJoaquinValley.pdf.

**Note:** Approximate location of the maximum land subsidence in the United States, showing the approximate relative position of the land surface in 1925, 1955, and 1977.

# Federal Activities and Authorities

The federal government directly and indirectly influences how groundwater is managed in the United States. Several federal agencies monitor groundwater directly or with partners—through measurements at wells and springs—and remotely using satellites or other remote sensing devices to provide information on groundwater flow, storage, depletion, and other characteristics that help inform state and local groundwater management. These include the U.S. Geological Survey (USGS), the National Aeronautics and Space Agency (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA). Congress has provided other federal agencies with the authority to make water delivered from or water stored at federal water resource projects available for groundwater recharge, storage, and recovery. These include the two principal federal water resources agencies: the U.S. Army Corps of Engineers (which operates nationwide) and the U.S. Bureau of Reclamation (which operates in the 17 coterminous states west of the Mississippi River).

Additionally, when the federal government reserves lands for a particular purpose (such as for a tribal reservation or national monument), it impliedly reserves a right to water necessary to accomplish the purposes for which the reservation was created. That federal reserved water rights doctrine has long been recognized for surface water; more recently, it is also being considered for groundwater. (See discussion under "Groundwater Rights.")

## Groundwater Monitoring and Assessment

Federal agencies that have no regulatory role in managing groundwater nonetheless collect data, make observations and assessments, and provide information on groundwater supplies that supports decisionmakers at the state and local levels. USGS likely provides the most direct groundwater information and support for groundwater management among the federal agencies, although NASA and NOAA also make pertinent observations and distribute groundwater-relevant information. USDA also collects groundwater data related to irrigation. Selected activities within those four agencies are briefly summarized below.

### U.S. Geological Survey

The Groundwater and Streamflow Information Program, within the USGS water resources mission area, funds activities that provide information directly relevant to groundwater management. About 11% ($7.6 million in FY2018) of the approximately $71 million program is directed at groundwater-related activities, including the National Groundwater Monitoring Network (NGWMN).[41] The NGWMN is a compilation of selected groundwater monitoring wells from federal, state, and local monitoring networks across the country. Data from the network are accessible through a portal that contains current and historical data.[42] USGS administers the program through cooperative agreements; in FY2018, Congress provided $3.9 million to USGS to fund the network, the same as the FY2017-enacted amount.[43]

USGS also maintains a distributed groundwater database, the USGS Groundwater Watch. It is locally managed and contains data from more than 850,000 wells compiled over the past 100 years. The long-term and distributed nature of the data is valuable to groundwater managers seeking information about regional groundwater trends over time. **Figure 7** shows an example of one of the products updated daily from groundwater well information within the database.

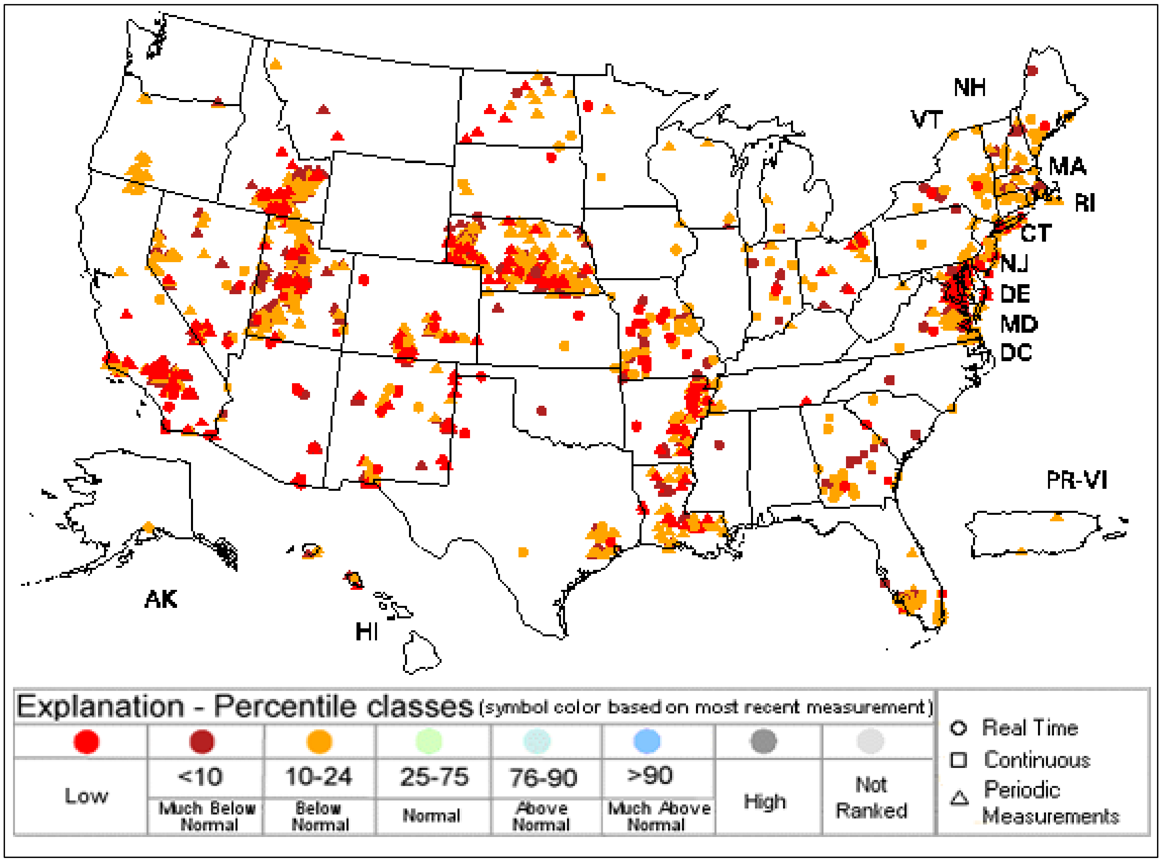
[41] Email from Elizabeth Goldbaum, USGS Congressional Affairs, April 12, 2018.

[42] Advisory Committee on Water Information, "National Ground-Water Monitoring Network," at https://cida.usgs.gov/ngwmn/index.jsp.

[43] Ibid. The FY2018 amount is as enacted in P.L. 115-141, the Consolidated Appropriations Act, 2018. The FY2017 amount was provided per email from Elizabeth Goldbaum, USGS Congressional Affairs, April 12, 2018.

**Figure 7. Below-Normal Groundwater Levels for Actively Monitored Wells**

(data from 3,855 wells)




**Source:** USGS, "Groundwater Watch," at https://groundwaterwatch.usgs.gov/net/ogwnetwork.asp?ncd=lwl. (Modified by CRS.)

**Notes:** Below-normal means that the wells shown in red or orange had groundwater levels at the 24th percentile or lower for the month the well was measured, compared to the entire period of record for the well. In other words, if the well has been measured for 50 years, it would be shown on this map if the water level was lower than 75% of the measurements taken over the past 50 years. Red dots indicate wells lower than the 10th percentile; orange shows wells at the 10th-24th percentile.

In addition to collecting and providing data, USGS conducts regional groundwater studies, such as assessing the groundwater availability in the Central Valley aquifer in California,[44] and national overviews, such as the *Ground Water Atlas of the United States*.[45] Several observers have suggested that although groundwater generally is locally managed in the United States, regional studies (such as those conducted by USGS) are important for documenting the status and trends of groundwater availability, as these trends affect local groundwater resources, particularly when changes in an aquifer occur beyond the local or state political boundaries.[46]

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[44] C. C. Faunt et al., *Groundwater Availability of the Central Valley Aquifer, California*, USGS, USGS Professional Paper 1766, 2009, at https://pubs.usgs.gov/pp/1766/.

[45] James A. Miller et al., *Ground Water Atlas of the United States*, USGS, 2000, at https://water.usgs.gov/ogw/aquifer/atlas.html.

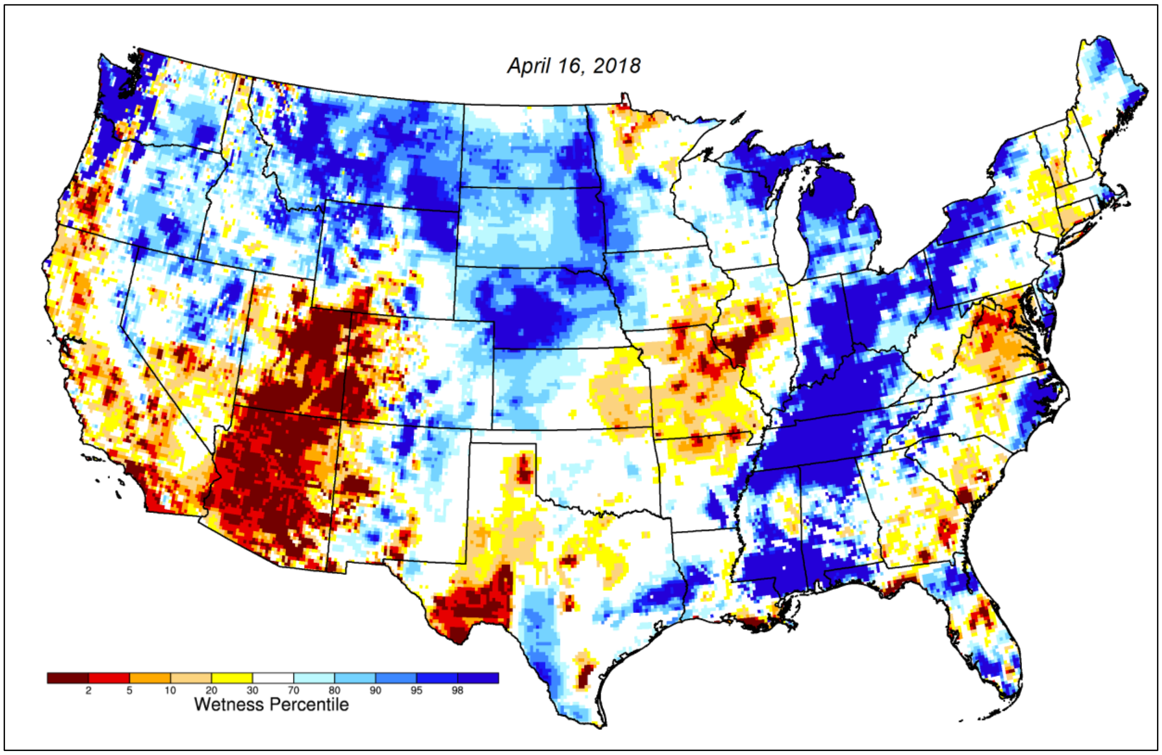
[46] See, for example, K. F. Dennehy, T. E. Reilly, and W. L. Cunningham, "Groundwater Availability in the United States: The Value of Quantitative Regional Assessments," *Hydrogeology Journal*, vol. 23, no. 8 (December 2015), pp.

## NASA

Earth-observing satellites can provide information to assess changes in the amount of groundwater stored in large aquifers; variations in the amount of soil moisture; and tiny fluctuations in land elevation that reflect how the water table is moving up and down.

Using data from NASA's GRACE and SMAP satellites,[47] integrated with other observations, scientists can analyze shallow groundwater and soil moisture levels that reflect drought conditions across the United States (**Figure 8**).

**Figure 8. Shallow Groundwater and Soil Moisture Comparison from NASA Satellite Data**




**Source:** The National Drought Mitigation Center, "Groundwater and Soil Moisture Conditions from GRACE Data Assimilation," at http://nasagrace.unl.edu/Default.aspx. (Modified by CRS.)

**Notes:** Map shows wet or dry conditions relative to the probability of occurrence using the baseline period from 1948 to 2012, expressed as a percentile. The lower values in the warmer colors indicate drier-than-normal conditions (30th percentile or less), and the cooler colors indicate wetter-than-normal conditions (70th percentile or more). Areas in white express 31st-69th percentile, spanning the midpoint of 50th percentile (the 50th percentile indicates that half the values are higher and half are lower).

Data from the GRACE satellite also have been interpreted to show changes in the amount of groundwater held in storage in large, regional aquifers, such as the Central Valley aquifer in California, the High Plains aquifer in the Midwest, and other large aquifers around the world.[48]

1629-1632; and Roland Barthel, "A Call for More Fundamental Science in Regional Hydrogeology," *Hydrogeology Journal*, vol. 22, no. 3 (May 2014), pp. 507-510.

[47] GRACE stands for Gravity Recovery and Climate Experiment satellite (see https://www.nasa.gov/mission_pages/Grace/index.html); SMAP stands for Soil Moisture Active Passive satellite (see https://smap.jpl.nasa.gov/).

[48] See, for example, NASA, Jet Propulsion Laboratory, "GRACE Tellus: Groundwater," at https://grace.jpl.nasa.gov/

One study using GRACE data indicated that the volume of groundwater in the Central Valley aquifer pumped out over a 78-month period was equivalent to nearly the capacity of Lake Mead.[49]

Scientists can use a special type of radar data collected by satellites using a technique called synthetic aperture radar interferometry to detect minute changes in the land-surface elevation caused when the water table moves up and down. In one study, NASA scientists and others used the technique to track how the aquifer in the Santa Clara Valley, California, recovered following depletion during a drought when conservation measures were put in place to limit groundwater pumping.[50] In that study, a cluster of Italian satellites provided the radar data; and NASA is planning a joint mission with the Indian Space Research Organisation in 2021 that will collect radar imagery of nearly every major aquifer in the world.[51]

## NOAA

NOAA coordinates and integrates drought research and forecasting from federal, state, tribal, local, and academic sources through the National Integrated Drought Information System. NOAA uses data from these and other sources to create drought maps, seasonal outlooks, and other drought indicators, including effects of drought on groundwater.[52] A typical U.S. Drought Monitor map, for example, indicates which regions of the country are experiencing short- and long-term impacts from drought. Long-term-impacted regions mean that drought has affected the region's hydrology, including groundwater resources.

NOAA's constellation of both geostationary and polar-orbiting weather satellites provides real-time atmospheric weather data that can be used to better understand the hydrologic cycle in regions across the country. The satellite data contribute to short- and long-term forecasts of precipitation that, for example, can inform groundwater models and other tools about water available for groundwater recharge. NOAA data from satellites and ground-based observing systems also feed into longer-term climate forecasts and climate models, which can be used to help understand the potential effects of climate change on groundwater supplies.

## USDA

The Census of Agriculture is required by law and authorizes the Secretary of Agriculture to conduct surveys deemed necessary to furnish annual or other data on the subjects covered by the census.[53] The census is a broad survey that includes questions about irrigation and water use, and is conducted every five years. A more detailed national assessment of irrigated agriculture in the United States is the Farm and Ranch Irrigation Survey (FRIS), also conducted every five years,

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applications/groundwater/.

49 About 31 cubic kilometers, or 6.8 trillion gallons. See J. S. Famiglietti et al. (2011), *Satellites Measure Recent Rates of Groundwater Depletion in California's Central Valley*, Geophys. Res. Lett., 38, L03403, at doi:10.1029/2010GL046442.

50 Estelle Chaussard et al., "Remote Sensing of Ground Deformation for Monitoring Groundwater Management Practices: Application to the Santa Clara Valley During the 2012-2015 California Drought," *Journal of Geophysical Research-Solid Earth*, vol. 122, no. 10 (September 21, 2017), pp. 8566-8582.

51 See, for example, NASA, Jet Propulsion Laboratory, "Satellites See Silicon Valley's Quick Drought Recovery," October 3, 2017, at https://www.jpl.nasa.gov/news/news.php?feature=6962.

52 See National Integrated Drought Information System (NIDIS), "What Is NIDIS?," at https://www.drought.gov/drought/what-nidis.

53 7 U.S.C. 2204g et seq.

and usually two or three years after the general census and under the same authority.[54] The most recent FRIS (2013), conducted by the National Agricultural Statistics Service in USDA, supplemented the basic irrigation data collected from all farm and ranch operators in the 2012 census.[55] The 2017 Census of Agriculture is currently under way.

## Federal Authority Related to Groundwater Recharge, Storage, and Recovery

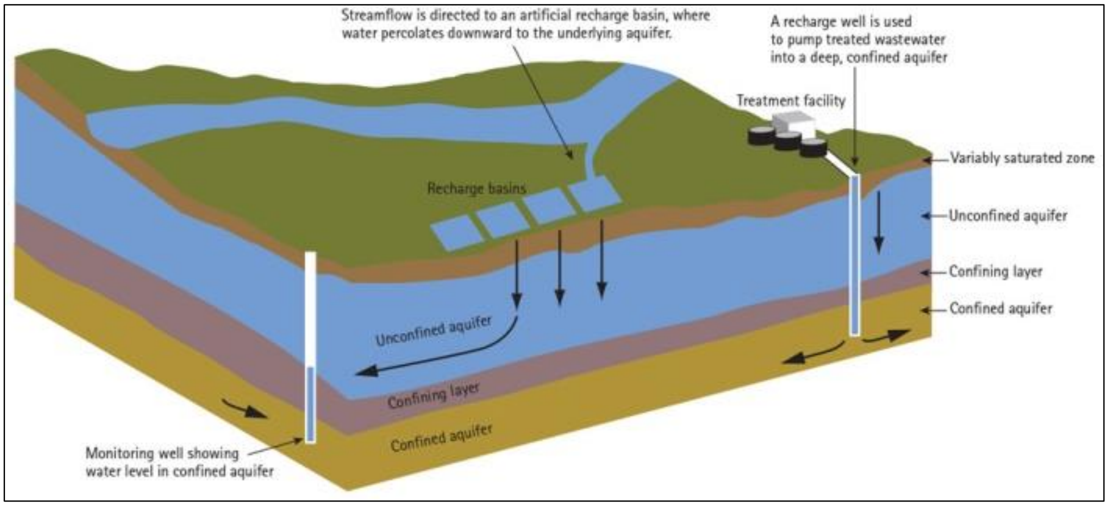
Recharging groundwater artificially with surface water is not a new concept, but interest in the practice is growing at the local, state, and federal levels for several reasons. When surface water supplies are curtailed because of drought, diversion for other uses, regulatory constraints, or other reasons, groundwater is often used to meet the demand. In addition, if demand for water supplies increases and additional surface water is not available, consumers may turn to groundwater. Along the coastline, groundwater extraction and the lowering of the water table sometimes have resulted in saltwater intrusion into the aquifer. Groundwater recharge may be used in those cases to replenish the aquifer and create a freshwater barrier to prevent seawater encroachment. Groundwater recharge, storage, and recovery also may be part of a conjunctive water management strategy in which both surface and groundwater are used, recharging groundwater in times of surface water surplus and extracting groundwater when surface water is in short supply.

Typically, groundwater recharge, storage, and recovery involves either injecting water into the aquifer from a well or allowing water to recharge from an impoundment (e.g., a pond) or a spreading basin (water is spread on the ground to percolate down to the aquifer). The water is stored in the aquifer until it is recovered by a pumping well for freshwater supply. **Figure 9** illustrates the process.

[54] For more information on the most recent Farm and Ranch Irrigation Survey (FRIS), see U.S. Department of Agriculture, Census of Agriculture, "2013 Farm and Ranch Irrigation Survey," at https://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/.

[55] The FRIS differs from the USGS water use estimates report in methodologies and reporting schedules and should not be compared directly. See footnote 6.

**Figure 9. Groundwater Recharge, Storage, and Recovery**




**Source:** National Groundwater Association (NGWA),"Managed Aquifer Recharge: A Water Supply Management Tool," NGWA Information Brief, 2014 (with permission). (Modified by CRS.)

**Notes:** The figure shows how the aquifer is recharged from a recharge well (on the right) and from recharge basins (middle of the figure). The recharge well is recharging a confined aquifer, and the recharge basins are recharging an unconfined aquifer.

According to several sources, more than 1,000 aquifer recharge wells and aquifer storage and recovery wells, along with many recharge basins, have been constructed across the nation.[56] In addition to technical, economic, and regulatory issues, identifying and providing a source of water for these activities is critical. Increasingly, federal water resource projects such as those managed by Reclamation and USACE are being considered as potential sources of recharge water. This section identifies federal authorities for groundwater storage, recharge, and recovery. CRS studied the *U.S. Code* for authorities and gathered information from Reclamation and USACE staff.

## Bureau of Reclamation

The Bureau of Reclamation, a federal agency of the Department of the Interior, owns and operates hundreds of dams and water diversion structures projects in the 17 coterminous U.S. states west of the Mississippi River. Reclamation was created by Congress in the Reclamation Act of 1902,[57] which authorized the Secretary of the Interior to construct irrigation works in western states. In addition to water supply, Reclamation facilities also provide flood control, recreation, and fish and wildlife benefits.[58] Reclamation cites several authorities for groundwater activities, including the authority to deliver project and excess water for aquifer storage and recharge and

[56] See, for example, U.S. Environmental Protection Agency, Underground Injection Control, "Aquifer Recharge and Aquifer Storage and Recovery," at https://www.epa.gov/uic/aquifer-recharge-and-aquifer-storage-and-recovery#inventory; and National Groundwater Association, "Aquifer Storage and Recovery: Need for Critical Analysis of the Technical, Economic, and Regulatory Issues," at http://www.ngwa.org/Media-Center/issues/Pages/Aquifer-storage-and-recovery.aspx.

[57] Act of June 17, 1902 (ch. 1093, 32 Stat. 388).

[58] For a brief synopsis of Reclamation project authorization and financing, see CRS In Focus IF10806, *Bureau of Reclamation Project Authorization and Financing*, by Charles V. Stern.

the authority to provide financial support for these activities. These authorities are discussed below.

### Reclamation Authority to Deliver Project or Excess Water for Groundwater Use

Overall, Reclamation reports no federal restrictions on its authority to deliver project or excess water for groundwater recharge, and contractors using these waters for groundwater recharge are not required to seek any special approvals beyond what is normally required by Reclamation. However, DOI officials also have acknowledged that Reclamation's existing authorities for groundwater use are general in nature, and increased specificity of these authorities may be useful.[59] Reclamation also reports that some state restrictions affect the use of these waters for groundwater activities. In general, Reclamation does not track the use of project or excess water for groundwater recharge, although these uses appear to be occurring in at least a few places.

- Section 9 of the Reclamation Project Act of 1939 (43 U.S.C. §485) is the general authority by which Reclamation is authorized to enter into contracts to furnish water for irrigation, municipal, and miscellaneous water supply purposes. Reclamation interprets the purposes of deliveries under this section to include groundwater recharge.
- Section 215 of the Reclamation Reform Act of 1982 (P.L. 97-293) is the authority Reclamation uses to enter into temporary water service contracts for un-storable or excess flood flows. Reclamation indicates that it has no restrictions on using these waters for groundwater recharge.
- Section 101(d) of the Reclamation States Emergency Drought Relief Act of 1991 (P.L. 102-250) authorizes Reclamation to participate in state-established *water banks* to respond to drought.[60]
- Section 3408((c), (d), and (e)) of the Central Valley Project (CVP) Improvement Act of 1992 (P.L. 102-575) authorize the *banking* of CVP water, consistent with and subject to state law.

### Reclamation Authority to Provide Financial Support for Groundwater Storage

- Title IX, Subtitle F (Secure Water), Section 9504 (Water Management Improvement) of the Omnibus Public Land Management Act of 2009 (P.L. 111-11) authorizes Reclamation to provide financial assistance through the WaterSMART program for groundwater projects.[61]
- Title III, Section 4007(c) of the Water Infrastructure Improvements for the Nation Act (WIIN Act; P.L. 114-322) authorizes Reclamation to participate in state-led storage projects, which are defined to include groundwater storage facilities, among other facility types.

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[59] Statement of Timothy Petty, Assistant Secretary for Water and Science, U.S. Department of the Interior, before the U.S. Congress, Senate Committee on Energy and Natural Resources, *Full Committee Hearing to Examine the 2018 Western Water Supply Outlook and Bills Related to Water Infrastructure and Drought Resiliency*, 115th Cong., 2nd sess., March 22, 2018.

[60] *Water banking* generally means the temporary storage of water in an aquifer for later extraction and use. See U.S. Bureau of Reclamation, *Groundwater Banking Guidelines for Central Valley Project Water* (under P.L. 102-575 §3408(d)), November 12, 2014, at https://www.usbr.gov/mp/waterbanking/docs/water-banking-guidelines.pdf.

[61] For more information on the WaterSMART program, see U.S. Bureau of Reclamation, "WaterSMART (Sustain and Manage America's Resources for Tomorrow)," at https://www.usbr.gov/watersmart/.

- Title III, Section 4009(a) of the WIIN Act amended the Water Desalination Act of 1996 (P.L. 104-298) to authorize Reclamation to provide financial support for projects that involve the desalination of brackish groundwater.
- Reclamation's Title XVI program (Title XVI of P.L. 102-575) provides Reclamation the authority to implement water recycling and reuse projects, which may include projects that recycle and reuse impaired groundwater.

## U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers, an agency within the Department of Defense, has both military and civil works responsibilities. Congress directs USACE's civil works activities through authorizations, appropriations, and oversight of the agency's study, construction, and ongoing operations of water resource projects. Its civil works responsibilities are to support coastal and inland commercial navigation, reduce riverine flood and coastal storm damage, and protect and restore aquatic ecosystems in U.S. states and territories. In undertaking projects for these purposes, USACE also may pursue additional project benefits related to water supply, hydropower, recreation, fish and wildlife enhancement, and other purposes. That is, USACE projects typically have navigation, flood control, and/or aquatic ecosystem restoration as a primary purpose; other purposes and benefits are generally secondary or incidental. Therefore, USACE projects may support groundwater recharge, but generally recharge is not the primary purpose or justification for the projects. Moreover, USACE activities generally are in support of, rather than a direct performance of, aquifer recharge; that is, how USACE operates its projects may affect how others perform groundwater recharge or may affect the water demand that is met by water stored at USACE reservoirs or by groundwater pumping.[62]

USACE water resource projects typically are for nonconsumptive water uses (e.g., dam that stores water to reduce the peak flow of a river during flood conditions), with a few specifically authorized exceptions; thus, the federal government generally has not acquired water rights from states for USACE projects. To access project water for water supply purposes, including groundwater recharge activities, nonfederal entities are responsible for securing any water rights pursuant to state law. USACE generally does not deliver water under contract, in contrast to Reclamation; instead, USACE provides storage at its reservoirs as a nonconsumptive service. USACE has some, albeit constrained, flexibility and authorities to operate its projects to benefit groundwater recharge.[63] That is, USACE projects with purposes of *water conservation* or *water supply storage* may be able to be operated in ways that support recharge.[64]

Prior to the WIIN Act in 2016, USACE had no general authority to include storage space in USACE projects for seasonal operations for water conservation that would benefit municipal and

[62] The effect that USACE projects may have on altering hydrology in a basin, including natural recharge in the floodplain, is beyond the scope of this report.

[63] CRS did not identify any federal restrictions on the use of water released from or water withdrawn from USACE reservoirs for groundwater recharge, as long as that use is consistent with state law (i.e., the entity capturing the water has a right to use the water pursuant to state law) and federal environmental protection laws (e.g., the Safe Drinking Water Act). USACE does not track whether water released from or water withdrawn from USACE reservoirs is used for recharge.

[64] Some USACE aquatic ecosystem restoration projects may have components that relate to groundwater (e.g., aquifers may provide minimum flows into certain streams during low-water conditions). Given this report's focus on the consumptive social uses of groundwater, USACE groundwater-related ecosystem restoration projects and authorities are not discussed further in this report.

industrial (M&I) water supply.[65] Notwithstanding those projects with specific authorization for water conservation, USACE policy and procedures indicated that seasonal operations for water supply could be conducted insofar as they were consistent with authorized project purposes and law and subject to hydrologic and hydraulic capability of the project. This water supply could be used to enhance groundwater replenishment, to increase downstream flow, or to otherwise enhance the general usage of the project for M&I purposes. Also, USACE has two long-standing general authorities related to M&I water supply: a surplus water authority and a water supply authority for permanent reallocations of storage at a reservoir.[66]

Title I of the WIIN Act addressed seasonal operation for water conservation and groundwater recharge in three sections:[67]

- **Section 1116**: In a state with a drought emergency between December 2015 and December 2016, the Secretary of the Army is authorized to evaluate and carry out water supply conservation measures, including releases for groundwater replenishment or aquifer storage and recovery.
- **Section 1117**: In a state with a drought emergency between December 2015 and December 2016, upon the request of the governor, the Secretary of the Army is authorized to prioritize the updating of the water control manuals for control structures in the state and incorporate into the update seasonal operations for water conservation and water supply for such control structures.
- **Section 1118**: At the request of a nonfederal interest, the Secretary of the Army may review proposals (except those involving a few excluded river basins) to increase the quantity of available water supplies at a federal water resources development project by modifying the project, modifying how the project is managed, or accessing water released from the project. Among other things, proposals may include diversion of water released or withdrawn from the project to recharge groundwater or for aquifer storage and recovery.
- As with other aspects of USACE reservoir operations, the storage or release of water to support nonfederal recharge activities pursuant to these authorities is to be consistent with the USACE project's congressionally authorized project purposes and subject to the project's capability.

## USDA

USDA does not have a federal mandate to control groundwater use, recharge, storage, or recovery on private agricultural lands. The disproportionate percentage of groundwater usage by agriculture relative to other industries, however, has led USDA to take an active role in research, conservation, and education related to groundwater and its agriculturally connected uses.

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[65] USACE Institute for Water Resources, *Comprehensive Water Supply Study*, September 2001, at http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/01-PS-1.pdf;USACE, *Planning Guidance Notebook*, ER 1105-2-100, April 22, 2000, at http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1105-2-100.pdf.

[66] For more on these authorities and how they are used, see CRS Report RL30478, *Federally Supported Water Supply and Wastewater Treatment Programs*, coordinated by Jonathan L. Ramseur.

[67] USACE has published implementation guidance for each of the WIIN Act provisions discussed below; they are available at http://www.usace.army.mil/Missions/Civil-Works/Project-Planning/Legislative-Links/wrda2016/wrda2016_impguide/.

### *Conservation of Groundwater*

USDA provides agricultural producers with financial and technical assistance, as well as research to conserve on-farm water use. A number of USDA agencies provide support through education, outreach, and research in addition to providing direct federal assistance for adoption of on-farm irrigation best management practices. For more information on irrigation in the United States and related best management technologies, see CRS Report R44158, *Irrigation in U.S. Agriculture: On-Farm Technologies and Best Management Practices*.

Financial assistance for irrigation conservation practice adoption is primarily authorized through omnibus farm bills. Most recently, the 2014 Agricultural Act (2014 farm bill; P.L. 113-79) authorized a number of programs that provide cost-share assistance to private farm and ranch land owners to adopt water conserving practices. [68] Technical assistance, which includes planning and design of on-farm water conservation measures, can be provided either in connection with financial assistance or through a separate irrigation water management plan.[69] The primary USDA agency administering both financial and technical assistance is the Natural Resources Conservation Service.

USDA also conducts research into groundwater-related areas, such as irrigation technologies, plant water use efficiency, hydrologic connectivity, and source water protection, to name a few. Primary research activities are conducted either through the Agricultural Research Service, USDA's intramural research agency, or the National Institute of Food and Agriculture, which administers extramural funding to support agriculture-related science and research, primarily at state universities.

## Federal Reserved Rights to Groundwater

The federal government typically defers to states to allocate water resources within the state.[70] An exception has been the right to regulate water supplies on federal reservations, stemming from the U.S. Supreme Court decision in *Winters v. United States*.[71] Under the *Winters* doctrine, when Congress reserves land (e.g., for an Indian reservation), Congress also reserves water sufficient to fulfill the purpose of the reservation.[72] The *Winters* case specifically addressed the priority and extent of Indian reserved water rights, but the Supreme Court also recognized these rights in non-Indian contexts. In 1976, the Court noted that it "has long held that when the Federal Government withdraws its land from the public domain and reserves it for a federal purpose, the Government,

[68] For example, the Environmental Quality Incentives Program (EQIP) provides financial assistance to address natural resource concerns, including water conservation, under the general authorities established in §§1240-1240G of the Food Security Act of 1985 (P.L. 99-198), as amended (16 U.S.C. 3839aa et seq.).

[69] Most conservation technical assistance is provided by USDA under the general authorities of the Soil Conservation and Domestic Allotment Act (P.L. 74-46), as amended (16 U.S.C. §590a et seq.).

[70] Some legal scholars observe that the federal government has authority to regulate water resources, based on the Commerce Clause and the Property Clause of the U.S. Constitution. For further discussion, see, for example, John D. Leshy, "The Federal Role in Managing the Nation's Groundwater," *Hastings West-Northwest Journal of Environmental Law and Policy*, vol. 11, no. 1 (Fall 2004), p. 2.

[71] Winters v. United States, 207 U.S. 564, 575-77 (1908). Also, in United States v. New Mexico, the Supreme Court noted that "the 'reserved rights doctrine' is a doctrine built on implication and is an exception to Congress's explicit deference to state water law in other areas." United States v. New Mexico, 438 U.S. 696 (1978).

[72] For more information on rights stemming from Winters v. United States, see CRS Report RL32198, *Indian Reserved Water Rights Under the Winters Doctrine: An Overview*, by Cynthia Brown (available upon request).

by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation."[73]

Although the *Winters* doctrine has been applied to federal reserved water rights generally, the federal reserved rights for groundwater are more ambiguous than the rights for surface water. Tribal rights to groundwater, for example, have not been legally established to the same extent as rights to surface water (and other natural resources, such as timber, oil and gas, and minerals).[74] However, an ongoing legal case involving a Southern California Indian tribe's rights to groundwater under the *Winters* doctrine may establish those rights more specifically.[75]

# Climate Change and Other Long-Term Influences on Groundwater Supply

Long-term changes to the climate affecting the United States, particularly rising temperatures and changes in the patterns, quantities, and type of precipitation (i.e., rain versus snow), could affect the availability of groundwater in the future. Changes in temperature and precipitation could affect the amount of water that recharges aquifers and therefore could shape how much groundwater is available for irrigation, domestic water supply, and other uses. However, the amount of natural recharge is just one variable (albeit an important one) influencing groundwater supply—its amount and availability. In some important aquifers, such as the Central Valley aquifer in California, the largest portion of recharge comes from irrigation return flow: excess water applied to the crops that is not lost to evapotranspiration or runoff.[76] Changes in irrigation practices and technology could significantly alter irrigation return flow in the Central Valley. For example, more efficient irrigation would use less water for the same yield yet conversely would contribute less return flow as recharge to the aquifer.

Policies that would enable greater artificial recharge, such as current authorities at Reclamation and USACE or new authorities in pending legislation (see **Table 1**), also may create long-term changes to groundwater supply and availability. In addition, broad changes in water demand, such as a transition to less irrigation and more municipal use, could influence how groundwater is used. All of these factors complicate any precise projection of changes to U.S. groundwater supply. Data collected and distributed by the USGS, NASA, NOAA, and the USDA will likely improve the understanding of long-term trends in groundwater storage and use. The long-term trends can be assessed against the effects of climate change in the future.

## Climate Change and Groundwater Recharge

Intense global interest in greenhouse gas-influenced climate change prompted a number of studies investigating how a changing climate could affect groundwater, particularly the amount of water

[73] See Cappaert v. United States, 426 U.S. 128, 138 (1976).

[74] For more information on Indian water rights and water settlements, see CRS Report R44148, *Indian Water Rights Settlements*, by Charles V. Stern.

[75] CRS Legal Sidebar LSB10048, *Supreme Court Declines to Review Ninth Circuit Decision Applying Federal Reserved Water Rights Doctrine to Groundwater*, by Alexandra M. Wyatt.

[76] Thomas Meixner et al., "Implications of Projected Climate Change for Groundwater Recharge in the Western United States," *Journal of Hydrology*, vol. 534 (January 4, 2016), p. 127. Evapotranspiration is the combination of evaporation and respiration by plants.

available for recharging aquifers.[77] These studies have helped identify the many complexities involved in forecasting long-term consequences of climate change on groundwater supplies. Two broad review studies published in 2016 and 2017 are summarized below.

One study (by Meixner et al., 2016) synthesized the results of several other studies in an attempt to gauge the impacts of future climate change on the western United States (states west of the 100th meridian).[78] The study focused at the scale of major aquifers (specifically, eight aquifers),[79] because the study authors considered that global-scale studies are too broad to inform policymaking and local-scale studies do little to illuminate potential changes across larger regions, such as states, which are important for setting water policy. The western United States was selected because of the importance of groundwater in that area relative to the more humid east, with its more abundant supplies of surface water.[80]

A conclusion from the study is that a "wet gets wetter, dry gets drier" scenario may prevail in the West, meaning generally that the already arid southwest is predicted to become drier, reducing the availability of precipitation for recharge, and the northern portion of the western United States may get wetter, increasing the availability of water for recharge. However, even for regions experiencing wetter conditions, higher average temperatures in the future could cancel out some of the gains, because of higher evaporation and other effects. Mountain systems, in which snowpack plays an important role in water supply and recharge, are likely to provide less water because of lower precipitation (in the south, particularly) and because of a transition to less snow and more rain in the northern ranges. However, the study notes that the impacts of expected snow-to-rain shifts on groundwater are uncertain due to a lack of robust knowledge about mountain system aquifers.[81]

A finding in the Meixner et al. study was that knowledge gaps in forecasting changes in the frequency and intensity of future precipitation events will translate into uncertainty in predicting changes to recharge. **Figure 10** captures possible broad changes indicated in the study between current conditions and potential future climate conditions for the western United States under a greenhouse gas-induced global warming scenario.[82]

Another study (Smerdon, 2017) essentially provides a broad synopsis of the published science. It summarized six review articles published between 2011 and 2016 on groundwater and climate change, noting common conclusions on aspects related to predicting changes in groundwater recharge.[83] The study noted that varying predictions of future recharge result from uncertainty inherent in the distribution and trend of future precipitation as predicted in climate change models (also called *general circulation models*, or GCMs). The study reported additional uncertainty in

[77] See, for example, the 2014 National Climate Assessment, U.S. Global Change Research Program, *Key Message 4: Groundwater Availability*, at https://nca2014.globalchange.gov/report/sectors/water. The next national climate assessment is underway and is scheduled to be available in late 2018. Hereinafter the 2014 National Climate Assessment.

[78] 2014 National Climate Assessment.

[79] These included the Ogallala (or High Plains aquifer; NE, CO, KA, TX, NM, AZ), San Pedro (AZ), Death Valley (NV, CA), Wasatch Front (UT), Central Valley (CA), Columbia Plateau (WA, OR, ID), Spokane Valley-Rathdrum Prairie (WA), and Williston Basin (ND, MT) aquifers.

[80] 2014 National Climate Assessment, p. 125.

[81] 2014 National Climate Assessment, p. 136.

[82] 2014 National Climate Assessment, figure 1, p. 126.

[83] Brian D. Smerdon, "A Synopsis of Climate Change Effects on Groundwater Recharge," *Journal of Hydrology*, vol. 555 (September 28, 2017). One of the six reviewed articles in the Smerdon synopsis is the Meixner et al., 2016, study discussed in this section.

groundwater recharge forecasts because of uncertainties in downscaling GCM results from the global to the regional scale, similar to the findings in the paper discussed above.

One of the articles reviewed suggests "the role of vegetation is shown to be paramount for the recharge process, where change in precipitation could be accommodated by natural adjustment in evapotranspiration in some cases."[84] The finding implies that making predictions of recharge could be difficult because the water consumed by vegetation would not be available to recharge an aquifer. Other articles reviewed in the Smerdon study pointed out that GCMs do not directly incorporate changes in groundwater; in other words, groundwater recharge was not directly modeled in the GCM approach, so changes to groundwater can only be inferred from other model results.

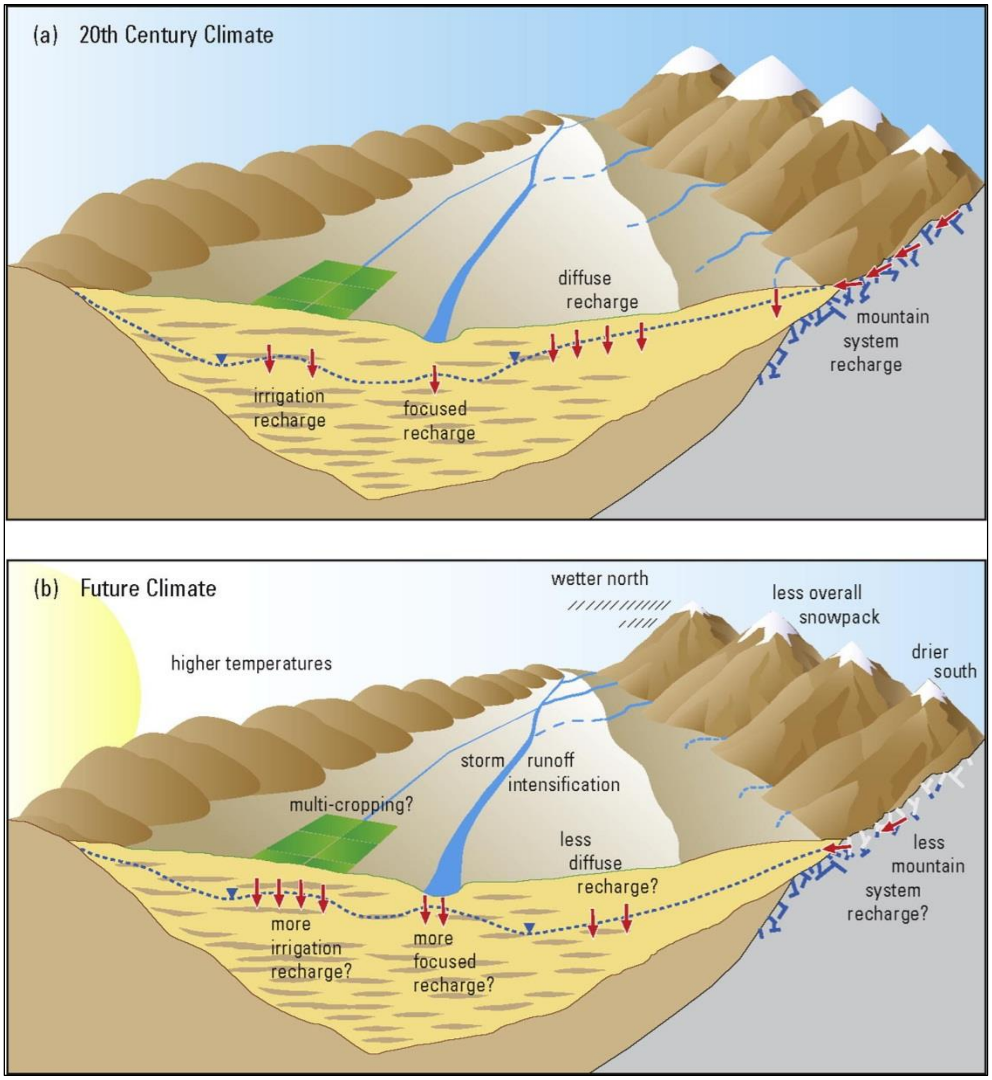
One conclusion from the study is that forecasting future groundwater supplies requires better long-term groundwater observations to match the long-term changes in climate in order to investigate their relationship. The Smerdon study notes that given all the uncertainties, several of the articles reviewed indicate that even the direction and magnitude of change to groundwater recharge is difficult to predict; some GCM modeling results suggest recharge could decrease, whereas other GCM results suggest the opposite for similar regions. Mountainous regions likely will be the most sensitive to changes in climate, according to the review.[85]

[84] 2014 National Climate Assessment, p. 126.

[85] 2014 National Climate Assessment, p. 127.

**Figure 10. Conceptual Illustration of Recharge Mechanisms Under Two Different Climate Scenarios**

(for the western United States)




**Source:** Thomas Meixner et al., "Implications of Projected Climate Change for Groundwater Recharge in the Western United States," *Journal of Hydrology*, vol. 534 (January 4, 2016), p. 126, figure 1, (with permission).

**Notes:** Four different recharge mechanisms are illustrated: *diffuse recharge*—resulting from infiltration of precipitation and direct recharge of the aquifer; *focused recharge* from rivers, streams, and lakes; *mountain system recharge* from where snow melts and infiltrates at the mountain front; and *irrigation recharge* from excess irrigation water that infiltrates the ground and reaches the water table. Under a greenhouse gas-induced warming climate (b), some of the recharge mechanisms may be diminished (such as mountain system recharge) and some may be enhanced (such as focused recharge) compared to 20th century conditions (a).

## Other Factors

Other factors may also have profound influence on groundwater recharge and groundwater supply. For example, the International Panel on Climate Change Fifth Assessment noted that changing land use is expected to affect freshwater systems globally, including groundwater.[86] The report noted that increasing urbanization, for example, may decrease groundwater recharge.[87] How irrigation practices evolve likely will influence the use and availability of groundwater, particularly for regions of the country where surface water supplies may decrease due to increasing aridity over the long term and where groundwater would substitute for surface water supplies during short-term droughts, much as it does today. Alternatively, regions experiencing wetter conditions could see reduced demand for groundwater if surface water supplies become more abundant. Because most groundwater in the United States is used for irrigation, more efficient irrigation practices may reduce overall water demand, which could place less stress on groundwater resources. A possible exception would be for aquifers that depend on excess irrigation flows for aquifer recharge (e.g., the Central Valley aquifer).

# Summary and Conclusions

Congress generally has deferred management of U.S. groundwater resources to the states, and that practice appears likely to continue. Several bills introduced in the 115th Congress, for example, contain language directing that the federal government not "assert any connection between surface and groundwater that is inconsistent with such a connection recognized by State water laws." (See, for example, S. 1230, S. 2563, H.R. 23, and H.R. 2939.) Those same bills also would prohibit the federal government from requiring the transfer of water rights to the United States, or obtaining a water right in the name of the United States, as a condition for receiving, renewing, amending, or extending "any permit, approval, license, lease, allotment, easement, right-of-way, or other land use or occupancy agreement." In addition, the bills contain language asserting that federal reserved water rights would not be limited or expanded by the legislation.

While confirming congressional deference to state water law, several bills would address the effects of drought in part authorizing or recognizing activities that could increase the ability to artificially recharge aquifers and provide for aquifer storage and recovery (e.g., S. 1460, S. 2563, and H.R. 23, and others). Severe and widespread droughts over the last 10 years in California, the Midwest, and Texas and a longer period of drier-than-normal conditions in the Southwest have contributed to increasing congressional attention to the effects of drought on increased groundwater pumping and the depletion of groundwater supplies. This has led to legislation in the 115th and earlier Congresses that would support augmentation of water supplies by enhanced aquifer recharge and the ability to store groundwater in an aquifer for later recovery when surface water supplies are curtailed by drought. Existing authorities for Reclamation and USACE allow for federal projects to be involved in aquifer recharge, storage, and recovery in some way, and proposed legislation (such as S. 2563 and other bills) would augment those authorities.

A connection between federal water projects and groundwater enhancement already exists in Arizona, as part of the Central Arizona Project, and is implemented via state law. More recently, California enacted three groundwater laws known collectively as the Sustainable Groundwater Management Act (SGMA), which directed the California Department of Water Resources to identify water available for replenishing groundwater in the state. Because the Central Valley

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[86] Jimenez Cisneros et al., "Freshwater Resources," Intergovernmental Panel on Climate Change, in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, contribution of Working Group II to the *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2014, p. 240.

[87] Increasing urbanization may include more covered surfaces, such as roads, parking lots, and other types of materials that are less permeable to precipitation than natural surfaces and could decrease the amount of water that infiltrates the ground and reaches the water table.

Project is integral to the water supply and delivery infrastructure of the state,[88] it also recognized as part of the surface water resources potentially available for recharging aquifers as the SGMA is implemented.[89] Other western states with significant Reclamation water infrastructure also may look to enhance their sources of water for aquifer recharge by tapping the federal projects.

Further technological developments in desalinating brackish or saline groundwater could help make those water supplies available for domestic, agricultural, or other uses.[90] Congress authorized an assessment of brackish groundwater in Section 9507(c) of P.L. 111-11 in 2009, and USGS released its assessment report in 2017.[91] In general, the assessment found that deeper wells had more brackish groundwater than shallower wells. Seventy percent of wells between 1,500 feet and 3,000 feet below the surface were brackish or highly saline, whereas less than 20% of wells 50 feet deep or shallower were brackish.

USGS reports that many water providers are turning to brackish groundwater to augment or replace freshwater for drinking and other uses, such as power generation, irrigation, aquaculture, and uses in the oil and gas industry (e.g., hydraulic fracturing).[92] For greater use of this potential resource, more detailed evaluations of specific aquifers likely are required. Technological and economic analyses would be needed to determine if brackish groundwater, especially from the deeper wells, could be used economically on a greater scale in the future.

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[88] For more information, see CRS Report R44456, *Central Valley Project Operations: Background and Legislation*, by Charles V. Stern and Pervaze A. Sheikh.

[89] See California Department of Water Resources, Sustainable Groundwater Management Program, *Water Available for Replenishment*, draft report, January 2017, at http://wdl.water.ca.gov/groundwater/sgm/wafr.cfm.

[90] Brackish water generally is more saline than fresh groundwater but less saline than seawater, containing total dissolved solids in concentrations ranging between 1,000 and 10,000 milligrams per liter (mg/l). Water with less than 1,000 mg/l is considered fresh; water with more than 10,000 mg/l is considered highly saline. Seawater is about 35,000 mg/l on average.

[91] Jennifer S. Stanton et al., *Brackish Groundwater in the United States*, USGS, Professional Paper 1833, 2017, at https://pubs.er.usgs.gov/publication/pp1833.

[92] Jennifer S. Stanton and Kevin F. Dennehy, "Brackish Groundwater and Its Potential to Augment Freshwater Supplies," USGS, Fact Sheet 2017-3054, July 2017, at https://pubs.er.usgs.gov/publication/fs20173054.