United States Government Accountability Office

Report to Congressional Requesters

May 2014

FRESHWATER

Supply Concerns Continue, and Uncertainties Complicate Planning

GAO-14-430

GAO Highlights

Highlights of GAO-14-430, a report to congressional requesters

May 2014

FRESHWATER

Supply Concerns Continue, and Uncertainties Complicate Planning

Why GAO Did This Study

The nation's water bodies have long supplied Americans with abundant freshwater, but recent events, such as the ongoing California drought, have focused attention on competing demands for this limited resource. In the United States, the states are primarily responsible for managing freshwater resources, and many federal agencies influence states' management decisions. In 2003, GAO issued a report providing an overview of trends in freshwater availability and use, as well as states' views on ways the federal government could assist states to help meet future water management challenges.

GAO was asked to report on changes since 2003. This report examines (1) issues related to freshwater availability and use; (2) expectations for water availability and use over the next 10 years and how these expectations may affect water planning; (3) steps, if any, states have taken to manage freshwater resources; and (4) actions, if any, federal agencies have taken to support management of freshwater availability and use and perspectives from state water managers, experts, and literature on what the federal government can do to enhance its support. GAO conducted a survey of 50 state water managers with a response rate of 100 percent. GAO also reviewed reports and documents from entities, such as federal agencies and environmental organizations, and interviewed federal officials and experts, including environmental and industry officials, to understand freshwater issues across the nation.

GAO is not making recommendations.

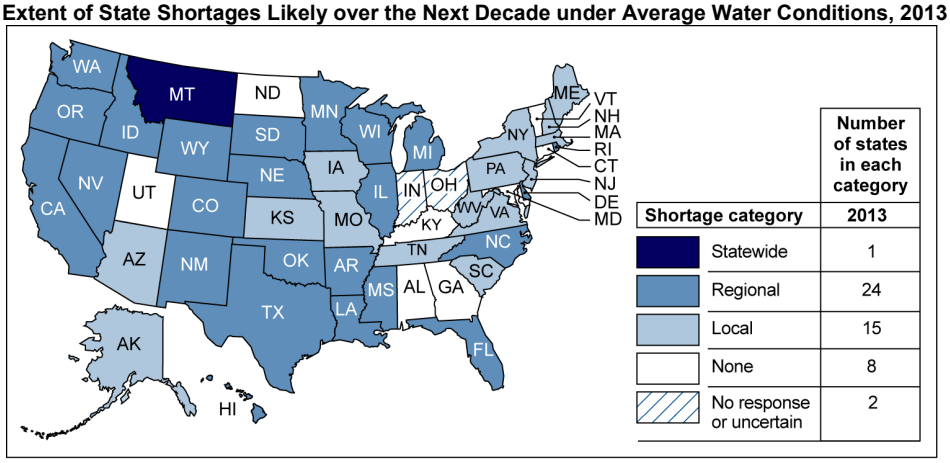
View GAO-14-430. For more information, contact Anne-Marie Fennell at (202) 512-3841 or fennella@gao.gov.

What GAO Found

Key issues related to freshwater availability and use—such as concerns about population growth straining water supplies, lack of information on water availability and use, and trends in types of water use—remain largely unchanged since 2003, according to state water managers, experts, and literature. In addition, GAO's review found certain issues, such as the impacts of climate change and extreme weather events, including droughts and floods, on water resources and the effect of the energy sector on water quantity and quality, have gained prominence.

According to state water managers, experts, and literature GAO reviewed, freshwater shortages are expected to continue into the future. In particular, 40 of 50 state water managers expected shortages in some portion of their states under average conditions in the next 10 years (see fig.). However, uncertainty stemming from factors, such as patterns of economic growth and land use change, is likely to complicate future state water managers' planning efforts.

Extent of State Shortages Likely over the Next Decade under Average Water Conditions, 2013



Sources: GAO analysis of state water managers' responses to GAO survey; Map Resources (map).

GAO's review found that over the last decade states have taken a number of steps to improve management of freshwater availability and use. These include conducting freshwater resource studies and assessments, developing drought preparedness plans, developing water management tools, taking conservation actions, and taking steps to address climate change impacts on water resources.

Since 2003, federal agencies have taken various actions to support freshwater management. For example, the Department of the Interior's U.S. Geological Survey initiated the National Water Census to assess water availability and use across the nation. Also, numerous agencies participate in the National Drought Resilience Partnership, created in 2013. In addition, state water managers, experts, and literature GAO reviewed identified actions the federal government could take to support state water management efforts, including increased collaboration among federal agencies and with states and other stakeholders, and maintaining and collecting key data.

Contents

Figures

Abbreviations

Commerce	U.S. Department of Commerce
Corps	U.S. Army Corps of Engineers
CWCB	Colorado Water Conservation Board
DNR	Department of Natural Resources
DOE	U.S. Department of Energy
EPA	Environmental Protection Agency
FWS	Fish and Wildlife Service
GRACE	Gravity Recovery and Climate Experiment
IBWC	International Boundary and Water Commission
Interior	U.S. Department of the Interior
IWRSS	Integrated Water Resources Science and Services
LCC	Landscape Conservation Cooperatives
mgd	million gallons per day
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NIDIS	National Integrated Drought Information System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
Reclamation	Bureau of Reclamation
SMAP	Soil Moisture Active Passive
SNOTEL	Snow Telemetry
SWOT	Surface Water Ocean Topography
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WestFAST	Western States Federal Agency Support Team
WRIA	Water Resource Inventory and Assessment
WWCRA	West-Wide Climate Risk Assessment

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

May 20, 2014

The Honorable Peter DeFazio
Ranking Member
Committee on Natural Resources
House of Representatives

The Honorable Edward J. Markey
United States Senate

The nation's lakes, rivers, streams, and underground aquifers have long supplied Americans with abundant freshwater, but due in part to climatic variability and population growth, this vital resource is not always available when and where it is needed or in the amount or quality desired. In the past decade alone, parts of the United States have experienced severe and recurrent droughts, while other parts have been flooded in powerful storms. In October 2012, for example, while a large portion of the Great Plains was experiencing "exceptional drought," according to the U.S. Drought Monitor,[1] states along the eastern seaboard were suffering from intense flooding caused by Hurricane Sandy. Moreover, disagreements have erupted over dwindling water supplies, particularly among arid western states. In times of shortage, competing demands for freshwater—such as for irrigation, power production, municipal water supplies, and supporting aquatic life—increase, heightening conflicts over limited resources.

In the United States, the states are primarily responsible for managing freshwater resources, and no one federal agency has primary oversight of water resource management. Rather, many federal agencies influence states' management activities through the implementation and enforcement of federal laws, as well as various federal programs. For example, the Department of the Interior's (Interior) U.S. Geological Survey (USGS) has primary responsibility for collecting, analyzing, and

[1]Nationwide drought data are reported weekly by the U.S. Drought Monitor, which is produced in partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the U.S. Department of Agriculture (USDA), and the Department of Commerce's (Commerce) National Oceanic and Atmospheric Administration (NOAA). In addition, the U.S. Drought Monitor uses the National Aeronautics and Space Administration's (NASA) remote sensing data to develop these weekly reports.

sharing data on water availability and use. Other agencies, such as Interior's Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (Corps),[2] construct, operate, and maintain large water storage infrastructure, such as dams and reservoirs.

In 2003, we issued a report providing a comprehensive overview of trends in freshwater availability and use, as well as state views on expected shortages and ways the federal government could help states meet future challenges.[3] Specifically, we reported that trends at the time indicated increasing demands on the nation's freshwater supplies, and state water managers expected freshwater shortages in the near future. The report also noted that, among other things, federal collection of water data at more locations and more consultation with states would benefit states in meeting their freshwater resource needs. Since our 2003 report, competing demands on the nation's freshwater resources have elevated the importance of carefully managing freshwater supply and prompted renewed interest in assessing the status of the nation's freshwater availability and use.

You asked us to update our 2003 report in light of new and continued stresses on water supplies. This report examines (1) issues related to freshwater availability and use; (2) expectations for water availability and use over the next 10 years and how these expectations may affect water planning; (3) steps, if any, states have taken to better manage freshwater resources; and (4) actions, if any, federal agencies have taken to support management of freshwater availability and use and perspectives from state water managers, experts we spoke with, and literature we reviewed on what the federal government can do to enhance its support of states.

We analyzed three key sources of information to complete this work for all four objectives. First, we conducted a Web-based survey of state water managers from all 50 states; the response rate to our survey was

[2]The Corps has Military and Civil Works programs. The Military program provides, among other things, engineering and construction services to other U.S. government agencies and foreign governments, and the Civil Works program plans and manages water for transportation, recreation, energy, wildlife habitat, aquatic ecosystems, and water supply, among other things. This report only discusses the Civil Works program.

[3]GAO, *Freshwater Supply: States' Views of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages*, GAO-03-514 (Washington, D.C.: July 9, 2003).

100 percent. Because not all respondents answered every question, the number of states responding to any particular question will be noted throughout the report. The survey was largely identical to the survey we used in 2003, with the addition of a few new questions. Specifically, the survey contained 67 questions about topics such as state water management, federal agencies' collection and dissemination of water quantity data, and drivers of change that may affect water supplies in the next 10 years. Second, we analyzed key documents (e.g., peer-reviewed studies and government-sponsored reports) to gather information on current and future freshwater conditions. Third, we interviewed experts to gather additional perspectives on freshwater issues. Experts included representatives from regional entities with freshwater knowledge; industry, such as an organization that represents municipal water treatment plants; environmental organizations; and academia. We identified these experts using an iterative approach in which we solicited names from agency officials and others we interviewed; we also interviewed experts identified during our analysis of reports and key documents. For the purposes of reporting the results of our analyses, we used the following categories to quantify the responses of state water managers and experts: "some" refers to at least two state water managers or experts, "several" refers to at leave five managers or experts, and "many" refers to eight or more managers or experts. As part of our review, we identified three states for inclusion as illustrative examples—Colorado, Maryland, and Michigan. These states were selected on the basis of criteria including variation across the states in their responses to our 2003 survey and types of water use within those states. We also interviewed agency officials from a number of federal agencies—such as the U.S. Department of Agriculture's (USDA) Forest Service and Natural Resources Conservation Service (NRCS), the Corps, Reclamation, and USGS—to understand steps they have taken to support freshwater management and their responses to concerns identified by state water managers and experts. Appendix I provides additional information on our objectives, scope, and methodology.

We conducted this performance audit from November 2012 to May 2014, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Water is one of the earth's most abundant resources, covering about 70 percent of the earth's surface. Freshwater that is available for use by humans and ecosystems, however, makes up less than 1 percent of the earth's water. While freshwater flows abundantly through the nation's lakes, rivers, streams, and underground aquifers, people neither always have access to freshwater when and where they need it, nor in the amount or quality they need. To make water more available and usable throughout the United States, federal agencies have built water storage and conveyance projects and have engaged in other water development, management, and regulatory activities. Federal agencies manage some water use, such as on federal lands or in interstate commerce, but water allocation and use are predominantly governed by state laws.

Federal and State Authorities Regarding Water Availability and Use

The federal government derives authority to manage certain water resources from several constitutional sources but recognizes the states' authority to allocate and use water within their jurisdictions. The Commerce Clause,[4] one source from which federal authority is derived, permits federal regulation of water that may be involved in or may affect interstate commerce,[5] including efforts to preserve the navigability of waterways.[6] In addition, the Property Clause[7] permits federal regulation of water as necessary for the beneficial use of federal property.[8] Federal laws often require federal agencies engaged in water resource management activities to defer to state laws or cooperate with state officials in implementing federal laws. For example, under the Reclamation Act, Reclamation must defer to and comply with state laws governing the control, appropriation, use, or distribution of water unless applying the state's law would be inconsistent with an explicit congressional directive regarding the Reclamation projects.[9] Other federal acts—including the Water Supply Act of 1958, Clean Water Act, and the

[4]U.S. Const. art. I, § 8, cl. 3.

[5]*See e.g.,* Utah v. Marsh, 740 F.2d 799, 803 (10th Cir. 1984); United States v. Byrd, 609 F.2d 1204, 1210 (7th Cir. 1979).

[6]United States v. Rio Grande Dam & Irrigation Co., 174 U.S. 690, 703 (1899).

[7]U.S. Const. art. IV, § 3, cl. 2.

[8]*Rio Grande Dam & Irrigation Co.*, 174 U.S. at 703.

[9]43 U.S.C. § 383; *see* California v. United States, 438 U.S. 645 (1978).

Endangered Species Act—explicitly recognize nonfederal interests in water supply development.[10]

Varied state laws govern the allocation and use of surface and groundwaters. Specifically, the allocation and use of surface water can generally be traced to two basic legal doctrines: (1) the riparian doctrine, often used in the eastern United States, and (2) the prior appropriation doctrine, often used in the western United States. States may rely on either doctrine, a mix of both doctrines or, in a few cases, other approaches to allocate water.[11] Under the riparian doctrine, water rights are linked to land ownership, where owners of land bordering a waterway have a right to use the water that flows past their land for any reasonable purpose. Landowners may, at any time, use water flowing past their land even if they have never done so before; all landowners have an equal right to use the water, and no one gains a greater right through prior use.

In contrast, the prior appropriation doctrine does not link water rights with land ownership. Water rights are instead linked to prior and beneficial water use—parties who obtain water rights first (known as "senior water rights holders") generally have seniority for the use of water over those who obtain rights later (known as "junior water rights holders"), and rights holders must put the water to beneficial use or abandon their right to use it. Simply put, "first in time, first in right" and "use it or lose it." Because water rights are not tied to land, water rights can be bought and sold without any ownership of land, although the rights to water may have specific geographic limitations. For example, a water right generally provides the ability to use water in a specific river basin taken from a

[10]The Water Supply Act of 1958 states that it is the policy of the Congress to recognize the primary responsibilities of the states and local interests in developing water supplies for domestic, municipal, industrial, and other purposes and that the federal government should participate and cooperate with states and local interests in developing such water supplies in connection with the construction, maintenance, and operation of federal navigation, flood control, irrigation, or multiple purpose projects. 43 U.S.C. § 390b. The Clean Water Act states that it is the policy of the Congress that the authority of each state to allocate quantities of water within its jurisdiction shall not be superseded, abrogated, or otherwise impaired by the act, and that federal agencies shall cooperate with state and local agencies to develop comprehensive pollution solutions in concert with programs for managing water resources. 33 U.S.C. § 1251(g). The Endangered Species Act states that it is the policy of the Congress that federal agencies cooperate with state and local agencies to resolve water resource issues in concert with conservation of endangered species. 16 U.S.C. § 1531(c)(2).

[11]Other approaches can include no regulation of water allocation by the state.

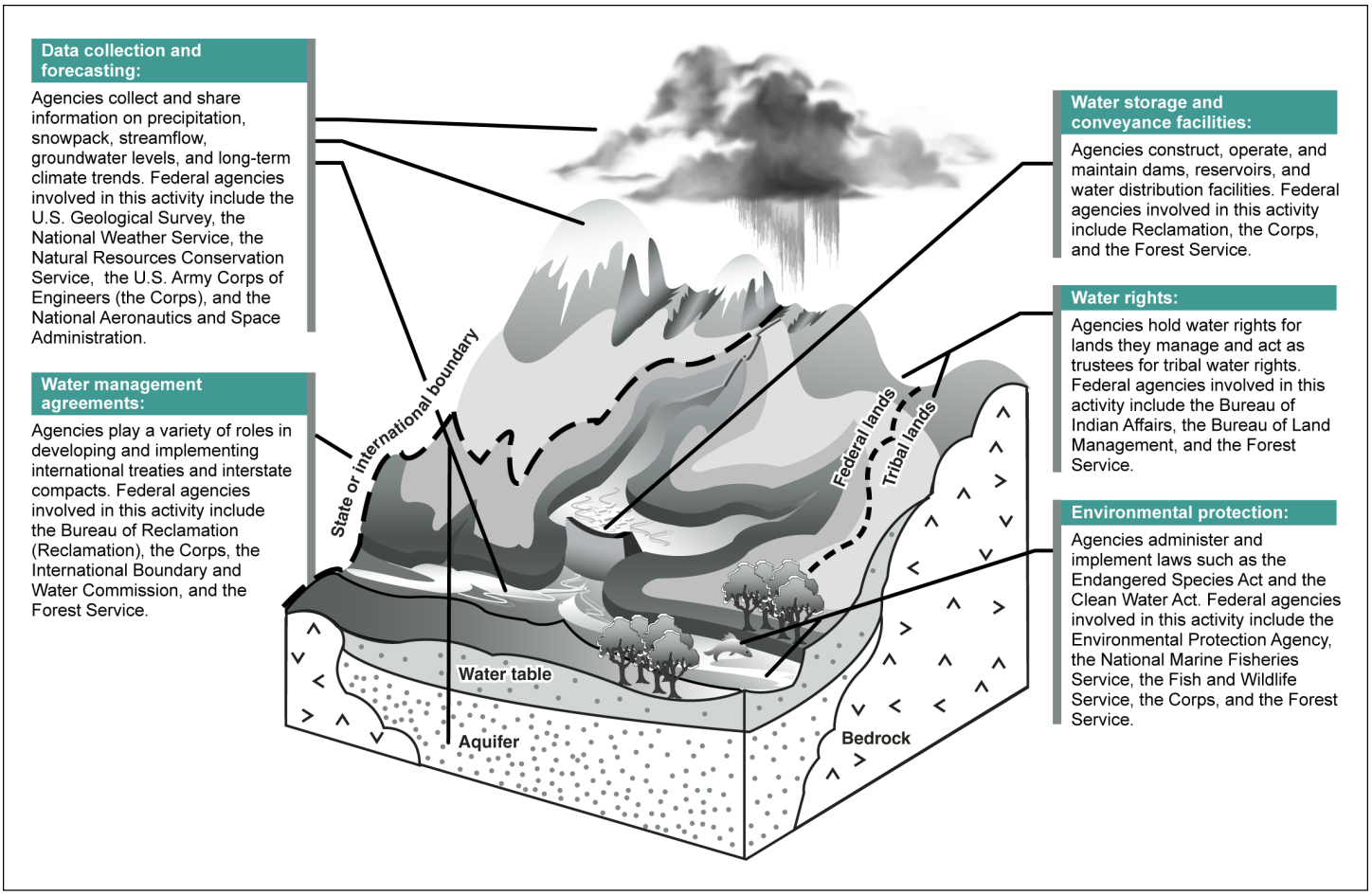
specific area of the river. When there is a water shortage in prior appropriation states, shortages fall first on those who last obtained a legal right to use the water. As a result, a shortage can result in junior water rights holders losing all access to water, while senior water rights holders retain access to their prior entire allotment.

While groundwater allocation can follow principles of surface water management, many states use different approaches. For example, many states use the prior appropriation doctrine to allocate groundwater rights in a manner similar to surface water. Other approaches to groundwater allocation include granting rights to all the water that landowners can capture; granting landowners the right to water beneath their land, provided the use is restricted to an amount necessary for reasonable use; dividing rights among landowners based on acreage; and not regulating groundwater allocation.

Federal Activities Affecting Water Management

Many federal agencies play a role in managing the nation's freshwater resources through key activities, as shown in figure 1. Specifically, federal agencies collect and share water availability and use data; assist in developing and implementing water-management agreements and treaties; construct, operate, and maintain large water storage and distribution facilities; hold water rights for federally managed lands and act as trustees for tribal water rights; and administer clean water and environmental protection laws.

Figure 1: Overview of Federal Activities Related to Freshwater Management



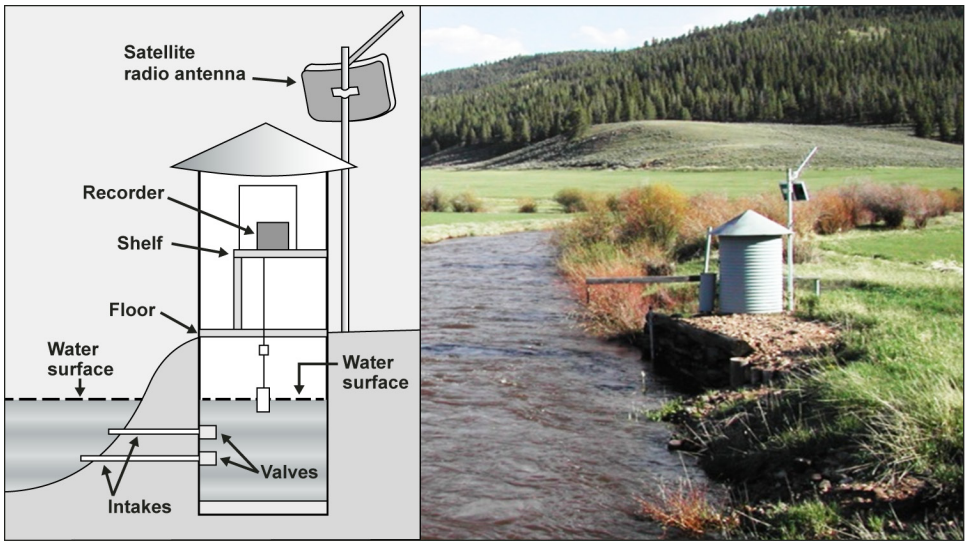
Source: GAO.

Data Collection and Forecasting

Several federal agencies maintain a number of water resource data collection networks to collect information on streamflows, groundwater availability, precipitation, and water use trends and other water resources. Agencies may maintain networks through their own programs or in partnership with other federal agencies and entities, such as state and local governments. In some cases, federal agencies rely on states to supply most of the data. Major federal water data collection efforts include the following:

- *Streamflow data*. USGS's National Streamflow Information Program collects surface water availability data through its national streamgage network,[12] which continuously measures the level and flow of rivers and streams at 8,025 active continuous gages nationwide for distribution on the Internet. Figure 2 shows a USGS streamgage. USGS staff measure streamflow and calibrate the streamgages frequently. Other agencies can provide funding to maintain streamgages that are important to their specific mission.

Figure 2: Diagram of a U.S. Geological Survey Streamgage



Source: U.S. Geological Survey.

- *Groundwater data*. USGS continuously monitors groundwater levels and works with state and local agencies to collect additional groundwater data under its National Water Information System. USGS or USGS cooperators, such as state agencies, continuously monitor groundwater levels at 3,303 wells across the United States. In total, USGS's National Water Information

[12] USGS's National Streamflow Information Program defines a "streamgage" as an active, continuously functioning device placed in a river or stream to measure water levels to aid in the estimation of mean daily streamflow throughout the year.

System included 27,205 wells where at least one measurement was taken in fiscal year 2012.

- *Precipitation data***.** Federal agencies collect data on snowpack and rainfall. USDA's NRCS operates 885 Snow Telemetry (SNOTEL) sites in the western United States, which transmit snow depth and climate parameters in near real time. Through its snow course network, NRCS also conducts manual surveys of snow depth at about 956 sites in the United States. The Department of Commerce's (Commerce) National Weather Service also collects snowfall and snowpack data and estimates rainfall with 155 weather radars and 10,000 gages mostly owned and operated by agencies, providing data for weather and climate forecasts. The vast majority of those rain gages are owned and operated by other federal agencies and state, municipal, and tribal governments, with only a few gages owned and operated directly by the National Weather Service.

- *Water use trend data and other water resource data***.** The USGS National Water Use Information Program compiles extensive national water use data collected from states every 5 years for the purpose of establishing long-term water use trends. States and other entities also collect and share water resource data, such as surface water or groundwater data, through USGS's Cooperative Water Program. Both Commerce's National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautic and Space Administration (NASA) maintain several satellite programs that can be used to collect data for managing water resources. For example, NOAA operates a Data Collection System on their geostationary satellites that collects and distributes the water resource measurements from the streamgages and other observation networks operated by USGS, the Forest Service, the National Weather Service, and other federal and state government agencies.[13] In addition, NASA has extensive satellite observations, modeling, and research focused on many aspects of the water cycle. Examples include (1) the Moderate Resolution Imaging Spectroradiometer (MODIS) Global Evapotranspiration project,[14] which, among other things, develops

[13]Geostationary satellites have been used by the United States since the 1970s to provide meteorological data for weather observation, research, and forecasting.

[14]Evapotranspiration is water lost through evaporation from the soil and plants.

evapotranspiration data that can be used to calculate information for water resource management, such as water balance and drought mapping, and (2) the Gravity Recovery and Climate Experiment (GRACE) satellites, which have been used since 2002 to measure changes in the amount of water stored on and beneath Earth's surface, including groundwater, and to quantify drought conditions.[15]

Federal agencies also collect water data or conduct research on water resources in support of their own specific missions. For example, Interior's National Park Service and USDA's Forest Service collect streamflow data for the lands they manage to supplement USGS's streamgage information; Interior's Bureau of Indian Affairs conducts some research on water availability on tribal lands as a part of the agency's trust responsibilities to tribes; Reclamation and the Corps collect data on reservoir levels and water flows through their facilities; and USDA's Agricultural Research Service conducts and the National Institute of Food and Agriculture funds water quantity and quality research related to agriculture, natural resources, and the environment. In addition to collecting data, federal agencies often conduct analyses of water data that can be used by water managers to make more informed decisions. For example, the National Weather Service and NRCS combine their data with USGS streamgage data to forecast water supplies and floods. They post water supply forecasts twice a month on the Internet and through other communication channels. In addition, the National Weather Service issues sub-daily, sometimes hourly, flow forecast information, from low flows for navigation to high flows for warnings.

Water Management Agreements

States can enter into interstate compacts to address water allocation, quality, and other issues on rivers and lakes that cross state borders. For example, according to Interior's Fish and Wildlife Service (FWS), at least 26 interstate compacts address river water allocation between two or more states; 7 address water pollution issues; and 7 address general water resource issues, including flood control, falling under the agency's purview. An example of an interstate compact is the Great Lakes-St. Lawrence River Basin Water Resources Compact.[16] The compact, which

[15]GRACE's mission has been extended past its 5-year mission life, and NASA officials expect that it will remain in operation until at least 2015. A follow-on mission, GRACE-FO, is scheduled for a 2017 launch.

[16]Pub. L. No. 110-342, 122 Stat. 3739 (2008).

was ratified by eight Great Lakes states, approved by the Congress, and signed by the President in 2008, was developed to address water withdrawals from the Great Lakes Basin.[17] The agreement between the states established a common framework in which each state would establish its own water withdrawal regulation and management programs governing Great Lakes Basin water. Federal agencies may assist in developing and implementing these compacts, provide technical assistance, participate in and consult with oversight bodies, develop river operating plans, act as stewards of tribal and public natural resources, and enforce compacts. For example, the Congress provided the Secretary of the Interior with certain authority regarding the appropriation of Colorado River waters under the 1922 Colorado River Compact.[18] Under the compact, the Colorado River Basin is divided into the Upper Division (Colorado, New Mexico, Utah, and Wyoming) and Lower Division (Arizona, California, and Nevada). The compact specifies that the states of the Upper Division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 million acre-feet of water for any period of 10 consecutive years.

The United States can also enter into international treaties that affect water availability and use in the United States. Through treaties with Canada and Mexico, the United States coordinates activities such as water allocation, flood control, water quality, and power generation, as well as resolves water-related disputes along the nations' international borders. For example, the 1944 Water Treaty with Mexico provided the International Boundary and Water Commission (IBWC), a binational commission to help the member nations coordinate water management activities, monitor water resources, and resolve disputes, with the responsibility for carrying out the treaty.[19]

Water Storage and Conveyance Facilities

Reclamation and the Corps construct, operate, and maintain large projects to store and manage untreated water, including many of the largest storage projects in the United States, holding huge quantities of

[17] *Id.*

[18] *See* Boulder Canyon Project Act of 1928, 45 Stat. 1057 (1928). The U.S. Supreme Court upheld the Secretary of the Interior's authority to carry out the allocation of the waters of the Colorado River, within the bounds of the act, in *Arizona v. California*, 373 U.S. 546 (1963).

[19] Treaty Relating to the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, U.S.-Mex., Feb. 3, 1944, 59 Stat. 1219.

water for a wide variety of purposes, such as agricultural, industrial, and municipal uses.[20] Reclamation's water delivery quantities are usually specified under long-term contracts, while the Corps provides water storage space in reservoirs, also under long-term contracts. Some of these projects serve other purposes, such as flood control, energy production, and recreation. Reclamation has constructed water storage and distribution infrastructure, as well as irrigation projects, throughout the 17 western continental states and currently manages 337 reservoirs with a collective storage capacity of 245 million acre-feet of water.[21] In total, Reclamation's water management projects provide water for about 10 million acres of farmland and nearly 31 million people. The Corps, through its Civil Works program, manages 541 reservoirs all across the country with a collective storage capacity of 330 million acre-feet of water. The Corps also has responsibility for other key water infrastructure that can be important for water management, including 14,673 miles of levee systems for flood control, 55,390 miles of lakeshore and other recreation areas, and 12,000 miles of commercial inland waterways for navigation. In addition, the Forest Service permits storage facilities that are operated by entities such as municipalities and irrigation districts on national forest lands, according to agency officials.

Water Rights

Numerous federal natural resource management agencies and the Bureau of Indian Affairs are trustees for the water rights on federal and tribal lands. The states grant the great majority of water rights to these agencies, but the agencies also have federal reserved rights—water rights that are used to fulfill the purposes of federal lands such as maintaining national forests, national parks, wildlife refuges, and tribal lands. The exact number and amount of federal reserved rights are not known,[22] although officials from Interior's Bureau of Land Management

[20]Other federal agencies have facility management responsibilities not directly related to water storage and distribution. For example, the Federal Emergency Management Agency within the Department of Homeland Security is responsible for coordinating dam safety efforts, and the Federal Energy Regulatory Commission—an independent five-member commission appointed by the President and confirmed by the Senate—licenses and regulates nonfederal hydropower projects.

[21]An "acre-foot" of water is the volume of water required to cover 1 acre of land to a depth of 1 foot. An acre-foot is equivalent to approximately 326,000 gallons.

[22] Interior officials told us that the Bureau of Land Management's offices collect data on these rights, but the data were not consolidated at its state offices and, therefore, were not able to be readily provided to officials in headquarters.

estimate that 20 percent of the agency's water rights are federally reserved, largely for underground springs. In addition, the Bureau of Indian Affairs, as trustee for tribal resources in the United States, has the primary statutory responsibility for protecting tribal water rights. The U.S. Supreme Court has found that water rights in a quantity sufficient to fulfill the purposes of the reservations are implied when the United States establishes reservation lands for a tribe.[23] Tribes typically use water rights to ensure water is available for domestic use, irrigation, industrial development, hydropower, and the maintenance of instream flows.

Environmental Protection

Several federal agencies administer clean water and environmental protection laws that affect water resource management. The Environmental Protection Agency (EPA) administers the Clean Water Act[24]—the nation's principal federal law regulating surface water quality. In addition, the Corps administers Section 404 of the act, the principal federal program that provides regulatory protections for wetlands, which include bogs, swamps, and marshes.[25] States and localities also play a significant role in its implementation. The act can affect available water supplies by, for example, reducing offstream use or return flows to address water quality concerns. In addition, federal land management agencies ensure that water uses on federal land meet the act by requiring best management practices in special use permits, according to Forest Service officials.

In addition, FWS and Commerce's National Marine Fisheries Service (NMFS) are responsible for administering the Endangered Species Act.[26,27] This act requires federal agencies to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any listed species of plant or animal or adversely modify or destroy designated critical habitat.[28] The Endangered Species Act can

[23] *See* Winters v. United States, 207 U.S. 564 (1908).

[24] 33 U.S.C. §§ 1251-1387.

[25] 33 U.S.C. § 1344.

[26] 16 U.S.C. §§ 1531-1544.

[27] FWS is responsible for administering the act for land and freshwater species, and NMFS is responsible for marine species, including Pacific salmon, which spend part of their life spans in freshwater.

[28] 16 U.S.C. § 1536(a)(2).

affect water management activities, for example, by necessitating certain stream flow levels be maintained to avoid jeopardizing listed species or their critical habitats.

Since 2003, Issues Related to Freshwater Availability and Use Have Not Changed Significantly, Although Certain Issues Have Gained Prominence

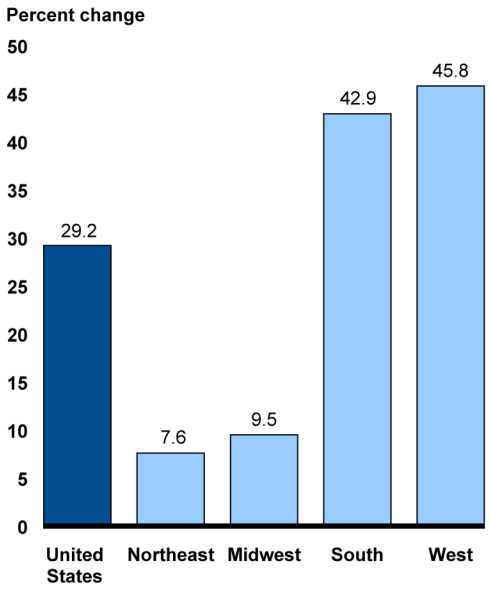
Our review found that, since 2003, key issues related to freshwater availability and use—such as concerns about population growth straining water supplies, lack of information on water availability and use, and trends in types of water use—remain largely unchanged. In addition, certain issues—the impacts of climate change and extreme weather events on water resources, concerns about maintaining ecological and recreational flows, interactions between surface water and groundwater, and the effect of the energy sector on water quantity and quality—have gained prominence.

Key Issues Related to Freshwater Availability and Use Continue to Make Freshwater Management and Planning Difficult

Our review found that key issues surrounding freshwater availability and use have not changed significantly over the last decade. In particular, concerns about population growth straining water supplies, lack of comprehensive information on water availability and use, and trends in types of water use remain and continue to make freshwater management and planning difficult. As in 2003, population growth remains a concern, particularly in certain states where water supplies are already limited. Data from the U.S. Census Bureau project that the U.S. population will increase by approximately 29 percent between 2000 and 2030, and the western and southern regions are projected to experience the greatest growth during this time (see fig. 3). According to data from USGS,[29] some states in these regions have among the highest water withdrawal rates in the United States.

[29]J.F. Kenny, N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin, "Estimated use of water in the United States in 2005," *U.S. Geological Survey Circular 1344* (2009).

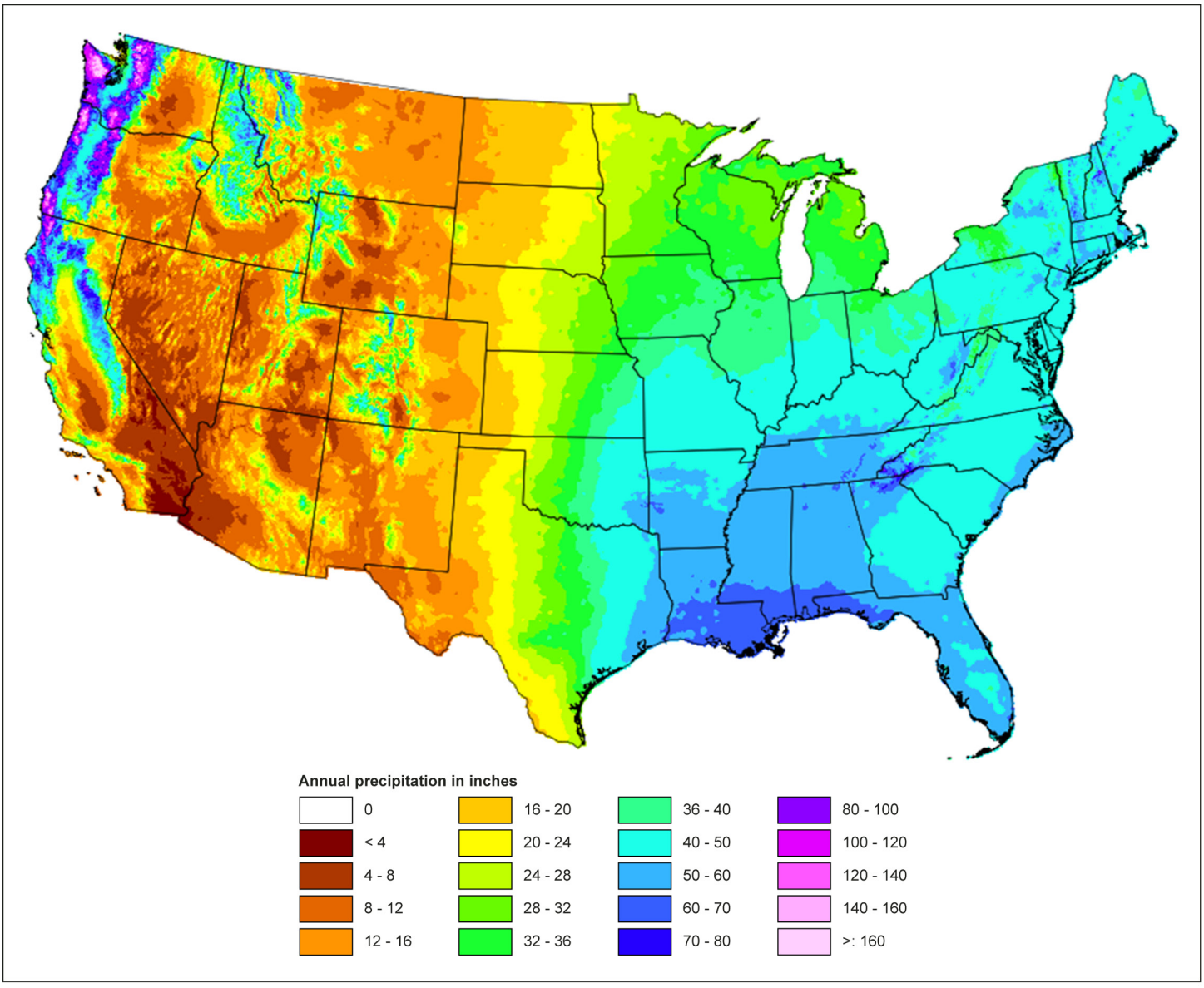
Figure 3: Projected U.S. Population Growth by Region, 2000-2030



Source: U.S. Census Bureau, Population Division, Interim State Population Projections, 2005.

Furthermore, according to data from the U.S. Census Bureau, Nevada and Arizona are the two states with the greatest projected growth—population is projected to more than double between 2000 and 2030. Both states, however, are located in the arid Southwest, which has historically received some of the lowest annual precipitation amounts in the nation, according to data from Oregon State University (see fig. 4).

Figure 4: Average Annual Precipitation in the Continental United States, 1981-2010



Source: Copyright ©2013, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu.
Map created Nov. 18, 2013.

Moreover, our review found that population growth can stress freshwater supplies in areas that have not historically been concerned with limited water availability. For example, while state water managers in Maryland

told us that they do not expect statewide water shortages in the near future, they noted that there are concerns with population growth straining water supplies in some parts of the state. Specifically, these officials told us that a large number of people working in the Washington, D.C., metropolitan area have migrated to central and southern Maryland counties, thereby putting increased pressure on water supplies in those regions. Urban areas within central Maryland rely primarily on surface water reservoirs, and rural and exurban areas in the region rely on groundwater wells to meet their freshwater needs. The officials told us that there is little chance of building new surface reservoirs in the long term and therefore they expect increased groundwater use in this region; however, due to the region's geology, it is not well suited for high-production groundwater wells. These factors make it possible that some towns and small communities in the region may have difficulty finding sufficient water supplies to meet the needs of the growing population, according to the officials.

In addition to population growth concerns, our review found that there continues to be a dearth of data related to water availability and use. Specifically, as we reported in 2003, national water availability and use had not been—and still has not been—comprehensively assessed since 1978. The U.S. Water Resources Council, established by the Water Resources Planning Act in 1965,[30] assessed the status of the nation's surface water and groundwater resources and reported in 1968 and 1978 on the resources' adequacy to meet present and future water requirements. The 1978 assessment described how the nation's freshwater resources were extensively developed to satisfy a wide variety of users and how competition for water had created critical problems, such as shortages resulting from poorly distributed supplies and conflicts among users. Since 2003, the Subcommittee on Water Availability and Quality has called for an updated assessment.[31] However, USGS officials told us that while there are related efforts under way to assess water availability and use at national and regional scales,[32] a comprehensive

[30]Pub. L. No. 89-80, 79 Stat. 244 (1965). Although the act has not been repealed, the council has not been funded since fiscal year 1983.

[31]This subcommittee is made up of 25 federal agencies that collectively are responsible for all aspects of federal water research and water resource management. It is under the Office of Science and Technology Policy's National Science and Technology Council.

[32]One such effort is the National Water Census, a USGS-led research program designed to comprehensively assess water availability and use across the nation.

assessment of freshwater availability and use has not been completed over the last decade.

In addition, trends in types of water use have not changed significantly in the last few decades. Specifically, as shown in figure 5, the majority of water withdrawals have consistently been for thermoelectric power and for irrigation.[33] According to USGS,[34] total withdrawals in 2000 and 2005 were the largest since 1980 when withdrawals peaked, and thermoelectric power has remained the type of use with the largest withdrawals since 1965, making up 49 percent of total withdrawals in 2005.[35] As our past work on the energy-water nexus found,[36] water is a key component in the production of electricity because thermoelectric power plants rely heavily on water for cooling, and plants have already reduced electricity production due to limited water availability in some areas. The Department of Energy (DOE) is projecting that U.S. electricity generation will increase by approximately 28 percent from 2013 through 2040, although an agency official added that the water use profile of future electricity generation will be different than the profile of current generation because of projected changes in technology. We noted that limited freshwater may make it more difficult to build new power plants, particularly in communities concerned about the adequacy of their water supply and maintaining the quality of aquatic environments.

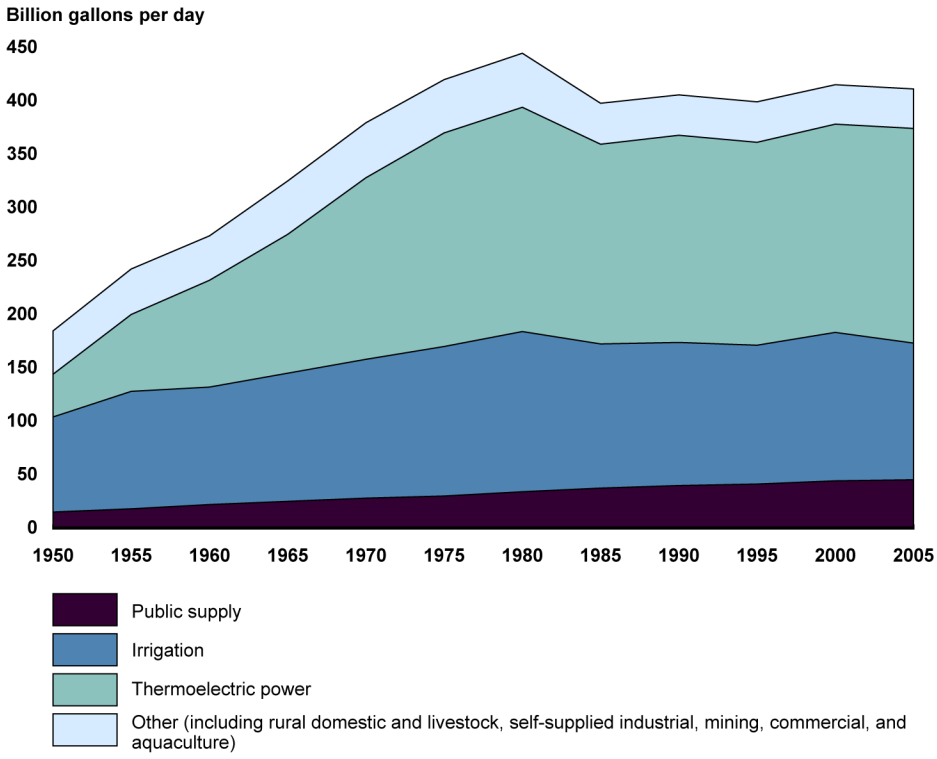
[33]Freshwater can be withdrawn or consumed by users. Freshwater withdrawal refers to water removed from the ground or diverted from a surface water source, such as a river or lake. Freshwater consumption refers to the portion of the water withdrawn that is no longer available to be returned to the water source, such as when it has evaporated. For the purposes of this report, we distinguish between withdrawal and consumption, when necessary.

[34]Kenny et al., "Estimated use of water in the United States in 2005."

[35]The 2005 data are USGS's most current estimated use data; USGS has not yet released data for 2010.

[36]GAO, *Energy-Water Nexus: Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use*, GAO-10-23 (Washington, D.C.: Oct. 16, 2009).

Figure 5: Trends in U.S. Water Withdrawals by Use Categories, 1950-2005



Source: U.S. Geological Survey.

Note: The figure includes USGS's most current (2005) estimated use data; USGS has not yet released data for 2010. The data include both freshwater and saline water.

Irrigation was the second largest source of withdrawals in 2005, accounting for 31 percent of total withdrawals, according to USGS. Although irrigation remains a significant use of freshwater, the average application rate for irrigation water has declined between 1950 and 2005 as a result of more targeted irrigation, according to USGS. State water managers have concerns with freshwater use for irrigation, according to our survey. Specifically, in responding to a question about the uses of greatest concern in terms of affecting water availability for other uses, state water managers most often cited irrigation, with 24 out of 37 state water managers responding as such.

Certain Issues Have Gained Prominence Since 2003

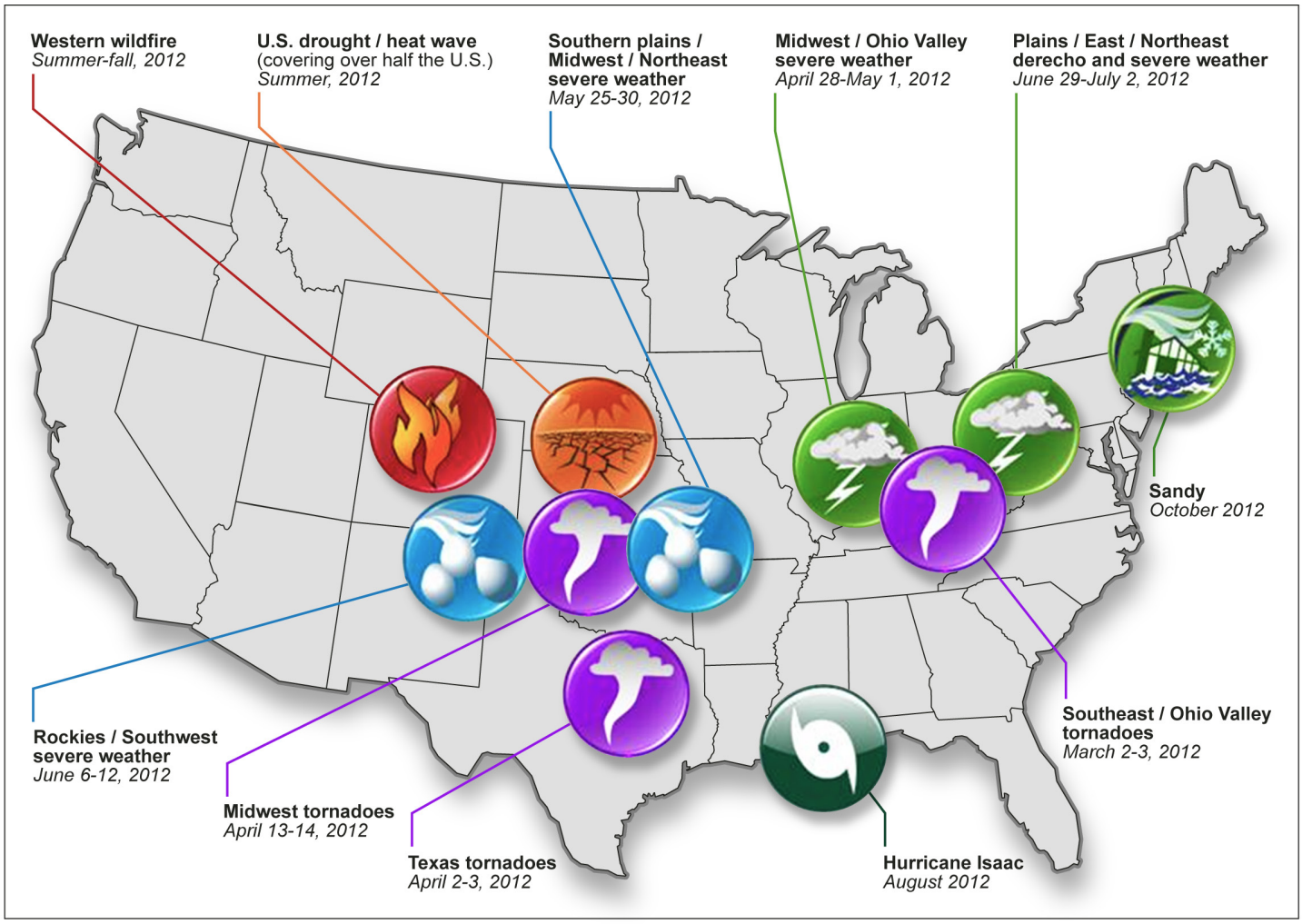
Since 2003, certain issues related to freshwater availability and use have drawn more attention. Specifically, our review found that concerns about impacts of climate change on water resources, maintaining ecological and recreational flows, interactions between surface water and groundwater, and the effect of energy production on water quality and quantity have gained prominence over the last decade.

Climate Change and Extreme Weather

In 2003, we reported that climate change made future supply and demand conditions uncertain, and, as part of our current review, many experts told us that the impacts from extreme weather events occurring in the last 10 years have led to increased attention to the impacts of climate change on freshwater resources. In 2009, the United States Global Change Research Program reported that the impacts and costliness of weather disasters—resulting from floods, drought, and other events such as tropical cyclones—are expected to increase in significance as previously "rare" events become more common and intense due to anticipated changes in the global climate system.[37] Moreover, according to NOAA's National Climatic Data Center, which tracks and evaluates climate events in the United States that have great economic and societal impacts, the two most costly years in terms of weather and climate disaster events have occurred over the last decade. Specifically, 2005 saw 5 events with losses exceeding $1 billion for a total of approximately $190 billion (2013 dollars) in damages, followed by 2012 with 11 events over $1 billion, resulting in over $115 billion in total damages. Figure 6 displays these 11 events in 2012.

[37]Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, eds. *Global Climate Change Impacts in the United States* (New York, NY: Cambridge University Press, 2009). This document, referred to as the 2009 National Climate Assessment, is a publication of the U.S. Global Change Research Program. The program coordinates and integrates the activities of 13 federal agencies that conduct research on changes in the global environment and their implications for society. During our review, the 2009 National Climate Assessment was in the process of being updated, as the Global Change Research Act of 1990 requires that a scientific assessment be provided to the President and the Congress not less frequently than every 4 years. Pub. L. No. 101-606, § 106, 104 Stat. 3096, 3101 (1990) (codified at 15 U.S.C. § 2936). On May 6, 2014, the administration released the third U.S. National Climate Assessment.

Figure 6: U.S. Billion Dollar Weather and Climate Disasters, 2012



Sources: National Oceanic and Atmospheric Administration; Map Resources (map).

Note: A derecho is a widespread, long-lived windstorm associated with a band of rapidly moving showers or thunderstorms and must include wind gusts of at least 58 miles per hour or greater along most of its length.

Drought is one type of weather extreme that has drawn increased attention since 2003. According to NOAA, the 2012 drought and heat wave was the most extensive in the United States since the 1930s, with more than half the country under moderate to extreme drought conditions for most of 2012. More recently, the California drought caused the state's governor to declare a "State of Emergency" in January 2014. According to the U.S. Drought Monitor, as of April 22, 2014, approximately 77 percent

of the state was under “extreme drought” or “exceptional drought” conditions,[38] whereas no portions of the state were in those categories at the same time last year. Furthermore, this was the first time in the 15-year history of the U.S. Drought Monitor that 100 percent of the state was in “moderate” to “exceptional” drought. Given the projection that 2014 will become the driest year on record, the governor directed state officials to take a number of actions, including assisting farmers and communities that are economically affected and ensuring the state can respond if Californians face drinking water shortages. Drought also can impact groundwater resources. A recent study using NASA data found that, if current drought conditions continue over the next several years, groundwater in the Central Valley portion of California, which produces one-quarter of the nation’s food, will fall to historically low levels.[39] As the study noted, drought conditions and groundwater depletion in the Central Valley have resulted in detrimental impacts such as land subsidence, reductions in planted acreage, higher food costs, reduced river flows, and ecological damage. One expert told us that, during the last 10 years, there has been increased awareness that limited water availability caused by drought also negatively effects other water uses beyond agricultural production, such as producing energy, providing drinking water for populations, and maintaining flows necessary to support ecosystems and tourism.

At the other extreme, flooding over the last decade has also increased attention given to the impacts of climate change. For example, according to the National Climatic Data Center, Hurricane Katrina caused over $148 billion (2013 dollars) in damages and over 1,800 deaths due to severe storm surge, high winds, levee failure in New Orleans, and flooding in multiple states in August 2005. More recently, Hurricane Sandy was the costliest event in 2012, resulting in over $65 billion (2013 dollars) in damages and 159 deaths. Extreme events may also have indirect impacts on freshwater resources. For example, as we previously reported, climate-related changes will likely adversely affect many aspects of the natural environment in the United States, including

[38]The U.S. Drought Monitor uses five categories to classify drought severity. The categories, ranging from least to most severe, are “abnormally dry,” “moderate drought,” “severe drought,” “extreme drought,” and “exceptional drought.”

[39]UC Center for Hydrologic Modeling, “Water Storage Changes in California’s Sacramento and San Joaquin River Basins from GRACE: Preliminary Updated Results for 2003-2013,” *Water for California*, Feb. 3, 2014, http://www.ucchm.org/publications/.

increases in wildfires.[40] High-intensity rainfall in steep, burned watersheds are likely to move large amounts of suspended and dissolved material into downstream water supplies, resulting in, among other things, increased sedimentation and nutrient loading in water supply reservoirs and increased cloudiness from suspended materials, which may increase the need for chemical treatment, according to USGS.

Ecological and Recreational Flows

In 2003, we reported that the public values leaving water instream for endangered species and recreation, which may alter how water is allocated for existing uses and the development of new supplies. Many experts told us that, over the last decade, more attention has been paid to maintaining sufficient flows for these purposes. The events in the Apalachicola-Chattahoochee-Flint River Basin serve as an illustration.[41] Specifically, water in the basin is needed for municipal water supply, hydropower dams, and cooling of thermoelectric power plants, among other uses. According to a report from the Congressional Research Service, competition among the various uses, however, has created conflicts between Alabama, Florida, and Georgia due, in part, to the need to maintain sufficient flows to support oysters in the Apalachicola Bay. Oysters from Franklin County, located on Apalachicola Bay in northwestern Florida, account for more than 90 percent of Florida's oysters and 10 percent of the nation's oyster supply, according to the Apalachicola Bay Chamber of Commerce. Moreover, the basin is home to four species protected under the Endangered Species Act: Gulf sturgeon, fat threeridge mussel, Chipola slabshell mussel, and purple bankclimber mussel. In November 1997, the Congress passed the Apalachicola-Chattahoochee-Flint River Basin Compact, which was ratified by all three states.[42] The compact was intended to improve relations between the states and establish an agreement on how to apportion surface water within the basin, among other things, but the states did not reach agreement by the August 2003 deadline. Tensions in the basin have continued to intensify. In August 2013, Florida filed a lawsuit in the U.S. Supreme Court against Georgia, in which Florida claimed that the state's

[40]GAO, *Climate Change: Various Adaptation Efforts Are Under Way at Key Natural Resource Management Agencies*, GAO-13-253 (Washington, D.C.: May 31, 2013).

[41]The basin is located in the southeastern United States and flows through the states of Alabama, Florida, and Georgia.

[42]Pub. L. No. 105-104, 111 Stat. 2219 (1997).

fisheries have suffered declines as a result of Georgia's water storage and consumption. The case is pending as of the time of this report.

Our review also found that attention has grown over the last decade to protecting freshwater resources for recreational purposes. Some experts told us that recreational uses contribute enough to the economy that the public understands the importance of leaving water in the streams for fishing, boating, and other recreational uses. As one expert explained, in applying the prior appropriation doctrine in the past, recreation was not included among acceptable uses since it was not viewed as contributing to the economy. This expert said, however, the recreational sector has played a more significant role in the economy over time and, therefore, the value of leaving water instream for recreational purposes has similarly increased. Reclamation officials added that many western states have adopted statutes recognizing various "beneficial uses" associated with leaving water in natural waterways, and have established legal mechanisms to administer instream flow rights along with the appropriative rights of more traditional out-of-stream water uses.

Interactions Between Surface Water and Groundwater

Our review also found that the need to incorporate the links between surface water and groundwater into freshwater management has drawn increased attention since 2003. Groundwater and surface water are interconnected—streams and rivers recharge aquifers, and, conversely, groundwater replenishes surface water bodies. According to USGS,[43] the contribution of groundwater to annual streamflow volume may be as large as 90 percent in some parts of the country. As a consequence, depletion of lakes and streams can negatively affect groundwater and vice versa. Although the two resources can be integrally linked, they have historically been managed separately due, in part, to a limited understanding of their interactions. Our review found, however, that over the last decade there have been increased efforts to understand the linkages and to manage the resources together. For example, 38 of 47 state water managers responding to our 2003 survey reported that their state uses conjunctive management—coordinated management of surface water and groundwater resources to maximize their availability and reliability; in 2013, the number of managers responding that their states manage the two resources together increased to 42 of 50 state water managers.

[43]P.M. Barlow and S.A. Leake, "Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow," *U.S. Geological Survey Circular 1376* (2012).

Some states that reported conjunctively managing surface water and groundwater in 2003 have taken steps to increase their focus on this. For example, in April 2004, the Nebraska governor signed Legislative Bill 962 to better integrate management of hydrologically connected groundwater and surface water resources in the state by aiming to prevent conflicts between water users and establishing principles and guidelines to resolve existing conflicts.[44] The bill required Nebraska's Department of Natural Resources (DNR) to annually determine which basins, sub-basins, or reaches in the state are fully appropriated or overappropriated.[45] If DNR determines that the basin, sub-basin, or reach is fully appropriated or overappropriated, new groundwater and surface water uses are suspended, and the affected natural resource districts and DNR must jointly develop and implement an integrated management plan.[46] This plan is to include, among other things, clear goals and objectives with a purpose of sustaining a balance between water uses and supplies so that the economic viability, social and environmental health, safety, and welfare of the basin, sub-basin, or reach can be achieved and maintained for both the near term and the long term.

According to a report from USGS, managing the interactions between surface water and groundwater poses challenges that are important for water managers to understand.[47] For instance, the effect of a groundwater withdrawal on the timing, rates, and locations of streamflow depletions differs substantially from effects caused by surface water withdrawals. Specifically, surface water withdrawals have immediate effects on the rate of streamflow at the point of withdrawal, but the effect of groundwater withdrawals on surface water may lag. For example, the delay between when a well begins to pump and when the impact of that pumping on a connected stream is realized ranges from days to decades. Managing potential threats to water quality also adds complexity to the groundwater and surface water links, according to USGS. For example, surface water containing chemicals or biological contaminants can

[44]2004 Neb. Laws, L.B. 962 (codified as amended at Neb. Rev. Stat. §§ 46-701 – 753 (Cum. Supp. 2004)).

[45]In general, a reach is a section of a river.

[46]In Nebraska, DNR regulates surface water and some aspects of groundwater, and 23 Natural Resource Districts regulate groundwater within their respective jurisdictions.

[47] Barlow and Leake, "Streamflow depletion by wells."

infiltrate connected groundwater sources, posing a threat to people who may ingest the contaminated groundwater. In addition, reductions in streamflow stemming from groundwater pumping can result in warmer stream temperatures during the summer and cooler temperatures during the winter, potentially affecting fish and other aquatic organisms.

Energy Production

Our review found that more attention has been paid over the last decade to the impacts of energy production on both water quantity and quality. Specifically, after irrigation, energy production was the second greatest concern of state water managers in terms of affecting water available for other uses, with 14 of the 37 managers who responded to the question citing this concern, according to our survey. Some of the literature we reviewed and experts we spoke with attribute the increased attention to the effects of energy production on water resources, in part, to the rise of hydraulic fracturing as a production method to extract shale oil and natural gas. Hydraulic fracturing involves the injection of water, sand, and chemical additives under high pressure to create and maintain fractures in underground formations to allow the release of oil and gas. As we found in September 2012,[48] from 2007 through 2011, annual production of shale oil and gas has experienced significant growth. Specifically, shale oil production increased more than 5-fold, and shale gas production increased approximately 4-fold over this 5-year period.

Also, as we previously found,[49] the cumulative effects of using surface water or groundwater at multiple oil and gas development sites can be significant at the local level, particularly in areas experiencing drought conditions. For example, officials from Colorado told us that, over the last 10 years, energy production, particularly shale oil and gas production, has increased significantly in the state, and they are monitoring for its potential impact on water resources. Similarly, anticipated increases in energy production could further drive demand for water use in the state in the future. According to the Colorado Oil and Gas Conservation Commission, although the percentage of state water use for hydraulic fracturing is currently small (0.08 percent in 2010), the commission projects that the annual demand of water for hydraulic fracturing will increase approximately 35 percent between 2010 and 2015. Such use

[48]GAO, *Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks*, GAO-12-732 (Washington, D.C.: Sept. 5, 2012).

[49]GAO-12-732.

could pose problems in certain areas because the state receives 12-16 inches of precipitation annually, and drought occurs frequently. Our September 2012 report found that shale oil and gas development also poses risks to water quality from contamination of surface water and groundwater as a result of spills and releases, erosion, and underground migration of gases and chemicals used in the fracturing process.[50] Water quality degradation affects water quantity because if water resources are contaminated, they are not readily available for uses that require high-quality water, such as for public water supply or for ceremonial purposes on tribal lands.

Between 2009 and 2012, we issued six reports on interdependencies between energy and water in which we found that many aspects of energy development and delivery, including resource extraction, refining and processing, generation, storage, and transportation, can affect water resources.[51] For example, we reported in November 2009 that water supply and quality can be affected by many stages of the biofuel life cycle.[52] Specifically, to cultivate biofuel feedstocks, crops can be either rain-fed, with all needed water provided by natural precipitation and soil moisture, or irrigated, with at least some portion of their water requirements met through water applied from surface or groundwater sources. Water is also used in the fermentation, distillation, and cooling processes of converting the feedstock into biofuel.

[50]GAO-12-732.

[51]GAO-10-23; GAO, *Energy-Water Nexus: Many Uncertainties Remain about National and Regional Effects of Increased Biofuel Production on Water Resources*, GAO-10-116 (Washington, D.C.: Nov. 30, 2009); GAO, *Energy-Water Nexus: Amount of Energy Needed to Supply, Use, and Treat Water Is Location-Specific and Can Be Reduced by Certain Technologies and Approaches*, GAO-11-225 (Washington, D.C.: Mar. 23, 2011); GAO, *Energy-Water Nexus: A Better and Coordinated Understanding of Water Resources Could Help Mitigate the Impacts of Potential Oil Shale Development*, GAO-11-35 (Washington, D.C.: Oct. 29, 2010); GAO, *Energy-Water Nexus: Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production*, GAO-12-156 (Washington, D.C.: Jan. 9, 2012); and GAO, *Energy-Water Nexus: Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs*, GAO-12-880 (Washington, D.C.: Sept. 13, 2012).

[52]GAO-10-116.

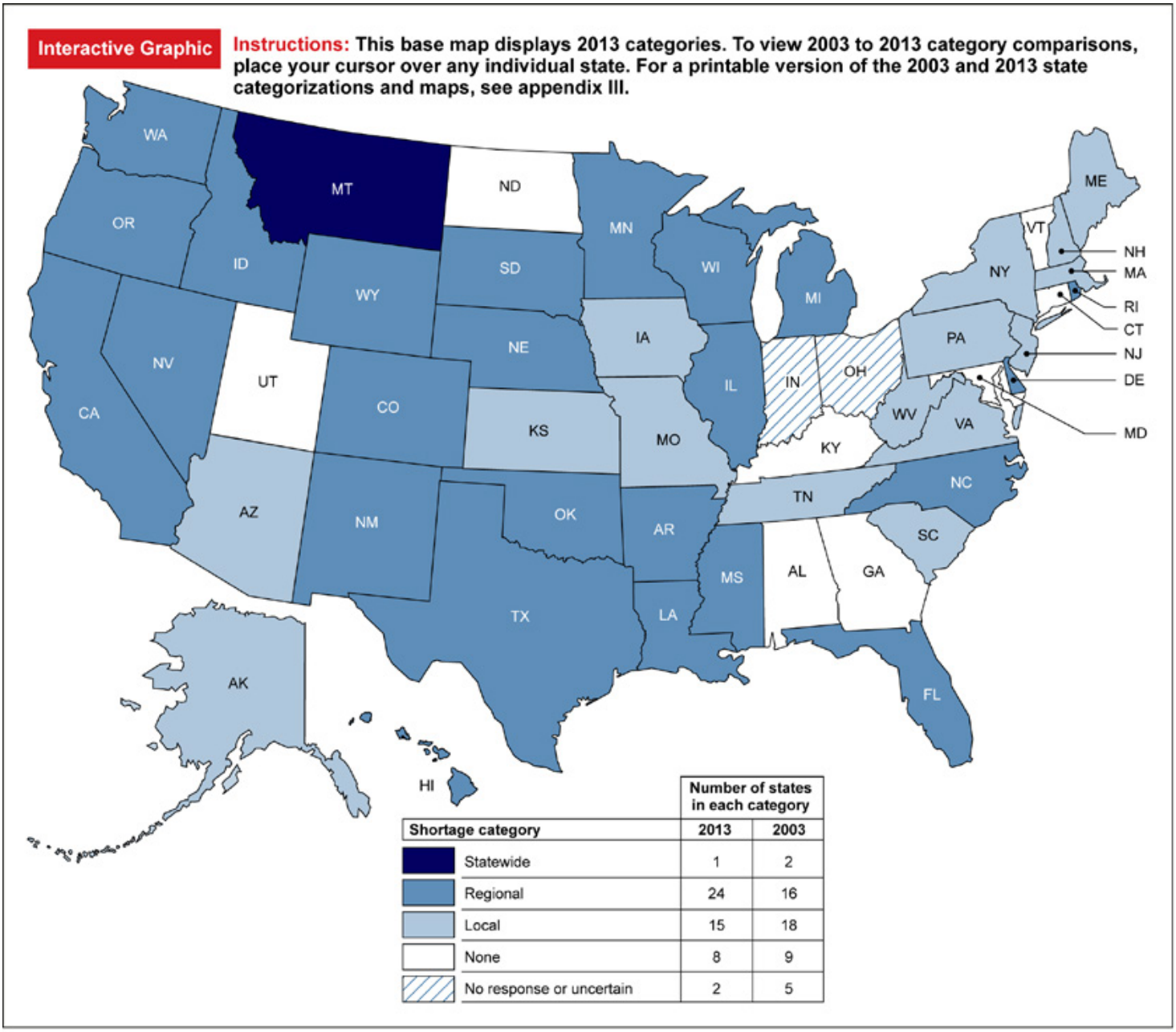
Future Freshwater Shortages Are Expected, but Planning Is Complicated by Uncertainty Related to Freshwater Availability and Use

According to state water managers and experts we spoke with, as well as the literature we reviewed, freshwater shortages are expected to continue into the future and will vary by location. However, uncertainty stemming from patterns of economic growth, changes in water use patterns, land use change, and climate change is likely to complicate state water managers' planning efforts into the future.

More Widespread Freshwater Shortages Are Expected and the Extent Will Vary by Location

State water managers continue to expect widespread freshwater shortages in the future, according to our survey. In comparison with 2003, a slightly greater number of state water managers reported in 2013 that they expected freshwater shortages within the next 10 years. Specifically, 40 of 50 state water managers responding to our 2013 survey expected shortages in some portion of their states under average conditions in the next 10 years, whereas 36 of 47 state water managers who responded to our 2003 survey had expected shortages under similar conditions over the same time frame (see fig. 7, an interactive map, and app. III for additional information). Moreover, an increased number of state water managers expect shortages over wider geographic areas; specifically, 24 respondents to our 2013 survey reported that they expected freshwater shortages at regional scales, in comparison with 16 respondents who expected shortages at regional scales in 2003.

Figure 7: Extent of State Shortages Likely over the Next Decade under Average Water Conditions, 2013



Sources: GAO analysis of state water managers' responses to GAO survey; Map Resources (map).

Furthermore, state water managers in 2013 continue to expect shortages in the longer term, as compared with respondents in 2003, according to our survey. Specifically, 42 of the 50 state water managers responding to our 2013 survey expected shortages under average conditions in the next 10-20 years; whereas in 2003, 39 of 47 managers responded that they expected such shortages. Similarly, literature that we reviewed modeling the potential effects of climate change on freshwater availability and use highlights growing challenges to the water supply over longer periods of time. For example, a Forest Service study found that the vulnerability of the water supply is expected to increase between 2020 and 2060 as the effects of climate change become more prominent, though the extent of the vulnerability depends on the specific climate scenario.[53] Moreover, from 2005 to 2090, most of the continental United States is expected to experience at least a 25 percent increase in water withdrawals as a result of climate change, according to an academic study.[54]

Drought conditions are expected to increase the probability of future shortages, according to the results of our survey and experts with whom we spoke. Specifically, all 50 state water managers reported that they expect shortages in their state under drought conditions over the next 1-10 years, according to our 2013 survey. Similarly, according to an expert from the National Drought Mitigation Center, current climate models are predicting that there will likely be more extreme droughts in the future. The expert also noted that the nation will face numerous vulnerabilities due to increased competition for limited freshwater supplies; therefore, issues related to allocation of water under limited supplies should be anticipated. For example, the southern and western United States, which an academic study projects will become drier as a result of climate change in the future,[55] are, as we previously noted, the two areas projected to have the greatest growth in population, exacerbating demand for water supplies in these areas.

[53]U.S. Department of Agriculture, Forest Service, *Future Of America's Forests and Rangelands: Forest Service 2010 Resources Planning Act Assessment,* Gen. Tech. Rep. WO-87 (Washington, D.C.: August 2012).

[54]T.C. Brown, R. Foti, and J.A. Ramirez, "Projected Freshwater Withdrawals in the United States Under a Changing Climate," *Water Resources Research* 49 (2013).

[55]Mark Cowell and Michael A. Urban,"The Changing Geography of the U.S. Water Budget: Twentieth-Century Patterns and Twenty-First-Century Projections," *Annals of the Association of American Geographers* 100, no. 4 (2010).

Several of the experts we interviewed and documents we reviewed also highlighted that future freshwater availability and use will vary by location and region of the country. For example, states in the western and southeastern United States are projected to experience decreases in freshwater availability due to increasing temperatures and changing patterns of precipitation, according to the 2009 National Climate Assessment.[56] In contrast, the report also found that states located in the Northeast and Midwest are expected to receive greater precipitation, thereby increasing their risk of flooding. Similarly, western states generally expected more widespread shortages under average conditions than eastern states, but some states such as Florida ran counter to that general trend in 2013, according to our survey.

Within states, conditions related to freshwater availability and use can vary substantially. For example, USGS officials in Maryland told us that drought may stress freshwater supplies throughout the state while rising sea levels could affect freshwater supplies in the state's eastern and southern regions. These regions primarily rely on the coastal plain aquifers for their water supplies; sea level rise can cause saltwater to infiltrate into shallow, coastal freshwater aquifers, making the groundwater unfit for consumption without desalination, a costly treatment process. Moreover, water availability within a state can vary at a given point in time. For example, in September 2013, the governor of Colorado declared a state of disaster emergency due to flooding in over 10 counties located in the northern, central, and eastern portions of the state. Destruction from the flooding included fatalities and damage to a gas distribution pipeline, a wastewater treatment system, and buildings on the University of Colorado-Boulder campus. During this same time, however, much of the southeastern portion of the state was suffering from "extreme drought" or "exceptional drought," according to the U.S. Drought Monitor.

Uncertainty Related to Future Freshwater Availability and Use Complicates Planning

Our review found that uncertainty stemming from economic growth, changes in water use patterns, land use change, and climate change is likely to complicate state water managers' planning efforts into the future. For example, water is integral to many portions of the economy, and changes in economic activity can affect water demand. Over the last decade, several cities, such as Las Vegas and Phoenix, experienced a

[56]Karl et al., "Global Climate Change Impacts in the United States."

decrease in water demand as result of foreclosures and the economic downturn, according to one expert we spoke with. Uncertainty as to whether these changes are short or long term can complicate water management planning because, for instance, utilities need to decide whether to invest in building new infrastructure or repairing existing infrastructure to meet future demands if the economy, and related water use, rebound to previous levels, according to the expert.

Changes in water use patterns can further complicate water management planning because they add uncertainty about future demands for water. For example, the energy sector has the potential to undergo significant changes in how it uses water to extract energy resources and generate electricity. As we previously found in September 2012,[57] developing unconventional energy sources, such as oil shale, could have significant impacts on the quantity and quality of water resources, but the magnitude of these impacts is unknown because of uncertainty about the future scale and scope of oil shale development. In addition, the specific method used to generate energy can lead to substantial differences in water use because different energy production approaches require differing amounts of water. For example, thermoelectric power generation requires substantial amounts of water, while some renewable sources like solar photovoltaic panels and wind turbines consume relatively minimal water during normal operation, according to our September 2012 report.[58] Furthermore, studies we reviewed show that accurately predicting water use within certain sectors, such as agriculture, can be difficult because of challenges with modeling various factors that affect use. For example, changes in the amount of farmland irrigated depend on a mixture of factors including land prices, crop yields, agricultural policies, subsidies, and specific irrigation factors (e.g., energy prices, irrigation technologies, and demand for water in other uses), making it difficult to accurately model all of these factors, according to an academic study we reviewed.[59]

[57]GAO-12-880.

[58]Solar photovoltaic panels and wind turbines use small amounts of water for panel and blade washing, respectively. However, concentrating solar power plants that use wet cooling could significantly increase water demand, consuming up to twice as much water per unit of electricity produced as traditional fossil fuel power plants.

[59]Brown et al., “Projected Freshwater Withdrawals.”

In addition, our review found that uncertainty about land use change also poses problems for state water managers. For example, land use decisions have a substantial effect on the flow of the Potomac River Basin system, which is the major water source for the Washington, D.C., metro area, according to experts familiar with water supply issues in the basin. Specifically, the basin has experienced an increase in impervious surfaces, such as roads and buildings, to support growing populations. Increases in impervious surfaces, however, lead to increased runoff of precipitation into nearby surface water bodies, thereby reducing the amount of precipitation that seeps into the ground to replenish aquifers. Moreover, the runoff diminishes water quality by transporting pollutants into surface water bodies, posing problems for water utilities that draw the water for municipal supplies from these sources.

Uncertainty in climate change projections and limitations in data make water resources planning difficult. For example, a 2011 federal interagency review of the potential impacts of climate change on water resources stated that current down-scaled global climate models have significant limitations, and confidence in projections of future hydrology conditions is weak.[60] The 2009 National Climate Assessment noted that climate change has the potential to alter water use patterns in the future, but the extent of these changes, such as on the agricultural sector, is uncertain.[61] Specifically, some changes that may result from climate change, such as higher temperatures, are expected to increase the need for irrigation. Other changes, such as plants being able to use water more

[60]Global climate models are numerical models representing physical processes in the atmosphere, ocean, cryosphere, and land surface. They are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. Federal Interagency Panel on Climate Change and Water Data and Information, *Report to Congress—Strengthening the scientific understanding of climate change impacts on freshwater resources of the United States* (August 2011).

[61]Karl et al., "Global Climate Change Impacts in the United States."

efficiently,[62] may decrease that need. Similarly, state officials in Michigan told us that there is the possibility of climate change altering the growing season for agriculture, causing agriculture to expand into more northern parts of the state. This shift in the location of agriculture in the state could create new conflicts between water users in those areas.

Climate uncertainty and extreme weather events can also make water infrastructure planning challenging. According to an interagency report by USGS, the Corps, Reclamation, and NOAA,[63] the nation's aging infrastructure may not always be able to meet its designed level of performance under current conditions and could be more vulnerable to failure under future climate scenarios, such as heavy precipitation and high runoff events. For example, extreme events, such as floods, have the potential to damage existing water infrastructure, as seen in Nashville, Tennessee, in 2010 when the city experienced "a 1,000 year flood."[64] This 2-day event damaged two of the city's three wastewater treatment plants and one of its two water treatment plants. In response, the city is considering adaptive measures—adjustments in natural or human systems to a new or changing environment that exploit beneficial opportunities or moderate negative effects—for its infrastructure, at an

[62]Carbon dioxide also makes some plants more water-use efficient, meaning they produce more plant material, such as grain, on less water. Karl et al., "Global Climate Change Impacts in the United States." J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, and D. Wolfe, 2008: Agriculture. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [P. Backlund, A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3, U.S. Department of Agriculture (Washington, D.C.: 2008).

[63]L.D. Brekke, J.E. Kiang, J.R. Olsen, R.S. Pulwarty, D.A. Raff, D.P. Turnipseed, R.S. Webb, and K.D. White, "Climate change and water resources management—A federal perspective," *U.S. Geological Survey Circular 1331* (2009).

[64]A 1,000 year flood refers to the return period of a given flood, or the average number of years between floods of a certain size. The actual number of years between floods of any given size varies a lot because of the naturally changing climate.

estimated cost of about $39.6 million, according to a report by the American Water Resources Association.[65]

Infrastructure planning challenges related to climate uncertainty are exacerbated by concerns about the condition of the existing water infrastructure. In our 2013 survey, state water managers cited infrastructure challenges as a great or very great concern over the next 10 years more frequently than any other factor. Moreover, the American Society of Civil Engineers' 2013 infrastructure report card rated the nation's existing water resource infrastructure, including dams and drinking water infrastructure, at a D or below.[66] The costs of modernizing infrastructure, however, are substantial, according to experts we spoke with and documents we reviewed. For example, in 2011, the EPA estimated it would cost $384.2 billion to upgrade drinking water infrastructure in the United States over the next 20 years.[67] In 2012, the American Water Works Association estimated it would cost over $1 trillion over the next 25 years to replace and expand buried water infrastructure.[68]

The high cost of infrastructure replacement is further complicated by low water prices, which do not cover all of the costs to supply water.

[65]AWRA is a nonprofit professional association for professionals working in water resources management, research, and education. American Water Resources Association, Policy Committee, *Proactive Flood and Drought Management: A Selection of Applied Strategies & Lessons Learned from around the United States* (Middleburg, VA, 2013).

[66]A report card grade of a D means that the infrastructure is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. Specifically, wastewater, drinking water, and dam infrastructure all received D grades, while levees and inland waterways received D- grades. American Society of Civil Engineers, *2013 Report Card for America's Infrastructure* (2013).

[67]For the purposes of this survey, EPA only includes projects eligible for, but not necessarily financed by, Drinking Water State Revolving Fund monies. The fund is designed to supplement, not replace, investment funding by states and localities, as well as rate payers. Projects eligible for funding include the installation of new infrastructure and the rehabilitation, expansion, or replacement of existing infrastructure. Environmental Protection Agency, *Drinking Water Infrastructure Needs Survey and Assessment: Fifth Report to Congress*, EPA 816-R-13-006 (Washington, D.C.: April 2013)

[68]The American Water Works Association is a scientific and educational association focused on water management and treatment issues. American Water Works Association, "Buried No Longer: Confronting America's Water Infrastructure Challenge," 2012, http://www.awwa.org/portals/0/files/legreg/documents/buriednolonger.pdf

Specifically, according to studies we reviewed and some experts we spoke with, artificially low water rates can lead to overuse of water and general undervaluing of the resource by the public. Low prices also present a challenge to many water utilities. Because the reduced water prices may not cover the actual costs incurred by the utilities to treat and provide the water, some utilities do not generate the additional revenue to implement necessary upgrades.[69] The need for revenue creates a challenge for utilities to balance goals like water conservation with generating enough revenue to maintain infrastructure and operations without raising water prices, according to an expert who represents municipal water utilities.

States Have Taken Steps to Better Manage Freshwater Resources

Our review found that over the last decade states have taken a number of steps to improve management of freshwater availability and use. These include conducting freshwater resource studies and assessments, developing drought preparedness and water supply plans, developing water management tools, developing new supplies and conservation initiatives, establishing water transfers and voluntary markets, and taking steps to address the impacts of climate change on water resources.

Conducting Freshwater Resource Studies and Assessments

A number of states have completed studies and assessments since 2003 to help better understand their freshwater availability and use. (See table 1.) Specifically, since 2003, slightly more states have assessed statewide water availability and withdrawals, and approximately the same number of states has assessed statewide water consumption.

[69]We have also previously found that many drinking water and wastewater utilities do not cover the full cost of service—including needed capital investments and operation and maintenance costs—through their user charges. GAO, *Water Infrastructure: Comprehensive Asset Management Has Potential to Help Utilities Better Identify Needs and Plan Future Investments*, GAO-04-461 (Washington, D.C.: Mar. 19, 2004).

Table 1: Number of States That Have Assessed Statewide Availability, Withdrawals, and Consumption, 2003 and 2013

Type of assessment	Number of states in 2003	Number of states in 2013
Availability	25 out of 47	28 out of 50
Withdrawals	36 out of 47	39 out of 50
Consumption	24 out of 47	25 out of 49[a]

Source: GAO analysis of survey data.

[a]In 2013, only 49 state water managers responded to this question.

For example, a number of studies have been conducted in Maryland to better understand water availability and use in the state. In particular, a 2005 executive order from the governor called for the creation of a committee to advise the state in implementing programs and policies related to the management, development, conservation, and protection of the state's water resources. As called for in the order, the committee issued a report in 2008 (referred to as "the Wolman report"), which urged the state to develop and fund a more robust, comprehensive, fully integrated state water resources management program. To help the state achieve this goal, the committee developed a number of recommendations calling for, among other things, development of a statewide water plan; establishment of a broader, more reliable monitoring network; and funding for two hydrologic studies in the state. According to state officials we spoke with, the recommendation calling for the hydrologic studies is particularly important because they plan to combine findings from the studies and the Wolman report to create a comprehensive water supply plan for the state. A statewide plan would help local and county governments integrate their water plans with statewide goals and priorities, according to state officials. Although the state, in cooperation with the USGS Water Science Center of Maryland, began work on the hydrologic studies, these efforts were discontinued due to limited funding and resources, according to state officials. As a result, Maryland does not have a comprehensive strategy that addresses statewide water supply needs.

Developing Drought Preparedness and Water Supply Plans

In 2013, more states reported having drought preparedness plans than in 2003. Specifically, in response to our 2013 survey, 38 of 48 state water managers responding to a question about drought preparedness plans reported that their states have these plans, whereas, in 2003, 23 of 47 respondents indicated that they had such a plan. An expert we spoke with explained that plans should be reassessed and revised, as needed, after a drought and highlighted Colorado's drought planning efforts as being

particularly effective because the state revised its plan numerous times since it was created in 1981, most recently in 2010 and again in 2013.

In addition, in response to our 2013 survey, 28 of 47 state water managers responding to a question about water supply plans indicated that their states have such plans.[70] Some state water officials we spoke with told us that, although their states did not currently have water supply plans, they are in the process of developing plans or strategies. For example, in May 2013, the governor of Colorado issued an executive order directing the Colorado Water Conservation Board (CWCB) to begin working on a draft Colorado Water Plan.[71] According to officials, the plan is intended to address a number of issues, including the gap between water supply and demand, the state's drought conditions that could affect the water supply gap, the link between water quantity and quality, and interstate water concerns. The order directs CWCB to develop a draft of the plan by December 10, 2014, with a final plan to be completed one year later. Similarly, Michigan officials told us that their state has also initiated work on a water strategy in response to a November 2012 request from the governor. This strategy is expected to use an ecosystem-based approach that enhances human use while preserving the ecological integrity of water resources, according to officials. The plan is being developed with input from various stakeholders—such as state agencies, environmental organizations, industry, and academia—and is expected to cover water withdrawal, use, and conflict; invasive species; and water quality and infrastructure, among other topics. Work on the strategy is under way with a final strategy expected in 2014, according to officials.

In addition, over the last decade some states have revised or are in the process of revising existing water plans. For example, Oklahoma completed an update to its comprehensive water plan in 2011 after extensive public input during a 4-year update process. The plan projected that between 2010 and 2060 statewide consumptive demand for water will increase by 33 percent, and demand for surface water will exceed available supply in 55 of the 82 plan basins by 2060. The plan also included recommendations to address the findings and other important

[70]We did not ask state water managers whether they had such plans in our 2003 survey.

[71]CWCB is an agency whose mission is to conserve, develop, protect, and manage Colorado's water for present and future generations. The board's responsibilities include protecting the state's streams and lakes, water conservation, drought and water supply planning, and protecting the state's water apportionments, among others.

water issues in the state, such as Oklahoma's growing water and wastewater infrastructure needs, ecological and recreational flows, tribal water claims, and conservation.

Developing Water Management Tools

Some states have also developed new tools to improve their freshwater management. For example, Michigan began requiring use of an online Water Withdrawal Assessment Tool in 2009 to estimate impacts of new or increased large quantity water withdrawals on nearby streamflows and fish populations. This tool acts as a screening mechanism for potential large-volume water users seeking to make new water withdrawals. The prospective water user enters their proposed withdrawal information into the tool, which determines whether the proposed withdrawal would be likely to have an adverse effect on resources, as measured by likely effects of changed streamflow on local fish populations.

Colorado also has developed tools to help manage its water resources. In 2005, the state passed the Colorado Water for the 21st Century Act that established nine basin roundtables to facilitate discussions within and between basins on water management issues, as well as an Interbasin Compact Committee to govern and guide negotiations between these roundtables.[72] The act also calls for the roundtables to assess future water supply needs, including for nonconsumptive uses such as environmental and recreational uses. As part of this effort, CWCB officials told us that they have worked with the roundtables to better understand the state's environmental and recreational water needs and developed a "toolbox" to assist in this effort. One tool included in the toolbox is the Watershed Flow Evaluation Tool, which was developed by the Nature Conservancy to assess the ecological risk of changes in streamflow to certain fish species and plant communities at basin scales.[73] The tool is being used to assess locations for streamflow restoration and estimate flow needs for restoration, among other uses, according to the CWCB officials.

In 2011, Wisconsin developed a new water management tool to address the quality of freshwater resources. The state, in collaboration with NOAA, USDA, and USGS, developed the Wisconsin Manure Management Advisory System to reduce contaminants from manure—

[72]2005 Colo. Sess. Laws ch. 314 (codified as amended at Colo. Rev. Stat. §§ 37-75-101 – 107).

[73]The Nature Conservancy is an environmental nonprofit organization working to protect ecologically important lands and water around the world.

which can impair water quality and may threaten drinking water supplies—flowing into rivers and lakes. The tool consists of a model and maps to alert farmers to the likelihood of runoff events that may occur on a given day and on specific fields, depending on weather, soil, and landscape conditions. Farmers generally apply manure and other nutrients in spring and early summer, times during which there is a high risk of runoff due to snowmelt and spring rains.

Developing New Supplies and Conservation Initiatives

According to our survey, a greater number of states in 2013 are developing new water supplies to supplement their existing freshwater resources, as compared with 2003 (see table 2).

Table 2: Number of States Developing New Water Supplies through Reclaimed Water, Recycling Storm Water, and Desalination, 2003 and 2013

Type of new supply	Number of states in 2003	Number of states in 2013
Reuse of reclaimed water	23 out of 47	36 out of 50
Recycling of storm water	5 out of 47	19 out of 49[a]
Desalination	9 out of 47	18 out of 50

Source: GAO analysis of survey data.

[a]In 2013, only 49 state water managers responded to this question.

For example, Florida is one of the states pursuing reuse of reclaimed water—wastewater that has been treated to meet certain quality criteria necessary for beneficial use. According to May 2013 data from the state's Department of Environmental Protection, Florida's reuse increased 24 percent in a decade, from 584 million gallons per day (mgd) in 2002, to 725 mgd in 2012. Moreover, the state's reuse capacity grew 47 percent during this time, from 1,162 mgd in 2002, to 1,711 mgd in 2012. According to the department, reusing 725 mgd of reclaimed water is estimated to have avoided using over 141 billion gallons of potable water while adding more than 84 billion gallons of water back to groundwater supplies.

States continue to use conservation to address current and future water supplies. For example, in our 2013 survey, 43 of 50 state water managers responded that their states have encouraged, required, and/or provided incentives for water conservation, while in 2003, 40 of 47 managers reported using conservation initiatives. Since our 2003 report, some states have enacted legislation that includes conservation requirements.

For example, in 2009, California enacted Senate Bill X7-7 that requires water suppliers to increase water use efficiency.[74] Among the requirements for urban water conservation, the state is to achieve a 20 percent reduction in urban per capita water use in California by December 31, 2020, with an interim requirement of at least a 10 percent reduction on or before December 31, 2015.[75] In addition, the legislation requires agricultural water suppliers to prepare and adopt agricultural water management plans by December 31, 2012, and to update those plans by December 31, 2015, and every 5 years thereafter.[76] Agricultural water suppliers are required to implement specified efficient water management practices.

Water Transfers and Voluntary Transfer Markets

Since 2003, more states are using interbasin water transfers and voluntary transfer markets to address freshwater needs, according to our survey (see table 3).[77]

Table 3: Number of States Using Interbasin Transfers and Voluntary Transfer Markets, 2003 and 2013

Type of action	Number of states in 2003	Number of states in 2013
Interbasin transfers	28 out of 47	36 out of 50
Voluntary transfer markets	15 out of 47	21 out of 49[a]

Source: GAO analysis of survey data.

[a]In 2013, only 49 state water managers responded to this question.

In the western United States, the Western Governors' Association and Western States Water Council reported in 2012 that although water markets have been active for decades, the number of transfers has

[74]2009 Cal. Stat., S.B. 7 (codified in scattered sections of div. 6 of the Cal. Water Code).

[75]Cal. Water Code § 10608.16.

[76]Cal. Water Code § 10820(a). The legislation defines an "agricultural water supplier" as a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding recycled water, and includes a supplier or contractor for water, regardless of the basis of right, that distributes or sells water for ultimate resale to customers. Cal. Water Code §§ 10812, 10608.12(a).

[77]Water transfers are voluntary agreements that result in a temporary or permanent change in the type, time, or place of use of water and/or a water right. Interbasin transfers are transfers of surface or groundwater between water basins.

generally increased between 2003 and 2008.[78] According to their report, irrigation accounts for the majority of freshwater use in western states. Farmers can sell or lease their water rights to other users, at which point the water is no longer available to the farmers for irrigation purposes. Many water rights held by farmers are senior rights, meaning that these rights are the first to be met in times of shortages, according to the report; as a result, agricultural water rights are often the source of water transfers to more junior uses, such as municipal, industrial, and environmental uses. In addition, between 1988 and 2009, Colorado saw the greatest number of water transfers (1,977 transfers) of the western states, although the transfers were for smaller volumes, according to the report. Officials in Colorado told us that intra- and interbasin agricultural transfers in the state are common, particularly in eastern portions of the state, because municipalities are buying water rights from farmers to support growing populations. Moreover, the Western Governors' Association and Western States Water Council report stated that, due to increasing demands for limited water supplies, 12 of the 17 western states surveyed indicated that water transfers are an important component of their long-term water planning.

Although more states have pursued interbasin transfers and voluntary transfer markets since 2003, our review found that there can be challenges to implementing these approaches such as state policies that may restrict such transfers or unintentional impacts may occur from such transfers. For example, although many transfers within Colorado occur from irrigation use to municipal use, state officials told us that concerns exist regarding the declining number of farms and the potential adverse impacts on rural communities as farmers sell their water rights. To address this issue, the state is encouraging alternative approaches, such

[78]Western Governors' Association and Western States Water Council, *Water Transfers in the West: Projects, Trends, and Leading Practices in Voluntary Water Trading* (December 2012).The report cautioned that the data illustrate general trends in water transfers, and the numbers represent the minimum number of transfers that have occurred as the data do not include all transfers. The Western Governors' Association is an independent, nonpartisan organization of governors from 19 western states, 2 Pacific-flag territories, and 1 commonwealth, that addresses policy and governance in natural resources, the environment, human services, economic development, international relations, transportation, and public management. The Western States Water Council is an organization consisting of representatives appointed by 18 western governors and works closely with the Western Governors' Association on water issues of concern to the governors.

as interruptible supply agreements and temporary, rather than permanent, transfer of water rights, in some instances.[79]

Developing Steps to Address the Impacts of Climate Change

Over the last decade, a number of states have acted to prepare for various climate impacts ranging from severe droughts to increased flooding. For example, Maryland's Department of Environment's Water Supply Program developed a brochure to assist water utilities in planning for the impacts of climate change, such as infrastructure damage from increased flooding and more frequent and intense storms, saltwater intrusion in coastal aquifers, and higher pollutant loads in source water stemming from changes in precipitation and increased runoff. The brochure includes guidance on steps utilities can take to adapt to changes in water availability, such as managing demand through water conservation strategies and diversifying water supplies.

In addition to states, officials from the National Tribal Water Council, an organization that advocates for tribes in matters pertaining to water, told us that tribal water managers have also devoted more attention to addressing climate change issues. For tribes, water has economic, cultural, and spiritual aspects; therefore, protecting the resource for future generations is an important focus. To help tribes adapt to climate change, the council has developed training and curricula, although the officials noted that the effort can be difficult because tribes vary in their readiness and resources available to take action. Moreover, the impact of climate change on freshwater resources experienced by tribes varies, depending on where the tribes are located. For example, the Hualapai Tribe, located in northwestern Arizona, is projecting that they will run out of water by 2035, and they are building rainwater harvest systems as a means to adapt to limited water supplies, according to the officials. In contrast, the Shishmaref Tribe, located in Alaska, is dealing with melting permafrost and coastal villages that are at risk of falling into the ocean due to flooding and erosion.

[79]Interruptible supply agreements are temporary arrangements in which water available under a particular water right is transferred for a specified time for use in another location while use is suspended by the owner of this water right at the original location.

Since 2003, Federal Agencies Have Taken Actions Supporting Freshwater Management; Additional Collaboration and Data Collection Could Enhance Support of States, but Federal Agencies Face Challenges

Our review found that federal agencies have initiated or updated a number of efforts since 2003 to support management of freshwater availability and use. In addition, our review identified actions the federal government could take to support state water management efforts, including increased collaboration among federal agencies and with states and other stakeholders, and maintaining and collecting key data. Federal agency officials, however, noted that they face challenges, such as limited funding, to implement additional actions.

Federal Agencies Have Taken Various Actions to Support Freshwater Management

Over the last decade, federal agencies have initiated or updated a number of programs to support management of freshwater availability and use. These programs include Interior initiatives, other federal agency initiatives, multiagency initiatives, and federal assessments and reports. For example, USGS initiated the National Water Census to assess the nation's water availability and use. As part of this effort, USGS plans to consistently quantify water supply and demand across the entire country; identify and fill in gaps in existing data; enhance understanding of the connection between water availability and quality; and make the information available to users, such as state agencies with water management responsibilities, according to an agency document. USGS anticipates that information gathered through the National Water Census will allow water managers to anticipate water shortages and develop plans to mitigate the impacts of and possibly prevent water shortages, among other benefits. In addition, under Interior's WaterSMART program, established in February 2010, the agency funds a variety of freshwater projects through competitively awarded grants to nonfederal partners, including states, tribes, water districts, municipalities, and universities to improve the efficiency of water delivery, conserve water, and demonstrate advanced water treatment technologies, among other things. For example, under the WaterSMART Water and Energy Efficiency Grant program, a total of $21.4 million was awarded in 2013 for projects such as

installing water flow meters and converting open ditches to pipes, which can reduce water loss due to evaporation and leakage.

Other federal agencies have also bolstered data collection efforts since 2003. For example, in February 2014 NASA and the Japan Aerospace Exploration Agency launched the Global Precipitation Measurement Core Observatory, which is a joint earth-observing mission to provide frequent next-generation global rain and snow observations. According to NASA, data from the mission will be used to quantify when, where, and how much it rains or snows around the world, allowing scientists to better understand and predict changes in freshwater supply. In addition, the National Integrated Drought Information System (NIDIS), established by the Congress in 2006 and administered by NOAA, provides the nation with a drought early warning system. One key component of NIDIS is the U.S. Drought Portal, a one-stop shop for drought-related information, such as maps and tools, that provides users with information about current drought conditions and impacts, as well as projections of the length of the drought, which can be used to prepare for and mitigate the effects of drought, according to agency officials.

Multiple federal agencies have also partnered together or with others to initiate actions to address freshwater availability and use. For example, in response to a November 2013 executive order directing federal agencies to prepare the United States for the impacts of climate change,[80] the National Drought Resilience Partnership was created. This USDA and NOAA-led partnership, which also includes participation from Interior, EPA, the Corps, and other agencies, focuses on increasing the amount of available drought information, building a national soil moisture network to help improve drought forecasting, and initiating a pilot resilience plan in western states. Participating agencies plan to create a Web-based system to increase access to federal drought resources, host more regional forums to distribute drought information, and create a single federal point of contact for drought information for the public, according to an agency document. In addition, the Western States Federal Agency Support Team (WestFAST), a collaboration of 12 federal agencies, states, and other stakeholders, was formed in 2008 to address water issues in western states. WestFAST, in collaboration with the Western

[80]"Preparing the United States for the Impacts of Climate Change," Exec. Order No. 13,653, 78 Fed. Reg. 66,819 (Nov. 1, 2013).

States Water Council, Western Governors' Association, and DOE has created a water data exchange to serve as a repository for water data maintained by states and federal agencies, according to federal officials.

Moreover, federal agencies have issued a number of assessments and reports on various aspects of freshwater availability and use. For example, the Subcommittee on Water Availability and Quality issued reports in 2004 and 2007 outlining the need for coordinated science and technology efforts to better understand U.S. water supply and demand and identifying areas for future emphasis by federal water science and technology programs.[81] In addition, the Interagency Climate Change Adaptation Task Force issued National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate in October 2011. The plan establishes a national goal for government agencies and citizens to collaboratively manage freshwater resources, among other things. (See app. IV for additional examples of federal actions taken since 2003.)

Additional Collaboration and Data Collection Could Enhance Federal Support of State Freshwater Management but Poses Challenges for Federal Agencies

Experts we spoke with, state water managers we surveyed, and literature we reviewed identified additional collaboration among federal agencies and between federal agencies, states, and other stakeholders, as well as enhanced data collection efforts, as actions that could bolster state water management activities. Federal agency officials, however, noted that they face challenges, such as limited funding, to implementing additional actions.

Collaboration among Federal Agencies

Our review found that additional collaboration between federal agencies could help states better manage freshwater resources, according to literature and experts we spoke with; however, differing agency priorities and funding constraints make such collaboration challenging. Specifically, our review of literature identified concerns with limited coordination

[81]National Science and Technology Council, Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality, *Science and Technology to Support Fresh Water Availability in the United States* (Washington, D.C.: Nov. 15, 2004). National Science and Technology Council, Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality, *A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States* (Washington, D.C.: Sept. 4, 2007).

among federal agencies regarding freshwater resources. As we found in our energy-water nexus and high-risk work,[82] federal agencies often operate in a "stovepiped" manner and do not take a holistic, collaborative approach to crosscutting issues, such as freshwater availability and use. Similarly, the Congressional Research Service noted that the fractured nature of federal water policy has been a recurrent theme for decades. Further, a 2011 federal interagency review of the potential impacts of climate change on water resources stated that, although significant federal efforts are devoted to measuring and monitoring water resources, there is a lack of coordination among the efforts, in some cases, because of differing data collection purposes, methods, and data quality objectives.[83]

Many experts also cited the need for better collaboration among federal agencies. For example, several experts explained that numerous federal agencies have water oversight responsibilities, each with their own specific missions, priorities, and "silos" of information, which can serve as barriers to collaboration. Moreover, these experts told us that having water-related programs spread across a number of federal agencies makes it difficult to understand how all of the programs fit together.

Although federal agencies have collaboratively addressed some issues related to freshwater management, as identified earlier in this report, several agency officials told us that differing agency priorities and funding constraints are challenges to additional collaboration among federal agencies. For example, USGS officials explained that many federal agencies consider the assessment of freshwater availability and use as a secondary mission to their primary mission of protecting water quality and forests, providing safe drinking water, or managing rangelands or navigation, among other priorities. According to NRCS officials, federal agencies have seen their staff sizes diminish over time without efforts to backfill these positions. As a result, the officials noted that agencies are struggling to meet their core missions and complete their baseline work. Moreover, USGS officials added that while more coordination may be

[82]GAO-12-880 and GAO, *High-Risk Series: An Update*, GAO-13-283 (Washington, D.C.: February 2013).

[83]Federal Interagency Panel on Climate Change and Water Data and Information, *Report to Congress—Strengthening the scientific understanding of climate change impacts on freshwater resources of the United States.*

needed, they reiterated that federal agencies do collaborate with one another. Specifically, the officials stated that they hold quarterly coordination meetings with other federal agencies with water resource responsibilities, such as EPA, the Corps, the National Weather Service, and NASA. In addition, NOAA officials pointed to collaborative efforts with other federal agencies as part of NIDIS. Specifically, the officials noted they leverage existing system infrastructure, data, and products from other agencies, such as snow depth data from USDA and reservoir level information from Interior and the Corps, and added that such collaboration will continue to be an important component of future NIDIS work.

Collaboration between Federal Agencies, States, and Other Stakeholders

Better collaboration between federal agencies and other stakeholders could enhance federal support for state water management activities, according to state water managers we surveyed, experts we spoke with, and literature we reviewed, but agencies are limited by legislative and regulatory requirements and concerns about overstepping states' rights to manage water resources. For example, state water managers wanted more input into federal oversight of water resources, according to our 2003 and 2013 surveys. Specifically, they want more flexibility in implementing environmental laws, such as the Clean Water Act and the Endangered Species Act. Moreover, some experts from organizations composed of water management professionals we interviewed told us that federal environmental standards, such as water quality standards, can be too restrictive, and the states want more flexibility in determining how to meet those standards.

In addition, in responding to our 2003 and 2013 surveys, state water managers identified seeking more state input in the operation of federal storage facilities as one of the most useful actions federal agencies can take to help states meet their water management goals. Moreover, some experts we spoke with told us that states want to be treated as collaborators rather than having federal agencies hand down directives for them to follow. For example, one expert explained that states indicated they are not involved early enough in the process of developing regulations; specifically, EPA is charged with oversight of the Clean Water Act, but states are usually the primary regulators and are generally not made aware of proposed regulatory changes until they are posted publicly. While some experts we met with said they see a role for federal agencies in water management, such as providing funding for water projects and bringing stakeholders to the table, some also emphasized the need to ensure that primary management of freshwater remains at the state level. For example, one expert we interviewed said that while

western states want access to federal data and funding, these states want to maintain control over the water resources in their state and do not want the federal government to dictate how they use or allocate those resources.

Our past work also highlighted concerns about limited collaboration between federal agencies and other stakeholders. For example, in 2009, we found that the federal government's climate adaptation activities were carried out in an ad hoc manner and were not well coordinated across federal agencies or with state governments.[84] Moreover, in 2013,[85] we found there is a need for better coordination, noting that federal agencies need to work with state and local governments, as well as volunteer agencies to produce and evaluate information so that they can fully assess risk and make appropriate response and recovery decisions related to climate change impacts.

Federal agency officials told us that there are challenges to collaborating with states and other stakeholders. For example, some officials told us that the amount of flexibility they can provide may be limited by the legislation that they are required to implement. For example, an official from FWS, which oversees the Endangered Species Act along with NMFS, said that unlike the Clean Water Act, which allows states to assume primacy in administering the law, the Endangered Species Act does not allow for such delegation of responsibility to states. The official noted, however, that although the Endangered Species Act requires FWS and NMFS to work with state and local agencies to resolve water issues in concert with conservation needs of protected species, the primary responsibility for overseeing the act lies with the federal agencies. Moreover, some officials noted that they are limited by funding and logistics. For example, according to NASA officials, although the agency works to build relationships with and reach out to state water managers on issues related to freshwater availability and use, it is difficult to do so with 50 states, numerous regional authorities, and constrained federal budgets. Similarly, Corps officials noted that declining budgets can reduce the time officials have available for collaboration with stakeholders to address freshwater availability and use.

[84]GAO, *Climate Change Adaptation: Strategic Federal Planning Could Help Government Officials Make More Informed Decisions*, GAO-10-113 (Washington, D.C.: Oct. 7, 2009).

[85]GAO-13-283.

Further, some experts and federal agency officials told us that there is great tension between federal agencies and states over management of freshwater resources, which can make collaboration difficult. For example, NRCS officials told us that there may be historical tension between federal and state agencies when it comes to water supply management, which is viewed as primarily a state-level responsibility. According to the officials, any perceptions that federal agencies may be trying to increase the federal presence regarding water availability could be met by strong resistance from the states. In addition, BLM officials told us that they are bound by law to protect federal reserved water rights created by legislation or executive order from uses that may harm the purpose for which the reserved right was created. These protections may run counter to the decisions of state water boards, legislatures, or governors on how best to allocate the water resources, resulting in the impression that federal agencies are usurping states' authority to manage water resources, according to the officials. Similarly, according to a report from the Congressional Research Service, at the state level, concern arises when the federal government is perceived to be infringing on the concept of state primacy in water allocation or controlling water management decisions.

Despite these challenges, federal officials told us that they do have efforts under way to include states and other stakeholders in water management decisions. For example, Reclamation officials told us that they coordinate with state and local partners in developing resource managements plans related to management of fish, wildlife, and recreation at Reclamation reservoirs. Reclamation also provides technical assistance to states and other nonfederal entities through a variety of grant and cost-share programs, such as water treatment projects, basin studies, and rural water supply appraisal studies. These collaborative efforts enable Reclamation to work with partners to increase water use efficiency, improve water management, explore innovative technologies, and understand the potential impact of climate change on water management and resources, according to the officials.

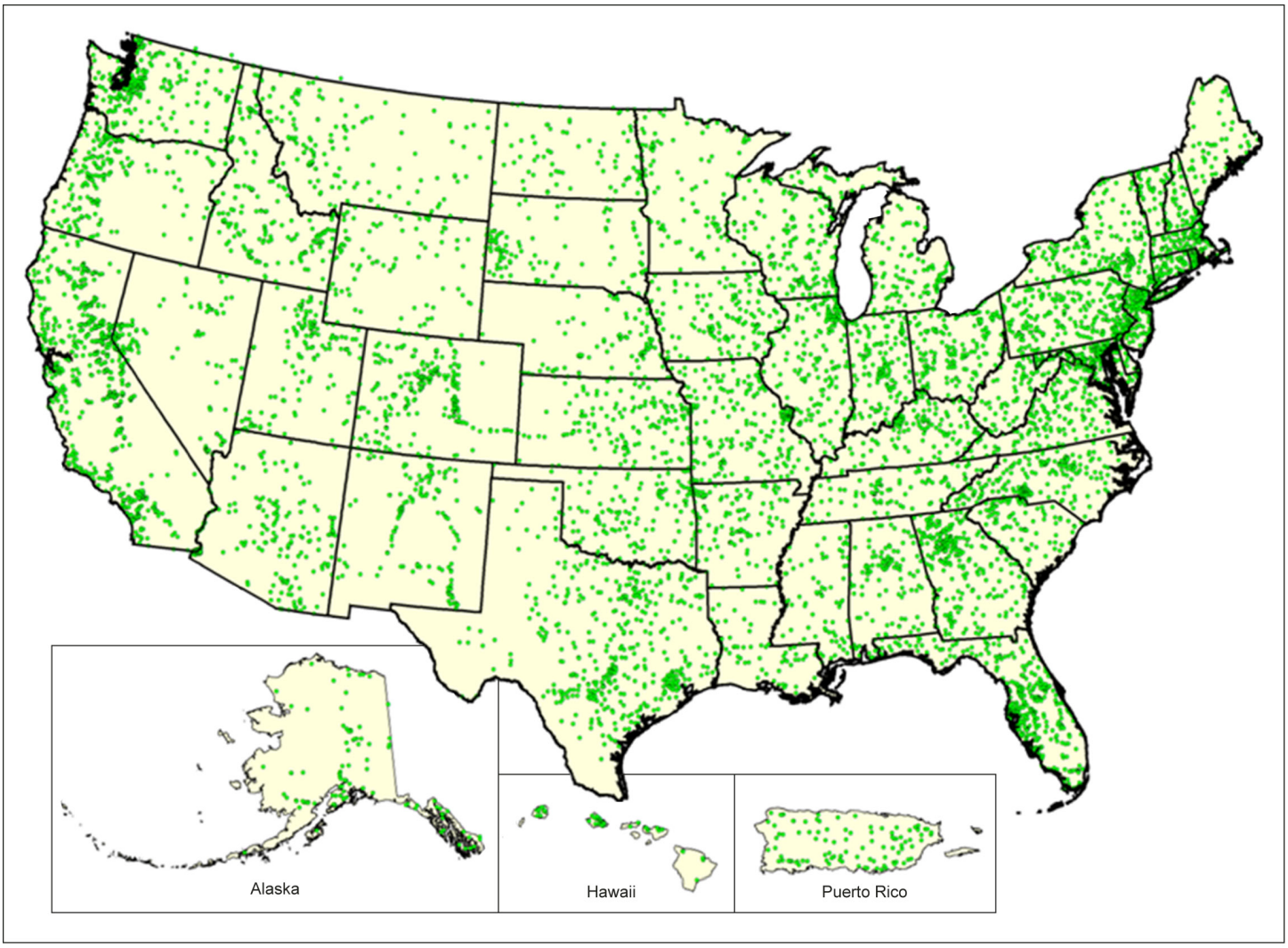
Data Collection

Survey respondents, experts we spoke with, and literature we reviewed also identified maintaining and collecting key data related to freshwater availability and use as an area in which the federal government could better support state water resource management; however, federal officials told us their agencies face funding challenges that limit their capacity to collect all the data that are needed. Some experts told us that providing data is one of the areas where the federal government can be most helpful with respect to freshwater management. In addition to

current data collection efforts, state water managers responding to our 2013 survey again reported that they would benefit from federal data collection at more sites. Specifically, 42 of 49 state water managers responding to a question about actions that the federal government could take with respect to collection and dissemination of data identified collecting water data at more locations as the most useful action. In addition, one expert noted that there are not robust federal data collection efforts for water use by the end user similar to that for energy, and this hampers efforts to advance water efficiency initiatives. Experts we spoke with, state water managers we surveyed, and literature we reviewed highlighted the following three additional actions federal agencies could take to improve water data collection:

- *Maintaining and enhancing streamgage network data.* State water managers and other experts we interviewed said maintaining the streamgage network is critical, especially in light of the uncertain impacts of climate change on freshwater resources. Specifically, 40 of 50 state water managers identified collecting data to determine the quantity of available surface water, a function that streamgages provide, as very or somewhat important, according to our 2013 survey. Moreover, many state water managers reported that increasing the number of streamgages to collect water quantity data would be a useful action federal agencies could take to assist states' water management efforts. USGS works in partnership with more than 850 federal, state, tribal, and local agencies to operate and maintain the network of over 8,000 streamgages around the United States (see fig. 8). These data can be used to support a wide range of water management activities such as administering water rights, mitigating hazards associated with floods, determining the timing of reservoir releases, meeting requirements of interstate compacts and international treaties, and protecting stream ecology, among many others.

Figure 8: U.S. Geological Survey's Nationwide Streamgage Network as of Fiscal Year 2012



Source: U.S. Geological Survey.

Although USGS has added streamgages since 2003, several experts and USGS officials told us that the agency periodically faces the possibility of having to discontinue gages because of budget restrictions, which is a concern for data users. For example, one expert explained that once data collection at a gage has stopped, the lost data cannot be replaced and that, even if the gage is put back into operation at a later date, gaps in the data record will exist, thereby

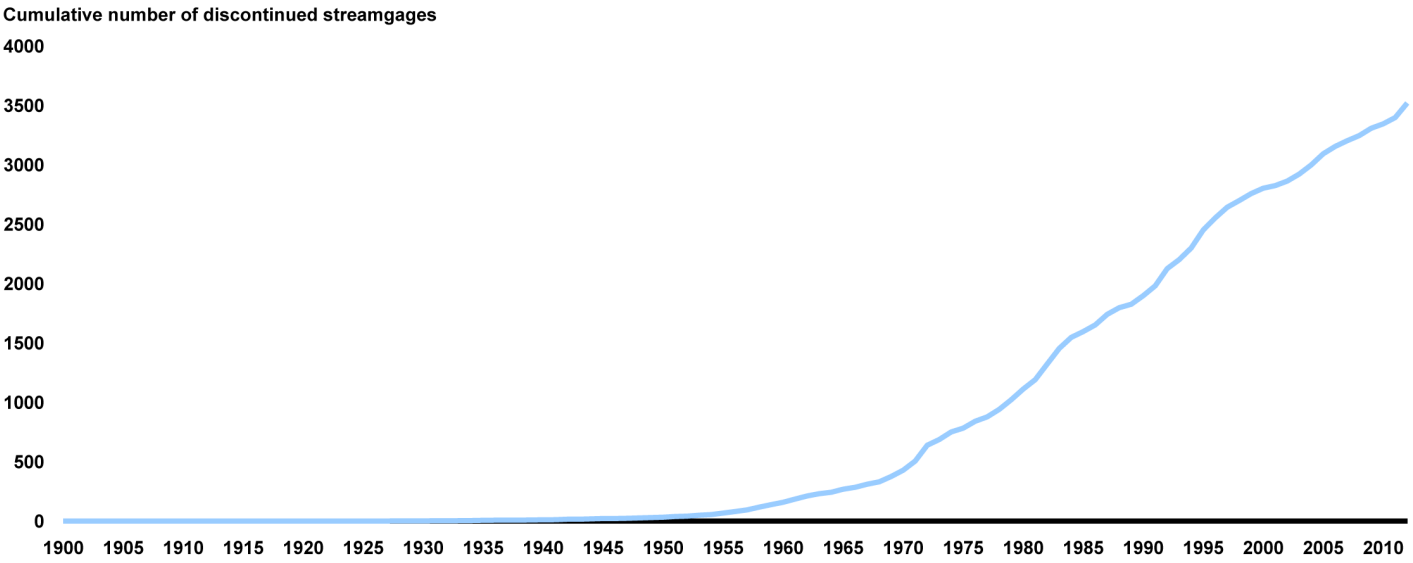
limiting the usefulness of the data. USGS maintains a list of threatened and endangered gages, which currently shows that approximately 2 percent of gages in the network have recently been discontinued primarily due to a lack of funding to support their operation. Recognizing the concerns over the impact of budgetary constraints on USGS's monitoring efforts, in November 2012, Interior's Assistant Secretary for Water and Science requested advice from the Advisory Committee on Water Information in identifying approaches and options to sustain and enhance water monitoring and related science, including ideas on ways to improve the streamgage program.[86] As of March 2014, a draft report with recommendations has been submitted to the Assistant Secretary's office, but a final report has not yet been released.

Several experts we interviewed also emphasized the importance of long-term streamgage data records and expressed concern over the loss of some of these gages. Long-term streamgages are important due to the amount of data they make available for assessments of trends over time and of the effects of land use, water use, and climate change. As we reported in 2009,[87] USGS's network of streamflow gages and groundwater monitoring stations provide the only national data of their kind on water availability over long periods, which state officials said are instrumental, for example, in predicting how much water is likely to be available in a river under a variety of weather conditions. Figure 9 shows the cumulative number of USGS streamgages discontinued from 1900 through 2012, with at least 30 years of streamflow data when they were discontinued.

[86]The Advisory Committee on Water Information is a working group composed of various member organizations, including federal agencies, nongovernmental organizations, industry, and states. According to organization documents, the committee works to improve water information for decision making about the management of natural resources and environmental protection.

[87]GAO-10-23.

Figure 9: Cumulative Number of Discontinued Streamgages with 30 Years or More of Data, 1900 to 2012



Source: U.S. Geological Survey.

- *Expanding collection of groundwater and precipitation data.* State water managers noted that groundwater data is necessary to adequately manage water resources in their state. Specifically, 34 of 50 state water managers indicated that data used to determine the quantity of available groundwater are very or somewhat important to freshwater management in their state, according to our survey. In addition, several experts we spoke with and literature we reviewed said that groundwater is far less understood than surface water, and that existing groundwater data are either limited or of poor quality. For example, one expert explained that using GRACE satellite data, researchers can monitor aquifer depletion and replenishment by tracking monthly changes, but currently the data resolution is not at the level desired. Our past work found there is a need for more data and research into groundwater resources and hydrological processes, such as aquifer recharge rates.[88] Such data and research could be used to improve water supply planning, protect tribal waters, and better understand the impacts of climate change and hydraulic fracturing on water resources, according to experts we spoke with. In

[88]GAO-12-880.

addition, several experts highlighted the need for additional precipitation data, including snowpack data since many western states rely on the snowpack for their water supplies. Some experts also told us that there is not a good rainfall measurement system in place since the current system lacks adequate coverage and rain gauges to be able to accurately track precipitation patterns. Other areas that may benefit from additional research and data include soil moisture, water consumption rates, evapotranspiration, and availability and use of alternative water sources.

- *Improving data accuracy and timeliness.* State water managers responding to our 2013 survey also identified improved federal data accuracy and timeliness as actions that could assist their state water management efforts. One expert pointed to USGS's publicly available estimated use reports, which are not timely as evidenced by USGS's 2010 data not yet being released. Such delays in reporting data can make determining current water use trends across the nation difficult.

In response to these data concerns, federal officials told us that insufficient funding is a primary barrier to expanding their data collection efforts. For example, an USGS official told us that the agency is committed to expanding data networks, but USGS's ability to collect data at more locations, improve timeliness, and conduct additional analyses is severely hampered by funding constraints. To help address this, the administration has proposed increases in funding for the National Streamflow Information Program in the last two fiscal year budgets, according to the Council on Environmental Quality and the Office of Science and Technology Policy. The President's fiscal year 2014 budget proposed $7.2 million in increases for streamgage funding, with the Congress appropriating $6 million in increases in the fiscal year 2014 Omnibus bill over the fiscal year 2013 budget. In the President's fiscal year 2015 budget, proposed funding for the program increases by another $1.2 million, building on the increase in fiscal year 2014. This funding is designed to stabilize the federal backbone of streamgages included under the National Streamflow Information Program, according to the Council on Environmental Quality and the Office of Science and Technology Policy. Similarly, NASA officials said that the agency has several concepts for missions designed to improve water resources monitoring that are awaiting funding. Moreover, some officials noted that budget constraints have caused their agencies to limit their data collection specifically to mission critical information. For example, Forest Service officials told us that steadily declining resources for freshwater and hydrologic data collection has led to limiting most of the water-related data collection directly supported by the agency to activity-related

evaluation and monitoring or specific research projects. NRCS faces similar reductions to its snow monitoring network. Specifically, an NRCS official told us that, due to budget limitations, NRCS has reduced the number of Snow Survey Program sites, a network of sites where snow measurements are manually collected once per month. For example, in fiscal year 2012, the Montana Snow Survey Office discontinued measurements at 38 locations to reduce program costs. Funding for the program over the last few years has varied—$10.9 million in fiscal year 2011, $8.55 million in fiscal year 2013, and $9.3 million in the 2014 budget.

According to USGS officials, adequate funding also poses a challenge for the National Water Census and estimated water use reports. The SECURE Water Act[89] authorized $20 million per fiscal year for the National Water Census for fiscal years 2009 through 2023, but enacted appropriations have been below the authorized amounts with $6 million appropriated in fiscal year 2012.[90] USGS officials said the agency intends to fully implement all elements of the National Water Census, with implementation taking longer than USGS had originally planned given funding constraints. For example, USGS is working on an analysis of water use by the public supply sector, which an official estimated completing within 3 years but plans to extend the time frame to over 5 years due to funding constraints. In addition, funding and resource constraints affect the timeliness of USGS's estimated use report, according to USGS officials. Specifically, the agency gathers water use data from all 50 states and other federal agencies, which can be challenging to ensure that the data will be consistent and received from the sources in a timely manner.

Agency Comments

We provided a draft of this product to the Departments of Agriculture, Commerce, Defense, Energy, the Interior, and State; EPA; NASA; the Council on Environmental Quality; and the Office of Science Technology and Policy for review and comment. The Department of the Interior, NASA, the Department of State, the Council on Environmental Quality,

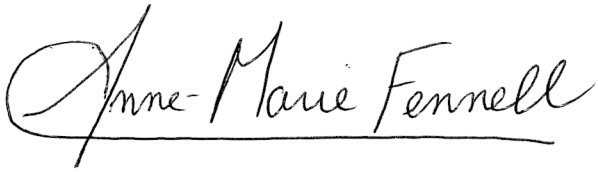
[89]Pub. L. No. 111-11, tit. IX, subtit. F, 123 Stat. 991, 1329 (2009) (codified at 42 U.S.C. §§ 10361-10370).

[90]The first appropriation for the National Water Census was $4 million in fiscal year 2011.

and the Office of Science Technology and Policy provided technical comments, which we incorporated, as appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees; the Secretaries of Agriculture, Commerce, Defense, Energy, the Interior, and State; the Administrators of EPA and NASA; the Chair of the Council on Environmental Quality; the Director of the Office of Science Technology and Policy; and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or fennella@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.



Anne-Marie Fennell
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

Our objectives for this review were to examine changes since 2003 in (1) issues related to freshwater availability and use; (2) expectations for water availability and use over the next 10 years and how these expectations may affect water planning; (3) steps, if any, states have taken to better manage freshwater resources; and (4) actions, if any, federal agencies have taken to support management of freshwater availability and use and perspectives from state water managers, experts we spoke with, and literature we reviewed on what the federal government can do to enhance its support of states.

To address these objectives, we used three primary methods. First, we conducted a Web-based survey of state water managers from all 50 states; the response rate to our survey was 100 percent. Because not all respondents answered every question, the number of states responding to any particular question we are reporting on is noted throughout the report. The survey was largely identical to the survey we used in 2003, with the addition of a few questions. In order to maintain the validity of comparing survey results from the 2003 and 2013 survey, the majority of the new questions were added to the end of the survey. Minor changes to select survey questions were tested and expertly reviewed in order to ensure comparisons between the 2003 and 2013 surveys. Specifically, the 2013 survey contained 67 questions compared with 56 questions in our 2003 survey. The questions covered various topics relevant to water availability and use including state water management; federal agencies' collection and dissemination of state water quantity data; federal water storage and conveyance within states; the effects of federal environmental laws on state water management; the effects of interstate compacts and international treaties on state water management; the effects of federal and tribal rights to water on state water management; and drivers of change that may affect water supplies in the next 10 years. We pretested the content and format of the survey with state water managers in Colorado, Maryland, and Washington. During the pretest, we asked the state water managers questions to determine whether (1) the survey questions were clear, (2) the terms used were precise, (3) the survey placed an undue burden on the respondents, and (4) the questions were unbiased. We incorporated their suggested changes, as appropriate.

We posted the survey on GAO's survey website. State water managers were notified of the survey with an e-mail message sent before the survey was available. When the survey was activated, an e-mail message informed the state water managers of its availability and provided a link that respondents could click on to access the survey. This e-mail

message also contained a unique user name and password that allowed each respondent to log on and fill out their own survey. To maximize our response rate, we sent reminder e-mails and contacted nonrespondents by telephone and e-mail resulting in a 100 percent response rate. We performed analyses to identify inconsistencies and potential errors in the data and contacted respondents via telephone to resolve discrepancies. A technical specialist reviewed all computer programs for analyses of the survey data.

We analyzed open-ended survey responses using different approaches, depending on the nature of the question. For example, for a question asking the respondent to name federal agencies which provide water data used by their state, we counted the number of times each agency was mentioned. For other more general open-ended questions, we conducted a content analysis of the responses. Content analysis is a methodology for structuring and analyzing written material. To conduct this content analysis, we developed codes to characterize the state water managers' responses. The coding was conducted independently by two GAO analysts after checking for intercoder reliability. We developed agreement statistics and discussed and resolved any discrepancies in coding. Aggregated responses of the survey are in appendix II.

Second, we analyzed key documents (e.g., peer-reviewed studies and government-sponsored reports) to gather information on current and future freshwater conditions. To identify relevant documents, we searched several databases, such as ProQuest and Academic OneFile, using key words and phrases developed by the team. Search terms included "freshwater," "groundwater," "shortage," "drought," and "withdrawal," among others. In addition, the team identified and collected documents throughout the engagement as new reports were issued and interview subjects mentioned reports of interest. From these documents, we identified over 40 key studies for review and included those studies that are dated from 2003 to the present; peer-reviewed studies, government-sponsored reports, and reports from other credible organizations; relevant to our research objectives; and address water issues within the United States, among other criteria. A methodologist reviewed the research studies used in this report to ensure they met sufficient quality standards. We analyzed these documents and developed summaries of key findings for each research objective.

Third, we conducted semistructured interviews with a range of individuals that we identified as having expertise on freshwater availability and use issues. We identified these experts using an iterative approach in which

we solicited names from agency officials and others we interviewed; we also interviewed experts identified during our analysis of key documents. These experts represented a variety of organizations including representatives from water industry associations, such as the Association of Metropolitan Water Agencies, which represents municipal water treatment plants; representatives from regional organizations, such as the Western States Water Council, an organization consisting of representatives appointed by 18 western governors to address water issues of concern to the governors; academics; and relevant nongovernment organizations, such as the Pacific Institute, a nonpartisan research institute that works to advance environmental protection, economic development, and social equity. We also interviewed officials from federal agencies that have responsibilities related to freshwater issues. The agencies included the U.S. Department of Agriculture, including the Forest Service and Natural Resources Conservation Service; the U.S. Army Corps of Engineers; the Department of Energy; the Department of the Interior, including the Bureau of Reclamation and the U.S. Geological Survey (USGS); the Environmental Protection Agency; the Office of Science and Technology Policy and the Council on Environmental Quality within the Executive Office of the President; the National Aeronautics and Space Administration; the Department of Commerce's National Oceanic and Atmospheric Administration; and the Department of State. We used the following categories to quantify the literature and responses of experts: "some" refers to at least two studies or experts, "several" refers to at least five studies or experts, and "many" refers to eight or more studies or experts.

In addition, we collected and analyzed information on three states (Colorado, Maryland, and Michigan) to serve as illustrative examples of state water management issues. We selected these states on the basis of criteria including variation across the states in their responses to our 2003 survey and types of water use within the states. To better understand freshwater issues in each state, we analyzed reports and other documents on state water issues and conducted semistructured interviews with individuals knowledgeable about state and regional issues. These interviews included state water managers; USGS Water Science Center officials from each state; academics; and representatives from other organizations relevant to the local situation, such as the Interstate Commission on the Potomac River Basin, an organization that works with the Potomac River Basin states, including Maryland, and the federal government to enhance, protect, and conserve the water and associated land resources of the basin. We identified interview subjects in

an iterative fashion using referrals from prior interview subjects, as well as through our review of documents from the states.

We conducted this performance audit from November 2012 to May 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: GAO Analysis of Our Survey of the Effects of Federal Activities on State Water Availability, Management, and Use

To obtain states' views on how federal activities could better support state water management efforts to meet future demands, we conducted a Web-based survey of state water managers in the 50 states with a response rate of 100 percent. The survey was largely identical to the survey we used in 2003, with the addition of a few questions. Specifically, the survey contained 67 questions compared with 56 questions in our 2003 survey. The questions covered various topics relevant to water availability and use including state water management; federal agencies' collection and dissemination of water quantity data; federal water storage and conveyance within their state; the effects of federal environmental laws on state water management; the effects of interstate compacts and international treaties on state water management; the effects of federal and tribal rights to water on state water management; and drivers of change that may affect water supplies in the next 10 years.

1. Has your state conducted any of the following assessments?[1]

	Yes, statewide (most or all regions of your state)	Yes, only for some regions or localities within your state	No	Uncertain	Total number of respondents
a. Water availability assessment	28	18	3	1	50
b. Water withdrawals assessment	39	9	2	0	50
c. Water consumption assessment	25	15	9	0	49

2. Has your state conducted any of the following assessments, either for all of your state or for portions of your state?

	Yes	No	Uncertain	Total number of respondents
a. Actual economic effects of recent water shortages, including drought	11	28	10	49
b. Potential economic effects of future water shortages, including drought	16	24	9	49
c. Actual environmental effects of recent water shortages, including drought	18	20	11	49
d. Potential environmental effects of future water shortages, including drought	17	21	11	49

[1]Questions 1-12 asked about water management in each state. Some questions asked about water availability and/or water withdrawal. Water availability refers to the total quantity of water available in streams, rivers, snowpacks, and groundwater basins, including reclaimed water. Water withdrawal refers to the quantity of surface water diverted or groundwater withdrawn for use.

3. Does your state have any of the following plans?

	Yes	No	Uncertain	Total number of respondents
a. Water supply plan	28	18	1	47
b. Drought preparedness plan	38	5	5	48
c. Drought response plan	39	4	4	47

If yes, did your state receive any federal funds for the following plans?

	Yes	No	Uncertain	Total number of respondents
a. Water supply plan	7	19	2	28
b. Drought preparedness plan	2	30	6	38
c. Drought response plan	5	28	6	39

4. In the next 1-10 years which, if any, portions of your state, are likely to experience water shortages under average water conditions?[2]

Entire state (most, or all, of your state)	One or more regions within your state	One or more small localized areas within your state	None of the above	Uncertain	Total number of respondents
1	24	15	8	2	50

5. In the next 1-10 years which, if any, portions of your state, are likely to experience water shortages under drought conditions?

Entire state (most, or all, of your state)	One or more regions within your state	One or more small localized areas within your state	Total number of respondents
13	28	9	50

[2]For questions 4, 5, 6, and 7, respondents were instructed to use the last 10-20 years to determine average water conditions for their state. In addition, drought refers to a deficiency of precipitation, including snow, over several consecutive years.

6. In the next 10-20 years which, if any, portions of your state, are likely to experience water shortages under average water conditions?

Entire state (most, or all, of your state)	One or more regions within your state	One or more small localized areas within your state	None of the above	Uncertain	Total number of respondents
3	23	16	5	3	50

7. In the next 10-20 years which, if any, portions of your state, are likely to experience water shortages under drought conditions?

Entire state (most, or all, of your state)	One or more regions within your state	One or more small localized areas within your state	Total number of respondents
14	28	8	50

8. In the last 1-10 years which, if any, portions of your state, experienced water shortages under average water conditions?[3]

	Entire state (most, or all, of your state)	One or more regions within your state	One or more small localized areas within your state	None of the above	Uncertain	Total number of respondents
a. Same as 2003 survey response	1	14	13	7	N/A	35
b. Different from 2003 survey response	0	1	3	4	1	9
c. No 2003 survey response provided	0	3	1	1	0	5

If your expectation in 2003 did not match what your state experienced, please briefly describe the factors that may have contributed to the difference between estimated and actual conditions, and whether these factors continue to affect your state's estimates of future water conditions.

[3]This question is a simplified version of the questions asked to respondents in our survey because respondents received different versions of this question depending on whether and how they responded to our 2003 survey.

[Open-ended answers not displayed]

9. In the last 1-10 years which, if any, portions of your state, experienced water shortages under drought water conditions?[4]

	Entire state (most, or all, of your state)	One or more regions within your state	One or more small localized areas within your state	None of the above	Uncertain	Total number of respondents
Same as 2003 survey response	6	26	5	0	N/A	37
Different from 2003 survey response	1	5	2	1	0	9
No 2003 survey response provided	1	2	0	1	0	4

If your expectation in 2003 did not match what your state experienced, please briefly describe the factors that may have contributed to the difference between estimated and actual conditions, and whether these factors continue to affect your state's estimates of future water conditions.

[Open-ended answers not displayed]

10. Are any of the following actions being taken by your state government and/or by regional or local authorities to address current and future water needs in your state?

	Yes	No	Uncertain	Total number of respondents
a. Developing markets to allow voluntary water transfers among users	21	22	6	49
b. Developing new water supplies through reuse of reclaimed water	36	10	4	50
c. Developing new water supplies through recycling of storm water	19	22	8	49
d. Developing new water supplies using desalination (seawater or brackish groundwater)	18	29	3	50
e. Encouraging, requiring, and/or providing incentives for water conservation	43	4	3	50
f. Improving vegetation management along streams and rivers to increase stream flow	28	10	8	46

[4]This question is a simplified version of the questions asked to respondents in our survey because respondents received different versions of this question depending on whether and how they responded to our 2003 survey.

	Yes	No	Uncertain	Total number of respondents
g. Improving riparian buffers to enhance water quality and increase water quantity	42	2	5	49
h. Increasing storage capacity, including surface storage reservoirs or artificial groundwater recharge	39	6	4	49
i. Managing surface and groundwater together (conjunctive management) so that these sources can be used in combination or alternately	42	5	3	50
j. Monitoring water availability and withdrawals within the state	49	1	0	50
k. Pursuing water price restructuring	27	14	8	49
l. Requiring local water agencies to conduct water availability assessments before approving new development or changes in land use	22	23	5	50
m. Using cloud seeding to induce precipitation where it might not occur naturally, or in greater quantities than might occur naturally	8	39	3	50
n. Using inter-basin transfer of water	36	10	4	50
o. Other actions being taken to address water needs	18	7	3	28

If you checked “other” (above), please provide a brief description in the textbox below.

[Open-ended answers not displayed]

If you indicated that your state encourages, requires, and/or provides incentives for water conservation (i.e., checked “yes” to Question 10e above), please describe the key actions your state takes below.

[Open-ended answers not displayed]

11. In general, what is the legal doctrine used by your state to govern the allocation of surface water?

Prior appropriation	Common-law riparian	Regulated riparian	A combination of prior appropriation and riparian	State does not regulate surface water allocation	Other	Uncertain	Total number of respondents
17	5	16	4	2	5	1	50

If you checked “other” (above), please describe how your state governs the allocation and use of surface water.

[Open-ended answers not displayed]

12. In general, what is the legal doctrine used by your state to govern the allocation of groundwater?

Correlative rights	Reasonable use	Prior appropriation	Absolute ownership	State does not regulate groundwater allocation	Other	Total number of respondents
1	18	12	1	3	14	49

If you checked "other" (above), please describe how your state governs the allocation and use of groundwater.

[Open-ended answers not displayed]

13. Overall, about how much of your state's data on water availability and withdrawals is provided by federal agencies?[5]

	Little or none	Less than half	About half	More than half	All or almost all	Total number of respondents
a. Data on groundwater availability	12	20	8	8	1	49
b. Data on groundwater withdrawals	35	8	4	2	1	50
c. Data on surface water availability	8	10	9	17	6	50
d. Data on surface water withdrawals	35	6	5	2	2	50

14. Please provide the name(s) of the federal agency(ies) that provide water availability and/or withdrawal data to you.

[Open-ended answers not displayed]

[5]For questions 13-22, "federal agencies" refers to all federal entities that provide data to your state, including, for example, agencies, offices, and commissions.

15. Overall, how important are data provided by federal agencies to your state's ability to complete each of the following activities? (Note: If your state does not use data from a federal agency for this activity or your state does not conduct an activity, please check "Not applicable.")

	Very important	Somewhat important	Equally important and unimportant	Somewhat unimportant	Very unimportant	Not applicable	Total number of respondents
a. To determine the quantity of available groundwater	19	15	2	7	4	3	50
b. To determine the quantity of groundwater withdrawals	2	11	5	15	9	8	50
c. To determine the quantity of available surface water	32	8	6	2	1	1	50
d. To determine the quantity of surface water withdrawals	2	13	9	5	11	8	48
e. To determine the quantity of consumptive water use	3	12	8	7	12	8	50
f. To assess the economic effects of water withdrawals	2	11	4	2	12	15	46
g. To assess the environmental effects of water withdrawals	8	16	7	8	5	6	50
h. To plan environmental mitigation or restoration	6	15	8	5	6	8	48
i. To monitor the terms of water allocation agreements that distribute water among multiple parties (such as states)	10	12	6	2	7	13	50

16. What type(s) of water quantity data, not currently being collected by the federal government, would be most useful in helping your state with its water management?

[Open-ended answers not displayed]

17. Which actions, with respect to federal collection and dissemination of data, would be most useful to your state? Rank each of the following actions from most useful (1st) to least useful (6th). (Select the action you think would be most useful and rank this action 1st by entering the number "1" in the box provided next to that action. Select the next most useful action and rank it second by entering the number "2" in the box provided. Do the same for all the remaining actions, ranking them 3rd, 4th, 5th, and 6th.)

	1	2	3	4	5	6	Mean ranking	Total number of respondents
a. Collect data at more locations	42	4	1		2		1.29	49
b. Improve the accuracy of data currently being collected	2	9	9	7	9	12	4.00	48
c. Improve the timeliness of dissemination		11	10	12	9	6	3.77	48
d. Improve access to data previously collected (for example, historical)	1	10	15	10	10	2	3.50	48
e. Provide data in a more usable format	1	5	5	10	16	11	4.42	48
f. Provide more analyses of data	3	10	8	9	2	17	3.98	49

18. Are there other actions federal agencies could take to improve their collection and dissemination of water quantity data?

[Open-ended answers not displayed]

19. Has your state incorporated ecosystem services[6] and ecological flows[7] into your water management?

Yes	No	Uncertain	Total number of respondents
33	13	4	50

Respondents who answered no, uncertain, or no response to this question skipped to question 21

20. If you answered "yes" to Question 19 above, what ecosystem services or ecological flows data collected by federal agencies does your state use in its water management? Please also indicate the source(s) of the data.

[Open-ended answers not displayed]

21. Does your state have ecosystem services or ecological flows data needs?

Yes	No	Uncertain	Total number of respondents
34	3	12	49

Respondents who answered no, uncertain, or no response to this question skipped to question 23

22. If you answered "yes" to Question 21 above, what ecosystem services or ecological flows data currently not collected by federal agencies would be most useful to help your state's water management?

[Open-ended answers not displayed]

[6]Ecosystem services refer to natural processes that benefit human populations by, for example, purifying water and cycling and dispersing nutrients.

[7]Ecological flows refer to the maintenance of water levels and volumes to support robust animal, plant, and microbial populations in water bodies.

23. How much of your state's water is stored using facilities constructed, operated, or maintained by the federal government?[8]

Little or none	Less than half	About half	More than half	All or almost all	Uncertain	Total number of respondents
14	**14**	**3**	**7**	**9**	**3**	**50**

24. How likely is it that your state will add storage capacity within the next 10 years?

Very likely	Somewhat likely	Equally likely and unlikely	Somewhat unlikely	Very unlikely	Uncertain	Total number of respondents
15	7	4	10	10	4	50

25. Has your state estimated the cost to add storage capacity?

Yes	No	Uncertain	Total number of respondents
14	24	8	46

If you checked "yes" (above), please provide the year the estimate was made.

1980	2008	2010	2011	2012	Total number of respondents
1	1	4	2	4	12

26. Does your state plan to seek federal assistance for the addition of storage capacity?

Definitely yes	Probably yes	Probably no	Definitely no	Uncertain	Total number of respondents
5	12	17	3	12	49

[8]Questions 23-36 asked about the infrastructure for storage and conveyance of raw (untreated) water. Respondents were instructed to exclude infrastructure related to the treatment or delivery of treated water, wastewater treatment, desalination or infrastructure with the sole purpose of flood-control.

27. Have federal agencies participated in any of the following activities during the past 5 years with respect to non-federal storage infrastructure in your state?

	Yes	No	Uncertain	Total number of respondents
a. Planning of facilities	22	18	9	49
b. Reviewing plans for facilities	22	20	7	49
c. Operating and/or maintaining facilities	9	33	7	49
d. Constructing facilities	6	34	9	49

28. Within the last 5 years, has your state requested that a federal agency modify its operation of a federal storage facility to better meet the state's water management goals?

(Note: A "federal storage facility" is one that is owned and/or operated, either jointly or fully, by the federal government.)

Yes, many times	Yes, a few times	Yes, but only once or twice	No	Our state does not have any federal storage facilities	Uncertain	Total number of respondents
6	19	7	10	4	4	50

If you checked "yes" (#1, #2, or #3, above), please provide some examples of the types of changes requested and the agencies that you requested make the changes.

[Open-ended answers not displayed]

29. How much of your state's water is conveyed using facilities (for example, an aqueduct or canal) constructed, operated, or maintained by the federal government?

Little or none	Less than half	About half	More than half	All or almost all	Uncertain	Total number of respondents
32	8	2	4	1	3	50

30. How likely is it that your state will add conveyance capacity within the next 10 years?

Very likely	Somewhat likely	Equally likely and unlikely	Somewhat unlikely	Very unlikely	Uncertain	Total number of respondents
11	12	2	11	13	1	50

31. Has your state estimated the cost to add conveyance capacity?

Yes	No	Uncertain	Total number of respondents
11	30	8	49

If you checked “yes” (above), please provide the year the estimate was made.

2003	2007	2010	2011	2012	2013	Total number of respondents
1	1	2	2	2	1	9

32. Does your state plan to seek federal assistance for the addition of conveyance capacity?

Definitely yes	Probably yes	Probably no	Definitely no	Uncertain	Total number of respondents
5	14	17	6	8	50

33. Have federal agencies participated in any of the following activities during the past 5 years with respect to non-federal conveyance infrastructure in your state?

	Yes	No	Uncertain	Total number of respondents
a. Planning of facilities	9	22	18	49
b. Reviewing plans for facilities	9	21	19	49
c. Operating and/or maintaining facilities	2	30	17	49
d. Constructing facilities	2	33	14	49

34. Has the lack of maintenance (e.g., repair or rehabilitation) of federal storage or conveyance facilities reduced water availability in your state within the last 5 years?

Yes, many times	Yes, a few times	Yes, but only once or twice	No	Our state does not have any federal storage or conveyance facilities	Uncertain	Total number of respondents
4	5	3	19	7	12	50

If you checked “yes” (#1, #2, or #3, above), please provide example(s) of poor maintenance and how it affected water availability in your state.

[Open-ended answers not displayed]

35. Which actions would be most useful in helping your state meet its water management goals with respect to the storage and conveyance of water? Rank each of the following actions from most useful (1st) to least useful (6th). (Select the action you think would be most useful and rank this action 1st by entering the number “1” in the box provided next to that action. Select the next most useful action and rank it second by entering the number “2” in the box provided. Do the same for all the remaining actions, ranking them 3rd, 4th, 5th, and 6th.)

	1	2	3	4	5	6	Mean ranking	Total number of respondents
a. Improve the maintenance of federal facilities	0	2	6	8	7	22	4.91	45
b. Increase federal technical assistance for the planning, construction, operation, or maintenance of state storage and conveyance infrastructure	6	4	10	10	9	5	3.61	44
c. Increase federal financial assistance for the planning and construction of state storage and conveyance infrastructure	16	14	6	4	3	2	2.33	45
d. Increase federal financial assistance for the operation and maintenance of state storage and conveyance infrastructure	6	11	10	6	6	7	3.35	46
e. Seek more state input in the operation of federal storage facilities	12	6	8	4	11	4	3.18	45
f. Streamline federal review processes of proposed state storage and conveyance facilities	7	9	5	12	8	4	3.38	45

36. Are there other actions federal agencies could take to improve their participation in the planning, review, construction, operation, and/or maintenance of federal water storage and conveyance infrastructure?

[Open-ended answers not displayed]

37. What effect has each of the federal laws listed below had on water availability, for instream purposes, in your state within the past 5 years?[9]

	Greatly increased water availability	Somewhat increased water availability	Had no effect on water availability	Somewhat decreased water availability	Greatly decreased water availability	Uncertain	Total number of respondents
a. Clean Water Act	3	19	11	6	1	8	48
b. Coastal Zone Management Act	0	2	24	4	0	11	41
c. Endangered Species Act	1	21	9	8	3	5	47
d. Energy Policy Act of 2005	0	1	14	2	1	29	47
e. Federal Land Policy and Management Act	0	0	13	2	1	31	47
f. Federal Power Act	1	6	11	4	1	23	46
g. Fish and Wildlife Coordination Act	0	7	14	2	1	23	47
h. Food, Conservation and Energy Act of 2008	0	3	14	1	1	27	46
i. National Forest Management	0	5	11	3	1	27	47

[9]Questions 37-40 asked about federal laws concerning the environment and how these laws may affect the ability of your state to develop, manage, use, and protect its water. Instream use is defined by the U.S. Geological Survey as water that is used, but not withdrawn, from a surface water source for such purposes as hydroelectric power generation, navigation, water quality improvement, fish propagation, and recreation. Instream water use estimates for hydroelectric power were included in some previous water use circulars but were omitted for 2000 to present. Offstream use is defined by USGS as water withdrawn or diverted from a groundwater or surface water source for aquaculture, commercial, domestic self supply, industrial, irrigation, livestock, mining, public supply, thermoelectric power, and other uses.

	Greatly increased water availability	Somewhat increased water availability	Had no effect on water availability	Somewhat decreased water availability	Greatly decreased water availability	Uncertain	Total number of respondents
j. Rivers and Harbors Appropriation Act	0	2	20	1	0	22	45
k. Safe Drinking Water Act	2	13	20	4	0	9	48
l. Secure Water Act	0	5	16	0	0	26	47
m. Water Resources Development Act of 2007	0	8	16	1	0	23	48
n. Wild and Scenic Rivers Act	0	12	15	5	0	14	46
o. Wilderness Act	0	3	14	4	1	24	46
p. Other federal law(s)	0	5	7	0	1	22	35

If you checked “Other federal law(s)” above, please specify the law(s) below.

[Open-ended answers not displayed]

38. What effect has each of the federal laws listed below had on water availability, for offstream purposes, in your state within the past 5 years?

	Greatly increased water availability	Somewhat increased water availability	Had no effect on water availability	Somewhat decreased water availability	Greatly decreased water availability	Uncertain	Total number of respondents
a. Clean Water Act	3	8	13	15	1	7	47
b. Coastal Zone Management Act	0	2	25	2	0	14	43
c. Endangered Species Act	0	3	9	24	5	6	47
d. Energy Policy Act of 2005	0	0	16	3	0	28	47
e. Federal Land Policy and Management Act	0	1	15	2	0	29	47
f. Federal Power Act	0	1	13	6	0	27	47

	Greatly increased water availability	Somewhat increased water availability	Had no effect on water availability	Somewhat decreased water availability	Greatly decreased water availability	Uncertain	Total number of respondents
g. Fish and Wildlife Coordination Act	0	1	15	5	0	25	46
h. Food, Conservation and Energy Act of 2008	0	3	12	1	0	30	46
i. National Forest Management	0	4	15	3	1	23	46
j. Rivers and Harbors Appropriation Act	0	1	19	2	0	23	45
k. Safe Drinking Water Act	1	10	17	9	0	11	48
l. Secure Water Act	0	4	18	1	1	24	48
m. Water Resources Development Act of 2007	0	5	16	1	1	25	48
n. Wild and Scenic Rivers Act	0	3	14	10	2	17	46
o. Wilderness Act	0	1	16	6	3	20	46
p. Other federal law(s)	0	2	6	1	3	19	31

If you checked “Other federal law(s)” above, please specify the law(s) below.

[Open-ended answers not displayed]

39. Which actions would be most useful in helping your state fulfill the requirements of federal environmental laws while meeting its water management goals? Rank each of the following actions from most useful (1st) to least useful (4th). (Select the action you think would be most useful and rank this action 1st by entering the number "1" in the box provided next to that action. Select the next most useful action and rank it second by entering the number "2" in the box provided. Do the same for all the remaining actions, ranking them 3rd, 4th, 5th, and 6th.)

	1	2	3	4	Mean Ranking	Total number of respondents
a. Charge for the use of water from federal storage and conveyance facilities and use funds to help mitigate damage to environment from projects	2	2	4	38	3.7	46
b. Give the states more flexibility in compliance or administration of federal environmental laws	24	11	9	3	1.81	47
c. Improve coordination among federal agencies in implementing environmental laws	8	12	27	2	2.47	49
d. Seek more state input into development, revision and implementation of federal environmental laws	15	23	7	3	1.96	48

40. Are there other actions federal agencies could take to help your state fulfill the requirements of federal environmental laws?

[Open-ended answers not displayed]

41. Does your state participate in an interstate compact or international treaty to allocate water among multiple parties?[10]

Yes	No	Uncertain	Total number of respondents
34	14	2	50

Respondents who answered no, uncertain, or no response to this question skipped to question 48

[10]Questions 41-47 asked about interstate compacts and international treaties and the effects they have on your state's ability to manage its water supplies. For purposes of this questionnaire, an interstate compact or international treaty is an agreement to distribute water among multiple parties (such as states) that has been ratified by the U.S. Congress or issued by a federal court.

42. About how much of your state's water is affected by an interstate compact and/or international treaty?

Little or none	Less than half	About half	More than half	All or almost all	Total number of respondents
3	19	2	6	4	34

43. Within the last 5 years, have any federal agencies participated in any of the following activities affecting water availability in your state?

Interstate Compact(s)

	Yes	No	Uncertain	Total number of respondents
a. Development	7	24	3	34
b. Implementation	22	8	3	33
c. Enforcement	12	18	4	34

International Treaty(ies)

	Yes	No	Uncertain	Total number of respondents
a. Development	6	22	1	29
b. Implementation	14	14	2	30
c. Enforcement	9	17	4	30

44. Within the last 5 years, have federal agencies participating in the development, implementation, or enforcement of an interstate compact(s) and/or international treaty(ies) affecting water allocation fulfilled their responsibilities?

All agencies have fulfilled all responsibilities	One or more agencies have not fulfilled their responsibilities (Please specify the agency(ies) and frequency in the textbox below.)	Not applicable (no federal participation)	Uncertain	Total number of respondents
11	9	5	6	31

If you checked #2 (above), please specify the agency(ies) and briefly describe how often responsibilities have not been fulfilled.

[Open-ended answers not displayed]

45. Does your state plan to propose, negotiate, or participate in a new interstate compact or international treaty within the next 5 years?

Definitely yes	Probably yes	Probably no	Definitely no	Uncertain	Total number of respondents
1	4	16	8	5	34

46. Which actions would be most useful in helping your state with respect to the development, enforcement, and implementation of interstate compacts and international treaties? Rank order each of the following actions from the most useful (1st) to the least useful (6th). (Select the action you think would be most useful and rank this action 1st by entering the number “1” in the box provided next to that action. Select the next most useful action and rank it second by entering the number “2” in the box provided. Do the same for all the remaining actions, ranking them 3rd, 4th, 5th, and 6th.)

	1	2	3	4	5	6	Mean ranking	Total number of respondents
a. Better coordinate federal participation with the state	12	10	6	2	2	0	2.13	32
b. Better coordinate participation among federal agencies	3	9	8	6	6	0	3.09	32
c. Create a market-based allocation system for water shared by states	0	1	1	2	5	20	5.45	29
d. Develop alternative tools for resolving water allocation conflicts among the states	3	6	6	7	6	3	3.52	31
e. Increase technical assistance to assist the states with development or implementation	12	4	10	5	1	2	2.56	34
f. Make it easier to amend or revise existing agreements	4	3	1	9	10	4	3.97	31

47. Are there other actions that would be useful in helping your state with respect to the development, enforcement, and implementation of interstate compacts and international treaties?

[Open-ended answers not displayed]

48. Do any federal agencies hold or claim water rights in your state?[11]

Yes	No	Uncertain	Total number of respondents
27	14	9	50

Respondents who answered no, uncertain, or no response to this question skipped to question 53

49. Currently, about how much of your state's water is allocated to fulfill federal water rights?

Little or none	Less than half	Uncertain	Total number of respondents
13	10	4	27

50. If all federal claims to water in your state were quantified, about how much of your state's water would be allocated to fulfill these rights?

Little or none	Less than half	About half	Uncertain	Total number of respondents
11	9	1	6	27

51. How important is the quantification of federal water rights to your state's ability to manage its water?

Very important	Somewhat important	Equally important and unimportant	Somewhat unimportant	Very unimportant	Uncertain	Total number of respondents
6	8	3	5	4	1	27

[11]Questions 48-60 asked about the role of federal agencies in the implementation and enforcement of federal and tribal rights to water. Federal "agencies" refers to all federal entities that manage lands with reserved water rights.

52. Within the last five years, has your state experienced any conflict between how a federal agency employed its water rights and your state's water management goals?

Yes, many times (Please specify the agency(ies) in the textbox below.)	Yes, a few times (Please specify the agency(ies) in the textbox below.)	Yes, but only once or twice (Please specify the agency(ies) in the textbox below.)	No, our state has not experienced any conflict	Uncertain	Total number of respondents
4	4	5	9	5	27

If you checked yes (#1, #2, or #3, above), please specify the agency(ies) in the textbox below.

[Open-ended answers not displayed]

53. Do any tribal governments hold or claim water rights in your state?

Yes	No	Uncertain	Total number of respondents
24	20	5	49

Respondents who answered no, uncertain, or no response to this question skipped to question 58.

54. Currently, about how much of your state's water is allocated to fulfill tribal water rights?

Little or none	Less than half	Uncertain	Total number of respondents
13	9	2	24

55. If all tribal claims to water in your state were quantified, about how much of your state's water would be allocated to fulfill these rights?

Little or none	Less than half	More than half	Uncertain	Total number of respondents
7	8	1	7	23

56. How important is the quantification of tribal water rights to your state's ability to manage its water?

Very important	Somewhat important	Equally important and unimportant	Somewhat unimportant	Very unimportant	Uncertain	Total number of respondents
8	5	3	2	4	1	23

57. Within the last five years, has your state experienced any conflict between how a tribal government employed its water rights and the state's water management goals?

Yes, many times (Please specify the tribal government(s) in the textbox below.)	Yes, a few times (Please specify the tribal government(s) in the textbox below.)	Yes, but only once or twice (Please specify the tribal government(s) in the textbox below.)	No, our state has not experienced any conflict	Uncertain	Total number of respondents
1	5	3	11	3	23

If you checked yes (#1, #2, or #3, above), please specify the tribal government(s) in the textbox below.

[Open-ended answers not displayed]

58. If you have indicated that no federal agencies or tribal governments claim water rights in your state, you can skip Questions 59 and 60, by clicking on "Go to Question 61" below. Otherwise continue to Question 59.

Skip Questions 59 and 60.	Continue	Total number of respondents
19	20	39

Respondents who selected skip questions 59 and 60 skipped to question 61.

59. Which actions would be most useful in helping your state fulfill federal and tribal rights to water while meeting your state's water management goals? Rank each of the following actions from most useful (1st) to least useful (6th). (Select the action you think would be most useful and rank this action 1st by entering the number "1" in the box provided next to that action. Select the next most useful action and rank it second by entering the number "2" in the box provided. Do the same for all the remaining actions, ranking them 3rd, 4th, 5th, and 6th.)

	1	2	3	4	5	6	Mean ranking	Total number of respondents
a. Better coordinate participation among federal agencies in the establishment and use of federal or tribal water rights	2	1	7	1	2	4	3.71	17
b. Clarify federal policy on tribal governments' authority to sell water rights	0	1	2	5	3	6	4.65	17
c. Improve the efficiency of water use, including increasing conservation when applicable, on federal and tribal lands	3	4	1	4	3	3	3.50	18
d. Increase financial and technical assistance to states for adjudication of federal and tribal water rights	1	3	2	4	5	2	3.88	17
e. Seek more state input into the use of federal or tribal water rights and potential effects on state water management goals	10	4	1	2	1	1	2.11	19
f. Streamline federal processes to quantify federal or tribal water rights	3	5	4	1	3	3	2.94	17

60. Are there other actions that federal agencies could take to help your state fulfill federal and tribal rights to water while meeting your state's water management goals?

[Open-ended answers not displayed]

61. How much of a concern to your state are the following drivers of change in terms of anticipated impact on water supplies in the next 10 years?

	Very great concern	Great concern	Moderate concern	Slight concern	Not a concern	Uncertain	Total number of respondents
a. Climate change	6	9	23	7	1	2	48
b. Drought	18	14	17	1	0	0	50
c. Population growth	5	12	23	8	0	0	48
d. Infrastructure challenges	17	19	13	1	0	0	50

	Very great concern	Great concern	Moderate concern	Slight concern	Not a concern	Uncertain	Total number of respondents
e. Loss of storage due to sedimentation of reservoirs or over pumping of aquifers	3	14	18	15	0	0	50
f. Increased use of freshwater for energy production	3	7	24	11	4	0	49
g. Increased use of freshwater for irrigation	8	9	18	10	4	0	49
h. Deteriorating quality of freshwater resources	4	12	16	14	3	1	50
i. Maintenance of ecosystem services or ecological flows	4	18	14	8	1	4	49
j. Land use change	6	15	16	10	2	0	49
k. Increased interbasin transfers	1	10	16	13	8	1	49
l. Tribal water rights	2	7	6	5	26	0	46
m. Other (Please specify below)	2	1	2	0	1	0	6

If you checked “other” (above), please specify the other driver(s) of change that are currently of greatest concern regarding water supplies.

[Open-ended answers not displayed]

62. To what extent is degraded water quality impacting your state’s overall water availability?

Great extent	Moderate extent	Some extent	Little to no extent	Total number of respondents
2	17	22	9	50

63. Is your state currently using, or planning to use in the future, alternative sources of water to meet water needs?

(Examples of alternative sources of water may include saline groundwater or reclaimed wastewater, among others.)

Yes	No	Uncertain	Total number of respondents
29	11	9	49

Respondents who answered no, uncertain, or no response to this question skipped to question 65.

64. If yes, please describe the alternative water source(s) you are currently using or plan to use.

[Open-ended answers not displayed]

65. Are there particular types of water use (e.g., irrigation, thermoelectric power production, etc.) that are of greatest concern for your state in terms of impacting water availability for other uses? If so, please describe below.

[Open-ended answers not displayed]

66. Are there particular types of water use (e.g., irrigation, thermoelectric power production, etc.) that would be most vulnerable to restricted water availability in your state? If so, please describe below.

[Open-ended answers not displayed]

67. If you would like to make additional comments concerning any topic related to water availability, management, or use, please feel free to use the space below, or, if you would prefer, send an email message

[Open-ended answers not displayed]

Appendix III: Extent of State Water Shortages in 2003 and 2013 (Corresponds to Fig. 7)

This appendix provides additional details on state water shortages, including rollover information, on interactive figure 7. Table 4 shows whether states expected local, regional, statewide, or no shortages in the next 1-10 years under average water conditions, as reported by our 2003 and 2013 surveys.

Table 4: Survey Results for Expected Shortages in the Next 1-10 Years under Average Water Conditions, 2003 and 2013

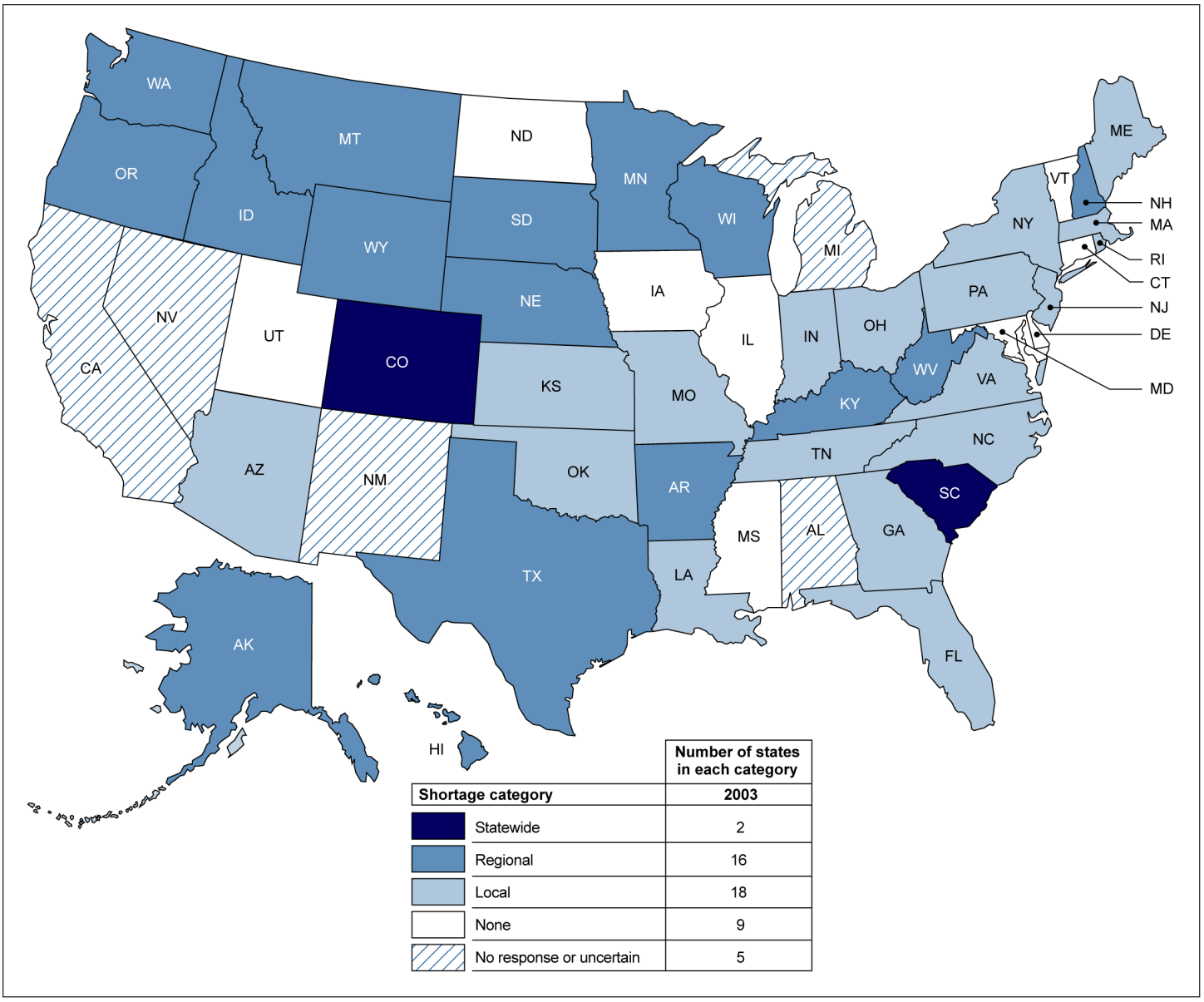
State	2003 Survey results	2013 Survey results
Alabama	No response or uncertain	None
Alaska	Regional	Local
Arizona	Local	Local
Arkansas	Regional	Regional
California	No response or uncertain	Regional
Colorado	Statewide	Regional
Connecticut	None	None
Delaware	None	Regional
Florida	Local	Regional
Georgia	Local	None
Hawaii	Regional	Regional
Idaho	Regional	Regional
Illinois	None	Regional
Indiana	Local	No response or uncertain
Iowa	None	Local
Kansas	Local	Local
Kentucky	Regional	None
Louisiana	Local	Regional
Maine	Local	Local
Maryland	None	None
Massachusetts	Local	Local
Michigan	No response or uncertain	Regional
Minnesota	Regional	Regional
Mississippi	None	Regional
Missouri	Local	Local
Montana	Regional	Statewide
Nebraska	Regional	Regional
Nevada	No response or uncertain	Regional
New Hampshire	Regional	Local

State	2003 Survey results	2013 Survey results
New Jersey	Local	Local
New Mexico	No response or uncertain	Regional
New York	Local	Local
North Carolina	Local	Regional
North Dakota	None	None
Ohio	Local	No response or uncertain
Oklahoma	Local	Regional
Oregon	Regional	Regional
Pennsylvania	Local	Local
Rhode Island	Local	Regional
South Carolina	Statewide	Local
South Dakota	Regional	Regional
Tennessee	Local	Local
Texas	Regional	Regional
Utah	None	None
Vermont	None	None
Virginia	Local	Local
Washington	Regional	Regional
West Virginia	Regional	Local
Wisconsin	Regional	Regional
Wyoming	Regional	Regional

Source: GAO analysis of survey data.

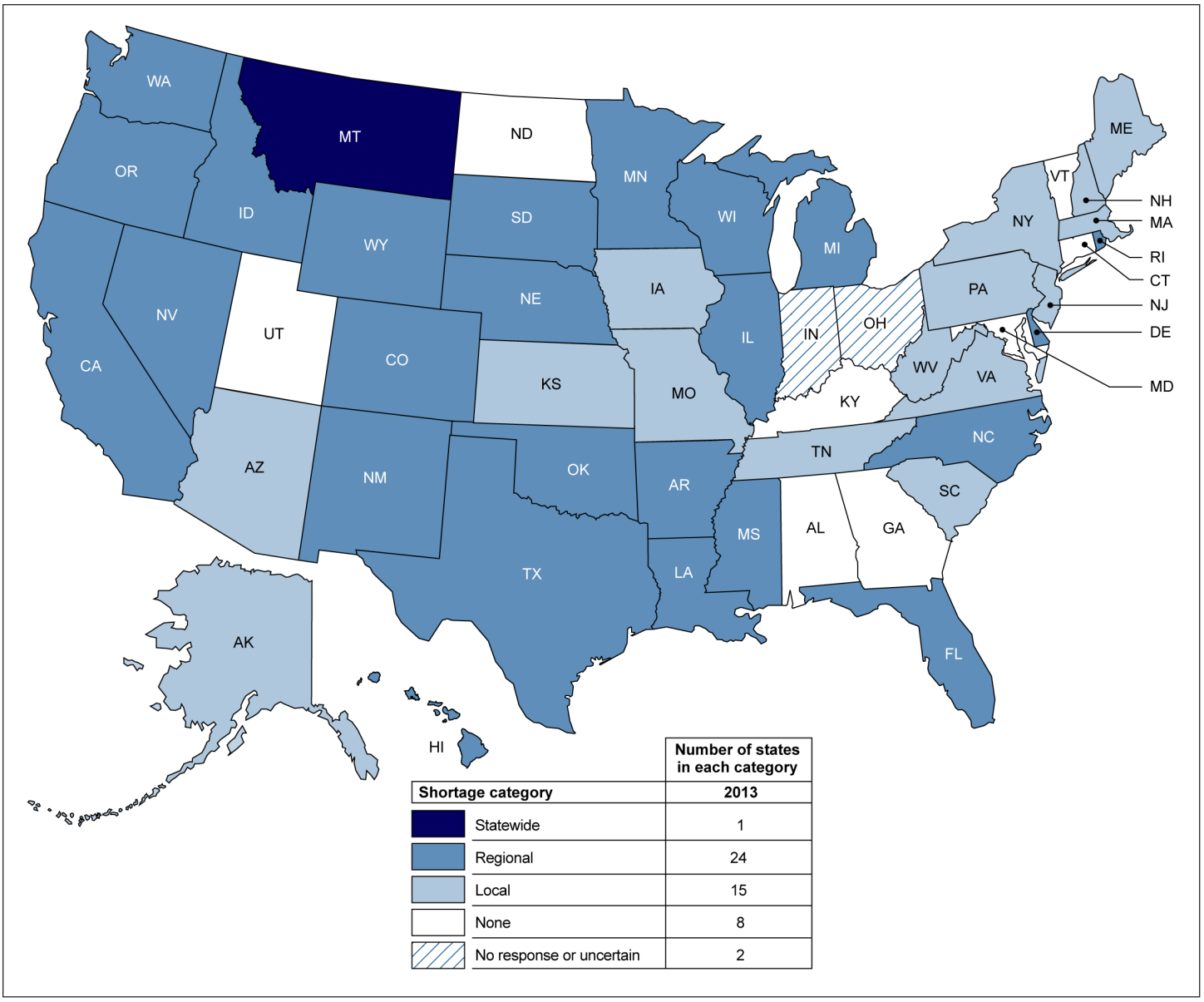
Below are the maps of state shortages likely over the next decade under average water conditions for 2003 (see fig. 10) and 2013 (see fig. 11).

Figure 10: Extent of State Shortages Likely over the Next Decade under Average Water Conditions, 2003



Sources: GAO analysis of state water managers' responses to GAO survey; Map Resources (map).

Figure 11: Extent of State Shortages Likely over the Next Decade under Average Water Conditions, 2013



Sources: GAO analysis of state water managers' responses to GAO survey; Map Resources (map).

Appendix IV: Examples of Actions Taken by Federal Agencies Since 2003

Over the last decade, federal agencies have initiated or updated a number of programs to support the management of freshwater availability and use. These programs include (1) initiatives of the Department of the Interior (Interior), (2) other federal agency initiatives, (3) multiagency initiatives, and (4) federal assessments and reports.

Interior Initiatives

Interior has taken a number of actions, some of which were in response to the SECURE Water Act, as well as additional actions not related to the act (see table 5).[1]

Table 5: Examples of Interior Initiatives Related to Water Resources

Program name	Description	Examples of activities
National Water Census	In 2009,[a] Congress authorized the U.S. Geological Survey (USGS) to establish a national water availability and use assessment program to provide a more accurate assessment of the status of the water resources of the United States, among other things.[b] Through the National Water Census, USGS plans to consistently quantify water supply and demand across the entire country; identify and fill in gaps in existing data; enhance understanding of the connection between water availability and quality; and make the information available to users, such as state agencies with water management responsibilities, according to an agency document. USGS anticipates that information gathered through the National Water Census will allow water managers to make more effective decisions; anticipate water shortages; and develop plans and make investments to adapt to, mitigate the impacts of, and possibly prevent water shortages, among other benefits.	Currently, USGS is developing plans for and conducting the National Water Census in collaboration with other federal and nonfederal agencies, universities, and other organizations. This collaborative effort is intended to ensure that information produced by the National Water Census is compatible with other data relevant to water availability—such as population statistics, land use, water costs and pricing, and ecosystem water requirements—and to allow for aggregation and analysis of the data by users, according to an agency document. The long-term objective of the National Water Census is to make data available on a monthly basis in order to capture seasonal variations that affect water availability and use. As part of the National Water Census, USGS is conducting Geographic Focus Area Studies to report on issues in different areas of the United States where competition over water resources between human and ecological needs is already occurring. The geographic areas initially selected for study are the Apalachicola-Chattahoochee-Flint, Colorado, and Delaware River Basins. In addition, as part of the National Water Census, USGS is developing a means to estimate flows at ungaged surface water stations and has developed models used to estimate flows for selected basins, according to an agency document. To better understand groundwater resources, USGS plans to conduct a water availability study on each of the nation's principal aquifers and to consolidate all groundwater monitoring information into a centralized location using a uniform format. As of October 2013, studies of 8 of the nation's 62 principal aquifers have been completed, and 5 more are under way.

[1]Omnibus Public Land Management Act of 2009, Pub. L. No. 111-11, tit. IX, subtit. F, 123 Stat. 991, 1329 (2009) (codified at 42 U.S.C. §§ 10361-10370). The SECURE Water Act noted that, although states bear the primary responsibility and authority for managing water resources in the United States, the federal government should support states, as well as regional, local, and tribal governments by carrying out a number of actions, including nationwide data collection and monitoring, research, and taking a lead role in assessing risks to water resources, among other actions. 42 U.S.C. § 10361.

Program name	Description	Examples of activities
National Groundwater Monitoring Network	USGS is spearheading the National Groundwater Monitoring Network. According to USGS officials, the network's pilot phase successfully demonstrated a collaborative approach to compile groundwater level and groundwater quality data from federal, state, and local monitoring agencies. The network is intended to provide vital groundwater data that can be used to evaluate the status and trends of groundwater levels and quality, according to the officials.	In June 2011, a portal for the network came online, consisting of a map-based tool that provides current and historic groundwater levels and groundwater quality. The National Groundwater Monitoring Network is awaiting funding to transition from the pilot phase to full implementation.
WaterSMART grants	Interior established the WaterSMART program in February 2010 to pursue a sustainable water supply for the nation by establishing a framework that provides federal leadership and assistance for efficiently using water, integrating water and energy policies to support the sustainable use of all natural resources, and coordinating the water conservation activities of various Interior offices.[c] Under WaterSMART, there are several programs that fund a variety of freshwater projects through grants to improve the efficiency of water delivery, conserve water, develop climate analysis tools, and demonstrate advanced water treatment technologies.	Under the WaterSMART Water and Energy Efficiency Grant program, a total of $21.4 million was awarded for 42 projects in fiscal year 2013. The projects, for example, install water flow meters and convert open ditches to pipes, which can reduce water loss due to evaporation and leakage. Since establishment in 2010, WaterSMART grants have provided more than $161 million in competitively-awarded funding to nonfederal partners, including states, tribes, water districts, municipalities, and universities.

Program name	Description	Examples of activities
The Bureau of Reclamation's (Reclamation) climate change impact assessments	As we reported in November 2013,[d] Reclamation has broadly assessed how climate change may affect water resources in the western United States as part of the Basin Study Program it established to meet the requirements of the SECURE Water Act. It is primarily doing so through two programs—West-Wide Climate Risk Assessments (WWCRA) and Basin Studies. • *WWCRAs*. These assessments are high-level, baseline assessments of the potential impacts of climate change on future water supplies—including impacts on Reclamation's ability to deliver water and hydropower—for each major river basin where Reclamation owns and operates water management infrastructure.[e] • *Basin studies*. Reclamation is partnering with nonfederal entities, including state and local partners, to conduct more focused assessments, known as Basin Studies, to identify specific water resource vulnerabilities and to implement the SECURE Water Act's requirement that Reclamation consider and develop strategies to mitigate climate change impacts on water supplies.[f] Each study includes projections of future supply and demand by river basin, analyses of how the basin's existing water and power operations and infrastructure will perform in response to the projections for future supply and demand, and development of options to improve operations and infrastructure to supply adequate water in the future; and trade-off analyses of the options identified, findings, and recommendations as appropriate.	• *WWCRAs*. Reclamation is now conducting WWCRAs that focus on future water demand and will combine this information with its water supply assessments to form a more complete picture of the potential impacts of climate change on its water infrastructure. Reclamation officials told us that these combined assessments will be included in Reclamation's next SECURE Water Act report that is due in 2016. • *Basin studies*. As of January 2014, 5 Basin Studies have been completed, and an additional 12 studies have been funded and are under way. Some of the Basin Studies cover entire river basins—such as the Colorado River Basin—while other studies cover sub-basins or tributaries within the boundaries of the major river basins—such as a tributary of the Columbia River. Reclamation officials told us that they next intend to initiate feasibility studies for adaptation strategies identified in completed Basin Studies by making funds available to nonfederal partners, beginning with an initial feasibility study in 2013.
The Water Resource Inventory and Assessment (WRIA)	Initiated in 2010, WRIA is a multiyear project led by the Fish and Wildlife Service (FWS) that collects information on water features, water rights, water monitoring, water quality, water-related infrastructure, and hydroclimate for FWS refuges and hatcheries. WRIA also provides an assessment of threats to the water resources on FWS lands.	As part of the program, FWS is developing a centralized database application to store and retrieve WRIA information. According to FWS, the WRIA effort helps FWS more effectively manage water resources on federal lands managed by the agency by, among other things, providing the agency with an inventory and assessment of water quantity and quality necessary to identify needs and threats and to prioritize its work.

Program name	Description	Examples of activities
Interim Guidelines for the Operation of Lake Powell and Lake Mead	In 2007, after an extensive public comment process and collaboration with the seven Colorado River Basin states,[g] Reclamation released guidelines for the operation of the Lake Powell and Lake Mead reservoirs in the Colorado River Basin. The guidelines were developed, in part, in response to the multiyear drought dating back to 2000 that has continued into 2014. Each year, the Secretary of the Interior is required to declare the Colorado River water supply availability conditions for the lower basin states as "Normal," "Surplus," or "Shortage."	While regulations and operations criteria had previously been developed for Normal and Surplus conditions, detailed guidelines for Shortage conditions had not been established prior to developing interim guidelines. According to a Reclamation document, the interim guidelines will allow the Secretary, through Reclamation, to better manage and operate the basin's key reservoirs while also providing water users and managers with a greater degree of certainty regarding the amount of annual water deliveries in the future, particularly under drought and low reservoir conditions. Barring any modification to the guidelines, they will remain in effect through 2025.
USGS Water Science Centers	USGS operates 47 Water Science Centers located throughout the United States. Through the Water Science Centers, USGS provides technical assistance—such as data collection and analyses—and works with state and local officials, among other partners, on water management activities.	Since 2003, the Water Science Centers have worked with state, tribal, and local officials on various water activities. For example, an agency official told us that the USGS Michigan Water Science Center frequently works with state agencies and local communities on water supply and quality issues. The official told us that the center worked with Kalamazoo County to issue a 2004 report on the county's water use and management. Moreover, the center has also worked with utilities in Eaton, Ingham, and Clinton counties to refine an existing groundwater flow model and issue a 2010 report about the process. The refined model and associated report have been used to aid planning, develop protection areas for wells, and interpret observed changes in groundwater quality in the area.
Landscape Conservation Cooperatives (LCC)	In FY 2011, Reclamation and FWS established the Desert and Southern Rockies LCCs—partnerships between federal and state agencies, tribes, universities, nongovernmental organizations, international entities, and local governments, formed to develop and share applied science tools and approaches that support resource management at the landscape scale. These two LCCs span the upper and lower Colorado River Basin and together include portions of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Texas.	According to agency officials, Reclamation and FWS work with LCC partners to evaluate the science and technical capabilities needed to support the Desert and Southern Rockies LCCs. These efforts include: (1) building and expanding on existing applied science tools and capabilities to identify gaps that can be addressed through Interior's Climate Science Centers, universities, and other sources; (2) providing support for ongoing adaptation and conservation efforts in the LCCs, including facilitating data sharing, developing and implementing adaptive management techniques and monitoring plans; and (3) identifying and implementing potential new adaptation strategies to address climate change impacts.

Source: GAO analysis of agency information.

[a]The SECURE Water Act authorized the Water Census in 2009, but USGS did not receive the first appropriation until fiscal year 2011.

[b]USGS initiated the National Water Census to fulfill the reporting requirements in section 9508(d) of the SECURE Water Act, which requires the Secretary to submit a report to the Congress not later than December 31, 2012, and every 5 years thereafter, that provides a detailed assessment of the current availability of water resources in the United States and significant trends affecting water availability, including each documented or projected impact to the availability of water as a result of global climate change, among other issues. *See* 42 U.S.C. § 10368(d).

[c]Section 9504 of the SECURE Water Act authorizes the Secretary to provide grants or enter into agreements with eligible applicants to assist them in planning, designing, or constructing any improvement to conserve water, to increase water use efficiency, and to enhance water management, including increasing the use of renewable energy in the management and delivery of water, among other things. 42 U.S.C. § 10364(a).

[d]GAO, *Climate Change: Federal Efforts Under Way to Assess Water Infrastructure Vulnerabilities and Address Adaptation Challenges*, GAO-14-23 (Washington, D.C.: Nov. 14, 2013).

[e]Section 9503(b)(2) of the SECURE Water Act requires the Secretary to assess specific risks to water supplies. 42 U.S.C. § 10363(b)(2).

[f]Section 9503(b)(4) of the SECURE Water Act requires the Secretary to, in consultation with appropriate non-federal participants, consider and develop appropriate strategies to mitigate each impact of water supply changes analyzed. 42 U.S.C. § 10363(b)(4).

[g]The Colorado River Basin states are divided into lower and upper basin states. Colorado, New Mexico, Utah, and Wyoming make up the upper basin states, whereas Arizona, California, and Nevada make up the lower basin states.

Other Federal Agency Initiatives

Other federal agencies also have initiated or updated efforts to support freshwater management (see table 6).

Table 6: Examples of Other Federal Agency Initiatives Since 2003 Related to Water Resources

Initiative name	Description	Examples of activities
National Integrated Drought Information System (NIDIS)	Established by the Congress in 2006, the Department of Commerce's (Commerce) National Oceanic and Atmospheric Administration (NOAA) administers NIDIS, a program to provide the nation with a drought early warning system.[a] According to NOAA officials, the primary goals of NIDIS are to improve (1) public awareness of drought and its impacts and (2) the coordination and ability of states, watersheds, and counties to proactively reduce the risks of drought.	One key component of NIDIS is the U.S. Drought Portal, a "one-stop-shop" for drought-related information—such as maps and tools—that provides users with information about current drought conditions and impacts and projections of the length of drought, which can be used to prepare for and mitigate the effects of drought, according to agency officials. To accomplish the goals of NIDIS, NOAA relies on the participation of agencies and institutions that have historically focused on drought risk assessment and response, including the U.S. Department of Agriculture (USDA), the Department of Energy (DOE), Interior, the Environmental Protection Agency (EPA), and the National Aeronautics and Space Administration (NASA), among others.
WaterSense	Initiated in 2006, WaterSense is a voluntary conservation program administered by EPA that works with a variety of stakeholders to reduce municipal water use across the country by labeling products that use 20 percent less water and perform as well as—or better than—conventional product models. The program also has specifications to label water-efficient new homes and professional services, such as irrigation design.	Since the program's inception, EPA officials told us that they have worked with more than 1,400 partners, including manufacturers, retailers, builders, and water utilities, to promote water-efficient products and practices. The officials estimate that such products have saved more than 487 billion gallons of water, and saved $8.9 billion on water and energy bills through 2012. WaterSense also works with local partners, such as state and local governments, to promote water conservation by providing outreach and educational tools that the partners can use to promote water efficiency both indoors and outdoors. EPA officials told us that WaterSense has several efforts underway to expand its work, including adding products and local partners to the program. EPA is also working to involve commercial sector entities, such as hotels, in the program by promoting best management practices for water users.
Federal Support Toolbox	As we reported in November 2013,[b] the U.S. Army Corps of Engineers (Corps) and NOAA have developed a federal Internet portal to provide current, relevant, and high-quality information on water resources as well as climate change data applications and tools for assessing the vulnerability of water programs and facilities to climate change.	Referred to as the Federal Support Toolbox, this Corps-hosted online data portal allows agencies to share water resources information and tools for planning and management and has direct links to valuable databases, innovative programs and initiatives, and state-of-the-art models and tools. Corps officials said that the information-sharing and learning facilitated by the website can promote data utilization, support critical water needs nationwide and internationally, and foster domestic and international partnerships.

Initiative name	Description	Examples of activities
Landsat 8	In 2013, NASA launched Landsat 8,[c] a remote sensing satellite system that collects image and thermal data used by water managers to administer water rights, manage interstate compacts, monitor water use for irrigated agriculture, and assess drought conditions. Landsats 7 and 8 are operated by the USGS, which downloads Landsat data, archives it, and makes all of the 41-year Landsat data freely available for all users in the world.	USGS and state and local agencies use Landsat data in combination with streamflow and other data to estimate evapotranspiration across the nation. According to USGS officials, evapotranspiration data are not well quantified at spatial and temporal scales, but are essential in water resources management in improving understanding of climate and land change and in improving the ability of resource managers to quantify runoff to reservoirs and recharge of aquifers. USGS is developing the capability to provide regular evapotranspiration estimates at a 1 kilometer grid scale for the continental United States, starting in 2014. Additional regular Landsat-based products in development include snow-covered extent and burned area extent.
The Surface Water Ocean Topography (SWOT) mission	NASA is working on the SWOT mission, which aims to make the first global survey of Earth's surface water and measure how water bodies change over time. Officials said this mission will provide significant improvements to the knowledge of river, wetlands, and lake dynamics. For example, officials told us that data from the satellite could be used to estimate changes in water storage in rivers that will be helpful in providing data for those areas that do not have streamgages in place.	NASA is currently planning to launch the SWOT mission in 2020.
Soil Moisture Active Passive (SMAP)	NASA is working to launch SMAP, which will provide global measurements of soil moisture and its freeze/thaw state. These measurements will be used to enhance understanding of processes that link the water, energy, and carbon cycles, and to extend the capabilities of weather and climate prediction models. SMAP data will also improve short-term weather forecasts and long-term climate change projections, the ability to monitor droughts and predict floods to mitigate the impacts of such events, and predictions of plant growth and agricultural productivity, according to agency documents.	NASA is currently planning to launch SMAP in November 2014.
Global Precipitation Measurement Core Observatory	The Global Precipitation Measurement Core Observatory is a joint earth-observing mission between NASA and the Japan Aerospace Exploration Agency to provide next-generation global rain and snow observations every 3 hours. According to agency officials, the data provided will be used to unify precipitation measurements made by an international network of partner satellites to quantify when, where, and how much it rains or snows around the world.	The mission was launched on February 27, 2014. GPM is performing checkout activities and internal calibrations in preparation for full operations, according to officials.

Initiative name	Description	Examples of activities
DOE Energy-Water Nexus Program	As we reported in September 2012,[d] the Energy Policy Act of 2005 directed DOE to carry out a program to address the energy-water nexus and assess the effectiveness of existing DOE and other federal programs that address the nexus.[e] Our report found, however, that DOE had not established the program; therefore, we recommended that DOE implement the program as called for in the act.	In response to our recommendation, DOE officials told us in January 2014 that DOE is currently scoping program activity and drafting a program plan. DOE also told us that the agency has been strengthening its relationships with other agencies on topics related to the energy-water nexus. In addition, over the last decade, DOE and its national laboratories have issued a number of reports on various aspects of the energy-water nexus, such as DOE's 2006 report to the Congress that discussed the use of water in thermoelectric, biofuel, and renewable energy production.
Minute 319	In November 2012, officials from the United States and Mexico signed Minute 319,[f] an agreement that provides for cooperation between the two countries regarding water management operations within the Colorado River Basin.[g] Key components of the agreement include a shared surplus provision, whereby Mexico has the right to share surplus waters from Nevada's Lake Mead; a shared shortage provision, whereby Mexico would accept cuts to its annual allocation under certain low reservoir level conditions; and the Intentionally Created Mexican Allocation, whereby Mexico may store water in the United States until Mexico determines that it needs to withdraw the water. In addition, the agreement identified conservation incentives and put into place environmental restoration measures, which specify that a certain quantity of water reach the southernmost end of the Colorado River to support ecological processes that depend on the river's flow.	Minute 319 is currently in its second year of a 5-year interim period, which U.S. officials said is intended to test whether such proactive reservoir management works, and whether a more permanent approach is warranted.
Forests to Faucets Project	The Forest Service's Forests to Faucets Project identifies land areas that are most important to public water supplies and threatened, for example, by wildland fire impacts or development. According to an agency document, a partnership project can be used to protect public surface drinking water quality and to educate the public about the link between forests and the provision of surface drinking water—a key watershed-based ecosystem service.	The Forest Service has initiated a number of partnerships since 2003. For example, the Forest Service and Denver Water, the public water utility for the city of Denver and many surrounding suburbs, initiated a partnership in August 2010. This partnership was intended to improve the health and resiliency of forests and watersheds in areas critical for providing water to the city and county of Denver. According to the Forest Service, under the program, forest restoration efforts will help protect water resources for Denver's residents as well as millions of downstream beneficiaries, including businesses and agriculture. The restoration efforts will also help the forests become more resistant to future insect and disease epidemics, reduce wildfire risks for communities, and improve habitat for fish and wildlife.

Source: GAO analysis of agency information.

[a]NIDIS was established under the National Integrated Drought Information System Act of 2006. Pub. L. No. 109-430, § 3, 120 Stat. 2918, 2918 (codified at 15 U.S.C. § 313d).

[b]GAO-14-23.

[c]Landsat 8 was launched in February of 2013 by NASA, but USGS will manage the satellite's operations and data.

[d]GAO-12-880.

[e]Pub. L. No. 109-58, § 979, 119 Stat. 594, 905 (codified at 42 U.S.C. § 16319).

[f]The agreement is officially titled the "Interim International Cooperative Measures in the Colorado River Basin through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California," but it is often referred to as Minute 319. The agreement was administered by the International Boundary and Water Commission (IBWC), an international body with responsibility for applying the boundary and water treaties between the United States and Mexico and settling differences that may arise in their application. IBWC has a U.S. Section and a Mexico Section, which are administered independently of each other. According to an IBWC official, the U.S. Section of IBWC is a stand-alone federal agency, but it receives funding from Title I of the Department of State's Foreign Operations budget.

[g]Minute 319 only covers surface water; it does not include groundwater.

Multiagency Initiatives

Over the last decade, a number of efforts involving multiple federal agencies have been initiated to address freshwater availability and use (see table 7).

Table 7: Examples of Multiagency Initiatives Since 2003 Related to Water Resources

Initiative name	Description	Examples of activities
Integrated Water Resources Sciences and Services (IWRSS)	Formalized in 2011, IWRSS is a multiagency federal initiative between NOAA, USGS, and the Corps to collaboratively support water-related planning and preparedness and response activities through a national water resources information system.	According to USGS officials, recent accomplishments of IWRSS include holding four river basin stakeholder meetings to inform stakeholders about IWRSS activities, identify information gaps that IWRSS could potentially fill, and discuss pilot projects. Additional meetings are scheduled for 2014 for the Ohio and Russian River Basins. In addition, under the initiative, officials have established requirements for producing, sharing and disseminating flood inundation maps, and they made improvements to water-related models that will, for example, allow weather forecasts and groundwater pumping information to be integrated into a flow-forecasting model when completed.
Western States Federal Agency Support Team (WestFAST)	Established in 2008, WestFAST is a collaboration of 12 federal agencies, states, and other stakeholders formed to address water issues in western states.[a] WestFAST was established to support the Western States Water Council and the Western Governors' Association in coordinating federal water resource efforts in areas such as water availability, water use, and climate change.	Currently, WestFAST, in collaboration with the Western States Water Council, Western Governors' Association, and DOE and its national laboratories, has created a water data exchange to serve as a repository for water data maintained by states and federal agencies, according to federal officials.
Western Watershed Enhancement Partnership	In July 2013, Interior and USDA established a partnership to work with local water users in identifying and mitigating risks to water supplies and hydroelectric facilities from wildfire in western states. Flows of sediment, debris, and ash into streams and rivers after wildfires can impair water quality and often require millions of dollars to repair damage to habitat, reservoirs, and facilities. The partnership aims to restore forests and watersheds and to proactively plan for post-wildfire actions to protect municipal and agricultural water supplies, according to an agency document.	Six pilot projects are currently under development as part of the partnership, according to Reclamation officials.

Initiative name	Description	Examples of activities
National Drought Resilience Partnership	In response to a November 2013 Executive Order directing federal agencies to prepare the United States for the impacts of climate change,[b] a USDA and NOAA-led partnership focused on drought resilience was created. The partnership, which also includes participation from Interior, EPA, the Corps, DOE, and the Department of Homeland Security's Federal Emergency Management Agency, will focus on increasing the amount of available drought information, building a national soil moisture monitoring network to help improve drought forecasting, and initiating a pilot drought resilience plan in western states.	Through the partnership, participating agencies plan to create a Web-based system to increase access to federal drought resources, host more regional forums to distribute drought information, and create a single federal point of contact for drought information for the public, according to an agency document.
Joint Reclamation-USDA's Natural Resources Conservation Service (NRCS) Agricultural Conservation Projects	In 2011, Reclamation and NRCS began a new partnership to leverage funding for water delivery agencies and agricultural producers in California. The joint effort is in response to the 2009 Interim Federal Action Plan for the San Francisco Bay/Sacramento-San Joaquin Delta. Through a competitive process, Reclamation makes funding available to irrigation districts so that improvements that save water or improve water management can be made in the systems that deliver water to farmers. NRCS, in turn, provides funding to farmers who receive water from those districts so that on-farm conservation improvements can also be made throughout those districts.	Funding for the partnership has been made available each year since 2011. Reclamation and NRCS are extending that partnership beyond California to other western states. Applicants for Reclamation's WaterSMART Grants receive additional funding consideration if proposals would result in water delivery improvements that also facilitate future on-farm improvements that could be funded through NRCS programs. In February 2014, Reclamation and NRCS announced that they will provide up to $14 million in FY 2014 funding for water districts and associated growers to conserve water and improve water management in California.

Source: GAO analysis of agency information.

[a]The 12 federal agencies participating in WestFAST are Interior's Bureau of Land Management, the Corps, the Department of Defense, DOE, EPA, NASA, NOAA, NRCS, Reclamation, FWS, Forest Service, and USGS.

[b]Preparing the United States for the Impacts of Climate Change, Exec. Order No. 13,653, 78 Fed. Reg. 66,819 (Nov. 1, 2013).

Federal Assessments and Reports

Since 2003, federal agencies have issued numerous assessments and reports on various aspects of freshwater availability and use (see table 8).

Table 8: Examples of Federal Assessments and Reports Developed Since 2003 Related to Water Resources

Report name	Description
Estimated use reports	Every 5 years since 1950, USGS has published reports that include estimates of water withdrawals broken down by state; source of water such as fresh or saline; and category of use such as thermoelectric power, irrigation, or public supply. The most recent report, presenting 2005 water use data, was published in 2009, and USGS officials said they expect that the next report presenting 2010 data will be issued in 2014.
Farm and Ranch Irrigation Surveys	USDA's National Agricultural Statistics Service conducts an irrigation survey every 5 years, as authorized by the Census of Agriculture Act of 1997.[a] The report includes information on estimated quantities of water applied to irrigated land, the number of irrigation wells on farms, and barriers to making water conservation and energy reduction improvements, among other information. The National Agricultural Statistics Service published a report presenting 2008 results in November 2009 and plans to release results of the 2013 irrigation survey in October 2014.
2010 Resources Planning Act assessments	The Forest Service prepares an assessment of renewable natural resources, including water resources, every 10 years, as required by the Forest and Rangeland Renewable Resources Planning Act of 1974.[b] The most recent report for 2010 was published in 2012, and it includes information on the relationship between water resources and climate change and increased competition between water users, among other topics. Forest Service officials said that research for a mid-cycle update is in progress with an anticipated 2015 release, and they are beginning to examine options, such as working with other agencies on developing scenarios, for the 2020 assessment.
The Subcommittee on Water Availability and Quality reports	In November 2004, the Subcommittee on Water Availability and Quality issued a report outlining the need for coordinated science and technology efforts to better understand water supply and demand in the United States.[c] In addition, the directors of the Office of Science and Technology Policy and the Office of Management and Budget issued a joint memorandum requesting federal agencies, through the Office of Science and Technology Policy's National Science and Technology Council, to develop a coordinated, multiyear plan to improve research on processes affecting water availability and quality. In response to the memorandum, the subcommittee issued a second report in September 2007 that identified areas for future emphasis by federal water science and technology programs.[d] The report focused on topics that would benefit from increased collaboration between agencies and with other stakeholders, such as private entities and tribes.
The Importance of Water to the U.S. Economy synthesis report	In November 2013, EPA issued a synthesis report highlighting the findings of its study on the importance of water to the U.S. economy. The report identified key water data gaps and described the implications of the study's findings for future research. EPA officials said that while they do not have any concrete next steps to meet the needs highlighted in the report, they are hoping the report will be a catalyst for more discussion and work on the issues identified in the report.
Watershed Condition Framework	The Forest Service's Watershed Condition Framework is an approach for implementing integrated restoration on priority watersheds on national forests and grasslands. According to agency documents, the framework will help focus agency efforts in a consistent and accountable manner and facilitate new investments in watershed restoration that will provide economic and environmental benefits to local communities. The agency also produced a technical guide that provided the protocol for the agency's first national assessment of watershed condition across all 193 million acres of National Forest System lands.

Report name	Description
National Action Plan – Freshwater Resources	In October 2011, the Interagency Climate Change Adaptation Task Force issued National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate. According to the plan, the Task Force used the latest science on climate risks to freshwater resources to establish a national goal for government agencies and citizens to collaboratively manage freshwater resources in response to a changing climate to ensure adequate water supplies; to safeguard human life, health, and property; and to protect water quality and aquatic ecosystems. To accomplish the goal, the plan made six recommendations, including establishing a planning process to adapt water resources management to a changing climate, improving water resources and climate change information for decision-making, and expanding water use efficiency.

Source: GAO analysis of agency information.

[a]Pub. L. No. 105-113, § 2, 111 Stat. 2274, 2274 (1997) (codified as amended at 7 U.S.C. § 2204g).

[b]Pub. L. No. 93-378, 88 Stat. 476 (1974) (codified as amended at 16 U.S.C. §§ 1600-1614).

[c]National Science and Technology Council, Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality, *Science and Technology to Support Fresh Water Availability in the United States* (Washington, D.C.: Nov. 15, 2004).

[d]National Science and Technology Council, Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality, *A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States* (Washington, D.C.: Sept. 4, 2007).

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

Anne-Marie Fennell, (202) 512-3841 or fennella@gao.gov

Staff Acknowledgments

In addition to the individual named above, Elizabeth Erdmann, Assistant Director; Eric Charles; Melinda Cordero; E.E. Eischen; Kirsten B. Lauber; Patricia Moye; Dan C. Royer; Rebecca Shea; Lisa Vojta; and Elizabeth Wood made key contributions to this report. Antoinette Capaccio, Nirmal Chaudhary, Ellen W. Chu, John Delicath, Mehrzad Nadji, Carol Patey, and Stephen Sanford provided additional technical assistance.