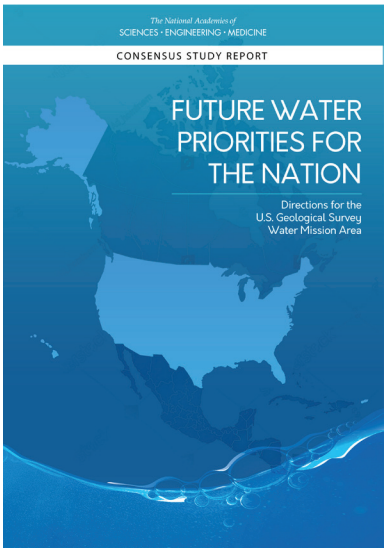
Consensus Study Report
HIGHLIGHTS
September 2018

Future Water Priorities for the Nation: Directions for the U.S. Geological Survey Water Mission Area



"The provision of adequate fresh-water resources for people and ecosystems will be one of the most critical and potentially contentious issues facing society and governments at all levels during the 21st century." —American Meteorological Society

There is broad agreement that solving problems related to use of water resources will be of paramount importance in coming decades. In the United States and abroad, water resources are under increasing pressure from growing populations, climate change, extreme weather, aging water-related infrastructure, and burgeoning demand for food, energy, and industrial production. That pressure threatens water availability and quality in ways that can increase exposure to hydrologic extremes and hazards, affect economic and policy decisions, and make the tradeoffs between human and ecological water uses even more difficult.

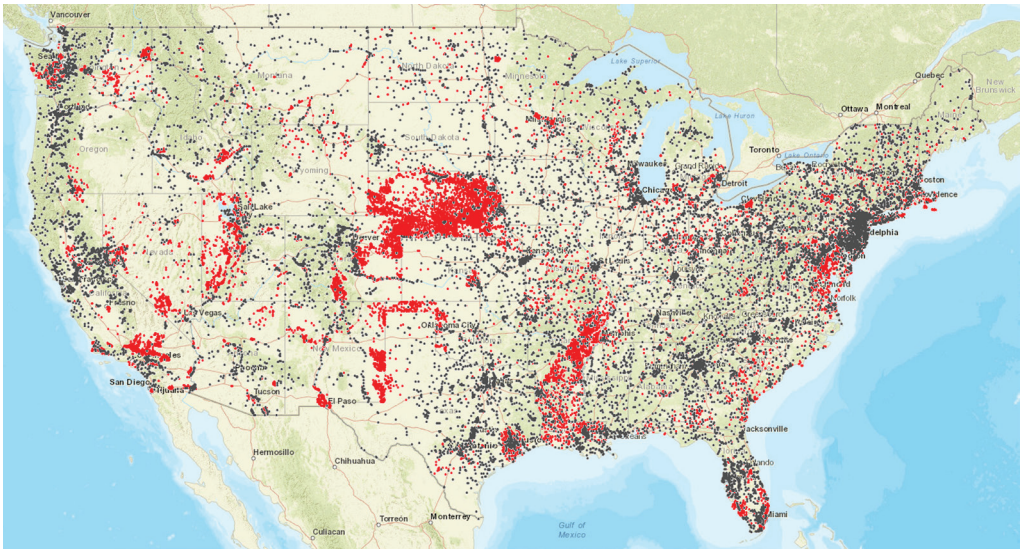
The Water Mission Area (WMA) of the U.S. Geological Survey (USGS) has a long-established reputation for collecting and delivering high-quality, unbiased scientific information related to the nation's water resources. Federal, state, and local agencies, the private sector, nongovernmental organizations, academia, and the public rely on WMA observations and analysis to inform decisions ranging from rapid responses during emergencies such as hurricanes, floods, and forest fires to the long-term management of water resources.

Produced at the request of USGS, this report identifies the nation's highest-priority water science and resources challenges over the next 25 years, summarizes WMA's current water science and research portfolio, and recommends strategic opportunities for WMA water science and research that would address the highest-priority national water challenges.

WATER SCIENCE AND RESOURCES CHALLENGES

To help focus its guidance to WMA, the report's authoring committee identified the highest-priority water science and resources challenges over the next 25 years. Using published work on the subject and input from experts from the federal, state, local, nongovernmental, and academic communities, the committee identified the following cross-cutting challenges:

- **Understanding the role of water in the Earth system**: As water moves through the atmosphere, lithosphere, and biosphere, it facilitates physical, chemical, and biological processes. Understanding how the water cycle responds and feeds back to global change remains a key challenge in Earth system research.
- **Quantifying the water cycle**: Effective management of water resources demands knowledge of how much water there is, its state, and where it is located. Quantification of the hydrologic cycle is exceedingly difficult because the stocks, flows, and residence times of water vary spatially and temporally.



The USGS Water Mission Area delivers high-quality information about the nation's water resources, including data gathered from surface water (gray dots) and groundwater (red dots) monitoring sites across the United States. Source: USGS.

- **Developing integrated modeling**: Models are essential tools for integrating and synthesizing disparate observations, for understanding complex interactions and testing hypotheses, and for reconstructing past conditions and predicting future trajectories of co-evolving systems.
- **Quantifying change in the socio-hydrological system:** Understanding how human activities influence water resources is critical to managing these resources in the United States and globally.
- **Securing reliable and sustainable water supplies:** Society is dependent on the availability of clean, reliable, and affordable surface water and groundwater for drinking water, food and energy production, industrial activities, healthy ecosystems, and recreational activities and tourism.
- **Understanding and predicting water-related hazards:** Water-related hazards represent some of the world's costliest natural disasters in both economic and human terms and are increasingly exacerbated by human activities and climate change.

QUESTIONS TO ADDRESS GLOBAL ISSUES AND ADVANCE USGS STRATEGIC SCIENCE

To further hone its guidance, the report identifies 10 overarching science questions that, if addressed, would make the most significant contributions to these water science and resources challenges in the future. This set of questions was further narrowed to five priority questions that would best utilize USGS strategic scientific resources for the benefit of the nation on the basis of the following criteria: scientific importance, societal need, relevance to the USGS mission, and relevance to USGS partners.

The five questions that would have high potential to benefit USGS strategic science are:

1. **What is the quality and quantity of atmospheric, surface, and subsurface water, and how do these vary spatially and temporally?**
2. **How do human activities affect water quantity and quality?**
3. **How can water accounting be done more effectively and comprehensively to provide data on water availability and use?**
4. **How does changing climate affect water quality, quantity, and reliability, as well as water-related hazards and extreme events?**
5. **How can long-term water-related risk management be improved?**

The other five questions, while still highly important, may be addressed by the broader water research and resources communities, including USGS, as resources allow. These are:

6. **How does the hydrologic cycle respond to changes in the atmosphere, the lithosphere, and the biosphere through Earth's history and in the near future? And how do the hydrologic responses feed back to and hence accelerate or dampen the changes in the atmosphere, the lithosphere, and the biosphere?**
7. **How can short-term forecasting for climate, hydrology, water quality, and associated social systems be improved?**
8. **How do institutions and governance and institutional resilience impact the quantity and quality of water?**
9. **How can understanding of the connections between water-related hazards and human health be improved?**

10. **How can competing uses for water resources be managed and maintained to sustain healthy communities and ecosystems in a changing world?**

EMERGING AND INNOVATIVE TECHNOLOGIES

Emerging technologies will help advance the response to each of the challenges identified. Over the next 25 years, observations will come from a wider array of sources, be more affordable, offer data from previously inaccessible locations, provide "fit-for-purpose" temporal and spatial resolution, and deliver measurements of new parameters. The wide adoption of new technologies will require development of systems (e.g., hardware, software, management frameworks, protocols) that can rapidly collect data from disparate sources, assess those data for quality, store and process them, and share them in near real-time in formats that are informative and accessible for users.

New sensors will advance observations and analyses of water resources, but technical challenges exist with respect to measuring and monitoring water quality. Microsensors remain an area of research and development that shows great promise and is advancing rapidly. Environmental DNA (eDNA) methods can already detect invasive species from a single sample of water, and new insights into environmental health and resilience will follow.

Developments in managing "big data" and integrating data from multiple sources and of different types will support improved scientific understanding, development of improved models (such as coupled natural-human system modeling), interdisciplinary model integration, and decision-making under uncertainty.

RECOMMENDATIONS FOR WMA

Based on the cross-cutting challenges and high-priority questions identified above, the committee arrived at the following recommendations.

Enhance data collection, include citizen science, and develop Web-based analytical tools. To enable the nation to meet future water resources challenges, WMA should (1) strategically enhance the temporal and spatial collection of water quantity, quality, and water-use data using robust, innovative technologies to develop readily accessible "fit-for-purpose" information; (2) further infuse citizen science into USGS data-collection activities to augment traditional monitoring networks; and (3) develop innovative, intuitive Web-based data analysis and visualization tools for the nation to better understand the status and trends of its water resources.

Coordinate with agencies and organizations on data delivery. As part of the national effort to deliver water quantity and quality data and information, WMA should coordinate with other agencies and relevant organizations to co-develop accessible, open, and codified data formats, protocols, interoperability, and software tools. This will allow integration across data streams and encourage synthesis of multiple observations in order to detect trends, patterns, and changes in water quantity and quality.

Increase focus on the relationships between human activities and water. WMA should prioritize investigations of the relationships between human activities and changes in surface water and groundwater quantity, quality, and water-related hazards through a careful synthesis of observations and coupled natural-human systems models forced by climate and socioeconomic factors.

Develop a robust water accounting system. WMA should conduct studies to understand how to best and most efficiently execute water accounting and how to assess and present uncertainty in the reported data. Water accounting should go beyond measurement of the resource itself to consider the biophysical and societal constraints on water use and should include estimates of consumptive versus non-consumptive water use.

Collaborate with agencies and organizations on water-data standards and categories of use. As part of the national effort to collect water-use data and information, WMA should collaborate with other agencies and relevant organizations to co-develop standards, protocols, and clear definitions for categories of water use, and should adhere to common format standards across states, counties, and watersheds.

Ensure that monitoring networks provide adequate information to assess changing conditions. USGS should periodically assess the state of surface water and groundwater monitoring networks to ensure that these networks can provide data for hydrologic impact analyses as environmental conditions change due to climate, agriculture and other land uses, and urbanization.

Focus on long-term prediction and risk assessment of extreme water conditions. WMA should prioritize activities that address long-term prediction and risk related to hydrologic causes such as floods, droughts, and water-borne contaminants. WMA should seek to understand how climate change, land-cover and land-use change, and other biophysical and socio-economic factors affect the nation's water resources, including water quantity and quality, extreme events, and other hydrologic hazards. USGS should further develop integrative models that can help predict future hydrologic conditions under these changing climate

conditions. These activities will require integrative studies with other USGS mission areas and should include resource managers, decision makers, and social scientists.

Develop multiscale, integrated, dynamic models that encompass the full water cycle. WMA should prioritize multiscale and integrated modeling efforts that dynamically couple above- and below-ground hydrologic stores and fluxes, water quantities and qualities, and natural and human drivers and interactions, and utilize diverse observations ranging from ground-based sensing to Earth observations from airborne and space-borne platforms.

Collaborate as appropriate both within and outside of USGS, including agencies and the private sector. Given that water resources challenges are inherently interdisciplinary, WMA should continue to build and maintain strong collaborations. WMA should maintain and strengthen ties with other USGS mission areas to maximize the impact of its work on observing, understanding, predicting, and delivering water data and issues. WMA should maintain and strengthen ties with other federal and state agencies, and as appropriate, international agencies (especially regarding transboundary water issues) to meet these water resources challenges. WMA should also evaluate and, where deemed advantageous, engage in private-sector collaborations to develop new data sources and platforms, and to enhance the dissemination of data and information, models, and other products.

Build a workforce ready to take on new water challenges. WMA should align its current and future workforce to meet critical strategic needs, specifically building capacity for improved water monitoring; coupled natural-human systems modeling; and data analysis, analytics, visualization, and delivery using reliable, accurate, robust, and innovative methods.

COMMITTEE ON FUTURE WATER RESOURCE NEEDS FOR THE NATION: WATER SCIENCE AND RESEARCH AT THE U.S. GEOLOGICAL SURVEY

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For More Information . . . This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report *Future Water Priorities for the Nation: Directions for the U.S. Geological Survey Water Mission Area* (2018). The study was sponsored by the U.S. Geological Survey. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Water Science and Technology Board web page at http://www.nationalacademies.org.

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