Significant opportunity exists to raise awareness of the role of groundwater in climate adaptation and actions that can lead to a more sustainable and resilient water supply future. Just as there are examples of groundwater overexploitation, there are many examples of good groundwater management with timely, comprehensive data collection and analysis that provide insight to future directions.

Safeguarding groundwater is a global challenge, but the primary sustainable management solutions are found at the local and aquifer or groundwater basin level. Groundwater occurs in aquifers that are highly variable across the country in size, geology, climate, overlying land use, and water demands. Aquifers are natural infrastructure providing groundwater storage, subsurface conveyance, and surface water flow and often are sinks receiving waste fluids. They require individualized attention at state and local levels, states to develop and implement regulations and laws to ensure best practices for management and monitoring, and to have the regulatory authority to step in where local groundwater management is ineffective. Effective groundwater management and governance also require active participation of groundwater users and stakeholders in the planning, decision-making and implementation processes. These key concepts are central to sustainable groundwater management. The science of groundwater is well established today with a large community of groundwater professionals.

As States are the resource managers of groundwater in the United States, they are responsible to enact and revise laws and regulations that apply the science within their legal-political frameworks. These frameworks must address the local needs of 40 million people on private household wells and nearly 93 million that use publicly-supplied water from 38,000 groundwater systems, 36,000 of which serve 10,000 or fewer people. Additionally, groundwater is used in a range of agricultural, commercial, and industrial applications. Clearly, there are many stakeholders.

The quality of groundwater affects its availability for use. Emerging and legacy contaminants present continuing challenges to safe groundwater supply and use. Remediation of locations of concentrated contamination require continuing attention and funding support. Overpumping aquifers can induce water of lower quality to be abstracted. Saltwater intrusion from excessive pumping and sea level rise can impact coastal wells, requiring additional treatment. Conversely, utilizing deeper brackish and saline groundwater may be essential for chronically water-short communities willing to pay for treatment.

In many cases, significant improvements can be accomplished by recognizing and managing groundwater and surface water conjunctively. This includes working toward local and state laws, regulations and incentives that encourage use of surface water during wet periods, including storm and flood waters, for both supply and groundwater replenishment to prepare for increased groundwater use during droughts.

Considerable attention is currently being given to ways to purposefully recharge aquifers for later recovery when needed for supply or for environmental benefit—a practice known as managed aquifer recharge (MAR). It is a mature and growing approach worldwide that encompasses a wide variety of water sources (including stormwater and treated wastewater), recharge methods (e.g., recharge wells and infiltration basins), and storage management practices. In the southwest US, the recent realization that hydrology has changed and there are more dry years and droughts has catalyzed a flurry of activity to increase recharge during the wet season and wetter years.

The sophistication of MAR has grown in the past 50 years with innovative strategies, institutional arrangements, scalable applications, and enhanced monitoring to improve performance and accounting of water recharged, stored, and recovered. Recycled water is also playing a much larger role as a reliable source water for MAR. Best practices must be implemented to ensure the compatibility of recharge water with the chemistry of the local groundwater and the geology of the groundwater basin or aquifer.

Data on the status of the U.S. groundwater resource is essential, as we cannot manage what is not measured. An important source of data is the National Ground-Water Monitoring Network (NGWMN). Operated by the U.S. Geological Survey (USGS), the NGWMN is composed of groundwater monitoring wells from Federal, State, and local groundwater monitoring networks across the nation. The data collected through the NGWMN play a crucial role in monitoring the health and supply of our nation's groundwater and is an important tool when water policies are being considered. The USGS also maintains a national Climate Response Network of wells to monitor the effects of climate variability and change on groundwater levels.

A "one-water" approach views all water, including groundwater, surface water, wastewater, and stormwater, as a single resource. We should place a high social value on maintaining water resources at benchmarks set through evidence-based data-driven evaluation to protect human health and vital environmental systems.

Responding to specific questions regarding actions addressing groundwater challenges:

- How can we enhance the timely collection of data on groundwater inventory, use, recharge, and flow across the United States to gain a whole-of-country picture of the nation's groundwater resources?

  RESPONSE: Significant investment in groundwater monitoring has made water level and water quality data available across a range of programs supported by federal, state, and local governments. To pull these data together, the Advisory Committee on Water Information chaired by the Department of the Interior dismantled in the previous administration created the National Ground-Water Monitoring Network. Thirty-four states have connected data to the Network, a network-of-networks. The NGWMN is underfunded to meet its goals for a national network. Actions needed:
  - Invest more in the National Ground-Water Monitoring Network, USGS Climate Response Network and related surface water monitoring to incentivize all states to participate in reporting their groundwater and related surface water data.
  - Require other federal agencies to provide access to their groundwater data through a semantic translator to the NGWMN as states are already doing through this national network of state and local networks.

  - Reestablish the Advisory Committee on Water Information (or similar entity) under the Department of the Interior with new objectives to meet this need, including the addition of groundwater recharge and flow. Consider adding state and local partners to bridge the state and local management with federal team members.
  - Continue to support groundwater to benefit communities’ residents and businesses by means of enhanced federal support to local agencies and organizations who are best positioned to manage the resource.

- How can we effectively model and predict changes in the inventory, recharge, and flow of groundwater in the context of the overall water cycle and provide that information to stakeholders and decision-makers?

  RESPONSE: Modeling is a tool best developed and applied locally to groundwater basins and aquifers typically to address specific conditions and questions. Future climate scenarios need to be integrated into models to comprehensively predict changes in groundwater resources. States typically roll up their local information and data for statewide water planning. Actions to be taken are:

  - Continue the role of the USGS and other federal agencies to inform continued development of groundwater models (for example, MODFLOW) and integrated groundwater-surface water models for the range of geologic conditions in which groundwater exists. Adding state and local partners to define and address the state and local management perspective with federal team members will support refinement of model application.

- How can we efficiently scale groundwater recharge while mitigating risks?

  RESPONSE: Groundwater recharge is currently occurring on a range of scales, typically at the local level responding to local water needs. Efficient managed aquifer recharge is currently being done in many groundwater basins, especially in the southwest US using the latest technologies, including surface infiltration and underground injection wells. Potential risks to groundwater quality include emerging contaminants and mobilization of naturally occurring contaminants, both of which can be addressed by the application of best practices with currently available science. Actions to take are:

  - Continued due diligence to test and address new contaminants as they are discovered in recharge source water and groundwater.
  - For new chemicals annually registered in the Toxic Substances Inventory, have a process in place to reduce the toxic and recalcitrant chemicals that may enter the environment and create groundwater contamination and health problems.
  - Continue the development of a robust National Water Reuse Action Plan including further research supporting protection from chemical and microbial contaminants.
  - Compile best practices for managed aquifer recharge that addresses appropriate planning, investigation, monitoring, and pilot testing including case studies of MAR projects at a variety of scales.

  - Forecast Informed Reservoir Operations (FIRO) is one way to help generate more usable water out of the surface water system from an existing dam on an annual and seasonal basis, which can then be used for recharge.

- How can we ensure clean and safe groundwater, especially for the communities that are affected most by groundwater contamination and depletion?

  RESPONSE: Among the key concerns today is widespread contamination by per- and polyfluoroalkyl substances (PFAS) after decades of inaction to address these toxic and recalcitrant chemicals. This emphasizes the necessity of making groundwater protection a key priority in government policy. It is also important to maintain vigilance on other legacy contaminants. For example, in many rural areas, nitrate and naturally occurring contaminants such as arsenic are the major contaminants of concern and need continuing attention.
  Groundwater depletion can be mitigated, but to avoid economic hardships from immediate demand reduction, it takes time and other activities to bring aquifers and basins into sustainable groundwater management practices. Basins in depletion should at a minimum develop plans to address the water budget, inventories of wells and pumping volumes, monitoring of sustainability indicators (groundwater levels, groundwater quality, change in storage, land subsidence, seawater intrusion, and interconnected surface water), action thresholds for sustainability indicators, projects to increase supply, and approach to demand reductions over a reasonable period. Actions to take include:

  - Incentivize and support state and local programs to mitigate effects on residential and small community supply wells addressing wells going dry and water quality degradation.
  - Establish a national groundwater basin/aquifer status inventory, prioritization and needs assessment
    - Prepare a national inventory of the state of groundwater resources and contamination by groundwater basin or aquifer, with Federal and state agencies working with local groundwater managers.
    - Conduct a prioritization of groundwater basins/aquifers based upon defined criteria. Examples of state efforts are those by California and Texas.
    - Provide federal support and incentives for state and local managers to mitigate ineffective processes and contaminated conditions.
  - Reinvigorate federal programs to protect against contamination and depletion including reassessment of source water protection areas around wells and incentives for water efficient plumbing fixtures to replace old fixtures, and for enhanced water reuse.

- How can we engage with communities to successfully ensure a sustainable supply of groundwater, including for agriculture, industry, energy, human consumption, and healthy ecosystems and biodiversity?

  RESPONSE: Developing targeted local and household information, educational materials and media that is actionable is key to community acceptance of revised public performance objectives and informed decisions. Actions to take are:

  - Consider a Groundwater Academy modeled after EPA's Watershed Academy to similarly include Learning Modules, Webcasts, Kid's Corner, and Resources (management resources, publications, and state and federal training).
  - Provide federal incentives and guidance for local outreach; also where federal government has presence (U.S. Army Corps of Engineers, Bureau of Reclamation), participate and support the local outreach.

- What strategies and incentives can help limit groundwater over-use?

  RESPONSE: Groundwater depletion has occurred in every state at some scale. The federal government can provide technical and economic support to states. Actions to take include:

  - Facilitate development of groundwater sustainability plans (or comparable means) to establish basin or aquifer level water budgets and sustainable management criteria for groundwater levels, groundwater storage change, groundwater quality degradation, groundwater extraction related land surface subsidence, saline (brackish, seawater) intrusion, and groundwater extraction related surface water depletion, including consideration of current and future climate trends. Plans to include projects and demand management actions to reach and maintain sustainability. Further federal support and funding for sustainability projects to include managed aquifer recharge using stormwater capture and recycled water, increased use of recycled water for irrigation and other beneficial uses, increased water use efficiency, recognition of water conservation as way of life, and demand reduction where necessary to achieve groundwater sustainability. Recognizing that the time for depletion took decades, the time frame for achieving sustainability while urgent, should be reasonable to minimize economic hardships in adjusting to reduced water demand through land use changes from water intensive use where necessary.
    - Strategies should include further development and application of best available science into best suggested practices to better understand the inherent complexities and improve management of the critically important resources of the nation's groundwater systems.
    - Strategies should also include incentivizing ***nature-based solutions*** that integrate sustainable planning, design, environmental management and engineering practices that weave natural features or processes into the built environment to promote adaptation and resilience and use natural features and processes to address climate change while reducing flood risk.
    - Incentives should include grants and loans to assist state and local agencies to do the work and projects needed to achieve and maintain sustainable groundwater resources.
  - Increase federal funding for USGS and other federal agencies to provide technical assistance for best applicable science including monitoring, modeling, and decision-making.