

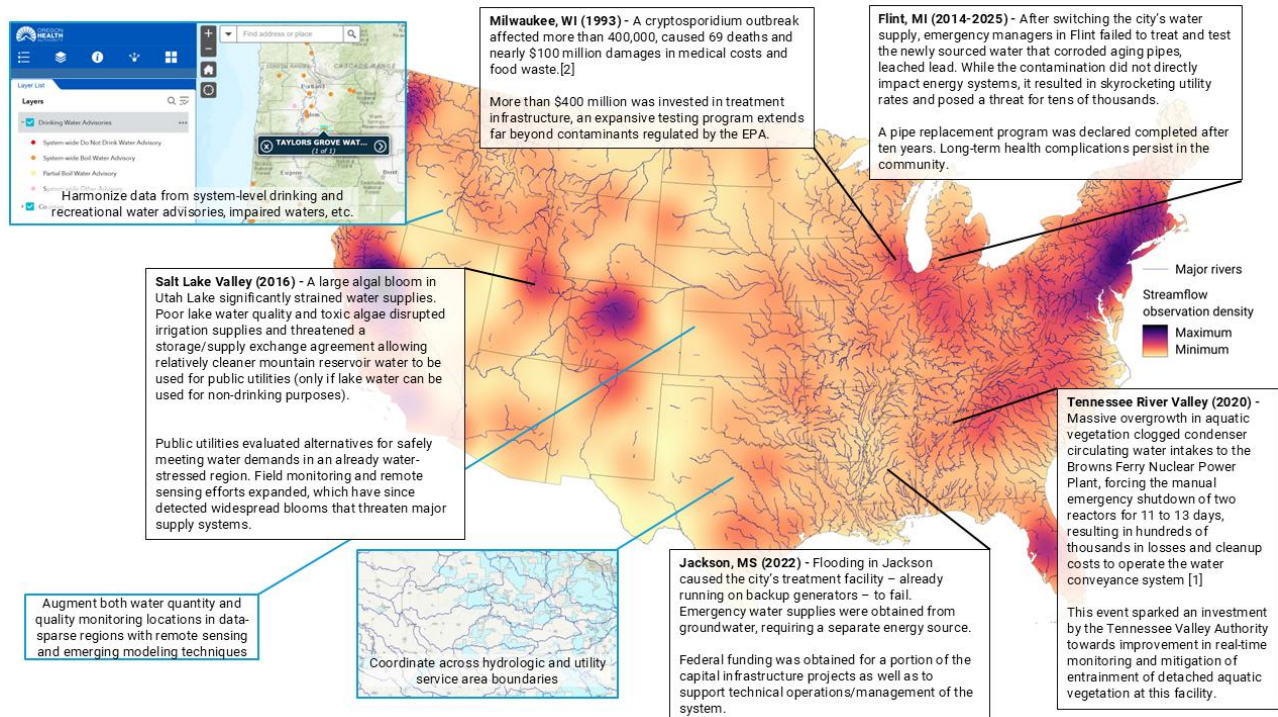
## Monitoring, Planning, and Management of Water Quality and Quantity for Resilient Water and Energy Systems

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**Focal Area:** Waterbodies used for energy production, such as hydropower reservoirs or rivers feeding nuclear and thermoelectric cooling systems, are often part of complex multi-purpose systems which require energy for treatment and operation. On top of basic water availability (quantity) requirements, operations in these systems are subject to varying environmental conditions (quality). Addressing gaps in environmental health and infrastructure condition/capability data will advance modeling, planning, management, and coordination at the intersection of the water and energy sectors.

**Existing Challenge and Opportunities:** Challenges in managing complex water and energy systems are evident across the United States, although situations vary from location to location. Increasing and excessive growth of algae and aquatic vegetation combined with other environmental health concerns such as the presence of pathogens or toxins can be a common occurrence. In several cases, these events have threatened or caused significant disruptions and impacted public health (Figure 1).



**Figure 1.** Examples of water quantity/quality challenges throughout the US, overlaid with a heatmap of streamflow observation density. Opportunities for addressing data and modeling gaps are also called out.

In many cases, while the *quantity* of water has been available, the existing monitoring techniques fail to identify risks and treatment/conveyance infrastructure and to provide *clean* water for critical energy production, irrigation, or water supply. When rapid and extreme deteriorations in water quality are coupled with aging or inadequate infrastructure, system failures can quickly move from inconveniences like temporary beach closures, losses that are factored into distribution costs [3] or adjustments in treatment strategies to far-reaching disruptions of fundamental water and energy access. In some cases, they may seriously impact environmental and human health. Many water systems are ill-equipped to proactively address issues quickly despite known risks.

Below, we have described three near-term opportunities, strategic partnerships, and products that would address critical gaps related to water quantity and quality connections in the water and energy sectors. These actions can advance understanding and representation of environmental and supply dynamics within complex systems, ultimately enabling proactive planning and management to mitigate risks in both water supply and energy production systems. In addition, we suggest how success of such an approach could be measured.

**1. Identify areas with poor data coverage for near-real-time information about surface water supply systems and environmental health.** Studies show that the onset, duration, and severity of algal bloom events are changing [4] and adaptations of opportunistic pathogens present ongoing risks for water supply systems [5]. System operations based on historical conditions may no longer be appropriate. While remote sensing and other emerging technologies can help fill monitoring gaps, the level of effort to develop accurate and up-to-date information about environmental health risks remains a hurdle for many water systems. Comprehensive mapping of monitoring capabilities and variables describing environmental health should mirror how water quantity/use is tracked throughout the US (i.e., USGS water use reports) and how water rights data sharing is evaluated by the Western States Water Program Capabilities Assessment. To address this gap, products like a regular (e.g., semi-annual) report and accompanying geospatial dataset would provide asset owners and funding agencies with a way to understand the state-of-monitoring and enable efficient investments.

**2. Document redundancies, mitigation capabilities, and flexibility in infrastructure operations.** While many important physical attributes of US dams are catalogued in the National Inventory of Dams, it does not reflect operational flexibility or mitigation capabilities, such as variable-depth intakes or dissolved oxygen and temperature augmentation, or drawdown schedules. Examples of fish passage and sediment mitigation datasets from ORNL represent important but narrow improvements to documentation of our nation's water-energy infrastructure [7].

To advance dynamic representation of multi-purpose systems in models and decision-support tools, a catalog describing water quality and public health criteria must be related to water supply and conveyance systems (dams, power plant intakes, irrigation networks, or treatment plants) that may be directly downstream or indirectly impacted by environmental health in these systems. National laboratories need to work with partners across different scales, from local to regional utilities, tribal resource managers, private asset owners, to federal agencies. Coordination across these groups should drive the production and maintenance of the mitigation and operational flexibility catalog.

**3. Develop workflows to analyze information that crosses physical and management boundaries relevant to water-energy systems.** Hydrologic boundaries often do not correspond with geopolitical boundaries. Transboundary water and energy transfers, and the demands, markets, and rights that govern the movement of energy and water result in elaborate patchworks of information, complicating the representation of resource management and coordination. Reviews of successful transboundary water management point to the need for institutions with complementary jurisdictions to collect and share information for mitigating environmental and public health concerns [6]. Tools built by hydroinformatics and geospatial experts such as Internet of Water (GeoConnex and BoundarySync) and the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI, HydroClient) can aid in identifying and linking information owners and movement of resources.

Open-source geospatial processing workflows that build on these tools, retrieve data, and translate information across boundaries are needed to delineate the quality and quantity footprints of water and energy systems. The workflow must be able to handle information for processes/decisions that influence the systems as well as those that depend on and are impacted by their operations.

**Measures of success:** Connecting existing data, building workflows, and better documenting capabilities within multi-purpose systems would enable screening for various risks and infrastructure needs. Success of this approach would be assessed based on (1) the numbers of components that can be documented and (2) implementation of new approaches and connections within test cases. The components of water-energy systems to be documented include users, sources, quantity and quality constraints. New data processing and connection workflows based on this information should be tested across a range of pilot systems of various sizes and technologies. Ultimately, the positive impact of data and workflow improvements can be quantified in terms of reductions in system failures and losses as well as improved public health outcomes.

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