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Future of Water Infrastructure and Innovation Summit

Workshop Report

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List of Acronyms

AI	artificial intelligence
AQPI	Advanced Quantitative Precipitation Information System
BREW	Business, Research and Entrepreneurship in Water
CAPEX	capital expenditure
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EERE	Energy Efficiency and Renewable Energy
EPA	U.S. Environmental Protection Agency
IOM WASH	International Organization for Migration Water, Sanitation, and Hygiene
INL	Idaho National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LIFT	Leaders Innovation Forum for Technology
NASA	National Aeronautics and Space Administration
NCSE	National Council for Science and the Environment
NOAA	National Oceanic and Atmospheric Administration
NORM	naturally occurring radioactive material
PNNL	Pacific Northwest National Laboratory
R&D	research and development
RO	reverse osmosis
Sida	Swedish International Development Cooperation Agency
USAID	U.S. Agency for International Development

Executive Summary

In October 2020, the U.S. Department of Energy convened experts and practitioners across the water and wastewater sectors to (1) develop a vision for the future of the domestic water and wastewater infrastructure, and (2) identify the necessary technology and innovation advances needed to meet this vision.

The attendees envisioned a more integrated water and wastewater infrastructure approach compared to today's water system operation. From the attendees' perspective, the future water system will operate to implement resource recovery of nutrients and energy within wastewaters, coordination of electric and water grids to optimize system operation, fit-for-purpose water requirements that allow for water treatment systems to treat wastewater to different quality requirements for the desired end use, and increased utilization of non-traditional water sources.. Further, the future infrastructure identified would be more decentralized allowing end users to optimize their own water resources and treatment at a community and regional level. These decentralized systems could be coordinate with centralized water systems to achieve optimization of the broader system, but could act autonomously to allow for greater local and regional resiliency, like microgrids in the electric sector. Operations and decision-making processes would be informed by real-time data gathered with improved sensors, in conjunction with smart controls, to facilitate optimization of the connected systems. This future infrastructure would benefit from a well-trained workforce, robust financial mechanisms to support infrastructure improvements, a regulatory environment that facilitates innovation, and collaboration across all levels of governance and relevant functions (e.g., regulation promulgation, implementation, and enforcement).

The attendees identified the following needs with respect to technology developments and evolution of the innovation ecosystem to reach the envisioned future state.

Summary of Participants' Recommendations:

- Water/wastewater treatment and distribution improvements:
    - Improve the selectivity of membranes at a reduced cost without sacrificing permeability
    - Constructing membranes out of renewable and sustainable (i.e., biodegradable) materials
    - Develop low water and low or zero liquid discharge processes that can treat concentrated solutions across all scales
    - Develop multi-flow pipelines that can carry any fluid without mixing and contamination issues
- Water system level improvement:

    - Develop sensor network systems that incorporate artificial intelligence and can monitor water quality issues, detect problems, use data to perform root cause failure analysis, implement a solution, evaluate results, and inform management decisions
    - Develop and installing modular systems supporting distributed desalination, distributed water treatment technologies, and water reuse applications
    - Explore the subsurface water energy nexus, such as groundwater and geothermal energy integration, for providing multiple benefits (e.g., energy to waste, water reuse, and groundwater remediation)
    - Incorporate adaptable design elements to address aging water infrastructure coupled with climate change, such as integration with existing energy infrastructure systems (e.g., pumped storage hydropower)
- Water end-use improvements:
    - Advance digital, additive, and other advanced manufacturing techniques to support the efficient use of water

Priority Innovation Ecosystem Opportunities:

- Collaboration among stakeholders:
    - Facilitate cross-sector collaboration, including public-private partnerships, to develop and implement an integrated regional vision for water infrastructure that incorporates and supports technology innovation
    - Create markets and a policy landscape that is more supportive of technology adoption (e.g., matchmaking platforms for fit-for-purpose water producers and users)
- De-risking innovation and investment:
    - Accelerate technology testing and validation with quality control monitoring to help de-risk investment
    - Develop stakeholder informed roadmaps that incorporate improved technology testing and validation facilities, dedicated finance, and multi-organizational buy-in
- Workforce development:
    - Foster a new generation of technically competent and innovation-minded water/wastewater sector employees, through strong and consistent investment in education and workforce development to overcome the looming wave of retirements

This report summarizes the proceedings and discussions of the workshop.

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1 Introduction

Energy and water systems are interdependent, and the U.S. Department of Energy (DOE) has invested in energy and water for several years, including the Energy-Water Desalination Hub (led by the National Alliance for Water Innovation, NAWI), and research and development (R&D) in resource recovery from wastewater, among other areas. The Future of Water Infrastructure and Innovation Summit was held to inform the understanding of future opportunities in the water space. The organizers gathered information from a diverse group of relevant water and wastewater stakeholders representing academia, industry, government, nongovernmental organizations, and local/regional utilities.

The virtual summit was held on October 27 and 28, 2020. The first day’s discussions were themed around technology research and development needs to support the future physical water infrastructure. Topical breakout rooms were facilitated by subject-matter experts from the DOE, U.S. Environmental Protection Agency (EPA), and DOE National Labs. Topics of these discussions included: desalination, water and wastewater treatment/recovery, produced water, industrial management of water, and hydropower, conveyance, and water systems. These breakout rooms focused on the following questions, with some customization made at the facilitator’s discretion:

- What aspects of today’s infrastructure are not optimal for 2050?
- What existing or envisioned aspects would be optimal for 2050 nationally or regionally?
- What are the barriers to achieving the 2050 vision and how can they be mitigated?
- What technical breakthroughs would be transformative?

For the second day breakout sessions, attendees were asked to vote on their top aspects of future water infrastructure from the first day to guide their vision for 2050. Breakout session participants selected crosscutting topics for discussion including but not limited to, regional water management, the regulatory landscape, technology transfer, workforce development, business models, innovative financing, and community partnerships. These topics underlie the innovation ecosystem for water infrastructure. Questions addressed included:

- How can this crosscutting topic support accelerating the innovation pipeline?
- How can the crosscutting topic change to transform the future of water infrastructure?
- What aspects of the 2050 vision are the most important to tackle now?

This report is intended to summarize discussions that took place as part of the Summit, not to serve as a comprehensive treatment on any one topic area. The report is structured as follows: the first section hones in on the current state of water related physical infrastructure or technologies and the top aspects participants identified as needing attention to achieve an optimally water secure future. The last portion of the report discusses how crosscutting topics through the innovation ecosystem—including regional water planning, technological scale-up, and workforce development—will enable the future of water infrastructure and innovation.

2 Current State: Physical Infrastructure and Technologies

All information presented in this section is a summary based on the comments from participants during workshop discussions. During the breakout sessions, participants identified and voted on key aspects for the future water system; these prioritized actions are identified in the summary but do not represent the entire opportunity space. Other efforts, such as the National Alliance for Water Innovation (NAWI)[1], which has a roadmap in progress, may more accurately represent the different sectors and R&D needs.

2.1 Desalination

Workshop participants cited that desalination projects in the United States are relatively limited in number and scope when compared to other global regions (e.g., Middle East). Desalination of seawater and brackish groundwater can create access to new water resources, especially in desert and arid climates. However, participants cited past and current debates (e.g., some in California and Florida) with local ratepayers if use of desalination technologies should increase. Desalination plants can create new water resources for a region, but they can also burden ratepayers with higher water prices to pay off the large capital expenditure (CAPEX) investment and operations and maintenance cost, e.g. energy. Often, desalination plants have large throughput capacities to reduce volumetric costs through economies of scale, but this can come with higher CAPEX cost paid over many years. More recent plants (e.g, Claude "Bud" Lewis Carlsbad Desalination Plant) have reduced ROI by running at higher efficiencies than designed and this trend may continue with technology advancements. Plant designs must balance cost with regional water needs; participants noted that access to modular systems could reduce volumetric treatment costs and lead to targeted deployment in regions where there is the greatest need.

Current desalination projects in the United States utilize reserve osmosis (RO), which often treats water to a higher quality than needed. After RO treatment, operators will add back necessary constituents (e.g., calcium for drinking water), which can lead to cost inefficiencies through overtreatment. Participants focused on technology improvements that would enable fit-for-purpose[2] water treatment that allows operators to selectively screen out constituents. Another issue identified was the creation of a highly saline brine that is currently left over after RO treatment that is discharged back into the ocean or disposed via underground injection. Disposal requires transport, thereby increasing water treatment costs and presenting a possible risk to the environment. Some plants have explored using a brine line (e.g., the Inland Empire brine line) or trying to valorize the brine, but both solutions are highly dependent on local conditions and buyers. Creation of these brines will increase as more desalination plants are constructed. This

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[1] https://www.nawihub.org/

[2] The use of the term “fit-for-purpose” is meant to convey the use of water at its minimum of quality for a specific use. For example, agricultural water does not have to meet the same (i.e., more stringent) standard of quality as does potable or drinking water.

could also lead to competition with other industries for access to disposal wells and treatment options. Beyond the potential technological improvements, there needs to be market incentivization and policy assistance to make sustainable desalination a reality.

Future Aspects for 2050

- *Modularize technology and standardize components and devices.*
- *Create a national, regional, and local infrastructure for brine management and disposal.*
- *Develop flexible, fit-for-purpose treatment technologies that match end use requirements.*

2.2 Hydropower, Conveyance, and Water Systems

For the purposes of this summit, hydropower and water conveyance systems were included in the same session given some of the physical similarities of the infrastructure and the multiple uses of water. For example, a reservoir created by a dam with hydropower may also serve water supply, flood control, fire protection, recreation, and many other functions.

One of the unique aspects of this category of water infrastructure is that it is very established, and with that comes legacy problems that further complicate achieving a vision for its future. Hence, a frequent critique of the water sector is its outdated structures and operations. Much of America's water conveyance infrastructure was built more than 50 years ago, with some of it reaching a century in age. This reality results in infrastructure that was designed for a different time and a different need. The challenge is amplified when considering the combination of acceleration through the hydrologic cycle due to climate change, a degradation of infrastructure due to aging, and in some cases deferred maintenance. As volume and timing of flow greatly affects hydroelectric plants, occurrences like high runoffs often equate to loss of potential power because some water spilled, bypassing the electric turbines to prevent flooding upstream. Conversely, in periods of drought which routinely plague the west, water shortages stress smaller hydropower systems and are unable to accommodate power demand. Hydropower operations protocols were established years ago and some participants note that there is a lack of ability and flexibility to modify and optimize hydropower operations for changing needs, such as adjusting to shifting patterns of precipitation and extreme weather events due to climate change.

Data was another aspect that was discussed in detail. Aspects of today's water infrastructure that are not optimal for 2050 include the limited amount of data, as well as access to it and its management, storage, and validation. In particular, it was noted that data quality issues are common in many cases and in other cases, data simply does not exist. Examples of areas where there is a lack of data include water conveyance and use in agricultural applications, evaporation losses and water from snowpack. The age of our water systems also means that the equipment and operations are based on technologies of the past and water systems do not yet benefit from all of the advancements made in the last decades. Due to budget constraints, maintenance of many water systems tends to be reactive rather than proactive. In general, innovation in the water sector as a whole tends to develop and spread slowly. Implementation of advanced sensors and tools could be a relatively easy way to detect potential problems and optimize efficiency. All of these issues persist as climate change is shifting precipitation patterns and causing extreme weather events. Participants emphasized the need for an integrated approach to power and water with all efforts being supported by robust data collection, management, and analytics. Advancements in artificial intelligence (AI) and remote sensing capabilities present an opportunity for fast, high quality data to improve operations and support decision making. Participants also suggested that the water infrastructure of the future will be more distributed in nature with secure communications and data platforms.

As the nature of water's multiple uses necessitates an understanding of the true "cost of water" valuation, there is a need to use data to make more informed decisions. For example, increased deployment of energy storage can help to eliminate the need for hydro peaking, which would improve river health. Markets today do not have the information necessary to educate stakeholders; therefore, they do not reflect hydropower's true value with respect to the transition to the clean energy grid and the trade-offs between various uses of water—from revenue streams in hydropower generation, to conveyance in agriculture irrigation, to reuse in other places. Attendees also stated that the sector lacks market mechanisms that could potentially enable opportunities for synergistic cooperation. The Pacific Northwest sharing hydropower with California provides an example of symbiosis: the Pacific Northwest has excess power generated from greater rainfall patterns while California needs green power. As Southern California started to install massive amounts of solar panels, for the first time, they are able to provide power to the Pacific Northwest during certain periods of the year. However, other attendees indicated that the Colorado River system still has a ways to go before it is fully optimized. Part of the problem in determining water's true cost is a disconnect between the various states' water legal and regulatory authorities, whose resulting legislation on water rights and allocation do not mesh. Valuation methodologies and policy changes could support adaptive use and management of water. Above all, flexibility and adaptability will be critical in an uncertain future and planning investments that meet societal needs under a range of future scenarios.

In summary, the group considered the key barriers to achieving this vision, and what technical breakthroughs are necessary. The primary challenges for making any of these changes are money and resources, but there are also other considerations. Current barriers include data quality and availability, a lack of remote and in situ sensing capabilities, and an overall framework for operationalizing needed data acquisition which could assist in other challenges, like water valuation. Separate from the technical barriers is the need for a mechanism for supporting the workforce development.

Future Aspects for 2050

- *Incorporate artificial intelligence (AI) and remote sensing to provide water information that can scale and deliver near real-time data to support decision-making and improve resource monitoring.*

- *Leverage technologies and infrastructure that support adaptive and flexible management approaches that are climate resilient, i.e. responsive to watershed runoff and varying consumptive water use.*
- *Understand and identify the true "cost of water" across infrastructure systems and an improved ability to value water across disparate uses (particularly beyond a freshwater portfolio) to allow for a fair democratization of water and infrastructure.*

2.3 Industrial Management of Water

Discussions on industrial water use focused on nutrient/contaminant recovery and valorization. In characterizing the current state, attendees identified a lack of economic incentives for companies to implement reuse/recovery technologies. Specifically, water is often inexpensive compared to other operational expenses, such as energy and labor, making it difficult to economically justify innovation. Further undermining any attempts at advancing water technologies is the lack of water metering at facilities. Without quantifying the amount of water used by particular processes, it is difficult to calculate resource and cost savings associated with the adoption of new technologies and approaches. Similarly, the current regulatory landscape does not incentivize innovation (see Regional Planning section). However, the attendees did identify a few aspects of the current environment that could lead to greater water and contaminant recovery. For highly contaminated waters that cannot be treated onsite or at the local wastewater facility, trucking wastewater is very expensive, and that increased cost incentivizes the adoption of onsite treatment technologies.

Attendees called out the capabilities of large versus small facilities in terms of water and contaminant recovery. While some technologies may be inefficient or uneconomical at small scales and for smaller facilities, they may scale-up well and be appropriate at larger scales and for larger facilities. The opposite warrants exploration too, where large technologies can efficiently scale down. In addition, the contaminant and/or nutrient loading of wastewaters will vary greatly, making recovery easier for some sectors than others (possibly even within subsectors).

In terms of technology needs, attendees identified the application of advances in digital, and other advanced manufacturing techniques to the efficient use of water. For example, the ability to monitor equipment/process performance, detect when a problem is occurring, use data to perform root cause analysis and identify the problem, implement a solution, and evaluate the results to see if the problem was fixed is available for energy services (e.g., fault detection, model predictive controls) but not for water. There is also a need to develop cost and energy efficient technologies to treat a variety of brine concentrations across all scales. The development of efficient and easily operable membrane and chemical-based treatment technologies designed for the manufacturing sector could meet this need. Similarly, the development and application of zero liquid discharge technologies and processes to fit a manufacturer's needs and serve as alternates to crystallizers could also meet this need. In terms of water conservation, the development of technologies and processes to use little or no water is needed.

Outside of technology development needs, pathways for supporting technology adoption were discussed. Creating avenues for manufacturers to access markets for the nutrients/contaminants they recover would support adoption of treatment and valorization technologies. Changes to the regulatory landscape such that water conservation, reuse, and resource recovery are better incentivized is also needed. Additionally, greater access to information on water efficiency, reuse, and nutrient/resource recovery would support technology adoption.

Future Aspects for 2050

- *Recover nutrients and other resources from manufacturers' wastewaters and either reuse the recovered products in their own processes or sell them to another manufacturer (or entity from any sector); "one factory's waste is another factory's treasure."*
- *Integrate energy, water, and waste sustainability programs.*
- *Create greater access to and use of fit-for-purpose water that meets but does not exceed the water quality requirements of the process/end use.*

2.4 Produced Water

Participants shared the view that today's produced water infrastructure lacks a coordinated vision to guide development at multiple scales. The physical infrastructure is fragmented. Producers do not have strong relationships with potential water customers outside of the oil and gas sector, and in some locations, there are few potential customers beyond irrigation. Efforts like *Sourcewater.com* and collaborations between the *Groundwater Protection Council* and the *New Mexico Consortium* seek to gather and analyze data to infer oilfield activity that could affect the produced water sector. However, there still is a need to connect producers with the appropriate customers to leverage resources. For example, platforms and tools to provide real-time information could help link supply to demand. Participants shared that there are no analytical and modeling tools to inform integrated system design and optimization, and interest from investors in water infrastructure is sluggish. Therefore, operators continue to develop infrastructure incrementally and independent from one another, and these developments are generally not interoperable. Capital asset costs are not fully accounted for and may be stranded. The belief was shared that such suboptimal infrastructure for today's oil and gas development will affect connectivity and economics in the future.

Participants stated that there are competing priorities and volatile economics driving oil and gas development, and these lead to a range of approaches to managing produced water resources. In addition, a widely held sentiment expressed by participants is that regulatory frameworks often do not provide flexibility for water use to enable operators to manage risk at scale. There were differing views among participants on whether the best solution is to develop gathering systems (apart from the Permian) and large-scale produced water treatment facilities (e.g., Antero Clearwater) or to pursue modular mobile treatment systems. In either case, energy requirements for water treatment also have to be considered in cases where wells are distant from the grid or natural gas lines. Currently, much of the infrastructure is dependent on trucks for delivery of produced water. A further complication is that the situation changes over time. For wells, the amount of water needed for hydraulic fracturing would be expected to decline just as the volume of produced water increases with the extraction of oil and gas. Participants also shared that contamination could drive reuse costs up. For example, dissolved radium, (i.e., naturally occurring radioactive material, NORM) is of concern for some uses. In addition, there are limited economical treatment options for high salinity brines, other than recycling for oilfield purposes. In addition to the costs, there are also public perception issues. Produced water is perceived to be contaminated with constituents posing health risks, and there can be a lack of trust that water will be treated to sufficient quality.

Future Aspects for 2050

- *Pinpoint co-location opportunities and dynamic water quantity and quality data of available water resources in real time, to optimize the movement of water and the right-size water investment.*
- *Build strong relationships with water users and contributors (e.g., potash mines, power industry, municipal effluent, cooling water).*
- *Enact laws that protect the environment yet encourage innovation.*
- *Share lessons learned from different regions.*

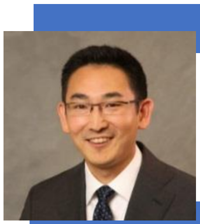
2.5 Water, Wastewater Treatment, and Recovery

The major focus of the attendees' discussion focused on inefficient, legacy infrastructure and its problems, the lack of continuous and affordable water quality monitoring, the lack of the industry's connection to renewable integration, governance issues, and public acceptance of water reuse.

Attendees discussed the challenges and balance between using centralized and decentralized water systems. With instances of high leak rates from pipes and high generation of non-revenue water in centralized systems, many argue that the high capital and maintenance cost is not conducive for the needs of certain communities that can benefit from distributed, fit-for-purpose treated water. Meanwhile, other areas, such as many of the sprawling communities in the western US, have an overwhelming number of systems, with little incentive to consolidate. Underprivileged communities are particularly harmed by less expensive decentralized systems that, although flexible in design, more often have water contamination issues than centralized systems do. The challenge is to better understand the optimal balance of centralized and decentralized systems that works best for different communities to foster innovation, ensure financial sustainability, and protect public health and the environment.

Specific technical challenges in the wastewater sector include rapid screening for contaminants at low concentrations and selective removal of these components, which often comes at a high energy cost. A number of technological contenders to screen contaminants can meet effluent quality parameters of total suspended solids, including biological treatment, phase-changing methods, and advanced oxidation technologies. However, these standard techniques have limited effectiveness with chemicals of emerging, persistent emerging, or persistent concern. Hence, attendees stressed the need for more research into the dynamics of these contaminants in the water system, as some advanced water treatments that do address these contaminants (e.g. reverse osmosis, ion exchange, etc.) require high capital and operational costs and can generate a new problem of managing waste concentrates.

Then there is the outdated energy, carbon, and solids management infrastructure for wastewater recovery systems, which expends a high economic and environmental cost to transport biosolids to their next treatment destination. Recovering the energy from biosolids can be done by thermal conversion, hydrolysis, pyrolysis, and gasification, but more efficient methods of drying biosolids or technologies that can utilize wet solids all need additional research to become



ALBERT CHO
XYLEM, INC.

Chief Strategy and Digital Officer at Xylem, Albert Cho, provided a digital technology vision for water systems.

Major developments in the water sector have learned from the past and applied lessons to the present—for the future. Germ theory and the first chlorination of water in the 1900s led to the elimination of typhoid fever in about 30 years, a feat enabled by technology and knowledge. In the 1930s and ‘40s, industrial-scale pollution incited technological and regulatory changes into the 1960s and ‘70s, with the introduction of the first commercial dissolved oxygen meter and the Clean Water Act. Likewise, this 30 year trend continues, with decreasing cost and rapid advances in computing posing an opportunity for digital technology to play a role in water’s resilient renewal by 2050.

Digital technology can address one of water’s biggest and costliest issues today: uncertainty. The city of South Bend, Indiana, serves as an example of leveraging the power of data. To combat their wet region’s challenge of uncertainty with their combined sewer outfalls, South Bend invested in a distributed sensory network and used artificial intelligence/machine learning and hydraulic models to build a digital twin that identified the location of sewage in a number of scenarios. This allowed for controlled movement and management of water, cutting overflow volumes by almost 70% and potentially saving the city $500 million.

By 2050, digital technology can make water infrastructure more sustainable, resilient, and equitable. Alongside diversification, it can help secure the U.S. water portfolio against water supply variability while improving customer confidence, arming them with relevant information and real-time recommendations. This digital vision could be a watershed moment.

viable. Testbed validation of innovative concepts is needed, as well as effective tech transfer mechanisms to address needs of utilities ranging from large cities to agricultural regions. State and federally incentivized operator and maintenance training to effectively implement these new technology innovations with a ready workforce could be transformative.

Attendees pointed out that regulatory, legal, and authority issues become barriers to pricing water at cost and prevent innovation in this sector, as the low valuation of water makes new and emerging technologies difficult to be cost competitive before reaching economies of scale. Regulations for water reuse and recycling are not necessarily aligned with technology solutions, and some emerging technology solutions are in preliminary stages that have yet to be tested and validated at larger scales. Attendees described how state and local governments have water regulations and laws in place that need to be carefully considered at the local level for water infrastructure improvements. In the Southwestern US, and California in particular, disputes over land-use and water rights over limited supply continue to hamper improvements in the agriculture and residential sectors alike. An attendee stated that even older laws such as California's Proposition 218[3], can potentially result in disproportionate rates on things like retail water if cities and utilities are unable to make sufficient revenue from taxes to fund for these infrastructure investments. Continual additions of federal and state legislation that affect the all aspects of water make it difficult to coordinate infrastructure planning and construction to benefit stakeholders.

Finally, there can also be misconceptions from the general public, leading to concepts like potable water reuse not being publicly accepted as protective of public health when properly implemented. This dearth of transparency and education about the quality and quantity of water resources available leads to the general public's lack of knowledge of where their water comes from, its true cost, and issues that they and the infrastructure face.

Future Aspects for 2050

- *Employ advanced, large-scale validated technology that integrates water reuse, energy recovery (i.e., heat harvesting), and carbon management—a triple climate-relevant bottom line.*
- *Transform the sector digitally through tools that can monitor systems in real time (i.e., low-cost sensors with on-board diagnostics) and provide analysis of data that is interoperable, transparent, and accessible.*
- *Campaign on water quality and quantity publicly to help communities embrace "one water" which can lead to eliminating the barriers to pricing water at its cost.*

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[3] Proposition 218, also cited as the "Right to Vote on Taxes Act," constrains the local governments' ability to raise property tax; it is intended to provide effective tax relief and to require voter approval of tax increases. Legislative Analyst's Office. 1996.

3 Innovation Ecosystem

On Day 2 of the Summit, meeting participants selected the top aspects of the future of water infrastructure generated in Day 1 to describe a future of water infrastructure that the group was collectively envisioning. Several themes resonated across breakout rooms. Participants envisioned "One Water," where drinking water, wastewater, and stormwater are treated as an integrated system. The water system would capitalize on advanced technologies that integrate water reuse, energy recovery, and carbon management—delivering a triple (and climate-relevant) bottom line to utilities and communities. Part of that picture was infrastructure financing supporting water resilience and security, as well as the pricing of water across infrastructure at its true cost. Some groups' visions embraced other aspects, including technology modularization, advanced sensing, and adaptive water management.

Participants were asked to rate and discuss the top curated crosscutting topics that would have a large impact on the water infrastructure innovation ecosystem. The prompt was to identify non-technology solutions that would support water innovation in the water industry. Those discussions are summarized here and organized into three topical areas: regional water planning, technology commercialization and scale-up, and workforce development.

3.1 Regional Water Planning

The American Society of Civil Engineers reported that over 1.3 trillion USD in investment is needed in the drinking water and wastewater sectors to address and upgrade the aging U.S. water infrastructure. Rather than just replacing the current infrastructure, regional water planning activities can use infrastructure investments to advance its current state by accommodating new, adaptive, and innovative technologies and operational practices. These could include issues such as flexible pumping schedules, drinking water, wastewater, and recycled water conveyance infrastructure, and building-integrated treatment technologies. Across all sessions on the innovation ecosystem, four major water planning themes emerged: (1) coordination on policy, implementation, and enforcement across relevant stakeholders; (2) leveraging the role of regulations; (3) breaking down financial barriers; and (4) improving information sharing. These are summarized here.

At all geographic levels, there are shared interests across agencies with respect to water infrastructure. These include protecting public health and the environment, providing consistency and repeatability of technology solutions across locations and regions, ensuring water and food security, enabling recreational activities (e.g., water sports, fishing), and supporting regional economies. Coordination on policy making, implementation, and enforcement across levels of government and infrastructure actors is needed to ensure new technologies and operational practices do not inhibit these interests. However, the relevant government agencies and actors are often working in silos, creating barriers to the success of any innovation ecosystem. In general, the roles of federal and state agencies were described as a "patchwork" system for ensuring adequate water supplies. This patchwork system sometimes leads to misalignment of actions intended to support shared goals. Relevant agencies cited by attendees included the EPA, other state and national regulators, and the Public Utility Commissions. Relevant infrastructure actors cited by attendees included dam, hydropower system, and electric grid operators, as well as water and energy utilities.

Federal and state regulators are charged with ensuring delivery of water resources, management services, and enforcement of water quality requirements. They are spurred to action by regional agencies when creating regulations. Attendees indicated that regional agencies can react reflexively to topics that their constituents raise. Further, regional regulatory bodies develop regulations faster than national bodies, creating a potential barrier for technologies to be applicable at a national scale.

Once regulations are established, enforcement is generally the responsibility of state and federal agencies while implementation is the responsibility of utilities. The implication is that the division of policy, enforcement, and implementation responsibilities creates bureaucratic barriers and inconsistencies. Further, stakeholders outside of the regulatory process can be left out of the process because council/government meetings are often during the day. Unless they secure an advocacy group to work on their behalf, their needs may not be voiced. Attendees noted that engagement from these outside stakeholders in the coordination process is “essential.”

Attendees offered some ideas for improving the patchwork system through better coordination of state/regional and national regulations. Also, they recommended that governments provide increased clarity in direction across all stakeholders by establishing and maintaining long-term goals with short-term milestones aimed to bring the innovation ecosystem to its desired status. Attendees proposed targeting funding for regional collaborative projects to incentivize stakeholder collaboration.

Attendees also identified changes to the regulatory climate that could support the innovation ecosystem. With its sole focus on compliance with permits, attendees noted that existing regulatory frameworks can act as a hinderance on technological and process innovation rather than an accelerant. Additionally, regulations can be a barrier to accessing capital, as most

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National Council for Science and the Environment (NCSE)

On top of extreme weather events that stress an already outdated water system, more than 2 million Americans lack regular access to safe drinking water according to the *US Water Alliance*. The need for innovation in water infrastructure is severe. Executive Director Michelle Wyman highlighted different transformative strategies and funding that address both local interim crises as well as long-term systemic problems in water.

One such project in Sonoma County, California, is the *Advanced Quantitative Precipitation Information* (AQPI) system, a collaboration of county and water agency engineers and academic scientists from Sonoma State University, University of California at San Diego, and Colorado State University, as well as the federal agency NOAA. The tool increases the ability to anticipate rainfall and flooding in real time, thereby elucidating rainfall patterns and surges to mitigate impacts. What this project reveals is that by leveraging the strengths from across industry, government, and particularly academia, truly effective and coordinated solutions can emerge.

Project *IOM WASH* provides another example of a simple, scaled innovation: a sun-powered borehole provides clean, continuous water for 60,000 Nigerian residents. Supported by the Nigeria Humanitarian Fund, the Republic of Korea’s Ministry of Foreign Affairs, USAID, and Sida, this effort proves cross-collaboration not only serves local communities but also fuels the global vision of the United Nation’s sustainable development goals.

The innovation ecosystem for water by 2050 can look a lot like AQPI and IOM WASH: diverse and impactful. Engaging multilevel relationships can transform today’s old infrastructure into tomorrow’s sustainable solutions.

financial institutions want to finance technologies that have been proven to be safe and effective. However, attendees highlighted that regulations could create a necessity for technology innovation and help ensure access to the industry by new entrants. Regulations can expedite technology development by “creating a need,” and a lack of regulation in a space can delay private investment with no other incentives in place. For example, requirements for organics diversion from landfills are driving change in this area. The attendees provided ideas for changes to the regulatory structure to better promote technology innovation, such as standardization of regulations (e.g., discharge limits) and practices. Attendees noted that regulatory structures need to provide flexibility to allow for innovative technologies (e.g., establishing performance-based outcomes rather than prescriptive approaches). For example, a reexamination of restrictions on organic agriculture as it relates to applying biosolids could support enhanced resource recovery of wastewater. Depending on the state and local regulations, recycled water can be applied to various crops for irrigation. Attendees indicated that biosolids cannot. Regulatory flexibility could be expanded to allow for the makeup of biosolids to be considered before outright disallowing their use on crops. Testing would be needed to allow for innovation while still meeting permit restrictions. To this end, testing and validation of emerging technologies could unlock capital (see the section on information sharing below). Insofar as regulations can drive innovations, the budget process is an important driver that is not highlighted as frequently as the rulemaking process. Federal budget allocations can impair or significantly accelerate regulatory processes.

Financial barriers, including lack of public funding, misaligned rate structures, lack of financial incentives, and myopic business models were identified as inhibiting the innovation ecosystem. Once needed infrastructure improvements are identified and prioritized, funding programs and public-private-partnerships are needed to finance infrastructure improvements and upgrades. A potential path to secure funding is to update pricing and rate structures through the Public Utility Commissions. For example, incorporating a price on carbon would help finance projects that result in carbon savings. There will need to be some balance between raising water rates to finance these projects and the public benefits accrued from the upgrades. Careful design of these programs is needed to ensure equitable access to water and not unfairly burden ratepayers; attendees noted that utilities are interested in minimizing rates for their customers. To gain support for raising rates, buy-in from the public to fund water infrastructure projects is needed. To this end, a greater connection needs to be made between the third-party benefits of infrastructure spending (e.g., employment, skills development) and the public good, and these benefits need to be communicated to the public. Beyond raising rates, federal and regional funds will be needed to leverage and secure greater financing levels. To this end, working with partners, communities (e.g., National Institutes for Water Resources) and policymakers to identify or initiate federal programs could accelerate the innovation process. An increase in public-private partnerships could also lead to increased financing, but a barrier to these partnerships is misalignment in fiscal outlooks; public entities have a longer outlook than private companies, which tend to have shorter outlooks. Government funds could be used to address this misalignment by encouraging the private sector participation in these projects.

Outside of public funding, the business model for delivering water resources is key to transforming the water sector and advancing innovation. Understanding and incorporating compensation for beneficial actions would allow for optimal water management. For example, resource recovery, such as capturing nutrients from agricultural operations, benefits downstream users. Realignment of cost and benefits sharing schemes could accelerate resource recovery. Infrastructure upgrades could be promoted by subsidies, such as rebates for conservation and reuse and appreciation/monetization of larger scale benefits. If such subsidies were implemented, technologies that enable system level benefits (e.g., water, energy, land use, environment) would be more likely to be adopted.

A key to supporting the innovation ecosystem, as identified by attendees, is improved information sharing. A first step towards addressing this need is to identify or develop a platform to share information. A range of information could be shared, such as a compilation of risk frameworks, best practices, and clear information about future conditions (regionally and more broadly). To this end, resources and tools are needed to evaluate the possible range of regional water supply and demand conditions. Additionally, sharing results of testing and validation of new and emerging technologies under field conditions at different scales (small versus large demonstrations) would help de-risk adoption of the technology by others. In a similar vein, encouraging multidisciplinary collaborations (e.g., between the Department of Defense and NASA) and bringing advanced technologies (e.g., nano-sensors and 3D origami photothermal materials for water purification) and research to water infrastructure applications would also drive the adoption of new and emerging technologies. However, data concerns could hinder information sharing. There may be resistance to gathering data when stakeholders may not understand the data's significance. Further, due to cybersecurity concerns, stakeholders may not want to open data channels to the internet. Efforts to help industry view data sharing as a positive instead of a negative would support utilization of data sensing and information sharing.

3.2 Technology Commercialization and Scale-up

Access to programs that enable technology commercialization and scale-up was identified as an innovation ecosystem need during both days of the workshop. There is a need to expand testbeds to validate technology and incubators to support/accelerate commercialization of technology. These can lower the risk proposition of adopting new technologies and overcome the "valley of death" phenomenon that prevents promising technologies from commercialization. There are currently some programs that address this need (e.g., LIFT,[4] BREW,[5] Isle Utilities) but they are

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[4] The Leaders Innovation Forum for Technology (LIFT) is an initiative of the Water Research Foundation and the Water Environment Federation.

[5] The Business, Research and Entrepreneurship in Water (BREW or BREW 2.0) is an initiative of the Water Council that helps water technology startups grow.

limited in scope and regionality. These technology testbeds can often allow novel technologies to be tested with potential clients, but design of the program needs to include commercialization paths or funding arrangements to prevent continued federal investment over the life or technologies. Also, there is a need for a pipeline of technologies from academia and national labs into the water industry. Matching technology demonstration and pilots with interested industry parties would help prove the feasibility of these new technologies and foster industry involvement in their development. As noted above, technology vendors and partners need to work with regulators to ensure that pilots can meet regulations while still allowing for innovation. Fostering innovation in the water sector can be accomplished without compromising public health and safety.

An initial need identified by industry participants was to improve methods for reducing the risk of adopting new technologies ("no one in the water industry wants to be the first adopter"). These methods to reduce risk include improving validation methods, more transparent data sharing and access, methods for instilling confidence in new technology (e.g., information sharing, clearinghouses, innovation centers, third-party adoption) to ensure confidence. Technology vendors are often asked to fund their pilot/demonstration projects with no assurance that water users will buy their products. Ensuring that water utilities are interested in the technology and involved in the pilot/development process can reduce the risk of "wasted" money spent during a demonstration by ensuring a project pipeline and users for the technology exist. Including end users in the pilot process also allows technology vendors to be clear on the needs and requirements of their clients that will benefit the technology development process. Improvements to technology commercialization and scale-up will need buy-in from many different partners (regulatory, academic, utilities, technology vendors, technology incubators) and water industry groups, to ensure that a program is in place to encourage wide-scale technology innovation.

3.3 Workforce Development

As is true in other engineering industries, such as oil and gas and construction, there is a looming wave of retirements in the water industry, leading to a lack of people in the workforce pipeline with the relevant skills and background to perform the work. Also, the skillset needed for the water industry is evolving. For example, data analytics skills are needed to manage the increasing number of sensors. However, a data analytics background needs to be coupled with direct, real world water industry expertise and experience. As one participant noted: "sensors and systems fail, so the workforce needs to be able to manually operate systems." As participants noted, the culture of the water industry can be conservative in nature, due to prioritization of compliance with permit limits rather than innovation and operational improvements. Based on these trends, younger career staff who are interested in innovation and "changing" the water industry might be dissuaded from joining, depriving the water workforce of future visionaries and leaders.

Participants identified several crosscutting needs to assist with revitalization of the water industry workforce. First, reflecting the “true cost of water” could potentially raise salaries for workers in the water industry, to better compete with higher paying industries (e.g., oil and gas, chemical). Second, incorporating technology and data analytics into water operator training certifications would better prepare operators for new technologies, sensors, and subsequent data analytics. Finally, partnering with universities to create a curriculum that prepares future engineers and operators and provides in-plant experience would provide fresh graduates with real world experience. Some of these actions can be done within the water industry with partnerships, but there will be a need for policy decisions to reflect the true cost of water. These actions will reinforce the water industry and ensure that the workforce is trained to meet the industry’s future needs.

Appendix A. List of Registrants

List of Registrants*

First Name	Last Name	Organization Name	Organization Type
Khalid	Abedin	U.S. Department of Energy	Federal Government
Ezinne	Achinivu	Department of Energy - Advanced Manufacturing Office	Federal Government
William	Adams	Select Energy and Permian Basin Water Management Council	Industry
Joshua	Adler	Sourcewater, Inc.	Industry
Vee	Adrounie	KnowledgeOps	Industry
Janita	Aguirre	EPA Office of Water	Federal Government
Cristina	Ahmadpour	Isle Utilities	Industry
Habeeb	Alasadi	University of Dayton	Other
Feridun	Albayrak	BCS, LLC	Other
John	Albert	The Water Research Foundation	Non-Governmental (NGO)
Seema	Alim	USAID	Federal Government
David	Alleman	U.S. Department of Energy	Federal Government
Brent	Alspach	Arcadis	Industry
Sean	Amini	University of Alabama	Academia
Kristen	Atha	AECOM	Industry
David	Ayers	Xylem	Industry
Hunter	Ball	N/A	Other
Tim	Bartholomew	National Energy Technology Laboratory	National Lab
Sonya	Baskerville	Bonneville Power Administration	Industry
Diana	Bauer	DOE EERE	Federal Government

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* The authors of this report are not responsible for the accuracy of the information contained in the list of registrants. The information shown may be incorrect and/or incomplete due to human and/or machine error (e.g., spelling mistakes).

Kelly	Bennett	B3 Insight	Industry
Robert	Bergeron	Cawley Gillespie & Assoc.	Other
Asfaw	Beyene	San Diego State University, Industrial Assessment Center	Academia
Mukul	Bhatia	Texas A&M University	Academia
Theodora	Bird Bear	none	Other
Tad	Bohannon	Central Arkansas Water	Local Government
Sidney "Bill	Boyk	Ameristar Solar, LLC	Other
Kate	Brauman	DoD - OSD A&S Environment	Federal Government
Katie	Brodersen	National Renewable Energy Laboratory	National Lab
Morgan	Brown	Water Environment Federation	Non-Governmental (NGO)
Randy	Brown	City of Pompano Beach Utilities	Local Government
Dustin	Brownlow	Antelope Water Management	Investor
James	Bruner	ORAU	Other
Scott	Bryan	Imagine H2O	Non-Governmental (NGO)
William	Buchsbaum	CryoDesalination LLC	Industry
Dennis	Cakert	The National Hydropower Association	Industry
Bond	Calloway	University of South Carolina	Academia
Joaquin	Camacho	San Diego State University	Academia
Laura	Capper	EnergyMakers Advisory Group	Industry
Cristian	Cardenas-Lailhacar	University of Florida	Academia
Keeli	Carlton	Winter Haven	Local Government
David	Cercone	DOE NETL	National Lab

Kate	Ceste	National Council for Science and the Environment	Non-Governmental (NGO)
Chuck	Chaitovitz	U.S. Chamber	Industry
Harold	Chase	NSF International	Non-Governmental (NGO)
Jie	Chen	IAC	Academia
Junhong	Chen	Argonne National Laboratory	National Lab
Albert	Cho	Xylem	Other
Jun-Ki	Choi	University of Dayton	Academia
Youngchul	Choi	Saudi Aramco	Industry
Ami	Cobb	EPA	Federal Government
Gabriel	Collins	Baker Institute for Public Policy	Academia
Donald	Colliver	KY Industrial Assessment Center, Univ of KY	Academia
Peter	Colohan	Internet of Water, Duke University	Academia
James	Constantz	Startup company	Industry
Theodore	Cooke	Central Arizona Project	Local Government
Brett	Creeser	Guidon Energy	Industry
Brian	Currier	OWP at Sacramento State	Academia
Nicole	Darby	California Department of Water Resources	State Government
Edward	Davis	Pegasus Group	Industry
Joseph	deAlmeida	Occidental Petroleum	Industry
Blake	Deeley	WH	Federal Government
Justin	Deeley	Restaurant association	Non-Governmental (NGO)
Scott	DeNeale	Oak Ridge National Laboratory	National Lab
Myles	DeRouen	DeRouen Designs	Other

Ashwin	Dhanasekar	The Water Research Foundation	Non-Governmental (NGO)
Mary Ann	Dickinson	Alliance for Water Efficiency	Non-Governmental (NGO)
Elizabeth	Do	EPA	Federal Government
Natenna	Dobson	U.S. Department of Energy	Federal Government
David	Drake	Cinco Municipal Utility District 7	Local Government
Markus	Drouven	DOE-NETL	Federal Government
Patrick	Dube	Water Environment Federation	Non-Governmental (NGO)
John	Durand	XRI Holdings, LLC	Industry
Steve	Dye	Water Environment Federation	Non-Governmental (NGO)
Laura	Ehlers	National Academies of Sciences, Engineering and Medicine	Non-Governmental (NGO)
Elizabeth	Eide	National Academies of Sciences, Engineering, and Medicine	Non-Governmental (NGO)
Leroy	Ellinghouse	Department of Water Resources	State Government
Angelica	Errigo	University of Dayton	Academia
Anna	Evans	NREL	National Lab
John	Fazio	NW Power and Conservation Council	State Government
Adriana	Felix-Salgado	U.S. Environmental Protection Agency	Federal Government
Christobel	Ferguson	The Water Research Foundation	Other
Tom	Ferguson	Burnt Island Ventures	Investor
Aaron	Fisher	Water Research Foundation	Non-Governmental (NGO)
Peter	Fiske	Lawrence Berkeley National Laboratory	National Lab

Patrick	Fitzgerald	LBNL	National Lab
Lisa	Flores	Valley Water	Local Government
Greg	Fogel	WateReuse Association	Non-Governmental (NGO)
Marina	Foster	Crystal Clearwater Resources, LLC	Other
Christian	Fredericks	California Energy Commission	State Government
Vivian	Fuhrman	Princeton University's Andlinger Center for Energy and the Environment	Academia
Aliza	Furneaux	WateReuse Association	Non-Governmental (NGO)
William	Gaieck	Department of Energy	Federal Government
Carlos Alberto	Garay	Dianohia Academy College	Academia
Susana	Garcia	ORNL	National Lab
Roger	George	Exterran	Industry
Samuel	Ghormley	University of Nebraska-Lincoln Industrial Assessment Center	Academia
Daniel	Gingerich	The Ohio State University	Academia
Neil	Glasgow	Solaris Cybernetics	Investor
Erica	Goldman	National Council for Science and the Environment	Non-Governmental (NGO)
Marcos	Gonzales Harsha	U.S. Department of Energy	Federal Government
Sharon	Green	Los Angeles County Sanitation Districts	Local Government
Mike	Gremillion	University of Alabama	Academia
Ann	Grimm	US EPA	Federal Government
James	Griswold	New Mexico Oil Conservation Division	State Government
Tara	Gross	Ground Water Protection Council	Non-Governmental (NGO)
Jeff	Guild	BlueTech Research	Industry

Delicia	Gunn	Indigo Engineered	Industry
Hugo	Gutierrez	Marathon Oil	Industry
Alison	Hahn	Department of Energy	Federal Government
Brent	Halldorson	RedOx Systems	Industry
Mark	Handzel	Xylem Inc.	Industry
Katherine	Harsanyi	DOE	Federal Government
Lisa	Henthorne	Water Standard and Produced Water Society	Industry
Elkin	Hernandez	DC Water	Industry
Max	Herzog	Cleveland Water Alliance	Non-Governmental (NGO)
Nick	Hines	Oilfield Water Logistics	Industry
Margi	Hoffmann	Farmers Conservation Alliance	Non-Governmental (NGO)
Tim	Hogan	TWB Environmental Research and Consulting, Inc.	Other
Juliet	Homer	Pacific Northwest National Laboratory	National Lab
Nathan	Howell	West Texas A&M University	Academia
Naomi	Huff	EPA	Federal Government
Sara	Hughes	University of Michigan	Academia
Zoe	Huo	NREL	National Lab
Tsisilile	Igogo	National Renewable Energy Lab	National Lab
Karr	Ingham	Texas Alliance of Energy Producers	Other
Michael	Ingram	NREL	National Lab
Emily	Isaacs	PG Environmental	Other
Kevin	Jayne	Gov	Federal Government
Kathryn	Jackson	DOE	Federal Government

Megan	Jennings	Energy Conservation Works	Other
Kristen	Johnson	Coachella Valley Water District	Other
Nick	Karki	Lawrence Berkeley National Laboratory	National Lab
Kevin	Kasprzak	PERENfra	Industry
Donald	Keer	Altair Equipment Company, Inc.	Industry
Paula	Kehoe	Utility	Local Government
Rozella	Kennedy	Elemental Excelerator	Non-Governmental (NGO)
salil	Kharkar	dc water	Local Government
Todd	Kirk	Exterran	Industry
Fredrik	Klaveness	NLB Water LLC	Industry
Melissa	Klembara	US DOE	Federal Government
Xiangjie	Kong	Xylem	Industry
Kenneth	Kort	Department of Energy	Federal Government
Brian	Kuh	WPX Energy	Industry
Peter	Lake	Texas Water Development Board	State Government
Stephanie	Lavey	AlexRenew	Local Government
Kimberly	Lawrence	Jacobs	Industry
Mark	Layne	Ground Water Protection Council	Non-Governmental (NGO)
William	Lear	University of Florida	Academia
Chris	Leauber	Water & Wastewater Authority of Wilson County, Tennessee	Local Government
Douglas	Lee	Suez	Industry
Casee	Lemons	Sourcewater, Inc.	Industry
Eli	Levine	US DOE	Federal Government

Yu-Feng	Lin	Illinois Water Resources Center, University of Illinois at Urbana-Champaign	Academia
Barry	Liner	Water Environment Federation	Non-Governmental (NGO)
Jeff	Lopes	Xylem Inc.	Industry
Justin	Love	Blackbuck Resources	Industry
Cissy	Ma	764	Federal Government
Ramzi	Mahmood	California State University, Sacrament - Office of Water Programs	Academia
Felicia	Marcus	Stanford University	Academia
Rudolf	Marloth	SDSU iac	Academia
Stephen	Martin	Virginia Tech	Academia
Justin	Mattingly	U.S. EPA	Federal Government
Meagan	Mauter	Stanford University	Academia
James	McCall	National Renewable Energy Laboratory	National Lab
Jane	McClintock	Smart Energy Design Assistance Center	Academia
Casey	McKinne	CCR	Industry
Elena	Melchert	U.S. Department of Energy / Office of Fossil Energy	Federal Government
Ariel	Miara	NREL	National Lab
Rick	Miller	HDR Engineering	Industry
Julie	Minerva	Carpi & Clay	Industry
Julie	Minton	WRF	Non-Governmental (NGO)
Patrick	Mirick	Pacific NW National Lab	National Lab
Siddharth	Misra	Texas A&M	Academia
Jason	Modglin	Texas Alliance of Energy Producers	Non-Governmental (NGO)

Jeff	Mosher	Carollo Engineers	Industry
Thomas	Mosier	Idaho National Laboratory	National Lab
Michael	Muller	Rutgers University	Academia
Collin	Mummert	PG Environmental	Other
Mirko	Musa	Oak Ridge National Laboratory	National Lab
Mary	Musick	Ground Water Protection Council	Non-Governmental (NGO)
Pamala	Myers	U.S. EPA Region 4	Federal Government
Sharon	Nappier	US EPA	Federal Government
Marvin	Nash	Encore Green Environmental	Other
Colleen	Newman	DOE contractor	Federal Government
Tremayne	Nez	Avid Core	Other
Sachin	Nimbalkar	Oak Ridge National Laboratory	National Lab
Neil	Nowak	SCS Engineers	Industry
Amy	Ochello	PERENfra	Industry
Julie	O'Shea	FCA	Non-Governmental (NGO)
Kyra	Ozuna	ANUZO PRODUCTIONS	Other
Clayton	Palmer	WAPA	Federal Government
Mike	Paque	Ground Water Protection Council	Non-Governmental (NGO)
Nicole	Pasch	Xylem Inc.	Industry
Krushna	Patil	Oklahoma State University	Academia
Mark	Patton	Hydrozonix	Industry
Ashley	Pennington	FEMP	Federal Government
Catherine	Pennington	The MITRE Corporation	National Lab
Amy	Peterson	City of Surprise Water Resource Management	Local Government

Ryan	Pfingst	B. Riley Securities, Inc.	Investor
Tuan Anh	Pham	Lawrence Livermore National Laboratory	National Lab
Mark	Philbrick	DOE	Federal Government
Stephen	Picou	Louisiana Water Economy Network	Non-Governmental (NGO)
Dirk	Plante	HDIAC	Other
Yuliana	Porras Mendoza	Bureau of Reclamation	Federal Government
Rajiv	Prasad	Pacific Northwest National Laboratory	National Lab
Daniel	Pugliese	DOE LPO	Federal Government
Joanna	Quiah	North Carolina State University	Academia
Francisco	Ragonese	Ragonese Holdings LLC	Industry
Heather	Ramamurthy	Central Contra Costa Sanitary District	Local Government
Jaime	Ramos	UTRGV	Academia
Prakash	Rao	Lawrence Berkeley National Laboratory	National Lab
Rebbie	Rash	none	Other
Ali	Razban	IAC-IUPUI	Academia
Tara	Rejino	Texas Water Development Board	State Government
Jason	Ren	Princeton University	Academia
Fisher	Reynolds	Office of the Governor of Texas	State Government
Scott	Richards	MISWACO Schlumberger	Industry
Matthew	Richardson	US EPA	Federal Government
Mike	Rinker	DOE EERE AMO and WPTO - on assignment from PNNL	National Lab
John	Robitaille	Water Reuse	Industry
Dennis	Rodarte	Aguadulce Environmental	Industry

Rebecca	Roose	NMED	State Government
Eric	Rosenblum	Eric Rosenblum PE Water Resource Consultant	Industry
Eric	Rosenfeldt	World Fuel Services	Industry
I. Holly	Rosenthal	Phoenix Water Services	Local Government
Cathy	Ross	None	Non-Governmental (NGO)
Dave	Ross	EPA Office of Water	Federal Government
Kirk	Rostron	Mt. Vernon Partners	Investor
Zlatko	Rozic	Owner	Non-Governmental (NGO)
Zachary	Sadow	Antelope Water Management	Industry
Adrienne	Sandoval	NM Oil Conservation Division	State Government
Marc	Santos	Isle Utilities	Industry
Sami	Sarrouh	Premier Engineering Technologies	Other
Colin	Sasthav	Oak Ridge National Laboratory	National Lab
Matthias	Sayer	NGL	Industry
Bridget	Scanlon	Univ. of Texas at Austin, Bureau of Economic Geology, Jackson School of Geosciences	Academia
John	Schmidt	Utah State University	Academia
Bob	Schmitt	US DOE/EERE	Federal Government
Gia	Schneider	Natel Energy	Industry
Andrew	Schrader	University of Dayton	Academia
Madden	Sciubba	WPTO	Federal Government
Gregg	Semler	InPipe Energy	Industry
Youngwoo (Young)	Seo	University of Toledo	Academia

Linda	Severs	ORAU	Other
Lea	Shanley	University of Wisconsin-Madison	Academia
Charlie	Sharpless	Andlinger Center for Energy and the Environment, Princeton University	Academia
S.A.	Sherif	University of Florida	Academia
Jonathan	Shi	Louisiana State University	Academia
Vanessa	Shoenfelt	DOE - LPO	Federal Government
Dev	Shrestha	University of Idaho	Academia
Avi	Shultz	DOE - Solar	Federal Government
Daniel	Simmons	U.S. Department of Energy	Federal Government
A.J.	Simon	Lawrence Livermore National Lab	National Lab
Patricia	Sinicropi	WateReuse Association	Non-Governmental (NGO)
John	Smegal	DOE	Federal Government
Brennan	Smith	Oak Ridge National Lab	National Lab
David	Smith	US EPA Region 9	Federal Government
Karen	Smith	Pacific Northwest National Laboratory	National Lab
Seth	Snyder	Idaho National Laboratory	National Lab
Parisa	Soleimanifar	EPA	Federal Government
Shannon	Spurlock	Ochotona LLC	Other
mathini	Sreetharan	Dewberry	Industry
Eva	Steinle-Darling	Carollo Engineers, Inc.	Other
bill	Stevens	Panhandle Producers and Royalty Owners Association	State Government
Mae	Stevens	Signal Group	Other
Jennifer	Stokes-Draut	Lawrence Berkeley National Laboratory	National Lab

Drew	Story	USGCRP	Federal Government
Heather	Strathearn	ORISE for US EPA	Other
Jayne	Strommer	Delta Diablo	Local Government
Chinmayee	Subban	PNNL	National Lab
Svetlana	Taylor	Current Innovation NFP	Non-Governmental (NGO)
Vincent	Tidwell	Sandia National Laboratories	National Lab
Maria Narine	Torres Cajiao	University at Buffalo	Academia
Mai	Tran	DOE-EERE-AMO	Federal Government
Marisa	Tricas	City of Roseville	Local Government
Bill	Turrentine	NLB Water	Industry
Erik	Tynes	Energy Recovery, Inc	Industry
LouAnn	Unger	EPA Region	Federal Government
Kirsten	Verclas	NASEO	Non-Governmental (NGO)
Brenda	Vitisia	NCSE	Other
Ryan	Vogel	Pure Blue Tech	Industry
Hitesh	Vora	Oklahoma State University	Academia
Jonathan	Vorheis	AWWA Water Reuse Committee	Industry
Matt	Walls	BKR	Industry
Sheree	Watson	USGS	Federal Government
W	Weaver	PNNL	National Lab
Timothy	Welch	DOE/WPTO/Hydropower	Federal Government
Briggs	White	DOE	Federal Government
Janice	Whitney	EPA	Federal Government
Mark	Wigmosta	DOE PNNL	Federal Government
Mel	Wil	ORAU	Industry
Melissa	Williford	ORAU	Other

Aaron	Wilson	Idaho National Laboratory	National Lab
Shayla	Woodhouse	Biohabitats, Inc.	Industry
Eric	Wooten	Occidental Oil & Gas	Industry
Kimberly	Wurtz	Dennis & Wurtz PLLC	Other
Michelle	Wyman	National Council for Science and the Environment	Non-Governmental (NGO)
Nick	Wynn	IProTech	Industry
Zheng	Yao	Lehigh University	Academia
Dan	Yates	www.gwpc.org	Non-Governmental (NGO)
Ngai Yin	Yip	Columbia University	Academia
Beckie	Zisser	Santa Clara Valley Water District	Local Government

Appendix B. Summit Agenda

Summit Agenda

The Future of Water Infrastructure and Innovation Summit

Tuesday, October 27, 2020, 12:30 PM – 5:00 PM Eastern
Wednesday, October 28, 2020, 1:00 PM – 5:00 PM Eastern

Tuesday – October 27, 2020 (DAY 1)

12:30 – 12:40 PM	**Welcome**
12:40 – 1:00 PM	**Plenary Session** *Moderator*: • **Blake Deeley** – Office of American Innovation (OAI) *Panelists*: • **Mary Neumayr** – Chair of the Council on Environmental Quality (CEQ) • **Kelvin Droegemeier** – Director of the Office of Science and Technology Policy (OSTP)
1:00 – 1:30 PM	**Plenary Session** *Moderator*: • **Daniel R Simmons** – Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy (DOE) *Water Subcabinet:* • **Tim Petty** – Assistant Secretary for Water & Science, U.S. Department of Interior (DOI) • **David Ross –** Assistant Administrator for Water, Environmental • Protection Agency (EPA) • **RDML Timothy Gallaudet** – Deputy Administrator, National Oceanic and Atmospheric Administration (NOAA) • **Bette Brand** – Deputy Under Secretary for Rural Development, United States Department of Agriculture (USDA)
1:40 – 2:10 PM	**A Vision for Water Infrastructure** • **Albert Cho**, Vice President and General Manager for Advanced Infrastructure Analytics, Xylem Inc.
2:10 – 2:20 PM	**Coffee Break**
2:20 – 3:50 PM	**Breakout Session 1 – Innovation in Physical Infrastructure**

Desalination

- **Avi Shultz**, U.S. Department of Energy (DOE)
- **Melissa Klembara**, U.S. Department of Energy (DOE)

Water & Wastewater Treatment and Recovery

- **Mark Philbrick**, U.S. Department of Energy (DOE)
- **Adriana Felix-Salgado**, Environmental Protection Agency (EPA)

Produced Water

- **Elena Melchert**, U.S. Department of Energy (DOE)

Hydropower, Conveyance, Water Systems

- **Thomas Mosier**, Idaho National Laboratory (INL)
- **Juliet Homer**, Pacific Northwest National Laboratory (PNNL)

Industrial Management of Water

- **Prakash Rao**, Lawrence Berkeley National Laboratory (LBNL)

3:50 – 4:00 PM **Coffee Break**

4:00 – 5:00 pm **Report Outs and Discussion**

Wednesday – October 28, 2020 (DAY 2)

1:00 – 1:10 PM **Welcome**

1:10 – 1:40 PM **A Vision for Water Infrastructure**

- **Michelle Wyman** – Executive Director of the National Council for Science and the Environment (NCSE)

1:40 – 1:45 PM **Break**

1:45 – 3:15 PM **Breakout Session 2 – Innovation and Cross-cutting Topics**

Topics covered include, but are not limited to: regional water management; regulations; business models; tech- transfer; workforce development; and community engagement.

Room 1

- **Justin Mattingly**, Environmental Protection Agency (EPA)

Room 2

- **Katherine Harsanyi**, U.S. Department of Energy (DOE)

Room 3

- **Eli Levine**, U.S. Department of Energy (DOE)
- **John Smegal**, U.S. Department of Energy (DOE)

Room 4

- **Kathryn Jackson**, U.S. Department of Energy (DOE)

Room 5

- **James McCall**, National Renewable Energy Lab (NREL)

3:15 – 3:25 PM **Coffee Break**

3:25 – 4:35 PM **Report Outs and Discussion**

4:35 – 5:00 PM **Next Steps and Closing Remarks**

- **Diana Bauer**, U.S. Department of Energy (DOE)

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