ENSURING WATER QUALITY: INNOVATING ON THE CLEAN WATER & SAFE DRINKING WATER ACTS FOR THE 21ST CENTURY

A REPORT FROM THE 2019 ASPEN-NICHOLAS WATER FORUM

Duke
NICHOLAS INSTITUTE
FOR ENVIRONMENTAL POLICY SOLUTIONS

THE ASPEN INSTITUTE
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ENSURING WATER QUALITY: INNOVATING ON THE CLEAN WATER AND SAFE DRINKING WATER ACTS FOR THE 21ST CENTURY - A REPORT FROM THE 2019 ASPEN-NICHOLAS WATER FORUM. 2019. Lauren Patterson, senior policy associate, the Nicholas Institute for Environmental Policy Solutions at Duke University; Martin Doyle, director of the Water Policy Program, the Nicholas Institute for Environmental Policy Solutions at Duke University; and Greg Gershuny, Executive Director, Energy & Environment Program, The Aspen Institute.

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The 2019 Aspen-Nicholas Water Forum is the eighth water forum in the Aspen Institute and Nicholas Institute partnership. The first, in 2005, on water, sanitation, and hygiene in the developing world, produced A Silent Tsunami, which made a material contribution in advancing priorities in U.S. foreign assistance for basic water services. The report ultimately helped spur passage of the Paul Simon Water for the Poor Act. The third forum, in 2015, on water and big data, catalyzed a dialogue series that led to the 2017 report: Internet of Water: Sharing and Integrating Water Data for Sustainability whose recommendations are currently being implemented by the Internet of Water project at the Nicholas Institute. The success of these endeavors provided the impetus for additional forums focused on water concerns in the United States.
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PREFACE

The Clean Water (1972) and Safe Drinking Water (1974) Acts created a framework for water quality protection in the United States. This canon of federal water legislation is nearly a half century old and while they have succeeded in meeting their original goals — improving surface water quality and the provision of safe drinking water — do they have the capacity and flexibility to efficiently and effectively address the opportunities and challenges that have emerged over the past five decades? Since the 1970s, the nation's population has grown by nearly 60% and redistributed to the south and west, the personal computer and internet came online, markets emerged as a mechanism for regulatory compliance, sensor technology can detect more constituents at lower concentrations, and climate has warmed some regions by several degrees. Amid such staggering transformations, how can legislation keep pace with change and ensure sufficient protection of the quality of our waters to meet a wide variety of uses? How do we balance regulatory certainty with adaptive flexibility?

The 2019 Aspen-Nicholas Water Forum explored the ideas that undergird these two acts, their successes, shortcomings, and unintended consequences in order to envision how the Clean Water and Safe Drinking Water Acts might adapt to allow more innovation to meet the realities of the 21st century. The central question was how can innovation and regulation at local, state, and federal levels address chronic and emerging water quality challenges across the U.S.?

The annual Aspen-Nicholas Water Forum convenes thought leaders to address ongoing challenges to water sustainability in the United States. Participants come from the private sector, government, academia, and non-governmental organizations—representing expertise in industry, finance, philanthropy, government, academia, agriculture, food and technology companies, investors and entrepreneurs. Topics discussed include big data, innovative financing, groundwater, reaching scale to address geographically expansive challenges, and now water quality. The common thread linking each forum is the fundamental question of what does good water governance look like for the United States? More pointedly, how can we as a society balance the competing demands of equity with liberty and community with efficiency?

Each year, the Nicholas Institute and Aspen Institute coauthor a summary of the forum. Not all views were unanimous nor was unanimity and consensus sought. Forum participants and sponsors are not responsible for this summary's content.

We thank the following sponsors for their generous support of the forum: Bechtel Foundation, Schlumberger, Walton Family Foundation, Xylem, Spring Point Partners, Water Asset Management, Esri, Suez, the Campbell Foundation, Van Ness Feldman, and Arizona State University.

VISION

The fundamental question at each Aspen-Nicholas Water Forums is "what constitutes good governance for water?" What does water governance look like in terms of balancing equity and liberty with efficiency and community (**Figure 1**)? What is the legacy of these broad ideals on water governance, and what do we want our future to be? For instance, the provision of drinking water in the United States historically prioritized liberty and efficiency, resulting in a multitude of independent water systems with wide variation in the safety of the water provided. In response, the federal government established the Safe Drinking Water Act (SDWA) to apply uniform drinking standards across all water systems. In essence, the federal government attempted to shift governance towards community and equity. Similarly, the Clean Water Act (CWA) attempted to provide uniform technological standards to improve the quality of all discharges into a water body. In both instances, the desire to protect human and ecosystem health preceded the science and technology of the times. This led to a focus on using the "best available technology" equally across all communities to comply with regulations. The federal government provided funding to help address affordability and equity challenges, particularly of smaller systems.

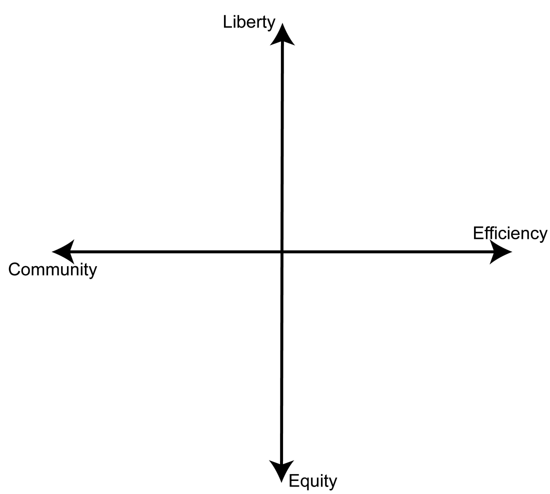

Figure 1. Adopted from *The Executive's Compass: Business and the Good Society,* James O'Toole, 1993.

The question of what constitutes good governance remains at the forefront of the CWA and SDWA. These acts were successful in that rivers no longer catch fire and, in most places, water is reliable and safe to drink all of the time. Yet, issues of affordability and equity remain a challenge for many utilities. The costs of meeting current regulations, let alone regulations that will be necessary to address emerging contaminants, are becoming increasingly prohibitive. The CWA and SDWA established procedural approaches to ensure minimum standards were being met to provide equitable protection of communities; however, this approach may now be hindering the potential for innovation and adoption to more affordably and efficiently meet standards. Yet, these regulations are critical to ensure the continued protection of public and ecosystem health. Not all innovations will succeed and so we must manage the risk of failure. The 2019 forum attempted to define an approach to drive shared outcomes at an optimal scale that best serves the needs of local communities while efficiently and equitably addressing chronic problems. The forum discussed underlying principles for good water governance pertaining to water quality.

EXECUTIVE SUMMARY: WHAT CONSTITUTES GOOD GOVERNANCE FOR WATER?

What does good water governance look like in the context of a good society, particularly for water quality? Are federal regulations, particularly the CWA and SDWA, able to deliver sufficient benefits under changing climate, growing/redistributing population, and aging infrastructure? How do we continue to protect water quality and move forward with regulatory uncertainty? How much flexibility should there be in regulations to de-risk innovation while protecting public and environmental health? How do we balance market, outcome-based solutions with procedural-based regulations that are affordable? The forum explored these and many other over-arching questions, but the constant underlying theme was that good water quality governance must balance the flexibility to allow for innovation and adapt to changing conditions with the regulatory stability and rigorous enforcement that protects water quality and public health. The following reflect key takeaways from this year's forum.

THE CWA AND SDWA HAVE BEEN EFFECTIVE, BUT EFFECTIVENESS HAS PLATEAUED

After a half-century of implementation, water quality in the United States has improved dramatically in many rivers and lakes and most utilities consistently provide safe drinking water. Yet there was also general agreement that these improvements have plateaued. While early investments were effective, further improvement is increasingly costly and difficult to implement; requiring even greater investments for marginal, but important, gains. Questions arose over whether plateauing could be sufficiently addressed by additional resources, new regulations, and/or enforcement of the existing regulations. Chronic and emerging challenges may best be met by developing a modular, incremental framework that can be more readily resourced and is able to achieve small, surgical strikes to address these types of challenges. It is unlikely that a single innovation will create immediate, widespread improvements in water quality. There is no panacea to solve our water quality ills. Instead, the steady accrual of incremental changes will accumulate to achieve greater impacts.

IMPROVING WATER QUALITY IN MEANINGFUL WAYS WILL REQUIRE TAKING ON RISK

The water sector is risk adverse, and there is little incentive to shift away from business as usual (low risk in the short-term) and embrace innovation (higher risk). Significant improvements in water quality will likely need a disruptor that requires innovation, such as rigorous enforcement of regulations (e.g. consent decrees), natural disasters coupled with integrative planning, technology that can maximize returns on investment, or new collaborations that enable all the above. Safe harbors, public-private partnerships, and collaborations between the regulators and the regulated community can lower risk and provide the ingredients for innovations that more affordably and efficiently address water quality challenges.

REGULATORY UNCERTAINTY INHIBITS INNOVATION

Widespread innovation occurs when there is both strong regulation (drives a response) and capacity (the ability to respond). If there is too much flexibility with enforcement or uncertainty around regulations, then innovation will only occur by those with the capacity to absorb unnecessary risk. Several innovative approaches espoused by participants occurred because of rigorous enforcement that required innovation to develop affordable solutions. These innovations often created additional benefits beyond what was initially envisioned.

RELATIONSHIPS AND TRUST ARE ACCELERANTS TO INNOVATION

Trust and partnerships are an accelerant to innovation, particularly when partnerships are between the regulated and regulatory community. To drive innovations, regulators must create a setting for alternative compliance that entails assurances, robust monitoring, enforcement of minimum standards, and incentivizes meeting multiple benefits or achieving higher standards aligned with current regulations. Such a framework provides some risk forgiveness with the caveat that it is time limited and must lead to achieved outcomes.

DIFFERENT ROLES FOR DIFFERENT RISK TOLERANCES

Government and the private sector have different institutional structures and incentives with different risk tolerances. The heart of government is procedural, and this focus on procedure and process can slow down innovation. Governments may prioritize investing in low risk projects guaranteed to meet desired outcomes (i.e. no regret actions). The heart of the private sector is to achieve outcomes at reduced cost, and as such, it is incentivized to take risk. Private investors may have a portfolio of investable, high-risk projects that have market returns and can create multiple, significant, and quantifiable benefits for water quality in the short and long-term. Can we bridge the gap between the life cycle of the private sector and the institutional procedures embedded within government to allow more innovation?

PAYING FOR WATER QUALITY

There was a disconnect among forum participants between the seemingly vast amounts of federal money available for investment in water resources and the on-the-ground reality or perception by local governments and growers that there is not enough money. Federal financing options are functionally inaccessible to many who either are not receiving information that these options exist or do not have the capacity to manage lengthy and complicated applications. Case managers or "CFOs-to-go" may help communities better access federal and state financing options. This is particularly pertinent for small water systems.

WHAT ARE THE CLEAN WATER & SAFE DRINKING WATER ACTS?

The presence of cleaner, safer water today is a testimony to tremendous political, scientific, technological and financial achievements. The canon of water quality legislation was passed nearly 50 years ago with the Clean Water Act (CWA) in 1972 and the Safe Drinking Water Act (SDWA) in 1974. These acts preceded the science needed to establish causal links between pollutants, water quality, and public health. However, Congress recognized that it was at best foolish and at worst unethical to dump pollutants into the very water bodies we would later drink. The CWA sought to protect water quality by requiring dischargers to use the best available technology to treat water prior to entering streams. The SDWA established uniform, drinking water standards before the science existed to clearly link constituents to human health outcomes. Treating water is expensive and both acts have evolved in how they balance costs with potential benefits. Several similarities are worth noting.

- Both acts were aspirational in attempting to ensure cleaner and safer water prior to the scientific evidence or technological advancements needed to achieve those goals.
- Both acts included the capacity for citizen suits to ensure government was complying with regulations to counteract the lack of enforcement in earlier legislation.
- Both acts included significant federal funding through grants that did not need to be repaid. Later, grants evolved into State Revolving Funds that provide low interest loans that must be repaid.
- Both acts struggle to meet the unique financial, managerial, and technical capacity challenges of small systems while enforcing regulations. Small systems often cannot afford to be financially penalized and they cannot afford upgrading their treatment technology.
- Both acts adopted a federalism-based approach, with the federal government establishing minimum water quality standards and states having the option

to adopt more stringent standards and apply for administrative rights to implement and enforce regulations. This creates ongoing experiment in environmental policy-making, regulation, technology, and public-private partnerships with multiple state-level implementation experiments.

CLEAN WATER ACT

Prior to World War II water pollution control was primarily a state and local responsibility. The Federal Water Pollution Control Act of 1948 was the first comprehensive effort by the federal government to engage directly with water quality by providing financial and technical assistance to state and local governments to research and address water pollution problems (**Figure 2**). The federal government did not establish any requirements, objectives, limits, or guidelines. During the mid-1950's to 1960's, a series of events drew attention to environmental pollution, and the public began to demand greater actions by the federal government.

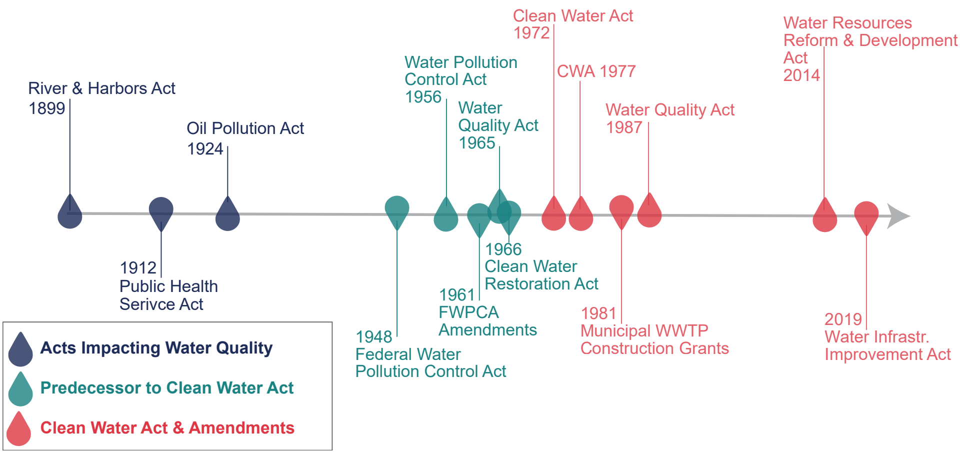

Figure 2. Timeline of legislation and amendments pertinent to the Clean Water Act.

Prior to 1972, federal water pollution control efforts were "sporadic, inconsistent, and improvised on an ad hoc basis".[1] The objective of the CWA was "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" with the initial goal to make waters of the U.S. fishable and swimmable by 1983. The primary mechanism to achieve this objective was to eliminate the discharge of *all* point source pollutants into navigable waters by 1985.

[1] Glicksman & Batzel. 2010. Science, Politics, Law, and the Arc of the Clean Water Act: The Role of Assumptions in the Adoption of a Pollution Control Landmark. *Washington University Journal of Law & Policy* (32) 1.

The two major thrusts of the CWA, often termed a technology-forcing statute, were (1) use the best available technology to control pollutants entering water bodies from point sources and (2) authorize the provision of financial assistance for municipal sewage treatment plants to afford new treatment technologies.[2] There were four primary focuses that have shaped CWA implementation and subsequent amendments:[3]

- **No discharge of pollutants.** This goal set a moral tone that no one has the right to pollute water and spurred efforts for technological research to improve water quality.
- **Surface water.** The CWA explicitly states "navigable waters" as its geographic scope, and then defines this scope as "waters of the United States" (often referred to as WOTUS or Jurisdictional Waters). WOTUS has been litigated on multiple occasions, creating regulatory uncertainty around which waters are included in the CWA. Wetland protection was implied, but never explicitly stated, creating additional uncertainty. Groundwater has consistently remained outside the scope of the CWA.
- **Point source pollution.** The CWA exclusively focused on the regulation of point source (PS) pollution, leaving the management of non-point source (NPS) pollution to states. While it was known that NPS pollution contributed to water quality degradation, there (1) was no readily available means to control or measure NPS pollution and (2) the diffuse nature of NPS pollution requires the use of best management practices (BMPs) and enforcing BMPs was viewed as equivalent to land use control.
- **Technology rather than water quality controls.** Science was not able to demonstrate a cause-and-effect relationship between discharges and ambient water quality. The inability to make those connections constrained selecting and enforcing effluent limits. As a result, the CWA focused on preventing pollution by setting effluent limits for all point source pollution based on the best available technology (enforceable) and using ambient water quality as the metric of CWA performance (impact).

The pollutants covered by the CWA expanded in the 1987 Water Quality Act from conventional pollutants (such as suspended solids, bacteria, and pH) to toxic substances (such as pesticides, organic chemicals, and heavy metals). The scope of the CWA also expanded the definition of point sources to include stormwater discharge, requiring industry and municipalities to obtain National Pollutant Discharge Elimination System (NPDES) permits and meet CWA regulations.

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2 Copeland, C. 2016. Clean Water Act: A Summary of the Law. CRS Report.

3 Glicksman & Batzel. 2010. Science, Politics, Law, and the Arc of the Clean Water Act: The Role of Assumptions in the Adoption of a Pollution Control Landmark. *Washington University Journal of Law & Policy* (32) 1.

CURRENT STATUS AND TRENDS FOR THE CWA

Decades of ambient water quality data collected by the United States Geological Survey (USGS) suggest the following water quality trends (reflecting the impact of the CWA):

- **Occurrence of major organic contaminants in ambient waters.** Pesticides, volatile organic compounds, pharmaceuticals, and so on are present in streams. These contaminants often occur in concentrations that exceed aquatic life criteria, posing a high risk to aquatic ecosystems. However, contaminant concentrations rarely pose a substantial risk to human health, with the exception of commonly used organic compounds, such as atrazine, which require treatment by drinking water systems. There are also substances that pose unknown risks to human health, such as Per- and polyfluoroalkyl substances (PFAS) – which includes PFOA, PFOS, and GenX – that were created by manufacturing processes since the 1940s.
- **Point source pollution has decreased.** There were dramatic improvements in ambient water quality gained from PS treatment that have since plateaued.
- **Trends in nonpoint source pollution vary.** Trends in nutrients, sediment, pesticides and other constituents associated with NPS often have mixed results across constituents and geographies. For instance, one region might show improvements while the next region worsens, or sedimentation might improve while nitrogen concentrations worsen in the same watershed. Similar to major organic contaminants, NPS constituents are negatively affecting aquatic life, but rarely pose a threat to human health, with the exception of nitrate in groundwater.
- **Increased recognition of the interplay between groundwater and surface water quality.** Most threats to groundwater quality are naturally occurring – such as arsenic or uranium. Nitrate has emerged as the primary anthropogenic compound threatening drinking water quality from groundwater. There is increased recognition that the application of nitrogen and other chemicals on the land surface affects groundwater. Conversely, groundwater contamination can contribute to nutrients and other contaminant loadings in surface water bodies over decades. The interplay in water quality and quantity between surface and groundwater sources has implications for the best management practices for NPS pollution.

The CWA is an adaptive, technology centric policy for controlling pollution to preserve and/or improve water quality. A common criticism of the CWA is its focus on controlling rather than preventing pollution. The CWA was largely successful in its implementation of technology to control point source pollution through permits and regulation. While controlling pollution at point sources has improved water quality, it has largely not been sufficient to attain water quality goals specified for water bodies to meet their designated purposes (total maximum daily loads – TMDL). Indeed, the number of impaired streams are growing, but few are improving enough to come off the impaired stream list, posing significant risks and degradation to ecosystem health. The CWA is unlikely to meet their TMDL goals as long as NPS pollution management is achieved primarily through voluntary engagement.

SAFE DRINKING WATER ACT

The Public Health Service (PHS) established the first drinking water regulations in the 1912 PHS Act, and in 1914, the Treasury Department established the first federal, numerical drinking water standards for bacteria. Several state and local governments adopted these standards as guidelines even though they were only legally binding to water systems used by interstate carriers. New chemical and physical water quality parameters were added over time, and by the 1962 PHS Act, there were standards for 28 constituents (**Figure 3**).[4] All 50 states accepted these guidelines with minor modifications, but they remained only legally binding for 700 public water systems (PWS; fewer than 2% of PWS).

In the late 1960's the Bureau of Water Hygiene tested 969 PWSs and found that 41% did not meet the 1962 guidelines and were deficient in aspects of source water protection, disinfection, clarification, and/or pressure in the distribution system.[5] The study noted that smaller systems had the greatest difficulty in meeting guidelines and that while the majority of the U.S. population had adequate water, several million were being supplied inadequate water quality and 360,000 were potentially consuming dangerous water.

Congress passed the 1974 SDWA as a comprehensive regulatory framework to protect public water supplies from harmful contaminants. The SDWA also created regulations for source water assessment and protection programs for groundwater protection (primarily regulating underground injections). The SDWA had three primary impacts for drinking water: (1) created enforceable standards, (2) provided government financing, and (3) required greater public transparency. The federal government set minimum, national water quality standards and provided funding to enable states to become the primary implementers and enforcers. To have primacy, states must adopt regulations at least as stringent as national requirements, develop adequate procedures for enforcement (including conducting monitoring and inspections), adopt authority for administrative penalties, conduct inventories of water systems, maintain records and compliance data, and report to EPA.

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4 Pontius. 1993. SDWA: A Look Back. *Journal of the American Water Works Association* 85 (2).

5 Ibid.

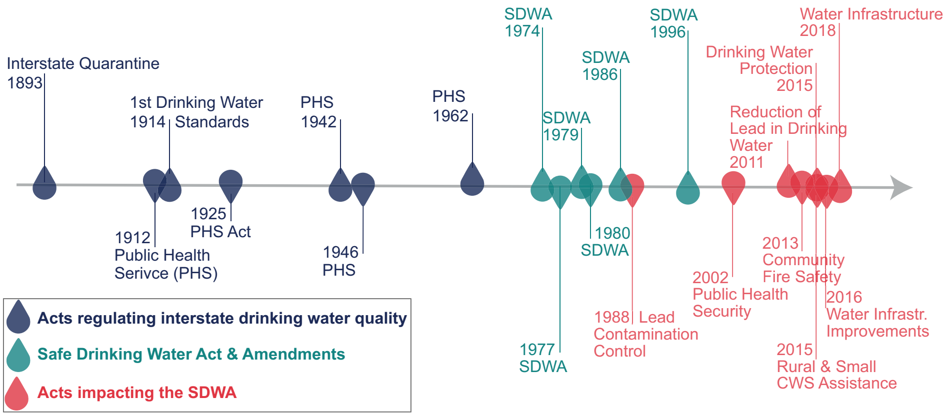

Figure 3. Progression of drinking water quality regulations over time.

Two challenges have plagued the SDWA from its inception: keeping pace with emerging contaminants and adequate financial capacity. First, keeping pace with emerging contaminants and providing new drinking water quality standards is challenging because it takes time to establish causal links between contaminants and human health. The 1996 amendments established three criteria for developing new drinking water quality standards: (1) the contaminant may have an adverse health effect, (2) the contaminant is known or likely to occur at levels of public health concern, and (3) regulations provide a meaningful opportunity for health risk reduction. All three criteria require data and research to establish new drinking water quality standards (a lengthy process), and the subjectivity of "meaningful risk reduction" has created uncertainty. Today, the SDWA regulates 91 contaminants and provides non-regulatory health-based advisories for 171 constituents.

Second, drinking water directly impacts public health, and yet our drinking water infrastructure is aging and often under-funded. As a result, the federal government continues to provide financial support for drinking water infrastructure to protect public health and help maintain the affordability of drinking water rates. This challenge is exacerbated by the overwhelming presence of very small and small water systems that comprise 82% of PWS's but serve only 9% of the population. These small systems do not have the revenue base to support infrastructure costs and face chronic financial, and often compliance, challenges.

CURRENT STATUS AND TRENDS FOR THE SDWA

The SDWA has achieved remarkable improvements in drinking water quality with more than 90% of community water systems achieving all water quality standards all of the time.[6] This is an incredible accomplishment. Despite widespread success, there are numerous challenges facing the SDWA:

- **Capacity.** The majority of community water systems that fail to meet drinking water standards are small systems with little technological, managerial, or financial capacity. These systems may also be experiencing an aging and/or declining population and cannot afford to make long-term investments with their shrinking revenue base. These systems are more likely to have water quality challenges, but enforcement is problematic when a system simply does not have the resources to adequately treat their water. What is the future for these smaller systems?

- **Climate Change.** Warmer temperatures and greater extremes in the water cycle amplify the challenges water systems face. This can mean increased flood risk, less reliable water supply, increased treatment costs, harmful algal blooms, and so on. How can water systems proactively adapt and increase their resilience to a changing climate?

- **Infrastructure Cost and Affordability.** Since 1973, Congress has provided more than $100 billion for core wastewater and drinking water infrastructure (~$2.2 B/yr).[7] However, much of this infrastructure is decades old and the American Water Works Association estimates that $1 trillion are needed to maintain and expand service to meet demand over the next 25 years (~$40 B/yr). This is on top of rising water treatment costs from new regulations and warmer temperatures. Many PWSs are struggling to finance infrastructure upgrades at affordable rates for their customers. Can PWSs address infrastructure and regulatory needs more cost effectively?

- **Source Water Protection.** PWSs are constantly addressing emerging challenges, such as PFAS and PFOS. These contaminants come from locations that need to be managed, but the only option for PWSs are to treat the contaminants at the treatment plant. It may be more cost effective (and better overall for the environment) for PWSs to have the capacity to address contaminants at the source rather than at the intake pipe. What mechanisms are available for PWSs to invest in source water protection and engage in integrative planning with upstream stakeholders?

- **Communication and Trust.** Drinking water crises, regardless of whether driven by external factors (e.g., harmful algal blooms in Toledo, OH or chemical spills in Charleston, WV) or internal factors (e.g., lead contamination in Flint, MI or abrupt changes to water bills) damage the

[6] Weinmeyer et al. 2017. The Safe Drinking Water Act of 1974 and its Role in Providing Access to Safe Drinking Water in the United States. *AMA Journal of Ethics* 19 (10).

[7] Copeland. 2015. Funding for EPA Water Infrastructure: A Fact Sheet. CRS Report R43871

public perception of PWSs. More and more people do not think it is safe to drink tap water, instead purchasing bottled water and installing filtration systems. PWSs must do a better job communicating and educating the public, especially as the ability to detect new contaminants is outpacing our ability to quantify risks. How can water systems improve public trust?

THE POLICY TRILEMMA

The CWA and SDWA succeeded in achieving their original intended purposes, but now struggle to meet the emerging challenges of the 21st century. The regulated community is stuck in a policy trilemma[8], where there are several goals that cannot all be achieved simultaneously: (1) maintain business as usual, (2) maintain affordability, and (3) innovate to meet investment needs (**Figure 4**).

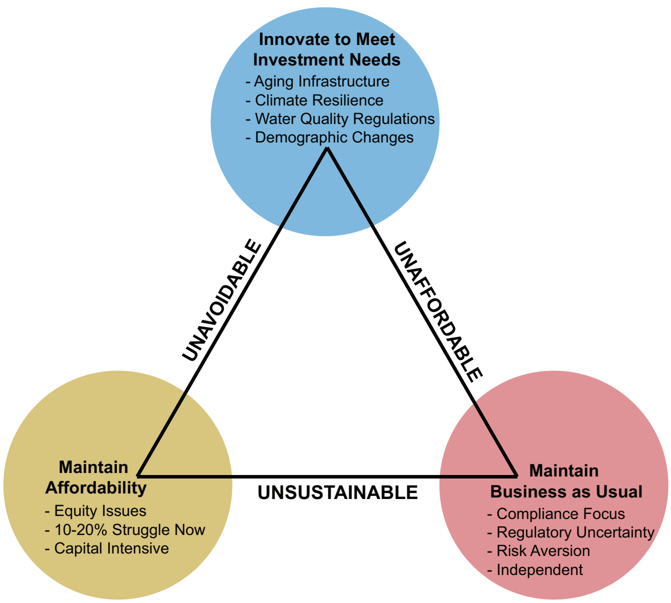

Figure 4. The water policy trilemma. Currently, water utilities straddle between maintaining business as usual and affordability. The financial needs of aging infrastructure alone makes this current stasis unsustainable. If investment needs are addressed while maintaining business as usual, water will become unaffordable. Innovation is needed to meet investment needs while maintaining affordability.

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[6] Patterson et al. 2018. Reaching watershed scale through cooperation and integration. A report from the 2018 Aspen-Nicholas Water Forum.

Currently, wastewater and water utilities are prioritizing maintaining business as usual and affordability. However, this approach is not sustainable as the costs of treatment rise with warmer temperatures and new regulations. Business as usual refers to the fragmented nature of the water industry, with each water system focused on maintaining autonomy through ensuring regulatory compliance and minimizing risk. Risk and regulatory uncertainty are key motivators to maintaining business as usual.

Affordability refers to the challenges of financing annual operating costs, rising infrastructure needs, and complying with regulatory demands (e.g. consent decrees, new regulations) while providing water and wastewater at affordable rates. Already 12% of Americans find current water rates unaffordable, and this number could triple to 36% as rates increase to meet investment needs.[9] The rising costs to comply with water quality regulations may drive utilities towards innovation just to maintain affordability.

Innovation is the adoption of unconventional approaches to afford the investment needs required to meet the challenges of aging infrastructure, respond to climate or regulatory changes, address the ramifications of growing or shrinking demand, and so on. Innovation may be around technology, policy, financing, and/or collaborations. There often needs to be a disruptor to interrupt the status quo and spur innovation. Potential disruptors for the CWA and SDWA include regulatory enforcement, disasters, technology, the private sector, and inter-sectoral collaborations.

- **Regulatory Enforcement.** Regulations have a significant role in catalyzing innovation. Many PWSs have embraced innovation in order to meet consent decrees while simultaneously keeping water rates affordable (see Consent Decrees Driving Innovation Section). For example, to address combined sewer overflows, the cities of South Bend and Buffalo invested in a novel technological approach using their current infrastructure, while DC Water developed novel financial instruments to fund new infrastructure. Here, regulatory enforcement triggered innovation, but only when coupled with regulatory flexibility to allow innovation.
- **Disasters.** Natural disasters have the opportunity to drive change when coupled with integrative planning (see Integrative and Proactive Planning Section). In order to move from reactive to intentional, proactive responses, there must be a vision, common goals, and actionable items – a plan – created ahead of time. Integrative planning should include science and technology to design interventions that will achieve desired outcomes,

9 Mack and Wrase. 2017. A Burgeoning Crisis? A Nationwide Assessment of the Geography of Water Affordability in the United States.

but they must also actively engage with the value systems of the public and decision-makers. Science may guide designing which actions to take, but changing behavior requires engaging with value systems to motivate taking action.

- **Technology.** Technology may enable a shift to outcomes-based solutions, quantifying benefits to create incentive structures, and/or layering multiple benefits to create leveraging opportunities for funding (see Technology Section). New technology can be a response to another disruptor, or it can be the disruptor. For instance, the rapid rise in low-cost water quality sensors can change our understanding of problems and expand solution sets, creating opportunity for precision regulation, market mechanisms, or citizen science engagement.
- **Private Sector.** The private sector may also heavily influence innovation with NPS pollution. Private companies with global footprints are incentivizing the adoption of new technology and cleaner practices in areas such as carbon, climate, and plastics; issues that are impacting their bottom line and recognize no physical boundaries. Industries and growers are facing supply side challenges as the companies purchasing their products are adopting increasingly rigorous standards that go beyond current regulations. Walmart, Land O'Lakes, and other private businesses are beginning to require their agricultural supply chains to adopt these technologies and embrace BMPs. The private sector may play a more formative role than government in the future of agricultural land practices.
- **Collaboration.** Investments in relationships and trust are critical to achieving large-scale water quality improvements. Transparency of information may help regain public trust and communicate the why behind decisions. Increased public trust may allow PWSs to engage in innovative financing mechanisms that extend beyond traditional jurisdictional boundaries (see Innovations in Financing). A collaborative, learning relationship between the regulators and the regulated community can simultaneously lower the risk of innovation while increasing potential rewards. Philanthropy has a unique role in driving innovations that require long-term investment, relationship building, and/or fill regulatory gaps. For instance, philanthropy is supporting a collaborative effort between growers and PWSs in Iowa where growers are paid to implement BMPs and then monitor the impact on nutrient loads and flooding in downstream communities. Philanthropy can provide resources to meet needs that are not otherwise being met through current policies or regulations, to facilitate collaborative efforts, and incubate innovation between stakeholders.

RISK-REWARD FRAMEWORKS

The current risk-reward framework creates little incentive for a PWS to move away from business as usual and accept the risk of innovation. The consequences of a PWS failing to deliver a basic need are potentially enormous (such as loss of life from contaminated drinking water or sewer overflows), and so PWSs are naturally risk adverse. The business as usual approach is low risk (in the short-term) and the costs and water quality impacts of established procedures are known and pre-approved by regulators. As such, innovation will always be higher risk. Innovations may succeed, allowing a PWS to meet, and perhaps exceeded, regulations at a fraction of the cost. Innovations may also fail, leading to poor water quality outcomes and requiring the PWS to absorb the cost of a failed innovation and re-invest in a solution. Often a PWS will only accept the risk of innovation if business as usual becomes too costly or there are mechanisms to de-risk innovation.

Short election cycles and the fear of being sued are two mechanisms that maintain the current risk-reward framework. First, government election cycles are often 2 to 4 years, creating little incentive for elected leaders to take risks, particularly if it could negatively impact their chances of being re-elected. Instead, unpopular decisions (and the risks of not making those decisions) are deferred onto their successor. Second, the rampant environmental law suites associated with the CWA and SDWA inhibit trust and the willingness for public agencies to take risks. While litigation can be a necessary tool for bad actors, it can also create barriers for genuine innovation and collaborative approaches. Litigiousness leads to silos because it erodes trust and it is hard to be transparent – to risk innovation – when you fear lawsuits.

The risk framework can be proactively shifted through public-private partnerships. The private sector should take on risk (whether technology, political, or market-based) where it is not appropriate for the public sector to place the risk on their citizens. In exchange for taking on risk that should not burden ratepayers, the private sector actors who successfully achieve the stated outcomes (many will not and will lose their investments) should be financially rewarded. Public-private partnerships can establish continuity and exceed the challenges of short election cycles. An additional instrument of risk-sharing can be between the PWS and regulators, most notably through the use of safe harbor agreements to encourage experimentation and innovation. A partnership between regulators and the regulated community might include increased time and agreed upon decision-points to implement, monitor, and adjust an innovative approach without penalty. While regulations should be enforced, a collaborative approach dedicated to learning how to more cost effectively and efficiently meet those regulations can create trust and space for taking measured risks. This requires sustained leadership and partnership to reimagine the fundamental relationship between the regulator and the regulated to be one of continual learning and collaboration. There must also be good communication and education with the public to garner support and not lawsuits.

INNOVATIONS IN GOVERNANCE

BRIDGING GOVERNANCE AND REGULATORY SILOS

Water governance has many silos. Such silos can help efficiently address a component of a system, or a specific geographic area, but can be problematic at addressing an entire system. Silo mentality is a challenge that occurs beyond the water sector and creates a culture that resists sharing resources or information within and between organizations. A silo can result in localized, disconnected decision-making and a lack of ownership or willingness to collaborate and change. While a single part may be efficient at addressing a particular problem or type of problem, the overall system may suffer. The water sector will benefit from integrative approaches that can achieve multiple benefits for the whole, rather than fixating on meeting specific rules or using specific tools to benefit a part of the system (sometimes at the expense of the whole).

At the federal scale, the EPA is the primary overseer of water quality; however, there are aspects of water quality that cross bureaucratic boundaries. There are thirteen federal agencies with water in their purview, and while they partner on site-specific challenges via working groups, these working groups are largely siloed. The federal government is attempting to integrate across agencies by developing a federal "water subcabinet" to focus on a subset of broad challenges. The water subcabinet currently consists of Interior (DOI), Agriculture (USDA), Energy (DOE), Defense (Army Corps), Commerce (NOAA), Homeland Security (FEMA), and EPA (see box: Interagency Collaboration). The five priority areas the water subcabinent is focused on are: drought resiliency, water quality and nutrient management, flood resiliency, technology and forecast modeling, and infrastructure.

In many states, water quantity and water quality are managed by different departments; however, there is a growing recognition for the need to coordinate efforts. In 2014, North Carolina formally consolidated the divisions of water quality and water resources as the State recognized that *"it just makes sense to integrate our regulation of water quality and quantity. It doesn't matter how much water you have if it's not clean, and likewise a shortage of water, even if it is clean, isn't acceptable."* [10] In

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[10] ASkvarla, J. 2013. DENR Secretary announces merging of state water programs to create efficiency, better customer service.

INTERAGENCY COLLABORATION: WATER REUSE

Water reuse is an emerging opportunity and challenge in the United States. For instance, the USDA needs more water in the Colorado River Basin to improve the drought resiliency of agricultural communities. The USDA worked with EPA to develop a water reuse action plan that would enable wastewater to be sold to Reclamation for use by agricultural communities in drought. DOE participated in the technology and energy components of the reuse action plan. Similarly, EPA, DOE and the state of New Mexico are working on a water reuse action plan. Oil and gas production is increasing in New Mexico and the produced water (projected to reach 2 million AF per year) is currently injected underground because of regulations. This plan would allow produced water to be treated and sent to BoR to supplement surface water needs. The EPA is facilitating and coordinating the development of a national Water Reuse Action Plan with DOI, USDA, DOE, and others.

Texas, the Texas Water Development Board (TWDB) handles water quantity while the Texas Commission on Environmental Quality handles water quality; however, these two agencies prioritize at least monthly meetings to stay informed and create efficiencies around projects.

Similar to governance, regulations are often siloed into quantity (primarily regulated by states) and quality (primarily regulated by federal government and implemented by states), with further siloes for surface water and groundwater. Yet, something as simple as combined sewer overflows (CSOs) highlights the interconnectedness between quality and quantity. CSO's occur when intense rainfall exceed the capacity of combined sewer and stormwater systems, resulting in sewerage spills that affect water quality and create risks to human health and economic activity. Or consider groundwater recharge where wastewater is now being treated and injected into aquifers as a future source of water supply. Within water quality, the CWA was used to address the quality of wastewater discharges into streams (and later stormwater) while the SDWA was used to address the quality of water withdrawn for drinking purposes. Local governments mirror this separation and often have separate water, wastewater, and stormwater utilities. Silos may even occur within a single utility with operations, financing, and customer relations handled by different departments. Yet, those utilities that have integrated their departments improved performance as they could more readily address non-revenue water loss, impacts of operational or financial changes on behavior, and so on. There seems to be widespread opportunities to integrating governance and regulatory silos.

INTEGRATIVE AND PROACTIVE PLANNING

Integrating across silos is one form of innovation. Integrative planning looks beyond a single organization to plan across multiple functions, levels, and locations. It is dependent on collaboration and requires sustained leadership with a long-term view that exceeds political cycles. Philanthropy and NGOs are particularly interested in the concept of integrative planning. The One River concept seeks to integrate natural and built infrastructure to improve water quality, provide flood control, and create community amenities. The EPA is creating financial instruments with the flexibility to finance integrative planning projects (wastewater, drinking water, and stormwater) within a local government and at a watershed scale (such as NPS or water reuse projects). While EPA is creating these financial mechanisms, it will be essential for recipients, particularly local governments to have the capacity to accept funding for projects that exceed traditional jurisdictional boundaries. Many utilities have enterprise funds that are incredibly rigid and present significant challenges for financing integrative projects. Integrative planning may be essential to address NPS pollution, particularly if its management remains voluntary.

An example of an approach that blurs previously conceived bureaucratic boundaries is natural disasters, which are becoming increasingly prevalent and costly. FEMA provides significant resources for post-disaster recovery, but local communities and states are not often in a position to think about infrastructure and do long-term planning in the aftermath of a major disaster. As a result, disaster recovery has historically focused on rebuilding back to normal, which is becoming increasingly unsustainable. The federal water subcabinet is exploring how integrative planning of stormwater, flood control, wastewater, and drinking water systems could improve post-disaster recovery. For instance, New York used Hurricane Sandy Recovery money to address challenges with wastewater, drinking water wells, sea level rise, and nutrients. The EPA recently signed an MOU with FEMA to allow State Revolving Fund dollars to restore vital water infrastructure in times of disaster.[11] Despite these movements, regulatory structures would need to change to facilitate the use of FEMA disaster money for integrative planning that includes mitigation and adaptation.

Texas had to overcome similar hurdles when they adopted integrative planning following a significant drought in the 1950s. The State assigned TWDB to lead the development of a state water plan. To incentivize participation, the TWDB created a State Water Implementation Fund (SWIFT) to provide low-cost funding for water supply that is contingent on the approval of local government plans as part of the state water plan. Local governments must provide data and science to support their plan and the neighboring regions must vote to approve the plan for it to become

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[11] EPA Signs MOU with FEMA to Support Recover and Restoration of Water Infrastructure After Disaster Strikes. June 4, 2019.

part of the state water plan. The TWDB saw a significant increase in participation when they required communities to provide plans to be eligible for SWIFT money. The TWDB also required the use of standardized methods to estimate capital costs for each project in order to compare plans and costs across the state; creating a means for nearby communities to partner together to lower costs. The TWDB was recently tasked with mitigating flood risk and intends to take a similar approach by requiring each region to update flood maps and submit flood mitigation plans that will be voted on by their neighbors in order to be applicable to receive money. This process provides incentive structures for local involvement in regional and state water planning and it creates a platform to learn from one another's innovative solutions.

INNOVATION LABS: STATE AND LOCAL GOVERNMENTS

The CWA and SDWA were passed during an unusual window of time, when the bulk of environmental regulation received bi-partisan support (e.g., National Environmental Policy Act, Clean Air Act, Endangered Species Act). Further, the focal point of water quality issues were relatively simple: point discharges. While there has been large-scale success in improving water quality and providing safe drinking water writ large, some seemingly intractable challenges remain. Today, the societal and governmental atmosphere are not favorable to revisit and pass new, comprehensive federal regulations around water quality. Instead, much of the innovation and legislation are occurring at state and local levels.

STATE GOVERNMENTS

The federal government provides a stable floor, a baseline minimum for water quality and an important backstop to ensure environmental and human health. Its role is to be slow and stable. Unfortunately, the pace of emerging contaminants and challenges in water quality require faster responses, or at least streamlined approval, to enable state and local governments to engage in innovative approaches. The inability to keep pace with challenges and innovations creates regulatory uncertainty, which is problematic because local and state governments need regulatory certainty to make wise and responsible long-term capital infrastructure investments. States may respond to regulatory uncertainty in three primary ways: (1) wait for the federal government to create certainty, (2) proactively adopt more stringent requirements in-line with global trajectories, and/or (3) create state legislation to provide regulatory certainty for local governments.

The first approach – waiting for the federal government – is relatively risk-free in the short-term, but defers consequences, likely increasing both costs and consequences in the future, and does not incentivize innovation. The second approach – voluntarily adopting requirements that are more stringent – occurs when there seem to be clear trajectories or issues that need to be resolved (e.g., emerging recognition of PFOS/PFAS). In these cases, state or local governments may choose to adopt regulations or invest in technologies that exceed federal requirements because they believe future regulations will likely occur or become more stringent. Opportunistic investments in treatment technology now may create future financial flexibility if regulations become more stringent because they will already have the appropriate technology to meet standards and will avoid the costs of additional infrastructure, consent decrees, and/or litigation. The third approach – creating state legislation to provide regulatory certainty for local governments – occurs when a state passes legislation because of the intractability of the current level of regulatory uncertainty for local governments. For instance, Kentucky passed legislation that is driving utility consolidation, North Carolina promoted CWA-focused compensatory mitigation banking, and Maryland is regulating and incentivizing nutrient applications for growers. Here, state governments were proactive in addressing the existing high levels of uncertainty, and in so doing, allowed their local governments (and associated private industries) to innovate rapidly within this newly created certainty.

CONSENT DECREES DRIVING LOCAL INNOVATION

While it would be ideal for local governments and water service providers to innovate proactively, in reality, many times they are forced to act in response to enforced regulations, particularly through consent degrees. Consent decrees are a favored enforcement mechanism that avoids costly litigation and settles on a plan of action to address pollution. Consent decrees have become a driver of investment decisions by local governments, and thus a disruptor that can catalyze innovation.

As an example, DC Water has a $6B capital investment program in the next 10 years, of which $2.6B is for a consent decree to address CSOs. While CSOs are clearly important, like all water service providers, DC Water has long-term investment needs, some of which may include pressing infrastructure needed to meet strategic goals, that can be superseded by a consent decree. One of the concerns facing DC Water is affordability; with only 130,000 accounts, the average monthly customer bill is $108. This bill is projected to increase to $185 over the next ten years, making the rate of increase much greater than the expected rate of inflation. DC Water has created a stakeholder alliance consisting of residents, faith based organizations, hospitals, hotels, and others to discuss how DC Water should invest their resources and address their growing affordability crisis. The stakeholder alliance considers the risk and opportunities of various investment strategies and presents their recommendations neighborhood by neighborhood. Neighborhoods are more receptive to the investment strategy when they know their peers have been part of the planning process.

Another example is with the Hampton Roads Sanitation District (HRSD), which serves 1.7 million people in southeastern Virginia. The HRSD has an independent rate setting authority with broad enabling legislation that allows them to move money between the 18 counties and cities they serve to ensure the entire system is functioning well. The HRSD believes regulatory instability is their biggest threat over the next 50 years because each five-year permit cycle typically brings new regulations. HRSD chose to adopt requirements that are more stringent and will begin treating wastewater to drinking water quality standards to avoid future regulatory uncertainty from CWA standards. They developed a program to inject their high quality wastewater into the depleted Potomac Aquifer, creating multiple benefits by slowing or reversing land subsidence and subsequent sea level rise impacts, recharging the aquifer for future water supply, and reducing the amount of nutrients discharged into the Chesapeake Bay. The catalyst for this program was regulatory uncertainty coupled with a consent decree, which if addressed in isolation, would have required HRSD to do aggressive rate increases. To mitigate high costs, HRSD obtained federal and state support to modify the consent decree to recharge the aquifer while maintaining compliance with both the CWA and the SDWA. This example also shows how innovative approaches require partnering with, and the flexibility of, regulatory agencies.

INNOVATIONS IN THE PRIVATE SECTOR

Technological advancements are crucial to address emerging, large-scale challenges, yet wide-scale adoption in the water sector is lacking. While there are a few innovators and some early adopters, the majority are slow to embrace change, particularly if there are significant financial or regulatory risks. Because many water quality technologies are related to (or driven by) regulatory compliance, innovations must not just be financially viable, they must also be acceptable to regulators. As a result, the relationship between the regulators and the regulated community must allow for continuous learning and cross-fertilization to create space for new technology to have widespread adoption.

The role for regulators in providing a well-defined playing field for innovation requires providing clear boundaries that are enforced while allowing the flexibility to innovate within those boundaries. When boundaries are set and are either not enforced or enforced inconsistently, there is little incentive to innovate, as there is as much potential gain to be made in advocating for (or lobbying for) relaxing enforcement standards. For instance, EPA established a timeline for meeting new municipal separate storm sewer system (MS4) permits; however, when several public agencies struggled to meet those goals, EPA relaxed the deadline without penalties, eroding the incentive to innovate in order to meet strict guidelines. Enforcement can be the impetus for innovation, but it must also allow space and provide resources for it to occur. Continuing with the MS4 example, EPA could provide a request for proposal (RFP) template for public utilities to engage the private sector. Both California and Maryland used RFPs and received bids from the private sector that achieved permit compliance within their deadlines at 30 to 40% of the costs predicted by public agencies. This approach allows public agencies to more cost effectively meet regulations and emboldens regulators to enforce regulations because they know their permits and guidelines are achievable.

TECHNOLOGY

Digital technology has made data collection easier and more affordable. Analyzing and visualizing data reveals trends and creates insights that lead to improved operations and efficiencies. Yet, the majority of water infrastructure is embedded in the technology that was available 25 to 100+ years ago. Traditional gray infrastructure is expensive, static, and cannot readily adjust to changing conditions. Digital technology provides an opportunity to maximize the performance of infrastructure investments under changing conditions, particularly the use of:

- **Sensors.** Sensors are becoming cheaper and performing better, allowing detection of underground leaks, early warnings of algal blooms, and so on. The cheaper costs allow for greater deployment across water systems and farms, enabling the detection and mitigation of small problems before they become large, expensive challenges.

- **Data Analytics.** Artificial intelligence and the internet of thing is allowing for machine learning that can extract greater value from the growing volume of data. Communications technology enables real-time information to inform decision-making, while predictive tools can create forecasts to inform future decisions.

- **Optimization Strategies.** Sensor networks also allow utilities, industries, and growers to observe the impacts of decisions on other components of the system and to adapt in real-time (see Box Technology Optimizes Grey Infrastructure). Monitoring will become increasingly important to achieve desired outcomes in integrative planning and risk management approaches.

TECHNOLOGY OPTIMIZES GREY INFRASTRUCTURE

In 1950, Buffalo had a population of 580,000 and was the 15th largest city in the United States. Today, Buffalo's population has shrunk by half and the city is facing large challenges with aging infrastructure and consent decrees. Buffalo considered spending hundreds of millions of dollars to build a tunnel to address their consent decree; however, this would have created an immense financial burden for residents. Instead, the city partnered with a technology company (EmNet) and EPA to use sensors to meet their consent decree, saving $100 million. South Bend, Indiana was the first to take this approach and currently saves ~$1.5 million annually and reduced dry weather overflow events, avoiding one billion gallons of overflow each year.[12]

Each public or private entity collecting data holds a piece of information relevant to the management of a watershed or aquifer. Sharing data, or deploying public sensor networks across a watershed or aquifer, allows for better understanding of how different components of a system interact and influence one another. The USGS is deploying dense monitoring networks in ten watersheds (Next Generation Water

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12 EmNet. 2018. https://www.emnet.net/clients/south-bend-indiana

Observing System), and are seeking to collaborate with state, local, and citizen science groups to create greater densities of data in other watersheds. These data can enhance integrative planning efforts and enable prioritizing efforts to achieve the highest environmental return on investment. That said, the reliance on "the best available science" and new technology is not risk free. Science changes and evolves with technology, and is sometimes proven to be incorrect. For instance, the best available science in the 1990's told the agricultural community they could apply as much phosphorus as needed. Today, the best available science blames their use of phosphorus for destroying Chesapeake Bay.

TECHNOLOGY AND TRUST

Trust must be cultivated between new technology, the regulated community, and regulators to create space for innovation with agreed upon risk parameters that do not significantly jeopardize human and ecosystem health. Companies typically test new technology for several years before piloting with a municipality or grower. There are many proven technologies with more than three years of data showing their success, but few are widely adopted, particularly by utilities. Utilities often require piloting new technology within their system to ensure it works for their particular circumstances. The risk of a new technology failing is immense, particularly because failures can have tremendous consequences and jeopardize public health.

Third party verification could de-risk the adoption of new technology and lower the transaction costs if both the EPA and states (regulators) and utilities (the regulated community) can go to a single location to observe the performance of new technologies. Verification can allow regulators to provide stamps of approval across the U.S. (rather than case by case) to implement new technology to meet regulations. This will become increasingly important for small communities to have lower transaction costs to adopt more affordable solutions to meet regulations. There is also a need for facilitators to broker deals between the public and private sector. It took significant resources to amend the consent decree for DC Water to allow the use of green infrastructure to meet a portion of their CWA obligations. The transaction costs for allowing private sector engagement must become smaller, particularly after proven successes.

Private industry may also collaborate with NGO's and philanthropy to vet new technologies. For instance, Perdue Farms recently developed a new lateral drain system that retained more nutrients and water on the field. They are partnering with the Chesapeake Bay Foundation to test the performance and financial viability of this new technology on other types of farms to see if this solution can scale and create significant reductions in nutrients to the Chesapeake Bay at affordable costs.

Adopting new technology might reveal previously unknown problems. A public utility or grower might choose to sustain current practices rather than risk the costs, and potential regulatory violations, associated with new technology or discovering a previously unmonitored, and therefore unknown problem. Regulators might incentivize the adoption of technology by providing a safe harbor, in terms of time to reach compliance, should a problem be uncovered. For instance, the TWDB is working with the oil and gas industry to develop mechanisms for private industry to submit groundwater data to TWDB anonymously and confidentially. This process is saving the state millions of dollars in data collection for their water quality mapping efforts while decreasing the chances of liability for initial participants.

INNOVATIONS IN FINANCING

Water quality management is expensive, whether point source, nonpoint source, or drinking water treatment. As such, there is considerable interest in identifying financial mechanisms to improve viability for water quality improvements, particularly as the sources of federal funding diminish. There was an interesting disconnect at the forum between the seemingly vast amounts of federal money available for investment in water resources and the on-the-ground reality or perception by local governments and growers that there is not enough money. Federal programs and financing options are functionally inaccessible to many organizations who either are not receiving information that these programs exist or do not have the capacity to manage lengthy and complicated applications.

Two potential solutions were offered to bridge this disconnect. First, a trusted NGO or philanthropic organization could serve as a matchmaker, matching the needs of a community with a potential funding source. Second, the federal government provides caseworkers, akin to TWDBs' "CFO-to-go" where they send an accountant to help communities with their finances. A local government would call their caseworker with a problem and the caseworker would tell them which funds they are eligible to apply for and provide guidance through the application process.

MUNICIPAL FINANCING

There is a legacy of the federal government subsidizing municipal water infrastructure because water is the most capital-intensive utility. Historically, Construction Grant programs provided free money to municipal governments to build their infrastructure. In 1987 (CWA) and 1996 (SDWA), the federal government transitioned to State Revolving Fund (SRF) programs that provide low interest loans to local governments. The CWA and SDWA have provided more than $100 billion for wastewater and drinking water infrastructure since 1973.[13] The federal government continues to provide many opportunities for local governments to afford infrastructure investments. The primary instrument is through loan programs like

[13] Copeland. 2015. Funding for EPA Water Infrastructure: A Fact Sheet. CRS Report R43871.

SRF, where interest rates for water infrastructure are incredibly low: SRF interest rates vary between states but typically range between 0 and 3.0% below market rate. For smaller communities, the USDA has invested considerably in rebuilding and improving rural water infrastructure through various grant programs with a baseline interest rate of 1.5%. Most recently, the Water Infrastructure Finance and Innovation Act will provide an estimated $6B in 2019 (on top of the $2B already issued).[14] Some states are providing additional funds to support water infrastructure, such as the 10% budget surplus in Virginia, Proposition One in California ($7.5 billion for water related projects), and the SWIFT program in Texas.

Despite federal and state financial resources, many water systems are struggling to make ends meet. Some utilities are dramatically raising rates to their customers to maintain sufficient revenue to meet debt obligations, as well as ongoing maintenance and operations, let alone the increased costs of replacement or repair of aging infrastructure that are inadequate for current needs. As a result, customers are struggling to pay their water bills, bringing affordability to the forefront of financial considerations. Some utilities are trying to address affordability challenges through tiered volumetric pricing with low prices for basic water usage needs and increasing prices for larger volumes of water associated with discretionary uses. Others, particularly Philadelphia, are experimenting with new rate structures that link water rates to income. Regardless, there is a tremendous amount of innovation and attention needed around ensuring water affordability, as well as equal access to clean water services. Financing water utilities will only become more challenging as baby-boomers continue to retire, resulting in less tax revenue for local, state, and federal governments. The nation will need to adapt to address water infrastructure and affordability challenges with fewer financial resources.

NONPOINT SOURCE FINANCING

The majority of NPS funding comes from the USDA, which supports rural communities of 10,000 or less by forming cooperatives between organizations involved with housing and utilities (telecom, electric, and gas). USDA administers its program largely through their 400 field offices, allowing them to tailor solutions and work with the communities they serve. The USDA has found the presence of councils and working groups to improve outcomes because stakeholder groups are aware of the challenges and engaged in developing holistic solutions. Additionally, USDA has begun engaging and educating local chambers of commerce and mayors, who are often the final decision-makers.

[14] EPA. 2019. EPA Announces new WIFIA Funding for Water Infrastructure.

USDA's Rural Development is the fifth largest bank in the U.S. with a portfolio of more than $200 billion. The Water and Environmental Development branch receives $2 billion annually and provides funding to support water, wastewater, solid waste, stormwater, and surface water, with enormous flexibility in leveraging funding and forming partnerships. The decentralized structure of USDA facilitates building partnerships because they have local offices and live within these communities. They offer tiered interest rate structures depending on financial feasibility with an end goal of graduating borrowers to commercial markets. They can work with private lenders because they have a robust loan guarantee program. They provide grants for tribes, colonias, and disadvantaged communities and have funds dedicated for disaster responses. The USDA can leverage state revolving funds, private dollars, and so on because they have flexibility in their policies and have local partnerships. The USDA will also leverage federal dollars from HUD, Army Corps, EPA, and NRCS to do blended projects that address large-scale issues.

The 2018 Farm Bill provides some revenue to the USDA and NRCS to support NPS pollution best management practices. The 2018 Water Infrastructure Act created a new regulatory instrument that encouraged integrated planning between the CWA and SDWA as community water systems must undertake an assessment of the risks to, and resilience of, its system and source waters.[15]

Local governments, such as the Milwaukee Metropolitan Sanitary District (MMSD) are also engaging in innovative financing options to address NPS pollution. The MMSD has a robust water quality monitoring network that they use to inform land purchases and establish easements to improve water quality. MMSD created a soils program to pay farmers for runoff management and a green infrastructure program to pay municipalities to install green infrastructure. Much of the work to manage NPS pollution is outside of their service area. Traditional funding mechanisms are through ratepayers, taxes, or loans that are constrained to the service area. As such, the MMSD actively pursues non-traditional funding to implement new programs.

MARKET-BASED APPROACHES

Aside from funding basic infrastructure needs, investments are also needed to significantly improve the nation's water quality. The federal government has spent billions on the CWA and SDWA since 1973 without intentional, programmatic monitoring of the impact of those dollars. Technological improvements are making it possible to quantify impact and estimate the highest environmental return on investments, in other words creating viable markets. A market-based approach provides a mechanism to shift from paying for programs and activities to paying for outcomes with accountability (see Box: Delivering Outcomes and Multiple Benefits).

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[15] Water Infrastructure Act. 2018.

Over the past two decades, there has been considerable interest in water quality trading, but few actual transactions. The EPA released a memorandum on Feb 6, 2019 updating their water quality trading policies in an attempt to promote market-based mechanisms. EPA believes that market-based solutions will enable stakeholders to comply with the CWA and achieve greater improvements in water quality at lower cost. EPA believes market-based programs should:

- be optimal at the watershed scales. Water quality challenges will differ across watersheds and a larger geographic area may facilitate more market opportunities not available with smaller, homogenous regions.
- allow for adaptive management to enable adjusting approaches based on their performance at achieving water quality goals.
- allow for banking and future use of water quality credits to encourage early adoption of pollutant reduction strategies and reduce the risk of new approaches that under-perform.
- establish simple and flexible baseline concepts that are clearly understood by the community to create regulatory and market certainty.
- allow a single project to generate credits for multiple markets, encouraging holistic approaches to environmental stewardship (e.g., planting riparian vegetation may simultaneously create credits for cooler water temperatures and carbon sequestration).
- explore innovative financing mechanisms to promote integrated PS and NPS pollutant reduction strategies. These may include program-based mechanisms, such as grants, SRFs, and water infrastructure finance and innovation funds. Funding mechanisms may also shift to outcome-based models such as pay for success, pay for performance, and green bonds.

The memorandum provides significant opportunities for PS and NPS trading. For instance, the Iowa Soybean Association is working with drinking water utilities to improve source water protection. They have largely leveraged USDA funding to get capital onto the landscape because it is much cheaper to treat the source of pollution than to treat pollution in the water. EPA wants to create as much market opportunity as possible to improve water quality in streams and affordability in utilities. They also want to link market opportunities to integrative planning that allows a single activity to produce multiple environmental outcomes and be eligible to receive funding from multiple revenue streams.

DELIVERING OUTCOMES AND MULTIPLE BENEFITS

The Freshwater Trust began in the 1980s to recover fish populations through conservation. In the early 2000's they were not achieving fish recovery. Restoring a stream mile should take a week, but regulatory barriers extend it to a multi-year process. The Freshwater Trust realized there are a limited number of ways to restore a river. They developed a tool that matched solutions with problems and funding; decreasing project completion time by 70%. They also quantified the environmental benefits, creating a portfolio of investable options for funders that show the anticipated impact for each investment. Robust water quality markets require standardized water quality currencies (such as a kilocalorie or a pound of Nitrogen) that can be sold and traded. For example, the Freshwater Trust used their tool to advise a small town in Oregon to plant riparian vegetation at strategic locations to lower the water temperature for their consent decree. This approach achieved multiple benefits as the town spent 32.5% of the costs of the original gray infrastructure approach, water temperatures and fish populations improved along the stream instead of at one location, and by hiring local citizens to plant vegetation they created awareness and generated revenue within the community.

SHIFTING FROM PROCEDURAL- TO OUTCOMES-BASED REGULATION

The last fifty years of the CWA and SDWA have focused on procedural based solutions, such as investing in the best available technology for water treatment. A procedural approach was necessary when the data, science, and technology did not exist to link activities to water quality impacts and water quality impacts to public and environmental health. The science and technology now exist to allow us to shift to an outcome-based approach where investors can buy outcomes (such as pounds of Nitrogen or tons of sediment), creating market opportunities and investment portfolios. The private sector participants were keen on shifting to an outcome-based approach that could lead to higher returns on environmental benefits, and by extension investments. Some industries are shifting towards investing in conservation projects with measurable outcomes that demonstrate how they relate to the industry's business model.

However, several participants voiced concerns. First, the regulated community is protected by agreeing to a process (more likely to succeed) than agreeing to achieve a specific outcome. For instance, DC Water is spending billions on a tunnel (process) to meet their consent decree, but that will not make the Anacostia River fishable or swimmable (outcome). If regulations shifted to outcome-based, DC Water's approach cannot guarantee the river will become fishable or swimmable.

The regulated community cannot afford to make investments that do not provide certainty and safety against litigation.

Second, while the federal government is de-risking innovative, outcomes-based approaches, it is imperative for them to maintain a regulatory backstop or baseline minimum to ensure water quality meets ecosystem and human health requirements.

Third, an outcomes-based approach may create the very silos that the water sector is trying to break down. This approach may improve a single constituent (everyone buys Nitrogen outcomes), but lead to overall water quality degradation because there might be desirable outcomes that produce lower returns on investment or are not currently measured. For instance, if the outcome was to lower stream temperature, you may only invest in riparian vegetation on the south side of streams. However, there may be other benefits, not of interest or measured, by creating habitat on the north side of streams.

There appears to be a shift from "doing good deeds" to "quantifiable deeds" regarding conservation projects as investors seek demonstrable environmental impact in return for capital. Will this create win-wins or will it create greater inequalities and hot-spots of pollution? Should agencies, such as USDA have competing interests of buying environmental performance and holding land titles? How do we navigate the belief that a market-based outcomes approach will solve water quality challenges for all communities in an equitable fashion when prioritizing liberty and efficiency in the past did not protect water quality or public health (Figure 1)? Is an outcome-based approach more viable for currently unregulated communities? Is there a way for outcomes to also be embedded in non-market solutions that place greater emphasis on community and equity? These types of questions must be considered as we embrace market-based approaches to water quality management.

OPPORTUNITIES AND CHALLENGES

CELEBRATE AND COMMUNICATE SUCCESS AND NEGATIVE PUBLIC PERCEPTIONS

Were the CWA and SDWA successful? Largely, yes. However, these successes remain mostly invisible because modern U.S. society often takes clean water for granted. Water systems remain invisible until something breaks, and then the implications, and public perception, can be disastrous (e.g. Flint, MI or Toledo, OH). Similarly, agricultural communities have adopted best management practices to improve downstream water quality, but the benefits of those efforts are largely invisible. Increasing the visibility of these successes is important to build trust in these systems that have been so successful. Public support and behavioral changes can occur through pricing signals, but they can also occur because people understand the importance of an issue and choose to participate. How do we intentionally communicate the complexity of water systems in a manner that resonates with the public and informs their behaviors?

The low public perception of safe drinking water is a significant communication challenge. A growing number of public water customers do not trust the quality of the water coming from their tap. They compensate for this lack of trust by purchasing much more expensive bottled water. It is important to focus on communication and education upfront because it is hard to displace fear and regain lost trust. Communication and education will become increasingly important as technology enables the detection of more things in our water. Just as technology in the medical field allows us to find more things in the body, technology allows us to find more things in our water. At first, we do not know what new findings mean, whether good or bad. For instance, a CT scan for lung cancer only saves the lives of a small fraction of the people who get scans. At the same time, CT scans often find other things – many of which are not life threatening – but result in more tests, more costs, and more worry. How do we balance the risk of looking and finding something in our water with the costs of additional testing, science, treatment and worry that comes when we do not currently have enough information to understand those findings?

SMALL WATER SYSTEMS

While 90% of community water systems meet all SDWA requirements all the time, the other 10% are often small systems with limited capacity to meet regulations or respond to enforcement. The result is that EPA rarely gives a consent decree to small systems because it would lead to bankruptcy and EPA would become responsible for the system. How can EPA distinguish between coming alongside a struggling community and bad actors who are benefitting from non-compliance? Chronically non-compliant systems are not sustainable and pose public health hazards. What does sustainable mean for small, rural community water systems that don't serve a population that can generate sufficient revenue to be financially (and by extension managerially and technically) sustainable? Do we create moral hazards by continuing to provide grant money to support systems that will never be self-sustaining and pose a public health risk?

Small systems may gain capacity if there was a program for larger, resource-rich systems to adopt poor systems and provide managerial, financial, and technical expertise. There might also be a mechanism where smaller systems can piggyback on the retainer fees of wealthier systems, reducing costs. There are some mechanisms provided by federal and state governments to provide such aid. For instance, Texas uses federal dollars for consulting engineers to evaluate small systems and develop capital improvement plans, and they contract with certified public accountants to audit and provide financial advice to small communities. The USDA provides free technical assistance to rural water systems through partnerships with AWWA, and EPA offers some dedicated technical assistance to small systems.

Another approach is the formal consolidation of small systems into nearby systems (public or private). One challenge is that there are no incentives to take on the costs and risks of these small systems. The federal government may provide incentives, such as safe harbors that provide time to reach compliance prior to being penalized, for larger systems to agree to consolidation. State governments are the best situated to incentivize both systems to consolidate. Kentucky is currently doing amazing things with their legislation driving consolidation, reducing their number of community water systems by 59% since 1974.

WHAT IS THE FUTURE VISION FOR WATER QUALITY?

The water quality challenges of the 21st century are increasingly different from those of the mid-20th century. Today, they are more complex, more inter-related, and occur within a rapidly changing society. While the challenges and contexts are more complex, the CWA and SDWA are cornerstone legislations that provide regulatory certainty around point source regulation and drinking water protection. Rather than revamping or fundamentally revisiting the CWA or SDWA through major changes, there are a series of modular changes in the policies and processes embedded within current regulations. The country is facing a diversity of difficult issues in the water space to address the cumulative impacts that have been building for centuries. These chronic challenges are often short-changed as resources are spent to address the most pressing issue each year. The development of agile efforts to put out these emergencies will become increasingly important. Within the context of reactivity, a modular, incremental framework that targets a broad issue can be more readily resourced and able to achieve small, surgical strikes to address emerging challenges. Once there is significant movement around a targeted issue, the focus can shift to the next issue. It is unlikely that a single innovation will create immediate, widespread improvements in water quality. There is no panacea to solve our water quality ills. Instead, the steady accrual of incremental changes will accumulate to achieve greater impacts. A key question is whether this approach will lead to improvements soon enough?

As a nation, many water challenges we face are intractable, but they may be addressable at a local scale through incremental, place-based approaches most often enabled by state and federal governments. This approach could easily cause a return to silos and a focus on efficiency at the expense of the system if governance and markets are not tailored to the scale of the problem (e.g. a river basin). Innovation must occur around existing governance and market structures to overcome the legacy of firm political and market force boundaries to reach the scale of the problem. This solution cannot be within a bureaucracy, but rather must have bureaucracy at the table. Rather than reforming the CWA and SDWA we should innovate around extra-governmental institutions that are spatially compatible with and designed to address specific challenges with mechanisms for transactional learning. If we scale governance to the problem, is there a mechanism to pool compliance at the same scale? For instance, if a watershed must remove 4,000 tons of sediment, can all stakeholders succeed or fail together? Such a decree would incentivize collaboration and efforts to find the most cost-effectively solutions to achieve those reductions. The challenge would be ensuring equity in the process, particularly when addressing private lands and personal decisions. This approach would require not only good science, but also trust and relational capital.

We have an inherent belief that the next problem we solve will be the last problem. We need a new paradigm that acknowledges there will always be problems and encourage new ways to approach problems. A modular, incremental framework implemented at the scale of the problem is more likely to yield long-term improvements and good solutions for today's challenges.

APPENDICES

APPENDIX I: FORUM AGENDA

THE ASPEN-NICHOLAS WATER FORUM

ENSURING WATER QUALITY: ADAPTING THE CLEAN WATER & SAFE DRINKING WATER ACTS FOR THE 21ST CENTURY

May 29 – June 1, 2019
Aspen, Colorado

WEDNESDAY, MAY 29

6:30 – 9:00 PM **Opening Reception and Dinner**
Walter Isaacson Center, Aspen Meadows

THURSDAY, MAY 30

9:00 – 9:15 AM **Welcome and Introductions:**

A brief introduction from the hosts around the focus and goals of the Forum.

Greg Gershuny, Executive Director of the Energy and Environment Program, Aspen Institute

Martin Doyle, Director of the Water Policy Program, Nicholas Institute for Environmental Policy Solutions, Duke University

9:15 – 10:30 AM **Session One: Water quality status and trends**

Prior to the Clean Water Act (CWA), rivers, lakes, and estuaries were often treated as public dumping ground for all manner of waste. The Safe Drinking Water Act (SDWA) followed reports of millions of Americans receiving inadequate drinking water and subsequent illnesses. Both acts have relied on the federal government providing millions of dollars each year to subsidize and sustain public agency efforts to improve and maintain the health of water bodies, and to provide reliable, safe drinking water to the public. What is the current status of water quality in the US? What have the trends been over time?

Discussants:

Water Quality Status & Trends	**Dianna Crilley**, USGS
Drinking Water Status & Trends	**Peter Grevatt**, Water Research Foundation
Ecosystems Status & Trends	**Melissa Ho**, World Wildlife Fund US

Moderator: **Martin Doyle,** Duke University

10:45 AM – 12:15 PM

Session Two: State and local implementation and evolution

In both the CWA and SDWA, the federal government established minimum standards and allowed states to take responsibility for adopting, implementing, and enforcing those standards. Federal agencies would also provide funding and technical assistance to support state compliance and enforcement work. Amendments in the 1980s and 1990s to the CWA and SDWA have significantly added to the breadth and scope of the original legislation, but often failed to clarify roles and responsibilities of the federal, state, and local governments. Since those amendments, the current era and that of the foreseeable future appears to be one of state and local governments spearheading the development of new standards and environmental policymaking in a context of regulatory uncertainty. How are state and local governments meeting regulatory requirements and proactively addressing emerging challenges? How are state and local governments meeting funding and financing gaps created by the escalating costs of regulatory compliance? Can small or financially challenged communities realistically afford the costs to comply with current regulations, let alone treating emerging contaminants?

Discussants:

Challenges of Small/Med Utilities	**Kevin Shafer**, Milwaukee Metropolitan Sewerage District
Agriculture/Rural Perspectives	**Lee McDaniel**, Indian Spring Farm, LLC
State Government Perspective	**April Long**, Water Quality Control Commission & City of Aspen

Moderator: **Radhika Fox**, US Water Alliance

1:30 – 3:00 PM **Session Three: Innovations in private sector and collaborations**

The CWA and SDWA are both technology-focused regulations that require the adoption of best available technology to clean water for discharging or drinking. The regulations focused on technology because the science was not readily available to link the cumulative impact of pollutants to health and ecosystem outcomes. Since the passing of these legislations, the personal computer was invented, internet has revolutionized how we collect and share data, and the big data revolution is well underway. Similarly, new partnerships have allowed meeting water quality goals at lower cost. The capacity to address water quality issues more efficiently and effectively is rapidly evolving. What new technologies exist? Are these solutions more affordable and can they be scaled across the US? What barriers are preventing widespread adoption and implementation?

Discussants:

Stormwater Innovations	**Dax Blake**, EmNet, a Xylem brand
Geospatial Technology	**Christa Campbell**, Esri
Innovations in Agriculture	**Stephan Levitsky**, Perdue Farms
Partnerships for Water Quality	**Paul Wolfe**, Walton Family Foundation

Moderator: **Radhika Fox**, US Water Alliance

FRIDAY, MAY 31

9:00 – 10:30 AM **Session Four: Innovations in policy, funding, and finance**

Since the passing of the CWA and SDWA there have been a number of significant policy and financing innovations at the federal, state, and local levels; as well as innovations by the private sector and NGOs. Many of these innovations have been in interpretation of how major regulations can be implemented and have required strong partnerships between public and private sectors, along with NGOs. These partnerships are necessary to address the risks of failure or non-acceptance by regulators. What have some of these innovations been and what were the enabling conditions? How were policy and funding challenges addressed? Why are some states or localities better able to innovate than others?

Discussants:

Muni-NGO Partnerships	**Kristyn Abhold**, Spring Point Partners LLC
Innovations for Rural Development	**Edna Primrose**, USDA
Municipal Wastewater Innovations	**Edward Henifin**, Hampton Roads Sanitation District
Merging Technology & Policy	**Joe Whitworth**, The Freshwater Trust

Moderator: Martin Doyle, Duke University

10:45 AM – 12:00 PM

Session Five: 50 years of regulation: what has worked, and what hasn't?

The political landscape of 2019 is drastically different from what was present 50 years ago when the canon of water quality regulations were being developed. After a half-century of implementation, one might say the CWA was successful in that rivers no longer catch fire and the SDWA has resulted in overall improvements in utilities providing safe drinking water. Can we say, then, that these regulations fulfilled their intended goals? Are these regulations meeting current water quality challenges, from accumulation and interaction of pollutants to the emergence of new contaminants? Are they financially sustainable? What are realistic expectations of the federal government in water quality, whether for emerging challenges or funding shortfalls?

Discussants:

Water Quality & Water Supply	**Timothy Petty**, DOI
Ag & Rural Perspective	**Bill Northey**, USDA
CWA & SDWA Implementation	**David Ross**, EPA

Moderator: **Martin Doyle**, Duke University

6:30 PM

Optional Participant-Led Thematic Dinners

Reservations have been made at restaurants in town to facilitate the following thematic discussions in small groups:

A. Future of wetlands, streams, and ecosystems
B. Future of agriculture and NPS regulation
C. Future of equity and affordability
D. Future of emerging risks to drinking water and public health

SATURDAY, JUNE 1

9:00 – 11:00 AM **Session Six: What is the vision for the future of water quality?**

The fiftieth anniversary of the CWA and SDWA are a few years away. The current political, technological, societal, and environmental contexts are radically different from fifty years ago. The CWA and SDWA were cutting-edge, technology focused legislation for their time. Yet, these regulations are insufficient, filled with uncertainty, and rigid for today's challenges and opportunities. Could it be possible to engage in precision regulation, allowing for more experimentation and innovation that are cross-sectoral and perhaps more cost efficient and effective? Can we adequately assess the risk of such efforts? Can we afford not to? Amidst such staggering transformations, how can regulation keep pace with change and ensure the quality of our water is sufficiently protected across a wide variety of uses?

Moderator: **Martin Doyle**, Duke University

Forum Adjourns

APPENDIX II: FORUM PARTICIPANTS

Kristyn Abhold, Water Sustainability Program Officer, Spring Point Partners LLC

Jerad Bales, Executive Director, Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)

Belgin Baser, Water Business Manager, Schlumberger

Dax Blake, Client Program Strategist, EmNet, a Xylem brand

Alan Boyce, Executive Chairman & Co-Founder, Materra, LLC

Eric Braun, Water Resources Manager, Town of Gilbert, Arizona

Peter Brooks, Senior Advisor, Ginkgo Bioworks

Christa Campbell, Industry Specialist (Water), Esri

Mark Canavan, Director- Real Assets, New Mexico Educational Retirement Board

Robyn Colosimo, Strategic Advisor, Office of the Assistant Secretary of the Army (Civil Works)

Dianna Crilley, Deputy Director, Office of Planning and Programming, USGS Water Resources Mission Area

Disque Deane, Co-Founder, Water Asset Management

Michael Deane, Independent Consultant

Sheila Deely, Assistant General Counsel – Environmental, Freeport-McMoRan Inc.

Nicholas Dilks, Managing Partner, Ecosystem Investment Partners, LLC

Greg DiLoreto, Chair, American Society of Civil Engineers (ASCE) Committee for America's Infrastructure

Matthew Diserio, Co-Founder and President, Water Asset Management

Martin Doyle, Director, Water Policy Program, Nicholas Institute for Environmental Policy Solutions, Duke University (*moderator*)

Alex Echols, Program Director – Agriculture, Keith Campbell Foundation for the Environment

Kirsten Evans, North America Urban Water Director, The Nature Conservancy

Tera Fong, Director, Performance Integration & Delivery, DC Water

Radhika Fox, CEO, US Water Alliance (*moderator*)

Peter Grevatt, CEO, Water Research Foundation

Maurice Hall, Associate Vice President for Ecosystems – Water, Environmental Defense Fund

Kerry Harpole, Corporate Water Management Advisor, Marathon Oil Company

Edward Henifin, General Manager, Hampton Roads Sanitation District

Melissa Ho, Senior Vice President, Freshwater and Food, World Wildlife Fund US

Scott Houston, President, West Basin Municipal Water District

Ingrid Irigoyen, Deputy Director, Aspen High Seas Initiative, The Aspen Institute

Peter Lake, Chairman, Texas Water Development Board

Stephan Levitsky, Vice President of Sustainability, Perdue Farms

April Long, Clean River Program Manager, City of Aspen; Member, Water Quality Control Commission

Martin Lowenfish, Branch Chief, Areawide Planning, USDA National Resources Conservation Service

Shelley Luce, President & CEO, Heal the Bay

Matthew Mahoney, Vice President, SUEZ North America

Felicia Marcus, Former Chair, California State Water Resources Control Board

Lee McDaniel, Owner/Operator, Indian Spring Farm, LLC

Bill Northey, Under Secretary for Farm Production and Conservation, United States Department of Agriculture

Lauren Patterson, Senior Water Policy Associate, Nicholas Institute for Environmental Policy Solutions, Duke University (*rapporteur*)

Margaret Peloso, Partner, Vinson & Elkins LLP

Helen Petach, Senior Science Advisor, Global Health, U.S. Agency for International Development

Timothy Petty, Assistant Secretary for Water & Science, Department of the Interior

Amy Pickle, Director of State Policy, Duke University

Edna Primrose, Assistant Administrator, United States Department of Agriculture

Tim Profeta, Director, Nicholas Institute for Environmental Policy Solutions, Duke University

Thomas Richichi, Principal, Beveridge & Diamond, PC

Terese Richmond, Partner, Van Ness Feldman

Adam Riggsbee, President, RiverBank Conservation, LLC

David Ross, Assistant Administrator, Office of Water, Environmental Protection Agency

John Sabo, Director, Future H2O, Knowledge Enterprise Development, Arizona State University

Andrew Sawyers, Director of the Office of Wastewater Management, Environmental Protection Agency

Kevin Shafer, Executive Director, Milwaukee Metropolitan Sewerage District

Bill Teichmiller, CEO, EJ Water Cooperative

David Totman, Director of Asset Management, Innovyze

Michael Warady, Senior Advisor, Ginkgo Bioworks

Emily Warren, Water Program Officer, The Cynthia and George Mitchell Foundation

Joe Whitworth, President, The Freshwater Trust

Paul Wolfe, Program Officer, Walton Family Foundation

THE ASPEN INSTITUTE

Greg Gershuny, Executive Director, Energy & Environment Program, The Aspen Institute

Anna Giorgi, Assistant Director for Environment & Climate, Energy & Environment Program, The Aspen Institute

Kate Henjum, Program Associate, Energy & Environment Program, The Aspen Institute

APPENDIX III: ACRONYMS

Army Corps	Army Corps of Engineers
AWWA	American Water Works Association
BMP	Best Management Practice
BoR	Bureau of Reclamation
CSO	Combined Sewer Overflow
CWA	Clean Water Act
EPA	Environmental Protection Agency
HRSD	Hampton Roads Sanitation District
MMSD	Milwaukee Metropolitan Sanitation District
MS4	Municipal Separate Storm Sewer System
NGO	Non-governmental Organization
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Services
PS	Point Source
PWS	Public Water System
SDWA	Safe Drinking Water Act
TMDL	Total Maximum Daily Load
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WIFIA	Water Infrastructure Finance and Innovation Act