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Water Diplomacy: A Negotiated Approach to Manage Complex Water Problems

*Shafiqul Islam[1,2] and Amanda C. Repella[1]

[1]*Civil & Environmental Engineering, Tufts University*
[2]*Fletcher School of Law and Diplomacy, Tufts University*
**Corresponding Author*

Abstract: Many water management decisions have evolved from addressing simple problems, such as accessing water near its source, to complex problems of managing and allocating water in the face of multiple and competing demands in the natural, societal and political domains. The Water Diplomacy Framework (WDF) is emerging as an alternative to traditional techno- or values-focused approaches to water management. The WDF is an approach that diagnoses water problems, identifies intervention points, and proposes sustainable resolutions that incorporate diverse viewpoints and uncertainty as well as changing and competing demands. As such, WDF rests upon diverse forms of contextual inquiry of and intervention in complex water problems, with negotiation functioning as the fulcrum of diagnosis and intervention. Several case studies from this volume are used to highlight the utility of this framework for understanding and managing complexity, uncertainty and contingency when addressing complex water problems. We invite the reflective water community to identify and analyze water case studies - from different places, settings, and scales - that will contribute to our collective effort of developing actionable approaches to manage complex water problems in our AquaPedia database.

Keywords: *complexity, contingency, uncertainty, emergence, AquaPedia*

Today we face an incredibly complex array of interconnected water issues that cross multiple boundaries: Is water a property or a human right? How do we prioritize between economic utility and environmental sustainability? Do fish have more rights to water than irrigated grain? Can we reconcile competing cultural and religious values associated with water? How much water do people actually need? Many of the questions raised above share two key defining characteristics: (a) competing values, interests and information to frame the problem; and (b) differing views - of how to resolve a problem - are related more to uncertainty and ambiguity of perception than accuracy of scientific information. In the public policy world, problems with these attributes are called wicked or complex problems (Rittel and Weber 1973; Islam et al. 2010).

Over-utilization of easily available water resources is creating constraints on our planet. We can debate the nature and implications of those constraints and how they are manifested across water, energy, food, climate change, and nano-, bio-, and info- sectors; but these constraints are creating an uncertain water future. Water, as a limited resource, lends itself to conflicts over how it should be allocated, managed and prioritized for use. While scientific formulation and engineering solutions are needed to address to find technical solutions to some of these complex water problems; effective synthesis of societal and political solutions have not been an integral part of long-term and adaptive resolutions of many of these complex water problems. Water security concerns combined with uncertainty associated with water availability and access create contentious arguments over water allocation for human needs, agriculture, development and ecosystems.

Our challenge is how to translate solutions that emerge from science and technology into the messy context of the economy and politics. In this edited volume, we hope to address this challenge by seeking linkages across domains and scales that will

allow us to understand the nature and scope of the complexity that defines the management of water resources. These linkages involve the competition, interconnections, and feedback among variables, processes, actors and institutions.

In this paper, we show how water management has evolved from addressing simple to complex problems. Many of our contemporary and emerging water problems are complex. We need to define what makes a class of water problems complex and how to resolve competing and often conflicting needs inherent to these complex water problems. We hope to show that the Water Diplomacy Framework (WDF) is emerging as an alternative to traditional techno- or values-focused approaches to water management problems. The WDF diagnoses water problems, identifies intervention points, and presents sustainable solutions that are concurrently sensitive to diverse viewpoints and uncertainty as well as changing and competing needs of the stakeholders (Islam and Susskind 2012). The WDF actively seeks value-creation opportunities by blending science, policy, and politics in innovative and contextually appropriate ways.

This overview sets the stage with an informal discussion of the evolution of water management problems and provides an overview of the Water Diplomacy Framework before providing examples for how complexity, uncertainty, and contingency are addressed with specific examples from the papers included in this issue.

Water Management: A Historical Look and an Alternate Perspective

In ancient societies, water management was hyper-local. As settlements grew into cities, new water sources and water storage were needed; canals and cisterns were developed, expanding the scale of water management to regional scales. Industrialization led to a surge in urban populations and a need to address water on a larger scale - to ensure supply of water by introducing national scale policies and institutions. These policies and institutions have led to modern water infrastructure and provided the quantity, quality and reliability of water supply that many enjoy today. Yet, there is a global recognition that this sectoral water management approach is fragmented and needs to be integrated across usages, sectors, scales, and institutions. However, as the complexity of meeting competing needs across multiple sectors and the claims to water by multiple stakeholders - including the needs of ecosystems - grow, this conventional approach has reached its limits for many reasons. Therefore, multi-level management of water resource problems - that is adaptable to an uncertain and changing future - is needed.

We can examine the historical evolution of water management problems using the simple-complicated-complex lens to understand how different types of water problems require different management strategies (Table 1). The first water management problems were simple and solved at the community and household levels by bringing water from the source to the place of use via simple diversions or shallow wells. Water could be directly collected and put to immediate use. As society grew and water needs changed, the challenge of providing water management became complicated. In Boston, this began in the mid-19th century when small reservoirs within the cities could no longer support the water needs of the growing population and a reservoir/canal system was built to transfer water from 30 km away to the city (MWRA 2014).

Table 1. Different types of problems require fundamentally different responses.

Problem Type	Definition
Simple	Cause-effect relationships are well-understood; best management practices are effective.
Complicated	Cause-effect relationships are not straightforward; range of possible solutions are possible for a given management intervention; analysis and intervention requires experts with contextual knowledge.
Complex	Cause-effect relationships are ambiguous; uncertainty, nonlinearity and feedback are inherent; emergent properties dominate system behavior and response.

Supplying the water to the growing city became more complicated as additional reservoirs were connected via canals. Finally, in the early 20th century, the large Quabbin reservoir was built outside of Boston's watershed to meet Boston's regional water needs. Building the Quabbin reservoir transformed the complicated engineering challenge to a complex water problem as four towns were selected to be eliminated and inundated to create the reservoir. How do we reconcile the rights of people from those four towns with the competing development agenda for Boston to grow? This is not a scientific question with a precise and predictable answer. Resolution of this class of complex water problems with conflicting needs requires a different framework. The Water Diplomacy Framework is a step in that direction.

Water Diplomacy Framework

The WDF begins by asking "Know Why" before prescribing "Know How" (Figure 1). In other words, the WDF makes a distinction among values, interests, and tools and suggests ways of thinking about these issues before prescribing a solution. Values are the deeply held beliefs that shape how people view the world. These values include economic, political, cultural, religious, and ethical considerations. For example, religious values shape stakeholders' perspectives on water such as regarding a water source (such as the Ganges) as sacred; values can prioritize a desire to preserve a way of life that relies on access to a water source and its ecological productivity; or even lead to viewing access to water as a basic human right. Interests on the other hand are the reasons and objectives that underlie positions that develop to secure or advance the values held by stakeholders. In the context of negotiation - interests are the "why" behind the "what" sought by a stakeholder (e.g., Fisher et al. 1991). An example of an interest common to water negotiations is the desire to support a robust agricultural sector; this will require a discussion of tradeoff among competing uses of water for multiple sectors. Finally, Tools are the techniques and processes that can be used to answer specific questions in support of understanding the range of outcomes that are possible from a policy, management, or infrastructure based intervention. Tools such as optimization, cost-benefit analyses, and scenario analysis can aid decision making for complex problems, but cannot provide sustainable solutions.

It follows that beginning from a "know-why" perspective allows the examination of how values and interests shape the definition of a water problem, which in turn influences how tools are employed to explore pathways for resolutions (Figure 1). For example, for a complex problem similar to the construction of the Quabbin reservoir and elimination of four cities, the WDF begins by involving relevant stakeholders to discuss and agree on what values and interests need to be recognized and how to arrive at a set of tools to resolve their competing and conflicting needs.

For centuries we have taken nature apart and analyzed its components in ever-increasing detail (de Weck et al 2011; Miller and Page 2007). Now we realize that this process of "reductionism" provides limited insight. We recognize that a system is more than the sum of its parts and that "systems engineering" only works well when systems are

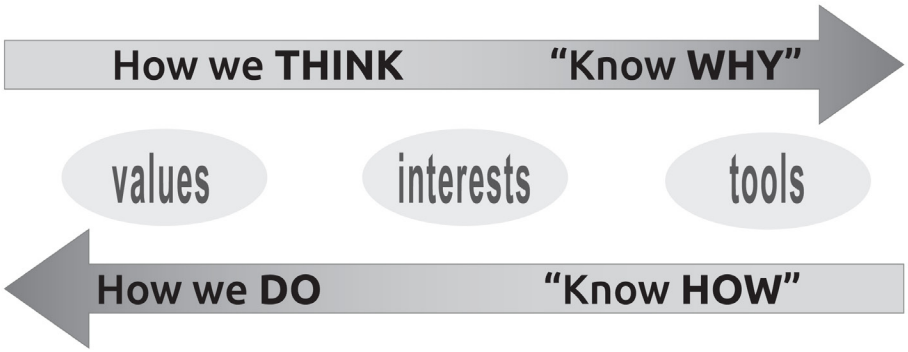


Figure 1. *Know Why vs. Know How* - a distinction between roles of values, interests and tools in the processes of understanding (*how we think*) and determining appropriate action (*how we do*).

bounded and cause-effect dynamics are known (de Weck et al 2011). For open and purposeful systems like water resources management, where system boundaries are ill-defined and cause-effect relationships are ambiguous, an indiscriminate use of the systems engineering approach can provide little insight (Kauffmann 1993; Barabasi 2003; Miller and Page 2007). A key difference - between addressing predictable systems (simple and complicated) and complex systems - lies in our differential capacity of understanding and managing them. We can understand and optimize simple and complicated systems by taking them apart and analyzing the details; however, we cannot understand and manage complex systems by applying a reductionist strategy. A failure to appreciate this difference could cause us to apply exactly the wrong approach to the right water problem or the right approach to the wrong problem. In general, continued efforts to refine existing tools like cost-benefit analysis and optimization algorithms to address complex problems have not worked when systems are complex (e.g., Ackoff 1979; Bennis et al. 2010; Stiglitz et al. 2010). While best practices can be used to address simple problems (such as the design of a household's water system) and systems engineering can be used for complicated problems (such as meeting domestic water demand within a water distribution system for a city), these tools are not suited for complex problems. We need a different approach to address complex water management problems.

Complex problems are ill-defined, ambiguous, and often associated with strong moral, political and professional values and issues. For complex water problems, certainty of solutions and degree of consensus varies widely. In fact, there is often little consensus about what the problem is, let alone how to resolve it. Furthermore, complex problems are constantly changing because of interactions among the natural, societal and political forces involved. Addressing these problems requires a differentiation between systems thinking and systems engineering. Systems thinking remains useful for systems containing feedback loops, uncertainty and poorly understood relationships between and among parts and the whole; however, systems engineering requires a clear understanding of the system, its boundaries, its interactions at those boundaries (inputs/outputs), and the ways in which perturbing parts of the system will change outcomes and flows.

A complex adaptive systems (CAS) approach is more appropriate for managing complex water problems than a typical systems engineering approach (de Weck et al 2011; Miller and Page 2007). CASs are characterized by non-linearity and interdependency, in which small changes can create large impacts. Complex behaviors from these systems can emerge from simple rules applied locally within a CAS. Managing a CAS requires co-production of knowledge because co-evolution is inherent in the system through the process of emergent possibilities.

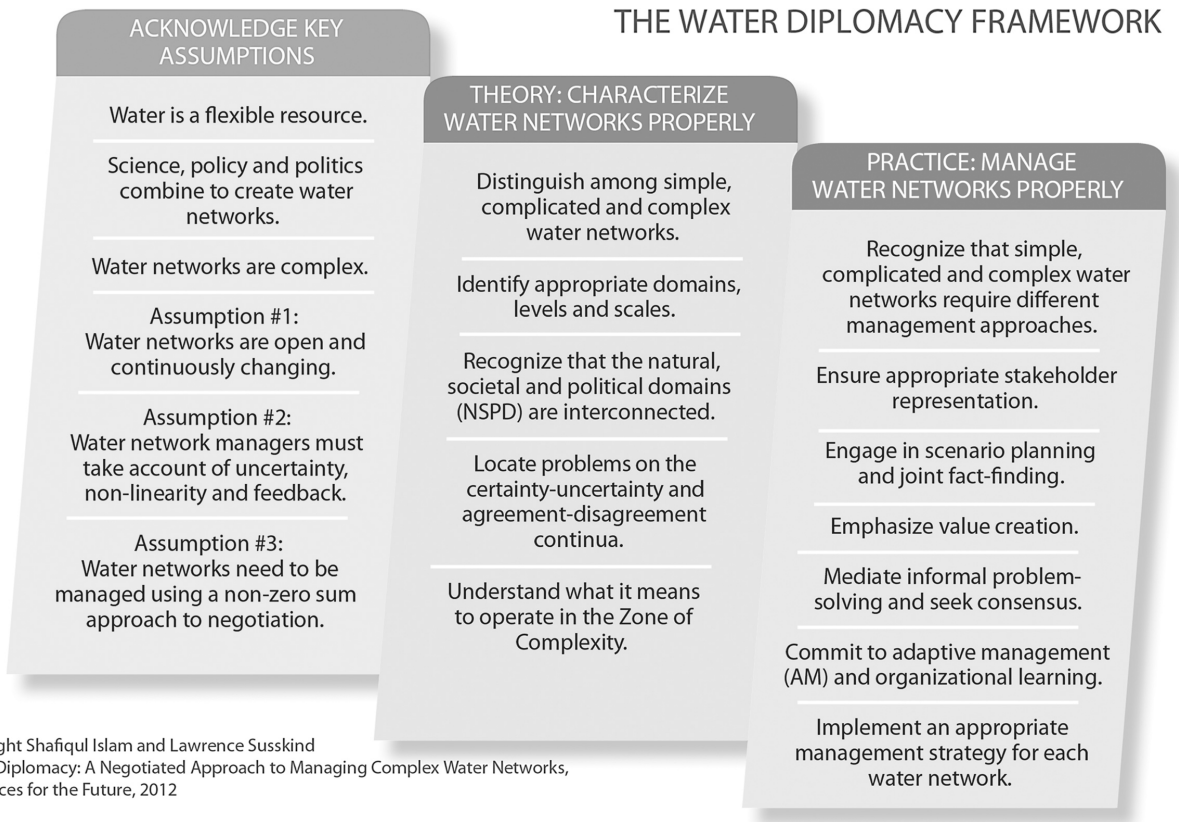
A watershed is a common unit of analysis for assessing inputs and outflow for a water resource and traditional water management - for example, integrated water resource management (IWRM) - advocates for basin level resource characterization and management (Agarwal et al 2000). However, a watershed may not always be aligned with "problem-shed" and "policy-shed" for effective and efficient management for a given water problem (Islam and Susskind 2013). Cohen and Davidson (2011) argue that there are at least five recognized challenges associated with the watershed approach to water resource management: the difficulties of boundary choice, accountability, public participation, and asymmetries with "problem-sheds" and "policy-sheds".

Complex water problems cross multiple domains (natural, societal, political) at different scales (space, time, jurisdictional, institutional), and aspects of these problems occur at different levels within each scale (e.g., short or long term duration, extent across a city, within an organizational hierarchy). The interactions between domains or scales at various levels contribute to the complexity of a water system and preclude solutions that were applicable for simple and complicated systems.

Water Diplomacy's related initiatives are rooted in ideas of complexity theory as well as mutual gains approaches to arriving at a negotiated resolution in the midst of competing and conflicting water needs. A key goal of the Water Diplomacy initiatives has been to refine and test a framework to facilitate the production and use of "actionable knowledge" for the characterization and management of complex water problems.

Bridging Theory and Practice: Managing Complexity and Uncertainty

The Water Diplomacy Framework (Figure 2) is emerging as an alternative to the conventional ways of addressing boundary-crossing water management problems (Islam and Susskind 2012). The WDF challenges conventional thinking about water management in three important ways: (1) it assumes water is a flexible not a fixed resource; (2) science, policy and politics combine to create water networks; and (3) water networks are complex and need to be treated as open-ended and unpredictable rather than closed and predictable systems. The three key assumptions embedded in the WDF have important consequences for how water disputes should be approached. In Figure 2, we present the WDF, including the theoretical basis of the framework and a guideline on how to apply the framework in practice. Our effort to theorize about water systems has been vast, but the set of tools and techniques available to pursue and implement these theories in practice has often led to a science that is "smart but not wise." This is because we do not have the tools and techniques to integrate our "scientific learning" with the "contextual reality" of water problems that are filled with uncertainty, ambiguity, nonlinearity and feedback. Yet, solutions to most real world water problems demand integration of such contextual realities with scientific knowledge. The promise of policy science to provide useful prescriptive advice, and its failure to do so, has led to the recognition of the need to bridge the divide between "theory and practice," or between "know-why" and "know-how." The most significant insight that policy science has generated from its inability to effectively integrate theory and practice is an understanding that the problems that must be addressed in a public policy context are not like the problems for which the tools of systems engineering or optimization were designed. This realization is often conveyed in terms of the "messiness" or "wicked" nature of the problems that arise when science, policy, and politics are intertwined with uncertainty, ambiguity, nonlinearity, and feedback



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Figure 2. The Water Diplomacy Framework.

loops (e.g., Rittel and Webber 1973; Bar-Yam 2004; Milly et al. 2008; Orlove and Caton 2010).

The problem identification phase - simple, complicated and complex - sets the stage to describe and bound the range of certainty or consensus and defines the types of effective and efficient approaches to address a problem (Figure 3). Simple problems are amenable to optimization because they involve easily identified and neatly bounded elements of water management systems that respond in predictable ways and pose challenges about which there is almost complete agreement with regard to means and ends. Complicated water management problems involve water systems that operate in somewhat unpredictable ways or those in which the means and ends of action are contested. Complex water management problems lie in the zone between certainty and uncertainty and between agreement and disagreement; managing problems in this zone of complexity requires reliance on network theory and the theory of multiparty negotiation.

In our assessment, water management problems such as allocating supplies among contending interest groups or deciding whether to deploy a new technology that might "expand" water supplies, but at the same time could jeopardize water quality, fit into the complex category. Approaches to address many complex water management problems lie somewhere between certainty and uncertainty, defining the "zone of complexity." The dynamics in this zone is neither entirely certain nor uncertain. Agreement about means and ends is far from clear, but within reach if the right procedures are followed. Complexity Theory - drawing on assumptions about nonlinearity, emergence, interaction, feedback, mutation and adaptation - can be used to identify the parameters of management problems that fall into this zone of complexity. Problem solving in this zone is distinct from what works in simple and complicated settings. Below, we discuss features of several papers from this volume regarding different ways WDF has been applied in practice.

The ideas of Water Diplomacy are emerging as an alternative framework because conventional approaches appear to be not flexible and adaptable enough to address complex problems with multiple sources of conflicts involving values, interests, risks, and uncertainty. Through synthesis of student perspectives from the Water Diplomacy program at Tufts, Read and Garcia (2015) offer a case study illustrating the benefits and challenges of the interdisciplinary graduate education in addressing complex water issues with competing and conflicting needs. While students in the Water Diplomacy program come from very different backgrounds and apply different research methods, they share a common perspective shaped by four principles: the importance of both values and science in addressing complex water problems; the need to recognize the importance and limitations of disciplinary lenses; a

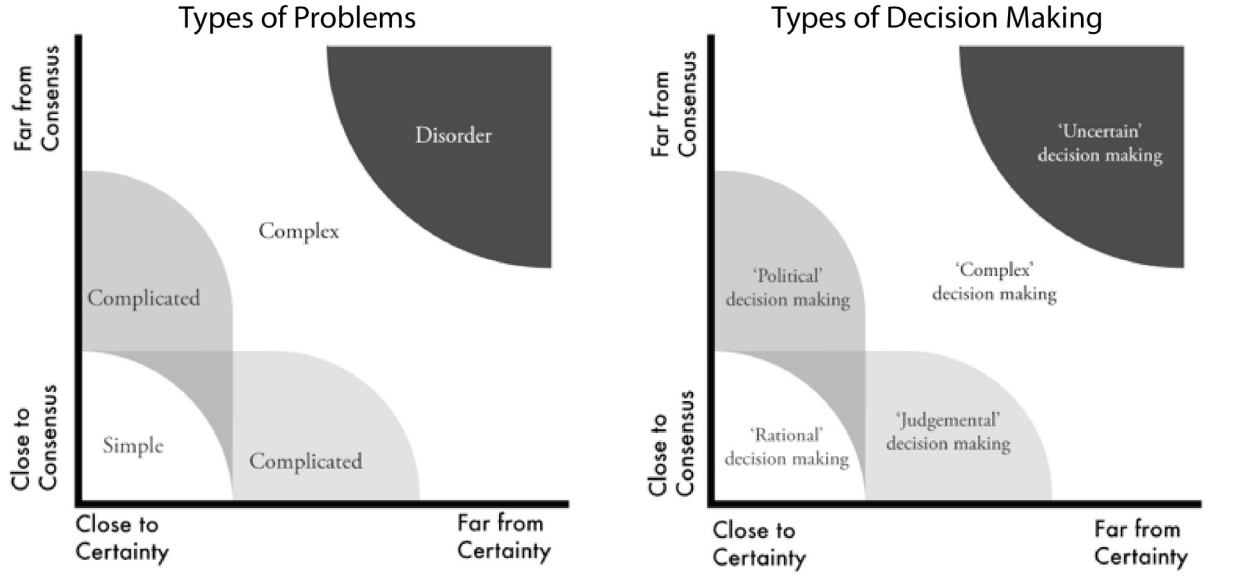


Figure 3. Degree of certainty and consensus: a lens to describe different types of decision making for different types of problems (Islam and Susskind 2012).

deep appreciation of understanding, characterizing and modeling water systems as complex adaptive systems; and an overarching goal of producing actionable knowledge with measurable outcomes despite inherent uncertainties.

Read and Kuhl (2015) discuss centrality of risk across a range of water problems and suggest that effective resolution of these problems necessitates interdisciplinary consideration of risk and risk management. They have highlighted the importance of risk-related challenges and management approaches for several water problems including water quality, water allocation agreements, climate adaptation planning, and infrastructure investments. From the articles reviewed, they have noted that understanding and managing risk did not feature in the discussion of key capacities for a water professional, or components of a water curriculum. This is a critical gap that needs to be addressed to prepare the next generation of water professionals.

Van Rees and Reed (2015) provide a case study from O'ahu, Hawaii in which water management focused on freshwater availability for municipal or irrigation use - at the expense of systems that rely on runoff or infiltration - such as aquifers, near-shore fisheries, coral reefs and wetlands. By neglecting systems that rely on runoff or infiltration (and stakeholders in these systems), problems that were viewed as ranging from simple to complicated - maximizing the availability of freshwater through technological means for growing urban development - grew to complex issues with poor quality runoff impacting near-shore ecosystems and increased flood risk due in part to land development-related wetland loss. They argue that a "zero-sum" perspective treating ecological water needs as constraints to management and overly simplistic and phenomenological data may not properly describe system behavior to design and implement effective intervention strategies. They provide an intuitive method for integrating ecological factors into the WDF by treating ecosystems, focal species, and other ecological phenomena of interest as "surrogate stakeholders" as part of the negotiations approach of the WDF. This increases opportunities for discovering mutual-gains solutions to water management conflicts involving ecological factors and encourages a hypothesis-based, deductive approach to research on the ecology of water management. By differentiating between the "positions" and "interests" of ecological stakeholder surrogates, water decision-makers can make greater use of the potential added value of ecosystem services in water management and avoid costly misunderstandings of the behavior of ecological systems affected by management.

Opportunities to examine and address water problems using the WDF continue to expand as we face increasing recognition that we must identify and address sources of uncertainty in complex water problems through negotiated agreements or management policies. Agreements on water made 50 years ago - such as the Columbia Water Treaty discussed in Brady et al. (2015) or the Indus Waters Treaty discussed by Choudhury and Islam (2015) - could not anticipate emerging issues that are of importance today, such as climate change, changing water needs with population growth and agricultural expansion, or the true breadth of stakeholders and their interests. Consequently, new approaches are needed to address emerging complex water management challenges where values, interests, and position are intertwined. Once one starts "unpacking" a complex problem for possible solutions or remedial actions, the solution space becomes practically unbounded. Debates about what to do are not likely to end because there are no definitive solutions given the endless variability of problem definitions based on values, interests and perceptions. The only way to effectively address (not solve) complex problems is to design a decision-making process that can produce politically legitimate and tentative (rather than once-and-for-all or one-size-fits-all) prescriptions. This implies that concerns about water stress will give rise to normative debates (e.g., Water for whom? At what cost?). While science can help inform these debates, technical inputs will not solve them.

Choudhury and Islam (2015) focus on a particular class of complex water problem: allocation of transboundary water (TW). They argue that two universally emerging goals - sustainability and equity - provide the normative anchors to address the values and interests of the stakeholders involved in managing complex TW problems. The nature and resolution of TW issues need to be understood as complex and contingent because of dynamic and contextual changes occurring in the knowledge

and political communities as well as those that are inherent in the interaction among variables and processes operating within these two communities.

Brady et al. (2015) contribute to understanding transboundary water agreements by analyzing the Columbia River Treaty renegotiation from the perspective of contract theory. They demonstrate the importance of the concept of contract completeness in identifying efficient contractual arrangements that can consider the tradeoffs of increased flexibility. The limited objectives of the first treaty - signed in 1961 - meant that it was possible to write a complete contract. Climate change and more complex stakeholder interests have moved any future agreement into the realm of incomplete contracts. Alternative types of incomplete contracts may be considered as potential future treaty arrangements. The approach suggested by Brady et al. (2015) has the potential to provide a more general framework for working through potential treaty designs for emerging wicked water problems.

On a similar note, Koebele (2015) suggests that to address complex water issues, collaborative governance of water resources is emerging as a widespread strategy that develops solutions that integrate diverse stakeholder needs and create consensus-driven solutions. She emphasizes that linking the outcomes of collaborative processes to improved water sustainability is difficult because of a multitude of scales and settings. Using data from 28 in-depth interviews with key participants involved in Colorado's statewide water plan, Koebele (2015) highlights not only what outputs and outcomes may be produced through a high-stakes collaborative process, but also what barriers exist to actualizing the outcomes desired by stakeholders. Gaining a better understanding of outputs, outcomes, and barriers from similar case studies related to collaborative water governance process can provide insight into improving future decision-making processes and stakeholder participation for a variety of complex water problems.

For instance, Abdelhady et al. (2015) describes the diverse stakeholders, issues and interests in the construction of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile. While the historical political relationship between Ethiopia and Egypt impacts their discussions of use of the Nile water; the conversation about the GERD changes at different scales - the everyday politics occurring at the local scale of communities impacted by the project, the national scale within Ethiopia and at international and global scales through its impacts on the Nile system and transboundary use of Nile water (Abdelhady et al. 2015).

Aytur et al. (2015) proposes adaptive governance as a distinct framework that explicitly focuses on decentralized decision-making through social processes such as collaborative learning, networking, and promotion of cross-sectoral partnerships to enhance adaptive capacity. They explore an ongoing engagement process for climate change adaptation planning in Exeter, New Hampshire, and its alignment with key characteristics of adaptive governance. They demonstrate the importance of synchronizing modeling activities with a portfolio of engagement strategies to meet the needs of diverse stakeholders and emerging complex water problems.

Looking Forward

Issues related to water access, need, usage, and management are recognized as complex due to the crossing of multiple boundaries: political, social, and jurisdictional, as well as physical, ecological and biogeochemical. Sustainability and equity are emerging as two globally acceptable normative anchors to address values and interests of stakeholders involved in resolving complex water problems. These normative anchors provide overarching principles to guide water management strategies; however, given the contextual nature of complex water issues, neither can be pre-specified. They need to be debated and negotiated through an open participatory process, as they are contingent upon the issues and the stakeholders involved in a water conflict.

This volume provides multiple examples and perspectives on issues, challenges, and opportunities to develop a consistent framework to effectively diagnose and manage emerging complex water problems. The Water Diplomacy Framework is used as an example to demonstrate how values, interests, information, and tools need to be synthesized to address complex water problems. The WDF facilitates the process of resolving water conflicts involving multiple stakeholders with conflicting

or divergent interests and issues encompassing substantial scientific and political uncertainty by finding creative sustainable options that ensure mutual gains.

We invite the reflective water community to help us identify, characterize, and analyze water case studies - from different places, settings, and scales - and build an actionable theory of managing complex water problems guided by globally emerging normative anchors of sustainability and equity that is deeply informed by practice and complexity of local conditions.

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Author Bio and Contact Information

Shafiqul Islam is a professor of civil and environmental engineering and a professor of water diplomacy at the Fletcher School of Law and Diplomacy at Tufts University, USA, and director of its Water Diplomacy Program (http://waterdiplomacy.org/). His research interests include the availability, access, and allocation of water within the context of climate challenges, health, and diplomacy, using solutions based upon complexity theory and mutual gains. He is a consultant for several national and international organizations as well as for governmental agencies, on topics such as flood forecasting in India, national water planning in Bangladesh, and water initiatives in South Asia. He can be contacted at Shafiqul.Islam@tufts.edu.

Amanda Repella is the Water Diplomacy Global Network Coordinator at Tufts University. She can be contacted at Amanda.Repella@tufts.edu.

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