Water 2100: A synthesis of natural and societal domains to create actionable knowledge through *AquaPedia* and water diplomacy

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Abstract Water issues are complex because they cross multiple boundaries and involve various stakeholders with competing needs. The origin of many water issues is a dynamic consequence of competition, interconnections, and feedback among variables in the natural and societal domains. When viewed as a limited resource, water lends itself to destructive conflicts over its division; knowledge of water, however, can transform a finite water quantity into a flexible resource. To generate such a transformative knowledge base for water, we need a framework to synthesize explicit (scientific) and tacit (contextual) water knowledge. Such a framework must build on scientific objectivity and be cognizant of contextual differences inherent to water issues. Water 2100 builds on this framework to develop an interactive, searchable, web-based repository of water case studies from across the world, called *AquaPedia*, that will facilitate the sharing of water knowledge and promote discussion among stakeholders to resolve wicked water problems through negotiated solutions.

Key words water diplomacy; *AquaPedia*; actionable knowledge; synthesis

CROSSING MULTIPLE BOUNDARIES: A WICKED WATER PROBLEM

Water problems are complex, not only because they involve various stakeholders (e.g. farmers, industrial users, urban developers, environmental activists) competing for a limited and common resource, but also because they cross multiple boundaries (e.g. physical, disciplinary, jurisdictional). As a result, there is rarely an acceptable solution for water problems with multiple objectives and competing needs.

Water resources are increasingly over-used, water quality is sub-optimal, and ecological integrity is excessively strained. Many water-related problems are framed from a contested terrain in which various actors (individuals, communities, businesses, NGOs, states and countries) compete to protect their own and often conflicting interests. Most water problems are typically local in nature; however, water policies are formulated for and impacted by a range of local, regional, national, and international scales. Although significant local knowledge exists for a variety of water issues, it is neither readily accessible nor easily transferable to other regions.

We argue that the origin of many water problems may be understood as a dynamic consequence of competition, interconnections, and feedback among variables in the Natural and Societal Domains (NSDs) as shown in Fig. 1. Within the **natural domain**, we recognize that triple constraints on water – quantity (Q), quality (P), and ecosystem (E) – and their interdependencies and feedback may lead to constraints and conflicts. Such inherent and multifaceted constraints of the natural water system cannot be easily separated from societal domain variables. Within the **societal domain**, interdependencies and feedback among social values and norms (V), economy (C), and governance (G) interact in a variety of ways to create intractable contextual differences (Gao *et al.*, 2009).

The observation that natural and societal domains are linked is not novel. Our argument here, however, is that business as usual with strong disciplinary boundaries between these two domains will not produce answers to wicked water problems arising from the coupled NSDs. Currently, a commonly accepted vocabulary and framework that can translate information between natural and societal domains to derive synthesized water knowledge does not exist. A key goal of Water 2100 is to create a framework and a network of students, faculty, external partners and stakeholders to

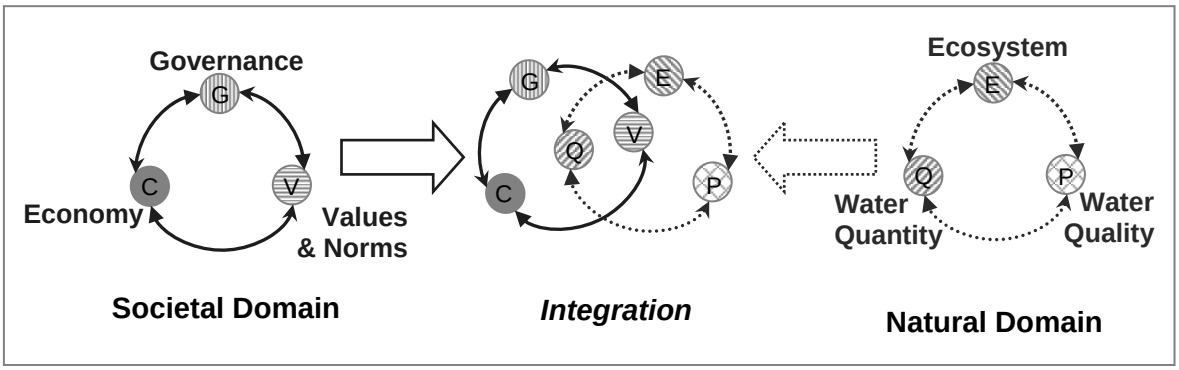

Fig. 1 Natural and societal domains (NSDs) framework.

facilitate the production of actionable knowledge across scales and locations. This framework will synthesize ***explicit*** (*scientific*) and ***tacit*** (*contextual*) water knowledge that is reliable, relevant and readily actionable. Within this context, we will focus on two particular challenges: (a) mechanisms to integrate knowledge from various science and policy domains to **formulate** and **frame** the questions; and (b) methods to create **actionable knowledge** by involving relevant users and knowledge producers and developing negotiated solutions for water problems with competing needs.

To contextualize the complexities of water problems and illustrate the reciprocal relationships between natural and societal domains, we begin with two examples: one from the Apalachicola-Chattahoochee-Flint (ACF) River basin shared by three states (Georgia, Florida and Alabama) in the USA and the other from the Ganges basin shared by three countries (Bangladesh, India and Nepal). The ACF dispute began in 1989, when after a series of droughts and continuing growth of water supply demand in the basin, the USACE (US Army Corps of Engineers) proposed to re-allocate water in an upstream reservoir called Lake Lanier to supply more water to the growing metropolitan Atlanta. This resulted in several lawsuits among the USACE and the three states. The major competing uses of water are water supply, irrigation and environmental flow for the river. To solve the dispute, the three states created the ACF River Commission and entered into an inter-state compact to negotiate a water allocation formula. Despite 20 years of deliberation, the states could not reach an agreement on the allocation formula and the negotiation failed. The compact expired and the matter was settled by the court in July 2009. The US District Court ruled that USACE had been illegally re-allocating water from Lake Lanier to meet metro Atlanta's needs, and that Georgia had been taking more water than permitted under the law. The Court ordered that all water withdrawals be frozen at current levels for the next three years until congressional authorization is given or some other resolution is reached. Georgia is now under great pressure to assess its water supply options.

Analysis of the ACF water allocation negotiation process (Clemons, 2004; Leitman, 2005; Feldman, 2008) identified several problems related to incorporation of technical and scientific data and socio-economic considerations into the tri-state negotiation: (a) a lack of appropriate scope in the Comprehensive ACF Water Resources Study; specifically over scientific evidence for the impacts of alternative streamflow regimes on downstream ecosystems; (b) a lack of agreement on methods of data collection and for analysis of scenarios generated by the decision support model developed by USACE; (c) differences in frames of references that led different stakeholders to question the validity and legitimacy of data and methods of analysis; and (d) a lack of consensus over specific criteria for what constitutes an acceptable water allocation formula.

Drawing the second example from the Ganges basin, we now discuss additional layers of complexities and diplomatic limitations in transboundary water issues between India and Bangladesh. The conflict began as India constructed a barrage in 1975 to divert dry season flow from the Ganges to keep the Calcutta Port navigable. Bangladesh protested against the move and demanded a resolution as it faced severe water shortages and disastrous environmental

consequences downstream. After much deliberation, the two countries successfully signed a water sharing treaty in 1996 for equitable sharing of the dry-season flow in the Ganges. However, within a couple of years of signing the treaty, water shortages became so severe both upstream and downstream of the diversion that India has been unable to provide Bangladesh the stipulated amounts promised in most years. Due to strong nationalistic viewpoints, lack of political will, and few economic incentives, these countries have not been able to adapt the treaty towards a resolution.

These two examples from very different settings demonstrate how a lack of common understanding of natural and societal aspects of the issues can prevent involved parties from reaching an agreement. Consequently, Water 2100 is envisioned not necessarily to find "the solution" to wicked water problems. Rather, it is to create a framework to **formulate and frame acceptable** solutions through recognizing and critically evaluating the salient **natural** and **societal** variables and constraints that create and affect these wicked water disputes. Developing solutions "acceptable" to multiple parties requires a process that is perceived as fair to the stakeholders involved, i.e. an outcome that meets at least some of the needs of all parties with an understanding that it is impossible to simultaneously maximize two or more competing objectives.

WATER 2100: A PROCESS FOR ACTIONABLE SOLUTIONS TO WICKED WATER PROBLEMS

In Water 2100, we argue that water can be viewed as a flexible and expandable resource because of an ongoing fundamental change in the conceptualization and sharing of a more basic resource of human society – knowledge. For example, the distinction between blue and green water fundamentally changes the amount of water available for competing uses. To create such a transformative knowledge base for water, we need a framework to synthesize ***explicit*** (*scientific*) *water information* and ***tacit*** (*contextual*) *water knowledge.* Such a synthesis is the main feature of Water 2100.

We have introduced a framework that captures the dynamic consequence of competition, interconnections, and feedback among variables in the NSDs (Fig. 1). As both sides of NSDs are porous, coupled, and interactive, we cannot explain – much less predict – the behaviour of these systems without treating both sides as endogenous. Formulation and framing of water problems are intricately linked; consequently, variables in natural and societal domains cannot be treated independently. The natural domain perspective is just as important in problem framing as the societal domain viewpoint, because problem framing from each of these viewpoints involves human perception and goals that must be met. For example, an irrigation canal is both a conveyance instrument for water and a device creating a relation of dependence between an upstream and a downstream user. Separating analysis of these two meanings of the canal and putting them in separate systems will not resolve water problems with competing needs. Consequently, research on integration of natural and societal processes has to identify the most useful way(s) to frame and formulate a question for a given scenario. Such a formulation and framing must recognize that natural and societal domains are linked in specific ways for specific problems, and some may be more relevant than others for a given context.

Identification of the need for integration is not new (e.g. Biswas, 2004; Lankford & Cour, 2005; Pahl-Wostl *et al*., 2006). What is new in Water 2100, however, is the recognition that uncertainties and incomplete information about interconnections, feedbacks, and complexities within and between societal and natural domains pose high barriers to finding and reaching an effective resolution of a given water problem. Sharing of knowledge across river basins can catalyse this learning process. Yet, each water problem is usually highly contextual and the relevant knowledge may be local and tacit. A management intervention that works in one basin may not be applicable to another due to differences in socio-economic context and natural settings. We recognize that knowledge of real world water issues exists both at tacit and explicit states that may not be readily accessible and transferable to different settings.

An overarching question is: *How do we integrate heterogeneous knowledge from natural and societal domains within a diagnostic framework where qualitative and quantitative aspects are relevant?* More specifically: Why do certain management interventions work in one river basin but not in another? What can one learn by studying effects of a particular management intervention (e.g. rules of reservoir operations) across different river basins?

A main hypothesis we examine is: *Differences in socio-economic context and natural settings lead to different outcomes for the same water management intervention and these outcomes can be organized into functional patterns*. We begin by identifying and characterizing these patterns as a function of six interacting variables (Fig. 1). We study the basin characteristics and identify the dominant variables in the natural (E, P, and Q) and societal (C, G and V) domains that are likely contributors to existing disputes or are expected to escalate in the future. The presence or absence of one or more of these variables (C, V, G, Q, P and E) can be used to differentiate water problems and conflicts from different settings, scales, and regions. For example, the implementation and success of a specific environmental policy in a river basin may depend on the stakeholder support and input in the formulation of the policy. However, the same policy may fail in another river basin where the interactions among C, G and Q are weak because of ill-conceived incentive instruments (C) and ineffective implementation and follow-up plans (G) that affected allocation of water (Q).

An underlying goal of the Water 2100 research agenda is to identify and prioritize variables and feedbacks in NSDs by examining a large number of real-world water disputes. Ideas from decomposability of complex subsystems and nested conceptual maps (Ostrom, 2007) will be used to identify secondary variables, critical feedbacks and interactions of NSDs. Our preliminary results of examining 12 water case studies (Table 1) from our highly successful interdisciplinary Water and Diplomacy Seminar at Tufts University suggest that certain functional patterns are identifiable. Each case study was examined by a group of two to three students and faculty members with complementary expertise and disciplinary background (Islam *et al.*, 2009).

Table 1 Characterization of water conflict case studies as a function of NSDs variables.

Case study	E	P	Q	C	G	V
Ganges			X	X	X	
Aral Sea				X	X	
Euphrates-Tigris	-	X	-	X	X	-
La Plata	X	X		X		
Titicaca			X	X	X	
Volta		X	X	X	X	
Indus			X	X	X	
Baker	X		X	X		X
Rio Grande	-	-	-	-	X	X
Congo					X	
Mekong	X			X	X	
Victoria	X			X		

A tangible result of Water 2100 would be further development and refinement of an emerging framework and *knowledge* database we call ***AquaPedia*** (aquapedia.tufts.edu) which is a web-based, wiki-style, self-learning repository of interactive and extractable water disputes from around the world (Islam *et al.*, 2009). We view *AquaPedia* as a repository of water information and collective contextual knowledge, bringing together people across the globe to discuss and craft possible solutions for a water problem through joint fact finding and interactive learning, by creating a social network through web-based collaboration and interaction. Currently, *AquaPedia* is undergoing beta-testing with contributions from a network of students and academics involved with the Water and Diplomacy Seminar (Table 1). We categorize water case studies within the

framework of the six variables (Q, P, E and V, C, G). *AquaPedia* will summarize the key findings from water case studies, suggest relevant literature, and provide relevant data and modelling links.

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