Modeling, Analysis & Decision Making for Coupled Water Systems in the Presence of Significant Uncertainty

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Goals. Recent hurricanes (e.g. Harvey, Irma, Maria, Nate) have reminded the nation that it is too costly not to plan for future events. In this project, we will be examining the state-of-the-art of current water management systems and how it can be improved with the use of technology and mathematical models to enable better cost-benefits-risk analysis in the presence of system and organizational social-political-economic-implementation uncertainty. We will be specifically examining how water is stored, processed, redirected, and how decisions are currently made in the presence of uncertainty. The project is designed to establish a framework for systematically examining and discovering fundamental tradeoffs and answer critical planning questions like: what investments will be required in order for anticipated risks and losses to be acceptable? This project directly aligns with Fulton’s sustainability research theme.

Background. In the past models used for managing water resources were largely modeling only the physical aspects of a water resource system. The issue is that models need to incorporate all factors that impact these systems including social, economic, legal, and environmental aspects [1]. The need for better management of natural resources is required for a sustainable future. This is specifically necessary for the Southwest United States because the Colorado River Basin which feeds the Colorado River has been in a drought since the year 2000 [12]. Arizona, California, Nevada, and Mexico get much of their water through the Colorado River which is fed partly through Lake Mead. The drought has impacted this reservoir greatly. Arizona officials have been trying to reduce usage so that levels in Lake Mead do not drop below 1075' which would cause a large cut in Arizona’s supply due to an interstate agreement in 2007 [13].

In this research, I want to examine ways to improve current management methods by incorporating the various factors highlighted above into the current methods. One way in which this is already being partly addressed is with, Integrated Water Resources Management (IWRM) - a concept created by the Global Water Resources Partnership [4]. This concept has increased in popularity as the scientific community has begun to recognize how critical it is that models are understood by stakeholders who do not understand the complexity of analytical models. The idea is that once a system (like a city) has been modeled, the model can be used by decision-makers as a reusable source of information that shows important critical interrelations [2], [9]. The planning utility and predictive power of these models will become increasingly more important as the population grows and the public demands accountability in water management [6]. One approach to accomplishing the latter is using “graphical system models.” The goal of “graphical models” is to show stakeholders (with minimal technical language) the consequences of different actions/decisions and how the components of a system are interrelated [4], [8].

Objectives. The main objective of the proposed work is as follows: How can we improve water resource management modeling, sensing, and decision making when faced with uncertainty by properly incorporating cost-benefit-risk analysis and social-political-economic factors? Determining the answer to this question requires us to answer some critical questions related to important factors, modeling, sensing, use of new technologies, parameter estimation, decision making, optimization, planning, policy implementation, and enforcement.
Critical Questions. Critical Questions to be addressed in this work are as follows:

1) **Important Factors.** Who and what are the important factors that impact the analysis and decision making of a water system? We need to determine how decisions are currently made, who/what impacts these decisions, and how the decisions are currently implemented. Ideas for addressing these questions are provided within [1]-[11], [14-17].

2) **Modeling.** How can we model the characteristics of an integrated water resource system? What are the current state-of-the-art models being used today? We need to do this so that we can understand what is missing in order to more carefully (and comprehensively) examine cost-benefit-risk tradeoffs and other critical planning questions. To do this, we will begin by modeling the basic system with no uncertainty. This will be done using simple leaky bucket models to capture available coupled water resources championed by Dr. Rodriguez and his team of sustainability scientists [14]. Once we have completed the latter, we will model the uncertain components of the system (e.g. demand, organizational). To achieve this and answer these questions we will use ideas and concepts from [5], [8]-[11], [15], [16].

3) **Enhanced Modeling.** How can we improve the models to better estimate things like supply and demand through the use of sensing, parameter estimation, and model fitting/optimization techniques? We want to optimize the models we will use so that we can minimize worst-case scenarios and improve efficiency in water management to provide a sustainable future. We will address this by using the techniques found in [3], [6], [7], [11], [15], [16].

4) **Empowering Decision Makers.** How can we reduce the complexity/simplify the information from these modeling techniques in order to provide decisions-makers with the ability to make better decisions? The information provided from the models being used is often not easily understood by the decision-makers. Therefore, the information needs to be better organized or simplified so that it can be better understood. Toward this end, we’ll use the ideas within [4], [8].

**Case Study.** To focus the proposed work, we will concentrate on water management in Arizona, California, Nevada and Mexico [12], [13], [17]. We will specifically, begin by examining the models and methods within [1-11], [15], [16]. We will then apply the “bucket modeling” ideas from [14] and add critical socio-political-economic effects. All project results will be documented in a comprehensive final report.

**Career Relevance.** I am very passionate about “intelligent” (model-based) water management in the presence of uncertainty. For this reason, I have selected the proposed project. This project will provide an excellent step toward my next goal – to complete a direct Ph.D. here at ASU in the area of “intelligent” (model-based) water management. I look forward to continued work with Dr. Rodriguez and other sustainability scientists that he works with (see below).

**FURI ADVISOR.** Dr. Rodriguez has worked in the area of renewable resources and food, energy, water, infrastructure management for over the past 10 years with leading sustainability scientists (e.g. Dr. Marty Anderies, Dr. Marco Janssen, Dr. Hanna Breetz, Dr. Elinor Ostrom – 2009 Nobel Laureate). He has supervised over 50 graduate theses and over 300 projects. He is also the PI of a 5 Year, $5M NSF funded Scholarship program. Each scholar is required to work on a career-shaping project. The proposed FURI will permit me to work with Dr. Rodriguez alongside a team of highly motivated graduate and undergraduate students.
References

Project Timeline for

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