# Study of Potential Integrated Management of Water Resources in Las Vegas Valley

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### *Abstract*

Water resource management under short term system perturbations such as storms and longer-term systemic changes caused by climate change such as droughts is a challenge when multiple agencies are involved. To address this challenge this research focuses on water management under changing climate conditions and population growth through understanding the agency water jurisdictions, management strategies, and modes of operation in Las Vegas Valley. A framework for integrated management through sharing data and models is presented that combines drinking water supply, flood control, and waste water treatment. This framework can be adopted to improve coordination among different water management agencies.

## Introduction

Water resource management under short term system perturbations such as storms and longer-term systemic changes caused by climate change such as droughts is challenge when multiple agencies are involved. Many semi-arid regions in western USA are experiencing rapid urban population growth, resulting in increase in water demand (Ahmad 2016). At the same time, climatic changes in the hydrological processes have resulted in decreased water supply. These reinforcing changes have resulted in rendering the conventional urban water management approach of use-and-release as ineffective and a paradigm shift towards water reuse, water conservation, and water sequestration at an urban scale. With the adoption of new strategies by the urban water management agencies, the process of decision making has become complex due to interdependence and competition. In addition, the creation of specialized departments to monitor and manage different aspects of the water resource system has led to the development of data management and computational systems within each agency focused on their own decision-making scope. However, the stakes for coordinated decisions are rising, especially in arid and semi-arid regions where the buffer between supply and demand is small. Uncertainty brought by future climate change, increased pressure on a range of natural resources, and growing demand make efficient decisions critical. At the same time, the potential for better integration across the water resource system has also increased, as more data are collected and computational power have advanced.

In Las Vegas Valley (LVV), three agencies manage water resources.

1. **Southern Nevada Water Authority (SNWA)** procures the share of Nevada from the Colorado River and distributes water to purveyors such as city of Henderson or Las Vegas Valley Water District to meet urban demand in the Las Vegas Valley.
2. **Clark County Water Reclamation District (CCWRD)** is responsible for collection and treatment of municipal waste water. This water is returned to Lake Mead and Las Vegas Valley gets a return flow credit.
3. **Clark County Regional Flood Control District (CCRFCD)** manages infrastructure composed of 32 detention basins and 7 flood channels to mitigate flood risks and remove storm water after a rainfall. LVV does not get any return flow credit for returning storm water to Lake Mead.

The coupled behavior of supply water, stormwater, and wastewater in LVV can be analyzed through a multi-agency coordinated point-of-view to identify ways to improve water efficiency and management efficacy. For example, stormwater and treated wastewater can augment water supply.


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Multi Agency Coordination is a challenging problem. The factors affecting multi-agency working include, agency differences, local authority structures and boundaries, staffing arrangements and time investment, individuals' and agencies' expectations and priorities, agencies' aims and objectives, budgets and finances, and confidentiality and information-sharing protocols (Atkinson et al, 2001). A shared vision is vital for effective coordination and can be achieved through shared information among various water jurisdictions.

This research focuses on improving the water management under changing climate conditions and population growth. This is achieved through understanding the agency water jurisdictions, management strategies, and modes of operation in Las Vegas Valley. A framework is presented where SNWA, CCRFCD, and CCWRD can share data and models necessary for integrated water management. This framework, with appropriate modifications, can be used by other cities to improve coordination among different water management agencies resulting in better management of water resources.

**Water Management in Las Vegas Valley**

Water management in LVV has been undertaken by SNWA, CCRFCD, and CCWRD. SNWA is tasked with supplying water to Clark County from Lake Mead and groundwater pumping. Likewise, the job of CCRFCD is to manage infrastructure to mitigate flood risks. Similarly, CCWR treats the urban wastewater and releases into Las Vegas wash and thus, back into Lake Mead, the source of water supply for the LVV. Evidently, SNWA, CCRFCD, and CCWRD have interrelations that could be used to improve an integrated water management of all types of water.

Decision making by LVV water management agencies is deeply dependent on their mechanisms of knowledge creation and thus ability of learning. Typically, this learning takes place by the individuals of the organization and knowledge is stored in various forms of media. The learning happens through the analysis of the feedback data of a given action. Interaction among the three organizations is either through protocols mandated by a higher level management or evolving point-to-point connections from individuals of one organization to another. There are also coordination and advisory committees formed to promote integrated solution to local problems such as Integrated Resource Planning Advisory Committee, Las Vegas Wash Coordination Committee and Las Vegas Valley Watershed Advisory Board. The interagency integration can be improved through a shared learning of the state of water and knowledge of decision space of each organization.

Each agency is operating very efficiently and the effort to conserve water has paid off. Some examples in this effort include WaterSmart Landscape, WaterSmart Homes, and Pool Cover Rebate by SNWA. Despite a remarkable success by an individual agency, the coordination among multiple water management agencies can be improved. Since water morphs seamlessly between organizational jurisdictions, a strong interrelation exists between action and feedback of one organization to those of another organization. Therefore, multiagency data and model sharing framework can help each agency make decisions cognizant of holistic water point-of-view of the valley. For example, Las Vegas has a consumptive use allocation of 300,000 acre-feet of water, but SNWA can draw 500,000 acre-feet of water because CCWRD returns 200,000 acre-feet of treated water back to the lake (Qaiser et al., 2013). If this water stays in the city and is directly supplied to the consumers (reuse), energy use and related carbon footprint can be significantly reduced. Moreover, the quality of water in Lake Mead can be improved thus benefiting the environment. Despite the dry weather, the Las Vegas Valley does experience intense rainfalls from time to time that result in flooding (Forsee and Ahmad, 2011; Thakali et al., 2016). During the flooding, the CCRFCD must drain the water to the lake as soon as possible to prevent damage in the city. During high flows, untreated water may be released to the lake when sometimes flow exceeds treatment plant capacity. This water carries significant load of pollutants and contaminants (Venkatesan et al., 2011a and b). If the treated water or storm water stays in the city and is used for irrigating golf courses and yards, the cost of energy use can be significantly reduced (Shrestha et al., 2011, 2012). If other agencies cooperate to boost their processing and storage capability temporarily before and after the event, a larger portion of the water can be treated properly and the environmental contamination can be reduced accordingly. This treated water can be used directly at the city without drawing extra water from the lake, thereby saving electricity.

Long-term water resource management is also complicated because of changes in water demand due to population growth and water supply due to climate change (Dawadi and Ahmad, 2012; 2013; Kalra and Ahmad 2011, 2012; Tamaddun et al., 2016). Las Vegas Valley has experienced rapid urban population growth, resulting in significant increase in water demand (Qaiser et al., 2013). At the same time, climatic changes in the hydrological processes have resulted in decreased water supply (Sagarika et al., 2014). These reinforcing changes have resulted in revealing the shortcomings of the conventional urban water management approach of use-and-release. Therefore, water reuse, water conservation, and water sequestration at an urban scale are gaining interest by water researchers and managers. With the adoption of new strategies by the urban water management agencies, the process of decision-making has become more complex due to interdependence and competition. Without multi-agency coordination, the water resources cannot be managed optimally.

**Potential for Integrated Water Management**

An integrated water management must add value to the core mandates of the individual agencies while developing an interagency synergism. Water is the lynchpin among SNWA, CCRFCD, and CCWRD, and therefore, effectiveness of integrated management is tantamount to sharing information and accommodating priorities of other agencies in decisions. In particular, a framework for integrating water management must be an enabler of shared sense of water security through providing data analytics. Following is a brief discussion of potential integrating factors of pairs of agencies.

*SNWA and CCRFCD*

At first glance, SNWA and CCRFCD almost seem to be in an antagonistic relation. SNWA aims to procure supply water to meet urban demand, whereas CCRFCD aims to remove stormwater from an urban environment. According to SNWA, water security is compromised under shortage of clean supply water, whereas for CCRFCD, it relates to excess of stormwater. SNWA water treatment is ensuring quality for urban consumption, whereas CCRFCD water quality control is for stormwater receiving bodies and ecosystems. Though apparently in opposition, the two priorities can be coupled. The logically most obvious and straight forward coupling relates to using stormwater for urban consumption. Nevertheless, this coupling does pose some challenges that need to be addressed e.g., storage of this water for treatment and distribution. Moreover, an economic value has to be attributed to the stormwater urban usage for accounting purpose and allocating appropriate credit.

*CCRFCD and CCWRD*

CCRFCD and CCWRD have similar mandates as both remove water from urban areas. CCWRD treats sewer water to EPA standards and releases into Las Vegas Wash as return flow to Lake Mead. For CCWRD, water security implies to successfully collecting wastewater from city and releasing treated water to Las Vegas Wash. Although sewer and storm drainage systems operate independently, stormwater always finds its way into sewer drains increasing influent to treatment plants. Under extreme storm conditions, wastewater treatment plants may be unable to process influents thus releasing untreated water into Las Vegas Wash. Conversely, sewer overflow can also leak into storm drainage system resulting in untreated water reaching Las Vegas Wash. Evidently, CCRFCD and CCWRD are closely coupled during a storm event and a shared management could ensure water quality.

*SNWA and CCWR*

SNWA and CCWRD reflect a synergism similar to that found in living organisms where one agency delivers clean water while the other removes the waste water. This is a step-up from the conventional approach of use-and-release towards the approach of use-treat-and-release. In case of LVV, the treated water returned to Lake Mead is converted into a return credit available to SNWA for pumping. Therefore, in a way SNWA and CCWRD are already coupled through the return credit accounting of treated water. Nevertheless, the water released undergoes gravity flow to reach the lake, which subsequently has to be pumped with significant energy demand. This represents an opportunity of a stronger cyclic coupling between SNWA and CCWRD i.e., use-treat-and-reuse.

**Framework for Integrated Water Management**

The framework for integrated water management is expected to create synergism among the three agencies in terms of shared vision of water service and security. One key mechanism is through shared data analytics with a backdrop of systems level thinking. We propose a framework based on the double loop learning and decision making model (Argyris, 1976). A single loop learning only feedback to the action space, whereas double loop learning also provides feedback to underlying models of reality and protocols that generate decisions. A double loop learning enables problem solving by adjusting actions as well as underlying mandates. An agency operating in this learning mode is expected to be more cooperative in a multiagency coordination.

Figure 1 shows the single agency management model with weak linkage showing connections to other agencies. The operations of SNWA, CCRFCD, and CCWRD can be considered partially aligned with double loop learning model with potential of further alignment. For example, SNWA has addressed the water shortage problem by exhausting many options in the solution space. Some noteworthy actions include water conservation, augmentation of water resources, and coordination with other Colorado River Basin States. SNWA has also responded to ongoing 16-year drought, changing climate, and rising population. Other agencies have similar modes that can be somewhat aligned with double loop learning model. Nevertheless, within this model, the interagency coordination can be improved and needs a higher level model inclusive of individual agency models.

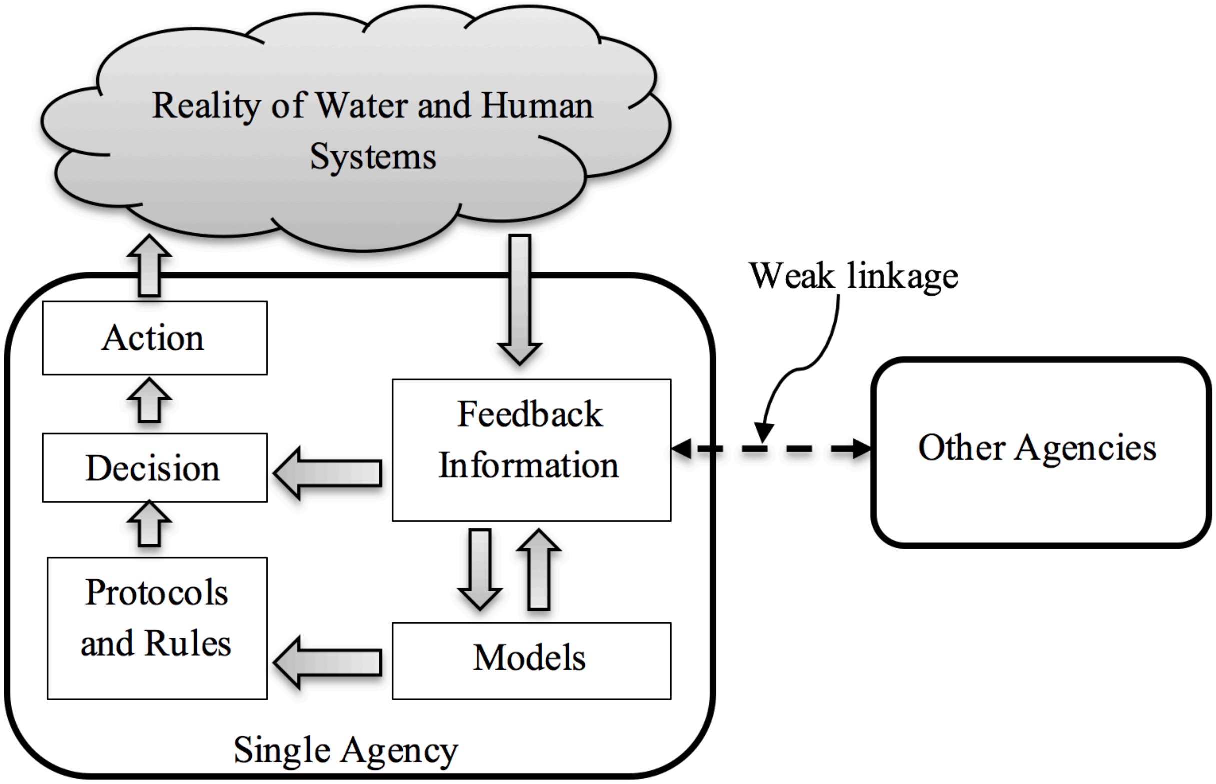


Figure 1: Double loop learning based decision model of a single agency.

A decision support system (DSS) is an interactive software-based system intended to help decision makers compile useful information from a combination of raw data, documents, and personal knowledge, or business models to identify and solve problems and make decisions. A DSS generally consists of database knowledge base, models, and the user interface (Ahmad and Simonovic 2006). An integrated DSS is developed that contain the rules and policies from multiple agencies. What-if engine performs simulation analysis and show the results of an action. We present a multiagency DSS (MDSS), where the linkage among agencies is strengthened through a system that integrates selected feedback information from individual agencies and is capable of performing scenario analysis. Other researchers have also discussed and explored the use of multiagency DSS e.g., Elmahdi and McFarlane, 2012; Everitt, 2010; Soeth and Walters, 2013. This system consists of multiagency database and computational infrastructure along with a mechanism to interact with them. The system database receives information about key variables from all agencies and updates the appropriate database tables. It provides agency representatives with an ability to view data and pass various control commands to the computational infrastructure to perform different what-if scenario analyses to facilitate decision making. Figure 2 shows the layout of multiagency decision support system.


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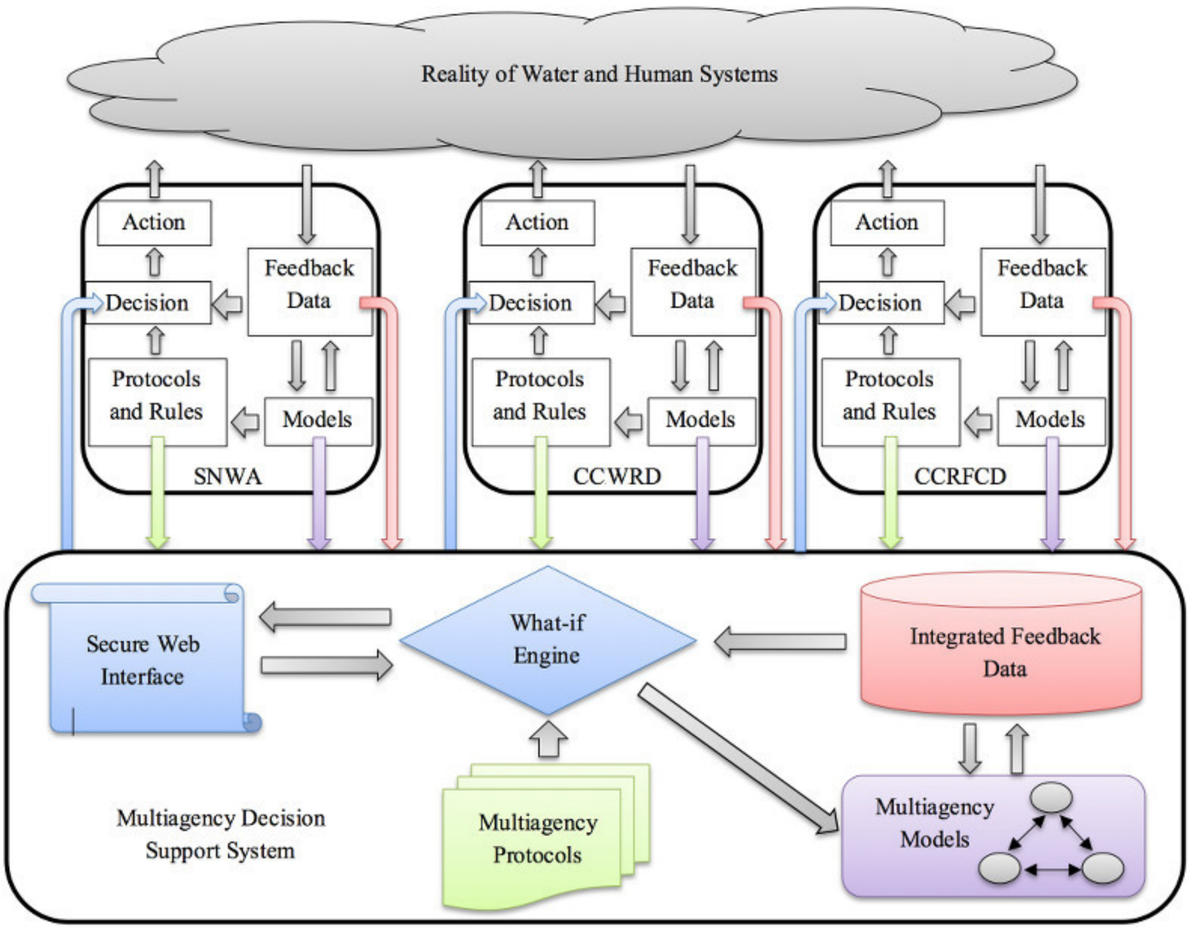


Figure 2: Flowchart showing components and interactions of the proposed multiagency decision support system.

The MDSS have the following five components.

*Multiagency Protocols*

The multiagency protocols are created through merging individual agency protocols and rules and represent the most vital component for a sustainable MDSS. This merging process follows a bottom up approach and must not restrict or oppose individual agency protocols. When dealing with opposing protocols of two or more agencies, MDSS creates alternative scenarios for each protocol. This is the true spirit of MDSS as it can inform individual agencies about the potential consequences of their actions relevant to other agencies. Therefore, the double loop learning model within the agency enables adjustment of mandates with a multiagency scope.


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*Integrated Feedback Database*

This database holds the selected feedback data of all agencies, especially those with mutual interest. Such sharing of information expands the horizon of each agency giving a wider information base for decision making. Moreover, the MDSS can utilize this information in simulating multiagency what-if scenarios. For example, CCRFCD receives real time measurements from field gages about rainfall and stage during a storm. This information could be translated for CCWRD to predict potential increase in in the influents at a treatment facility.

*Multiagency Models*

The multiagency models are developed through coupling of individual agency predictive models. The integrated models relate the individual agency decisions and feedback data to potential impacts on the other agencies. For example, SNWA decisions about water resource portfolio may depend upon Lake Mead predictive models of US Bureau of Reclamation. A multiagency model including CCWRD return credits could provide further analysis about long-term feasibility of reuse of treated water. Similarly, operational model of CCRFCD detention basins and drainage infrastructure could be simulated in tandem with the sewer drainage models during a storm events.

*What-if Engine*

The What-if engine represents a database of questions that could be of interest to all agencies. For example, what will happen if the Lake Mead elevation lowers below critical points. Or what will happen to the drainage system under an extreme storm event. Since the urban infrastructure is continuously changing, the answers to such questions continue to evolve as well. In particular, the answers to these questions under varying decisions undertaken by each agency could be different. Therefore, the What-if engine will help ask these questions using models and feedback data and generate potential scenarios helpful for each agency.

*Web Interface*

Web interface provides a mechanism for each agency to communicate with MDSS. It facilitates inter-agency communication in real-time. It helps in visualizing the current status of water resources, the operational status of the water treatment facilities, and the operation of the decision support system. A sample user interface is shown in Figure 3.

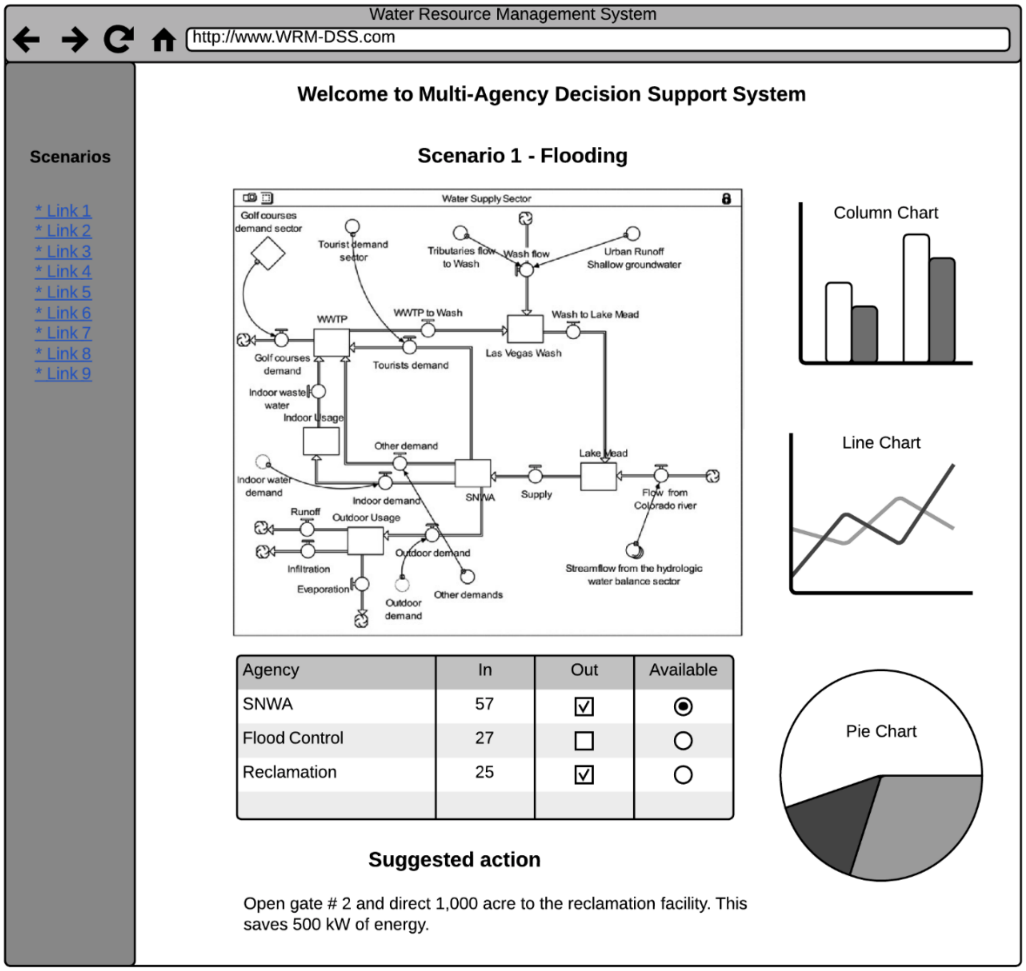


Figure 3. A sample web page of multi-agency coordination system user interface

## Summary and Conclusion

In Southern Nevada, multiple agencies manage water resources: SNWA procures and distributes water to meet urban demand in the Las Vegas metropolitan area, the CCRFCD manages infrastructure to mitigate flood risks, and CCWRD is responsible for collection and treatment of wastewater. The system as a whole is subject to national water quality and other environmental standards. Managing this system effectively and efficiently means consistently satisfying a complex set of objectives that include meeting urban water demand, minimizing distribution and energy costs, and mitigating human and environmental health and safety risks over the long-term. Changing future climate conditions, increased pressure on a range of natural resources, and growing demand make efficient decisions critical. At the same time, the potential for better integration across the water resource system has also increased, as more detailed data is becoming available and computational power is improving. Better integration across agencies has the potential to yield more efficient and sustainable management of water resources. This is especially critical for water management in semi-arid regions, where the relationship between water supply and water demand is particularly tight.

We present framework of a multi-agency decision support system to improve the integration of water resource management. This framework builds on the double loop learning based decision model in each agency with a higher level integration through information sharing. This high level integration is achieved through five components i.e., multiagency protocols, integrated feedback database, multiagency models, what-if engine, and web interface. The focus of the system is on information sharing and coordinated decision making. Information sharing is achieved through a database framework where responses of key urban variables of water system from different agencies are recorded. A multiagency modeling and analysis approach of these records guided by multiagency leads to metrics that can be used in the decision making process. This ensures decisions that have input from all agencies managing urban water.

In a typical urban system, water exists in many forms such as drinking water, storm water, wastewater, and groundwater. Different agencies typically manage different aspects of the water system – water supply, flood control, wastewater treatment – in spite of the fact that these are rather arbitrary divisions given that the metamorphosis of urban water from one from to another is a continuous and seamless process. A multiagency decision support system, as presented in this paper, can facilitate an integrated management of water in urban systems.

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