Using System Dynamics to Evaluate and Communicate the Effects of Water Management Strategies in Las Vegas, Nevada

Part I: A Model for Examining Water Management Policy Options in Las Vegas, Nevada

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Project Overview

How to use system dynamics most effectively to improve public participation in resource management?

Water policy-makers and managers increasingly face the challenge of building public or stakeholder support for resource management policies. They rarely can make and implement decisions in isolation from stakeholders. At a minimum, management decisions generally require stakeholder support of funding initiatives or legislative changes. In some cases resource management policies require stakeholders to make behavioral changes. Successfully implementing water conservation programs, for example, depends on convincing water users to reduce individual water use (e.g. Platt and Delforge 2001). While some success can be achieved through economic incentives and legal measures, stakeholders are more likely to fully support policies if they understand the causes of the problem and consequences of policy decisions. Building support for environmental management decisions involves raising awareness of the problem/issue and developing understanding of the connections between potential solutions and system consequences (Hale 1993).

System dynamics modeling can help managers communicate with resource stakeholders at several levels (Costanza and Ruth 1998). Models can be used as a structured way to convey information <u>to</u> stakeholders, they can be used in a facilitated forum to stimulate a <u>two-way exchange</u> of information and ideas, or they can be used to fully <u>engage stakeholders in partnership</u> with resource managers by involving them in the model building process (e.g., Vennix 1996, Van den Belt 2000). The process of building a system dynamics model helps unify and organize information about the resource system such that those involved in the model development develop a shared understanding of how the system works. Participation in model development facilitates sharing assumptions among the participants.

There are fundamental tradeoffs, however, between the level of stakeholder involvement, the number of stakeholders that can be involved, and the resources required. Involving stakeholders in group model building requires a high degree of participant commitment to the process. Facilitating group discussions around system dynamics models is labor-intensive, and can reach only a limited number of people.

This project investigates the use, on three levels, of a system dynamics model for building stakeholder understanding of the effects of conservation on supply and demand in the Las Vegas, Nevada water system. On the first level, a system dynamics model can be used to clarify the definition of the problem to stakeholders and demonstrate the effects of different policy options. This might be termed "one-way" communication with stakeholders, where system dynamics is used to better explain and justify the decisions managers make. On a second level, the system dynamics modeling process can be used in a facilitated format to elicit feedback from stakeholders in addition to informing them about the problem, the system and its dynamic behavior, and the effects of potential management interventions. System dynamics has been used successfully for this kind of "two-way" communication with stakeholders in group model-building exercises (e.g., Vennix 1996, Anderson and Richardson 19xx, ...) and mediated modeling (van den Belt 2000). Facilitated workshops can be very effective, but they are resource-intensive. They require that participants make a substantial time commitment to the process and they require facilitators trained in system dynamics. Facilitated workshops for promoting two-way communication among stakeholders generally require a commitment of at least 3-4 hours, and often involve more intensive meetings that last several days, or extend over several months. In addition, the number of stakeholders that can be served in this format is limited. Facilitated workshops are most effective with groups on the order of 10-30 participants. The limitations of facilitated workshops raise the question of how system dynamics might be used to communicate with resource stakeholders in an unfacilitated format. In this project we explore this third level as the use of a system dynamics model on the web without a real-time facilitator. This kind of interface has great potential for giving the stakeholder who uses it a lot of flexibility, but raises questions about how to help users interpret the experiences they have with the model.

Part I of this poster presentation describes the water supply and demand management problem and presents the model that was developed to communicate the problem and discuss potential policy options with water system stakeholders. Part II describes the results of using the model in facilitated workshops to promote better insight and communication among stakeholders. Part III proposes a web-based use of the water model and discusses design and technical concerns that such an unfacilitated format raises.

Part I Abstract

This poster describes a system dynamics model for evaluating water quantity management options for the Las Vegas, NV water system. Water demand is likely to exceed water supply for the rapidly growing metropolitan area in approximately 2025. The model was developed to evaluate options for extending the point at which demand exceeds supply and to build stakeholder understanding of potential management strategies.

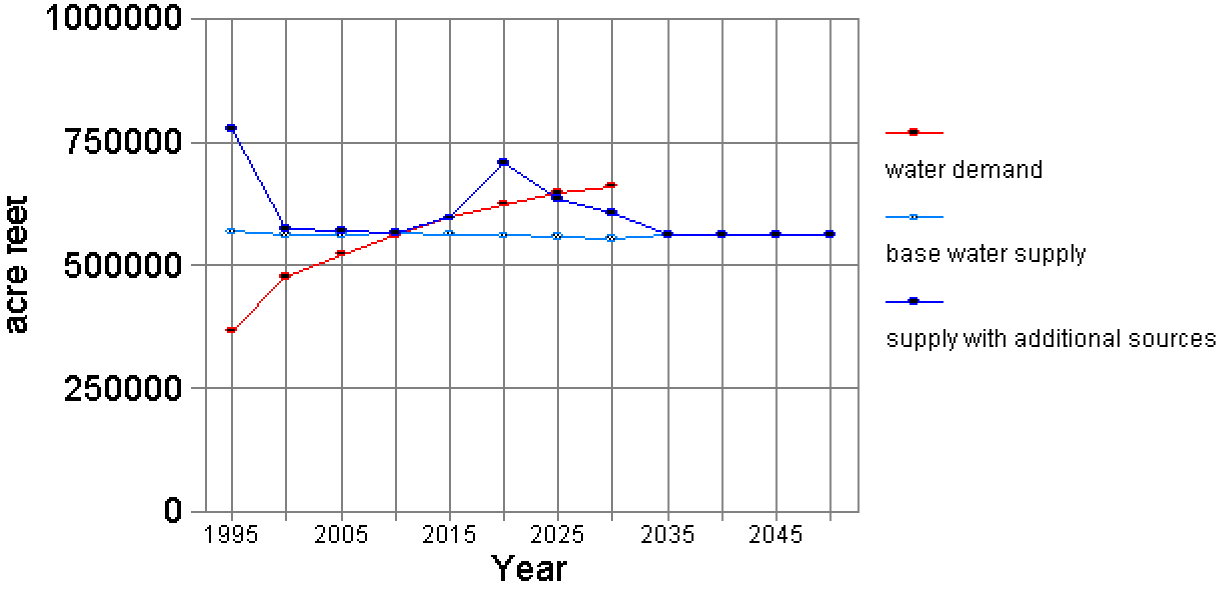
Six management strategies suggested by water system stakeholders are analyzed using the model. Analysis shows that reduction of residential outdoor water use has a much greater effect on the relationship between supply and demand than the same reduction of residential indoor water use.

Problem Statement

The Southern Nevada Water Authority (SNWA) projects water demand will exceed water supply in the Las Vegas region around the year 2025 as shown in Figure 1 (SNWA 1999). Las Vegas is one of the fastest growing metropolitan areas in the U.S., located in one of the country's most arid regions. Already at 1.4 million people, the population continues to increase by 5,000 people per month (CCA 2000), straining available water resources.

Figure 1 shows water supply fluctuating around 650,000 acre-feet per year and demand increasing with population. Built into the demand projection is the expectation that per capita water use will decrease 25% over the 1990 rate by 2010 and 26.5 % by 2020. The water authority aims to achieve this reduction through conservation and changes in water pricing. Simply to meet these goals, SNWA must convince consumers to change water use habits; to extend the time that supply exceeds demand beyond 2025 will require even more consumer support. This study used a system dynamics model to help water users understand the water system and elicit their input about potential water management options.

Figure 1: LV Water Supply vs. Demand



Source: SNWA (1999)

The Las Vegas metropolitan area is contained within a 1,586 mile^2 drainage basin that extends ~40 miles southeast from the Spring Mountains to Lake Mead (Figure 2). The Las Vegas Wash is the primary drainage for the basin, discharging to Las Vegas Bay in Lake Mead. 85% of the water supply comes from Lake Mead; 15% is withdrawn from groundwater in the Las Vegas valley.

Water used indoors is sent to one of three wastewater treatment plants. All three plants discharge their treated effluent to the Las Vegas Wash. Water used outdoors (for irrigating lawns and golf courses, e.g.) returns to the atmosphere through evapotranspiration, contributes to subsurface soil moisture, or flows through street drains and flood channels to the Wash. Figure 3 shows the path of water in the system. Las Vegas Wash discharges into Lake Mead six miles upstream from the city's drinking water intake.

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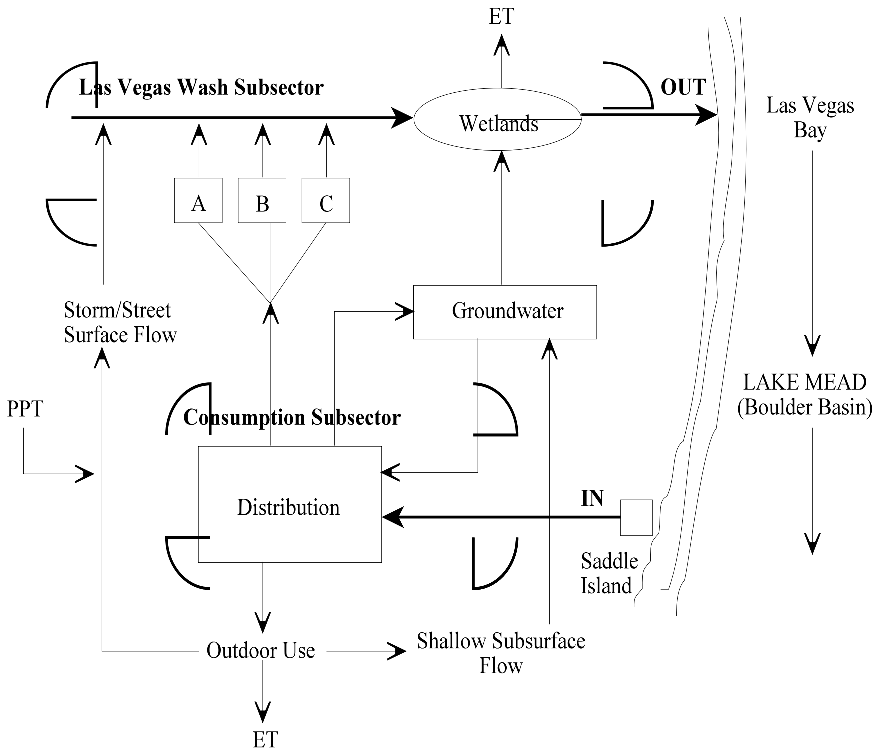
Figure 3. Schematic Diagram of the Las Vegas Water System

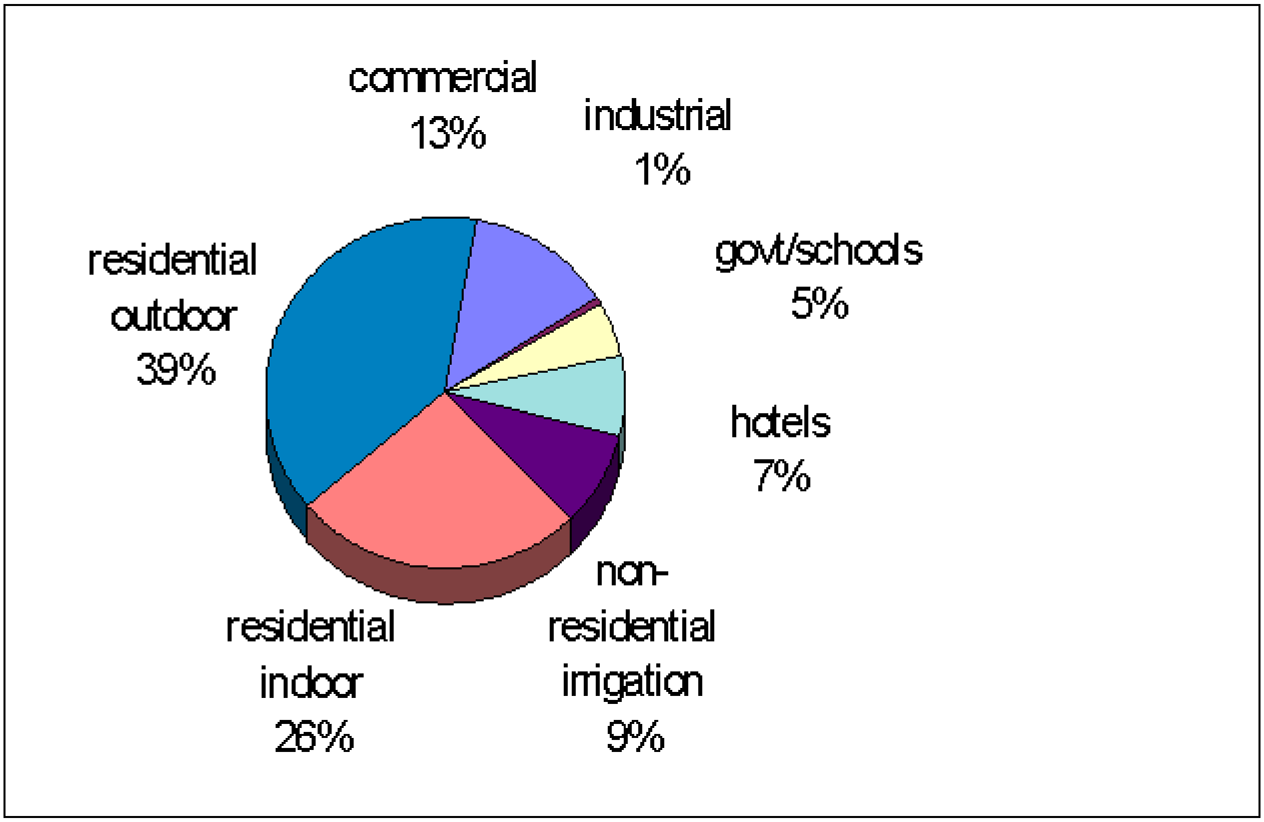


Water supply is a function of the circular nature of the water system. The amount Las Vegas can withdraw from Lake Mead was determined by the Colorado River Compact, an agreement among the states in the Colorado River watershed, in 1921. Nevada's allotment is 300,000 acre-feet per year. Las Vegas also gets credit for water withdrawn from the river that it returns to the river from wastewater treatment plants. This "return-flow credit" increases the total available for withdrawal. In 2000, return-flow credit was approximately 150,000 acre-feet, increasing the total supply to 450,000 acre-feet.

Water demand is driven largely by residential use. As shown in Figure 4, sixty percent of municipal water is used by residential customers. Of that, approximately 35% is used indoors and 65% is used outdoors.

In spite of the salience of water issues in the arid Las Vegas environment, there is little understanding among residents of the metropolitan area about sources and uses of water in this system. Per capita water use, at an average of 260 gallons per person per day is among the highest in the U.S. Most residents are relatively recent arrivals from other parts of the U.S., many from more humid climates with greater annual precipitation. They seem to prefer landscapes that include green lawns and lush vegetation rather than native desert vegetation. Hence, 30% of all water used in Las Vegas is used for residential irrigation, most for watering lawns. Few residents see any need to conserve water.

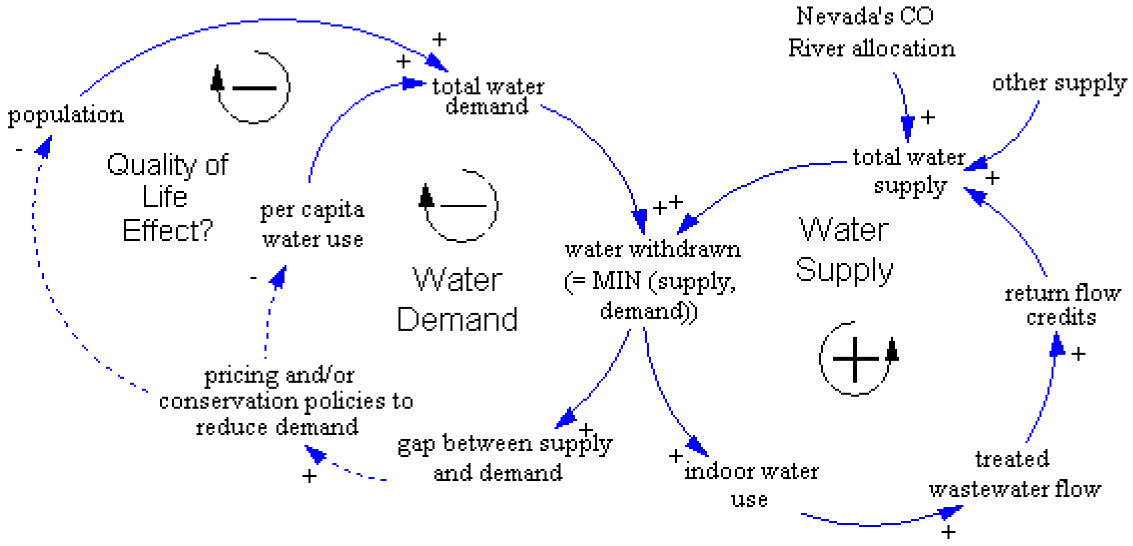
Figure 4. Water Use Distribution



Dynamic Hypothesis

Model boundary includes the primary source of water supply (Colorado River at Lake Mead), primary pathways of flow in the Las Vegas valley, and Las Vegas resident population. Figure 5 shows the two major feedback loops in the system.

Figure 5. LV Water System Causal Loop Diagram



Supply changes in response to external sources, but also in response to changes in water use, through the mechanism of return flow credit. As population increases, demand increases. Because water use increases, treated wastewater flow, and thus, return flow credit, also increases, increasing supply. But because demand increases faster than supply, demand eventually equals, then exceeds supply.

Major Assumptions in the Model

- System structure will remain essentially the same into the future. No major new sources will be procured, return-flow mechanism will not change, CO River will remain principal sources of LV water.
- Types of consumers and distribution of water among them will remain the same.
- When demand exceeds supply, the amount withdrawn is equal to supply (you cannot withdraw more water than you have available). Available water is distributed equally among users.
- The most significant factors affecting the change in population are inmigration and outmigration. The model does not account for births and deaths. For the base run, the *perceived attractiveness of LV as a function of population* is set such that the population growth follows the projections of the Nevada State Demographer.

Model structure

The model structure, shown in Figure 6, represents the path of water flow in the Las Vegas Water System. Water is withdrawn from Lake Mead, distributed among customers based on water demand, some is treated at municipal wastewater treatment plants, then discharged into the Wash, which eventually returns it to Lake Mead. Water treated in the wastewater treatment plants becomes part of water supply, as return flow credit. Water demand is based on population and per capita water demand.

Validation

Figure 7 shows the base case output of the model using the assumptions described above and the population projections of the Nevada State Demographer. Comparing Figure 7 to Figure 1 shows the model reproduces the general observed and expected trends that define the water management problem.

Figure 6. Las Vegas Water System Model Structure

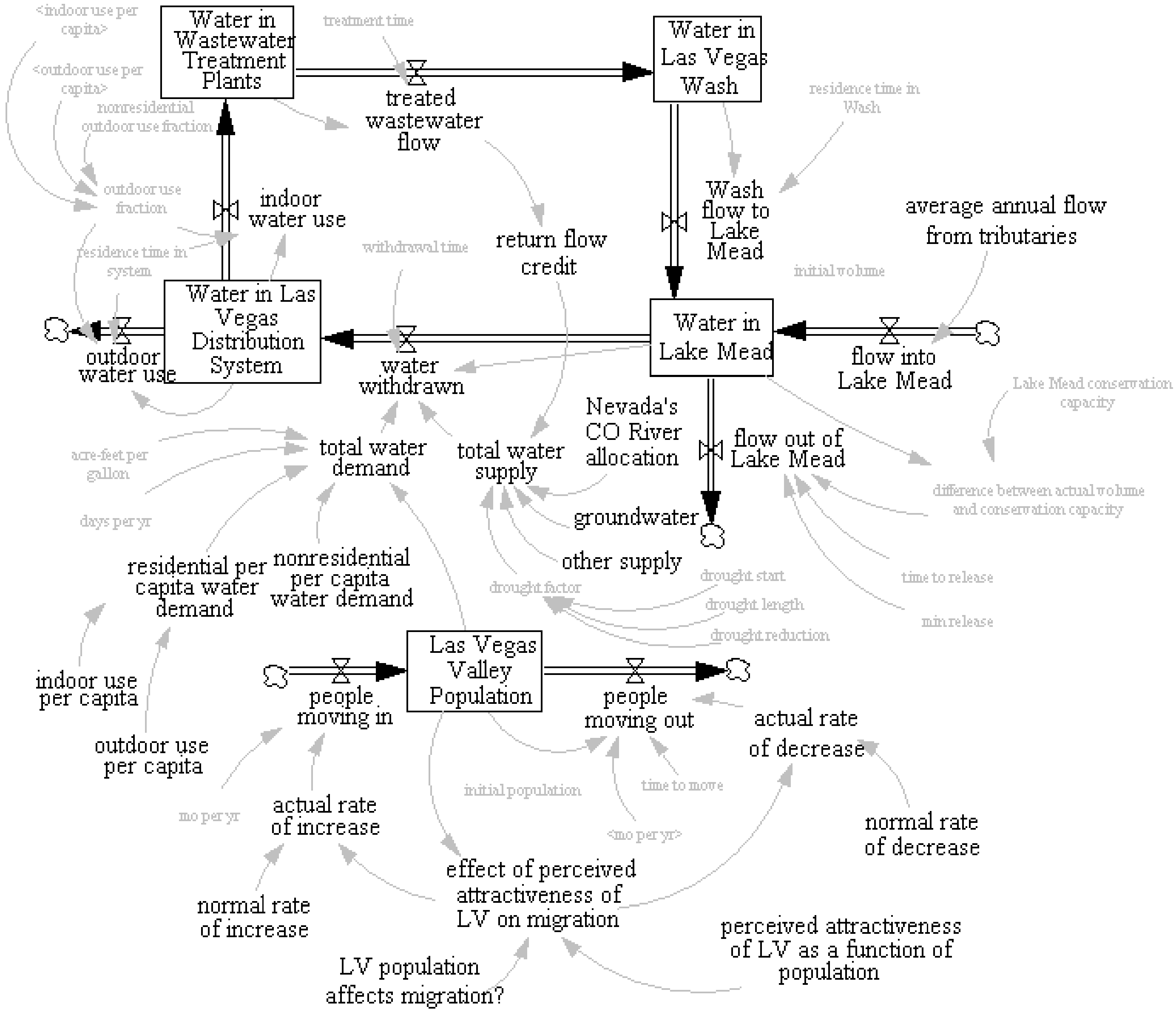
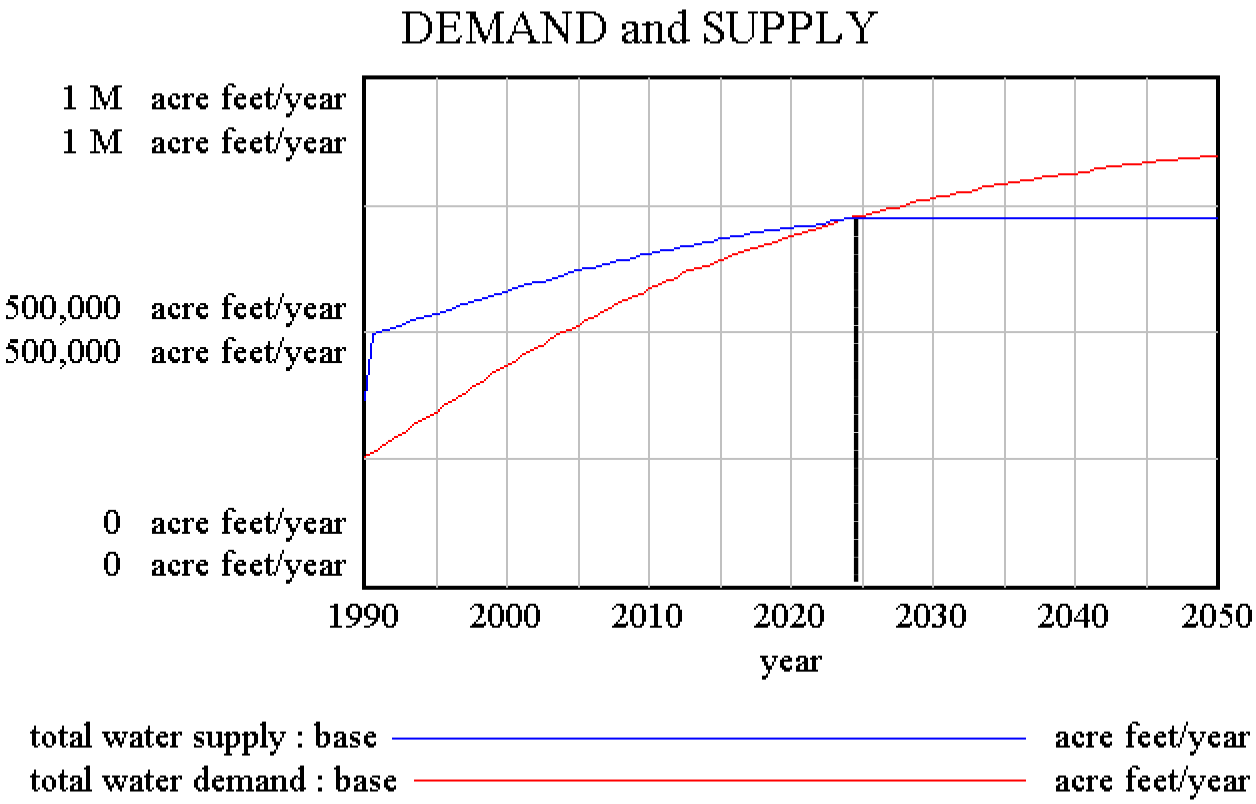


Figure 7. Base Case Output



Policy Tests

Policy identification

This strategic-level model was used in seven public workshops with a total of 67 participants. (Part II: Cloud and Stave describes the workshop research). Participants included teachers, students, environmental professionals, and retired citizens ranging from 18 to 65 years old. Participants suggested the following strategies for extending the time it takes for water demand to exceed supply:

- **Increase supply**

  Even though participants felt it would be expensive to find new sources of supply, they thought eventually increasing supply would be necessary. To increase supply, increase *Nevada's CO River allocation* or *other supply.*

- **Decrease population (or slow growth)**

  There was much debate about whether or not this would be politically feasible. Some participants felt that population growth would begin to decrease without deliberate action as problems such as traffic congestion and air pollution worsen, making Las Vegas a less attractive place to live. To test the effect of decreasing growth, either decrease the *normal rate of increase*, increase the *normal rate of decrease*, or change the *perceived attractiveness of LV as a function of population.*

- **Reduce residential water use.**

  Reduce indoor consumption per capita.
  This could be achieved with low-flow showerheads, more water-efficient appliances, low-flush toilets, or price-based incentives to decrease personal water use. To reduce indoor consumption, decrease *indoor use per capita.*

  Reduce outdoor consumption per capita.
  This could be achieved through conversion of lawns to xeriscape, for example. To reduce outdoor consumption, decrease *outdoor use per capita.*

- **Make hotels conserve**

  Water use by hotels accounts for 7% of *total water demand* and is accounted for in the variable *nonresidential per capita water demand.* If *total water demand* is approximately 290 gpcd, hotel use is approximately 7% * 290 ~= 20 gpcd. To reduce hotel water use, reduce *nonresidential per capita water demand* by up to 20 gpcd.

- **Combination of policies.**

  Participants felt the most realistic solution would be to increase supply a little and focus on conservation of outdoor water use.

Simulation Results

Figure 8a.   Increase Supply by 50,000 ac-feet/year

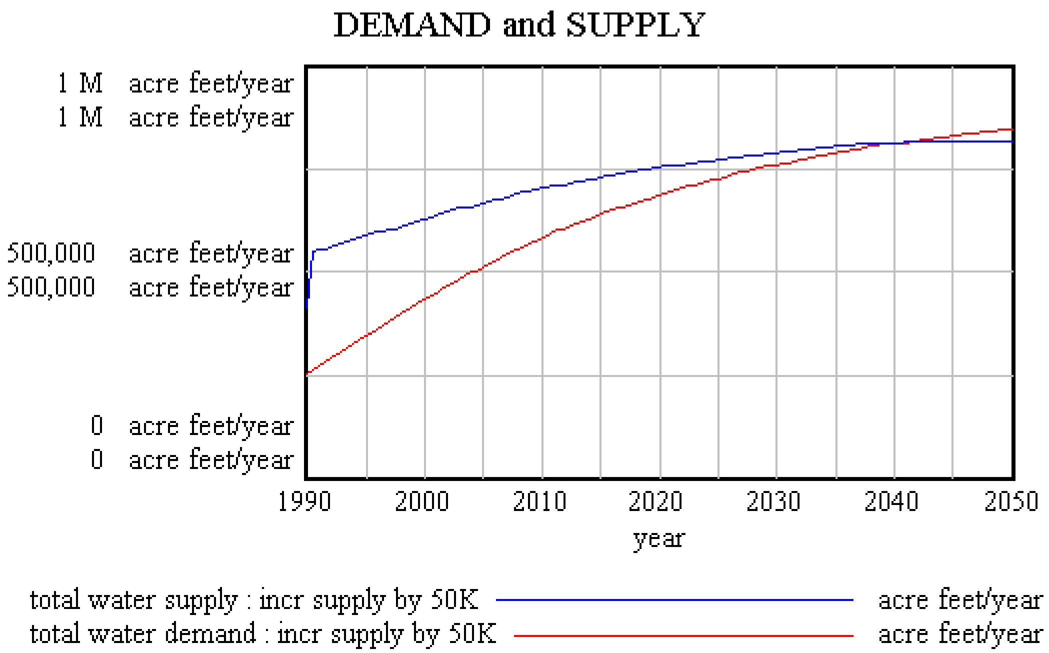


Figure 8b.   Decrease inmigration by2000 people/month

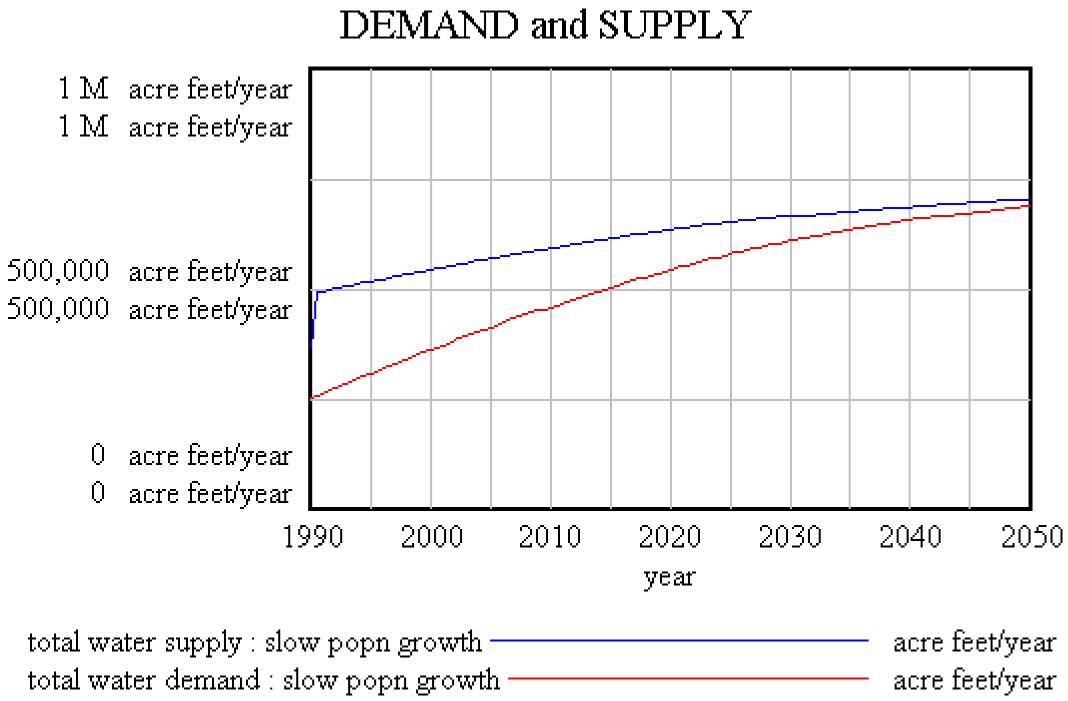


Figure 8c. Reduce residential indoor use by 25 gpcd

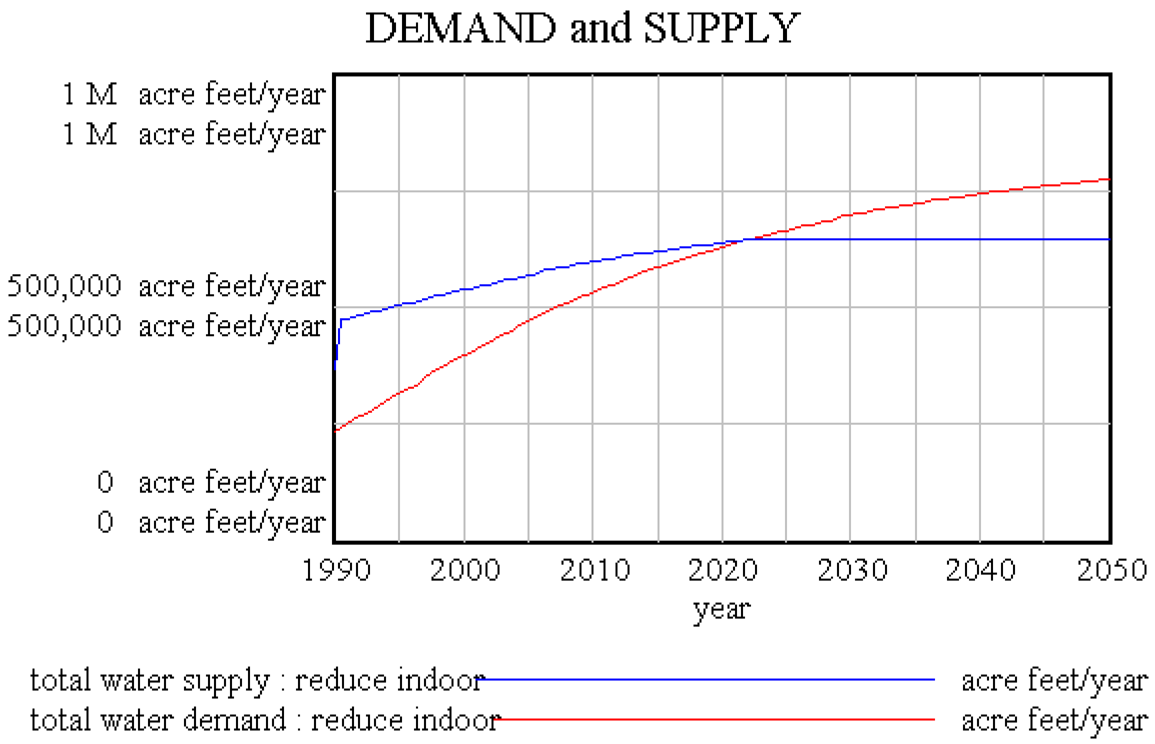


Figure 8d. Reduce residential outdoor use by 25 gpcd

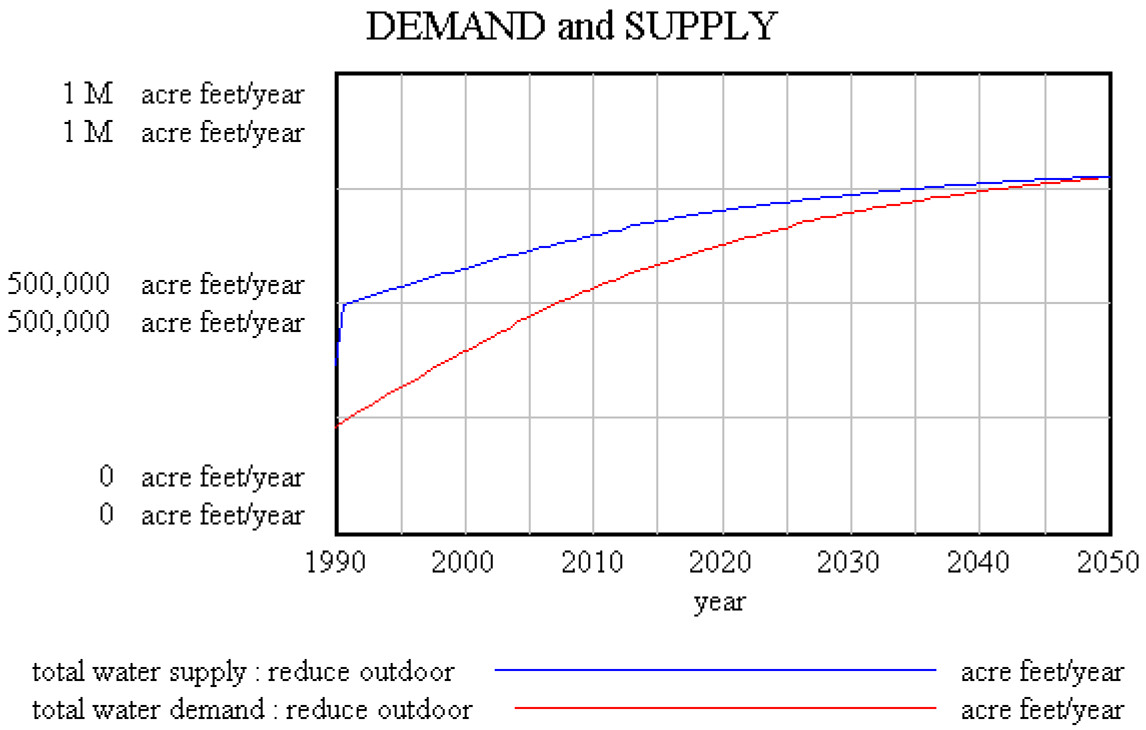


Figure 8e. Reduce hotel use by 50%

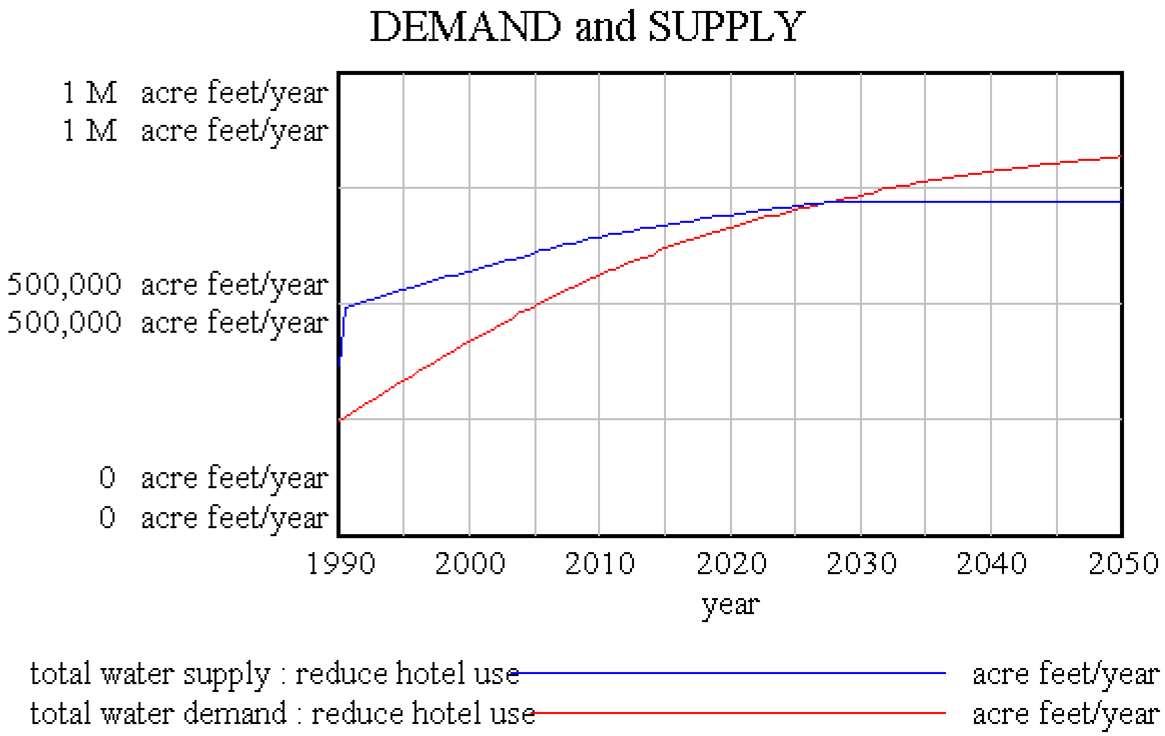
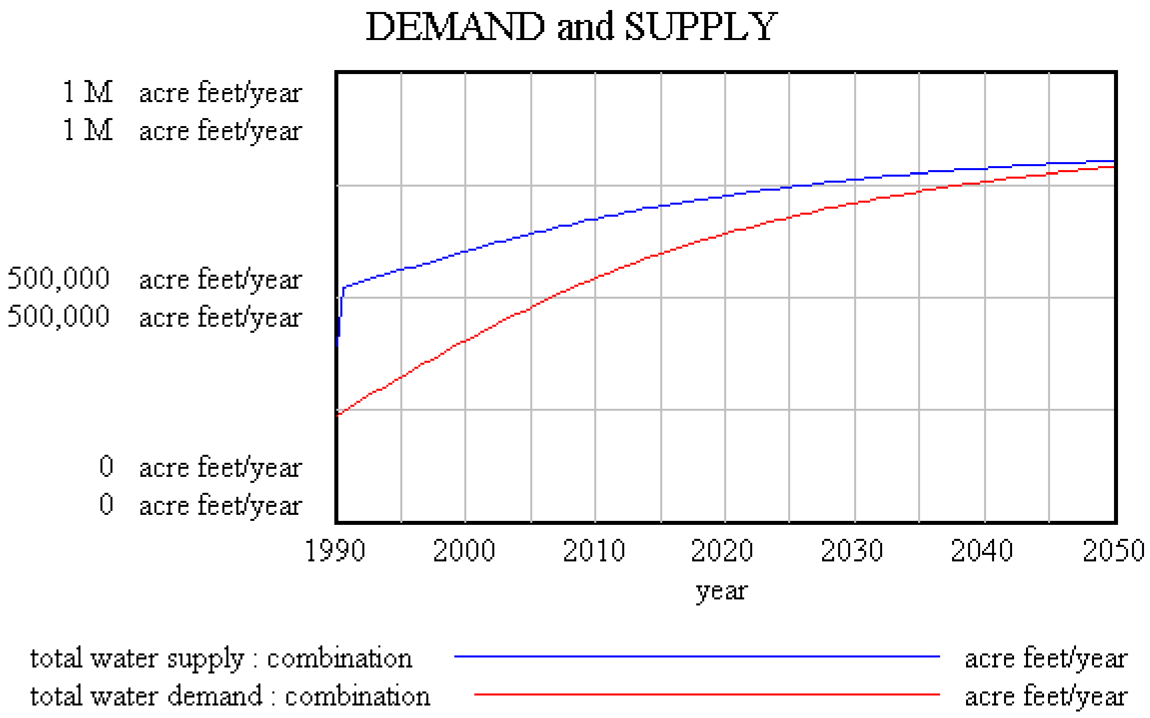


Figure 8f. Combination: Reduce outdoor use by 20 gpcd and increase supply by 25,000 acre-feet/year



Discussion

The model analysis shows a somewhat counterintuitive result, that reducing outdoor water use even a small amount can significantly reduce water demand, and has a greater effect than equivalent reductions in indoor use. The first guess of these participants was that increasing supply would have the greatest effect. Even without accounting for the economic and political costs of increasing supply, the model shows that supply would have to be increased substantially to make a difference.

This system, which appears straightforward, is dynamically complex. Because of the return-flow credit mechanism, the relationship between supply and demand is not clear. Supply *increases* with increased *indoor* water use, because indoor water is sent to the wastewater treatment plants and is counted for return-flow credit. Decreasing indoor water use therefore decreases supply at the same time it decreases demand, and thus does not produce the expected effect on the supply-demand crossing point. Decreasing outdoor water use, however, has a great effect, because it decreases demand and does not reduce supply. The model thus illustrates the much greater water conservation benefit of decreasing outdoor use over decreasing indoor water use. It also illustrates that decreasing consumption has a much greater, and longer-term effect than increasing supply. This kind of system dynamics model can help resource managers and policy-makers communicate the technical subtleties of a system to a broad audience and demonstrate the value of apparently counterintuitive strategies.

Acknowledgments

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