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Testing the potential of system dynamics models for improving public participation in resource management

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TESTING THE POTENTIAL OF SYSTEM DYNAMICS MODELS FOR IMPROVING PUBLIC PARTICIPATION IN RESOURCE MANAGEMENT

by

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ABSTRACT

Testing the Potential of System Dynamics Models for Improving Public Participation in Resource Management

by

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This thesis describes and discusses research which proposes that a system dynamics based-workshop can promote meaningful public participation in the resource management decision making process. The research tested the effectiveness of a system dynamics computer model for: 1) improving communication about technical data and stakeholder views; 2) increasing learning and insight into resource management issues; and 3) enhancing public trust in the decision making process. Seven research workshops were conducted to test the effectiveness of the model-based workshop for facilitating public participation in the management of the Las Vegas, NV water system. Workshop analysis showed that the system dynamics-based approach aided the workshop process. This thesis describes criteria for meaningful participation and the use of system dynamics for satisfying that criteria, development of the model and research workshops, data analysis, and the results and discussion of that analysis.

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CHAPTER 1

INTRODUCTION

This thesis summarizes the results of a study which tested the use of a system dynamics computer model for improving public participation in resource management. Research in the field of public participation in resource management is important because there is a growing interest in the role of the public in management decisions. An increasing number of citizens, resource managers, and policymakers have begun to recognize a need for a decision making process that allows for genuine public dialogue about the issues and restores public confidence in the decision making process. This study tested the use of a system dynamics-based workshop for improving public understanding of, and participation in, the Las Vegas Valley conservation program to achieve their target of 25% reduction in Valley water use by 2010.

This research included the construction of a system dynamics model of the Las Vegas Valley water system. Seven research workshops were conducted to evaluate the use of the model for water management and policy decision making. The system dynamics-based workshops were evaluated through the analysis of participant responses to pre- and post workshop surveys. Survey results of the workshops found that the system dynamics-based approach increased participant awareness of the problem,

enhanced discussions and shared understanding among participants, lead to improved participant insight, and improved participant perceived legitimacy of the decision making process.

Continued research in this field is important for developing well-defined participatory structures which incorporate the best available techniques and tools, dispute resolution, and other specializations which could increase the effectiveness of participation efforts.

The Need for Improved Public Participation in Resource Management

The notion of public participation in resource management has an extensive record in both political theory and practice. The premise is that the public, when given the opportunity to learn and evaluate resource problems and potential solutions, can contribute in a positive way to the deliberation process. These contributions help decision makers to develop better decisions, where "better" is defined as more widely acceptable and less open to challenge, easier to implement, and more sustainable.

Often, however, requests for public involvement in resource decisions are met with a sense of unease and distrust by both decision makers and citizens (Doerksen and Pierce 1976, Hale 1993, Johnson 1993). Resource managers feel that public involvement is in some way a scrutiny of their management skills. Also, some fear that involving the public could inhibit the step from decision making and planning to implementation. The shift from planning to implementation, coupled with tremendous monetary investments,

makes resource management particularly susceptible to extreme losses caused by delays (Doerksen and Pierce 1976). Educating the public on important technical issues to a level where they can contribute meaningful input is often seen as a potential delay in planning and implementation. Additionally, citizens often feel their efforts at involvement are of little or no use. They feel their input is not seriously considered and is only noted for "the record" (Gregory 2000). Sometimes, open dialog is prevented by overly formal deliberation procedures which leave the participants uncomfortable with, or incapable of, voicing their own perspectives and ideas. Making public participation forums more effective and useful, where both the public and resource managers come away with a sense of accomplishing goals and objectives, could provide a greater trust in the decision making process and increase the perceived legitimacy of forthcoming decisions.

A System Dynamics-Based Approach

System dynamics modeling is an approach that helps decision makers better understand the relationships between decisions, actions, and results (Costanza and Ruth 1996). Construction of system dynamics model is an iterative process. The model is built in "steps" of increasing complexity until the model replicates the observed behavior of the system. Ford (1999:171-181) describes eight steps in the modeling process: 1) get acquainted with the system, become familiar with the people in the system and their problem; 2) be specific about the dynamic problem by graphing the problem variables in a reference mode; 3) construct the stock-and-flow diagram, i.e. the model structure; 4) draw the causal loop diagram, to better understand the key feedback loops in the model; 5) estimate the parameter values, taking advantage of all sources of information available;

6) run the model to get the reference mode, to verify that the model is accurately replicating the system; 7) conduct sensitivity analysis, to determine if the model generates the same general pattern of behavior despite uncertainties in parameter values; and 8) test the impact of policies through simulations which will reveal whether the policies lead to the desired changes or not. This process is iterative and many of the steps will be repeated until an accurate model of the system behavior is produced. Decision makers can use a well-developed model to better understand the problem, the variables and relationships within the problem system, and the potential outcomes of intervention.

The "dynamics" in "system dynamics" refers to the patterns of change which occur within a system. System dynamics models help to explain why these patterns occur. Simulating the dynamics of a system requires that we move away from looking at isolated "events" and their "causes", and begin to look at the organization of a system made up of interacting parts. Kirkwood (1997) explains that, when we are faced with a management problem, we often assume that some external, one time, event caused it (see also Vennix 1996 and Sterman 2000). A systems approach encourages an alternative viewpoint - that the problem is more often generated by the internal structure of the system than by isolated external events. For example, the decline in the salmon populations in the Northwest U.S. fishing industry correlates with an overall decline in the worldwide fishing industry (Ford 1999). One could initially be tempted to examine variables within each struggling company for solving over-fishing. However evidence suggests that the structure of the industry as a whole, its markets and its technological developments, drives over-fishing by individual companies by compelling them to overshoot their sustainable limits. This view looks at the structure of the system as the

underlying source of the problem. By shifting from individual company behavior to the internal system structure of the industry as a whole one has a better chance of effectively addressing the problem. System dynamics practitioners believe that system structure is the underlying source of the difficulty. Unless you correct the structure, it is likely that the problem will resurface, or be replaced by an even more difficult problem (Forrester 1969, Sterman 2000) .

Through the development of a simulation model one builds into the representation of the system the initial conditions, parameter values, and functional relationships that affect, and are affected by, events related to the system. Once developed, the user simulates the model to play out scenarios of associated dynamics. Simulation provides an ability to observe the elements of a system in action, as well as the effects of change within that system. People can experience the outcome of a decision or policy, whether it affects them or a neighborhood miles away, or if the effect occurs tens or hundreds of years in the future. For instance, we can test both the short- and long-term effects of technological improvements in the fishing industry, how they might affect total fish catches and how these changes could affect fish populations. By simulating the effects of differing management strategies, system dynamics modeling can provide greater insight and guidance for decisions on complex and interrelated issues.

However, system dynamics is most appropriate for certain types of decisions or problems: ones that are dynamically complex because of underlying feedback processes (Vennix 1996:104-108). These are decisions that will generate consequences over time, both intentional and unintentional, which are not easily identified without the aid of a computer model. This excludes "static" policies, which address an "existing situation at

some point in time," (Vennix 1996:105). For example, a system dynamics model would not be particularly useful for determining the site for a landfill. A decision like this would perhaps be better addressed by a method which can lead to an optimal choice given a number of choices, such as the decision tool *Multi Attribute Utility Decision* (Vennix 1996:106). However, a system dynamics simulation model would be useful for better identifying and understanding the "side-effects" of a particular site decision, "including environmental, cultural, and moral implications," (Sterman 2000:32).

Additionally, system dynamics models typically address long-term problems, often ones which have been addressed unsuccessfully in the past. Sometimes a particular policy will work well in the short-term but not over the long-term. Often this is a result of the feedback processes within the system which "counteract the assumed effectiveness of the policy," (Vennix 1996:106). The purpose of a system dynamics approach is to identify policies which are effective over time. "In short, system dynamics is appropriate in situations where the problem is dynamically complex because of feedback processes and one looks for robust long-term solutions," (Vennix 1996:106).

Public participation needs and system dynamics capabilities suggest a potentially powerful role for system dynamics in promoting meaningful public participation in resource management. Eliciting and incorporating the values, preferences, and assumptions of system stakeholders is central to system dynamics modeling. Using the modeling process explicitly to facilitate the discussion of views and wishes among stakeholders, and to generate shared understanding, are key objectives of group modeling (Vennix 1999, 1996; Vennix et al. 1997). The simulation models themselves provide the key mechanism for determining the consequences of a given policy option.

This thesis adds to the public participation literature by evaluating the potential of system dynamics models to enhance public participation in natural resource management and policy decisions. With my advisor, Dr. Krystyna A. Stave, I conducted research which tested the use of a system dynamics-based workshop for improving public understanding of, and participation in, the Las Vegas Valley conservation program to achieve their target goal.

This thesis reports the results of this research study. It begins by defining public participation, examines what constitutes "more meaningful public participation" and how a system dynamics-based approach can contribute to the participation process. It describes the method used here for testing a system dynamics-based approach in a public participation forum, as well as the process development, and discusses the results of the research tests.

CHAPTER 2

PUBLIC PARTICIPATION

In recent years, conflicts over resource management have become increasingly complex and pervasive. Policy debates can often be extensive and expensive. In an effort to better address problem solving tasks many stakeholders are calling for greater public involvement in resource management decision making. Peter Johnson (1993) for example, notes that including the public in the decision making process helped resource managers to make better decisions, describing a case where, he says, "...by involving the public in the decision-making process itself, we gained authority and legitimacy, and avoided costly lawsuits and political challenges, and arrived at creative solutions to seemingly intractable problems. Overall, our policy-making improved."

Public involvement in political decision making, while a "vigorously accepted democratic ideal among most citizens," (Arnstein 1969), remains a problematic and, at times, an elusive goal (Hale 1993; Arnstein 1969). Despite the virtues of public involvement in decision making there are limits to its appropriateness. For example, there may be risk decisions, such as public health protection, which cannot be made based on public understanding and perceptions, or majority interests (Perhac 1998). We do not allow the public to set drinking water standards or emission standards. Nor is a simple

majority vote considered sufficient for making changes to the U.S. Constitution. The challenge is to determine which aspects of decisions are so fundamental that they should not be based in public sentiment. Public participation methods should be developed in a way that allows for making decisions within the appropriate scientific, political, and environmental contexts.

McComas and Scherer (1998:347) note, however, that appropriate methods for public participation are not always evident and, as Robin Gregory (2000) and others have noted, there is little guidance in how to produce *meaningful* public participation. Therefore, public participation tends to be limited to the gathering of stakeholder views and concerns, after which decision makers return to their traditional decision making methods to incorporate technical information, and make critical tradeoffs between stakeholder interests. Consequently public participation efforts are viewed with suspicion and very little legitimacy among citizens.

Gregory (2000:35-36) says that, in order to move beyond simple invitations to participate to meaningful involvement of all stakeholders in decision-making, a more structured forum for deliberation is needed. In particular, he believes there needs to be better communication of technical information, a mechanism for building a common understanding of how the system in question works, and a process which promotes learning and builds public trust through meaningful public involvement. The improved process would include a deliberative process which would be judged fair and in which decisions would be judged wise (Apostolakis and Pickett 1996). This process must include mechanisms for incorporating technical analyses which are needed to help

participants work through the consequences of decisions and to show how policy options affect the things stakeholders value (Dietz and Stern 1998).

The Public Participation Process

The purpose of this research is to evaluate, not only, the system dynamics-based approach but also the development of the public workshop process. Many professionals in the fields of group learning and workshop facilitation have called for increased research in the development of the tools and procedures for facilitating public workshops and forums, "[m]uch further work is need to test the utility of the tools and protocols, evaluate their impact on individual and organizational learning, and develop effective ways to train others to use them," (Sterman 2000:39). It is necessary that facilitators learn from others' work and share their own experience in conducting group forums. In the system dynamics literature there are several examples of group learning approaches which follow a more or less standard approach (see for example Richmond 1987; Anderson and Richardson 1997; Vennix 1996). However, no two efforts are alike and facilitators must adapt facilitation approaches to each project. Without experience and guidance this can be a very daunting task. Hentschel (1997:188) finds one of the greatest challenges to conducting workshops to be facilitator planning and training "...my graduate students had little or no experience designing programs,". Andersen and Richardson (1997:108) suggest that the "collective process" can be moved forward if "...small-group scripts are written down and tried out by others working in the field.". In the long term, a collection of tested and refined procedures would be of great help to the established field and to those new to workshop design and structure. Part of this thesis is designed to add

to this collection. The development process of the workshop structure and its script is detailed so that future facilitators can learn from this research experience.

The Public and Stakeholders

Explicitly defining public participation in resource management decisions can be a tricky endeavor itself. What is involvement? Who are the participants? How do they participate? How do we gauge success and failure? These, and many other questions, encompass the scope of *public participation.*

Defining "the public" is a little like fitting an oddly cut piece of carpet in a square room: just when you get one corner fit properly another corner pops out of place. When we try to "properly fit" people into a definition of the public we inevitably have individuals and groups who have been left out. Or else we are chided for including too many people who have only remote or "ulterior"interests in the issue at hand. Additionally, we can't include *everyone* because that would simply be logistically impossible and functionally destructive to the involvement process. The National Environmental Policy Act (NEPA), in its guidelines for public participation defines the public as "the people as a whole" in the sense that participation efforts should focus on the inclusion of any specific peoples who have "particular interest" in decisions which affect them (NEPA 1992). This can mean individual homeowners in rural areas or neighborhood community groups in towns and cities. Special interest groups, association and organization members, public officials, taxpayers, industry, and a limitless number of other potential interested peoples make up "the people as a whole" (Gott 1995:9).

For the purpose of this study, I have defined the public in the spirit of NEPA's

"people as a whole", meaning a representative selection of a localized population, including a broad range of age groups, income and education levels, and experience with no particular special interest necessary other than a minimal interest in public involvement and local resource management decisions. Thus when I write "public" or "the public" I intend a notion of practical representation of local interested citizenry.

Generally, when organizing public involvement forums, those members of the public most likely to be affected by the decision making process, referred to as "stakeholders", are identified and specifically targeted for inclusion. Stakeholder participation allows those affected by decisions to join in determining what information is necessary and how it is shared, the selection of goals and objectives, and policy alternatives, among other decision factors (Arnstein, 1969, Cobb and Elder, 1972).

This study addresses a community-wide issue of water conservation and all residential water users are considered stakeholders. The stakeholders are defined as those who are *affected by the enactment of policy decisions.* A more detailed description of the sampling of stakeholders participating in this research is found in chapter 4.

What Is Public Participation?

Hale (1993) describes three degrees of public involvement: public awareness, public education, and public participation. Public awareness is when the public becomes aware that a problem exists. The public can learn of these problems through different means, but the most common means are through the media, such as television, radio, the newspaper. Generally, in this situation, the public has a simplified notion or "sound bite" of the issues which make up the problem.

Hale's second level of public involvement is public education, which requires a more in-depth presentation and understanding of issues. Public education efforts provide enough information to citizens so they can understand the decisions and actions of government, "[S]omeone who is aware of a program may not be educated in the issues, but someone who is educated will necessarily be aware," (Hale 1993:17).

The third level of public involvement is a much deeper level of involvement, where contributions are considered valid and useful. Public participation is the notion of giving citizens the opportunity to *influence* policy decisions. An informed member of the public, when given an opportunity to collaborate with management professionals and decision makers, can effectively participate in the decision making process (Hale 1993). This deeper level of involvement, public participation, is the focus of this research. Specifically, this research tests the use of a system dynamics model in public forums for promoting awareness, shared understanding, insight, and communication among stakeholders.

Why Promote Public Participation?

Doerksen and Pierce (1975) and Johnson (1993) suggest that greater public participation will lead to *better* resource management decisions, where better means more widely accepted and less open to challenge, easier to implement, and more sustainable. But the connection between public participation and better decisions is not clear. Many resource management professionals are finding that by inviting the public into the decision making process, listening to their concerns and soliciting their advice, the decisions made gain greater legitimacy with the public. Additionally, agencies avoid

some costly challenges and delays and they arrive at creative and unexpected solutions to seemingly uncontrollable problems. The public gains a sense of being included in their own future, (Johnson 1993, Arnstein 1969, Weeks 1995, Preister and Kent 1997). Temple (1983) lists 36 positive effects of public participation ranging from providing information to affirmation of democracy.

One of the fundamental needs of resource management is *providing education* about a problem to the public affected by it (Hale 1993, Johnson 1993). As a source of practical knowledge public forums can help provide citizens with necessary information for analyzing choices. If resource managers wish for stakeholder input into management decisions, they must have an effective and efficient means for providing the public with the knowledge they need to develop and examine options (Fleming 1997). The sufficient exchange of technical knowledge, between and among participants and professionals, is vital to the participation process.

Likewise, public participation can *provide for direct feedback from stakeholders* about their values, concerns, and ideas. By exchanging information and enhancing two-way communication participants can identify disagreements early in the process and possibly avoid or limit unexpected conflict or address it before it escalates (Costanza and Ruth 1996). Decision makers can better define an issue and develop appropriate ways to address problems with input from stakeholders.

A potential outcome of public participation is *enhancing the legitimacy* of management decisions and *improving the public's trust* in agencies' and government's ability to effectively address problems. The result could be the promotion of a greater "buy-in" for the decision among the public. If stakeholders feel their views and ideas

have been included in deliberation, if they can actively participate in discussions about the appropriateness of data and its uses, and if they feel that their input was of value to the decision process, then stakeholders have an increased trust in the managers and agencies to make effective decisions (Apostolakis and Pickett 1998). Participants then are more likely to perceive these decisions as legitimate.

Obstacles to Public Participation

There are, however, obstacles to achieving meaningful public participation. As Gregory (2000) and others have noted, very few guidelines exist for how to *create* meaningful public participation. Akkermans and Vennix (1997) and Vennix (1999) note that two-way communication is vital for making participation meaningful. It allows participants and experts to exchange knowledge and information and to better understand differing views and ideas.

Additionally, just as increased trust and legitimacy can be a positive outcome of meaningful public involvement a lack of trust and legitimacy can also stands in the way of *doing* public participation. As public involvement efforts have evolved over the past one hundred years in the U.S., there have been credibility issues with participation efforts among the public (Arnstein 1969; Gott 1995). Often public participation has meant that agencies and organizations inform the stakeholders about decisions and options available, note questions, comments, and concerns, and then disappear behind closed doors to discuss trade-offs and make decisions (Gregory 2000). At best there may be follow-up meetings or mailings which outline management decisions. Participants are left feeling that their recommendations are ignored (Hale 1993:18). Thus the process holds a low

level of credibility with the public while trust in the decision makers' willingness to achieve meaningful public participation declines. When the public does not feel their ideas are being used, "citizen burnout," as Hale calls it, (1993:18), can often be the result of involvement efforts.

The Purpose of this Thesis

This basis of this research was the proposal that a system dynamics model could provide a forum for analytic deliberation, in which scientific analyses are combined with structured discussion about values and objectives. To test the potential of system dynamics to facilitate this kind of communication among stakeholders, a system dynamics simulation model was developed representing the water conservation problem and used in seven research workshops. The model-based workshop could be considered effective if it: 1) improved communication about technical data and stakeholder views; 2) increased learning and insight into the management issue; and 3) enhanced public trust in the decision making process. The following section examines the criteria for the use of technology, specifically system dynamics models, for promoting meaningful public participation. Chapter 3 intoduces the research hypotheses and methodology. Chapter 4 describes the development and facilitation of workshop forums which tested the system dynamics-based approach. In Chapter 5 the results of these workshops, in the form of facilitator observations and participant surveys, are examined. Chapter 6 discusses the research results.

Criteria for Meaningful Public Participation

It is suggested that a broad range of stakeholder contribution to the deliberative process will result in greater trust with the process among concerned parties. Susskind and Cruikshank (1987) describe the deliberative process as wise if it is perceived as fair by the disputants and the community at large and contains the most relevant information. Thus, a deliberative process that provides decision makers and stakeholders the opportunity to share and utilize relevant technical information, promotes feedback about perceived values and ideals, and demonstrates the consequences of policy options could help reduce conflict, improve trust, and potentially lead to fair and wise decisions.

Dietz and Stern (1998) describe a process called "analytic deliberation" for improving the decision making process. This process includes defining the problem, identifying the values and outcomes of concern, distinguishing disagreements that must be addressed through compromise and tradeoffs, and agreement on appropriate ways to collect and interpret needed information. Analytic deliberation relies on people's ability to communicate and develop mutual understanding. However, there are concerns that technical information would "fall to the wayside" in efforts to reduce conflict and improve stakeholders trust in the process (Apostolakis and Pickett 1998) or remain solely the responsibility of scientists and professionals. Thus, while analytic deliberation can potentially reduce conflict and improve public trust, stakeholders should be careful to keep vital data intact and maintained in discussions in order to secure technically and economically feasible solutions (Susskind and Dunlap 1981). Incorporating analytic deliberation into public participation efforts could improve the process for both the public

and decision makers. To test this idea, we must first identify the criteria for achieving meaningful public participation.

Peter Johnson (1993:56) calls meaningful participation *real involvement*, where public involvement leads to "real changes in decisions based on what [decision makers] heard." Real and meaningful involvement means that stakeholders' input helps shape policy. The policy decisions which include stakeholder input result in better, more wise decisions (Johnson 1993; Susskind and Cruikshank 1987; Dietz and Stern 1998; Apostolakis and Pickett 1998).

Akkermans and Vennix (1996) list the following needs for improving group decision making:

- improved awareness of a problem or issue
- better exchange of technical data
- shared understanding among stakeholders
- improved learning about the problem among stakeholders
- more effective communication
- improved consensus about the problem among stakeholders
- greater trust in the process and legitimacy with decisions

When satisfied in the deliberative process, these factors can lead to more meaningful public participation efforts.

Improved Awareness about a Problem

An pivotal factor of exchanging necessary data lies in increasing stakeholders' awareness about a problem. Unlike the "sound-bites" received through the media about a problem, a public forum, designed to inform and educate, would necessarily increase stakeholder awareness of the issues at stake. While awareness is not meant to be equated

with meaningful participation, it is necessary for *achieving* meaningful participation. A stakeholder must be aware of a problem and its many facets before the problem can be effectively addressed (Hale 1993).

Better Exchange of Technical Data

All resource management decisions begin with observations: there is a perceived change in a fish population; water demand for a community begins to exceed supply; resource economic interests conflict with recreationalist interests. Questions must be answered, such as: Who and what is affected by these issues? How? What can be done to effect change? A seemingly endless supply of scientific and technical data and knowledge must be accumulated and sorted in a way that allows the most effective and efficient solutions to be identified (Apostolakis and Pickett 1998). This data must also be shared with stakeholders so they may be able to participate in discussions and help make informed decisions (Rycroft, Regens, and Dietz 1987). It is crucial to have a deliberative process which makes the exchange of technical information as easy and effective as possible so that stakeholders and decision makers can then open the discussion toward designing solutions (Rycroft, Regens, and Dietz 1987, Stern 1991, Apostolakis and Pickett 1998, Dietz and Stern 1998).

Greater Shared Understanding

When forming decisions that affect a wide range of stakeholders other kinds of necessary information, beside technical, must be exchanged. Social and cultural data must also be considered. Values and goals of the local community should be identified as

well as the knowledge that community members can bring to the deliberation. Including community input can help to identify options that may not have been previously considered. These kinds of data make information more representative of the real world so that decision makers can achieve greater insight into the problems they face (Stern and Dietz 1994, Costanza and Ruth 1996, Dietz and Stern 1998).

By eliciting and understanding stakeholders ideas about how the world works and how it should work and by knowing their values and preferences, better and more effective solutions can be formed (Cramer, Dietz, and Johnston, 1980, Stern and Dietz 1994, Costanza and Ruth 1996, Apostolakis and Pickett 1998, Dietz and Stern 1998). But eliciting these kinds of information, sharing it and understanding it, can be difficult. It requires a willingness and ability to move from one-way communication to two-way, from the simple dissemination of information to actively exchanging information.

Improved Insight About the Problem Among Stakeholders

The essence of greater insight into a problem lies in *how* a problem is understood. It is a step beyond acquiring new facts or knowledge about a problem and its environment. It is a shift in how a person thinks about the causes of problems and their solutions, improving the way they understand the problem, the things that cause and affect it, how those things are related, how they work together. People begin to look at possible outcomes of their actions differently, perhaps more broadly to better capture a wider range of impacts. Smith (in Senge 1990:377) explains that gaining insight means, "[t]o see more clearly [one's] own and others' assumptions, actions, and consequences of both." Greater insight into a problem gives stakeholders new understandings and new

behaviors for forming effective solutions. Rather than assigning numbers to options or to rely on the results of any summary mathematical analysis a primary goal of public participation should be improved thinking about critical concerns and tradeoffs in decision making (Gregory 2000:36).

Need For and Benefits Of More Effective Communication

Vennix (1999) points out that the way group members communicate can be one of the biggest problems in troublesome managerial situations. Information and knowledge about a problem must be communicated between different segments of the group. But individuals have difficulty processing information effectively due to weaknesses in listening skills, defensiveness, and an inclination to evaluate data subjectively (Vennix 1999). These weaknesses in communication skills can, in turn, delay and adversely effect the quality of decisions and inhibit group creativity (Vennix 1999 and Sterman 2000).

If simple dissemination of information were all that was required for involving the public in resource decisions then a basic one-way kind of communication would be sufficient. The public could be informed through lecture style presentations by resource management professionals, or they could receive reports and data through the mail. But truly meaningful public participation requires a deeper level of communication where *feedback* becomes equally as important as the information itself.

Two-way communication, unlike one-way communication, involves responses to, and discussions of, the information between parties. Feedback from stakeholders can allow the management team to know if information is being understood. Feedback from the management team allows the public to re-affirm newly acquired knowledge. But it

also allows the public to question the accuracy and appropriateness of information. Clear mechanisms for feedback between managers and the public ensures that the science addresses all issues of concern, that value discussions are well informed by technical information, and that the science is accepted as appropriate to the decision (Dietz and Stern 1998:2).

Improved two-way communication influences all other aspects of public participation, it leads to better exchange of data and information, improves shared understanding and consensus among stakeholders, and can lead to greater commitment to outcomes (Stern 1991, Akkermans and Vennix 1996, Dietz and Stern 1998, Vennix 1999).

Greater Trust in the Process and Legitimacy of Decisions

Perhaps the greatest obstacle to effective deliberation is lack of trust in, and perceived legitimacy of, the deliberative process. Stakeholders often feel their input is not used by decision makers and sense that the final decisions were actually made before the public was involved (Arnstein 1969). They come to view public forums with very little faith and a considerable amount of suspicion. It is critical that public involvement efforts provide stakeholders with a forum in which they actively participate in the deliberative process, for their own empowerment and trust in the system (Gott 1995). When participants see the process as fair, having included their input, then they will give greater legitimacy to decisions and will have greater commitment to seeing them succeed (Gott 1995. Apostolakis and Pickett 1998, Gregory 2000).

How Can System Dynamics Improve Public Participation?

A system dynamics modeling approach provides a mechanism for improving analytic deliberation in public participation forums. By focusing on interrelationships within a system, system dynamics organizes and unifies knowledge, makes assumptions explicit, and can "help to build mutual understanding, solicit input from a broad range of stakeholder groups, and maintain a substantive dialog between members of these groups," (Costanza and Ruth 1996:185).

Additionally, modeling can serve as a tool to foster consensus about the appropriateness of assumptions and management options and help build consensus across academic disciplines and between science and policy and stakeholders (Costanza and Ruth, 1996, Yankelovich 1991, Weisbord 1992, Weisbord and Janoff 1995).

Professionals in the field of system dynamics promote systems thinking and system dynamics as an effective tool for "addressing challenge," (Richmond, 1990). System dynamics develops knowledge and understanding of a *system* - an interdependent group of items, or variables, which operate toward a common purpose. A dynamic model provides stakeholders and decision makers with an interactive tool for learning and thinking about how a system functions and responds to changes over time. System dynamics models, whether they are used in business systems, ecological systems, or any other system, are designed to generate understanding and insight and to test theories of intervention and change. Hence, a system dynamics model of a resource system, which includes stakeholder participation, could provide a valuable tool for discussing and analyzing problems and their solutions, while promoting insight and understanding of the impacts of those solution.

Renn, et al, (1993) note a need for a model that combines technical knowledge and rational decision making with public values and preferences. A model which aids discussions and the exchange of information and knowledge, and structures and tests participant input would greatly benefit the deliberative process.

System dynamics can be such a model. Central to system dynamics models is the elicitation and incorporation stakeholders' values, preferences, and assumptions concerning the system. The modeling process motivates the discussion of stakeholders views and thus generates shared understanding. By integrating decisions with actions and results model simulations provide the key mechanism for determining the consequences of a given policy option. In these ways, system dynamics can be used to promote meaningful participation.

Research Approach

System dynamics models have been used widely to improve organizational management (e.g., Vennix 1996, Andersen and Richardson 1997, Richmond 1997). Experience using systems dynamics interventions to build stakeholder participation in resource management, however, has been more limited. Costanza and Ruth (1998) used the modeling process to scope problems, help build consensus about the way the system works, and evaluate management options in three environmental management cases. They found dynamic modeling to be a useful tool for including input and expert judgement from a broad range of stakeholders. Ruth and Lindholm (1996) used system dynamics to facilitate dialog among participants in fisheries management.

Their experience suggests a role for computer simulations in enabling

stakeholders to develop their shared understanding of a system's workings. However, these apparent successes have not been systematically evaluated (Huz et. al 1997). General questions such as the following remain unanswered:

- Do individuals who experience a system dynamics-based deliberative process change the way they think about a problem of interest after they participate?
- Does the quality of group communication improve with a system dynamics-based process?
- Does the overall legitimacy of management decisions shift in a measurable way due to this process?

If measurable changes do occur, then "a second tier" (Huz et al.1997:150) of questions must be asked which focus on what aspects of the system dynamics-based process contribute to these changes. These include: what is it about system dynamics that make the deliberative process successful? What aspects of the process such as the use of a simulation model or the application of group activities successfully contribute to the deliberative process?

Answering these questions can be a challenge, especially in the public sector, where trust in decision makers and the process itself is often low to begin with. Additionally, most participants in the public sector are involved for a specific decision goal and are not interested in experimental manipulation of the process. Facilitators who design and implement public participation forums often lack the time or motivation to engage in systematic evaluation. Furthermore, as pointed out by Huz et al., (1997:150) conceptual problems that surround the evaluation effort are vast "because the

interventions involve individual cognitive process and complex group interaction, as well as the analysis of a dynamically shifting organizational environment."

Thus, in order to more closely determine the effectiveness of a system dynamics-based deliberative process we must examine two separate aspects of the forum experience: 1) does the deliberative process produce an overall beneficial experience for participant stakeholders and 2) what specific aspects of the experience are most valuable?

CHAPTER 3

METHODOLOGY AND HYPOTHESES

Technology, particularly computer simulation models, holds considerable potential for actively engaging stakeholders in the deliberative process. Leaning-by-doing is intuitively an effective educational strategy and collaborative exercises "promote creative thinking and the formulation of multiple working hypotheses," (Taylor et al. 1997:148). The Accounting Education Change Commission (1990:5) recommended in its changes in university accounting education that "[l]earning by doing should be emphasized. Working in groups should be encouraged. Creative use of technology is essential."

Geographic Information Systems (GIS) technology has recently been used for enhancing public participation in decision making as a support tool. Studies have found GIS to be useful when deliberation requires access to current, relevant, and comprehensive information in a way that recognizes the inter-relationships among data (Barndt 1998:279). Emily Talen (2000:279) describes the use of GIS as "...a spatial language tool for acquiring local knowledge and communicating residents' perceptions, rather than conveying only objective facts."

Additionally, if using a system dynamics computer model for public participation, it is particularly important to understand its role in group learning (Anderson and Richardson 1997). Technology's role in group learning has been discussed extensively in both educational and technology literature. Some studies have suggested that active involvement and interaction among students may be more important for education than the content of the curriculum (Taylor et al. 1997). Research suggests that, through discussions and problem solving activities conducted by small groups, people are more likely to remember what they have learned and to generate more creative solutions to complex problems (Will 1997). Others propose that actively engaging participants in the deliberative process promotes diversity of voices, consensus, retention of new information, and greater "buy-in" to the process (Imel 1996; Johnson, Johnson, and Smith 1991; Kadel and Keehner 1994). Matray and Proulx (in Korfiatis et al. 1999) found that biological concepts can be more effectively communicated with computer technology than through the more traditional means of lectures, discussions, etc. Carson (1996) and others have pointed out that besides enhancing knowledge and comprehension, computer simulations can improve skills relating to the analysis and application of ecological models.

Therefore, there is some basis for proposing that system dynamics technology can help improve public participation in resource management. Like GIS, system dynamics

emphasizes interrelationships and allows participants to communicate perceptions as well as facts. Likewise, it provides a framework for group process and communication by incorporating visualization, information, analysis procedures, and the mechanisms for decision support. It promotes active participation in the learning process by engaging participants and encouraging their input.

There are, however, "pitfalls" to using simulation models (Sterman 2000:35-37). Simulations are effective when people use them to think about a problem, to reflect over causal relationships, and learn how to accomplish useful change. While simulation models are powerful tool for learning in dynamically complex systems, "they are not sufficient to overcome the flaws in our mental models, scientific reasoning skills, and group processes," (Sterman 2000:35). Many times modelers and workshop participants become so involved in the "excitement" of the simulation experimentation that they do not reflect on discrepancies between expectations and outcomes, nor do they form hypotheses explaining these discrepancies, or devise experiments to test for change. "A commonly observed behavior among modelers and in workshops using management flight simulators is the video game syndrome in which people play too much and think too little," (Sterman 2000:36). Sterman recommends "protocols for the use of simulations" which are structured to encourage appropriate problem solving procedures such as disciplined scientific reasoning (2000:36).

Other perils associated with using simulations in group environments are "defensive routines" and "group think". Exchanging information, suggesting options, and voicing opinions can be very threatening and can trigger defensive reactions which obstruct learning (Sterman 2000:36). Sometimes group decisions can be poor because of

group dynamics, such as when group cohesion is maintained at the expense of critically evaluating decisions. Occasionally, group discussion can change an individual's views for reasons unrelated to critical reasoning, such as to gain approval or conform to the norm. Facilitators should be cautious to build participant comfort and trust in the process so that their true knowledge, opinions, and mental models can be explored objectively and fairly.

Research Hypotheses

Several claims have been made in the literature about the effectiveness of system dynamics models for improving public participation in resource management decisions: that they promote greater awareness and understanding of a resource problem (Akkermans and Vennix 1996; Ruth and Costanza 1996), they improve communication and the exchange of information between stakeholders (Vennix 1996), and they help determine the consequences of a given policy option (Vennix 1996 and Sterman 2000). The following hypotheses distinguish specific aspects of the role of system dynamics in meaningful public participation.

- Hypothesis 1 - System dynamics-based workshops increase participants' awareness of a problem.
- Hypothesis 2 - System dynamics-based workshops help facilitate the exchange of data and technical information among participants.
- Hypothesis 3 - System dynamics-based workshops enhance shared understanding among stakeholders.
- Hypothesis 4 - System dynamics-based workshops lead to improved participant insight.

- Hypothesis 5.1 - System dynamics-based workshops provide a common language for participant discussions.
- Hypothesis 5.2 - System dynamics-based workshops promote discussion.
- Hypothesis 5.3 - System dynamics-based workshops promote participant comfort with communicating their ideas to each other during the deliberation process.
- Hypothesis 6 - System dynamics-based workshops improve participants' perceived legitimacy of the decision making process.

Hypothesis 1 - System dynamics-based workshops increase participants' awareness of a problem.

The idea that involvement leads to greater awareness of a problem is straightforward: if you are involved in the deliberation you will become more aware of the issues. However, as Akkermans and Vennix (1996:21) note about the relationship between involvement and insight, a participant could generally learn a great deal, whether they become deeply involved or not. But insight provides a more explicit kind of awareness - an awareness not just of the problem, but of the range of solutions and their influences on results. So while basic involvement can boost stakeholder awareness, insight gained from a system dynamics-based forum should better improve stakeholder awareness over more traditional participation forums.

Hypothesis 2 - System dynamics-based workshops help facilitate the exchange of data and technical information among participants.

A system dynamics-based approach could improve the gathering and processing of information. They bring attention to important issues of a problem, allow people to

focus on relations within a complex system, and to consider those structures when discussing problem solutions. By providing a tool for capturing and working with technical data a simulation model helps to prevent necessary information from "falling to the wayside", a problem related to deliberation efforts pointed out by Apostolakis and Pickett (1998). The model maintains the integrity of the system's complex structure. Stakeholders are thus able to more rigorously examine the variables of a problem. They can test the accuracy and appropriateness of the data, add to the information, and discuss the assumptions built into the data.

The description of complex systems is one of the focal points of system dynamics. Vennix (1999) considers simulation to be the primary contribution to the improvement of a group's information processing capacity. Vennix also points out that the associated diagrams help to keep track of complex structures and add rigor to the analysis and group discussion (1999).

Hypothesis 3 - System dynamics-based workshops enhance shared understanding among stakeholders.

Another opportunity for improving communication lies in the identification and exchange of the *mental models* which people use to understand the world around them. Mental models are the representations that people have in their minds about how the world works. They are often the unrecognized and unstated images we base our decisions upon. As Forrester explains, "[m]ental models are fuzzy, incomplete, and imprecisely stated. Furthermore, within a single individual, mental models change with time, even

during the flow of a single conversation. The human mind assembles a few relationships to fit the context of a discussion. As debate shifts, so do the mental models. Even when only a single topic is being discussed, each participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open. Goals are different but left unstated," (1995:3). Underlying assumptions, if not addressed, can jeopardize consensus and, if incorrect, can lead to solutions which fail. "[t]he human mind is not adapted to understanding correctly the consequences implied by a mental model. A mental model may be correct in structure and assumptions but, even so, the human mind–either individually or as a group consensus–is apt to draw the wrong implications for the future," (Forrester 1995:4). A system dynamics model allows us to represent, unify, and operationalize mental models into a form in which they can be examined and better understood. According to Vennix, "[s]ystem dynamics can be helpful to elicit and integrate mental models into a more holistic view of the problem and to explore the dynamics of this holistic view," (1996:3).

Building and validating system dynamics models in small groups encourages the exchange of ideas and viewpoints and consequently helps to clarify mental models which dictate how a problem or issue is addressed. The elicitation of these mental models promotes a shared understanding among stakeholders about each other's perspective of how the world works and how the problem being addressed fits into this perspective while providing a tool for drawing implications about decisions made.

Hypothesis 4 - System dynamics-based workshops lead to improved participant insight.

System dynamics modelers propose that simulation generates insight into a problem or issue. Simulation models allow stakeholders to test out possible solutions and see the outcome of intervention. It allows them insight into the consequences of their decisions and helps them guide options toward the goals they seek. Akkermans and Vennix's (1996:20) assessment study in group model building confirmed the idea that "...through conducting simulation experiments one learns about a problem." However, they note that there are other ways to gain insight from a model than just quantified simulation. For example, a qualitative model can lead to learning and insight as well.

Akkermans and Vennix (1996:21) also say learning and insight is generated by participation in the modeling process itself. However their study did not demonstrate a positive relationship between the two. They determined that participants (clients) tend to learn a great deal whether everyone participates or not. The influence of system dynamics on stakeholder insight is still not completely clear (Vennix 1999, Vennix and Rouwette 2000). This research further tests the relationship between a system dynamics-based approach and participant insight into a problem and its potential solutions.

Hypothesis 5.1 - System dynamics-based workshops provide a common language for participant discussion.

Hypothesis 5.2 - System dynamics-based workshops promote discussion.

Hypothesis 5.3 - System dynamics-based workshops promote participant comfort with communicating their ideas to each other during the deliberation process.

System dynamics can promote the kind of effective two-way communication crucial for fostering meaningful public participation. One of the ways that system dynamics can improve discussion is by providing a tool for eliciting common language among stakeholders. A common language helps participants to talk about a problem. Stakeholders often have different levels of experience, knowledge, specialties, and positions. A common language can help participants exchange and share a wide variety of information quickly and easily.

System dynamics models aids in group discussion by providing a tool around which a common language can develop. Models help stakeholders to *see* the system. The model structure, the stocks and flows and informational arrows, provides an easy to understand diagram which helps participants discuss the system. Additionally, models can improve stakeholders' comfort with expressing their ideas. Romme (1995:311) notes that insecurity among participants, due to "authoritarian power structures," can hinder the deliberative process. A simulation model can provide a more neutral focal point for discussion. It can promote comfort among participants to express their ideas and opinions.

If system dynamics models can bring underlying assumptions to the surface and place them on the table for examination, stakeholders can achieve a greater understanding of each others' views, positions, and ideas. If stakeholders gain an increased understanding of each others perspectives then it is possible that stakeholders could reach an improved state of consensus about the problem - what it is, what causes, and how you can address it. Costanza and Ruth (1996:185) note the modeling process "...can help to build mutual understandings, solicit input from a broad range of stakeholder groups, and

maintain a substantive dialog between members of these groups." Akkermans and Vennix (1996:19) found that "good communication" coincided with "fair to high levels of consensus."

> Hypothesis 6 - System dynamics-based workshops improve participants' perceived legitimacy of the decision making process.

One of the most promising aspects of a system dynamics-based workshop lies in its usefulness in improving stakeholder trust in, and perceived legitimacy of, the decision making process. A key point is that a simulation model allows decision makers to see and work through the consequences of possible solutions. Simulation results can guide decision makers to the most effective and efficient solutions or allow them to recognized and manage complications that arise with different solutions. In a workshop with stakeholders participating in solution discussions, simulation models give stakeholders the opportunity to see their own ideas in action. Thus stakeholders could have a greater perceived legitimacy with decisions.

If stakeholders feel the process is fair, in that it includes stakeholders ideas and perspectives, then their trust in the process increases. Additionally, this way of testing potential solutions, seeing the results of their own ideas, provides stakeholders with a sense of ownership of the decisions. As legitimacy of the participation process improves and stakeholders gain a greater sense of ownership of decisions, we can expect stakeholders to become more committed to decisions and their implementation.

Framework for Measurements and Evaluations

To understand the impact of a system dynamics-based process for public participation in resource management, we developed an evaluation framework based on a framework developed by Huz, Anderson, and Boothroyd (1997). Table 1 presents an outline of the evaluation framework being used in the experiment. As suggested by Huz, et al., attempts at evaluating system dynamics-based processes must proceed along levels of deepening analysis. At the first level, workshop facilitators reflect formally and informally on their own performance and the effects of the process. At the second level, participants give self-reports of what has been the impacts of the process on their attitudes, beliefs, understanding of the system, and effectiveness of the process.

Table 1 Huz, et. al. ten areas of measurement and evaluation used to assess impact of system dynamics based process (1997:151)

Level I:	**Reflections of the modeling team**	
	Domain 1:	Modeling team's assessment of the intervention
Level II:	**Participant self-reports of process impact**	
	Domain 2:	Participants' perceptions of the intervention
	Domain 3:	Shifts in participants' goal structure
	Domain 4:	Shifts in participants' change strategies
	Domain 5:	Alignment of participant mental models
	Domain 6:	Shifts in understanding how the system functions
Level III:	**Measurable system change and "bottom line" results**	
	Domain 7:	Shifts in network of agencies that support services integration
	Domain 8:	Changes in system-wide policies and procedures
	Domain 9:	Changes in outcome for clients
	Comparative conditions that may explain intervention's effectiveness	
	Domain 10:	Group member characteristics

Each of the two broad levels are operationalized using multiple areas of measurement and analysis. Table 2 shows how we adapted seven of Huz's areas of measurement for our study.

Table 2 Seven areas of measurement and evaluation used to assess impact of system dynamics-based process in this study

Level I:		**Reflections of the modeling team**
	Area 1:	Modeling team's assessment of the process
Level II:		**Participant self-reports of process impact**
	Area 2:	Shifts in understanding how the system functions
	Area 3:	Perceptions of mental models/assumptions
	Area 4:	Perceptions of insights
	Area 5:	Perceptions of process effectiveness
	Area 6:	Shifts in two-way communication and exchange of ideas/viewpoints
	Area 7:	Shifts in legitimacy and ownership of decisions

The area of analysis in this research experiment includes reflections of the facilitators and pre-workshop and post workshop questionnaires for the participants.

CHAPTER 4

METHOD

There were several steps in conducting the research for testing the usefulness of a system dynamics model in public forums. First was the identification of the Las Vegas Valley water management problem. As discussed in detail in the following case study section, as water demand in Las Vegas Valley approaches supply, conservation becomes increasingly important. The Southern Nevada Water Authority (SNWA) has set a target of 25% reduction in Valley water use by 2010. To achieve this reduction, water managers are counting on individual behavior to change dramatically. So a key step to achieving their goal is to raise awareness and increase public support of the conservation policy. Our research designed a public workshop for this purpose.

Our first step was to develop a system dynamics model of the water system for use in research workshops. Three pilot workshops were conducted in the summer of 2000 for the design and development of the seven research workshops. The research workshops were conducted from October through December 2000 and were evaluated for their usefulness for promoting meaningful public participation in January and February 2001.

This chapter explains the development of the model and the workshop format. The chapter is intended to add to the collection of data emphasizing the importance of

workshop design and planning (see Anderson and Richardson 1997; Vennix 1996). I first discuss the case study used in the workshops for discussion and decision making: the Las Vegas Valley water conservation problem. Next I discuss the development of the system dynamics model, the workshop structure and script, and the survey for evaluating the effectiveness of a system dynamics-based approach to public participation.

Case Study: The Las Vegas Valley Water System (from Stave and Cloud 2000)

This section is taken verbatim from Stave and Cloud 2000. Citations of this section should read: Stave, K. and S. Cloud. 2000. Using System Dynamics Models to Facilitate Public Participation in Water Resource Management: A Pilot Study Using the Las Vegas, NV Water System. *Proceedings of the 18th International System Dynamics Conference 2000.* System Dynamics Society, Bergan, Norway.

The Las Vegas water system serves 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. The Las Vegas metropolitan area is contained within a 1,586 square mile drainage basin that extends approximately 40 miles from the Spring Mountains in the west to Lake Mead in the southeast. All sewage effluent from the city, shallow subsurface groundwater, and stormwater drains the metropolitan area via a 12-mile natural wash to Lake Mead, discharging into the lake six miles upstream from the city's drinking water intake. Water taken from Lake Mead for the Las Vegas metropolitan area's water supply returns to the Las Vegas Valley upstream from the Wash, creating a physical loop in the metropolitan area's water system. Water not withdrawn from Lake Mead eventually passes by Hoover Dam and continues down the Colorado River toward California and Mexico.

The physical loop in the water system makes the dynamic connections between urban development, ecosystem change, and water quality trends especially important for water management. One important connection between human activity in the watershed and environmental characteristics in the Wash is the link between urban development and the hydrology of the Wash. The phenomenal rate of population growth in the Las Vegas Valley in the last several decades has led to widespread changes in water use and urban infrastructure. The resident population of the drainage area has grown from a few people at the turn of the century, to 200,000 in the late 1960's to over 1.4 million today. The number of tourists visiting the Valley has also been growing, topping 43 million people per year. Eighty-five percent of the water that sustains this population is brought into the Valley from Lake Mead; the rest is withdrawn from groundwater in the Valley. Thirty percent of the water is used in homes and sent to one of the Valley's three sewage treatment plants, all of which discharge into the Las Vegas Wash. Another 30 percent is used for residential irrigation, much of which reaches the Wash as urban runoff or shallow subsurface flow.

Dry weather flows in the Wash are sustained primarily by effluent from the three sewage treatment plants in the valley, which discharged 138 million gallons per day in 1997 (LVWCC 2000). Urban area, including roads, parking lots, drainage channels, and residential and commercial buildings, covered 22,000 acres (less than 2% of the drainage area) in 1960 and more than 187,000 acres (18% of the drainage area) in 1999 (LVWCC 2000). Urban development replaces natural vegetation with impervious surfaces, moving greater volumes of stormwater and urban runoff to the Wash faster than they might otherwise.

All these changes have led to increased wash flow, from dry weather flows of less than 1 ft^3/sec in 1928 (Roline and Sartoris 1998) to over 260 ft^3/sec in 1999 (LVWCC 2000), and have intensified the effect of flash floods. Following storm events, flow in the Wash can range from 500 to 10,000 cfs (LVWCC 2000). These changes in the Valley have caused ecological changes in the Wash, turning a nearly dry wash into a rich wetland, and then to an eroded and channelized system, and water quality changes at the outlet of the watershed into Lake Mead.

Water supply issues are also affected by 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 about how the water was to be allocated. Nevada's allotment is fixed at 300,000 acre-feet per year. Las Vegas gets credit, however, for any water withdrawn from the river that it returns to the river. This "return-flow credit" increases the total amount available for withdrawal to 450,000 acre-feet.
Over 20 local, regional and federal entities, as well as local businesses and residents, have interests in this water system, each identifying different system characteristics as problematic. Management challenges include identifying and addressing diverse stakeholder objectives, communicating information about the dynamics of the interconnected urban and environmental system, and changing public behavior.

In spite of the salience of water quantity and quality issues in the arid Las Vegas environment, there is remarkably 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 somewhere else, and many come from more humid climates with more natural precipitation. They tend to prefer landscapes that include green lawns and lush vegetation, perhaps representing landscapes where they came from, 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.

As water demand approaches supply, however, water conservation becomes increasingly imperative. The water authority has set a target of 25% reduction in water use by 2010. To achieve this reduction, water managers are counting on individual behavior to change dramatically. Such behavioral changes will require both incentives and consequences, and even the "sticks" need some measure of public support to be politically palatable. So a key step in management is raising public consciousness and enlisting public support. Raising awareness and increasing public support through public participation is the goal of the workshops in this study.

Model Development

The model was developed in three phases, reflecting the shifts in focus of the project. The initial purpose of the project was to develop a predictive model of the Las Vegas Water System for assisting with water resource management decisions that could also be used to facilitate communication with the public. Based on feedback from water management professionals in February 2000, it became clear that the model could better serve as a tool for communication between experts and non-experts than as a tool for management support. Thus, the project direction shifted from predictive to descriptive modeling and the primary purpose from management support to public outreach, particularly, communicating technical information about the water system to, and facilitating discussion among, stakeholders, and developing public support for the water authority's conservation decisions.

Initial Model

From ongoing studies of water quality in and around Las Vegas Bay and Boulder Basin, by government agencies such as the Bureau of Reclamation and the U.S. Geological Survey (USGS), the initial model development focused on how water is used and influenced in the Las Vegas Valley. USGS findings have isolated urban activities as having been primary sources of nutrients, pesticides, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and trace elements which gave been detected in and downstream of the Las Vegas urban area (USGS, 1998). Therefore, early subsectors of the model focused on the Las Vegas Wash, where treated sewage water is discharged and runoff from urban areas collect and flow to Lake Mead. Subsequently, an

additional subsector of the model focused on the *consumption* side of the water system, where water distribution throughout the valley is a consequence of urban water demand. Investigation focused on the public's role in water demand and the water authority's approach to changing consumer behavior. Eventually, the demand and consumption subsector evolved into the simulation model for the workshops.

The model(s) focus on the water system between intake (water withdrawn from Lake Mead at Saddle Island) and its return to Lake Mead via Las Vegas Wash at Las Vegas Bay. They divide the system into three major subsectors: 1) the consumption subsector in which water is distributed to the valley's users (both homeowners and businesses), used in some manner, and transported to the Wash via the Valley's sewage treatment facilities or through ground infiltration; 2) the water treatment sector where indoor water is treated and released into the Las Vegas Wash; 3) the Wash subsector, beginning with the effluent from the treatment plants being added to upstream flow, to the water's discharge downstream into Las Vegas Bay .

In order to accurately conceptualize the Valley's water system we constructed a series of causal loop diagrams (CLD) (Figure 1) to help us analyze the complex system with special emphasis on the role of information feedback. Thus, we "traced back" from the amount of water used for residential lawn irrigation to help understand the desire for a residential lawn. We examined the roles of population migration in and out of the valley, the economic structure of the city, the housing industry, etc. The CLD is used as a communication tool to make our assumptions (causal relations) about the roles of human activity in the Valley explicit. It helps us think about and understand the underlying

feedback loop structure of the Valley's water system, which is key to understanding the system's dynamic behavior.

Once we conceptualized the system we developed the simulation model from the causal hypotheses represented in the CLD. We designated *stock variables*, which represent where accumulation or storage take place in the Valley's water system. We next added the *flow variables* to the model. Where stock variables summarize where you are in a system at a given time, say today, flow variables are the actions to change the system to a new state tomorrow. Flows directly influence stocks, thus a stock of water in a distribution center flows to a stock of water at a home, then flows to a stock of water at a treatment plant, and so forth. Having developed the material flow of water through the valley from intake at Saddle Island to discharge back into Las Vegas Bay, we added *information variables*, the aspects which influence the flow of water from stock to stock and through the system.

Shift in Model Focus

Two subsectors of the larger Las Vegas Valley water system model were further developed: 1) the Las Vegas Wash subsector; and 2) the consumption subsector.

The Wash subsector of the Las Vegas water system is focused on the natural wash east of Las Vegas. The subsector stocks (thirteen segments) were determined by the location of Bureau of Reclamation sampling points as described in Roline and Sartoris (1998). In this subsector graduate student Audrey Rager worked on the this sector to incorporate mean total dissolved solids (TDS), mean orthophosphate phosphorus (PO_4^-P) concentrations, and mean nitrate nitrogen (NO_3-N) concentrations. However, after initial

development, we chose to not pursue this approach because the level of detail required for this subsection was outside the scope of the project purpose.

The consumption subsector of the model estimates Las Vegas Valley residents' behavior, and consequently determines the water demanded and potential policy options for influencing demand in the Valley.

A meeting on November 17, 1999 with Phillip Halvorson, Research Analyst at the Southern Nevada Water Authority (SNWA), helped determine what issues and factors could be important to the SNWA for determining potential policy options. Mr. Halvorson identified pricing policy options as being a potentially worthwhile use of the model for SNWA decision makers. Based on his suggestions, we used the SNWA project report *Water Price Elasticities in the Southwestern United States: Single Family Homes*, (Whitcomb 1996) to identify variables useful in the Las Vegas Valley for interpreting the relationship between water price and consumer demand (price elasticity). We added water demand to the model as a factor determining annual water withdrawal from Lake Mead and implemented a price elasticity function for testing pricing policy options.

Change in Emphasis Based on Feedback on System Model

The model (Figure 2) was presented at the water authority in February 2000 for their review. The model was generally well received at the meeting, but the discussion raised several important points which shaped our following work. While the participants understood the model's potential for capturing important technical data, some did not see the usefulness of the model for testing the effectiveness of management options, and others did not see a need for facilitating more discussion of the water system among

stakeholders. Some participants said that the model was at too high a level of aggregation for supporting specific management decisions such as groundwater withdrawal planning. Others were very interested in seeing specific portions of the model relating to their work developed more fully.

From this discussion, we determined there was no consensus about whether, or how, such a model could be used for water planning or management in the SNWA or related agencies. It was also clear that the complexity of the model and the way the model was presented affected participants' perception of the model's utility. Thus the emphasis of the project shifted from developing a highly-detailed model for management support to refining the use of the model for facilitating communication. This required simplifying the model and improving the way it was presented.

Final Model

This section is taken from a paper describing the model that will be published separately. Citations of this section should cite the published paper.

The model addresses the problem shown in Figure 1, SNWA's (1996) projection of water supply and demand. Figure 1 shows water resources fluctuating around a level of approximately 650,000 afy, and water demands increasing steadily. The graph projects that demands will exceed resources around the year 2025. The model was developed to evaluate options for extending the point at which demand is projected to exceed supply.

The model structure, shown in Appendix 1, represents the basic 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, through the mechanism of return flow credits. Water demand is based on population.

The problem being modeled is the relationship between supply and demand in the Las Vegas water system. Based on the fundamental systems premise that a system's structure generates its behavior, that is, that the system's behavior is a function of endogenous structural relationships (e.g., Forrester 1968, Sterman 2000), the first step of this modeling process was to identify the supply and demand structure of the Las Vegas water system. The supply side of the system consists of the physical flows of water; the demand side of the system centers on the resident population and the distribution of water use. The model boundary includes the primary source of water supply, the Colorado River at Lake Mead and the primary pathways of flow within the Las Vegas Valley. It also includes the Las Vegas resident population. Two major feedback loops in the system exist in the system: the loop for water supply and the feedback loop for water demand. Together, these loops represent the dynamic hypothesis, or preliminary explanation of the structural relationships that lead to changes over time in supply and demand. Water demand increases as population increases. Supply changes in response to external sources, but also in response to changes in water *use* changes, through the mechanism of return flow credit. As population increases, demand increases. Because water use increases, treated wastewater flow, and therefore, return flow credit, also increase, increasing supply. But because demand increases faster than supply, demand eventually equals, then exceeds supply.

Assumptions In The Model

Water demand:

Water use calculations are based on the following SNWA 1996 estimates:

residential water use	=	190 gpcd
residential water use	=	65% of total water use
indoor residential use	=	40% of residential water use
outdoor residential use	=	60% of residential water use
non-residential use	=	35% of total water use (includes hotels, commercial, industrial, irrigation, govt/schools)

Calculations:

total water use	=	190 gpcd/.65	~=	290 gpcd
non-residential use	=	total - residential use	~=	290 - 190 = 100 gpcd
total water demand	=	residential + nonresidential per capita demand * Population		

Further assumptions:

outdoor fraction of non-residential use = [all irrigation (9%) + .6 * govt/schools (5%)]/ non-residential use (35%)] = 12%/35% = .34

indoor fraction of non-residential use = 1 - .34 = .66

When demand exceeds supply, the amount of water withdrawn is equal to supply (you cannot withdraw more water than you have available). The model apportions the available water equally among residential and non-residential uses,

and assumes it is distributed in the same proportions to indoor and outdoor uses. Therefore, although population continues to increase after water demand exceeds supply, return flow credit reaches a maximum value as soon as demand exceeds supply. Potential return flow credit increases are offset by decreases in per capita water available and, thus, use. Total water supply, therefore, reaches a maximum constant value as soon as demand equals supply.

total water demand (acre-feet/yr) = [residential per capita water demand (gpcd) + nonresidential per capita water demand (gpcd)] * Population * days/yr * acre-feet/gallon

residential per capita water demand (gpcd) = indoor use per capita (gpcd) + outdoor use per capita (gpcd)

initial value of *indoor use per capita* = .40 * 190 gpcd = 76 gpcd

initial value of *outdoor use per capita* = .60 * 190 gpcd = 114 gpcd

Population:

The model assumes that the most significant factors affecting the change in Population are inmigration (people moving in) and outmigration (people moving out). 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.

Water use:

The model assumes water losses in the system are negligible.

Research Workshops and Participants

We held seven workshops between October 25, 2000 and December 14, 2000 with a total of 67 participants. Table 3 shows the workshop location, date, and number of attendants, and participant age range and professions.

Table 3 Workshop participants

Workshop	Date	Location	# Participants	Age Range #	Professions #
1	10/25	UNLV	14	16 to 25 6 26 to 35 3 36 to 45 3 46 to 55 2	student 7 administrative 4 service industry 1 education 1 resource mgmt 1
2	11/04	UNLV	8	16 to 25 7 26 to 35 1	student 5 administrative 2 service industry 1
3	11/11	UNLV	7	16 to 25 6 26 to 35 1	student 5 service industry 2
4	12/02	UNLV	12	16 to 25 6 26 to 35 2 36 to 45 1 46 to 55 3	student 4 service industry 5 education 3
5	12/04	Desert Demo Gardens	17	16 to 25 7 26 to 35 6 36 to 45 1 46 to 55 3	student 4 administrative 3 service industry 4 education 4 resource mgmt 2
6	12/13	Haz Mat Explo Conference	7	16 to 25 1 26 to 35 2 36 to 45 3 65 or older 1	administrative 1 resource mgmt 6
7	12/14	Haz Mat Explo Conference	2	26 to 35 1 46 to 55 1	administrative 1 service industry 1
Total			67	16 to 25 33 26 to 35 16 36 to 45 8 46 to 55 9 65 or older 1	student 25 administrative 11 service industry 14 education 8 resource mgmt 9

Three groups of participants were identified for the research workshops. Each represents a broad range of local resource stakeholders.

Group 1: graduate and undergraduate students in UNLV environmental studies courses

UNLV's students provides a cross-section of the Valley's population with respect to age, interests, income level, area of study, and workforce experience. Most of these student participants were enlisted through ENV 100, Humans and the Environment, classes and were offered extra credit for their attendance. Workshop 1 consisted of students in a beginning system dynamics modeling class. Additionally, some students voluntarily responded to campus postings and received no compensation for their attendance.

Group 2: local volunteers

Workshop 5, held at the Desert Demonstration Gardens at the Las Vegas Water District was advertised for volunteers through the Demonstration Gardens' outreach. This workshop consisted of UNLV students, Water District employees, and local residents.

Group 3: professionals in municipal planning

Workshops 6 and 7 were held in two sessions of the 2000 Hazardous Material Conference in Las Vegas, Nevada. Participants held administrative positions and/or were resource managers. These participants presented the perspective of those who have had experience in planning and implementing environmental management decisions.

The workshop participants represented a broad demographic sampling of Las Vegas residents. Most participants were volunteers from UNLV's student population, which is quite diverse. Seventy-five to eighty-five percent of the student population are Nevada residents. Non-traditional students, representing a broad range of ages, interests, and experience, make-up a relatively large proportion of the UNLV student population. These characteristics were represented among the workshop participants and reflect Las

Vegas' overall population. Ages ranged from sixteen to over sixty-five years. Forty-one participants had some college experience, while twenty had college degrees. Participants categorized their professions among a wide range of interests and experience, namely, administrative, service industry, resource management, and education. Income levels ranged between less than $15,000 to over $100,000. Participants' residence time in Las Vegas ranged between three months and fifty years. While a few, younger students considered Las Vegas to be a second home while pursuing their degrees, most participants considered themselves residents of Las Vegas and stakeholders in how water is managed in the Valley.

Development of Workshop Structure

Following a February 2000 presentation of the simulation model at the Southern Nevada Water Authority offices we determined that the workshops should have a definite structured approach, a "script". A script, according to Andersen and Richardson (1997:107) is a collection of "fairly sophisticated pieces of small group process(es)...placed end-on-end to create a continuous stream of small-group activity that generates products such as a stakeholder analysis, a precise description of a problem to be solved, a sketch of model structure, or the determination of a set of actions to be taken." Following Andersen and Richardson's group model building approach we developed a script for integrating presentation and group interaction that would generate

familiarity with both the modeling process and the Las Vegas Valley water system, and facilitate open group discussion for generating policy options for testing.

The initial pilot workshop script (Appendix 3) called for a formal lecture style introduction to systems thinking and system dynamics concepts, and iconography and language. These concepts were then demonstrated by using increasingly complex models of the Valley water system. The participants were allowed time to "experiment" with one of the models, in groups of two, at individual computer stations in order to test the usability of the models. This was followed by an informal discussion of what the participants had learned about the system so far. We then had the participants work on building a small section of the model themselves. We concluded the workshop with discussion of participants' feedback about the workshop process and the system dynamics approach in general. We conducted two additional pilot workshops and from participant feedback from these three pilots we developed the final script for seven research workshops (Appendix 3).

In the final script we started with simple models which used visual cues for introducing the concepts. That is, we showed participants a map of the valley basin, pictures from the Las Vegas Wash, and a schematic of the water system. We used more simplified models of the water system than previously and greatly slowed the pace for stepping through the models with the participants. We also included a handout of basic information about the Valley water system (Appendix 4). Instead of breaking the group into subgroups, as we did in the pilot workshops, we kept them together and experimented with the model as one group, which aided in interactive discussion. We started the groups off with the Las Vegas water management problem, taken from the SNWA's residential water reduction plan. Appendix 4 shows the water authority's 1996 supply and demand graph showing demand exceeding supply by 2025. SNWA's

approach to this problem is to reduce residential water use by 25 percent by 2010. This problem definition was presented to the workshop participants and their discussions were based on its feasibility and potential effectiveness.

Additionally, we determined it was unnecessary, in the process of the workshop, to introduce systems thinking and system dynamics concepts, as we had done in the pilot workshops. We felt that it distracted from the simulation exercises because it presented too many confusing concepts. Specific systems concepts were removed from the structure. Therefore, the modeling language was simplified and generalized. For example, simulation output graphs were simply referred to as "graphs", without explaining their role as a reference mode for the model ("reference mode" is a common system dynamics term used for discussing dynamic behavior). The most specific modeling language/iconography we included in the process was the use of the terms *stocks* and *flows* and *variables*. This allowed the participants to focus on the model for simulation exercises without being distracted by unnecessary information.

Another challenge was eliciting simulation suggestions from the group without prompts from the facilitators. This was solved with the removal of the systems thinking concepts section. We replaced it with a 30-40 minute discussion session in which we introduced the problem definition and asked the groups if they thought the SNWA's approach was feasible, and if so, how could it be achieved. Participants' contributions to the discussions where noted on large sheets of paper and posted around the workshop room, allowing participants to remember and reflect on different comments and questions. The resulting open discussions allowed the groups to become comfortable

with expressing ideas and to incorporate their ideas into simulation tests for the following half of the session.

Following a brief break we incorporated the participants' comments into policy options for addressing the problem. We spent the remainder of the workshop testing out the group's ideas through model simulation. This allowed the groups to see the consequences of their suggestions. Our hopes were to provoke a change in how the participants *thought* about the problem they were examining.

Participants were asked to fill out the post workshop survey after which they were free to leave or could remain afterward to talk with the facilitators and other participants. They were asked to include specific comments about their experience in the post workshop survey.

This script structure came to be the most efficient and effective approach to the workshop and allowed the workshop time to be reduced to under 2.5 hours.

Location

The seven research workshops were held in three different locations. Workshops 1 through 4 were held on UNLV's campus in the Environmental Studies Computer Lab. In all seven workshops, the meeting room was set up with all participants facing each other around a large conference table. This was done to help facilitate discussions. The overheads and model were projected on a screen at the front of the room. Workshop 5 was held at the Desert Demonstration Gardens located at the Las Vegas Water District. Workshops 6 and 7 were held as part of the National Hazardous Materials conference held at the Orleans Hotel in Las Vegas, Nevada, December 13 - 15, 2000.

Equipment

All seven workshops required the following equipment:

- overhead projector for introduction to management issue and the simulation model
- laptop computer capable of running computer program and a projector to display the simulation model for all participants to see
- easel with large pad of paper for capturing and posting participants' ideas and comments
- survey packets for distribution and collection of questionnaires
- handouts for participants' use during workshop
- pencils and marking pens
- refreshments

Handouts

In addition to the pre- and post workshop surveys, which were handed out at the beginning and end of the workshops and later collected, there were several other forms and handouts necessary to the research project and the workshop itself.

The University of Nevada, Las Vegas requires all research subjects (in this case, participants) to read and sign an Informed Consent Form (Appendix 2). This is to ensure that the participants were aware of their rights as human subjects. Participants also received a signed letter on Department of Environmental Studies letterhead thanking the participants for their cooperation, briefly describing the research project, and providing participants with contact information should they have any questions concerning the workshop, their input, or the research results.

We also provided several handouts to supplement discussions of the water system and the model. Participants were given a graph of the SNWA's projected water supply and demand from 1990 to 2050 and the *Las Vegas Water System Fact Sheet* consisting of water information for the Valley and for general home water use (Appendix 3).

Participants also received a printed copy of the model structure to help them to see it clearly and for reference purposes during simulation exercises.

Survey Design

We administered two surveys (Appendices 5 and 6) - one at the beginning of the workshop and one at the end of the workshop. The survey questionnaires collected demographic data, information about any previous workshop experience among participants, participants' knowledge of the water system, and their appraisal of the system dynamics-based workshop experience.

The questionnaires contain a number of items designed to evaluate each of these hypotheses. An example of a question on common language is "The model helped participants communicate their ideas to each other." The responses are formulated on a Likert scale from 1 (strongly agree) to 5 (strongly disagree). In addition to questions on the hypotheses, participants were asked to rate the overall usefulness, efficiency, and success of the workshop and the modeling approach.

The importance of the water issue to participants was measured in both the pre- and post workshop surveys in order to see if the workshop changed any of the respondents' views of the water issues in Las Vegas. Examples of the items are "I worry about water issues in Las Vegas," and "the future of Las Vegas depends on how water is managed."

Participants were also asked to the rate the quality of the modeling workshop compared to traditional public participation forums. Participants were asked to answer

the following question: "Compared with similar discussions you have participated in, would you say the workshop":

- gave you more insight into the issues being discussed than other workshops?
- helped you understand the issues more quickly than other workshops?
- resulted in better communication among participants?
- developed shared understanding of the issues among the participants?

The questionnaire also consists of a number of questions on the contribution of various elements of the sessions on the overall effect of the workshop, such as the format of discussions and the simulation based on group input.

Survey Analysis

Questionnaire data was entered into a *SPSS*® data file for analysis. Ninety-one survey items were analyzed for sixty-seven cases. Analysis was for frequencies, demographic data, and for mean and standard deviation of the responses to the Likert style questions.

Pre- and post workshop responses of participants were compared to test the effect of the workshop. After determining the changes in frequencies between the pre- and post section we performed a t-test for testing the statistical significance of these changes. The t-test p value identifies the likelihood that a particular outcome may have occurred by chance. Specifically the t-test was used to determine if pre-workshop responses differ significantly from post workshop responses. Results from t-tests are shown in Appendix 8.

An alpha reliability test, Chronbach's alpha (also referred to as coefficient alpha or α), was performed on sets of questions which were grouped together as indicators for

the hypotheses. The alpha is a coefficient that describes how well a group of items focuses on a single idea or construct. This is called inter-item consistency. Like questions from the survey were grouped together and responses compared in order to determine if respondents were answering these similar questions consistently. The alpha provided us with a measure of reliability for the responses within these groupings.

In addition to entering the Likert data into the *SPSS* ® data file, participant comments from the questionnaire were entered into a spreadsheet file for cataloging. These comments were examined for participant feedback about the workshop experience.

CHAPTER 5

RESULTS

This chapter summarizes the results from the survey questionnaire and facilitator observations. Several related questions were asked to test each hypothesis. The post workshop questionnaire contained four to six questions measuring each hypothesis. The reliability of each scale was calculated using the alpha reliability coefficient. Chronbach's alpha is designed as a measure of internal consistency (George and Mallery 2000); that is, do respondents answer consistently on the items we think mean the same thing? Alpha is measured on the same scale as a Pearson *r* (correlation coefficient) and varies between 0 and 1. The closer the alpha is to 1.00, the greater the internal consistency of items in the instrument being assessed. Van den Brink and Melenbergh (1998) consider a reliability of .80 or higher to indicate high consistency.

Five to eight survey items were used to evaluate each of the research hypothesis. Analysis showed improvements in participant awareness, shared understanding, insight, communication, and legitimacy. Table 4 shows the alpha reliability coefficient for grouped items.

Table 4 Reliability coefficients of selected survey items which supported the research hypotheses

Hypothesis	N*	α**
H1: awareness (5 items)	51	.87
H3: shared understanding (6 items)	41	.86
H4: insight (6 items)	60	.83
H5.2: common language (5 items)	64	.83
H7: legitimacy	50	.86

N = Number of respondents
α = Chronbach's alpha

These indicate that we can be confident in what these scales show. The following section shows results for each hypothesis.

Hypotheses

We looked closer at the specific items used to measure each area of interest (frequencies for all survey questions are tabled in Appendix 7):

- Hypothesis 1 - System dynamics-based workshops improve participant awareness of the problem.

Five survey items were examined to determine changes in participant level of awareness of the Las Vegas water issue. Table 5 shows the results from these survey items. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 5 Summary of responses to items indicating that participants' level of awareness about the Las Vegas water system increased during the workshop (alpha = .87)

Survey Question	N**	strongly agree/ agree	neither agree nor disagree	strongly disagree/ disagree	Mean	SD*
The workshop helped me better understand how the Las Vegas water system works	51 (100%)	46 (90%)	3 (6%)	2 (4%)	1.61	.85
I know more about Las Vegas water issues than I did before this workshop	66 (100%)	61 (92%)	2 (3%)	3 (5%)	1.58	.77
The workshop changed my perception of water problems in Las Vegas	65 (100%)	50 (77%)	7 (11%)	8 (12%)	1.98	1.04
Using modeling is a good way to learn about water management issues	67 (100%)	61 (91%)	6 (9%)	0	1.63	.65
All in all I think the model was useful for improving participant understanding about Las Vegas water issues	67 (100%)	65 (97%)	2 (3%)	0	1.55	.56

** N = Total number of respondents
* SD = Standard Deviation

Responses indicate that participants agreed that the workshop, and use of the model, improved their awareness of the water issues. Responses indicated strongly (97%) that the model was useful for improving their understanding about the water issues. The smaller percentage (77%) of those agreeing that the workshop had changed their perception of the Las Vegas water problem, however, could demonstrate that some participants came to the workshops with knowledge of Las Vegas water issues. This is supported by pre-workshop survey comments which show that several participants felt water and water quality were among the most urgent issues facing the Las Vegas community.

Other items in the pre- and post workshop sections of the survey supported

Hypothesis 1. Before and after each workshop, participants were asked to rank their knowledge of Las Vegas water issues and the level at which they felt these issues relate to their life(style). A t-test showed that the pre-workshop responses differed from the post workshop responses at a $p = .001$ level of significance. Table 6 shows the results from these survey items. Scores range from 1 (strongly agree) to 5 (strongly disagree). Lower scores indicate greater agreement.

Table 6 Changes in pre- and post workshop means indicating an increase in participant awareness of water issues

Survey Item	Pre-Mean	Post Mean	t-test value
I know a lot about water issues in Las Vegas	2.82	2.03	.0001
I have to deal with problems related to Law Vegas' water management in my life(style)	2.52	2.09	.001

The shift in means, from close to neutral to agreement, demonstrates that participant awareness of the water issue changed significantly following the workshops. But, does this mean that the system dynamics approach was useful for improving awareness? Of the 67 participants, 41 had participated in other, non-system dynamics-based public participation forums. Table 7 shows that, among participants with other workshop experience, the system dynamics-based approach did influence a change in there perception of the Las Vegas water problems.

Table 7 Summary of responses among participants who had attended other types of workshops that the system dynamics-based workshop changed their perception about the Las Vegas water management problem

Survey Question	N	strongly agree/agree	neither agree nor disagree	strongly disagree/ disagree	Mean	SD
The workshop change my perception of the water problems in Las Vegas	30 (100%)	19 (63%)	5 (17%)	6 (20%)	2.23	1.14

Hypothesis 1 is also supported by participant comments on the survey and during workshop discussions. A survey respondent from workshop 5 noted: "I [didn't] know much about water in Las Vegas and now I do!" Several participants noted on the questionnaire that they had gained knowledge about the Las Vegas water system during the workshop.

- Hypothesis 2 - System dynamics based workshops help facilitate the exchange of data and technical information among participants.

The survey data did not directly test this hypothesis. However some evidence of the workshops' and model's use for improving participant understand was available in the questionnaire. Sixty-five (97%) of the respondents agreed/strongly agreed that the model was useful for improving participant understanding about Las Vegas water issues. None disagreed. Table 8 shows the survey results for those participants who had participated in other forums previously. Compared with other workshops, respondents found the system dynamics-based approach to be helpful for more quickly understanding the issue.

Table 8 Summary of responses among participants who had attended other types of workshops indicating they had quickly understood the water issues

Survey Question	N	strongly agree/agree	neither agree nor disagree	strongly disagree/ disagree	Mean	SD
Compared with other workshops you have participated in, would you say this workshop helped you understand the issues more quickly than other workshops?	27 (100%)	17 (63%)	9 (33%)	1 (4%)	2.11	.89

Observational notes taken during the workshops and participant comments in the post workshop survey gave an even stronger indication of system dynamics effectiveness for improving the exchange of data among participants. Once the participants were introduced to the model they would often refer to the structure when discussing technical aspects or asking specific questions about the water system. The model was particularly useful for explaining the unusual aspect of "return-flow credits" within the Las Vegas water system. A process which credits-back, for future use, to SNWA water returned to Lake Mead after treatment, the model structure and behavior helped participants to more quickly understand this atypical aspect of a water system. Usually, at some point, in most of the workshops, an unexpected result from a policy test would be traced back through the structure of the model to the return-flow credit. This unique, and generally unknown, technical aspect of the water system was more easily understood by most participants through the use of the model.

- Hypothesis 3 - System dynamics-based workshops enhance shared understanding among stakeholders.

Six items were used to indicate the level of shared understanding among participants in each of the seven workshops. Table 9 shows the results from these survey items. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 9 Summary of responses to items indicating workshop/model's effectiveness for enhancing shared understanding among participants (alpha = .86)

Survey Question	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/disagree**	**Mean**	**SD**
The workshop helped me understand the opinions and ideas of other participants	66 (100%)	62 (94%)	3 (5%)	1 (1%)	1.61	.72
The model simulations helped me understand the opinions and ideas of other participants	67 (100%)	59 (88%)	7 (10%)	1 (2%)	1.73	.71
The workshop developed shared understanding of the issues among the participants better than other workshops	41 (100%)	35 (85%)	5 (13%)	1 (2%)	1.83	.83
The model helped participants communicate their ideas to each other	67 (100%)	61 (91%)	5 (7%)	1 (2%)	1.66	.69
All in all I think the model was useful for improving participant understanding about Las Vegas water issues	67 (100%)	65 (97%)	2 (3%)	0	1.55	.56
All in all I think this workshop was useful for improving participant understanding about Las Vegas water issues	66 (100%)	62 (94%)	2 (3%)	2 (3%)	1.62	.76

Responses indicate a general agreement that the workshop(s) and model were useful for improving shared understanding among participants. But was the system dynamics approach a factor in these responses? Table 10 shows that, of the participants who indicated on the survey that they had attended other workshops, 85% found the system dynamics-based approach more helpful for improving shared understanding among participants.

Table 10 Summary of responses among participants who had attended other types of workshops that the system dynamics-based workshop developed shared understanding

Survey Question	N	strongly agree/agree	neither agree nor disagree	strongly disagree/ disagree	Mean	SD
Compared with other workshops you have participated in, would you say this workshop developed shared understanding of the issues among the participants better than other workshops?	27 (100%)	23 (85%)	4 (15%)	0	1.74	.71

Participant comments on the survey also supported these findings. Several participants noted that hearing others' opinions and points of view was interesting and useful. A workshop 1 participant noted that she/he liked hearing about "[e]xperiences related to others regarding water use or abuse situations." And a participant from workshop 2 wrote: "I liked how all present had the opportunity to share [and see the outcome] of their ideas." Overall, participants liked the opportunity, presented by the workshop, to share and learn about each others' personal and professional experiences with water use and management.

- Hypothesis 4 - System dynamics-based workshops lead to participant insight.

Six items were used to measure changes in participant insight into the water management issue. Table 11 shows the results from these survey items. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 11 Summary of responses to items indicating workshop/model's effectiveness for enhancing participant insight into management options (alpha = .83)

Survey Question	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/ disagree**	**Mean**	**SD**
The workshop gave more insight into the issues being discussed than other workshops	41 (100%)	32 (78%)	6 (15%)	3 (7%)	2.15	.85
The workshop helped me see potential solutions to Las Vegas water problems that I hadn't considered before	66 (100%)	54 (82%)	7 (11%)	5 (7%)	1.85	.95
The model simulations helped me evaluate the merits of different ideas	51 (100%)	47 (92%)	4 (8%)	0	1.55	.64
Seeing the ideas simulated made me more interested in the issue	53 (100%)	48 (91%)	4 (7%)	1 (2%)	1.58	.72
I referred to the model in discussing the pros and cons of possible solutions to the water problem	65 (100%)	47 (72%)	15 (23%)	3 (5%)	2.08	.82
I understood how the model could be used to address management issues	65 (100%)	63 (97%)	2 (3%)	0	1.49	.56

Responses were favorable for the use of the model simulations for learning about management options. Table 12 shows that, among participants with previous, non-system dynamics workshops, the system dynamics-based approach was more useful than other workshops for improving participant insight.

Table 12 Summary of responses among those who had attended other workshops that the workshops promoted participant insight

Survey Question	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/ disagree**	**Mean**	**SD**
Compared with other workshops you have participated in, would you say this workshop gave you more insight into the issues being discussed than other workshops?	27 (100%)	22 (82%)	3 (11%)	2 (7%)	2.04	.81

Other indicators for the usefulness of the system dynamics model for improving participant insight were facilitator observations and participant comments. Facilitators observed that participants quickly and enthusiastically responded to seeing different policy options tested. Participants adjusted their policy choices based on the simulation outcomes. A participant from workshop 3 noted: "it made me able to see my ideas in action" and "we do not have to actually do something in 'real life' to see the results." Overall, the policy simulations helped participants learned about the expected and unexpected consequences of management options.

- Hypothesis 5.1 - System dynamics-based workshops provide a common language for participant discussions.

Five items were used to indicate the level at which the model aided development of a common language among participants. Table 13 shows the results from these survey items. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 13 Summary of responses to items indicating development of a common language among participants (alpha = .83)

Survey Questions	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/ disagree**	**Mean**	**SD**
The model helped participants communicate their ideas to each other	67 (100%)	61 (91%)	5 (7%)	1 (2%)	1.66	.69
The model helped me communicate my ideas to others	67 (100%)	51 (76%)	15 (22%)	1 (2%)	1.96	.77
I referred to the model in discussing the pros and cons of possible solutions	65 (100%)	47 (72%)	15 (23%)	3 (5%)	2.08	.82
Using the model is a fast and easy way to learn about water management issues	66 (100%)	61 (92%)	5 (8%)	0	1.56	.64
All in all I think the model was useful for improving discussions among participants about Las Vegas water issues	67 (100%)	64 (96%)	3 (4%)	0	1.55	.58

Respondents found the model to be a fast and easy way to learn about water management issues. Seventy-two percent of the respondents self-report that they referred to the model when discussing policy options. Facilitator and observation notes indicate that

participants referred to the model often when discussing policy options and simulation results. Additionally, participants used modeling language, such as stock and flow, when discussing different views and options. These responses and notes indicate that a common language for discussing water management developed among the participants through the use of the model.

- Hypothesis 5.2 - System dynamics-based workshops promote discussions.

A majority of respondents agreed that the workshop and the model were useful for aiding discussions among participants. Table 14 shows the results from survey items used to measure improvements in discussion. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 14 Participant responses supporting the usefulness of the workshop and model for promoting discussion

Survey Question	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/ disagree**	**Mean**	**SD**
All in all I think this workshop was useful for improving discussion among participants about Las Vegas water management issues	66 (100%)	64 (97%)	1 (1.5%)	1 (1.5%)	1.59	.68
All in all I think the model was useful improving discussions among participants about Las Vegas water management issues	67 (100%)	64 (96%)	3 (4%)	0	1.55	.58

Many participants listed, in the comment section of the survey, the format of discussion as what they liked best about the workshop. A participant from workshop 2 noted: "[t]he

format of the workshop really encouraged participation of everyone present." "Group discussions," "debating," "giving ideas," and "openness" were common comments among the respondents. Participants strongly felt that the group discussion(s) were effectively conducted and valuable.

Overall, participants felt that communication was effective in the workshops. Two survey items were used to measure the effect of the model on participant comfort with communicating their ideas to one another. Table 15 shows the results from these survey items. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 15 Summary of items indicating effective communication among participants

Survey Question	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/ disagree**	**Mean**	**SD**
The model helped participants communicate their ideas to each other	67 (100%)	61 (91%)	5 (7%)	1 (2%)	1.66	.69
The model helped me communicate my ideas to others	67 (100%)	51 (76%)	15 (22%)	1 (2%)	1.96	.77

The system dynamics model was found to be helpful for improving participant communication of their ideas. Participants who indicated on the survey that they had attended other workshops supported the hypothesis that the system dynamics-based approach improved communication among participants (Table 16).

Table 16 Summary of responses among participants with other types of workshop experience indicating that the system dynamics-based approach promoted communication among participants better than others

Survey Question	**N**	**strongly agree/agree**	**neither agree nor disagree**	**strongly disagree/ disagree**	**Mean**	**SD**
Compared with other workshops you have participated in, would you say this workshop resulted in better communication among participants?	27 (100%)	21 (78%)	6 (22%)	0	1.78	.80

A participant from workshop 3 noted the "interaction among participants" as one of the best aspects of the workshop.

- Hypothesis 6 - System dynamics-based workshops improve participants' perceived legitimacy of the decision making process.

Five items were used to measure a change in participant trust in and legitimacy of the decision making process. Each item reflects participant comfort with and trust in the deliberation process. For example, the statement "the model simulation included my ideas" reflects the sense that individual participants felt that their input was being recognized and addressed. Table 17 shows the results from these survey items. Possible rankings were: 1 (strongly agree); 2 (agree); 3 (neither agree nor disagree); 4 (disagree); and 5 (strongly disagree).

Table 17 Summary of items indicating improvement in process legitimacy among participants (alpha = .86)

Survey Question	N	strongly agree/agree	neither agree nor disagree	strongly disagree/ disagree	Mean	SD
The model simulations included my ideas	53 (100%)	45 (85%)	8 (13%)	1 (2%)	1.79	.82
The model simulations helped me evaluate the merits of different ideas	51 (100%)	47 (92%)	4 (8%)	0	1.55	.64
This kind of workshop is a good way to get more people to care about water issues	52 (100%)	44 (85%)	6 (11%)	2 (4%)	1.60	.91
Using modeling is a fast and easy way to learn about water management issues	66 (100%)	61 (92%)	5 (8)%	0	1.56	.64
Using modeling is a good way to learn about water management issues	67 (100%)	61 (91%)	6 (9%)	0	1.55	.56

Aside from the survey results, the strongest indicator of participant perception of the process legitimacy came from direct comments by the participants. A participant from workshop 5 commented during the workshop said: "testing ideas gave a sense of ownership" to decisions. Another participant, early in the pilot workshops, who worked for the water authority, felt that seeing options tested and examining the results could give a greater sense of legitimacy to decision outcomes. Overall, participants voiced strong support for using simulation for gaining greater confidence in differing policy options.

Forty-one of the sixty-seven participants indicated that they had prior (other) public participation experience. Table 18 summarizes comparison of the system dynamics-based approach with other experiences.

Table 18 Summary of responses for comparison with other workshops which found the system dynamics-based approach favorable

Survey Question Compared with similar discussions you have participated in, would you say this workshop...	**N**	**strongly agree**	**agree**	**neither agree nor disagree**	**disagree**	**strongly disagree**
helped you understand the issues more quickly than other workshops?	41 (100%)	11 (27%)	16 (39%)	12 (30%)	1 (2%)	1 (2%)
resulted in better communication among participants?	41 (100%)	16 (39%)	16 (39%)	8 (20%)	0	1 (2%)
developed shared understanding of the issues among the participants better than other workshops?	41 (100%)	15 (37%)	20 (49%)	5 (12%)	0	1 (2%)
gave you more insight into the issues being discussed than other workshops?	41 (100%)	7 (17%)	25 (61%)	6 (15%)	2 (5%)	1 (2%)

Overall, participants ranked the system dynamics-based workshop better than other workshops. The majority (65% or more) of respondents agreed or strongly agreed that the system dynamics-based workshop helped participants to more quickly understand the issues, resulted in better communication, developed shared understanding better, and gave greater insight into the issue that other workshop experiences.

CHAPTER 6

DISCUSSION

In chapter 2 it was proposed that the model-based workshop could be considered effective for promoting meaningful participation if it: 1) improved communication about technical data and stakeholder views; 2) increased learning and insight into the management issue; and 3) enhanced public trust in the decision making process. This study found that system dynamics models have great potential for enhancing public involvement in natural resource management and policy decisions.

Of the participants who had attended public workshops other than these research workshops, more than half felt that the prior forums had not succeeded in their stated objective(s) and felt dissatisfied with the outcome(s). Comments in the pre-workshop survey show their reasons for dissatisfaction with the forums were quite similar to what was found in the literature review for this research. Many felt strongly that public forums would be successful if participants' input is considered in final decision(s). Those that were dissatisfied with the efforts often cited a lack of "accomplishment", saying that "...nothing [changed] as a result of all the meetings held." Comments, in response to open-ended questions in the pre-workshop survey (Appendix 4), such as, "my vote was

not counted". "the decision was already made for the public". "political forces direct or limit intelligent planning", indicate a lack of trust in the public participation process and its outcomes.

Respondents also felt that public forums were unsuccessful because too much technical information got in the way of deliberation. "Too technical for the public" and "the public did not understand the process" indicates that the exchange of technical information can be perceived as a stumbling block in the deliberation process. Finally, dissatisfaction was felt in the structure of discussions: "too many people talking and not enough listening to the other side of the issue" and "they actually had people pre-picked for discussion." These and other comments like them indicate that participants are aware of a lack of two-way communication in many public forums. They indicate a real need for pursuing more meaningful public participation. Respondents indicated a perceived need for involving the public in decisions which touch their lives, would like to be better informed, and see their input included in the decision making process. However, as discussed in chapter 5, these participants felt that the system dynamics-based workshop was better than other types of workshops for helping participants to understand the issue, promoting better communication and share understanding, providing greater insight in to the water problem, and improving perceived legitimacy of the decision making process.

Hypotheses

Participants in this study felt that the use of a system dynamics model in public forums is both an efficient way for approaching problems and was applied successfully. They felt the quality of communication and shared understanding, exchange of technical information, awareness, insight, and legitimacy were high.

Communication among participants was candid and the forum of discussions was praised by several participants in all workshops. Comments, in response to open-ended questions in the post workshop survey (Appendix 5), were often in the form of "...the forum encouraged [group] discussion," to "[I liked best] the round table [style] of discussions." By the end of each workshop, the level of shared understanding among participants was also encouraging. Several participants noted that they liked "listening to other opinions" and "sharing ideas." Many participants commented that understanding each others' opinions and ideas was important to them and that having the chance to "share" these things was what they liked best about the workshop(s). Ninety-seven percent of survey respondents found the workshop useful for improving discussions among participants. Compared to traditional public forums, the system dynamics-based approach helped develop participants' shared understanding about the water issue and each others' perspectives.

Facilitator observations of the workshops found that technical information (some complex) was easily exchanged among participants and the facilitators. A resource manager with the SNWA commented that the model would be especially useful for "educating the public" about Valley water issues. A participant in workshop 2 commented that the "diagrams helped explain our ideas," and a participant from

workshop 1 commented that the model structure was a good "visual for understanding [the water system]." Eighty-five percent of the participants who had attended other types of workshops strongly agreed/agreed that the system dynamics-based workshop developed shared understanding of the issues among the participants better than other workshops.

Awareness of the water conservation problem was definitely increased among participants. Several learned about their role as residential consumers, while many gained new knowledge about the valley basin, valley growth, and the city's infrastructure. Ninety-two percent of survey respondents strongly agreed/agreed that they knew more about Las Vegas water issues than they did before the workshop.

Simulation provided a great amount of insight into the relationships between decisions, actions, and results. In each workshop participants expressed surprise at several results of the policy tests. Participants would often "rethink" their approaches and adapt policy options to better achieve their goals. Nine-two percent of the survey respondents felt that the model simulations helped them to evaluate the merits of different management options. All in all, participants learned quite a lot about how the water system works and ways that intervention can influence it.

Finally, legitimacy of both the process and potential solutions among participants was improved by the simulation tests. Many participants noted in the survey that they like "seeing" their input "put into action". The experience generally left them feeling that they had actually participated in the process and that the outcomes were a result of their knowledge and ideas. Overall, the experience was positive for most participants and many expressed a desire to see the system dynamics-based approach used for other

types of resource management decisions. Seventy-three percent of the survey respondents agreed that they would be interested in participating in other workshops like these.

Introducing The Model To Participants

When we presented the model to SNWA and in pilot workshops, participants indicated a concern about the models' accessability to the general public. Many were concerned the structure would "scare participants off." They felt the complexity of the diagrams would confuse participants and prevent them from fully appreciating the experience. We, as facilitators, also sensed that the model structure distracted participants from the simulation exercises. At the original presentation at SNWA few participants volunteered options for the policy tests. In pilot workshop 1 participants were eager to "play" with the model but didn't seem to want to focus on specific model building exercises. However, after we simplified the workshop script, research workshop participants seemed comfortable, on the whole, using the model for testing policy options. They were quick to volunteer creative policy tests and appeared genuinely intrigued with the results. We concluded that the change in participant comfort with, and understanding of, the systems approach was due to the changes in the workshop structure, particularly in the way system dynamics was introduced. Between the pilot and research workshops we realized that explicit introduction to systems concepts was unnecessary. Participants were easily able to appreciate the use of the model for testing options without having to know the intricacies of how the model was developed. In fact, systems concepts, in the abstract, seemed to add to the confusion in the pilot workshops. When we presented system concepts, in the course of presenting the model, we found participants followed

easily. Additionally, we found that by presenting the model structure in a progression from the physical model of the water system to the more abstract model structure made it easier for the participants to understand the model representation of the system. Participant responses to the questionnaire strongly reflect their comfort with the model and the ease with which they were introduced to it.

One other element in the research workshops that had a tremendous effect on participants' comfort and willingness to experiment with the model was the structure for discussions. Having their ideas written and posted on the walls for all to see and discuss was particularly well received. Additionally, having their ideas translated into testable policy options seemed to give many of them feeling that their input was of use and that their time was not wasted in the deliberation.

What I Would Do Differently

If I were to re-design this research project within the framework of this thesis, I would make two critical changes for evaluating the process. I would re-design the survey instrument in order to test some the hypotheses more specifically. Effectively addressing the hypothesis in the evaluation process is crucial. I would also involve workshop observers earlier in the research, providing them with a better opportunity to familiarize themselves with the literature in small group behavior and learning dynamics.
This would make the job of recording participant responses easier for the observers and the recordings more reflective of the group dynamics.

Future Research

Because participants had no predetermined stakeholder agenda when they volunteered, it was not possible to test for the usefulness of the system dynamics-based approach for consensus building. One of the next research steps would be to find an issue where participant opinions are more clearly polarized. In this case participant ideas were either not fully developed (because they hadn't thought much about the issue) or they started out by agreeing. Thus, further research should be applied to resource management decisions which involve dispute resolution. Ultimately, evaluation of the use of system dynamics in resource and environmental decision making should continue in order to add to the statistically validity of this, and other studies.

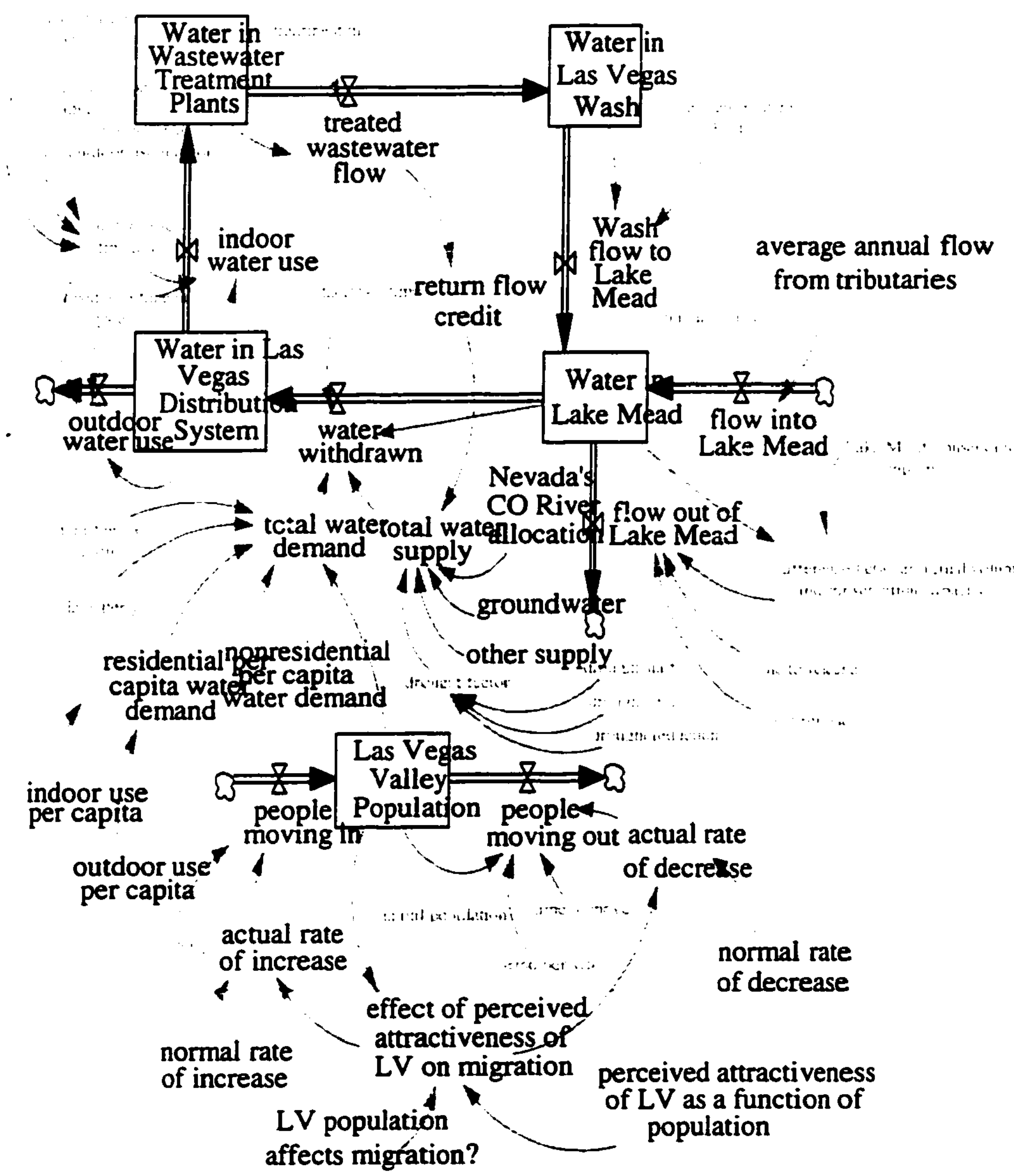
My Final Thoughts

This research demonstrated to me that meaningful public participation in management and policy decisions is possible. Seeing stakeholders achieve a greater level of awareness and insight into a problem, seeing enthusiasm for communication and exchange of ideas, and having a sense that there can be a greater level of trust in the decision making process has left me feeling very satisfied with the research efforts. I agree with one of the participants' comments in the survey: "It was wonderful!"

APPENDIX 1

MODEL STRUCTURE

MODEL STRUCTURE



APPENDIX 2

INFORMED CONSENT FORM AND

PARTICIPANT INFORMATION LETTER

INFORMED CONSENT FORM

Testing the Potential of System Dynamics Models for Improving Public Participation in Resource Management

Informed Consent Form

We are Dr. Krystyna Stave. Assistant Professor of Environmental Studies. and Sarah Cloud. Masters student in the Department of Water Resource Management at the University of Nevada. Las Vegas.

You are being asked to participate in a study about whether system dynamics models are useful for improving public participation in resource management. Your participation is voluntary. If at any time during this workshop you wish to withdraw your participation, you are free to do so.

In the questionnaires at the beginning and end of the workshop we are asking about what experiences. if any. you have had in similar workshops. what aspects of this workshop were useful. what you thought of the quality of the presentation. and what suggestions you have for improving these workshops. This workshop will last about three hours. We ask only that you participate in the discussions and answer the questions on the surveys as best as you can. The results will be used to evaluate and improve the workshops.

All information will be treated confidentially and anonymously. The consent forms will be stored separately from questionnaires in a locked filing cabinet located in Dr. Stave's office at UNLV (MPE-136) for a period of three years. If you are interested in the results of this questionnaire you can request a copy of the results by indicating so below and printing your mailing address.

Thank you for your participation.

Authorization: I have read the above and understand the nature of this study. I understand that by agreeing to participate in this study I have not waived any legal or human rights and I may contact the researchers at the University of Nevada, Las Vegas (Dr. Krystyna Stave or Sarah Cloud. 702-895-4833) at any time. I agree to participate in this study. In addition, I understand that if I have any questions regarding my rights as a research subject. I can contact the Office of Sponsored Programs. at the University. at 702-895-1357.

Participant's signature: ______________________ Date: ________

Facilitator's signature: ______________________

I would like a copy the results of this questionnaire to be forwarded to me. Yes No

Mail the results to the following address:

PARTICIPANT INFORMATION LETTER

Dear workshop participant,

Thank you for agreeing to participate in this study. The purpose of the study is to evaluate the utility of systems thinking and modeling for improving public participation in water resource management. Specifically, we are testing whether this approach is useful for improving understanding of water management issues in Las Vegas and for improving discussions among stakeholders in water management issues.

We will be holding seven of these workshops for different groups in the next two months. Your participation and comments are very helpful to us. Based on the results of the workshops, we hope to revise the workshops and use them to increase public participation in local water management decisions.

If you have any questions about the study, please feel free to contact either Dr. Krystyna Stave (895-4833, kstave@ccmail.nevada.edu) or Sarah Cloud (895-4771) at any time.

Thank you again,

APPENDIX 3

PILOT WORKSHOP SCRIPT AND

RESEARCH WORKSHOP SCRIPT

PILOT WORKSHOP SCRIPT

Action	Intent
1) Introduction to workshop	1) Set context
2) "Two boys on playground" model	2) Introduction to feedback a) CLD representation of feedback and distinction between event and trend b) Introduction to stock from CLD distinguish between things that accumulate and others c) Reference mode- to show trend d) Create stock/flow structure
3) Bathtub with transition to Lake Mead a) schematic structure of tub i) interactively create ref. mode for inviting thoughts potential outcomes	3a) make connection between relationship of flow to dynamic of stock
b) interactively identify a problem over time from the ref. mode (overflow of tub - relative to observer's desire)	b) make connection of event vs. trend describe behavior
c) add decision lever (feedback)	c) put actor in control of system [make connection to playground model]
d) make shift to Lake Mead model "we can consider Lake Mead as a similar stock of water" e) first Lake Mead model parallel to bathtub f) simulate model g) CLD	e-g) analogy to connection to playground model
4) Expanded model with wash return build by overlays [5 steps] discuss constant water demand a) add population and demand [6th stock] b) connect with ref. mode to indicate problem and point of decision lever c) present simulation model	4) participant opportunity to put SD knowledge into action and to open table to discussion/interaction
5) Pizza Begin discussion of how to test policies. run suggested simulations	5) Convey informality of process
6) Discuss options for changing per capita water use	6) discussion/interaction and further incorporating utility of SD modeling for management discussion/decisions

RESEARCH WORKSHOP SCRIPT

Script for Workshop

Action	Intent
1) -Introduction to workshop -Read Informed Consent Form, ask participants to sign -Pass out handouts: - Water system fact sheet - SNWA supply/demand graph	1) Set context Get the audience up to speed on how SNWA has defined the problem and their potential solution to the problem
-State problem statement for participants' consideration: SNWA predicts that water demand will exceed supply by 2025. Is it feasible, and if so how, to decrease residential use by 25% by the year 2010?	
2) Group discussion of problem KS - Do you think 25% is possible by 2010? If Yes: How? If No: Why not?	2) Scope problem - Get the audience comfortable with expressing their opinions/ideas and get them to start *thinking* about SNWA's problem definition and what it means.
-Encourage discussion by asking questions	- Try to elicit as many participants as possible - Brainstorm ideas about SNWA's actions; original questions about problem def. *Eliciting their causal assumptions*
-Why is it a problem?	
-Who says it's a problem?	
-Why should we care?	
-What do you think we can do about this?	*Eliciting their effect assumptions*

-What can be done?

- develop ideas for possible solutions

-Write down and post participants ideas for simulating

Coffee and snack break

Intro to System Dynamics

-Make transition from problem discussion to the simulation model

3) Model as a tool for facilitating analytic

3) introduction to model: what it represents and how it is represented

deliberation and testing management ideas

-Gradual introduction with overheads:
- introduce the physical water system by using valley basin map from Roline and Sartoris 1996
- abstract schematic of water system
- introduce model with simple progression stock and flows
1 Lake Mead
2 Lake Mead and Distribution to Las Vegas and residential users
3 project simulation model for policy testing

4) Simulation

4) intro to what model does

- demonstrate a base run and the output from the simulation to show the participants how the model is used

-Simulate ideas from participant discussions
-let participants chose options for testing

- test ideas, but also to get group involved in discussion of policy tests

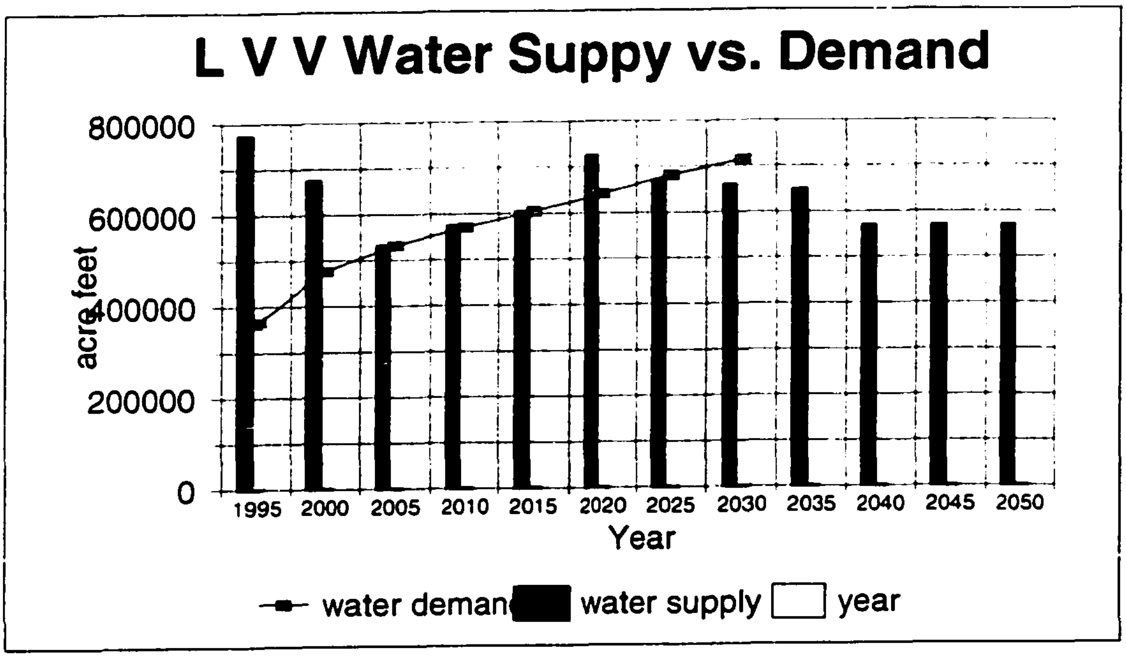
5) Discussion of the tests
6) Wrap-up workshop
-thank participants for attending
7) Hand out post workshop surveys
Freeform post workshop discussion with participants

APPENDIX 4

SNWA GRAPH AND

WATER DATA SHEET

SNWA GRAPH


L V V Water Suppy vs. Demand
800000
600000
400000
200000
0
acre feet
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
water deman
water supply
year

Las Vegas Valley Water System Data

- **Water usage** in the Las Vegas Valley averages **190 gallons per day per resident** (7500 gallons per month per resident)
- Most of our **drinking water - about 85%** - comes from the Colorado River via **Lake Mead**
- The remainder of our drinking water comes from a **deep groundwater aquifer** beneath the Valley, which we use during the summer months to meet peak demand
- **Average monthly flow into Lake Mead** from tributaries is **1,250,000 acre-feet per month** (15,000,000 acre-feet per year)
- The **average volume** of Lake Mead is **27,000,000 acre-feet**
- Nevada's Colorado River allocation, that is, the amount we are **allowed to consume** from Lake Mead, is 25,000 acre-feet per month (**300,000 acre-feet per year**)
- **Total water use is 450,000 acre-feet per year**
- The amount of **water withdrawn from Lake Mead** for Valley water demand is a combination of **Nevada's Colorado River allocation** and the Valley's **return flow credit** from the Las Vegas Wash
- **Residential water use** accounts for **65% of all water use in Southern Nevada**
- Most of our residential water demand - **about 60% - is used for outside irrigation**
- The remaining **40% is used for indoor use**, such as showers, dishwashers, and washing machines
- **Commercial water use** accounts for **13% of all water use in Southern Nevada**
- **Outdoor irrigation** accounts for **9% of all water use in Southern Nevada**
- **Hotel water use** accounts for **7% of all water used in Southern Nevada**

- The Southern Nevada Water Authority's conservation plan calls for a **25% reduction in water usage by the year 2010**

Sources: SNWA 1997 Water Budget

APPENDIX 5

PRE-WORKSHOP SURVEY

PRE-WORKSHOP SURVEY

Workshop on Public Participation in Water Management

Pre-workshop Survey

Please answer the following questions. All information will be kept anonymous and confidential. We will use this information in analyzing the usefulness of the workshops.

1) Age:
- 16 to 25 years old ____
- 26 to 35 years old ____
- 36 to 45 years old ____
- 46 to 55 years old ____
- 56 to 65 years old ____
- 65 or older ____

2) Highest level of education completed (check one):
- High School Graduate ____
- Some college ____
- Undergraduate degree ____
- Graduate degree ____
- Post-graduate degree ____

3) How many years have you lived in Las Vegas? ________

4) What city, region or country (if not U.S.) do you consider "home"? ______________

5) How would you categorize your profession?
(Indicate your primary profession with a "1", any secondary profession with a "2", etc.)
- Student ____
- Administrative ____
- Service industry ____
- Resource Management ____
- Education ____
- Retired ____
- Not currently in labor force ____
- Other (please specify) ______________

6) Income level: (check one)
- Less than $15,000 per year ____
- $15,001 - $30,000 ____
- $30,001 - $60,000 ____
- $60,001 - $100,000 ____
- $100,001 - $200,000 ____
- Over $200,000 ____

7) What do you consider are the three most urgent issues facing the Las Vegas community?

1. ______________________________

2. ______________________________

3. ______________________________

8) If it were possible, would you like to have some input into management decisions which affect the Las Vegas community?

Yes ____ No ____ Don't know ____

9) Have you ever attended public forum(s) for management decisions which affected your community?

Yes ____ No ____

10) If yes: Indicate the topic(s) of the forum(s) you attended (check all that apply):
- ____ Land use/zoning
- ____ Water
- ____ Taxes/Bond issues
- ____ Wildlife
- ____ Air pollution

_____ Other(s):

11) Did you feel the forum(s) *succeeded* in its(their) stated objective(s) Yes_____ No _____

12) If yes, what made them successful? If no, why did they fail?

13) Did you feel *satisfied* with the outcome of the forum(s)? Yes _____ No _____
14) If yes, what made them satisfying? If no, why were they not satisfying?

15) Were all participants allowed an opportunity to voice their opinions adequately?
Yes _____ No _____

16) Was enough information/data important to the management decision(s) discussed among the participants? Yes _____ No _____

17) If you could have improved the experience(s) what would you suggest?

18) From what sources have you gathered your knowledge/understanding of the Las Vegas water system (check all that apply)?

_____ Media (television/radio)
_____ Water district/authority mailings
_____ Newspaper articles
_____ Internet websites
_____ Public meetings
_____ School
_____ Workplace
_____ Other (please specify):

19) What do you consider to be the biggest water concerns for local residents, if any?

20) Do you think Las Vegas residents should be more involved water management decisions?

Yes _______ No _______

21) <u>Importance of Las Vegas water issues</u>
The following questions ask about your views on water issues in Las Vegas. Please respond to each statement by checking one of the categories.

	strongly agree	agree	neither agree nor disagre e	disagre e	strongly disagree
I worry about water issues in Las Vegas.					
Water issues in Las Vegas have gotten my attention.					
I know a lot about water issues in Las Vegas.					
I want to know more about water issues in Las Vegas.					
Las Vegas water managers should worry more about municipal water issues.					
Las Vegas residents should worry more about municipal water issues.					
I have to deal with problems related to Las Vegas' water management in my life(style).					
Poor water management in Las Vegas would have serious implications for me.					
Whether I stay in Las Vegas in the future depends on how water is managed.					
The future of Las Vegas depends on how water is managed.					

APPENDIX 6

POST WORKSHOP SURVEY

POST WORKSHOP SURVEY

Workshop on Public Participation in Water Management
Post workshop survey

Please respond to the following statements by checking one of the categories. Please write any additional comments on a particular answer on the back of the questionnaire.

1. Importance of Las Vegas water issues
   The following questions ask about your views on water issues in Las Vegas. We are asking these questions again to see if the workshop changed any of your responses.

	strongly agree	agree	neither agree nor disagree	disagre e	strongly disagree
I worry about water issues in Las Vegas.					
Water issues in Las Vegas have gotten my attention.					
I know a lot about water issues in Las Vegas.					
I want to know more about water issues in Las Vegas.					
Las Vegas water managers should worry more about municipal water issues.					
Las Vegas residents should worry more about municipal water issues.					
I have to deal with problems related to Las Vegas' water management in my life(style).					
Poor water management in Las Vegas would have serious implications for me.					
Whether I stay in Las Vegas in the future depends on how water is managed.					
The future of Las Vegas depends on how water is managed.					

2. Effect of this workshop on understanding and communication

	strongly agree	agree	neither agree nor disagree	disagre e	strongly disagre e
I know more about Las Vegas water issues than I did before this workshop.					
The workshop changed my perception of water problems in Las Vegas.					
The workshop helped me better understand how the Las Vegas water system works.					
The workshop helped me understand the opinions and ideas of other participants.					
The workshop helped me see potential solutions to Las Vegas water problems that I hadn't considered before.					
This kind of workshop is a good way to get more people to care about water issues.					
All in all I think this workshop was useful for improving participant understanding about Las Vegas water issues.					
All in all I think this workshop was useful for improving discussion among participants about Las Vegas water management issues.					

3. <u>Comparison with other workshops</u>
If you have never participated in other workshops or discussion forums about environmental or community issues, skip to the next section. If you have participated in other workshops, please compare this experience with other workshops or forums in which you have discussed similar problems.

Compared with similar discussions you have participated in, would you say this workshop	strongly agree	agree	neither agree nor disagree	disagre e	strongly disagre e
gave you more insight into the issues being discussed than other workshops?					
helped you understand the issues more quickly than other workshops?					
resulted in better communication among participants?					
developed shared understanding of the issues among the participants better than other workshops?					

4. <u>Workshop format</u>
The following section is about how useful different aspects of the workshop are for promoting understanding and discussion.

a. Please indicate how well each part of the workshop promoted your **understanding**.

	Promoted understanding			Obstructed understanding	
	very much	somewhat	no effect	somewhat	very much
The format of discussions.					
The length of time allowed for discussions.					
The use of gradually more complex diagrams to introduce the model.					
Explanation of how the model worked.					
Simulation based on group input.					
The fact sheet provided about the water system.					

b. Please indicate how well each part of the workshop promoted **discussions** among participants.

	Promoted discussion			Obstructed discussion	
	very much	somewhat	no effect	somewhat	very much
The format of discussions.					
The length of time allowed for discussions.					
The use of gradually more complex diagrams to introduce the model.					
Explanation of how the model worked.					
Simulation based on group input.					
The fact sheet provided about the water system.					

5. <u>Workshop content</u>
The following questions ask about the information presented about the water system.

	strongly agree	agree	neither agree nor disagree	disagre e	strongly disagre e
The water system was described well.					
The water conservation problem was identified well.					
I believe the model was a valid representation of the Las Vegas water system.					

6. Effect of the model on understanding and communication

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
The model helped participants communicate their ideas to each other.					
The model simulations helped me understand the opinions and ideas of other participants.					
Using modeling is a fast and easy way to learn about water management issues.					
Using modeling is a good way to learn about water management issues.					
Using modeling is a confusing way to learn about water management issues.					
The model helped me clarify my own ideas about the system.					
The model helped me communicate my ideas to others.					
I referred to the model in discussing the pros and cons of possible solutions to the water problem.					
The model simulations included my ideas.					
Seeing the ideas simulated made me more interested in the issue.					
The model simulations helped me evaluate the merits of different ideas.					
All in all I think the model was useful for improving participant understanding about Las Vegas water issues.					
All in all I think the model was useful for improving discussion among participants about Las Vegas water management issues.					

7. Your experience in the workshop

	strongly agree	agree	neither agree nor disagree	disagre e	strongly disagre e
I felt free to disagree with other participants.					
I felt free to question the model.					
I felt free to suggest my ideas.					
I understood the model.					
I understood how the model could be used to address management issues.					
I wanted more introduction to the model.					
The model was presented too quickly.					
I would be interested in participating in other workshops like this one.					

8. Suggestions to help improve future workshops

What did you like best about the workshop?

1.

2.

What did you like least about the workshop?

1.

2.

What specific suggestions would you make to improve future workshops like this?

APPENDIX 7

TABLE OF SURVEY RESPONSE FREQUENCIES

TABLE OF SURVEY RESPONSE FREQUENCIES

Pre-Workshop Survey

Please answer the following questions. All information will be kept anonymous and confidential. We will use this information in analyzing the usefulness of the workshops.

1) Age:

16 to 25 years old	33
26 to 35 years old	16
36 to 45 years old	8
46 to 55 years old	9
56 to 65 years old	0
65 or older	1

2) Highest level of education completed (check one):

High School Graduate	6
Some college	41
Undergraduate degree	11
Graduate degree	8
Post-graduate degree	1

5) How would you categorize your profession?
(Indicate your primary profession with a "1", any secondary profession with a "2", etc.)

Student	25
Administrative	11
Service industry	14
Resource Management	9
Education	8
Retired	<2>
Not currently in labor force	<4>
Other (please specify)	<2>

6) Income level: (check one)

Less than $15,000 per year	24
$15,001 - $30,000	15
$30,001 - $60,000	14
$60,001 - $100,000	10
$100,001 - $200,000	1
Over $200,000	1

8) If it were possible, would you like to have some input into management decisions which affect the Las Vegas Community?

Yes 43 No 9 Don't know 15

9) Have you ever attended public forum(s) for management decisions which affected your community?

Yes 31 No 36

11) Did you feel the forum(s) *succeeded* in its(their) stated objective(s) Yes 14 No 16

13) Did you feel *satisfied* with the outcome of the forum(s)? Yes 12 No 17

15) Were all participants allowed an opportunity to voice their opinions adequately?

Yes 20 No 11

16) Was enough information/data important to the management decision(s) discussed among the participants? Yes 16 No 12

21) Importance of Las Vegas water issues

The following questions ask about your views on water issues in Las Vegas. Please respond to each statement by checking one of the categories.

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
I worry about water issues in Las Vegas.	17	35	13	1	1
Water issues in Las Vegas have gotten my attention.	19	34	11	2	1
I know a lot about water issues in Las Vegas.	6	20	23	15	3
I want to know more about water issues in Las Vegas.	17	38	10		1
Las Vegas water managers should worry more about municipal water issues.	23	27	14	2	1
Las Vegas residents should worry more about municipal water issues.	25	31	9	1	1
I have to deal with problems related to Las Vegas' water management in my life(style).	14	19	19	10	3
Poor water management in Las Vegas would have serious implications for me.	26	24	15	1	1
Whether I stay in Las Vegas in the future depends on how water is managed.	6	12	24	14	8
The future of Las Vegas depends on how water is managed.	31	20	11	3	1

Post Workshop Survey

1. <u>Importance of Las Vegas water issues</u>
The following questions ask about your views on water issues in Las Vegas. We are asking these questions again to see if the workshop changed any of your responses.

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
I worry about water issues in Las Vegas.	28	36	2		1
Water issues in Las Vegas have gotten my attention.	33	30	3	1	
I know a lot about water issues in Las Vegas.	16	37	9	3	1
I want to know more about water issues in Las Vegas.	25	28	10	2	
Las Vegas water managers should worry more about municipal water issues.	39	23	2	2	1
Las Vegas residents should worry more about municipal water issues.	42	22	2		1
I have to deal with problems related to Las Vegas' water management in my life(style).	18	33	10	2	3
Poor water management in Las Vegas would have serious implications for me.	28	29	7	2	1
Whether I stay in Las Vegas in the future depends on how water is managed.	16	14	22	12	2
The future of Las Vegas depends on how water is managed.	40	21	3	2	1

2. Effect of this workshop on understanding and communication

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
I know more about Las Vegas water issues than I did before this workshop.	36	25	2	3	
The workshop changed my perception of water problems in Las Vegas.	25	25	7	7	1
The workshop helped me better understand how the Las Vegas water system works.	28	18	3	1	1
The workshop helped me understand the opinions and ideas of other participants.	32	30	3		1
The workshop helped me see potential solutions to Las Vegas water problems that I hadn't considered before.	28	26	7	4	1
This kind of workshop is a good way to get more people to care about water issues.	32	12	6	1	1
All in all I think this workshop was useful for improving participant understanding about Las Vegas water issues.	32	30	2	1	1
All in all I think this workshop was useful for improving discussion among participants about Las Vegas water management issues.	31	33	1		1

3. Comparison with other workshops

If you have never participated in other workshops or discussion forums about environmental or community issues, skip to the next section. If you have participated in other workshops, please compare this experience with other workshops or forums in which you have discussed similar problems.

Compared with similar discussions you have participated in, would you say this workshop	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
gave you more insight into the issues being discussed than other workshops?	7	25	6	2	1
helped you understand the issues more quickly than other workshops?	11	16	12	1	1
resulted in better communication among participants?	16	16	8		1
developed shared understanding of the issues among the participants better than other workshops?	15	20	5		1

4. Workshop format

The following section is about how useful different aspects of the workshop are for promoting understanding and discussion.

a. Please indicate how well each part of the workshop promoted your **understanding**.

	Promoted understanding		no effect	Obstructed understanding	
	very much	somewhat		somewhat	very much
The format of discussions.	38	26	1	1	
The length of time allowed for discussions.	35	28	3	1	
The use of gradually more complex diagrams to introduce the model.	34	25	5	2	
Explanation of how the model worked.	37	25	5		
Simulation based on group input.	47	15	5		
The fact sheet provided about the water system.	43	20	4		

b. Please indicate how well each part of the workshop promoted **discussions** among participants.

	Promoted discussion			Obstructed discussion	
	very much	somewhat	no effect	somewhat	very much
The format of discussions.	38	25	3		
The length of time allowed for discussions.	29	29	7	1	
The use of gradually more complex diagrams to introduce the model.	30	25	9	2	
Explanation of how the model worked.	35	24	6	1	
Simulation based on group input.	44	18	3		
The fact sheet provided about the water system.	37	22	6		

5. <u>Workshop content</u>

The following questions ask about the information presented about the water system.

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
The water system was described well.	32	1			
The water conservation problem was identified well.	29	7	2		
I believe the model was a valid representation of the Las Vegas water system.	37	6	1		

6. Effect of the model on understanding and communication

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
The model helped participants communicate their ideas to each other.	30	31	5	1	
The model simulations helped me understand the opinions and ideas of other participants.	27	32	7	1	
Using modeling is a fast and easy way to learn about water management issues.	34	27	5		
Using modeling is a good way to learn about water management issues.	31	30	6		
Using modeling is a confusing way to learn about water management issues.	2	8	9	32	16
The model helped me clarify my own ideas about the system.	18	36	12	1	
The model helped me communicate my ideas to others.	20	31	15	1	
I referred to the model in discussing the pros and cons of possible solutions to the water problem.	16	31	15	3	
The model simulations included my ideas.	21	24	7		1
Seeing the ideas simulated made me more interested in the issue.	28	20	4	1	
The model simulations helped me evaluate the merits of different ideas.	27	20	4		
All in all I think the model was useful for improving participant understanding about Las Vegas water issues.	32	33	2		
All in all I think the model was useful for improving discussion among participants about Las Vegas water management issues.	33	31	3		

7. <u>Your experience in the workshop</u>

	strongly agree	agree	neither agree nor disagree	disagree	strongly disagree
I felt free to disagree with other participants.	27	34	4	1	
I felt free to question the model.	30	28	7	1	
I felt free to suggest my ideas.	39	25	1	1	
I understood the model.	35	29	2		
I understood how the model could be used to address management issues.	35	28	2		
I wanted more introduction to the model.	5	11	22	23	4
The model was presented too quickly.	2	6	15	32	12
I would be interested in participating in other workshops like this one.	19	30	14	3	1

APPENDIX 8

T-TEST RESULTS OF
PAIRED SAMPLES TEST

T-TEST RESULTS OF PAIRED SAMPLES TEST

Paired Sample	N	Mean	Sig. 1 direction 1-test
Pair 1 - [pre] I worry about water issues in Las Vegas. [post] I worry about water issues in Las Vegas.	67	2.01 1.66	.0001
Pair 2 - [pre] Water issues in Las Vegas have gotten my attention. [post] Water issues in Las Vegas have gotten my attention.	67	1.99 1.58	.0001
Pair 3 - [pre] I know a lot about water issues in Las Vegas. [post] I know a lot about water issues in Las Vegas.	66	2.82 2.03	.0001
Pair 4 - [pre] I want to know more about water issues in Las Vegas. [post] I want to know more about water issues in Las Vegas.	64	1.89 1.83	.242
Pair 5 - [pre] Las Vegas water managers should worry more about municipal water issues. [post] Las Vegas water managers should worry more about municipal water issues.	67	1.97 1.55	.0001
Pair 6 - [pre] Las Vegas residents should worry more about municipal water issues. [post] Las Vegas residents should worry more about municipal water issues.	67	1.84 1.45	.0001
Pair 7 - [pre] I have to deal with problems related to Las Vegas' water management in my life(style). [post] I have to deal with problems related to Las Vegas' water management in my life(style).	64	2.52 2.09	.001
Pair 8 - [pre] Poor water management in Las Vegas would have serious implications for me. [post] Poor water management in Las Vegas would have serious implications for me.	67	1.91 1.79	.0985
Pair 9 - [pre] Whether I stay in Las Vegas in the future depends on how water is managed. [post] Whether I stay in Las Vegas in the future depends on how water is managed.	64	3.09 2.56	.0001
Pair 10 - [pre] The future of Las Vegas depends on how water is managed. [post] The future of Las Vegas depends on how water is managed.	66	1.86 1.56	.001

REFERENCES

Accounting Education Change Commission. 1990. Objectives of education for accountants. In J.D. Klein and M.S. Doran. 1999. *Implementing Individual and Small Group Learning Structures with a Computer Simulation.* ETR&D 47(1):97-110.

Akkermans, H.A. and J.A.M. Vennix. 1997. Clients' opinions on group model-building: an exploratory study. *System Dynamics Review* 13(1):3-31.

Andersen, D.F. and G.P. Richardson. 1997. Scripts for Group Model Building. *System Dynamics Review* 13(2):107-129.

Apostolakis, G.E. and S.E. Pickett. 1998. Deliberation: Integrating Analytical Results into Environmental Decisions Involving Multiple Stakeholders. *Risk Analysis* 18(5):621-634.

Arnstein, S. R. 1969. A Ladder of Citizen Participation. *American Institute of Planners Journal.* July:216-224.

Barndt, M. 1998. Public Participation GIS–Barriers to Implementation. *Cartography & Geographic Information Systems* 24(2):105-117.

Carson, S. R. 1996. Foxes and rabbits - and a spreadsheet. In K. Korfiatis, E. Papatheodorou, G. P. Stamou. 1999. An investigation of the effectiveness of computer simulation programs as tutorial tools for teaching population ecology at university. *International Journal of Scientific Education* 21(12):1269-1280.

Costanza, R. and M. Ruth. 1998. Using Dynamic Modeling to Scope Environmental Problems and Build Consensus. *Environmental Management* 22(2):183-195.

Cramer, J. C., T. Dietz, and R. A. Johnston. 1980. Social Impact Assessment of Regional Plans: a review of methods and issues and a recommended process. *Policy Sciences* 12:61-82.

Dietz, T. and P.C. Stern. 1998. Science, values, and biodiversity. *Bioscience* 48(6):441-445.

Doerksen, H. R. and J.C. Pierce. 1976. Citizen Influence in Water Policy Decisions: Context, Constraints, and Alternatives. In J. C. Pierce and H. R. Doerksen (eds.). 1996. *Water Politics and Public Involvement.* Ann Arbor, MI: Ann Arbor Science.

Fleming, J. A. 1997. The Workshop Through New Eyes. *New Directions For Adult And Continuing Education* 76:33-40.

Ford, A. 1999. *Modeling the Environment.* Washington, D.C.: Island Press, 401 pp.

Forrester, J. W. 1969. *Urban dynamics.* Cambridge, Mass: M. I. T. Press, 285 pp.

Forrester, J. W. 1995. *Counterintuitive Behavior of Social Systems.* Portland, OR: Productivity Press.

George, D. and P. Mallery. 2000. *SPSS for Windows Step By Step.* Needham Heights, MA:Allyn & Bacon, 357 pp.

Gott, N.C. 1995. *Environmental justice and participatory democracy: an emancipatory policy proposal.* Las Vegas, NV: University of Nevada.

Gregory, R. 2000. Using Stakeholder Values to Make Smarter Environmental Decisions. *Environment* 42(5):34-44.

Gunderson, L., C. S. Holling, and S. Light. 1995. Integrated regional models: Interactions between humans and their environment. New York, NY: Columbia University Press, 393 pp.

Hale, E.O. 1993. Successful Public Involvement. *Journal of Environmental Health* January/February:17-19.

Huz, S., D.F. Andersen, G.P. Richardson, R. Boothroyd. 1997. A framework for evaluating systems thinking interventions: An experimental approach to mental health system change. *System Dynamics Review* 13(2):149-169.

Imel, S. 1996. Leaning in Groups: Exploring Fundamental Principles, New Uses, and Emerging Opportunities. In A. M. Will 1997. Group Learning in Workshops. *New Directions For Adult And Continuing Education* 76:33-40.

Johnson P. 1993. How I Turned a Critical Public into Useful Consultants. *Harvard Business Review* January-February:56-66.

Johnson, D. W., R. T. Johnson, and K. A. Smith. 1991. Cooperative Learning: Increasing College Faculty Instructional Productivity. In A. M. Will 1997. Group Learning in Workshops. *New Directions For Adult And Continuing Education* 76:33-40.

Kadel, S. and J. A. Keehner. 1994. Collaborative Learning: A Sourcebook for Higher Education. In A. M. Will. 1997. Group Learning in Workshops. *New Directions For Adult And Continuing Education* 76:33-40.

Kirkwood, C. 1997. System Behavior and Causal Loop Diagrams (Chapter 1). *http://www.public.asu.edu/~kirkwood*

Korfiatis, K, E. Papatheodorou, G. P. Stamou. 1999. An investigation of the effectiveness of computer simulation programs as tutorial tools for teaching population ecology at university. *International Journal of Scientific Education* 21(12):1269-1280.

Liberatore A. 1995. The social construction of environmental problems. In P. Glasbergen and A. Blowers. *Perspectives On Environmental Problems.* London:Open University of The Netherlands.

Matray P. and S. Proulx. 1995. Integrating computer/multimedia technology in a high school biology curriculum. In K. Korfiatis, E. Papatheodorou, and G.P. Stamou. 1999. An investigation of the effectiveness of computer simulation programs as tutorial tools for teaching population ecology at university. *International Journal of Science Education* 21(12):1269-1280.

McComas, K.A. and C.W. Scherer. 1998. Reassessing Public Meetings as Participation in Risk Management Decisions. *16 Risk: Health, Safety & Environment* 347:347 - 360.

NEPA. National Environmental Protection Agency. 1992. 40 CFR Ch. 1 (7-1-92 Edition) §25.1-.14.

Perhac Jr., R.M. 1998. Comparative Risk Assessment: Where Does the Public Fit In? *Science, Technology, & Human Values* 23(2):221-241.

Preister, K. and J. A. Kent. 1997. Social Ecology: A New Pathway To Watershed Restoration. In J. E. Williams, C. A. Wood, and M. P. Dombeck (ed.). 1997. *Watershed Restoration: Priciples and Practices.* Bethesda, MD: American Fisheries Society.

Renn, O., T. Webler, H. Rakel, P. Dienel, and B. Johnson. 1993. Public participation in decision making: A three-step procedure. *Policy Sciences* 26:189-214.

Richmond, B. 1990. Systems Thinking: A critical set of Critical Thinking Skills for the 90's and beyond. Pages 934-947 in: Andersen, D., G. Richardson, and J. Sterman

(eds.) *System Dynamics '90* v. 2. Proceedings of the 1990 International System Dynamics Conference. System Dynamics society. Cambridge, MA.

Richmond, B. 1997. The *Strategic Forum*: aligning objectives, strategy, and process. *System Dynamics Review* 13(2):131-148.

Roline, R. and J. Sartoris. 1998. Las Vegas Wash Water Quality Monitoring Program: 1997 Report of Findings. Technical Memorandum No. 8220-98-6. U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center. Denver, CO.

Ruth, M. and J. Lindholm. 1996. Dynamic modelling of multispecies fisheries for consensus building and management. *Environmental Conservation* 23(4):332-342.

Romme L. and A. Georges. 1995. Non-participation and system dynamics. *System Dynamics Review* 11(4):311-319.

Rycroft, R.W., J. L. Regens, and T. Dietz. 1987. Acquiring and Utilizing Scientific and Technical Information to Identify Environmental Risks. *Science, Technology, and Human Values* 12(3&4):125-130.

Susskind, L. and J. Cruikshank. 1987. Braking the Impasse. In G. E. Apostolakis and S.E. Pickett. 1998. Deliberation: Integrating Analytical Results into Environmental Decisions Involving Multiple Stakeholders. *Risk Analysis* 18(5):621-634.

Susskind L. and L. Dunlap. 1981. The Importance of Non-Objective Judgements in Environmental Impact Assessment. In G. E. Apostolakis and S.E. Pickett. 1998. Deliberation: Integrating Analytical Results into Environmental Decisions Involving Multiple Stakeholders. *Risk Analysis* 18(5):621-634.

Sterman, J. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* McGraw-Hill.

Stern, P.C. 1991. Learning through conflict: a realistic strategy for risk communication. *Policy Sciences* 24:99-119.

Stern, P.C. and T. Dietz. 1994. The Value Basis of Environmental Concern. *Journal of Social Issues* 50(3):65-84.

Senge, P. M. 1990. The Fifth Discipline. New York, NY:Doubleday Currency, 424pp.

SPSS ® is a trademark of SPSS, Inc.

Stave, K. and S. Cloud. 2000. Using System Dynamics Models to Facilitate Public Participation in Water Resource Management: A Pilot Study Using the Las Vegas,

NV Water System. *Proceedings of the 18th International System Dynamics Conference 2000.*

Talen, E. 2000. Bottom-Up GIS. *Journal of the American Planning Association* 66(3):279-297.

Taylor, H.A., C.E. Renshaw, and M.D. Jensen. 1997. Effects of Computer-Base Role-Playing On Decision Making Skills. *Journal of Educational Computing Research* 17(2):147-164.

Temple, G. 1983. *Cooperative Extension and Citizen Participation in Public Policy Issues in Rural Areas.* University Park, PA:Pennsylvania State University.

USGS, U.S. Geological Survey. 1998. Water Quality in the Las Vegas Valley Area and the Carson and Truckee river Basins, Nevada and California, 1992-96. 98-1170.

Vennix, J.A.M. 1996. *Group Model Building: Facilitating Team Learning Using System Dynamics.* Chichester: J. Wiley & Sons. 297 pages.

Vennix, J.A.M. 1999. Group model-building: tackling messy problems. *System Dynamics Review* 15(4):379-401.

Vennix, J.A.M., D.F. Andersen, and G.P. Richardson. 1997. Foreward: Group model building, art, and science. *System Dynamics Review* 13(2):103-106.

Vennix, J.A.M. and E. Rouwette. 2000. Group Model Building: What Does The Client Think About It Now? *Proceedings of the 18th International System Dynamics Conference 2000.*

Weeks, P. 1995. Fisher Scientists: The Reconstruction of Scientific Discourse. Human Organization 54(4):429-436.

Weiss, J.A. 1989. The powers of problem definition: The case of government paperwork. *Policy Sciences* 22:97-121.

Weisbord, M. (ed). 1992. *Discovering common ground.* San Francisco:Berrett-Koehler. 442 pp.

Weisbord, M. and S. Janoff. 1995. Future search: An action guide to finding common ground in organizations and communities. San Francisco:Berrett-Koehler.

Whitcomb, J.B. 1996. *Water Price Elasticities in the Southwestern United States: Single Family Homes.* Las Vegas, NV: Southern Nevada Water Authority, 40 pp.

Will, A.M. 1997. Group Learning in Workshops. *New Directions For Adult And Continuing Education* 76:33-40.

Yankelovich, D. 1991. *Coming to Public Judgement.* Syracuse, NY: Syracuse University Press.

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