FINAL REPORT

Gila Planning Economic Forum
May 28, 2009
Western New Mexico University, Silver City, New Mexico

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Submitted to:
New Mexico Interstate Stream Commission
Southwestern New Mexico Stakeholder Group

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TABLE OF CONTENTS

SUMMARY

The Gila Planning Economic Forum was held on May 28, 2009, at Western New Mexico University in Silver City, New Mexico. The goal of the forum was to bring together experts to present an array of economic tools and techniques that could provide the Southwestern New Mexico Stakeholder's Group with additional decision making and management capabilities. In addition, the forum included presentations on two topics that the group suggested warranted update: projected hydrologic effects of climate change in southwestern New Mexico and an update of demographic and economic trends in the four Gila Basin Counties.

Eight speakers gave presentations at the Gila Planning Economic Forum. Dr. David Gutzler, Professor in the Earth and Planetary Sciences Department at the University of New Mexico discussed the expected changes in the hydroclimatology of the Gila River basin. Dr. James Peach, Regents Professor of Economics and International Business at New Mexico State University provided updated information on the population and economic activity of the four-county area. Dr. Steven Piper, Natural Resource Economist with the U.S. Bureau of Reclamation discussed residential and commercial water supply benefits and methodologies that can be used to estimate benefits under various water supply scenarios. Dr. Rob Davis, Agricultural Economist with the U.S. Bureau of Reclamation discussed techniques for estimating agricultural water supply benefits under changing water supply conditions. Dr. Don Coursey, Ameritech Professor at the Harris Graduate School of Public Policy Studies, University of Chicago discussed flexible water allocation institutions for multiple water uses. Dr. John Loomis, Professor of agricultural economics at Colorado State University discussed the economic values of instream flow for fish and recreation and guidance on transferring these values versus developing Gila River specific values. Dr. David Brookshire, Professor of Economics and Director of the Science Impact Laboratory for Policy and Economics at the University of New Mexico discussed valuing multidimensional ecosystem services. Finally, Dave Goodrich, a hydrologist at the Agricultural Research Service and the University of Arizona specializing in riparian zone evapotranspiration, talked about how the hydrological and biological sciences were integrated with the social sciences for decision-making on the Upper San Pedro River in Arizona and the Rio Grande in New Mexico. A lively 90-minute discussion between members of the audience and the panel of speakers followed immediately after the presentations.

PREAMBLE

From the NEW MEXICO INTERSTATE STREAM COMMISSION briefing package:

Mirroring New Mexico State statutes, Congress directed in the 2004 Arizona Water Settlements Act that the New Mexico Interstate Stream Commission approve any expenditures of monies or contracts for water received by New Mexico in the settlement. Even before the Act was signed into law, the Commission adopted a policy to guide it through the planning and decision process:

> **"The Interstate Stream Commission recognizes the unique and valuable ecology of the Gila Basin. In considering any proposal for water utilization under Section 212 of the Arizona Water Settlements Act, the Commission will apply the best available science to fully assess and mitigate the ecological impacts on Southwest New Mexico, the Gila River, its tributaries and associated riparian corridors, while also considering the historic uses of and future demands for water in the Basin and the traditions, cultures and customs affecting those uses."**

Under State statute, the Governor also is responsible for ensuring the equitable distribution of interstate waters. This policy was adopted and approved by the Office of the Governor, with the further directive that the process be carried out within a fully inclusive and transparent public involvement process.

The process used to decide and plan how best to utilize the benefits received in the 2004 Arizona Water Settlements Act must therefore be comprehensive, utilize the best available science and data, fully consider both present and future demands for water, employ the best and most efficient management, protect the unique and valuable ecology of the Gila Basin, and be fully inclusive and transparent. To mesh these often contradictory tasks will be neither easy nor simple. The Southwestern New Mexico Stakeholders group has been meeting for nearly two years and includes a diverse set of interests, including various State and Federal Agencies, irrigators, municipalities, environmental groups, business interests, and the general public. In addition to this Economic forum, the group has also funded the Ecological and Supply/Demand forums.

The Southwestern New Mexico Stakeholders group commissioned the Gila Planning Economic Forum. The effort was funded through the New Mexico Interstate Stream Commission.

GOALS

The goals of the Gila Planning Economic Forum were to:

1. Present economic tools and techniques from scientists to help inform decision making in the Gila River Watershed.

2. Provide an update on demographic and economic activity for the four county area.

3. Provide expected impacts of climate change on the watersheds of southwestern New Mexico.

4. Assist in the identification and prioritization of scientific and technical needs required to support water management decisions in the Gila River Basin.

PROCESS AND ORGANIZATION

A forum planning committee made up of Dr. Bobby Creel, Associate Director of the New Mexico Water Resources Research Institute at New Mexico State University, Dr. David Brookshire, Professor of Economics at the University of New Mexico, and Dr. Steven Piper, Economist with the U.S. Bureau of Reclamation, Denver, Colorado identified the topics, suggested experts that should be invited to present at the forum, and developed the forum program. A small number of experts who could discuss the topic areas were invited as forum panelists. While certainly not exhaustive, the topics areas chosen were: demographics and economic activity; climate change impacts, valuing multidimensional ecosystem services, valuing agricultural services, valuing domestic water uses, market systems, water allocation institutions, decision support systems, and transfer considerations.

The forum was designed as a one-day workshop, open to the public, and held at a local facility. A draft program was presented to the Technical/Implementation Committee of the Gila Stateholder's Group at their meeting on February 9, 2009. A number of suggestions and questions resulted in changes to the program and topics. The panelists who had been identified were invited and arrangements made for their participation. Arrangements were also made with Western New Mexico University in Silver City for use of meeting rooms and catering services. The date for the forum on May 28, 2009 was dictated by the availability of meeting rooms and the schedule of panelists. The final forum program was provided to the Stakeholder's Group for distribution.

The invitation letter to speakers is contained in **Appendix 1**.

The speakers were:

Dr. David Brookshire, Professor of Economics and Director of the Science Impact Laboratory for Policy and Economics at the University of New Mexico.

Dr. David Gutzler, Professor in the Earth and Planetary Sciences Department at the University of New Mexico.

Dr. James Peach, Regents Professor of Economics and International Business at New Mexico State University.

Dr. Steven Piper, Natural Resource Economist with the U.S. Bureau of Reclamation, Denver, Colorado.

Dr. Rob Davis, Agricultural Economist with the U.S. Bureau of Reclamation, Denver, Colorado.

Dave Goodrich, Hydrologist at the USDA Agricultural Research Service and the University of Arizona.

Dr. John Loomis, Professor of Agricultural Economics at Colorado State University.

Dr. Don Coursey, Ameritech Professor at the Harris School of Public Policy Studies, University of Chicago.

Two-page curriculum vitaes for each of the panelists are contained in **Appendix 5**.

Panelist were asked to prepare a 30-minute presentation, a five-page summary of their presentation, their current vitae (2-3 pages), a two- to three- page “State of the Art” on their topical area of research (this is distinct from the presentation and might include some “accessible citations”) , and three of the most often asked topical questions and their answers.

Background information on the 2004 Arizona Water Settlements Act was given to the panelists to facilitate their preparations. The Forum brochure, Forum flyer, and Forum day programs are contained **Appendices 2, 3 and 4**, respectively. These materials were also presented to the speakers along with a question and answer session at a forum day breakfast meeting by an ISC representative.

On May 28, 2009, each panelist gave a 30-minute public presentation at the Bessie-Forward Global Resource Center on the campus of WNMU. After all presentations were given, a 90-minute open panel discussion commenced with questions from the floor.

Complete PowerPoint Presentations are provided in **Appendix 6**.

CRITICAL QUESTIONS

David S. Brookshire and Craig D. Broadbent

1) *Can you place values on ecosystem services? Specifically what techniques are available?*
   There are two methodologies available to place values on ecosystem services: 1) stated preference techniques, 2) revealed preference techniques. Within stated preference techniques there are two methods know as choice experiments, and contingent valuation. A choice experiment allows a researcher to obtain the marginal values (values for incremental changes) in attributes by offerings respondents in a survey setting a choice over alternative bundles of ecosystem services. The contingent valuation method allows a researcher to obtain singular ecosystem marginal values for a policy change (e.g. groundwater levels). While stated preference methods ask individuals their willingness to pay for hypothetical scenarios revealed preference techniques such as the travel cost methods and hedonic pricing model rely upon data from a market that is closely related to the good being valued. Either of these methodologies allows economists to conduct non-market valuation in order to place values on ecosystem services.

2) *What is required to value Ecosystem Services?*
   In order to properly value ecosystem services a researcher needs to understand the underlying ecosystem functions and how the attributes of the ecosystem services respond to different scenarios. The use of integrated modeling within the context of a Decision Support System (DSS) allows researchers to properly determine the drivers, climatic and anthropogenic changes, that lead to changes in ecosystem services. Bundles of ecosystem services can be used to obtain the marginal values (values for incremental changes) for each attribute of the ecosystem service (e.g. surface water levels, vegetation composition, avian populations).

3) *What do you do with Ecosystem Values?*
   Unless ecosystem values are determined, then these values cannot be adequately juxtaposed with market values, which are traditionally the primary values considered. In an Integrated Decision Support System (DSS) framework, which incorporate ecosystem values, policy makers can better understand the benefits and societal values of non-market goods and the tradeoffs with market based goods. By integrating marginal ecosystem services values into a Decision Support System (DSS) the policy maker may ask questions within the context of alternative scenarios in order to evaluate tradeoffs in satisfying alternative uses of resources, both in a market and a non-market context.

Don Coursey

1) *Why would we use a market?*
   A market provides greater flexibility for water users.

2) *Would a person be forced to trade?*
   A person would never have to trade in any situation.

3) *What is needed for a water market?*
   A few things needed for a water market are property rights, measurements, hydrogeologic knowledge, and a trading platform.

By David C. Goodrich

1) *How can you replicate the scientific foundation and integration of science and decision making that has been carried out in the San Pedro?*
The very long-term development of process-based hydrologic research was greatly facilitated by establishment of the USDA-ARS Walnut Gulch Experimental Watershed (WGEW – www.tucson.ars.ag.gov) in the late 1950's in a subwatershed of the San Pedro. The significant knowledge and database develop in the WGEW in turn provided a foundation and magnet for larger scale interdisciplinary, interagency research. The increased interest in global change research fostered the expansion of research out of the WGEW into the larger San Pedro. Compelling research challenges and significant heterogeneity in the basin and its land use across the international border further attracted numerous researchers to the SALSA (Semi-Arid Land Surface Atmosphere) Research program (www.tucson.ars.ag.gov/salsa). The "free-market" research model of SALSA, where researchers largely provided their own resources, but agreed to actively support other's research efforts with coordinated field work and open data and knowledge sharing, was a key factor in the success of the program. The close integration of science, directly designed to aid the information needs of elected officials and decision-makers, was motivated by the high-stakes competing demands for water to: 1) Enable the US Army Ft. Huachuca military installation (one of the largest employers and economic engines in southern Arizona) to maintain and expand it mission in light of reviews by the Base Realignment And Closure (BRAC) Commission; 2) Maintain perennial flow in the globally important, San Pedro riparian ecosystem which, in 1988, was the first Congressionally designated National Riparian Conservation Area (administered by the BLM); and, 3) The possible imposition of actions by the Federal courts to preserve the San Pedro. This high-stakes situation brought together a diverse set of elected officials, agencies and NGO's to form the Upper San Pedro Partnership (USPP – www.usppartnership.com). Again, because of the high-stakes involved, each of the member agencies and NGO has committed significant resources and staff time to: 1) develop conservation and augmentation projects; 2) educate the public; 3) work with both member and non-member scientists to design and support research to provide critical information and data; 4) and effectively lobby to provide political support and resources to pursue their mission. This involves meetings of various committees and sub-committees of the USPP occurring three to four times per month for nearly ten years and counting. In other basins in which the Arizona Department of Water Resources has attempted to foster watershed partnerships there has been mixed success in forming strong and lastly integrated science and decision-making efforts. The success of the USPP is largely attributed to the high-stakes involved and fact that the nature of the problem (over pumping of the groundwater aquifers) is not an urgent crisis. The longer term nature of the threat, enabled formation of the Partnership; trust building; decision making by consensus; and time for research and study. There is also an important element of scale involved. In the WGEW (~150 sq. km) there are not enough stakeholders and urgent issues to compel diverse parties to come together, organize, and commit substantial time and effort. A number of researchers working in the San Pedro also have extensive experience working in the Upper Rio Grande. At that larger basin scale there are too many issues and too many stakeholders to attempt to organize with and meet with on a regular basis.

2) *Was building this scientific foundation expensive?*
Yes, but as they say, you get what you pay for. Many believe that the investment in science by the USPP was worth it to provide decisions that are defensible and firmly

based on good science. In addition, some feel the investment in science and data collection, that was agreed to and reviewed by all Partnership members, will avoid costly litigation. Even if there is litigation, many believe all parties will likely accept the data and peer-reviewed scientific conclusions but argue the interpretations.

3) *What would be the best initial investment to characterize a riparian system (asked by this group in the prior meeting as well as other groups)?*
   Multi-return airborne LIDAR with co-registered multi-band imagery. With interpretation, this data will enable detailed measurement of near stream topography and geomorphology; the type, growth stage, and canopy characteristics of the riparian vegetation.

David S. Gutzler

1) *How is streamflow in the Gila River likely to change in the 21st Century?*

Streamflows in southwestern rivers, especially in snow-fed rivers like the Gila, are expected to decrease significantly in this century. The decrease is due primarily to two causes, both associated with projected warming trends: (1) Large anticipated decreases in snowpack and earlier snowmelt (2) Increases in evaporation from open water surfaces and in evapotranspiration from riparian vegetation. These projected changes decrease the inflows into mainstem rivers such as the Gila and increase depletions from these rivers. A secondary cause of diminished projected streamflow is the potential decrease in overall winter precipitation projected by most climate simulations.

Associated changes in the seasonal hydrograph are also projected. The primary snowmelt runoff peak in the Gila, which currently takes place in February or March on average, will become much less pronounced and occur earlier in the year. It is possible that the Gila basin could lose its snowpack altogether by the end of the 21st Century, effectively eliminating seasonal snowmelt runoff. Streamflows from late winter into early summer would decrease most markedly, and the annual low flow period before monsoon onset would be particularly pronounced. Diminished streamflow would be especially exacerbated during drought episodes.

2) *How good are the climate projections on which these streamflow changes are based?*

The streamflow changes described above are based on projected temperature trends, which are the most robust results generated by the current generation of global climate models forced by increasing greenhouse gases. These models have demonstrated good skill in "hindcasting" the observed temperature changes in the 20th Century. Greenhouse gas forcing has become so pronounced that the warming trend associated with such forcing has emerged from natural interannual variability, and all global models project warming trends to continue, and probably accelerate, in the 21st Century. Precipitation is a less certain variable in the models, and precipitation exhibits higher levels of natural variability compared to temperature, so the projected precipitation changes are smaller and less robust than projected warming.

3) *Do we see evidence of these changes occurring already?*

We see unambiguous evidence that observed temperatures are increasing throughout New Mexico. Some of the largest and clearest warming trends in the lower 48 United States are observed at long-term weather stations around the Gila basin in the southwestern part of New Mexico. A study published last year described a sophisticated analysis of observed hydrologic trends across the western U.S. It concluded that the likelihood is very high that recent changes are outside the expected range of natural variability, and are associated with human-induced climate change. This result reinforces the expectation that current trends are very likely to continue in the 21st Century, because greenhouse gas concentrations will certainly continue to increase.

Dr. John Loomis

1) *Do agencies actually use non-market values?*
Yes. Non market values have been included in benefit-cost analyses included by the National Park Service (e.g., both use and non-use values) for the Elwha Dam Removal EIS, USFWS (e.g., both use and non-use values for Wolf Reintroduction EIS), USBR (e.g., Operation of Glen Canyon Dam, Final Environmental Impact Statement, 1995), and the U.S.Army Corps of Engineers (e.g. The Lower Snake River Juvenile Salmon Migration Feasibility Report/Draft EIS, December 1999—aka Lower Snake River Dam removal study). The U.S. Environmental Protection Agency routinely uses recreation benefits of water quality and visibility in determining how stringent non-health related environmental regulations need to be as part of their benefit-cost analysis.

2) *How accurate are non-market values?*
Recreation use values appear to be quite reliable as well as valid. This is based on more than a hundred comparisons of recreation use values estimated using actual behavior (i.e., the Travel Cost Method) and estimated using intended behavior (Contingent Valuation Method).

Passive Use or non-use values obtained from a Contingent Valuation Method survey may overstate actual willingness to pay (WTP) by a factor of 2-10. However, calibration methods have been developed to scale back stated WTP so it better matches actual cash. The other method of directly instructing the respondent to avoid overstatement of WTP has had some success in many but not all settings.

3) *Why use non market values when evaluating water resource trade-offs?*
If decision makers have economic values for agricultural use of water and municipal use, but not environmental uses, then this can lead people to believe there is an "environment versus economy" dichotomy. Some people think omission of economic values implies ***zero*** economic value. While non market valuation methods are not perfect, neither is weather forecasting either, but we still use it. The statistical confidence intervals around nearly all non market valuation studies estimates of average willingness to pay do not include zero. Thus the error of implying a zero value is far greater than the error involved in non market valuation.

Jim Peach

1) *Why do some regions grow faster than others?*
Regional economies, such as the four county Gila Basin Settlement area, grow for the same reasons that national economies grow. In the long run, economic growth is determined by many factors including: (a) the productivity of the labor force, (b), the industrial mix of the region, (c) proximity to markets, and (d) technological change. The productivity of the labor force is particularly important. Modern business needs highly educated and highly skilled workers. The industrial mix of the region is important because if a region has a high proportion of fast growing industries, then the region will grow fast. Proximity to markets may not be as important as it once was because transportation costs are a relatively small component of total product costs.

2) *What is the difference between economic growth and economic development?*
Economic growth is quantifiable and does not necessarily imply any fundamental changes in the economy being considered. Economic growth can be easily measured by changes in employment, income, or output. Economic development is a broader term than economic growth. Generally, economic development implies fundamental structural change in the economy. For example, dramatic shifts in industrial mix such as the transition from a predominantly agricultural economy to an industrial economy. Such structural change is more than a quantitative change and may involve shifts in political power from one group to another, and vast cultural changes such as those brought about by urbanization. Because of these shifts, economic development often generates considerable resistance from those who benefit most from the current economy.

3) *Why do many people have mixed feelings about population growth?*
Many people are concerned that the world has (or will have) too many people given available resources. More than two centuries ago, T.R. Malthus argued that humans are ultimately doomed to starvation by population growth. Malthus' influence on contemporary thinking about population remains alive and well. Whether or not Malthus was correct is hotly debated. In any case many people worry about some vaguely defined concept of over-population. On the other hand, at the local and regional level, public officials and business leaders are typically pleased by an increase in the local population –even if they seem worried about world population growth. I have never heard of the major of a city or the governor of a state brag about a declining population in their jurisdictions. In short, the same person can regard world population growth as a severe problem and local population growth as a beneficial development.

Steve Piper

1) *Is the potential business activity, income, and employment generated by a water supply project included as part of M&I water supply benefits?*
   The economic activity generated by an M&I project may fall into the category of regional economic impacts, which are not the same as economic benefits. If a water supply project is built in one area and that project pulls activity from another area, then the overall benefit to society may be very low but the impact to the area with the project may be very high and positive. Regional impacts may just be a re-location of activity while benefits are a measure of an improvement to the overall economy.

2) *If alternative costs are not a theoretically correct measure of M&I benefits, then why do many municipal water suppliers simply look at the available water supply sources and pick the lowest cost source to expand supplies?*
   In many cases the situation facing municipal water suppliers is how to meet the demand of an existing population and commercial/industrial base where current water supply sources are insufficient to meet future needs. In this case the costs of not meeting demand are very large and the criterion for using the alternative cost methodology is met and the use of alternative cost is appropriate.

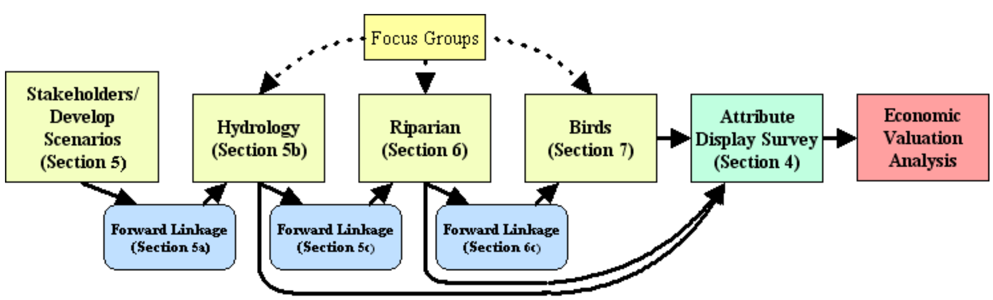
State of the Art on Topical Area of Research
as Identified by Each Speaker

Integrated Modeling and Ecological Valuation

David S. Brookshire, Jennifer Thacher, Craig D. Broadbent, Mark D. Dixon, L. Arriana Brand, Karl Benedict, Kevin Lansey, David Goodrich, Juliet C. Stromberg, Steve Stewart and Molly McIntosh

OBJECTIVES

Understanding how anthropogenic and climate-induced changes alter ecological systems and evaluating the effects of alternative hydrologic profiles on these ecosystems are important concerns in the semi-arid West. This research incorporates hydrologic, vegetation, avian, and economic models into an integrated framework to determine the value of changes in ecological systems that result from changes in hydrological profiles. We develop a hydro-bio-economic framework for the San Pedro River Region (SPRR) that considers groundwater, streamflow, recreation, riparian vegetation, and the abundance, diversity and distribution of birds in the region that includes the San Pedro Riparian National Conservation Area (SPRNCA). The SPRNCA is in southern Arizona and encompasses a stretch of the San Pedro River, which flows north from Cananea, Mexico, enters the U.S. near Sierra Vista, and eventually reaches the Gila River, a tributary to the Colorado River. The San Pedro River is one of the last free-flowing rivers in the desert southwest. It contains stretches of gallery riparian forest and represents one of the last remaining semi-arid flyways. The SPRR provides critically important habitat for resident, seasonally resident, and migratory birds, but is threatened by a decline in groundwater due to pumping of the regional aquifer (Rojo et al. 1998; Stromberg et al. 1996). Nearly 390 bird species have been recorded in the SPRR; 250 of these are neo-tropical migrants.



The objective of this research is to link realistic policy scenarios with alternative hydrologic, riparian and bird profiles in order to perform an economic valuation of ecological attributes. Figure 1 gives an overview of the research questions that we address. The arrows between the boxes exemplify our efforts to integrate the various disciplinary and represent either flows of scientific information or policy changes.

Existing ecological value studies predominantly use the travel cost method (Schwabe et al. 2001; Huszar et al. 1999; Jakus and Shaw 2001; Eiswerth et al. 2000; Cameron et al. 1996) or the contingent valuation method (Kline et al. 2000; Loomis et al. 2000), which focus on a single attribute of an ecological system, usually one that provides direct use value such as duck hunting (Kinnell et al. 2002), reservoir levels (Eiswerth et al. 2000), or recreational angling (Huszar et al. 1999). Some studies value multiple ecological attributes that are not varied independently, thus an assessment of precisely what drives the value statement cannot be made (e.g., Loomis et al. 2000; Danielson et al. 1995; and Berrens et al. 2000). Further, few studies exploit the ability to measure preferences for multiple attributes that another economic valuation technique provides known as choice modeling (Morrison et al. 2002; Kahn et al. 2001; Stewart et al. 2002; Stevens et al. 2000; Farber and Griner 2000; Johnson and Desvousges 1997; Adamowicz et al. 1998).

In the absence of integrated science information, traditional stated preference valuation studies are forced to rely on vague program descriptions and imperfect measures of the change in resource quality or quantity. This occurs because previous scientific studies were not designed to directly address valuation questions or re-examine the timescales or language that are relevant to the lay public. Our integrated model synthesizes existing hydrology, vegetation, and bird data on the SPRR, and the Middle Rio Grande, and makes spatial predictions of vegetation changes based on projections of groundwater and base flow changes from basin-scale hydrologic models. When combined with models that link bird habitat and vegetation structure, our predictions of vegetation change link the effects of hydrologic changes to songbird abundance, diversity, distribution, and ultimately the economic value of SPRR attributes. This framework represents a significant advancement in the methodology of stated preference valuation through its focus on science-based linkages between flow regimes, habitat quality, birds, and human values.

In addition science-based linkages only a few studies have examined the role of models across disciplines in a benefit transfer setting (Brookshire et al., 2007; Brookshire and Chermak, 2007). The literature on benefit transfers predominately relies on the science as given (Desvousges et al. 1998). While economic transfer studies are widely used, rarely is the quality of the science information underlying either the study site or transferred site considered. Our focus on integrating the natural and social sciences addresses variations in the quality of scientific information that can be available for benefit transfer studies.

ECONOMICS COMPONENT

The foundation of our research is framed by the following questions: 1) What is the ideal set of physical, natural, and social science information on which to build an economic research program to value ecological systems? 2) Can alternative suites of natural science information coupled with socio-behavioral information lead to a better understanding of both intra-site and inter-site benefit transfer functions?

Our research is based on four scenarios (two anthropogenic and two climatic) and use two stated preference techniques (contingent valuation and choice modeling).

Valuation Models

The choice model (CM), a variant of conjoint analysis, elicits an individual's preferences by asking the subject to consider a series of policy options (Ben-Akiva and Lerman 1985; Louviere et al. 2000). In contrast to contingent valuation (CV), which asks individuals to explicitly state their willingness to pay for a proposed policy change, choice models require the individual to choose from a series of possible policies, each having different levels of attributes (birds, in-stream flow, riparian vegetation and cost). This allows the researcher to obtain the marginal value of each attribute, as well as welfare measures for any policy that has attributes contained within the span of those presented in the survey. Both CV and CM models utilize a random utility framework to explain individuals' preferences for alternative hydrological/economic profiles in the SPRR and are directly estimable from CM and CV data (Roe et al. 1996; Stevens et al. 1997).

One frequently mentioned advantage of a CM is that it directly provides marginal values for attributes as well as willingness to pay (WTP) for policies that have multiple effects. In contrast, CV studies are designed to obtain the value for a single policy change. The policy can represent a change in a single attribute or multiple attributes.

Benefit Transfer

CMs are ideal for use in benefit transfer (BT) because evaluation of a range of attribute levels is part of the construction of the WTP function. Better still, if the original data is available, a WTP function can be estimated that restricts the model to consider attribute levels that are relevant for the transfer site.

We develop BT functions for both *intra*-site and *inter*-site transfers. For the SPRR, the intra-site effort, we apply the CM and the CV model frameworks using. Intra-site analysis will illuminate the role of the natural science information in the valuation of the good. Inter-site comparison of results will provide insight into the traditional BT framework where restrictions are required.

Defining 'The Good': Linking to the Natural Sciences

There are two major challenges in linking the good to the natural sciences. First, credible measures of economic value must be linked to endpoints of the hydrologic, riparian, and bird models. Secondly, the techniques used in the study must be consistent with economic principles of individual welfare maximization.

CM surveys are by nature complex. Each possible choice comprises bundles of attributes with each attribute having different levels. The large number of combinations of attributes and levels precludes analysis of each potential "policy" or combination. We use a modified fractional factorial design for our analysis that will allow us to span the attribute space with 16 choice sets. The sets are blocked into groups of eight for presentation to subjects.

Linkages to the Natural Sciences

One key component of this research is the use of state-of-the-art science and linkages between the sciences for the development of changes in resource stocks and flows. Another is the use of economics to inform the structure of the information flowing from and between the natural sciences. Much of the groundwork has already been laid for the information flow to the economics model. We use results from the Upper San Pedro Partnership efforts to provide a link between probable urban population growth scenarios and hydrological profiles for the San Pedro Valley. The AFS provides the hydrologic scenarios that drive the water-limited riparian system.

HYDROLOGY COMPONENT

The valuation effort has been conducted within the context of specific future scenarios in the SPRR. Considerable effort has been expended in developing a framework of scenarios and understanding the hydrology. These efforts set the basis for determining the changes in vegetation and birds. This research develops and parameterizes three relatively mature models of the San Pedro Basin hydrology together. They include a GIS-based MODFLOW groundwater model (–Pool and Dickinson 2007) using more realistic representations of riparian ET (Leenhouts et al. 2006); and, a model for functional riparian habitat classes which relates hydrologic measures to these classes (Leenhouts et al. 2006) Builds on prior science *** The models are used to produce maps and spatially explicit point predictions of groundwater depth under a range of alternative future scenarios. These predictions are provided over biologically meaningful "seasons," with groundwater depths predicted to a resolution of approximately 1 meter under both equilibrium and transient conditions. Using the hydrologic models discussed above, the hydrologic response of the San Pedro River to a variety of realistic scenarios from pumping demand changes These are used as inputs to the survey display component.

RIPARIAN COMPONENT

The objective of the riparian component is to determine how riparian vegetation distribution, composition, and structure respond to changes in groundwater levels in the SPRR.

We synthesize existing vegetation-hydrology data for the San Pedro and the Middle Rio Grande and make spatial predictions of vegetation change based on projections from basin-scale hydrologic models of groundwater and base flow change described in section 3. Our projections of vegetation change, when combined with bird habitat models, are used to predict the effects of hydrologic changes on songbird populations along the San Pedro River.

Existing Information

The riparian component is highly leveraged from previous and ongoing research funded by several organizations. Substantial information exists on how San Pedro vegetation structure, composition, and dynamics are related to floodplain groundwater depths (Stromberg et al. 1996). For example, Stromberg (1998) showed that woodlands of exotic tamarisk are replacing native Fremont cottonwood and Goodding willow stands due to declining groundwater depths along some reaches in the upper SPRR. Data on the relationships between mesquite stand structure and groundwater depths (Stromberg et al. 1992, 1993) are also available. Response of stand structural traits (e.g., canopy height, vegetation volume, canopy cover) to ground and surface water fluctuation are being addressed by ongoing studies (Lite and Stromberg, in prep.), as are response of diversity and richness of herbaceous and woody plants classified within stress-disturbance functional groups (Bagstad and Stromberg, in prep.). These known bio-hydrology relationships are being used to develop statistical and simulation models that project changes in vegetation communities with changes in groundwater depths and provide the necessary linkages for the bird modelers (Leenhouts et al. 2007).

Riparian Component Development

Using the backward linkages and extending the existing knowledge of riparian vegetation dynamics, we generate outputs for the bird change model. 1) We use hydrologically and geomorphically distinct reaches within the SPRNCA, the mapped distribution of riparian vegetation alliances, and field data from the delineated reaches to identify relationships between riparian vegetation structure and composition and reach hydrology (groundwater depth and surface flow frequency). On the SPRNCA, fourteen discrete reaches have been defined, based on floodplain width, spatial flow intermittency, and channel sinuosity. A map of vegetation types has been developed for the entire SPRNCA, including all study reaches, based on analysis of aerial photographs and field ground-truthing. Patch types are defined according to physiognomy (e.g., woodland, forest, shrubland) and dominant species or species group (e.g., mesquite, cottonwood). 2) We develop reach-scale indices of vegetation composition and structure based on the above bio-hydrology relationships and a longitudinal gradient in site hydrology that exists within our delineated reaches. Using space-for-time substitution, these indices are used to project reach-scale changes in riparian vegetation structure and composition (e.g., relative abundance of cottonwood vs. tamarisk), given scenarios of hydrologic change for each reach. This provides a course-scale, first approximation of vegetation change under the selected scenarios. 3) We model finer-scale, patch level riparian vegetation changes in response to scenarios of groundwater decline and changes in surface flow frequency. We develop a computer model in Powersim to simulate the effects of changes in hydrologic and other physical drivers on the distribution of riparian vegetation alliances on the SPRNCA.

BIRD COMPONENT

The objective of the bird component is to determine the impact of vegetation changes on bird populations and communities for differing type of reaches of the SPRR. Further, the bird component provides characterizations of bird abundance, productivity, and diversity for economic valuation models.

Existing Information

Data has been collected in the upper and middle reaches of the SPRNCA during the 1998 through 2001 field seasons. A total of 23 sampling areas were established on Bureau of Land Management (BLM) and private land on the upper and middle San Pedro. To the extent possible, these locations were placed randomly and selected by use of topographic maps and field reconnaissance. Attempts were also made to co-locate study sites with Stromberg's research such that 17 of 23 sites are in common with Stromberg's. Survey sites were placed at least 4 km apart so that they could be considered independent from the standpoint of bird territories. Sampling areas capture the full range in variability in hydrologic regime and consist of eight ephemeral, seven intermittent, and eight perennial reaches.

A substantial amount of data was obtained from 1998 to 2001 pertaining to avian density, productivity, and habitat utilization, using the most current population estimation methods. This data collection effort was designed to allow assessment of how variation in the hydrologic processes and associated vegetative communities affect avian population and community processes.

Established study sites enable estimation of bird density along habitat gradients perpendicular to the river corridor as well as parallel to the flow regime gradient. More than 19,000 detections of 124 different bird species were made during approximately ten different 5-minute surveys at each of 280 total point count locations during the 1998 to 2001 avian breeding seasons (May through July) following distance sampling methods (Buckland et al. 2001).

Approximately 1000 nests of 18 species were found and monitored during the 1999 to 2001 avian breeding seasons in the 23 sampling areas following BIRD protocol (Martin 1999). The selection of the 18 focal species was based on a number of criteria, including abundance, ease of finding and monitoring the nests, response to hydrologic regime, life history traits, conservation status, migratory status, and different habitat affinities within taxonomic affiliation.

Bird Component Development

The study assess bird-vegetation relationships associated with variation in hydrologic regime, and predicts the potential impact of alteration of the hydrology-driven vegetation composition and structure on riparian birds, using both standard statistical analyses and by application of a spatial modeling framework called the Effective Area Model (Sisk et al. 1997). This analysis utilizes the most current methods for assessing avian abundance (Buckland et al. 2001), productivity (Stanley 2000), species richness (Hines et al. 1999; Boulinier et al. 1998; Nichols et al. 1998) and diversity (Ludwig and Reynolds 1988; Magurran 1988). Specifically, we: 1) quantify avian diversity and richness, as well as species-specific abundance and productivity patterns based on the three to four reach types identified by Stromberg (coarse-scale modeling approach); 2) estimate avian population parameters at a spatial scale appropriate to explore patterns of covariation between attributes of the vegetation and avian communities and their relation to variation in hydrologic regime; 3) quantify how variation in the structure and composition of vegetation communities along a hydrological gradient affects avian population parameters, and identify hydrologic threshold values for key bird species with respect to riparian vegetation patch types associated with particular groundwater depths and surface flow frequency; 4) develop avian edge response functions using linear and nonlinear models to characterize species-specific bird density as a function of distance from edge; and 5) model avian population change through the Effective Area Model, a fine-scale, spatially explicit modeling framework incorporating avian edge response functions, along with habitat maps to assess the potential impacts of variation in vegetation composition, structure, and spatial arrangement resulting from different groundwater draw-down scenarios.

EXPECTED RESULTS

Riparian areas are typically studied in a piecemeal fashion, with little integration of the natural and social sciences. This research integrates a substantial amount of what is known about a critical southwestern ecosystem and examines its benefits to society. Such an analysis may be particularly useful on the San Pedro, where great challenges exist in trying to balance human water needs and uses, a variable climate outlook, and the need to protect a highly valuable ecological resource. Three central results will be obtained: 1) a fully integrated valuation framework using the best science and alternative valuation methods; 2) methodological insights into stated preference valuation frameworks; and 3) alternative benefit transfer functions that rely on alternative information gradients. These results will advance disciplinary and interdisciplinary methodology as well as provide input into public policy questions.

This research will lead to a realistic coupling of climate and anthropogenic change impacts on the hydrology, riparian habitat, avian populations, and economic value of the SPRR. Given the importance of the biotic resources associated with southwestern riparian systems and the threats to these resources from continued groundwater depletion and surface water diversion, a model linking riparian vegetation dynamics to groundwater and surface flow hydrology will provide an important tool for management and planning. The linkage of vegetation models with bird habitat models will be particularly significant, because of the noted conservation value of the SPRR for migratory songbirds. The explicit linkages between the sciences and the provision of information flows influenced by the economic needs should lead to valuation models that more accurately measure public preferences.

This research will lead to advances in the use of stated preference methods to value ecosystem services, especially as related to benefit transfer. The robustness of CM and CV methods across gradients of natural science information will be examined. Particular attention will be given to how the quality (gradients) of natural science information and representations of that information to the public affect value.

The research will provide insight into the use of benefit transfer using science and socio-economic information gradients that are likely to be encountered in the field and examine whether stand-alone scientific indices may be used as proxies for economic value.

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Vernon Smith, Economic Experiments, and the Visible Hand
Don Coursey

The Swedish Nobel Committee has awarded the 2002 Nobel Prize in economics to Vernon L. Smith, an economist at George Mason University. The committee noted that this award was based upon Smith "having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms." I join the committee in saluting Smith. I was a student of Smith's when I studied for my Ph.D. at the University of Arizona in the late 1970s. He has had a profound affect upon my own career, other students, and a large body of the public who has probably never heard of him. But what exactly are market experiments and what can researchers learn from them? What importance, outside of the academy, is the "study of alternative market mechanisms?" In this essay I explore these questions.


Vernon L. Smith

The first thing to say about economic experiments is what they are not. Economic experiments are not simulations or role-playing exercises. They involve real people who must make serious choices. Their decisions in the laboratory are as acute and as poignant as those made outside the laboratory. Through their efforts participants stand to make or lose substantial amounts of money.

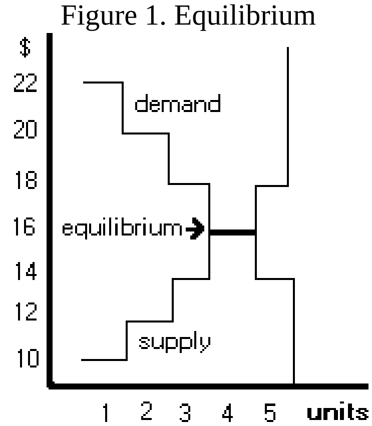
The simplest form of economic transaction—and the simplest experiment to conduct—is a two-person exchange. This experiment addresses how a single buyer and seller of an object reach, or fail to reach, mutually agreeable terms of trade for that object. In this experimental setting the researcher induces value on the object for the buyer and the seller. For example, the person assigned the role of seller of the object might be handed a card that indicates that his cost of production for the unit is $10. If he can sell this unit to the buyer in the experiment, then he will be awarded the difference between his sales price and $10. Likewise, the person assigned the role of buyer of the object might be handed a card that indicates his resale value of the unit is $22. This means that if he is able to acquire the unit for less than $22, he can then sell it back to the experimenter for $22 and keep the difference.

It is important to note here that although there is no actual physical object being traded, both the seller and the buyer have an incentive to behave exactly as if there were. The seller will desire a price well above $10 for his unit; the buyer will wish to pay as little as possible for his unit. What will happen? Logic says that two outcomes are possible. Either the seller and buyer find a mutually agreeable price between $10 and $22 or they fail to reach agreement and do not consummate a trade. Economics says that both sides have an incentive to make a deal , but nothing to say about how the benefits of that deal will be divided. Nor do we understand the conditions that would produce an equal division of the gains at a price of $16. We also do not have much to say about the frequency of occasions where the seller and buyer part company without making a trade. Many versions of this simple experiment have been conducted to explore these empirical issues.

The simple experimental design outlined above provides a building block for all subsequent experimental market designs. After all, a market at its core is nothing other than a place where bilateral trades are facilitated between multiple buyers and sellers. Suppose we want to construct a market with 5 sellers and 5 buyers. In this case we would hand a card to each seller indicating the cost of production. For example, one seller would be given a card indicating a cost of $10. The other four sellers would have costs of $12, $14, $16, and $18. People assigned to be buyers would receive a card indicating their resale value. Continuing the example, suppose these values were $22, $20, $18, $16, and $14. Each seller and each buyer in this design have the opportunity to make one transaction.

Given the range of values for buyers and the range of costs for sellers, what will occur when they are allowed to trade? Will sellers have the upper hand? Will the buyers? Will all trades that might benefit both buyers and sellers occur or will some beneficial trades fail to take place because of incomplete information or so-called market failure? When trades do take place will they be across a wide range of prices or a narrow band?

Figure 1. Equilibrium



Economic theory in its simplest incarnation of supply and demand makes a strong set of predictions. What are the supply and demand schedules here? Consider an axis set that has price on the vertical axis and quantity on the horizontal axis. The supply schedule answers the question "How many units would voluntarily be brought to the market at different prices?" Thus supply in this experimental structure is an ascending stair-step pattern that starts at $10 and rises $2 per step for each unit in the market. Above $18 the supply curve is vertical for no other than the fifth unit can ever be purchased in this setting. Likewise, the demand schedule answers the question "How many units will be voluntarily purchased in the market at different prices?" Using the same analysis as that for the sellers, we find that the demand schedule is a descending stair-step pattern that starts at $22 and falls $2 per step for each unit demanded in the market. Below a price of $14 the demand schedule also is vertical for no more than the five units are desired in this setting. For this scenario, textbook economics predicts that equilibrium will be reached where supply equals demand. In this case that means that four units would be traded at *the identical price of $16.*

Vernon Smith developed this basic structure for creating an experimental market almost fifty years ago. But his first creative insight was motivated by the severity of the textbook prediction for all prices to be exactly $16 as noted above. How could everyone in the market be forced to this conclusion? Neither the sellers, wanting high prices, nor the buyers, wanting low prices would necessarily be happy with this outcome. In other words, how was Adam Smith's invisible hand to do its work? Should we as economists really think of the "hand" as a guideline or rule of thumb? Was the "hand" really just an abstract construct useful for the parsimony of our models and the placation of our students.

Smith's second creative insight was that exploring these questions could not be done in an institutional vacuum. Half of the experimental structure was missing. The sellers and buyers in this structure cannot trade unless specific rules, forming the structure of a trading institution, are employed. In his early work Smith selected to use the rules of a double-oral-auction. These auction rules are similar to the rules used for trading at the New York Stock Exchange or the Chicago Board of Trade. It is "double" because both sellers and buyers participate (for example as opposed to a silent auction at a fundraising event where the seller is passive). It is "oral" because the participants call out their bids and offers publicly. They do this using an important rule called the **bid-asked-price-reduction-rule.** What it means is that sellers call out asking prices, these are posted publicly, and all subsequent asking prices must descend from this starting asking price. On the other side of the market, once the first buyer makes his bid, all subsequent bids must ascend from this starting bid price. Trade can occur in two ways. As a seller any buyer can accept your asking price or you can accept any buyer's bid. As a buyer any seller can accept your bid price or you can accept any seller's asking price.

When Smith ran these first experiments, the mechanics of the invisible hand became visible for the first time! Undergraduate student subjects were found to produce single-price market equilibria even though no one of them desired this outcome. When they repeated the exercise, prices were even tighter around the equilibrium. The number of units being transacted was also "efficient", exhausting the gains from trade without anyone being in charge of the market.

These results were big surprises. The textbook says that there should be perfect information for the market to equilibrate. But the subjects produced market equilibria having no knowledge about others and with little experience, if any, with trading in the double-oral-auction. Finally, when Smith manipulated the number of sellers and buyers he found that astoundingly small numbers of sellers and buyers would produce competitive equilibrium. A market with as little as four sellers and four buyers will produce the competitive outcome. Prior to this research, the textbooks said you needed infinite or "numerous" numbers of each. Smith's early research challenged this convention and opened up the possibility that many apparently "thin" markets (having few sellers and buyers) in the real world produce competitive outcomes.

By the late 1970s Smith was off to the races. All types of market institutions were being examined. English and Dutch single object auctions, sealed-bid auctions, posted-offer markets (like a grocery market where stores place take-it-or-leave-it prices), Treasury Bill markets, and others were all in play. At this time, Smith found a computer system at the University of Arizona that for its time was progressive. It offered both real time networking and touch-screen communication. All of his experimental markets were in the process of becoming computerized.

Before continuing the narrative of Smith's scholarship I want to say a few things about the simple oral double auction. I have left out only a few details about how to conduct such an auction in the classroom. I have used the double auction every year for the last 20 years. I conduct experiments mostly as an exercise for my undergraduate and graduate students. But I have conducted experiments with groups diverse enough to include eight year olds, communists, and professional traders. In all of these years and across all of these groups, the auction has never failed to produce the competitive result. Students learn so much from the experience and the post-experiment discussion. All of the important lessons of economics are right in their face. I have said for years that it is the best economics education a student can absorb if you only have an hour.

I started graduate school at Arizona in 1978 and Smith hired me to be one of his graduate assistants / programmers. I spent four years in the classroom and learned my economics. But I also spent four years in the back room of a computer laboratory with Vernon and other students watching the results of experiments in progress come flashing out onto the screen. What an education that was. We could see how different market institutions produced more efficient outcomes in different situations. We could see how monopolists and members of oligopolies could, or could not, wield their powers. We could see how command and control regulations in the market affected behavior and produced unexpected consequences. We also began to explore how problems with public goods might be addressed using market principles.

Smith's imagination was not limited to studying the extant taxonomy of market institutions. He was constantly on the prowl for novel trading structures that could expand the reach of economics into public affairs. Following are just two of the many areas where his research has had pragmatic affects on public policy.

At certain times of the day at large American cities more jets want to land and depart than can be handled by the airport. Demand for take-offs and landings exceed supply capacity during these periods. One obvious economic solution to this problem is to auction off the right to land and take off during the congested periods; to take the fixed number of scarce "slots" during this period and sell them to the highest bidders. This logic is correct. But Smith realized that it was incomplete. The problem is not just the fact that you want to land at O'Hare airport in Chicago on Friday in the 4:00 through 5:00 P.M. time slot. Typically you want other side conditions to be met. You might also want a slot out of O'Hare between 6:00 and 7:00 P.M. Additionally you may be flying from Chicago to another congested airport like Atlanta, so you will want a landing slot there as well and so on.

At its essence, slot allocation is a problem of balancing supply and demand. But the constraints associated with so many crowded, interconnected airports with so many airlines and aircraft competing for space make the simple problem seem impossibly complex. Smith did not think so. He was able to develop a system of combined auctions that solve this problem. These auctions were exhaustively tested in his laboratory and are now used as allocation tools in national airport management.

Electricity has three properties that make it different from other economic commodities. First, it is the only product where supply and demand have to be equal at all moments in time. Electricity suppliers promise to meet the use by demanders—when you switch on your lights, you expect them to come on. Second, electricity is hard to store. Third, electricity does not really move directly from its source to its ultimate user. Rather, when electricity is provided to a power grid, it is better to think of the grid as a great pond whose water level has just increased. These three factors have inhibited the trading of electricity across regions in this country. Smith, always on the lookout for market solutions that could improve efficiency cracked the complex technical problems associated with how to trade something so seemingly amorphous as electricity. His work in this area provided the basis for a radical new system of electricity and energy trading that swept the country during the 1990s. Smith advocated an open trading system for electricity in both the wholesale and retail markets. States that have adopted his system fully have benefited greatly. Other states that still use old regulatory regimes or, like California, only applied a partial market framework have struggled.

Vernon Smith fathered an entirely new research tool for understanding human behavior. To the non-economist an analogy from astronomy might be useful to explain the impact of his work. Were Smith an astronomer, he would not be the type that utilized existing optical telescopes to discover and explore ever more distant objects. Think of him as the inventor of the radio telescope. This new tool allowed us to understand known astronomical objects with a new precision. But more importantly, it allowed us to discover whole new classes of otherwise unknown objects and phenomena.

His work has had a profound effect on a generation of his, and others' students. The four years I spent with Vernon were intellectually the richest of my life. Each day in the laboratory promised the possibility of finding another economic Atlantis. When thinking of Vernon, as I have been doing so jubilantly since the Prize was announced, almost all of my thoughts hearken to the back room of his laboratory. It was where he shared with us an appreciation and understanding for the science in "economic science". But there was so much more. It was where so many of us learned from him the art of economic insight.

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Evaluation of Conservation Measures in the Upper San Pedro Basin

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ABSTRACT

Water resources management in Arizona is critical to the development and sustainability of local communities. Several regions in the state are facing immediate challenges to meet water demands. However, tools to assist the wide range of water interests understand the impact of decisions are lacking. This paper describes the development of a dynamic simulation based decision support system for the Upper San Pedro Partnership.

INTRODUCTION

The San Pedro River has been listed as one of the last great rivers (Figure 1). Slightly over 68000 people who populate the upper San Pedro Basin, Sierra Vista subwatershed live in four incorporated communities and the unincorporated Cochise County. The primary employer in the region is Fort Huachuca military base. In addition, the San Pedro Riparian National Conservation Area (SPRNCA) was established in 1988 to conserve, protect and enhance the desert riparian ecosystem along the river. The community has recognized that the water withdrawals exceed supply and the groundwater levels are falling and endangering the riparian zones' health and the long term sustainability of the communities. The Upper San Pedro Partnership (USPP), a consortium of 20 agencies and organizations, has been actively working together to ensure that the region has an adequate water supply to meet the reasonable needs of area residents and the SPRNCA by cooperatively developing water management plans including implementation of conservation measures (http://www.usppartnership.com/). Supplying the water needs of the public as well as ensuring the sustainability of the San Pedro River is extremely difficult. The wide spectrum of social, cultural and economic values and interests challenges decision makers to come up with an acceptable set of implemented measures. A water management tool based on dynamic simulation for the Upper San Pedro Basin, Sierra Vista sub-watershed has been developed. The objective of the decision support system (DSS) is to provide a platform for interested individuals and groups to assess alternative conservation plans with respect to water savings and groundwater levels. The DSS attempts to accurately capture the impacts of either individual measures or pre-defined groups of measures and will support the USPP in identifying water management options that

- Eliminates groundwater overdraft
- Allows for growth and development within the Upper San Pedro basin
- Maintains/raises groundwater levels at desired locations along the San Pedro River.

This paper briefly presents the planning that the USPP has undertaken to meet the challenges. The emphasis of the paper is the DSS description. Thus, the general formulation and some details of the modeling are presented. Finally, some preliminary results of the DSS comparisons and its future development conclude the paper.

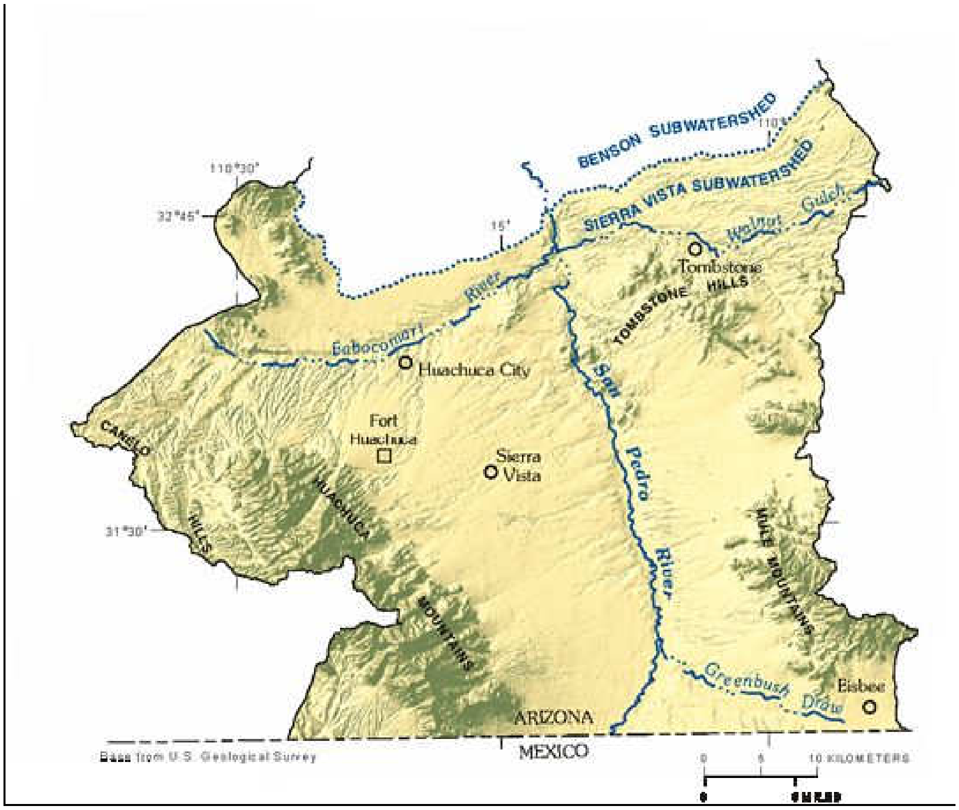

Figure 1. Location map of Sierra Vista Subwatershed/Upper San Pedro Basin

BACKGROUND

The USPP has been active in collecting data, supporting research and studies on hydrogeologic components and water use, developing potential conservation measures and plans including structural and non-structural approaches. For example, since the water source in the basin is groundwater, the USGS has installed a number of wells and conducted field studies to better monitor groundwater levels and estimate groundwater recharge. The National Science Foundation supported Center of Semi- Arid Hydrology and Riparian Areas (SAHRA) has also been involved in scientific studies on hydrologic components using tools such as tracers to determine groundwater travel times and this dynamic simulation modeling effort. In conjunction with engineering consultants, the Partnership developed and analyzed over 60 alternative conservation measures to reduce consumptive use within the watershed. The measures were originally considered in groupings associated with the impacted water use sector such as residential, commercial, agricultural, etc. The consultants attempted to quantify the cost and water savings from each of the measures based on expected usage (BBC, 2003). Recognize that distinguishing individual use within this rural area is extremely difficult. Many users own private wells and even with incorporated areas users are lumped in a total pumping when reporting to regulatory agencies. Some options and assumptions were slightly modified to account for Partnership-recommended changes. As evaluation of the measures matured, it became clear that some would not achieve significant benefits and could be dropped or for one of several reasons some were delayed for consideration. As part of their 2004 conservation plan, packages were developed by grouping measures with similar basis. Eight such package results as listed in Table 1. Details of the first package, Code Requirements, are provided in Table 2. The packages range from enforceable regulations and elimination of new agricultural development via legislation to education and structural water system changes.

DSS DEVELOPMENT

The tool is the first step in a comprehensive model for the basin and includes the major supply and demand sources in the system as components. DSS allows users to select alternative conservation measures from a set of identified potential alternatives. The model then performs a water balance for at least 20 years on an annual time step. Users can quickly examine different combinations to determine if their impact on overall water use and consumptive use over time. The Powersim software has been used as the dynamic simulation representation due to its general applicability and several extended options (Powersim, 2003).

Table 1: Conservation measure packages for 2004

	Title	Description
1	Code requirements	Set of regulatory requirements on water use within the community (listed in Table 2)
2	Water savings incentives	Four options to address the existing users that codes might not address likely through rebate/retrofit programs.
3	Water conservation surcharges	Exploration of potential tariff for excess water use with the purpose of modifying water use behaviors.
4	Public conservation awareness	Five options for public education.
5	Public facilities and school districts	Requirement of implementation of conservation measures for public entities
6	Irrigated agriculture restrictions	Restrict development of new agriculture development
7	Water demand management	Options to manage future water demand for the purposes of making best use of available resources, such as recharge capacity, and accommodating projected demand such as geographically shifting demand to areas served by POTW's.
8	Supply management	Approximately 15 infrastructure projects with emphasis on reuse, recharge and rainwater harvesting.

Table 2: List of code requirements considered for possible adoption in package 1 Category*

Category*	**Measure Number**	**Measure description**
R/C	15	Water wasting ordinance
R/C	11	Use mitigation with BMPs
R/C	2	Gray water reuse
R/C	16	Rainwater harvesting
R	11	Restrict new swimming pools (size and number)
R/C	14	Outdoor use restrictions
R/C	5	Landscaping standards (new users)
R	2	Restrict landscaping (parks/golf)
R	3	Restrict new golf course

Although the USPP is a regional planning group, it has not regulatory authority and each community may elect to implement any set of conservation measures. Therefore to allow this flexibility, water use in each city in the sub-watershed, Sierra Vista, Huachuca City, Bisbee, Tombstone, and Fort Huachuca and the unincorporated houses are modeled as separate components in detail. For each of these communities, a household is taken as a basis. Residential use is estimated from individual uses. The possible uses in a house are toilet use, shower use, faucets, fountains, outdoor irrigation, swimming pools, etc that are modeled separately (Figure 2). This detail is necessary as many of the conservation measures are focused modifications such as drip irrigation systems and fixture changes. This level of detail also requires accounting of new and existing homes, their locations, and growth over time.

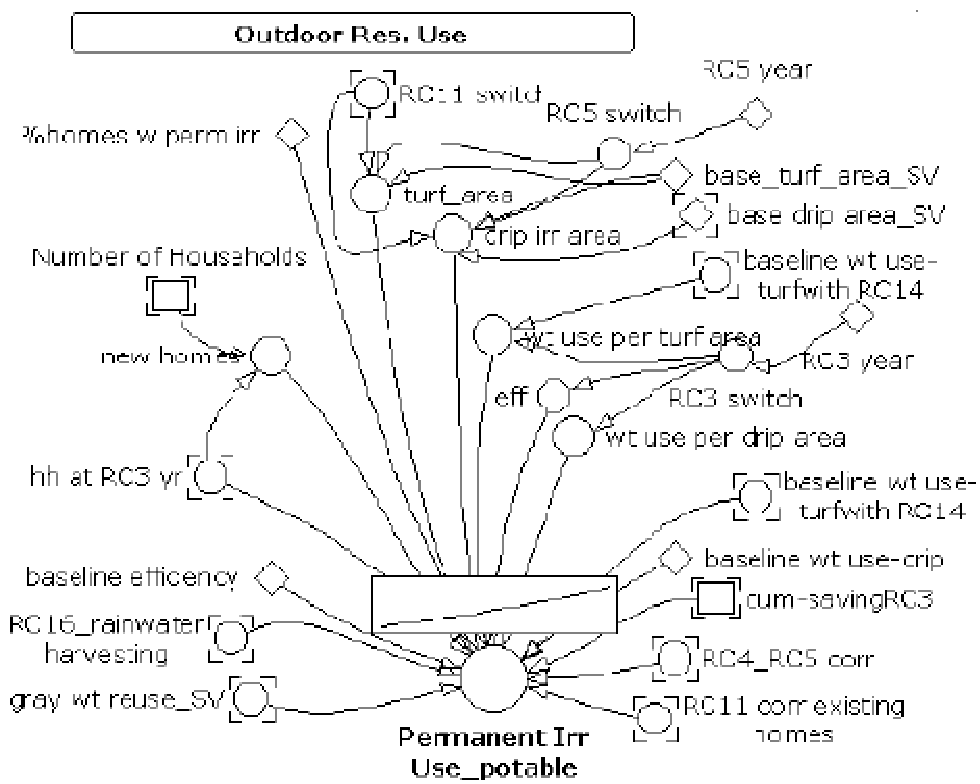

Figure 2. Residential permanent irrigation use as modeled within the model.

The interactions between uses and the water cycle can be convoluted. For example, residential gray water reuse of shower and dishwasher water has been identified as a code requirement option. However, retrofitting homes with these systems is likely too expensive for existing homes. Thus, an accounting of new homes by community after implementation of a gray water reuse ordinance is needed. Further, gray water will be used for outdoor watering and a number of residential irrigation requirements and limitations on green area are under consideration that will affect the need for irrigation water. So an average household irrigation demand must be computed with the selected options for irrigation system efficiency. This demand will be the maximum need to be provided from a gray water system. As seen in Table 1, rainwater harvesting is a second option for collecting irrigation water that further complicates conducting the household water balance.

Similarly, wastewater disposal in some areas in the watershed is through septic tanks while other areas flow is collected and treated at a POTW (publically owned treatment works). However, some POTW's release their discharge to evaporation ponds and others to groundwater recharge systems. All of these connections and the impact on the net groundwater withdrawal must be tracked within the DSS. Note in recognition of potential evaporation losses, package 7 (Table 1) relates to the potential of directing growth toward regions that are on collection systems. One major assumption here is that there are no leaks from the supply or collection systems and the deviations from average use values that are given in BBC Research and Consulting report (BBC 2003) are minimal.

Household level of detail is carried to a second-level component called "Local Water Balance" where the water use for each city is summarized (Figure 3). As shown in the schematic, consumptive uses are separated from those returned to facilities with a recharge endpoint. Finally, the residential components and other demand components such as irrigated agriculture and commercial use are combined in a total subwatershed water balance model (Figure 4). The supply side on this model is currently modeled as an average yearly value.

The user interface is simple to use with push buttons and tables. Decision makers for each community are free to choose any combination in 20 years of simulation period from many pre-defined alternatives that are described in detail in BBC Research and Consulting report (BBC 2003). The interface includes graphical outputs as well as the documentation of variables, conservation measures, and the assumptions in calculations. One goal of this project is provide the general public an opportunity to evaluate alternative plans via the web. Powersim has the capability of web-hosting and will be implemented in the next year.

RESULTS

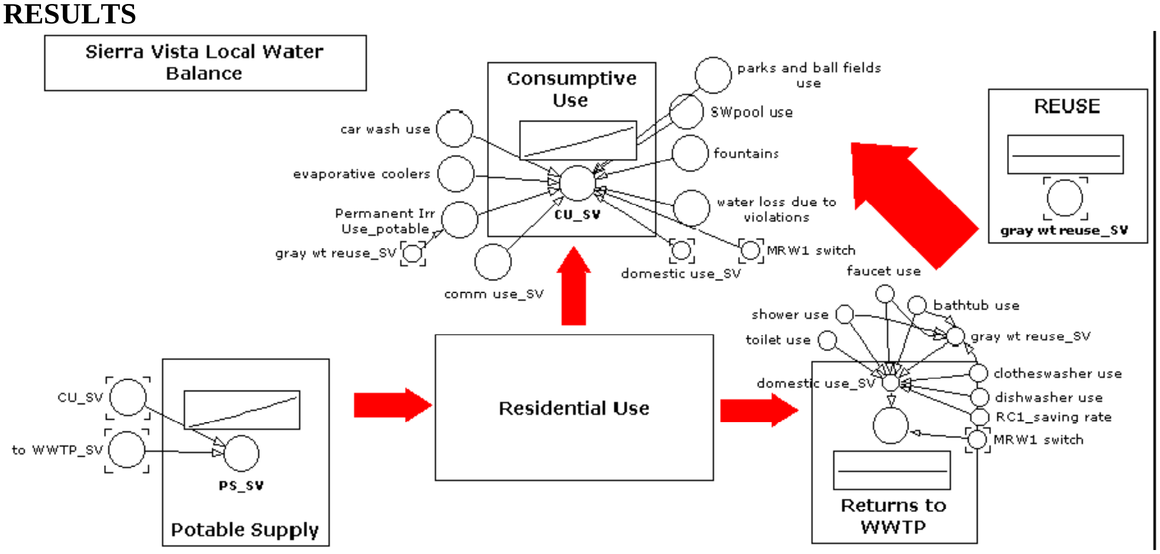

Figure 3. An example of local water balance model for a city.

To demonstrate the DSS, alternative conservations measures were selected for implementation from the list of potential code requirements (Table 2). Note, at present, a good estimate for volume of wasted water is not available so the DSS assumes no benefits from measure R/C 15. Also, R/C 11 is an avoidance rather than savings measures and further clarification on benefits is necessary before inclusion in the DSS.

Four cases were run to examine the sensitivity to the measures and summarized in Table 3. Case 1 includes all code requirements and results in an average annual reduction of consumptive use of about 500000 m3 (400 ac-ft) in year 1. Since the DSS accounts for changes in population and the savings increase to more than 3.4*106 m3 (2800 ac-ft) in year 20 as, over time, more households would be impacted by measure R/C 2, 5, 11 and 16. For the purposes of this simulation, consumptive use savings is water that would otherwise be used and evaporated to the atmosphere through plants or from evaporation ponds or pools rather than returned to the aquifer via recharge.

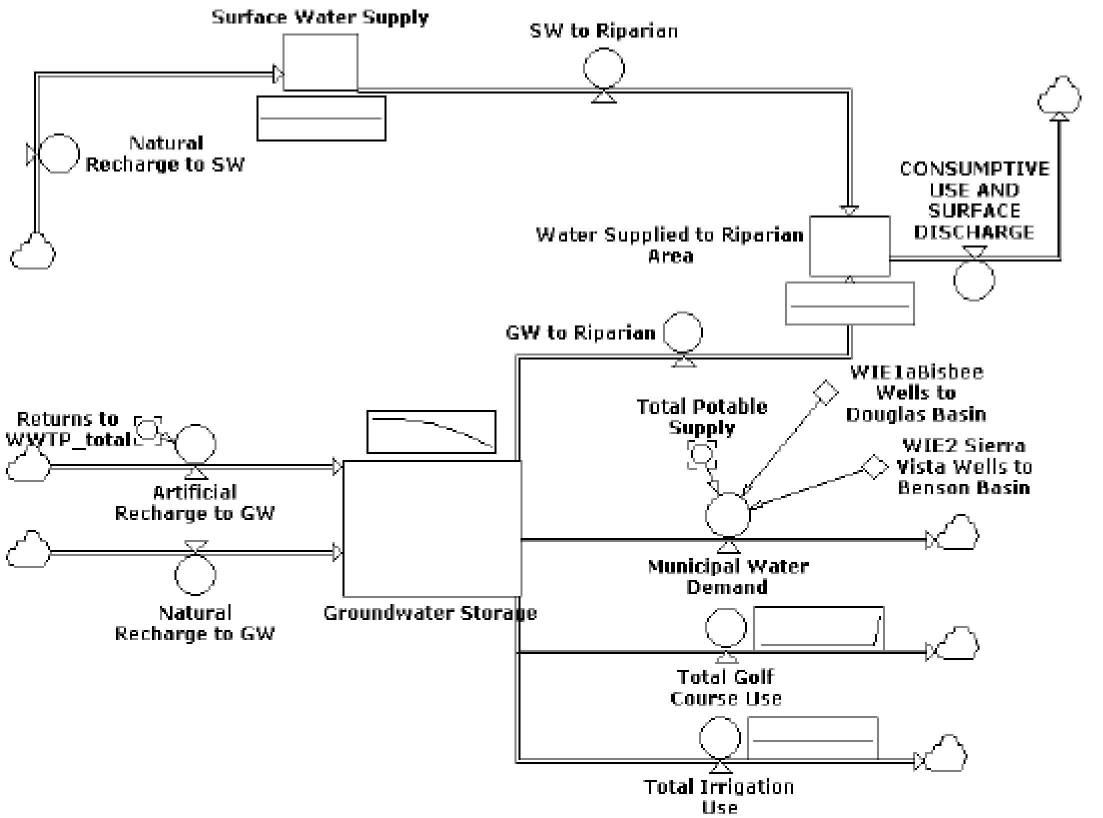

Figure 4. Overall water balance model for Sierra Vista sub-watershed.

Comparing the different cases allows one to distinguish the effect of subsets of the measures. For example, Case 2 includes all code requirements except outdoor use restrictions (R/C 14) and the savings decreases from 515*103 to 462*103 m3 (418 to 375 ac-ft) in year 1 that can be directly attributed to R/C 14. Similarly, Case 4 does not consider restrictions on new development for landscaping, rainwater harvesting and gray water use. The overall benefits of codes without these factors are relatively small compared to Case 1, particularly in year 20.

Table 3: DSS results for combinations of code requirements implemented in the first year of a 20 year simulation

		Potential Consumptive Use Savings (103 m3/yr)		Total Savings 106 m3/yr
	Conservation measures implemented	Year 1 103 m3/yr	Year 20 103 m3/yr	
Base condition	None	-	-	-

Case 1	RC2, 5, 14, 16, R2, 3, 11 (all)	516	3478	37.9
Case 2	RC2, 5, 16, R2, 3, 11	463	3416	36.7
Case 3	RC2, 5, 14, 16, R11	416	3377	35.9
Case 4	RC14, R2, 3	157	184	3.3

Note: these numbers are preliminary for the cases considered. Coordination between SAHRA staff and the Partnership regarding assumptions and benefits is ongoing. As the DSS is more fully developed, it is likely that the numerical results will be altered. The results are intended give an indication of the types of evaluations that can be completed.

COLLABORATIVE DEVELOPMENT

Development of this type of complex tool requires close interaction between model developers and the USPP committees. Over the course of the past year, these groups have met 6-8 times for several hours per meeting. In addition, modelers attended numerous technical working group meetings to learn about the system and data collection. These face-to-face exchanges clarified conservation measures, assumptions and model structure (input/output).

This communication is necessarily ongoing. Given the range of objectives of the alternative parties, the modeling has been dynamic in response to changes in desires. For example, the idea of packages was a late addition in the manner in which users perceived the conservation measure implementation. More recently, federal legislation has been introduced that will greatly accelerate the decision making process by requiring safe yield within 10 years. Similarly, additional data collection and analysis is currently being conducted by the Arizona Dept. of Water Resources that may modify assumptions in the DSS.

Conclusions and future plans

The goal of the DSS is to allow rapid evaluation of alternatives to provide consensus building and “weeding” out solutions. The model attempts to incorporate the true system and all of its complexities. Since a broad range of users are interested in the model results, documentation of the calculation procedures embedded in the DSS will be available on-line for review. This open system is seen as a positive to the USPP. A particular concern in the San Pedro basin is maintaining a viable riparian area in the SPRNCA. Groundwater levels along the San Pedro river are a key indicator of riparian zone health and a necessary input to the decision making process. To observe the effect of water management decisions on localized GW levels while avoiding time-consuming groundwater model simulations, an approximation of the regional groundwater model will be embedded in the DSS using linear response functions. The impact of future recharge sites and new well fields can then be assessed beyond the regional water balances.

The intent is for the DSS to remain as an interactive model so that alternative plans can be compared without long delays. Fast evaluation may require identifying critical locations to compute groundwater levels for general evaluation with options to compute more locations when deemed necessary.

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Regional Hydroclimatic Projections for the Southwest
David S. Gutzler

Climate change has become a reality in the Southwest. Existing data indicate clear upward temperature trends since the middle of the 20th Century, both globally and (much more rapidly) in the region encompassing the Gila basin. These observations have motivated a fast-growing body of research on current and projected climate change, which has recently included more focused studies on the effects of climate change on surface water resources in the Southwest. These studies are encapsulated in this document. Much more information can be found online; a short list of highly readable and freely available information is provided in the reference list.

Temperature change in southern New Mexico has been very pronounced over the past several decades, representing an amplification of global temperature warming trends. The warming trend evident at climate observing stations (such as the very long record available from Fort Bayard, NM) shows no evidence of abating. On a regional scale, temperatures averaged over New Mexico Climate Division 4, which includes the upper Gila River basin, have risen approximately 2°F in both winter and summer since the 1960s. A severe long-term drought, punctuated by several record-setting wet seasons, has afflicted the entire Southwest since the turn of the 21st Century. The huge decadal and seasonal fluctuations in precipitation make a long-term precipitation trend, if one exists, very difficult to detect in recent data.

There is an increasingly definitive body of research that points to greenhouse gas concentrations as the principal forcing agent for recent observed climate changes. This research incorporates both observations and global climate models. The models demonstrate ever-improving capability for accurately simulating the observed variations in climate during the 20th Century if, but only if, the models are forced by observed, human-caused changes in greenhouse gases and particulate pollution. A recent multi-variable analysis of the hydrologic cycle in the western U.S. recently concluded that recent trends in streamflow, winter temperature and snowpack could not be accounted for without including the effects of greenhouse-gas forced climate change. The apparent success of global climate models supports their use for making projections of future climate in the 21st Century. Model simulations consistently indicate that temperatures will continue to warm up. Projections of continued future warming have profound implications for 21st Century streamflow in the Gila River.

The quantitative uncertainties of climate change projections are large -- owing both to modeling uncertainty, and to the unknown future rate of greenhouse gas emissions -- but a 'mid-range' climate change scenario (the 'A1B' scenario developed by the Intergovernmental Panel on Climate Change) yields a trend in annual temperature of 7°F/century in southwestern New Mexico. Summer temperatures increase at a rate of about 7.5°F/century, whereas winter temperatures warm up somewhat less rapidly (5.8°F/century). A different scenario choice would generate somewhat more or less warming, but any realistic scenario for 21st Century greenhouse gas emissions results in model-simulated temperatures that are probably warmer by the end of the century than anything experienced in the past thousand years or more.

As a result of these warmer temperatures, winter snowpack in the Gila basin is projected to diminish dramatically, and may simply cease to exist as a climatological feature. Any snowpack would melt considerably earlier than at present. During the warm season, higher temperatures would promote higher evaporation rates off any soils that contain moisture; hence overall soil moisture is projected to decrease. Vegetation may therefore become sparser across much of the basin, although in areas not water-limited (such as the riparian zone along the river), warmer temperature and elevated CO_2 would both promote enhanced growth, hence more evapotranspiration.

The effects of these climate changes on streamflow have been explicitly modeled for the larger basins of the Rio Grande and Colorado Rivers. The probable effects on the Gila can be inferred from these studies. The net result of smaller (or no) snowpack, melting earlier, plus more evaporotranspiration thereafter, is that streamflows are likely to decline substantially in the Gila River. The present-day late winter streamflow peak would become much less pronounced, and would occur earlier in the year, so that December through February flows may actually increase so long as significant snowpack still exists. Flows during the present-day low-flow period (May, June and July) would be substantially decreased, and the low-flow period would extend into April (and ultimately perhaps into March). Total annual streamflow under these conditions is projected to be less than in the current climate, as is projected for the mainstem Rio Grande and Colorado Rivers.

Of course, the scenario outlined above refers to long-term changes in "average" conditions. Diminished streamflows in the Gila would be amplified during episodic droughts. Severe, decade-scale droughts (such as occurred in the 1950s, or worse) are known to have occurred for at least the past millennium, and there is no known reason to anticipate that projected climate change will override the frequency or intensity of drought episodes. Thus, we should anticipate that some future occurrence of a 1950's-style drought will occur sometime in the 21st Century, and the hydrologic effects of such a drought would be amplified by projected climatic trends.

Other changes to the Gila are also associated with projected climate changes. Water temperature would increase along with surface air temperature, affecting temperature-sensitive wildlife (especially cold-water fishes). Wildfires are projected to increase in frequency, and perhaps also in intensity, although the intensity changes could be tempered by sparser vegetation away from the riparian zone. Most climate models project that the overall *variability* of weather and climate will increase as temperatures warm up, but specific climatic modes of variability, such as the El Niño/Southern Oscillation (ENSO) cycle, are not reliably simulated in the models.

As mentioned previously, there are large quantitative uncertainties that current research has not resolved. Most climate models project that winter precipitation will decrease as temperatures increase, which would exacerbate the trend toward lower streamflow. However, winter precipitation variability is currently correlated with the ENSO cycle, and as mentioned above, this cycle is not well represented in climate change models. Significant long-term trends in summer precipitation (associated with the North American Monsoon) are not apparent in the data and there is no consensus among climate models as to future trends. All of these uncertainties, along with general improvements to retrospective climate reconstruction and future climate change projection capabilities, are targets of ongoing active research.

Despite these uncertainties, the climate change signal associated with warmer temperatures is extremely robust, and is completely consistent with the warming trend that is already observed. Therefore, long-term water management planning should incorporate the high likelihood of diminished snowpack, higher evaporation rates in summer, and concomitant changes to the hydrograph of the Gila River. The specific rate of change of temperature cannot be predicted, uncertainties associated with precipitation are large, and interannual and decadal variability will continue to be pronounced, making it impossible to confidently predict a quantitative decrease at any particular future time. A recent study of the middle Rio Grande

(Hurd and Coonrod 2008, cited below) outlines a range of streamflow decreases from about 10% less, to more than 30% less (depending on the precipitation scenario chosen), by the late 21st Century. Note that even their "wet" scenario results in diminished streamflow associated with warmer temperature. Qualitatively similar results should be expected to apply to the Gila River.

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Economic Valuation of Instream Flows & Related Ecosystem Services
Dr. John Loomis, Professor. Dept of Agricultural and Resource Economics, Colorado State University

There are several trends in economic valuation of instream flow. This includes explicitly valuing the particular ecosystem services supported by instream. For example, the individual values associated with native riparian vegetation (e.g., willows and cottonwoods) abundance and diversity of riparian dependent birds, native fish populations supported, number of angler days, water quality, etc. One recent method similar to the contingent valuation method in that it is a stated preference method, is called a choice experiment or conjoint analysis (Holmes and Adamowicz, 2003). But conducting a series of surveys where respondents indicate if they would pay a particular cost of providing the instream flows necessary to support a range of ecosystem services, the incremental value of each one of the ecosystem attributes can be valued. The resulting incremental values can the be applied to quantifying the benefits of the existing riparian ecosystem services and improved or degraded conditions. The presentation by Dr. David Brookshire of University of New Mexico entitled “Valuing Multidimensional Ecosystem Services” is an example of a state of the art application of this method to riparian areas in the southwest. The resulting values should have some transferability to the Gila River.

The state of the art for representing these values to respondents include using a combination of survey modes (phone, mail a survey booklet, and phone interview), videotape or internet surveys. While each of these methods have their advantages and disadvantages, they can be tailored to present fairly realistic depictions of how different instream flow levels translate into different levels of ecosystem services such as bird diversity and fish populations. Of course the ability to do this depends on the underlying science. Dr. David Goodrich’s presentation entitled “Science-based ecosystem valuation: Lessons learned from the San Pedro and Rio Grande” is an example of the state of the art in this area.

In the area of benefit transfer, the current state of the art would be to use a meta analysis equation so as to calculate values for the river and/or recreation activity and ecosystem service of your policy interest (e.g., Gila River) by drawing upon a synthesis of the existing a represented by the meta analysis equation. More recent exploratory advances in this area of benefit transfer is a “micro-meta” analysis. In contrast to traditional meta models that use average values per visitor day or per acre of wetland from the existing literature, the micro-meta model utilizes the raw data from each of these studies to estimate a benefit transfer function (Loomis and Rosenberger, 2006).

For more details on several of these topics see John Loomis’ paper in the conference on What Existing Studies Show are the Economic Values of Instream Flow & Guidance on Transferring these Values to the Gila River.

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Regional Economics and Demographics: State of the Art
Jim Peach

The analysis of demographic and economic trends in the four county region is based broadly on concepts and methods common in regional and demographic analysis. The state-of-the-art in these fields is far beyond the techniques needed here. A brief (and by definition incomplete) summary of the state of the art follows.

Demographic analysis: The meaningful sub-area of demographic analysis in this context refers to techniques of population projection. Population projection methods can be categorized into four main categories: (1) simple trend analysis, (2) cohort-component techniques, (3) econometric techniques, and (4) hybrid techniques.

Simple trend analysis is not state-of-the-art but remains a popular form of population projection. It is simple, easily understood, low-cost, and in some circumstances may perform as well as more advanced techniques. If total population is the variable of interest, simple trend analysis may be entirely appropriate. If detailed characteristics of the population (e.g., age, sex, race, and ethnicity) are needed simple trend analysis is generally inappropriate.

Cohort component techniques are based on two ideas. First, other than statistical error, population change depends on three components: births, deaths, and migration. Second, populations can be divided into cohorts –sub-groups of the population with similar characteristics (such as age and sex). The state-of-the art in cohort component analysis is to use single year of age cohorts for males and females –and often further disaggregation in terms of race and/or ethnicity. Each component is projected separately for each cohort. The result can be an expensive, time-consuming process, but the detail of the results is often worth the effort.

Econometric techniques generally involve the assumption that migration is, at least in part, determined by economic conditions in the area. Generally, the theory is that people will move away from areas of high unemployment and low income to areas of low unemployment and higher income. As a long run proposition, it may also be the case that fertility and mortality are partially determined by economic conditions. Econometric techniques are generally expensive and suffer from the short-coming that the economic variables (e.g. unemployment rates or income) must also be projected into the future –a difficult and daunting task.

Hybrid techniques of population projection refer to some combination of cohort component and econometric methods. A frequently encountered procedure is to determine migration based on econometric methods and use a more standard cohort-component approach for both births and deaths.

Regional Economics: As with demographic analysis, the state-of-the-art in regional economics is a curious mixture of old and new methods, and sometimes old methods used in new ways. The following description barely scratches the surface.

The most publicity regarding new theoretical and empirical models in recent years is the 'new economic geography' suggested by 2008 Nobel Prize winner Paul Krugman.[1] Essentially, the new economic geography uses general equilibrium techniques (think equilibrium in all markets simultaneously) to assess trade flows among regions and nations. A central question in

[1] See Paul Krugman, "What's new about the New Economic Geography?" *Oxford Review of Economic Policy*, Volume 14, number 2, 1998).

the new economic geography literature is why there is two way trade among regions for the same commodity. In other words, why does a single region both export and import the same item. Linked to economies of agglomeration, this approach allows nice theoretical models of why regions differ. The new economic geography has even found its way into regional forecasting models such as those produced by REMI, Inc (www.REMI.com). Krugman's critics argue that the new economic geography is really not new.

Commercially available regional models of economic activity are now readily available. These models are often used to assess the impacts of proposed changes in economic activity. A common example is to use these models to assess the economic impact of a military base closure (or expansion) on a local economy. Such models are generally based on an input-output matrix that describes relationships among industries. More comprehensive models incorporate the input-output approach with econometric modeling and also demographic models such as the cohort-component technique.
The three most widely used regional modeling systems are described below.

(1) RIMS-II is the Regional Input-Output Modeling System produced by the U.S. Department of Commerce, Bureau of Economic Analysis or BEA (www.bea.gov). Based on the national input-output model, BEA will create a model for any state or sub-state area consisting of counties. RIMS-II is used to assess economic impacts of proposed or actual economic changes in a region.
(2) IMPLAN is another economic impact analysis system that is input-output model based. IMPLAN is produced by the Minnesota Implan Group, Inc (www.implan.com) . The IMPLAN system is also based on the national input-output model created by BEA, and like RIMS, IMPLAN models can be created for any combination of counties. The IMPLAN software is easy to use and the models are updated frequently.
(3) REMI, Inc (WWW.remi.COM) produces regional models for any state or sub-state area consisting of counties. The REMI models are more comprehensive than either RIMS or IMPLAN. The REMI models include the input-output matrices of the other two models, but also rely on econometric and computable general equilibrium (CGE) techniques. The REMI models allow forecasting and simulation of alternative policy scenarios for vastly more variables than the other two models. In addition, the REMI models are dynamic in the sense of being able to simulate economic events annually over long time periods. The REMI models are used by both public sector and private sector clients. The REMI models are very expensive.

In addition, the state-of-the-art in applied regional economic modeling must include the numerous custom-built forecasting and simulation models such as those at the University of Texas El Paso, the University of New Mexico, and many other academic and non-academic institutions.

In many situations regional economists use techniques that are not state of the art but have the advantage of a long history. Examples include economic base studies and shift-share. Economic base studies are designed to examine the economic structure of a region while shift-share analysis is designed to examine the competitive advantages of a region(state or county) relative to a larger area (nation). A description of economic base studies can be found at:
http://arrowheadcenter.nmsu.edu/policy/faq/Economic%20Base%20Studies%202.pdf

Estimating Residential and Commercial Water Supply Benefits
Steve Piper

The majority of recent studies evaluating the benefits associated with the provision of improved municipal and industrial water supplies have used the stated preference approach of the contingent valuation method (CVM). A recent Asian Development Bank publication (Gunatilake, et, al., 2007) identified CVM as the basis for estimating reliable willingness-to-pay values for water supplies. The paper by Gunatilake, et al. paper provides a complete description of the planning and design issues associated with undertaking a CVM study, sampling strategies, development of CVM scenarios and defining the commodity, elicitation methods, and evaluating demand and willingness to pay.

The rationale for using CVM centers on the ability to deal with a wide variety of potential water supply issues (such as population growth, declining groundwater resources, changes in water supply reliability, and numerous potential water supply and demand management options) using surveys of water users. The CVM approach also has the advantage of producing very site specific benefit estimates. The potential shortcomings of using a hypothetical market based approach have been discussed at length in many articles and methods for addressing these concerns have been proposed and implemented. A good general discussion of the CVM approach and other approaches to valuing water resources is provided in Young (2005).

Due to the relatively high cost and length of time needed to implement an CVM study, government agencies have recently been using the revealed preference and benefits transfer methods to evaluate the value of municipal and industrial water supplies. Although these methods are generally less site specific and, therefore, potentially less accurate than the CVM approach, they can provide a reasonable estimate of water supply benefits. The use of aggregated water use and price data to estimate generalized municipal water demand functions has provided an approach to estimating benefits that is based on observed preferences rather than costs. There are numerous methodological and econometric issues to this approach that may limit the accuracy of the method.

Despite recent improvements in the methodology of applying benefits transfer, there are still questions about the accuracy of the method. The use of benefit function transfers, as opposed to transferring a point estimate such as a mean benefit value from study, has improved the methodology considerably. Benefit function transfer allows for a better understanding of the variability between the site from which the model is derived and the site where the model is applied. Applying demand curves from one site to another is likely to be less biased than applying mean benefit estimates. However, the potential for inaccurate estimates still exist. Use of the price elasticity of demand approach fits into the same general category as benefits transfer. These types of studies, while not as state of the art as stated preference, are an improvement over the use of alternative project costs as a measure of benefits.

It should be noted that other approaches, such as defensive expenditures, have also been used in the past to estimate domestic water supply benefits. The majority of these approaches have relied on costs of alternative sources as a measure of benefit and, therefore, are not a true measure of benefit.

Tables 1 and 2 below provide a partial list of studies that have estimated price and income elasticities and municipal and industrial water supply benefit studies that have been done that could be of use in evaluating municipal and industrial water supply benefits.

Table 1: Price and Income Elasticities Estimated in Previous Water Demand Studies

Author(s)	Date	Price Elasticities	Income Elasticities	Geographic Region
Agthe and Billings	1980		1.33 to 2.77	Tucson, AZ
- short run		-0.179 to -0.358	-	
- long run		-0.266 to -0.705	-	
Agthe, Billings, Dobra, Raffiee	1986			Tucson, AZ
- long run		-0.125 to -0.624	-	
- short run		-0.019 to -0.364	-	
Billings and Day	1989	-0.200 to -0.710	0.31 to 0.36	Tucson, AZ
Espey, Espey, and Shaw	1997	-0.51	-	U.S.
Foster and Beattie	1979			U.S.
- Rocky Mountains		-0.226	0.627	
- Southwest		-0.122	0.627	
Gottlieb	1963	-0.656 to -0.680	0.277 to 0.895	Kansas
Howe and Linaweaver	1967	-0.231	-	U.S.
Jones and Morris	1984	-0.14 to -0.44	0.40 to 0.55	Denver, CO
Martin and Wilder	1992	-0.32 to -0.70	-	Columbia, SC
Nieswiadomy	1992	-0.17 to -0.45	0.04 to 0.16	U.S.
Nieswiadomy and Molina	1989	-0.002 to -0.460	0.07 to 0.20	Denton, TX
Nieswiadomy and Cobb	1993			
- increasing block rate structure		-0.64	0.57	U.S.
- decreasing block rate structure		-0.46	-	
Piper	2003	-0.32	0.12	U.S.
Renwick and Archibald	1998			Southern CA
- all water users		-0.33	-	
- less than $20,000 income		-0.53	-	
- $20,000 to $59,999 income		-0.21	-	
- $60,000 to $99,999 income		-0.22	-	
- over $100,000 income		-0.11	-	
Renwick, Green, McCorkle	1998	-0.16 to -0.20	0.25	California
Schneider and Whitlach	1991			Columbus, OH
- residential		-0.110 to -0.262	-	
- commercial		-0.234 to -0.918	-	
- industrial		-0.112 to -0.438	-	
Weber	1989	-0.202	-	Oakland, CA
Williams	1985	-0.05 to -1.09	-	U.S.
Williams and Suh	1986			U.S.
- long run residential		-0.294 to -0.485	.638	
- long run commercial		-0.141 to -0.360	-	
- long run industrial		-0.438 to -0.735	-	
Wong	1972			Chicago area
- Cities over 25,000 people		-0.530	1.025	
- Cities 10,000 to 24,999 people		-0.817	0.840	
- Cities 5,000 to 9,999 people		-0.463	0.476	
- Towns less than 5,000 people		-0.257	0.576	
Young	1973	-0.41 to -0.60	-	Tucson, AZ

Table 2 – Examples of Previously Completed Water Supply Benefit Studies

Geographic Area	Concern	Annual Benefit Estimate*	Source of Estimate
Georgia	Water shortage in Atlanta	$1,577 - $10,675	Wade and Roach (2003)
West Virginia	Rural water quality	$320 – $1,090	Collins and Steinback

Pennsylvania	Giardia	$67 – $402	(1993)
Pennsylvania	Groundwater	$252 – $383	Laughland, et al. (1993)
North-Central U.S.	contamination	$65 – $84	Abdalla (1990)
California	General water quality	$167 - $947	Dahl (1992)
Colorado Front	Water supply shortage	$12 – $96	Alcubilla and Lund (2006)
Range	Supply reliability (WTP)	$54 – $193	Howe and Smith (1994)
Colorado Front	Supply reliability (WTA)	$66 – $193	Howe and Smith (1994)
Range	Improved quality	$64 – $125	Jordan and Elnagheeb
Georgia	Groundwater protection	$40 – $129	(1993)
Massachusetts	Groundwater protection	$52 - $63	Powell and Allee (1990)
New Hampshire	Iron and sulfates in supply	$49 – $138	Shultz and Lindsay (1990)
Minnesota	Reliability/future supply	$53 - $207	Cho, et al. (2005)
Montana	Reliability/future supply	$31 - $121	Piper (1998)
Western U.S.	Water-borne illness		Piper and Martin (1997)
Brazil			Casey, et al. (2006)

* All benefit estimates are on a per household basis, except for the Wade and Roach analysis for Atlanta, Georgia which is on a per acre-foot basis

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SUMMARIES OF SPEAKER PRESENTATIONS

Integrated Modeling and Ecological Valuation: A Framework for Application in the Semi-arid Southwest[2]

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ABSTRACT

Conservation of freshwater systems is critical in the semi-arid Southwest where groundwater and flood regimes strongly influence the abundance, composition, and structure of riparian (streamside) vegetation. At the same time these systems are in high demand for competing human use. To address this conflict, natural scientists must evaluate how anthropogenic changes to hydrologic regimes alter ecological systems. A broad foundation of natural science information is needed for ecological valuation efforts to be successful. The goal of this research is to incorporate hydrologic, vegetation, avian, and economic models into an integrated framework to determine the value of changes in ecological systems that result from changes in hydrological profiles. We have developed a hydro-bio-economic framework for the San Pedro River Region (SPRR) in Arizona that considers groundwater, stream flow, and riparian vegetation, as well as abundance, diversity, and distribution of birds within a protected area encompassing the San Pedro Riparian National Conservation Area (SPRNCA). In addition, we are developing a similar framework for the Middle Rio Grande of New Mexico (MRG).

Distinct valuation studies using the non-market techniques of Choice Modeling (CM) and Contingent Valuation (CV) are being conducted for each site with benefit-transfer tests to be conducted between the two sites. Conducting both CM and CVM questionnaires allows us to examine the each of the non-market techniques separately and for a comparison of the techniques. This research is novel in that it provides much more detailed scientific information for economic valuation models than is typically available. There are five research components for this project: (1) scenario specification and the hydrologic model, (2) the riparian vegetation model, (3) the avian model, (4) methods for displaying the information gradients in the survey instrument, and (5) the economic framework. As such, our modeling framework begins with the identification of factors that influence spatial and temporal changes in riparian vegetation on the two rivers. For the SPRR this is principally through impacts on the availability of surface water and groundwater, while in the MRG the impacts are through regulation of flooding and human restoration activities. We use the construct of "current conditions" as a basis for making spatial predictions of vegetation change and avian populations in both river systems through linked modeling

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frameworks. This framework utilizes the best available information through the direct focus on science-based linkages between flow regimes, habitat quality, birds, and human values.

INTRODUCTION

Conservation of freshwater systems is critical in the semi-arid Southwest where groundwater and flood regimes strongly influence the abundance, composition, and structure of riparian (streamside) vegetation. At the same time these systems are in high demand for competing human use (Stromberg et al. 20069, Alley et al. 2002). To address this conflict, natural scientists must evaluate how anthropogenic changes to hydrologic regimes alter ecological systems. A broad foundation of natural science information is needed for ecological valuation efforts to be successful. The goal of this research is to incorporate hydrologic, vegetation, avian, and economic models into an integrated framework to determine the value of changes in ecological systems that result from changes in hydrological profiles.

We have developed a hydro-bio-economic framework for the San Pedro River Region (SPRR) in Arizona, United States that considers groundwater, stream flow, and riparian vegetation, as well as abundance, diversity, and distribution of birds within a protected area encompassing the San Pedro Riparian National Conservation Area (SPRNCA). In addition, we are developing a similar framework for the Middle Rio Grande of New Mexico (MRG). Distinct valuation studies are being conducted for each site with benefit-transfer tests to be conducted between the two sites. This research is novel in that it provides much more detailed scientific information for economic valuation models than is typically available

In the absence of integrated science information, stated-preference valuation studies typically must rely on vague program descriptions and imperfect measures of the change in resource quality or quantity. The lack of a scientific foundation for economic valuation studies typically occurs either because (1) targeted scientific research on the topic of interest is lacking, or (2) scientific studies that do exist have not been adequately designed to directly inform valuation questions. Ideally, existing scientific information should provide forecasts for the area of interest, contain well-defined timescales, and speak in terms that are relevant and understandable to the lay public. This study attempts to address these issues through use of an integrated scientific/economic framework. The research team includes hydrologists, ecologists, ornithologists, geospatial geographers, facilitators, and economists, most of whom are centrally involved in varying degrees with research projects in both the SPRR and the MRG.

There are five research components for this project: (1) scenario specification and the hydrologic model, (2) the riparian vegetation model, (3) the avian model, (4) methods for displaying the information gradients in the survey instrument, and (5) the economic framework. As such, our modeling framework begins with the identification of factors that influence spatial and temporal changes in riparian vegetation on the two rivers. For the SPRR this is principally through impacts on the availability of surface water and groundwater, while in the MRG the impacts are through regulation of flooding and human restoration activities. We use the construct of "current conditions" as a basis for making spatial predictions of vegetation change and avian populations in both river systems through linked modeling frameworks. This framework utilizes the best available information through the direct focus on science-based linkages between flow regimes, habitat quality, birds, and human values.

OVERVIEW OF PROJECT COMPONENTS

Ecosystem Alteration Drivers, Decision Support Frameworks, and Scenarios

Extensive human use of dryland rivers has resulted in many changes to their biota. For example, on parts of the SPRR groundwater depletion and overgrazing by livestock have contributed to

shifts from cottonwood-willow (*Populus-Salix*) forests to *Tamarix* shrub lands (Stromberg 1998; Lite et al. 2005). The riparian ecosystem on the MRG has been impacted by flood control facilities, river channelization, land clearing, and agricultural activities. More recently, mechanical removal of introduced invasive species, motivated by both aesthetics and fire control, has influenced vegetation patterns in the MRG. Significant research effort has been allocated toward understanding the impacts of groundwater pumping on the SPRR biota and developing policy options that could be used to mitigate the impacts of groundwater pumping. Since agricultural activities have largely been eliminated from the SPRNCA region, the focus on policy options falls into four principal categories:
Infrastructure changes: changing the location of subdivisions and groundwater wells or recharge basins in order to reduce groundwater declines near the river;
Water augmentation: increasing the amount of water in the basin via inter-basin transfers;
Water conservation: decrease the consumption in the region through regulations and incentives;
Combination of all of the above

A Decision Support System (DSS) has been developed with the aid of systems dynamic modeling software (Tidwell et al., 2004 as an illustrative application of a DSS) by the San Pedro Partnership to provide the basis for understanding the impacts of alternative policy decisions and to identify the effectiveness of alternative water conservation measures for the Upper SPRR (Sumer and Lansey, 2004; Ritcher 2006[4]). The DSS, designed with the aid of systems dynamic modeling software, incorporates a USGS groundwater model, surface water supply, groundwater storage, and residential/commercial water uses. It allows temporally and spatially variable future population growth and associated water consumption. Each policy measure or combination of policies can be simulated for a 50 year period or less. The impacts of activities such as groundwater pumping can be determined spatially relative to specific river reaches.

Our research places additional demands upon the DSS, particularly the need to understand groundwater levels as well as changes in riparian vegetation with more spatial and temporal precision than is needed by SPRR water managers. Because the DSS is funded primarily by other entities, the more sophisticated features that this research requires can only be incorporated into major revisions of the DSS.

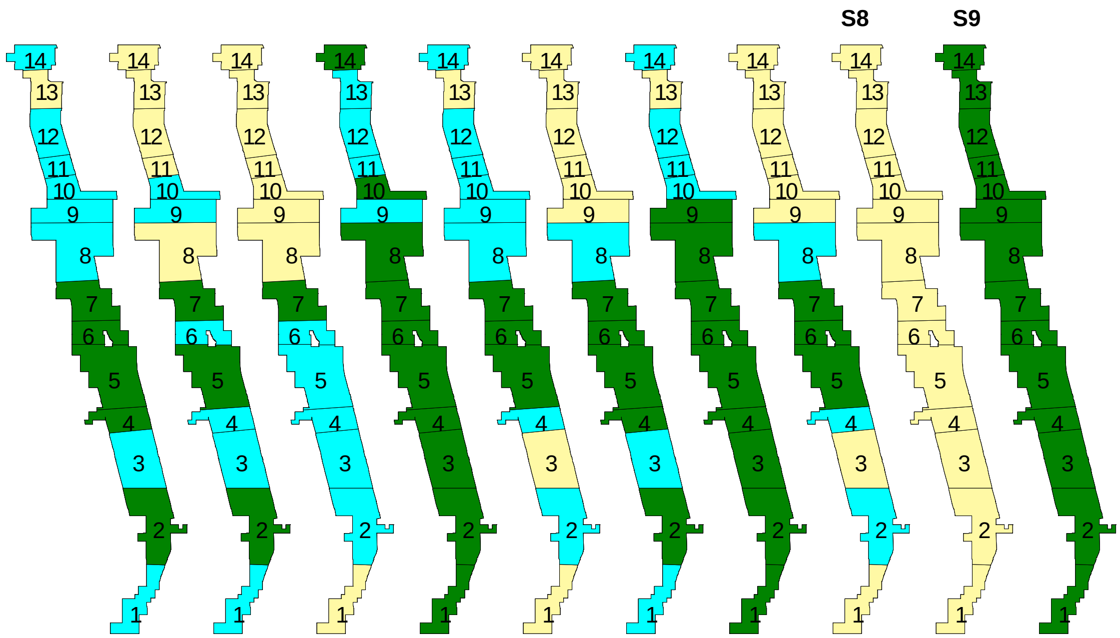
While operational, the DSS is still undergoing development. Additional features such as the condition class model, upon which much of this research is based, are being added to each new version of the model. Because the current version of the DSS does not include the condition class model to generate vegetation changes, we relied upon scientists' (D. Goodrich, personal communication) best estimate of the magnitudes of likely groundwater level changes in status quo, high growth and low growth/high conservation scenarios garnered from the understanding of the USGS groundwater model currently incorporated in the DSS (scenarios 4 - 7) in addition to uniform (scenarios 1 – 3), and end-member cases (scenarios 8 and 9) groundwater changes.
Scenario 1 = 0.5 m uniform decline in groundwater;
Scenario 2 = 1 m uniform decline in groundwater;
Scenario 3 = 0.5 m uniform increase in groundwater;
Scenario 4 = Continued and increased agricultural pumping near Palominas; new developments in unincorporated areas of Palominas and Hereford near SPRNCA;
Scenario 5 = Increasing cone of depression in Sierra Vista, Ft. Huachuca, and Huachuca City with impacts toward the lower Babocomari and northern SPRNCA;

[4]The USPP DSS has not been published in its entirety as it is still be vetted by the Upper San Pedro Partnership.

Scenario 6 = Large increases in groundwater due to recharge and conservation efforts in Sierra Vista and Bisbee;
Scenario 7 = combined from scenarios 4 & 5, representing effects of both agricultural pumping in the south and increasing cone of depression;
Scenario 8 = Low extreme - river essentially dries up;
Scenario 9 = High extreme - river essentially has surface flows throughout SPRNCA[5].

Figure 1depicts the impact on SPRNCA of the above hydrologic scenarios. Each graph shows SPRNCA divided into 14 reaches. Based on research from project ecologists, reaches have been classified into one of three types (condition classes): wet, intermediate, dry. This classification reflects variables such as annual surface water permanence, depth to groundwater, and vegetation composition (Lite and Stromberg 2005, Stromberg et al. 2006).
The SPRNCA currently consists primarily of wet and intermediate reaches; in our scenario analysis we assume that changes in groundwater levels from actions such as pumping and recharge results in shifts between stream classes.

Figure 1 Changes in San Pedro Riparian Condition Classes by Scenario



Riparian and Avian Components
One of the core challenges of this project has been to quantitatively link models across the natural science disciplines, and in turn, provide usable outputs for ecological valuation. The riparian and avian components each began with different goals. The objective of the riparian component was to determine how riparian vegetation distribution, composition, and structure respond to changes in surface flow and groundwater levels in the SPRNCA. As noted above, prior riparian research yielded a condition class model based on underlying hydrologic conditions. The objective of the avian component was to determine the impact of hydrologic and vegetation changes on bird populations and communities for the different reaches of the SPRNCA, and then express these

[5]The importance of developing plausible scenarios became apparent during the May 2006 focus groups where participants were generally frustrated with the choice question because the scenarios causing the changes in attribute levels was intentionally left ambiguous.

outputs in terms of bird abundance as inputs into the ecologic valuation models. Bird abundances were assessed by migratory status, nest height, and the degree of water-dependence.

The next step was to link the riparian condition class model with avian datasets. The modeling framework used the raw data that was available for vegetation and birds (e.g. average proportion of different habitat types within a condition class and bird densities by habitat type and hydrologic class), and projected how changes in groundwater, as reflected in the condition class vegetation model, would impact bird abundances as a function of the different hydrologic scenarios by reach. While the components of this work were not new (for example, the developed methodology applied some basic approaches in space-for-time substitution modeling and the delta method to calculate errors propagated across the vegetation and bird modeling levels), the development and programming of this model was specific to the data and problem at hand. This linkage was the key step required to provide a scientific foundation to the economic valuation effort.

Survey Component

The foundation of the survey research program is framed by the following questions:
What is the ideal set of physical, natural, and social science information on which to build an economic research program to value ecological service flow changes?
Can alternative suites of natural science information coupled with socio-behavioral information lead to a better understanding of both intra-site and inter-site benefit transfer functions?
The research incorporates two stated preference techniques, Contingent Valuation (CVM) and Choice Modeling (CM), with three alternative information gradients, "Fine", "Coarse" and "Traditional" for each technique. To date there have been few published comparisons of CVM and CM (Stevens et al. 2000; Margat et al. 1998; Barret et al. 1996; Boxall et al. 1996; Ready et al. 1995; Mackenzie 1993; Desvousges et al. 1987). All of these studies found substantial differences in willingness to pay (WTP) estimates between the various forms of CVM and CM analyses for equivalent policies. Various reasons for the disparity have been offered: first, CVM is a one shot procedure vs. the iterative nature of the CM (Takatsuka 2003); second, the presentation of alternative policies in the CM format suggests substitute (alternative) policies not available in CVM (Boxall et al. 1996; Ready et al. 1995); third, CMs allow explicit recognition of complements that CVMs may not (Morrison 2000, Stewart et al. 2002); fourth, the effects of data structure used for conditional logit vs. standard logit estimation vary (Stewart et al. 2002). In addition to these comparisons, benefit transfers will be conducted between the two test sites. The literature on benefit transfers predominately relies on the science as given (Desvousges et al. 1998). Few studies have examined the role of models across disciplines in a benefit transfer setting (Brookshire et al., 2007; Brookshire and Chermak, 2007), while few cross-method comparisons exist (Boxall et al. 1996; Stevens et al. 2000; Takatsuka, 2003).

CM, a variant of conjoint analysis, elicits an individual's preferences by asking the subject to consider a series of alternatives. In contrast to CVM, which asks individuals to explicitly state their willingness to pay for a proposed policy change, CM requires the individual to choose from a series of possible alternatives, each having different levels of the attributes (birds, in-stream flow, riparian vegetation and cost, for example). This allows the researcher to obtain the marginal value (implicit price) of each attribute, as well as welfare measures for any policy that has attributes contained within the span of those presented in the survey. Both the CVM and CM models utilize a random-utility framework to explain individuals' preferences for alternative profiles and are directly estimable from the CVM and CM data. Several iterations of the coarse scale CM surveys have been drafted with emphasis on the educational and scenario components. The educational component forms the foundation of all three information levels for both the CM and CVM surveys.

Information gradients are represented through different levels of spatial representation and / or levels of detail of ecological attributes. The "Traditional" scale will provide minimal spatial representation of the attributes[6], the "Coarse" scale will provide reach scale spatial representation[7] with the "Fine" scale providing reach scale spatial representation giving survey participants the option to 'drill-down' to more detailed information on hydrologic, vegetation, and avian attributes[8]. In this regard different levels of scientific information are coupled with the ability to present the attributes in more advanced forms. To ensure that responses are representative of the population, both mail and internet versions of the surveys are being developed. Figure 2 shows the types of comparisons that can be made across modeling approaches and the types of tests that can be conducted using a benefit transfer.

Figure 2 Benefit Transfer Tests

		Traditional Survey	**Coarse Survey**	**Fine Survey**
Choice Questions	**San Pedro**	**No spatial vegetation and bird information**	*Spatial vegetation and bird information*	*Spatial vegetation and bird information, plus the ability to drill down by reach for additional information*
	Rio Grande		Spatial vegetation and bird information	
DC / CVM	**San Pedro**		*Policy attribute chosen by scientist*	
	Rio Grande		Policy attribute chosen by scientist	

Educational component is the same

Educational component is the same

REFLECTIONS

This paper has presented a case study, highlighting some of the complexity involved in creating an integrated scientific/economic framework. As discussed in this paper, difficulties in creating such a framework for a single site include: the inherent contradictions in separately valuing ecosystem services as distinct, independent attributes; the cognitive difficulties posed for survey research in having primary scientific output; the challenges of integrating disparate disciplines; and the need to develop novel methods for connecting the output between the disciplines. These difficulties, while surmountable, are made even more challenging when the goal is to conduct benefit transfer between sites, as the 'best science' is traditionally geared towards understanding a

[6] The notion of the traditional scale is that much of the scientific research has enabled an understanding of the ecological processes of the river systems in spatial detail. If this work had not been done, we would have been faced with what might be a more traditional informational setting. That is, rather than being able to divide the river into stretches as they relate to groundwater levels, we would have been faced with information such as 35% is cottonwood, 50% mesquite, etc.

[7] Coarse scale information uses the best available science in a spatial setting but omits within the survey some of the available detail such as reference to all types of birds.

[8] The fine scale incorporates within the structure of the attribute set all of the available information. For instance, the 'drill-downs' will allow the respondent to examine in detail changes in a particular bird species.

specific site as opposed to broadly describing a set of sites. Accommodating scientific differences between sites and trying to remain scientifically accurate increases the cognitive burden placed on survey respondents while limiting the level of detail at which the problem can be addressed. The necessary result has been a number of pragmatic compromises.

While we present this experience with the hope of sparking discussion, we do so retaining the belief that while complex, the effort to integrate the disciplines remains essential. Working with other disciplines has been an interesting experience, highlighting the lack of full understanding of natural systems that economists bring to valuation exercises. In order to develop meaningful welfare estimates that can contribute to policy discussion, economists must better understand the possible trade-offs resulting from policy choices. In order for the science results to have policy impact, scientists must strive to make their results understandable and transferable. Additionally they must engage with policymakers. Better environmental policy requires integrated research.

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Water Markets for River Systems[9]

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ABSTRACT

The last two decades have witnessed the application of economic markets to address problems of environmental policy over a range of areas including the removal of lead from gasoline, the reduction of acid rain producing sulfur dioxide from the atmosphere and the limiting of carbon dioxide emissions. Markets have also been successfully utilized outside of the environmental policy area to address policy problems made complex by the laws of physics such as, the trading of electricity in a network and the combinatoric auction used to allocate scarce airport landing and take-off slots. However, during this same period, little attention has been paid in the application of markets to a most fundamental and important commodity, water. This paper explores the necessary components required to build a fully coupled economic and hydrological/engineering institution that will allow for the emergence of a genuine leasing market for water. The focus is on water leasing as a form of a market whereby the exchange is only temporal and spatial and not a permanent exchange of a water right per se. The structure utilizes a joint surface and groundwater hydrological model for a river basin that is responsive to trades of water that occur between economic agents.

INTRODUCTION

Many locations in the world derive consumptive water from river/basin systems. Water may be drawn directly from the river itself or from wells penetrating the basin to the underlying water aquifer. In many cases, the above ground river and the underground water reserves are best thought of as a joint system; removal of water from one source will directly affect the other source (Jones, 2002; Minier, 1998). This fact of nature describes the current situation in many areas of the western United States.

If the total supply of water in a given system was sufficient to meet the demands of all users, then water could be efficiently allocated by charging users an extraction cost for their water. However, in most of the American west, population changes and cyclical climatic conditions provide challenges for meeting the demands of all potential water users. In most of the western states, it is safe to say that there is an excess demand for water at currently regulated prices (Brookshire et al., 2002). Indeed, allocating water resources is now done in a mood of "crisis management" in much of the west. Most policy-makers expect that the situation will only get worse in the future (U.S. Department of Interior, Bureau of Reclamation, 2005).

This paper examines what role economic markets might play in the Western United States water future. As economists, we are trained to think of an "out of equilibrium market" when we hear the word "crisis". Under the assumption that water rights are fully adjudicated in a river/basin system, the natural solution to a water crisis is to allow buyers and sellers of water to freely trade water resources. However, there are two complicating aspects of water that make the application of a market problematic.

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The first challenging aspect of water relates to its physical and geophysical properties. In a river/basin system there is an interconnectedness between the river and the underlying groundwater aquifer.[11] A trade of water from one location to another may have systemic affects on the entire system. While these affects on the basin may be complex, they can often be accurately understood using sophisticated hydrological models. Another aspect of water in the western U.S. is that evaporation rates of water from the river can be quite large. This aspect can create asymmetries between water that is traded upstream (before it has a chance to evaporate) versus water that is traded downstream (and experiences evaporation losses). Finally, much of the water in the western U.S. originates from melting snow that accumulates during the winter months on mountain ranges. The total supply of water in a given year, ignoring for the moment the possibility of water storage, depends on a random accumulation of snow pack in that year, as well as carry over or depletions from previous years.

The second challenging aspect of water relates to how water rights are allocated (i.e. priority or riparian rights).[12] Typical claimants for property rights in a river/basin system include agricultural users, urban users, and Native American users (who primarily use water for agricultural purposes). However, many river systems often have a relatively new property rights claimant – endangered or threatened species. Typically, when such species are present, rules about water flow rates impose additional constraints upon the system (Woodward and Shaw; 2008; Thoyer. 2006; Boyd, 2003). For example, if an endangered fish is present, then a rule requiring a minimal flow rate at all places and at all times may be enforced. Any constraints of this nature may have an impact on the scope and scale of water trading allowable in the system.

The goal of this paper is to explore how the challenges posed by these two aspects might be overcome in creating a real-time, spot market for water. Because of the success of markets to resolve environmental policy problems such as the removal of lead from gasoline (Kerr and Newell, 2005), the reduction of acid rain producing sulfur dioxide from the atmosphere (Bellas and Lange, 2008) and the limiting of carbon dioxide emissions (Burtraw and Evans, 2008) it seems natural to apply a coupled market framework for the leasing (temporary transfer) of water rights. Using experimental economic techniques this paper examines a coupled institutional, economic and hydrologic system for the allocation of water.

The experiments are conducted using the Middle Rio Grande river/basin system in New Mexico as a point of departure. This portion of the Rio Grande incorporates a large portion of the state of New Mexico.[13] We chose this area of study for the following reasons. First, based upon early spring measurements of snowfall in the Rock Mountains of Colorado (where the great majority of Rio Grande water originates), a fixed formula is used to allocate this water to the states that draw from the system (Rio Grande Compact, 1939). In any given year, the amount of water available to New Mexico is determined by this formula. Second, the Middle Rio Grande section of the river is divided geographically into six exclusive subsections, or reaches, with a mix of water users found throughout the reaches. Agricultural users of water are found in every reach while Native American users are found in the northern reaches. There is only one large

[11]Rivers can broadly be classified as either a "gaining" or "losing" river with respect to the ground water aquifer. A "gaining" river will extract water from the groundwater aquifer where a "losing" river will add water to a groundwater aquifer.

[12] Water rights in the west are typically under the prior appropriate system meaning first in time, first in right, regardless of where the right is located upon the river. Under a riparian rights system all landowners whose property is adjacent to a body of water have the right to make reasonable use of it.

[13] The study region is located from Cochitti Dam (just south of Santa Fe, NM) to the inlet of Elephant Butte Reservoir (just north of Truth or Consequences, NM).

urban area, the City of Albuquerque, located in the second reach spreading south along the river. Also present in the river is an endangered species, the Silvery Minnow (*Hybognathus amarus*). The presence of this fish has caused minimal flow requirements to be put in place in each of the six reaches (U.S. Fish and Wildlife Service, 2003). Thus, from an experimental perspective, the Middle Rio Grande is a relatively closed system containing a typical mixture of water users found in the western U.S., and includes the presence of an environmental constraint.

Currently, very little trading (or leasing) of water occurs in the Middle Rio Grande (Washington State Department of Ecology, 2004). Water users are allocated a fixed amount of water for use. It is possible to lease small amounts of water from another user, but the process involves a lengthy regulatory review where decisions, if any, may take months to occur. It seems unlikely that under this status quo water is moving towards its most highly valued uses. In order for real-time markets to be in place for this area of study, the affect of any trade on the water system has to be known quickly, that is, fast enough so that the buyers and sellers do not notice any delays in consummating trades.

The remainder of this paper is as follows. Section 2 explains how a detailed hydrological model was developed to fulfill this requirement. Section 3 outlines constructed payout and demand functions for the experimental subjects who acted the role of the agricultural, urban, and Native American users of water and how we impose the environmental constraint for the Silvery Minnow. Section 4 describes the developed computerized double-oral-auction trading platform for use in a water context. Section 5 reports the results of experiments where the reward functions for the agricultural users are relatively simple or austere. In these experiments, the experimental subjects acting in the role of farmers grow crops (and in turn earn cash rewards from these crops) if, and only if, they can acquire a fixed amount of water. The final section reflects on the experimental results to summarize the economic, institutional, and policy conclusions from our work.

1. Water Supply and Movement: The PowerSim Hydrological Model

1.1. Physical Setting

The Middle Rio Grande basin of central New Mexico is characterized by basin and range topography with mountains on the eastern flank and arid valleys and mesas on the central and western flank. Engineered infrastructure for managing basin water resources include two reservoirs, for flood control and irrigation respectively. Diversion, conveyance and drain structures are located throughout the basin which are managed by the Middle Rio Grande Conservancy District. Demands on these resources and infrastructure include one urban sector, Albuquerque, with multiple smaller communities (Belin, Bernalillo, Los Lunas, Rio Rancho and Socorro). Currently municipal demands are met through pumping of deep alluvial aquifers that are directly connected to the Rio Grande. Along with these interests agricultural irrigators are present controlling the largest share of water allocation. Native Americans also have interests, primarily in the form of irrigated agriculture, with multiple reservations and pueblos.

1.2. Hydrologic Model Development

The hydrologic model is developed in a system dynamics framework employing the commercial software package Powersim Studio 2003. Adoption of a system dynamics structure facilitates the integration of the physical and engineering systems with an online water trading platform, within a computationally efficient framework allowing experiments to be conducted in real time. The hydrologic and engineering system models are physically based, formulated according to a temporally dynamic water budget. The spatially distributed model is structured according to six interactive reaches delineated by the major gages along the Middle Rio Grande. There are six environmental users, one per reach, assumed to be utilizing water to care for a specific environmental interest (i.e. Silvery Minnow) in that reach of the river. There is one urban consumer in the second reach representing the municipality of Albuquerque and its outlying communities, five agricultural users representing irrigated agriculture in the system and three Native American users representing reservations and pueblos. The distribution and type of users is structured to represent the basic water uses in each of the six reaches.

The hydrologic model operates on a yearly time step with two runs per period. The first run of the model is performed before the water leasing market opens in order to establish water allotments (consumptive use) for each participant, with the assumption that the river is fully adjudicated, thus all property rights are assigned. After the market closes the hydrologic model then runs a second time to account for water movement from voluntary trading. This process is repeated for each of the trading periods during the experiment.

Basic model elements include surface water and groundwater supplies balanced against municipal, agricultural, evaporative, and riparian demand. Specifically, the surface water system is comprised of the Rio Grande and the two area reservoirs. Inflows include the main stem of the Rio Grande, tributary flows, interbasin transfers from the Colorado River and wastewater returns. Losses from the surface water system include evaporation from the river and reservoirs, agricultural consumption, transpiration from the riparian corridor along the Rio Grande and pumping induced river leakage. Groundwater inflows include mountain-front recharge, interbasin flows and river leakage, while withdrawals include groundwater pumping and discharge to the river/shallow aquifer system. Evaporative losses are a function of climatic conditions and reservoir surface area, while transpiration losses depend on the climate, acreage and vegetation type.

Basic model inputs include Rio Grande inflows from the upstream reservoir and tributary inflows, which are based on historical gauged stream flow data. Additional inputs include basic meterologic data (e.g., precipitation, daily temperature, and humidity), crop/riparian acreages, and population. All other variables are dynamically calculated from these inputs.

1.3. Hydrologic Treatments

The experimental treatments employ four different climatic scenarios; baseline, dry, decreasing and increasing, with three treatments per scenario. In a baseline climatic scenario each user is allotted an amount of water that is close to the necessary minimum amount needed to obtain a positive payout from the developed payout function as illustrated in Figure 1. In a dry climatic scenario initial water allocations are always below the necessary minimum needed to obtain a positive payout. In a decreasing (increasing) scenario users begin above (below) the necessary minimum and end below (above) the necessary minimum to obtain a positive payout.

To parameterize the climatic scenarios, actual water year data was re-arranged and or repeated. This data was drawn from historical Rio Grande data for the period 1975-1999. Actual allocations for a given round were determined from the hydrologic model using input data for the selected year. Urban, environmental, agriculture and Native American users were allocated water according to current diversion standards if sufficient water was available, or shared equally in the event of a water shortage or a drought year. [14]

2. Water Demand: The Utility of Water and Experimental Incentive Functions

Our review of the water demand and endangered species valuation literature indicated that the highest use value of water occurs in the urban sector followed by environmental use for

[14] This practice is in accordance with current management practices in the Middle Rio Grande.

the Silvery Minnow, and followed in turn by the use of the water for agricultural practices (Gillon, 2007; Katz, 2007; Pecos, 2007; Berrens et al., 1998). This hierarchy is reflected in the numerical parameters used in constructing the utility and payout functions.

Agricultural users were motivated by a utility function of water represented as a step function. If a critical amount of water was obtained, they were able to grow a crop for that year. If they did not meet this step, then their crop output for the year was zero. Any amount of water over the step is redundant and does not yield additional crop output. The relevant geometry of what this implies for the water/crop yield function and for agricultural demand is illustrated in Figure 1.

A broad body of literature supports the notion that Native Americans value water over and above its mere use value due to both cultural and spiritual values (Moore, 1989; Snyder and Anderson, 1988). We have chosen not to address this complexity in the current paper and have constructed water/crop and demand functions for the Native American users that are identical to the agricultural users described in the previous paragraph.

The urban user was modeled based upon the existing situation on the Rio Grande. Albuquerque, under current conditions, already has claim to a share of the water in the basin. We have chosen to model the relationship between water and utility for the urban user as a typical decreasing marginal utility of water function emanating from the water/utility origin. This structure is also illustrated in Figure 1.

We considered different ways of capturing the value of the Silvery Minnow in our experimental structure.[15] What is presented in this paper is a structure that provides an experimental subject with an objective function that makes him or her an environmental trustee for the minnow. The objective of the subject/trustee is to acquire enough water to meet the minimum flow requirement for the minnow. This, in terms of both the water/utility and demand function is illustrated again in Figure 1. If the minimum water requirement is met or exceeded for the fish, then a positive outcome is affected which then results in a positive monetary payoff for the subject/trustee. If, however, this minimum is not obtained and a bad outcome for the fish results, then the subject/trustee pays a monetary penalty. In short, we are modeling a situation where the fish does not expire when there is not enough water but the trustee pays a penalty for allowing this situation to occur.

Figure 1 also reports the values for the actual parameters used in the first set of experiments. Using these parameters demand functions are computed and illustrated for each user group shown in Figure 2. Multiplying each of the user specific demand functions illustrated in Figure 2 by the number of participants in each user group and then horizontally summing the demand functions results in a market demand function illustrated in Figure 3. Three market equilibria under conditions of dry, normal, and wet water years are also depicted in Figure 3 as Q_1 Q_2 and Q_3 respectively. Finally, the mathematics behind the illustration in Figure 3 allows us to compute the expected market price (efficient price) under the hypothesis that trading is not allowed. This can then be compared to any efficiency losses or gains (welfare) that occur in the presence of a market trading institution. This institution is the subject of the next section.

Figure 1: Demand Functions

[15] Two possible methods were considered; First, allocate water rights to environmental trustees and allow them to participate in market transactions; second, design the market to include environmental goals as constraints.

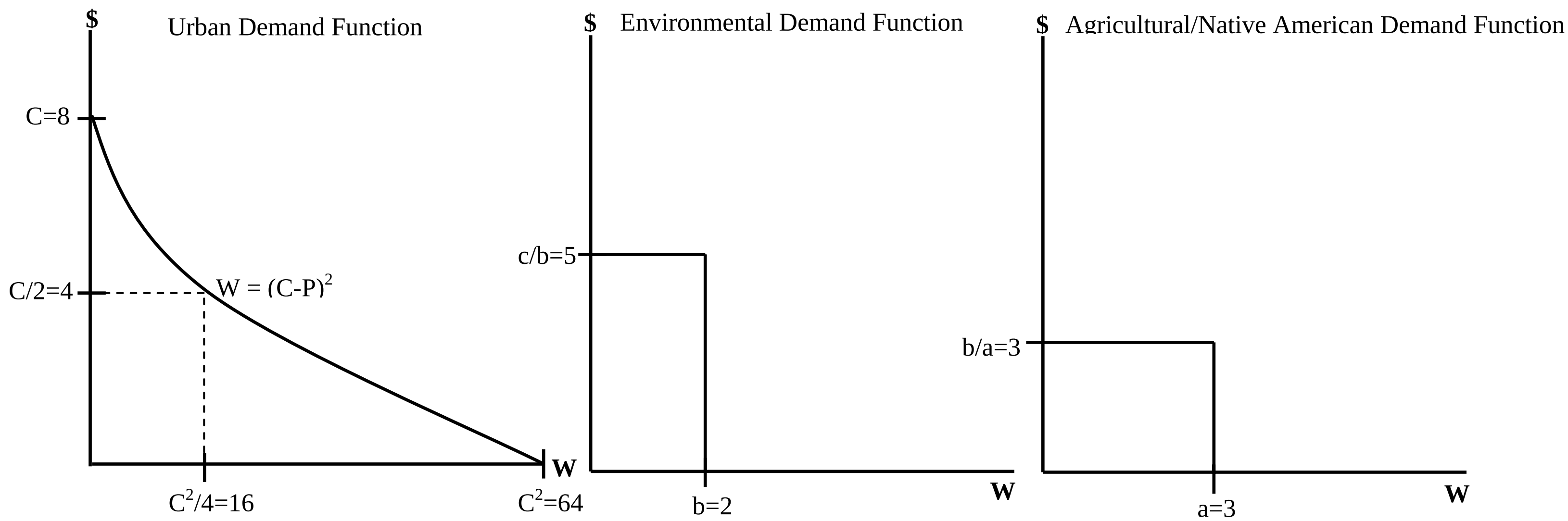


Figure 2: Payout Functions

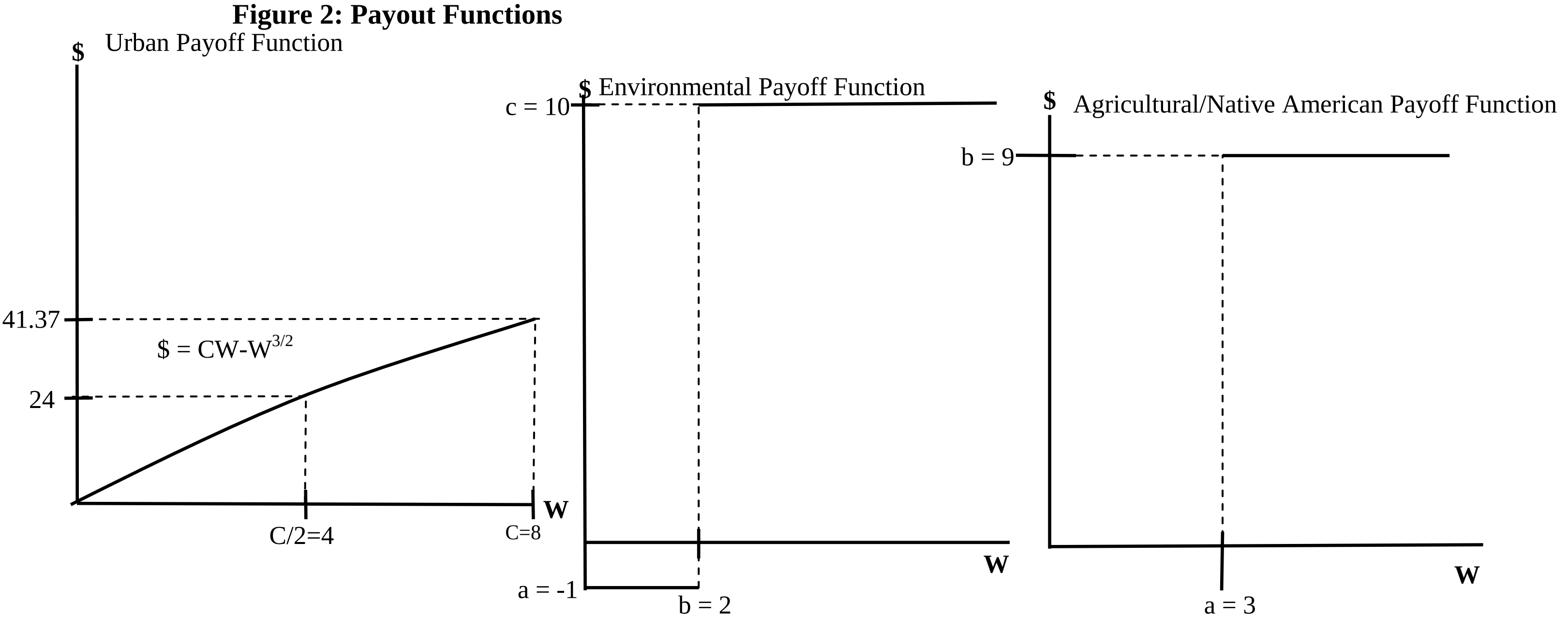
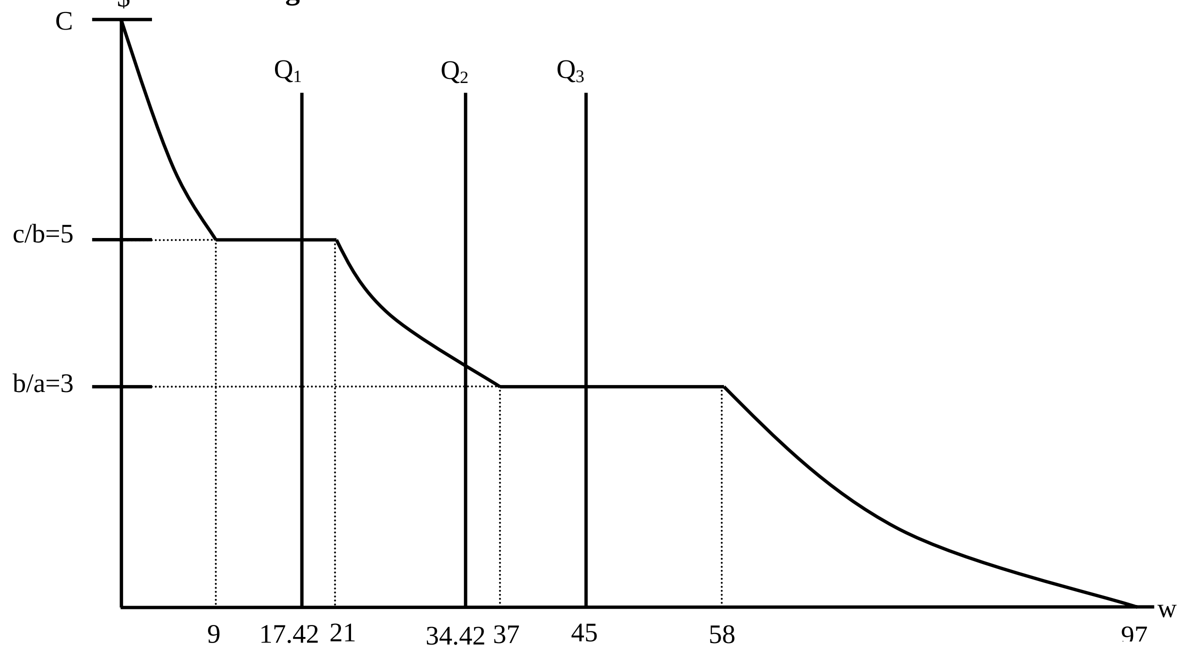


Figure 3: Market Demand Function



3. The Water Trading Platform Used in the Experiments

The experiments utilize a computerized market double-oral-auction trading institution. This general institution is well known to those who trade stocks and commodities and is familiar to students of the experimental economics literature (e.g. Davis and Holt, 1993). Rather than belabor the basic operation of this market, allow us to focus on the alterations of the basic trading structure that are used in our water trading environment. The trading screen available to an experimental subject is shown in Figure 4. The basic unit of trade is an acre-foot of water. Subjects could make bids and offers for any tenth of a fraction of an acre-foot unit.

Subjects are made aware of time, can make or retract bids or offers, accept standing bids and offers, examine the existing array of bids and offers, and see both a running protocol and graph of trades and prices all in the regular fashion. Bids and offers are submitted in the form of a two-touple. For example, a subject might make an offer of $5.00 for 0.5 acre-feet of water. The software displays these values to all traders as well as showing all traders this offer in terms of per-acre cost (in this case $10.00 per acre-foot) They can also observe their current water and cash balances, where they are on their water yield curve, and their location along the river system.

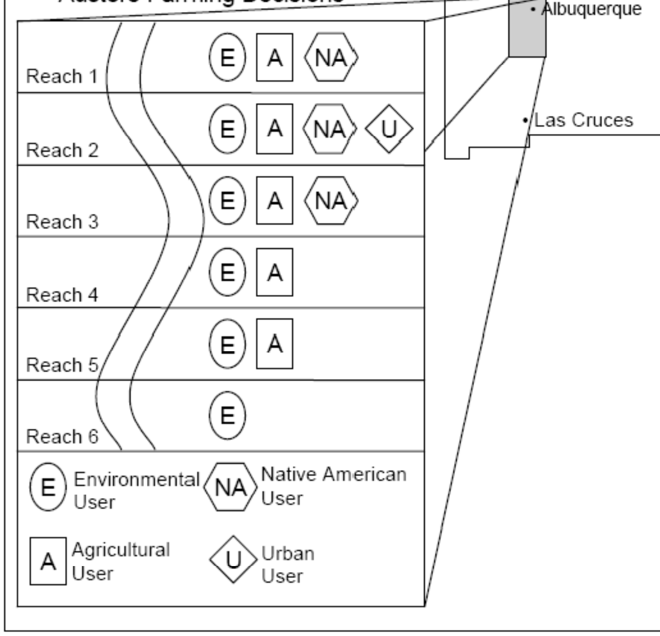
Figure 4: Trading Interface

There are three features of the trading platform that are different than most experimental trading platforms. First, unlike most experimental economics applications of the double-oral-auction, subjects can be both buyers and sellers in the same market. This provides the opportunity for speculative trading in the market. It also allows for the possibility for a change in strategic behavior during the course of a trading session. For example, an agricultural user may decide that he is going to attempt to obtain enough water during a given period to make his crop whole. But, somewhere into the trading period he may decide that the price of water is too dear and start selling back water he had bought earlier in the period.

The second feature unique to our use of the double-oral-auction structure is related to water evaporation. As discussed in Section 2, water that moves downstream will experience evaporative losses. Similarly, water traded up river will not be subjected to these losses. Since the subjects in the experiments are located on each of the six different reaches, the amount of water that they can collect or deliver depends on who they are collecting from or delivering to. Thus in the bids and offers box illustrated in Figure 4 each of the acre-foot quantities are computed from the perspective of that subject, after the hydrologic model has corrected for evaporative losses.

The third and final feature is that the computerized double-oral-auction software interacts with the hydrologic model on a trade-by-trade basis. Each prospective trade is examined for its physical plausibility. If a trade is consummated, then the affects of the redistributed water in the system are recomputed and reported at the end of each round of trading.

Figure 5: Layout of Traders in Austere Farming Decisions



4. Experimental Results with Relatively Austere Farming Decisions

In these experiments fifteen participants acting in the roles of irrigated agriculture, Native Americans, urban municipalities and environmental trustees were able to engage in market interaction. A stylized map of the river basin and the location of the subjects along the river are illustrated in Figure 5. In the experiments, subjects were not given prior knowledge or expectations about the period to period water availability. Each experiment consisted of ten years of trading with three experiments being conducted for each of the scenarios (decreasing, increasing, dry and baseline). All subjects in the experiments were drawn from the University of New Mexico student body and staff.

The first two trading years in each of the experiments exhibited low trading volume and high volatility in water prices. In subsequent periods, volume increased and prices tended to stabilize quickly. A typical pattern of price evolution for a trading round is displayed in Figure 6. In Figure 6 the moving mean, median and weighted average price per acre foot is displayed along with each transaction (denoted by the diamonds where the larger the diamond the larger the volume of water traded). The weighted average price is weighted by the volume of water traded and is probably the most relevant in Figure 6. The other statistics charted in this figure can be influenced by a pattern of behavior that was witnessed during the experiments. Because of the step function yield curve for the agriculture users and the environmental trustees, subjects that needed very small amounts of water to obtain the step were often willing to pay a high price for that marginal water. This resulted, for these trades, in spuriously high per acre-foot prices.

Figure 6: Trading Graph

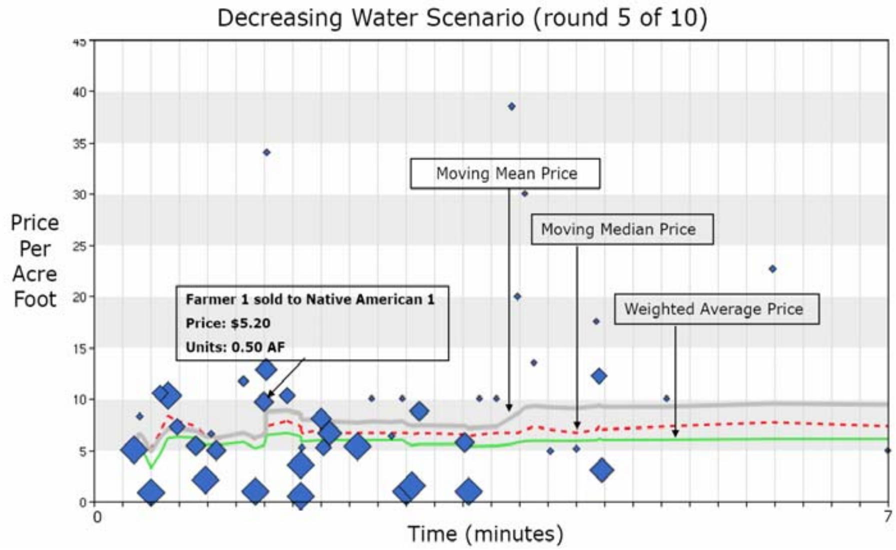


Table 1 reports the summary price statistics for each experiment by scenario. It appears that weighted average prices in all of the scenarios tend to move towards expected or efficiency prices. These appearances are confirmed by conducting Student t-tests. Student t-tests were conducted on round by round price per acre-feet data indicating that the weighted average price per acre-foot was not significantly different from the expected price per acre-foot across the hydrological scenarios. This test is reported as an asterisk in Table 1. In summary, the student subjects were able to respond quickly to changes that occurred in the supply of water with very few observed weighted average prices being statistically different from expectations.

Finally, the price formation process yielded higher welfare gains than the autarkic alternative as delineated in Table 2. The efficiency gains are anywhere between losses of 16% to gains of 86% for the aggregate market with the largest gains typically occurring in water scarce years.

Table 1: Weighted Average Prices and Standard Errors

	Trading Round									
	1	2	3	4	5	6	7	8	9	10
Decreasing1	6.54	8.18	9.92	9.43	6.06	9.62	11.35	8.50	10.33	9.57
	(7.01)[a]	(7.22)	(10.45)	(9.87)	(8.88)	(5.40)	(16.30)	(7.98)	(6.05)	(6.53)
Decreasing2	9.23	10.82	9.19	12.41	9.02	9.75	9.45	9.33	9.37	9.59
	(9.98)	(13.38)	(8.09)	(10.89)	(8.39)	(8.96)	(7.17)	(4.79)	(5.54)	(6.12)
Decreasing3	4.19	6.27	6.36	8.13	10.01	10.42*	10.35*	9.54*	8.38	8.73
	(2.71)	(2.56)	(2.54)	(4.15)	(4.18)	(1.70)	(2.27)	(2.34)	(2.34)	(2.09)
Increasing1	7.60	8.57	12.39	12.21	12.25	10.55	9.11	6.16	7.53	6.66
	(9.74)	(11.07)	(13.12)	(8.40)	(7.81)	(8.84)	(7.02)	(8.70)	(3.89)	(6.98)
Increasing2	5.95	8.81	11.27	10.81	9.48	9.23	6.66	7.06	5.11	3.71

	(8.78)	(13.30)	(13.38)	(9.25)	(6.80)	(7.25)	(6.70)	(3.59)	(2.98)	(1.25)
Increasing3	3.63	7.70	13.80	12.50	14.36	13.15	10.56	7.00	6.01	4.10
	(3.74)	(15.30)	(22.19)	(11.40)	(11.20)	(7.20)	(6.64)	(4.63)	(3.54)	(2.63)
Dry1	4.39	7.44	7.83	7.60	9.10	9.88	8.62	8.83	8.52	8.65
	(10.70)	(15.53)	(4.05)	(6.72)	(4.36)	(3.56)	(3.51)	(3.50)	(3.57)	(3.25)
Dry2	7.69	10.32	10.29	8.27	10.58	9.45	9.37	8.31	7.17	6.64
	(7.04)	(14.35)	(10.32)	(6.75)	(7.80)	(6.70)	(9.44)	(4.21)	(5.13)	(4.20)
Dry3	6.43	9.74	13.36	17.92	16.25	14.25	14.94	13.57	11.92	10.03
	(18.72)	(23.41)	(21.91)	(15.13)	(14.81)	(19.13)	(15.34)	(27.56)	(13.32)	(11.23)
Baseline1	5.52	5.89	6.60	7.07	6.95	7.50	5.17	6.36	6.80	4.57
	(16.56)	(9.95)	(7.76)	(19.01)	(7.33)	(4.75)	(4.42)	(4.19)	(5.38)	(2.20)
Baseline2	4.45	5.36	5.84	7.02	6.55	6.92	6.00	6.86	8.84	5.66
	(5.77)	(5.82)	(5.00)	(6.58)	(4.65)	(5.30)	(3.86)	(5.78)	(4.59)	(3.73)
Baseline3	5.96	11.04	13.57	11.80	9.40	8.45	9.05	8.03	8.57	5.20
	(4.60)	(14.94)	(25.06)	(9.57)	(17.45)	(7.91)	(5.67)	(8.85)	(5.89)	(5.59)

* denotes significantly different from expectations at the 5% level
[a] numbers in parentheses are standard errors

Table 2: Welfare Gains/Losses as a Percentage

	Trading Round										
	1	2	3	4	5	6	7	8	9	10	Sum
Decreasing1	-3.00	-5.99	-4.55	-9.05	84.34	51.63	71.52	47.91	39.66	41.66	21.14
Decreasing2	-4.57	-2.37	-10.04	-5.87	84.34	57.10	63.08	57.90	52.96	38.19	22.32
Decreasing3	-0.41	-2.35	-4.60	-4.24	85.01	38.77	52.60	60.38	42.13	46.07	21.84
Increasing1	11.73	31.77	40.86	67.60	50.81	86.66	-3.19	6.04	7.52	8.97	23.66
Increasing2	34.02	29.16	54.16	73.03	56.94	84.31	-0.63	-2.07	3.23	11.90	25.73
Increasing3	22.33	44.68	49.25	59.08	27.44	79.80	-3.29	-1.59	1.76	8.35	21.17
Dry1	51.14	44.65	57.83	71.53	53.22	53.84	63.85	39.29	40.11	73.65	54.91
Dry2	44.00	60.86	68.22	71.93	53.22	40.47	73.15	54.17	48.32	77.59	59.19
Dry3	43.21	49.11	58.52	58.08	51.34	33.09	60.07	39.95	23.15	68.09	48.46
Baseline1	45.29	-3.66	79.86	2.26	-3.46	83.73	-0.63	84.84	82.32	6.85	25.60
Baseline2	35.11	-5.82	56.21	-16.85	-3.61	80.90	-6.79	85.87	72.47	-2.91	17.58
Baseline3	56.07	1.91	69.83	1.20	-20.48	66.02	-2.78	65.50	72.16	-7.29	18.65

5. Economic, Institutional, and Policy Conclusions

As described before, most hydrological models are complex, and still in this day and age, require large computing capacity and relatively long turn-around times. This paper illustrates that these models can readily be stripped-down to the essentials necessary for their successful integration into a real-time economic trading environment. Water displacements caused by market trades can be instantaneously recalibrated into a river/basin model.

We were surprised at how quickly our participants, most of whom are jointly unfamiliar with trading in a double-oral-auction and the strategic problems of farming, were able to rapidly discover efficiency prices in these experiments. We were also surprised at how short the lag time was when efficiency prices had to be rediscovered in the decreasing and increasing water scenarios. This having been said, it is probably the case that if we relabeled some of the words in our experiment, for instance gasoline for water, pipeline for river, and leakage for evaporation, that the experiments might have resulted in similar outcomes. Our student-subjects had to pay attention and make smart decisions during the experiments if they wanted to earn higher cash payoffs. But in the end, the experiments did not affect their lifestyles.

As we consider the Rio Grande and dozens of other river/basin systems in the western U.S. as well as other arid regions of the world, it is clear that the efficiency outcome will often, in the long term, involve more transfers of water from farming and other agriculture uses to cities and various environmental concerns. This transition, either through command and control policies or through the use of markets, will affect peoples' lifestyles. The results reported in this paper combined with the evolving delineation of water property rights currently occurring in the western U.S. suggest that markets may play a pivotal role in framing water policy.

We began this paper with the notion that when people talk of crises, economists start looking around for market failures. We end with an old economic postulate: voluntary exchange leaves both parties to the exchange better off. The results of this paper illustrate that even when the political, physical, and property rights issues relating to water are added to the equation, the principle of voluntary exchange leaving both parties better off can still hold true for water.

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Estimating Agricultural Benefits Under Changing Water Supply Conditions
Rob Davis

INTRODUCTION

This report describes three methods for estimating economic benefit values for irrigation water.

The first methodology described is followed by the Bureau of Reclamation (and other government agencies) when estimating the agricultural benefits to an existing or proposed project. In this case, the Bureau of Reclamation has to follow the criteria for measuring National Economic Development (NED) benefits defined in The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, March 10, 1983 (P&G's). The P&G's are the federal guidelines by which Reclamation determines NED benefits of federal actions or project implementation. A P&G analysis of NED benefits is a "with and without" project comparison. The economic output estimated under the "without" project condition is compared quantitatively to the economic output of the "with" project condition to estimate the net benefits to the agricultural sector.

The second method has been used in an appraisal study on the Lower Republican River Basin and does not conform to the analysis prescribed by the P&G's. In this example, agricultural benefits arising from a small increase in water supply are driven by an estimated change in crop yields. Partial-crop budgets and a crop-yield estimator program were obtained from the University of Nebraska at Lincoln and used in the analysis. The net farm incomes for a "without" project condition and a series of "with" project conditions were estimated. Then, the net farm incomes from each "with" project condition were compared to the net farm income from the "without" project condition. After determining the net present value of agricultural benefits for each "with" project condition, a benefit-cost analysis was conducted to rank the "with" project conditions.

In the last example presented, agricultural benefits are defined as avoided pumping costs under differing scenarios of water deliveries. This example focused only on estimated on-farm pumping costs borne by farmers over the life of the project. Assumptions of the study included a steady water supply over the life of the project. Each acre in the district is assumed to receive 12 acre-inches of water each year. The 12 acre-inches delivered comes from natural flow rights, storage deliveries, and pumped groundwater. Because the reservoir is spring-fed and the amount of inflows is declining, storage water deliveries are intermittent and in small amounts on a per-acre basis. This example simply determines the changes in pumping costs and compares them between a "without" project condition and a "with" project condition.

CENTRAL VALLY OF CALIFORNIA AGRICULTURAL BENEFITS EXAMPLE

This study proposed a method for estimating National Economic Development (NED) agricultural benefits for multiple irrigation districts in the Central Valley of California. Before the advent of river basin level modeling, NED agricultural benefits were calculated for individual irrigation districts. It was feasible to estimate NED agricultural benefits for individual irrigation districts, or even as many as five or six irrigation districts at one time because the economist could gather the needed data and complete an NED agricultural benefits analysis in a fairly reasonable time frame.

After river basin level modeling became an effective tool, multiple irrigation districts (more than 10) were often involved in any reservoir re-operation or Safety of Dams studies in the Central Valley. Water operations in the Central Valley, even from a single reservoir, have implications for irrigated agriculture throughout the Central Valley. Because of the widespread effects of reservoir re-operations or Safety of Dams studies, and the fact that as many as 250 irrigation districts may be affected, the old method of estimating NED agricultural benefits becomes untenable. It would simply be too time-intensive and expensive for an economist (or a team of economists) to estimate NED benefits for every study undertaken in the Central Valley for that many irrigation districts.

The process for arriving at the NED agricultural benefits for a selected study used the following methodology. After a study, such as safety of dams or operations, has been initiated, the hydrology models estimate irrigation water deliveries from a reservoir. The output from the hydrologic model (water deliveries) is used as an input to an agricultural impact model (Central Valley Production Model, or CVPM). The CVPM estimates the changes in irrigated crop production for different production regions within the Central Valley of California based on the distribution of water deliveries. The change in irrigated crop production is shown as a change in irrigated acres.

The change in irrigated acres, when coupled with P&G agricultural benefits budgets, can be used to estimate the incremental changes in NED agricultural benefits. NED agricultural benefits are calculated by taking the difference between two modeled scenarios; one scenario shows the number of irrigated acres under a "without" project condition and the other shows the number of irrigated acres under a "with" project condition. For both the "without" and the "with" project conditions, the number of irrigated acres are multiplied by the NED agricultural benefit value, which is generally expressed as a dollar value per acre. The difference between the two conditions is the incremental agricultural benefit to the nation.

Crop budgets used for the NED agricultural benefits post-processing model were determined by selecting a representative, single budget for a crop in any of the 21 regions residing in the CVPM model. The budgets having the most common cultural practices and using the most common inputs were used for the study.

Normalized prices are used in NED agricultural benefit studies, as required by the P&Gs. Normalized prices are published by the United States Department of Agriculture (USDA) annually for common crops produced throughout the United States. If the USDA does not publish a normalized price for a crop, the P&Gs recommend using a three-year average of state-level prices as being comparable to the published normalized price.

In addition to requirements for prices used in an NED agricultural benefits analysis, the P&G's require specific assumptions about interest rates, debt-equity levels, and returns to the farmer's equity, management, and labor. Common assumptions were incorporated into all the enterprise budgets used in the Central Valley analysis.

After entering the information from the University of California, Davis (UCD) cost and return studies into the Bureau of Reclamation's farm budget program and changing the assumptions to satisfy the P&G requirements for NED agricultural benefits studies, the net results on a crop enterprise level were obtained. Table 1 shows the net benefit unit values by crop.

Table 1. NED Benefits by Crops.

Crop	CVPM Crop Name	Net Benefits Unit Value	Without Project Net Return	With Project Net Return
Almonds	AL_PIST	$4,577.86	-$1,213.71	$3,364.15
Alfalfa	ALFALFA	$209.99	-$290.97	-$80.98
Corn Silage	CORN	$56.24	-$290.97	-$234.73
Cotton	COTTON	$53.62	-$290.97	-$237.35
Broccoli	CUCURB	$-366.86	-$290.97	-$657.83
Dry Beans	DRYBEAN	$86.72	-$290.97	-$204.25
Wheat	GRAIN	$41.82	-$290.97	-$249.15

Cantaloupe	OTH_TRK	$-1,288.05	-$290.97	-$1,579.02
Grapes	VINE	$3,952.54	-$1,213.71	$2,738.83

NOTE: The row crop "without" project budget had a net return of -$290.97 per acre. The permanent plantings "without" project budget had a net return of $-1,101.93 per acre.

ESTIMATING AGRICULTYRAL BENEFITS WITH CHANGING YIELDS

This example is based on operational changes proposed for the Lower Republican River, including modification of the timing of flows, bypass flows, and increasing the storage capacity of a reservoir. The economic portion of the appraisal study estimated the economic benefits accruing from the changes to operations. The benefits were then compared to project costs arising from the implementation of the selected Alternative.

Only the most dominant crop for the area, corn, was modeled. The numbers used in the example are representative of local conditions for farmers in the affected area.

Methodology

One method for estimating irrigation benefits is to isolate the incremental net farm income from small changes in the irrigation water supply. To determine the incremental income, the net farm income in a "without project" baseline condition is compared to a "with project" condition. For small changes in the water supply, the best indicator of benefits comes from predicted changes in yields. Agricultural economists with the University of Nebraska in Lincoln (UNL) have published articles and provided spreadsheet models which estimate yields for varying water supply levels, several crops, and some of the more prominent soil types in Nebraska. Included in the UNL publications are model coefficients for different regions of the state and the ability to modify the models to a particular range of water supplies.

The spreadsheet model incorporates plant growth dynamics with respect to soil and water. Thus, the model can predict yield changes assuming all other plant requirements such as fertilizer, etc are met. The model includes factors for the type of irrigation system used (e.g., furrow or sprinkler), the maximum yield that could be obtained and evapotranspiration (ET) rates. Input factors also include the ET and yield for dryland crops. The model then estimates incremental yields starting from the dryland yield average and up to the suggested maximum yield.

For this example, published average yields for southcentral Nebraska were used in the crop yield model. These values include average irrigated corn yields from two irrigation districts, county-average dryland corn yields from the Nebraska Agricultural Statistics Service, irrigation efficiency rates, effective precipitation, and crop irrigation requirements.

Benefit Estimation

Normalized prices published by the USDA Economic Research Service (USDA, ERS) were used to determine the change in gross revenues. Variable costs of production were taken from farm budgets prepared by the University of Nebraska. The only cost expected to change with yield was the harvesting cost. Other production costs were assumed to not change.

The annual irrigation benefits were transformed into a present worth value by taking the annual benefit into the future 100 years and then discounting it back to the present. The Fiscal year 2003 federal discount rate of 5.875 percent was used.

Once the yield estimation model was modified to account for the range of water supplies estimated by the hydrology models, the yield estimation model gave a range of corresponding yields. Water supplies ranged from a low of 11.5 acre-inches to a high of 13.8 acre-inches under the proposed Alternatives. Estimated yields ranged from a low of 154.5 bushels per acre to a high of 161.1 bushels.

Once the yields had been estimated, gross and net revenues under each Alternative were calculated. After finding the net revenues, or benefits, per acre, the total annual net benefits are computed by multiplying the per-acre benefit by the total number of acres that will receive a benefit. The total number of acres receiving benefits equal 65,435; of these, 22,935 are located in Nebraska and 42,500 acres are in Kansas. Therefore, the baseline total annual benefits are $12,559,172 (net income of $191.93 times 65,435 acres). If this amount of benefits accrue each year over the next 100 years and is then discounted back to today's dollars using a discount rate of 5.875 percent, the net present value will be $213,064,200. If the same process is followed for each selected Alternative, the incremental change caused by the Alternative can be calculated by taking the difference between the Baseline and the selected Alternative.

Benefit-Cost Ratio Analysis
Benefit-cost ratio analysis is one means of evaluating potential projects that have an economic life greater than one year and that have differently shaped cost and benefit streams. A benefit-cost analysis also lends itself to comparing across differently sized projects or similar projects that have different levels of implementation costs

Total implementation costs for each Alternative were estimated and ranged from $1,650,000 for Alternative H to $25,000,000 for Alternative G. The estimated implementation costs are shown in Table 2 along with the estimated benefits.

Table 2. Estimated Benefits and Costs of Implementation for Each Alternative.

Alternative	Estimated Benefits	Implementation Cost	B-C Ratio
Alt A	$1,638,993	$13,000,000	0.13
Alt B	$3,992,391	$2,000,000	2.00
Alt C	$5,502,118	$15,000,000	0.37
Alt D	$11,030,384	$3,600,000	3.06
Alt E	$11,663,138	$16,500,000	0.71
Alt F	$15,182,134	$12,000,000	1.27
Alt G	$15,714,979	$25,000,000	0.63
Alt H	$6,956,341	$1,650,000	4.22
Alt I	$6,956,341	$14,500,000	0.48

As can be seen, benefits do not exceed costs for all of the Alternatives. The Alternatives where benefits exceed costs include Alternatives B, D, F, and H. Alternative B has benefits that exceed costs by $1,992,391. Benefits for Alternatives D, F, and H exceed their implementation costs by $7,430,384, $3,182,134, and $5,306,341, respectively.

PUMPING COST REDUCTION
This example is based on a study done in the Upper Republican River Basin and focuses exclusively on effects to irrigated lands in a 9,300-acre irrigation district. More specifically, this analysis focused solely upon the changes in pumping costs borne by farmers under each of the selected Alternatives of the study.

Irrigation water supplies came from three sources: natural flow, storage water from a reservoir, and groundwater pumping. Natural flows were about four acre-inches per year. Storage deliveries were intermittent and small in terms of the amount of water delivered to each acre in the irrigation district.

Results from each of the four "with" project conditions were compared to a "without" project condition. The differences between the "with" and "without" project conditions were based on the amount of irrigation water pumped by farmers. The "without" project condition provided 4 acre-inches of natural flow water every year, 3 acre-inches of storage water once every 5 years, and groundwater pumping made up the difference so that a constant 12 acre-inches of irrigation water was applied each year.

The four "with" project conditions looked at in this study included a Flow Through condition where no storage water deliveries were made. In this case, natural flows increased to 4.6 acre-inches and groundwater pumping averaged 7.4 acre-inches per acre per year.

The second "with" project condition was a Groundwater Recharge Alternative. No storage water was delivered under this Alternative. No natural flows were delivered. Irrigated acres within the District received 12 acre-inches of pumped irrigation water each year of the study period.

The third "with" project condition was a Recreation Without Storage Deliveries Alternative where no storage water was delivered. Irrigated acres within the District received 12 acre-inches of pumped irrigation water each year of the study period.

The fourth "with" project condition was a Recreation With Irrigation Deliveries Alternative. Under this Alternative, the District delivered 2 acre-inches of storage water every 5 years. Irrigated acres received 8 acre-inches of pumped water and 4 acre-inches of natural flow in four of every five years. In the fifth year, the acres received 5 acre-inches of pumped water, 4 acre-inches of natural flow, and 3 acre-inches of storage water.

Analysis Methodology

This analysis had the following assumptions:

1) Water applications were a constant 12 acre-inches for all years.
2) Storage water deliveries came every 5 years, at different rates for the selected Alternatives.
3) In years that storage water was available, pumping made up the difference between the storage water amount and the 12 acre-inches that was assumed to be the "full" supply.
4) Pumping energy costs were inflated 5 percent per year over the analysis period.

The basic assumption for this analysis was that 12 acre-inches of irrigation water was a "full" supply. In the years where storage water was delivered to District acres, there would be less pumping. For example, in years that no storage water is delivered to farms, 12 acre-inches of water per acre will be pumped. On the year that 4 acre-inches of storage water is delivered, only 8 acre-inches of water will be pumped. Thus, the impacts were based on a change in pumping costs.

Yield was held constant over the period of analysis. Pumping energy costs were inflated 5 percent per year.

After estimating the pumping cost for each year in the period of analysis and for the amount pumped under each Alternative, the costs were deflated back to current-year (2008) dollars. The current planning rate of 4.875 percent was used as the deflator. Once the pumping costs were estimated for each Alternative, they were compared to the Future Without Alternative.

Results
To complete the analysis, the results from each of the Alternatives were compared to the Future Without Alternative. Table 3 shows the sum of the pumping costs for each of the Alternatives.

Table 3. Sum of Pumping Costs for All Acres in the District, by Alternative.

Alternative	Acre-Inches Pumped	NPV of Total Costs	Difference
Future Without	8 or 5	$4,962,218	
Flow Through	7.4	$4,955,631	($6,587)
Groundwater Recharge	12	$7,761,089	$2,798,871
Recreation w/o Deliveries	8	$5,338,819	$376,601
Recreation w/ Deliveries	8 or 6	$5,074,924	$112,706

The Future Without Alternative had pumping costs of $4.962 million. In this Alternative, 3 acre-inches of storage water were delivered every 5 years over the period of study. Thus, a repeating cycle of pumping 8 acre-inches for four years was followed by one year of pumping 5 acre-inches of water. Each year, there were 4 acre-inches of natural flow delivered.

The Flow Through Alternative had 4.6 acre-inches of natural flow delivered annually. Thus, for each acre to receive a 12 acre-inch supply of irrigation water, 7.4 acre-inches were pumped. There were no storage water deliveries made in any year. Total pumping costs for the Flow Through Alternative, at $4.955 million were $6,600 lower than the Future Without Alternative pumping costs.

The Groundwater Recharge Alternative had no natural flow deliveries made, nor were there any storage water deliveries. Under this Alternative, the highest pumping costs are seen, estimated at $7.76 million. Pumping costs for this Alternative were $2.8 million higher than the Future Without Alternative.

The Recreation Without Deliveries Alternatives had no storage water deliveries. However, there were natural flow deliveries of 4 acre-inches annually, so the amount pumped per acre was 8 acre-inches. Total pumping costs came to $5.34 million under this Alternative, $377,000 higher than the Future Without Alternative pumping costs.

The Recreation With Deliveries Alternative pumping costs came to $5.07 million. A repeating cycle of four years of pumping 8 acre-inches of water combined with 4 acre-inches of natural flow deliveries was followed by one year of pumping 6 acre-inches of water combined with 4 acre-inches of natural flow deliveries and 2 acre-inches of storage water deliveries. The Recreation With Deliveries Alternative had pumping costs of $113,000 more than the Future Without Alternative.

Ecology and conservation of the San Pedro River: Integrating Science and Policy for Water Management

Holly Richter, David C. Goodrich,
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The politicization of science is undoubtedly a slippery slope. But so is the scientization of politics. The boundary organization does not slide down either slope because it is tethered to both, suspended by the coproduction of mutual interests.
(Guston 2001)

Introduction

Freshwater and the ecosystems from which it originates are indispensable to human health and survival. Yet, population growth, climatic variability, and land uses such as mining and agricultural practices along the U.S.- Mexico border challenge our ability to adequately manage this indispensable resource. As the Southwest grapples with ways to increase water supplies and ensure water quality for its burgeoning population, various institutional and political drivers of change, including government agencies at all levels and elected officials trying to serve their constituents' interests, directly affect water management policies in the region.

This chapter describes the collaborative efforts of scientists, agency representatives, non-governmental organizations, elected officials, and other stakeholders (table 21.1) to address water policy and management issues in the Sierra Vista subwatershed of the upper San Pedro River basin. The recent efforts of the Upper San Pedro Partnership (the Partnership) to manage groundwater resources through an adaptive management approach are described. Adaptive management has been described as implementing projects or policies as experiments (Holling 1978, Walters 1986). This approach does not postpone action until "enough" is known, but instead acknowledges that time and resources are too short to defer *some* action, particularly actions to address urgent problems (Lee 1999).

TABLE 21.1. **The twenty-one member agencies and organizations of the Upper San Pedro Partnership, as of 2007.**

Arizona Association of Conservation Districts
Arizona Department of Environmental Quality
Arizona Department of Water Resources
Arizona State Land Department
Audubon Arizona
Bella Vista Ranches
Cities of Sierra Vista, Tombstone, and Bisbee
Cochise County
Fort Huachuca (Department of Defense)
Hereford Natural Resource Conservation District
The Nature Conservancy
Town of Huachuca City
U.S. Agricultural Research Service
U.S. Bureau of Land Management
U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
U.S. National Park Service

The work of the Partnership has evolved the furthest of any watershed group in the San Pedro basin to date. This progress is at least partially attributable to the federal mandates and regulatory levers at play within this portion of the basin. However, there is a need for similar water management efforts in other portions of the basin, and the need for a more integrated basin-wide approach is apparent. The binational context of the upper San Pedro basin complicates integrated watershed management (Liverman et al. 1999), and the potential risks and uncertainty associated with ineffective basin-wide groundwater management remain high for all stakeholders. The Benson subwatershed is looking to Sierra Vista upstream for evidence of good management, and Sierra Vista is looking to the Sonoran portion of the basin for indications of progress in establishing watershed governance. Unfortunately, water within different portions of the basin have no effective venue for communication or coordination with one another. However, the Mexican Binational San Pedro Commission recently invited the Partnership to embark on a series of meetings for planning and information exchange.

Each of the three subwatersheds within the upper basin has responded in various ways to meet their respective groundwater-management challenges. Some efforts have made much more progress than others in terms of the implementation of technical studies and/or water management projects or policies. The ability to initiate studies or implement projects is largely dependent upon the resources available, which, in many cases, reflects the leverage provided from legal mandates and political context. Efforts in the Sierra Vista subwatershed have secured the most resources to date, where federal mandates associated with both Fort Huachuca and the San Pedro Riparian National Conservation Area (SPRNCA) strongly affect policy and decision making. However, even without this leverage, the motivation and initiative demonstrated by local residents in a given area can play a pivotal role in launching watershed initiatives, as has occurred in the Benson subwatershed.

In Mexico, the responsibility for water management has been decentralizing since the 1990s. The onus has shifted from the Mexican National Water Commission (CNA) to local water users such as state and municipal offices and agricultural water-use associations in irrigation districts (Browning-Aiken et al. 2004). The National Water Law in Mexico (Ley de Aguas Nacionales 1997) calls for the development of localized watershed councils and irrigation districts to serve water users, establish water infrastructure, and preserve water resources in the borderlands. However, in reality, Mexican municipalities along the U.S.-Mexico border remain very dependent upon the federal government or upon a mixture of national and international sources for investment in water infrastructure projects (Romero-Lankao 2002). Local initiatives along the northern Mexican border are linked to national policy demands. In addition, the CNA, despite its policy of decentralized water management, has been slow to support the development of a Mexican water council in the San Pedro, a necessary step in establishing good governance in the Mexican portion of the basin. Also complicating matters is the fact that Mexican environmental policy frequently runs counter to Mexican economic policy, especially in terms of mineral resources and maquiladoras along the northern border (Browning-Aiken et al. 2006). Considerable challenges to good governance remain with water policy implementation in Mexico, which hamper policy makers' abilities to address issues of equitable access to clean water, sustainable development of water resources, and ecosystem protection in the context of climate variability.

On the U.S. side of the border, the Sierra Vista subwatershed has been subject to considerable pressure from sociopolitical drivers with regard to water management over the past decade in the form of federal and/or international mandates, such as the Commission for Environmental Cooperation in 1999 and the Defense Authorization Act in 2004. Two significant national assets in that area, then SPRNCA and Fort Huachuca, home of the U.S. Army Intelligence Center, have resulted in a myriad of strong drivers and in the establishment of a highly developed, collaborative water management effort in this subwatershed.

In contrast, the Benson subwatershed, located downstream, lacks this level of federal participation. However, accelerated rates of residential development and large-scale master-planned communities are proposed for the area, likely a result of its proximity to Tucson. A newly established watershed coalition, the Community Watershed Alliance of the Middle San Pedro Valley, led by landowners, residents, and other organizations and government entities, was formed in 2005 to "promote collaboration and cooperation to advance research, education, and policies for the sustainable health of their watershed." They are assisting the U.S. Geological Survey and other agencies and organizations by helping to coordinate research and monitoring studies with private landowners in the area, and initiating watershed improvement projects, among other endeavors.

To a limited degree, monitoring and research data have been shared between individual scientists and agencies conducting studies throughout the upper San Pedro basin, yet regional water management planning or coordinated project implementation among the three subwatersheds has not begun. In addition, it remains unclear what entity might provide this type of integration in the future.

Drivers of Change in the Upper San Pedro:
Federal and International Mandates and State Programs

The upper San Pedro River was designated as the first Riparian National Conservation Area in the United States in 1988, when the San Pedro Riparian National Conservation Area (SPRNCA) was established by the U.S. Congress as part of Public Law 100-696. The SPRNCA's enabling legislation established the existence of federally reserved water rights to maintain the riparian ecosystem (B. Childress, personal communication). Approximately a decade after the SPRNCA's designation by Congress, a team of experts was commissioned by the trinational (Canada, United States, Mexico) Secretariat of the Commission for Environmental Cooperation (CEC 1999a) to produce an interdisciplinary study of the upper San Pedro basin, intended to "serve as an example of how to protect a transboundary watershed" (Udall Center 1998, Varady et al. 2000). This study elevated the San Pedro basin issues to national attention (Christiansen 1999, Kingsolver 2000).

Following the CEC report, during the 1999 binational Divided Waters, Common Ground conference on the upper San Pedro River basin (Brady et al. 2000), then – Secretary of the Interior Bruce Babbitt provided further incentive for local decision makers to work together for effective watershed management. The secretary noted that if effective local management could not be brought to bear on the San Pedro's water issues, then external forces, such as the federal courts, would impose restrictions or management plans. Collectively, these federal drivers began to highlight the growing need for more collaborative approaches toward water management.

In 1999, Governor Jane Hull established the Rural Watershed Initiative to address rural watershed-management issues throughout Arizona. Administered by the Arizona Department of Water Resources, this program was intended to stimulate rural watersheds to develop their own water management plans with input from local citizens and stakeholders. Funding for water resource studies was provided to those rural areas that created watershed groups. The Partnership was one of seven initial watershed groups that formed in response to this initiative. To formalize and document the Partnership's commitment to work together, a total of 21 private, public, and non-governmental organizations eventually signed a Memorandum of Understanding (MOU) that defined the purpose of the group: "to coordinate and cooperate in the identification, prioritization, and implementation of comprehensive policies and projects to assist in meeting water needs in the Sierra Vista Subwatershed of the Upper San Pedro River Basin" (http://www. usppartnership.com). Nothing within the MOU limits the respective legal authorities or decision-making ability of any of the participants or requires expenditures of funds; membership in the group is strictly voluntary. This group serves as a "boundary organization," as described by Guston (2001), in that it blurs the boundaries between science and politics, directly linking scientists with decision makers and, in the process, not only serves the mutual interests of both but also leads to more productive decision making. In 2002, the U.S. Fish and Wildlife Service issued Fort Huachuca a Biological Opinion on its compliance with Section 7 of the Endangered Species Act. The Biological Opinion addressed several endangered or threatened species potentially affected by Fort Huachuca's activities, including the southwestern willow flycatcher (*Empidonax traillii extimus*) and the Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*), both riparian species. Within this document the Sierra Vista subwatershed groundwater deficit was quantified as 5,144 acre-feet per year. Fort Huachuca committed to implement conservation measures resulting in water savings of 3,077 acre-feet per year toward this deficit. In addition, the Fort requested that the communities and agencies within the Partnership commit to reduce by 3,306 acre-feet per year the estimated groundwater pumping demands projected by 2011. Clearly, at this point, the role of the Partnership as a coordinating water management body had been recognized, even though the group had no formal regulatory authority.

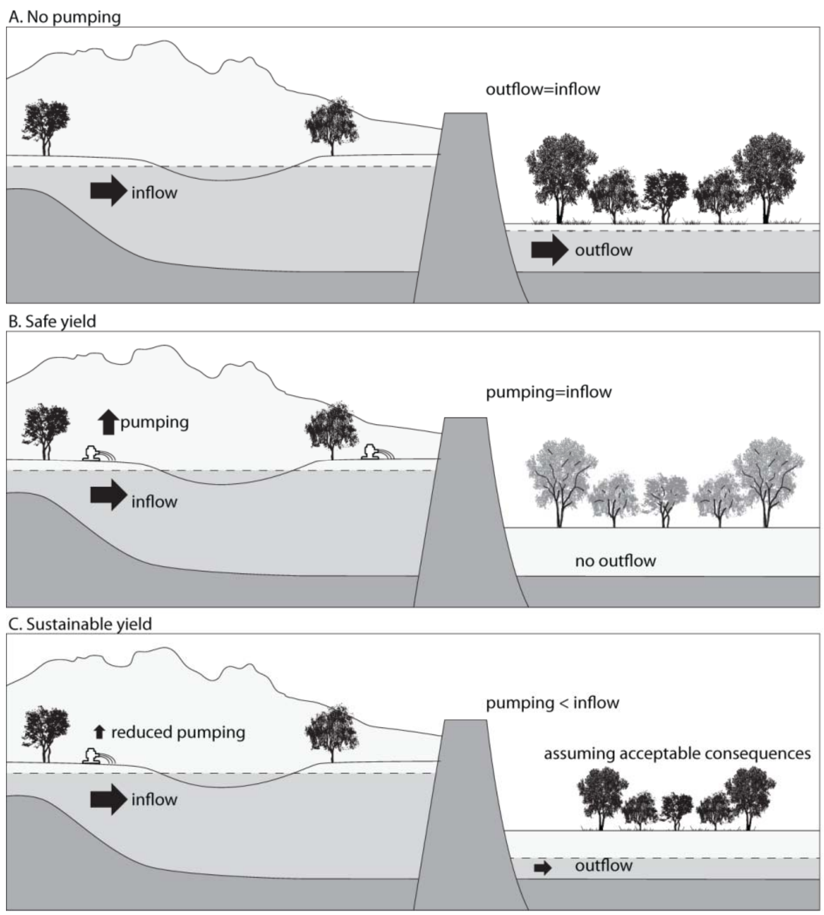

Fig. 21.1. Reservoir analogy to the response of a groundwater system to pumping comparing no pumping with safe yield and sustainable yield (USDI 2005).

One of the most recent legislative drivers within the Sierra Vista subwatershed is Section 321 of the National Defense Authorization Act of 2004, Public Law 108-136 (see chap. 22). The incentive, or "carrot," of this bill in terms of local interests is the potential for federal funding for conservation projects, scientific research, and monitoring needs. The cost, or "stick," is the requirement to report "measurable annual goals for the reduction of the overdrafts of the groundwater of the regional aquifer, identified specific water use management and conservation measures to facilitate the achievement of such goals, and identified impediments in current federal, state, and local laws that hinder efforts on the part of the Partnership to mitigate water usage in order to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011" (Upper San Pedro Partnership 2004 — Appendix 3). The legislation shifted the focus of groundwater- management efforts from balancing a water budget, or safe yield, toward the concept of sustainable yield, a more comprehensive concept involving broader social, economic, and environmental factors. Under safe yield, wherein total groundwater withdrawals are equal to total recharge, no groundwater is allocated toward riparian or instream uses (fi g. 26.1). The Partnership subsequently began to define criteria for meeting sustainable yield (table 2) through a consensus process (USDI 2005).

TABLE 22.2. Initial criteria established by the Upper San Pedro Partnership for sustainable yield of groundwater.

Social and economic

- Sufficient water quantity for human needs
- Fort Huachuca remains operational unless for reasons unrelated to water
- Cost of living, specifically affordable housing and the cost of doing business, remains within the means of a diverse population
- Maintain local participation in water management
- Sustain water quality

Environmental

- Groundwater levels in alluvial aquifer within the SPRNCA maintained
- Stream baseflow and flood flows maintained
- Accrete aquifer storage
- Riparian habitat and ecologic diversity maintained
- Water quality sustained in SPRNCA
- Overall riparian condition maintained
- Springs in the SPRNCA continue to flow

Constantly Rising Stakes: Increasing Demand and Prolonged Drought Conditions

Population growth and prolonged drought have also been key incentives for action. Increasing human demands on groundwater resources are widespread, as populations continue to grow on both sides of the international border. Much of the population growth within Cochise County on the U.S. side has occurred in unincorporated areas. The county as a whole experienced a growth rate of 10.6 percent from 2000 to mid-year 2004. The recent multi-year drought, which began in many areas in 1999, pales in comparison to earlier periods of aridity in the western United States over the past 1,200 years (E. Cook et al. 2004), but nonetheless it is an important factor affecting water demand and supply in the region. Risks associated with drought are a product of both the severity of the event and the vulnerability of society (and the environment) to the event. At a minimum, recent climatic trends have increased the awareness by local decision makers regarding the amount of variability in precipitation patterns, and the uncertainty and vulnerability associated with managing for “average annual” rates of precipitation and groundwater recharge. Water and climate surveys assessed the quality and usability of climate and hydrologic information available to water managers and communities in the Mexican portion of the San Pedro River basin. The surveys indicated that the central concern for urban residents is the lack of reliable potable water due to frequent service breakdown with climate change and variability, specifically drought and high temperatures, as contributing factors (Browning-Aiken et al. 2007).

Scientific Studies in the Sierra Vista Subwatershed

To meet the water management challenges presented by the federal mandates (i.e., federally reserved water rights, Biological Opinion for Fort Huachuca, Section 321 legislation), Partnership member agencies needed to establish sound research and monitoring programs that could be used to inform science-based decisions. The upper San Pedro basin has long served as an outdoor laboratory for scientific investigations aimed at increasing understanding of physical watershed processes. The U.S. Department of Agriculture’s (USDA) Walnut Gulch Experimental Watershed has been researching hydrologic processes and soil erosion for more than 40 years, and other research efforts date back to the nineteenth century.

Since 1988, research investigations in the upper San Pedro basin have progressed so as to allow scientific information to be a much more integral part of water management decisions. Interagency and interdisciplinary efforts, such as the Semi-arid Land-Surface-Atmosphere (SALSA) Program and the University of Arizona's Center for the Sustainability of Semi-arid Hydrology and Riparian Areas (SAHRA), a National Science Foundation Science and Technology Center, have allowed investigators to address larger spatial scales and more complex ecosystem processes. SALSA identified the consequences of natural and human-induced change on basin-wide water balance and on ecological complexity of semi-arid basins at event, seasonal, interannual, and decadal timescales. SAHRA identified stakeholder-relevant questions on which to focus its scientific research, all of which bear on management of water resources in semi-arid regions.

The Partnership has funded or facilitated technical studies that have served three primary purposes: (1) to identify and acquire key data sets that can increase understanding of hydrologic systems and/or processes that have water management implications, (2) to develop predictive modeling tools and forecast specific outcomes in response to land/water management actions, and (3) to investigate and develop new water conservation, recharge, or augmentation strategies. One of the leading studies facilitated by the Partnership was the "Hydrologic requirements of and consumptive groundwater use by riparian vegetation along the San Pedro River, Arizona" (see chap. 20). This interagency research effort by the U.S. Geological Survey, the USDA – Agricultural Research Service, and Arizona State University served both to estimate evapotranspiration losses from the riparian corridor and define the hydrologic context needed to sustain that ecosystem over the long term. Other studies have been undertaken to better understand stormwater and groundwater recharge processes, develop a regional groundwater model, and develop a decision support system. Additionally, costs and benefits for dozens of potential water conservation and reclamation projects were analyzed, and several augmentation alternatives were assessed.

Collaborative Learning Processes:
Bringing Scientists and Policy Makers to the Table

In addition to generating information, these technical investigations also served as a venue for initiating collaborative learning processes within and between groups of scientists and decision makers. This motivated them to jointly frame their information needs and initiate group processes toward building consensus on key issues. However, decision makers had to be patient enough to endure long technical discussions, and scientists had to engage in understanding fully the social, economic, and political sideboards and constraints. Discussion of the uncertainties involved and the potential risks associated with those uncertainties early on, even before actual results were produced, helped to manage expectations as to what science could actually deliver. In the long run, the process will hold participants more accountable to one another, increase confidence in results regardless of outcome, and help all participants attain a deeper understanding of complex information on which to base decisions.

Decision makers and scientists typically operate under different time frames and constraints, and often with misconceptions about one another. The world of decision makers revolves around societal values, beliefs, and perceptions; political considerations; definite deadlines; and limited budgets. The culture of scientists involves establishing facts, taking measurements, and making incremental progress over time (V. Baker 1998, Moran and Heilman 2000). Although scientists are often influenced, even unwittingly, by their own values and beliefs, their ability to work effectively with decision makers is greatly improved if they remain objective and unbiased by these factors as they design, implement, and ultimately communicate the results of scientific investigations. To work together effectively, scientists and decision makers must accommodate each other's needs.

Evaluating Success

In 2003, Partnership members and frequent attendees to Partnership meetings were surveyed to evaluate the midcourse effectiveness of the collaborative process (Browning-Aiken et al. in review). The survey's intent was to identify strengths and weaknesses in the group's collaborative process, and to pinpoint strategies in organizational structure and problem-solving processes from which other Arizona watershed organizations could benefit. Participants were asked about (1) the nature of basin water issues, (2) management goals and priorities, (3) organizational structure, (4) stakeholder identification and positions, (5) the method of selecting and interpreting scientific and technical information, (6) the nature of stakeholder collaboration within the watershed, (7) the processes of planning and decision making, (8) the method of leader or facilitator selection, including the qualities of effective leadership, and (9) the method of establishing authority within the regional community.

One clear finding was that success in accomplishing the group's mission was correlated with the extent to which scientific "research findings [have] been interpreted or used by the Partnership to make management decisions." Ninety percent of the Partnership members and participants considered scientific studies as one of the most important projects undertaken by the watershed initiative. This finding pointed to the key role of research and monitoring (from the viewpoint of participants in watershed group meetings) in achieving the group's mission of sustainably managing water. Another finding was that almost half (47 percent) rated both the group's accomplishment of its mission and its capacity to identify water problems as relatively high, while the Partnership's success in addressing basin water problems was rated either as very high (37 percent) or average (37 percent).

Adoption of an Adaptive Management Framework

Collaborative water-conservation planning efforts by the Partnership have continued to evolve since the establishment of the group in 1998. During their first two years, Partnership members focused on defining common ground: shared groundwater-management goals and objectives, and associated information needs. The original intent of these planning efforts was to develop one comprehensive, long-term conservation plan for the Sierra Vista subwatershed by 2005. By 2002, their initial goal of developing one definitive plan evolved into a more complex, yet flexible, ongoing adaptive management planning process. They began to recognize that certain key management concepts that became apparent during ongoing investigations could be applied to decision making before the studies were finalized, and they wanted to be able to assess the benefits of projects that were already underway so that they could adjust their objectives and strategies as appropriate. Finally, they continued to discover additional gaps in their knowledge as their understanding of key issues increased. Thus, they established an iterative planning process and produced their first annual plan in 2003.

To construct the plan, the Partnership inventoried and categorized all member agency water management projects, policies, and programs currently underway. From this baseline inventory, the Partnership prioritized additional collaborative efforts for the coming year and published this information in their "Working Water Conservation Plan" completed in 2003. This plan was subsequently updated and revised based on new information and developments, and an annual adaptive management cycle became established. The shift to an adaptive management approach, while representing perhaps the best chance for incorporating good science into decision making over the long term, also represented a huge increase in the commitment of the stakeholders. No single document now marks the end of their planning efforts, defines total funding needs for science, or even assures absolute certainty or success as a result of these efforts. The definition of success itself became even more of a moving target as a more comprehensive understanding of this complex hydro-ecological system was developed. The overall goal of the Partnership's adaptive management planning process is "to ensure an adequate long-term water supply is available to meet the reasonable needs of both the area's residents and property owners (current and future), and the San Pedro Riparian National Conservation Area" (http://www.usppartnership.com). This goal is interpreted in terms of the aforementioned legislative and regulatory drivers affecting the area.

STRENGTHS AND CHALLENGES OF THE ADAPTIVE, COLLABORATIVE MANAGEMENT FRAMEWORK

This adaptive management framework, like all others, involves active and focused learning on the part of both scientists and decision makers and an acknowledgement that their current understanding of the issues is not perfect. The process also has the potential to openly communicate the Partnership's increasingly detailed understanding of complex systems to external audiences, including the general public (Holling 1978, Walters 1986, 1997).

One great challenge in collaborative groundwater management relates to timing issues associated with planning, research, and the implementation of projects and policies. Research and conservation planning typically do not commence until there is a perceived problem that merits attention. Unfortunately, the acquisition of data of sufficient quality and credibility to enable decision making requires a substantial investment of time and resources. Therefore, decision making will be limited, at least at the onset of planning efforts, by the amount of information that is readily available and considered acceptable to all interests concerned. Additional data collection will likely be required, particularly to support decisions that involve high financial, political, or environmental risks, and/or high levels of uncertainty. Thus, certain decisions could be delayed due to lack of information. One strength of an adaptive management approach is that it allows actions that have low risk or uncertainty to be taken early on. Partnership member agencies realized that the implementation of certain water management strategies requires substantial information through monitoring, research, and modeling efforts as well as political assessments, while other projects represented relatively low-risk strategies whose implementation could be more immediate. In 2003, the Partnership identified more than 100 projects for immediate implementation, ranging from the repair of leaky infrastructure, car-wash water recycling, voluntary retirement of agricultural pumping through conservation easements, recharge of treated effluent, and reintroduction of beavers. In their 2004 Water Management and Conservation Plan, the Partnership prioritized additional projects for implementation, including the development of model codes and ordinances, the establishment of water-conservation surcharges for excessive use, exploration of a transfer -of- development-rights (TDR) program, and other measures. Other projects with greater uncertainty, higher political risks, and/or significant costs were targeted for additional feasibility studies and/or evaluation through use of a decision-support system (see Case Study Example #2).

Common Ground through Informed Decisions: Case Study Examples

EXAMPLE #1

One major point of controversy along the upper San Pedro River in the past revolved around the need for all water users in the basin who are part of the water problem to also be part of the solution. To reach equity among water users, many stakeholders believed that the riparian forest, which transpires considerable amounts of groundwater, needed to reduce its total consumptive water use. However, the concept of cutting down cottonwoods to keep the river flowing was not considered an acceptable management alternative by the U.S. Bureau of Land Management (BLM). Environmental and conservation interests also strongly opposed this concept, since one of the primary drivers for groundwater management in the basin revolves around providing adequate water to sustain the SPRNCA's riparian forest. The interagency study on groundwater use described previously (Leenhouts et al. 2006) resulted in information that created new management options and choices. Isotopic analysis of the water transpired by mesquite, including those plants that had established on floodplain grassland habitats, revealed that these shrubs were utilizing significant volumes of groundwater, in addition to opportunistically using precipitation. Removal of these recently established scrublands, in locations that historically had been sacaton grasslands, would significantly reduce per area water consumption rates, while also improving habitat conditions for some species and decreasing habitat for others (see chaps. 7 and 8). Vegetation mapping efforts revealed that the mesquite stands within the SPRNCA were far more abundant than cottonwood forests, and that the total consumptive use of groundwater by mesquite was approximately triple that of cottonwood and willow forests (mesquite used between 6448 – 8135 acre-feet of groundwater per year, while cottonwood/willow forests used a total of approximately 2569 acre-feet per year) (see chap. 3). Moreover, BLM had already developed the capacity to implement a prescribed-fire program.

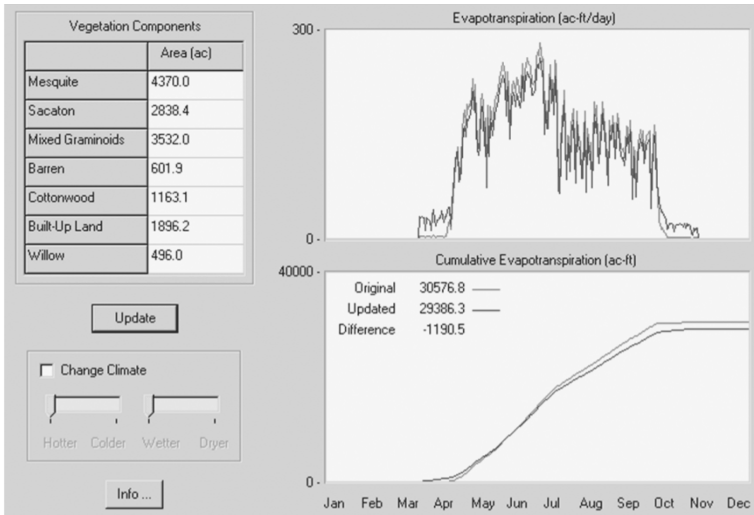

Fig. 21.2. "Screen capture" of a software program showing the change in SPRNCA evapotranspiration as a function of change in various vegetation types defined by the user to simulate potential land management actions (e.g., prescribed burn of mesquite and revegetation with desert grasses).

Another closely associated product of this same study is the Riparian Vegetation Evapotranspiration (ET) Tool (R. Scott, Watts et al. 2003). Although the ET Tool was developed based on extensive field work, large empirical data sets, and complex calculations and analyses, the result is a user-friendly GIS-based interface which can be employed by resource managers with basic training and support. This tool encapsulates many complex biophysical processes in a form that allows decision makers to easily evaluate what is important *to them* — various potential management scenarios and their resulting impacts on habitat conditions and riparian water use (fi g. 21.2). This new knowledge and tool enabled BLM management to prioritize burn plans with the incentive to maximize water savings, while still meeting the agency's ecological goals for the SPRNCA. It also enabled the BLM to contribute their part toward "equitable" groundwater management in the region. The effective use of such tools over the long term requires an ongoing commitment from scientists and programmers for training, support, and future modification as conditions and management issues change.

EXAMPLE #2

A decision support system (DSS), developed by SAHRA and linked to a regional groundwater model, is being used by the Partnership to evaluate different combinations of management options (scenarios), such as the possible relocation of municipal wells, construction of additional recharge facilities, and various water-augmentation strategies. Such a tool allows for the consideration of spatial and temporal groundwater-management concerns, as opposed to a simple annual "bottom line" water-budget approach. The former approach is essential for maintenance of the hydrologic context needed to sustain all 43 miles of the SPRNCA. Questions that can be asked of the DSS include: How will a proposed project, or group of projects collectively, influence groundwater levels at a specific point along the river? Or, where could municipal wells for a particular community be located to minimize the impact on the river?

Most importantly, development of the conceptual model upon which the DSS is based provided those Partnership members engaged in its development with a useful road map for understanding the complex and dynamic interaction of water management variables and functions (H. Richter 2006). A total of 74 individual water management options were initially identified for consideration within the DSS, and each was described in terms of estimated annual yield in acre-feet, cost per acre-foot, and other factors. As of 2006, the San Pedro DSS is now available online for decision-making purposes by Partnership members, but outreach applications have yet to be developed (Serrat-Capdevila and Browning-Aiken in review).

Meeting the Information Needs of Decision Makers

Very few elected officials and policy makers read scientific journals after spending a long day at city hall. Can we blame them? How often do scientists attend city council meetings in the evenings to improve their local political savvy? Given these realities, how then could we best ensure that local decision makers would have access to the best technical information currently available and that scientists would be aware of the complex political and social factors that might influence many aspects of their studies? Most scientists typically design their studies in response to themes suggested by their sources of research funding. Once tools and knowledge are developed, results are published in peer-reviewed professional journals. The pace at which this information diffuses into the decision making arena can be painfully slow, or non-existent. Efforts at technology transfer, in which research products or findings are transferred from their originators to users (E. Rogers 1995, Lai and Guynes 1997), represent a more proactive approach for scientists to get their knowledge and tools to decision makers. In this process, scientists identify a potential information user, or vice versa; thus, a scientist – decision maker relationship is established. In this type of knowledge transfer, the scientist develops his or her research protocol after direct communication with potential users or decision makers. In essence, the research and resulting information or products are conceived and designed by both the scientist and the decision maker.

Within the Upper San Pedro Partnership, scientists and decision makers have embraced this type of knowledge transfer. This represents a step beyond the traditional type of knowledge transfer resulting from strictly scientist-conceived research. This approach does not imply that scientists should eschew peer-reviewed journal publications. The journal publication process helps maintain currency of knowledge and is pivotal to the reward system of many research organizations and universities. The complexity of applied research issues typically allows ample opportunity for publishable research. However, those scientists who address applied management issues need to work more efficiently by continuing to publish while also making a commitment to work closely with policy and decision makers.

ESSENTIAL BUILDING BLOCKS OF THE SCIENTIST/DECISION MAKER INTERFACE

Making a long-term commitment to a partnership can be difficult for scientists if their research is largely supported by grants awarded on a typical three-year-or-less funding cycle. Many investigators have conducted research in the San Pedro basin under these circumstances. However, they are not the same scientists that decision and policy makers look toward as a reliable source of information over the long term. Decision makers recognize that these researchers will be providing only temporary assistance with their information needs, and therefore they do not invest the time to build strong working relationships. Several funding agencies have recognized this weakness and are now beginning to fund centers with substantially longer time horizons, such as SAHRA and the Climate Assessment for the Southwest project (CLIMAS; established with seed money from the National Oceanic and Atmospheric Administration).

A commitment by relatively senior scientists is necessary to effectively integrate science with policy. Elected officials and decision makers, who manage large staffs and significant budgets, expect to deal with scientific counterparts who can also make substantial programmatic commitments to their shared endeavors. While it is important that graduate students, postdoctoral researchers, and new researchers contribute to investigations, they are often not in a position to initiate or revise investigations in a relatively rapid manner. Several federal research agencies, and their senior scientists, have had a long history of conducting investigations in the upper San Pedro basin, and this has helped to develop mutual trust and respect between the agencies and local entities.

Senior technical-staff members are often expected to serve as facilitators in collaborative planning processes, in addition to their job responsibilities as scientists. While many technical specialists such as engineers or scientists can provide valuable experience and authority in this role (Wakeman 1997), the need for professional facilitation cannot be underestimated in complex collaborative decision-making processes if participants lack the time, neutrality, training, and/or experience to effectively facilitate a consensus-based process (Leach and Pelkey 2001, Browning-Aiken et al. 2004).

Effective communication is essential to building trust and to building successful watershed partnerships (Leach and Pelkey 2001). Successful communication requires openness, understanding, and listening. Openness and understanding imply patience to allow for the unimpeded sharing of everyone's ideas, information, and data. Scientists and decision makers both have an innate tendency to come to the table with their version of the answer already in mind. However, frequently the best answers in collaborative problem solving are generated from combining the input from multiple participants, or from an entirely new concept that emerges through well-facilitated group discussions (Imperial and Hennessey 2000, National Policy Consensus Center 2002, Pahl-Wostl 2002, Imperial and Kauneckis 2003).

Learning the nuances of the different vernacular spoken by scientists, decision makers, and laypersons takes commitment and patience, and may be no less difficult than committing to learning a foreign language. Scientists must make a conscious commitment not to communicate as if they were attending a scientific meeting. There is no quicker way to lose the attention of policy and decision makers than to speak in technical jargon and acronyms. This requires adopting a common language among partners that is comfortable for all. All partners also can benefit from developing an eye for glazed-over expressions and body language that suggest frustration or confusion.

Listening implies true two-way communication between scientists and partnership members. Sufficient discussion must take place during the design of research programs to ensure that researchers are properly focused on the real-life needs of the decision makers. On the other hand, the policy and decision makers must understand the limits and uncertainties associated with the scientific methods and research results. Because research is typically an iterative process, the principles of adaptive management and ongoing two-way communication between scientists and decision makers are essential.

Location is also an important factor in maintaining productive working relationships between partners. In most cases, it is essential to meet on the home turf of local managers and decision makers, within the basin or watershed of interest. These locations are typically not adjacent to research institutions, universities, or federal agency offices. Therefore, scientists must make an additional commitment to travel frequently and participate in partnership meetings in person, on-site.

Scientists should deliver results to decision makers that contain only the essential information needed to move forward. Many scientists want to study numerous facets of a problem in intricate detail and share all of that detail with others since it is fascinating to them. This tendency must be tempered by the time and resource constraints under which decision makers operate (V. Baker 1998). Data should be interpreted in straightforward terms that are relevant to the decisions at hand. If trust and transparency are developed early in investigative efforts, decision makers will be more confident that a strong foundation of data analyses underpins the bottom line results, allowing the conclusions to withstand close scrutiny by other interests.

The Importance of Community Engagement

Certain water management conservation strategies are more complex, costly, or politically difficult to implement than others. While some strategies, such as water conservation efforts in the home and the recharge of treated effluent, may be widely acceptable to most people, other strategies, such as the transfer of development rights, may require a much deeper level of understanding to attain support from residents. The process of engaging the general public in decision making can be just as important, if not more important, than the engagement of community leaders and decision makers. Elected officials in particular need to know that their constituency will support their decisions. Recent efforts in California provide an example of the importance of community engagement to the successful implementation of water management efforts. In 1999, a $55-million water reclamation project that Los Angeles officials claimed would drought proof the city was derailed by public outrage over the prospect of drinking recycled toilet water. In contrast, Orange County took a similar plan to the community. The county held neighbor pizza parties, water treatment plant tours, and scores of public meetings where they explained how water treatment processes would work. As a result, Orange County broke ground on a $487 million "toilet to tap" project that opened in 2007 and serves 140,000 families. The difference between these two efforts primarily revolves around differences in community engagement. Support solely by the scientific and political leadership is simply not enough. In the case of the San Pedro, complex and controversial strategies such as water importation, the transfer of development rights, and surcharges for excessive water use all have the capacity to divide the community, as did "toilet to tap." These particular issues must be carefully managed by direct engagement of the community early on in planning processes. Toward that end, the Partnership conducted a series of community connector meetings during 2004 to begin this type of strategy-specific dialog and to provide citizens with an opportunity to thoughtfully consider issues, help shape their own destiny, and provide meaningful input. A professional firm was hired to assist the Partnership with the process of facilitating public involvement and to ensure effective and equitable participation throughout the Sierra Vista subwatershed. The Partnership held workshops in public meeting rooms, as well as in the living rooms of interested volunteers within Sierra Vista and nearby communities. Residents clearly expressed a need for fairness between conflicting interests, and a need for clear and consistent information, as opposed to conflicting messages. There was a wide divergence between rural and urban perspectives, and between the need for mandatory versus voluntary measures. A distrust of public institutions about doing what they say they will do, especially in terms of the use of funds, was also evident.

Summary and Lessons Learned

The combination of a complex regulatory framework, coupled with a myriad of interacting environmental, social, and political factors, presents tremendous challenges related to groundwater management within the Sierra Vista subwatershed for local decision makers, elected officials, and the general public. The need to apply strong science and the best analytical tools is apparent. But, in addition, the role that collaborative learning processes play in effectively transforming this science into informed decisions will continue to be one of the most essential factors that determines the future of this river, and the fate of the waters that sustain it.

To transfer some of the lessons learned, we conclude with this checklist of questions that can serve as a guidepost for other watershed planning groups. To determine if science and policy are effectively being integrated into water management planning efforts for any watershed, participants must pose the following questions:

- Is the geographic scale of collaborative planning/learning efforts appropriate? Does the planning area represent a relatively homogeneous area within the watershed, without too many vast differences in political, social, or economic sideboards, or regulatory constraints, to overly confound efforts?
- If multiple water-management and planning efforts are underway within different parts of the same watershed, are they well coordinated with one another?
- If a watershed crosses international boundaries, what opportunities are available for bi-national dialogue that bridges language barriers, and institutional and policy differences, to address basic management concerns between decision makers, water managers, and scientists?

- Are professional facilitators integrated into planning and decision- making processes to ensure balanced participation and consensus building?
- Are the federal, state, and local drivers for policy change, and their associated implications, clear to scientists, decision makers, and the public?
- Has an adaptive management framework been adopted by water managers that allows for the immediate implementation of low-risk strategies while additional information is being collected for higher-risk projects, or for those with more uncertainty in outcome?
- Are the research, management tools, and monitoring results developed by scientists actually being used to make decisions by policy makers on an ongoing basis?
- Do face-to-face communications between scientists and decision makers occur regularly?
- Do these communications include openness, understanding, and good listening skills between participants, at on-site locations?
- Do political leaders at the federal and state levels acknowledge and support the efforts of locally based, collaborative decision-making processes? Are they advocates for transferring pertinent aspects of these efforts to other watersheds facing similar challenges?
- Are policy and decision makers eager to continue seeking out funding and resources for scientific support and monitoring efforts as needs continue to change over time?
- Are senior-level scientists easily accessible to local decision makers?
- Is the general public, in addition to elected officials and scientists, actively engaged in planning efforts for future conservation projects and policies, especially issues with a high potential for controversy?

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Projected hydrologic effects of climate change in southwestern New Mexico

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The climate of the Southwest is changing in ways that are expected to affect the flow and water quality of the Gila River. Here we summarize expected changes in the hydroclimatology of the Gila River basin. A representative climate change projection is downscaled to infer likely changes in Gila streamflow. The inferred changes are consistent with recent results of explicit streamflow modeling that has been carried out in other large river basins in the Southwest. The principal conclusions are (1) temperature is now clearly observed to be trending upward in southwestern New Mexico, and the warming trend is expected to continue through the 21st Century; (2) Streamflows are expected to decrease in the Gila, as the result of declining snowmelt runoff and increased evaporative losses associated with warmer temperatures; (3) water temperature is likely to increase, potentially affecting temperature-sensitive animals and plants in the river.

Flow in the Gila River is fed by melting snowpack in the late winter and monsoon precipitation in the summer. A representative average hydrograph on the Gila, taken from data at the Red Rock gauge (several miles upriver from the Arizona state line), exhibits two seasonal peaks. The primary peak occurs in late winter (February-March), associated with snowmelt runoff, and a second peak in August, associated with the seasonal maximum of precipitation during the summer monsoon. In between, the Gila's lowest monthly average flow of the year occurs in June, several months after snowmelt and just before the onset of the monsoon. Occasional tropical storm remnants dump intense but short-lived rainfall into the basin in late summer and early autumn.

Interannual variability of streamflow is very large, as unpredictable individual storm events in this semiarid region can strongly affect the hydrograph at any time of the year. Some of the variability is fairly predictable. The El Niño/Southern Oscillation (ENSO) cycle in tropical Pacific ocean temperatures (SST) is known to modulate cold season precipitation: El Niño winters, when Pacific waters are warm, tend to be wet across the Southwest leading to above-normal streamflow on the Gila, while the opposite (La Niña) phase of Pacific SST is associated with diminished precipitation and subsequent streamflow.

The Pacific Ocean also undergoes decadal fluctuations in temperature. Recent modeling studies suggest that these remote, long-term ocean temperature anomalies may be largely responsible for long-term drought and pluvial conditions across the Southwest, by forcing the winter storm track to shift north or south for years. Reconstructions of past climate and streamflow confirm that the Southwest has been subject to episodic, decade-scale fluctuations between drought and wet conditions for at least the past millennium.

The evidence for increasing temperature in recent decades is unambiguous in observational data. The Fort Bayard cooperative observer site, just east of Silver City, features one of the longest continuous records of temperature and precipitation in New Mexico. For many climate monitoring purposes, this record is averaged with several dozen other operational climate monitoring stations in southwestern New Mexico by NOAA to form monthly averages in so-called Climate Divisions. The state of New Mexico has been divided into 8 such divisions; Division 4 (henceforth denoted CD4), the "Southwest Mountains" Division, covers the upper Gila basin, extending east-west from Arizona to the western edge of the Rio Grande Valley, and north-south approximately from Grants to Silver City. Temperature in CD4 has risen approximately 2°F in both winter and summer since the 1960s.

Climate models must be used to diagnose the causes of these warming trends. On a global and continental scale, near-definitive attribution of warming trends in the 20th Century is possible with global models. Such models can accurately reproduce the gross features of 20th Century temperature variations if, but only if, anthropogenic forcings due to greenhouse gases and particulate air pollution are included in the model simulations. From this general result, the climate research community concluded several years ago (with increasing near-unanimity) that the late 20th Century warming trend, so pronounced in the data, is principally the result of anthropogenic greenhouse gas emissions. More recently, a similar study has been applied to late 20th Century hydrologic trends across the western United States and reached the same conclusion: observed diminishing streamflow and snowpack, and warmer winter temperatures, could be attributed largely to climate change associated with increased greenhouse gas concentrations.

We use the same climate models to make projections of future climate, based on different scenarios for 21st Century greenhouse gas concentrations. There is no way of knowing what future greenhouse gas emissions will be; this uncertainty, combined with continuing uncertainties in the models themselves, makes it impossible to produce definitive predictions of 21st Century climate analogous to a weather forecast. However all reasonable scenarios from indicate that warming trends will continue, probably at an accelerated pace. The rate of climate change depends strongly on the choice of greenhouse gas scenario, subject to additional uncertainty due to modeling (manifested in model-to-model differences when forced by the same scenario).

We have developed a representative scenario regional for 21st Century climate change based on a mid-range scenario of greenhouse gas increases, the "A1B" scenario as defined by the Intergovernmental Panel on Climate Change. In this scenario, atmospheric CO_2 concentration increases from its observed value of 369 ppm in 2000 to about 700 ppm in 2100. Simulated time series from eighteen separate models, forced by increasing greenhouse gases following this scenario, were averaged together to form a single A1B ensemble projection of time-varying 21st Century climate. Output was archived at Lawrence Livermore National Laboratory, where the model gridpoint values were averaged and interpolated to the NOAA-defined Climate Divisions.

At UNM we have used these time series to generate temperature and precipitation projections for each of the Climate Divisions in New Mexico, including the results for CD4 presented here. However the process of taking an 18-model average, which is designed to produce a statistically-optimized trend value, suppresses interannual variability. Therefore, for the UNM-generated scenarios we keep just the linear trend from the 18-model average of temperature or precipitation for each Climate Division starting in 2008, and add the trend to the climatological value for the current climate (defined over the years 1971-2007). We then add "realistic" interannual variability to the 21st Century trend, by adding to each monthly value in the 21st Century the observed annual anomaly for that month taken from observed data for the year exactly one century earlier. Thus, for example, the projected value of temperature T for January 2050 is derived from the sum of three terms (precipitation projections are calculated in exactly the same way):

T(Jan 2050) = T(Jan average, 1971-2007)
+ T(projected Jan trend from A1B, 18-model average for 43 years beyond 2007)
+ T(anomaly from 20th Century climatology for Jan 1950)

From the projections for CD4, we find that temperature trends are quite pronounced, with temperatures increasing faster in summer (warming trend = 7.5°F/century) than in winter (warming trend = 5.8°F/century). However both of these trends would almost certainly make the Gila basin far warmer by the end of this century, year round, than at any time in the history of human settlement. In addition, interannual variability is considerably less in summer than in winter. Summer temperatures in this scenario consistently exceed even the warmest anomalous 20th Century summer season values by the middle of the 21st Century, whereas until the late 21st Century "cold winters" are still similar to what would presently be considered an anomalously warm winter.

Nevertheless this winter temperature trend would easily decimate snowpack at high elevation by the middle-late 21st Century, with potentially profound effects on the Gila hydrograph. Increased summer temperatures would result in much-increased evaporation rates, and elevated water temperature in the river.

Precipitation trends are very modest by comparison. There is a modest but significant downward trend in winter precipitation; effectively no trend in summer in the A1B-forced simulations. Precipitation is less reliably simulated in global models compared to temperature. This uncertainty, combined with the smaller trend relative to interannual variability in precipitation compared to temperature, means that the principal climate change signal that water planners should anticipate is the hydrologic effect of rapidly increasing temperature.

The southwestern U.S. has been highlighted in numerous hydroclimatic studies as a region particularly vulnerable to streamflow decreases associated with warming trends. The Mogollon Mountains and the Black Range currently support one of the most southerly located snowpacks in North America, and therefore the snowpack feeding the Gila River is exceptionally vulnerable to warming trends of the magnitude described here. It is quite possible that seasonal snowpack would cease to exist as a climatological feature in these mountains within the next century.

In the absence of detailed studies of climate change effects specific to the Gila basin, we can draw upon recent studies of the Colorado and Rio Grande to make inferences about the Gila, although one must keep in mind that it is very difficult to be quantitative with these inferences. Decreases in annual streamflow by the late 21st Century of up to 30% have been documented for the mainstem Colorado and Rio Grande Rivers in recent studies. As we would infer for the Gila, these decreases are caused by diminished snowpack in the cold season, and increased evaporation in the warm season.

Smaller snowpack, and a shorter snow season, would obviously result in less snowmelt runoff and an earlier, much weaker peak in snowmelt runoff. Thus the flow in the Gila could increase somewhat during the present snow season, because a greater fraction of winter precipitation runs off into the river instead of remaining locked up in snowpack. Flows in late winter and spring, now supported by snowmelt, would decline significantly. Evaporative losses would increase during this part of the year, resulting in drier soils until the onset of monsoon season. Trends in summer monsoon-related precipitation, and associated streamflow during the latter half of the calendar year, are currently very uncertain. The overall effect of less snowpack and more evapotranspiration is to reduce streamflow as the climate gets warmer. How much decrease in streamflow, and how rapidly the change will occur, is quantitatively uncertain.

The climate change projections have other environmental implications for the Gila River system. Both the average and extreme surface water temperatures would increase markedly under the scenarios developed here. A new study of climate change downscaled to the headwaters of the Gila, using a different greenhouse gas scenario and a higher resolution model, has projected warmer average temperatures of 3-4°F by the mid-21st Century (very consistent with the projected CD4 temperature trend described above). This average temperature trend translates to a doubling of the number of summer days at high elevation when the temperature exceeds 310K, which represents a mortality threshold for Gila Trout (a threatened cold water species). From this projection, the total length of streams suitable for Gila Trout habitat decreases by about 70% relative to the trout's present-day habitat.

Wildfire management could be complicated by the trend toward more hot days as well. Wildfire models generally would project more frequent fires under warmer late spring/early summer conditions. Whether a corresponding upward trend in fire intensity would also occur will depend on how vegetation responds to the combination of increasing CO_2 concentration and longer growing season (promoting vegetation growth) vs. reduced streamflow and drier soils (retarding growth).

We have converted the temperature and precipitation scenarios into time series of the Palmer Drought Severity Index, and these results are very sobering. Increased temperature in the late 21st Century increases evaporation rates to the point where severe drought (as depicted by the PDSI algorithm with the current climate as a baseline) becomes the climatological norm in CD4. This result emphasizes the fact that temperature trends can force profound hydrologic changes, even in the absence of much change in precipitation.

Considerable uncertainty attends these projections, although the primary climate change signal (warmer temperatures) is very robust. By construction, the magnitude of interannual variability associated with the temperature and precipitation scenarios discussed here stays fixed, because we simply repeat 20th Century anomalies. Model simulations suggest that this may represent a very conservative estimate of future climate variability, as most global models simulate increased variability in a warmer climate. However, some important specific patterns of variability (including ENSO and longer-term Pacific decadal variability) are not reproduced with sufficient reliability in current global models to allow any definitive assessment of likely 21st Century changes. So, for example, we really do not know at this time whether to anticipate more or fewer, stronger or weaker El Niño winters, or whether El Niño will continue to be strongly correlated with wet winters in New Mexico. Changes in the monsoon and summer precipitation remain uncertain.

Continued climate change research promises to reduce, but not eliminate, these uncertainties. By incorporating a wide but plausible range of precipitation scenarios, studies of the middle Rio Grande system have shown that the general downward trend in streamflow occurs even if total precipitation increases, enhancing confidence in the general projection of decreased streamflow. The downward trend will be greatly exacerbated during anticipated, but unpredictable, decades of severe precipitation deficits (associated with episodic drought). Water planning for the Gila River should incorporate the high likelihood of significantly diminished flows and a much-reduced snowmelt runoff peak.

What Existing Studies Show are the Economic Values of Instream Flow & Guidance on Transferring these Values to the Gila River

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Instream Flow as a Public Goods

Adequate flows in rivers and streams provide many ecosystem services to people. Adequate flows provide habitat for recreational fisheries, native fishes, maintain riparian vegetation needed by many bird species as well as opportunities for bird watching. Of course adequate instream flows also provides whitewater boating and water purification to name just a few. Some of these ecosystem services are utilized at the river by visitors (e.g., anglers, boaters, bird watchers), and some by downstream municipal water consumers. These are what most people would call "direct use values".

Some people who may never visit the river may still derive enjoyment and satisfaction from knowing that adequate flows provide habitat for native fish and birds. These benefits are referred to by various names including existence values and bequest values (to future generations) or collectively, non-use values. The U.S. District Court of Appeals in 1987 referred to them as passive use values, in contrast to direct use values. Collectively, direct use and passive use values are frequently referred to as Total Economic Value (TEV).

Increasing instream flows to an optimum flow to maintain self reproducing game and native fish and riparian vegetation provides both the use and passive use values. Alternatively, reducing biologically desirable flow levels to a "minimum" instream flow level, often results in a reduction in use and passive use values.

The use and passive use values of instream flow have characteristics of what economists call "public goods". Unlike private goods which are often literally consumed by one person making that unit of the private good unavailable to others (e.g., hamburger, electricity, dental work, consumptive use portion of irrigation water diversions), public goods are used "non-consumptively". Specifically, one kayaker's use does not diminish the amount of water available for another kayaker. This is even more apparent with passive use values. The enjoyment I receive from knowing there is a self sustaining population of native fish does not preclude you from enjoying the benefits from the same self sustaining population of native fish. Thus, instream flows are often viewed as non-rival. As such, the additional cost of another person using the river for fishing or boating (up to the point of congestion) is zero. Economic benefits are maximized to society when the price equals the incremental or marginal cost of allowing another person to enjoy the good. Price is a measure of a society's willingness (and ability) to pay for one more unit of the good. If the incremental or marginal cost is zero, then the price should be zero. The logic is that if there is no additional cost to society from allowing another person to use the resource, we should not charge a price that may exclude them. Obviously it will not be profitable for a company to supply instream flows, if the economically efficient price is zero. For this reason alone markets would tend to undersupply instream flow.

But wait, there's more! Passive use values gained from enjoying the knowledge that there is sufficient flows for native fish and birds are also non-excludable. This second characteristic of a public good is that it is not technically or economically feasible to exclude people who do not pay from enjoying the passive use values that instream flows provide. Once again, a company that cannot exclude people who do not pay, are unlikely to provide instream flow, let alone the optimal amount. The two characteristics of instream flow as a public good is shared by national defense. The rationale that is used to justify the government provision of national defense through mandatory taxes, applies in the case of instream flow as well. In order to quantify the optimal amount of instream flow we need to know something about the benefits of these flows.

Primary Techniques to Measure Use and Passive Use Values of Instream Flows.
Direct Use Values. Despite the fact that most recreational fishing and kayaking is not provided by markets and do not have readily observable market price does not mean it does not have an economic value to the participants. Visitors have a value beyond their travel cost otherwise they would have stayed home. This willingness (and ability) to pay beyond their travel cost (what is sometimes called consumer's surplus) can be measured by several techniques developed economists and are federally recommended for use by federal water resource agencies (U.S. Water Resources Council, 1983).

Travel Cost Method. This method uses variations in visitor travel costs as a proxy for price, to trace out a demand curve for trips to the recreation site. As with other goods, the higher the travel cost (implicit price) the fewer trips are taken. From this demand curve we can calculate the **additional** amount a visitor would pay for a trip to that river, compared to substitute rivers. This demand curve also varies with flow levels. It is generally agreed by fisheries biologists that when instream flow increases, there is more fish habitat and hence increased fish populations. In addition higher flows allow for spreading out of users. All of these factors suggest that as flows increase the enjoyment or what economists call utility increase, at least up to a point. At a given trip cost determined by travel distance to the river, the higher utility, the more trips the visitor wishes to take. Thus the demand curve and number of trips taken increases with higher flows. For example, if 4 rafting trips per year was optimal at a travel cost of $10 per trip and instream flow of 1000 cfs, when flow increases to 1500 cfs, then the optimal number of trips might be 6. Examples of studies that have used the Travel Cost Method to estimate the value of instream flow include Loomis and Creel (1992) and Loomis and Cooper (1990). The values from these studies will be summarized below.

Contingent Valuation Method. Another method to estimate visitors' net willingness to pay is the Contingent Valuation Method or CVM. In this approach, a survey is used to construct a "hypothetical" market in which visitors are asked how much more they would pay for their trip to this site rather than not visit here. Recently, a dichotomous choice question format is used whereby a visitor is asked whether they would pay a specific increase in their trip costs to visit the site. The amount of this trip cost is varied across the sample, so that a demand curve like relationship is traced out. From this function net WTP is calculated. Daubert and Young (1981) and Walsh, et al. (1980) provide examples of the application of CVM to fishing and boating values. The values from their studies will be summarized below.

Combining TCM and CVM. If there is very little variation in flows or these variations are not known by the visitor ahead of time, it is often difficult to rely upon actual travel behavior to estimate the value of increases in instream flow. In these cases Ward (1987) demonstrated how the two methods could be combined to estimate a value for increased flows for rafting on the Rio Chama in New Mexico.

Passive Use Values. Estimating the existence or non use values of people who do not travel to the river posses a somewhat greater challenges than estimating WTP of visitors. In this case, we can only rely upon survey methods such as CVM or a new method called conjoint/choice experiments to construct a market or hypothetical referendum to elicit the passive use values that non-visiting households have. This method has been applied to estimating the benefits of maintaing instream flows in the Rio Grande in New Mexico for the Silvery Minnow (Berrens et al, 1998) and by Ekstrand and Loomis (1998) for desert fishes of the Colorado and Green Rivers. These values will be summarized below. One concern with using households' statements of their willingness to pay is whether they would actually pay that amount. There is mixed evidence on this point. Brookshire, et al, (1982) found that there was a close correspondence between CVM WTP for improving air quality in Los Angeles and what residents actually paid as evidenced by increased house prices in Los Angeles to live in an area with better air quality. Other studies

(Cummings and Taylor, 1999; Champ, et al., 1997) find CVM overstates actual cash WTP, but both propose approaches to reduce or eliminate the hypothetical bias in CVM surveys.

Empirical Estimates of Use and Passive Use Values of Instream Flows.
Table 1 presents the results of several TCM and CVM studies of recreational use values for boating and fishing. The values per acre foot are substantial, especially for fishing, and comparable to irrigated agricultural values of water for low value crops. Given the non-consumptive use of water, fishing and rafting values per acre foot should be added together on rivers that offer both activities. These values are also comparable to actual water market transactions for instream flows in California and Colorado. This not only indicates that the estimated non market values are similar to actual market transaction values, but that instream flow values are clearly competitive with low value agriculture otherwise farmers would not have leased water to the government. For the sources of these studies, see the bibliography.

While not evident in Table 1, several of these empirical studies demonstrate that the value of recreation increases with the level of flow. Thus benefits in excess of minimum instream do have additional value. These values can be used to address the mistaken emphasis on “minimum” instream flows. Since recreation values are often competitive with low value agricultural crops, it is often economically efficient to go beyond minimum instream flow necessary to keep a fish alive. As long as the incremental recreational benefits exceed the foregone agricultural values, additional water should be allocated to instream flow until the values per acre foot in the two uses are equalized.

Table 1. Examples of Recreation Use Values

State	River	Activity	Non Market Annual Value ($/Acre Foot)	Valuation Method	Market Transaction Values
California	San Joaquin	Fishing	$45 all year $116 August	TCM	$41
California	Feather River	Fishing	$46-$73	TCM	$41
Colorado	Western Colorado	Fishing	$43-$86	CVM	$41
Colorado	Western Colorado	Rafting	$7-$13	CVM	$10
Colorado	Western Colorado	Kayaking	$12-$24	CVM	$10
New Mexico	Rio Chama	Rafting	$900 (Present Value)	TCM & CVM	N/A

TCM= Travel Cost Method; CVM= Contingent Valuation Method

Table 2 presents example studies for passive use values for threatened or endangered fish. Several patterns are evident in this table. First is that there is a sizeable value per household for the silvery minnow and the desert fishes in the Colorado and Green River systems. Second, these values pass what is called a scope test, in that WTP for protection of more species and more miles of habitat is greater than WTP for just one species in one river. Third, even at $29 a household, since there are nearly a million households in New Mexico, the total annual value is close to $29 million. This total value reflects the features of non use as a public good, in that it can be simultaneously enjoyed by all households at the same time.

Table 2. Passive Use Values for Threatened and Endangered Fish in the Southwest

States	Resource being Valued	Annual Value per Household	Valuation Method
New Mexico	Habitat for Silvery Minnow in Rio Grande	$29	CVM
AZ, CO, NM, UT	1,000 miles of river habitat for 8 desert fishes in the Colorado & Green Rivers	$132 to $268	CVM

Techniques for Applying these Values to the Gila River: Benefit Transfer
Conducting an original TCM or CVM study of the use and passive use values of the Gila River as a function of flow would be the ideal way to determine how much flows are economically justified in comparison with other competing uses of water from the river. Such an undertaking could take as much as a year, and cost in the range of $200,000. If the costs of misallocating water, especially if it is a “once and for all decision” are high, then investing in a site specific study to inform such an important and long lived decision is worthwhile.

However, if these original TCM and CVM studies are either too expensive or time consuming, economists have developed the technique called Benefit Transfer (Brookshire and Neill, 1992) to provide a rough estimate of the direct recreational use and passive use values. A rough estimate of the economic values of recreation and passive use is often preferable and more informative than omitting economic values altogether. If decision makers have economic values for agricultural use of water and municipal use, but not environmental uses, it is easy to see that this feeds the “environment versus economy” dichotomy. Some decisions makers think omission of economic values implies ***zero*** economic value. Thus, having even rough estimates of recreation and passive use values helps to provide a more balanced picture for decision makers and society. A review of relative errors in benefit transfer estimates of the value of a day of fishing by Rosenberger and Stanley (2006) suggests most of the errors are within plus or minus 20% to 50% of the values from the original study. Thus conducting an original study is preferred. However, the error of implying a zero value is far greater than the error involved in benefit transfer.

Benefit Transfer Techniques
Definition of benefit transfer involves the transfer of existing valuation information from the study site where the information was originally collected to the policy site where valuation information is needed. There are two broad approaches to benefit transfer: (a) point estimate; and (b) value function.

Point Estimate Approaches. The first point estimate approach involves locating and transferring a value from a study that most closely matches the policy site in terms of values desired (e.g., visitor day, household TEV) and geographic area. A study of rafting on the Rio Chama in New Mexico might be a good candidate for the value of rafting on the Gila River. However often times, such a match cannot be found. For example, there may not be any trout fishing studies on desert river in New Mexico. However, there are numerous fishing studies, and so the analyst could take the average of stream and reservoir fishing values in the four corners region and use that for the value per fishing day on the Gila River. Loomis and Richardson (2008) have put together a set of tables on the value of fishing (and many other wildlife recreation activities) that can be found at http://dare.colostate.edu/tools/benefittransfer.aspx

Value Function Approaches. If there are no similar studies for the policy site, and the analyst believes it would be erroneous to take a simple average of fishing studies, there are valuation function approaches that allow calculation of a value per day (or per household for TEV) that reflects several of the species and geographic features of interest at the policy site. Meta analysis is one such commonly used approach to value function transfer in benefit transfer. In the case of fishing Loomis and Richardson (2008) programmed up in a spreadsheet the Boyle et al. (1998) fishing meta analysis. The meta analysis regression equation has variables to tailor or customize the calculated value per fishing day to type of species being fished for and type of water body. The meta analysis for sportfishing is also available at http://dare.colostate.edu/tools/benefittransfer.aspx.

Conclusion

Provision of adequate instream flows provide ecosystem services to visitors and to non-visiting households in the form of existence values. These values can be measured using federally recommended methods such as the Travel Cost and Contingent Valuation Methods. When original site specific studies cannot be performed due to cost and time, there are numerous estimates of fishing values per day and several whitewater boating values that potentially could provide a rough estimate of these values on the Gila River by using a benefit transfer protocol.

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Demographic and Economic Trends in Four Gila Basin Counties: Catron, Grant, Hidalgo, and Luna

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Economists often define a region as an area of study as a group of sub-national political units (e.g., counties) that are geographically contiguous and share many common characteristics. The four Gila Basin Settlement area counties in New Mexico (Catron, Grant, Hidalgo and Luna) are geographically contiguous and share some common demographic and economic characteristics. The four counties are, however, diverse enough that they may not meet the usual criteria for defining a region. Two of the counties (Grant and Luna) contain nearly 90 percent of the region's population and 85.6 percent of the region's employment. Grant and Luna Counties also contain the two largest cities Deming (2007 population 15,277) and Silver City (2007 population 9,977) in the region. These two cities serve as regional trade and employment centers for the region.

Despite the variability in size and other characteristics of the four counties, it is worthwhile to examine the region as a whole. Brief profiles of the individual counties will be presented later. The region is large geographically but contains a small portion of the state's population and economic activity[17]. Specifically,

- The region contains 17,308 square miles or 14.2 percent of the state's land area.
- In 2008, the region's population was estimated to be 65,386 or about 3.3 percent of the state's population of 1,984,396.
- Population density in the region in 2008 was 3.8 persons per square mile compared to New Mexico's 16.3 persons per square mile and the nation's 84.6 persons per square mile.
- Regional employment in 2007 was 30,444 full and part-time jobs or 2.7 percent of NM's total of 1,115,677 jobs.
- In 2007, four sectors accounted for more than two-thirds of all jobs in the region:
  - Government and government enterprises (6,932 jobs or 22.2 percent of total jobs)
  - Non-farm proprietors employment (6,461 jobs or 21.2 percent of total jobs)
  - Retail trade (3,792 jobs or 12.5 percent of total jobs)
  - Accommodation and Food Services (1,980 jobs or 6.5 percent of total jobs)
  - Construction (1,771 jobs or 5.8 percent of total jobs)
- In 2007, Total Personal Income (TPI) in the region ($1.5 billion) was 2.5 percent of the state's TPI of $60.3 billion.
- In 2007, per capita income in the region ($23,299) was 60.6 percent of the national figure ($38,615) and 76.2 percent of the state average ($30,706).

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[16] Leo Delgado (Policy Analyst at Arrowhead Center) and Amanda Alaniz (graduate Assistant at Arrowhead Center provided valuable assistance in data collection.

[17] Data sources for this description are:

(1) Land Area: U.S. Bureau of the Census, *2007 City and County Data Book* ,available at: http://www.census.gov/prod/2008pubs/07ccdb/tabb1.pdf

(2) County population estimates: U.S. Bureau of the Census, State and County Population Estimates file CO-EST2008-01-35, available at: http://www.census.gov/popest/counties/CO-EST2008-01.html

(3) City population estimates are from U.S. Bureau of the Census, City and County Total Population Estimates, file SUB-EST2007-04-35.xls, available at: http://www.census.gov/popest/cities/SUB-EST2007-4.html

(3) Employment and Income: U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System available at: http://www.bea.gov/regional/index.htm#state The employment and income data are available from 1969 to 2007.

Growth rates of the region's population, employment and per capita income have been highly variable and generally slower than comparable growth rates for the state or nation for several decades. Specifically,

- The region's population growth rates varied from -4.5 percent in the 1950s to a high of 24.3 percent in the 1970s.
- Census Bureau estimates (released in March 2009) indicate that the region's population growth rate between 2000 and 2008 was only 0.3 percent.
- Between 1969 and 2007, total employment in the region increased by 86.0 percent, while the comparable figures were 182.6 percent for New Mexico and 98.7 percent for the US.
- From 1970 to 2007, annual growth rates of employment for the region varied from 8.2 percent in 1981 to -10.2 percent in 1982.
- Regional employment growth from 2000 through 2008 averaged 1.4 percent per year compared to New Mexico's 2.0 percent per year and the nation's growth rate of 1.3 percent.
- From 1969 to 2007, Total Personal Income (TPI) in the region averaged 3.1 percent of the corresponding state figure.
- Per capita income growth in the region between 1969 and 2007 averaged 5.7 percent per year, while US per capita income grew by 6.3 percent per year and state per capita income grew by 6.4 percent per year.
- Between 2000 and 2007, per capita income growth in the region (5.2 percent per year) was higher than the corresponding state figure (4.9 percent) and the national figure (4.3 percent).

No attempt has been made here to provide demographic or economic projections of the region's future but some of the factors affecting regional growth are obvious. The demographic and economic trends discussed above suggest relatively slow growth in the region in the near term. Both population and employment in the region are growing slowly compared to the rest of New Mexico. Given the age distribution of the region's population, population growth will depend substantially on in-migration. But slow growth in the region is not inevitable and not necessarily something to be avoided.

The region is fortunate to be an area of great scenic beauty and fascinating historical attractions. The potential of the region to attract tourism related activities and in-migrants should not be discounted. The region is rich in natural resources and despite the volatility of international commodity prices the region's natural resource base will continue to be important. The region's major highway and rail transportation infrastructure create opportunities to take advantage of the growth of economic activity in surrounding areas and throughout the world.

While the people of a region can do a great deal to shape their own demographic and economic future, we live in an increasingly interdependent world in which many key variables at the local level are determined in national and world markets. Local tourist activities thrive when the national economy is performing well. Local mining activities increase or decline depending on national and international economic activity. Some things are simply beyond local or regional control.

The national recession that began in December 2007 has had an impact on nearly every region of the country including the four county Region. The data needed to assess the regional impacts of the national economic downturn in a comprehensive fashion are not yet available. However, labor force data released by the New Mexico Department of Workforce Solutions in April 2009 (http://www.dws.state.nm.us/) are adequate to present a preliminary picture. The unemployment rate in the Gila Basin Region increased from 7.9 percent in March 2008 to 13.3 percent in March 2009. Unemployment in all four counties increased during the last year. Regional employment decreased by 3.4 percent over the same time period –the same rate as in the nation during this time period.

Despite massive national programs to restore financial stability and stimulate the economy, few economists expect the national downturn to end before the second half of 2009. Even if the forecasts of modest growth in the last half of 2009 are correct, national and regional employment growth are not likely to resume until sometime after increases in output (GDP) and income are apparent. The region, like the nation, can expect continued labor market disruptions in the near term. The effects of the downturn on long-term demographic and economic growth in the region will not be known for several years.

COUNTY PROFILES

Catron County has the largest land area of the four counties (6,926 square miles) but the smallest of the four counties in terms of population (2008 population of 3,405). Catron County's population, employment and per capita income growth rates have been highly variable. Basic demographic and economic characteristics of the county are:

- Catron County contains 6,928 square miles or 5.71 percent of the state's land area.
- In 2008 Catron County's population was 3,414 or about 0.17 percent of the state total.
- Population density in Catron County (2008) was 2.03 persons per square mile compared to New Mexico's 16.3 and the US (84.6).
- Catron County's per capita Income in 2007 was $19,257 or 62.7 percent of state per capita income of $30,706 and 49.9 percent of US per capita income ($38,615).
- Employment in Catron County in 2007 was 1,760 full and part-time jobs or 0.16 percent of NM's total of 1,115,677 jobs.
- In 2007, the sectors with the highest percent of employment in the county included:
    - Government and government enterprises (326 jobs or 18.5 percent of total jobs)
    - Construction (138 jobs or 7.8 percent of total jobs), and
    - Farm employment (258 jobs or 14.7 percent of total jobs)

Growth rates of Catron County's population, employment and per capita income have been:

- Catron County's population growth rates varied from -21.5 percent in the 1950's to 24.6 percent in the 1970's and to -6.52 percent in the 1980s. Census Bureau estimates (released in March 2009) indicate that the region's growth rate between 2000 and 2008 was -4.51 percent.
- From 1970 to 2007, annual growth rates of employment for the Catron County varied from 9 percent in 1972 to -5.2 percent in 1982.
- In 2007, Total Personal Income (TPI) in Catron County ($65,743) was 0.10 percent of state TPI ($60.3 billion).
- Per capita income growth in the region between 1969 and 2007 averaged 5.6 percent per year, while US per capita income grew by 6.3 percent per year and state per capita income grew by 6.4 percent per year.

Grant County is the largest of the four counties in terms of population with a 2008 population of 29,688 and the second largest of the four counties in terms of land area (3,966 square miles). Grant County contained 45 percent of the population and 50.0 percent of employment in the region. Basic demographic and economic characteristics of Grant County include:

- Grant County contains 3,966 square miles or 3.27 percent of the state's land area.
- In 2008 Grant County's population was 29,844 or about 1.50 percent of the state total.
- Population density (2007) was 7.5 persons per square mile compared to New Mexico's 16.3 and the US (84.6).
- Grant County's per capita Income in 2007 was $26,007 or 84.7 percent of per capita income in New Mexico ($30,706) and 67.3 percent of US per capita income $38,615.

- Employment in Grant County in 2007 was 15,012 full and part-time jobs or 1.35 percent of NM's total of 1,115,677 jobs.
- In 2007, the sectors with the highest percent of employment included:
    - Government and government enterprises (3,803 jobs or 25.3 percent of total jobs)
    - Retail trade (1,757 jobs or 11.7 percent of total jobs)
    - Health care and social assistance (1,220 jobs or 8.1 percent of total jobs)
    - and Accommodation and food services (1,115 jobs or 7.4 percent of total jobs)

Growth rates of Grant County's population, employment and per capita income have been uneven.

- Grant County's population growth rates varied from, -13.6 percent in the 1950's, to 14.2 percent in the 1970's to 8.82 percent in the 1980s. Census Bureau estimates (released in March 2009) indicate that the region's growth rate between 2000 and 2007 was -3.9 percent.
- From 1970 to 2007, annual growth rates of employment for the Grant County varied from -8.2 percent in 1970 to 14.2 percent in 1981.
- In 2007, Total Personal Income (TPI) in Grant County ($772,097) was 1.28 percent of state TPI ($60.3 billion).
- Per capita income growth in Grant County between 1969 and 2007 averaged 5.9 percent per year, while US per capita income grew by 6.3 percent per year and state per capita income grew by 6.4 percent per year.

Hidalgo County contains 7.5 percent of the region's population. In recent years, both population and employment in Hidalgo County have been declining.

- Hidalgo County contains 3,447 square miles or about 2.84 percent of the land area in New Mexico
- In 2008, Hidalgo County's population was 4,910 or about 0.25 percent of the state total.
- Population density in Hidalgo County in 2008 was 1.4 persons per square mile compared to New Mexico's 16.3 persons per square mile and the nation's 84.6 persons per square mile.
- Hidalgo County employment in 2007 was 2,570 full and part-time jobs or .23 percent of NM's total of 1,115,677 jobs.
- In 2007, three sectors accounted for more than half of all jobs in Grant County:
    - Government and government enterprises (631 jobs or 24.6 percent of total jobs)
    - Retail trade (337 jobs or 13.1 percent of total jobs)
    - Farm Employment (342 jobs or 13.2 percent of total jobs)

- In 2007, Total Personal Income (TPI) in Hidalgo County ($117,748) was 0.19 percent of the state's TPI of $60.3 billion.
- In 2007, per capita income in Hidalgo ($23,967) was 62.1 percent of the national figure ($38,615) and 78.1 percent of the state average ($30,706).

Growth rates of the region's population, employment and per capita income have been:

- Hidalgo County's population growth rates varied from -2.63 percent in the 1950's, to 26.7 percent in the 1970s to -1.3 percent in the 1980s.
- Hidalgo County's population growth rate between 2000 and 2007 was -14.6 percent.
- Hidalgo County employment growth from 2000 through 2007 averaged -1.0 percent per year compared to New Mexico's 2.0 percent per year and the nation's growth rate of 1.3 percent.
- Between 2000 and 2007, per capita income growth in the region (5.3 percent per year) was higher than the corresponding state figure (4.9 percent) and the national figure (4.3 percent).

Luna County is the second largest of the four counties with a 2008 population of 28,605 (43.6 percent of the four county population total).

- Luna County contains 2,965 square miles or 2.44 percent of the state's land area.
- Luna County's 2008 population was 27,227 or about 1.37 percent of the state total.
- Population density (2008) was 9.04 persons per square mile compared to New Mexico's 16.3 and the US (84.6).
- Luna County's per capita Income in 2007 was $20,933 or 68.2 percent of New Mexico per capita income of $30,706 and 54.2 percent of US per capita income ($38,615)
- Luna County's employment in 2007 was 11,102 full and part-time jobs or 1 percent of NM's total of 1,115,677 jobs.
- In 2007, three sectors accounted for about half of all jobs in the region:
  - Government and government enterprises (2,172 jobs or 19.6 percent of total jobs)
  - Manufacturing (1,173 jobs or 10.6 percent of total jobs
  - Retail Trade (1,698 jobs or 15.3 percent of total jobs

Growth rates of Luna County's population, employment and per capita income have been:

- Luna County's population growth rates varied from 12.4 percent in the 1950's, to a high of 36.3 percent in the 1970's, to 15.6 percent in the 1980s. Census Bureau estimates (released in March 2009) indicate that the region's growth rate between 2000 and 2007 was 7.31 percent.
- From 1970 to 2007, annual growth rates of employment for Luna County varied from 7.2 percent in 1972 to -1.1. The average annual employment growth from 2000 to 2007 was 3.2 percent.
- In 2007, Total Personal Income (TPI) in Luna County ($561,112) was 0.93 percent of state TPI ($60,318,370).

Residential and Commercial Water Supply Benefits: Methodologies That Can be Used to Estimate Benefits Under Various Water Supply Scenarios
Steve Piper

INTRODUCTION

In order to evaluate the economic desirability of developing water supplies for municipal and industrial (M&I) use in the Gila River region, the economic benefits and costs associated with this use must be estimated. If the benefits generated by an M&I project exceed project costs, then the project is considered to be economically feasible. These benefits can occur as a result of increased water supplies, improved reliability, or improved water quality. Assuming benefits of an M&I water project exceed costs, the net benefits of M&I water use can then be compared with the net benefits associated with other water uses to determine the optimal allocation of available water supplies.

Economic feasibility requires estimation of both project benefits and costs. However, this paper focuses on the methods that can be used to estimate the benefits of a municipal and industrial water supply because M&I benefits are generally more difficult to quantify than costs. The costs of an M&I project include all engineering costs of construction, construction materials and equipment costs, annual operation and maintenance costs, and any environmental costs that may result from construction of a project or loss of water supplies in environmentally sensitive areas. Most of the engineering costs can be estimated using standard cost estimation procedures. It is recognized that some aspects of water supply project costs can be difficult to estimate—such as the environmental costs—but these costs are really based on the benefits lost for other water related activities and can be addressed in terms of benefit estimation for other water uses.

This paper describes the basic concepts and methods that can be used estimates the economic benefits of M&I water supply improvements. The strengths and shortcomings of the methods and different situations under which use of each method is most appropriate are also discussed.

CONCEPTUAL BASIS FOR ESTIMATING MUNICIPAL AND INDUSTRIAL WATER SUPPLY

The *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, referred to as the P&G's, (U.S. Water Resources Council, 1983) state that the conceptual basis for estimating M&I benefits is society's willingness to pay for the increase in the value of goods and services attributable to that supply. Willingness to pay is the dollar amount that a buyer is willing to give up (opportunity cost) to acquire a good or service. The willingness of consumers to pay for a reliable, good quality water supply depends on the satisfaction or utility they obtain from the water service as well as the utility consumers obtain from all other goods and services, constrained by available income. Willingness to pay is reflected through the demand curve for that good or service.

The relationship between willingness to pay and the demand curve allows the use of demand curves to measure the change in benefits to consumers that result from changes in price or output. However, due to the limited information available on how much water users will pay for water supplies with differing levels of quality and reliability combined with the non-competitive nature of some water supply markets, it may not be possible to derive a demand curve from actual market data. As a result, other techniques based on costs, surveys, or results from previous studies may need to be used.

TECHNIQUES THAT CAN BE USED TO MEASURE M&I WATER SUPPLY BENEFITS

Five different techniques are briefly discussed which could potentially be used to evaluate M&I water supply benefits in the Gila River region:

- An approach based on the resource cost of various water supply alternatives
- A benefits transfer approach using results from previously completed studies

- Using price elasticity of demand estimates to derive a demand curve
- A stated preference approach based on surveys of water users
- A revealed preference approach based on observed market behavior

Use of Alternative Costs as an Approximation of Benefit

The cost of the most likely alternative approach represents a fall back approach that can be used when direct measures of willingness to pay are not available. Using this method the benefits from a water supply project are approximated by the resource cost of the alternative most likely to be implemented in the absence of that plan. The most likely alternative is typically a structural alternative. However, the benefits of nonstructural measures can also be computed using the cost of the most likely alternative approach.

This method is a measure of water supply benefits only when restrictive conditions are met. First, it must be assumed that the benefits of providing the water supply are at least as large as the costs of the alternatives. In other words, the water supply needs are assumed to large enough to justify a water supply project. Second, all alternatives under consideration must provide essentially the same water supply service. If these assumptions hold, then the benefits of all alternatives are the same and the lowest cost alternative would provide the greatest net benefit to society.

The alternative cost technique is useful in completing a cost effectiveness analysis where a water supply improvement has been mandated by government agencies. However, the use of alternative costs is not a true measure of water supply benefits and is not useful in prioritizing water uses in terms of maximizing net benefits to society or a region. Therefore, this technique is not applicable to the Gila River region.

The Benefits Transfer Approach – Using the Results from Previously Completed Studies to Estimate Benefits

The benefits transfer methodology is based on the application of benefit estimates or models obtained from previously completed studies to a different site for which there are no benefit data. Generally the site where a detailed analysis has been completed and the study site should have similar characteristics. Similarity can be defined in terms of economic conditions, population characteristics, resources within an area, and other socio-economic characteristics.

The application of the benefit transfer method assumes that a general relationship exists between various socio-economic variables and the value of a resource. It is further assumed that this relationship can be estimated and applied to another geographic area. If these assumptions hold, then a model for a water supply that includes factors important in determining the value of municipal and industrial water can in theory be applied to another study site to estimate the benefits of a water supply improvement. Potential benefit transfer problems that must be considered include differences in water supply problems between sites and differences in socio-economic characteristics.

The over-riding considerations in the application of a benefit transfer model are the applicability of transferred model to the study site and the inclusion of all explanatory variables that are theoretically important. Some of the more important water supply benefit variables include: household size, age, income, cost of water, water quality, and the existence of any unusual hardship, such as the need to haul water or purchase bottled water for drinking.

Household size can be a proxy for use and can also be a measure of water supply importance, where larger households represent greater dependence on supplies. Age may be a reflection of attitudes, where experience with problems and situations affects how people perceive and react to difficulties. Income reflects the resources available to spend on all goods and services purchased by the household.

The cost of water indicates the current amount that must be spent for water at the current level of quality and reliability. Unusual hardships are an indication of the inconvenience associated with current water supplies.

The variable values that should be used in the transferred benefit model should represent conditions at the study site under consideration. The value could be the mean, median, or some other number that is representative of the study area population. More than one value could be used as a sensitivity analysis. Once the representative values are input into the transferred model, M&I water supply benefits can be estimated.
It is important to note that the quality of the estimates of benefits derived using benefits transfer are limited by the availability of technically sound water supply studies.

Using Price Elasticity of Demand to Estimate M&I Water Supply Benefits

Using price elasticity of demand to estimate benefits is essentially an extension of the benefits transfer technique. Price elasticity of demand is a measure of the change in the quantity of a good or service obtained as a result of a change in the price of the good or service. Previously completed studies estimating price elasticity of demand can be used as a source of information for demand curve estimation.

Price elasticity of demand is a useful measure because it can be used to estimate demand curves when sufficient price and quantity data are not available to estimate a demand curve. If the price elasticity of demand for a good is known, along with the current quantity exchanged in the market, then the effect of relatively small changes in the quantity supplied on prices can be predicted. Alternatively, if a project will lead to a predictable change in prices (rather than quantities), then the price elasticity of demand can be used to estimate the impact a project will have on the quantity demanded. Therefore, price elasticity estimates available on a regional basis could be used to help estimate the benefits of municipal water supplies.

The Stated Preference Approach – Use of Household Surveys

The stated preference approach can be used to directly measure M&I water supply benefits. Using this approach water users, both individuals and businesses, are asked directly what value they place on a water supply. The contingent valuation method (CVM) is a stated preference approach where survey responses to questions regarding water supply characteristics with and without a project are used to measure the benefits of a proposed change in the quantity or quality of a resource. Using CVM the benefits from a water supply improvement could be measured by asking water users their willingness to pay for increased water supplies, improved reliability of service, or improved water quality and using the willingness to pay estimates to estimate a hypothetical demand curve. The hypothetical demand curve can then be used to estimate the benefits of the proposed water supply improvement or the average willingness to pay from the surveys could be used to estimate total benefits.

Measurement of benefits using CVM is contingent upon the survey respondent understanding the proposed improvement and their ability to place a value on the improvement described in the survey. For example, the benefits to water users of converting from groundwater to surface water supplies could be estimated by asking users their willingness to pay for a surface water project. However, water users must understand how the conversion to surface water will affect water quality and reliability and the water users must be able place a monetary value on the change in terms of what water users are willing to give up (opportunity cost) to get the water supply change.

For CVM to produce reliable and unbiased estimates of resource values, survey respondents must be familiar with the good they are valuing and they must understand the proposed change in the resource. CVM is likely to provide representative benefit estimates for municipal and industrial water supply improvements compared to some other resource values because of the familiarity of water users with water supply problems and the familiarity with potential solutions to these problems such as pipelines and water treatment facilities. The steps that should be followed when estimating M&I benefits using CVM are:

- Determine the water supply conditions that will exist for each alternative under consideration, including the alternative of doing nothing. This becomes the basis for describing what survey recipients will be "buying."
- Determine the geographic area that will be affected by the improved water supply.
- Develop a survey questionnaire which includes a willingness to pay question with enough detail (as determined in Step 1) to allow the respondents to know what they are getting for their money. Questions also need to be included which represent variables that are expected to influence willingness to pay, such as income and household size.
- Conduct a survey of a representative sample of the affected water supply population.
- Estimate M&I benefit function based on the willingness to pay responses and responses to the other survey question data.

The Revealed Preference Approach - Benefits Based on Estimated Demand Curves

The revealed preference approach is based on observed market behavior or behavior in "market like" conditions. These observations of how consumers react to changes in price can be used to estimate a demand curve from which benefits can be estimated. Observed price-quantity combinations in municipal water markets reveal consumer preferences and will reflect willingness to pay for various quantities of water.

Theoretically, if we know two price-quantity combinations that represent points on a demand curve, then a linear demand curve can be estimated. If a large number of observed market-clearing price-quantity combinations are known, then a more accurate demand curve could be estimated and non-linear functional forms could be used. The supply curve can be estimated in a similar manner, showing price and quantity supplied combinations. Once the demand and supply curves are identified, the benefits associated with incremental changes in quantity can be estimated.

M&I demand curves can be estimated using time series data, cross-sectional data, or both. Time series data involves the use of data for a single entity over a period of time while cross-sectional data refers to data collected for many entities at one point in time or over a short period of time. It is generally more difficult to obtain a sufficient number of observations to estimate an M&I water demand curve using time series data for a water provider than for cross-sectional data for several water providers. Therefore, cross-sectional price and quantity information from various municipalities and rural water systems in the region of interest will generally be the best source of data for estimating M&I water demand curves. Data are needed for water price, the quantity of water purchased, income, household size, climate variables, and other variables expected to influence the quantity of water demanded. A demand curve for commercial water supplies would include price and quantity variables, along with a type of good or service variable that would indicate the importance of water as a production input, number of employees as a measure of business size, revenues, climate variables, and any other variables that would be expected to influence the quantity of water demanded.

It should be recognized that there are potential difficulties involved in estimating generalized demand curves using cross-sectional data. First, the water price and quantity information obtained from each water provider will be averages actually observed for each provider. Therefore, an aggregated demand curve based on averages from each provider will portray a representative demand relationship but will not portray an exact relationship for the specific site being studied. Second, it must be assumed that each price-quantity combination represents a market clearing equilibrium.

Conceptual Measure of Water Supply Benefits for Commercial Purposes

The value of water for commercial purposes is conceptually a little easier to measure than the value to households. The net value added from commercial output attributable to a water supply improvement is a measure of benefit. The techniques discussed above can also be applied to commercial water users. However, commercial benefits can also be estimated as the difference between the net value of output with the water supply and the net value of output without the water supply. Although this may be conceptually straight-forward, in practice many commercial water users are not anxious to provide detailed cost information necessary to evaluate the contribution of water supplies to net revenues. What is known is that for many industries requiring reliable water supplies of a certain quality, water supply availability will influence location decisions.

APPLICATION: POSSIBLE ECONOMIC VALUE OF MUNICIPAL WATER IN THE GILA RIVER REGION?

Although precise estimates of the value of municipal and industrial water in the Gila River region are not presented in this paper, a rough estimate of the magnitude of this value is presented for illustrative purposes below.

A 1997 study of willingness to pay for improved water supplies estimated at value of $11.63 to $17.29 per household per month for the Gallup-Navajo area of New Mexico. The willingness to pay estimate was based on a household survey. Assuming average monthly use of slightly less than 12,000 gallons per connection, the value of water for household use was estimated to be $315 to $465 per acre-foot. Using the consumer price index to index the values to 2008, the value is about $420 to $625 per acre foot. Assuming conditions are similar for the two areas, a very simple benefits transfer approach would be to apply the value to other areas of western New Mexico. A more accurate application of the benefits transfer approach would be to input site specific data for all model variables to estimate water supply values.

As another example, water rate and use data were obtained for 58 municipalities from the New Mexico Environment Department for 2006. The average cost per acre-foot of water for each municipality was estimated based on the average cost for 6,000 gallons of water. Additional data were obtained for average temperature, precipitation, income, and household size. Using this data a very rough demand curve was estimated using a double-log model. The results are summarized below:

$$\mathit{ln}\text{AF/HH} = -5.8202 - \underset{(-3.62)^{*}}{.5550328}{*}\mathit{ln}\text{COST/AF} + \underset{(1.84)^{**}}{.962978}{*}\mathit{ln}\text{TEMP} - \underset{(-2.27)^{**}}{.472511}{*}\mathit{ln}\text{PRECIP}$$
$$+\underset{(1.88)^{**}}{.5297598}{*}\mathit{ln}\text{INCOME} + \underset{(1.57)}{.8387134}{*}\mathit{ln}\text{HHSIZE}$$

where *ln*AF/HH = natural log of water use in acre-feet per household per year
*ln*COST/AF = natural log of the cost of water per acre-foot
*ln*TEMP = natural log of average annual temperature
*ln*PRECIP = natural log of average annual precipitation
*ln*INCOME = natural log of median annual household income
*ln*HHSIZE = natural log of average household size
F Statistic = 11.61*
Adjusted R^2 = .48
Observations = 58
Price Elasticity = -.555

One asterisk indicates significance at the 99% level and two asterisks indicate significance at the 90% level of confidence.

The benefits associated with the provision of municipal and industrial water supplies can be measured as the area under the demand curve between the relevant prices and quantities for a municipal and industrial water supply. The relevant quantities are represented by the amount of water purchased without a water supply project (or some other change in supply) and the quantity of water with a project (or some other change in supply).

The demand equation estimated above could be applied to Silver City to get an idea of the possible magnitude of municipal water supply benefits. The relevant quantities of water with and without a project cannot be known with certainty because future population growth, growth in commercial/industrial water demands, and future groundwater conditions cannot be known with certainty. However, assuming that a 10% increase in water use could be supported by an additional water supply and that current use is about .43 acre-feet per connection, the average benefit would be about $650 per acre-foot. The price of water used for Silver City was $14.23 per 6,000 gallons, average annual temperature was 54.9 degrees, annual precipitation was 16.08 inches, median household income was $25,881, and average household size was 2.4 persons.

SUMMARY

Five methodologies have been presented that can be used to estimate the benefits of municipal and industrial water supplies. The alternative cost approach is not applicable to the Gila River region due to the restrictive assumptions regarding water supply outputs and the variety of water uses that need to be compared in the area. The other four approaches can all provide measures of willingness to pay for M&I water supplies of varying degrees of accuracy and have different levels of complexity. These are summarized below.

Valuation Method	Complexity
Contingent Valuation Method	5
Demand Curve Estimation	4
Use of Price Elasticity Estimates	3
Benefits Transfer	2
Cost of Most Likely Alternative	1

1 – Simple to apply, does not require understanding of economic theory, only requires cost data.
2 – Requires knowledge of economic and social conditions, availability of study results, comparable characteristics between the study area and sites that have estimated relationships from previous studies.
3 – Requires an understanding of basic economic theory, requires general economic data, and requires the availability of previous study results.
4 – Requires rigorous economic analysis and a considerable amount of secondary site specific data.
5 – Requires design and implementation of questionnaire to obtain data, rigorous economic analysis conditions with project may be difficult to quantify, time consuming, need a large amount of information.

Valuation Method	Accuracy
Contingent Valuation Method	4-5
Demand Curve Estimation	4
Use of Price Elasticity Estimates	2-3
Benefits Transfer	2-3
Cost of Most Likely Alternative Without Project	1

1 – Not a theoretically correct, reliable, or accurate measure of benefits.

2 – Estimates based on general economic theory, but may not be accurate due to limited data and many potential sources of measurement error.
3 – Estimates are representative and accurate within a range of values. Not necessarily site specific, tend to be more regional.
4 – A greater level of certainty than for 3, but still uncertainty due to data errors, errors in data gathering, and errors in modeling. Sources of error can be identified but are not fully accounted for. Results are site specific.
5 – Very accurate and site specific result