Collaborative Water Resources Decision-Making through Participatory Modeling in the Rio Sonora Basin, Mexico

Alex S. Mayer, Kathleen E. Halvorsen, David J. Kossak, Michigan Technological University, USA
Enrique Vivoni, Arizona State University, USA
Agustín Robles-Morua, Instituto Tecnológico de Sonora, México
Acknowledgements

- Funding source: NSF CBET #101481 Interdisciplinary Research Program
- Workshop participants
- Daniel Che, Vivianna Gomez, Mariela Castenada, Kelsii Dana, Ana Cristina Pacheco...
Rio Sonora Basin (RSB)

- Climate is semi-arid, highly variable, with frequent, severe droughts.
- Major water uses include large-scale irrigated agriculture and large urban area.
- Water resources infrastructure system struggles to deliver sufficient water.
Water resources management is controversial, due to perceptions of water scarcity, conflicts among water users, and political backdrop.
We are studying decision-making for water resources management in anticipation of climate change in the Rio Sonora River Basin, Sonora, Mexico.

Primary question:
Can water resources systems modeling, developed within a participatory framework, contribute to management strategies in a context of water scarcity, conflicting water uses and highly variable and changing climate conditions?
Project focus: Participatory modeling

- Definition: process of collaboratively constructing a shared representation of a natural resources management system.

- Designed to:
  - gather and integrate a diversity of viewpoints from participants in the development of models...

  ...so that a collective management vision can be established and adapted as conditions change in the future.
Participatory modeling (PM) has been used in many contexts. But, evaluation of the outcomes is rarely done systematically (Robles-Morua et al. 2013). Many PM organizers assert outcomes with little empirical data to support their findings. Some conduct post-workshop qualitative interviews, but without pre-workshop baselines, causality is problematic. Gold standard is pre- versus post-workshop surveys, but rarely done (Robles-Morua et al. 2013).
Methods: Research Design

- Develop and assess conceptual models of beliefs about models
  - create, implement and analyze pre- and post-workshop surveys to analyze impact of workshops

- Develop models and forcings
  - hydrology: surface water and groundwater models
  - water resources system: supply and demand management, including infrastructure system
  - climate scenarios: downscaled climate predictions

- Conduct three participatory modeling workshops in 2013.
Baseline model of RSB water resources system

Development scenarios

Climate scenarios

Model inputs

HEC HMS

Watershed

Reservoirs

Outflows

Withdrawals

Return flows

Consumptive use

Aquifers

Outflows

Hermosillo

Rural Area

HEC HMS

(HEC HMS)

(STELLA®)

Withdrawals

Outflows

Return flows

Consumptive use
Climate forcings

**Weather Research and Forecasting (WRF) model**

- **Boundary conditions from GCM**
- **Regional Climate Model (WRF)**
- **IPCC Projections**

**Historic WRF Precipitation (1990-2000)**
- **1990-2000**: 267 mm

**Near Future WRF Precipitation (2031-2040)**
- **2031-2040**: 493 mm

**Far Future WRF Precipitation (2071-2079)**
- **2071-2079**: 400 mm
Workshop participants

- Participants included water agencies, academics, NGOs
- Number of participants:
  - workshop 1/2/3: 53/28/30
  - represented 18 organizations
- 18 participants attended all three workshops and completed surveys
Workshop description

- **Format**
  - Seminars and discussion
  - Practical modeling activities
  - Iterative model development

- **Topics**
  - RSB hydrology, climate, and water management system
  - Climate change in the RSB
  - Hydrologic systems modeling
  - Elaboration of future development scenarios
  - Supply and demand management in the RSB
## Survey scales summary

<table>
<thead>
<tr>
<th>Theme/Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant’s prior experience with models</td>
</tr>
<tr>
<td>Beliefs about personal capacity to use and understand models</td>
</tr>
<tr>
<td>Beliefs about “usefulness” of models</td>
</tr>
<tr>
<td>Beliefs about “exactness” of models</td>
</tr>
<tr>
<td>Beliefs about water quantity problems, causes, and solutions</td>
</tr>
<tr>
<td>Beliefs about water quantity problem impacts</td>
</tr>
<tr>
<td>Climate change-related beliefs</td>
</tr>
<tr>
<td>Results of the workshops &amp; Evaluation of the process</td>
</tr>
</tbody>
</table>

| Total questions: | Pre: 44 | Post: 49 |
The lack of water hurts agriculture and industry and reduces economic development in our region.

Overall scale results

Climate change-related beliefs

** Beliefs about water quantity problem impacts

Beliefs about water quantity problems, causes, & solutions

Beliefs about “exactness” of models

*** Beliefs about “usefulness” of models

*** Capacity to use and understand models

*** significant at p < 0.01

** significant at p < 0.025

Overall scale results
Selected pre- and post-survey results

- **Impacts of the problems**
  - More people believe that lack of water can cause ecological problems.
  - Fewer people believe that the lack of water can result in reduction in population in the region.
  - Fewer people believe that excessive exploitation of water **does not** exist in the Río Sonora.

- **Social impacts of water resources decision making**
  - More people believe that when there are conflicts between uses of water, priority should be given to domestic use.
<table>
<thead>
<tr>
<th>Water management strategy options</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Increase Capacity of Reservoir and Aqueduct</td>
</tr>
<tr>
<td>☐ Capacity of La Independencia Interbasin Transfer</td>
</tr>
<tr>
<td>☐ Desalination Capacity</td>
</tr>
<tr>
<td>☐ Reduction in Hermosillo Groundwater Supply</td>
</tr>
<tr>
<td>☐ Reuse of Wastewater for Industry or Aquifer Recharge</td>
</tr>
<tr>
<td>☐ Repair Hermosillo Distribution System</td>
</tr>
<tr>
<td>☐ Efficiency Gain/Loss in Residential, Industrial or Agricultural Water Use</td>
</tr>
</tbody>
</table>
Management strategies: Results

Mean and standard deviation of response

- Minimum Annual Supply/Demand
- Average Supply/Demand
- Efficiency Gain/Loss in Agricultural Water Use
- Efficiency Gain/Loss in Industrial Water Use
- Efficiency Gain/Loss in Residential Water Use
- Reduction in Groundwater Supply
- Repair Hermosillo Distribution System
- Reuse of Wastewater for Aquifer Recharge
- Reuse of Wastewater for Industry
- Desalination Capacity
- Capacity of Interbasin Transfer
- Increase Capacity of Reservoir and Aqueduct

fraction of maximum
Conclusions/Observations/Questions

- Most people were highly satisfied with the conduct of the workshop.
- Most people believed that they had contributed to the development of the models and that the models are useful.
- Full, rich, open dialogue about water resource decision making in the basin occurred.
- Preference of supply- and demand-side options was roughly equal.
- How do we increase participation in workshops?
- What will a broader array of climate projections reveal?