Overcoming Barriers between Hydro-economic Models and Policy Applications

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ICID Meetings
Saskatoon, Saskatchewan

FAO-Organized Session
Hydroeconomic modelling for transboundary river basin management :
Towards more integrated approaches

August 15, 2018

Issues

- Allocation of water among competing uses, in transboundary basins, especially agriculture, urban, and power: ongoing challenge.
- Any water use or source at any location in a basin affects use at different locations and time periods.
- Lots of moving and connected parts: science/policy
- Collaborative management and benefit sharing in TB basins difficult without basin scale analytical frameworks to inform policy design communicated to policymakers and diplomatic community.
- HEM: state of the arts decision support method to incorporate complex energy-water-food systems to track interacting elements
- Great potential to inform water-food-energy policy, esp. climate resilience policy
- Weak track record in doing so to date

Climate Resilience

- Climate resilience: Folke (2006) and Nelson et al (2007): capacity for a social-ecological system to:
  - absorb stresses and maintain function in the face of external stresses imposed upon it by climate change
  - adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts.

Barriers to HEM to informing policy debates

- Hard to track results of policy proposals through complex systems, even when evidence is available
- Hard to quickly change assumptions or model structure
- Hard to present assumptions/results to ministry staff
- Desire: Policymakers want to know economic/physical impacts of proposed policies (e.g., reservoir releases for food/environment) in many time periods into the future.
- Question: What if benefits or costs of various water / energy / food / environmental services change.

Ends (Goals)

- Present lessons learned to overcome barriers (bottlenecks) between HEMs and application to basin policy design, e.g. improve climate resilience to raise performance of water-food-energy nexus

- Describe some success stories

Approach

- Informal meta analysis
- Based on personal experience with HEMs since mid 1990s with academic and stakeholder audiences.

Going from complex optimization models to useable interfaces

- Learn today's big policy debates, and imagine where they are going.
- Find out what measures could be implemented to deal with them.
- Find out constraints that block measures from working.
- Find out what it would take to relax or dissolve those constraints.
- Find out a way to translate a basin's hydrology, economics, institutions, infrastructure, and policy choices, and implementation measures into

Indices	(year, location, economic sector)
Data	(observed or potential)
Variables	(unknowns)
Objectives	(what do you want to maximize, often DNPV, but not always)
Constraints	(e.g., US-Mexico 1906 treaty deliveries on RGR to Mexico)

Rio Grande HEM (USDA Funding, 2015-20)

Important Project Goal

Better understanding of the Rio Grande system from Elephant Butte to Presidio

How it operates
Let stakeholders experiment with operations
Carries implications for how it could operate

on/Calibration

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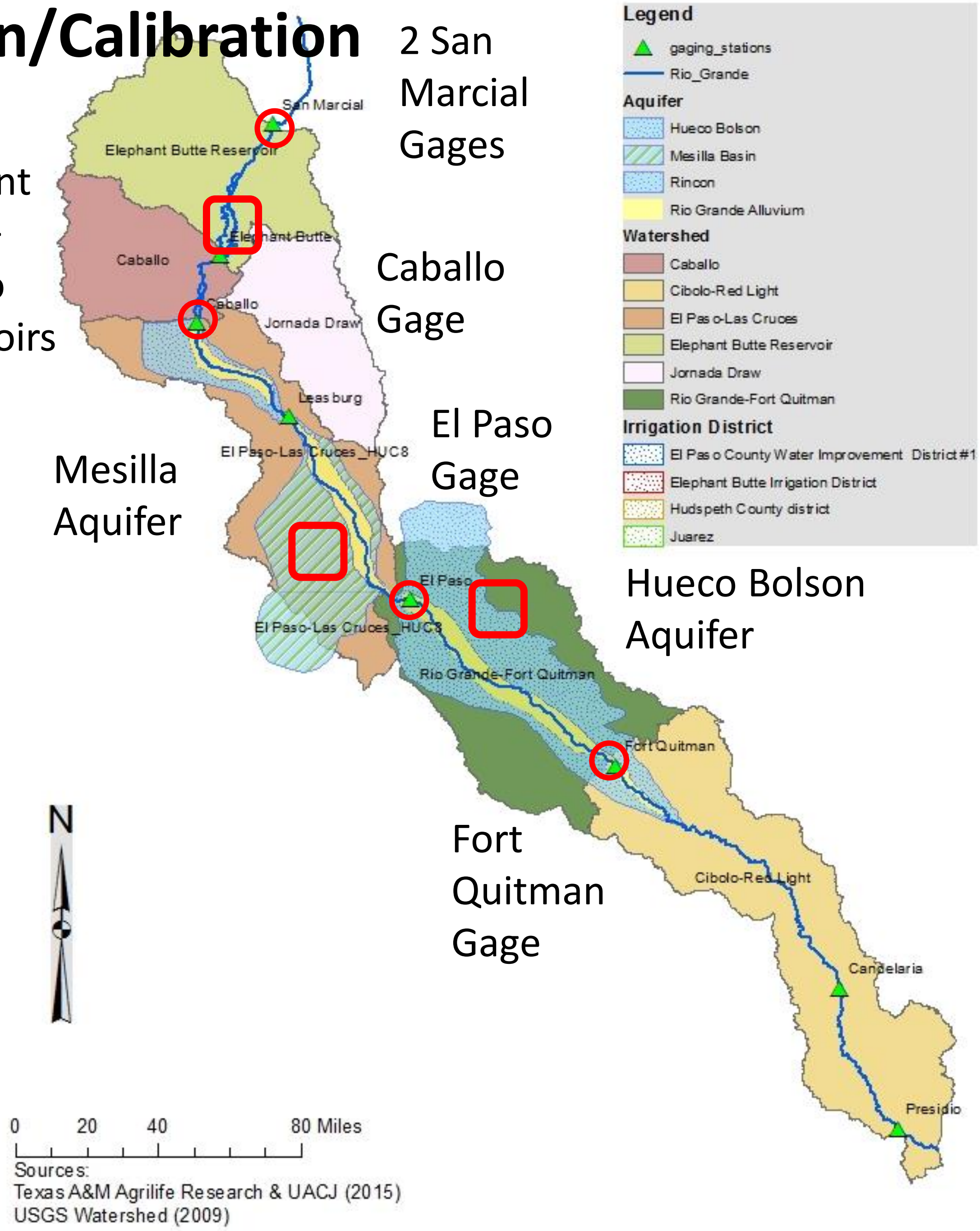


2 San Marcial Gages

Caballo Gage

El Paso Gage

Mesilla Aquifer

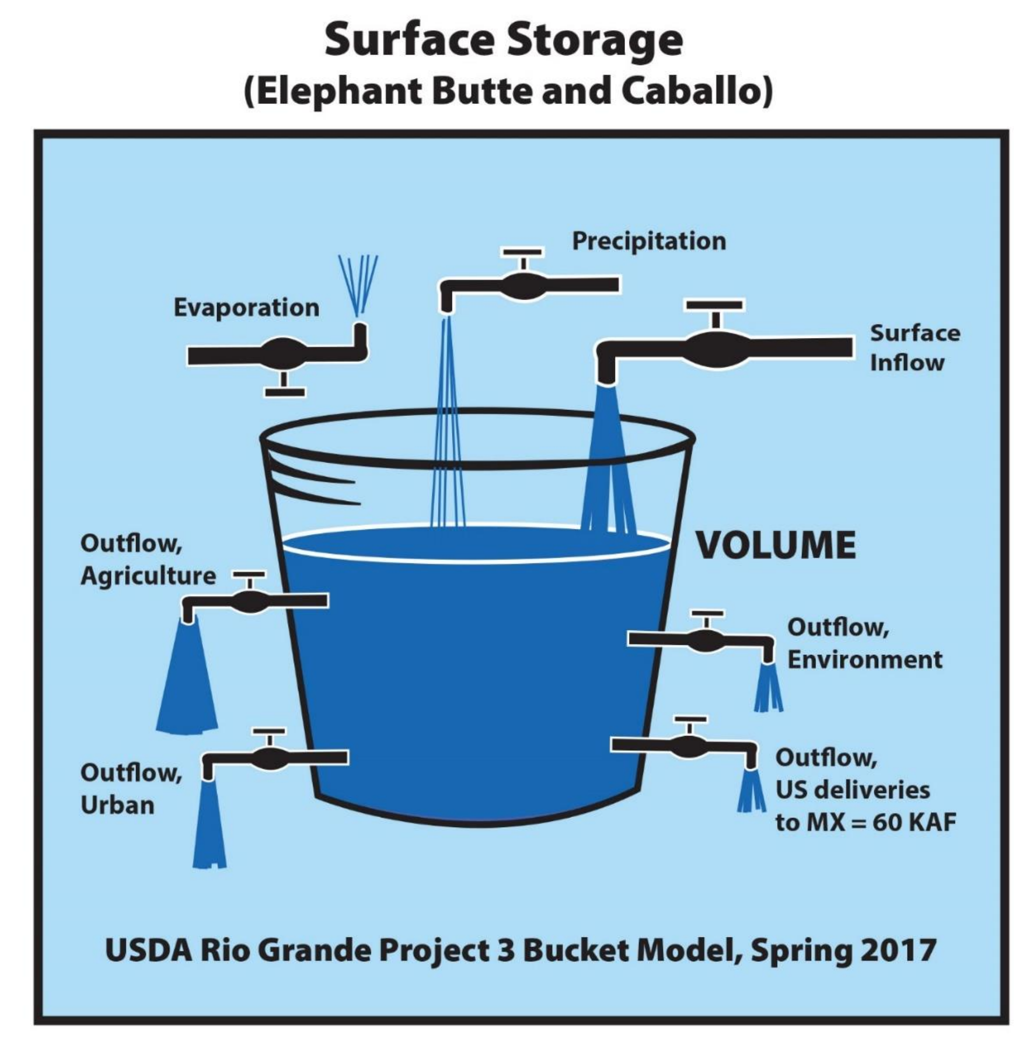
Hueco Bolson Aquifer

Fort Quitman Gage

Sources:
Texas A&M Agrilife Research & UACJ (2015)
USGS Watershed (2009)

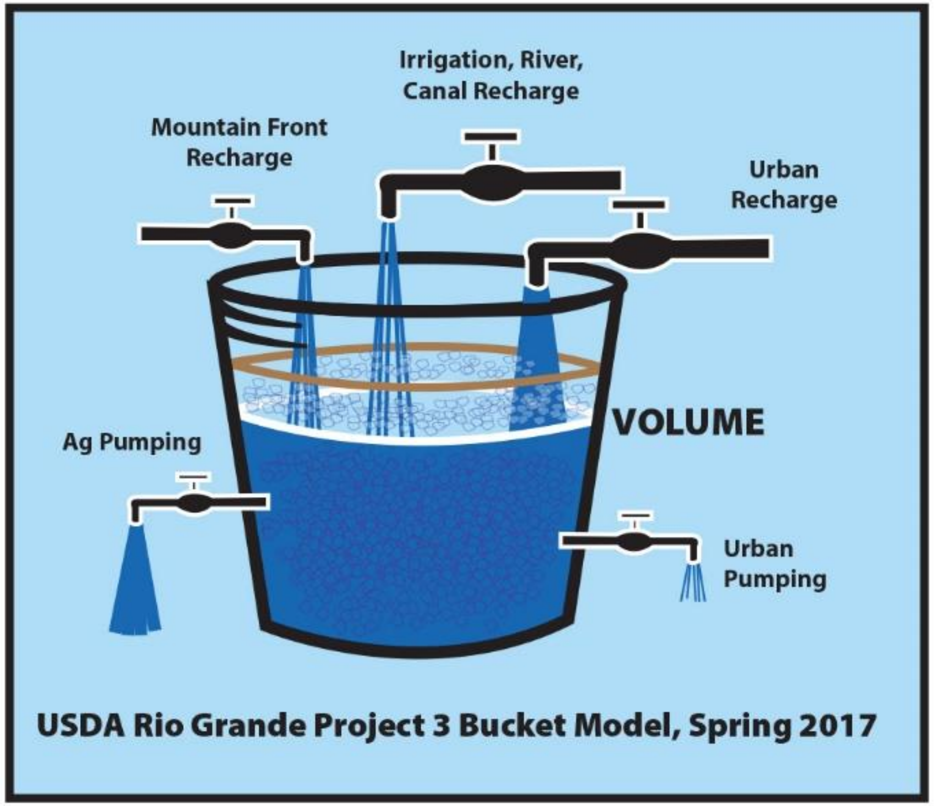
Buckets

Change in Storage = Inflow - Outflow



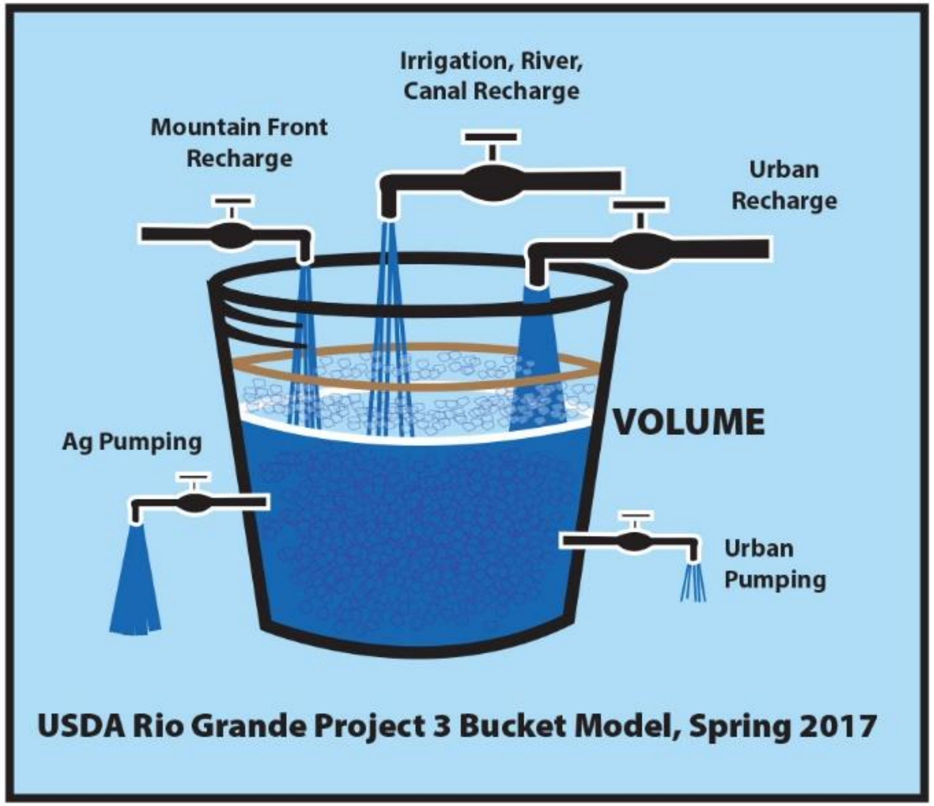
Change in Storage = Inflow - Outflow

Aquifer Storage (Mesilla)

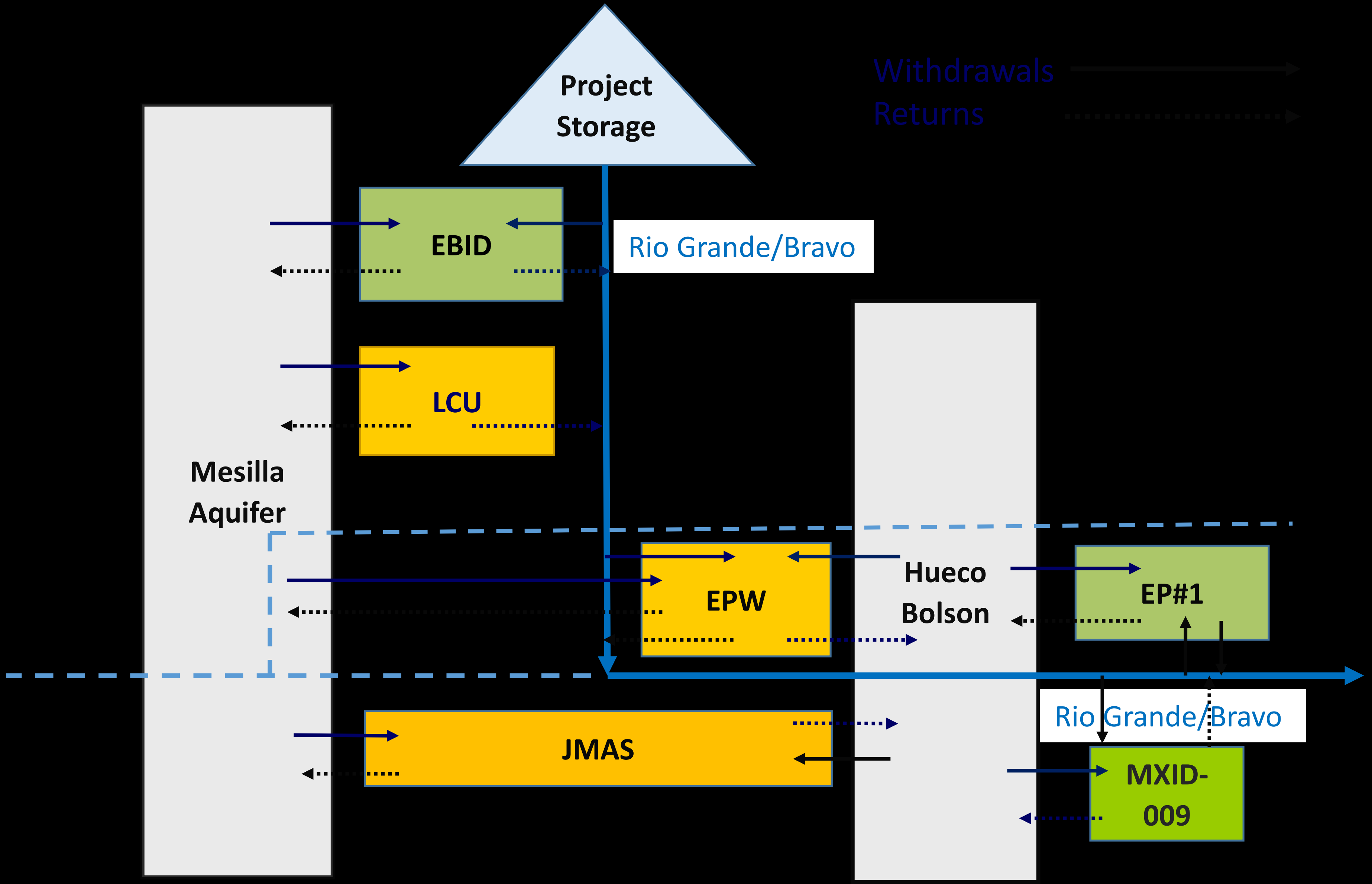


USDA Rio Grande Project 3 Bucket Model, Spring 2017

Aquifer Storage (Hueco)



USDA Rio Grande Project 3 Bucket Model, Spring 2017



Withdrawals

Returns

Project Storage

Rio Grande/Bravo

Mesilla Aquifer

EBID

LCU

EPW

JMAS

Hueco Bolson

EP#1

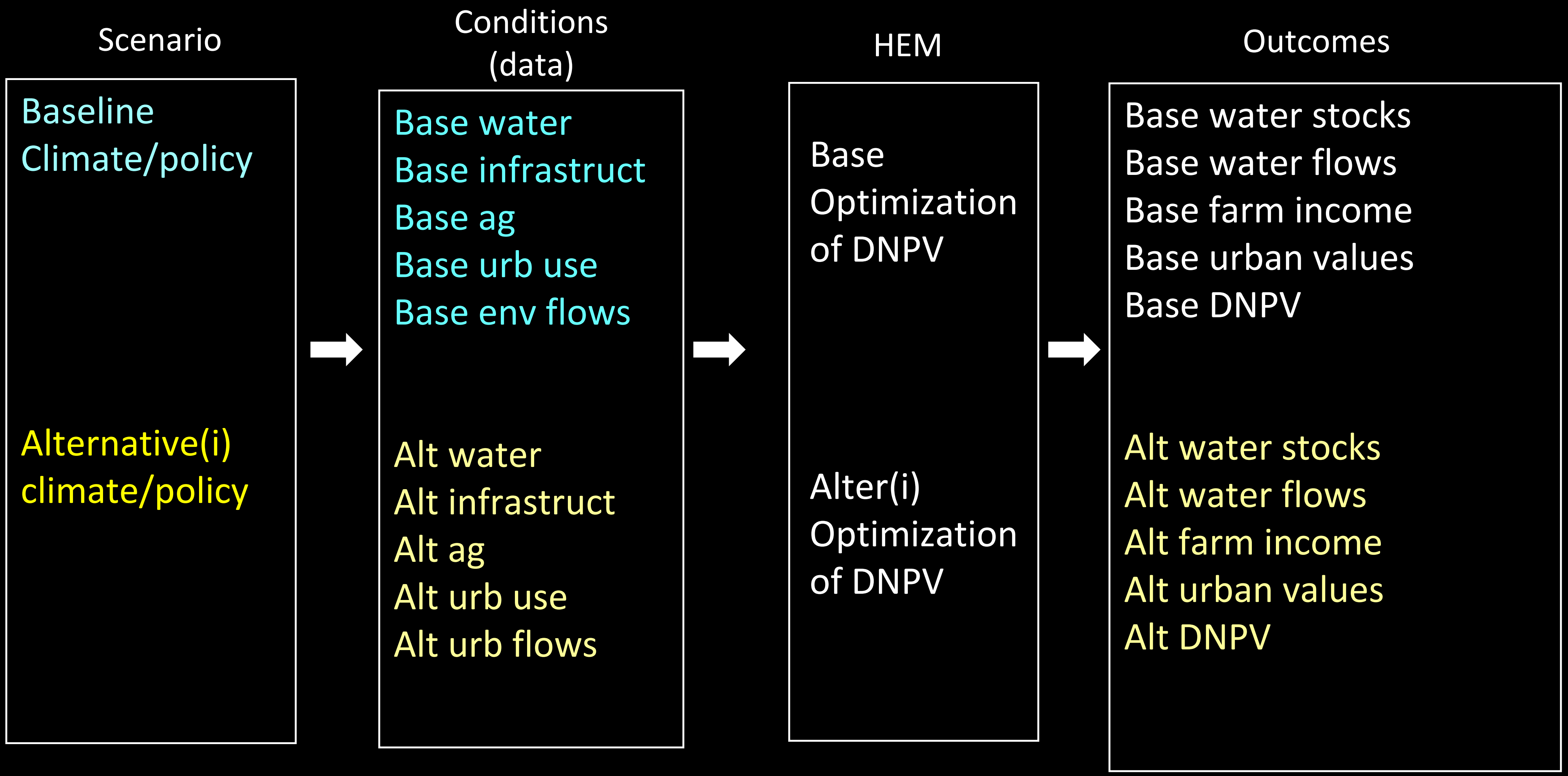
MXID-009

Rio Grande/Bravo

Basin Scale Hydroeconomic Model: water-food-energy nexus

- Maximize
  - Objective
    - Economic: values of water + food + energy + environment
    - Environmental
    - Social Justice
    - Hydrologic
- While Respecting Constraints
    - Hydrologic
    - Agronomic
    - Institutional
    - Economic

Policy Assessment Framework



Scenario

Baseline
Climate/policy

Alternative(i)
climate/policy

Conditions
(data)

Base water
Base infrastruct
Base ag
Base urb use
Base env flows

Alt water
Alt infrastruct
Alt ag
Alt urb use
Alt urb flows

HEM

Base
Optimization
of DNPV

Alter(i)
Optimization
of DNPV

Outcomes

Base water stocks
Base water flows
Base farm income
Base urban values
Base DNPV

Alt water stocks
Alt water flows
Alt farm income
Alt urban values
Alt DNPV

Model/Policy Connections

- Connections: HEM
  - Hydrologic: stocks, flows, over time, space
  - Agronomic: acreage, water use, crops
  - Demographic: urban income, population, demand
  - Objective: optimizes total economic benefits from uses
  - More Objs: e.g., human right to food, water, energy
  - Institutional: rules that limit use or require delivery

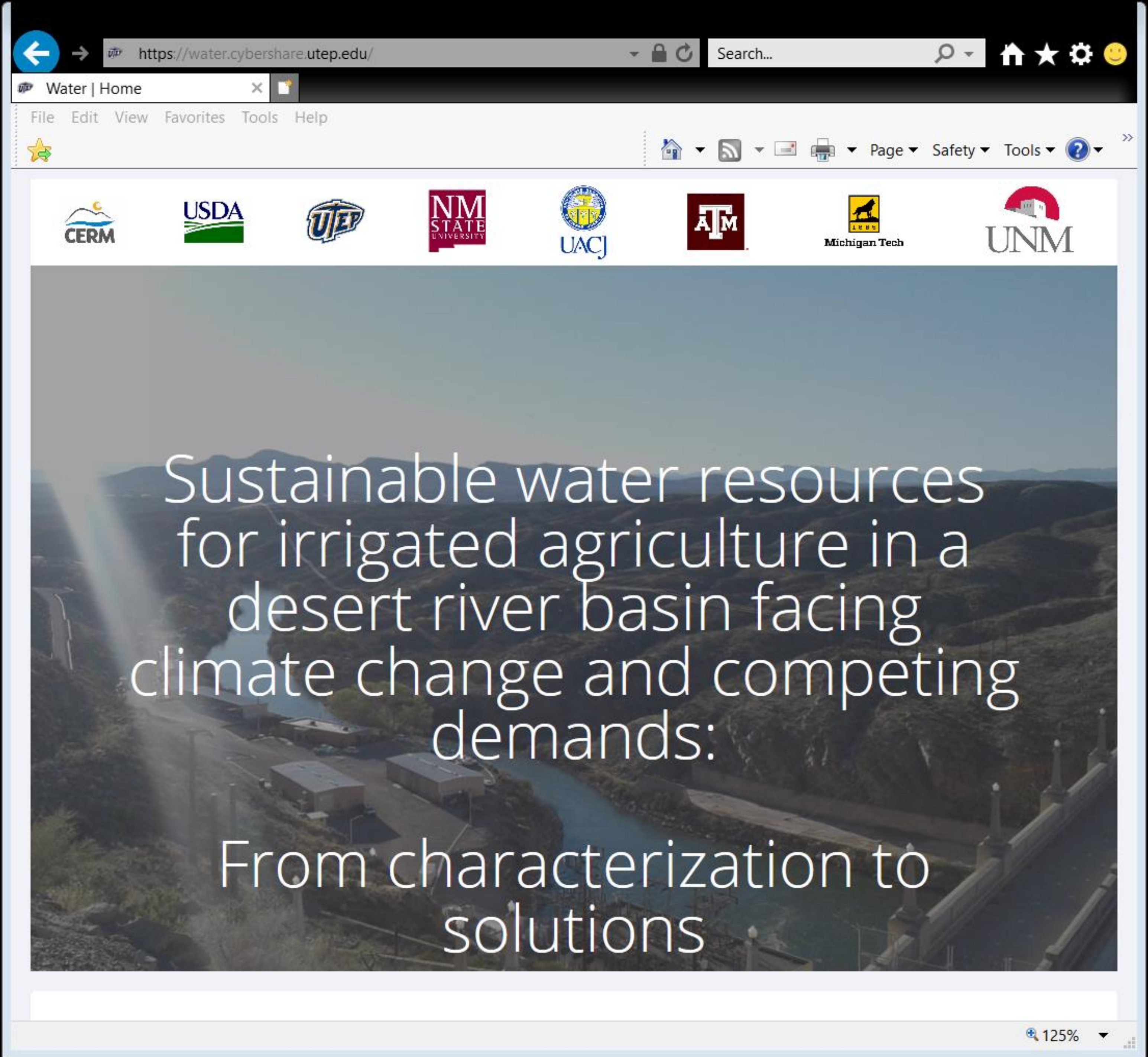
- Gain insights into policies that best adapt to climate: resilient stress adaption measures
  - For basin as a whole or part, e.g. Rio Grande Basin
  - For targeted users (farm, city, environment)

Sustainable Water Through Integrated Planning (SWIM) Platform

- Model users
  - create their own scenarios
  - modify data
    - climate-water supply, infrastructure, economic data, demographics, sustainability indicators
  - run the model (about 30 seconds)
  - get their own custom-made results
    - Hydrologic
    - Economic
    - Social Justice

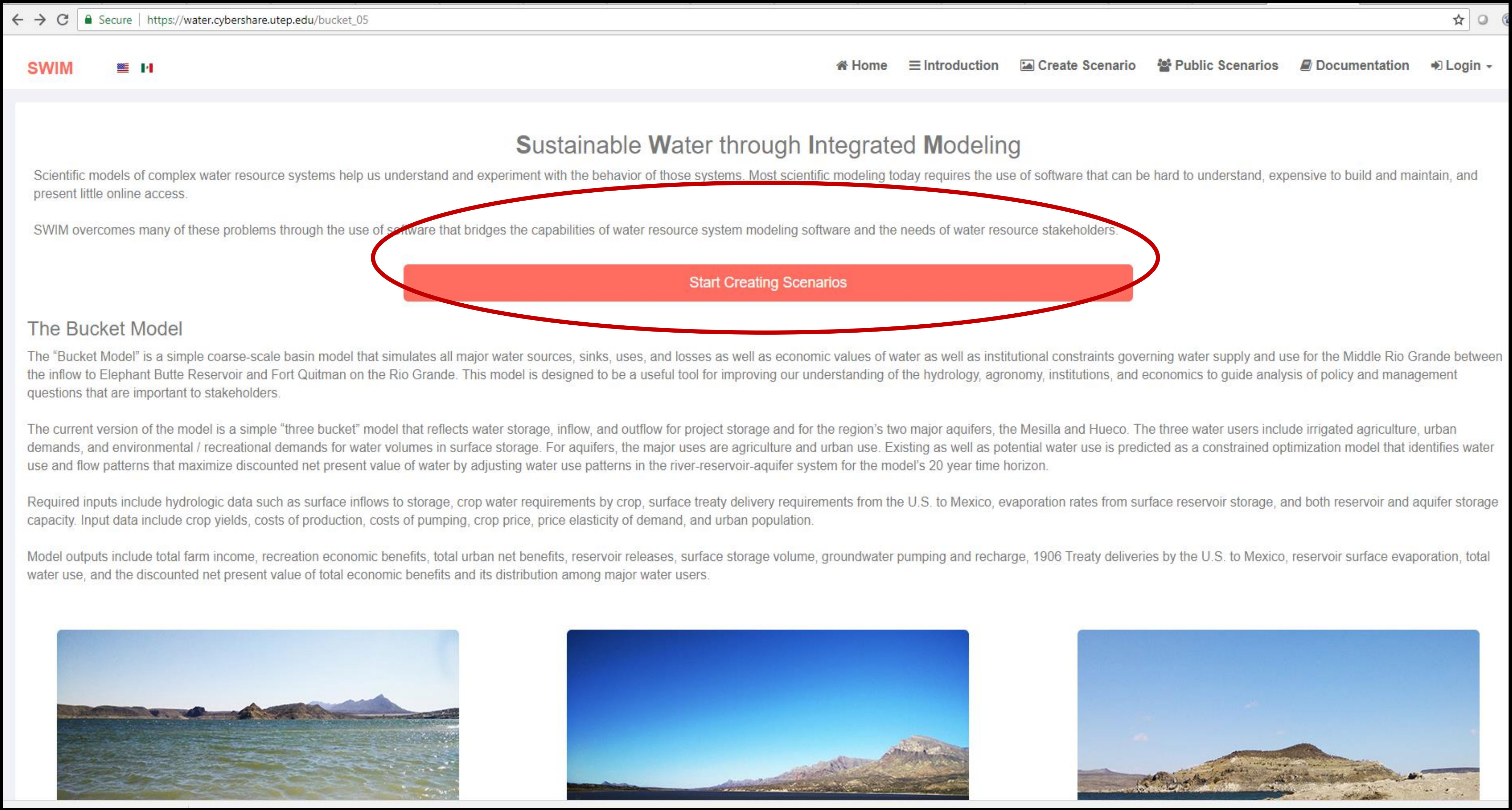
Sustainable Water Through Integrated Planning (SWIM) Platform

https://water.cybershare.utep.edu/



Sustainable water resources for irrigated agriculture in a desert river basin facing climate change and competing demands:

From characterization to solutions



Sustainable Water through Integrated Modeling

Scientific models of complex water resource systems help us understand and experiment with the behavior of those systems. Most scientific modeling today requires the use of software that can be hard to understand, expensive to build and maintain, and present little online access.

SWIM overcomes many of these problems through the use of software that bridges the capabilities of water resource system modeling software and the needs of water resource stakeholders.

The Bucket Model

The "Bucket Model" is a simple coarse-scale basin model that simulates all major water sources, sinks, uses, and losses as well as economic values of water as well as institutional constraints governing water supply and use for the Middle Rio Grande between the inflow to Elephant Butte Reservoir and Fort Quitman on the Rio Grande. This model is designed to be a useful tool for improving our understanding of the hydrology, agronomy, institutions, and economics to guide analysis of policy and management questions that are important to stakeholders.

The current version of the model is a simple "three bucket" model that reflects water storage, inflow, and outflow for project storage and for the region's two major aquifers, the Mesilla and Hueco. The three water users include irrigated agriculture, urban demands, and environmental / recreational demands for water volumes in surface storage. For aquifers, the major uses are agriculture and urban use. Existing as well as potential water use is predicted as a constrained optimization model that identifies water use and flow patterns that maximize discounted net present value of water by adjusting water use patterns in the river-reservoir-aquifer system for the model's 20 year time horizon.

Required inputs include hydrologic data such as surface inflows to storage, crop water requirements by crop, surface treaty delivery requirements from the U.S. to Mexico, evaporation rates from surface reservoir storage, and both reservoir and aquifer storage capacity. Input data include crop yields, costs of production, costs of pumping, crop price, price elasticity of demand, and urban population.

Model outputs include total farm income, recreation economic benefits, total urban net benefits, reservoir releases, surface storage volume, groundwater pumping and recharge, 1906 Treaty deliveries by the U.S. to Mexico, reservoir surface evaporation, total water use, and the discounted net present value of total economic benefits and its distribution among major water users.

1: Scenarios: Select Inflows, Population, Policy, Technology

- Observed Inflows at San Marcial Gauges
  - Uses observed historical inflows from 1994 to 2015. Inflow remains static after 2015, i.e. 2015 average inflow is repeated up to 2033 (1994-2014).
  - Custom percentage of observed annual average flow past the SM.
- Observed Inflows + Extended Drought
  - Uses observed historical inflows from 1994 to 2013. Appends 20 years of synthetic drought from 2014-2033.
  - Defined as the three year sequence of SM flows at the end of the baseline period (2011-2013), repeated over and over for the 20 years following 2013.
- Moderate Stress Climate Scenario
- Big Stress Climate Scenario
- After putting all that in, click right hand button: NEXT

2: Customize

Alter data we coded in model to, suit your beliefs

- Urban: Alter the population levels and growth rates and price elasticity of demand
  - For future, alter demand predictors like household size, lot size, income
- Agriculture: Alter cropped acreages by crop, price, cost, and yield. Watch out for falling prices or increased costs, or crops will drop out of production.
  - For future: account for consumer surplus, since growing crop supply reduces prices and increases food security worldwide
- Sustainability: alter the ending proportion required levels of
  - Reservoir Storage
  - Aquifer storage
- After putting all that in, click right hand button: NEXT

3: Review and Run

- Look at all the data you put in or accepted (check that you didn’t build a beast)
- After you check and like input data, click right hand button: RUN SCENARIO
- Model runs in about 30 seconds (300,000 variables to optimize, uses GAMS software with CONOPT solver)

4: Model Outputs
Shows you what your management achieves
Best to run in pairs (altered v. base)

- Summary
- Urban
- Agriculture
- Storage
- Flows
- Map

5: Provenance
Shows data sources

- In progress

Plans for stakeholder presentations Aug/Sept 2018

- Evaluate time path of recovery of Elephant Butte Reservoir under various constraints on reservoir releases
- Assess how that recovery path varies with alternative climate scenarios.
- Investigate least cost measures to bring EB to a set level at a set time period
- Show impacts of restrictions on groundwater pumping.
- Show impacts of alternative technologies, especially costs and quantities available of various kinds of substitute water.

May 2018 stakeholder meeting, UT El Paso, TX, USA

- Growers loved interface but wanted to know more about the back end. Were there real data and equations inside? Are we trying to hide something?
- Are we getting institutions right (e.g., project operating agreement ‘08)?
- Other Stakeholders: Let’s break it by asking it to do the impossible. Model has a backstop technology (desal) that always comes to the rescue, no matter how little water is available in the river and aquifers. But the cost is high.
- Policymakers want to see costs of water protection measures and size of subsidies needed to reduce that cost and/or protect water users.
- Summer 2018 questions: What if surface inflows in RGR fall to zero next year. What will be effect with and without subsidies of backstop technologies?
- Risk management: What if urban water supply is knocked out of commission? How much should invest in backstop in case no inflow next year?

Conclusions: Future Plans

- Stakeholder meetings: Find out what they need for a better interface
- Let stakeholders experiment with alternative objectives: alternative weights for ag, urban, energy, environment, social justice
- Let stakeholders choose from a list of climate resilience definitions and deterministic/stochastic model structure
- Let stakeholders build their own HEM for whatever basin they'd like. This requires letting them adjust
  - basin plumbing
  - reservoir sizes and locations
  - Irrigation/urban use locations
  - locations of key ecological assets
  - Data on economic costs and values
  - Data on institutional constraints