“Science exists to serve human welfare. It’s wonderful to have the opportunity given us by society to do basic research, but in return, we have a very important moral responsibility to apply that research to benefiting humanity.”

Dr. Walter Orr Roberts (NCAR founder)
Need “Actionable Information”

David Behar, Water Utility Climate Alliance, “We need actionable information to make changes or additions to capital investments..”, San Francisco Public Utilities

Marc Wagee, Manager of Water Supply, Denver Water, “Surprisingly, we haven’t dealt well with uncertainty.. Climate change is a wake-up to this fact”
MWRA and the “Boston Harbor Cleanup”,

[Image of a large water treatment facility near the harbor]
Study Approach

- Developing Decision Analysis tools that incorporate climate change information
- Risk-management approach to decision-making
- Worked with a set of water utility partners from the very start
Partnership Design and Decision Tools

Industry Research – AwwaRF

Utility Partners

Structured Process & Decision Tools

Project Team
NCAR, consultants

Climate Research – NCAR; Universities; Federal Agencies
Partnership Design and Decision Tools

- Partnership Facilitator, USAID-Eco-Asia
- Models, Tools, etc.
- Project Team Asia Utility
- US Utility + NCAR
- Climate Research – University, Institutes (Met, Clim)
Bottom-Up Approach: Decision Analytic Approach to Climate Change

- Problem Structuring
  - Problem Structuring
  - Goals
- Deterministic Formulation
  - Decision Model
  - Sensitivity Analysis
- Uncertainty Analysis
  - Probabilistic Representation
  - Future Projections
- Evaluation of Alternatives
  - Robustness
  - MCDA
  - EV
  - Triple Bottom
PROBLEM STRUCTURING - GOALS AND OBJECTIVES

Inland Empire Utility Agency
Focus on enhancing local supplies or rely on imports?

Colorado Springs Utilities
Integrated Resource Plan... how to link to current safe yield analysis?

MWRA
Safe Yield Analysis- What level of demand meets Quabbin storage targets under climate change

Palm Beach County
IRP in the face of major changes (Lake Okeechobee, future demand, environ interests, sea level rise, climate change, etc.)
Deterministic Formulation

• This Approach is Model-based: “All are wrong, Some are Useful”
  • Surprisingly, many water utility models are not “climate-enabled”

• Develop approach that can address the questions at hand: “Keep it simple as possible, and no simpler”

• Begin Climate Change Exploration
Need for An Integrating Model Framework

Pre-development
Temp, rh, wind

Precipitation

Runoff

Infiltration

Groundwater Discharge into Stream

Natural Watershed

Post-Development
Hydrology Model

Water imports
Planning Model

Deterministic Formulation
- Decision Model
- Sensitivity Analysis

Developed Watershed

Infiltration

Runoff

AQUIFER

Groundwater Discharge into Stream
**Critical question:** How does rainfall on a catchment translate into flow in a river?

**Critical question:** What pathways does water follow as it moves through a catchment? Runoff? Infiltration? ET? Seepage?

**Critical question:** How does movement along these pathways impact the magnitude, timing, duration and frequency of river flows?
Planning Model

Critical question: How operations be optimized to protect the services provided by the river?

Critical question: How should infrastructure (e.g. dams, diversion works, etc) be operated to achieve maximum benefit? How should water be allocated in shortage?

Critical question: How will allocation, operations and operating constraints change if new management strategies are introduced into the system?
Water Management Can Get Complicated

A multi-objective reservoir:
1. satisfy downstream demand
2. generate hydropower
3. provide flood protection
4. maintain environmental flows
5. provide recreational opportunities

Jan: 70
Feb: 110
Mar: 180
Apr: 220
May: 350
Jun: 140
Jul: 35
Aug: 20
Sep: 10
Oct: 5
Nov: 20
Dec: 30

Priority set according to:
1. Reservoir storage
2. The month
3. Recent conditions

Jan-Apr: 10
May-Aug: 40
Sep-Dec: 10
Integrated Water Resource Management

- Integrates hydrology and water planning model
- GIS-based, graphical GUI interface.
- Physical simulation of water demands and supplies.
- User-created variables and modeling equations.
- Scenario management capabilities.
- Seamless watershed hydrology, water quality and financial modules
- SEI-US.org, NCAR, Wat Res Fnd, USEPA

Yates et al. 2005, Water International, Pt. 1 and Pt. 2
# Methods to Climate Scenarios

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Delta Method</th>
<th>Scenario Approach</th>
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<tbody>
<tr>
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<td></td>
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<tr>
<td><strong>Ease-of-Use</strong></td>
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<td>Easy to Difficult</td>
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<td>Based on Historical Obs</td>
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Kissimmee Headwaters - Rapid Urbanization

Shallow Freshwater Lake - Reoperated for Flood Control

Largest Sugarcane region in Florida - some interest in ‘buying out’

Preservation of Wetland Habitat

Urbanizing Corridor

Inland Estuary - Freshwater flux to tide

Problem Structuring
- Problem Structuring
- Goals

PBCWUD
PBCWUD: Goal or Question:
Is there a “Robust” Capital Improvement Plan?

20-Year CIP Projects:

- ASR wells
- Surface Storage
- Water and WWTP Expansions
- New RO Treatment Facility
- Wellfield Expansions
- New Deep Injection Wells
WEAP Supply-Demand Model

Rigorous Representation

Deterministic Analysis
Uncertainty Analysis
Evaluation of Alternatives
WEAP Model- Model of Supplies

Kissimmee Inflows

Lake Okeechobee Storage

C-51 Outflow

Observed vs Simulated Values
Population: An Uncertain Future in South Florida?

PBCWUD Total Demand in 2008 - ~80 MGD

Regional Demand in 2008 - ~225 MGD
Statistics Downscaled
WCRP CMIP3 Climate Projections

This site has been optimized for Internet Explorer 6*, IE 7.*, and Firefox 2.*.
Requires JavaScript to be enabled

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Announcements (updated January 8, 2008)

Summary
This archive contains fine-resolution translations of 112 contemporary climate projections over the contiguous United States. The original projections are from the World Climate Research Programme’s (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. The “About” section on this website contains development information on these downscaled projection datasets (e.g. background, data attributes, and methodology).

Purpose
The archive was developed to provide planning analysts access to climate projections “downscaled” to a finer spatial resolution. Such access permits development of decision-support information and associated regional and local adaptive strategies under potential climate change. Several types of analyses are supported by this archive, including:

- regionally distributed assessments of projection frequency (Figure 1);
- location-specific assessments of projection frequency (Figure 2);
- climate change impacts assessments for social and natural systems;
- risk-based exploitation of planning and policy responses.

Terms of Use
These data are being distributed to interested users for consideration in research and planning applications. Such applications may include any project carried out by an individual or organized by a university, a scientific institute, public agency, or private sector entity for research or planning purposes. Any decision to use these data is at the interested user’s discretion and subject to the Disclaimer provided below.

Disclaimer
Microsoft Excel, MCDA Dashboard - Explore Uncertainties

MCDA (Excel) used to set parameters

WEAP

- Population Growth Scenario
- Water Use Rate (gpcpd)
- Climate (Historic or Model)
- Regulation
**MCDA**

Stakeholder Weights Assigned to Each Criteria

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<thead>
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<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
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Each Criteria is Evaluated for Each Alternative
HOW? Then Use Model to Evaluate Alternatives

Focusing in on an Alternative: Modified CIP + C51

WEAP Mathematical “Expression Builder” is used to mimic the operations of C-51, e.g. Fill during high flows, release during low flows.
Example Results – C-51 Reservoir
Monthly Mean Discharge, 2023-2030 (Historic climate ‘repeats’)

Storage in wet period, Decrease in discharge
Release in dry period, Increase in Discharge
Climate 2.0: Continental Scale Downscaling

**CCSM 1950 - 2100**

- **CCSM3**:
  - ~150 km
  - One *Current Climate* member (1950-1999)
  - Ensemble members from 2000-2100 under A2 and A1B scenarios (IPCC-AR4)
  - Resolution too low for hurricane development
  - Useful for statistical downscaling
Climate 2.0: Continental Scale Downscaling

Nested Regional Climate Model Setup I

- **NRCM:**
  - Time slices 1995-2005, 2020-2030 and 2045-2055 under A2 scenario
  - 36 km; No nudging; 3 Decadal Runs
Climate 2.0: Continental Scale Downscaling

Nested Regional Climate Model Setup II

- **NRCM:**
  - Time slices 1995-2005, 2020-2030 and 2045-2055 under A2 scenario
  - 12 km; downscaled from 36km run
  - 33 Discreet Annual Runs - May to June of the next year (13 months)
Biases in Climate Model Data

\[ FC = CC + \Delta CT \]
Climate 2.0: Continental Scale Downscaling

Nested Regional Climate Model: Results

Cat 3 Hurricane formed
Yr 2, 2050 Period

Track density of model tropical and extratropical storms
Jan-Dec 1995
http://www.isse.ucar.edu/awwarf/
http://waterresearchfoundation.org/
http://sei-us.org
http://weap21.org

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