# *A Proposal for Near-term Quantitative Support of Integrated Scenario Analysis for the California Water Plan Update 2009*

**David Purkey, Stockholm Environment Institute-US Center**
**David Groves, RAND**
**David Yates, National Center for Atmospheric Research**
**Andrew Draper, Montgomery Watson Harza**

**SWAN Meeting**

**10 December 2007**

# *Outline*

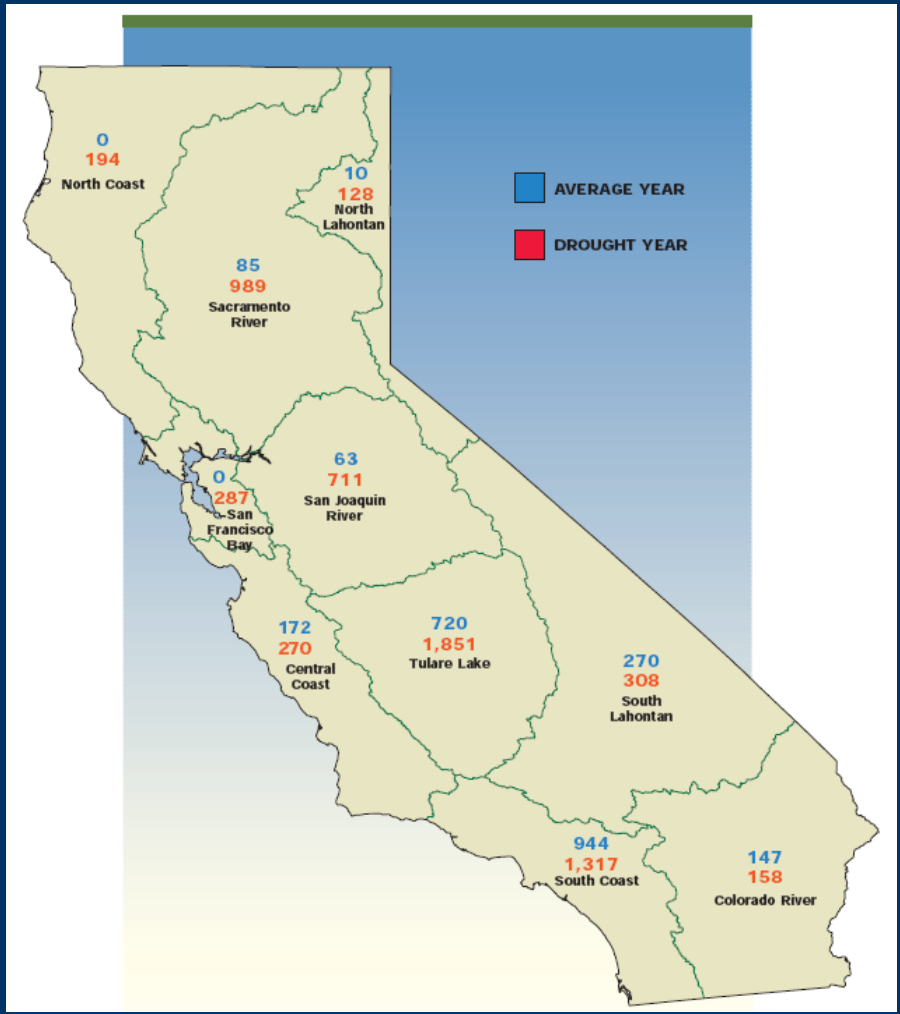
- **Motivate integrated scenario analysis framework for California Water Plan Update 2009**

- **Propose integrated approach to developing water management scenarios and evaluating response packages**
  - **Linkage to 2009 Synthesis Exercise**
  - **Water Evaluation and Planning (WEAP)**
  - **Quantitative scenario analysis method**
  - **Support for 2014+ Long-Range Strategy**

- **Elicit Feedback**

# *Previous CWP Updates Provide Gap Analyses*

2020 Shortages under Current System (CWP Update 1998)

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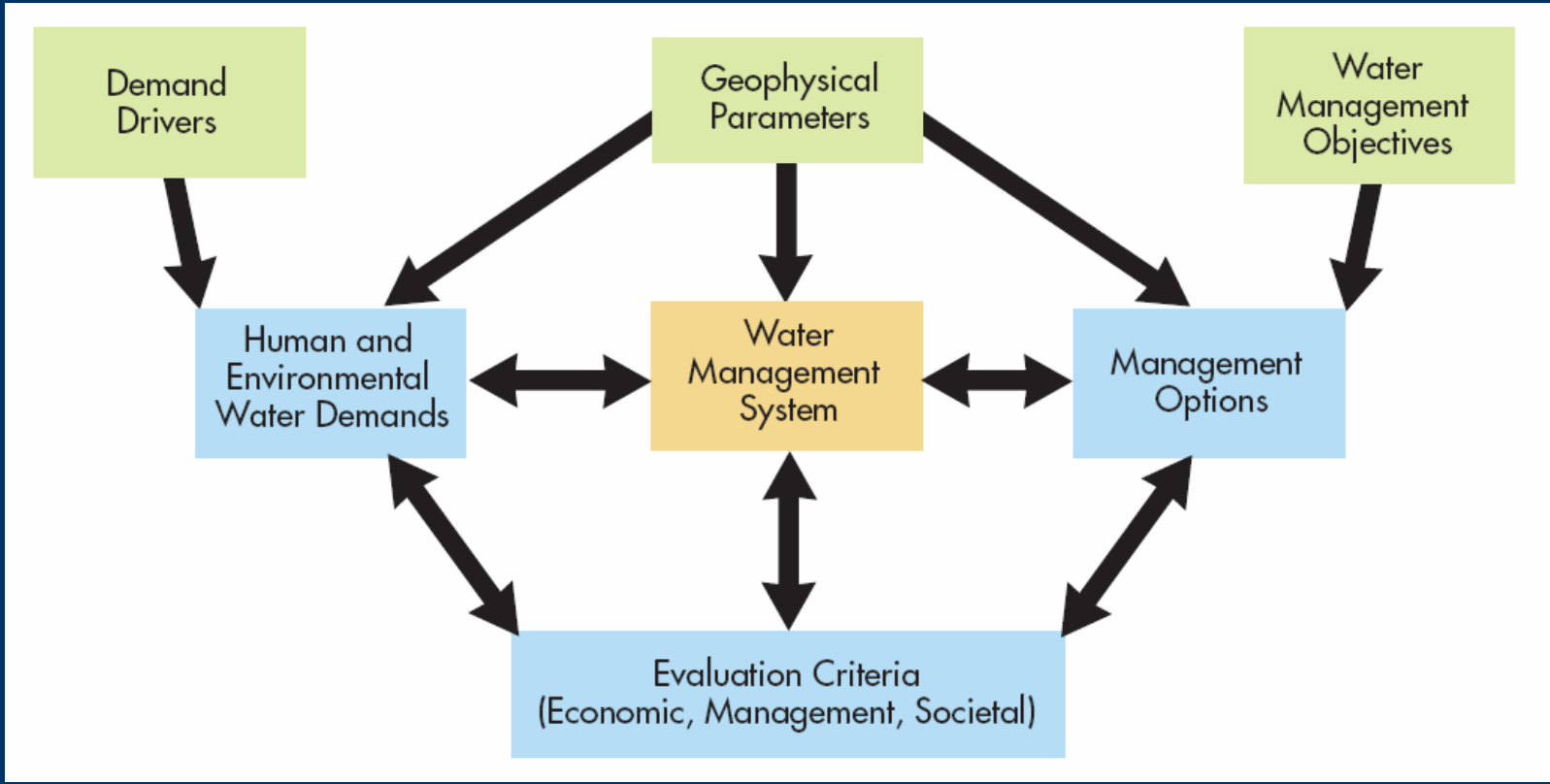
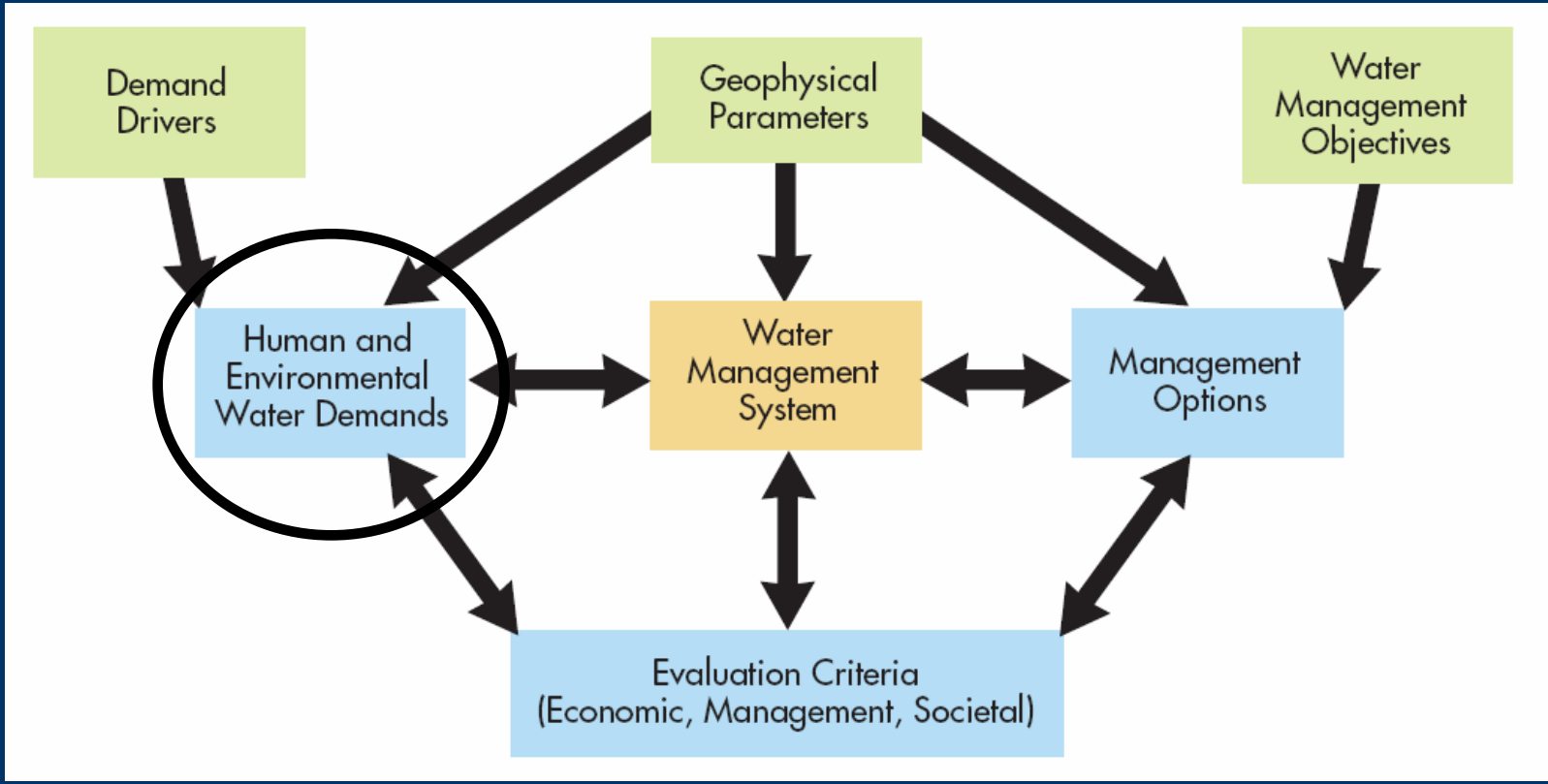
# CWP Update 2005 Began Move From Gap Analysis Towards Integrated Scenarios



# 2005 CWP Update Scenario Framework

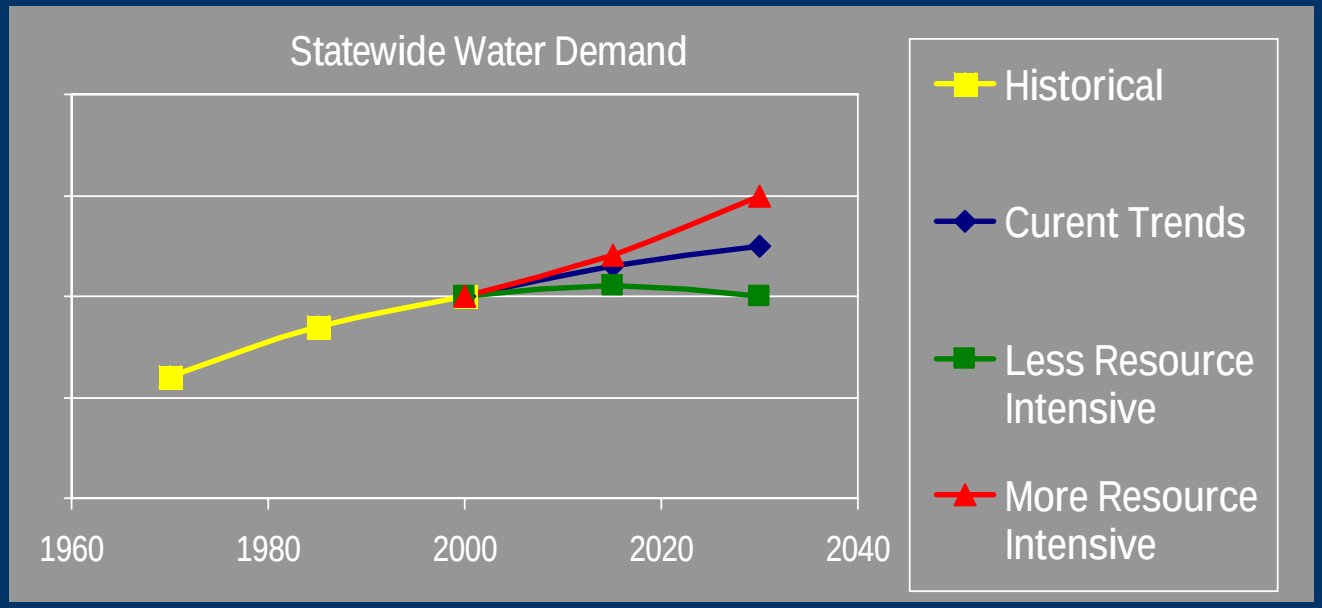


# *Developed Three Hand-Crafted Demand Scenarios…*

- **Identified key drivers**
  - **"Table 1"**
- **Focused on key parameters**
  - **Population growth, housing density, etc.**
- **Defined three narratives based on alternative assumptions for key drivers**
  - **Current trends**
  - **Less resource intensive**
  - **More resource intensive**

# …and Then Quantified Them

- Simple water demand by Hydrologic Region, developed in collaboration with RAND
- Defined parameter values consistent with narratives
- Evaluated demand by Hydrologic Region for each scenario, and aggregated to the statewide level



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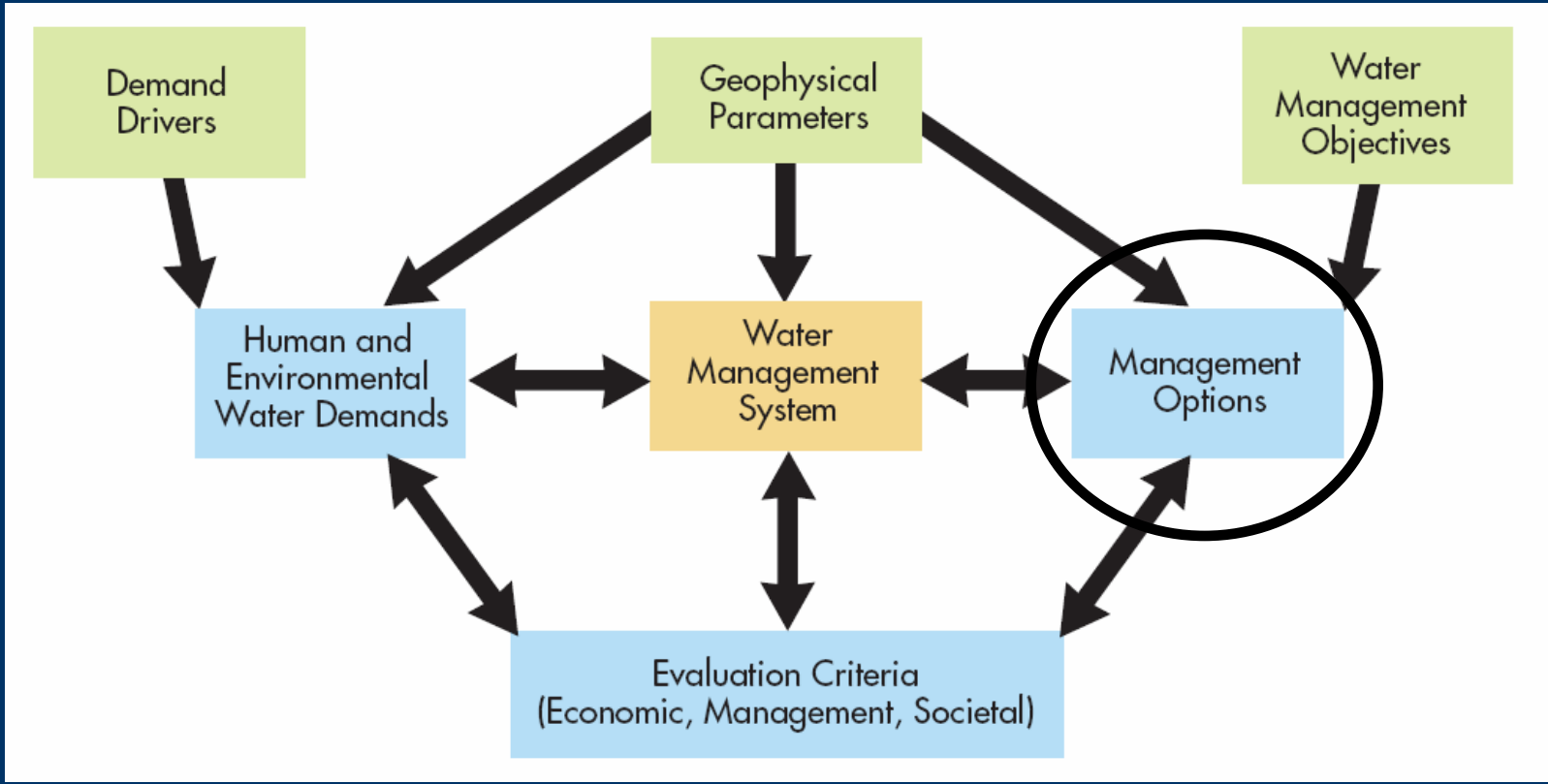

# Developed a List of Potential Response Package Components

Agricultural lands stewardship
Agricultural water use efficiency
Conjunctive management and groundwater storage
Conveyance
Desalination
Drinking water treatment and distribution
Economic incentives (Loans, Grants, and Water Pricing)
Ecosystem restoration
Floodplain management
Groundwater remediation/Aquifer remediation
Matching water quality to water use
Pollution prevention
Precipitation enhancement
Recharge areas protection
Recycled municipal water
Surface storage-CALFED
Surface storage-regional/local
System reoperation
Urban land use management
Urban runoff management
Urban water use efficiency
Water-dependent recreation
Watershed management
Water transfers

Other resource management strategies (includes crop idling for water transfers, dewvaporation, fog collection, irrigated land retirement, rainfed agriculture and water bag transport/storage technology)

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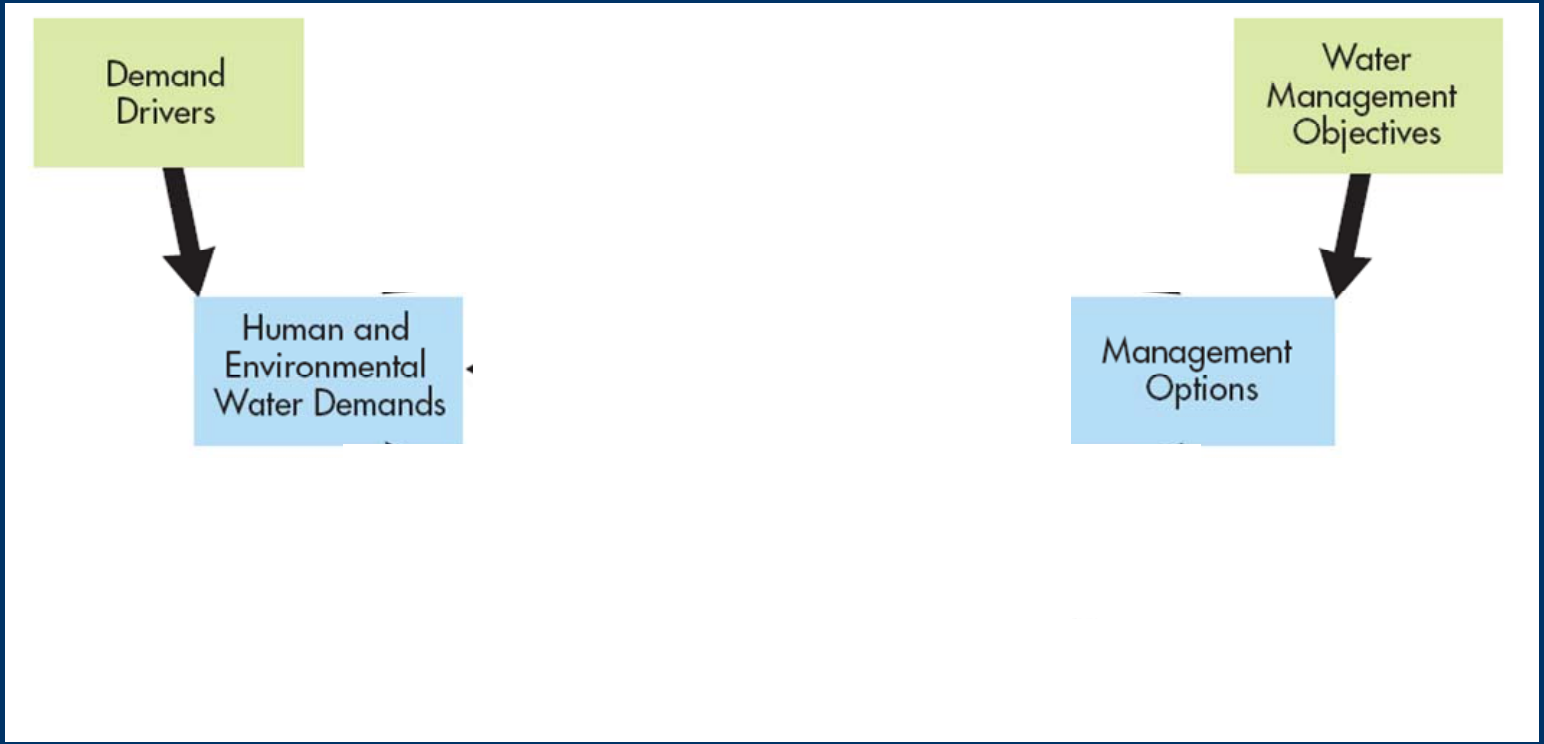
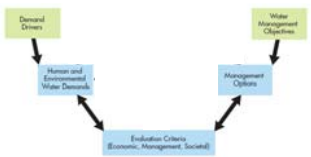
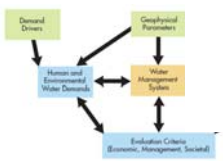
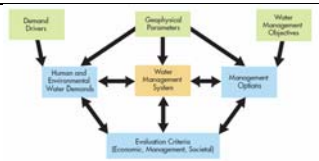
# *2005 Progress Relative to Scenarios Framework*



# *Post CWP Update 2005 Scenario Analysis*

- **Simple Supply and Demand Scenarios for the South Coast Hydrologic Region (RAND)**
- **Integrated water management scenarios for the Sacramento River Hydrologic Region (SEI, NCAR)**
- **Water management strategies to address climate change in the Inland Empire Utilities Agency region (RAND)**

# *Increasingly Comprehensive with Respect to Scenario Framework*

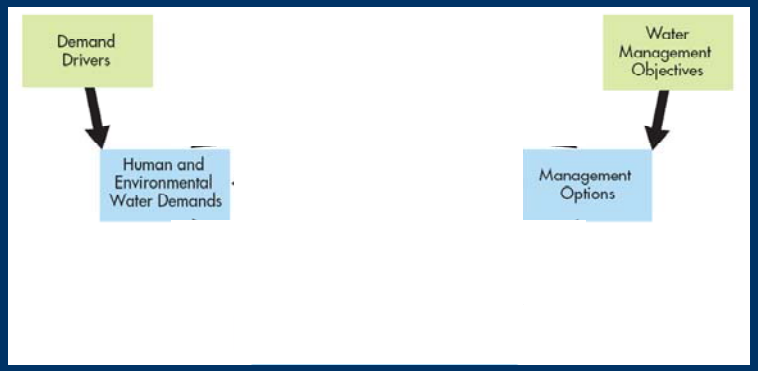
| | Scenario Framework | Geological domain | Level of integration | Level of System detail | Climate/hydrology |
|---|---|---|---|---|---|
| **2005 CWP** | | Statewide, by Hydrologic Region | No integration between demand scenarios and management options | Coarse demand factor representation. Management options derived from other studies | Annual data for past hydrology (water portfolios), no climate or hydrologic signal in scenarios |
| **Simple Scenarios for Southern California** |  | Southern California. Demand by county, supply by region | Arithmetic combination of supply and demand. Factor changes to baseline estimates | Coarse demand factor representation. Management options derived from other studies and related to supply and demand projections | Annual projections of supply and demand. No interannual variability. No climate signal. |
| **Sacramento WEAP application** |  | Sacramento Basin, including Bay-Delta and Trinity Diversion | Full integration with demand and supply elements interacting dynamically during simulation | Full system detail with all critical system components represented explicitly | Monthly precipitation, temperature, RH and wind. Rainfall/snowmelt simulation->runoff. Water quality simulation. |
| **Robust management strategies for IEUA** |  | Inland Empire Utilities Agency service area. | Integrated supply and demand and long-term water management plans | Aggregated representation of large system components. | Monthly precipitation, temperature, RH and wind. Rainfall/snowmelt simulation->runoff. Parameterizations of effects on imports. |
| **2009 CWP** | **???** | **???** | **???** | **???** | **???** |

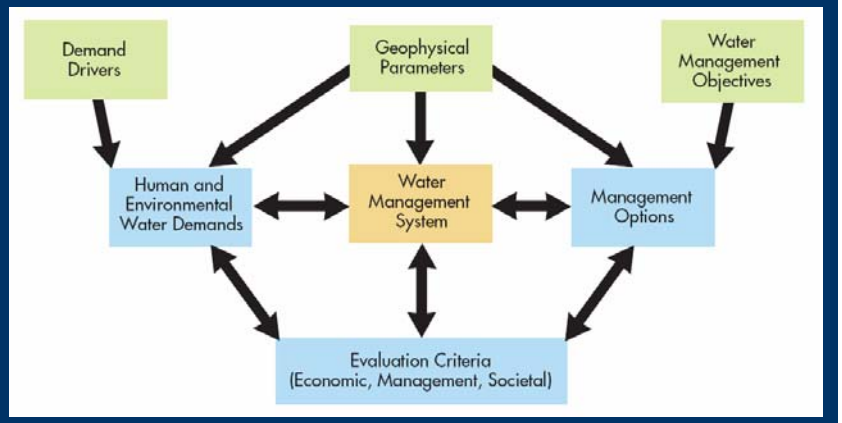
# *CWP Update 2009 Seeks To Build On 2005 Analysis*

- **Expand scenarios to consider**
  - **water supply**
  - **climate change**
  - **water quality**
  - **flood issues**

- **Refine scenario narratives**

- **Use analytical framework to support the evaluation of response packages**



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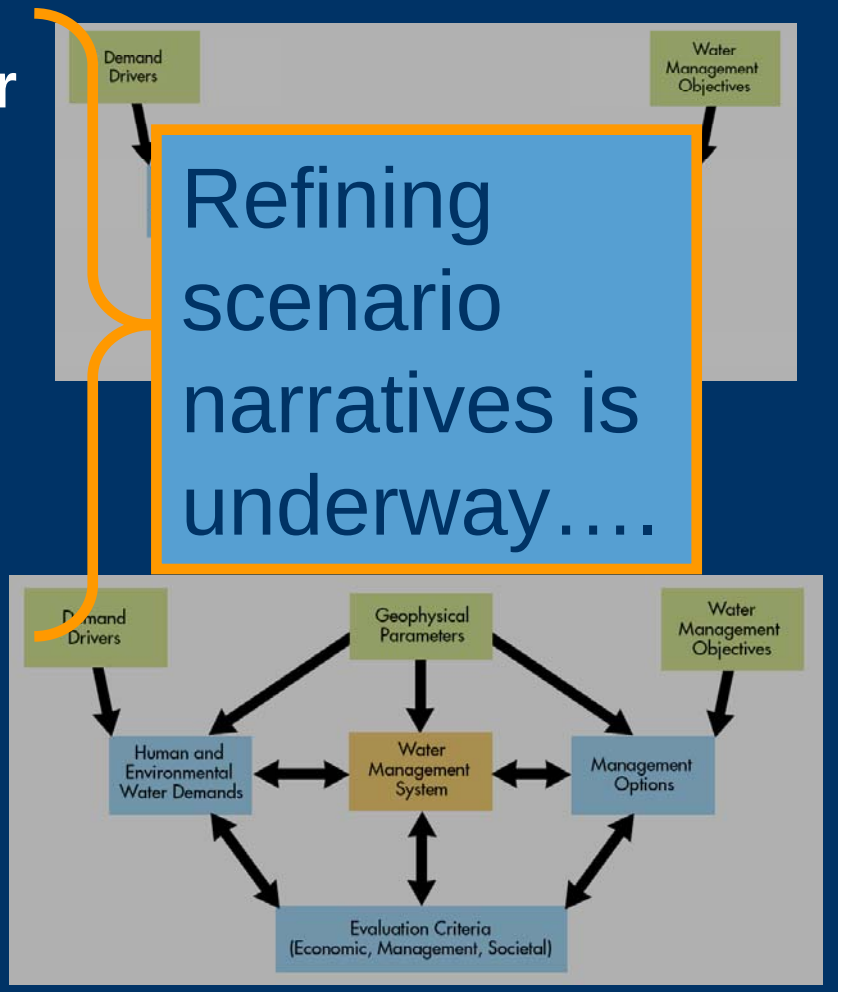

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  - Water Evaluation and Planning (WEAP)
  - Quantitative scenario analysis method
  - Support for 2014+ Long-Range Strategy
- Elicit Feedback

## *A Synthesis of Existing Technical Studies May Contribute Valuable Insight for 2009 CWP*

- **"Regional studies collectively represent a <u>tremendous investment of resources, expertise, and thought</u>".**
- **"These regional studies can serve as <u>a point of departure</u> for improving our understanding and analysis of California's water system".**
- **"<u>Challenges exist to synthesize and extract broadly applicable findings</u> from this body of regionally focused work".**

## *A Synthesis of Existing Technical Studies May Contribute Valuable Insight for 2009 CWP*

- **"Regional studies collectively represent a tre se, an**
- **"T of de nd an**
- **"C roadly ap lly focused work".**

**The proposed effort seeks to investigate how integrated scenario analysis can be used to provide synthesis of the existing body of regionally focused work.**

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# *Our Proposal*

- Develop two regional water management models
  - Sacramento River Hydrologic Region
  - South Coast Hydrologic Region
- Construct large ensemble of quantitative water management scenarios consistent with:
  - New 2009 Water Plan narrative scenarios
  - CEC climate change scenarios
- Evaluate response packages against scenarios at regional level

# *Proposed Activities*

- **Task 1: Scope scenario analysis (underway)**
- **Task 2: Support high level regional analysis using WEAP (led by DWR)**
- **Task 3: Enhance WEAP modeling environment**
- **Task 4: Develop detailed Sacramento analysis using WEAP**
- **Task 5: Develop detailed South Coast analysis using WEAP**
- **Task 6: Specify future scenarios**
- **Task 7: Evaluate response packages**
- **Task 8: Link to regional analyses**

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# *Some Clarification*

- **Task 2, led by DWR, will implement the high level, mass balance approach used in the earlier RAND South Coast analysis.**

- **Tasks 4 and 5 will adopt a more refined, system-level representation of two hydrologic regions, Sacramento River and South Coast, in order to test the performance of response packages against scenarios. These applications will allow for the introduction of climate change into the scenario analysis.**

# *Critical Issues to Explore*

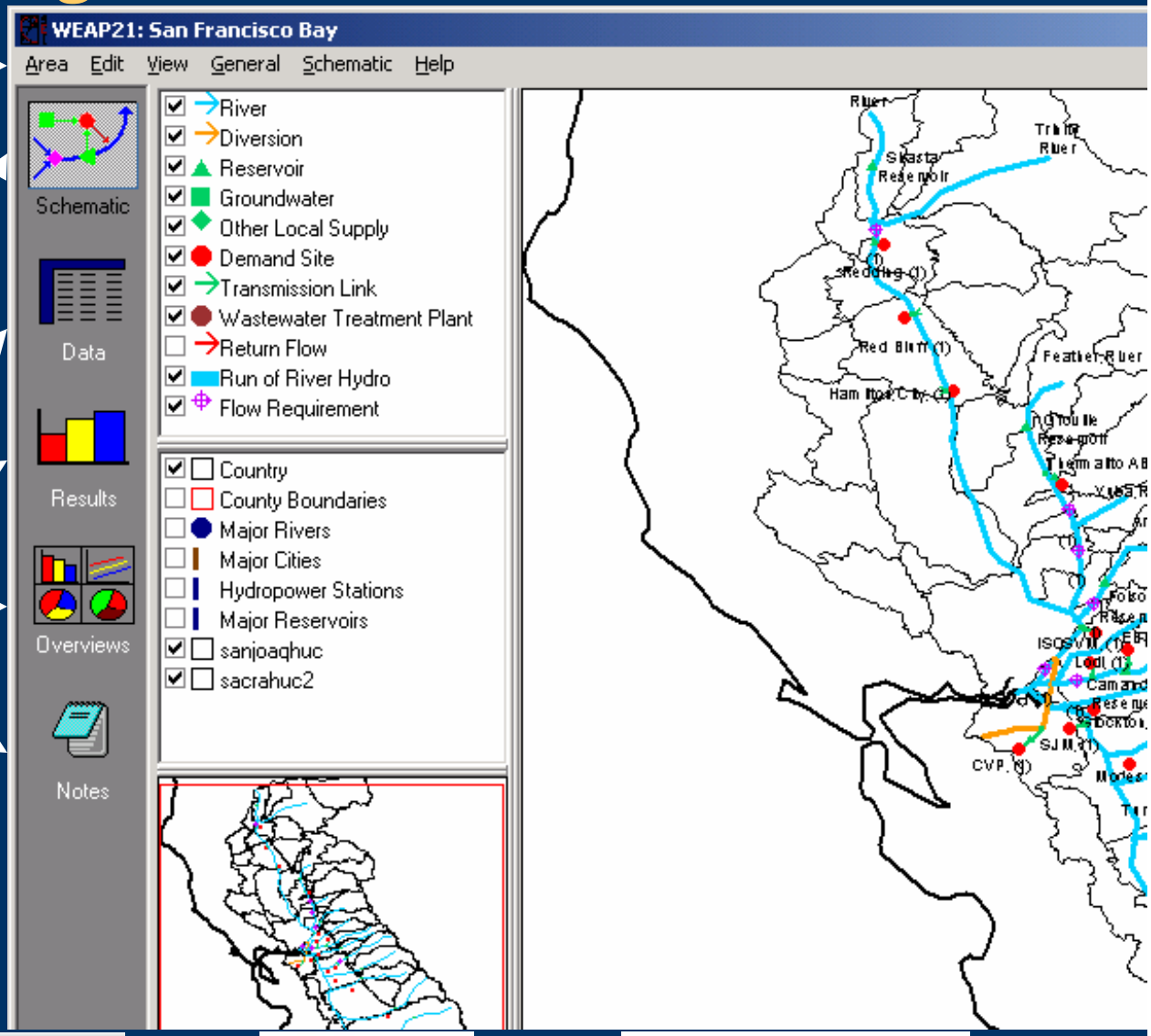
- **What is WEAP?**
- **How has WEAP been used for integrated scenario analysis in California?**
- **How can we integrate climate change into the integrated scenario analysis framework?**
- **How can WEAP support scenario analysis and response package evaluation?**
- **What are some potential strategies for linking regional analysis to statewide evaluation?**

# *What is WEAP?*

# Program Structure

Menu bar

5 Main Views

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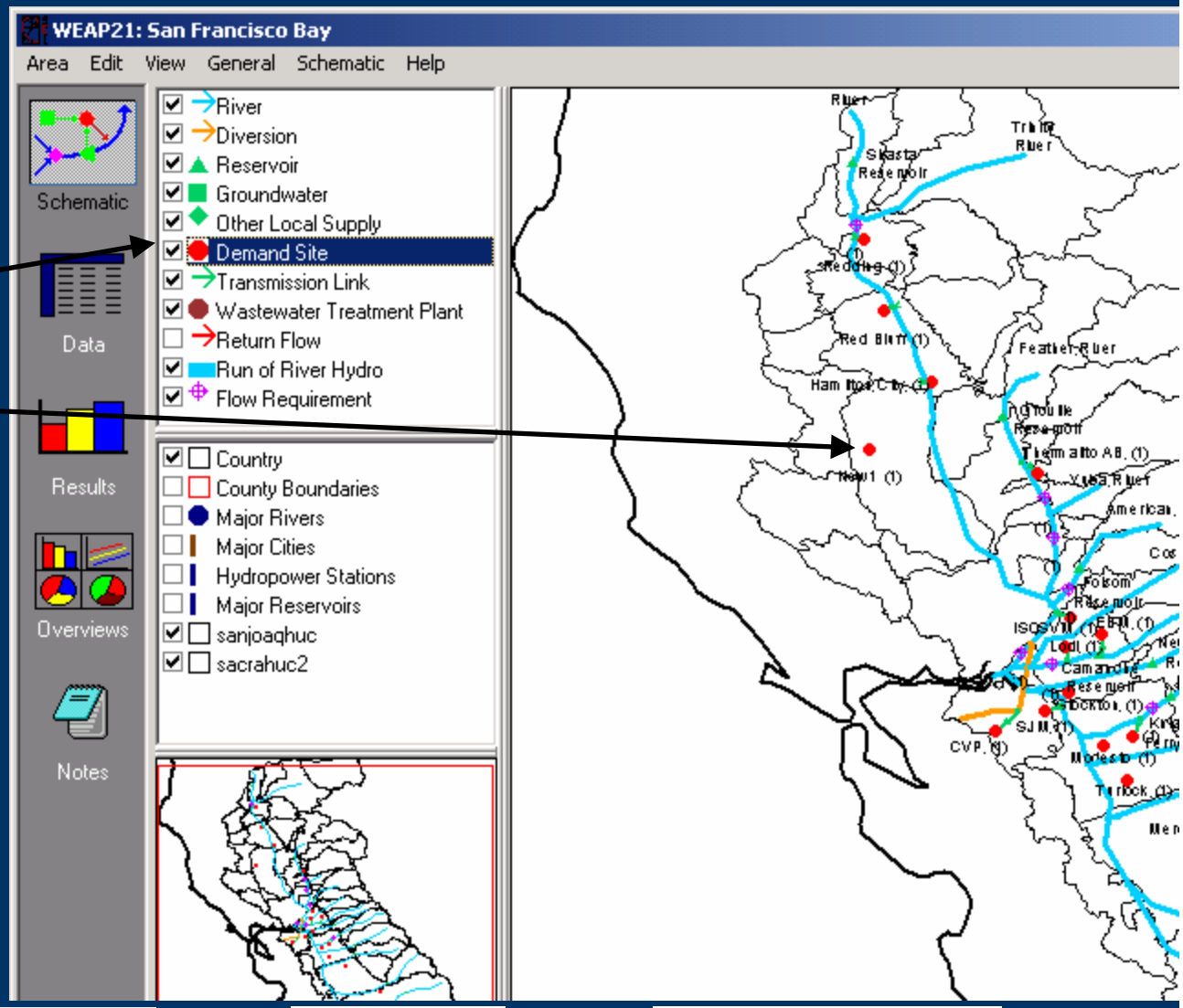
# Schematic View

Click and drag to create a new demand site

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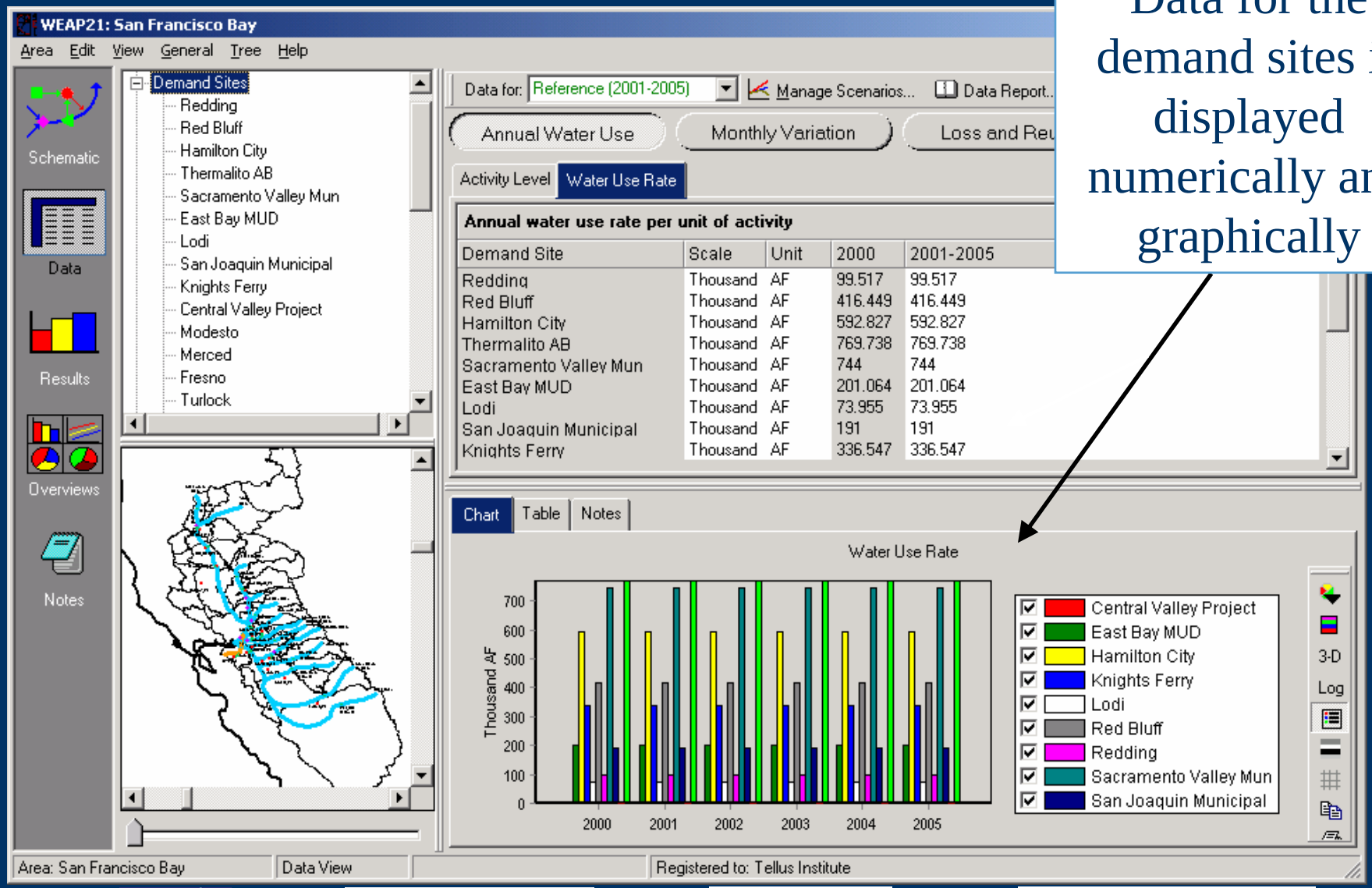
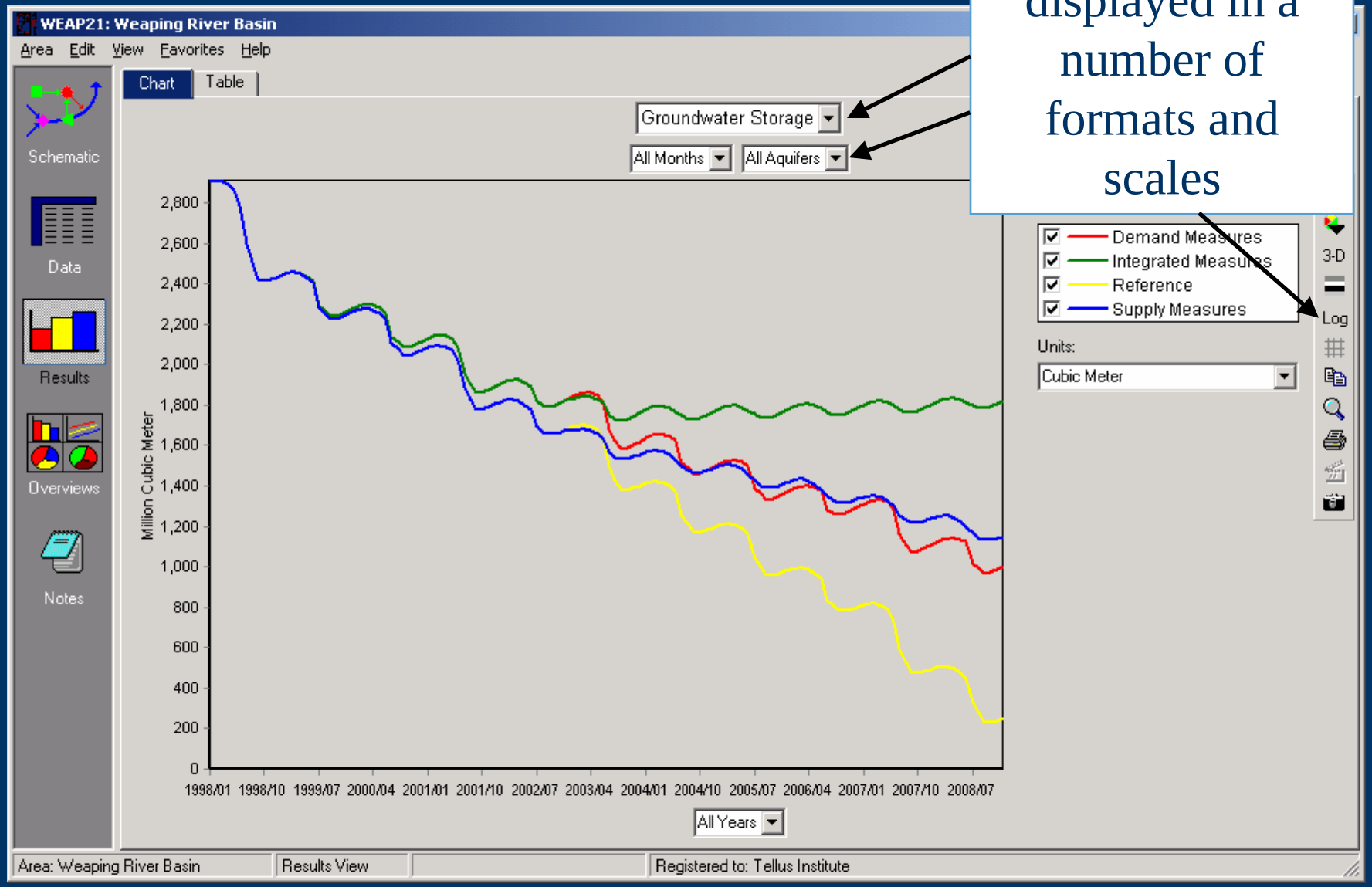
# Data View

Data for the demand sites is displayed numerically and graphically



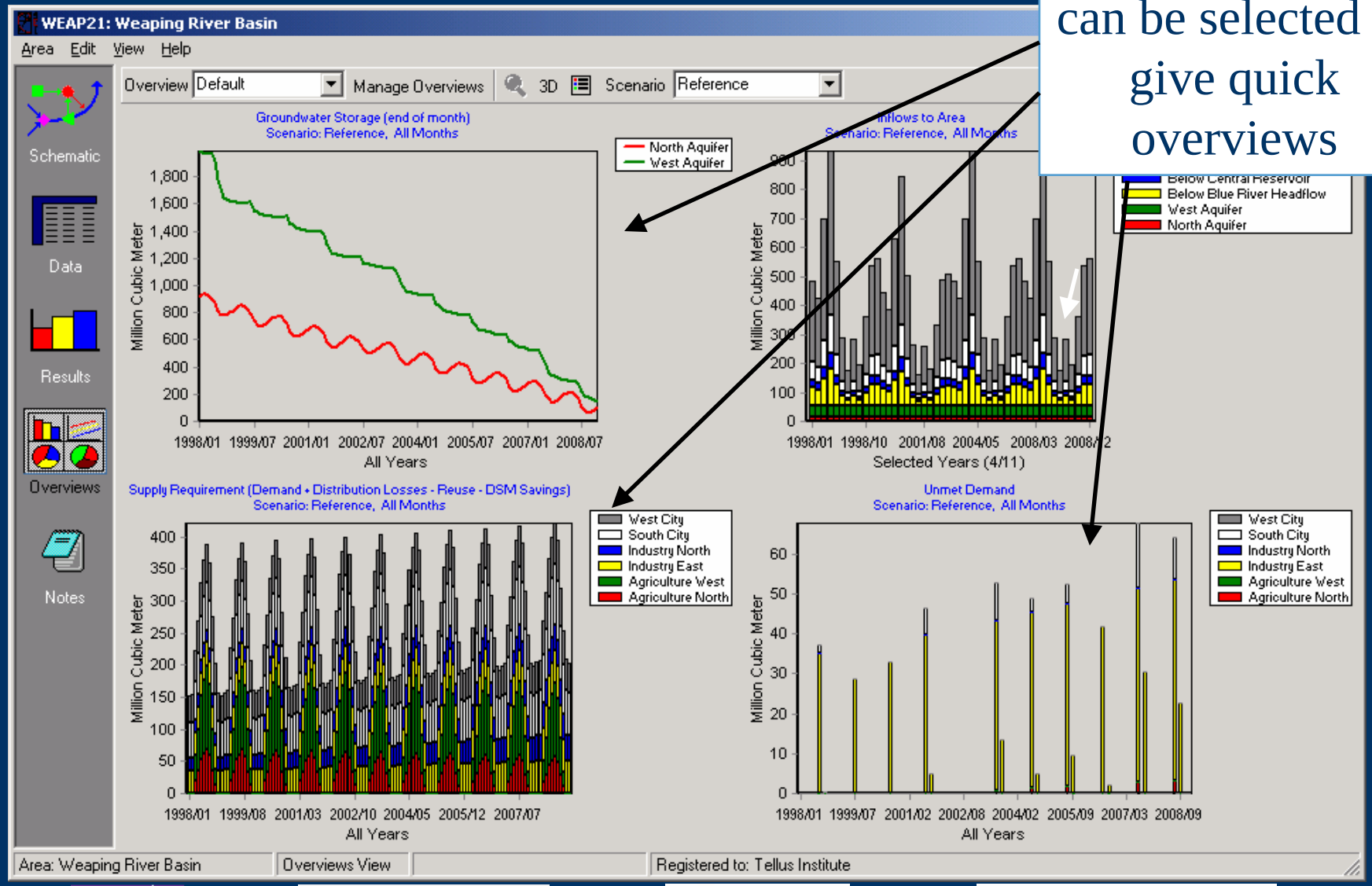
# Results View

Results can be displayed in a number of formats and scales



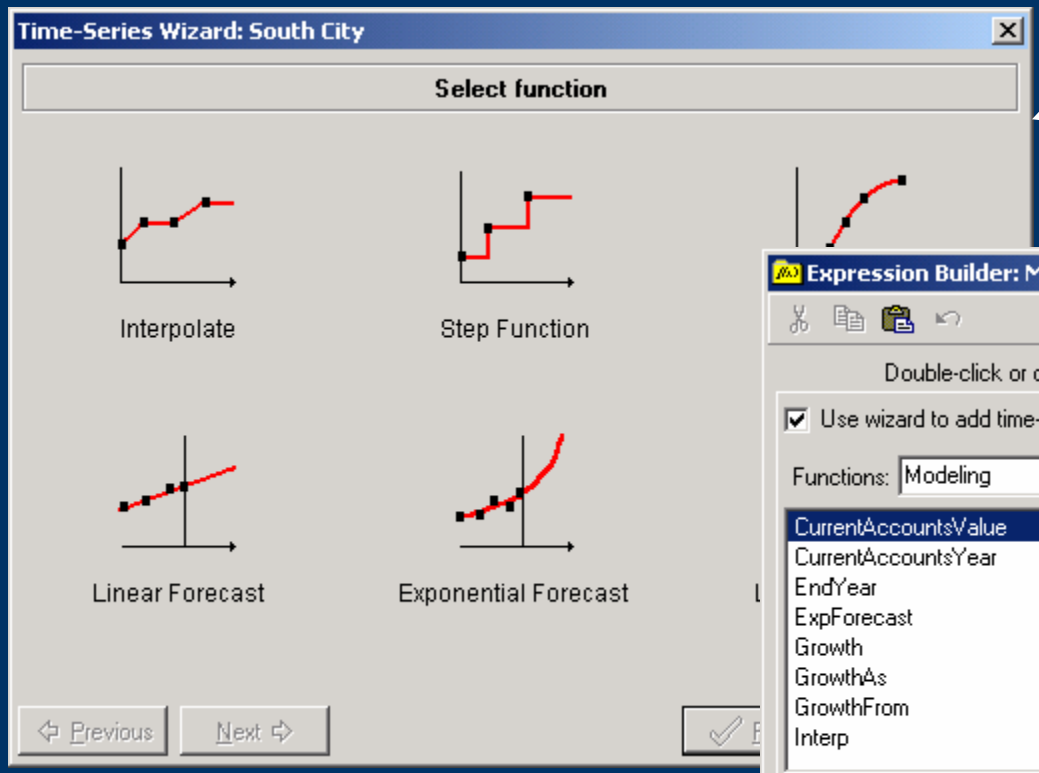
# Overview View

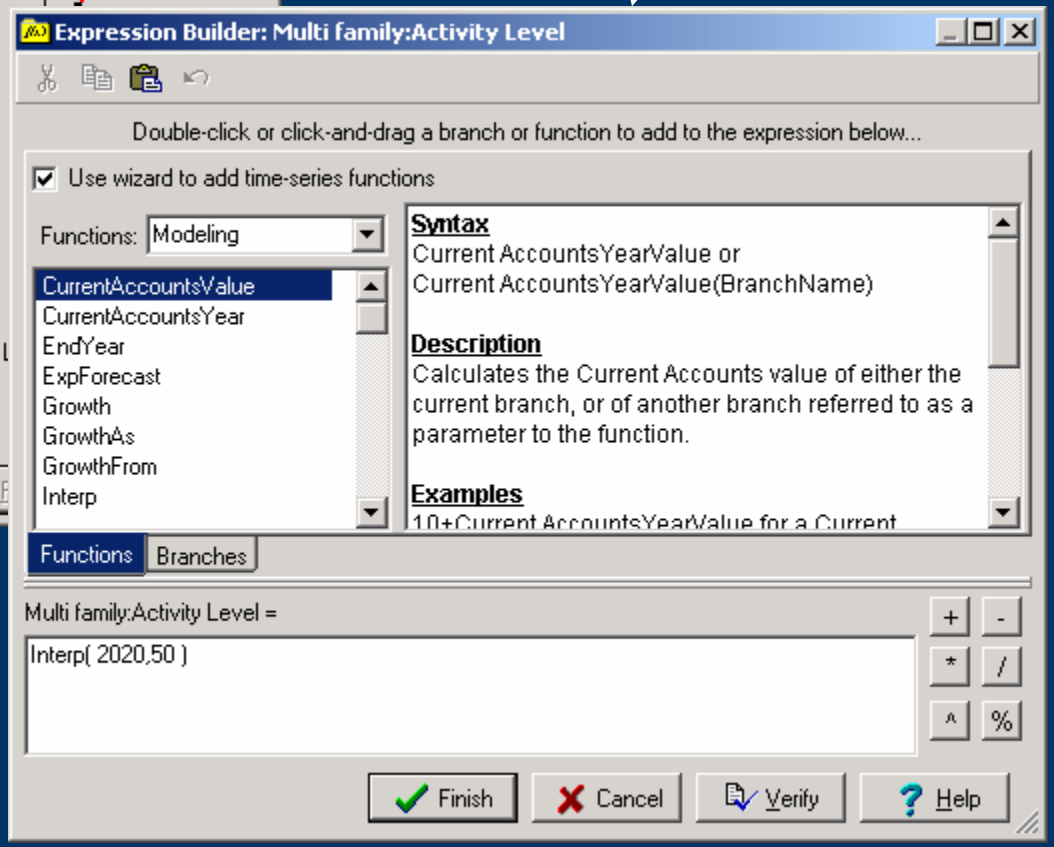
Favorite charts can be selected to give quick overviews



# Building expressions

Use the time series wizard or expression builder



## Study Definition

Spatial Boundary
Time Horizon
System Components
Network Configuration

## Current Accounts

Demand
Reservoir Characteristics
River Simulation
Pollutant Generation
Resources and Supplies
Wastewater Treatment

## Scenarios

Demographic and Economic Activity
Patterns of Water Use, Pollution Generation
Water System Infrastructure
Hydropower
Allocation, Pricing and Environmental Policy
Component Costs
Hydrology

## Evaluation

Water Sufficiency
Pollutant Loadings
Ecosystem Requirements
Sensitivity Analysis

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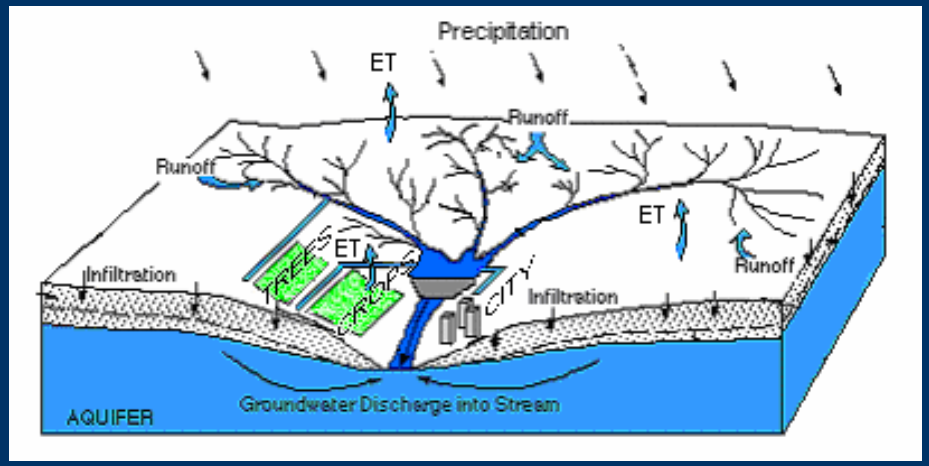
# *A Key Feature of WEAP: Climate Driven Scenarios*

# Planning Model




**Critical question:** How should water be allocated to various uses in time of shortage?

**Critical question:** How can these operations be constrained to protect the services provided by the river?

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

**Critical question:** How will allocation, operations and operating constraints change if new management strategies are introduced into the system?

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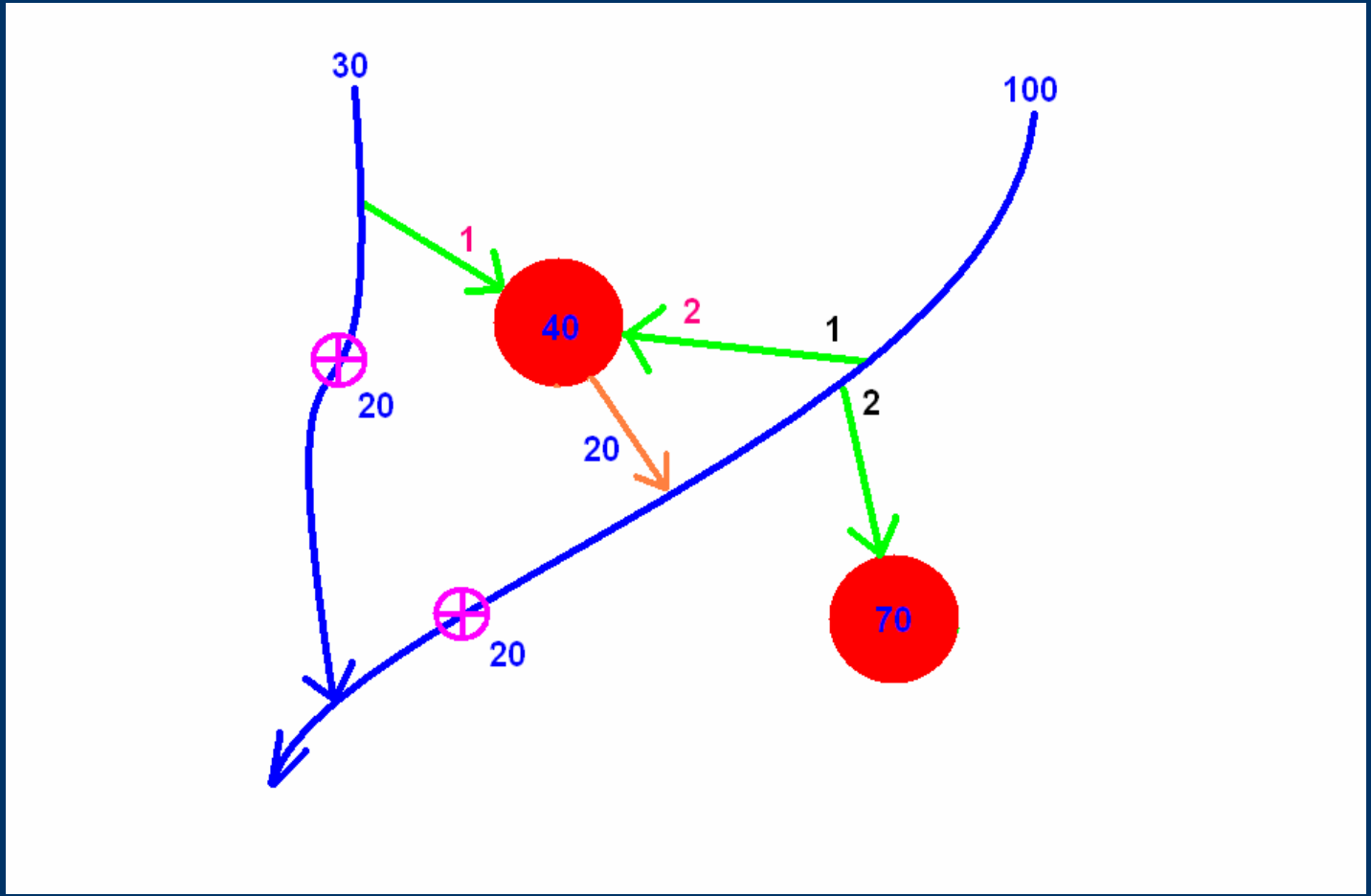
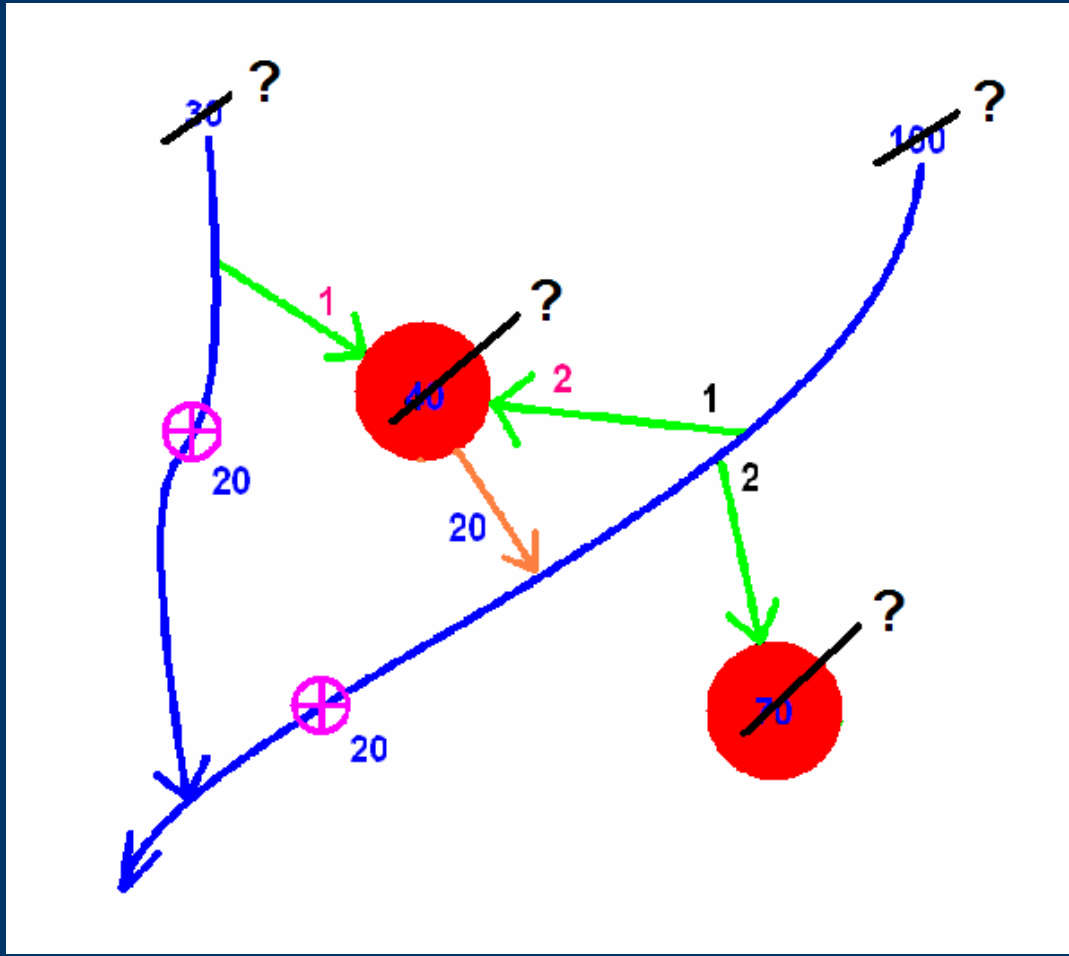
# A Simple Planning Model



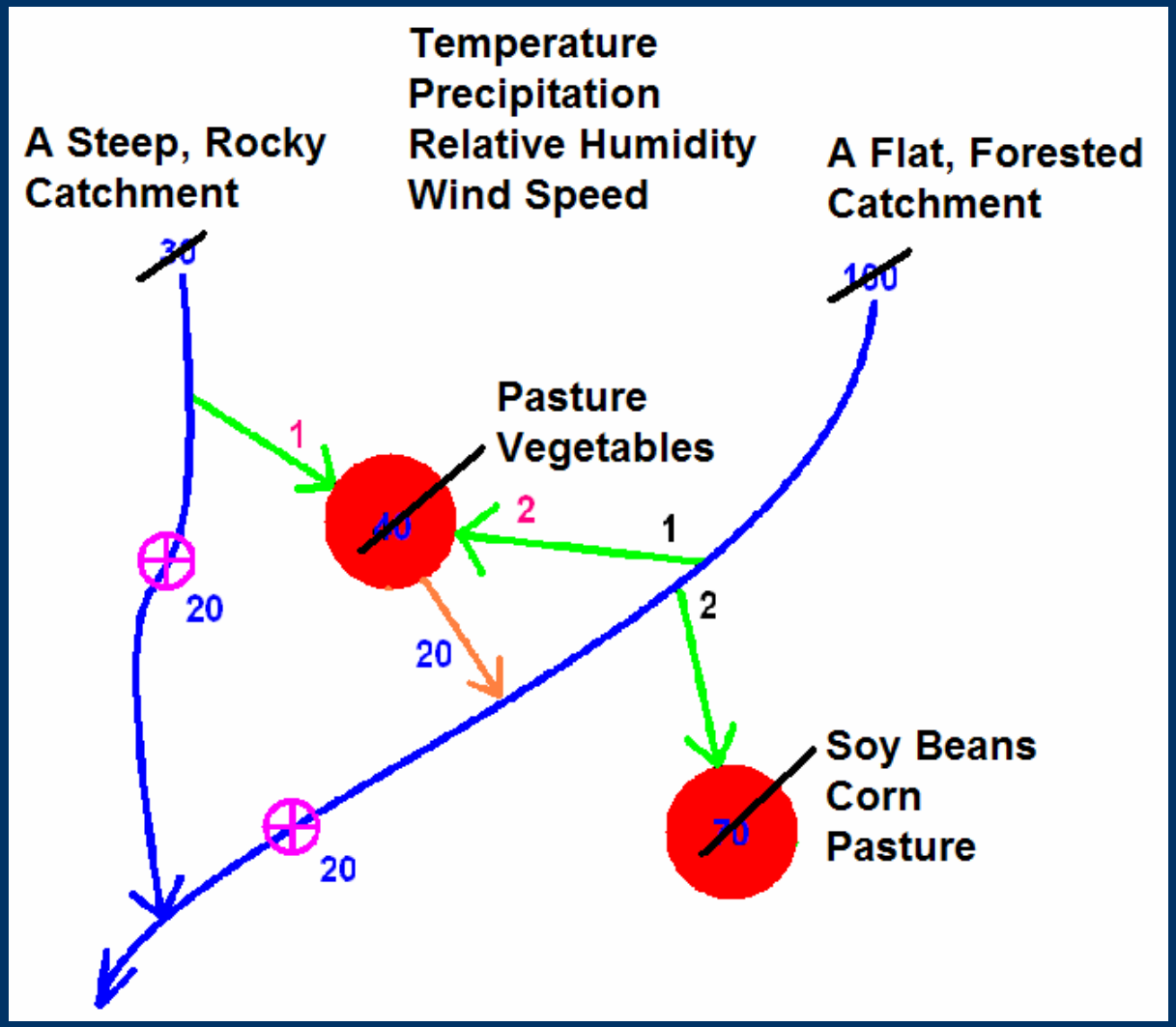
# *What are we assuming?*

1. **That we know how much water is flowing at the top of each river.**
2. **That we know how much water is flowing into or out of the river as it moves downstream.**
3. **That we know what the water demands are with certainty.**
4. **Basicly, that this system has been removed from it** HYDROLOGIC **context.**

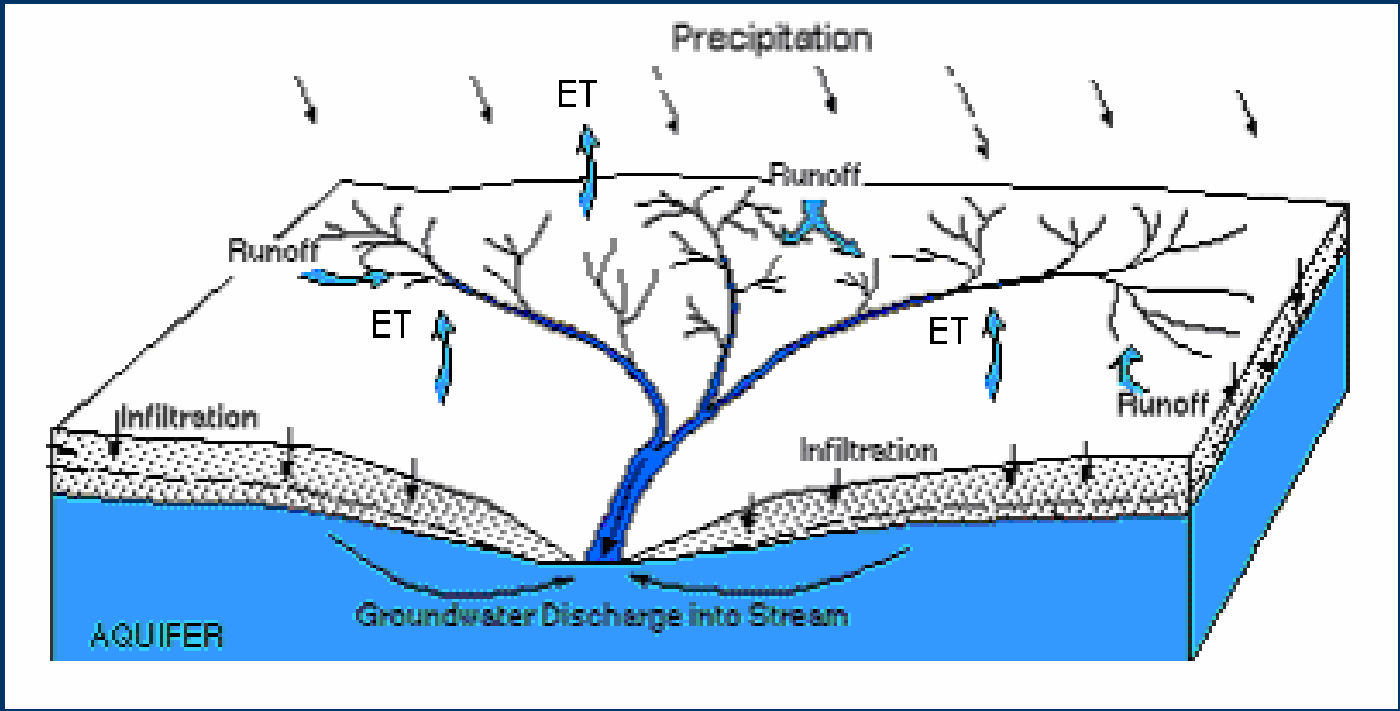
# *What do we do now?*



# ADD HYDROLOGY!



# Hydrology Model




**Critical question:** How does rainfall on a watershed translate into flow in a river?

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

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

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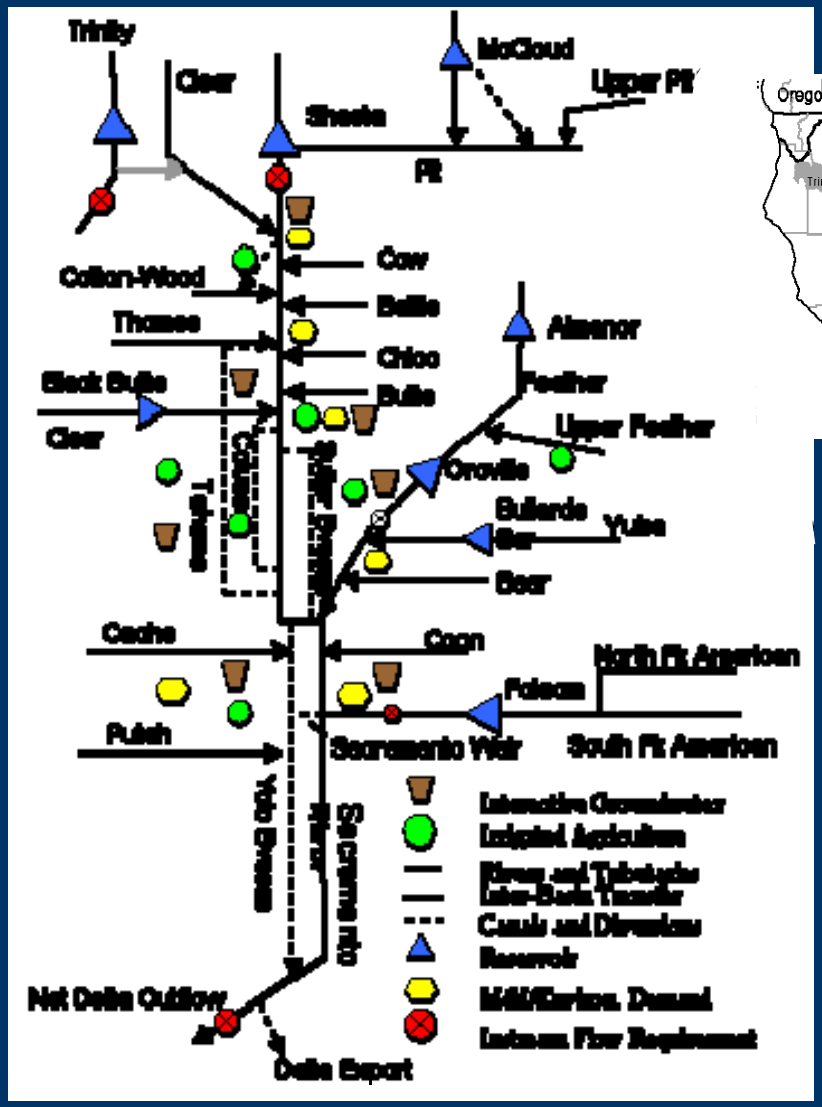
# Limitations

| Component | Limitations |
|---|---|
| Rainfall-Runoff | Parameters require calibration/validation<br>Land/use change is exogenous<br>Monthly Model/ No Flood Peaks |
| Stream Hydrology | No Explicit Routing<br>Demands met at each timestep |
| Reservoirs | Rules are stylized and relatively simple<br>Doesn't consider year-to-year operations |
| Groundwater | No local cones of depression<br>No exchange between GW objects |
| Agriculture | No explicit irrigation technologies<br>Cropping pattern changes are entered exogenously<br>Irrigation strategy depends on availability<br>No regional irrigation rights |
| Urban Demand | No regional conservation measures<br>Conservation is exogenously defined |
| Flood Conveyance | Monthly time-step, no-peak flows. |
| Canals and Diversion | Transmission losses are generic |

# *How has WEAP been used for integrated scenario analysis in California?*

# *Sacramento River Model*

- Comprehensive Representation of Sacramento System
  - 71 Catchments
  - 32 Rivers
  - 7 Groundwater Basins
  - 8 Diversions (e.g. Yolo)
  - 30 Urban/Ag Demands
  - 6 Ag Crop types
  - Rice Ponding/Storage
  - Instream flow Requirements
  - Delta Salinity Dynamics



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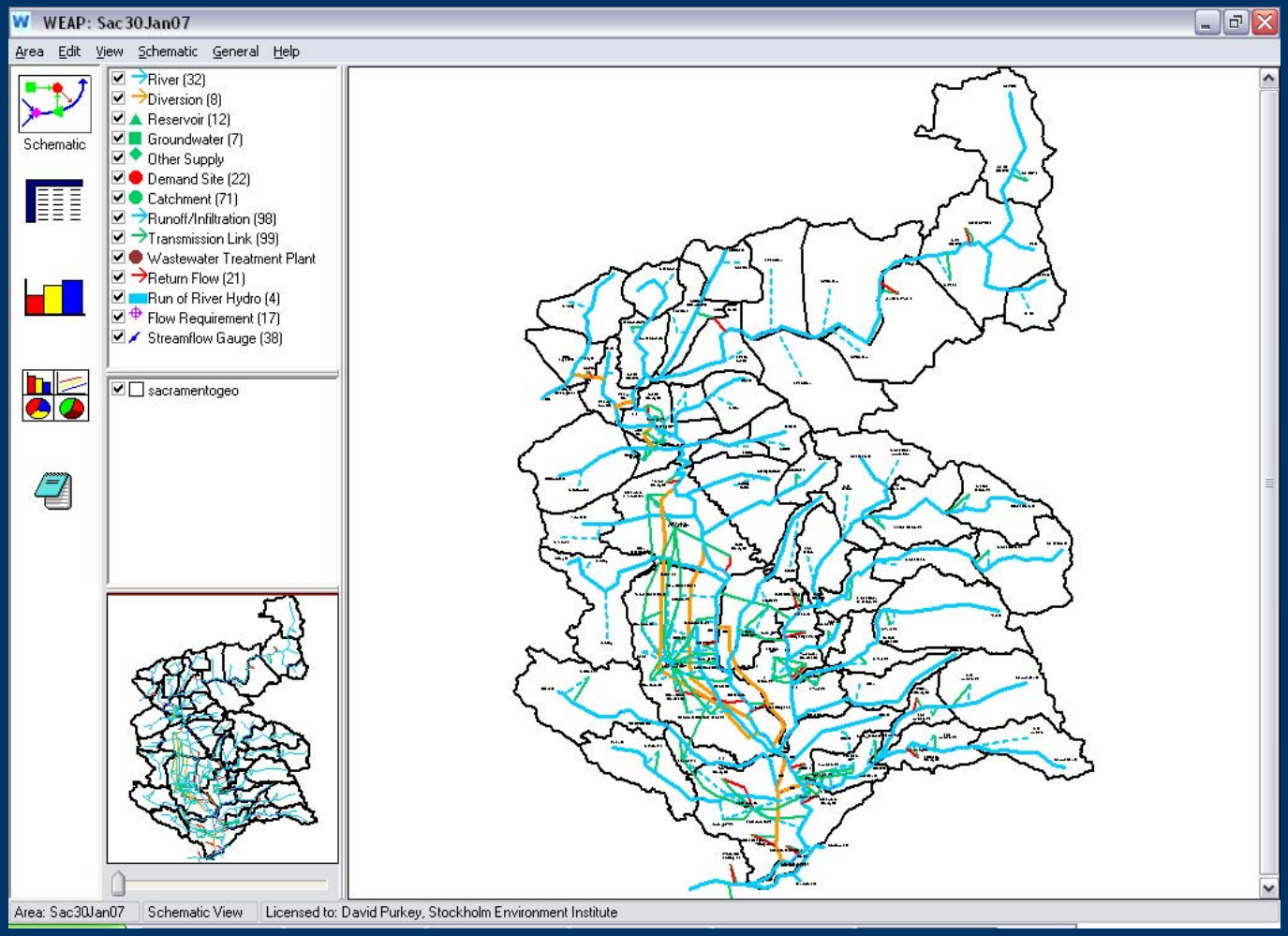
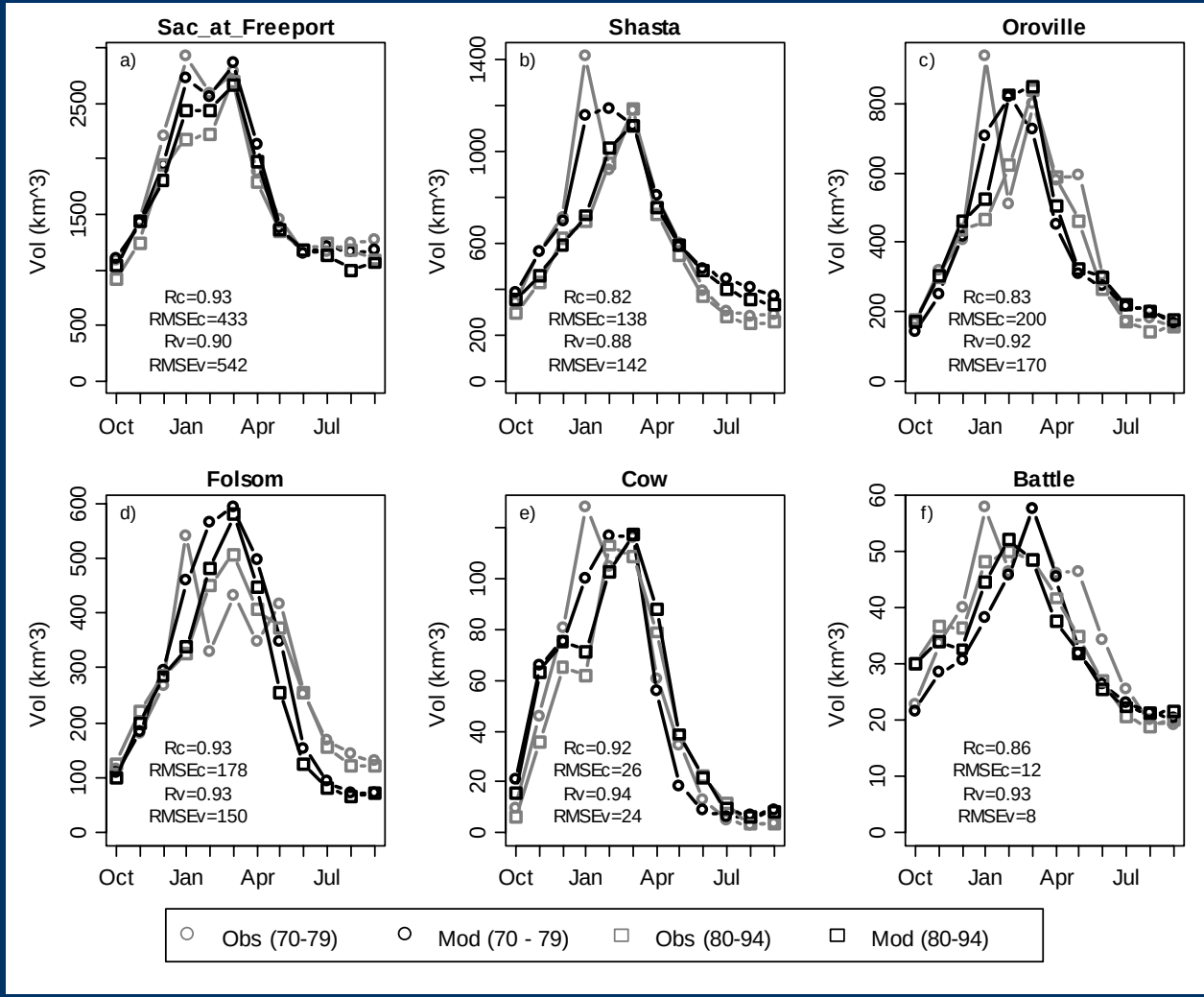
# Sacramento River Model

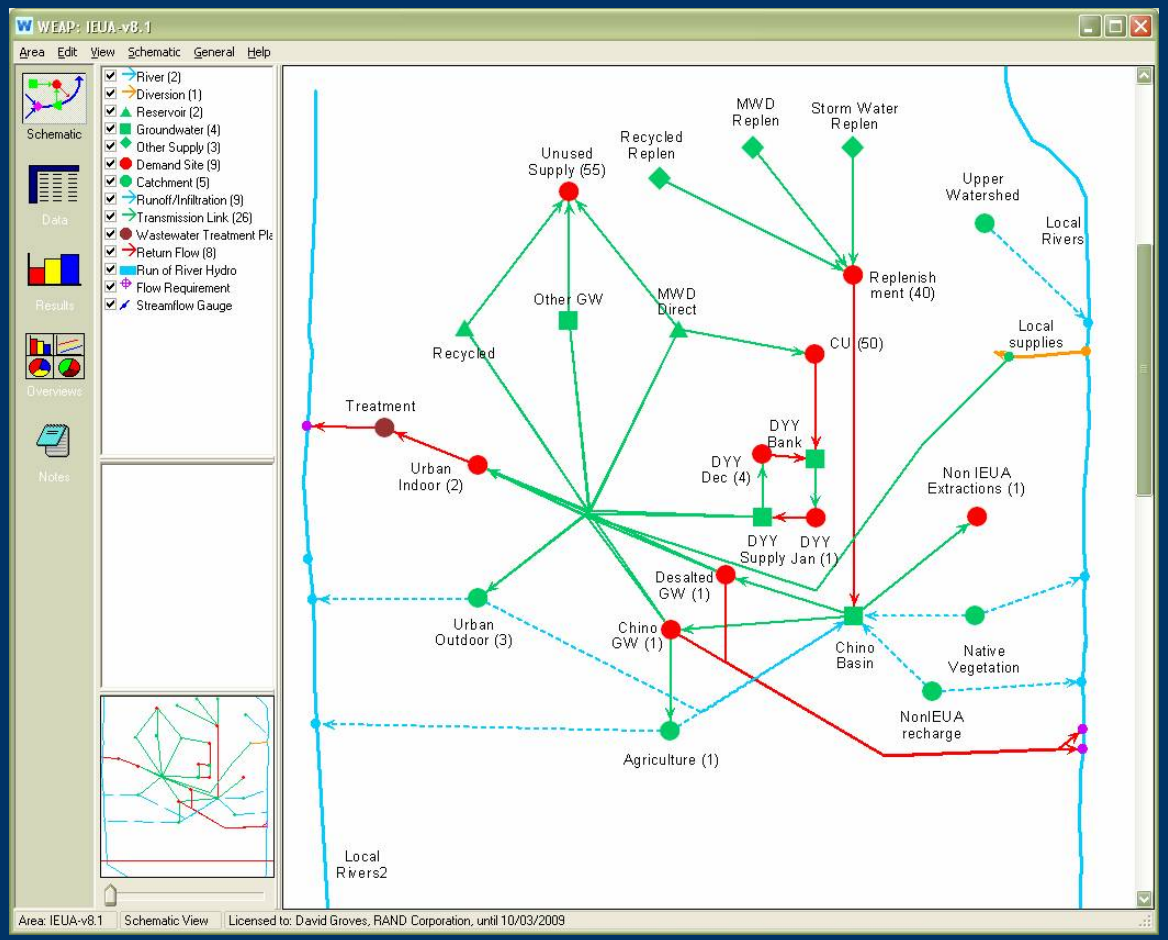


# Sacramento River Results

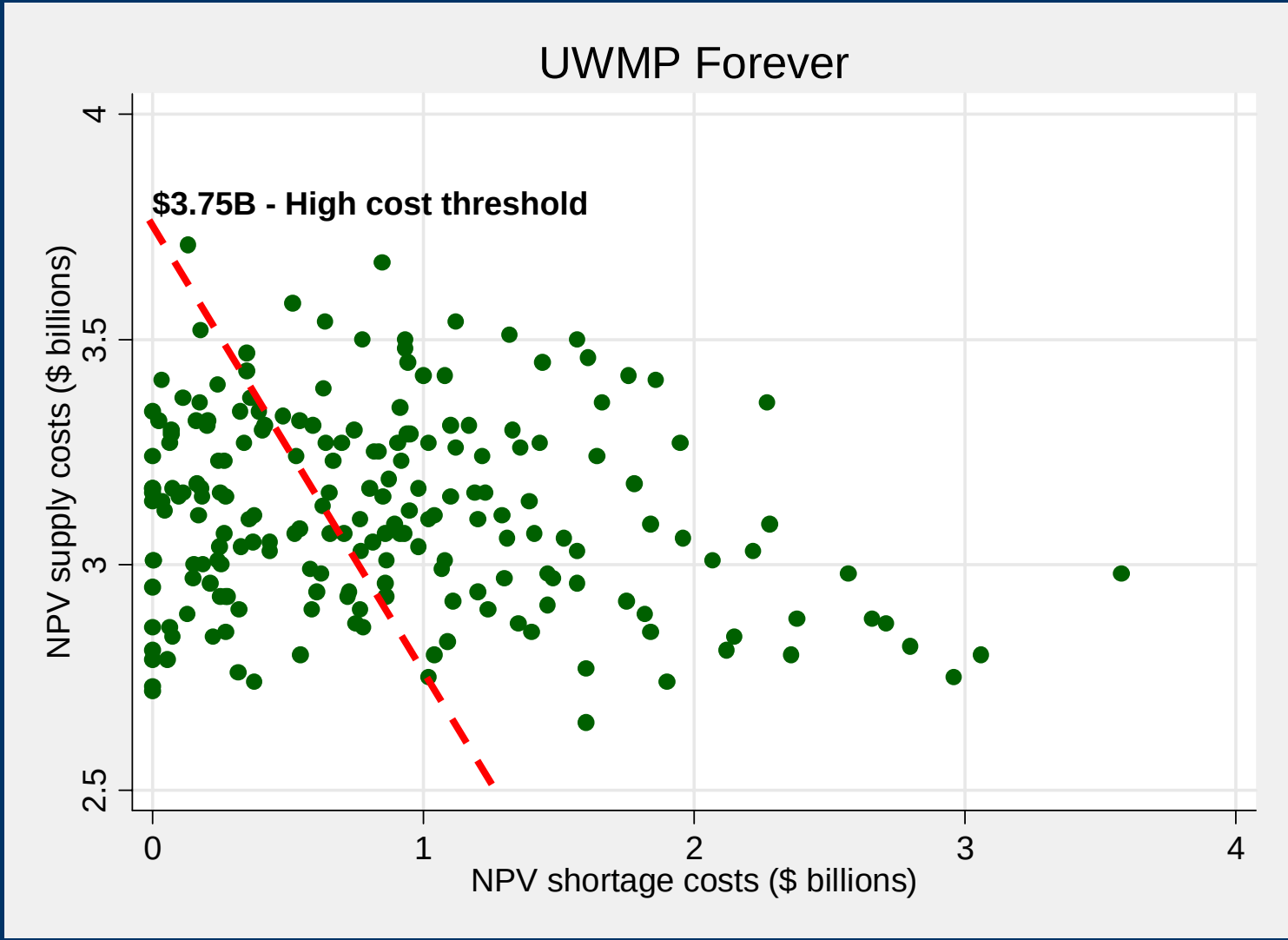


# *RAND Analysis with Inland Empire Utilities Agency Used WEAP to Evaluate Management Strategies*

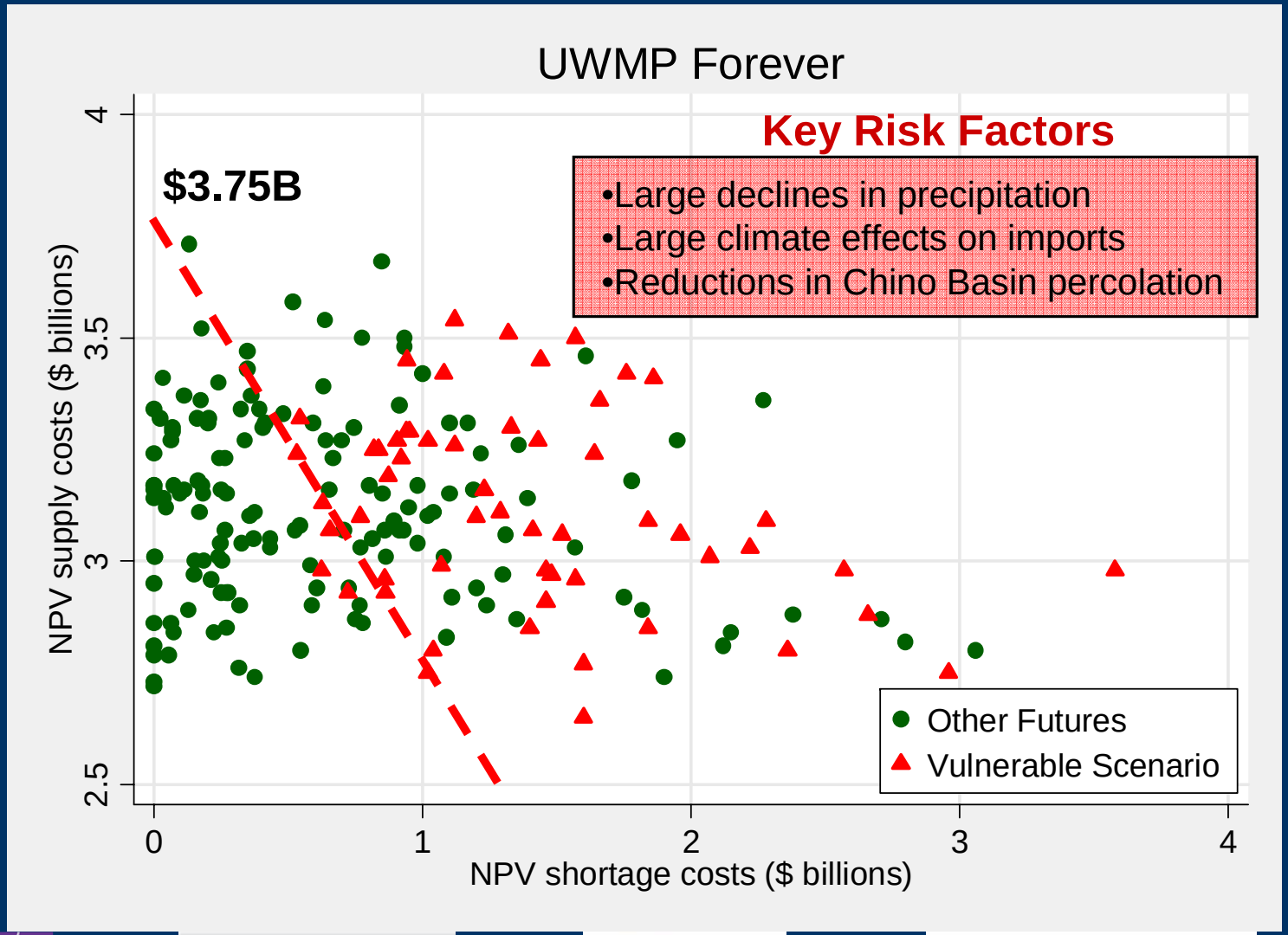
- **Sources**
  - Precipitation over catchments
  - Imports from MWD
  - Non-Chino Basin groundwater
- **Demands**
  - Urban indoor
  - Urban outdoor
  - Agricultural
- **Chino Basin groundwater**
  - Direct use
  - Desalted
  - Replenishment
  - Dry-year Yield program
- **Recycling**
  - Direct Use
  - Replenishment



# *We Created 200 Different Scenarios to Reflect Uncertainty about Climate Change and Other Factors*

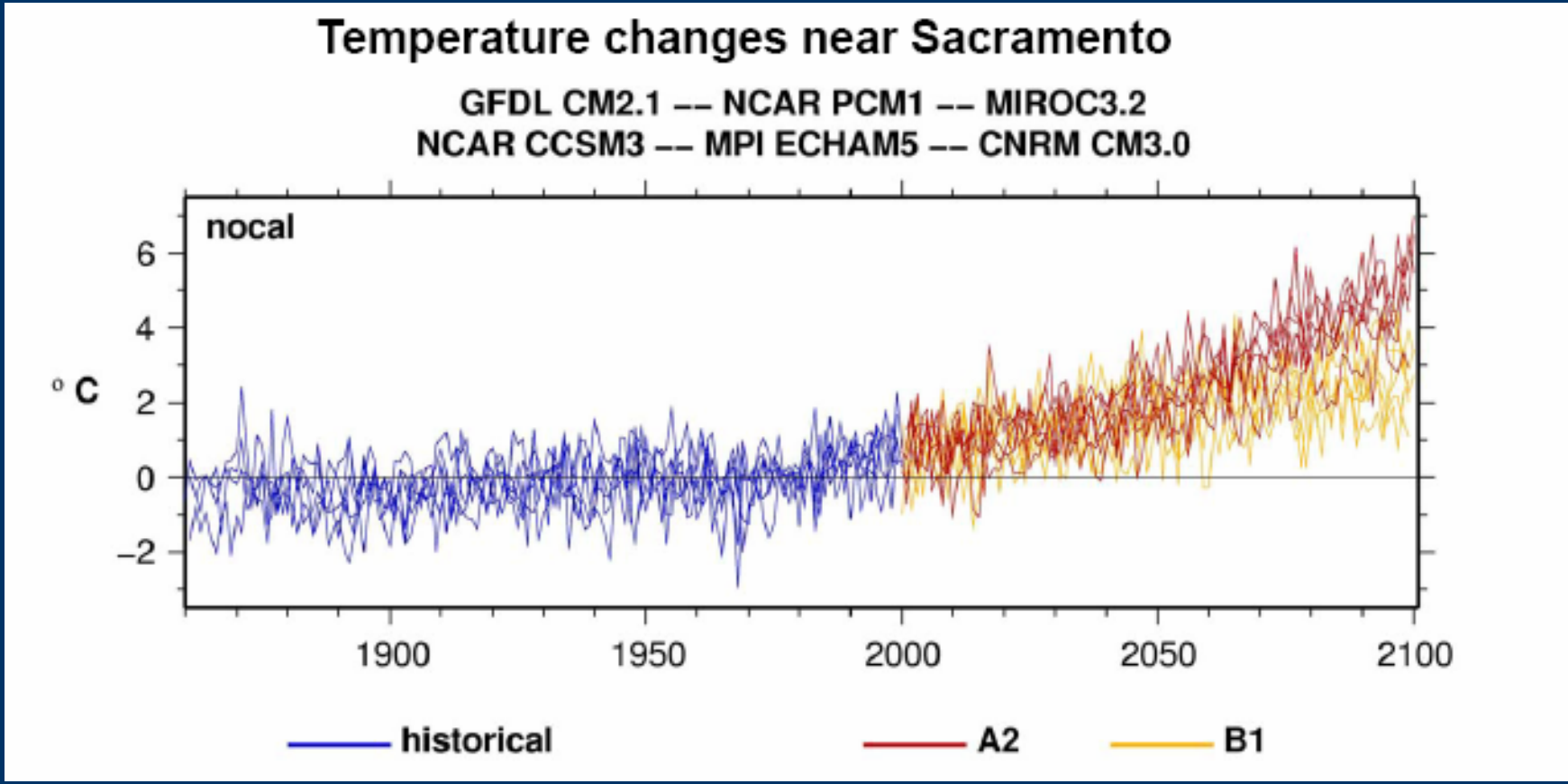


# *We Then Used Statistical Methods to Identify Key Risk Factors – Conditions that Lead to High Cost Outcomes*



***How can we integrate climate change into the integrated scenario analysis framework?***

# *We Will Use Temperature and Precipitation Projections Used By CEC*



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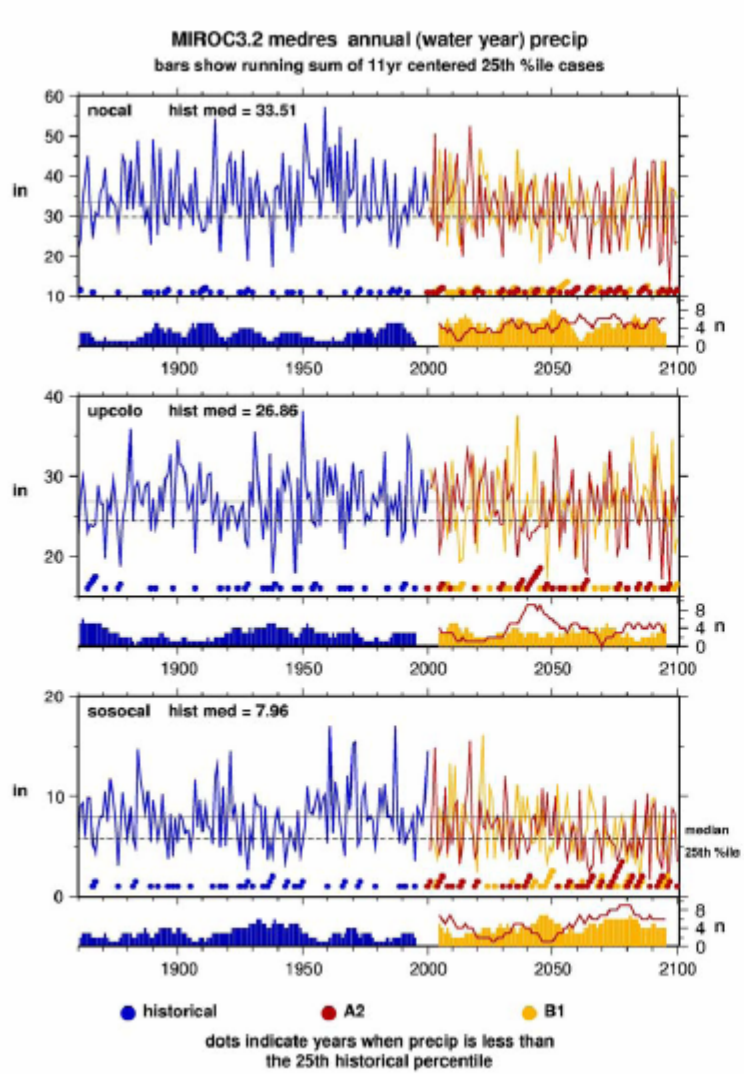


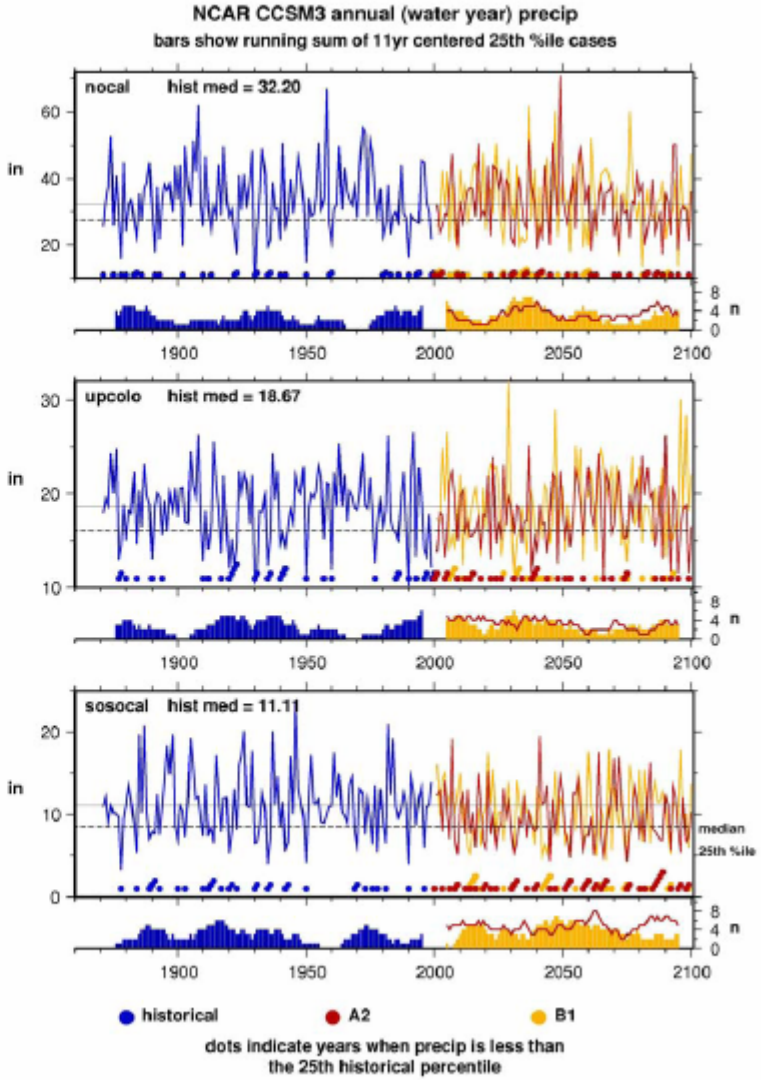


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# *How can WEAP support scenario analysis and response package evaluation?*

# *XLRM Helps to Organize the Components of a Scenario Analysis*

| Exogenous Factors (X) | |
|---|---|
| Uncertain factors outside of the control of water managers — Basis for "Scenarios" | |
| | |
| | |

# *XLRM Helps to Organize the Components of a Scenario Analysis*

| Exogenous Factors (X) | Management Levers (L) |
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| | |
| | |

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| | Performance Measures (M) |
| | Water outcomes of interest |

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| Exogenous Factors (X) | Management Levers (L) |
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| **Relationships (R)** | **Performance Measures (M)** |
| Mapping between combinations of exogenous factors (X) and levers (L) to outcomes (M) — a "Model" | Water outcomes of interest |

# *XLRM Helps to Organize the Components of a Scenario Analysis*

| Exogenous Factors (X) | Management Levers (L) |
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| **Relationship** | |
| Mapping between combinations of exogenous factors (X) and levers (L) to outcomes (M) — a "Model" | Water outcomes of interest |

$$X, L \xrightarrow{R} M$$

# *Scenario Framework Supports Quantitative Scenario Analysis of Response Packages*

- **Define response packages (L) as bundles of water management actions or policies**
- **Evaluate each response package (L) against a large ensemble of scenarios (X) using scenario model (R)**
- **Seek response packages (L) that**
  - **Are robust to uncertainties about the future (X)**
  - **Balance performance across objectives (M)**

## *What are some potential strategies for linking regional analysis to statewide evaluation?*

- **CalSim and CalSim-Lite are the key models of the SWP and CVP**
  - **Detailed accounting tools capture system logic in making storage and release decisions**
  - **Supplies and demands are used as model input**
  - **No climate driven hydrology or demands**
  - **No internal demand logic**

- **Demonstrate how output of regional scenario analysis could be used to inform a system-wide analysis on a CalSim platform**

# *Proposed Schedule of Activity*

| | 2008 | | | | | | | | | | | | 2009 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J |
| Task 0: Project Management | | | | | | | | | | | | | | | | | | |
| Task 1: Scenario Elements | | | | | | | | | | | | | | | | | | |
| Task 2: Regional Analysis | | | | | | | | | | | | | | | | | | |
| Task 3: Enhance WEAP | | | | | | | | | | | | | | | | | | |
| Task 4: Sacramento River Analysis | | | | | | | | | | | | | | | | | | |
| Task 5: South Coast Analysis | | | | | | | | | | | | | | | | | | |
| Task 6: Climate Scenarios | | | | | | | | | | | | | | | | | | |
| Task 7: Evaluate Scenarios | | | | | | | | | | | | | | | | | | |
| Task 8: Statewide Integration | | | | | | | | | | | | | | | | | | |
| Task 9: Training | | | | | | | | | | | | | | | | | | |
| Task 10: Documentation | | | | | | | | | | | | | | | | | | |

# *Support 2014+ Long-Term Strategy*

- **Institute for Water Resources has been engaged to implement a Shared Vision Planning effort to design a long-term analytical approach for the California Water Plan Update**

- **Proposed effort will provide a learning laboratory to evaluate:**
  - **The XLRM scenario development approach**
  - **The utility of an object oriented, visual modeling tool such as WEAP**
  - **Potential improvements to the process**

# *Outline*

- Motivate an integrated scenario analysis framework for California Water Plan Update 2009
- Propose integrated approach to developing water management scenarios and evaluating response packages
  - Linkage to 2009 Synthesis Exercise
  - Water Evaluation and Planning (WEAP)
  - Quantitative scenario analysis method
  - Support for 2014+ Long-Range Strategy
- **Elicit Feedback**