

# *Developing an Understanding of the Links between Energy, Water and Food*

[www.inl.gov](http://www.inl.gov)



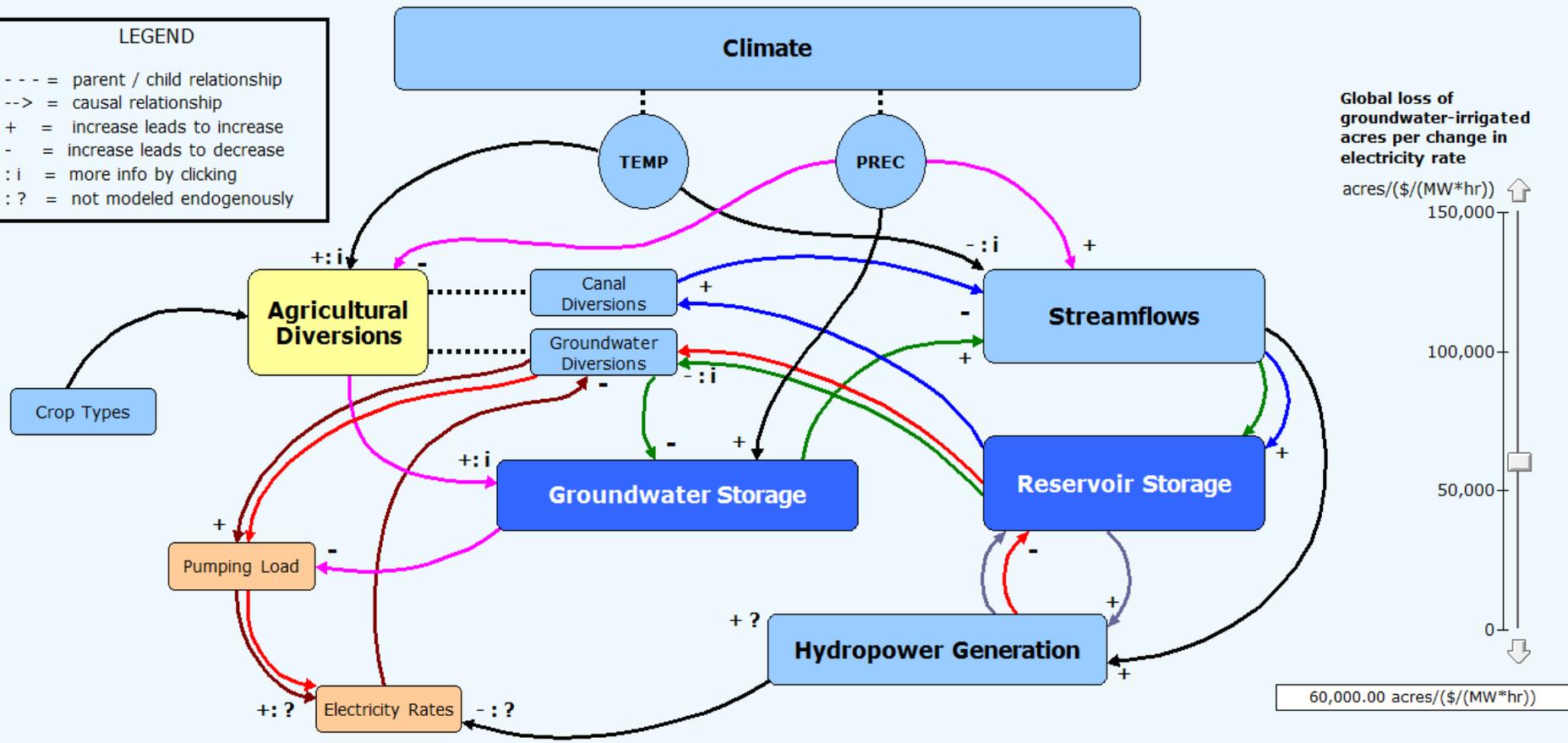
# The System

**Energy-Water-Ag System Relationships**

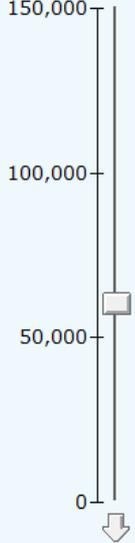
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**LEGEND**

- = parent / child relationship
- > = causal relationship
- + = increase leads to increase
- = increase leads to decrease
- :i = more info by clicking
- :? = not modeled endogenously



**Global loss of groundwater-irrigated acres per change in electricity rate**  
 acres/(\$/(MW\*hr))



60,000.00 acres/(\$/(MW\*hr))

- Canal Diversions Limiting Loop
- Groundwater Diversions Limiting Loop
- Hydropower Limiting Loop
- The Climate "Double Whammy"
- The Dry-climate GW-Hydro Vicious Circle
- The Slow-Motion GW-SW Diversion Circle

# So Why Use Models

There is a vast amount of research that shows that we are not very good at understanding even low complexity systems that have feedback with delays.

Testing new management scenarios on the real system is time consuming and expensive (especially if we get it wrong).

Models allow us to capture our mental models into a format that others can visualize and modify.

The modeling process helps us to formally define the relationships between different components in the system.

Models allow us to receive real-time feedback on management strategies.

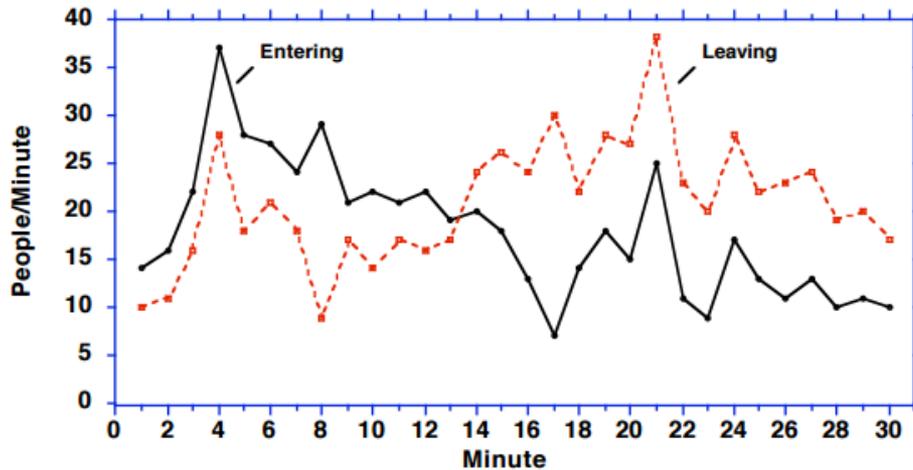
# Supporting Research

“Stock-flow problems, even simple ones, are unintuitive and difficult, even for highly educated people with substantial training in Science, Technology, Engineering, and Mathematics (STEM)”, John Sterman, MIT (Booth Sweeney & Sterman, 2000)

Graduate students at the MIT Sloan School of Management with a picture of a bathtub and graphs showing the inflow and outflow of water, were asked them to sketch the trajectory of the stock of water in the tub. Although the patterns were simple, fewer than half responded correctly. Performance remains poor in even simpler tasks (Cronin, Gonzalez and Sterman 2009)

# Test

The graph below shows the number of people *entering* and *leaving* a department store over a 30-minute period.



Please answer the following questions.

Check the box if the answer cannot be determined from the information provided.

1. During which minute did the most people enter the store?  
Minute \_\_\_\_\_  Can't be determined
2. During which minute did the most people leave the store?  
Minute \_\_\_\_\_  Can't be determined
3. During which minute were the most people in the store?  
Minute \_\_\_\_\_  Can't be determined
4. During which minute were the fewest people in the store?  
Minute \_\_\_\_\_  Can't be determined

Results:

N = 173

All had taken Calculus

Most were in STEMS fields

71% Higher Degree

40% Higher Grad Degree

Q1: 96% Correct

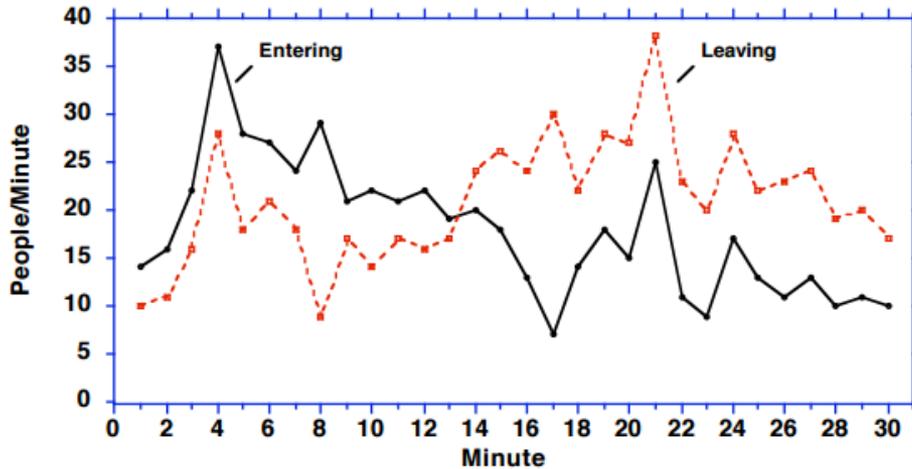
Q2: 95% Correct

Q3: 44% Correct

Q4: 31% Correct

# Answers

The graph below shows the number of people *entering* and *leaving* a department store over a 30-minute period.



Please answer the following questions.

Check the box if the answer cannot be determined from the information provided.

1. During which minute did the most people enter the store?

Minute 4

Can't be determined

2. During which minute did the most people leave the store?

Minute 21

Can't be determined

3. During which minute were the most people in the store?

Minute 13

Can't be determined

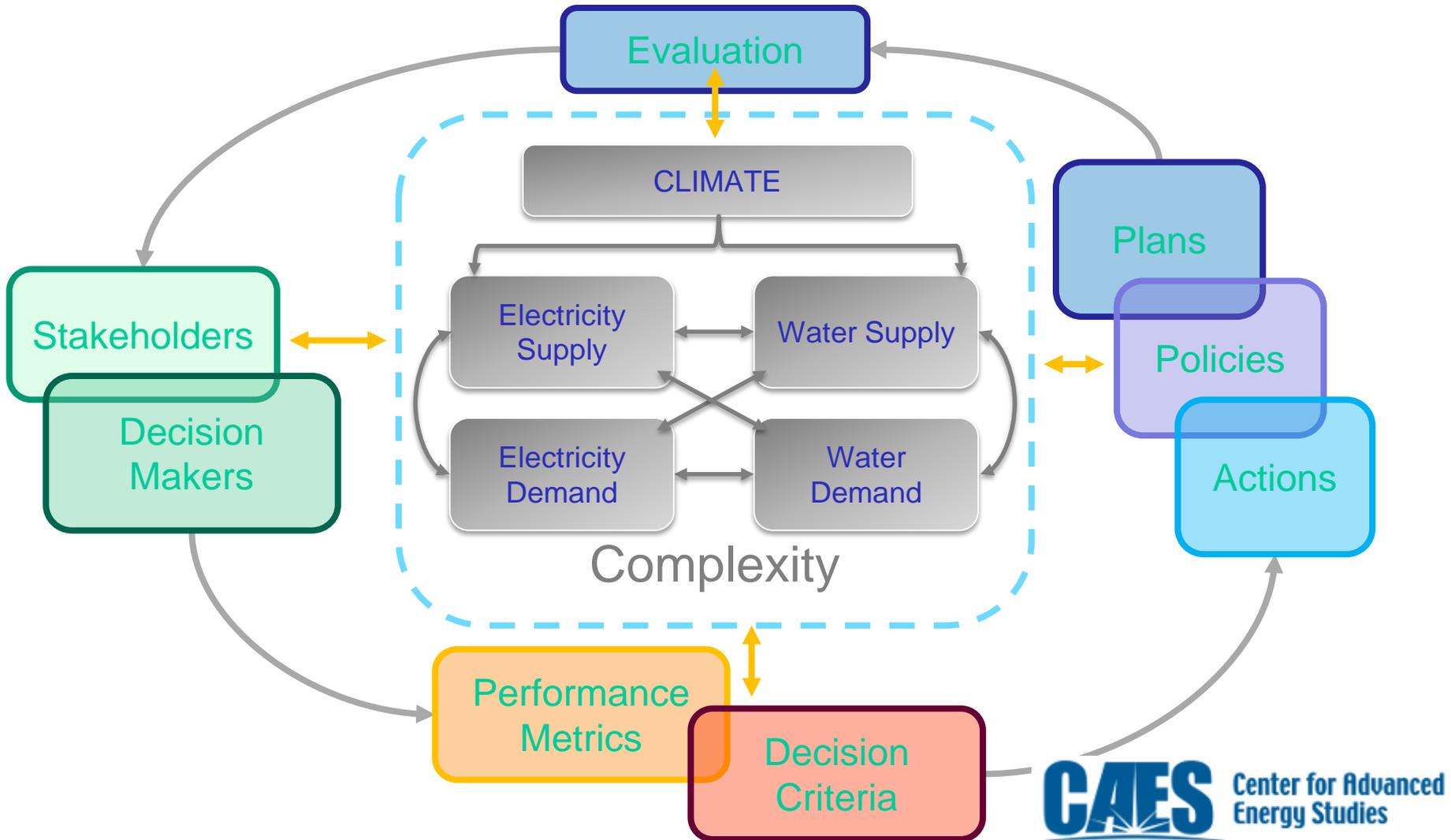
4. During which minute were the fewest people in the store?

Minute 30

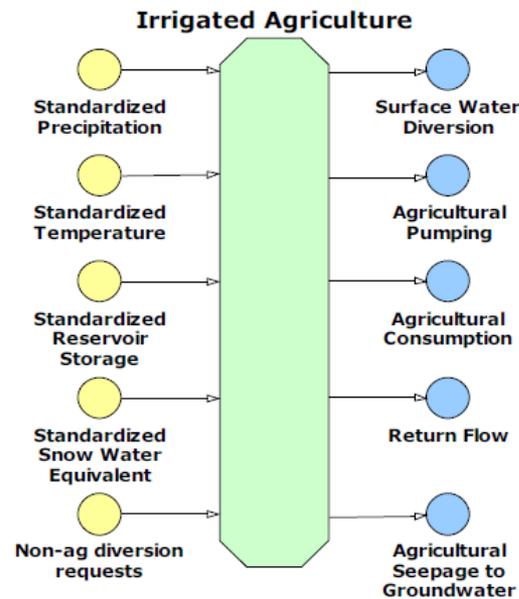
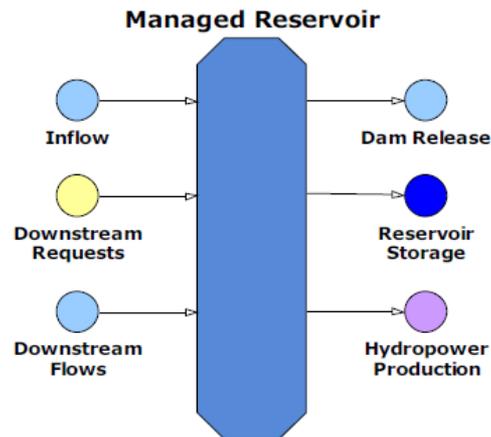
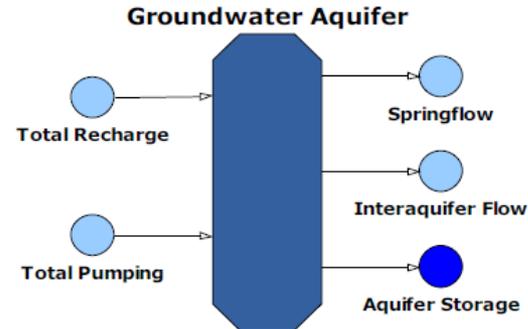
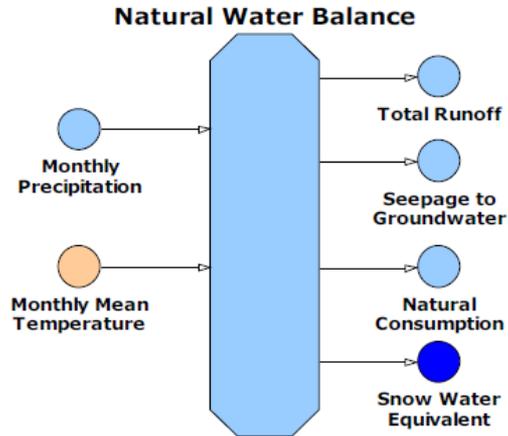
Can't be determined

# WEST

Water Energy Simulation Toolset

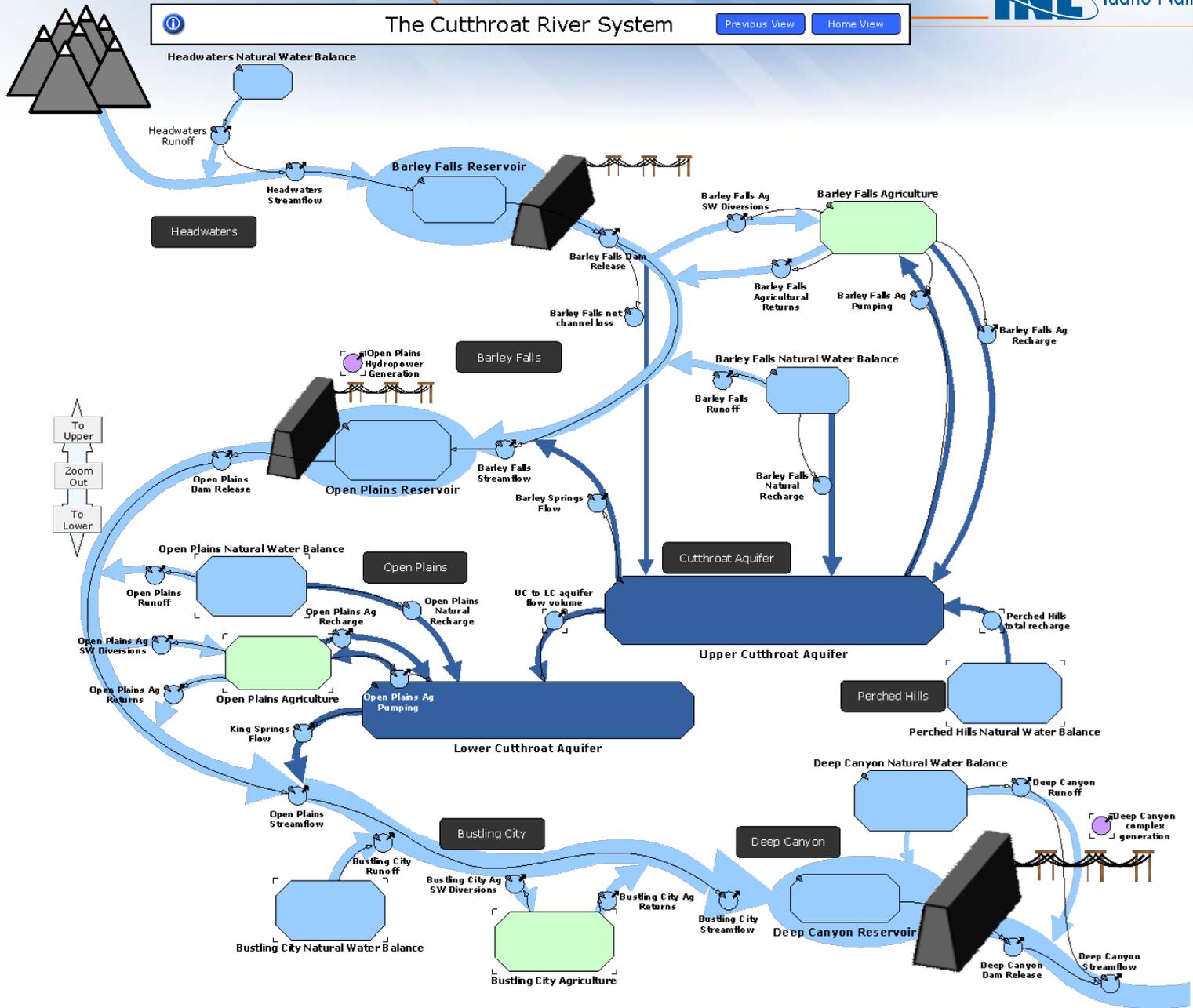


# Model Components



# The Cutthroat River System

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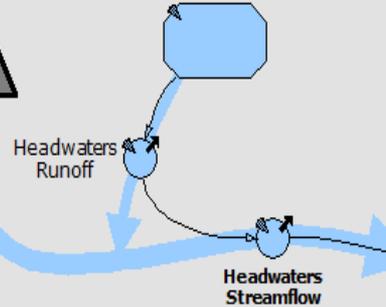
# The Cutthroat River System

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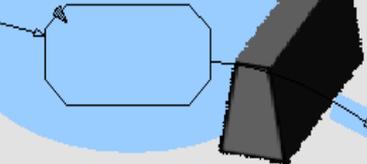


## Headwaters Natural Water Balance



Headwaters

## Barley Falls Reservoir

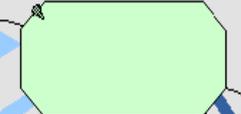


Barley Falls Dam Release

Barley Falls net channel loss

Barley Falls Ag SW Diversions

## Barley Falls Agriculture



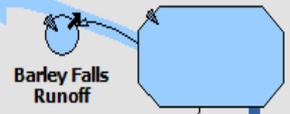
Barley Falls Agricultural Returns

Barley Falls Ag Pumping

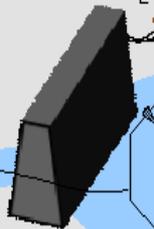
Barley Falls Ag Recharge

Barley Falls

## Barley Falls Natural Water Balance



Open Plains Hydropower Generation



## Open Plains Reservoir

Open Plains Dam Release

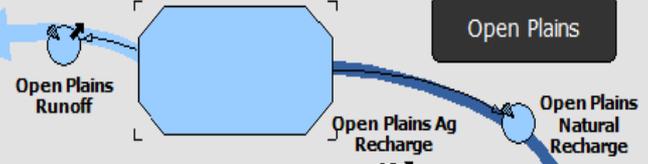
Barley Falls Streamflow

Barley Springs flow

Barley Falls Natural Recharge

To Upper  
Zoom Out  
To Lower

## Open Plains Natural Water Balance



Open Plains

Open Plains Runoff

Open Plains Ag Recharge

Open Plains Natural Recharge

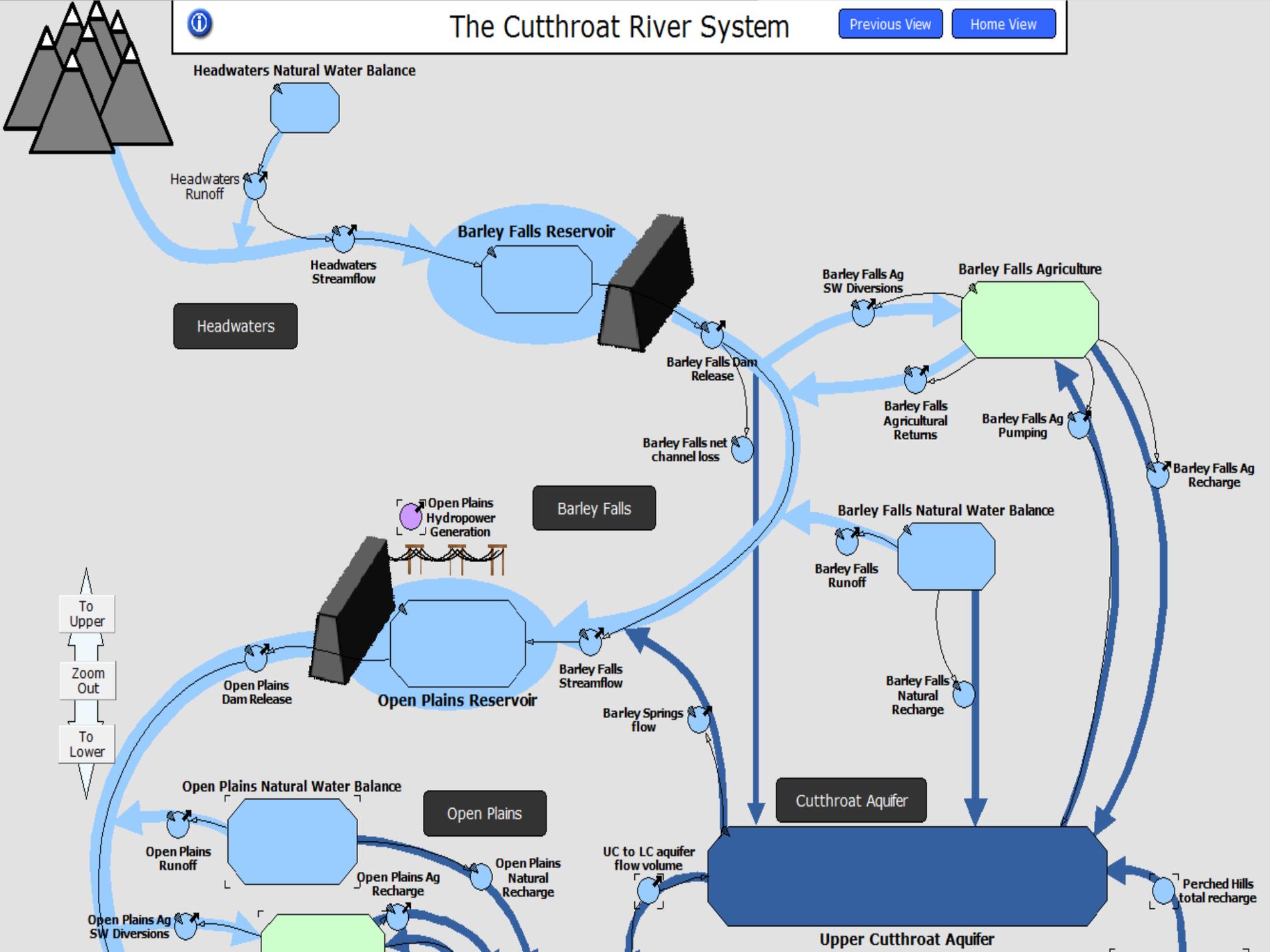
Open Plains Ag SW Diversions

Cutthroat Aquifer

UC to LC aquifer flow volume

Perched Hills total recharge

## Upper Cutthroat Aquifer



# Control Panel

MAIN



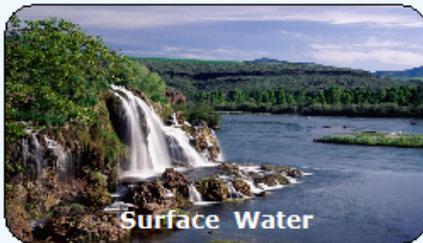
info WASHINGTON STATE UNIVERSITY

## The Cutthroat River Model

**INL** Idaho National Laboratory

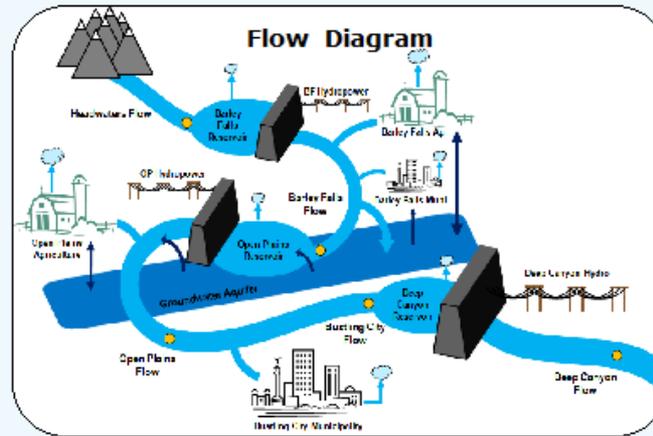
What can I do with WEST?

Historic Fit



Object Oriented System Dynamics

Energy and Water Interdependency



Run Control

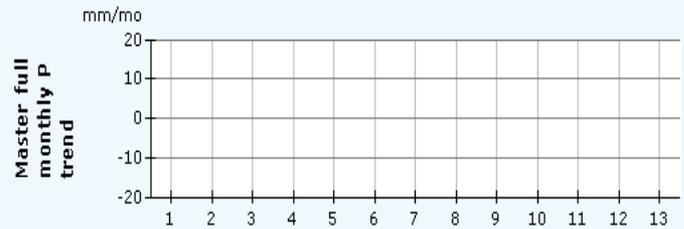
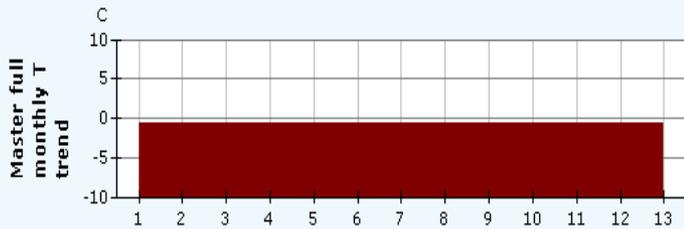
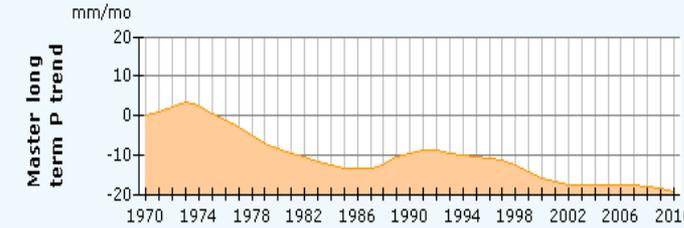
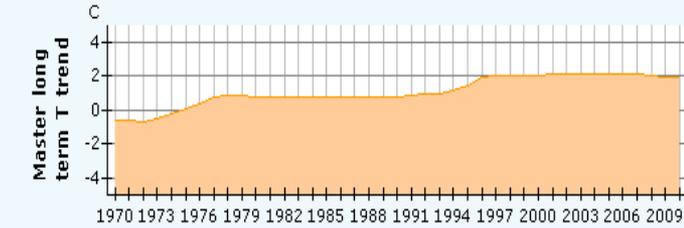
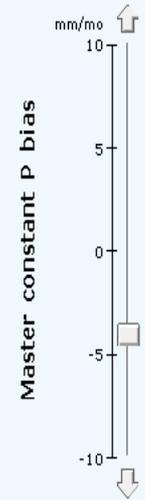
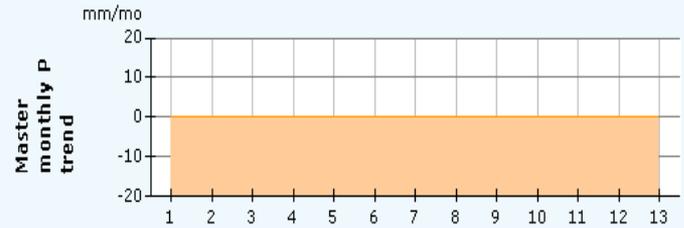
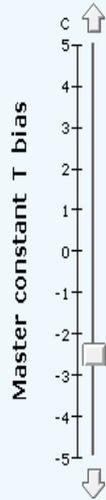
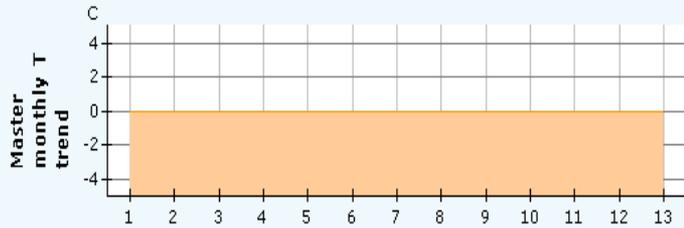


Performance Metrics



CLIMATE CONTROL

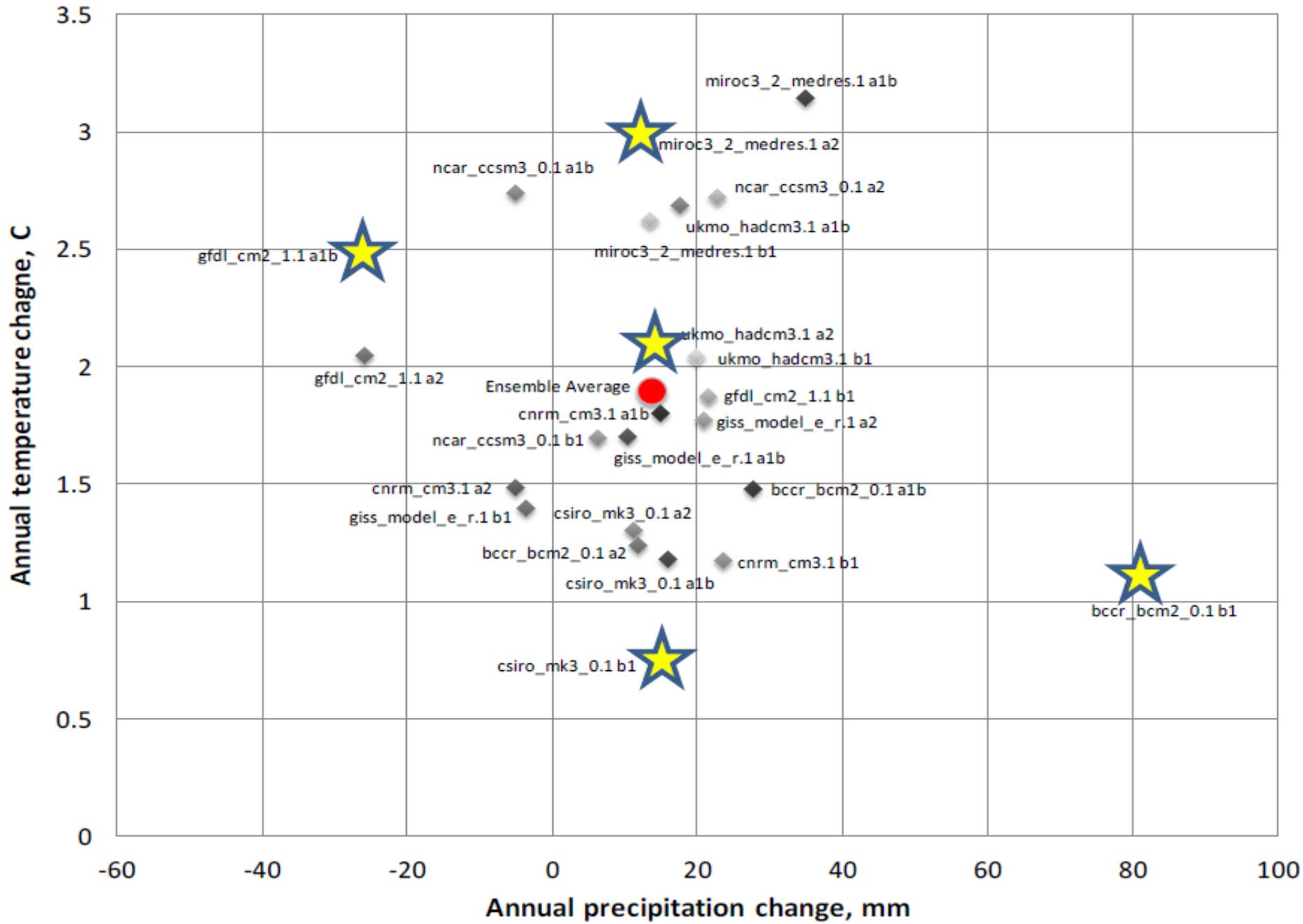
Master Climate Control Previous View Home View



Climate normalization? Year to normalize climate against:



# All FUTURE climate change scenarios, relative to 1970-2000





## Cutthroat Agriculture

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Agriculture is a major business in the Cutthroat River Basin. The primary crops are potatoes, barley, alfalfa, sugar beets (decreasingly), and corn (increasingly). Nearly all agriculture in the basin depends on irrigation.

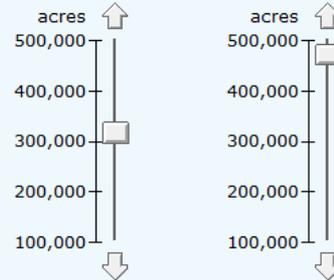
Barley Falls Agriculture

Open Plains Agriculture

Bustling City Agriculture

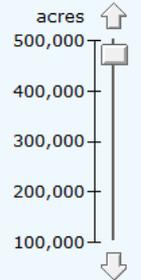
Electricity and Agriculture

**Barley Falls Surfacewater Irrigated Area**



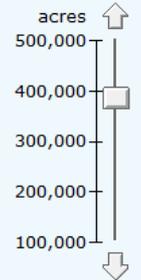
316,000 acres

**Barley Falls Groundwater Irrigated Area**



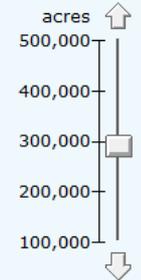
472,000 acres

**Open Plains Surfacewater Irrigated Area**



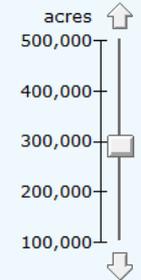
385,000 acres

**Open Plains Groundwater Irrigated Area**



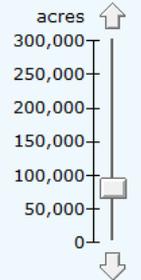
290,000 acres

**Bustling City Surfacewater Irrigated Area**



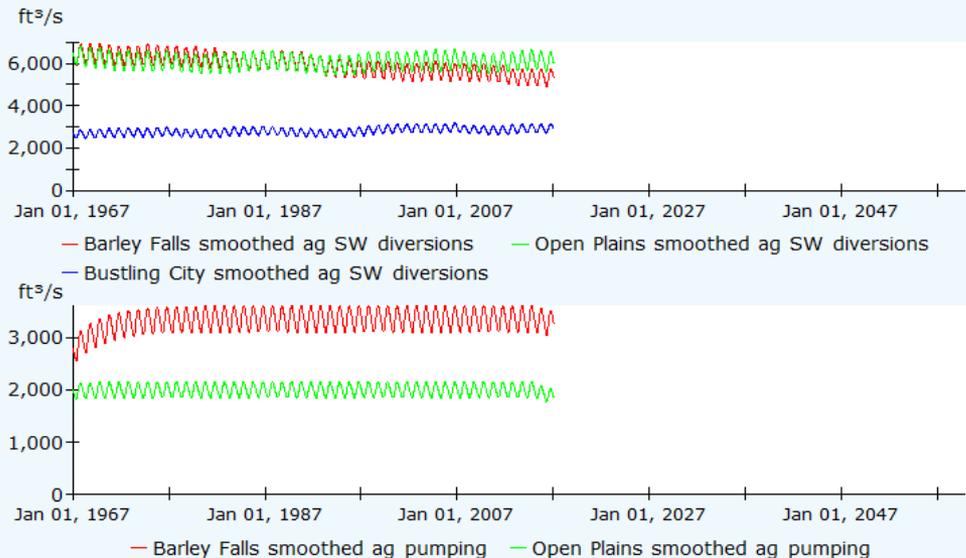
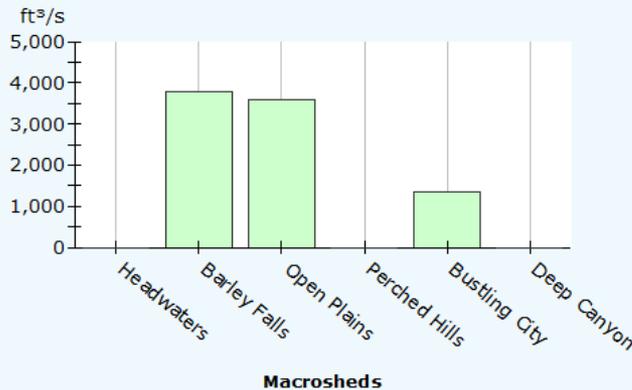
290,000 acres

**Bustling City Groundwater irrigated area**



80,000 acres

**Agricultural Consumption by Watershed**

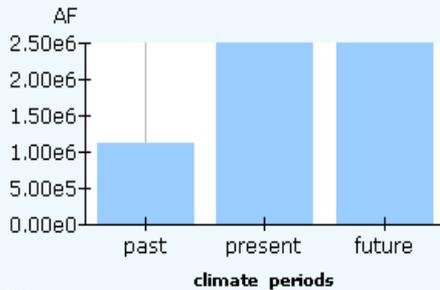




### Performance Metrics

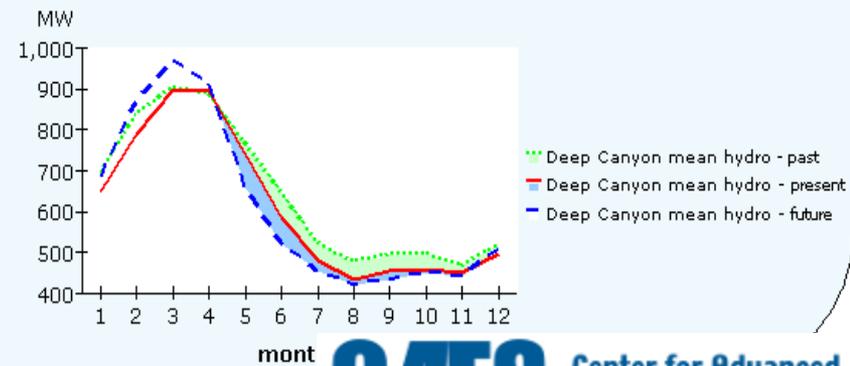
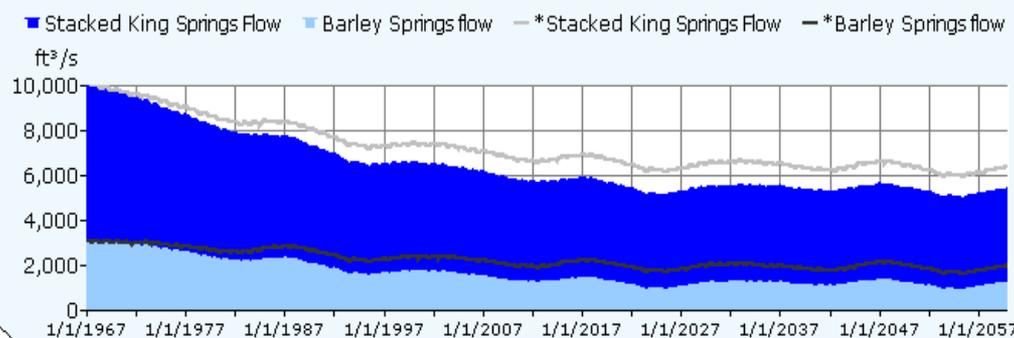
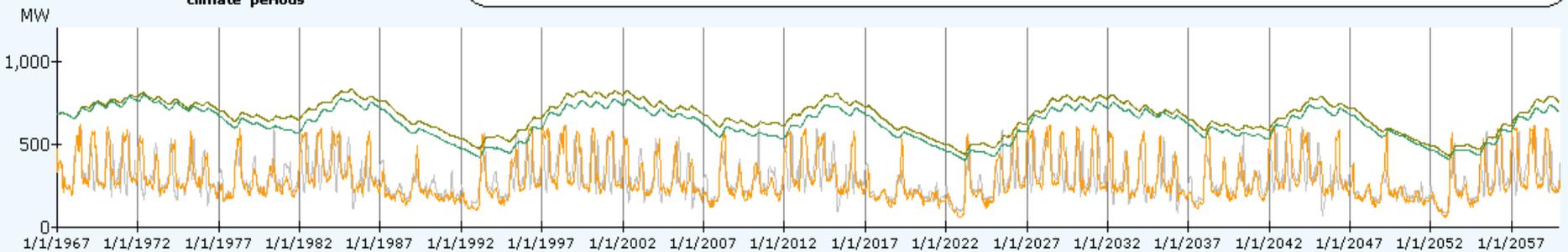
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Volume of water released from Open Plains supply for downstream power rights

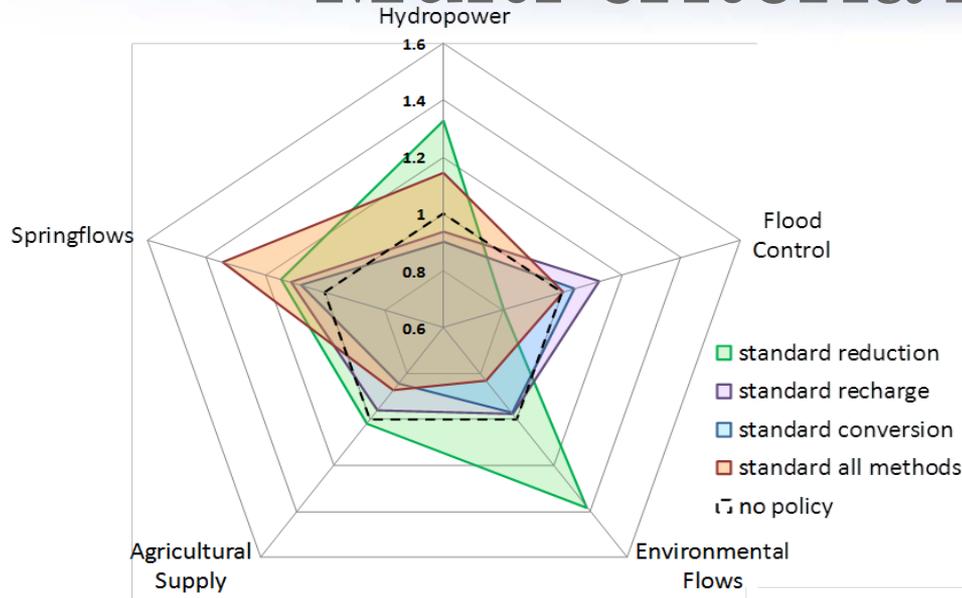


#### Management Category

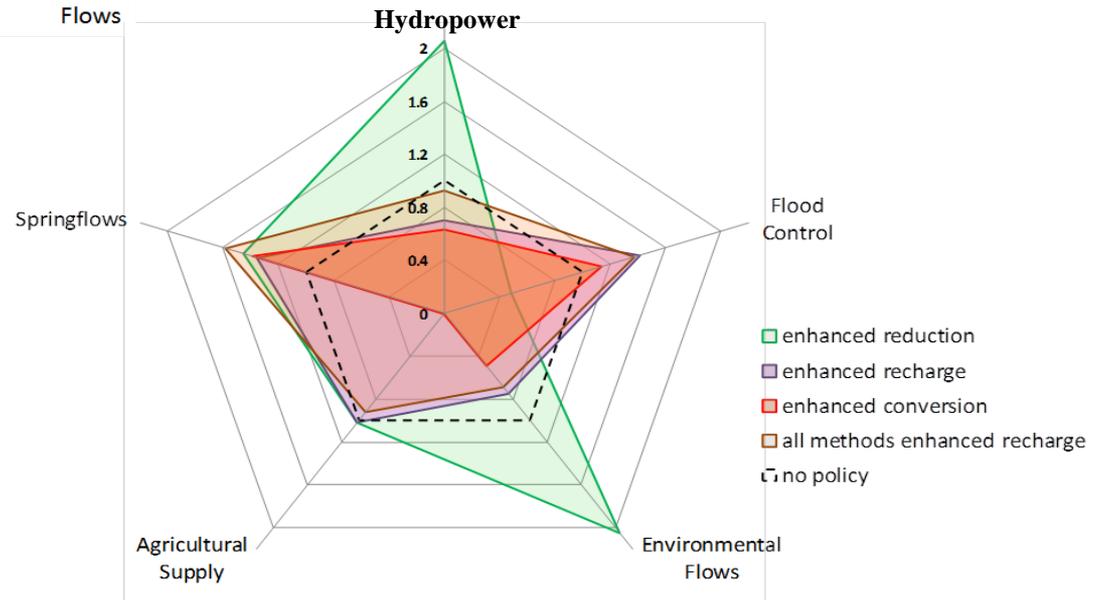
| Management Category | Performance Metric  | Current Run          | Reference Run        |
|---------------------|---|----------------------|----------------------|
| <b>Energy</b>       | IPC hydropower energy from Open Plains and Deep Canyon    | 532,311,540.13 MW*hr | 578,845,540.75 MW*hr |
| <b>Agriculture</b>  | Fraction agricultural requests delivered - all watersheds | 0.9861               | 0.9983               |
| <b>Flood</b>        | Volume of water above flood stage - all gauges            | 55,509 AF            | 208,956 AF           |
| <b>Groundwater</b>  | Mean elevation of Cutthroat Aquifer at simulation end     | 4,066'2"             | 4,091'2"             |
| <b>Minimum Flow</b> | Cumulative volume deficit below minimum flow - all gauges | 8,467,808 AF         | 4,309,626 AF         |



# Multi-criteria Analysis



**Normalized performance:**  
 $1 \pm (x - x_{base})/z$ ,  
 Such that 1 is normal, 0 is very "unwanted," and 2 is very "wanted"



# Summary

WEST is first and foremost a collaborative tool for resource management. It can help diverse groups negotiate policies that provide joint benefits across multiple criteria.

Currently INL working with EPA and U of I is adding in water quality components.

Future will include web-deployed models that can be used to educate as well as negotiate.

For Further Information on  
WEST contact:

Erin Searcy

208-526-0819

[erin.searcy@inl.gov](mailto:erin.searcy@inl.gov)