The Integrated Basin Scale Opportunity Assessment Initiative, Feb 1 Deschutes Workshop

Deschutes Basin Case Study: Work to Date, Current Status, Potential Next Steps

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Introduction

- Basin Scale Opportunity Assessment Overview
- Work to Date in the Deschutes
- Status of analysis
- Workshop Goals

Hydropower MOU

MOU for Hydropower among DOE, DOI and DOA

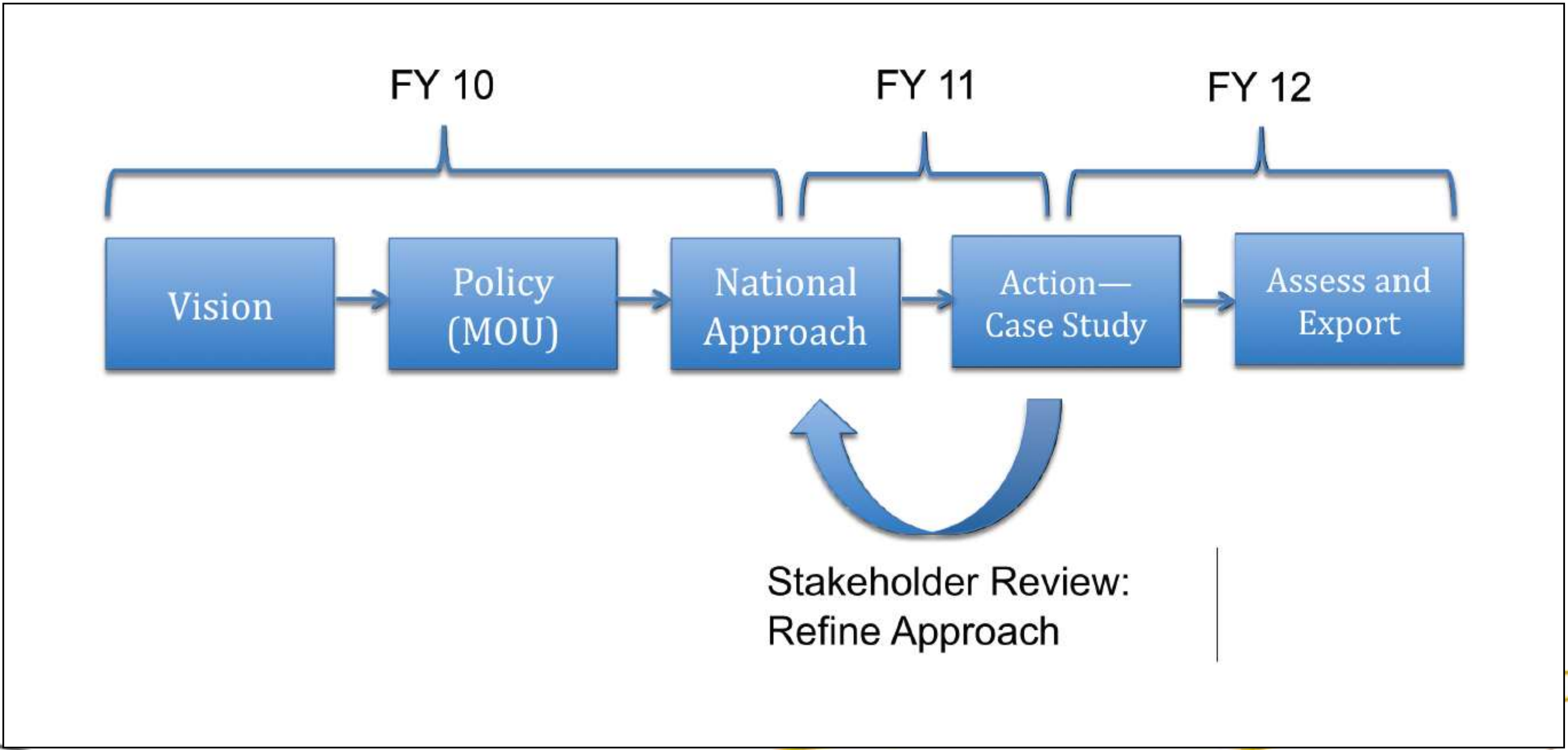
- Signed in March 2010, MOU highlights 7 key areas for interagency collaboration.
- Major ongoing activities to date
  - Assessments of energy generation potential and analysis of potential climate change impacts to energy generation at federal hydropower facilities
  - Exploring opportunities for collaboration across entire river basins to increase generation and improve environmental conditions
  - Green Hydropower Certification
  - Federal Inland Hydropower Working Group
  - Joint development and demonstration of advanced technologies
  - Renewable Energy Integration and Energy Storage
  - Facilitate permitting for federal and non-federal projects at federal facilities

National Goals for Opportunity Assessment

- Develop (in collaboration with stakeholders) an ***approach*** for basin scale identification and analysis of sustainable **hydropower** and **environmental** protection/restoration opportunities, within the context **of other water uses**.

  - **Stakeholder engagement**
  - **System-scale analysis**
  - **Data Aggregation, Display, and Dissemination**
  - **Inform—**Not meant to substitute for planning and regulatory processes

Initiative Process: Thousand-Foot View



Partners (to date)—It's a big tent…

- MOU Agency Leads—DOE, USACE, BOR
- National Steering Committee—
  - Hydro, Environment, NOAA, BOR, DOE, USACE
- Deschutes Basin Stakeholder Involvement
  - Logistics Team—PGE, BOR, BOC, TU, OWRD, DRC
  - Site Visit and Interviews—20+
  - Stakeholder Workshops (2)—40+
- Technical Team: PNNL, ORNL, ANL

Deschutes Basin Case Pilot Selection

- Objective criteria, considered by MOU agencies and Steering Committee
  - Potential for hydro (existing and new), environmental potential, active SH community, existing data, opportunity for learning
- Preliminary outreach in early 2011 with BOC, PGE, TNC, DWA, others—assessing stakeholder interest in working with us.
- Strong interest, but sensitivity around HCP and Crooked River processes—Assessment tools could be useful, but must also be careful to respect ongoing processes.
- Site visit in Spring, 2011 to scope further and preliminary ID of opportunities

Upper Deschutes/Crooked River Pilot Project

- Central Oregon, three sub basins
- Unusual hydrology, ground water connectivity
- 7 irrigation districts
- Major irrigation reservoirs on Upper Deschutes and Crooked Rivers.
- 300+ MW facility at Pelton-Round Butte
- Existing in conduit hydropower and desire for more
- Complex environmental and regulatory issues
- Model basin for collaborative problem solving

Assessment Activities in the Deschutes

- Spring, 2011—Site visit and meetings with environmental community, irrigators, and PGE.
  - Crooked and Upper Deschutes: Bowman, Wikiup, Juniper Ridge, Ponderosa, PRB
- Late Summer, 2011—Bend stakeholder workshop
  - 48 stakeholders
  - Opportunity identification
  - Research agenda
- October, 2011—Preliminary Assessment Report
- February, 2012—Seattle modeling workshop with Bureau, OWRD, and DRC
- July, 2012—Site visit II: Scenario scoping with "Logistics Committee"
- Feb1, 2013—Today's workshop

Upper Deschutes/Crooked River Pilot Project

- Hydro Opportunities
  - Powering non powered dams
    - BOR facilities
    - Municipal facilities
    - Opportunities related to irrigation reservoirs
  - New small hydro in irrigation canals and conduits
    - Build on existing success stories and assessments
  - Flow shaping to maximize hydro value
    - Pelton-Round Butte

Upper Deschutes/Crooked River Pilot Project

- Environmental Opportunities
  - Enhanced flows below reservoirs
  - Habitat restoration and water quality improvements
  - Explore creative ideas for new revenue streams for environmental work
  - Water conservation projects
  - Low impact development of hydro resources
  - Information: Assist HCP and other environmental planning processes through application of modeling tools and data aggregation.

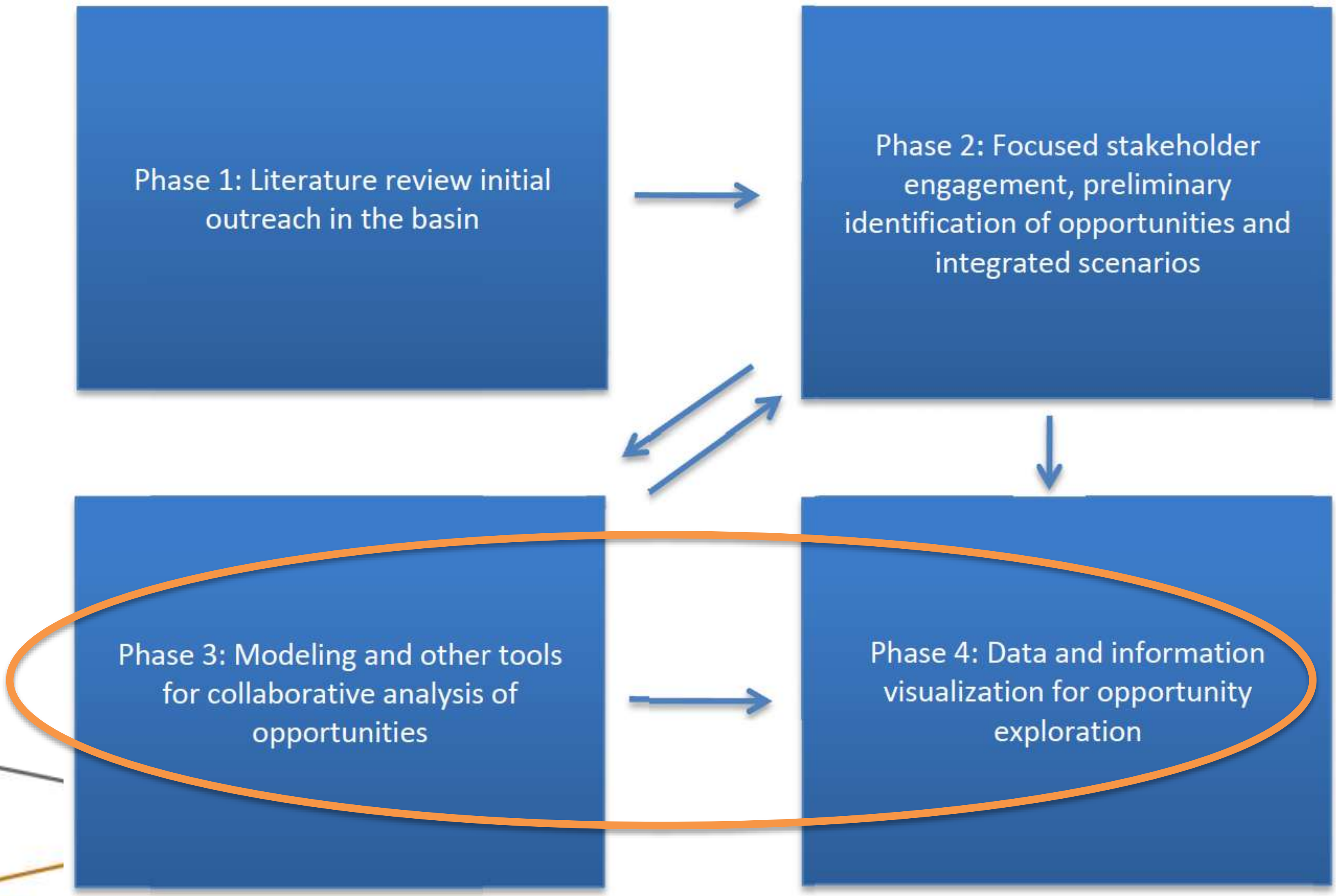
Upper Deschutes/Crooked River Pilot Project

- Understand context for opportunities
  - Irrigation intersects with many of the power and environmental opportunities
  - Flatwater recreation on reservoirs
  - Operate within context of HCP, existing environmental law, and other ongoing processes
- Integration
  - System-wide water balance model--hydropower, environmental flow, and irrigation
  - Aggregate existing data and model data into visualization tool

2012 Research Agenda

- Develop and refine opportunity **scenarios**
- Develop **daily-time step operational model**—Major reservoirs, existing infrastructure, proposed hydro, ground water, surface water, inflows
- **Simulation** of opportunity scenarios—looking across historic record 1928-2008
- **Small hydro case study**
- **Catalog** existing site specific hydro and environmental opportunities
- Develop **data visualization and collaborative analysis tool**
- **Collaborate** with local experts

Pilot Project Approach



Thoughts for Today's Workshop

- Assessment tools build on previous models and existing data.
- Scenario-based approach relies on stakeholder input and collaborative iteration.
- Start from the basics to understand tension between opportunities and build data infrastructure.
- Flexible architecture allows more detailed scenarios in the future.
- What you see today represents a first iteration. We hope to refine with your help!

Today's Goals

- Report on initial results from our analysis.
- Gain input from stakeholders on assessment tools and approach.
- Discuss next steps and potential for future uses of assessment tools.

Acknowledgements

We'd like to acknowledge support for this project from the Department of Energy, Wind and Water Power Technology Office, as well as our partnership with the US Army Corps of Engineers and the Bureau of Reclamation, through the Sustainable Hydropower MOU.

As well as all of the help and support from Deschutes Basin stakeholders.

Understanding Opportunity Scenarios

KENNETH HAM, SIMON GEERLOFS

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Objectives

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- Define the steps in Scenario Based Modeling
- Introduce the Scenario Based Modeling Process
- Briefly show how the process can be used by stakeholders

Outline

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- Define
  - Opportunity
  - Scenario
  - Scoping
  - Value Based Metrics
  - Scenario Based Modeling
    - Baseline
    - Scenario

Opportunity

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- An opportunity is a proposed change to the operation or management of the river system that is expected to provide some benefit

Opportunities Vary Among Stakeholders

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Install a Turbine

Implement Fish Passage

Alter Discharge Timing

Line a canal

Scenario

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- A scenario is a set of opportunities that combine to provide a mix of benefits.
  - If opportunities are not compatible, they must reside in different scenarios

A Scenario is a Set of Opportunities

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Line a canal

Install a Turbine

Scenario A

Implement Fish Passage

Alter Discharge Timing

Scoping

- Scoping is an incremental evaluation of an opportunity that reveals how the mix of benefits (positive and negative) changes across a range of management
  - Reveals tradeoffs among benefits

Scoping Explores the Range of an Opportunity

Line a canal

Install a Turbine

Scenario A

Implement Fish Passage

Alter Discharge Timing

Value Based Metrics

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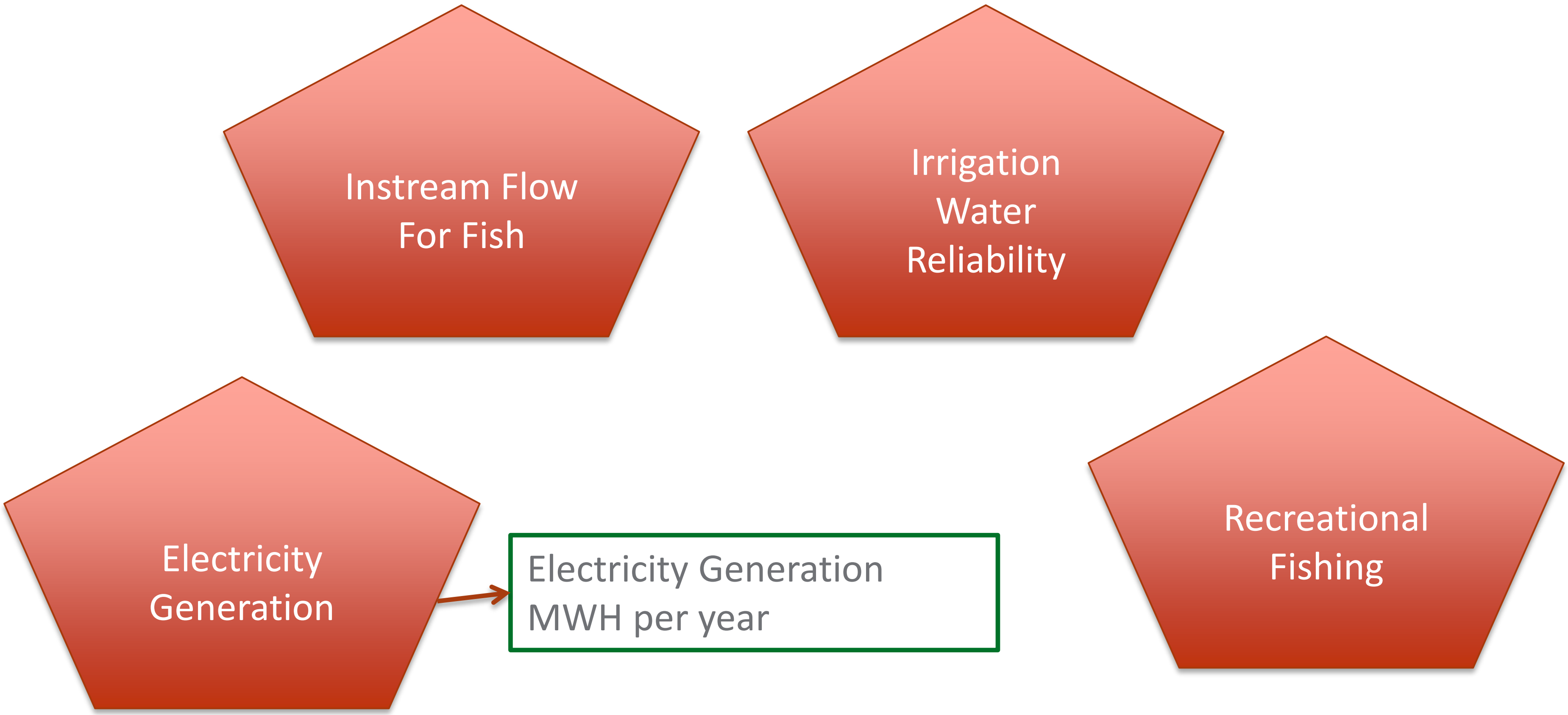
- A Value Based Metric is a representation of an aspect of the river system that is valued by a stakeholder
  - This value need not be common across stakeholder groups

Value Based Metrics Are Derived From Stakeholder Values



Scenario Based Modeling

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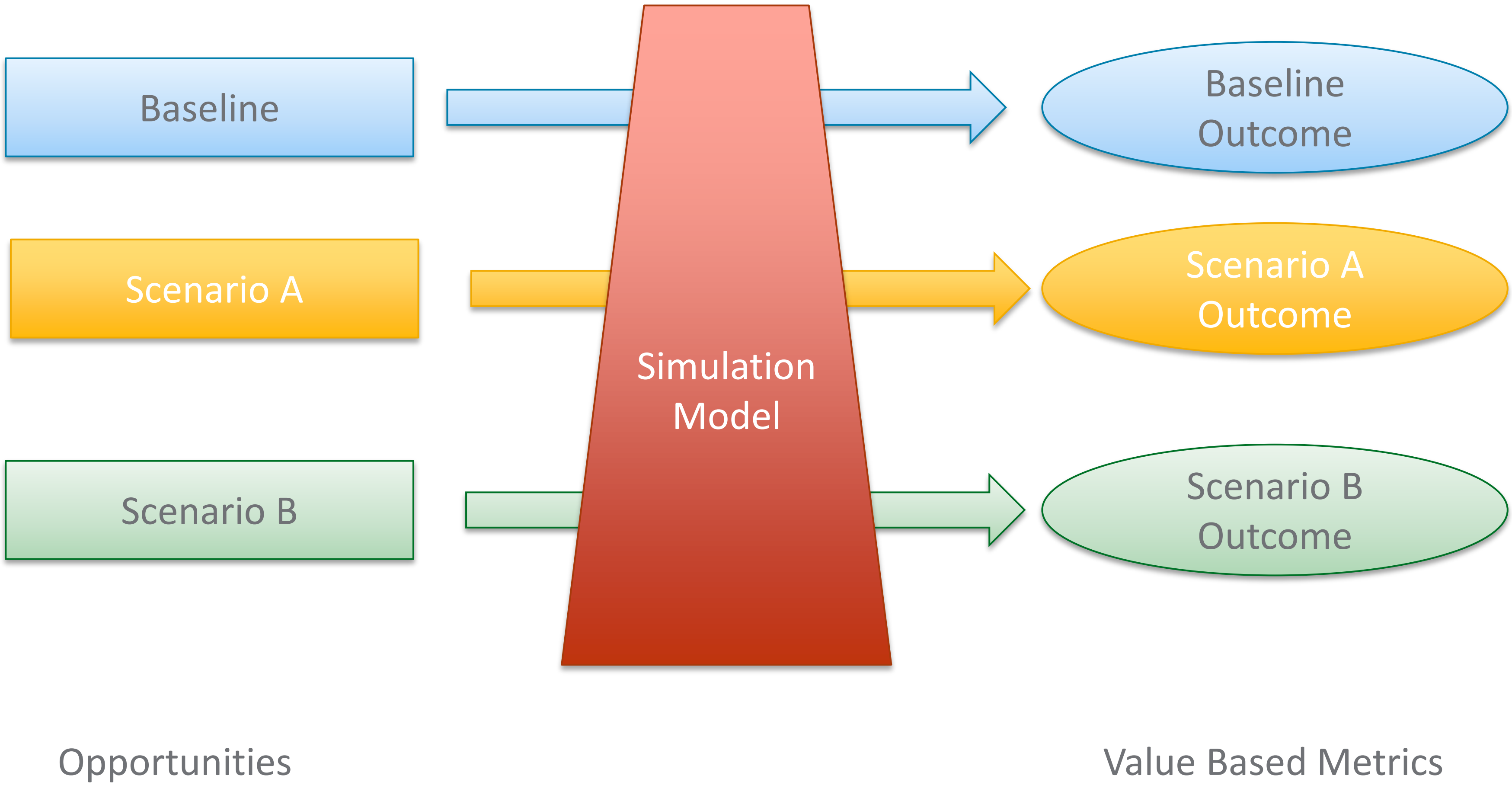
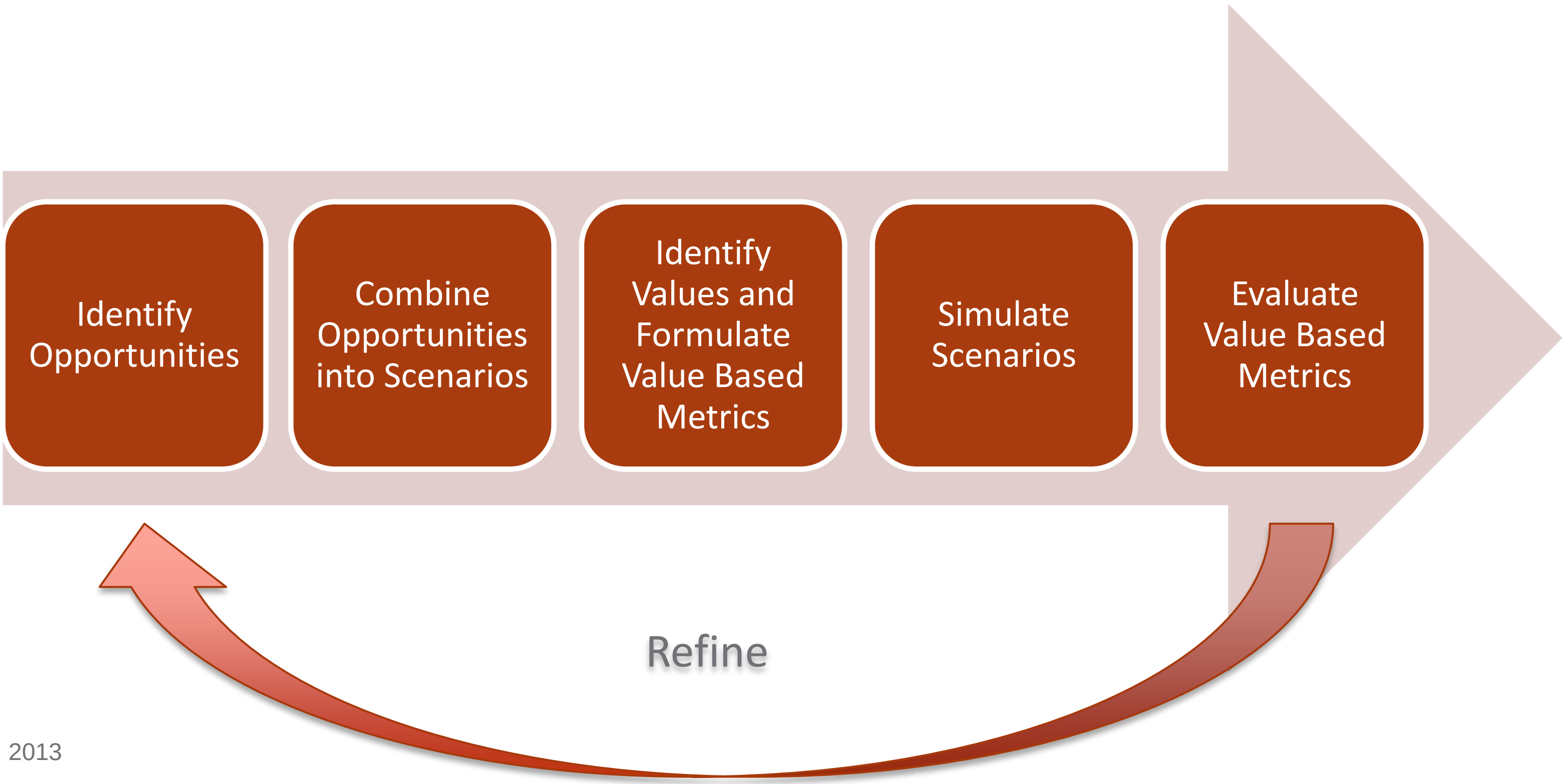
- Facilitates comparisons of management alternatives contained in one or more scenarios
- Benefits are evaluated by comparing value based metrics among scenarios

Scenario Based Modeling



Tools Facilitate Exploration and Communication

Inputs can be modified and additional alternatives can be evaluated



Rest of the day

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- Before Lunch
  - More detailed explanations of opportunities and the Scenario Based Modeling process
- After Lunch
  - In depth information on the simulation model
  - Input from stakeholders

Technical and Economic Feasibility Assessment of Small Hydropower Development in the Deschutes River Basin

Qin Fen (Katherine) Zhang
Rocio Martinez
Bo Saulsbury
Kevin Stewart
Brennan Smith

Deschutes Basin Stakeholder Workshop
February 1, 2013

Introduction

- Purpose: identify and assess opportunities for new small hydropower development in Deschutes Basin, along with technology needed to develop selected sites and economic feasibility of developing sites.

- Three likely scenarios for additional hydropower generation:

  - add new generators at non-powered dams (NPDs) and diversion structures;
  - add new generators in existing irrigation canals and conduits; and
  - increase generation at existing hydropower facilities.

- Focus: developing new projects, so assessment includes only adding new generators at (1) NPDs and diversion structures and (2) existing irrigation canals and conduits.

Introduction

- **Today: brief overview of assessment methodology and results for Deschutes Basin.**

- **In March: more detailed written report on assessment methodology and results for Deschutes Basin.**

- **After March: more detailed documentation on ORNL Hydropower Energy and Economic Assessment (HEEA) Tool, including availability for use in assessing other sites and basins in United States.**

Recent Assessments: NPDs

- National Hydropower Asset Assessment Program (NHAAP) database lists 64 NPDs/diversions in Upper and Middle Deschutes and Crooked basins. Three have potential capacity > 3 MW: North Unit Diversion Dam (4.65 MW), Wickiup Dam (3.95 MW), and Bowman Dam (3.393 MW).

- Reclamation (2011) *Hydropower Resource Assessment at Existing Reclamation Facilities* also models Wickiup with potential capacity of 3.95 MW and Bowman with potential capacity of 3.29 MW.

- *Reclamation 2011* ranks hydropower sites at Reclamation dams in Pacific Northwest based on benefit/cost ratio (BCR) (with green incentives) > 0.75. Bowman ranks highest in Pacific Northwest with BCR of 1.90 and internal rate of return (IRR) of 11.2 percent.

- Two other Deschutes Basin dams had BCRs > 0.75 in *Reclamation 2011*: Wickiup (0.98) and Haystack Canal (0.85). Three others (Crane Prairie, Lytle Creek, and Ochoco), did not meet 0.75 BCR threshold.

Recent Assessments: NPDs

Two NPDs have moved past assessment stage:

- **Symbiotics, LLC: FERC license application for Wickiup Dam Hydroelectric Project (installed capacity 7.15 MW and average annual energy production 21.15 GWh).**

- **Portland General Electric: FERC preliminary application document for Crooked River Hydroelectric Project at Bowman Dam (installed capacity 6.0 MW and average annual energy production 23.0 GWh).**

Recent Assessments: Canals/Conduits

- **Potential exemplified by SID's Ponderosa Project, COID's Juniper Ridge Project, and TSID's Main Canal Project.**

- **Black Rock Consulting (2009) *Feasibility Study on Five Potential Hydroelectric Power Generation Locations in the North Unit Irrigation District*. Three sites deemed economically feasible (i.e., BCR > 1.0) with Energy Trust of Oregon (ETO) grants, investment tax credits, and low-cost equipment and construction.**

- **ETO (2010) *Irrigation Water Providers of Oregon: Hydropower Potential and Energy Savings Evaluation*. Evaluates nine sites (six COID, one TSID, and two TID), but excludes NUID, OID, and SID sites because ETO investigations "already underway." Concludes that four districts (AID, COID, TSID, and TID) "deserve further evaluation."**

Recent Assessments: Canals/Conduits

- **COID and Oregon Department of Energy (ODE) (2011) *Feasibility Study for Six Central Oregon Irrigation District Potential Hydroelectric Power Generation Sites*. Two sites have estimated BCRs > 0.75.**

- **Reclamation (2012) *Site Inventory and Hydropower Energy Assessment of Reclamation Owned Conduits* assesses 393 sites in 13 states and ranks by potential annual energy and potential installed capacity.**

- ***Reclamation 2012* includes 39 NUID sites along North Unit Main Canal; four of top 25 sites in all 13 states are NUID sites.**

ORNL Assessment Methodology

- Used ORNL *Hydropower Energy and Economic Assessment (HEEA) Tool* (Version 1.0) being developed by Qin Fen (Katherine) Zhang and Rocio Martinez.
- Site-specific information (including available flow data) from recent NPD and canal/conduit assessments and from multiple data sources.
- Energy/economic assessment differentiates between economically feasible and infeasible sites. Ranks sites by BCR and IRR based on site-specific conditions and green incentives.
- Feasible = BCR $\geq$ 1.0 and IRR > 5.9% (Weighted Average Cost of Capital).
- Also investigated sensitivity of BCR and IRR to different turbine types from domestic and international suppliers.

ORNL HEEA Tool

- Can be incorporated into Deschutes Basin-Scale Water Management Model by:

  - collecting basic project and site information as input to Basin-Scale Model;
  - accepting flow and head data input from various flow scenarios simulated in Basin-Scale Model, and;
  - producing site-specific energy and economic assessment results as input to Basin-Scale Model

- Targeted application in Deschutes Basin is small hydro (100 kW to 10 MW), but can assess projects from 10 kW to 50 MW.

Methods for Design Flow & Turbine Type

- ORNL HEEA Tool automatically selects turbine type based on ranges of rated net head and design unit flow.

- Develops matrix of turbine types by referencing multiple sources (ESHA 2004; ASME-HPTC 1996; etc.).

- Matrix turbine flow ranges from 0.7 cfs to 2500 cfs, and head ranges from 6.6 ft to 3000 ft.

Turbine Type Selection Matrix

Head (m / ft)		Flow (cms / cfs)																											
		0.02	0.28	0.42	0.57	0.85	1.13	1.42	1.70	1.98	2.26	2.55	2.83	4.25	5.66	7.08	8.49	11.32	14.16	16.99	19.82	22.65	28.31	33.97	39.63	45.30	50.96	56.62	70.78
		0.7	10	15	20	30	40	50	60	70	80	90	100	150	200	250	300	400	500	600	700	800	1000	1200	1400	1600	1800	2000	2500
2	6.6	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
3	10	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
6	20	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
9	30	Propeller	Propeller	Propeller	Propeller	Propeller	Propeller	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
12	40	Propeller	Propeller	Propeller	Propeller	Propeller	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
14	45	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
15	50	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
18	60	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
21	70	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
24	80	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
27	90	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
30	100	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
40	130	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
50	165	Pelton	Pelton	Pelton	Cross-Flow	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
61	200	Pelton	Pelton	Pelton	Pelton	Cross-Flow	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
70	230	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Kaplan	Kaplan	Kaplan	Kaplan	Kaplan
91	300	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
122	400	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
152	500	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
183	600	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
213	700	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
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250	820	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
274	900	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
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335	1100	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
351	1150	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis	Francis
396	1300	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis	Francis	Francis
427	1400	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis	Francis
457	1500	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis	Francis	Francis
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518	1700	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis	Francis
549	1800	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Francis
610	2000	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton
762	2500	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton
914	3000	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton	Pelton

Method for Benefit/Economic Evaluation

Three revenue streams considered

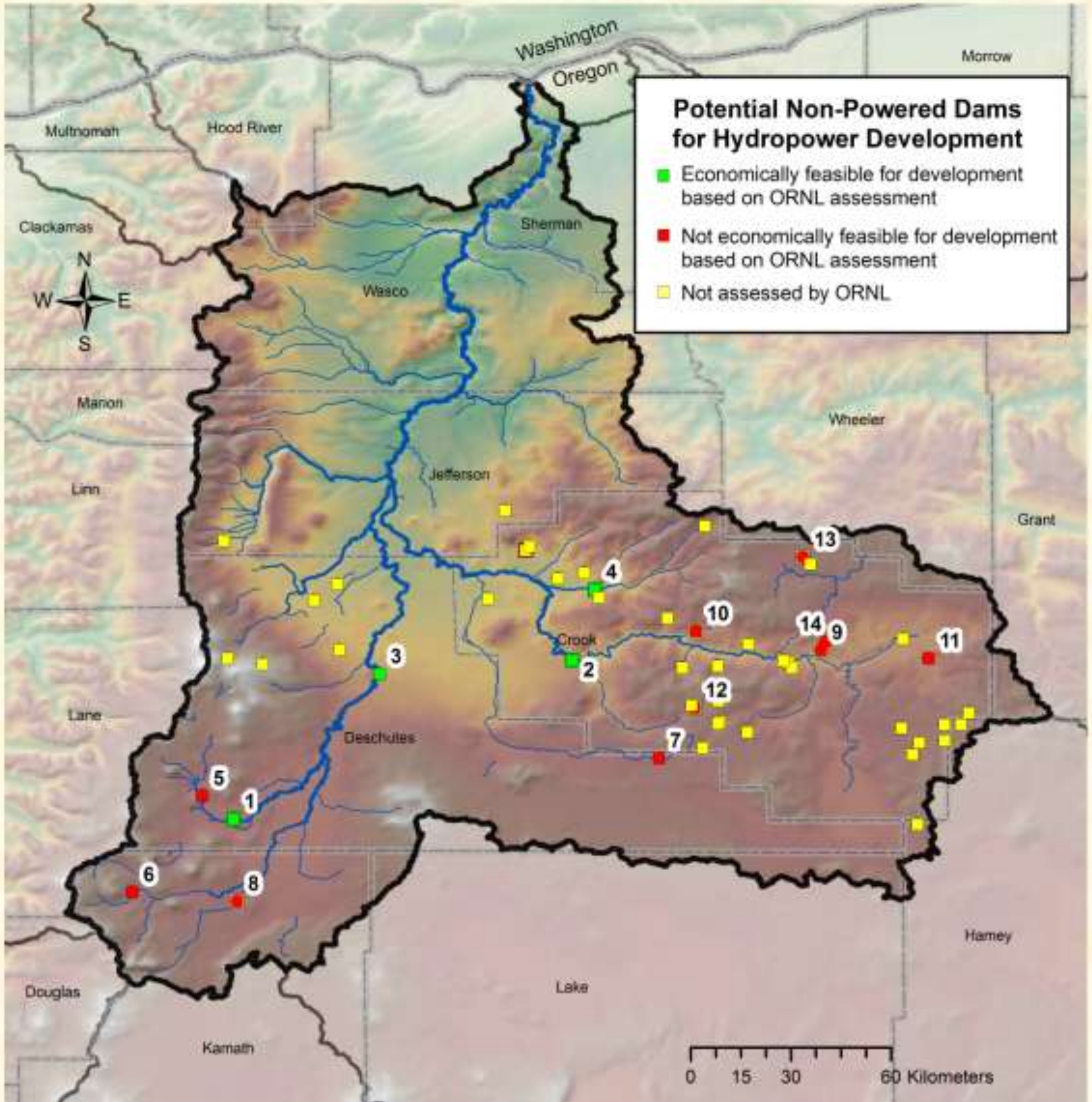
- Energy value: monthly generation data used, so energy value seasonality is taken into account.
- Capacity value: reflects avoided cost by utilities of buying energy through a power purchase agreement rather than producing it.
- Green incentives:
  - Renewable Electricity Production Tax Credit (PTC) or Business Energy Investment Tax Credit (ITC) included.
  - Renewable energy credits (RECs) and REC sales not included (yet).
  - State and local grants not included (yet).

Results: NPDs

- Assessed 14 NPD sites with sufficient historical flow data.
- For Wickiup, Bowman, North Unit Diversion, Crescent Lake, and Crane Prairie, used daily flow data from USGS. For all other NPD sites, used estimated monthly flow data from NHAAP database.
- Used HEEA Tool default input data and assumed 2-year construction period for projects > 3 MW and 1-year period for smaller projects.
- Initial incentive funds, length of new pipeline, and length and voltage of new transmission line from previous assessments.

Results: NPDs

- **Wickiup, Bowman, North Unit Diversion, and Ochoco (ranked by potential capacity) are economically feasible.**
- **Wickiup, Bowman, and North Unit Diversion have BCRs > 1.0 for almost all turbine types and manufacturers considered, even without green incentives.**
- **Total potential power capacity at all 14 NPDs about 17.8 MW, with 70.3 GWh annual energy generation.**
- **Total potential power capacity at four feasible projects about 17.0 MW, with 66.6 GWh annual energy generation .**



Site Name	Design Head (ft)	Design Flow (cfs)	Installed Capacity (kW)	Recommended Turbine Type	Annual Energy Generation (MWh)
Wickup Dam	67.0	1400	7,153	Kaplan	29,010
Bowman	163.9	485	6,036	Francis	19,556
North Unit Diversion Dam	33.0	1390	3,441	Kaplan (Pit or Bulb)	15,097
Ochoco dam	60.0	305.3	387	Francis	2,992
Crane Prairie	18.0	277	358	Kaplan (Pit or Bulb)	1,833
Crescent Lake dam	33.0	82	200	Kaplan (Pit or Bulb)	657
Fehrenbacker #2	14.0	41.6	39	Propeller	289
Gilchrist Log Pond	9.8	56.9	39	Natel	204
Merwin Res. #2	72.0	8.3	39	Cross-Flow	179
Bonnie View Dam	36.0	12.7	33	Propeller	128
Layton #2 Reservoir	18.0	23.6	30	Natel	121
Bear Creek (Crook)	57.0	5.5	20	Cross-Flow	94
Allen Creek	76.0	3.3	16	Cross-Flow	75
Watson Reservoir	30.0	28.7	15	Propeller	59

Results: Canals/Conduits

- Assessed 17 canal/conduit sites with some historical flow data available.
- For 45-Mile Site, used flow data from application for FERC Exemption (EBD Hydro 2010). For other sites, used flow data from previous assessments (Black Rock 2009; ETO 2010; COID and ODE 2011).
- Used HEEA Tool default input data and assumed 1-year construction period.
- Initial incentive funds, length of new pipeline, and length and voltage of new transmission line from previous assessments.

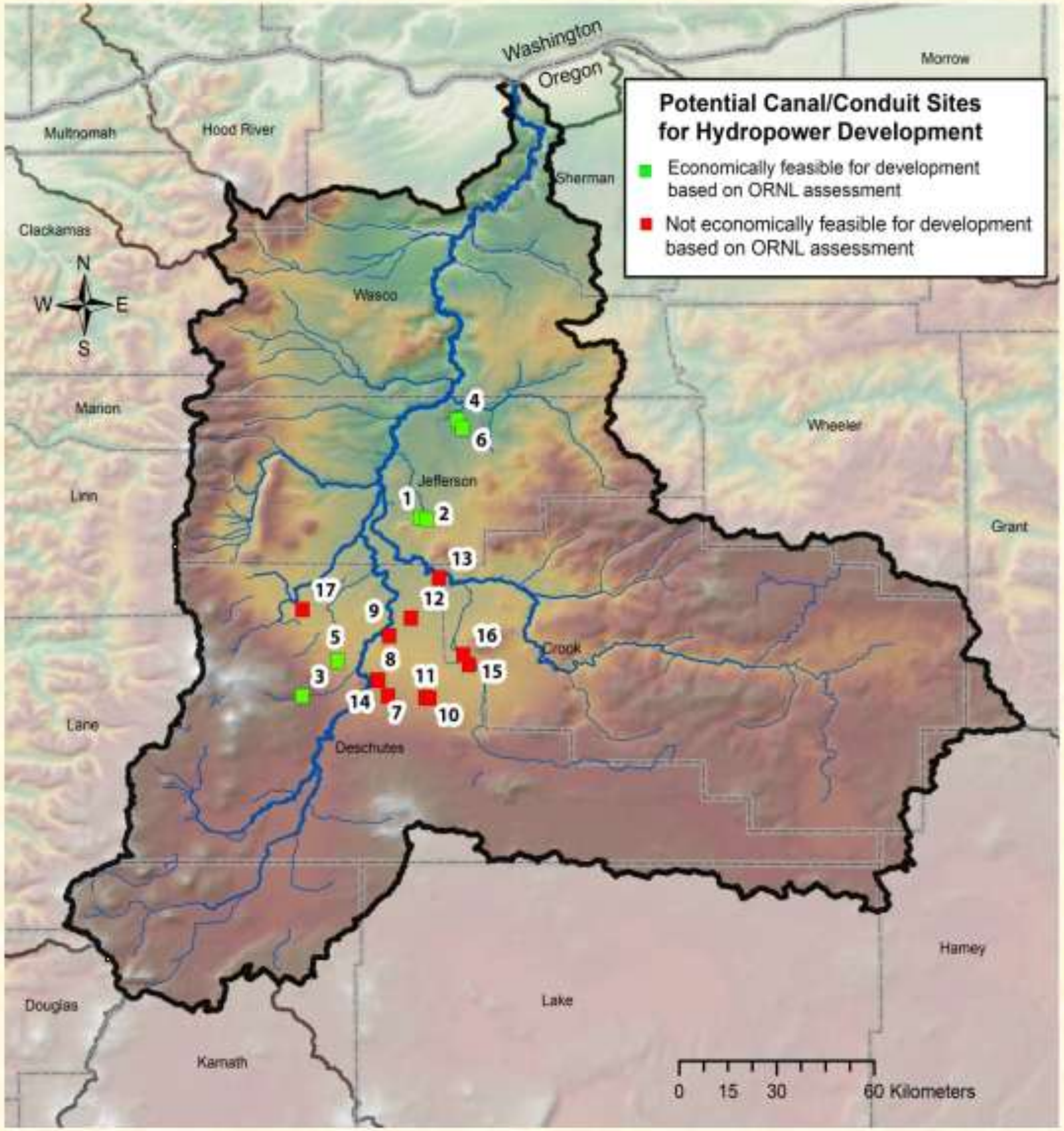
Results: Canals/Conduits

- Six sites (45-Mile, Haystack Reservoir, Columbia South Main, 58-11 Lateral, Columbia South Lateral, and 58-9 lateral) are economically feasible with green incentives.

- Without green incentives, only three (45-Mile, Haystack Reservoir, Columbia South Main) are economically feasible.

- Total potential power capacity at all 17 canal/conduit sites about 14.9 MW, with 67.6 GWh annual energy generation.

- Total potential power capacity at six feasible canal/conduit sites about 7.8 MW, with 36.6 GWh annual energy generation.



Site No.	Site Name	Design Head (ft)	Design Flow (cfs)	Installed Capacity (kW)	Recommended Turbine Type	Annual Energy Generation (MWh)
1	45-Mile	128.0	354.0	3400	Francis	15,428
2	Haystack Reservoir	85.0	270.6	1737	Con. Kaplan	8,079
3	Columbia S.(Main)	1005.0	30.0	2186	Pelton	10,765
4	58-11 Lateral	240.0	7.8	140	Pelton	560
5	Columbia S.(Lateral)	68.0	65.0	287	Cross-Flow	1,445
6	58-9 Lateral	150.2	6.8	76	Pelton	305
7	NC-2 Fall	17.0	407.7	484	Natel	1,880
8	Brinson Blvd.	30.5	444.9	1015	Propeller (Pit)	4,004
9	young Ave.	16.0	311.9	348	Natel	1,319
10	10-Barr Road	23.0	237.0	399	Kaplan (Pit)	1,672
11	Dodds Road	79.0	245.0	1396	Francis	6,690
12	Yew Ave.	42.0	164.0	516	Kaplan (S-type)	2,174
13	Smith Rock Drop	16.0	390.2	436	Natel	1,739
14	Ward Road	25.0	330.0	609	Propeller (Pit)	3,070
15	Shumway Road	79.0	150.0	850	Francis	4,071
16	Brasada Siphon	81.0	147.9	861	Francis	3,461
17	McKenzie Reservoir	96.0	30.0	187	Cross-Flow	942

Conclusions

- **Used ORNL HEEA Tool (Version 1.0) to evaluate power/energy potential and financial feasibility of adding hydropower generation to existing NPDs and irrigation canals/conduits with sufficient hydrologic data.**

- **Potential generation capacity across 14 NPD and 17 canal sites evaluated about 33 MW.**

- **With estimated lifecycle benefits/costs, only four NPD sites and six canal/conduit sites appear economically feasible.**

- **These 10 feasible projects could add about 25 MW of capacity, generate over 103 GWh of renewable energy each year, and avoid GHG emissions of 38,500 tonne of CO_2 equivalent each year.**

Conclusions

- ORNL HEEA Tool can be incorporated into Deschutes Basin-Scale Water Management Model.
- In March: more detailed written report on assessment methodology and results for Deschutes Basin.
- After March: more detailed documentation on ORNL HEEA Tool, including availability for use in assessing other sites and basins in United States.

Thank you!

A General
River and Reservoir
Modeling Tool

Developed at the University of Colorado Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES)
1993 to present through collaborative research and development with

Tennessee Valley Authority
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

Uses of RiverWare

- Planning, reliability assessment and decision-making for
    - New infrastructure development or new demands
    - policy development and evaluation
    - EIS, FERC
    - climate change
    - Compact or treaty negotiations

- Scheduling of Operations
  (reservoir releases, diversions, transfers, hydropower optimal generation)

- Water accounting, priority water rights allocation

- Facilitate stakeholder participation and collaborative decision-making

RiverWare's Inputs and Outputs

Hydrology

Forecast

OR

Historic Record

OR

Stochastic Ensemble

OR

Rainfall – Runoff Model

Demands for Water and Energy

Operating Objectives and Constraints (policies)

IN

RiverWare

Models interaction of

Hydrologic response of River /Reservoir system (includes Hydropower)

With

Multi-objective operating policies

OUT

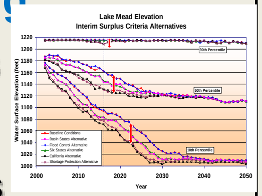
Values of Decision Variables

Values of Performance Indicators

Schedule for Operations (releases, diversions, power)

Water accounting data

Post-Processing



Statistical Analysis

Policy Analysis

Economic Analysis

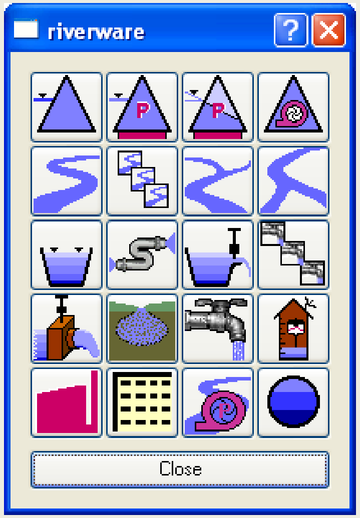
Environmental analysis

Tradeoff Analysis

Multi-criteria Decision analysis

RiverWare models….

- Reservoir and river flows, storages, gains and losses
- Reservoir releases, regulated and unregulated spill
- Hydropower / pumped storage generation and optimization
- Inline pumping and power plants
- Stream gages and control points for flood control regulation
- Diversions, consumptive use, distribution canals, return flows
- Groundwater – surface water interaction
- Water quality
- Water accounting and water rights
- Operating rules of any structure/complexity
- Timestep sizes: 1hr to 1yr (including daily, monthly)



Multiple objective modeling

River systems are operated for a variety of objectives

RiverWare's Solvers

1. Simulation

   Data-driven; input-output; what-if scenarios

2. Rulebased Simulation

   Solution driven by prioritized objectives (rules)

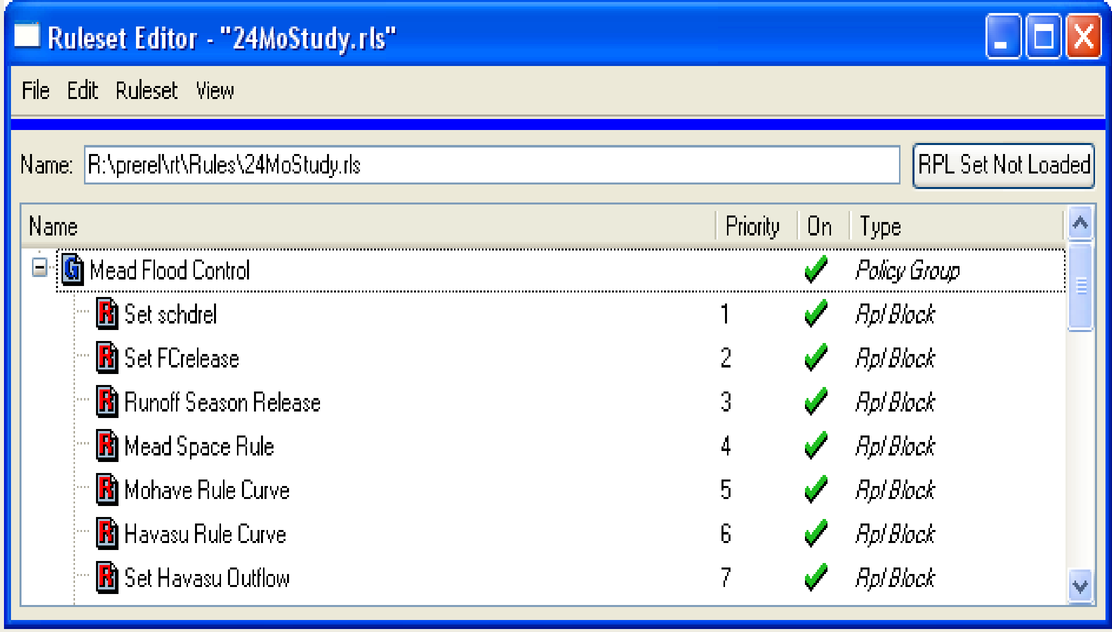
3. Optimization

   Pre-emptive linear goal programming solution; objectives and constraints are prioritized

4. Water Accounting (with or without rules)

   Models ownership, water type and water rights; can be coupled with rules

Rulebased Simulation



Simulation is under-determined

Operating policies are prioritized rules

IF (state of system)

THEN (set value of decision variables)

Rules execute to set values that drive solution

Decision variables are reservoir releases, storage level, hydro generation, diversions, etc.

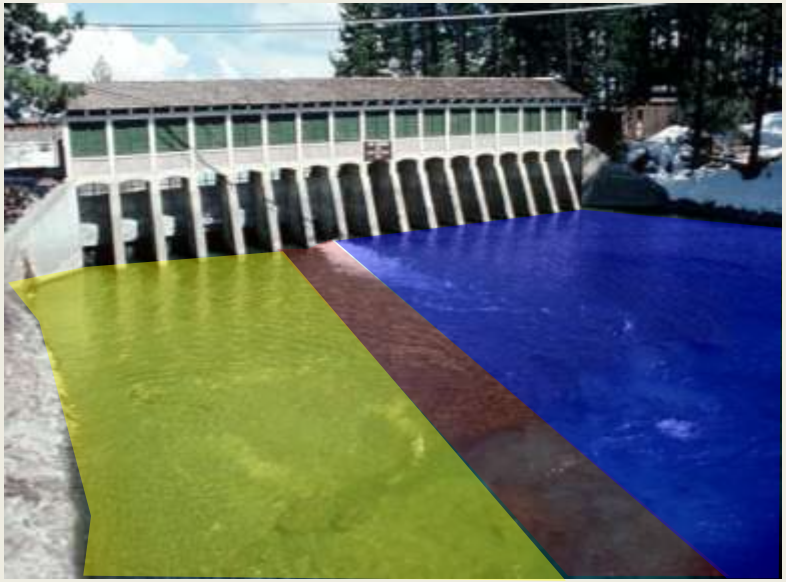
Water Ownership, Water Accounting, Water Rights

- “Paper” Accounting
- Storage, Instream Flow, Diversion Rights
- Classify Accts by Priority Date, Owner, Type
- Exchanges, Loans, Rents, Carryover, Accrual
- Drive the solution using (can be mixed):
  - User Inputs – Spreadsheet like solution
  - Mix with Rulebased Simulation
  - Prioritized Water Rights Allocation

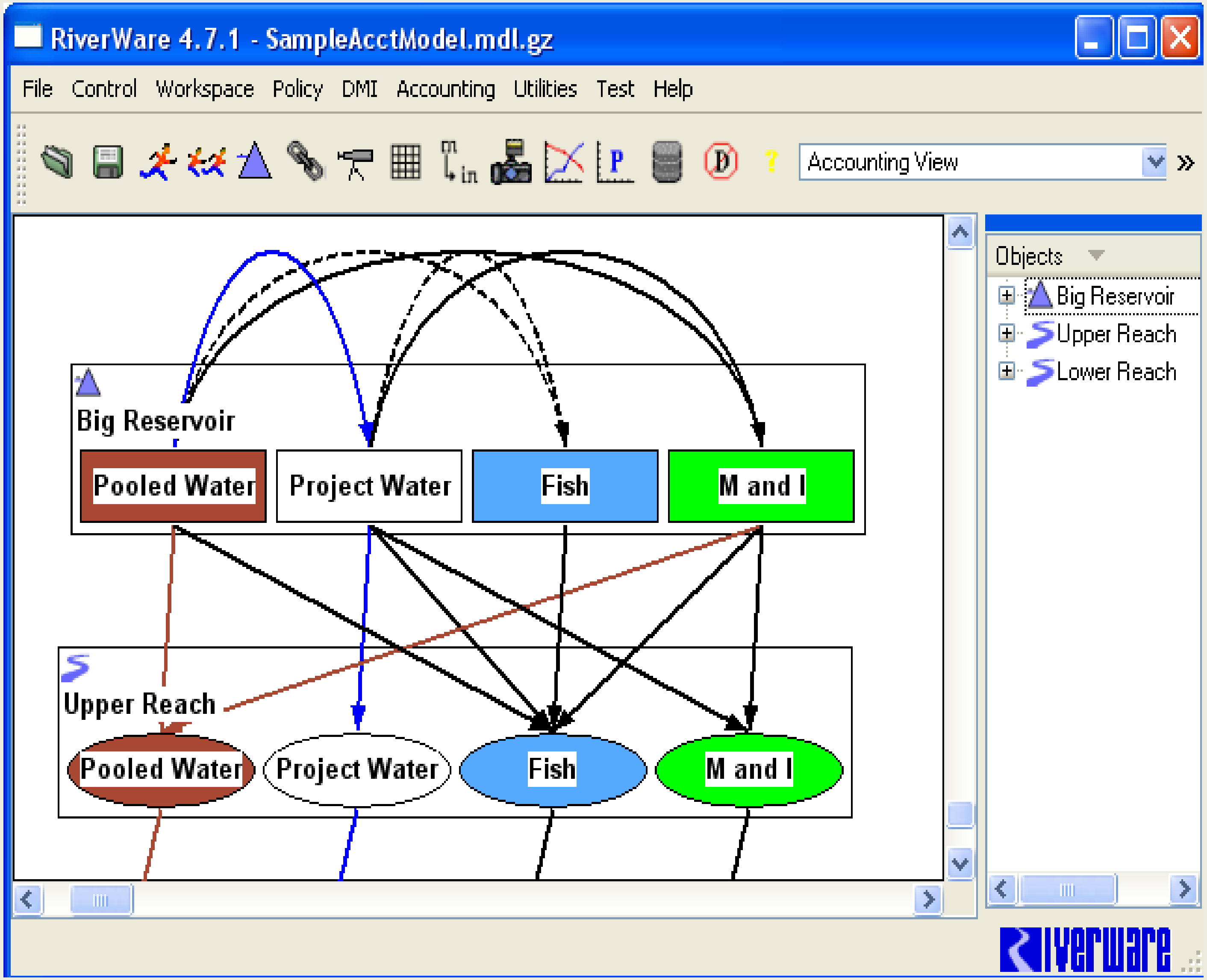
“Physical” vs. “Paper” water modeled in RiverWare

Paper Water - type and ownership (“color”):

Volume/flow of water classified by type or ownership. For example, a certain agency owns 5,000AF of 12,000AF of physical water in the reservoir.



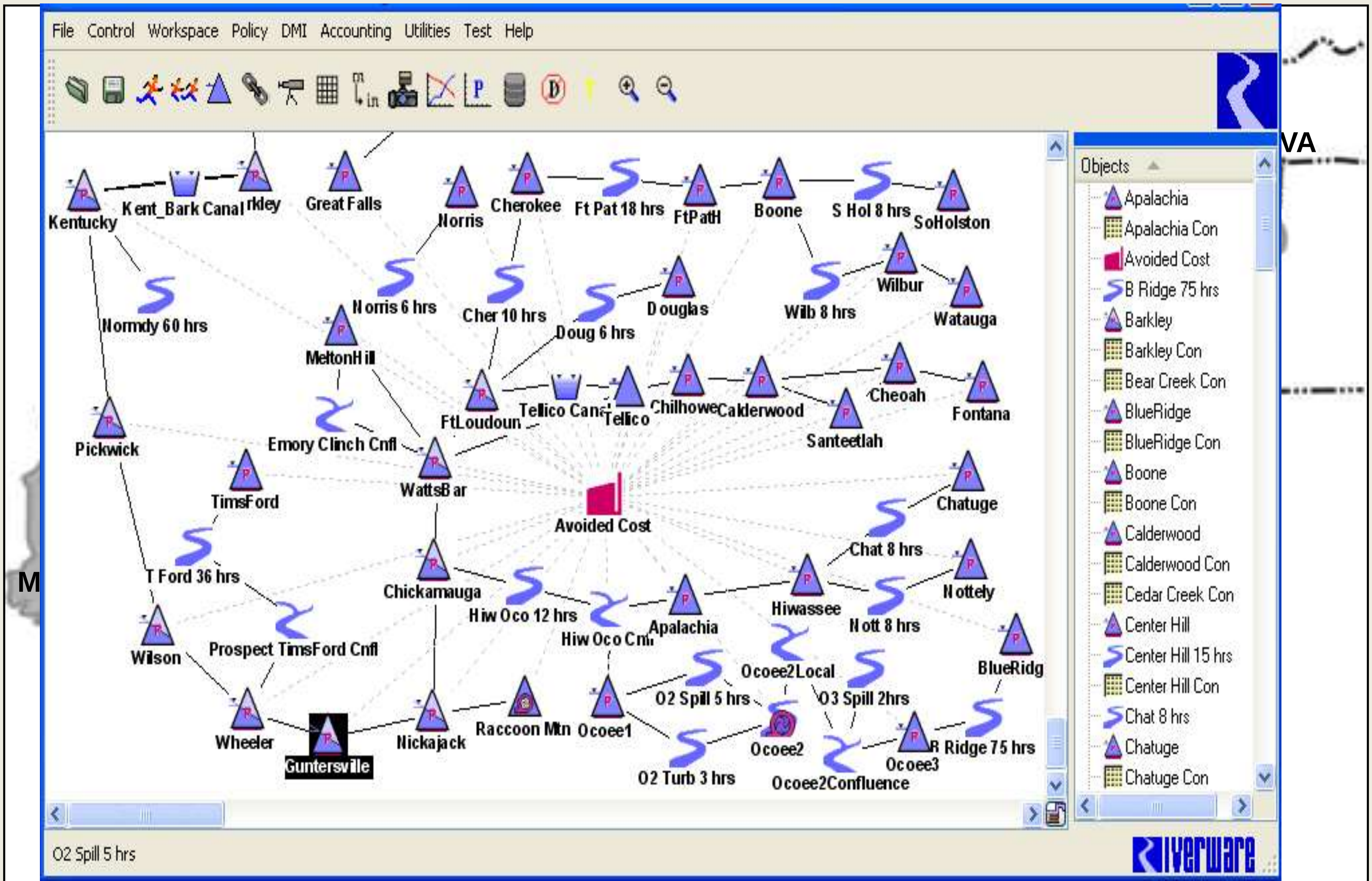
View Account Network on Objects



Optimization

- Pre-Emptive Goal Programming
  - Multi-objectives without user-defined penalties
  - Policies (Goals) are Prioritized
  - Soft Constraints - Minimize infeasibilty
  - Economic (hydropower) objective
  - Linear or Mixed-Integer Programming
- Goals/constraints formulated in RPL Editor
- Variables automatically linearized
  - User controls approximation
- Physical constraints generated by objects as needed
- CPLEX solver
  - Can "tune" parameters
- Post-optimization Simulation

TVA's reservoir system is modeled as a whole for hydropower optimization



Multiple Run Management

- Stochastic Input
- Stochastic Output
- Evaluate using GPAT (Graphical Policy Analysis Tool)
- Modes:
  - Concurrent
  - Consecutive
  - Iterative
- Distribute runs to many machines or processors

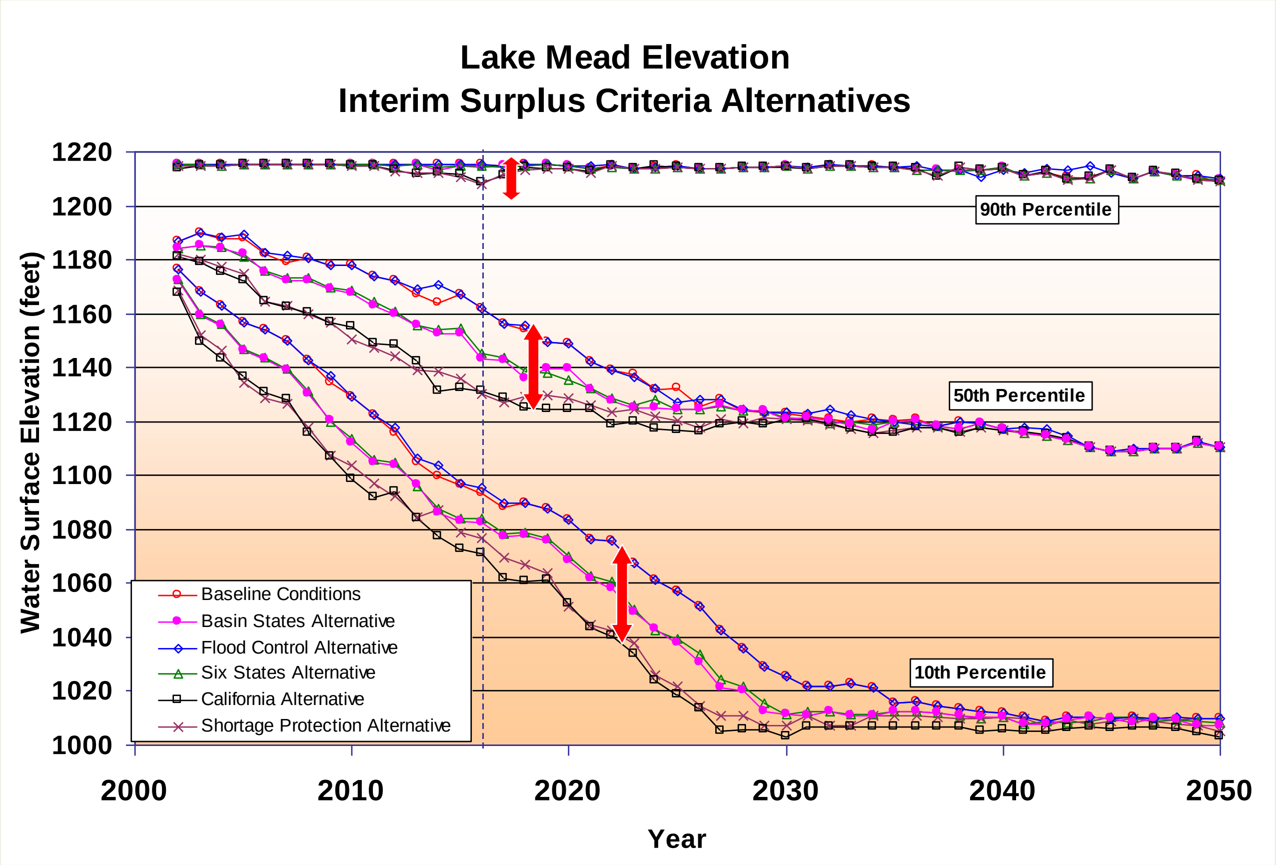
Graphical Policy Analysis Tool (GPAT)

Excel-based Tool for statistical analysis of ensemble output to compare:

- Probabalistic results
- Decision Variables and Performance Indicators

  e.g., storage, P.E., power, flow, risk of shortage

- Compare policies
- See trends over time



U.S. Bureau of Reclamation

Shortage Negotiations and Environmental Impact Studies for Endangered Species on Colorado River

CRSS – Colorado River Simulation System is primary modeling tool for planning operations and evaluating policy

Lake Powell – June 29, 2002

Lake Powell – December 23, 2003

Water Quality

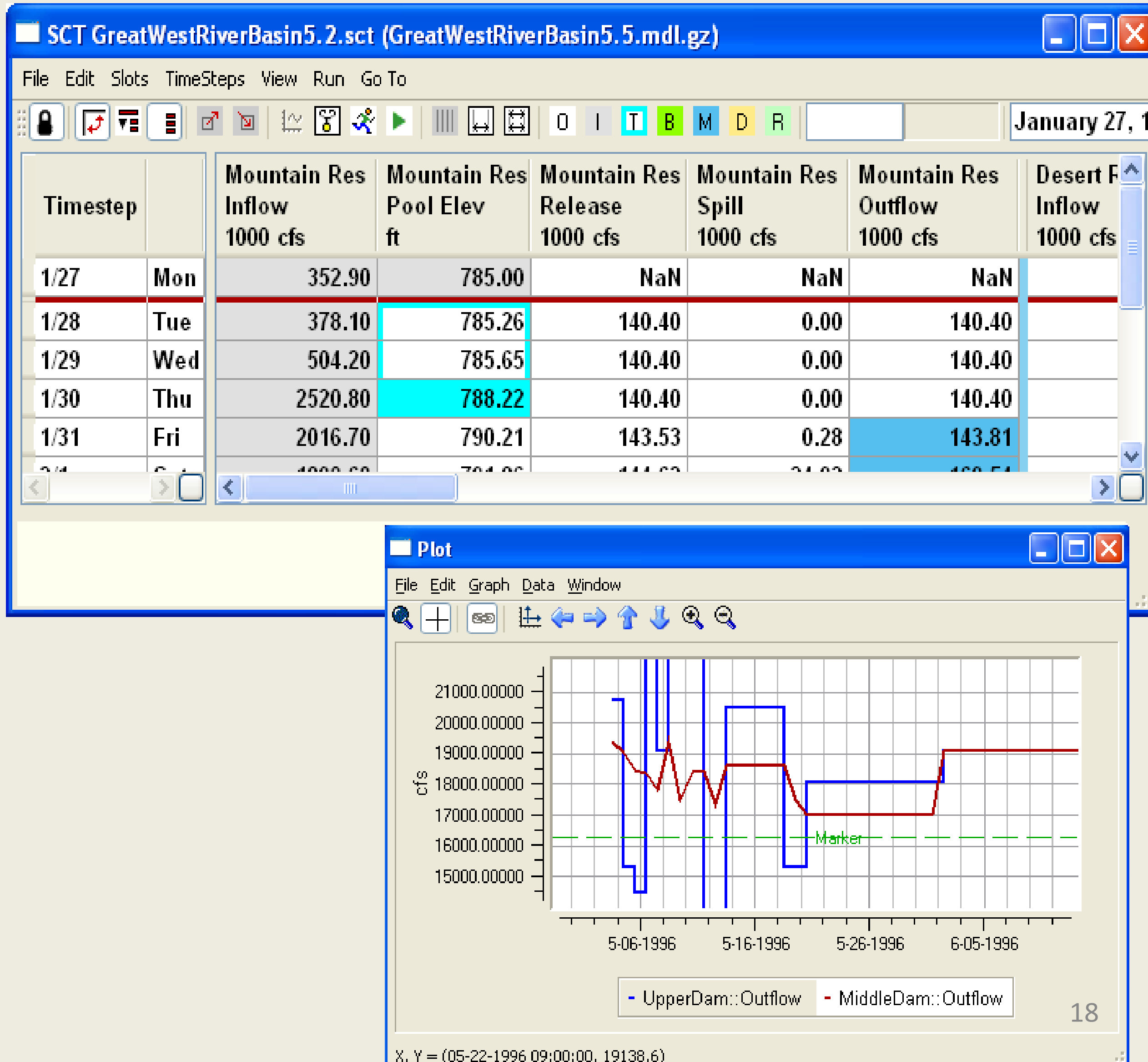

- Simple well-mixed Total Dissolved Solids (TDS)
- Dissolved Oxygen (DO), Temperature, TDS
    - 2-layer reservoir
    - coupled Reach Routing with Advection, Diffusion
- 2-Layer Groundwater modeling for TDS

Data Management Interface

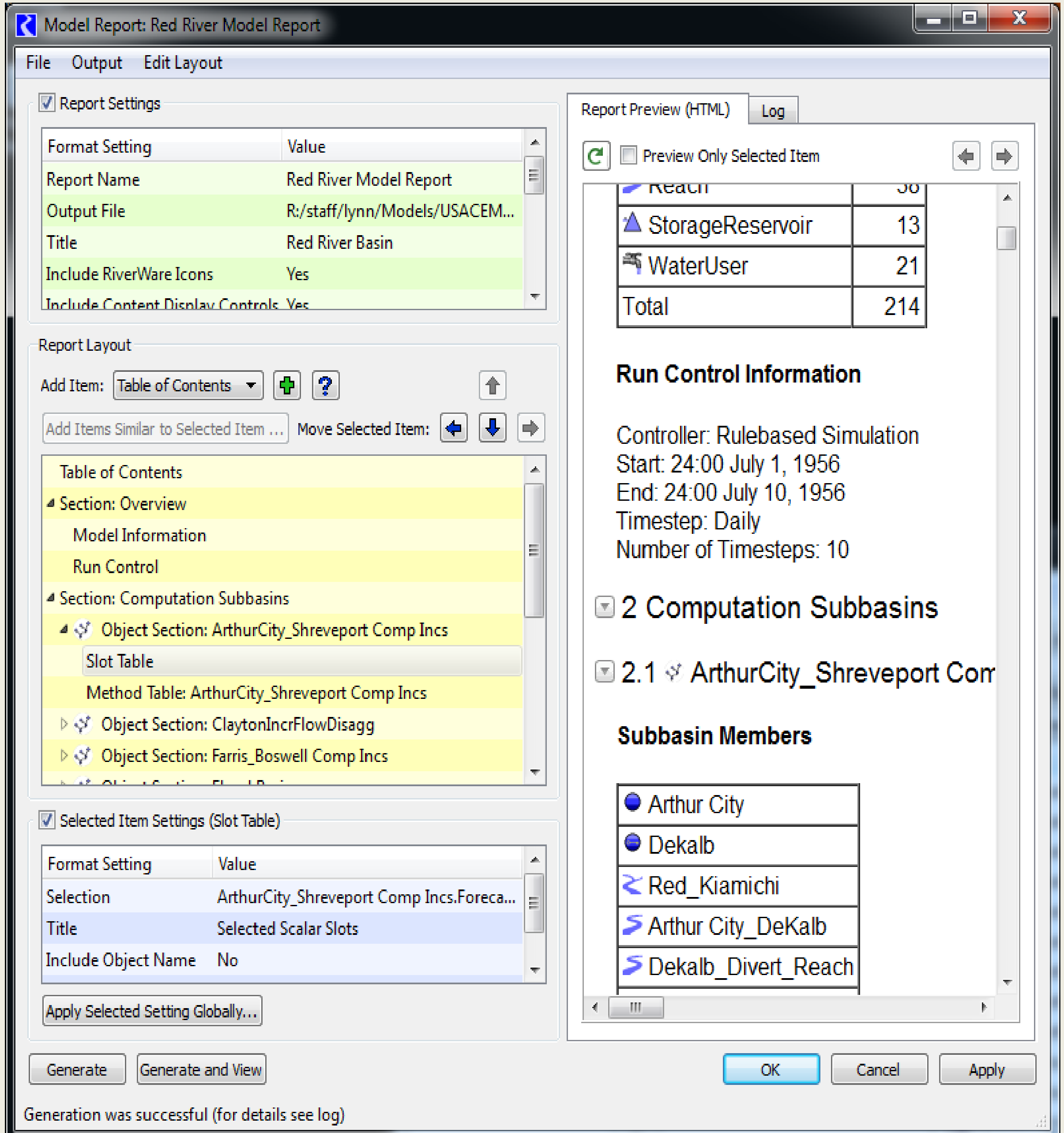
- Import or export data from/to any external source (files, databases, spreadsheets, Corps of Engineers DSS)
- Create external routines to tailor your applications
- Define the DMI and execute it from within the RiverWare user interface
- Extend or redefine start/stop time of the runs
- Group DMIs together for operational updates

Many other Features

- System Control Table (spreadsheet-like view of data)
- Diagnostics
- Analysis Features
- Output options



Dynamic Report Generation



Who uses RiverWare?

- **Water management agencies**

  Reclamation, Corps of Engineers, States, Cites, Water Districts
- **Federal Agencies and Tribes**

  BIA, USGS, National Park Service, National Forest Service, Fish and Wildlife Service, Intern'tl Boundary Water Commission
- **Water Utilities**

  TVA, Southwest Power, LCRA, Mid-Columbia PUDs, East Bay Municipal Utility District, Idaho Power
- **Consultants**

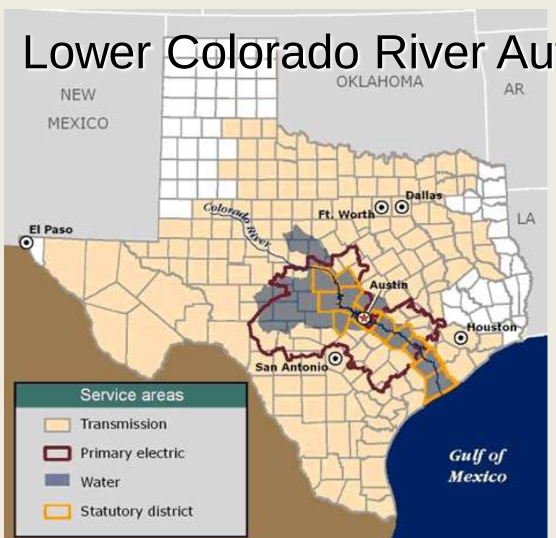
  Hydros, Stetson, Riverside Technologies, CDM, Tetra Tech, HDR, AECOM, …
- **Researchers and NGOs**

  Pacific Northwest and Oakridge National Labs, Universities, NGOs …
- **International Governments, Researchers, Consultants….**

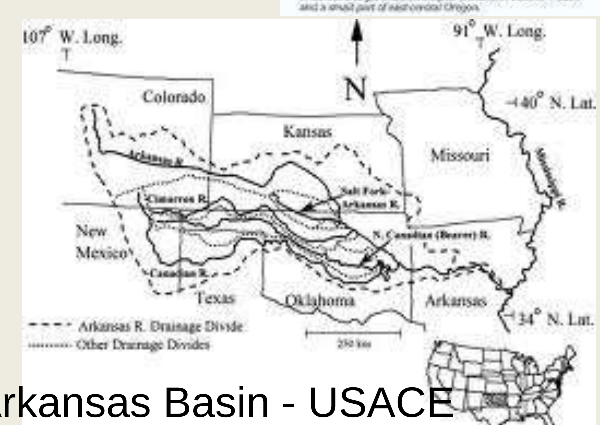
Example Applications

Snake River Basin

The Upper Rio Grande Water Operations Model



Lower Colorado River Authority Texas



Arkansas Basin - USACE

Truckee-Carson

RiverWare – a licensed software product

- Licensing
  - Available through the University of Colorado Office of Technology Transfer
  - License fees contribute to software maintenance
  - RiverWare VIEWER is free – can view models and results
- Developed with a team of professional software developers using standard development processes
- Source control; version control; issue tracking
- Training & User Support
- Continued Enhancements via contracts and grants from sponsoring agencies

Thank you

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Environmental Opportunity Assessment

Basin Scale Opportunity Assessment Workshop
Bend, OR
February 1, 2013

Jerry Tagestad & Kyle Larson

Goals

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- **Identify environmental opportunities within the context of other water uses and increasing hydropower**

- What it is an environmental opportunity?
  - Opportunity to improve river, riparian, or floodplain conditions
  - Primarily focused on management of the hydrologic regime

- DWA objective to “move stream flows toward a more natural hydrograph while securing and maintaining improved instream flow and water quality to support fish and wildlife” [1]

[1] Aylward, B. and D. Newton. 2006. *Long-range Water Resources Management in Central Oregon: Balancing Supply and Demand in the Deschutes Basin*. DWA Final Report.

Hydrology & Environment

- **Ecology of riverine environment is inextricably linked to the hydrologic regime**

- Direct effects → temperature, turbidity, erosion, transport, geomorphic complexity, connectivity, groundwater, etc.

- Indirect effects → water quality, habitat quality, bank stability, riparian condition, fish survival & reproduction, aquatic biodiversity, environmental cues

- Socioeconomic, cultural, and aesthetic implications

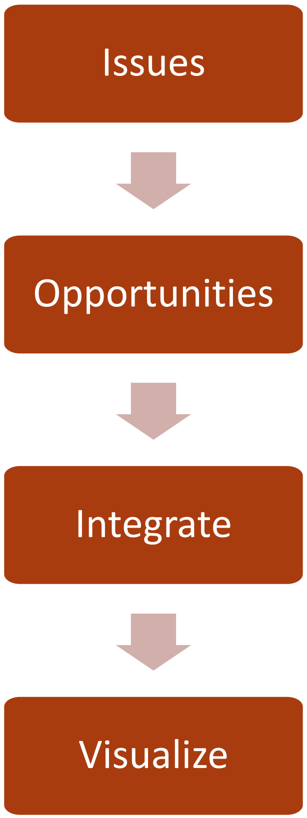
Opportunity Assessment Process

1. Identify important environmental issues in the basin

2. Identify opportunities to help address environmental issues

3. Integrate hydropower and environmental opportunities in a scenario-based modeling framework

4. Visualize scenario modeling results to explore tradeoffs amongst different interests



Deschutes Step 1

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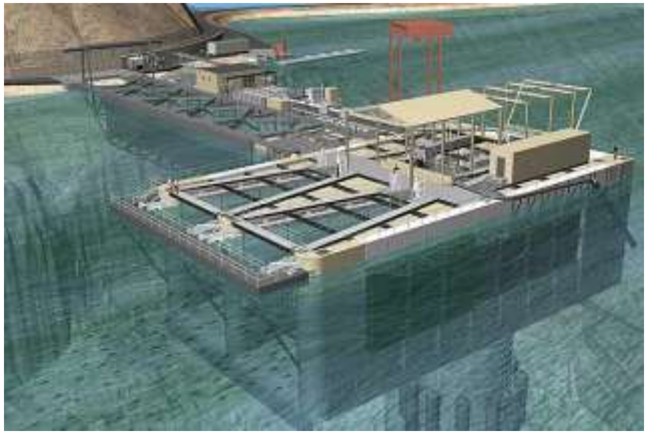
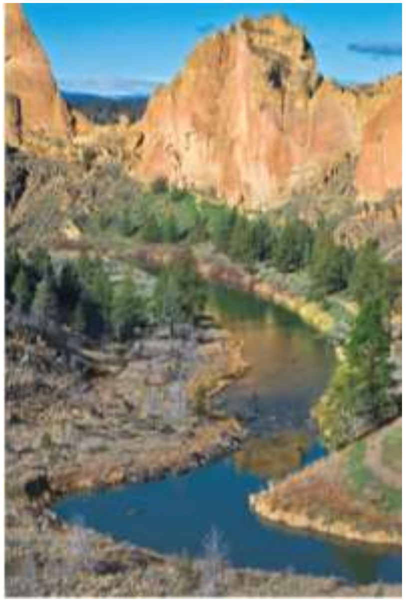
- **Identify important environmental issues in the basin**
  - Water quality, instream habitat, fish passage, natural storage, floodplain, protection status, etc.
- High-level scoping fed by stakeholder engagement and review of existing assessments
- Focus on reach-specific opportunities related to changes in hydrologic regime
  - Upper and Middle Deschutes River
  - Tumalo and Whychus creeks
  - Lower Crooked River



Source: PGE (www.deschutespassage.com)



Deschutes Step 2

- **Identify reach-specific opportunities to help address environmental issues**
  - Enhance flow (timing, magnitude, duration, conservation)
  - Restoration (riparian health, bank stability, stream complexity)

- Key assessments
  - *Deschutes Subbasin Plan* (NPCC 2004)
  - *Upper Deschutes Subbasin Assessment (UDWC 2003)*
  - *DWA Instream Flow in the Deschutes Basin: Monitoring, Status, and Restoration Needs* (Golden & Aylward 2006)

Deschutes Step 3

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- **Integrate hydropower and environmental opportunities in a scenario-based modeling framework**

> Scenario is a set of opportunities to alter water management to achieve a mix of benefits

- Scoping → simulation process aimed at revealing tradeoffs amongst different interests by incrementally adjusting variable levels
- Scoping variables represent management actions

Deschutes Scoping

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- Increase minimum flow below Wickiup Dam during the non-irrigation season from 25 cfs (baseline) to 350 cfs in ~75 cfs increments
- Simulate water conservation measures by reducing baseline irrigation demand by 10 and 20 percent

Environmental Opportunities

Modify timing and amount of instream flow in upper Deschutes to benefit fish, water quality, and other ecological processes

Model Implementation

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- **Combinations of scoping variables are implemented in a mass-balance river model to simulate different management scenarios**

Demand Reduction Levels

Flow Cases	0%*	10%	20%
25*	25, 0%	25, 10%	25, 20%
100	100, 0%	100, 10%	100, 20%
175	175, 0%	175, 10%	175, 20%
250	250, 0%	250, 10%	250, 20%
350	350, 0%	350, 10%	350, 20%

* Baseline level for scoping variable

Environmental VBMs

- Interest – increase flow in upper Deschutes River during the non-irrigation season
  - Purpose → prevent freezing/thawing of river bank and channel, improve bank stability, riparian condition, and aquatic habitat
  - Target → 300 cfs
  - VBM → Mean off-season (Oct 15 – Apr 15) flow at WICO gage as a percentage of 300 cfs flow target

- Interest – increase flow in middle Deschutes River below Bend during the irrigation season
  - Purpose → mitigate temperature and water quality issues to benefit salmonids and meet ODEQ criteria
  - Target → 250 cfs
  - VBM → percentage of summer (Jun 1 – Aug 31) where flow >250 cfs

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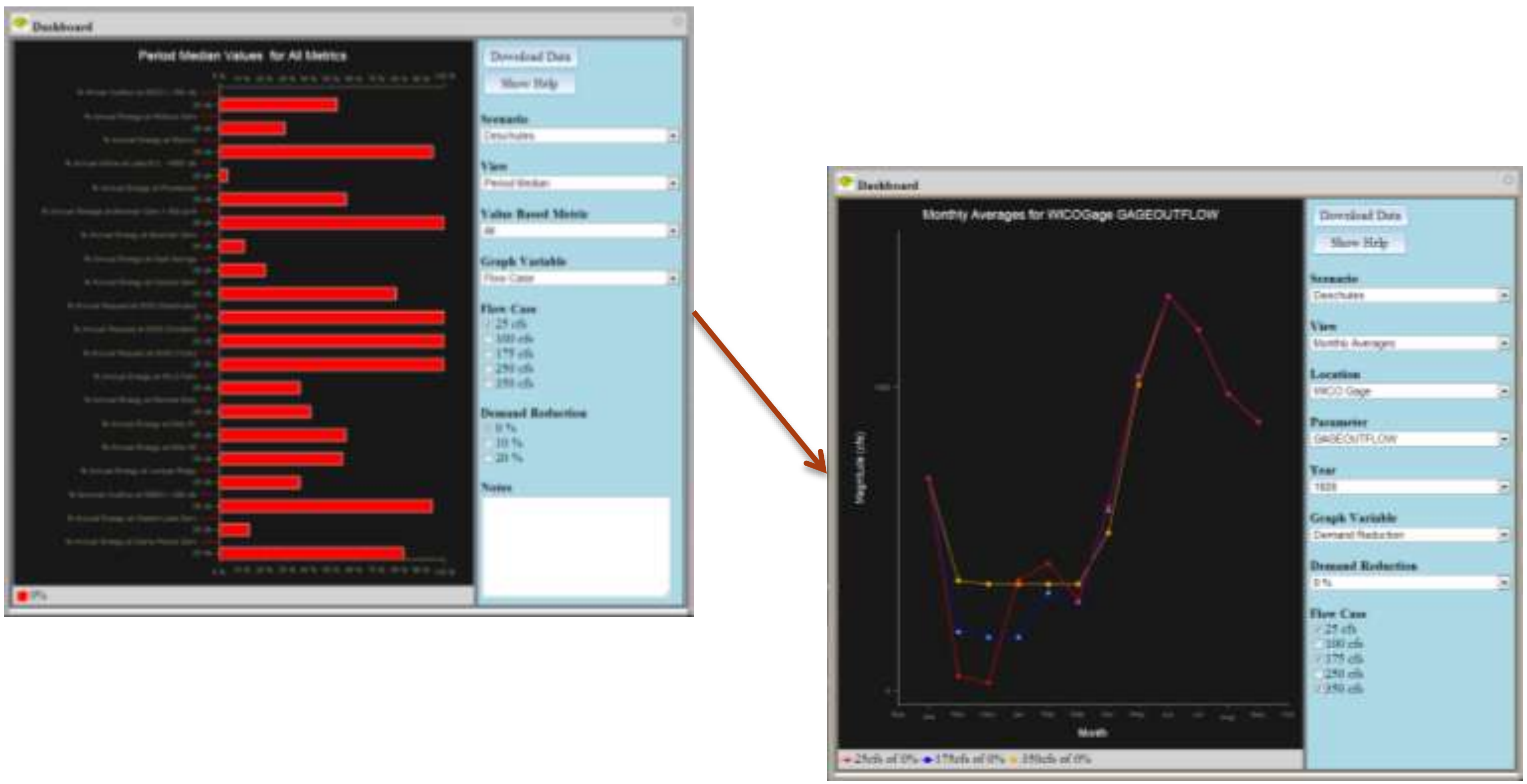
- **Visualize scenario modeling results to explore tradeoffs amongst different interests**



Future Considerations

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- Phase I assessments
  - Develop a conceptual framework for identifying key environmental issues and opportunities in the basin
  - More emphasis on the spatial context and quantification of environmental issues
- Recommendations from the Deschutes experience

Application of Riverware to Deschutes Basin Opportunity Assessment

Sara Niehus, Marshall Richmond and Nathalie Voisin

Pacific Northwest National Laboratory

Hydrology Group, Environmental Directorate

Richland, WA

Pacific Northwest
NATIONAL LABORATORY

Deschutes Case Study Outline

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Project Goal: *Identify opportunities to increase hydropower generation and environmental benefits while avoiding detrimental impacts to other water uses*

- Current Deschutes Basin Models and Data
- Deschutes Modeling Strategy
- Riverware Modeling Steps & Model Status
- Model Validation
- Model Inputs
- Infrastructure and Configuration
- Operations
- Model Outputs
- Model Uncertainties
- Future Projects Activities

Deschutes MODSIM Development - STATUS

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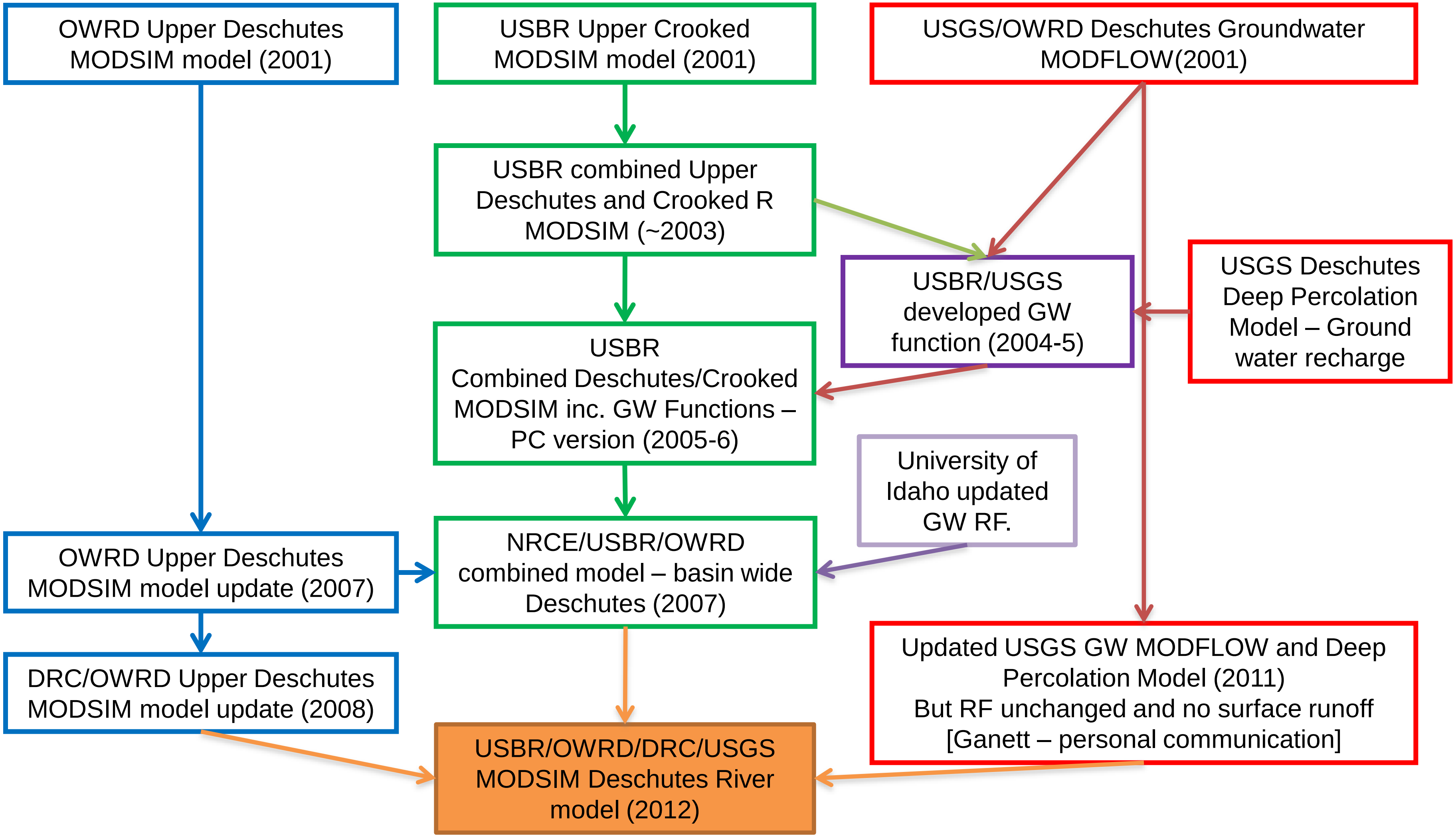
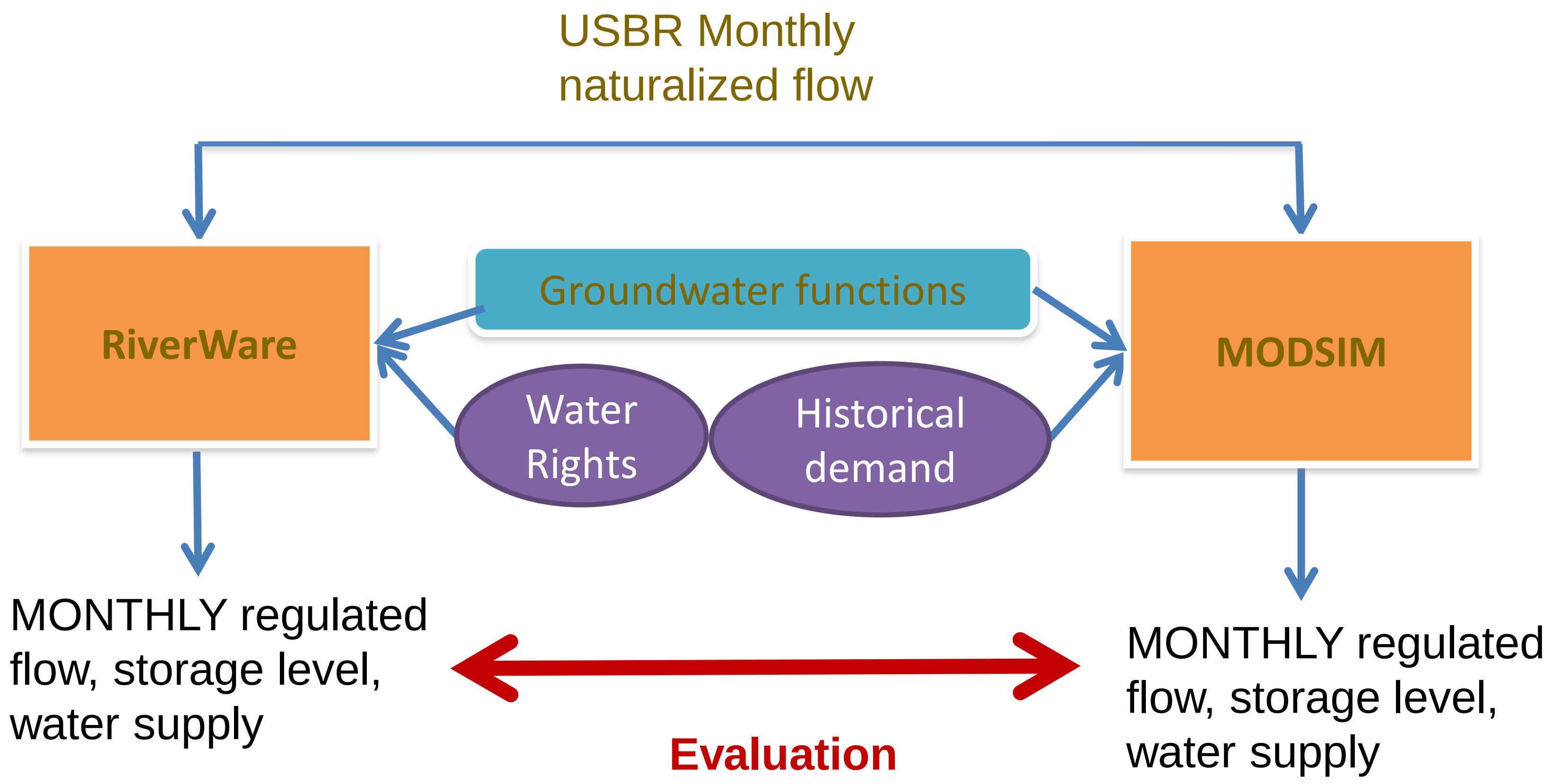


Baseline for BSOA and Monthly RiverWare

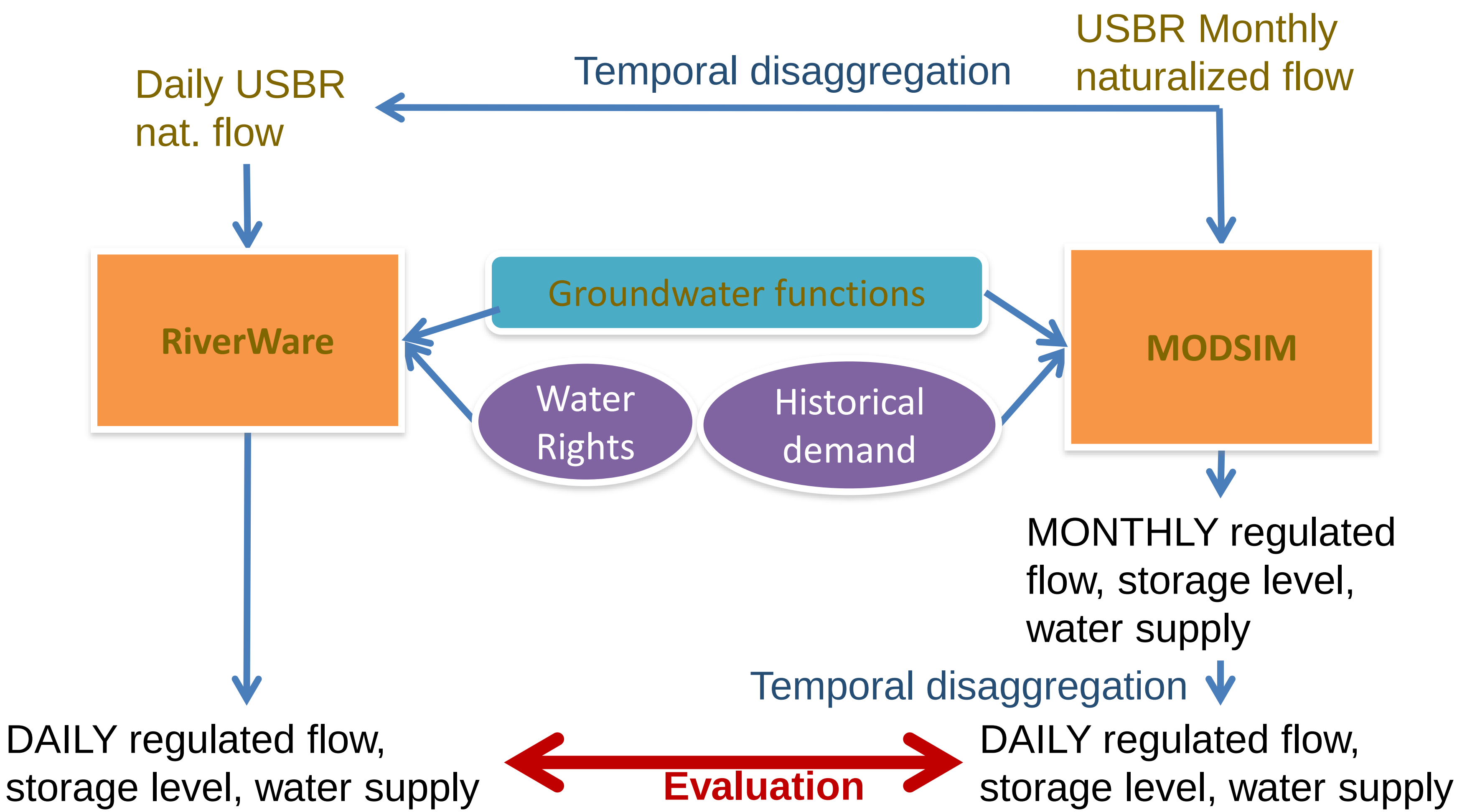
WHY RIVERWARE?

- If we have MODSIM why are we building another model?
- What are the capabilities Riverware offers?
  - Finer temporal scale - daily
    - Environmental Assessment
    - Hydropower
  - Water rights accounting
  - Groundwater interaction
  - Flexible coding for operational rules
  - Data-centered design for model update ease
  - Wide use and recognition

Deschutes Modeling Strategy

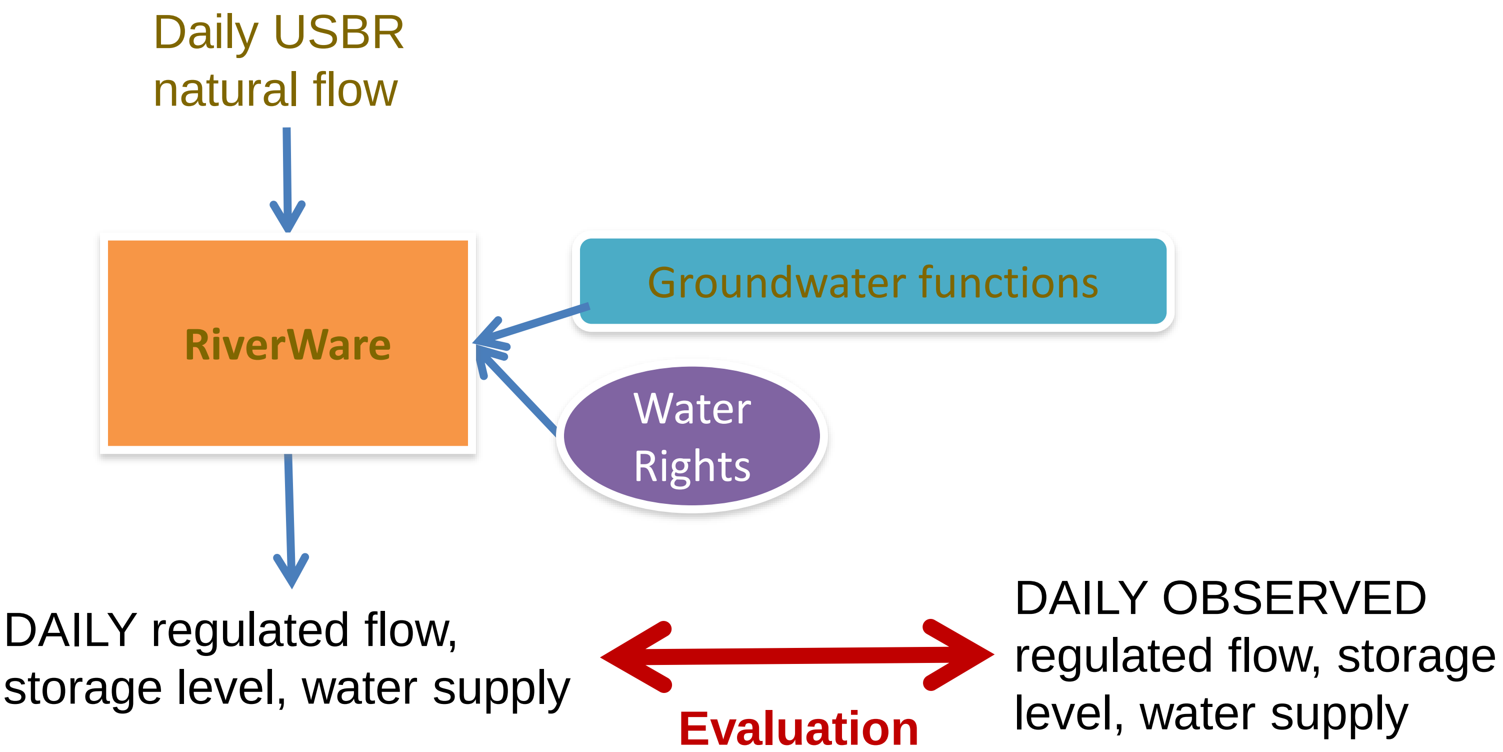


Evaluate the Change in Time Scale



Evaluate the Performance of the Daily Model

Daily time scale with respect to observations



Model Validation Strategy

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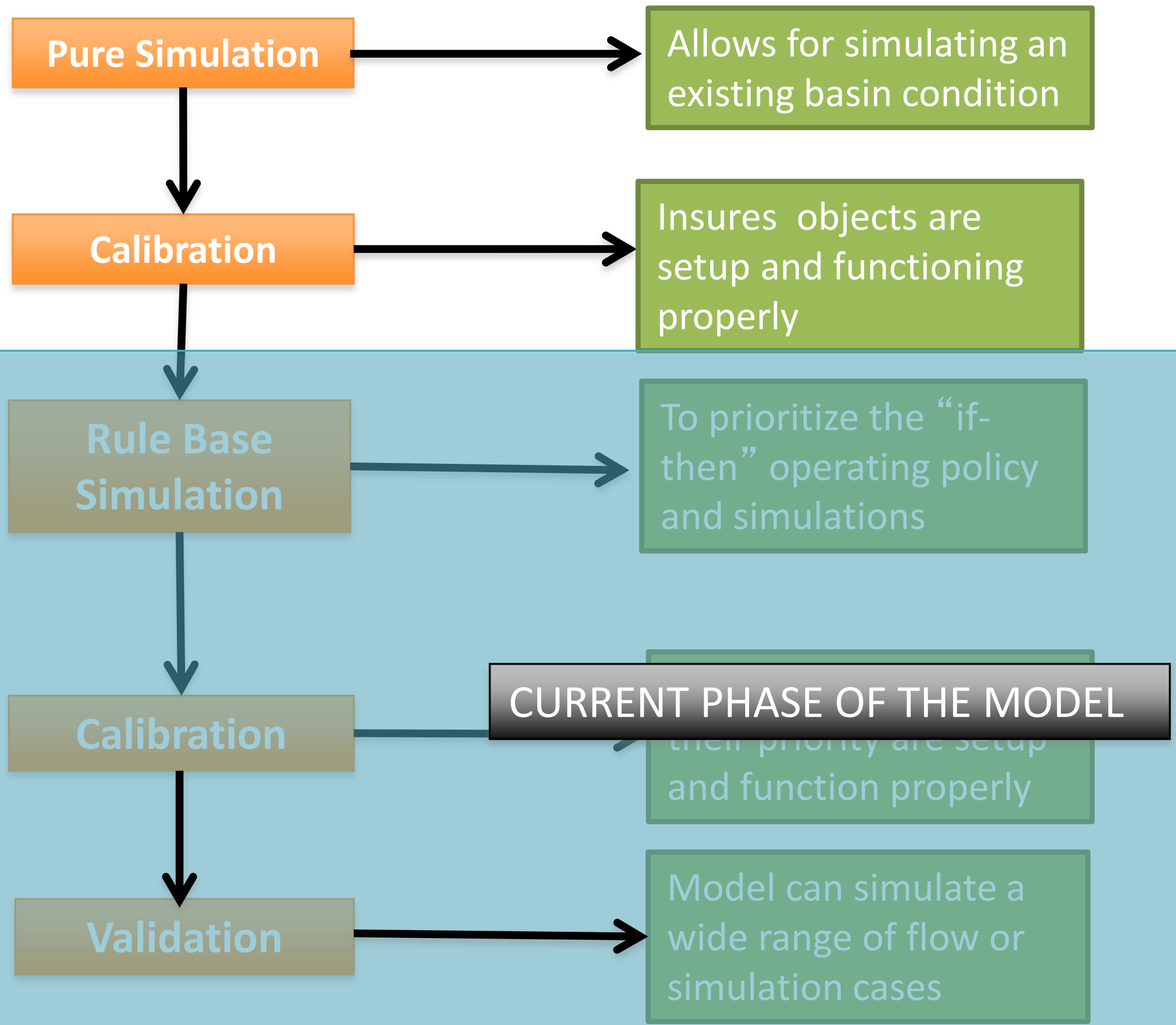
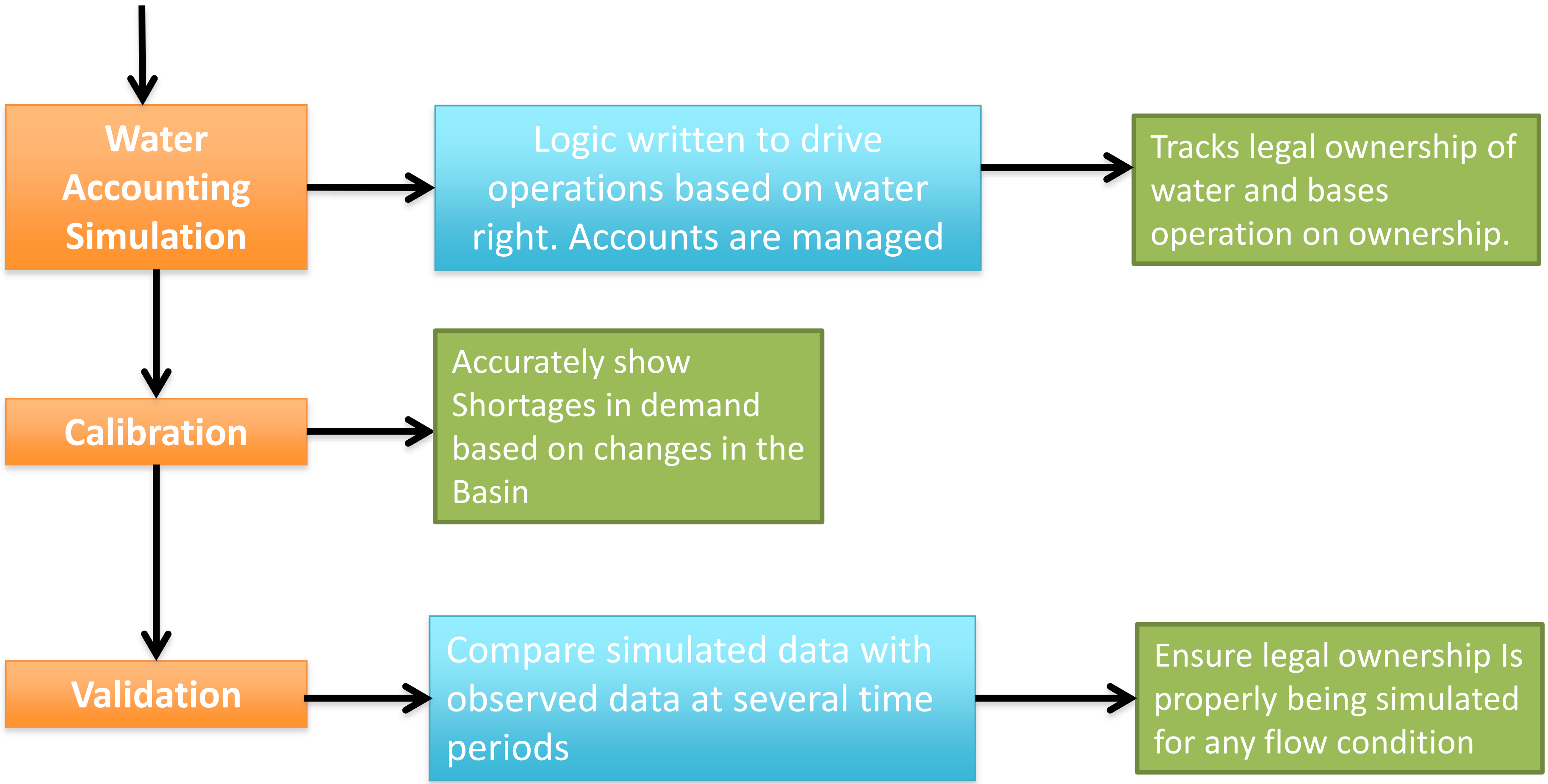
- Evaluate the modeling:
  - Monthly time scale using MODSIM as reference
  - Compare with observed data
- Evaluate the change in time scale on the modeling:
  - Daily time step: evaluate RiverWare using temporally disaggregated MODSIM output
- Evaluate performance of the model:
  - Daily time scale using observational data
- Metrics for validation and evaluation are:
  - Discharge
  - Storage
  - Water supply
  - Monthly/daily mean errors; monthly and daily variability; frequency of daily/monthly events

Riverware Modeling Steps



Riverware Modeling Steps



Model Inputs

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- Hydrology
  - Naturalized monthly inflows developed for MODSIM were input into a daily sequence from 1928 to 2008
  - A disaggregation technique from USBR & UI is currently being evaluated to develop daily inflow
  - Inflow locations include:
    - Inflow to Crane Prairie, Wickiup, Crescent Lake, Bowman, and Ochoco Dams
    - Significant Tributaries: Little Deschutes, Tumalo Creek, Whychus Creek, and Metolius River
    - Sideflow locations: above Benham Falls on Deschutes, and below Opal Springs

Model Infrastructure

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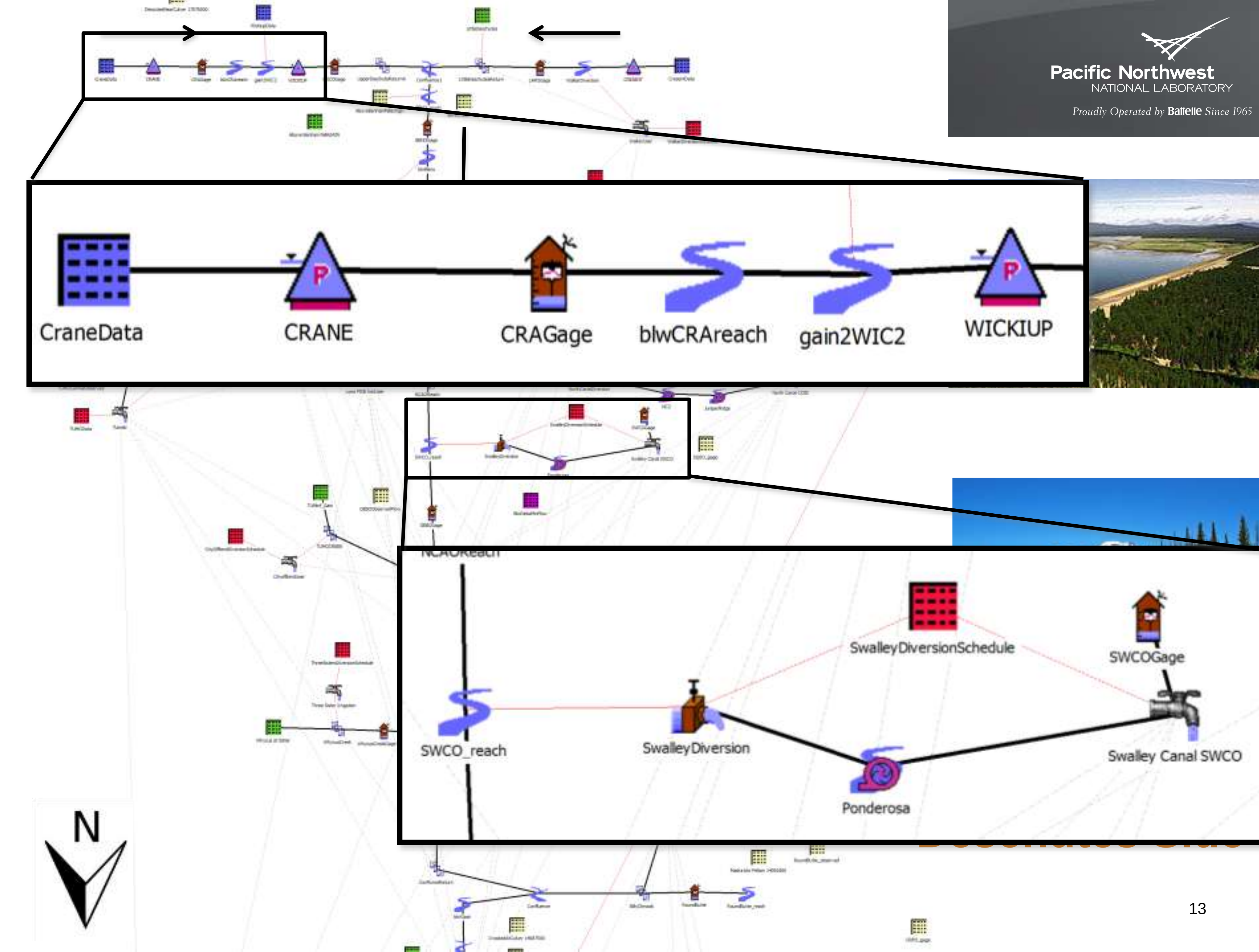
- Groundwater:
  - 50-year lag for return flow and was developed by USBR/USGS with MODFLOW
  - Each irrigation canal has between 3 to 15 return flow locations
  - Groundwater storage was not considered in modeling scope
- Dams:
  - Crane Prairie, Wickiup, Crescent Lake, Bowman, Ochoco
    - All include hydropower capacity
- Diversion/Water Users:
  - 28 diversions from Arnold, Central Oregon, North Unit, Ochoco, Three Sister, Swalley, Lone Pine and Tumalo irrigation districts
- Hydropower:
  - 8 locations: Opal Springs, Siphon, Juniper Ridge, Ponderosa, Monroe Drop, Mile 45, Mile 51, and NC-2
- Pumping Stations:
  - Ochoco Relift and Barnes Butte


Pacific Northwest
NATIONAL LABORATORY
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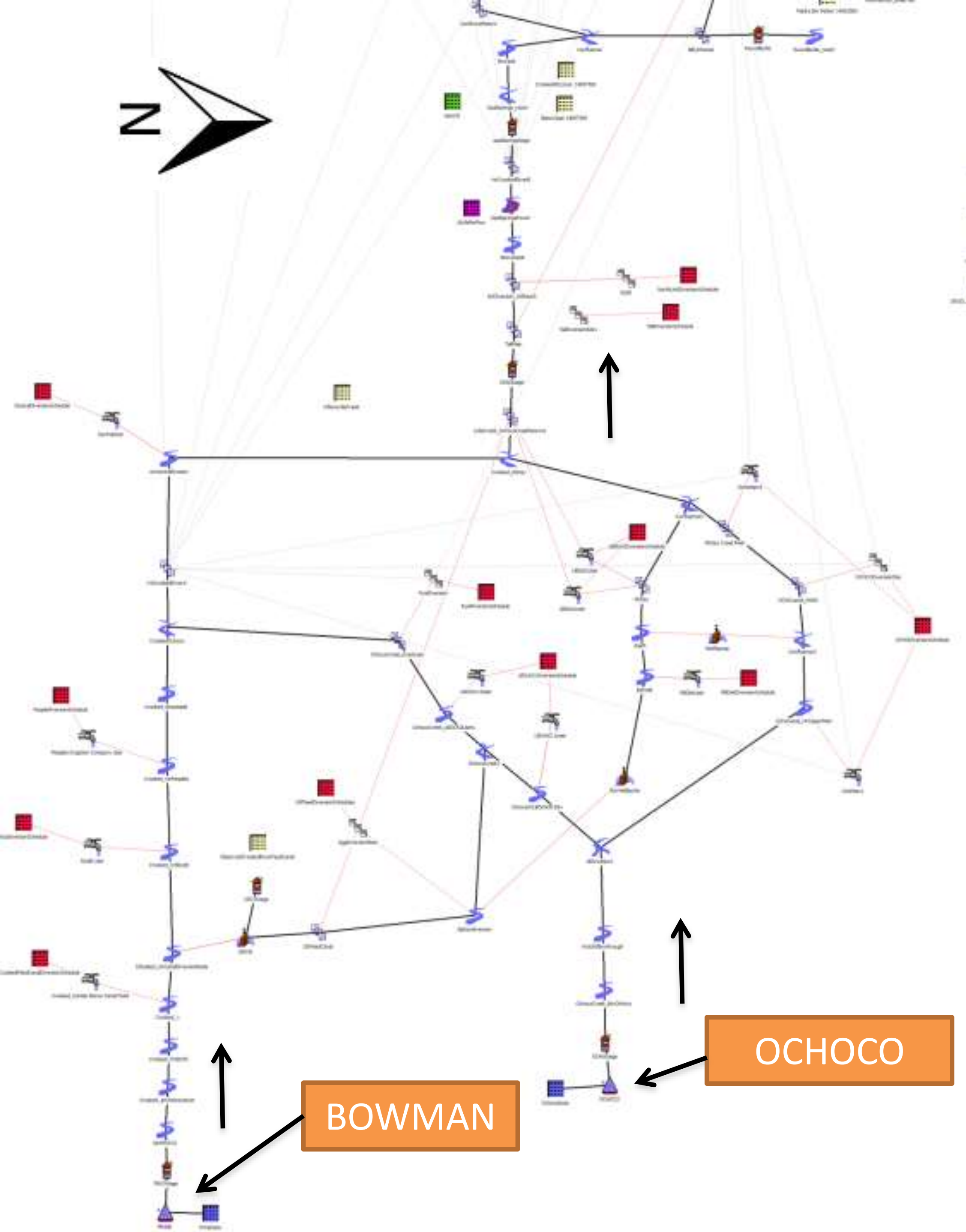
CraneData
CRANE
CRAGage
blwCRAreach
gain2WIC2
WICKIUP
NCAOReach
SWCO_reach
SwalleyDiversion
SwalleyDiversionSchedule
Ponderosa
SWCOGage
Swalley Canal SWCO
N



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Model View: Crooked River

Reservoir Operations

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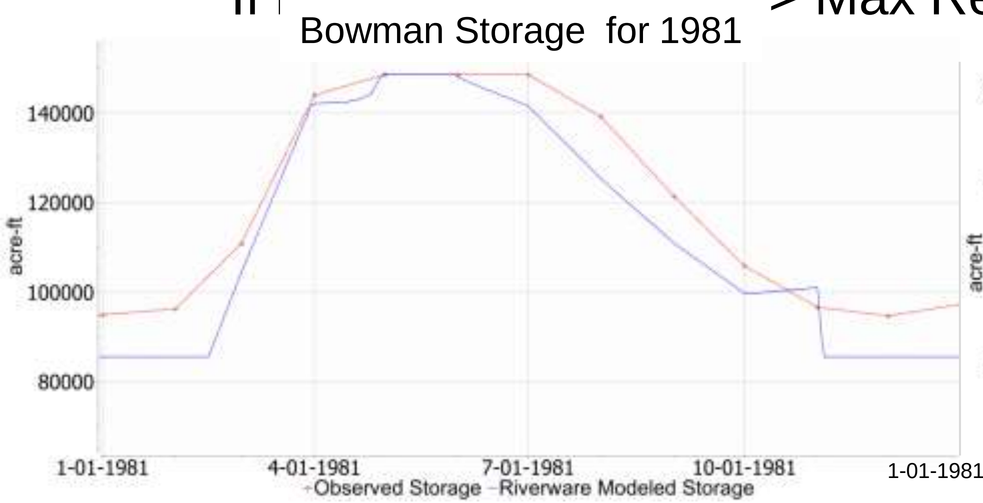
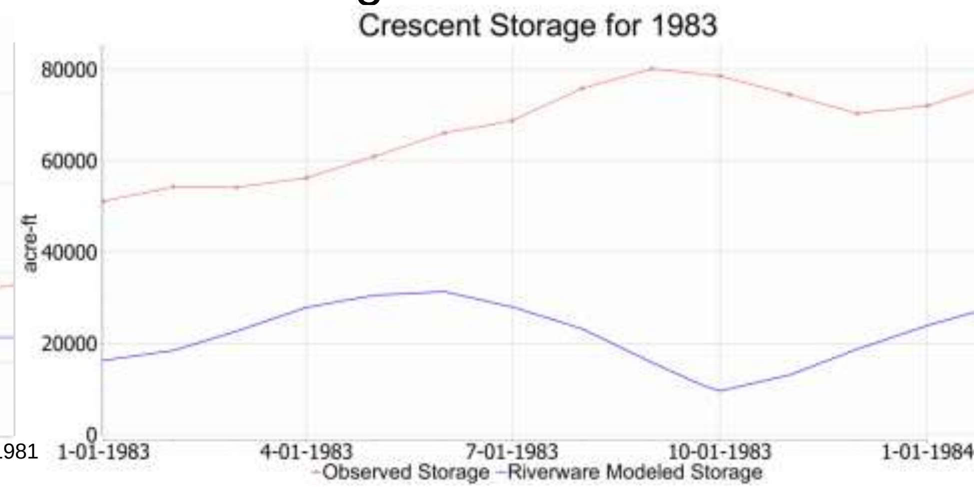
- Operations are driven by rules in most Riverware models

  If Reservoir Storage(t) > Max Reservoir Storage:





- Model accuracy depends on how well you define these operations

Accurate Rules

Insufficient Rules

Current Model Reservoir Operations

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Bowman and Ochoco Dams

- Flood control releases were set by storage criteria from USBR and USACE
- Irrigation release are made during Irrigation season
- Minimum environmental release

Crescent Lake Dam

- Supplemental irrigation releases are made for Tumalo irrigation district
- Minimum environmental flow releases
- Non-irrigation season releases are only made if the reservoir is full and must pass inflow

Current Model Reservoir Operations

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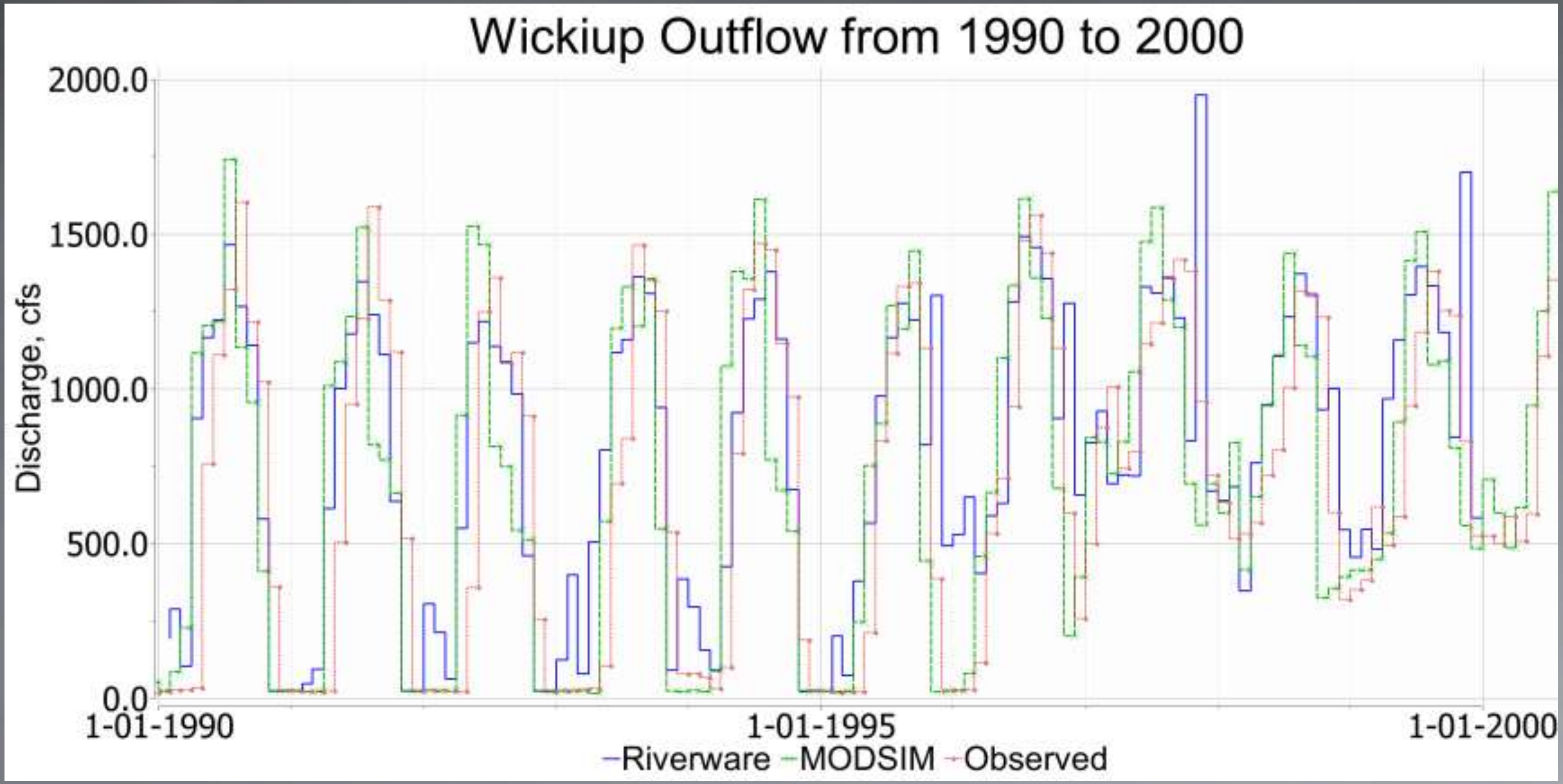
- **Wickiup and Crane Prairie Dams**
  - Operations are in tandem based on the IDA of 1938
  - Crane will only release non-irrigation flows if the reservoir is full and must pass inflow
  - In wet years during non-irrigation season:
    - Crane fills to maximum while releasing minimum required flows due to significant seepage.
    - Wickiup then fills until storage maximum while releasing minimum flows.
  - In dry years during non-irrigation season:
    - Wickiup fills first and then Crane Prairie.
  - Wickiup is also responsible for meeting minimum flows below Bend

Source of Model Uncertainties

- Flow:
  - Monthly inflow into reservoirs
  - Daily gains
  - Groundwater
    - Valid at the daily time scale
    - Spatial variability uncertainty:
      -> the number of reaches in RiverWare was increased
- Operations:
  - Unofficial agreements
  - Other operations
- Demands:
  - All linked together
  - Monthly data

Model Outputs – Wickiup Outflow



Model Outputs – Wickiup Storage

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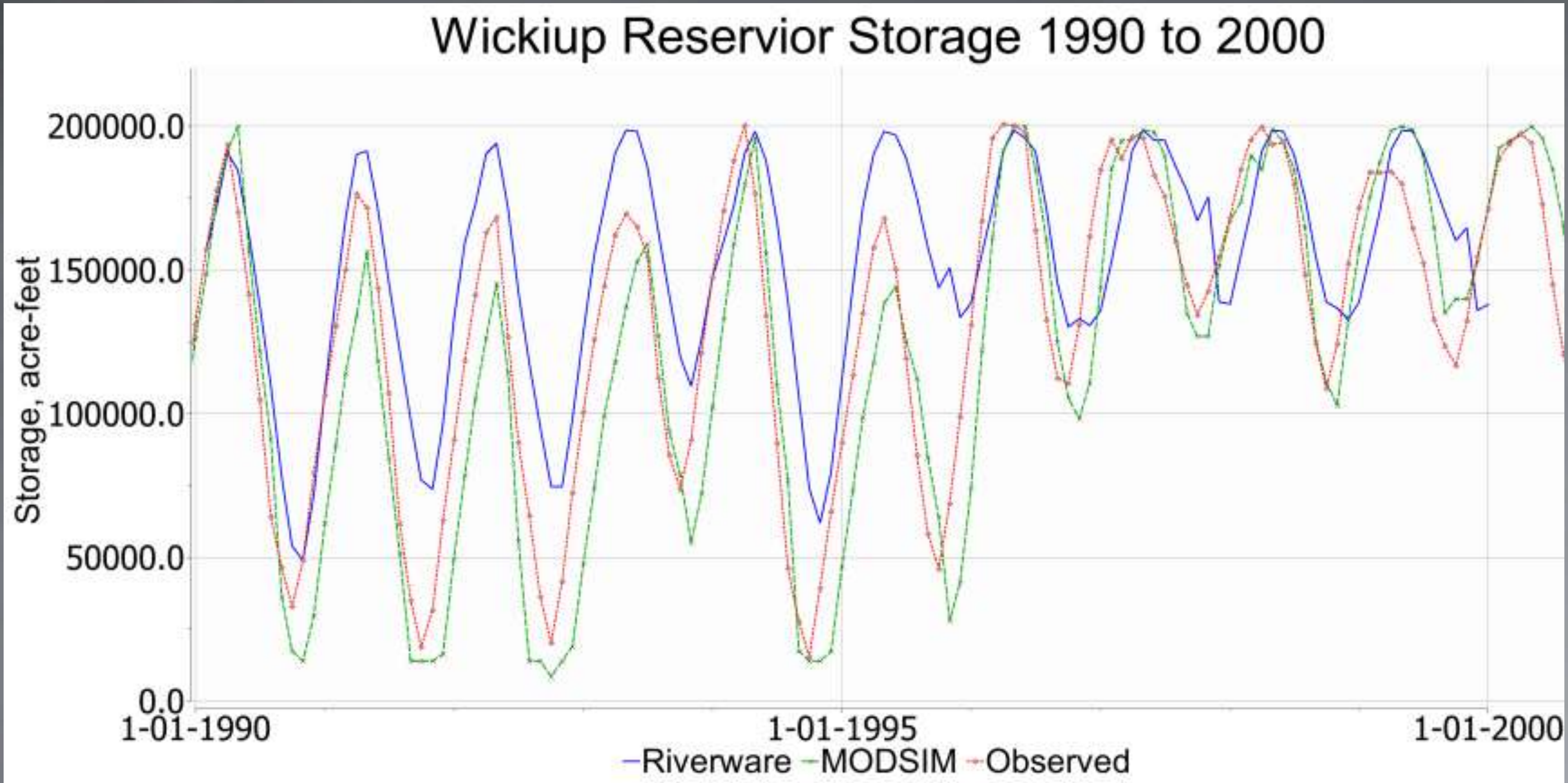

Model Outputs – Bowman Outflow

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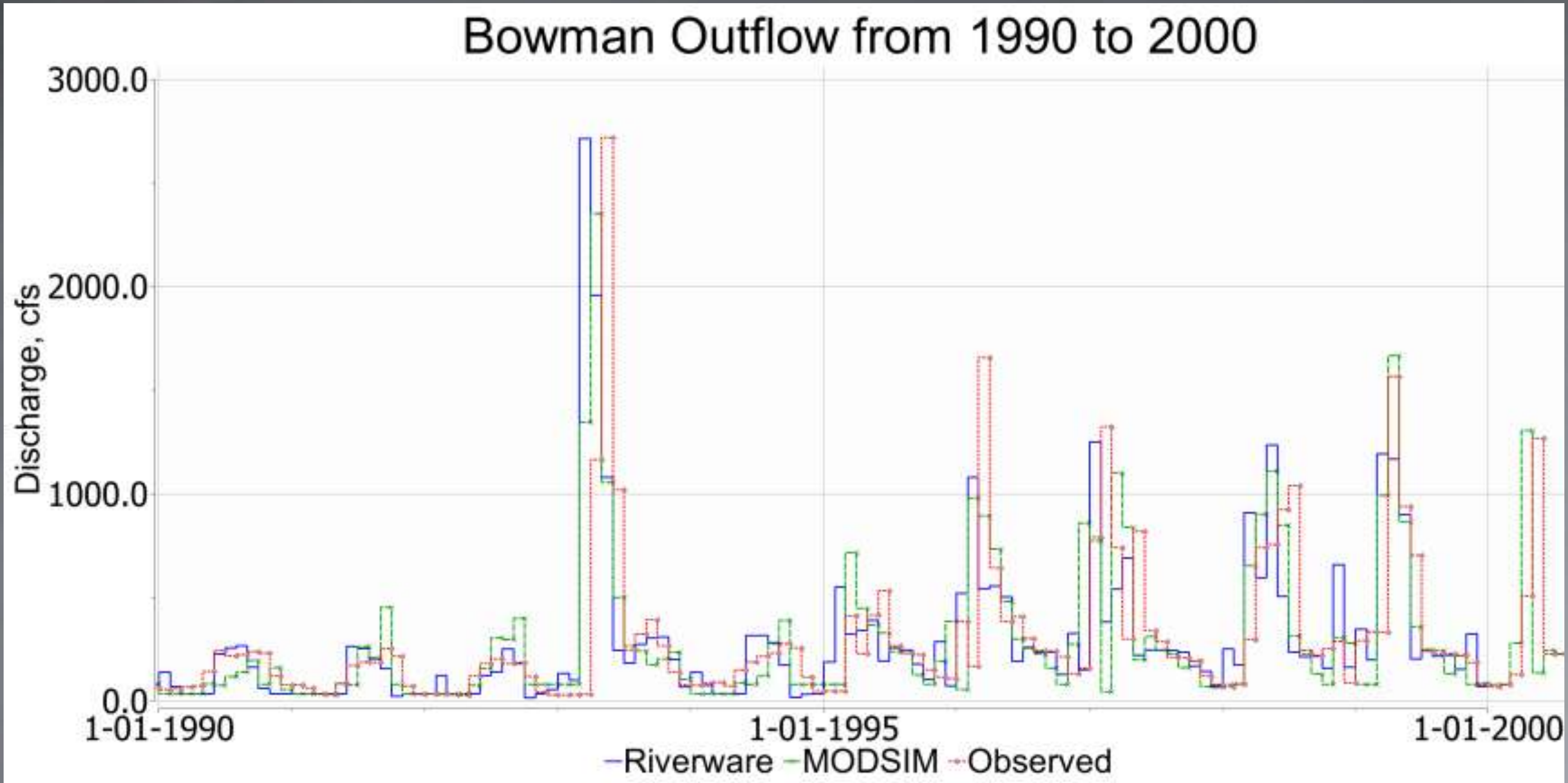

Model Outputs – Bowman Storage

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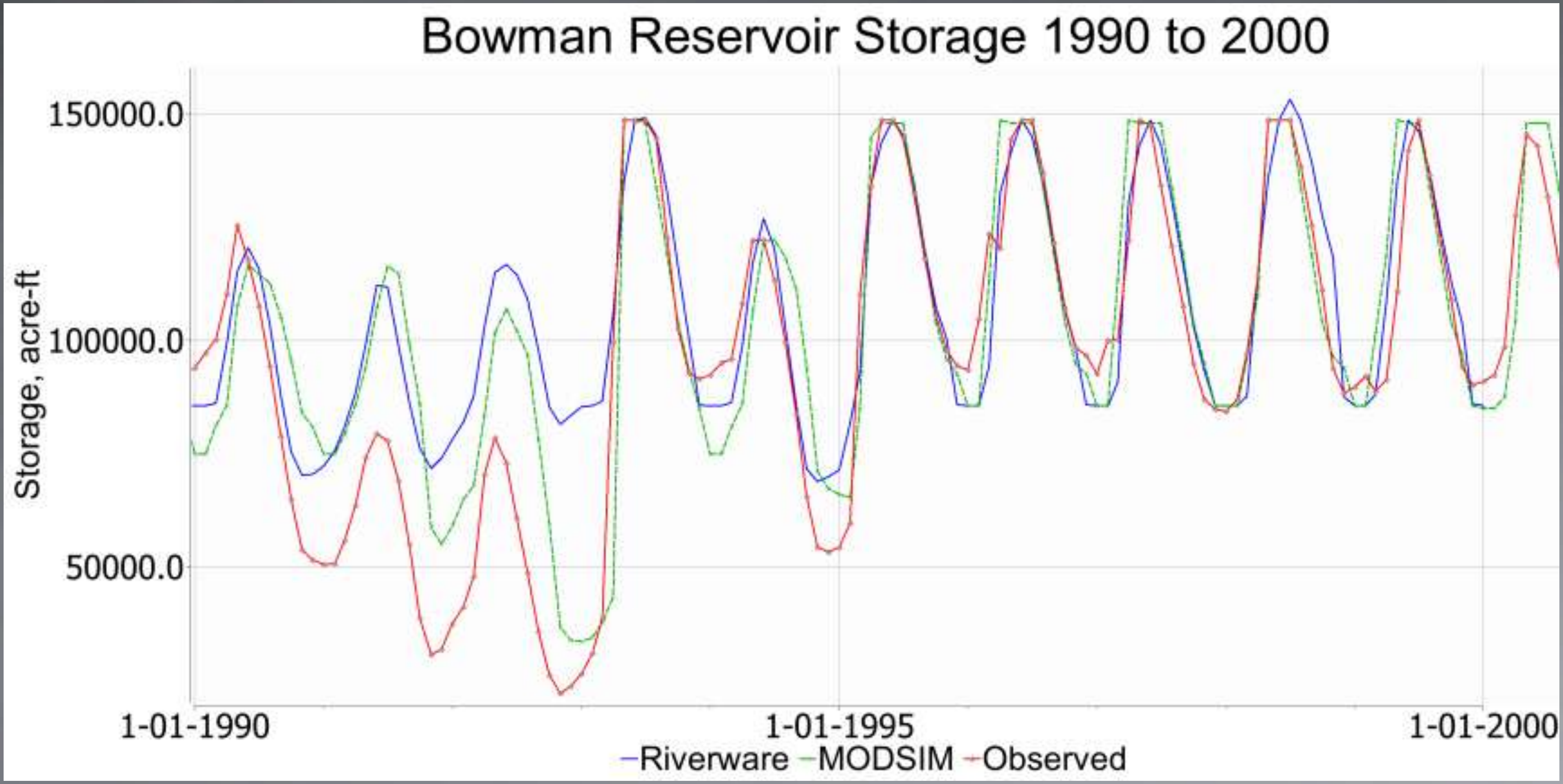

Model Outputs

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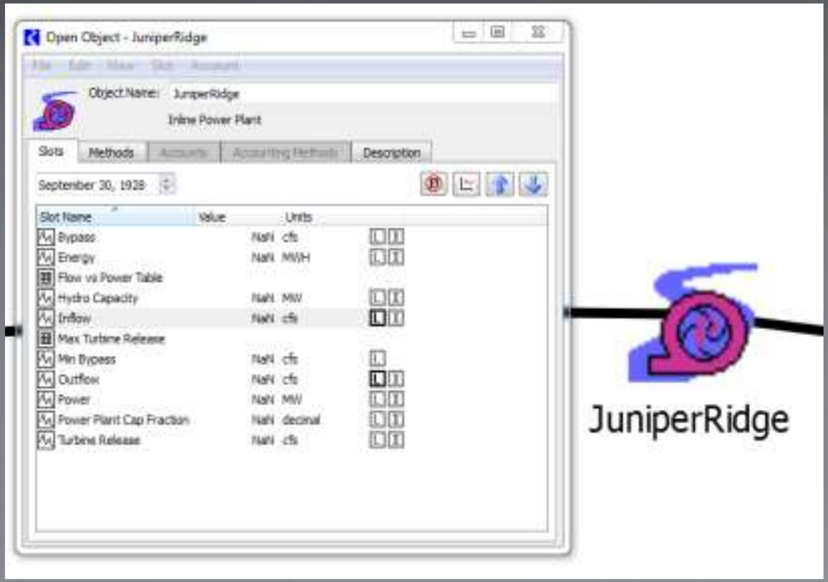
- Energy for all power objects (MWH)
- Diversion request and storages (cfs)
- Water accounting for all object
- Groundwater losses (cfs)
- Output file capabilities:
  - Plots
  - Excel format (.xlxs or .csv)
  - Riverware format file (.rdf)



Results

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- Monthly trends are relatively being captured
- Wet years are simulated better then dry years
- Improvements that need to be made:
  - Flood control releases need more detailed information for Crane and Wickiup
  - Wickiup needs more flexible rules during the irrigation season for simulations of increased baseline flow conditions
  - Refine rules to better capture dry years

Future Activities for 2013

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- Continue to work with OWRD & USBR to fine-tune reservoir operations
- Validate model at monthly and daily scale
- Increase detail for power generation equations
- Implement and validate water rights accounting model
- Model accessibility for other organizations