

Enhancing Water Supply Reliability

An Interdisciplinary Project to Improve Predictive Capacity in the Colorado River Basin

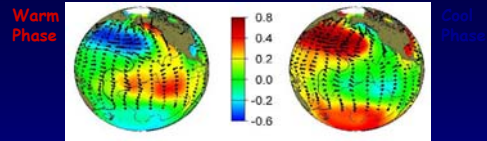
Bonnie Colby, Economics
 Kathy Jacobs, Water Management
 Dave Meko, Paleoclimate
 Bart Nijssen, Hydrology



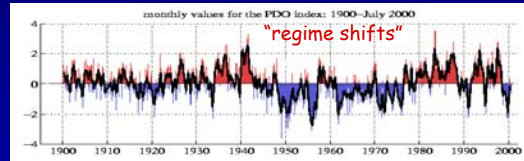
Courtesy USGS



Pacific Decadal Oscillation



Monthly Values for the PDO Index, 1900-2000



Courtesy of Nate Mantua

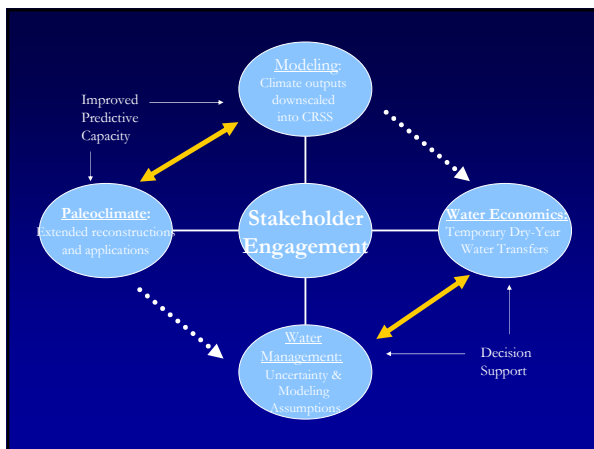
Upper vs Lower Basin Management

- Flows generated in upper basin
- Law of the River requires deliveries from Upper to Lower Basin, translated into specific releases from Lake Powell
- Forecast skill is primarily in Lower Basin; implications of tributaries
- USBR has three models that focus on different time frames: short term operations, the 24 month study model, and the long-term CRSS model



Project Objectives – Phase I

1. **Assess** current Bureau of Reclamation use of climate information in water resources modeling
2. **Identify** water supply predictive uses for paleoclimatology records and climate forecasts
3. **Evaluate** existing management tools to translate improved predictive capacity into enhanced supply reliability for water users
4. **Develop** practical supply reliability strategies for use by municipalities, irrigation districts and other stakeholders



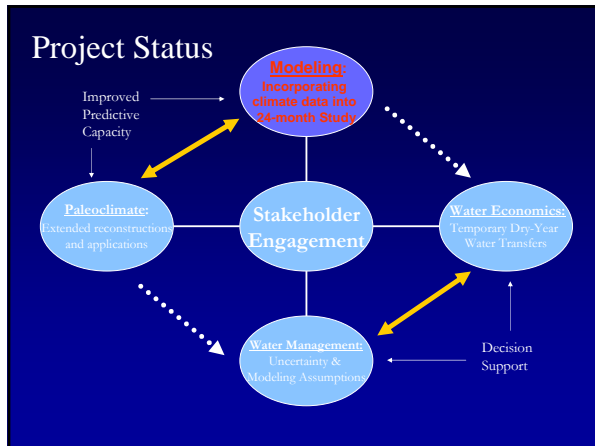
Climate Info and Modeling

A methodological approach to including outside information into USBR projections

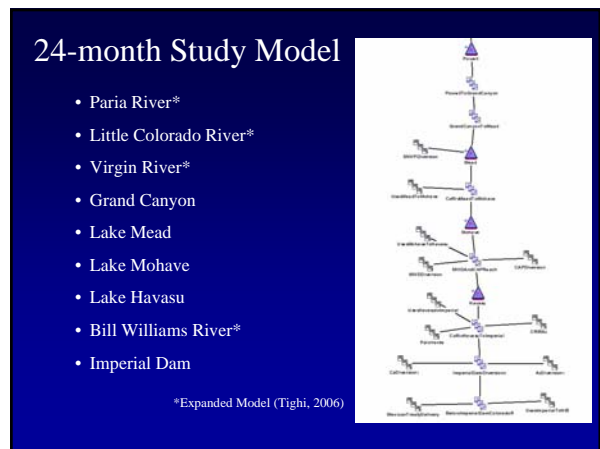
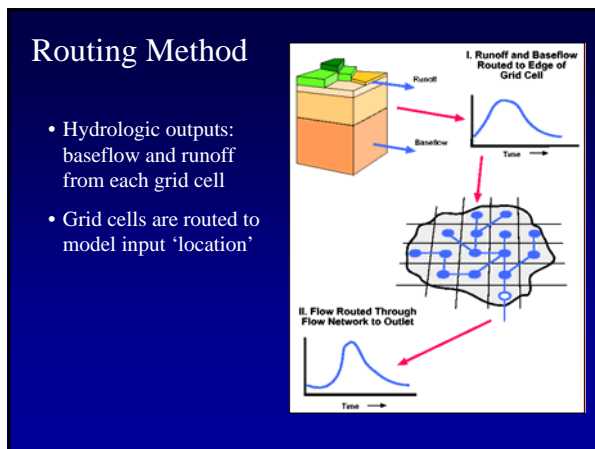
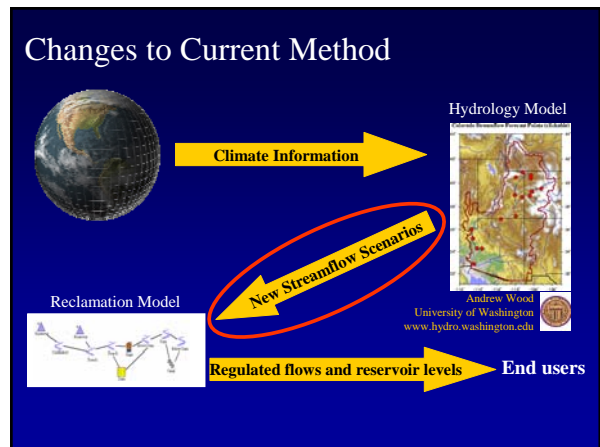
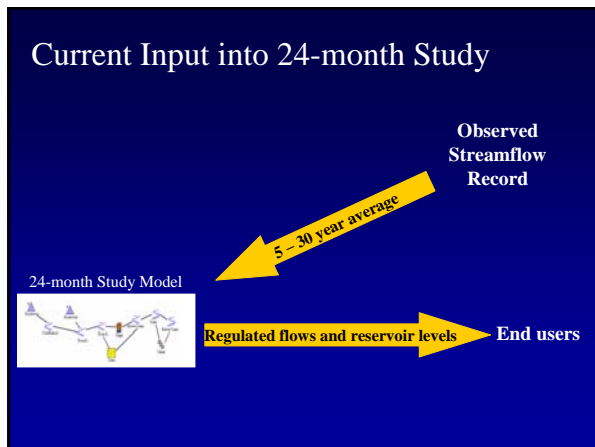
Laura Lindenmayer
 Bart Nijssen



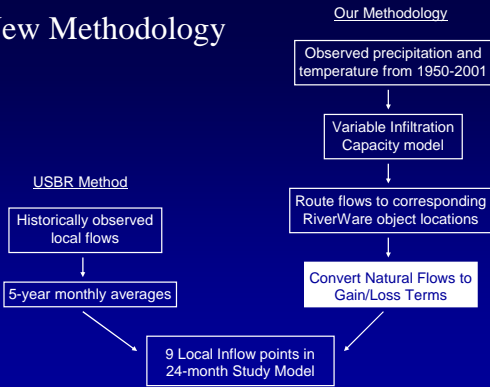
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- ### What We Are Doing:
- Demonstrating the methodology for incorporating outside information into Reclamation's 24-month Study
 - Focusing on the Lower Colorado River Basin
 - 12 month streamflow forecasts from a hydrology model at the University of Washington (Andrew Wood, Niklas Christensen, Dennis Lettenmaier)



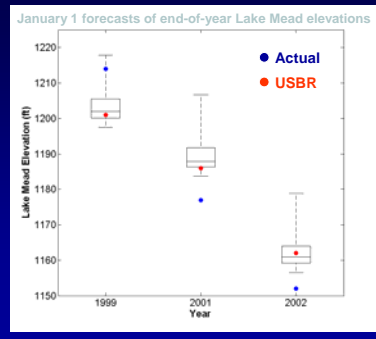
New Methodology



Model Analysis

- Three different 24-month Study models
 - 2001 (average inflow)
 - 1999 (above-average inflow)
 - 2002 (below-average inflow)
- Ensembles from 1950-2001 – Mead inflows/elevations, tributaries
- Ensemble percentile plots – Mead inflows/elevations, tributaries

Implications



Conclusions

- Developed a method with which to incorporate outside information/new flow scenarios
- Percentile plots allow for a better definition of possible outcomes

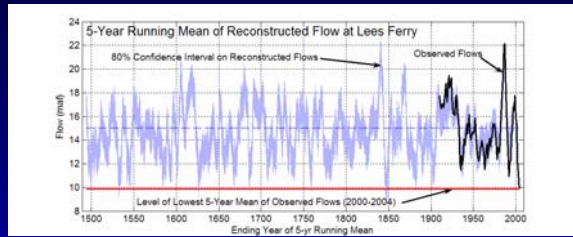
Updated Streamflow Reconstructions for the Upper Colorado River Basin

David Meko and Scott St. George

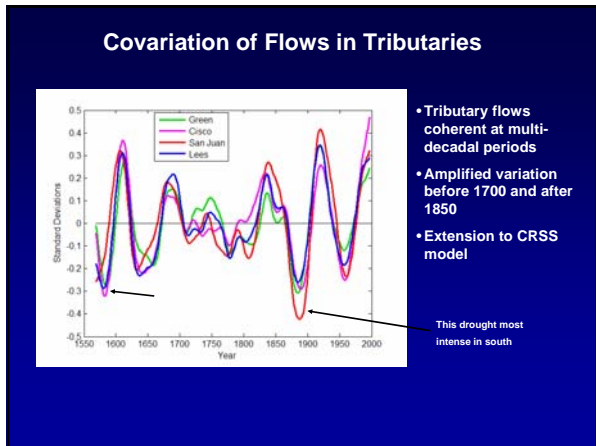


Woodhouse C. A., Gray S. T., and Meko D. M. (2006) Updated streamflow reconstructions for the Upper Colorado River Basin. *Water Resources Research* 42, W05415, doi:10.1029/2005WR004455.

Reconstruction of Lees Ferry Natural Flows, 1490-1997



- Probabilistic interpretation
- Long-term mean annual flow ~14.7 maf
- Severe sustained droughts
- Current drought in perspective
- Interfacing with river management models



Decision Making under Uncertainty: Shortage, Stakeholders, and Modeling in the Colorado River Basin

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Stakeholder-Driven Research Agenda

- What are the key modeling assumptions and sources of uncertainty in CRSS?
- What are the long-term planning implications of these assumptions?
- How can modeling outputs be tailored to aid decision making under uncertainty?

Who are the stakeholders?

Direct

- Arizona DWR
- Central Arizona Project
- Salt River Project
- Municipal CAP Contractors

Indirect through observation of AZ shortage sharing stakeholder workgroup

- On-River Users
- Irrigation Districts
- Power Providers
- Conservation Groups

Decision-Making Context: From Surplus to Shortage / Coordinated Mngt

Long Range Planning in the Colorado River Basin since Beginning of 2000 Drought

1999: Basin-wide storage at 95% Capacity (10/99)

2001: Interim Surplus Guidelines Promulgated (1/2001)

2002: Driest year on record (4.5 mil inflow to Powell)

2004: ADWR initiates informal shortage discussions

2005: Interim launches NEPA process

2006: Basin States Preliminary Proposal, Scoping Report

2006: Draft Project Alternatives Released (6/2006)

2007: Interim conducts first mid-year review

2007: Basin states drought mitigation negotiations

2008: Record of Decision

2008: Final EIS

2008: Draft EIS (2/2007)

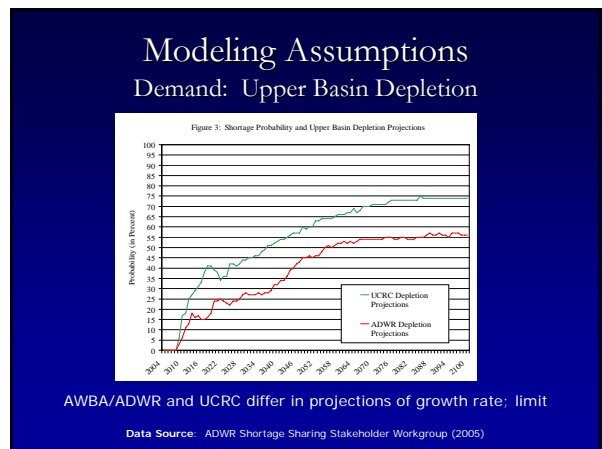
INTERIM SURPLUS GUIDELINES | **BASIN STATES PROCESS** | **COORDINATED MNGT & SHORTAGE EIS**

Analysis: Long Range Planning Assumptions in CRSS

- CRSS modeling assumptions and outputs

Outputs (reservoir levels and derived parameters, e.g. shortage probability) = **f** (inflow, depletion, physical process, operating criteria, initial conditions)

1. Inflow: Index Sequential Method; Data Validation
2. Depletion: Upper Basin
3. Operating Criteria: Surplus Guidelines; 602 (a) storage criteria
4. Initial Reservoir Conditions



The Worst-Case: Aligning Assumptions

Table 5: Combining Assumptions to Form Best- and Worst-Case Scenarios

Key Assumptions	Shortage Probability	
	HIGHER	LOWER
Inflow	Prolonged drought (e.g. 1999-2004)	Extended high flows (e.g. 1983-1986)
Demand – UB	Limit: 5.4 maf Rate: UCRC	Limit: 4.8 maf Rate: AWBA
Operating Policy: Surplus Criteria	Interim Surplus Guidelines	70R Strategy
Initial Conditions	Jan. 2005 (i.e. 50% capacity)	Jan. 2000 (i.e. nearly full)

Arizona Stakeholder Recommendations (2005)

- ✓ Articulate and document the assumptions in model runs
- ✓ Isolate the drivers of variability through sensitivity analyses and consistent constants
- ✓ Establish bounds on uncertainty by defining best and worst case scenarios
- ✓ Evaluate river system in terms of water user impacts instead of reservoir levels or other indirect measures
- ✓ Distinguish between sources of uncertainty over different time scales
- ✓ Foster trust, patience to deal with stakeholder groups with diverse levels of understanding and experience

Summarized from AZ Shortage Sharing Stakeholder Workgroup (Aug 19, 2005)

Irrigation Forbearance

- Voluntary participation
- Growers paid to suspend irrigation
- Economic rationale:
 - Senior ag rights, reliable supply
 - Forbear irrigation on lower value crops
 - Avert costs of municipal shortage
 - Provide environ. flow reqts



<http://www.magazine.noaa.gov/stories/mag51.htm>

On-Farm Economics of Forbearance

Arizona agriculture along the Colorado River

- Senior water rights
- Large acreage in lower-value crops



Image courtesy of Arlan Thompson, University of Arizona

On-Farm Water Value Estimates

- On-farm value estimated by calculating net returns over variable costs
 - Calculate gross returns/acre and variable costs of production (excluding cost of water)
 - Subtract variable costs from net returns to arrive at net returns over variable costs

Seasonal Timing of Forbearance

County:		Yuma		Durum Wheat		
Crop:		Durum Wheat		Total Variable Cost: \$441.88/acre		
Month	Operations	Class	Cost	% of Total Variable Cost	Running Total (%)	
Dec	Disk	Land Prep.	19.87	4.50	4.50	
Dec	Roll Beds	Land Prep.	2.38	0.54	5.04	
Dec	Laser Level	Land Prep.	42.88	9.70	14.74	
Dec	Apply Fert/Ground	Growing	63.34	14.33	29.07	
Dec	Plant	Land Prep.	34.02	7.70	36.77	
Jan	Make Borders	Growing	2.42	0.55	37.32	
Jan	Irrigate	Growing	5.12	1.16	38.48	
Feb	Apply Herb/Ground	Growing	27.58	6.24	44.72	
Feb	Irrigate/Run Fert	Growing	85.72	19.40	64.12	
Feb	Apply Herb/Ground	Growing	24.21	5.48	69.60	
Mar	Apply Insect/Air	Growing	17.34	3.92	73.52	
Mar	Irrigate	Growing	10.23	2.32	75.84	
Jun	Combine Harvest	Harvest	57.68	13.05	88.89	
Jun	Haul	Harvest	15.75	3.56	92.45	
Jun	Disk Residue	Land Prep.	12.82	2.90	95.36	
Misc.	Pickup Use		12.62	2.86	98.21	
Misc.	Op. Interest 6%		7.90	1.79	100.00	
	TOTAL		441.88	100.00	100.00	

Using Climate Science To Improve Dry-Year Agreements

- Improve on-farm planning & adaptation
- Improve local economic planning and adaptation
- Plans to finance water acquisition costs
- Tailor lease payments & 3rd party compensation
- Establish trigger mechanism for forbearance

Summary: Dry Year Forbearance

- Needs to be carefully structured
- Recommend long term contracts with districts
- Begin with fixed price, then grower bidding
- Effective examples worldwide, need not be high cost & conflictual
- Other ongoing work:
 - Drought impact on lease prices
 - Ag adaptation strategies
 - Risk adjusted forbearance econ, bargaining models