

Risk-Informed Decision Making for the Management of the Wind-Bighorn River

**Workshop on Forecast-Informed Reservoir Operation
September 12-13, 2019**

Oklahoma-Texas Area Office

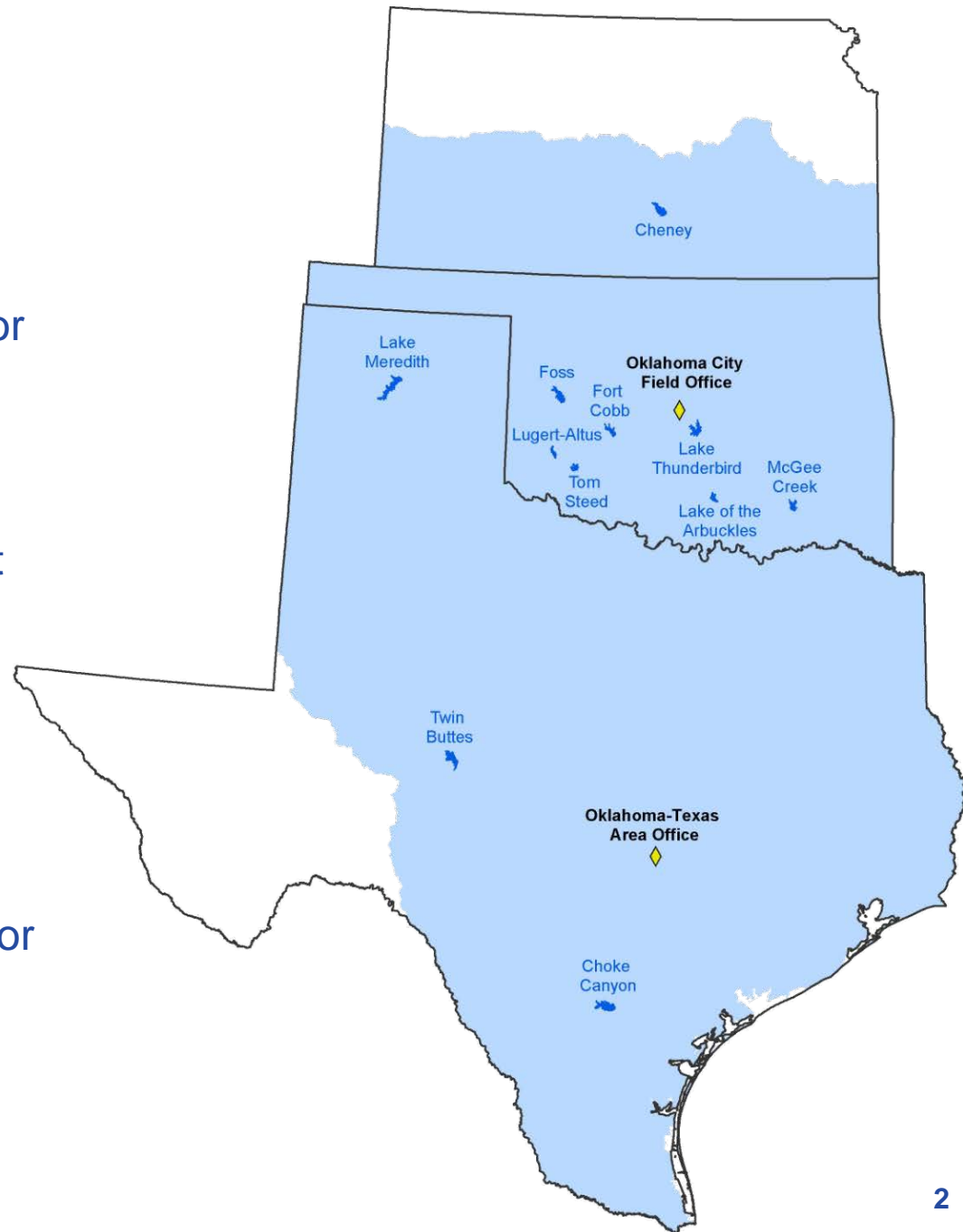
Ownership/oversight responsibility for 11 reservoirs with a total capacity of 4.2 million acre-feet.

Total water rights from projects:

- M&I - 571,000 acre-ft/yr to about 2.7 million customers.
- Irrigation - 110,600 acre-ft/yr for about 63,000 acres.

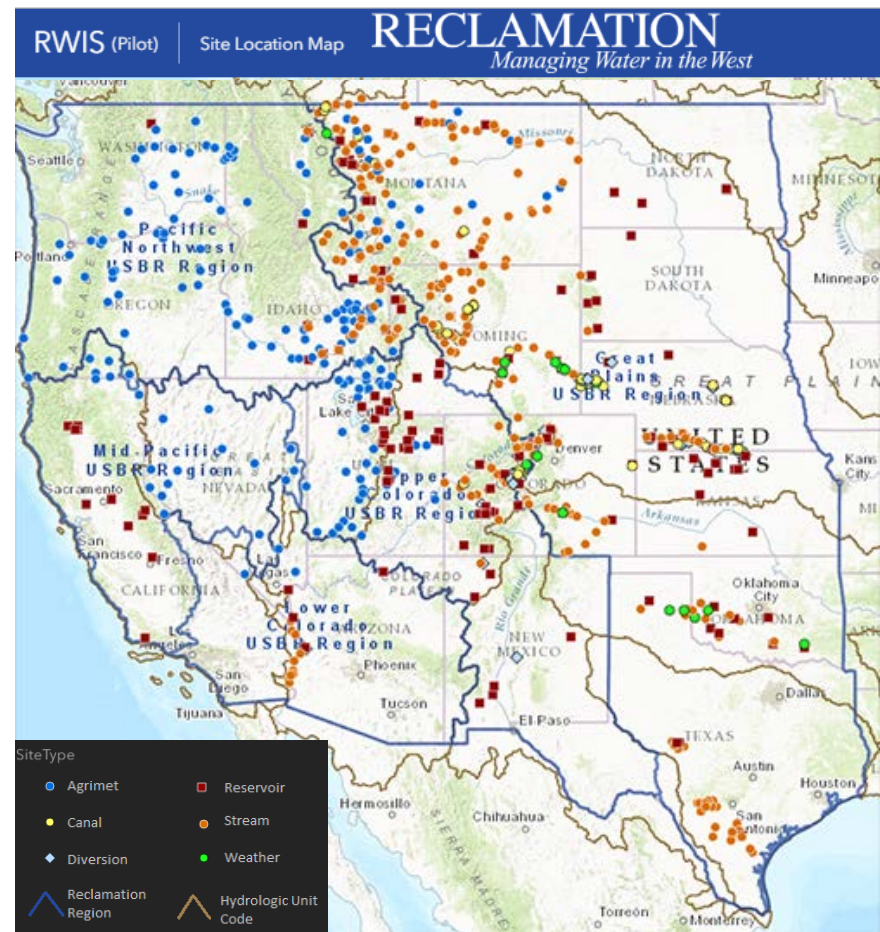
Annual recreation use of over 4 million visitor-days each year.

Ownership/oversight responsibility for 190,000 acres of Federal land



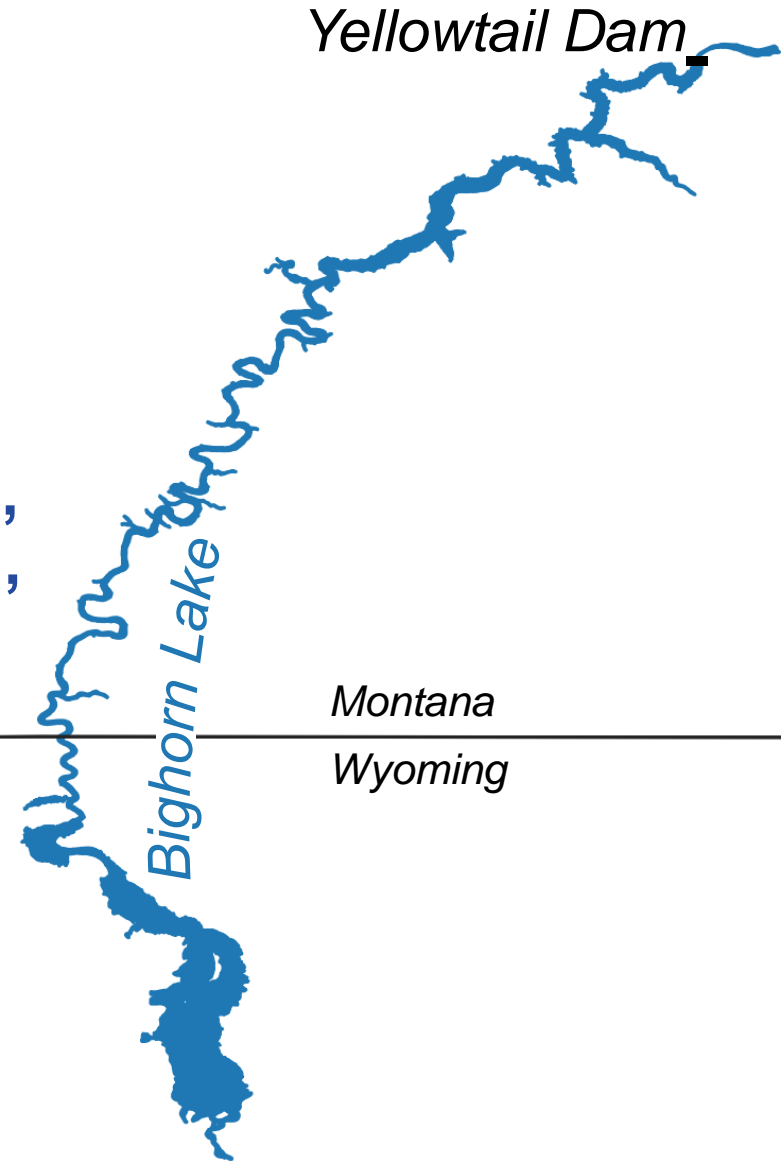
Study Goals

- Provide clarity to the decision-making process
- Model automation to rapidly evaluate numerous potential reservoir inflow scenarios
- Develop an operations model that accurately reflects physical system and operational policy
- Utilize forecasts that 'accurately' capture uncertainty in reservoir inflows



Yellowtail Unit of Wind-Bighorn River

- Snowmelt dominated basin
- Three upstream Reclamation reservoirs: Bull Lake, Boysen Reservoir, and Buffalo Bill Reservoir
- Project authorized for irrigation, power generation, flood control, fish & wildlife, and recreation
- Crow Tribe Water Right Settlement provided water rights and “exclusive right to develop and market power generation”



Management Challenges

- Maximizing value to all Congressional authorized uses
- Spring inflow volume and timing forecast uncertainty



Bighorn Lake recreation

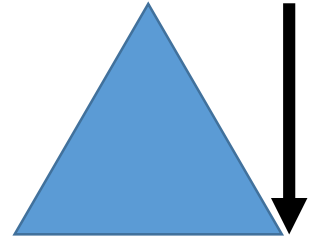


Bighorn River recreation

Mid-Term Operations

Current Practice

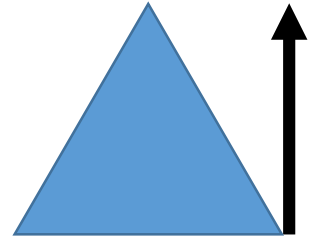
- Lots of information for an operator to process
- Operator subjectively quantifies forecast uncertainty
- Operator subjectively quantifies risk on a real-time basis
- Decisions are *not* easy
- Everyone not so happy



Mid-Term Operations

Best Practice

- Minimize data an operator is required to process
- Develop forecasts to quantify uncertainty
- Develop risk policies in advance
- Make operational decisions based on risk policy
- Allow for professional judgement *after* quantifying uncertainty and risk



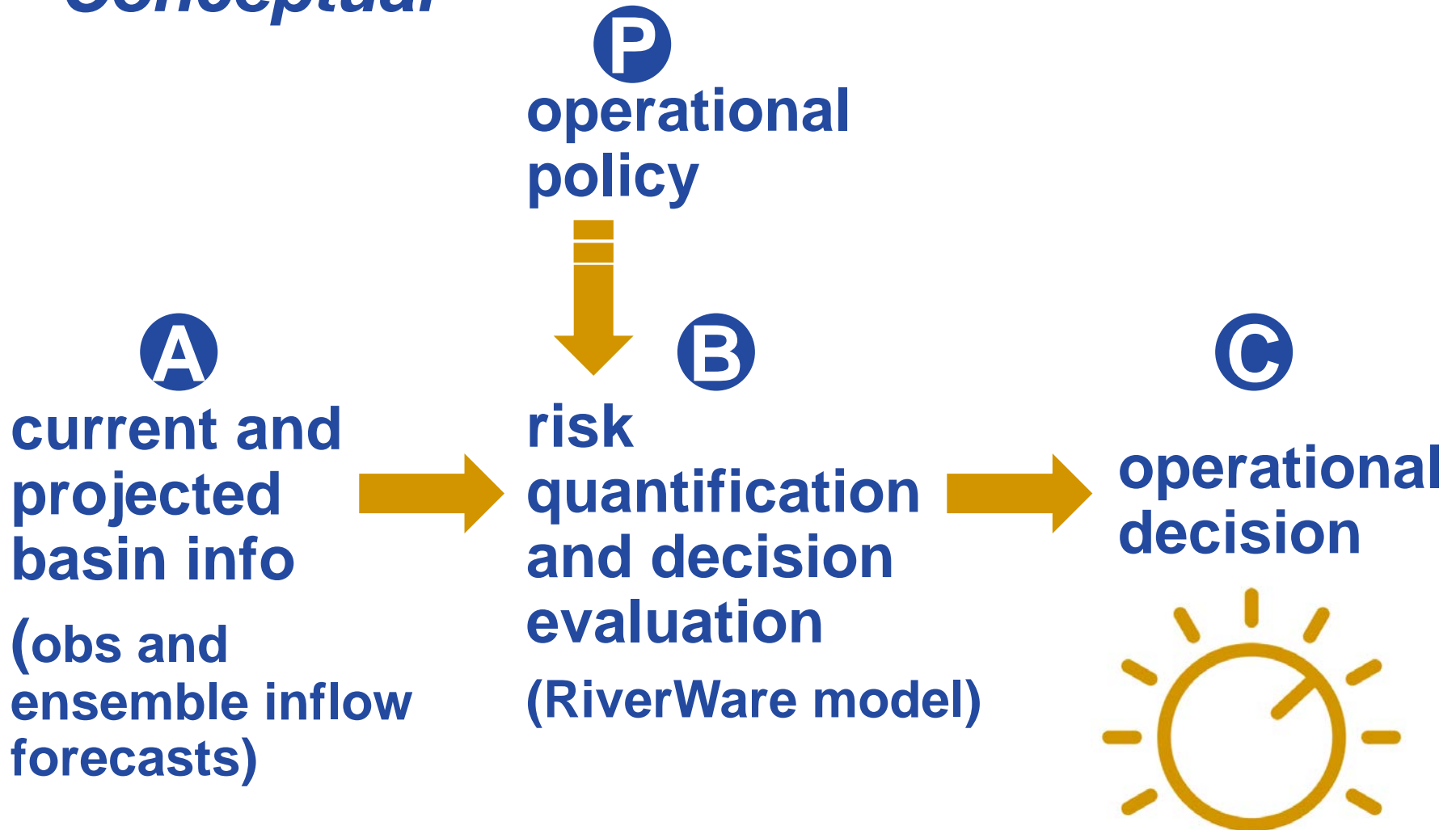
Risk-Informed Decision Making

How can a model suggest an operational decision?

- **Two-stage stochastic programming with recourse**
 - **Make decision over a shorter first stage (e.g. releases for the next 24 hours)**
 - **Apply decision to longer second stage (e.g. the following 13 days)**
- **Choose a first stage decision based on tradeoffs between the impacts on metrics of importance in BOTH stages**

Risk-Informed Decision Making

Conceptual



Risk-Informed Decision Making

A *Ensemble Inflow Forecasts*

***verification /
validation***



***bias correction /
post-processing***



input into model

Physically-Based Forecasts

***NWS Missouri River
Basin Forecast
Center***

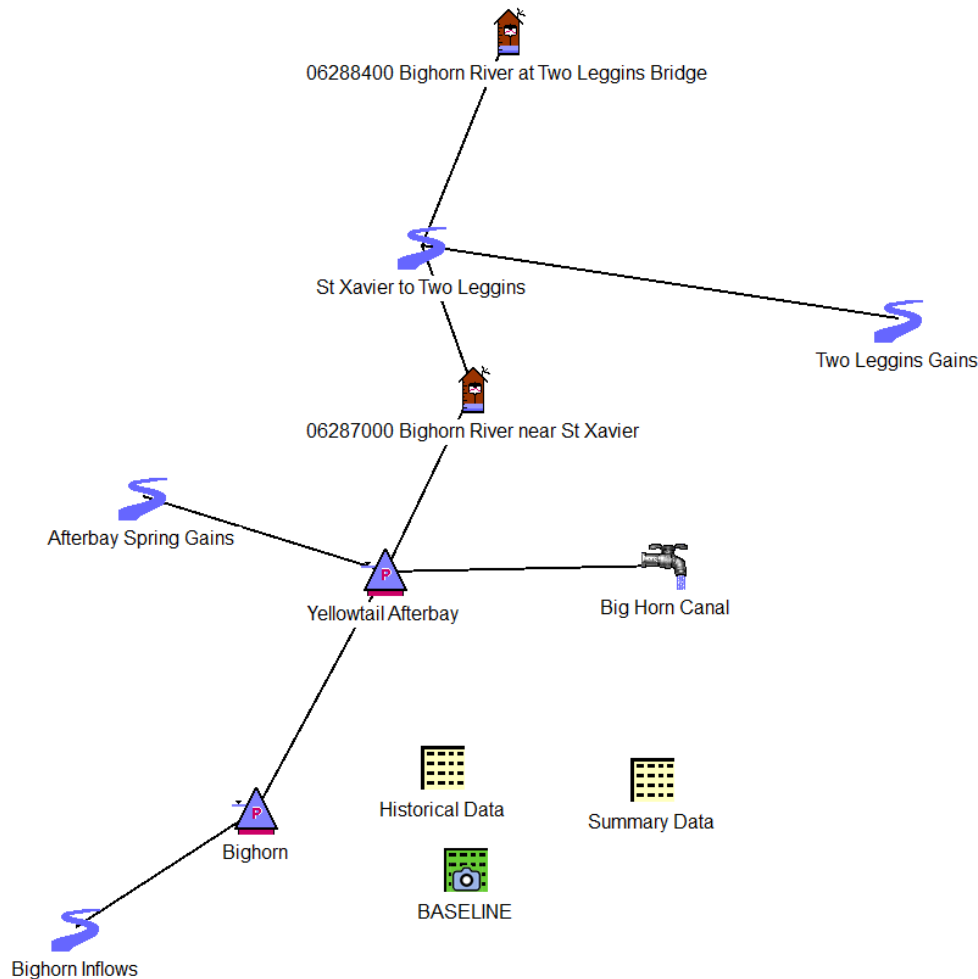
***National Center for
Atmospheric
Research***

Statistically-Based Forecasts

***Reclamation GP
Regional Office***

Risk-Informed Decision Making

B *RiverWare Model*



**Yellowtail RiverWare
model substantially
complete and tested**

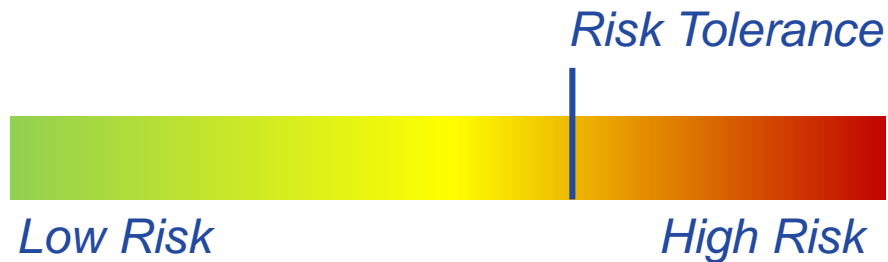
**CADSWES has
developed a
preliminary method for
stochastic programming
with recourse**

Risk-Informed Decision Making

B *Risk Quantification*

Defining risk

Defining risk tolerance



Risk-Informed Decision Making

Operational Decision

- Look at compiled information, risk thresholds
- Look at tradeoffs between competing objectives
- Make operational decision

Study Design

Operational Simulations

Look at operational decisions
for two timescales –

- short-term (5 to 14 days)
- mid-term (out 12 months)

Project Status

Complete and Ongoing

- RiverWare operations model is complete
- NWS and NCAR will provide ensemble forecast hindcasts this calendar year
- Reclamation will develop a methodology to post-process ensemble forecasts to include all aspects of uncertainty
- CADSWES has developed a preliminary method for stochastic programming with recourse
- Operators will determine approaches to risk this calendar year

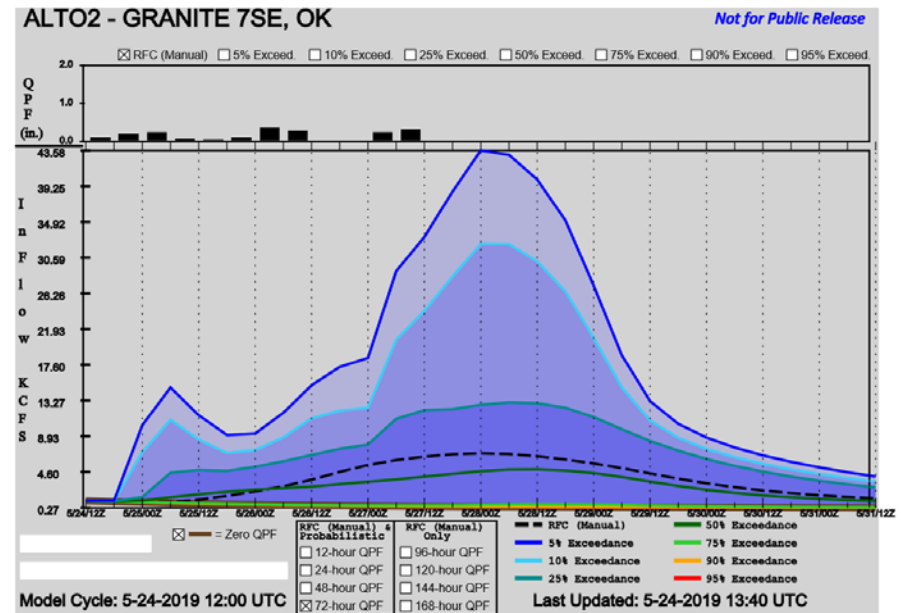
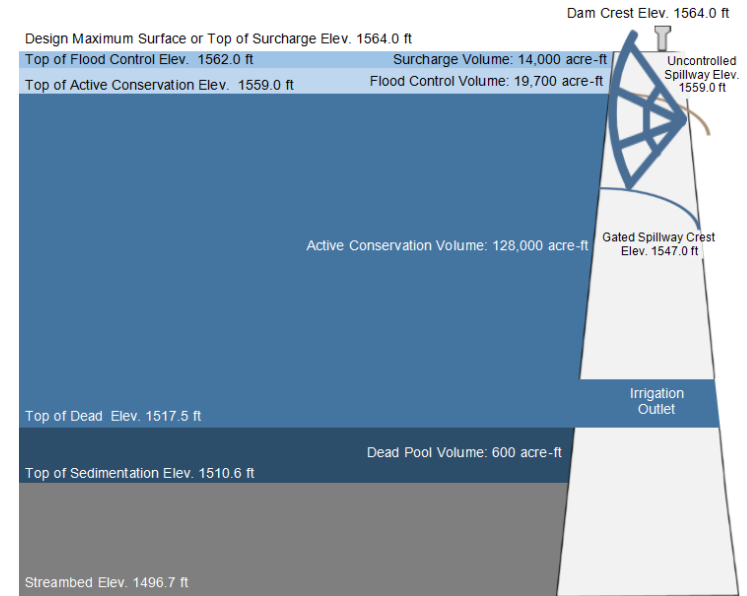
Next Steps

- Modeling scenarios in next calendar year

Other Applications

How could this work in our area?

- Water Supply Operations?
 - Balancing reservoir benefits
 - Optimizing irrigation and M&I
- Flood Operations?
 - HEFS ensembles from ARBRFC



Study Contributors

Jordan Lanini

Reclamation Great Plains Regional Office

Dan Broman and Marketa McGuire

Reclamation Technical Service Center

Edith Zagona and David Neumann

Center for Advanced Decision Support for Water and Environmental Systems

University of Colorado, Boulder

Andy Wood

National Center for Atmospheric Research

Contact Information:

Anna Hoag, P.E

Oklahoma-Texas Area Office

ahoag@usbr.gov, 405-470-4829