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Using Multi-Scale Uncertainty Information and Specific Forecast Skill to Improve Reservoir Operations

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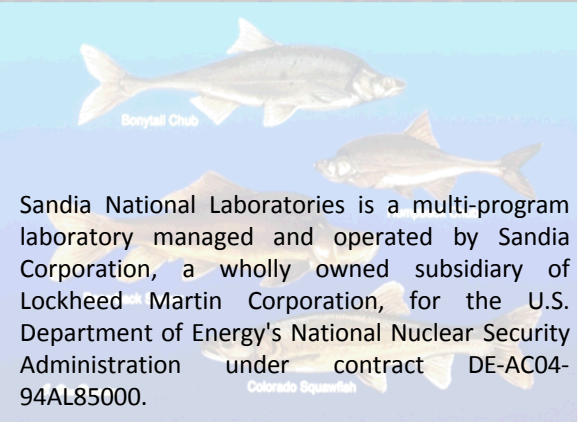

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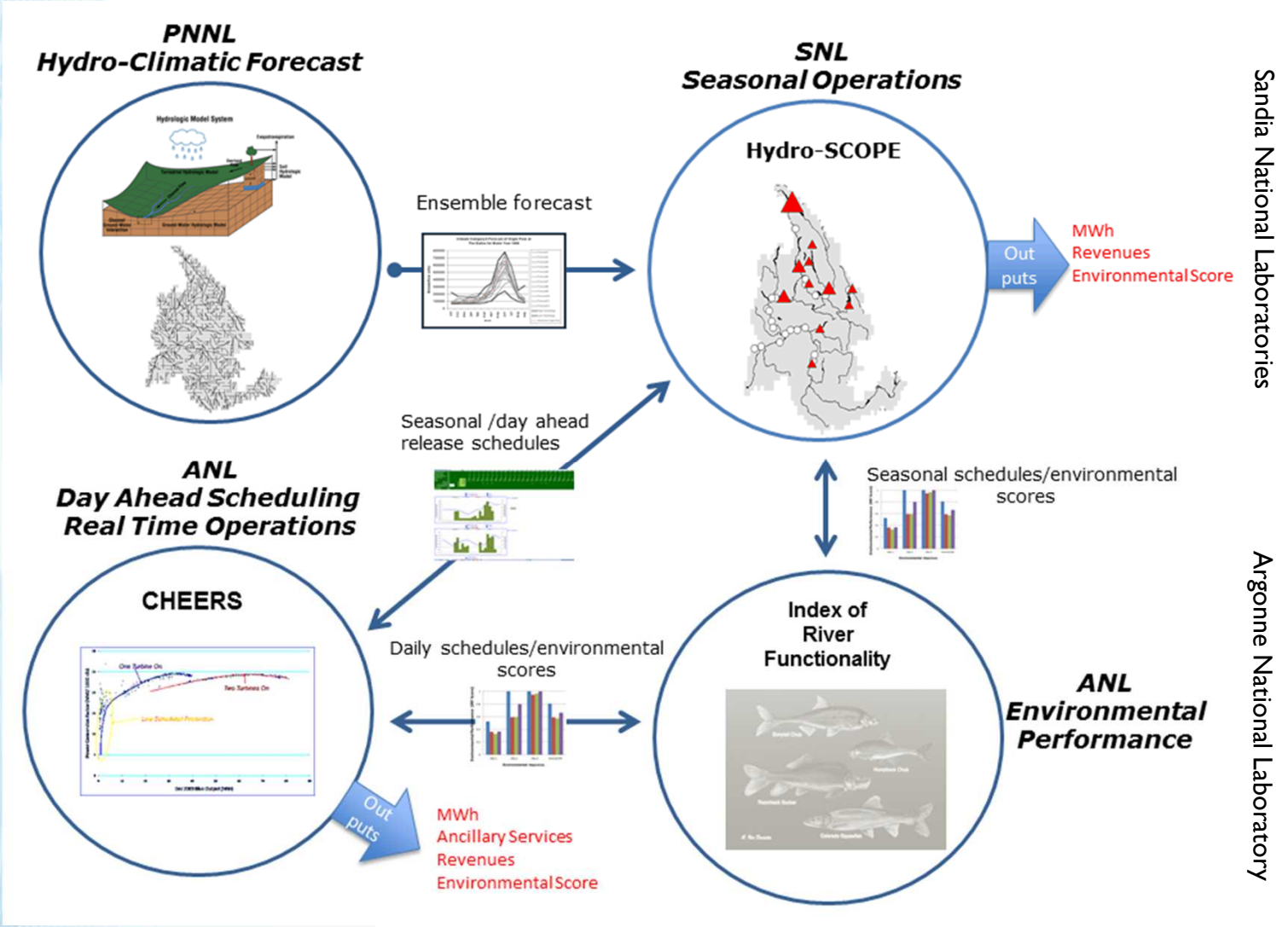
Introduction

QUESTIONS:

1. How does the temporally evolving skill of medium and seasonal ensemble forecasts influence operational risk?
2. How can we inform short-term operations to minimize medium and seasonal scale operational risk?

- Project Background: Water Use Optimization Toolset
- Operational risk, ΔRisk = Regret
- Example Application
- Conclusions

Background: Water Use Optimization Toolset



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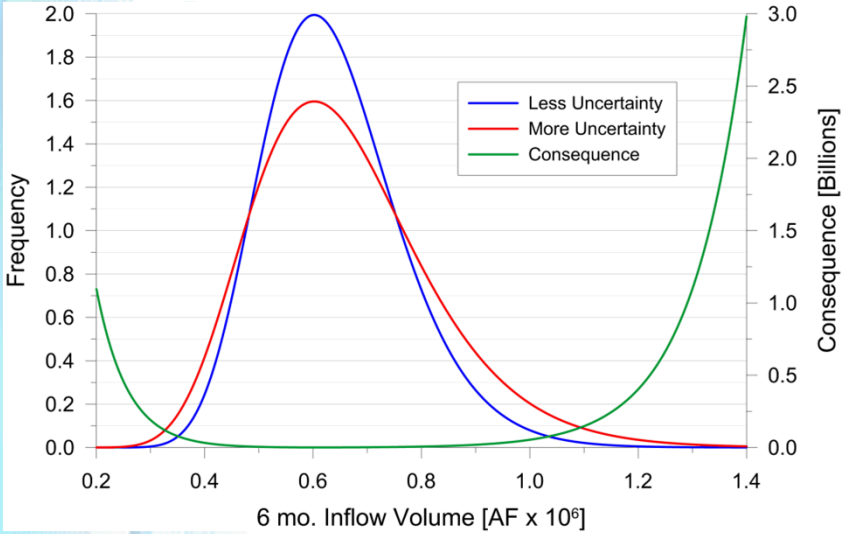
Operational Risk

aka: What we want to avoid

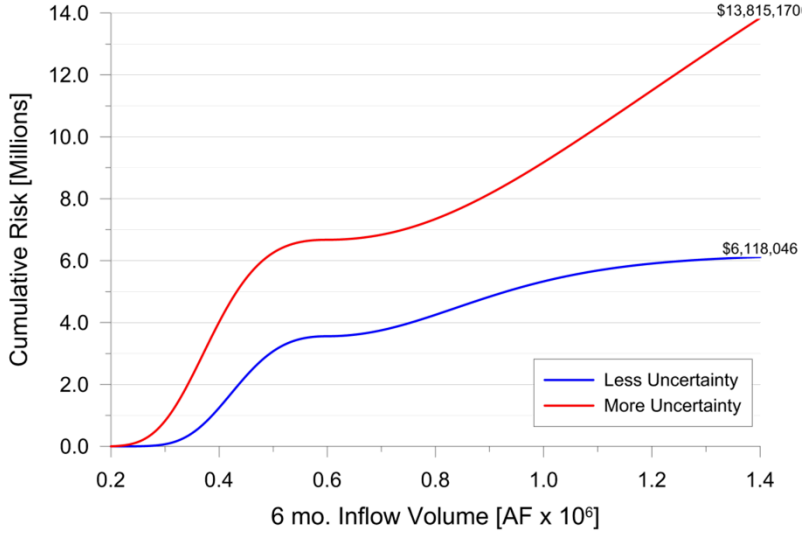
OPERATIONAL ASPECT	RISK
'Wasting' Water	1. Spilling water 2. Off-peak 3. Low efficiencies
Water Deliveries	Not meeting downstream requirements
Flood Control	Not maintaining adequate available storage
Environmental Impacts	1. Aquatic 2. Riparian 3. Avian
Recreational	1. Reservoir use (boating, fishing, camping, etc.) 2. Downstream use (fishing, rafting, etc.) 3. Tourism
Other	1. Non-market value 2. Cultural values 3. Perceived impacts 4. GHG emission's

Uncertainty = Risk, ΔRisk = Regret

Two Ensemble Forecasts
Different Uncertainties



Uncertainty Equates to Risk



Risk = Probability x Consequence

Regret is the difference in risk of assuming one possible future and realizing another

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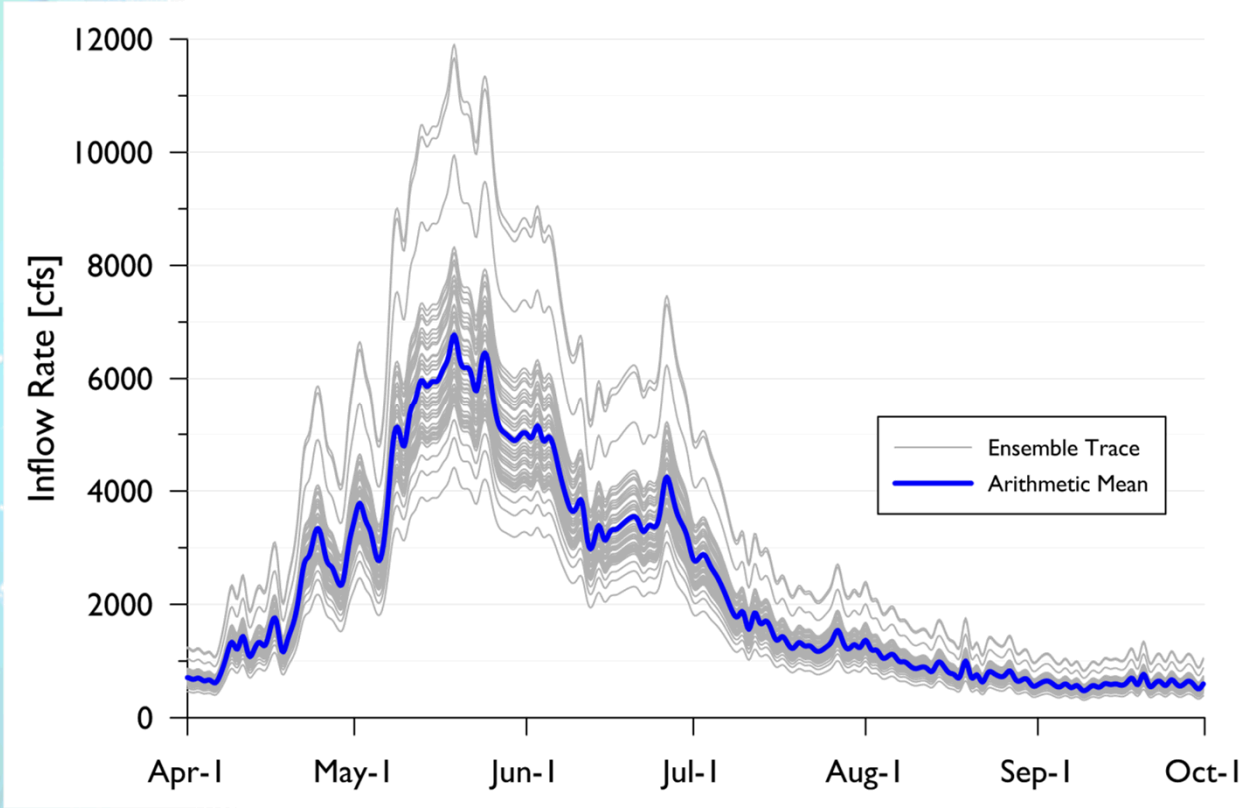
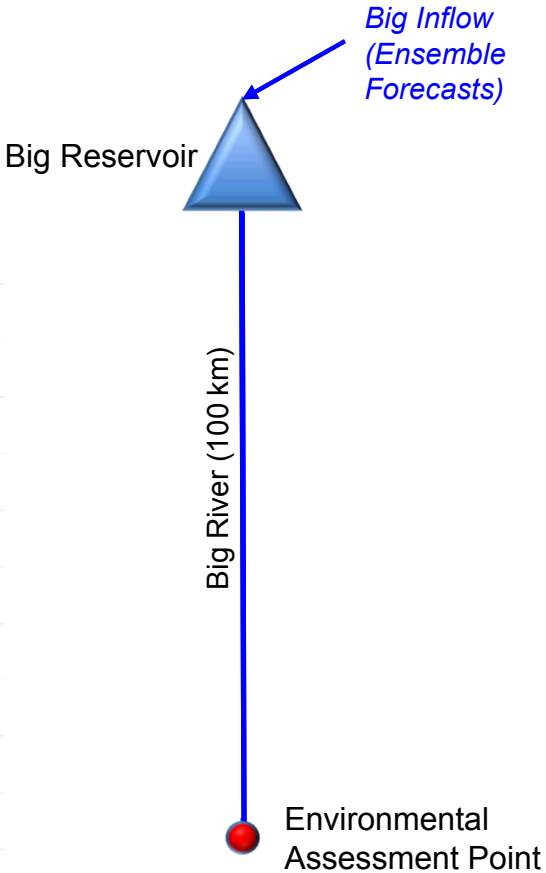
Forecast Accuracy

- Next 24 hours
  - Initial conditions and 24 hour weather forecast
- Medium Range Forecast (1 day to 2 weeks)
  - Initial conditions and 2 week weather forecast
- Seasonal Forecast
  - Initial conditions and historical meteorology
- Can optimize on 24 hour forecast
  - Doesn't leave room for tweaking operations to account for seasonal trends/concerns

Example Application

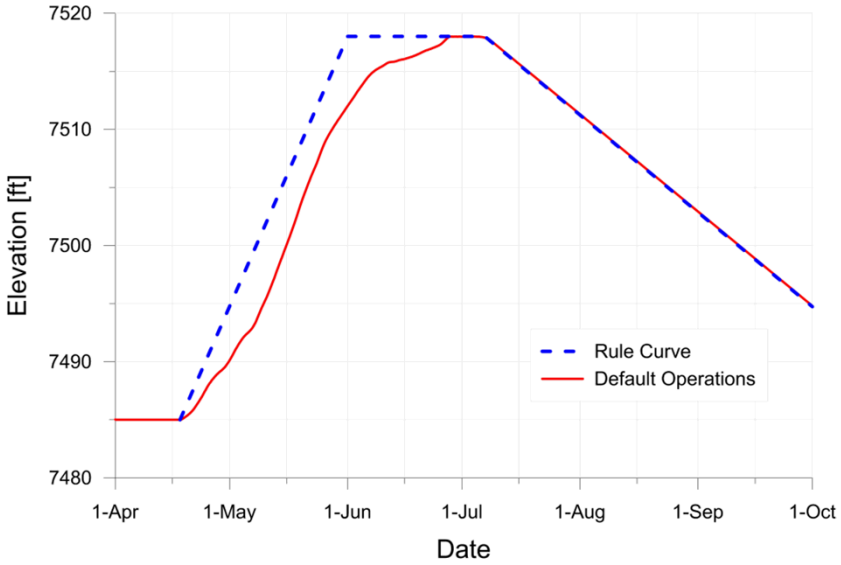
- One Reservoir System
- One River Reach
- One Env. Assessment Point





Example Application

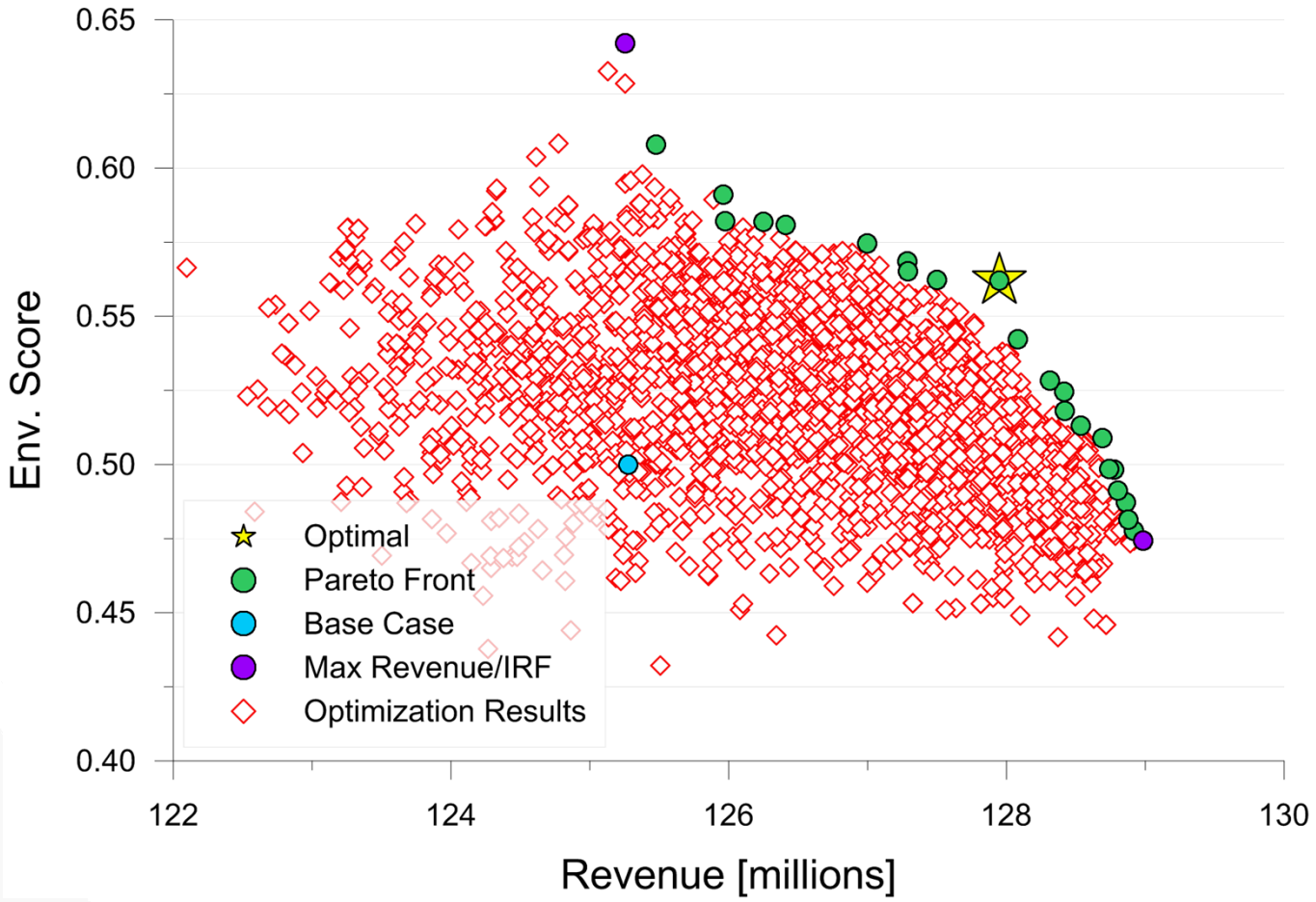
- April thru September
  - 183 days
  - 6-hr timestep (732 timesteps)
- Operations Based on Rule Curve
  - 28 day average inflow forecast
  - 28 day elevation target
  - Adjustments for:
    - Exceeding rule curve
    - Meeting minimum flow requirement (375 cfs)



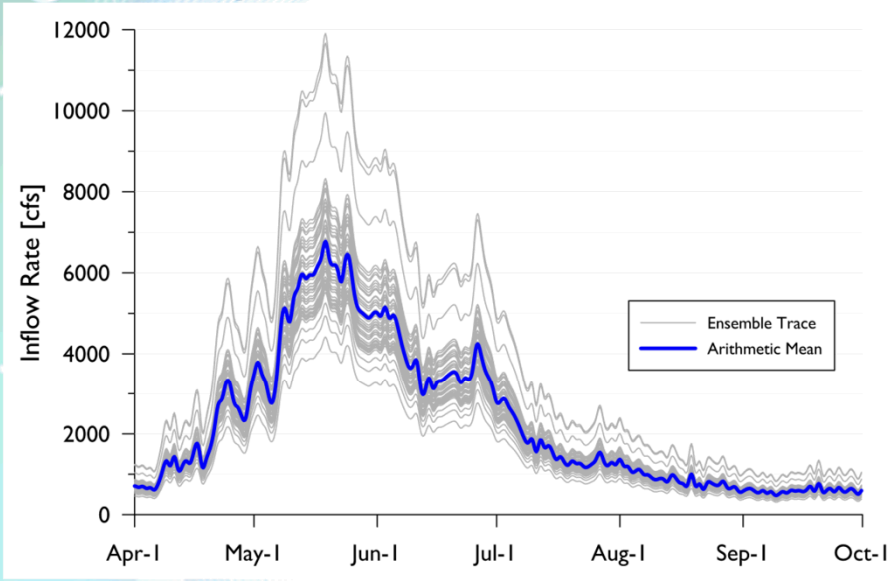
- Environmental Score
  - Minimize June-Aug average maximum daily temp
  - Minimize stage changes > 1ft/day
  - Relative to base case scenario
- Base Case Inflow = Ensemble Arithmetic Mean

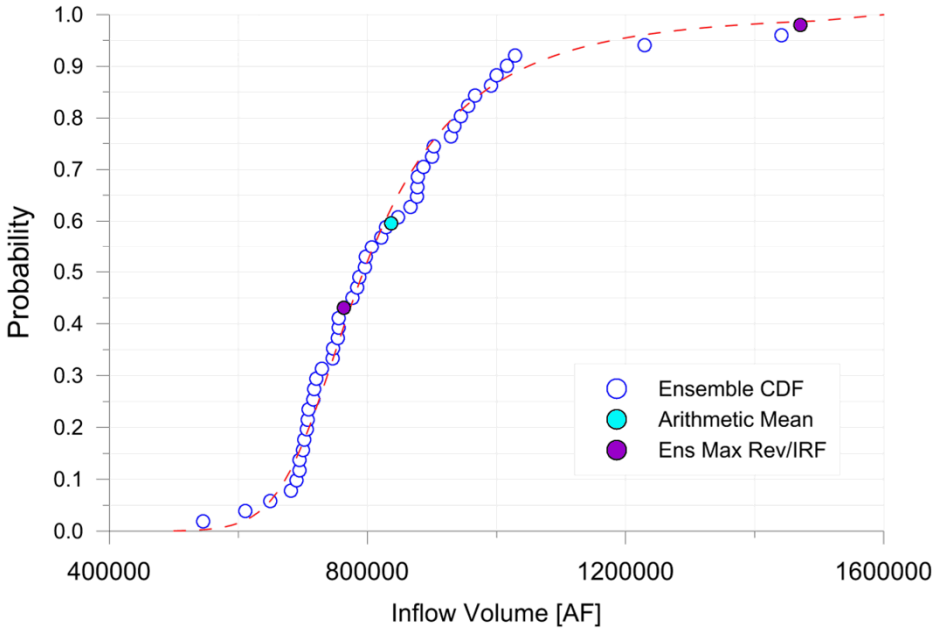
Base Case Optimization

- 2500 simulations
- Pareto Front defines line of tradeoff
- Base Case is default operations before optimization
- 24-hr Release
  - BC = 1366 AF
  - Opt = 1350 AF



Using Ensemble Forecasts





- Convert flow volumes to cumulative distribution function
- Optimize each instance
- Calculate risk as a function of probability and consequence

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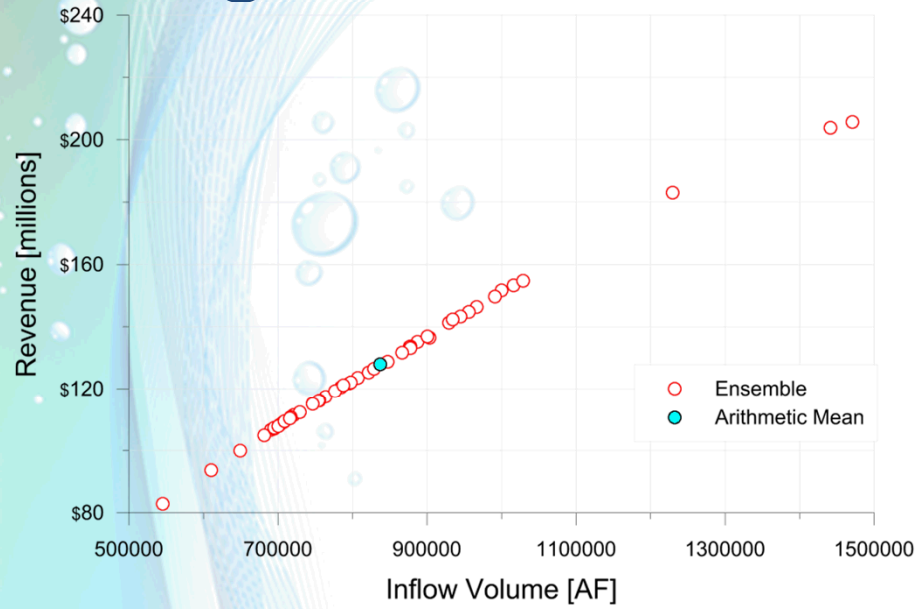
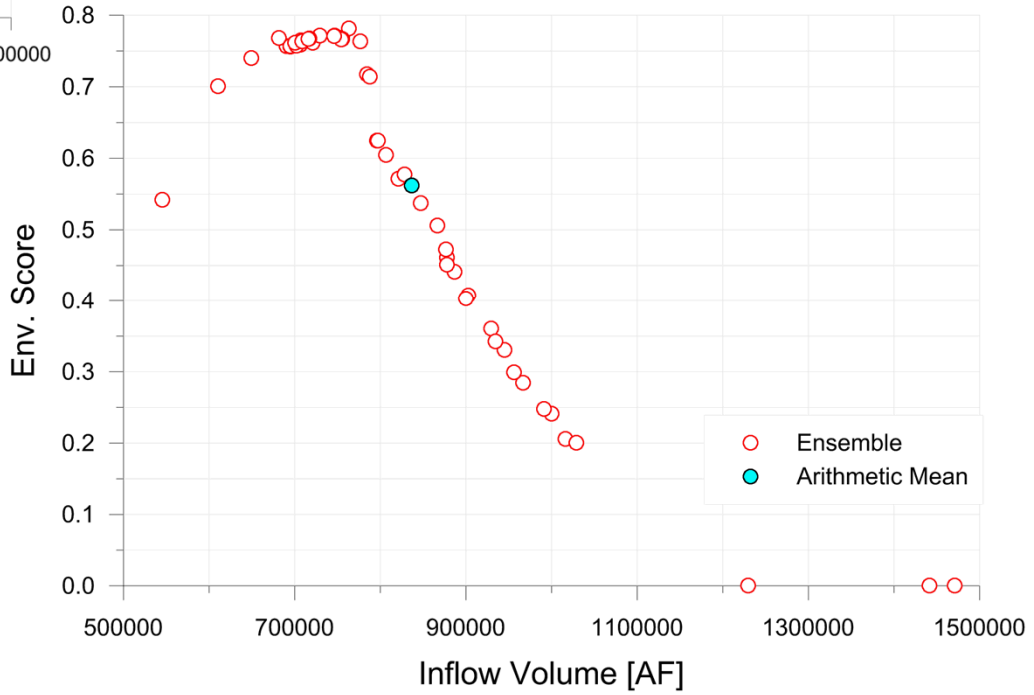
Using Ensemble Forecasts



- Revenue is monotonic w.r.t. inflow volume

- Environmental performance is more complex



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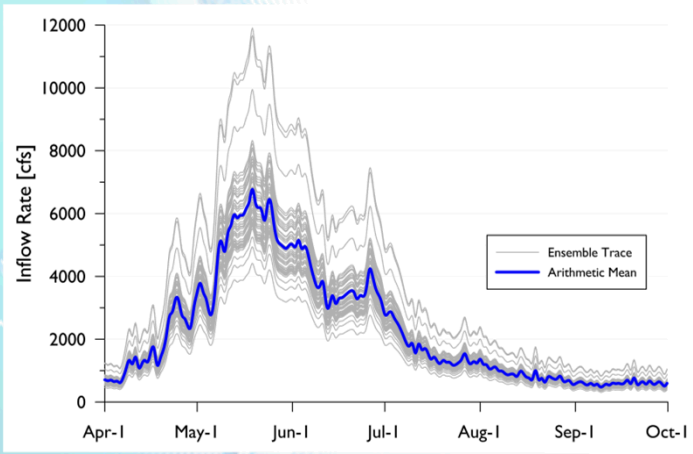
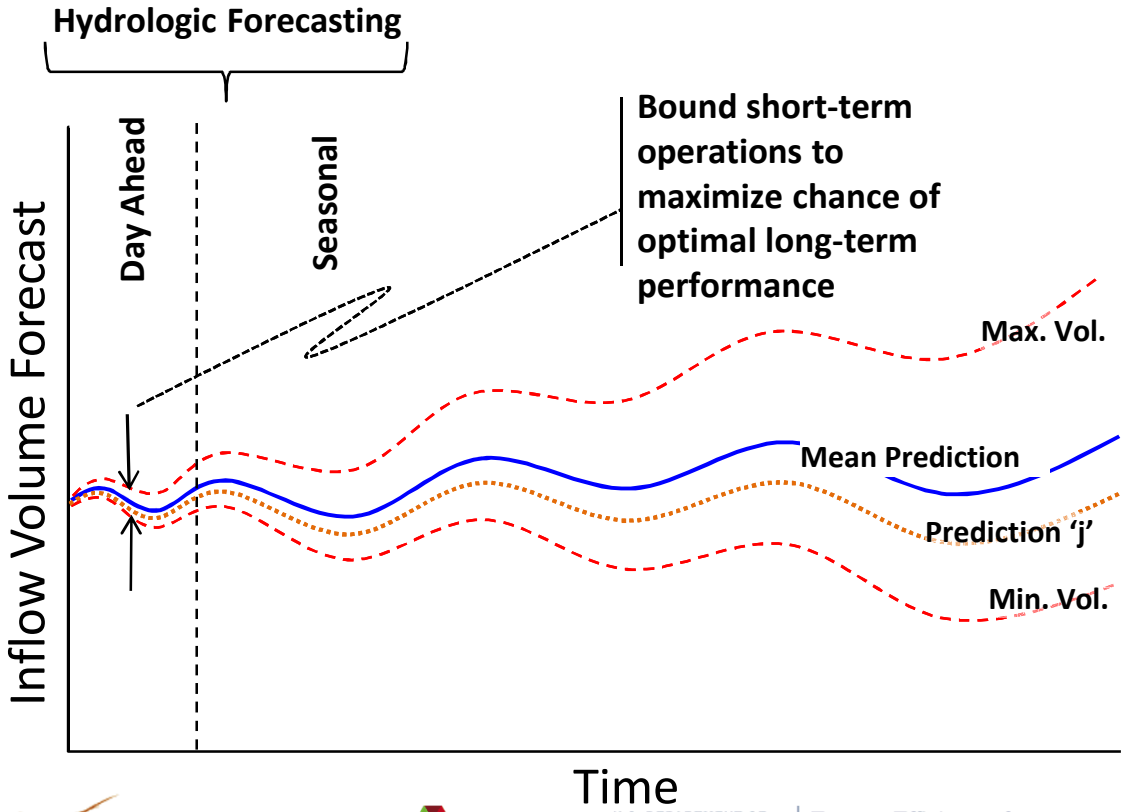
Risk and Regret

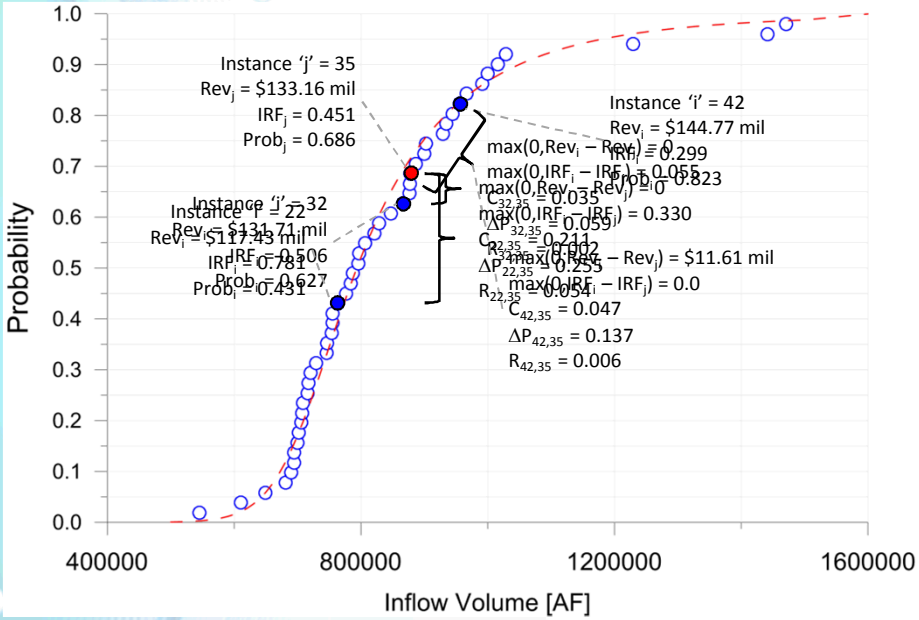
- Risk
  - Given an ensemble of ‘n’ forecasts, what is the risk of assuming forecast ‘j’ and realizing forecast ‘i’?
  - We want to minimize regret when we are wrong





Calculating Risk / Regret

- Risk
  - Given an ensemble of ‘n’ forecasts, what is the risk of assuming forecast ‘j’ and realizing forecast ‘i’?
  - We want to minimize regret when we are wrong



$$R_j = \sum_{i=1}^{n} R_{ij} = \sum_{i=1}^{n} C_{ij}\Delta P_{ij}$$

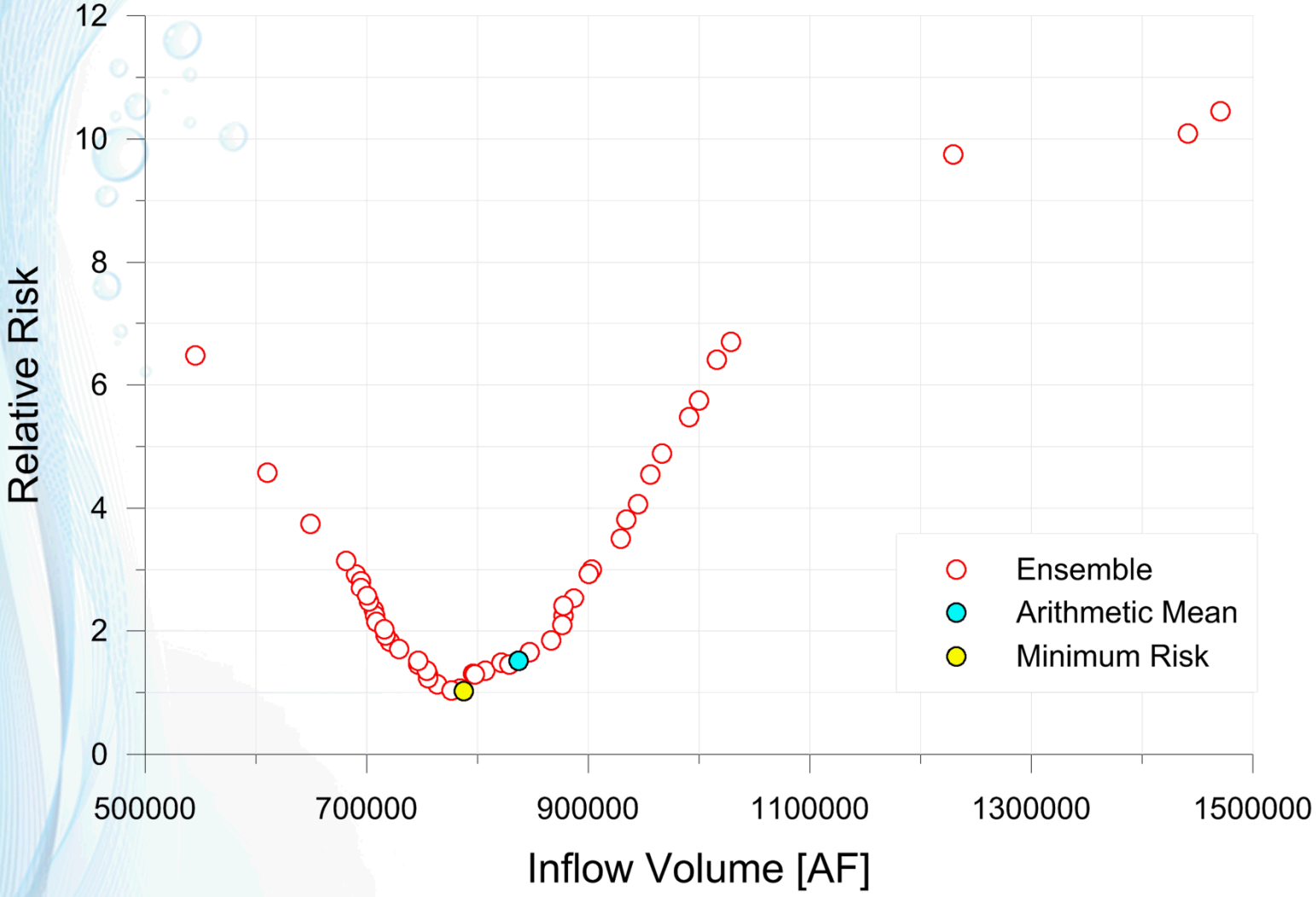
$$\Delta P_{ij} = \left| P_i - P_j \right|$$

$$C_{ij} = \left(\frac{max\left(0, Rev_i - Rev_j\right)}{Rev_{max} - Rev_{min}} + \frac{max\left(0, IRF_i - IRF_j\right)}{IRF_{max} - IRF_{min}} \right) \frac{1}{2}$$

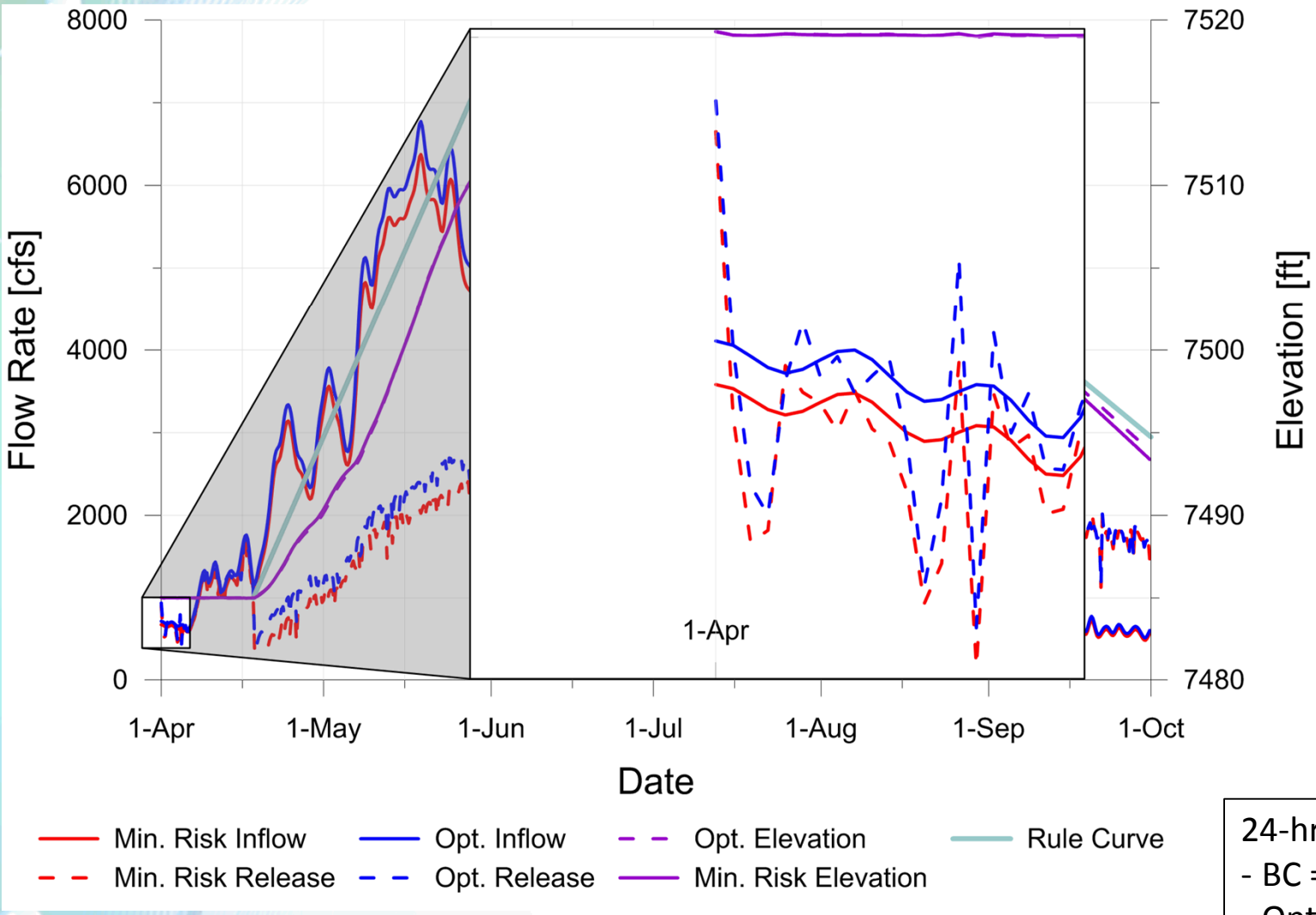
Rev$_{max}$ – Rev$_{min}$ = $122.80 mil

IRF$_{max}$ – IRF$_{min}$ = 0.781

Minimum Risk / Regret



Short-term Implications



24-hr Outflows
- BC = 1366 AF
- Opt. = 1350 AF
- Min. Risk = 1283 AF

Conclusions

- Risk is the product of the probability of an event occurring and the consequence of that event
- Regret is the difference in risk between assuming one possible future and realizing another
- Minimizing regret means minimizing our exposure to consequence/loss when we are wrong
- Using a mean of an ensemble does not include the impact of uncertainty – it misses the ‘tail events’