Reservoir Operations Analysis in the Willamette Water 2100 Project

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Willamette Water 2100 Project

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Overview

1. A request for input
2. WW2100 – Overview
3. Operations Modeling Approach
4. Reservoir Performance Metrics
5. Operations alternatives
6. Analysis of tradeoffs

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Willamette Water 2100 (WW2100)
Key questions to address

- Where are climate change and human activity most likely to create conditions of water scarcity?
- Where is water scarcity most likely to exert the greatest impact on ecosystems and communities?
- What strategies would allow communities to prevent, mitigate, or adapt to scarcity most successfully?

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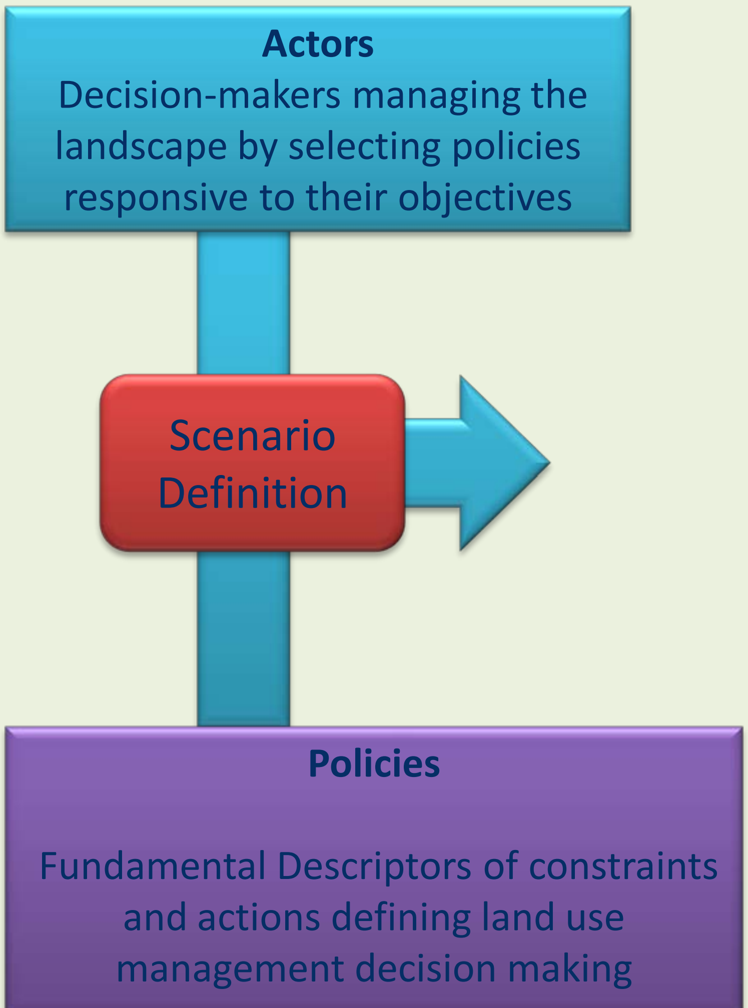
WW2100: Reservoir operations subgroup key questions to address

- How well do the Willamette reservoirs perform using current operations under future climate and demographic scenarios?

- What operations strategies, or combination of strategies are the most *robust* under future climate and demographic scenarios?

Envision – Conceptual Structure



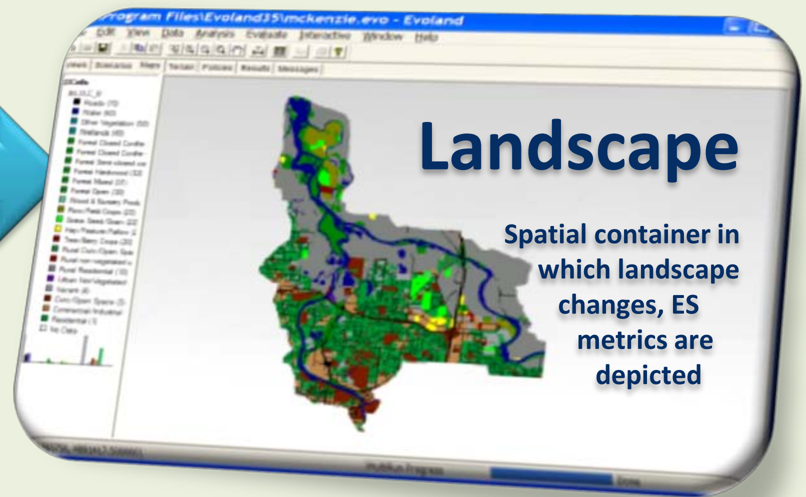
Envision – Conceptual Structure

Actors
Decision-makers managing the landscape by selecting policies responsive to their objectives

Scenario Definition

Multiagent Decision-making

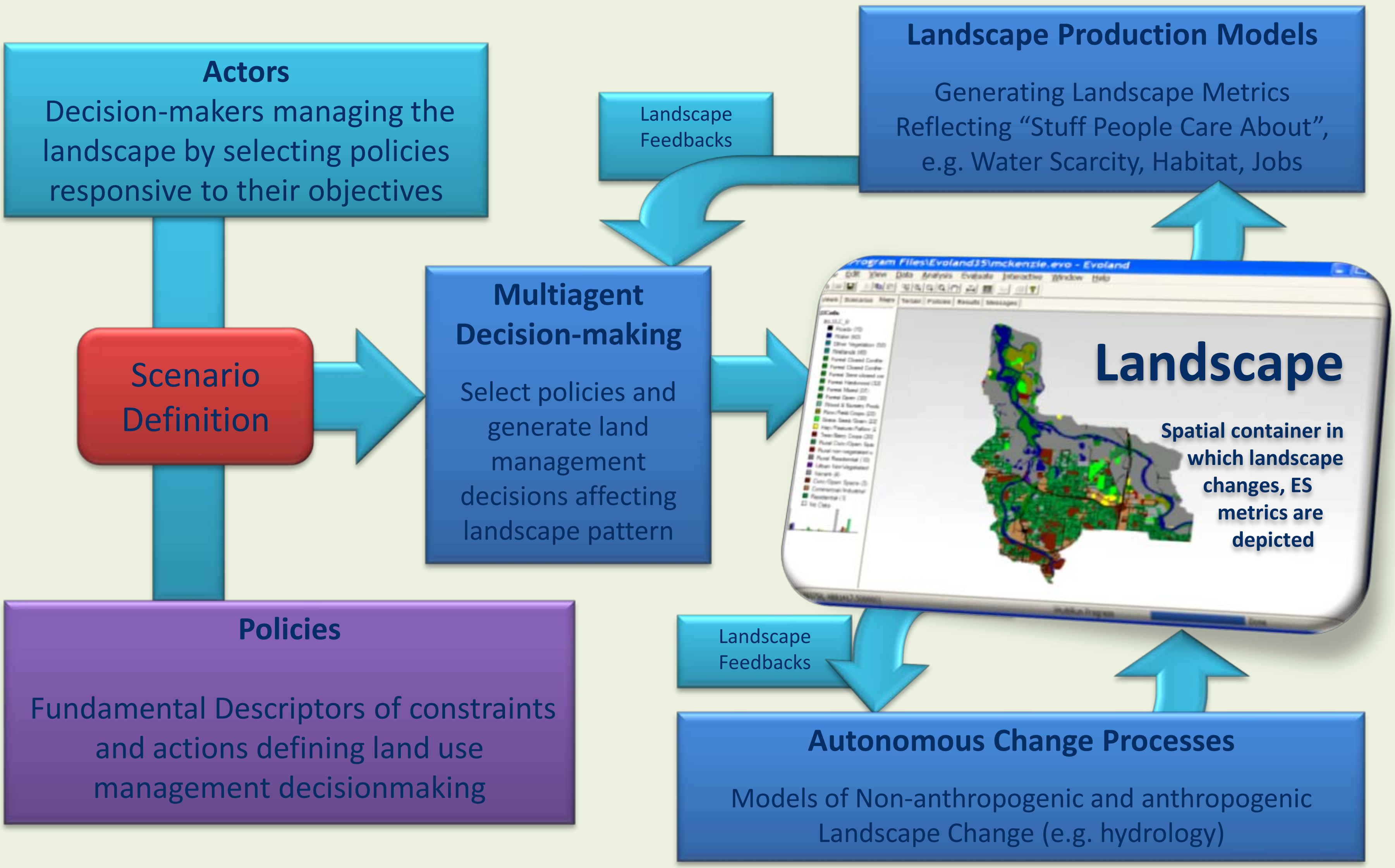
Select policies and generate land management decisions affecting landscape pattern



Policies

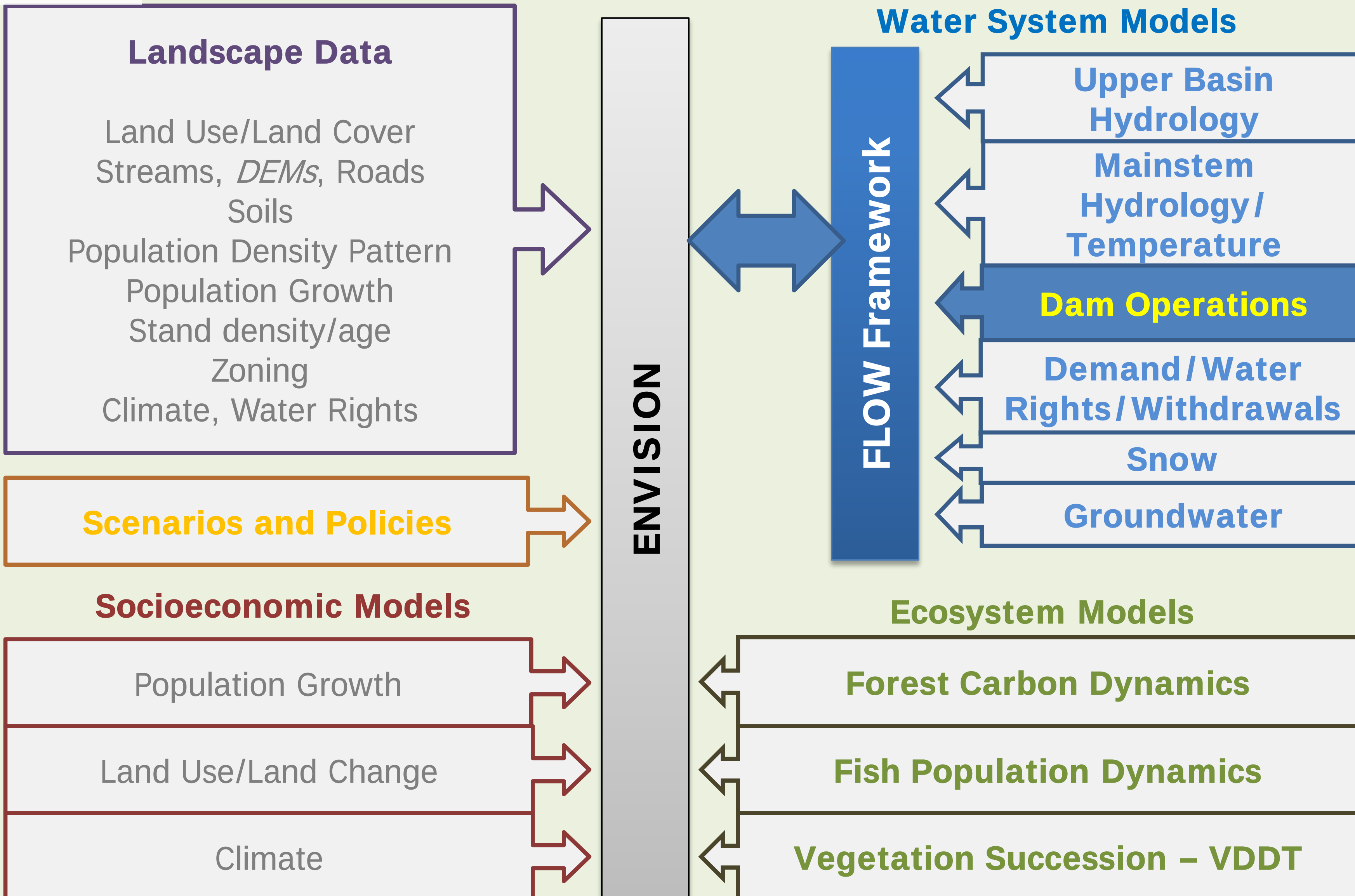
Fundamental Descriptors of constraints and actions defining land use management decisionmaking

Envision – Conceptual Structure

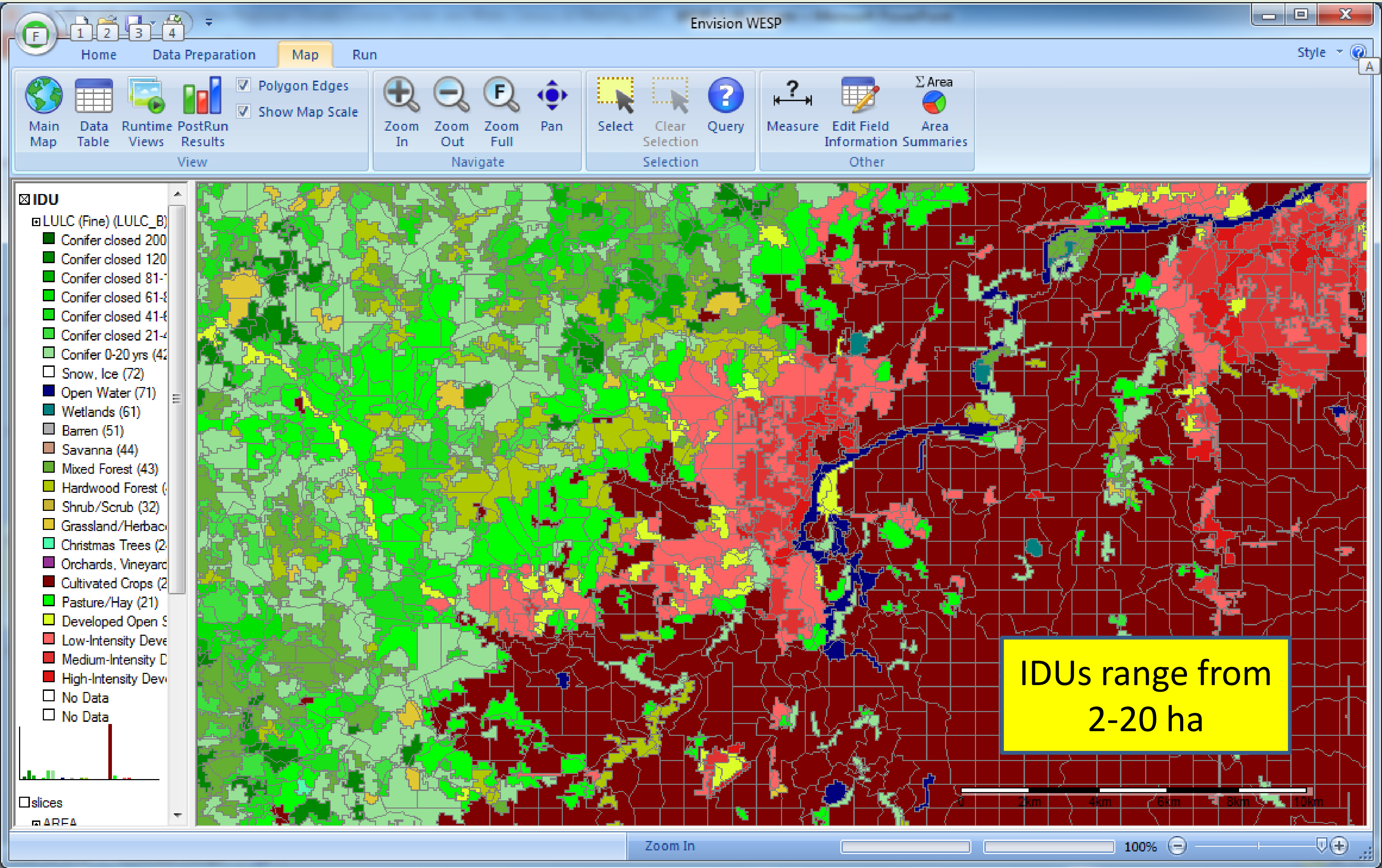


Willamette
Water 2100
Project

Envision Willamette 2100 v2 (Summer 2012)



Envision – Integrated Decision Units



Envision Scenario Development

Climate Change Magnitude	+	Spatial Patterns of Growth and Development	=	**Alternative Future Landscapes**
Severe	+	Low Density	=	
Moderate	+	Moderate Density	=	
Mild	+	High Density	=	

Reservoir operations: Representation within Envision

- Based on HEC-ResSim:
  - Current operations rule sets from the most recent Willamette ResSim model used by USACE (Dec 2011)
- Reservoir operations:
  - represented separately from other hydrologic elements (e.g. - routing, inflow)
- Calibration:
  - HEC-ResSim will be used to calibrate reservoir operations representation within Envision (using ResSim inflow data and routing assumptions)

Input Data

- Climate:
  - Current implementation: Historic data (Maurer et al. 2002) with future changes using the delta method
  - Future implementation: downscaled AR5 climate model results
  - Daily values of: air temperature, precipitation, humidity and wind speed
- Hydrology:
  - Rainfall/runoff model will generate inflow values to reservoirs
  - Snow model will represent storage/runoff processes associated with snowpack
- Land Use
  - From canonical scenarios chosen for the WW2100 project
- Model time step:
  - Daily

Reservoir operations: Analysis approach

1. **Identify metrics** to define system performance in the future

2. **Evaluate performance of current operations**
   a) under future climate change and land use scenarios
   b) use results as a baseline to identify shifts in performance metrics

3. **Investigate modified operations**
   a) Identify and evaluate **shifted/variable guide curves** at major dams to address lack of performance
   b) Evaluate the use of **landscape feedbacks** to improve efficiency of water use in the conservation season

4. **Examine tradeoffs** that arise between competing water uses for each analysis

Reservoir operations performance metrics

- Metric development:
  - Based on current targets (flow targets from the 2008 BiOP, control point channel capacities, etc..)
  - Attempt to encompass most relevant management objectives (both today and in future)
  - No 'a priori' weighting of metrics

- Formulated to address:
  a) The duration of failures: **reliability**
  b) The magnitude of failures: **vulnerability**

- Paired metrics (reliability/vulnerability) categorized by relevant management objectives:
  - Flood Control
  - Environmental Flows
  - Recreation
  - Hydropower
  - Water Supply

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Reservoir Performance Metrics: Environmental Flows

Performance Metric	Time Unit	Location(s)
Vulnerability of spring instream flow targets for outmigrating juvenile fish	Bi-monthly	Willamette River at Salem
Volumetric reliability of meeting minimum spring flow targets	Bi-monthly	Willamette River at Salem
Vulnerability of minimum summer/fall flow targets	Monthly	Willamette River at Salem
Volumetric reliability of meeting minimum summer/fall flow targets	Monthly	Willamette River at Salem
Vulnerability of temperature targets	Monthly	All control points
Time Reliability of maintaining temperature targets	Monthly	All control points

Reservoir Performance Metrics: Flood Control

Performance Metric	Time Unit	Location(s)
$3D5Y_{Dec\text{-}Jan}$; Probability of capturing a 3 day, 5 year event	Daily	Individual Reservoirs
$3D100Y_{Dec\text{-}Jan}$; Probability of capturing a 3 day, 100 year event	Daily	Individual Reservoirs
Vulnerability to Flooding (Maximum volumetric severity of system failures at a given control point)	Annual	All control points

Reservoir Performance Metrics: Water Supply

Performance Metric	Time Unit	Location(s)
Vulnerability of water supply	Monthly	Basin-wide
Volumetric reliability of water supply	Monthly	Basin-wide

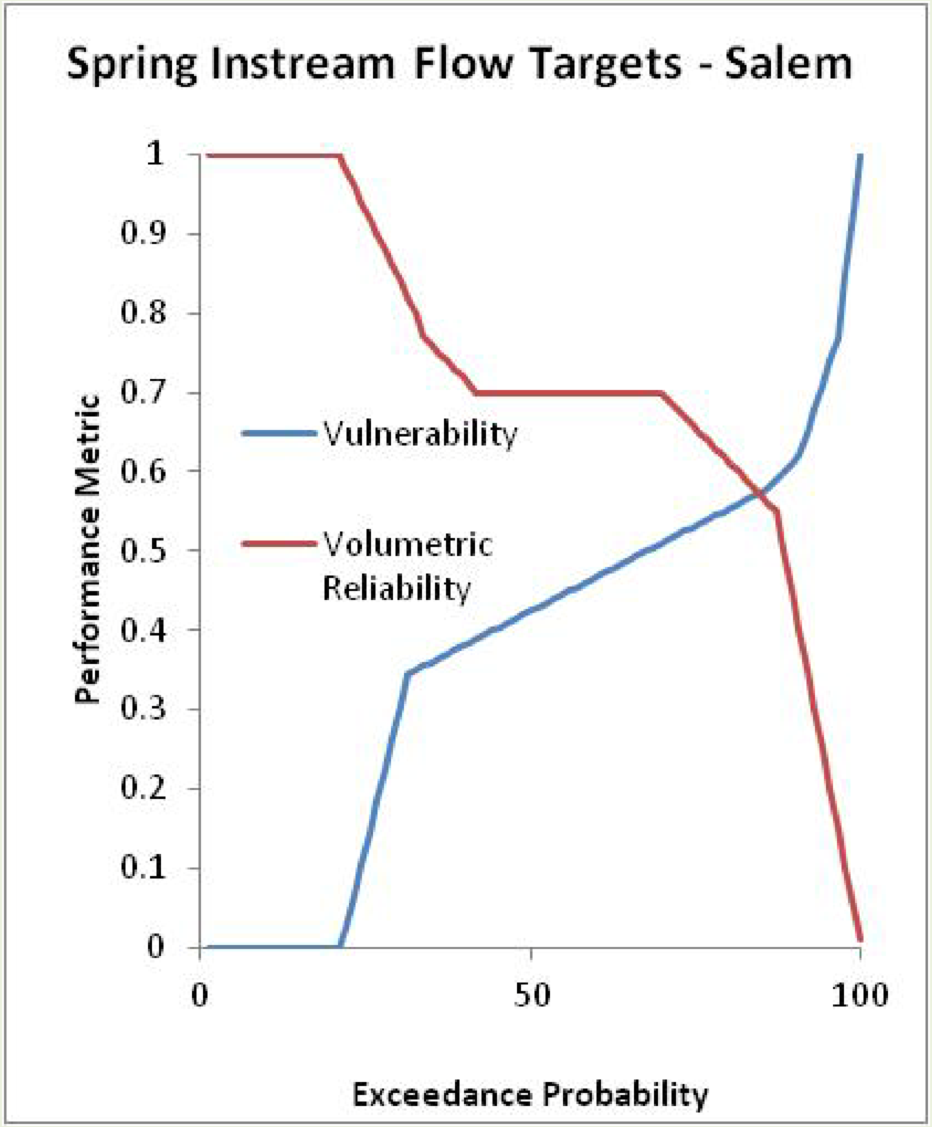
Reservoir Performance Metrics: Hydropower

Performance Metric	Time Unit	Location(s)
Time Reliability of Firm Load	Annual	Basin-wide
Power production efficiency	Monthly	Basin-wide

Reservoir Performance Metrics: Recreation

Performance Metric	Time Unit	Location(s)
Time Reliability of target recreation levels	Annual	Individual Reservoirs
Vulnerability of target reservoir recreation levels	Annual	Individual Reservoirs

Evaluate performance of current operations



Adapted from Georgakakos et. al. 2011

Analysis Steps:

1. Run the model repeatedly for the future time period
2. Calculate performance metrics at each reservoir or control point
3. Examine future performance probabilistically

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Investigate Modified Operations: Generation of Alternatives

1. Perform a sensitivity analysis using each future landscape trajectory
   - Identify high priority reservoirs for operational changes and develop variable or alternative guide curves for only these?

     (high priority = highly sensitive in one scenario or sensitive in all scenarios)

2. Minimize performance failures using each future landscape trajectory
   - Allow releases to vary within a particular range
   - Minimize performance failures at each time step
   - Modeled releases become new guide curves in future operations scenarios

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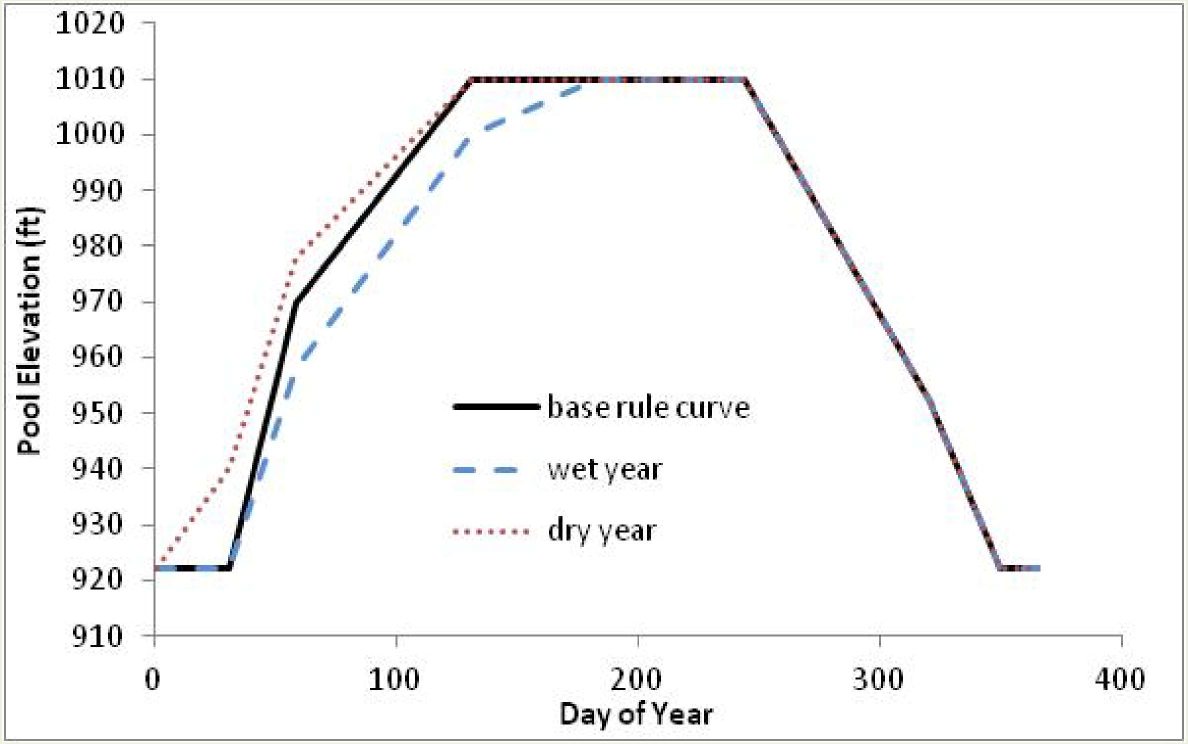
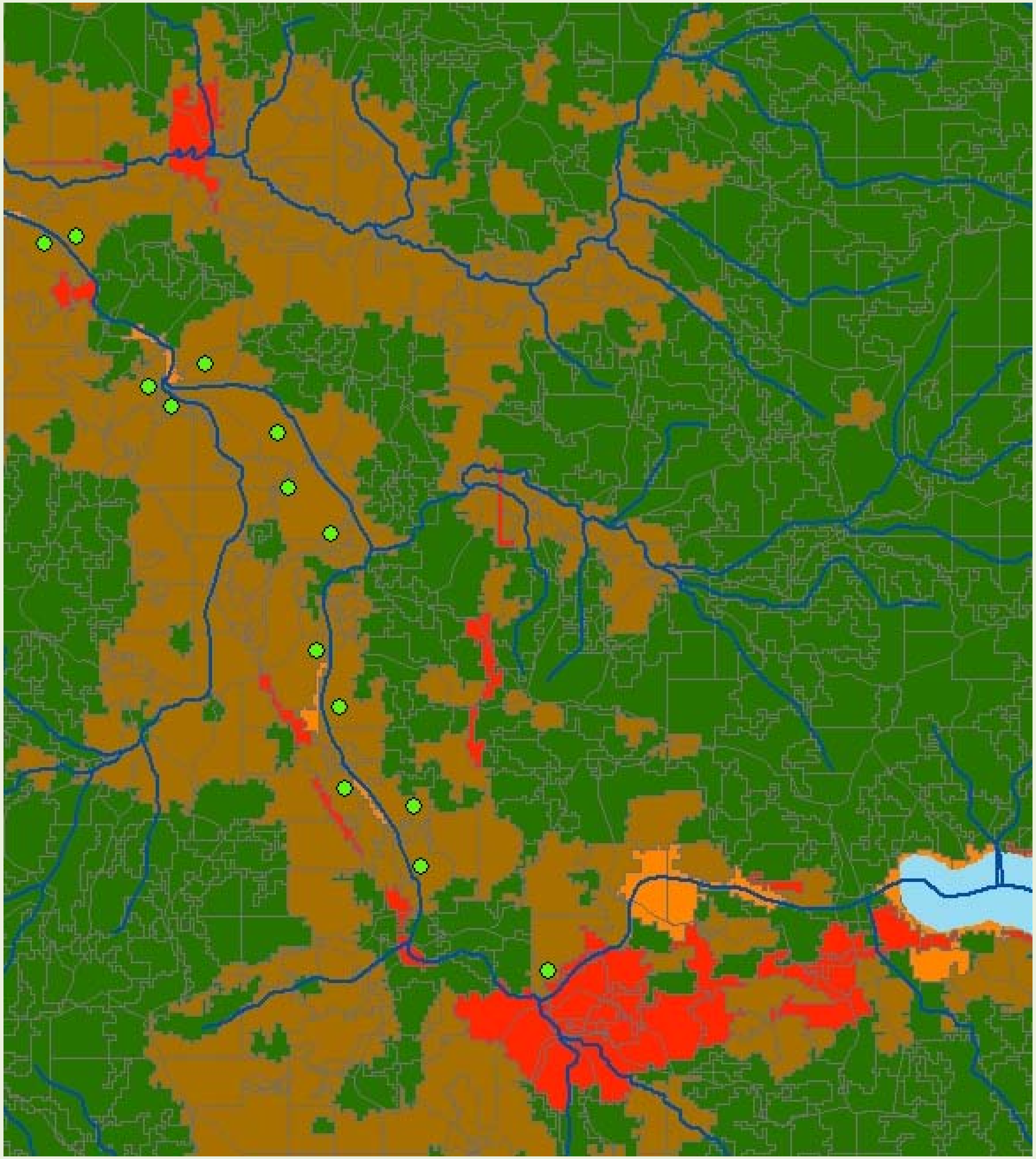
Operations alternatives: Variable rule curves



Rule curve updated monthly based on medium and long range forecasts



Operations alternatives: Incorporating Landscape Information

Example: irrigation

- Release decisions to incorporate information on water withdrawals from the preceding timestep

- Weekly, monthly and seasonal forecasts incorporated to release decision process during the summer

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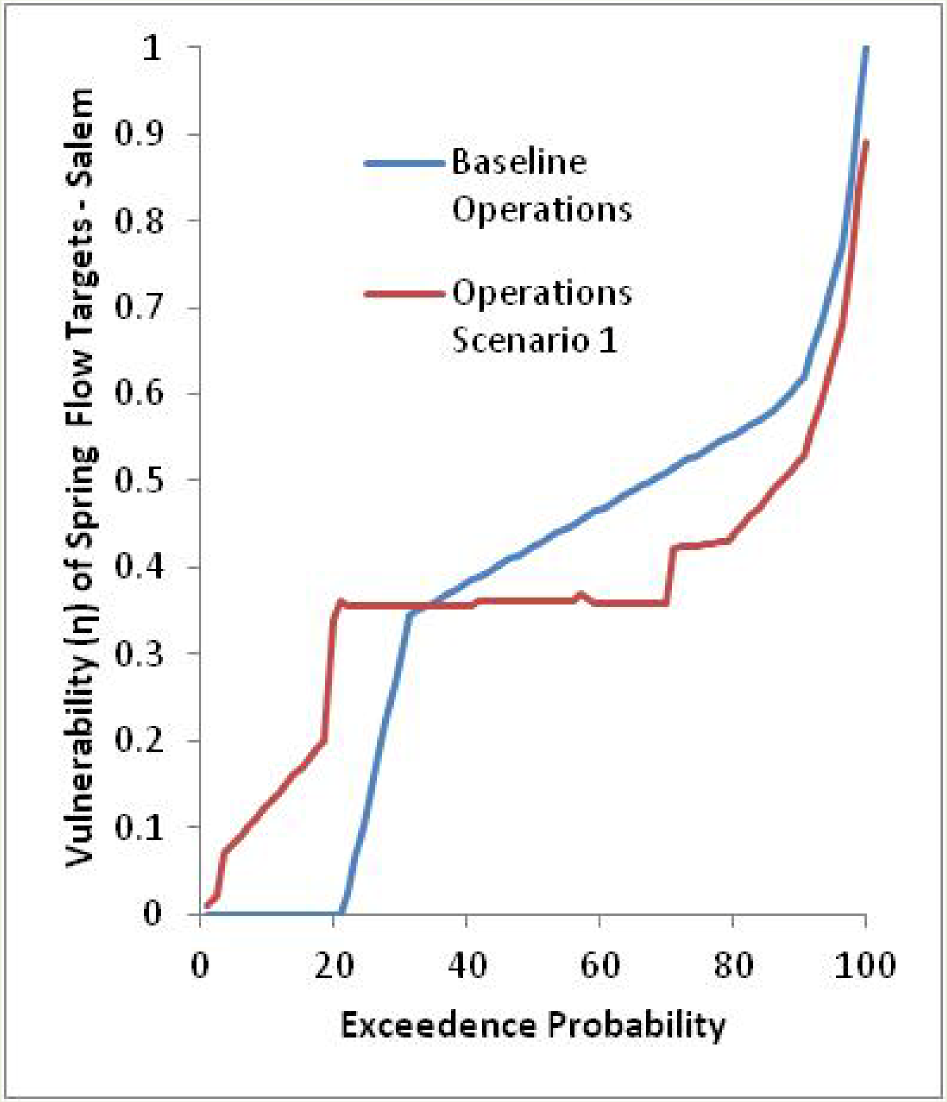
Analysis of operations performance



Adapted from Georgakakos et. al. 2011

Analysis Steps:

1. Run the model repeatedly for the future time period
2. Calculate performance metrics at each reservoir or control point
3. Examine performance probabilistically
4. **Compare alternative operations strategies**

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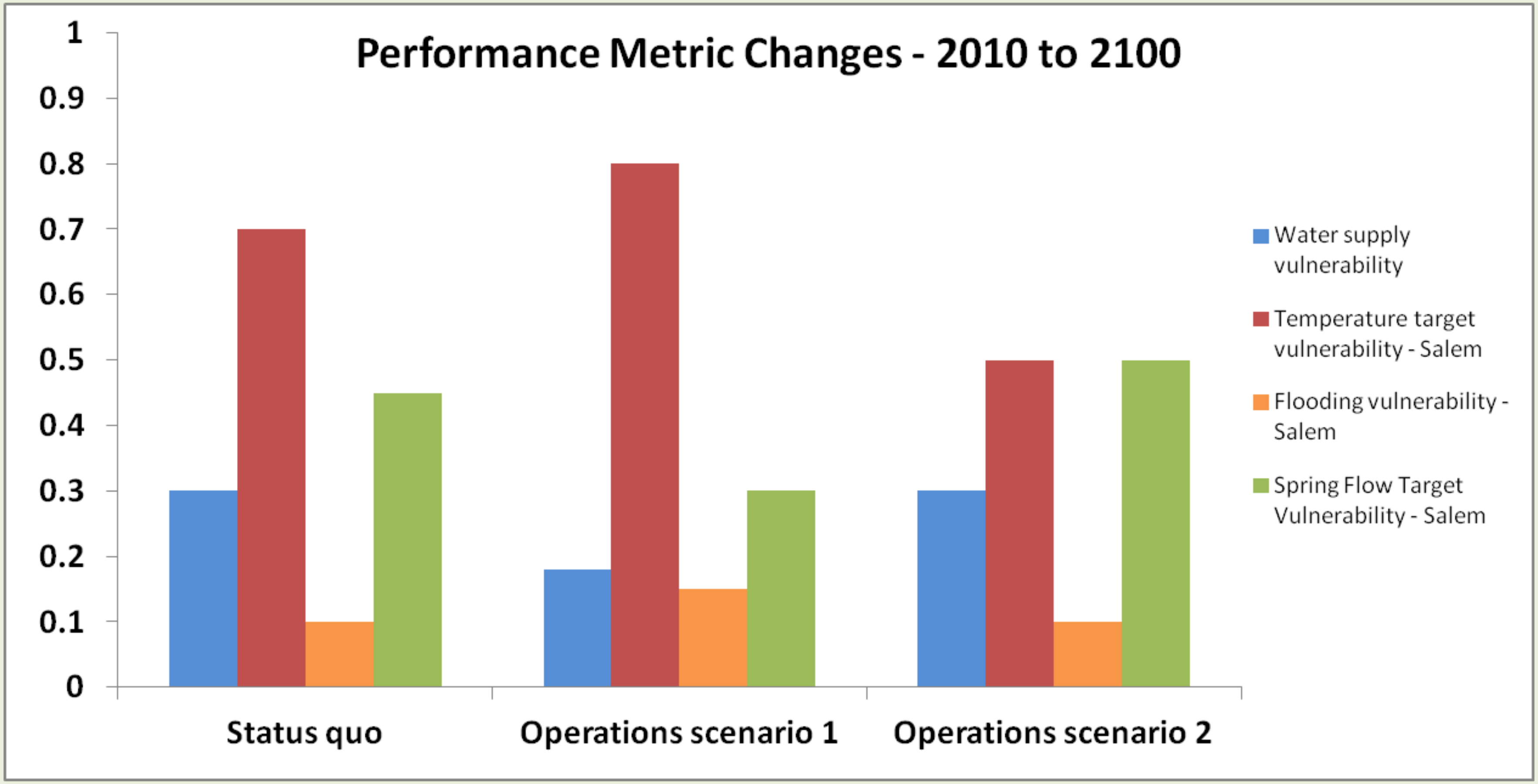
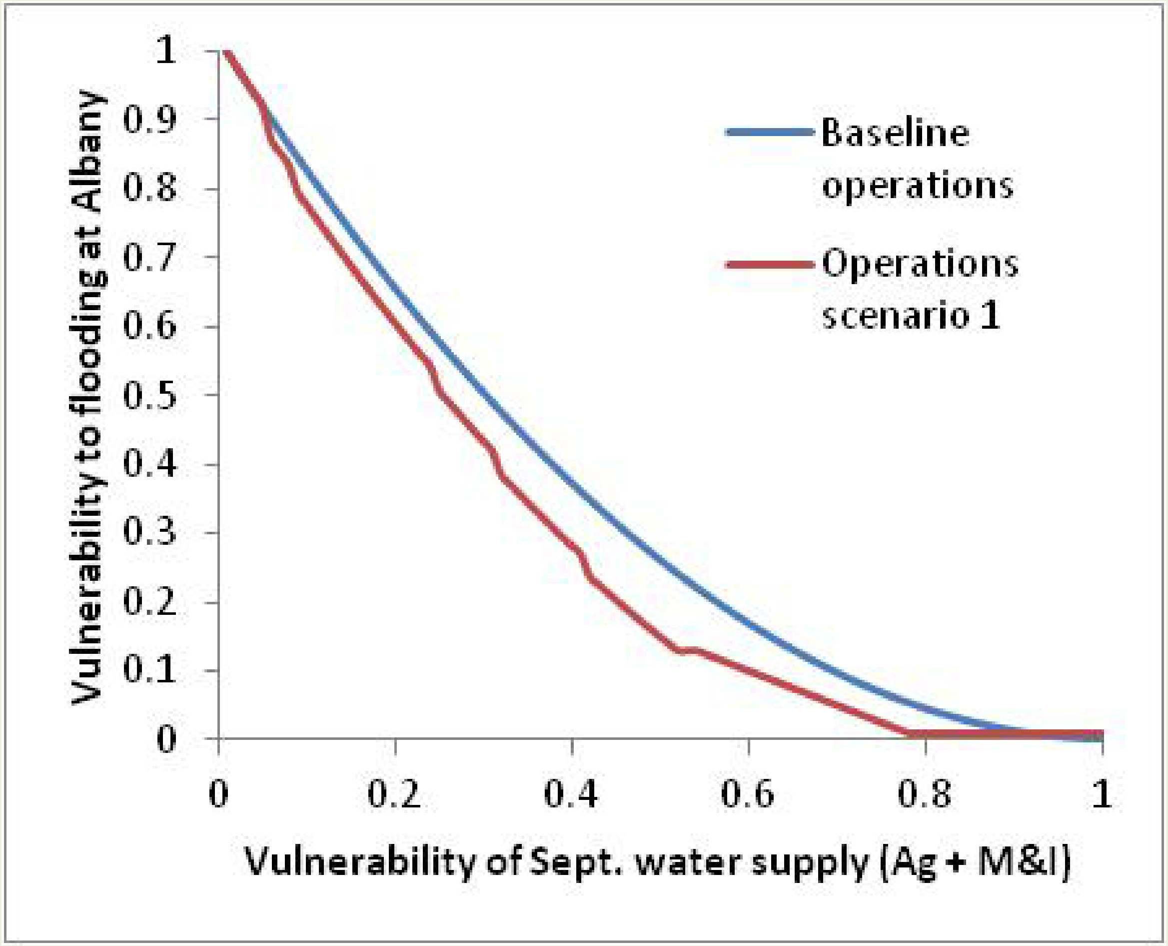
Analysis of tradeoffs



Analysis of tradeoffs



Comparison of metrics for competing water uses:

- Ranked metrics for 2 alternative scenarios compared
- Weighting (position on the pareto front) determined by decision maker

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A request for input and feedback

- We want to make this project as useful as possible for a wide range of water management agencies.
  - What questions are we missing here that need to be addressed?
  - Additional performance metrics?
  - Alternative operations scenarios?

- Please contact:
  - coxma@engr.orst.edu
  - desiree.tullos@oregonstate.edu

- More Project Information:
  - WW2100 - **http://water.oregonstate.edu/ww2100**
  - Envision **–** **http://envision.bioe.orst.edu**

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Discussion and questions

<u>Acknowledgements</u>

- John Bolte
- Kellie Vache
- Kara DiFrancesco, Cris Mateus, Gordon Grant, Allison Danner

Willamette Flood of 1996 – Photo: NWS Portland and USACE

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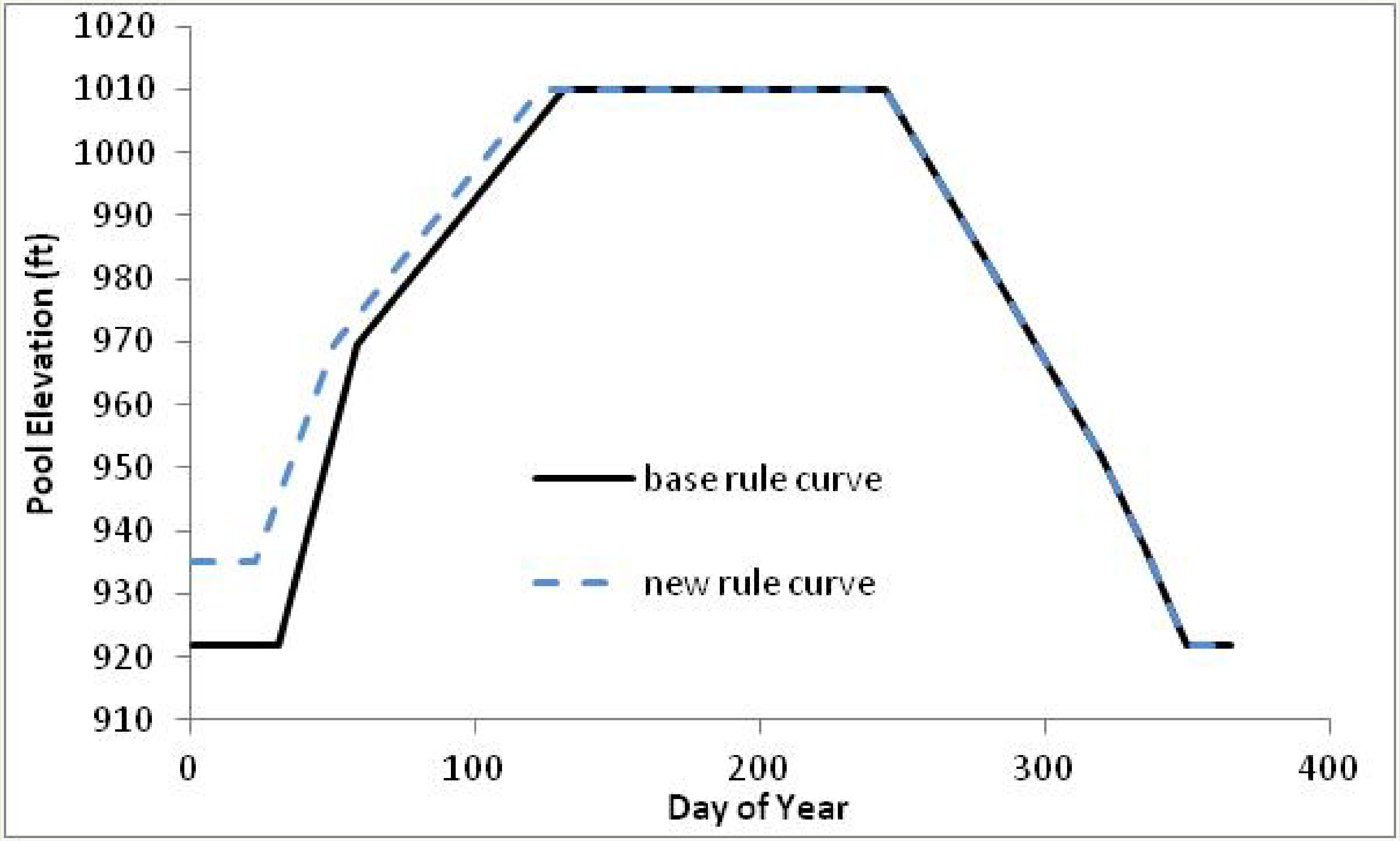
Extra Slides

Operations alternatives: Shifted rule curves



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Performance measure	Relevant management objective	Time unit	Equation/ Units	Reference
Vulnerability of spring instream flow targets for outmigrating juvenile fish	Environmental Flows	Bi-monthly	$\eta' = \frac{\sum_{j=1}^{f_s} \max(s_j)}{f_s}$ η'= vulnerability (m^3) f_s= # of cons. Failures s_j= vol. shortfall (m^3) $\eta = \frac{\eta'}{D_f}$ η= dimensionless vulnerability Df = target demand	Hashimoto et. al. 1982; McMahon et.al 2005
Volumetric reliability of minimum spring flow targets	Environmental Flows	Bi-monthly	volumetric reliability = $\frac{\text{(volume of water supplied)}}{\text{(target demand during the time period)}}$	Hashimoto et. al. 1982; McMahon et.al 2005