Many Objective Analysis to Optimize Pumping & Releases in a Multi-Reservoir Water Supply Network

Rebecca Smith[1,2], Joseph Kasprzyk[1], Edith Zagona[1,2], Laura Blaylock[3], John Carron[4], & Nick Mander[4]
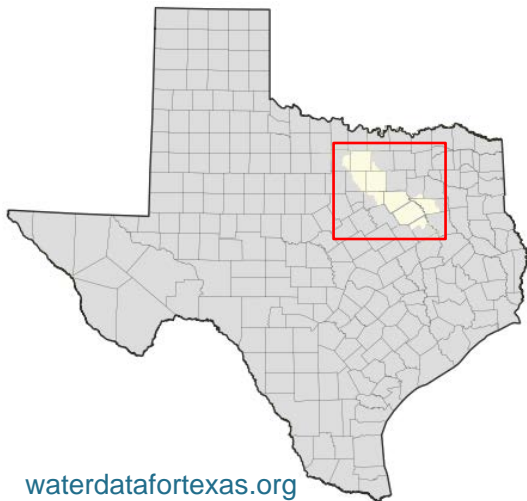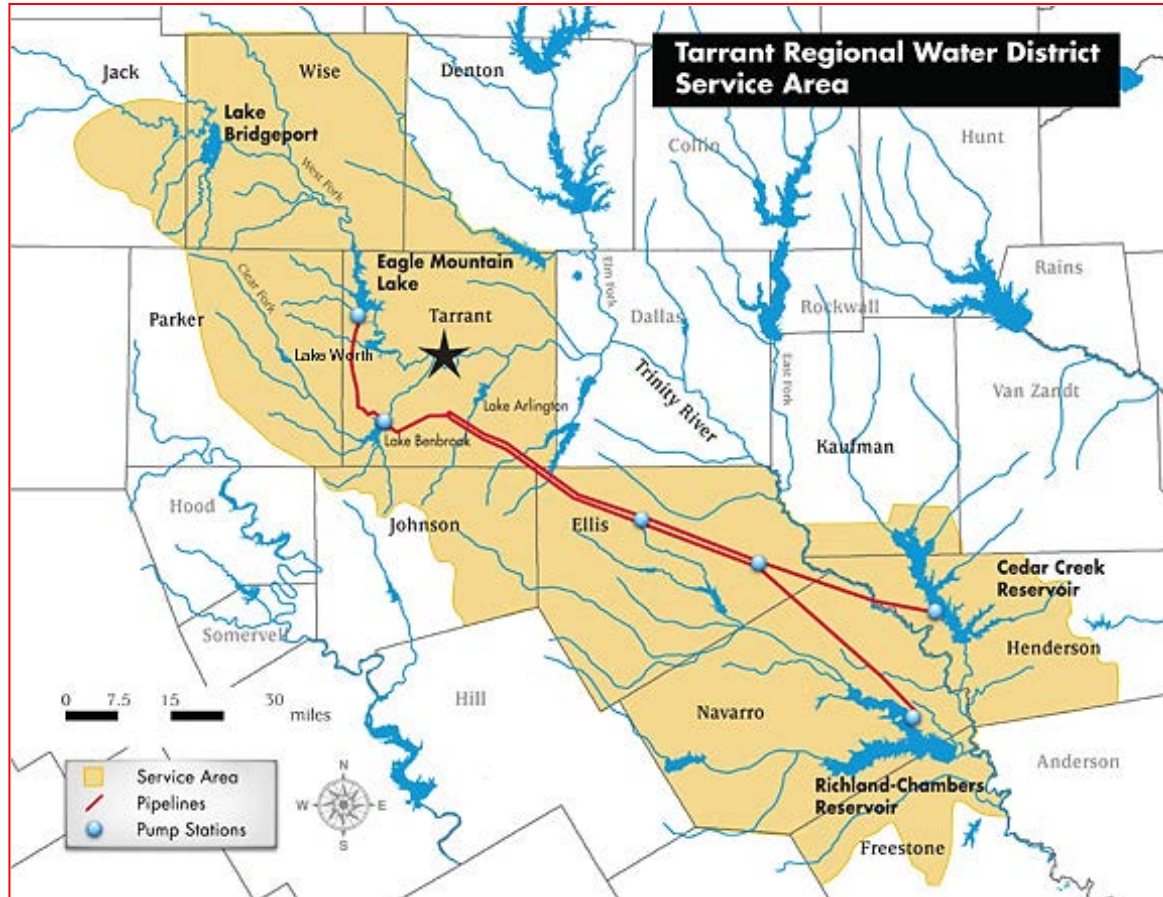
1. Civil, Env. and Arch. Engineering, University of Colorado Boulder
2. Center for Advanced Decision Support for Water and Environmental Systems
3. Tarrant Regional Water District   4. Hydros Consulting, Inc.

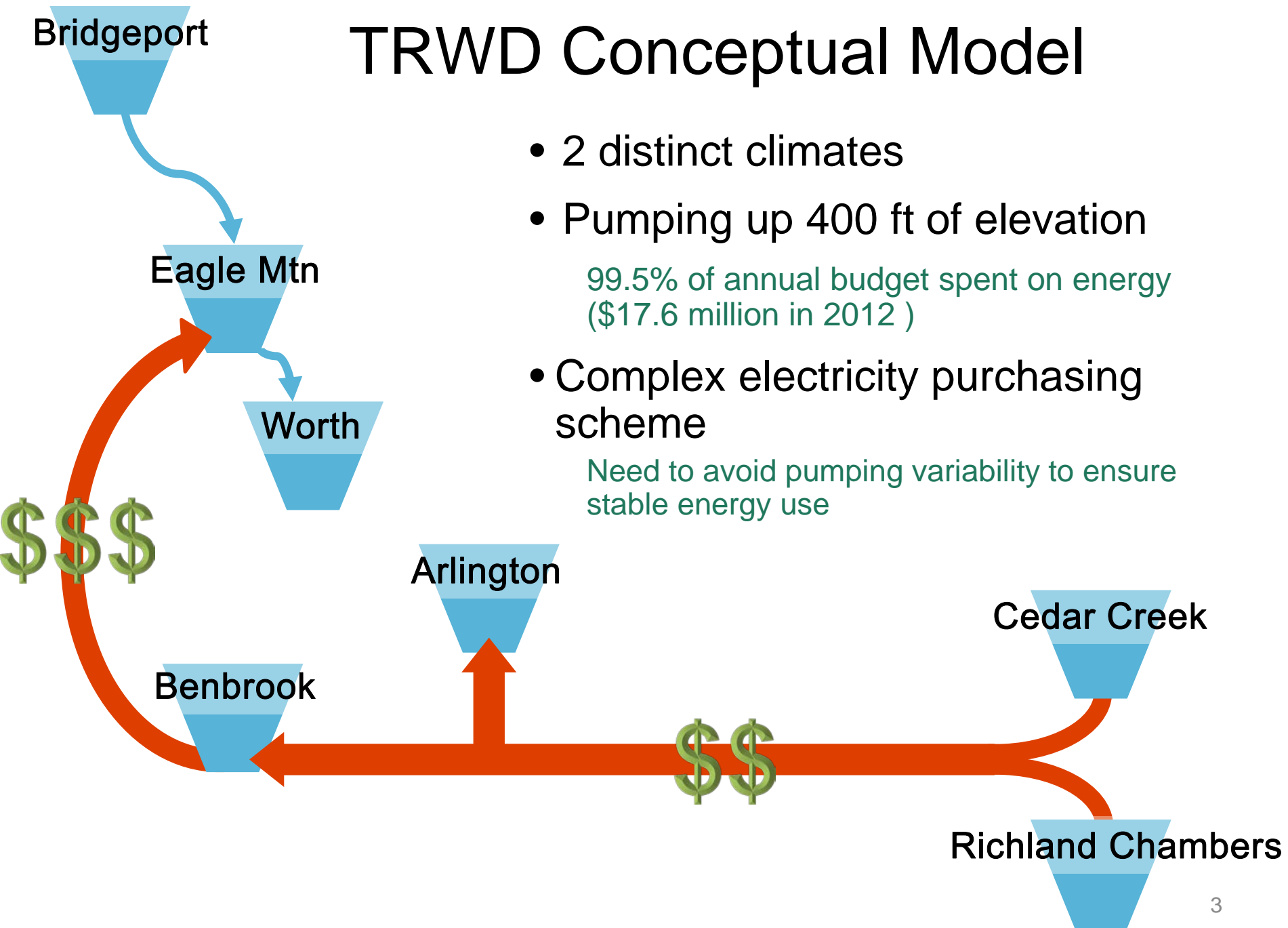**RiverWare User Group Meeting**
February 4, 2015

Tarrant Regional Water District (TRWD)

- 2nd largest water supplier in TX

- Provides raw water to 30 water treatment plants

- Serves >1.8 million people in 11 counties
  - Ft Worth & Arlington

trwd.com

waterdatafortexas.org

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TRWD Conceptual Model

Bridgeport

Eagle Mtn

Worth

$$$

Benbrook

Arlington

Cedar Creek

$$

Richland Chambers

- 2 distinct climates
- Pumping up 400 ft of elevation
  99.5% of annual budget spent on energy ($17.6 million in 2012)
- Complex electricity purchasing scheme
  Need to avoid pumping variability to ensure stable energy use
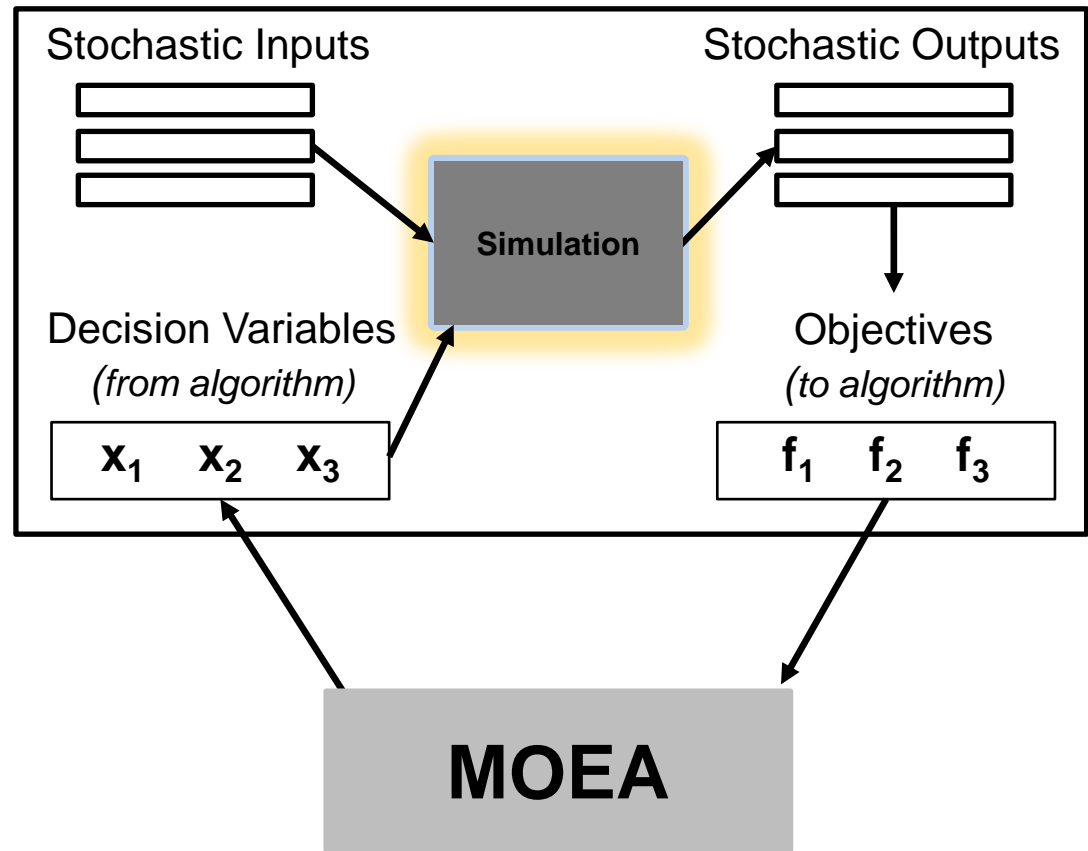
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TRWD RiverWare Model
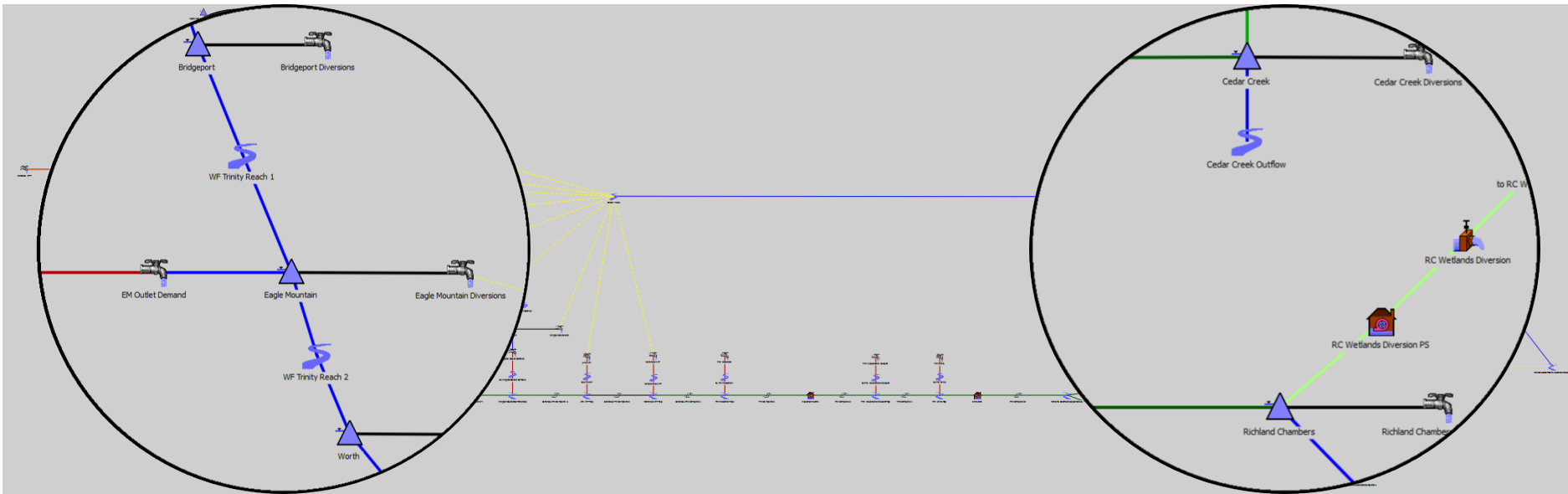
- Model any basin at multiple timesteps
- View detailed system performance over time
- Customize operational policy by writing rules
- Simulate infrastructure & mgmt alternatives

- > 400 custom rules & functions
- > 50 accounts to track "paper water"
- Stochastic hydrology & demand inputs
- Climate forecasting

Multiobjective Evolutionary Algorithms (MOEAs)

- Efficiently suggest and evaluate mgmt solutions

- Optimize multiple conflicting objectives- no aggregation!

- Our algorithm: **Borg** [1]

[1]Hadka, D & Reed, P.M. (2013). Borg: An auto-adaptive many-objective evolutionary computing framework. *Evolutionary* Computation, 21(2), 231-259.
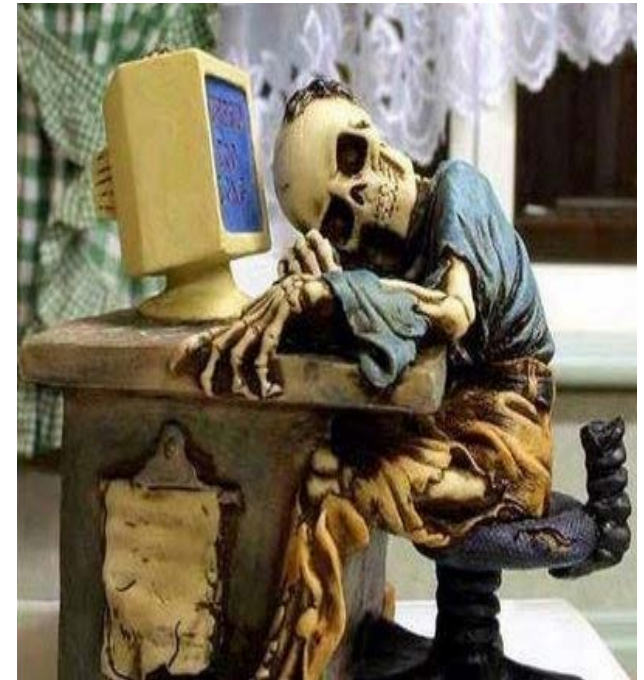
Computational Experiment

- Optimized by embedding RiverWare model in MOEA search

- 1 year simulation, daily timestep

- NFE ~ 3000

    Based on real-time visualizations of search progress

    ~4 days on a 12-core Windows computer

    Time per evaluation: 1 min 45 sec

- Limiting hydrologic traces: stressed & surplus sets chosen based on system response
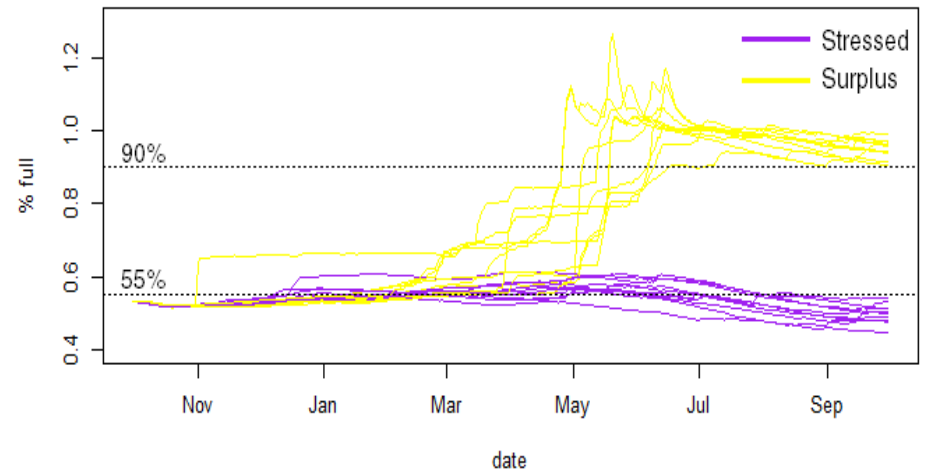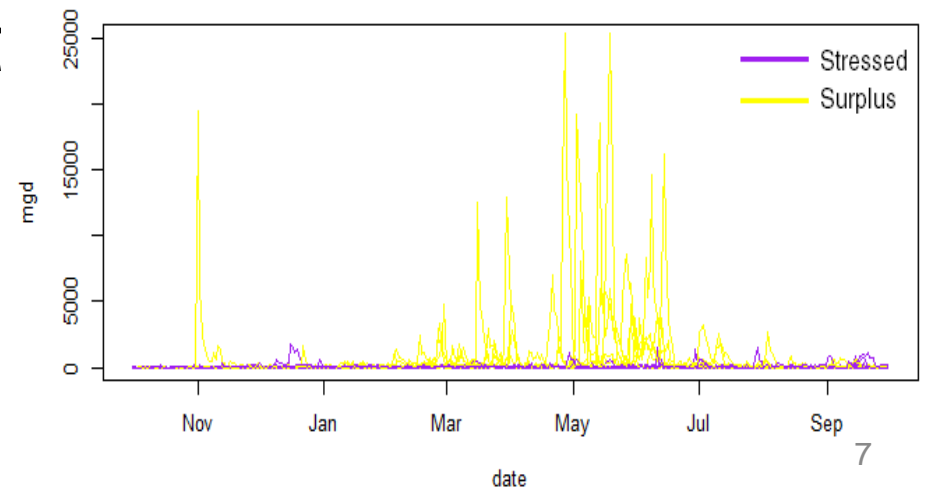
mwomercs.com

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Choosing Hydrologic Ensembles

- ## West Fork % Full

  combined % full of Bridgeport & Eagle Mtn conservation pools

- ## West Fork % Full on final day of 100 traces under *baseline* mgmt

- ## Mean +/- 1 sd

  55% ≤ "average" ≤ 90%

WF % Full 10 Stressed & 10 Surplus Traces

WF Inflows 10 Stressed & 10 Surplus Traces

Bridgeport

Balancing
Bridgeport Zones (3)
Eagle Mtn Zones (3)

Decision Variables
(24)

Eagle Mtn

Supplementing
Eagle Mtn Triggers (9)
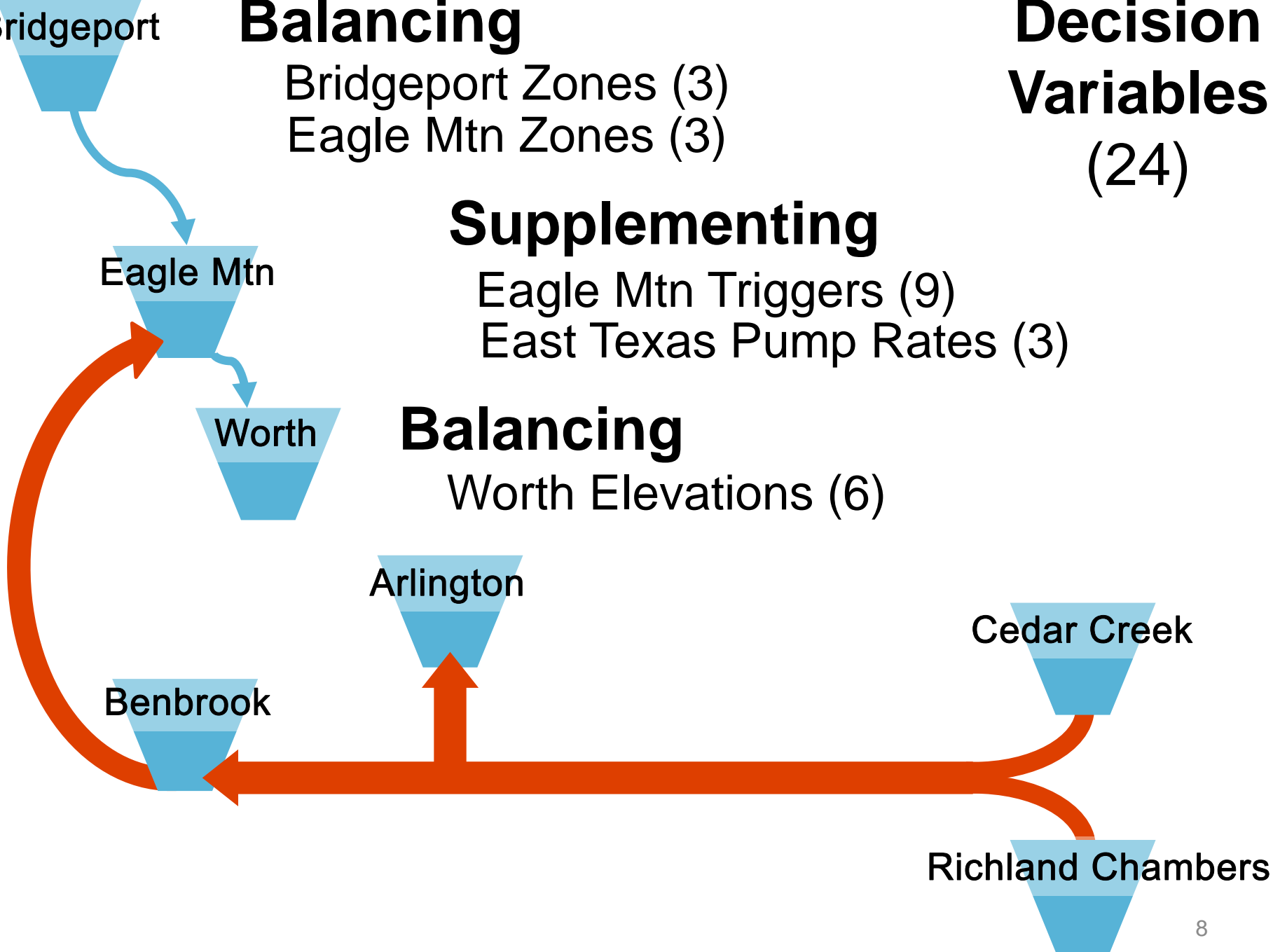East Texas Pump Rates (3)

Worth

Balancing
Worth Elevations (6)

Arlington

Cedar Creek

Benbrook

Richland Chambers

Systemwide Objectives

high supplement
high pump
spill
pump var

Minimize Occurrence
Minimize Value

Reservoir Objectives

$rel_{Bridgeport}$ 811.0 ft
$rel_{EagleMtn}$ 644.1 ft
rel_{Worth} 590.0 ft

Maximize elevation reliability

Bridgeport
Eagle Mtn
Worth
Arlington
Cedar Creek
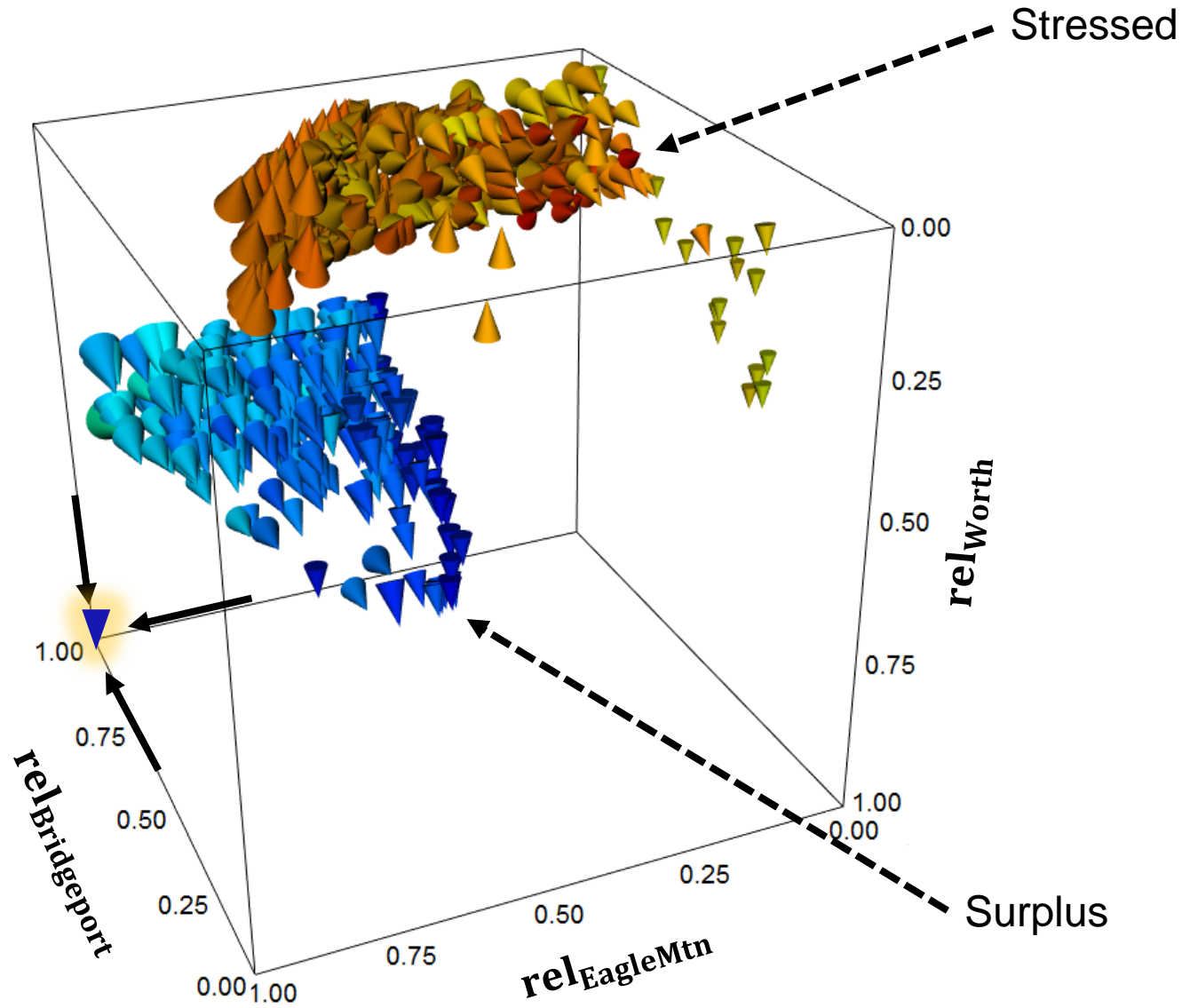Benbrook
Richland Chambers

Stressed & Surplus Results
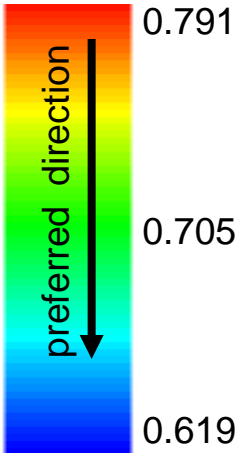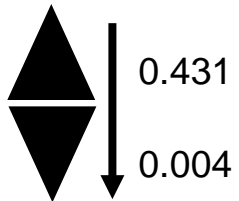
Stressed & Surplus, 360°
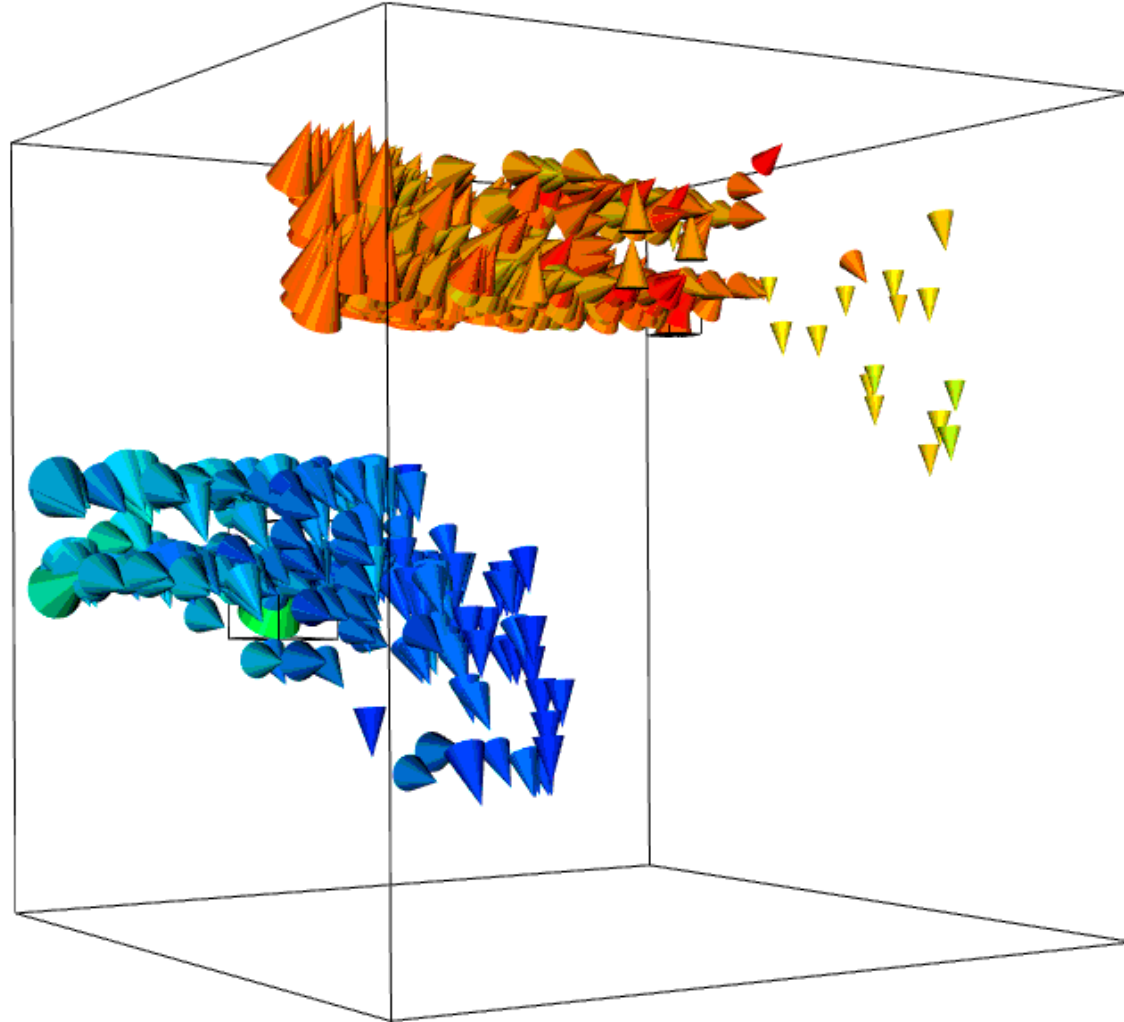
Stressed Results

high pump
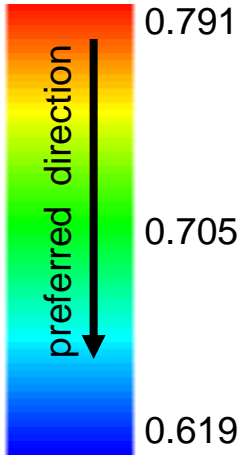
0.791

preferred direction

0.705

0.619

high supplement

0.431

0.004

pump var

79705

44763

Favor
Bridgeport

Favor
Eagle Mtn

Favor
Worth

Transparency

high pump > 0.65

rel_{Worth}

0.020

0.120

0.220

0.320

0.420

0.000

0.019

0.380

0.570

0.760

0.310

0.465

0.620

0.775

0.930

$rel_{Bridgeport}$

$rel_{EagleMtn}$

12
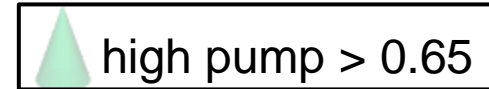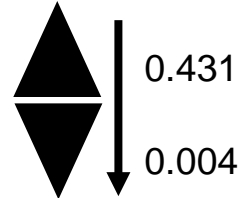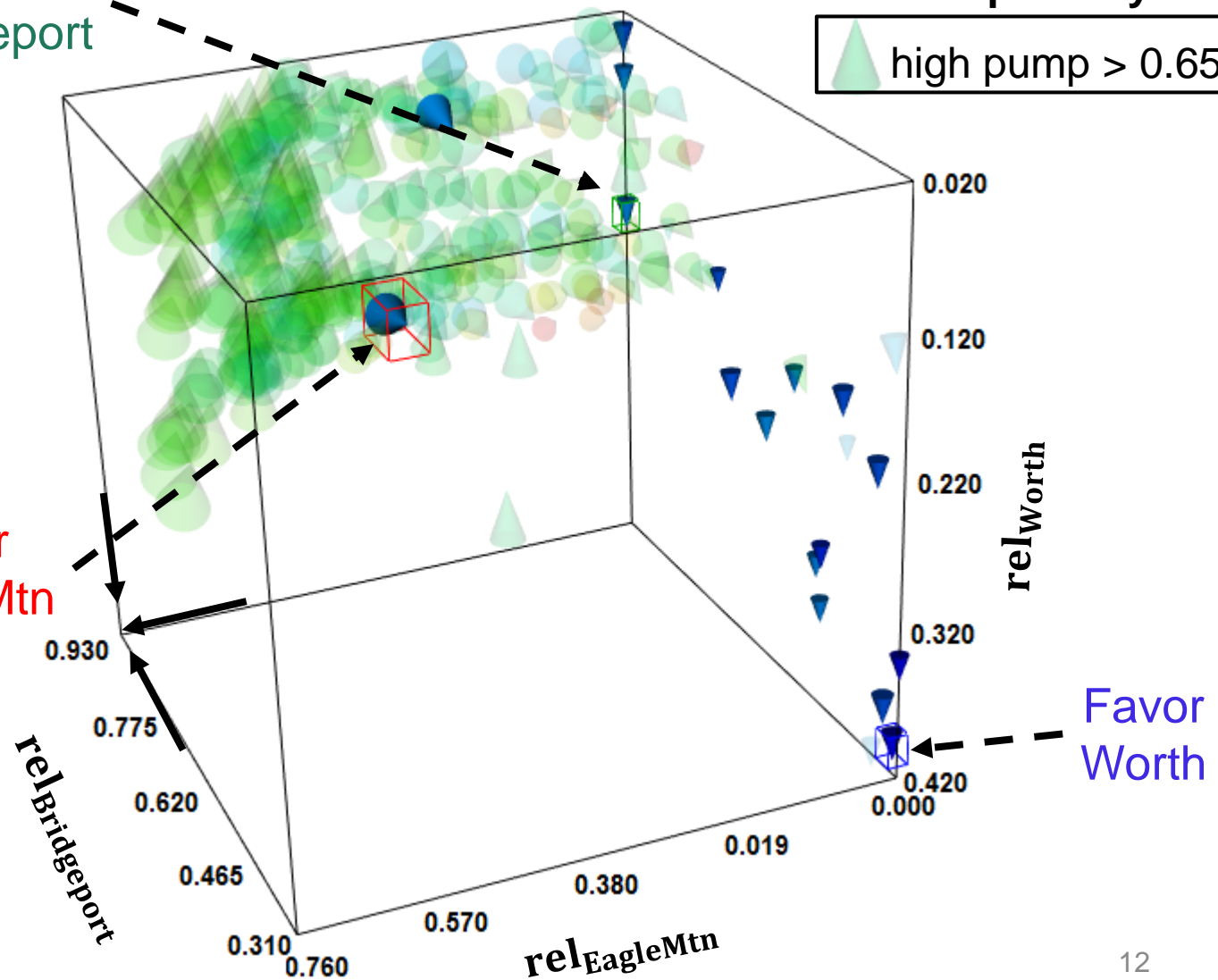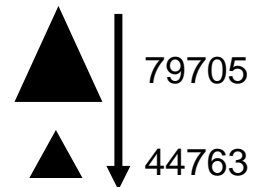
Detailed Comparison: Stressed

Baseline

Favor EM

Favor W

Favor BP

high   high pump   Eagle Mountain Pool Elevation $rel_{EagleMtn}$ rel_{Worth}

preferred direction

0.431   0.791   141   79705   0.31   0.00   0.02
0.004   0.619   0   44764   0.93   0.76   0.42

Feet

648

644 — Recreation 644.1

640 — Minimum 641.1

636

10/01/13   4/01/13   10/01/14

13
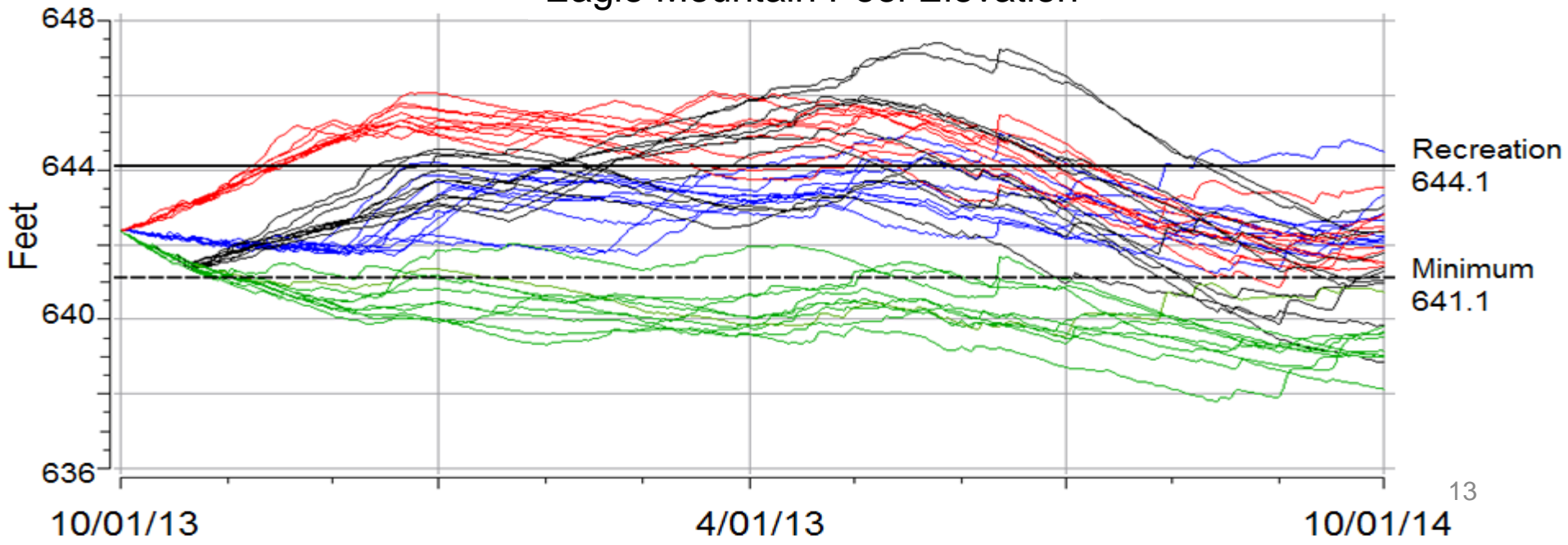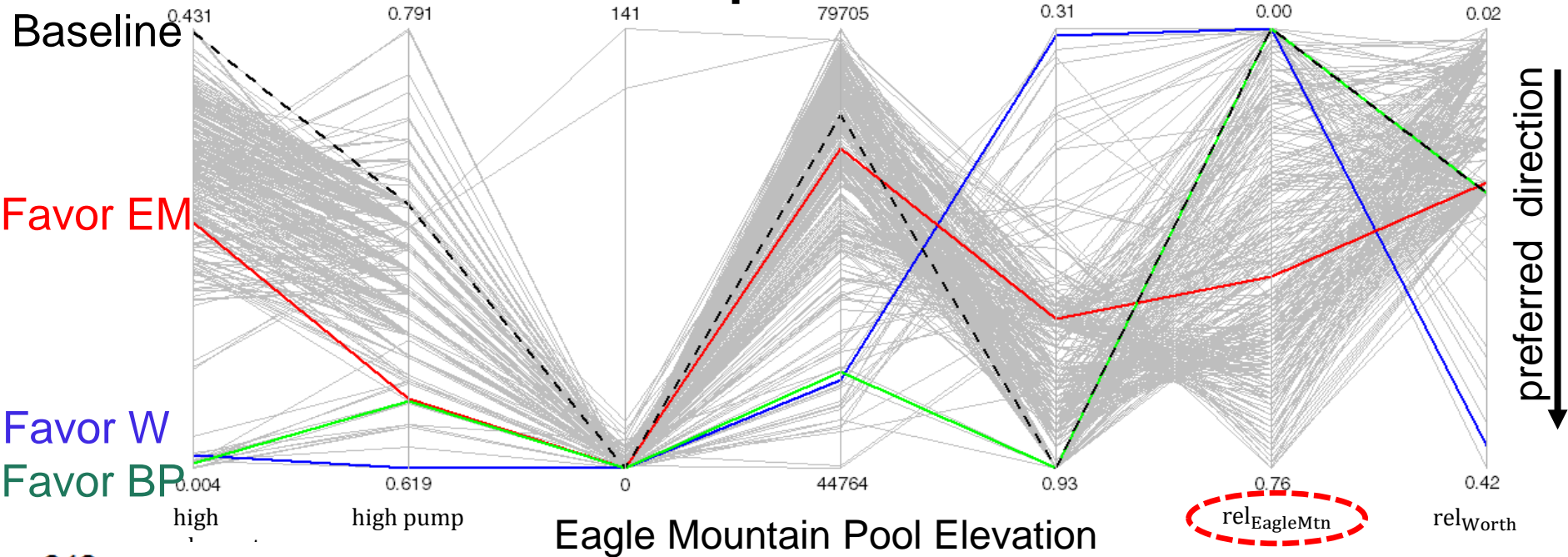
Conclusions

- MOEA + trusted, complex model = feasible mgmt solutions that **can be *readily* implemented by a utility**

- Limited function evaluations & hydrologic scenarios- can we still get good solutions without exhaustive search & variability… **YES**

- The ability to analyze solutions in RiverWare greatly facilitated learning, especially regarding conflicts between system-wide objectives and system component objectives

Thank You!

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John Carron, Nick Mander

Joe Kasprzyk, Edie Zagona

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Bill Oakley, Neil Wilson, Jim Pasquotto, Gwen Miller