OPTIMIZATION OF OPERATIONAL POLICIES FOR TARRANT REGIONAL WATER DISTRICT'S WEST FORK SYSTEM




RiverWare
2025 User Group Meeting

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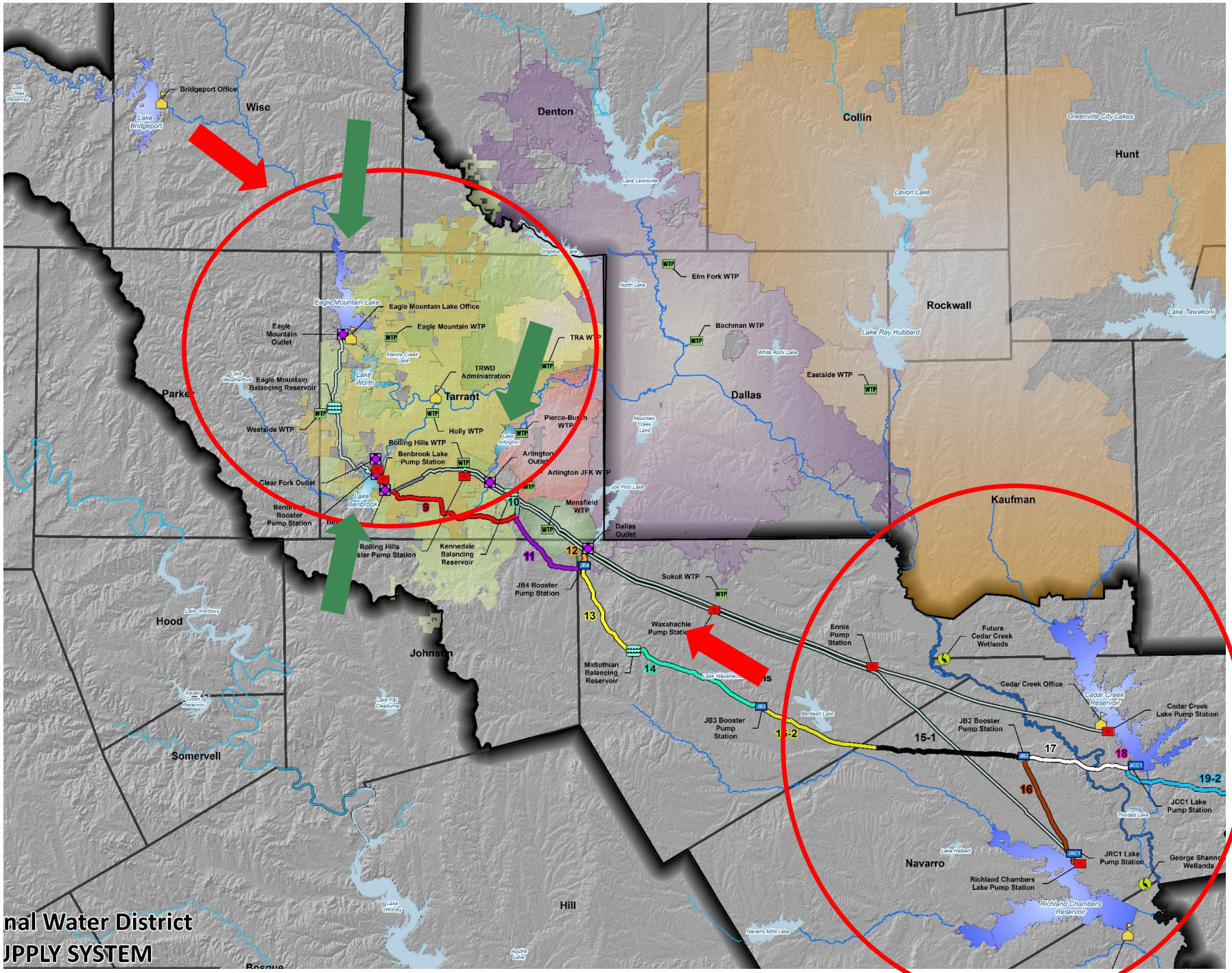
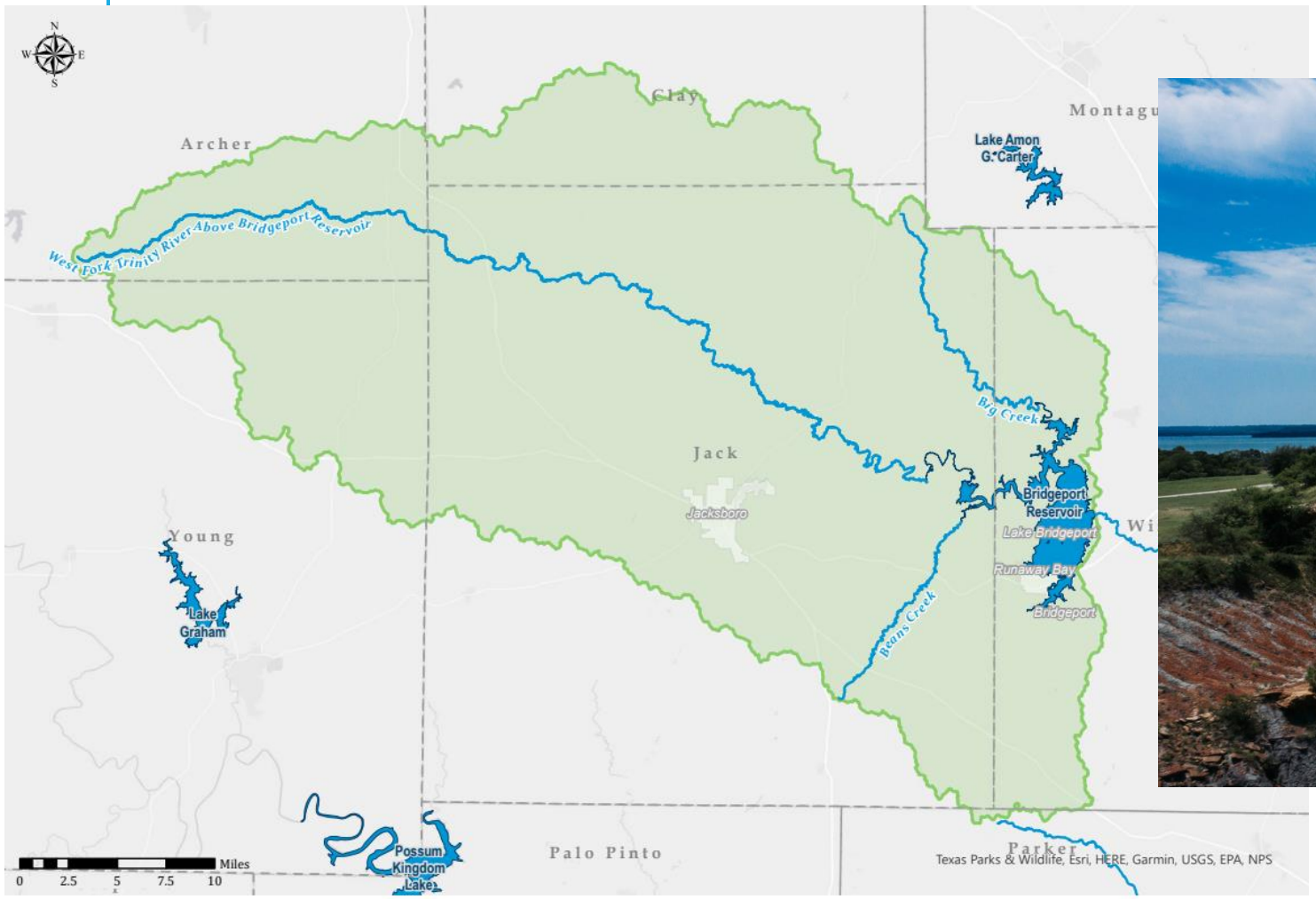
OVERVIEW OF THE TRWD TRANSMISSION SYSTEM

- TRWD provides Flood Protection, Recreation, and Water Supply
- TRWD serves 11 counties and ~2.5 million people
- TRWD has built 250 miles of larger diameter pipelines



THE WEST FORK SYSTEM

LAKE BRIDGEPORT



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LAKE BRIDGEPORT WATERSHED

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MAP PRODUCED ON 12/10/2021 11:20 AM

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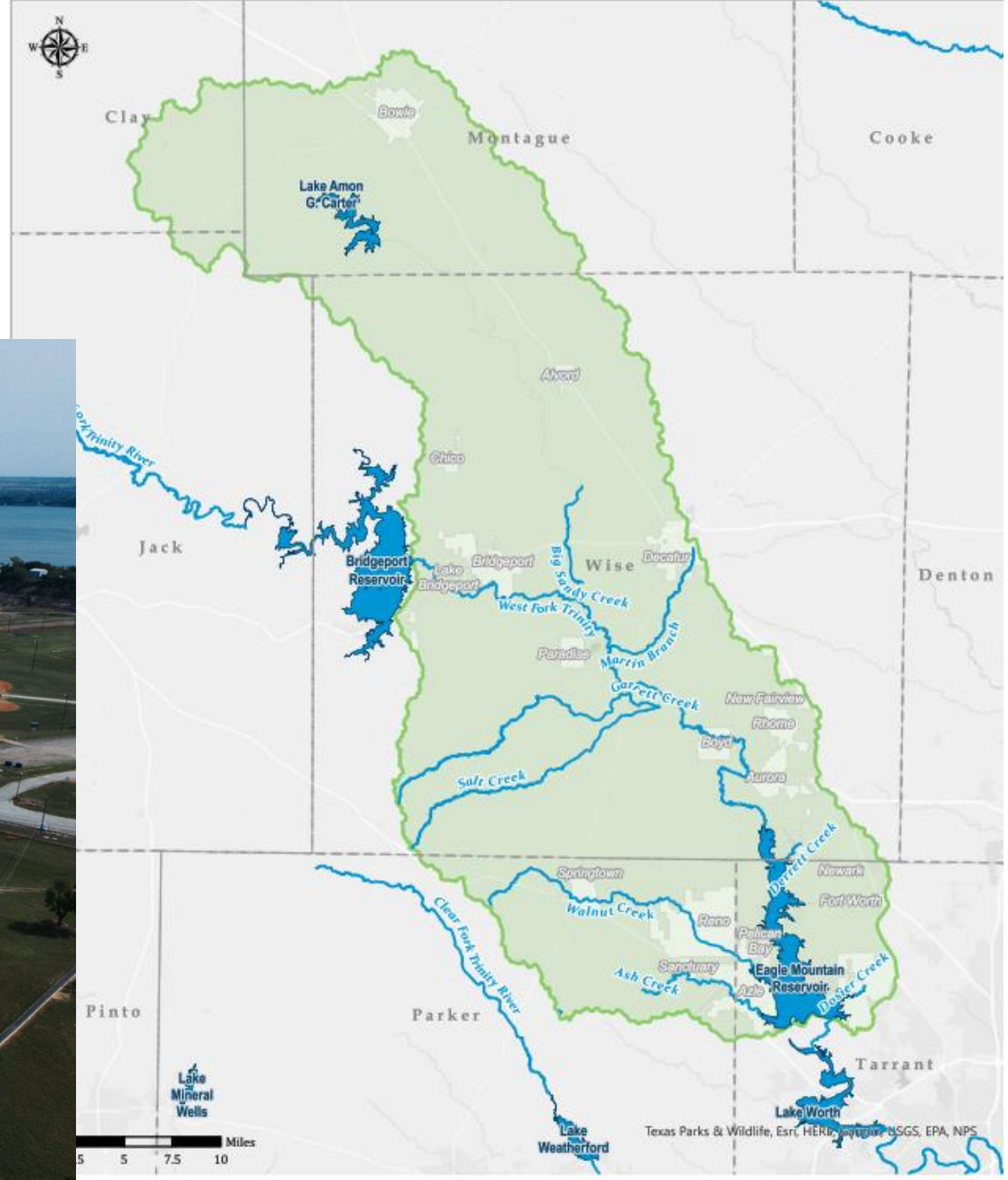
EAGLE MOUNTAIN LAKE



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EAGLE MOUNTAIN LAKE WATERSHED

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WEST FORK OPERATIONS AND HISTORY

- Drawdown ratio (BP:EM)

$$\text{BP:EM} = \frac{BP\ Departure\ from\ Conservation}{EM\ Departure\ from\ Conservation}$$

- Historical Drawdown Ratios

BP:EM Ratio	Outcome
2:1	EM Slightly Favored
Up to 3:1 (varying elevations)	EM Favored
1.5:1	BP Slightly Favored

- Minimum Elevation for Releases: 824 ft (-12 ft from conservation) (starting in 2012)

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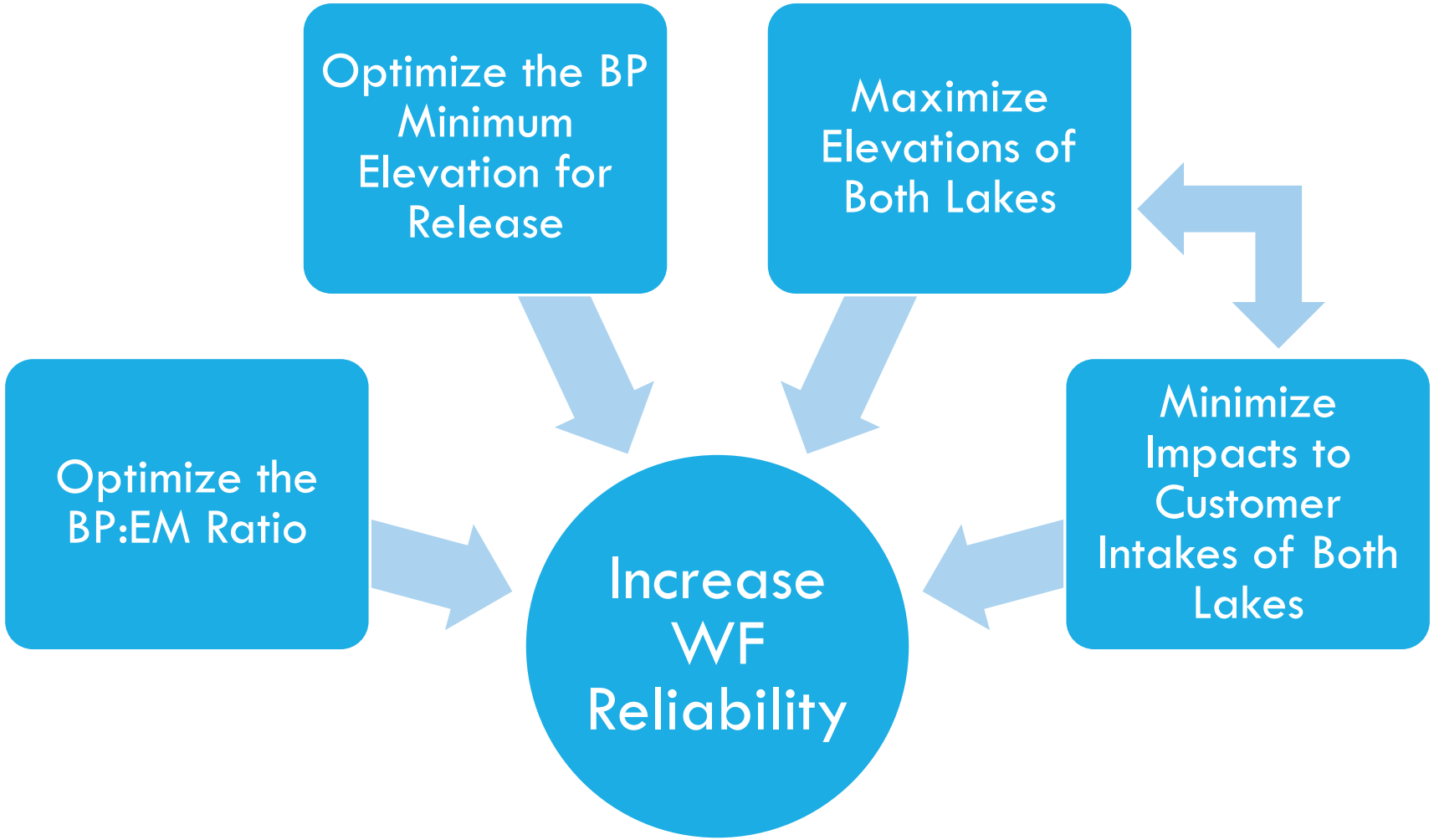
GENERAL OBJECTIVES



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MULTI-OBJECTIVE OPTIMIZATION PROBLEM

Baseline Model

- Planning model - monthly time-step
- Period of Record: 1941-2022 (82 years, 984 months)

Objectives

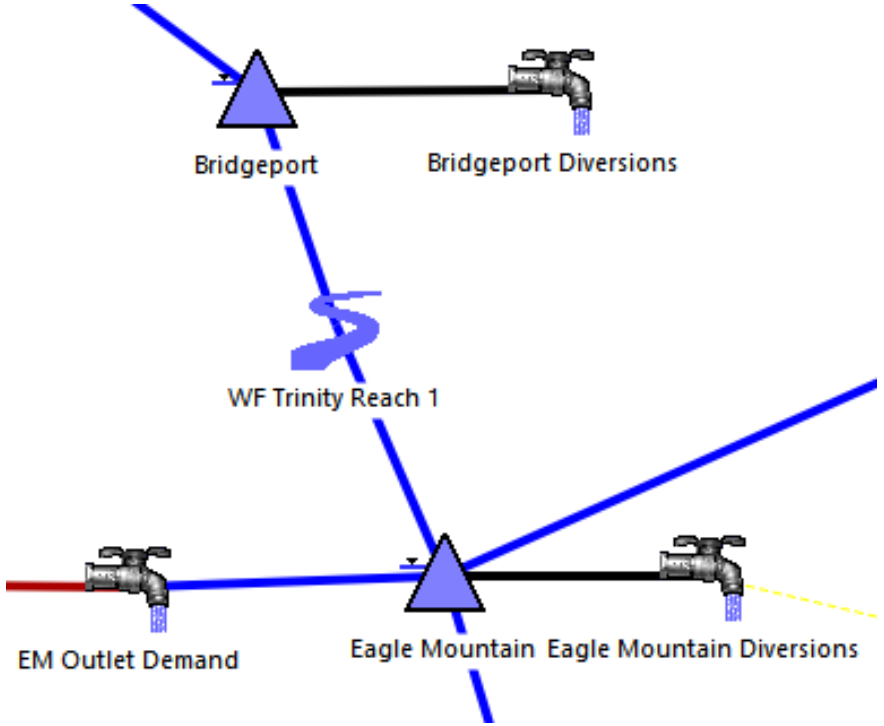
- Maximize Bridgeport Reservoir Pool Elevation
- Maximize Eagle Mountain Reservoir Pool Elevation

Decision Variables

- BP:EM Drawdown Ratio
- Bridgeport Minimum Elevation for Release

Constraints

- 4 Bridgeport Water User Minimum Intake elevations
- 4 Eagle Mountain Water User Minimum Intake elevations



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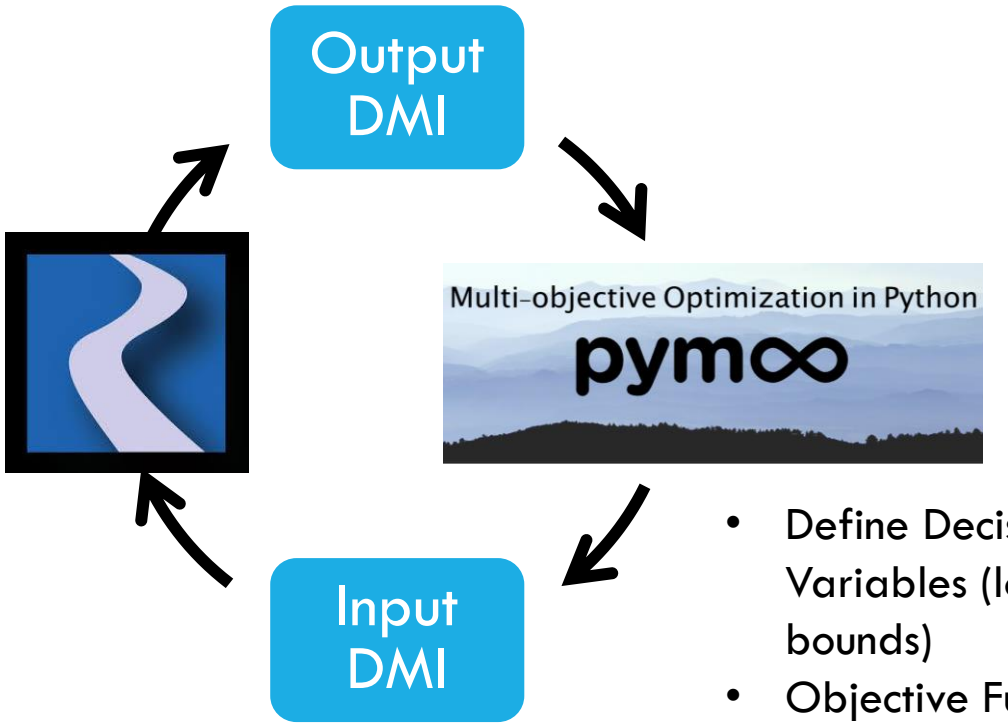
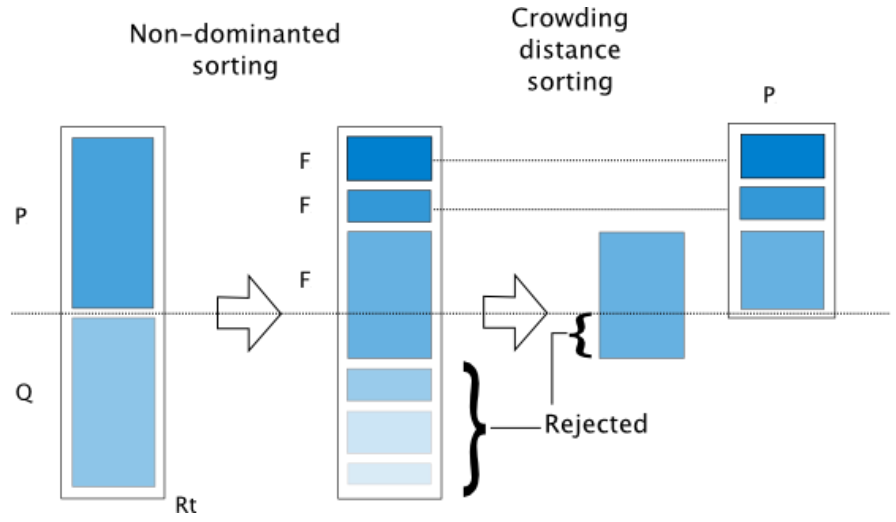
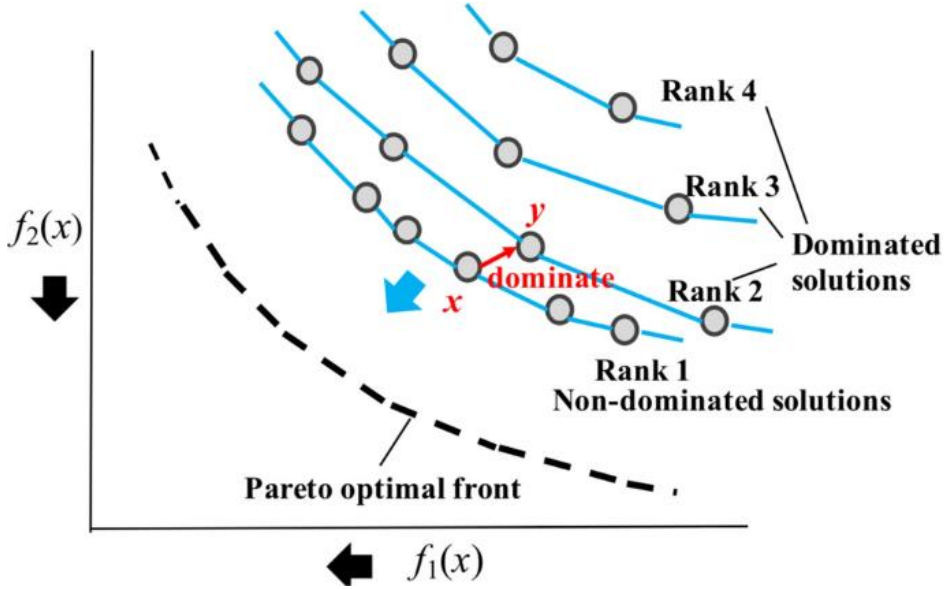
MULTI-OBJECTIVE OPTIMIZATION



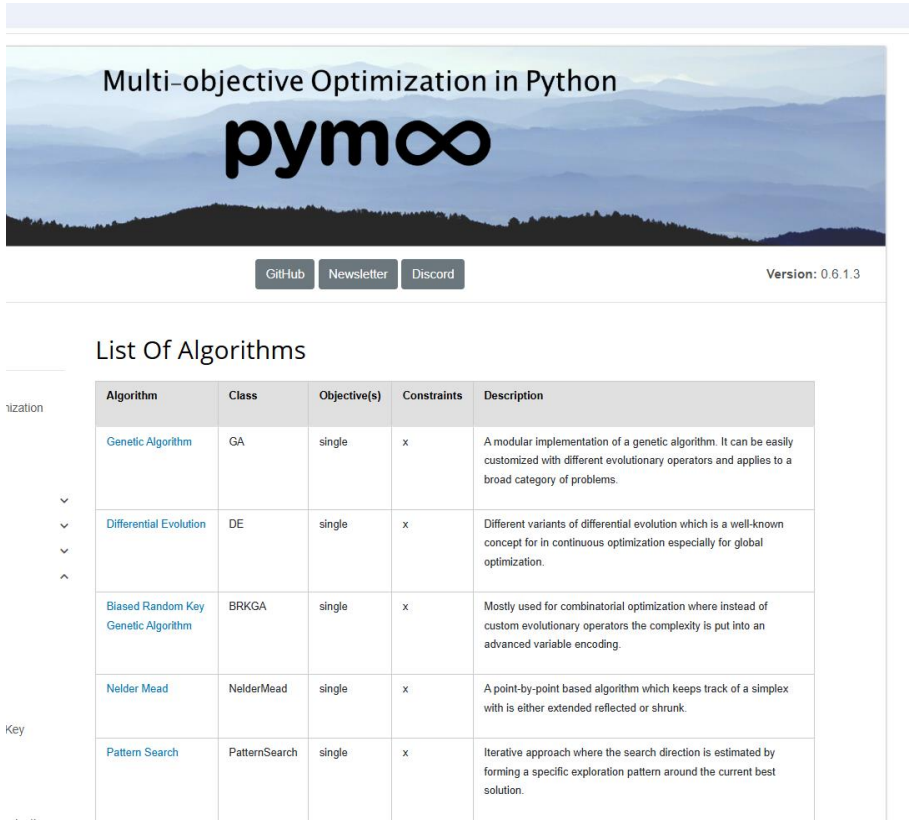
- Define Decision Variables (lower/upper bounds)
- Objective Functions
- Constraints





K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan. A fast and elitist multiobjective genetic algorithm: nsga-II. *Trans. Evol. Comp*, 6(2):182–197, April 2002. URL: http://dx.doi.org/10.1109/4235.996017, doi:10.1109/4235.996017.
Sato, Y., and Sato. M, Using Dominated Solutions at Edges to the Diversity
and the Uniformity of Non-dominated Solution Distributions in NSGA-II. SN Computer Science (2022) 3:432
https://doi.org/10.1007/s42979-022-01303-w August 2022

MULTI-OBJECTIVE OPTIMIZATION



Algorithm	Class	Objective(s)	Constraints	Description
Genetic Algorithm	GA	single	x	A modular implementation of a genetic algorithm. It can be easily customized with different evolutionary operators and applies to a broad category of problems.
Differential Evolution	DE	single	x	Different variants of differential evolution which is a well-known concept for in continuous optimization especially for global optimization.
Biased Random Key Genetic Algorithm	BRKGA	single	x	Mostly used for combinatorial optimization where instead of custom evolutionary operators the complexity is put into an advanced variable encoding.
Nelder Mead	NelderMead	single	x	A point-by-point based algorithm which keeps track of a simplex with is either extended reflected or shrunk.
Pattern Search	PatternSearch	single	x	Iterative approach where the search direction is estimated by forming a specific exploration pattern around the current best solution.

- Various multi-objective Python packages available
  - Pymoo, Pyomo, PyGMO, Platypus
  - Pymoo
    - Easy to implement
    - Good examples/documentation
    - Over 20 algorithms available

https://pymoo.org/
J. Blank and K. Deb, pymoo: Multi-Objective Optimization in Python, in IEEE Access, vol. 8, pp. 89497-89509, 2020, doi: 10.1109/ACCESS.2020.2990567

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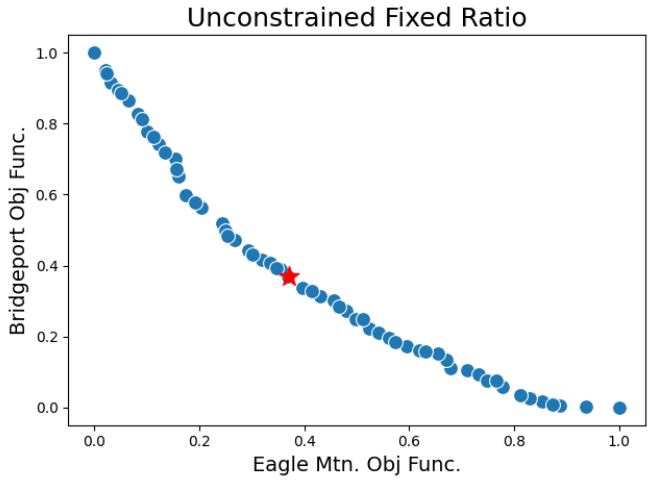
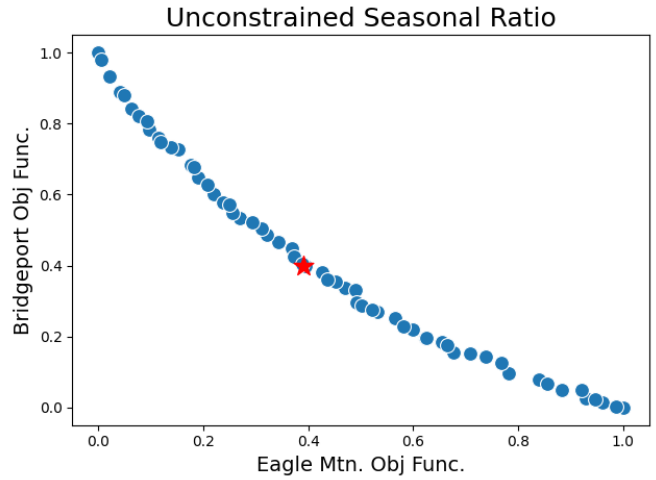
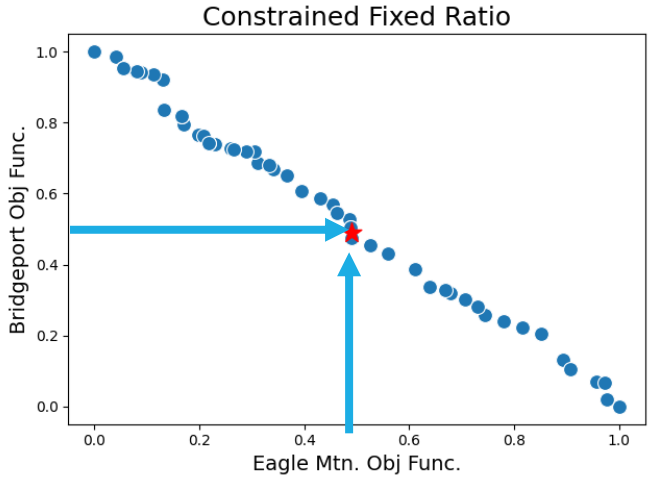
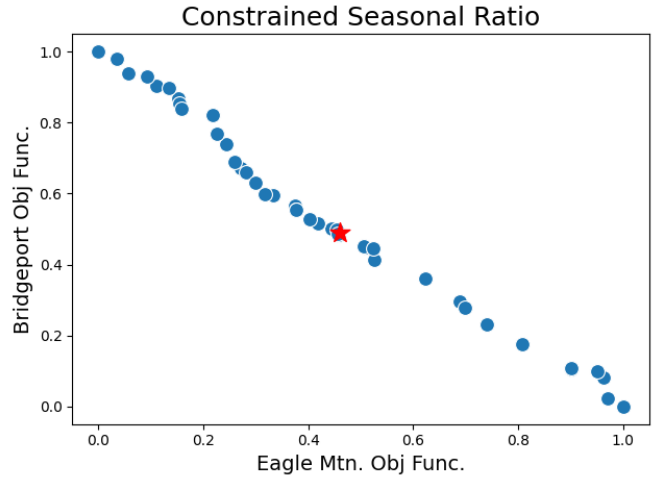
RESULTS

- Ran the optimization with and without constraints and a “fixed” and “seasonal” BP:EM Ratio
  - Each case involved approximately 300 evaluations of the RiverWare model
- Pareto-front becomes linear when including constraints making the trade-off between solutions more predictable
- Objective functions assigned equal importance therefore the midpoint is assumed to be optimal









RESULTS

Case	Winter BP:EM Ratio	Summer (full year) BP:EM Ratio	Min Release Elevation [ft]
Unconstrained Fixed	-	1.75	799.0
Constrained Fixed	-	1.74	800.5
Unconstrained Seasonal	1.13	1.82	795.6
Constrained Seasonal	1.10	2.00	798.3

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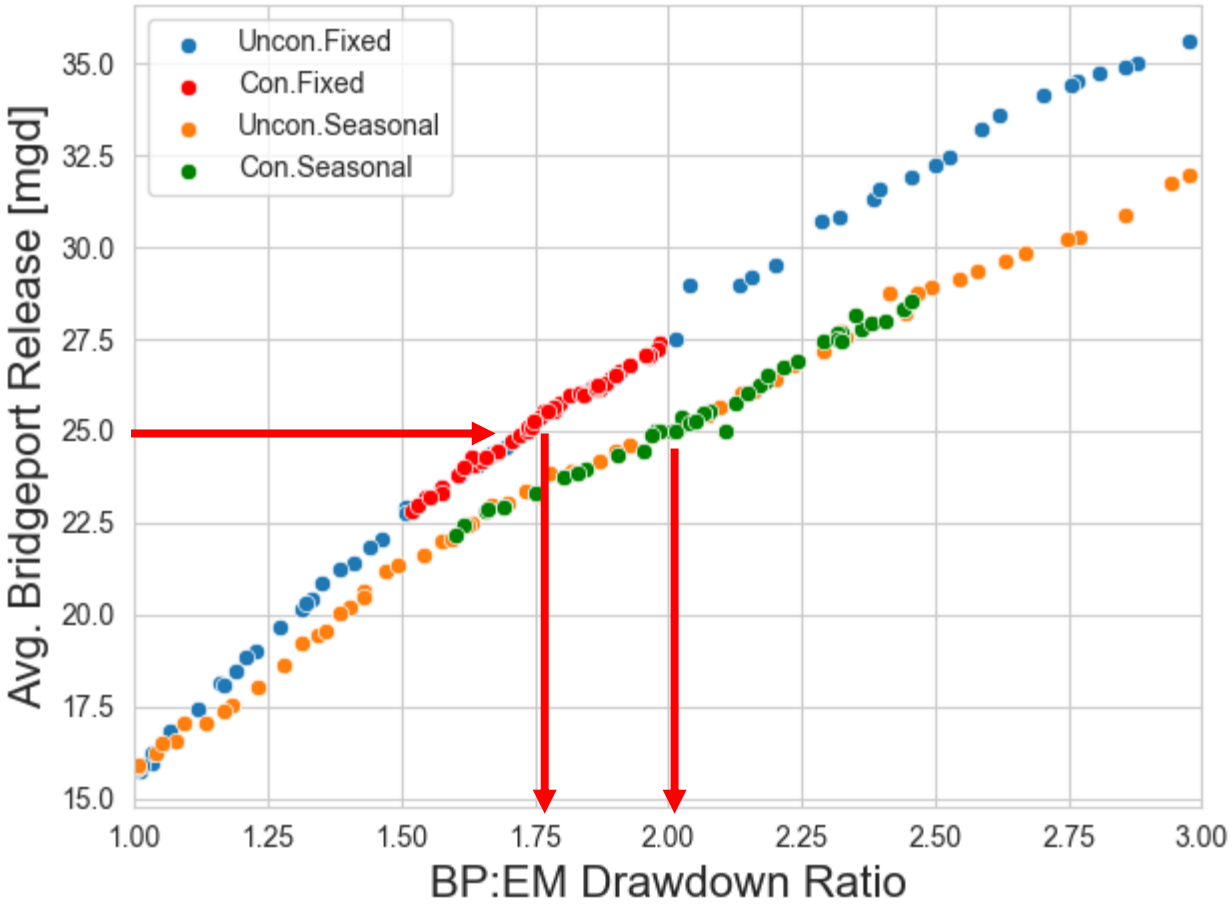
RESULTS



- A ratio less than 1.5 or greater than 2.0 would result in constraint violations
- A ratio of 1.75 corresponds to the midpoint of acceptable ratios (no constraints violated) and corresponds with the average Bridgeport release
- Allowing the ratio to vary between summer/winter results in a ratio of 2.0, which also corresponds approximately to the average Bridgeport Release
- The optimal ratio corresponds to a point where the average pool elevations intersect

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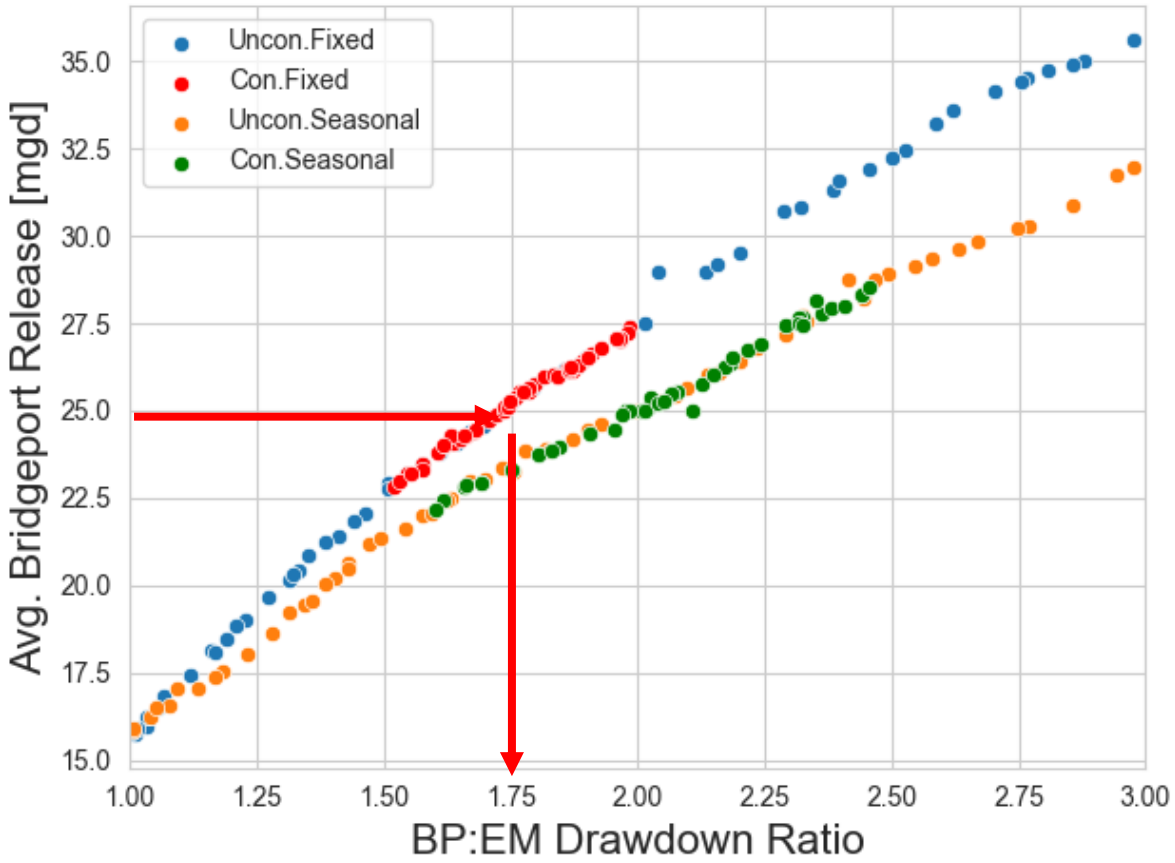
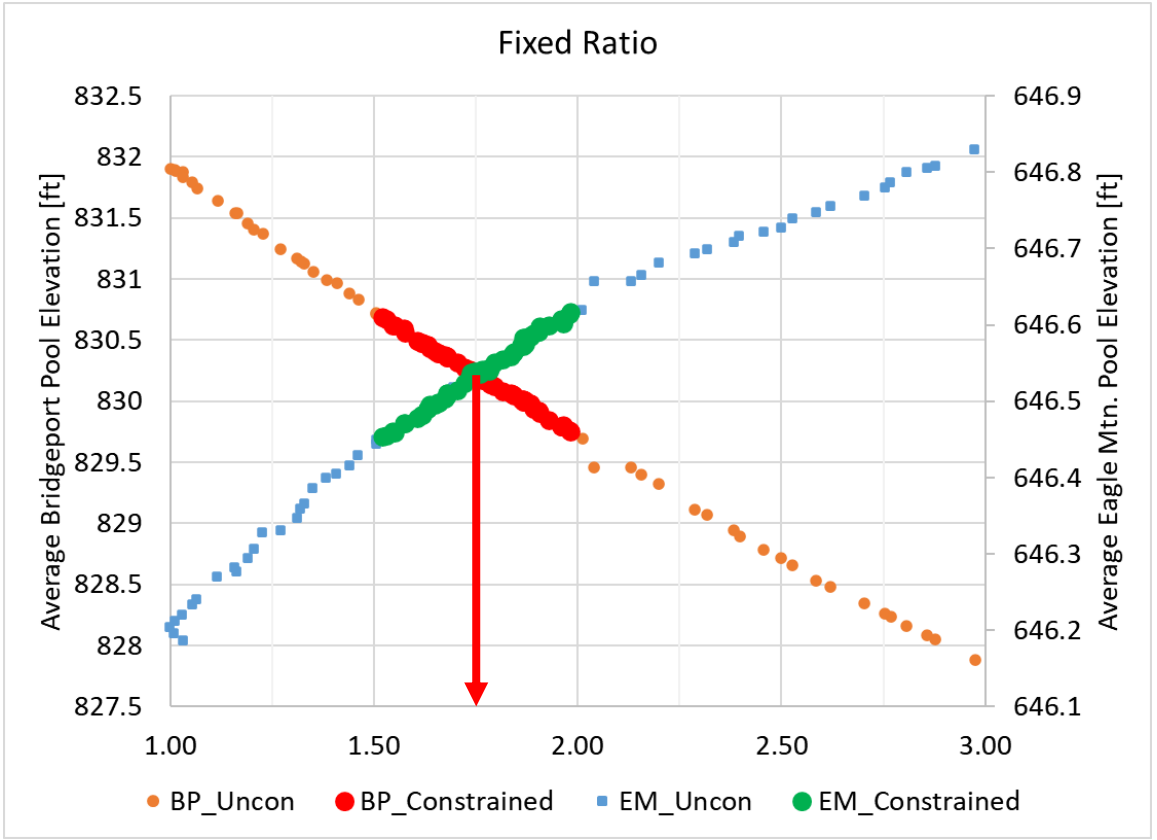
RESULTS



Average Bridgeport
vs Eagle Mtn Pool Elevation



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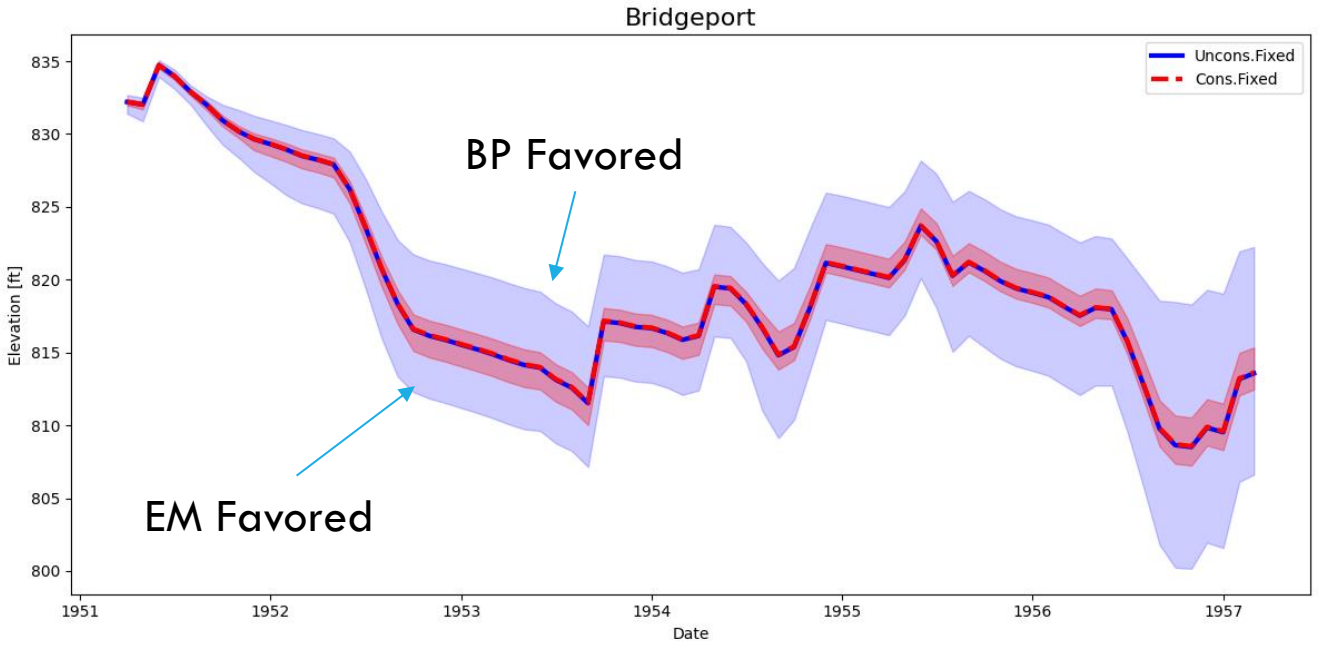
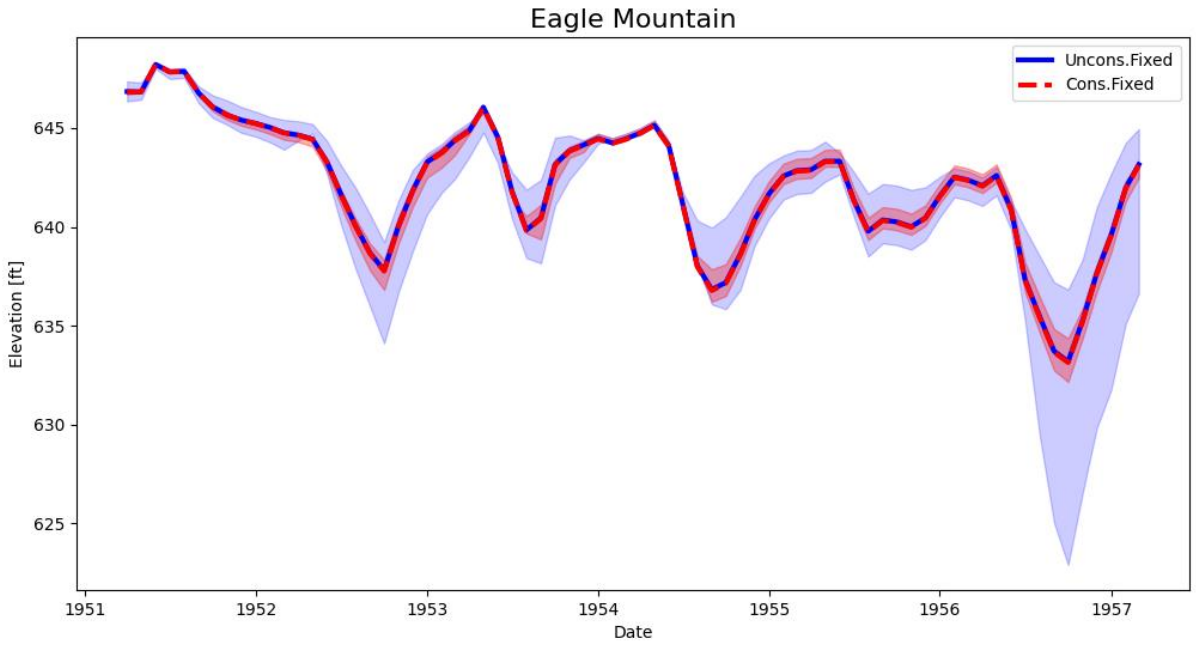
RESULTS





- Inclusion of water user intake constraints highlight the limited acceptable operating range
- With equal importance, both approaches converge on the same optimal solution (midpoint of average Bridgeport Releases) even with varying ratios

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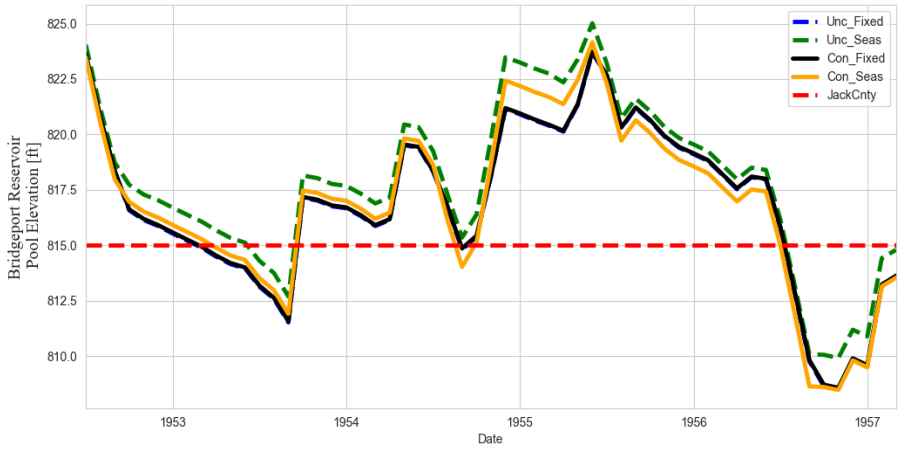
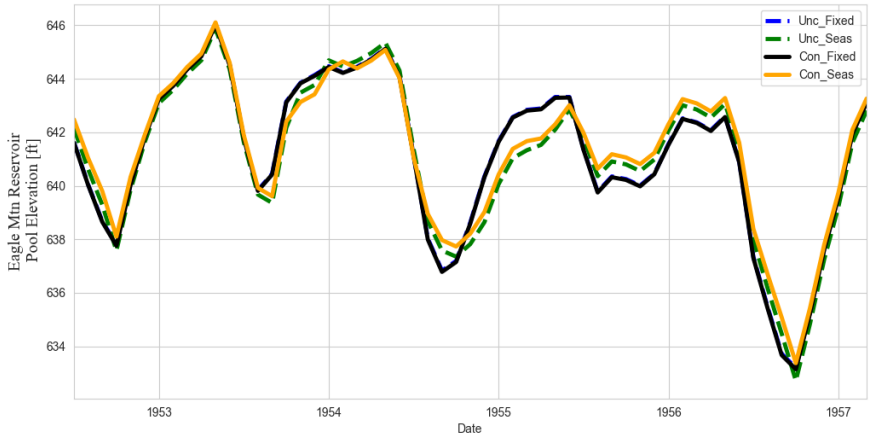
RESULTS





Case	Count of Times Reservoir Falls below Elevation Criteria							
	Bridgeport				Eagle Mountain			
	Bridge Port Shared Intake (757.56')	Runaway Bay (810.0')	Jack County/ WalnuCreek (815.0')	Burnco (796.34')	Azle (624.0')	Fort Worth (632.0')	Spring Town (638.0')	Community Water Suply (631.92')
Unconstrained Fixed	0	5	16	0	0	0	9	0
Unconstrained Seasonal	0	1	11	0	0	0	10	0
Constrained Fixed	0	5	16	0	0	0	10	0
Constrained Seasonal	0	5	16	0	0	0	7	0

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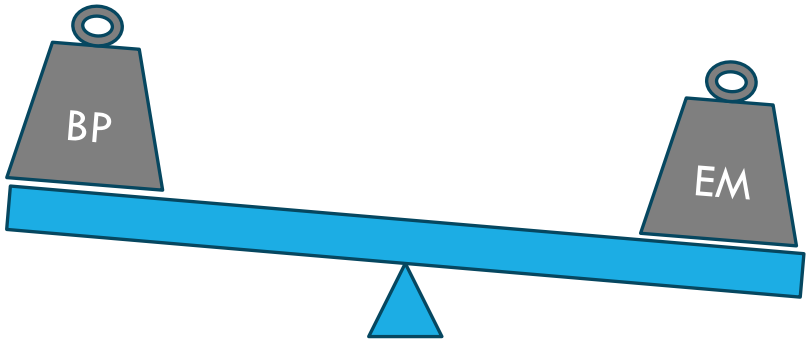
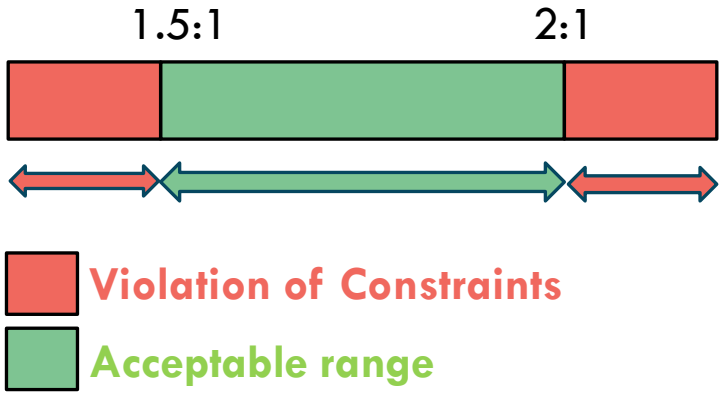
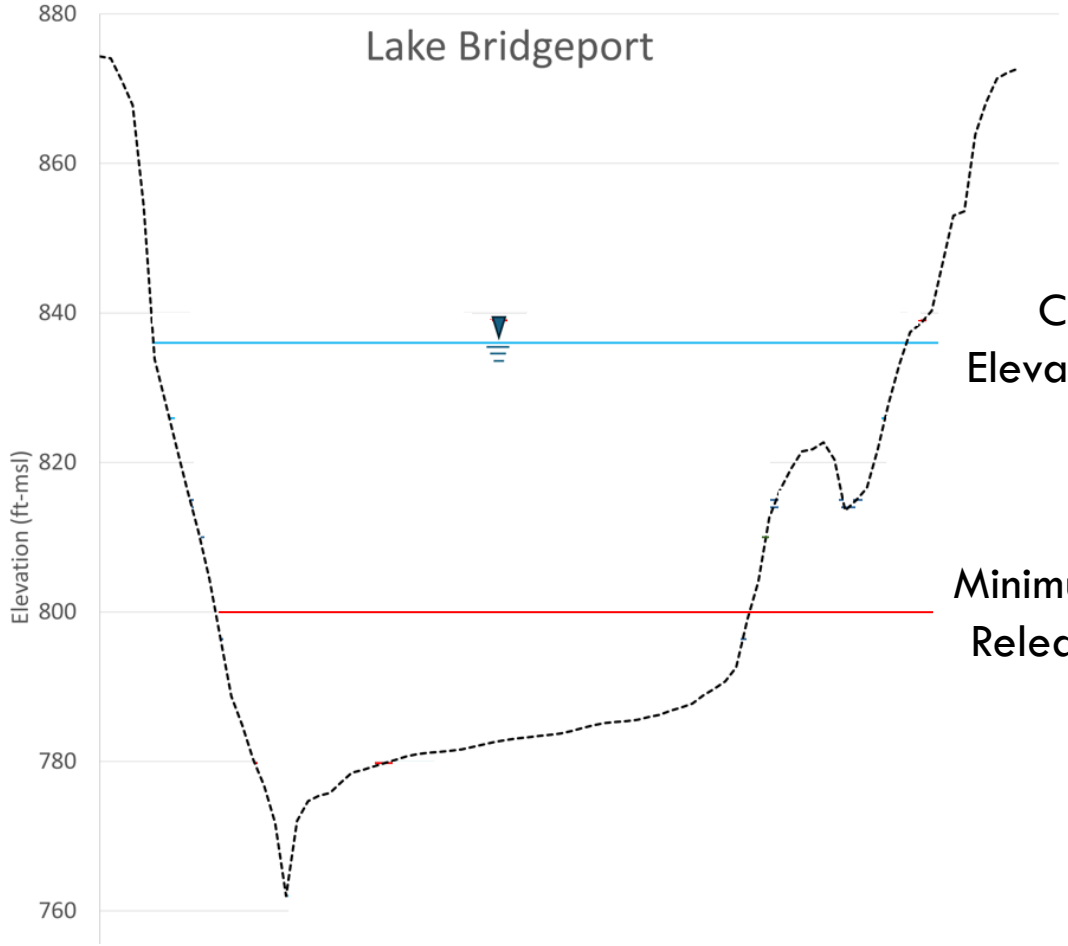
CONCLUSIONS

BP:EM Optimal Ratio: 1.75







Conservation Elevation: 836 ft-msl

Minimum Elevation for Releases: 800 ft-msl

- Customer intakes were affected less than 2% of the Period of Record (16 out of 984 months)

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THANK YOU!

Questions?

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