



Operations Support Tool (OST): Forecasting water supply conditions to guide the operation of NYC's water supply

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Water Supply Mission

Reliably deliver a sufficient quantity of high quality drinking water



Water Supply System Overview

- Three subsystems
 - Croton
 - Catskill
 - Delaware
- Surface water supply
- 19 reservoirs & 3 lakes
- Capacity: 568 billion gallons
- Serves 9.4 million people
- Delivers 1.1 billion gallons per day
- 2,000 square mile watershed
- Covers 8 upstate counties
- Releases impact 15 million people



Multiple Objectives and Challenges

- Supply reliability
- Drinking water quality
- Tailwater fisheries
- Ecological flows
- Recreation
- Spill mitigation
- Operating costs
- Hydropower
- Long-term supply/demand
- Regulatory changes
- Stakeholders
- Climate change



Computer system that allows managers to simultaneously consider all aspects of water supply for all reservoirs

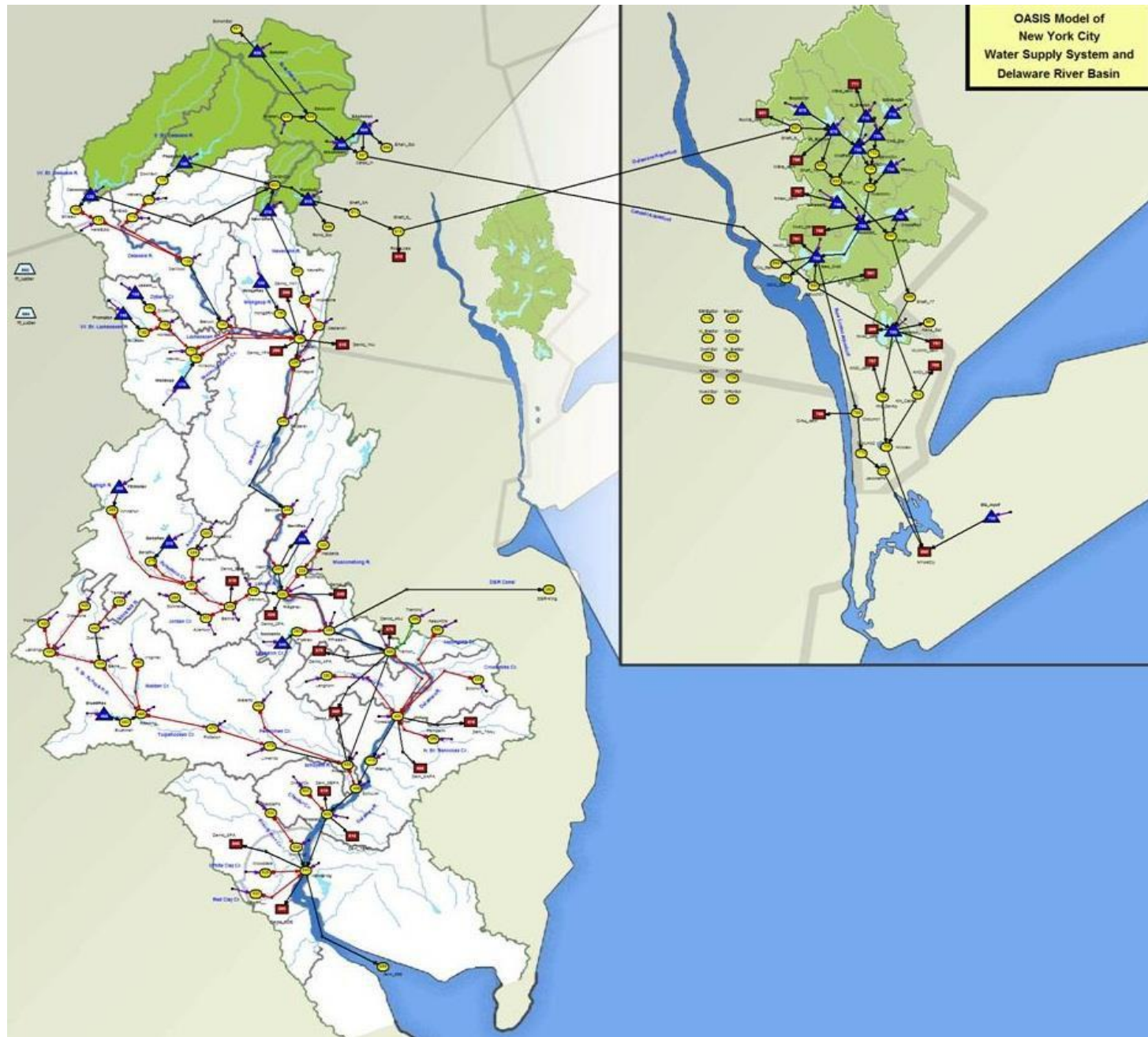
- Demand
- Quantity
- Quality
- Releases
- Diversions
- Inflows
- Infrastructure status
- Construction support

- Required large team of specialists
 - DEP scientists and engineers
 - Several consultants
 - NOAA/National Weather Service (NWS)
- 4 year development cycle 2009-2013
- \$8.5 million development cost

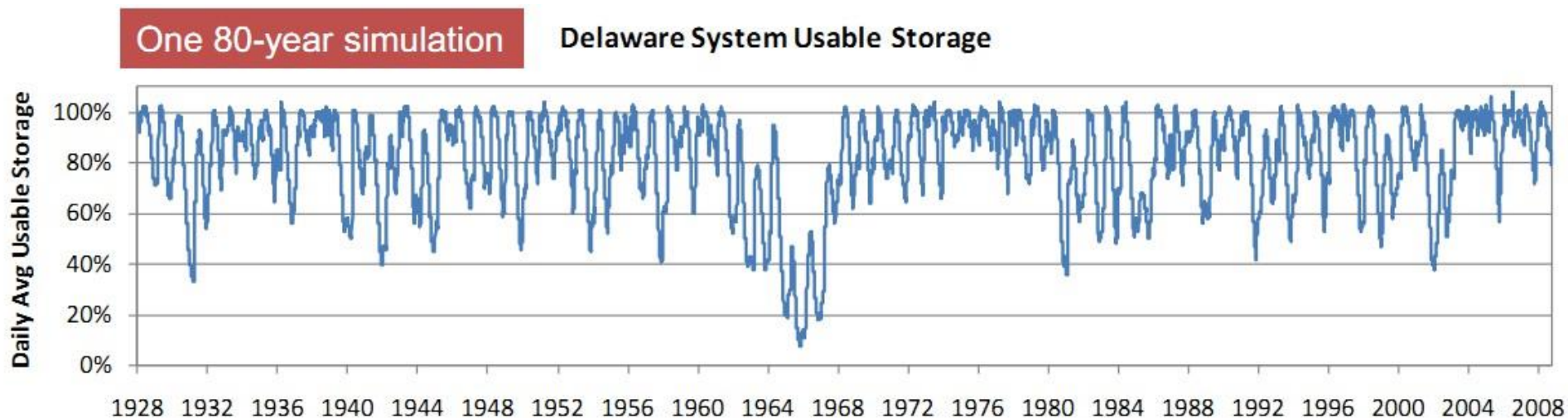


- Six components:
 1. Near-real-time data
 2. Inflow forecasts
 3. Quantity & operations model: OASIS
 4. Water quality model: CE-QUAL-W2
 5. Post-processing tools
 6. User interface
- Daily time step
- Simulates entire system and downbasin points

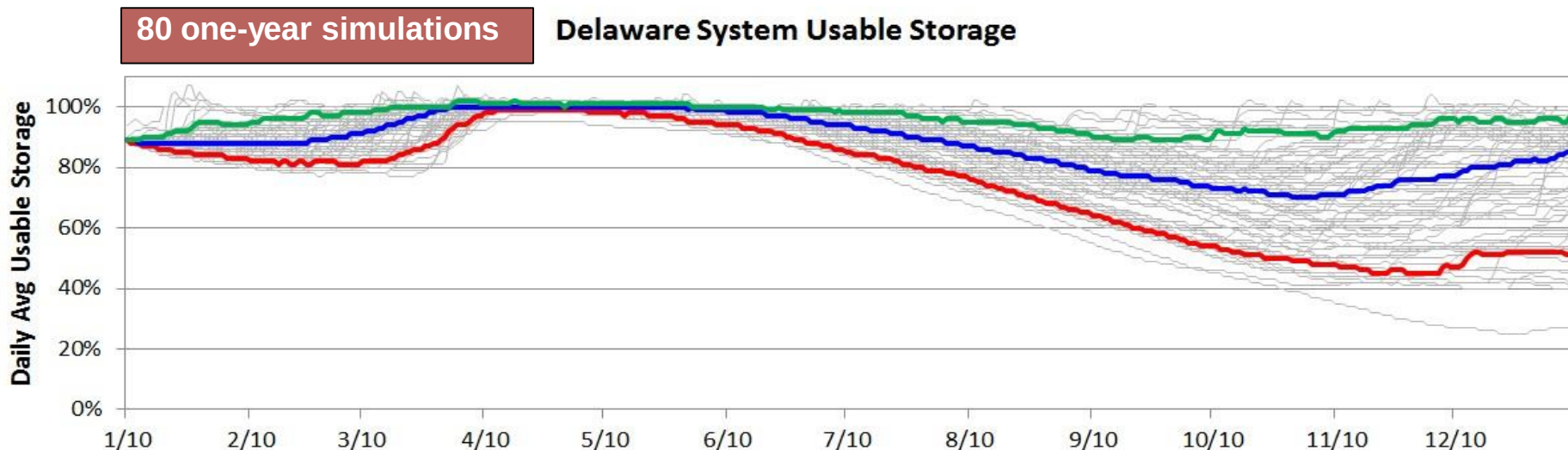
OST Geographic Coverage



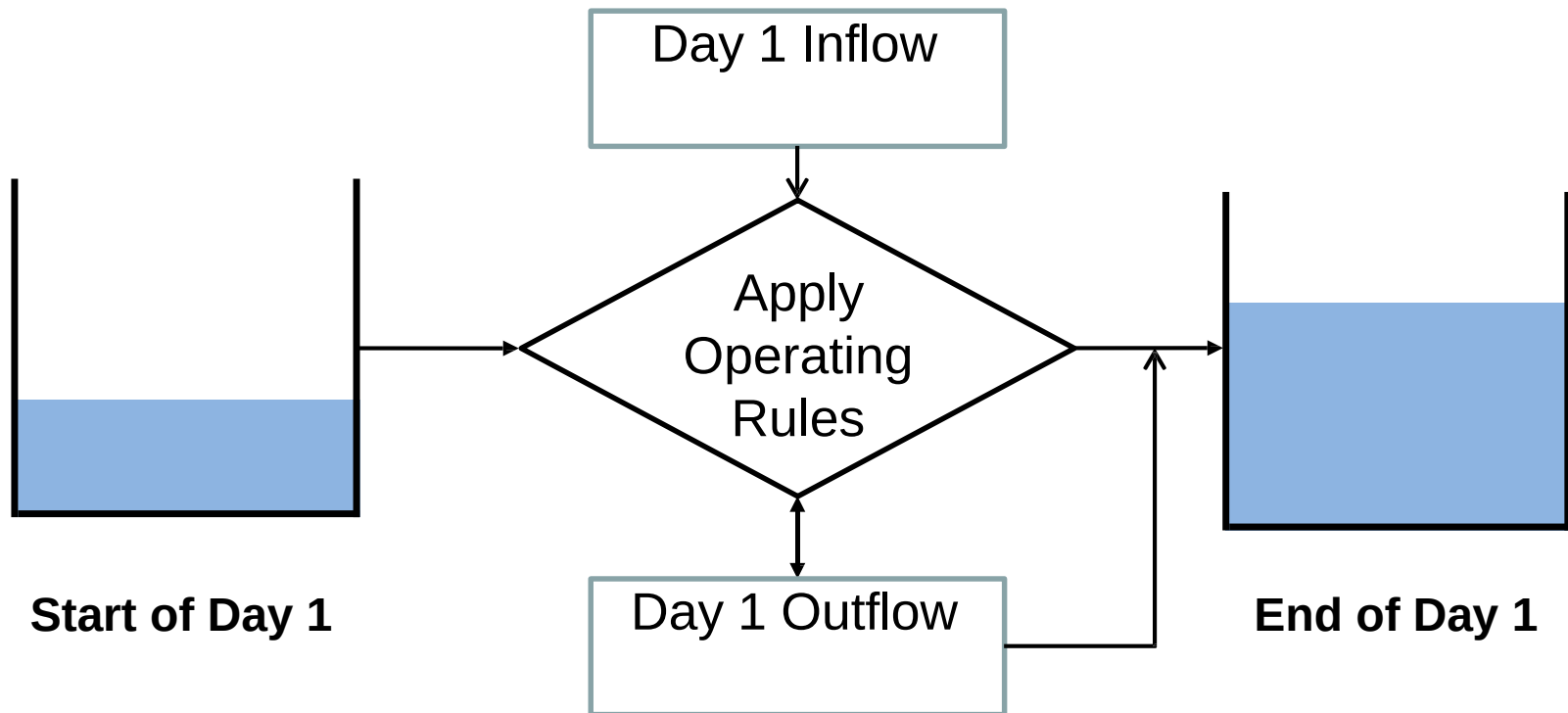
- Driven by one long water inflow time series
- Uses historical or synthetic inflow
- Usage
 - Testing operating rules
 - Climate change impact assessment



- Driven by multiple short time series
- Uses water inflow forecasts from National Weather Service
- Usage: routine operations
 - Releases, diversions, balancing reservoirs
 - Probability of refill

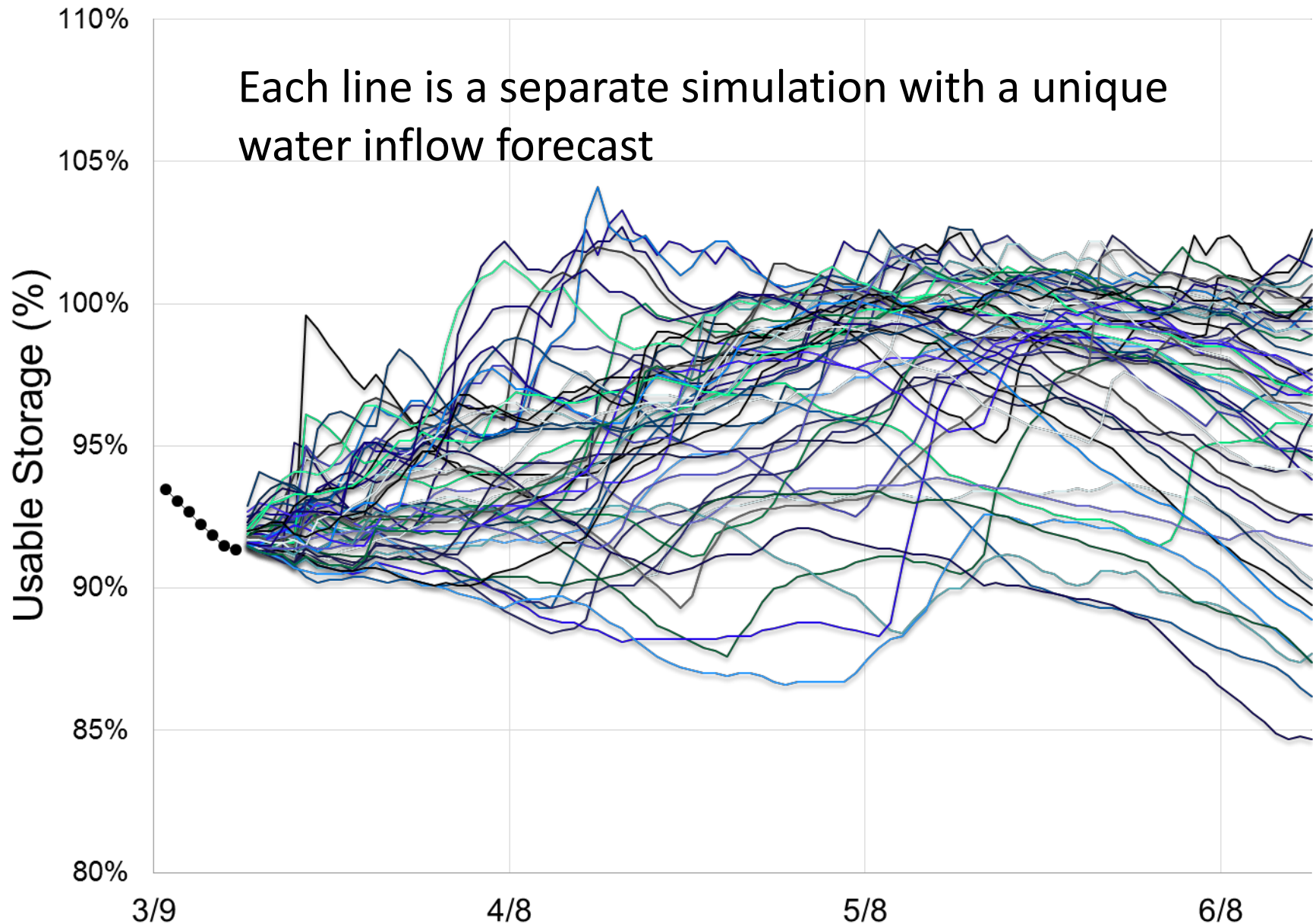


How does OST work?

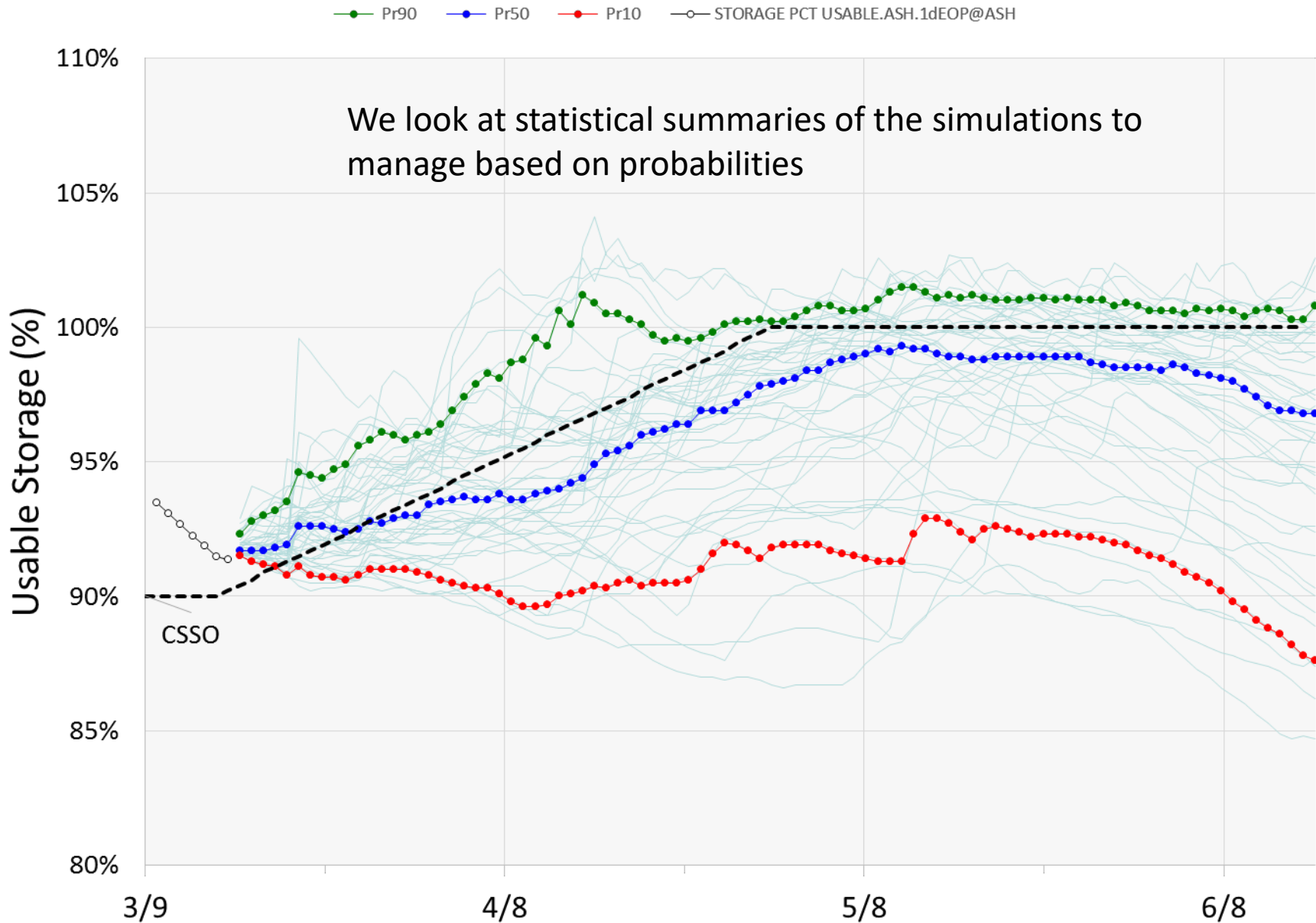


Operations are optimized using linear programming and weights

Ashokan Ensemble Storage Projection

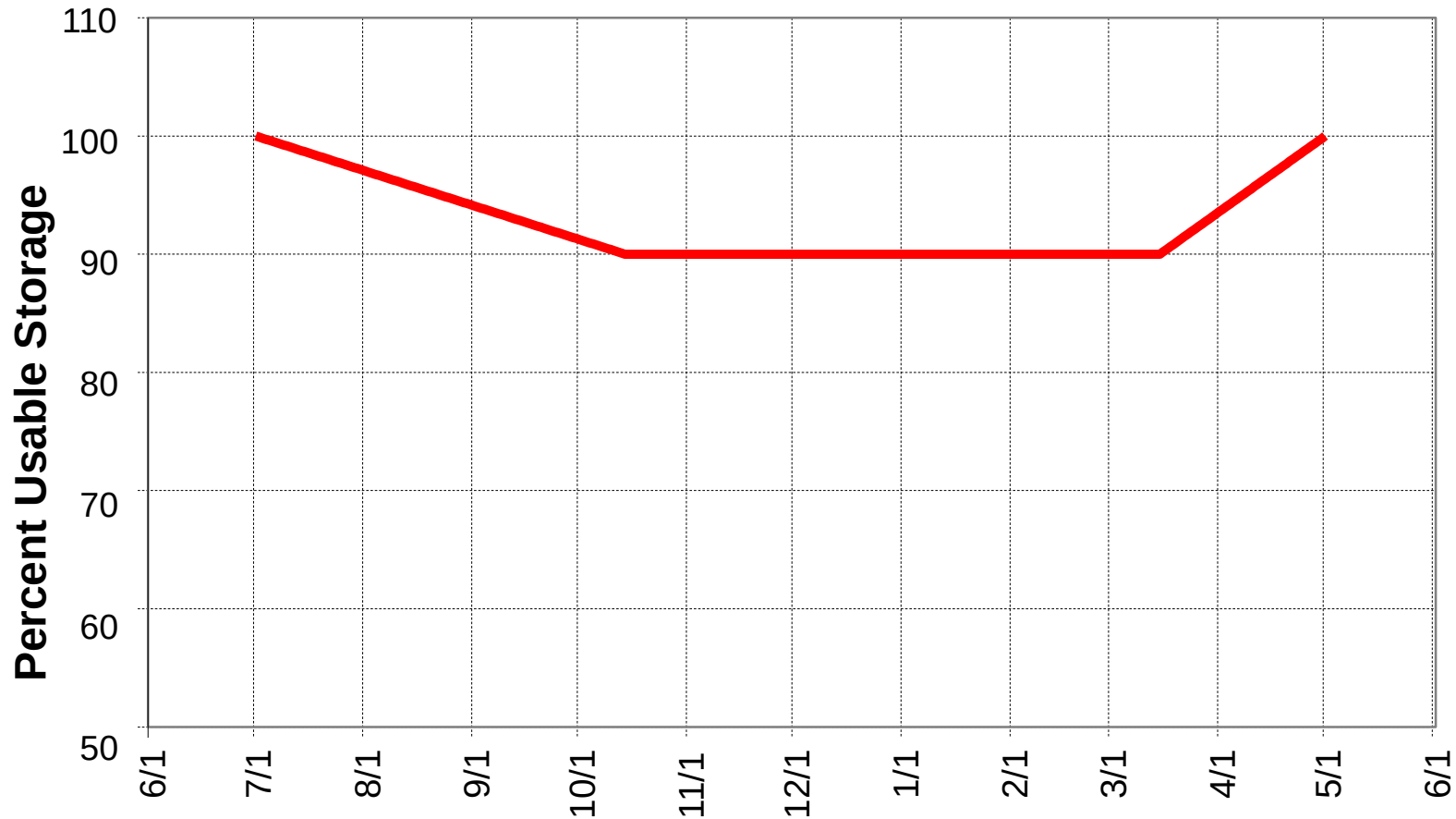


Ashokan Ensemble Storage Projection



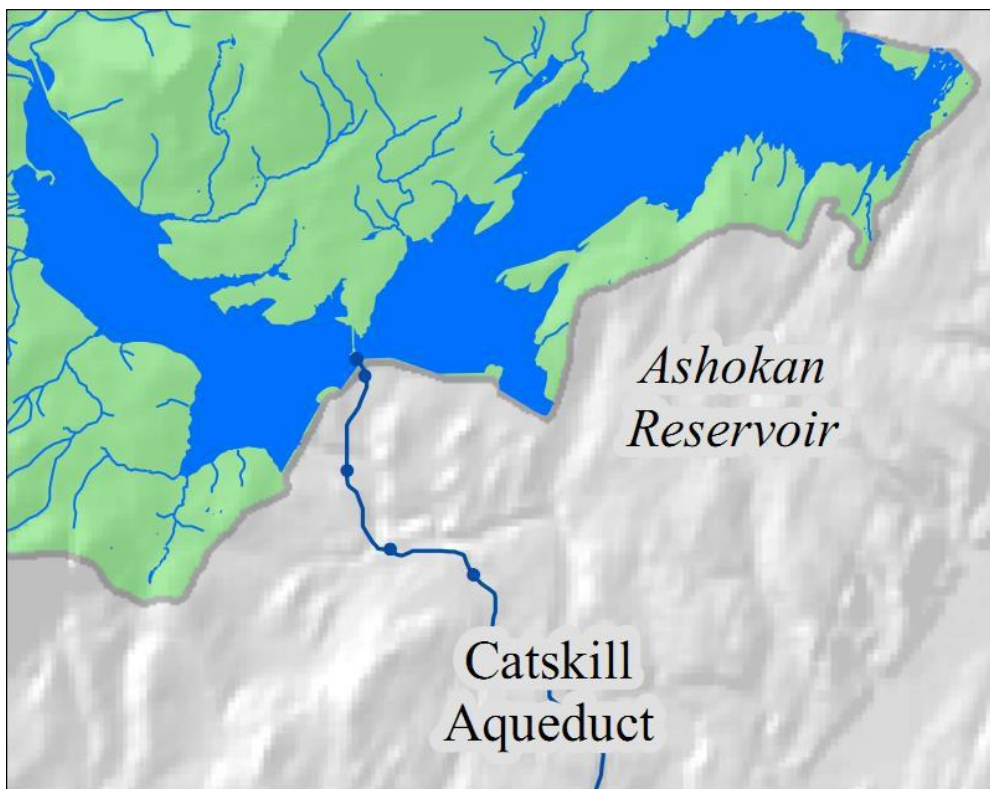
- Operational decisions
 - Diversions
 - Releases
 - Balancing
- Construction support
 - Rondout-West Branch Tunnel (RWBT) bypass
 - Shandaken Tunnel Intake Chamber (STIC) shutdown
 - Catskill Aqueduct shutdown
- Flows below Croton to support Hydrilla treatment
- Assess different spill mitigation protocols (CSSO)
- Schoharie HLO/LLO/HLI evaluation
- CatAlum EIS

Conditional Seasonal Storage Objective (CSSO)

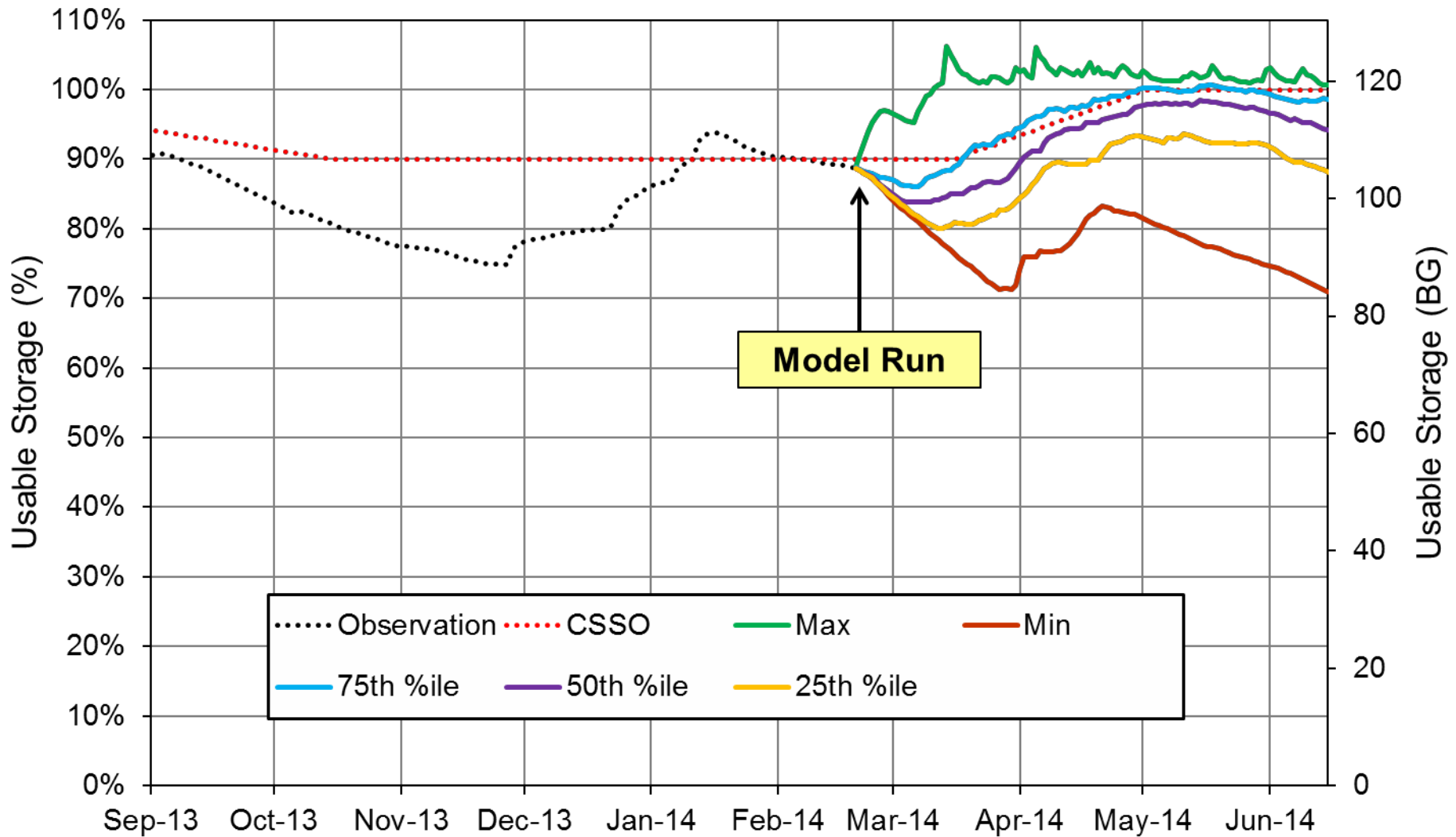


Ashokan Operating Protocol

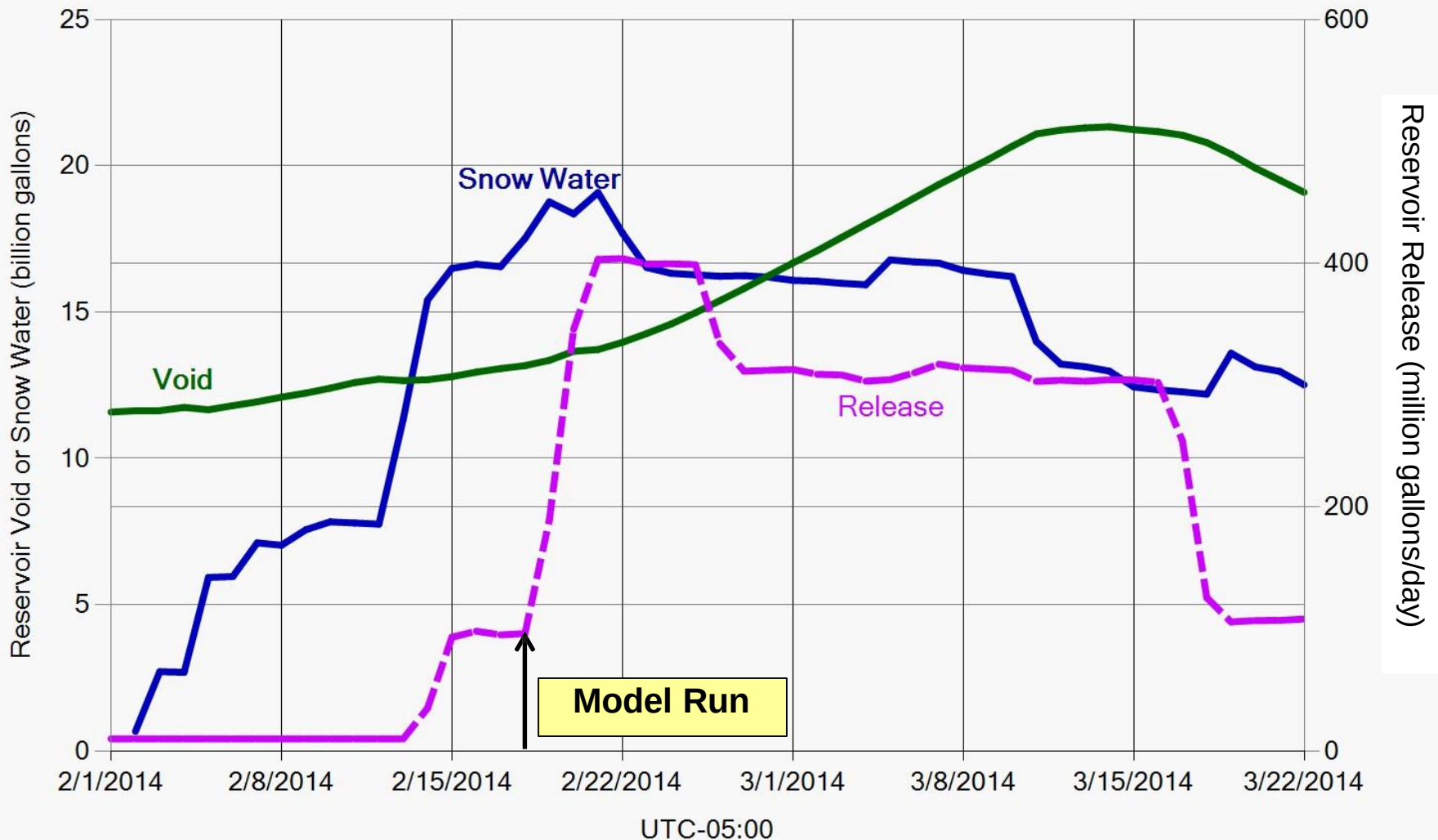
- Draw down west basin in spring
 - Create void to store potentially turbid inflow
 - Allow turbidity to settle out
 - Next slides test what would happen if we released for water to abate turbidity problem



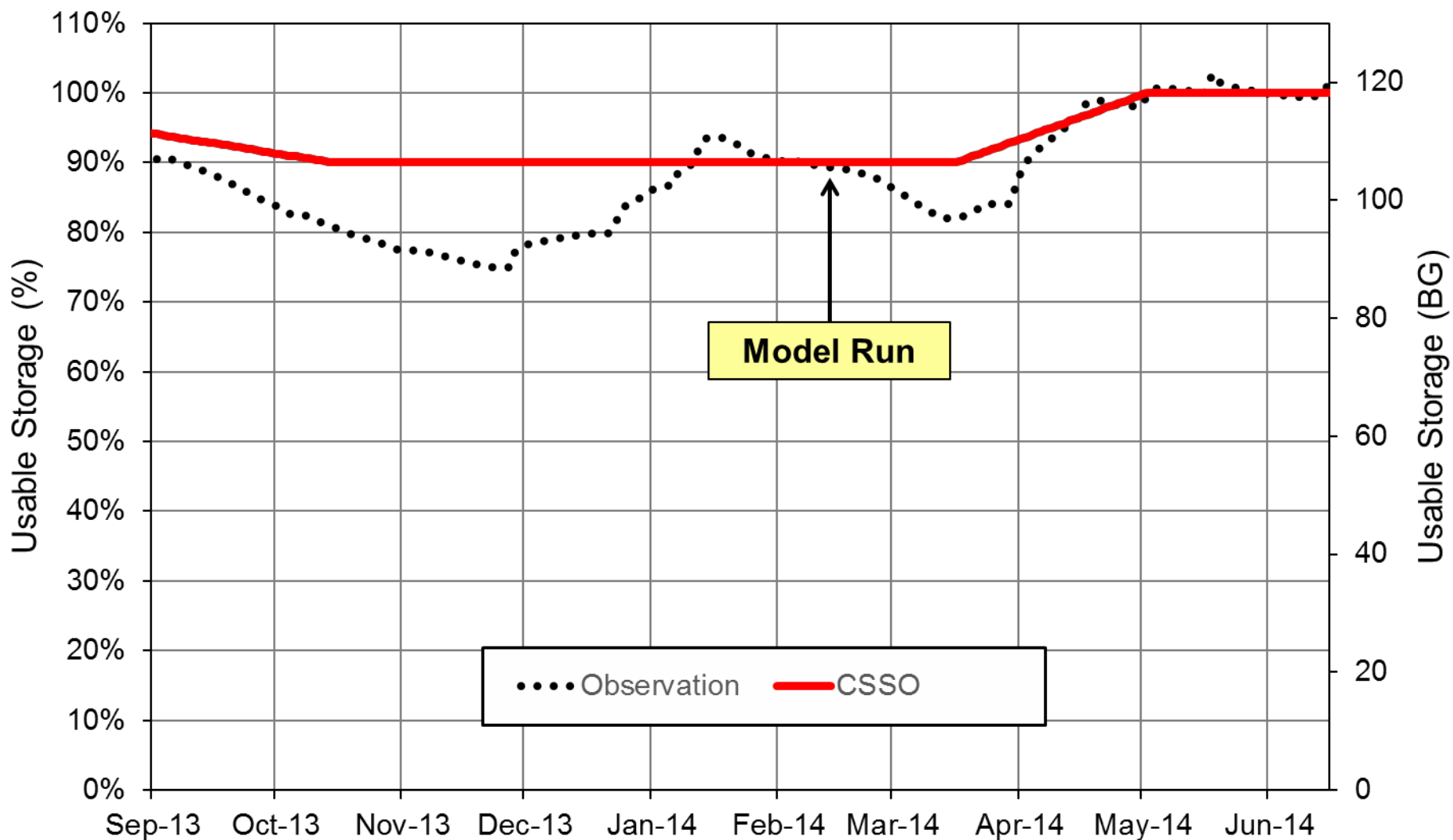
Ashokan Observed and Projected Storage - ARC 300 mgd



Ashokan 2014 Snow Water, Void, and Release



Ashokan Observed Storage



Our forecasts helped us hit CSSO target!

- Forecast skill for storm events from January to June 1st (2017-present);
- Used a simple mass-balance model to assess impact of forecast skill on reservoir operations;
- Examined medium- and large- sized events and impact of forecast skill on meeting storage target to minimize reservoir spills.

Storm event detection using NWS HEFS forecast (late winter-spring)

				January through June 1st					
				Event detected by lead-time					
				1-day		3-day		7-day	
Event	Start date	Peak date	Peak inflow West Basin(MGD)	50th	90th	50th	90th	50th	90th
1	4/30/2023	5/1/2023	3792	yes	yes	yes	yes	no	yes
2	4/7/2022	4/8/2022	6305	yes	yes	yes	yes	no	yes
3	4/13/2020	4/14/2020	4269	no	no	no	yes	no	yes
4	1/25/2019	1/25/2019	3600	yes	yes	no	yes	no	no
5	4/3/2017	4/7/2017	2729	yes	yes	no	yes	no	yes
6	4/16/2018	4/17/2018	2850	yes	yes	yes	yes	no	yes

				Forecast error (%)					
				1-day		3-day		7-day	
Event	Start date	Peak date	Peak inflow West Basin(MGD)	50th	90th	50th	90th	50th	90th
1	4/30/3023	5/1/2023	3792	-27%	-36%	-5%	1%	86%	-14%
2	4/7/2022	4/8/2022	6305	68%	45%	60%	87%	170%	150%
3	4/13/2020	4/14/2020	4269				270%	355%	287%
4	1/25/2019	1/25/2019	3600	8%	0%		344%	419%	
5	4/3/2017	4/7/2017	2729	-21%	-17%		-21%	62%	-3%
6	4/16/2018	4/17/2018	2850	1%	15%	-8%	-1%	89%	91%
Average				6%	1%	16%	113%	197%	102%
25th %ile				-21%	-17%	-6%	-1%	87%	-3%
50th% ile				1%	0%	-5%	44%	130%	91%
75th%ile				38%	30%	60%	288%	371%	218%

Chance of false event forecasting

18 forecast dates selected randomly

	90th%ile event detection		
	1-day	3-day	7-day
3/20/2017	CNE	CNE	SED
1/11/2018	CNE	MED	CNE
5/5/2018	CNE	CNE	CNE
2/20/2019	CNE	CNE	CNE
3/18/2019	CNE	CNE	CNE
4/26/2021	CNE	CNE	CNE
5/23/2021	CNE	CNE	WSED
1/17/2022	CNE	CNE	CNE
5/4/2022	CNE	CNE	CNE
4/17/2023	CNE	CNE	SED
5/29/2023	CNE	CNE	CNE
1/18/2017	CNE	CNE	WSED
1/26/2018	CNE	CNE	CNE
1/21/2019	CNE	CNE	WSED
5/26/2020	CNE	CNE	CNE
6/27/2021	CNE	CNE	SED
2/26/2022	CNE	CNE	CNE
2/23/2023	CNE	CNE	CNE
%correct	100	100	83

Correct forecast		Wrong forecast	
1-2 BGD	SED	wrong small event	WSED
2-5 BGD	MED	wrong medium event	WMED
>5BGD	LED	wrong large event	WLED
non-event	CNE	MISS	

Previous event-based analysis

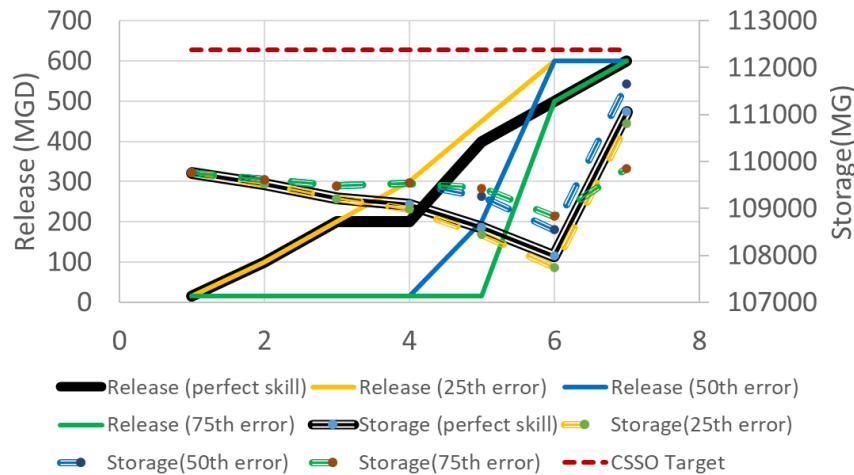
	90th%ile event detection		
	1-day	3-day	7-day
%correct	83%	100%	83%

Impacts of forecast error on operations

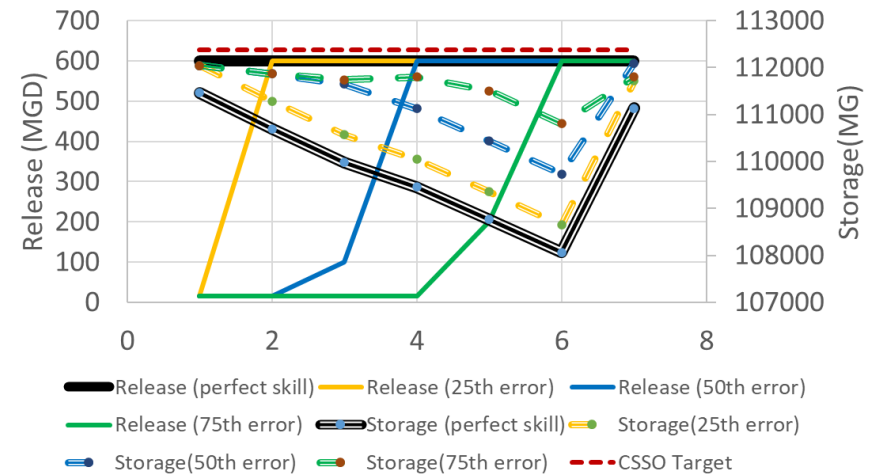
Medium-sized (~4.2 BGD) event;
start below target

Medium-sized (~4.2 BGD) event;
start at target

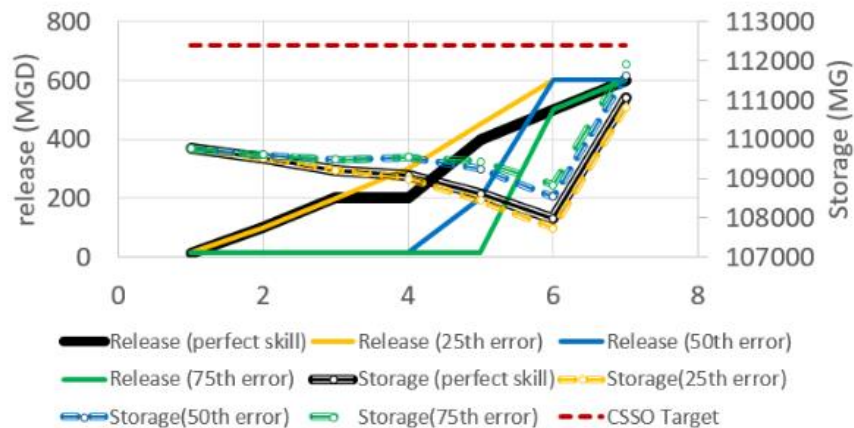
Forecasted storage (4 BGD event)



Forecasted storage (4.2 BGD event)



Forecast based operations and realized storage
(4 BGD event)



Forecast based operations and realized storage
(4.2 BGD event)

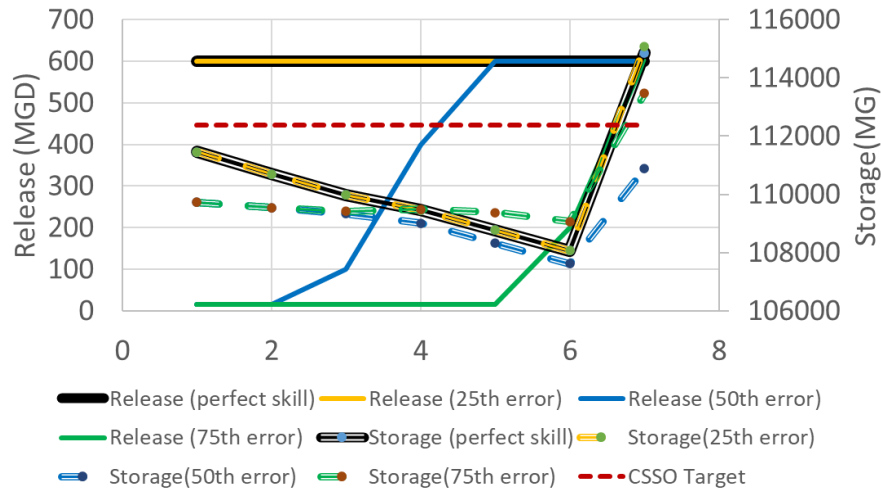


Storage target met using 90th%ile for decisions

Impacts of forecast error on operations

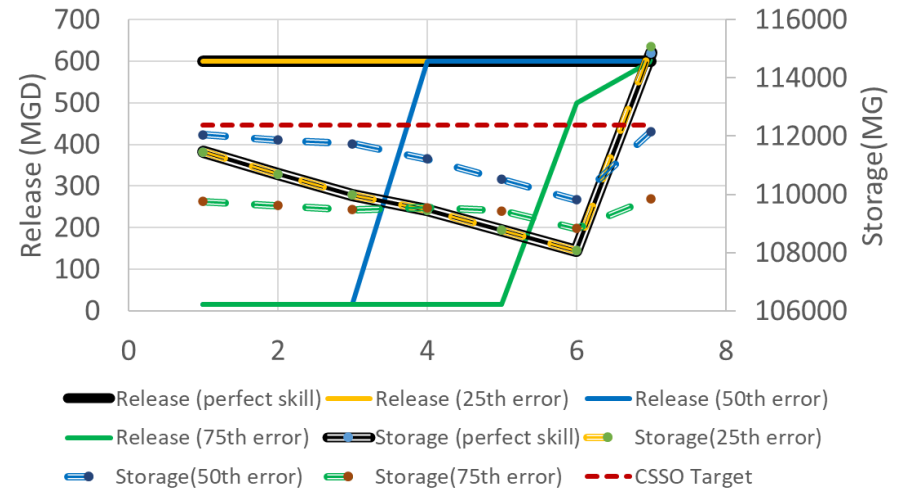
Large-sized (~8 BGD) event;
start below target

Forecasted storage (8 BGD event)

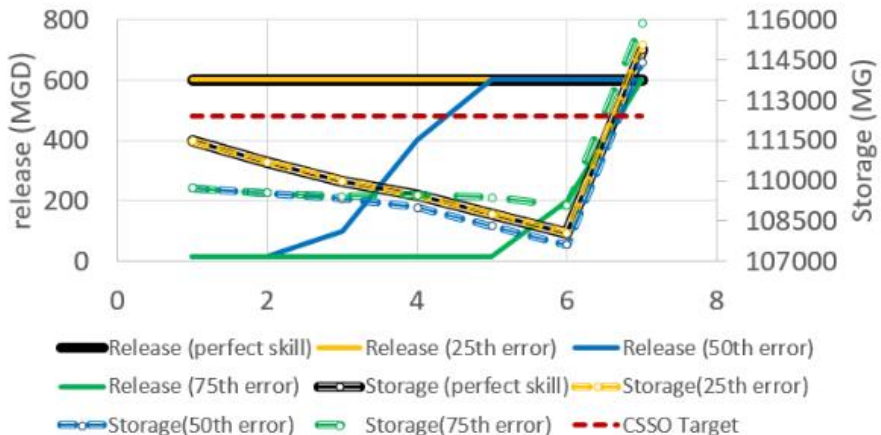


Large-sized (~8 BGD) event;
start at target

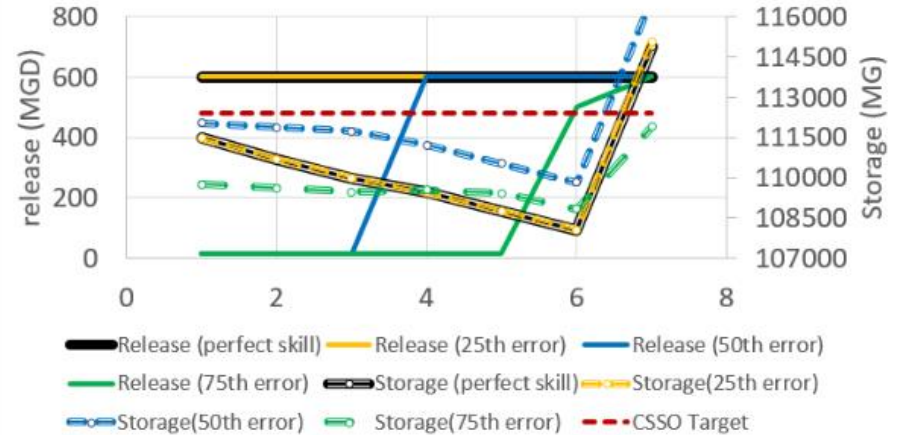
Forecasted storage (8 BGD event)



Forecast based operations and realized storage
(8 BGD event)



Forecast based operations and realized storage
(8 BGD event)



Storage target not met for most cases using 90th%ile for decisions

- Assumption that each trace in National Weather Service's HEFS forecast is equally likely to occur is false;
- Therefore, ensemble interpretation (e.g., percentile tracking and storm dynamics) is needed to use the ensemble approach effectively for short-term operations;
- NWS HEFS forecast works well at guiding operations to meet storm storage target (CSSO) for medium-sized events;
- NWS HEFS needs more skill to better guide operations for meeting CSSO during large events (Atmospheric Rivers?).