BUREAU OF — RECLAMATION

Update to Method of Developing 5-Year Colorado River System Projections

February 18, 2022

Overview

- Background

- Probabilistic Projection Comparison Project

- Comparison of 5-Year Projections

- February 5-Year Projections *(Provisional, to be published the week of February 21st)*
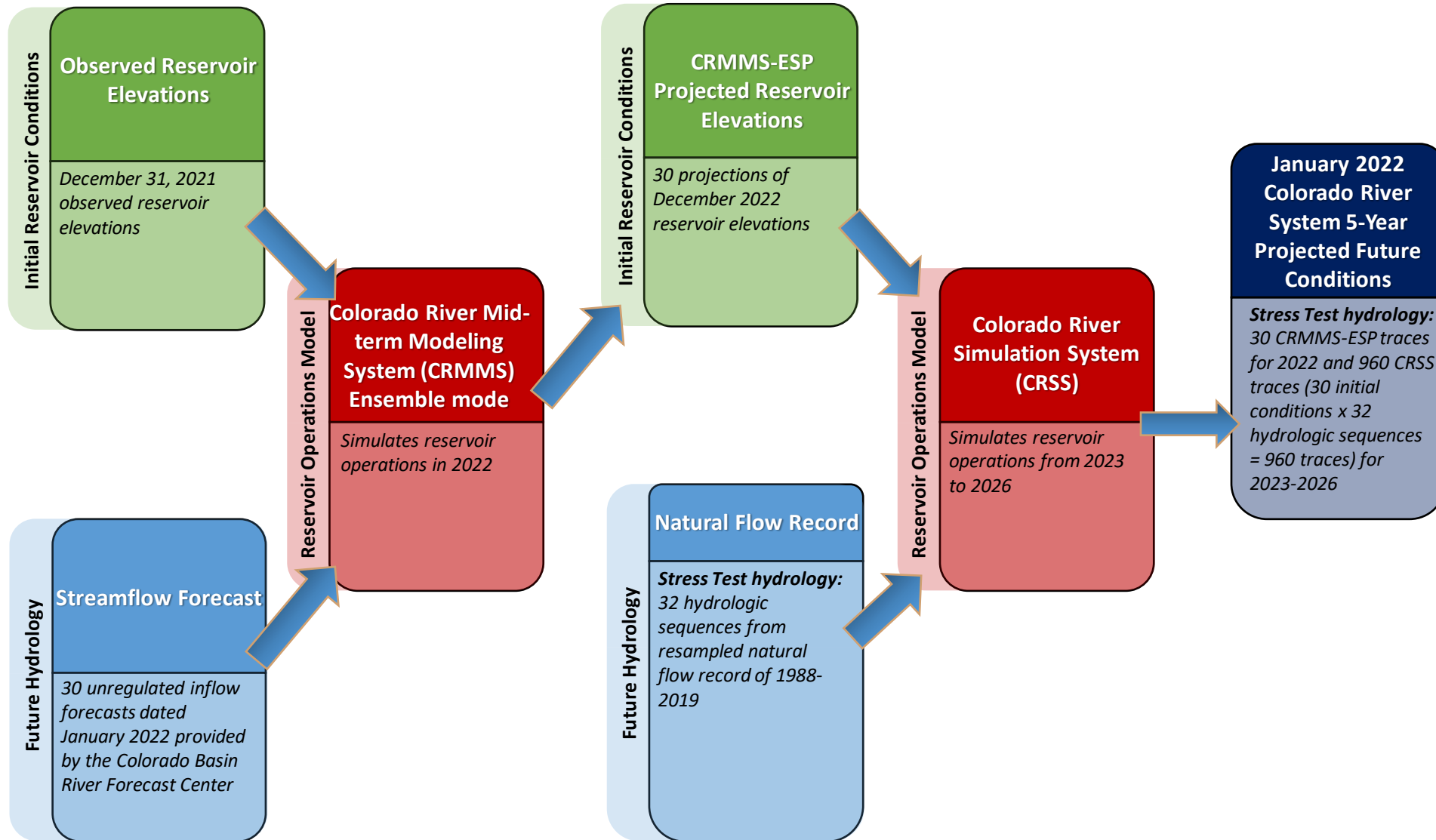
- Summary and Next Steps

Reclamation Operational Modeling
Model Comparison

	Colorado River Mid-term Modeling System (CRMMS)		CRSS
	24-Month Study Mode (Manual Mode)	**Ensemble Mode (Rule-based Mode)**	**CRSS**
Primary Use	AOP tier determinations and projections of current conditions	Risk-based operational planning and analysis	Long-term planning, comparison of alternatives
Simulated Reservoir Operations	Operations input manually	Rule-driven operations	
Probabilistic or Deterministic	Deterministic – single hydrologic trace	Deterministic OR Probabilistic 30 (or more) hydrologic traces	Probabilistic – 100+ traces
Time Horizon (years)	1 - 2	1 - 5	1 - 50
Upper Basin Inflow	Unregulated forecast, 1 trace	Unregulated ESP forecast, 30 traces	Natural flow; historical, paleo, or climate change hydrology
Upper Basin Demands	Implicit, in unregulated inflow forecast		Explicit, 2016 UCRC assumptions
Lower Basin Demands	Official approved or operational		Developed with LB users

January 2022 CRMMS-ESP / CRSS 5-Year Projections

Initial Reservoir Conditions

Observed Reservoir Elevations

December 31, 2021 observed reservoir elevations

Reservoir Operations Model

Colorado River Mid-term Modeling System (CRMMS) Ensemble mode

Simulates reservoir operations in 2022

Future Hydrology

Streamflow Forecast

30 unregulated inflow forecasts dated January 2022 provided by the Colorado Basin River Forecast Center

Initial Reservoir Conditions

CRMMS-ESP Projected Reservoir Elevations

30 projections of December 2022 reservoir elevations

Reservoir Operations Model

Colorado River Simulation System (CRSS)

Simulates reservoir operations from 2023 to 2026

Future Hydrology

Natural Flow Record

***Stress Test hydrology:** 32 hydrologic sequences from resampled natural flow record of 1988-2019*

January 2022 Colorado River System 5-Year Projected Future Conditions

***Stress Test hydrology:** 30 CRMMS-ESP traces for 2022 and 960 CRSS traces (30 initial conditions x 32 hydrologic sequences = 960 traces) for 2023-2026*

Probabilistic Projection Comparison Project

Probabilistic Projection Comparison Project

Evaluation of Reclamation's approach to 5-year probabilistic projections

Objectives

- Assess the uncertainty and error associated with hydrology and operational projections from the Colorado River Mid-term Modeling System (CRMMS) and the Colorado River Simulation System (CRSS) simulations.

- Recommend a modeling approach for Reclamation's probabilistic projections. Summarize findings in a technical report.

- Update current modeling approach based on findings.

Completed Tasks

- Analyze key modeling attributes: hydrology, demands, modeling assumptions
- Perform modeling hindcast simulations to compare projections

Historical Streamflow Hindcast

CRMMS outperforms CRSS

- Lake Powell:
  - CRSS under-projecting Powell inflow due to differences in natural flow and Upper Basin demand development methodologies, leading to compounding storage error at longer leads
  - CRMMS has minimal bias in Powell inflow, though errors remain, which compound resulting in under-projection of storage at longer leads
  - Minimal errors in operating tier and releases

- Lake Mead:
  - CRSS under-projects inflow slightly due to intervening flow between Lakes Powell and Mead
  - Both models' outflows are slightly over-projected, and are due to projections of Lower Basin shortage (more instances in CRSS) and intervening flows differences
  - Storage is under-projected by CRSS due to the errors in inflow and outflow; CRMMS storage errors are smaller and less biased

Assess models' performance given historical hydrology (single trace)

Study Period: January initializations of 2008-2019 for 5-year simulations Compared to observations (2008-2019)

Water Year Inflow, End-of-Water Year Storage, Water Year Outflow
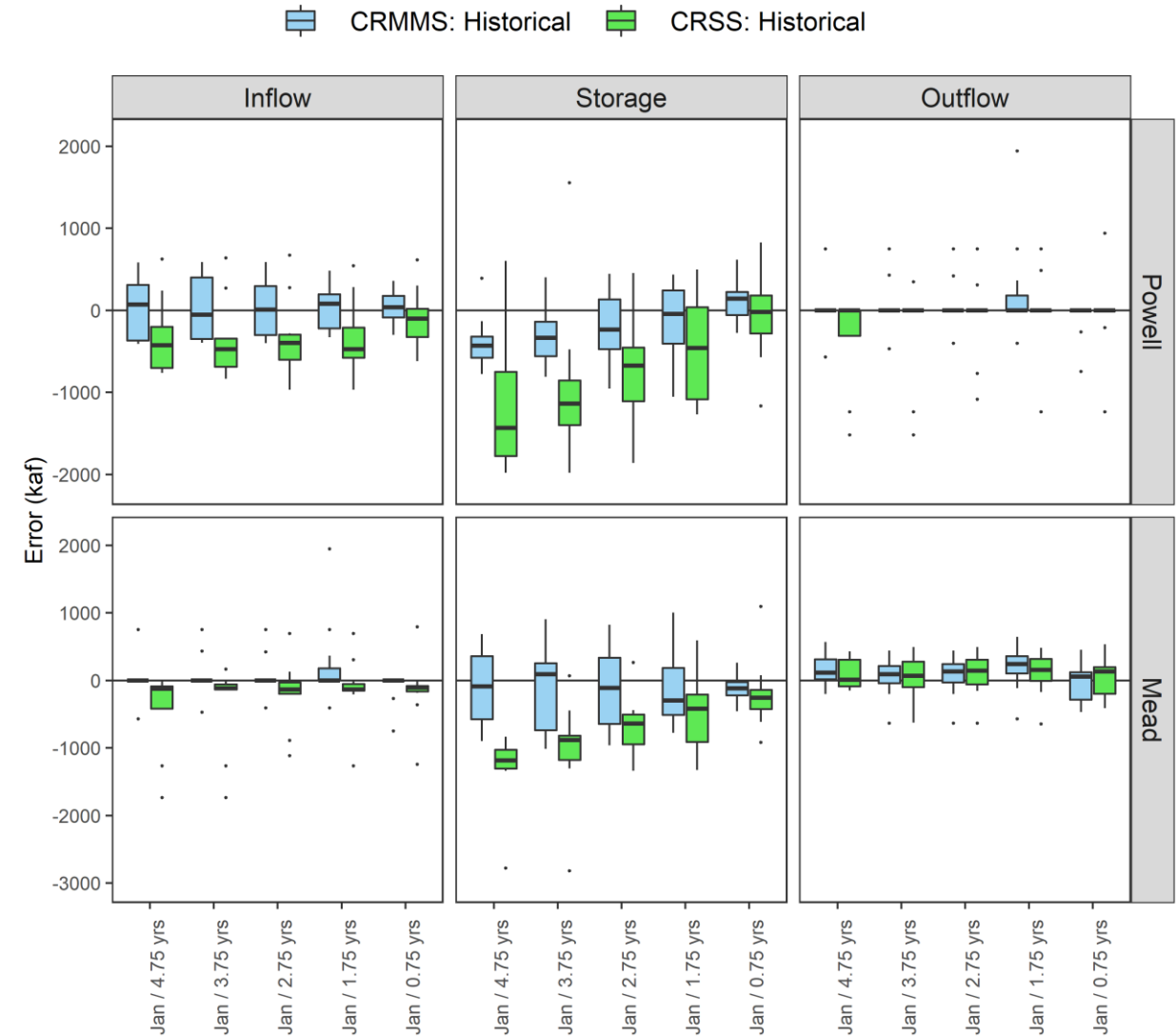
Recommendation

Recommend switching from the Colorado River Simulation System (CRSS) to the Colorado River Mid-term Modeling System (CRMMS) to produce the "official" Colorado River System 5-year projections

- This change will streamline the modeling process,

- provide more consistency with 24-Month Study (i.e., water use and modeling assumptions) and 2-year modeling projections, and

- result in better performance over the 5-year period.

Comparison of
5-Year Projections

Differences between CRSS and CRMMS-ESP

1. Upper Basin hydrology and demands methods
   - CRSS uses resampled natural flow and explicitly models Upper Basin demands, as projected by Upper Basin States
   - CRMMS-ESP uses CBRFC unregulated inflow forecasts with Upper Basin demands implicitly incorporated during calibration

2. Lower Basin intervening flows and phreatophytes
   - Lower intervening flows in CRSS between Powell and Mead due to intervening flow locations
   - Phreatophytes explicitly modeled in CRSS

3. Combining CRMMS-ESP and CRSS results in a wider range of future hydrology

Hydrology Sequences

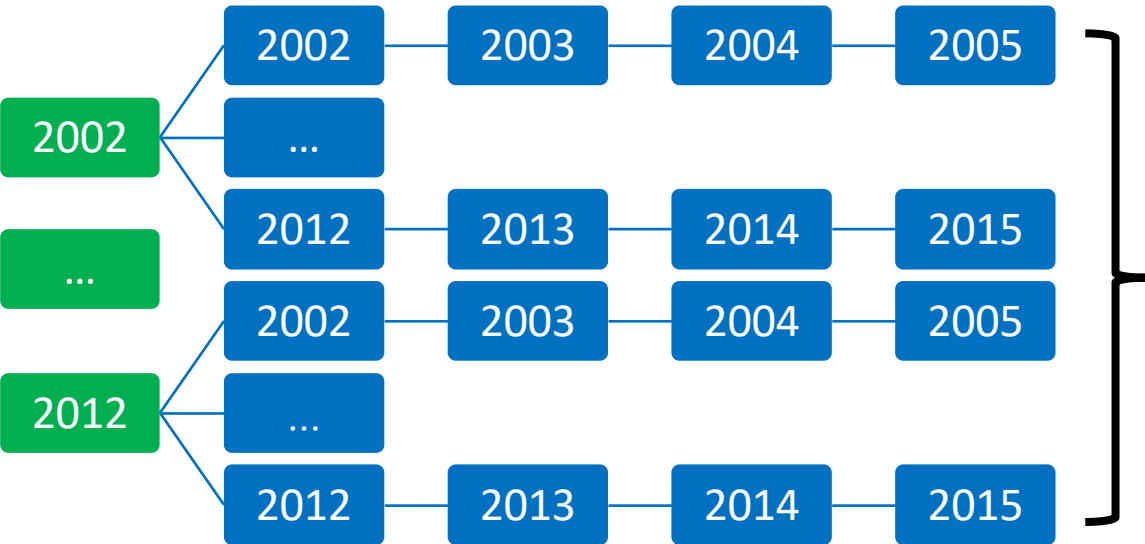## Years 1-5 Ensemble Streamflow Predictions (ESP)

CRMMS-ESP

| 2002 | 2003 | 2004 | 2005 | 2006 |

...

| 2012 | 2013 | 2014 | 2015 | 2016 |

Year 1 ESP combined with Years 2-5 Natural Flow

CRMMS-ESP / CRSS

2002
- 2002 — 2003 — 2004 — 2005
- ...
- 2012 — 2013 — 2014 — 2015

...

2012
- 2002 — 2003 — 2004 — 2005
- ...
- 2012 — 2013 — 2014 — 2015
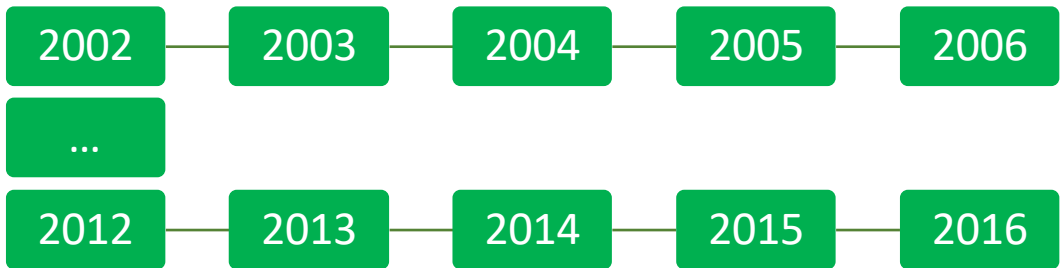
Inflow created by CBRFC using temperature & precipitation from 1991-2020

Resampled historical natural flow from 1988-2019

- Creates sequences not seen in the observed record
- Can result in a wider reservoir projections range

Comparison of 5-Year Projections

- January CRMMS-ESP / CRSS Projections *(published on February 4th)*

- January CRMMS-ESP Projections *(extension of 2-year projections published January 19th)*

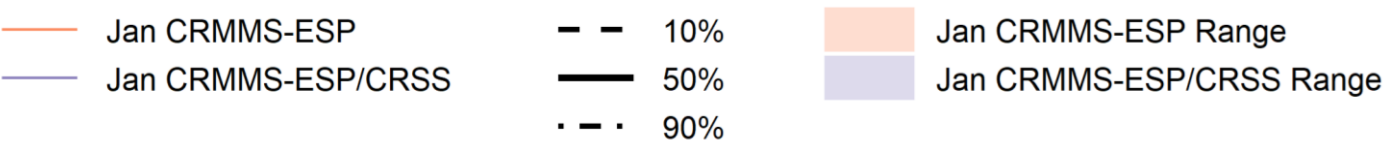- February CRMMS-ESP Projections *(Provisional, to be published the week of February 21st)*
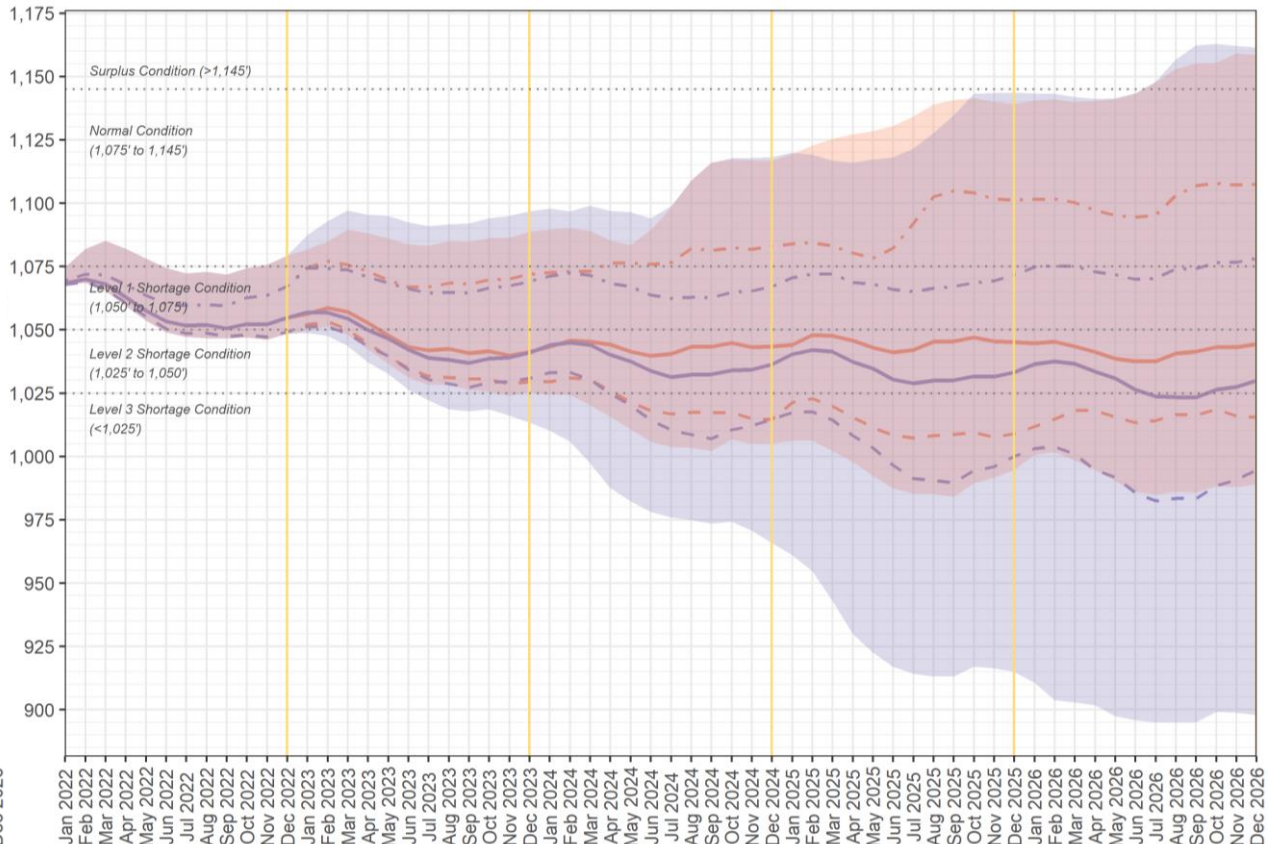
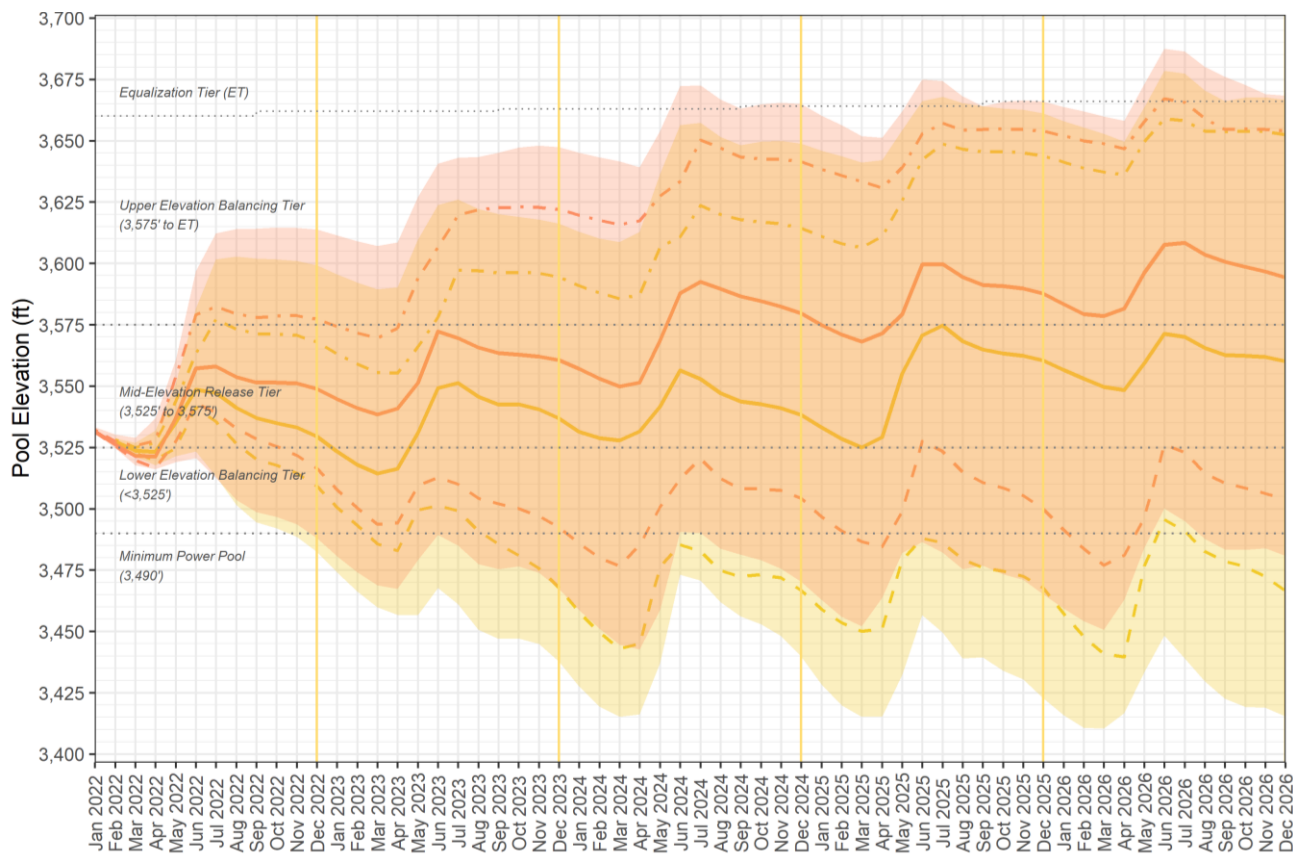# January 2022 CRMMS-ESP / CRSS vs. January 2022 CRMMS-ESP 5-Year Projections
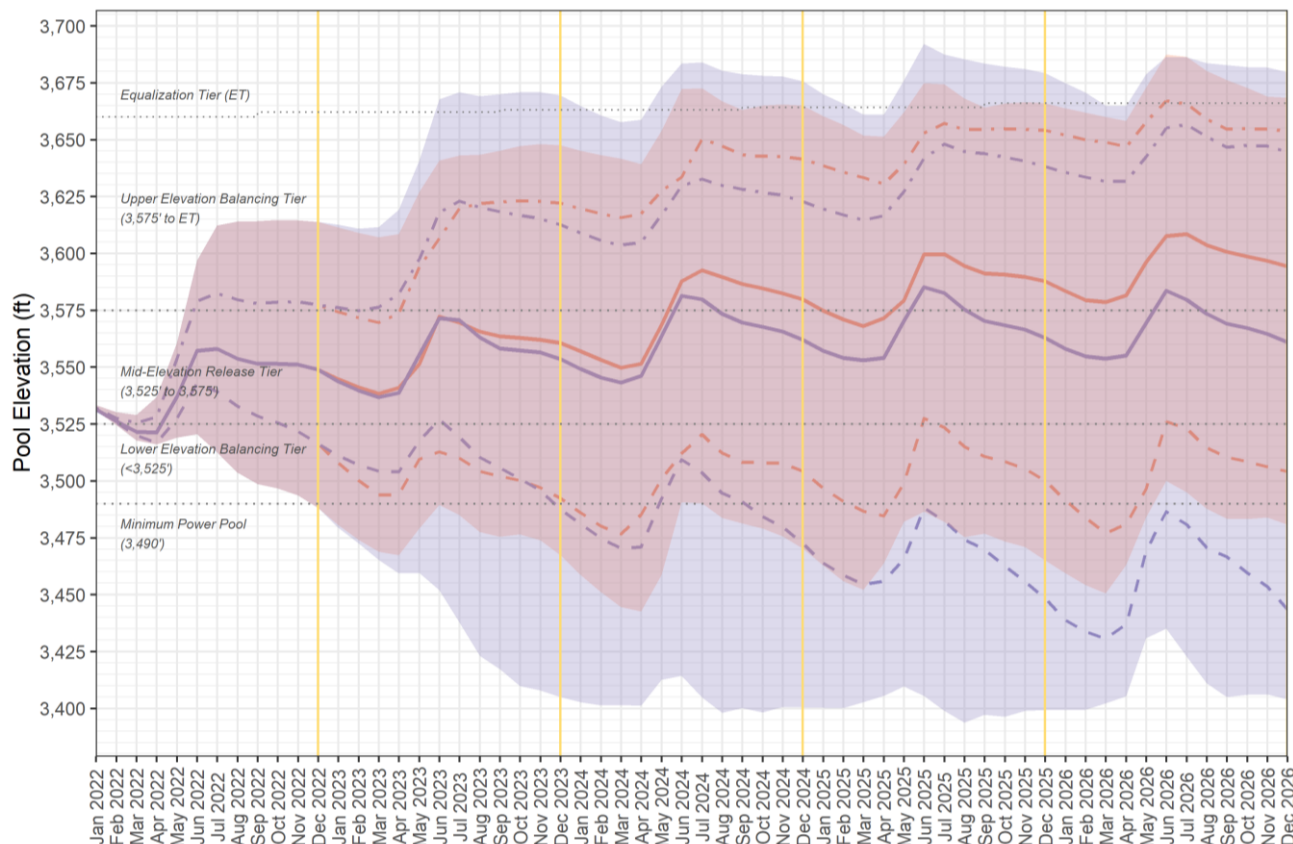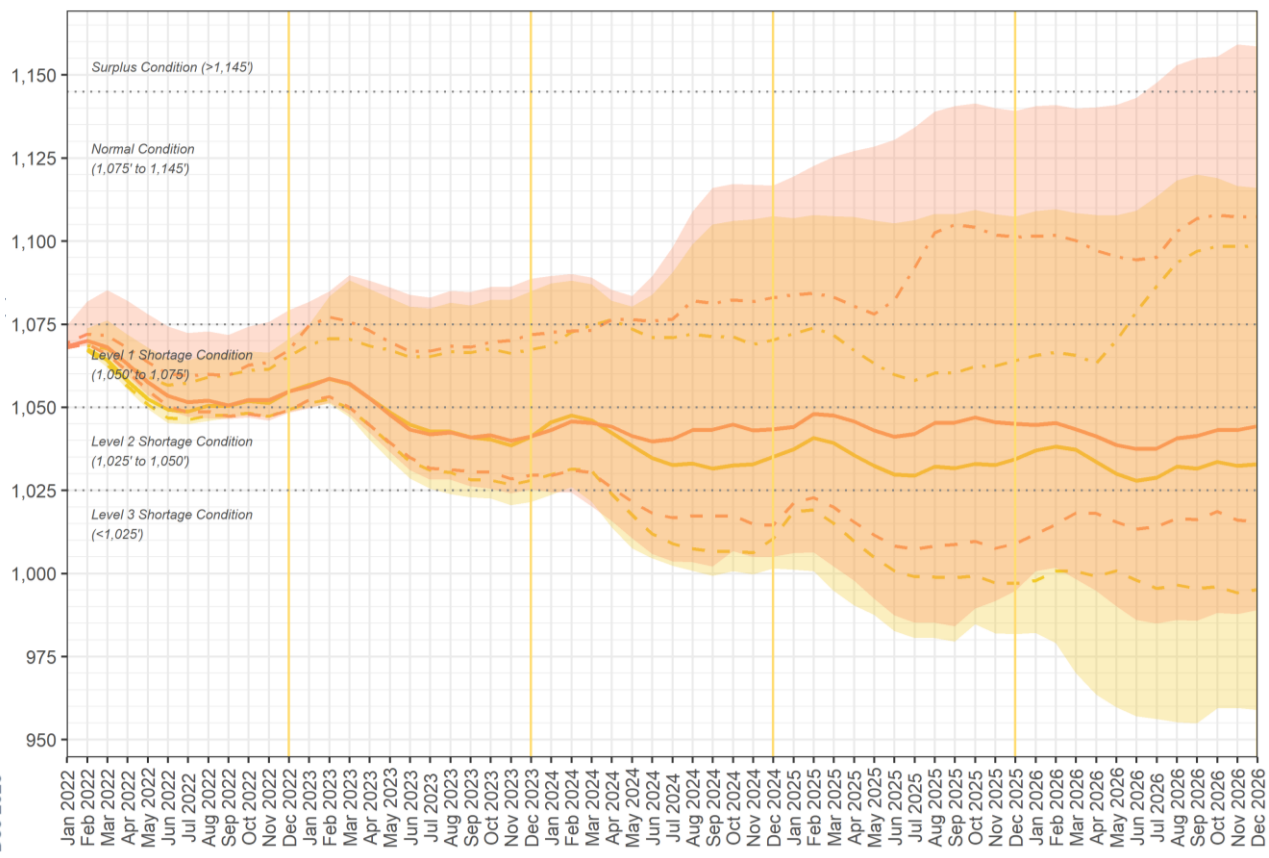

Lake Powell

Lake Mead

February 2022 CRMSS-ESP vs. January 2022 CRMMS-ESP 5-Year Projections

February 2022 CRMSS-ESP vs. January 2022 CRMMS-ESP/CRSS 5-Year Projections

Lake Powell / Lake Mead projection charts comparing Feb CRMMS-ESP and Jan CRMMS-ESP/CRSS with 10%, 50%, 90% bands.
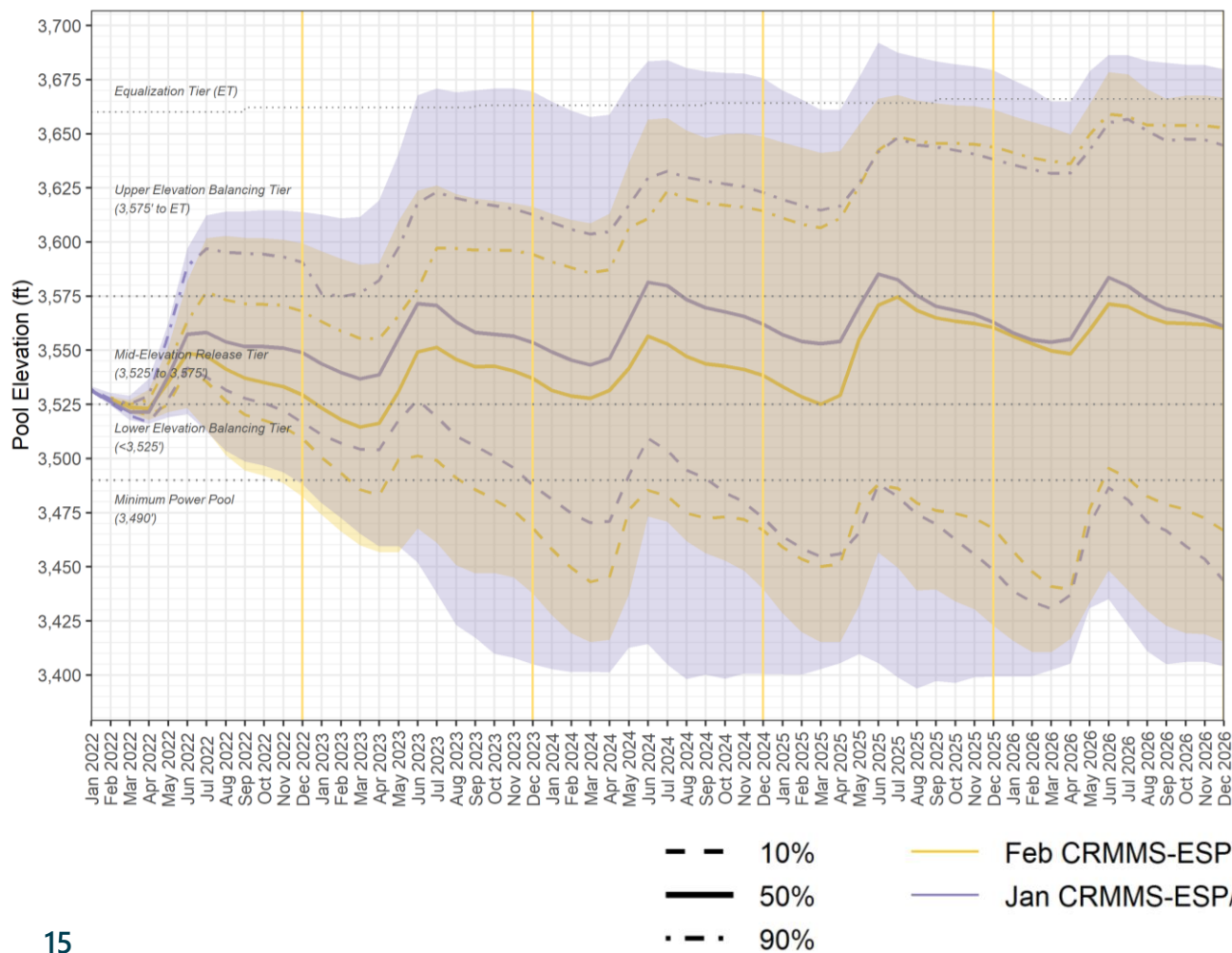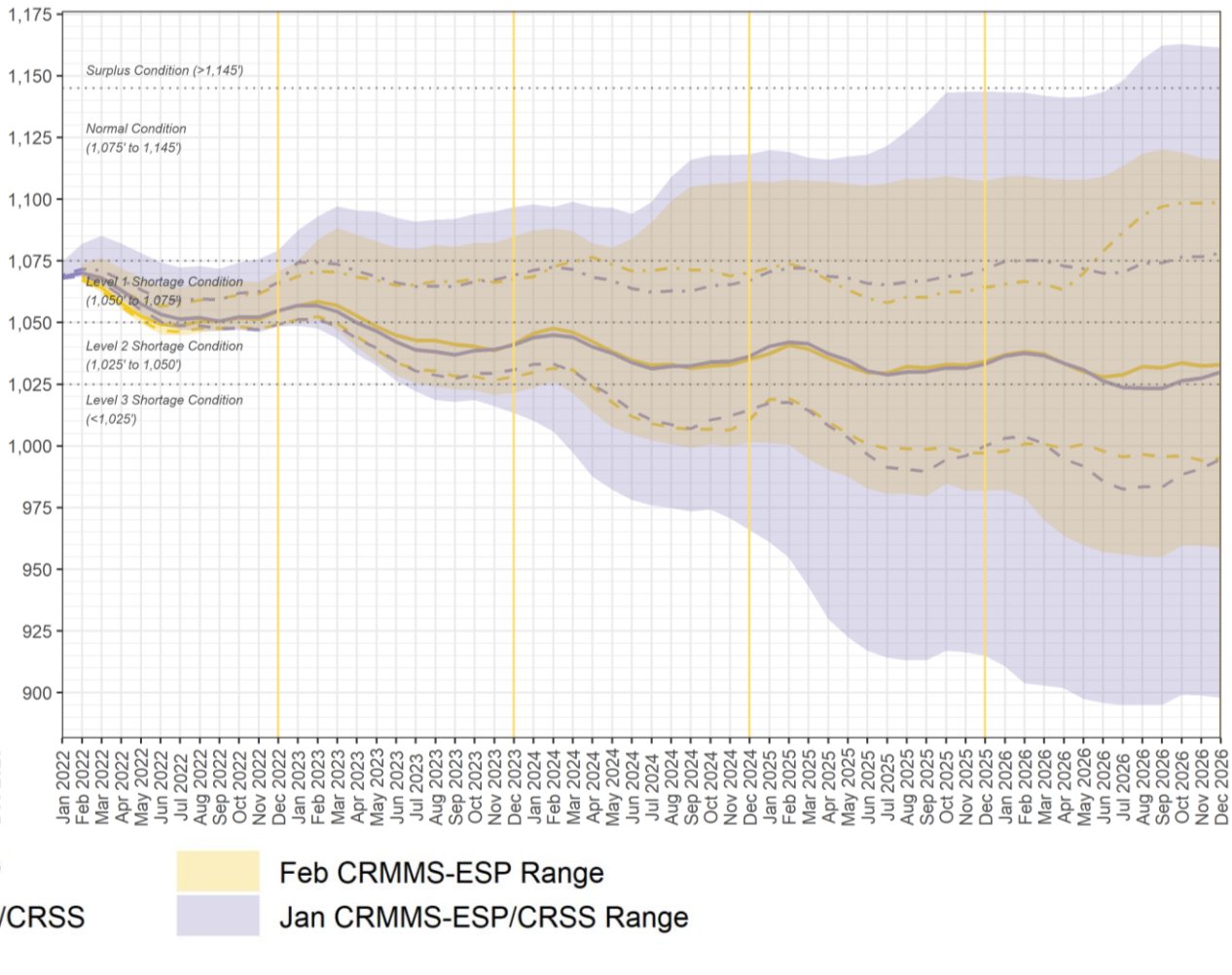
Provisional February 5-Year Projections

February 2022 CRMMS-ESP & January 2022 CRSS 5-Year Table

Percent of Traces with System Condition

Event or System Condition	CRMMS-ESP (February)					CRSS (January)				
	'22	'23	'24	'25	'26	'22	'23	'24	'25	'26
Equalization Tier (Powell ≥ EQ Elevation)	0	0	3	7	13	0	0	<1	4	6
Equalization > 8.23 maf	0	0	3	7	13	0	0	0	0	0
Equalization = 8.23 maf	0	0	0	0	0	0	0	0	0	0
Upper Elevation Balancing Tier (EQ > Elev ≥ 3,575 ft)	0	7	13	20	13	0	10	30	35	34
UEB > 8.23 maf	0	7	13	20	13	0	10	29	34	31
UEB = 8.23 maf	0	0	0	0	0	0	<1	<1	<1	3
UEB < 8.23 maf	0	0	0	0	0	0	0	<1	0	<1
Mid-Elevation Release Tier (3,575 > Elev. ≥ 3,525 ft)	100	43	50	33	43	100	60	42	34	33
MER = 8.23 maf	0	0	0	0	17	0	0	0	7	6
MER = 7.48 maf	100	43	50	33	27	100	60	42	26	26
Lower Elevation Balancing Tier (Powell < 3,525 ft)	0	50	33	40	30	0	30	27	28	28
LEB > 8.23 maf	0	20	17	17	10	0	9	10	9	9
LEB < 8.23 maf	0	30	17	23	20	0	21	18	19	19

Event or System Condition	CRMMS-ESP (February)					CRSS (January)				
	'22	'23	'24	'25	'26	'22	'23	'24	'25	'26
Surplus Condition (Mead ≥ 1,145 ft)	0	0	0	0	0	0	0	0	0	0
Surplus – Flood Control	0	0	0	0	0	0	0	0	0	0
Normal (< 1,145 and > 1,075 ft)	0	0	7	7	7	0	3	5	4	7
Mead >/≥ 1,110 ft	0	0	0	0	0	0	0	0	<1	<1
Mead ≤ 1,090 and > 1,075 ft	0	0	7	3	0	0	3	5	3	4
Shortage Condition (Mead ≤ 1,075 ft)	100	100	93	93	93	100	97	95	96	93
Shortage / Reduction – 1st level	100	87	23	17	27	100	80	22	27	23
Mead ≤ 1,075 and > 1,050 ft	100	87	23	17	27	100	80	22	27	23
Shortage / Reduction – 2nd level	0	13	67	47	27	0	17	72	40	35
Mead ≤ 1,050 and > 1,045 ft	0	13	10	13	7	0	17	7	8	6
Mead ≤ 1,045 and > 1,040 ft	0	0	10	3	3	0	0	19	6	6
Mead ≤ 1,040 and > 1,035 ft	0	0	27	10	7	0	0	21	7	6
Mead ≤ 1,035 and > 1,030 ft	0	0	10	10	3	0	0	18	9	8
Mead ≤ 1,030 and ≥/> 1,025 ft	0	0	10	10	7	0	0	7	10	9
Shortage / Reduction – 3rd level	0	0	3	30	40	0	0	<1	30	35
Mead </≤ 1,025 ft	0	0	3	30	40	0	0	<1	30	35

Percent of Traces Falling below Critical Elevations

	Run	2022	2023	2024	2025	2026
Lake Powell less than 3,525 ft	Jan 22	87%	42%	39%	36%	37%
	Feb 22	**90%**	**77%**	**50%**	**50%**	**37%**
	Difference	3%	35%	11%	14%	0%
Lake Powell less than 3,490 feet (minimum power pool)	Jan 22	N	8%	20%	23%	26%
	Feb 22	**N**	**23%**	**27%**	**27%**	**23%**
	Difference	-	15%	7%	4%	-3%
Lake Powell less than 3,375 ft (dead pool = 3,370 ft)	Jan 22	0%	0%	0%	0%	0%
	Feb 22	**0%**	**0%**	**0%**	**0%**	**0%**
	Difference	0%	0%	0%	0%	0%

	Run	2022	2023	2024	2025	2026
Lake Mead less than 1,020 ft	Jan 22	0%	<1%	36%	40%	47%
	Feb 22	**0%**	**0%**	**20%**	**33%**	**37%**
	Difference	0%	0%	-16%	-7%	-10%
Lake Mead less than 1,000 ft	Jan 22	0%	0%	3%	17%	20%
	Feb 22	**0%**	**0%**	**7%**	**13%**	**17%**
	Difference	0%	0%	4%	-4%	-3%
Lake Mead less than 950 ft (min power pool)	Jan 22	0%	0%	0%	<1%	3%
	Feb 22	**0%**	**0%**	**0%**	**0%**	**0%**
	Difference	0%	0%	0%	0%	-3%
Lake Mead less than 900 ft (dead pool = 895 ft)	Jan 22	0%	0%	0%	0%	<1%
	Feb 22	**0%**	**0%**	**0%**	**0%**	**0%**
	Difference	0%	0%	0%	0%	0%

All results computed as the chance of falling below the threshold in any month in the calendar (water) year for Lake Mead (Lake Powell).
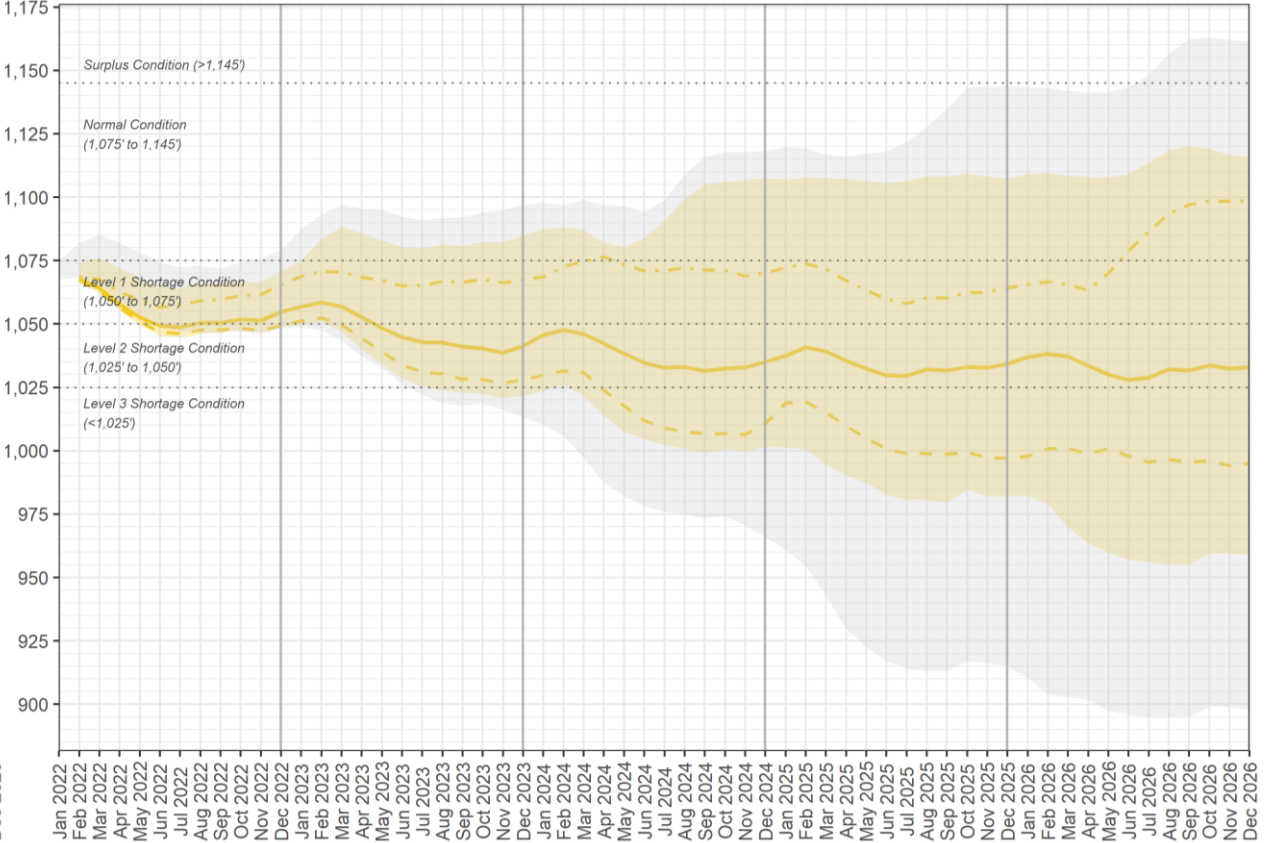
February 2022 CRMMS-ESP 5-Year Projections with CRSS Range of Uncertainty

Lake Powell — Lake Mead
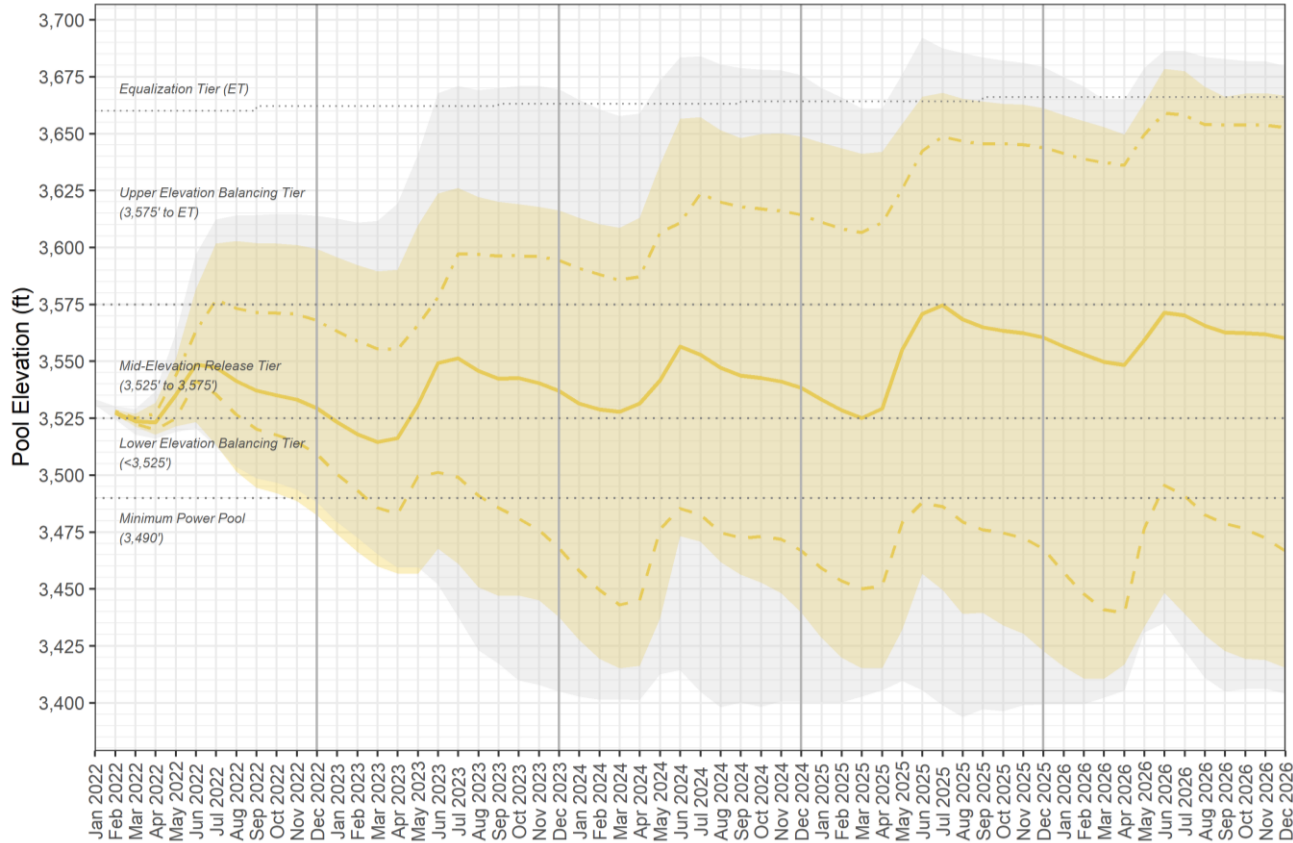
Summary and Next Steps

- This change will streamline the modeling process, provide more consistency with 24-Month Study (i.e., water use and modeling assumptions) and 2-year modeling projections, and result in better performance over the 5-year period.

- Provide updated 5-year projections for February 2022 using CRMMS-ESP by the end of next week
    - Continue providing 5-year projections in January, April, and August, and as conditions warrant

- Continue to use CRSS to support long-term planning and analysis, and for the development of basin-wide initiatives
    - Anticipate providing CRSS projections beyond 5 years 1-2x/year

- Continue model development in CRSS and CRMMS

Questions?

https://www.usbr.gov/lc/region/g4000/riverops/crss-5year-projections.html

https://www.usbr.gov/lc/region/programs/CRB-R2O.html

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