BUREAU OF RECLAMATION

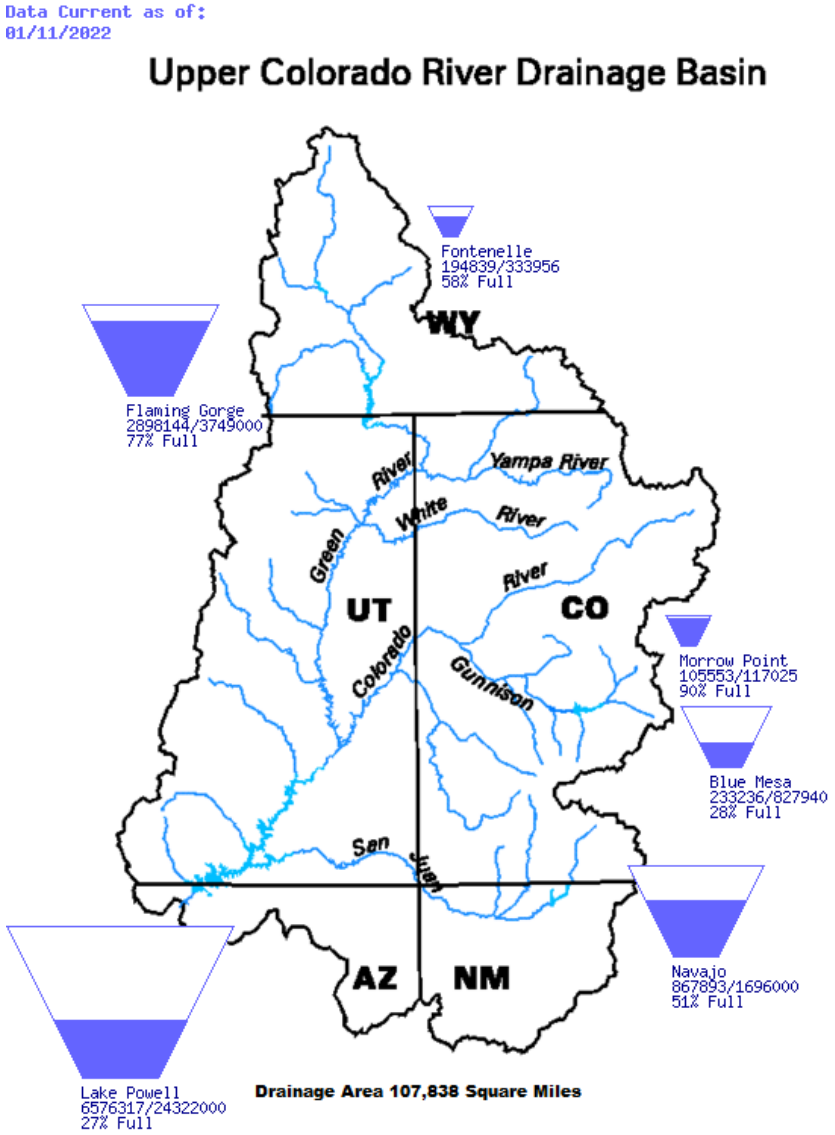
Glen Canyon Dam Technical Working Group

Basin Hydrology, Operations and Water Quality

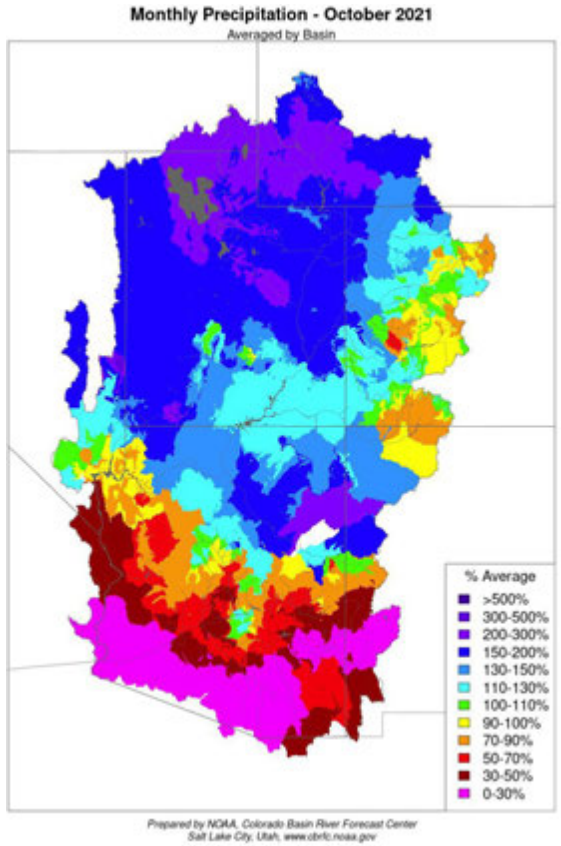
January 13, 2022

Upper Basin Storage (as of January 11, 2022)

Reservoir	Percent Current Live Storage	Current Live Storage (maf)	Live Storage Capacity (maf)	Elevation (feet)
Fontenelle	58	0.19	0.33	6,486.33
Flaming Gorge	77	2.90	3.75	6,017.67
Blue Mesa	28	0.23	0.83	7,434.91
Navajo	51	0.87	1.70	6,020.19
Lake Powell	27	6.58	24.32	3,535.25
UC System Storage	35	10.89	30.93	

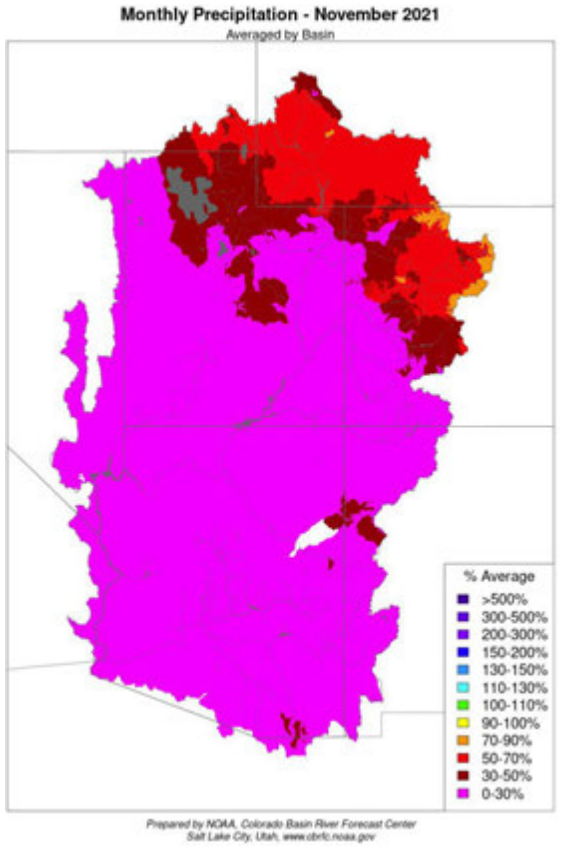


Water Year 2022 (October - December) Monthly Precipitation Summary



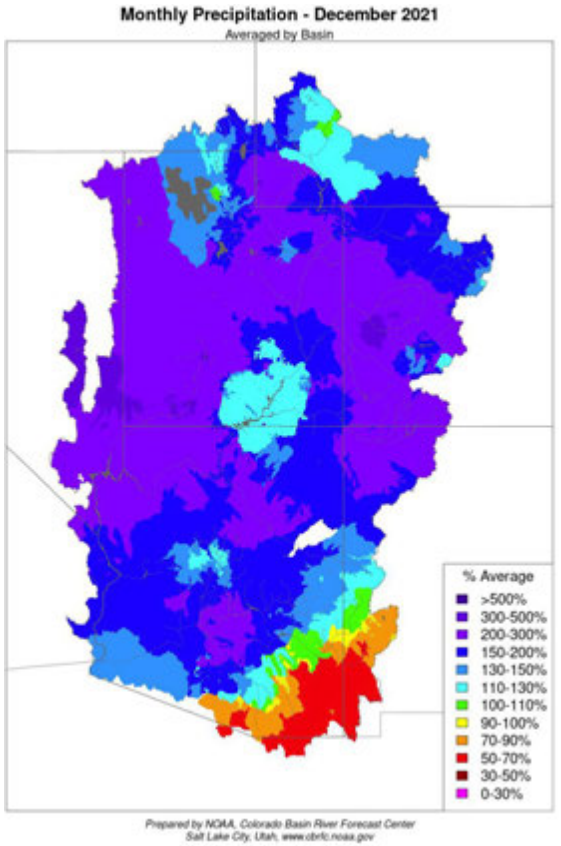
October precipitation was well above average across much of the region including southwest Wyoming, most of Utah, and northern Arizona.

Western Colorado had near average October precipitation while southern Arizona had below average precipitation during the month.



November's weather pattern was mostly very warm and dry with much below average monthly precipitation across most of the region.

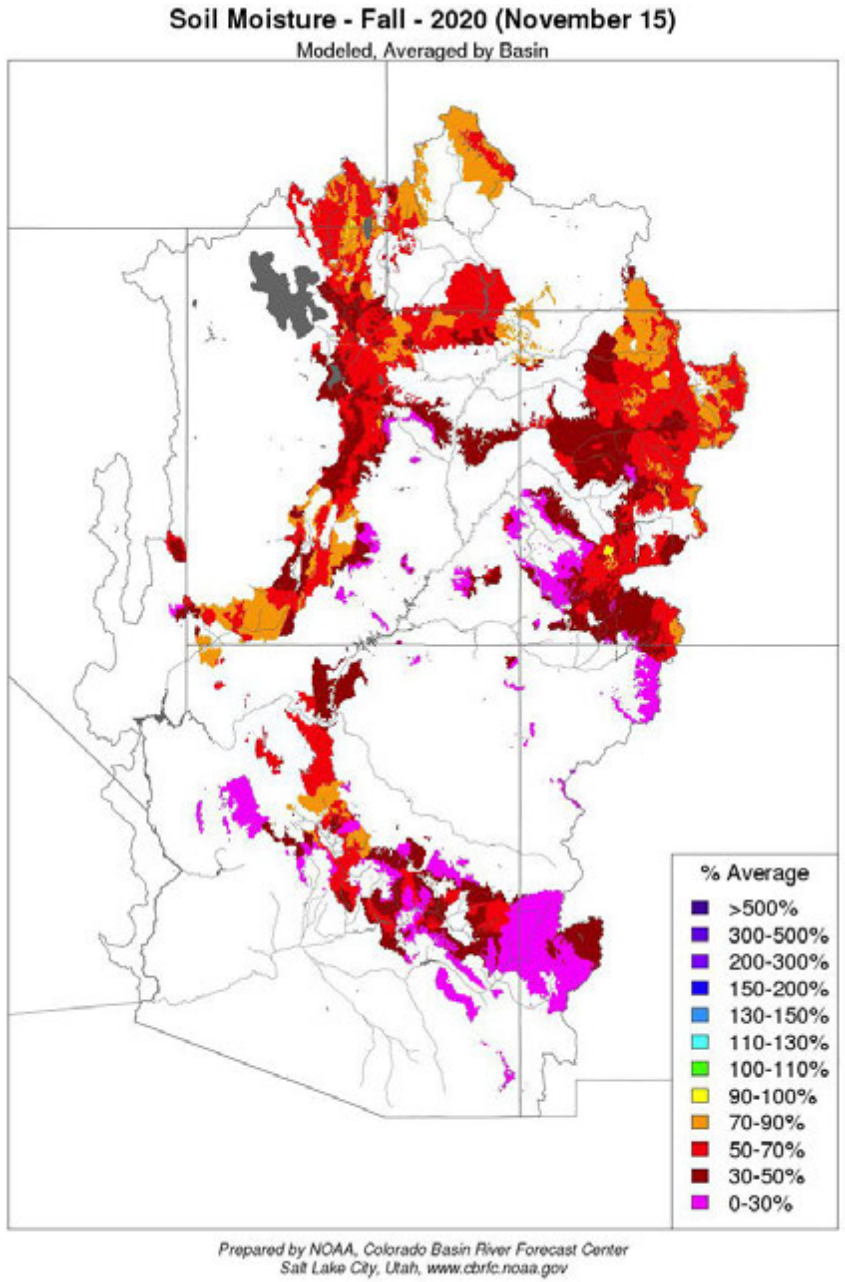
November precipitation fell in the bottom five at numerous SNOTEL stations across Utah, southwest Colorado, and central Arizona.



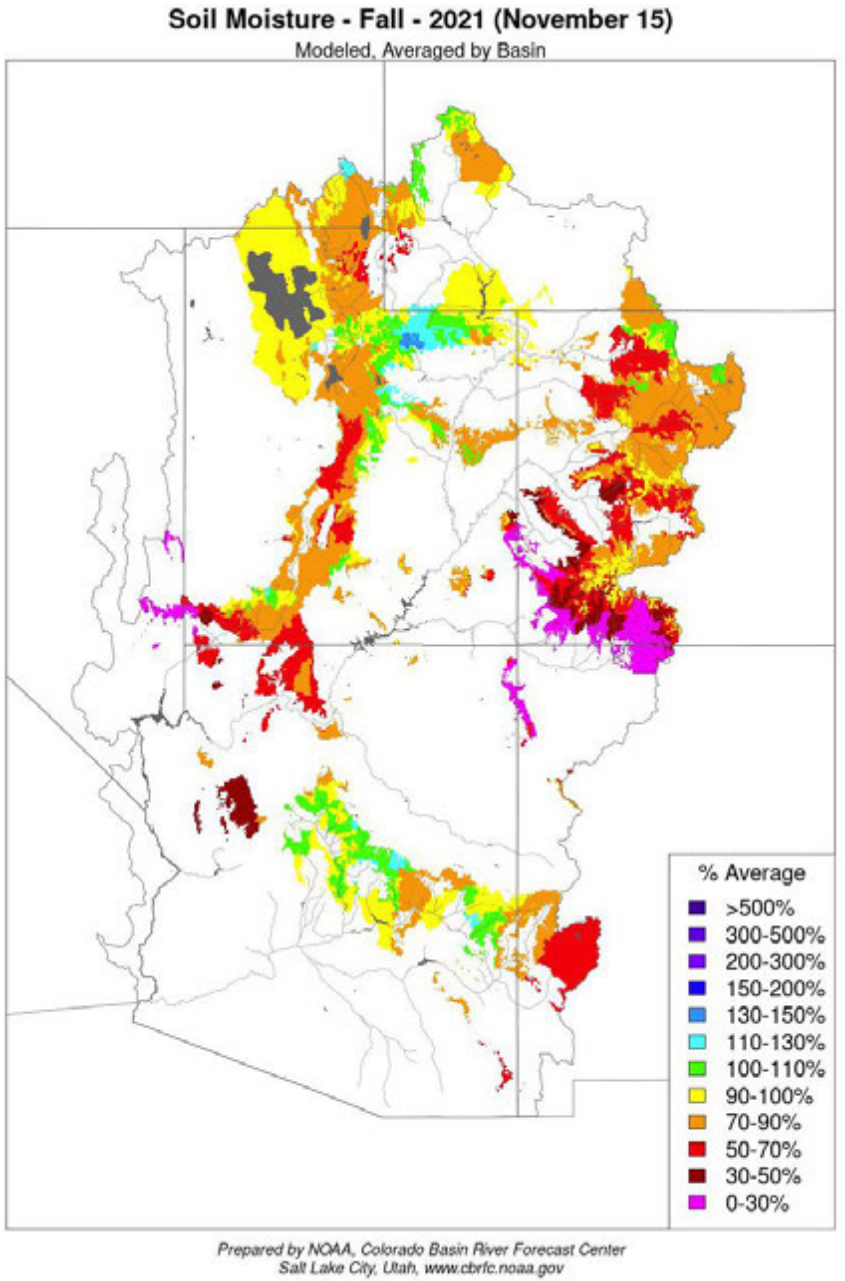
The weather pattern shifted during the second week of December towards colder and wetter conditions and featured multiple storm systems that brought widespread precipitation to most of the region during the last three weeks of the month.

The majority of SNOTEL sites across Utah and western Colorado and a few sites across central Arizona reported December precipitation values that ranked in the wettest five on record.

Fall Model Soil Moisture Conditions: 2020 vs. 2021

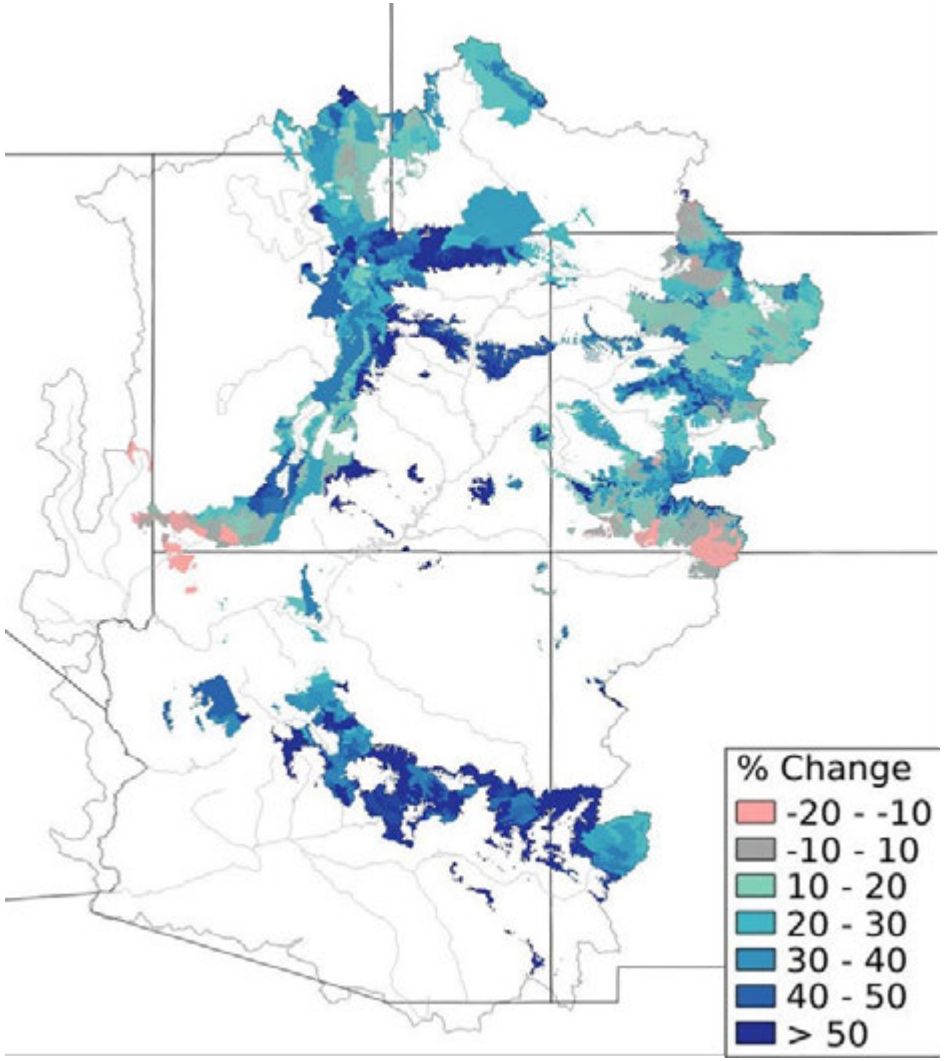


CBRFC model soil moisture conditions are improved from their record/near record dry levels a year ago but remain below to well below normal across many of the major runoff producing areas, notably western Colorado.



Fall Model Soil Moisture Conditions: 2020 vs. 2021

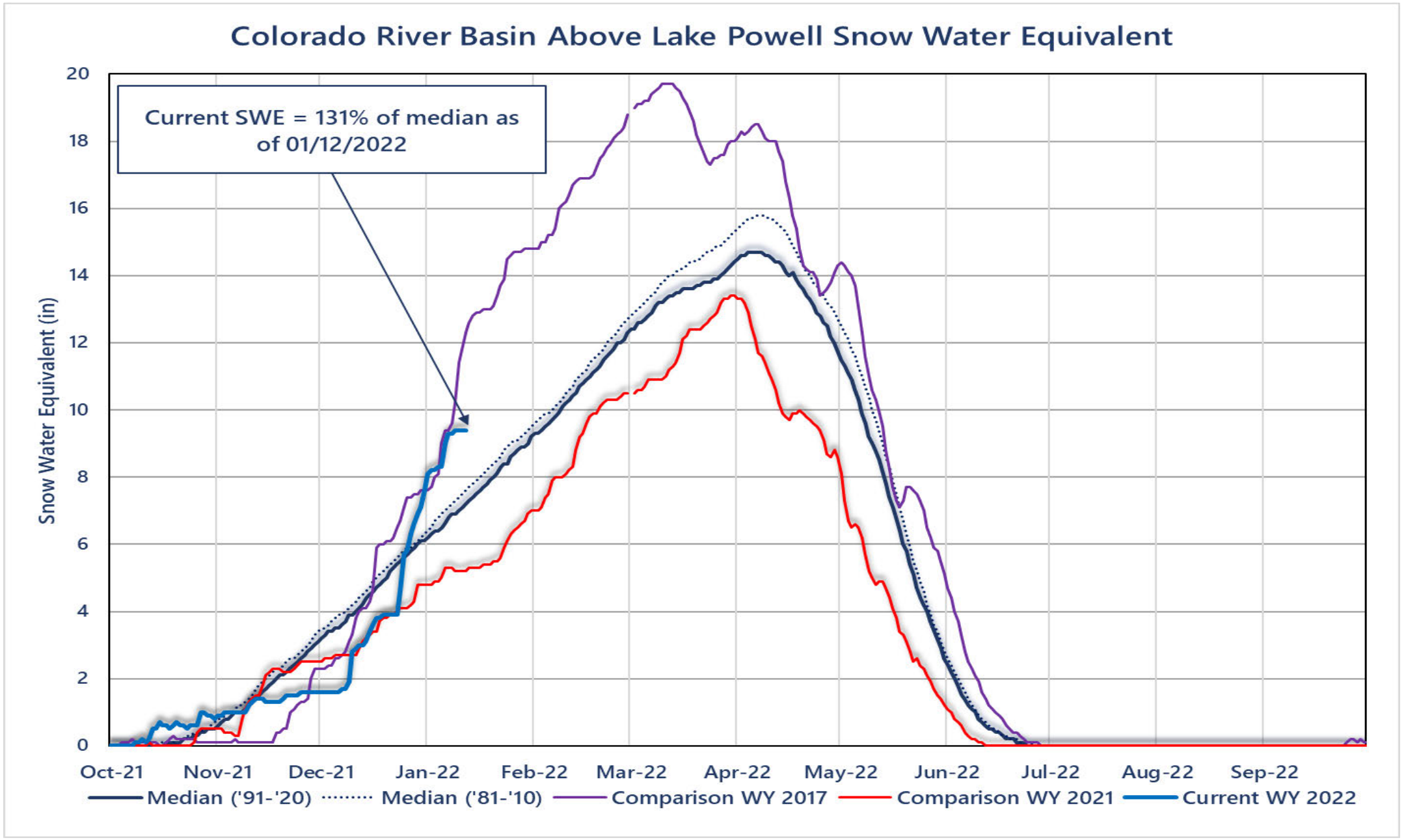
Soil Moisture - Fall (November 15)
Modeled, %Change
(2021-2020)



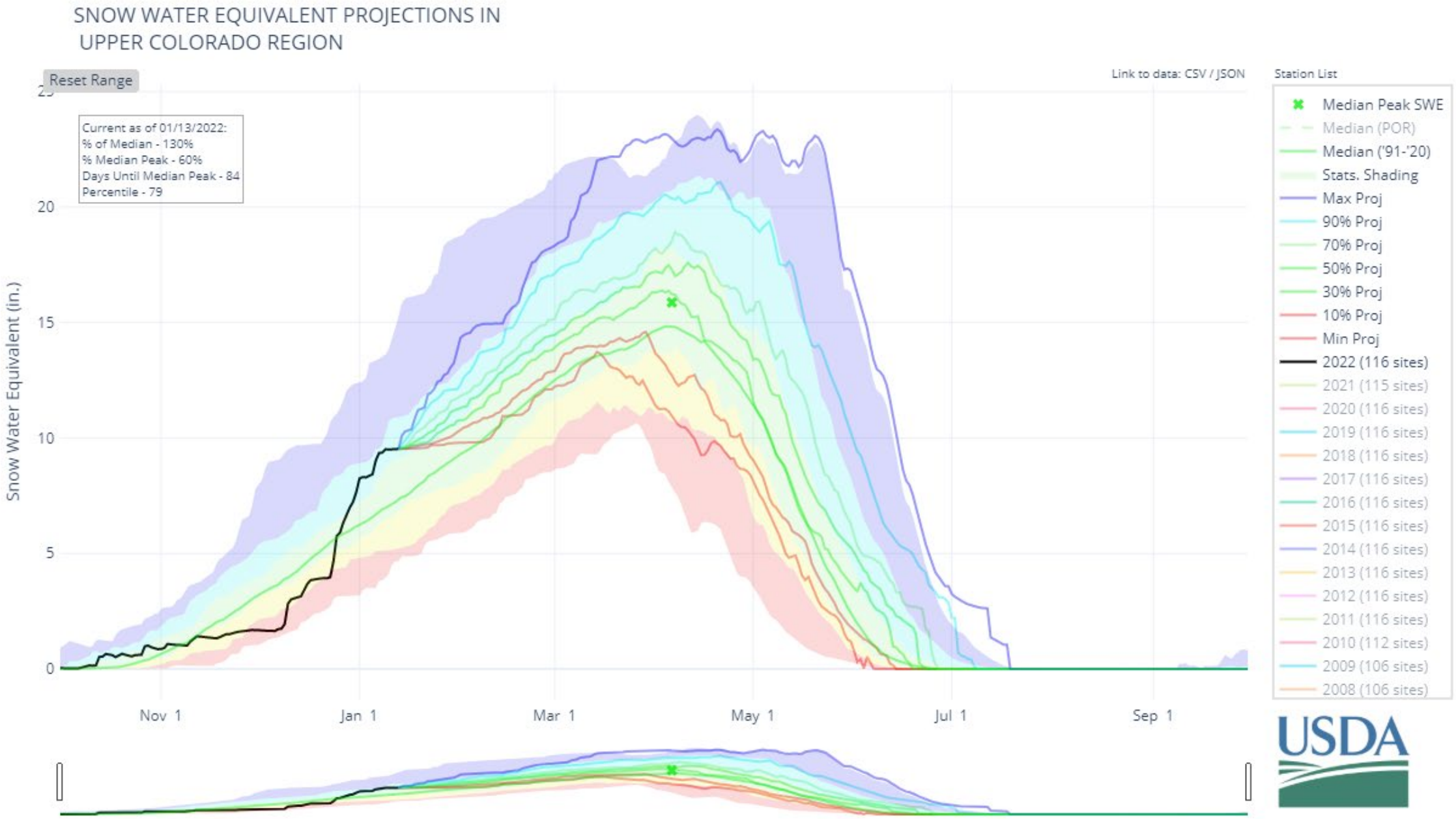
Prepared by NOAA, Colorado Basin River Forecast Center
Salt Lake City, Utah, www.cbrfc.noaa.gov

This is an experimental CBRFC soil moisture graphic.

Utah & Arizona model soil moisture conditions improved more compared to southwest Wyoming & western Colorado.

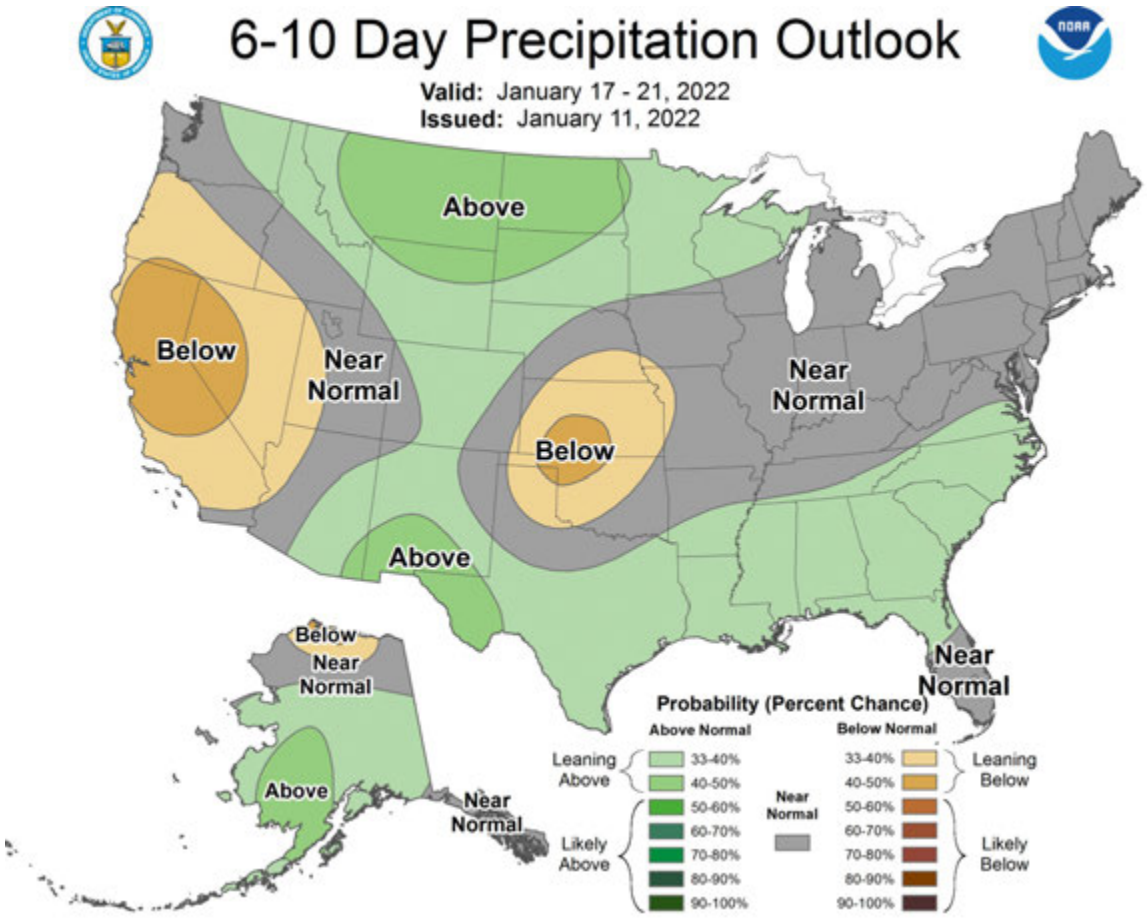


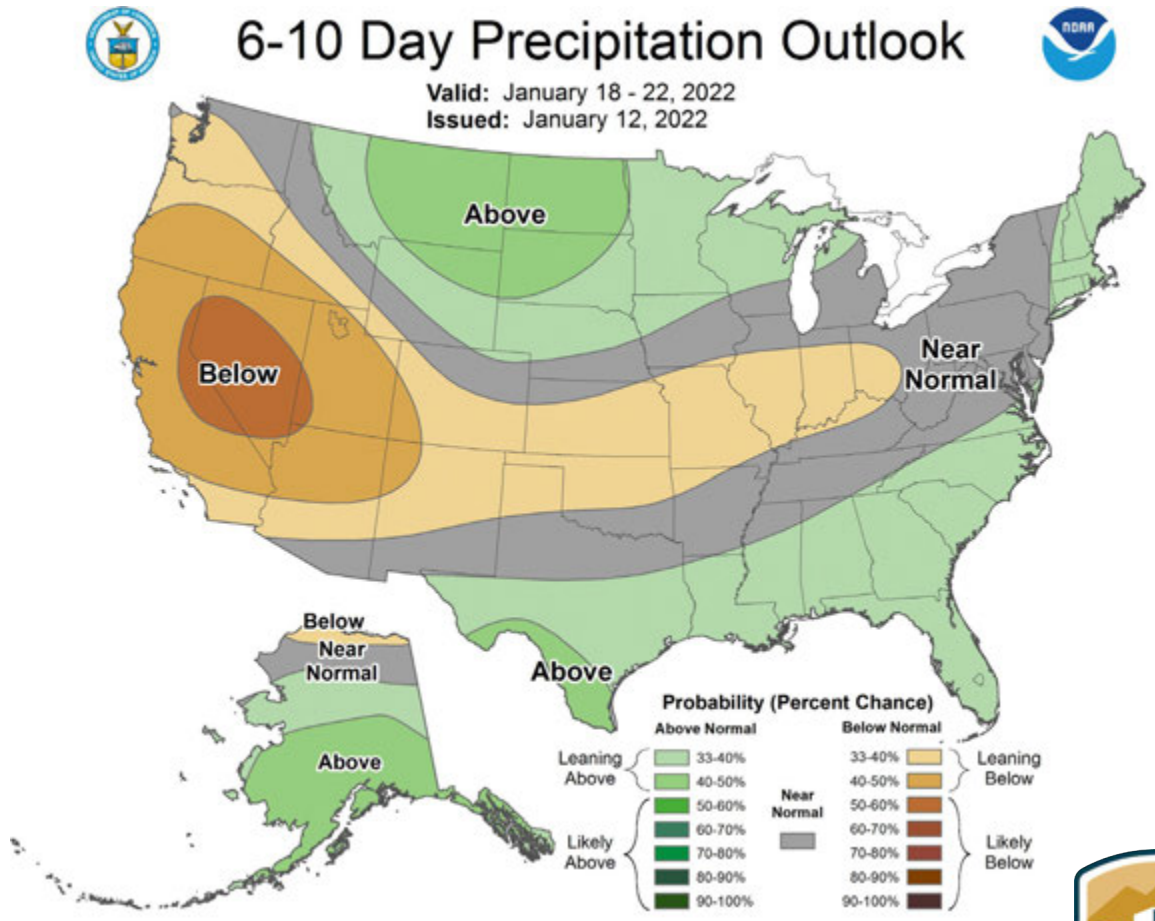
https://www.nrcs.usda.gov/Internet/WCIS/AWS_PLOTS/basinCharts/POR/WTEQ/assocHUC2/14_Upper_Colorado_Region.html



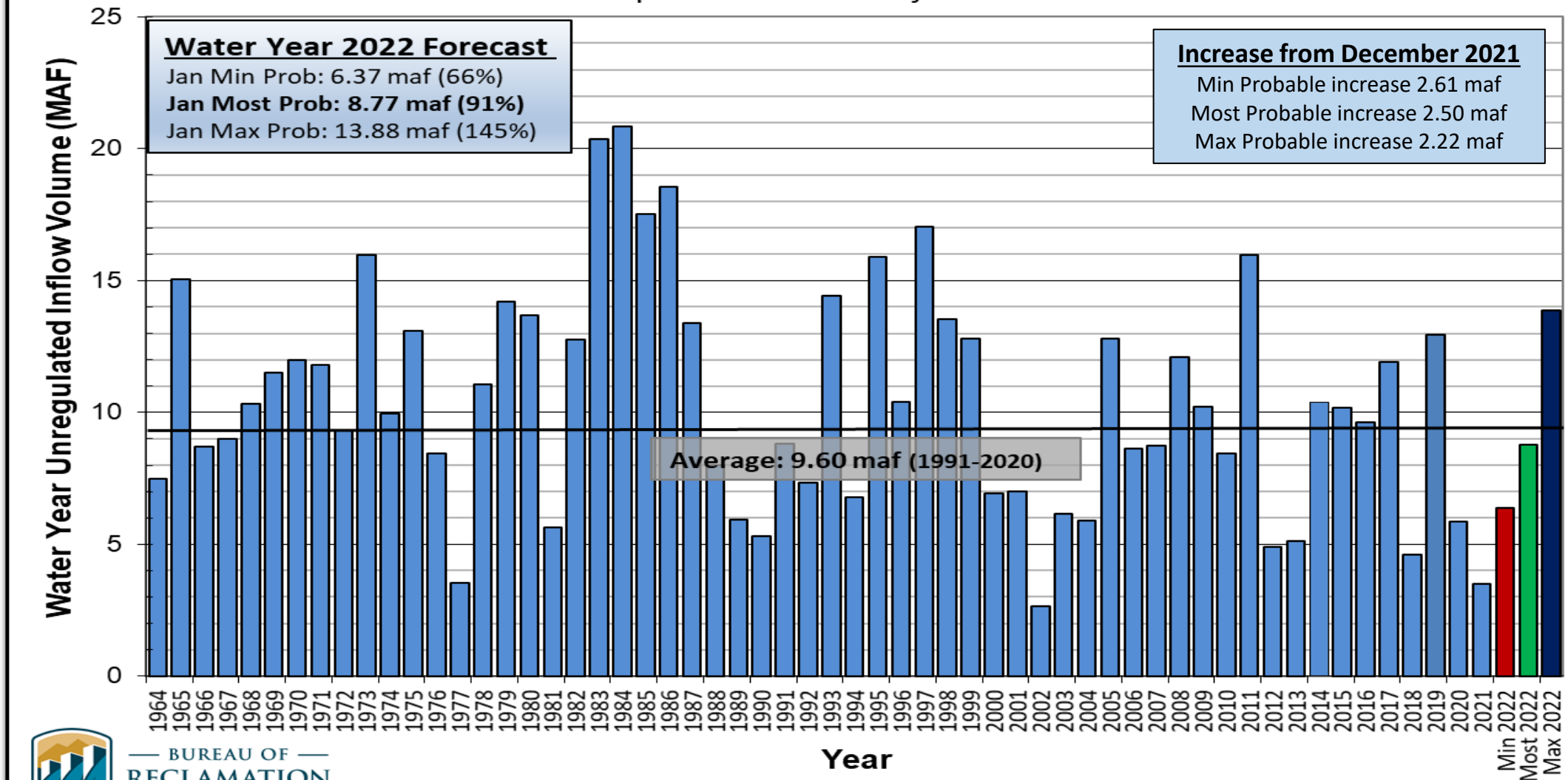
https://www.nrcs.usda.gov/Internet/WCIS/AWS_PLOTS/basinCharts/Proj/WTEQ/stdHUC2/14_Upper_Colorado_Region.html

NOAA Precipitation Outlook Comparison





Lake Powell Unregulated Inflow
Water Year 2022 Forecast *(issued January 5)*
Comparison with History



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Most Probable December Forecast Water Year 2022

Water Year 2022 Forecasted Unregulated Inflow
as of January 5, 2022

Reservoir	Unregulated Inflow (kaf)	1991-2020 Percent of Avg
Fontenelle	942	88
Flaming Gorge	1,216	86
Blue Mesa	880	97
Navajo	725	80
Powell	8,767	91

April – July 2022 Forecasted Unregulated Inflow
as of January 5, 2022

Reservoir	Unregulated Inflow (kaf)	1991-2020 Percent of Avg
Fontenelle	650	88
Flaming Gorge	840	87
Blue Mesa	650	102
Navajo	550	88
Powell	6,300	99

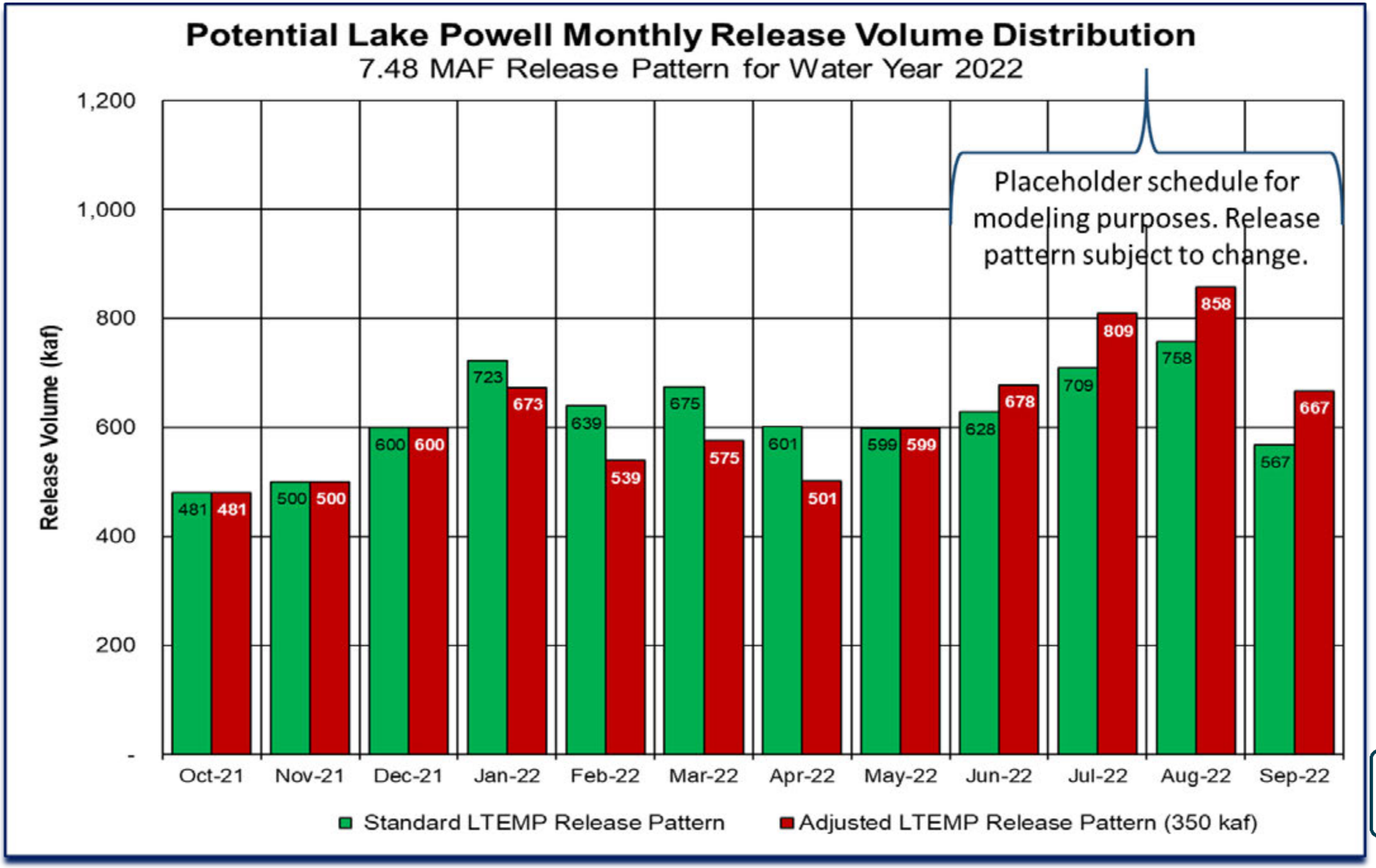
Current Upper Colorado Drought Response Activities

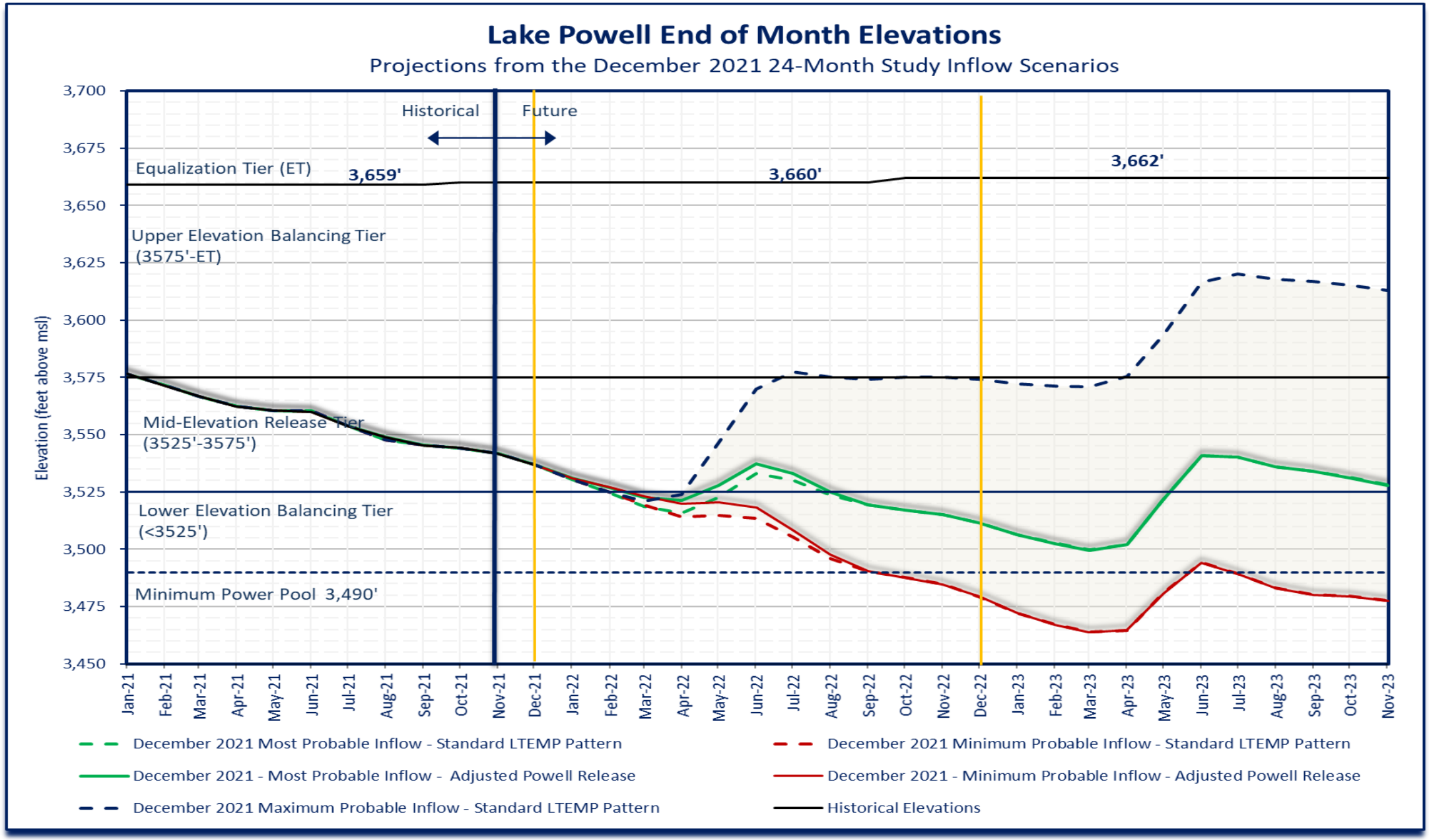
Drought Response Operations Agreement

- Effective May 2019
- Continues through 2026 (except recovery)
- 2021 DROA release volumes of 161 kaf completed in October 2021
- Glen Canyon Dam release adjustments under LTEMP flexibility beginning in January 2022

Drought Response Operations Plan

- Scheduled to be finalized in April 2022
- Draft framework document circulating for review
- Webinar in late January to be followed by comment period
- 2022 operational plans based on actual hydrology to be developed February through April


Potential Lake Powell Monthly Release Volume Distribution
7.48 MAF Release Pattern for Water Year 2022
Release Volume (kaf)
1,200
1,000
800
600
400
200
-
Placeholder schedule for modeling purposes. Release pattern subject to change.
481 481
500 500
600 600
723 673
639 539
675 575
601 501
599 599
628 678
709 809
758 858
567 667
Oct-21
Nov-21
Dec-21
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Sep-22
Standard LTEMP Release Pattern
Adjusted LTEMP Release Pattern (350 kaf)


Lake Powell End of Month Elevations
Projections from the December 2021 24-Month Study Inflow Scenarios
Elevation (feet above msl)
3,700
3,675
3,650
3,625
3,600
3,575
3,550
3,525
3,500
3,475
3,450
Historical
Future
Equalization Tier (ET)
3,659'
3,660'
3,662'
Upper Elevation Balancing Tier
(3575'-ET)
Mid-Elevation Release Tier
(3525'-3575')
Lower Elevation Balancing Tier
(<3525')
Minimum Power Pool 3,490'
Jan-21
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
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Nov-22
Dec-22
Jan-23
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Mar-23
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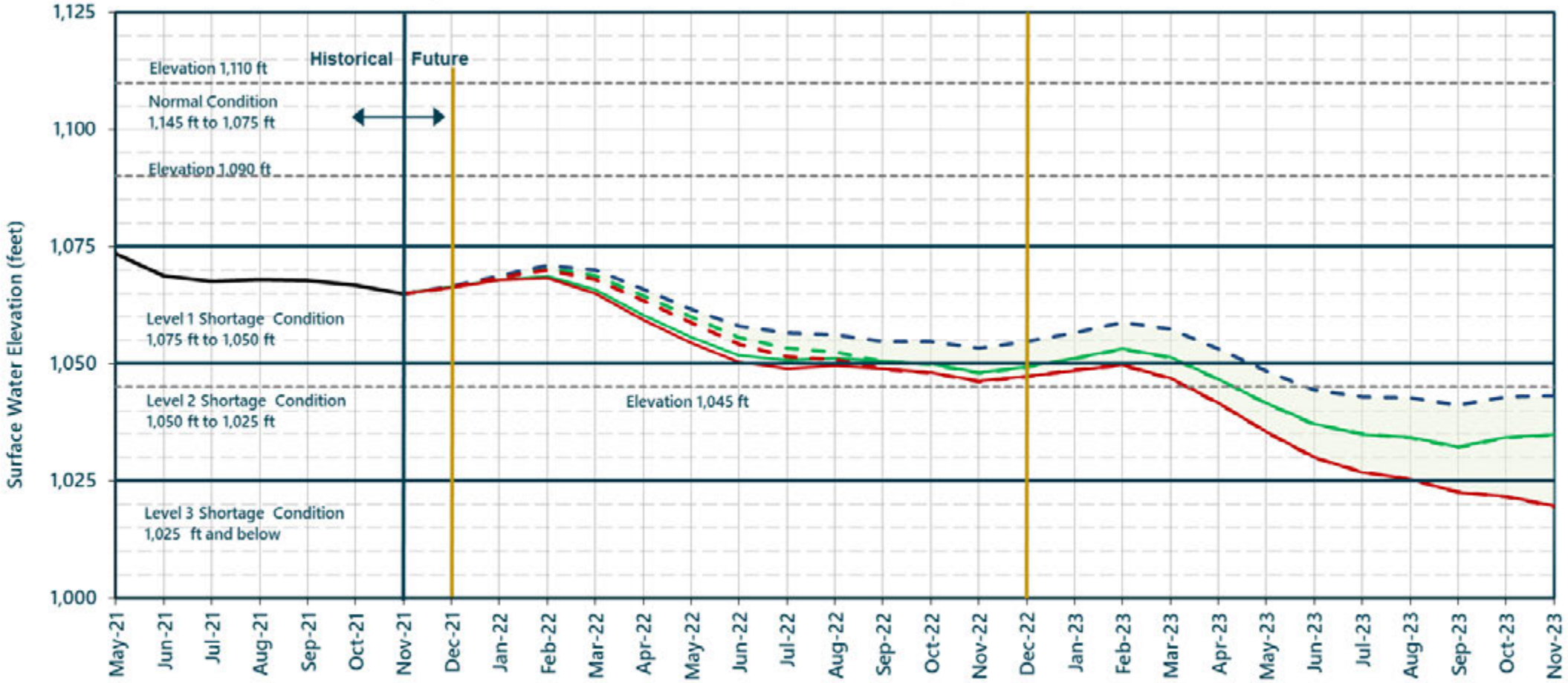
May-23
Jun-23
Jul-23
Aug-23
Sep-23
Oct-23
Nov-23
December 2021 Most Probable Inflow - Standard LTEMP Pattern
December 2021 Minimum Probable Inflow - Standard LTEMP Pattern
December 2021 - Most Probable Inflow - Adjusted Powell Release
December 2021 - Minimum Probable Inflow - Adjusted Powell Release
December 2021 Maximum Probable Inflow - Standard LTEMP Pattern
Historical Elevations

Lake Mead End of Month Elevations

Projections from the December 2021 24-Month Study Inflow Scenarios



The Drought Response Operations Agreement (DROA) is available online at: https://www.usbr.gov/dcp/finaldocs.html.

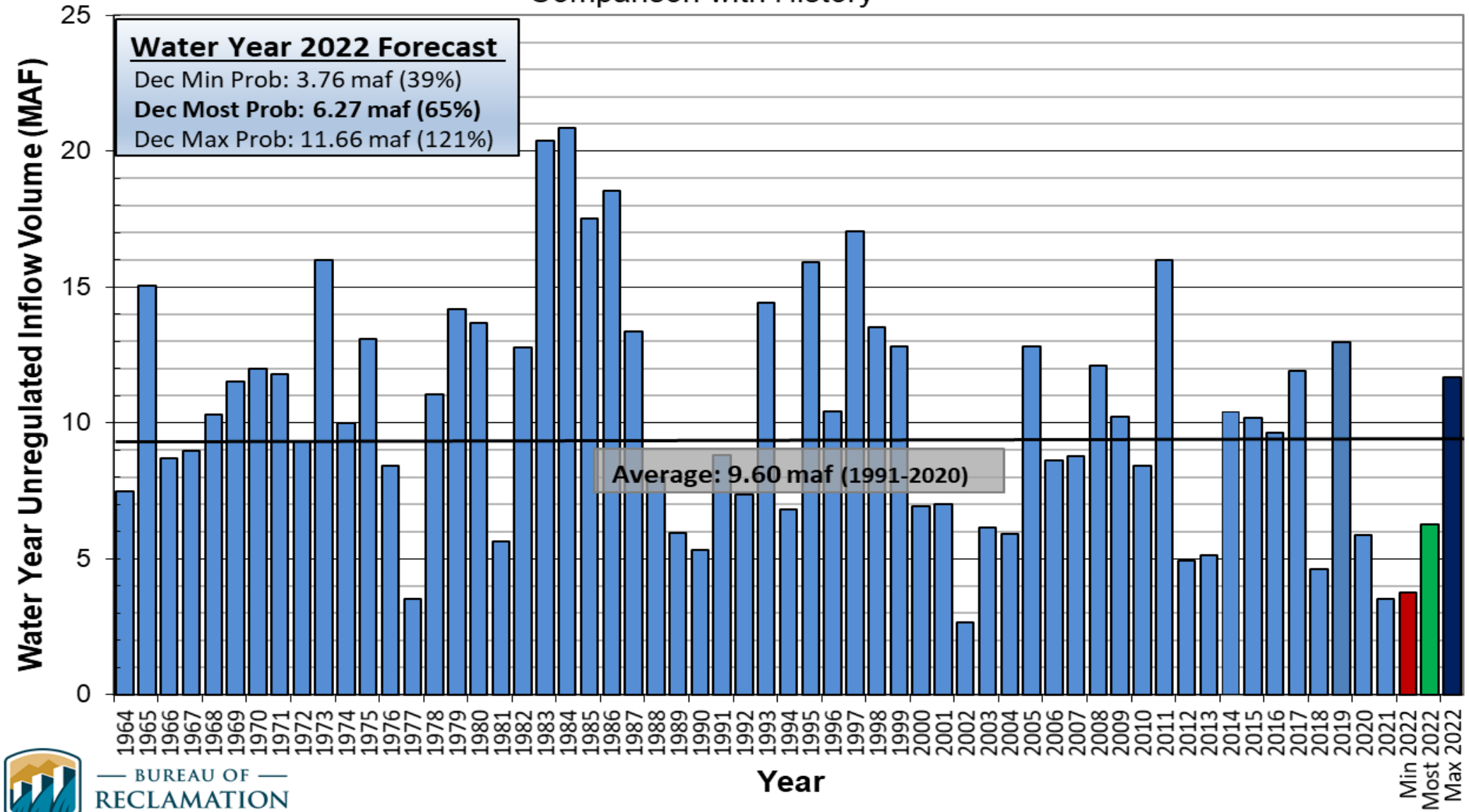
Upper Colorado Basin

Projected Operations for Water Year 2022 Based on December 2021 Modeling

Lake Powell Unregulated Inflow

Water Year 2022 Forecast *(issued December 1)*

Comparison with History



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Most Probable December Forecast Water Year 2022

Water Year 2022 Forecasted Unregulated Inflow
as of December 1, 2021

Reservoir	Unregulated Inflow (kaf)	1991-2020 Percent of Avg
Fontenelle	865	81
Flaming Gorge	1,096	78
Blue Mesa	689	76
Navajo	572	63
Powell	6,272	65

April – July 2022 Forecasted Unregulated Inflow
as of December 1, 2021

Reservoir	Unregulated Inflow (kaf)	1991-2020 Percent of Avg
Fontenelle	580	79
Flaming Gorge	720	75
Blue Mesa	480	75
Navajo	400	64
Powell	4,120	64

Lake Powell & Lake Mead Operational Table

Operating Determinations for Water Year/Calendar Year 2022

Lake Powell

Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf)[1]
3,700	**Equalization Tier** Equalize, avoid spills or release 8.23 maf	24.3
3,636 - 3,666 (2008-2026)		15.5 - 19.3 (2008-2026)
	Upper Elevation Balancing Tier[3] Release 8.23 maf; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 maf	
3,575		9.5
	Mid-Elevation Release Tier Release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf ***3,535.40 ft Jan 1, 2022 Projection***	
3,525		5.9
	Lower Elevation Balancing Tier Balance contents with a min/max release of 7.0 and 9.5 maf	
3,490		4.0
3,370		0

Lake Mead

Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf)[1]
1,220	**Flood Control Surplus or Quantified Surplus Condition** Deliver > 7.5 maf	25.9
1,200 (approx.)[2]		22.9 (approx.)[2]
	Domestic Surplus or ICS Surplus Condition Deliver > 7.5 maf	
1,145		15.9
	Normal or ICS Surplus Condition Deliver ≥ 7.5 maf	
1,105		11.9
1,075	***1,065.85 ft Jan 1, 2022 Projection*** **Shortage Condition** Deliver 7.167[4] maf	9.4
1,050		7.5
	Shortage Condition Deliver 7.083[5] maf	
1,025		5.8
	Shortage Condition Deliver 7.0[6] maf Further measures may be undertaken[7]	
1,000		4.3
895		0

Diagram not to scale

[1] Acronym for million acre-feet

[2] This elevation is shown as approximate as it is determined each year by considering several factors including Lake Powell and Lake Mead storage, projected Upper Basin and Lower Basin demands, and an assumed inflow.

[3] Subject to April adjustments which may result in a release according to the Equalization Tier

[4] Of which 2.48 maf is apportioned to Arizona, 4.4 maf to California, and 0.287 maf to Nevada

[5] Of which 2.40 maf is apportioned to Arizona, 4.4 maf to California, and 0.283 maf to Nevada

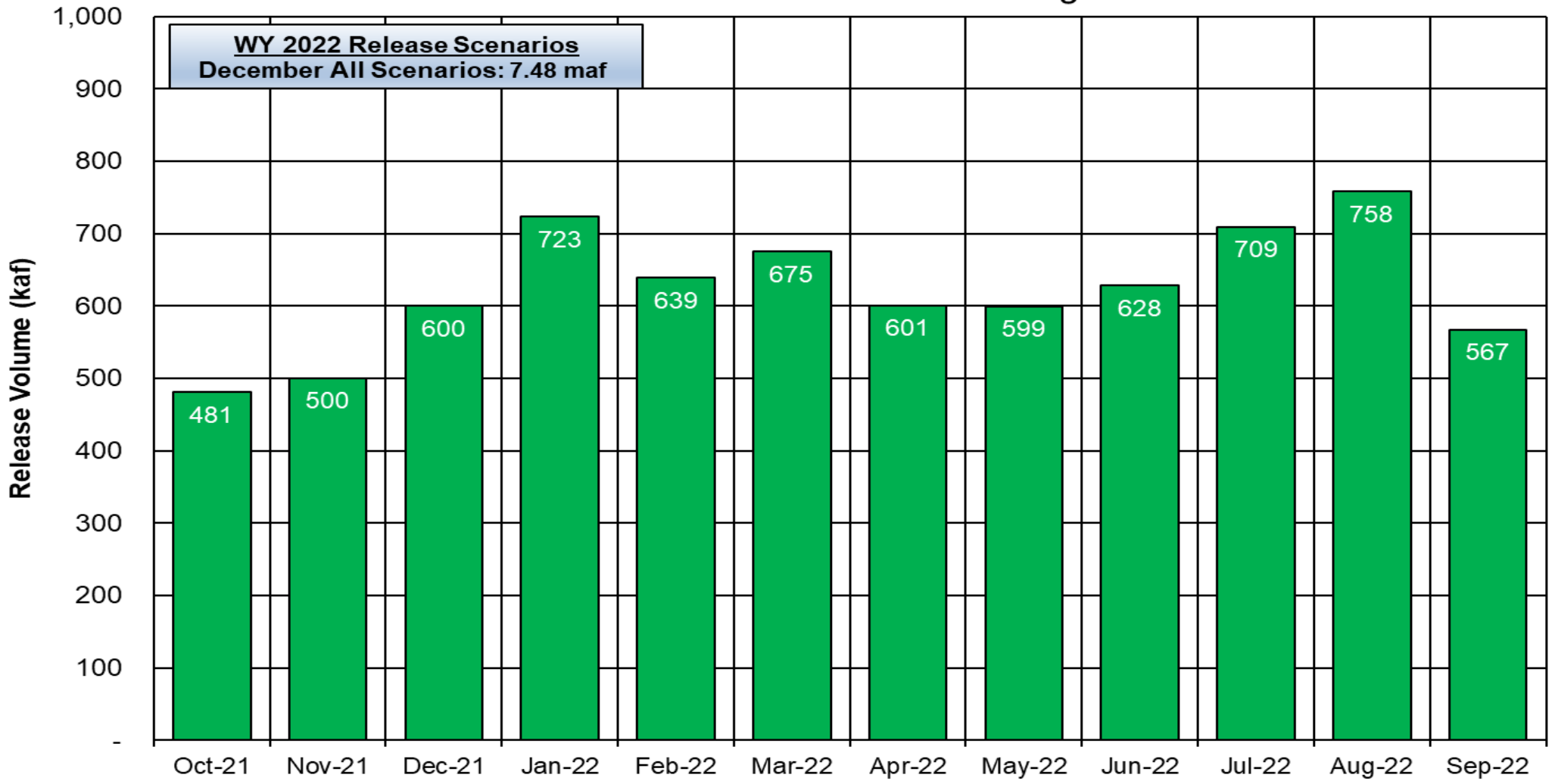
[6] Of which 2.32 maf is apportioned to Arizona, 4.4 maf to California, and 0.280 maf to Nevada

[7] Whenever Lake Mead is below elevation 1,025 feet, the Secretary shall consider whether hydrologic conditions together with anticipated deliveries to the Lower Division States and Mexico is likely to cause the elevation at Lake Mead to fall below 1,000 feet. Such consideration, in consultation with the Basin States, may result in the undertaking of further measures, consistent with applicable Federal law.

[1] Lake Powell and Lake Mead operating determinations are based on August 2021 24-Month Study projections consistent with the 2007 Interim Guidelines and 2019 Drought Contingency Plans. These determinations will be documented in the 2022 Annual Operating Plan for Colorado River Reservoirs.

Potential Lake Powell Monthly Release Volume Distribution

Release Scenarios for Water Year 2022
Based on December 2021 Modeling



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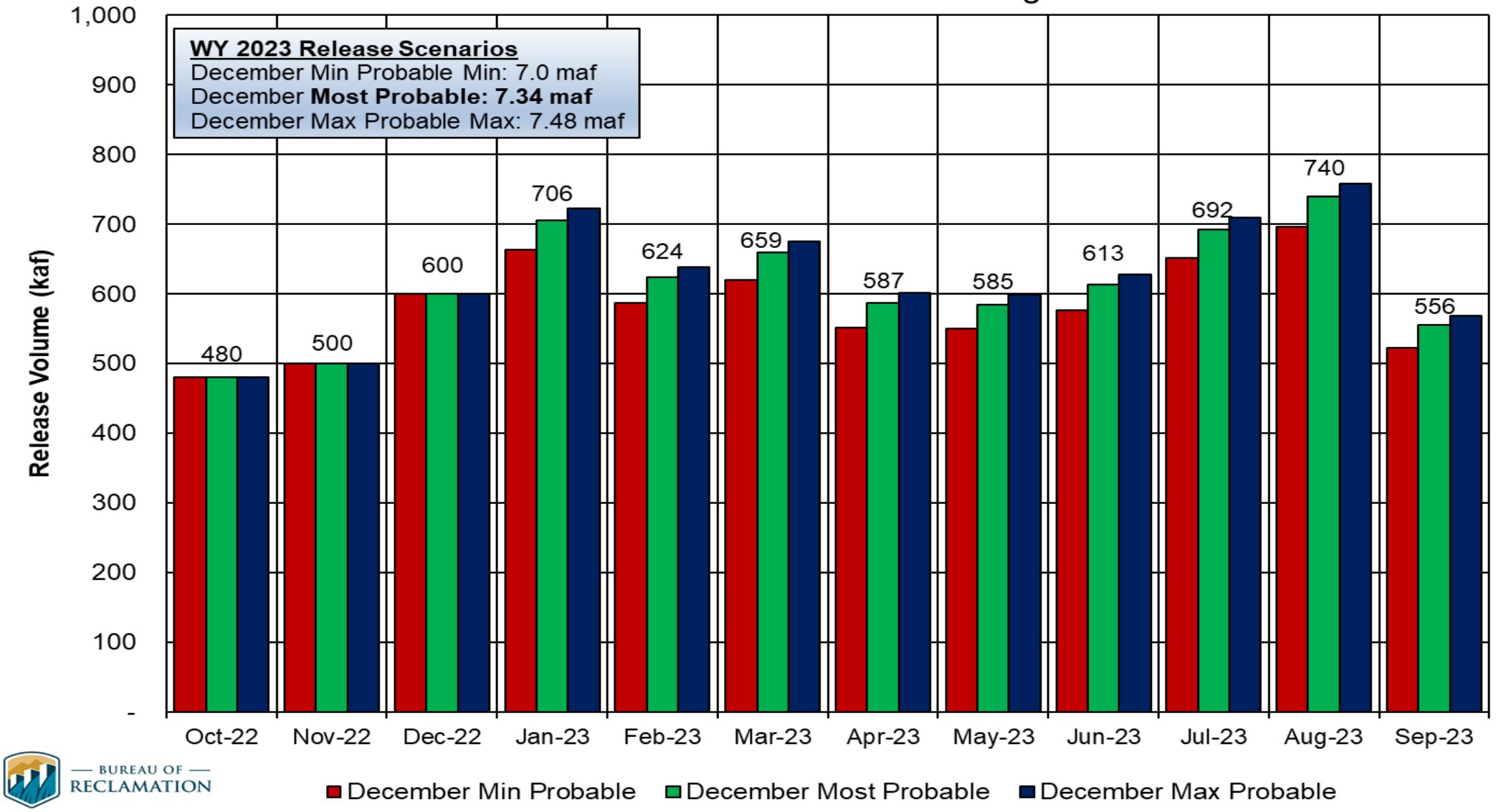
The Drought Response Operations Agreement (DROA) can be found here: https://www.usbr.gov/dcp/finaldocs.html

Potential Lake Powell Monthly Release Volume Distribution

Release Scenarios for Water Year 2023
Based on December 2021 Modeling



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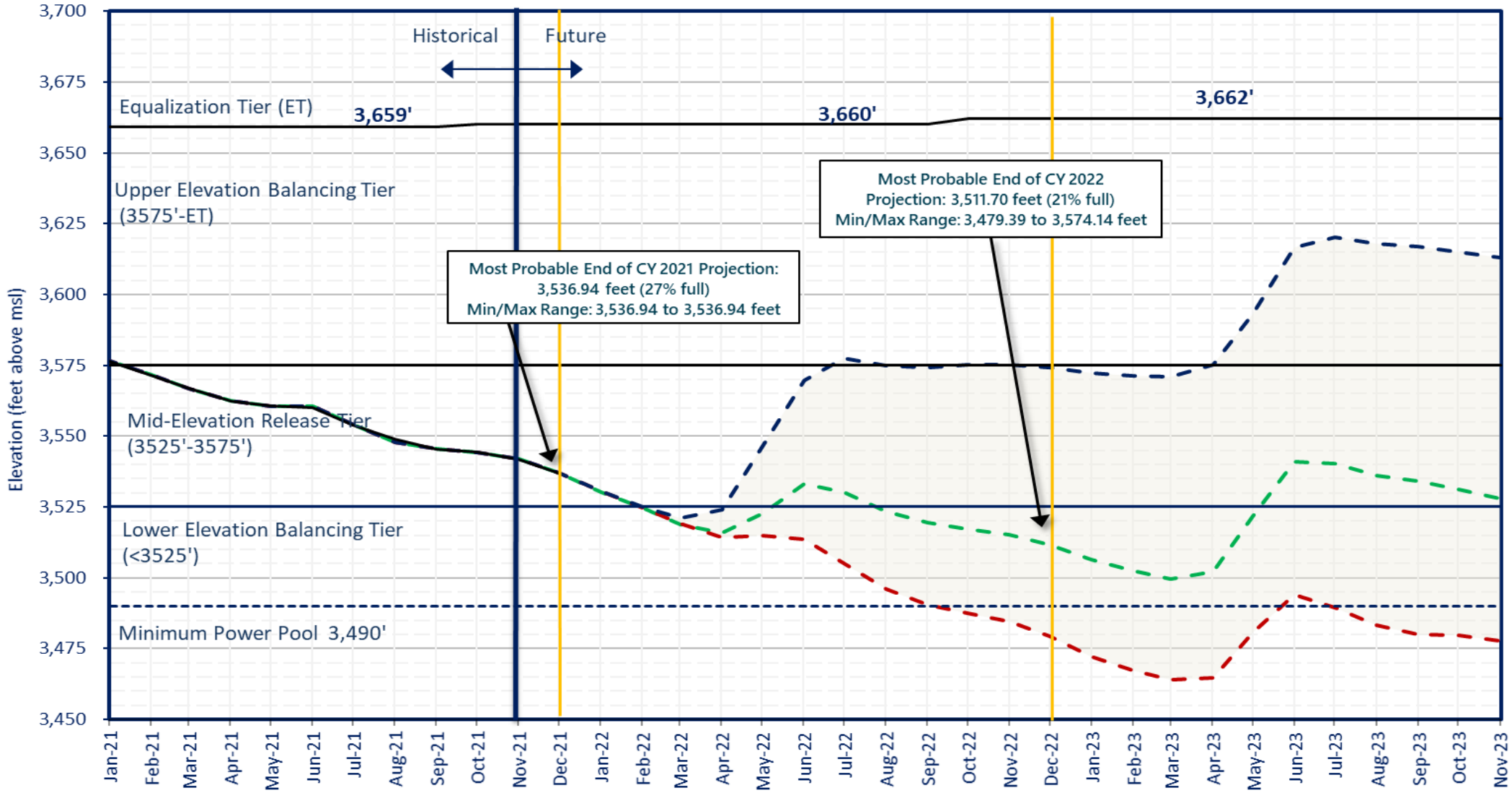
Reclamation Operational Modeling
Model Comparison

	Colorado River Mid-term Modeling System (CRMMS)		CRSS
	24-Month Study Mode (Manual Mode)	Ensemble Mode (Rule-based Mode)	
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 35 (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, 35 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

Lake Powell End of Month Elevations

Projections from the December 2021 24-Month Study Inflow Scenarios



December 2021 Most Probable Inflow - Lake Powell release of 7.48 maf in WY2022 and 7.34 maf in WY2023

December 2021 Minimum Probable Inflow - Lake Powell release of 7.48 maf in WY2022 and 7.0 maf in WY2023

December 2021 Maximum Probable Inflow - Lake Powell release of 7.48 maf in WY2022 and 7.48 maf in WY2023

Historical Elevations

*The Drought Response Operations Agreement (DROA) can be found here: https://www.usbr.gov/dcp/finaldocs.html

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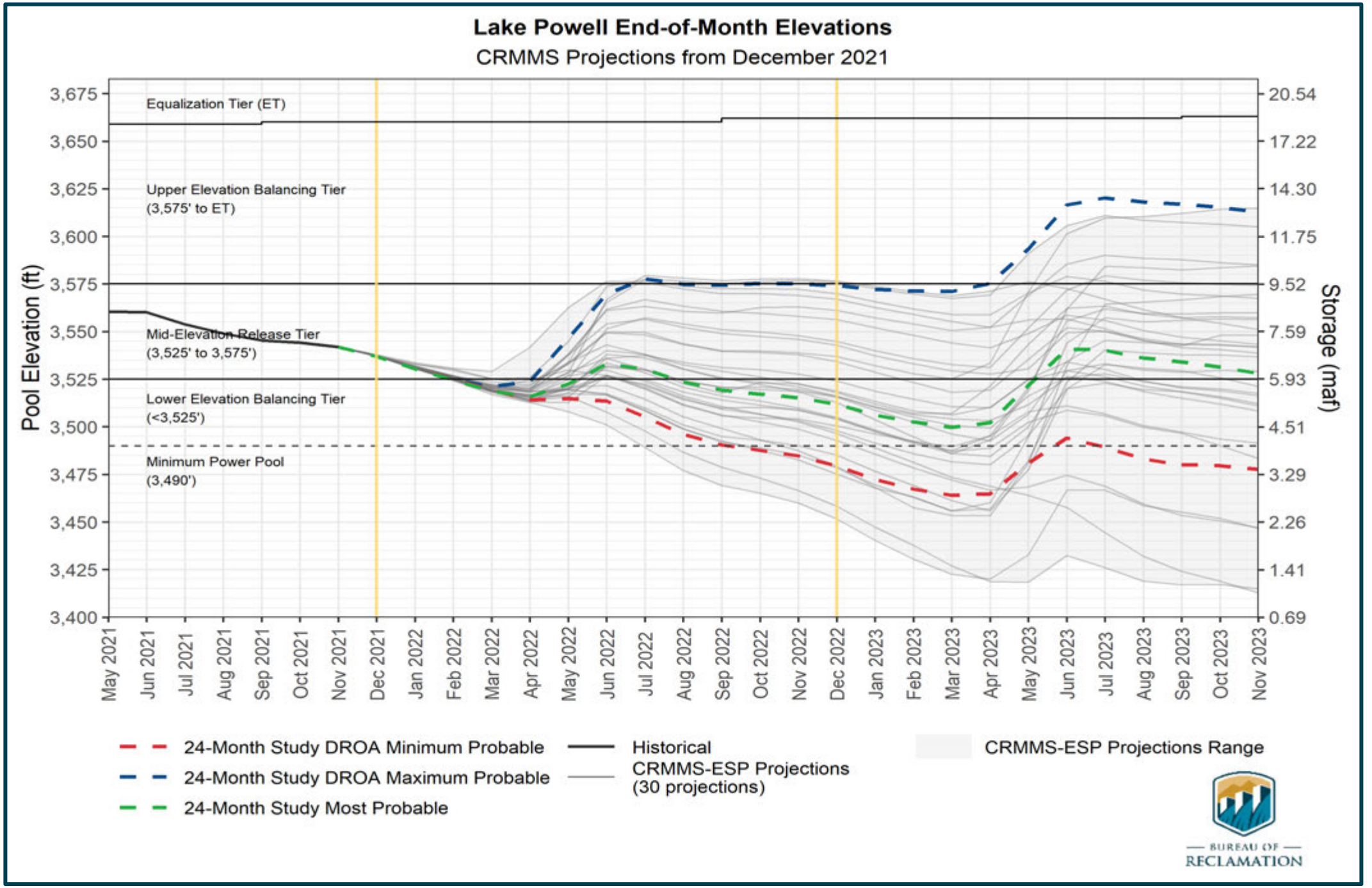
Lake Powell End-of-Month Elevations
CRMMS Projections from December 2021
Pool Elevation (ft)
Storage (maf)
3,675
3,650
3,625
3,600
3,575
3,550
3,525
3,500
3,475
3,450
3,425
3,400
20.54
17.22
14.30
11.75
9.52
7.59
5.93
4.51
3.29
2.26
1.41
0.69
Equalization Tier (ET)
Upper Elevation Balancing Tier
(3,575' to ET)
Mid-Elevation Release Tier
(3,525' to 3,575')
Lower Elevation Balancing Tier
(<3,525')
Minimum Power Pool
(3,490')
May 2021
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Jan 2023
Feb 2023
Mar 2023
Apr 2023
May 2023
Jun 2023
Jul 2023
Aug 2023
Sep 2023
Oct 2023
Nov 2023
24-Month Study DROA Minimum Probable
24-Month Study DROA Maximum Probable
24-Month Study Most Probable
Historical
CRMMS-ESP Projections
(30 projections)
CRMMS-ESP Projections Range
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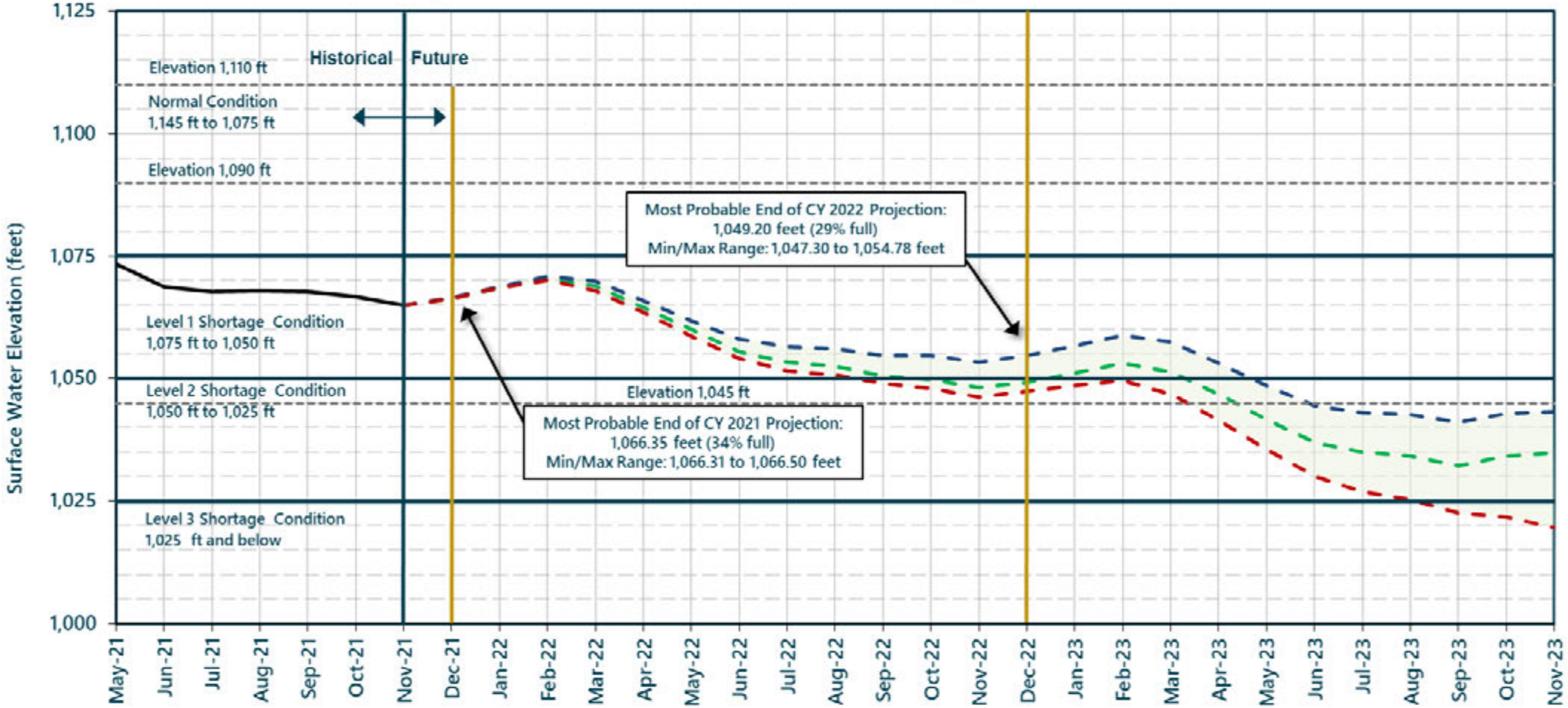
Lake Mead End of Month Elevations

Projections from the December 2021 24-Month Study Inflow Scenarios



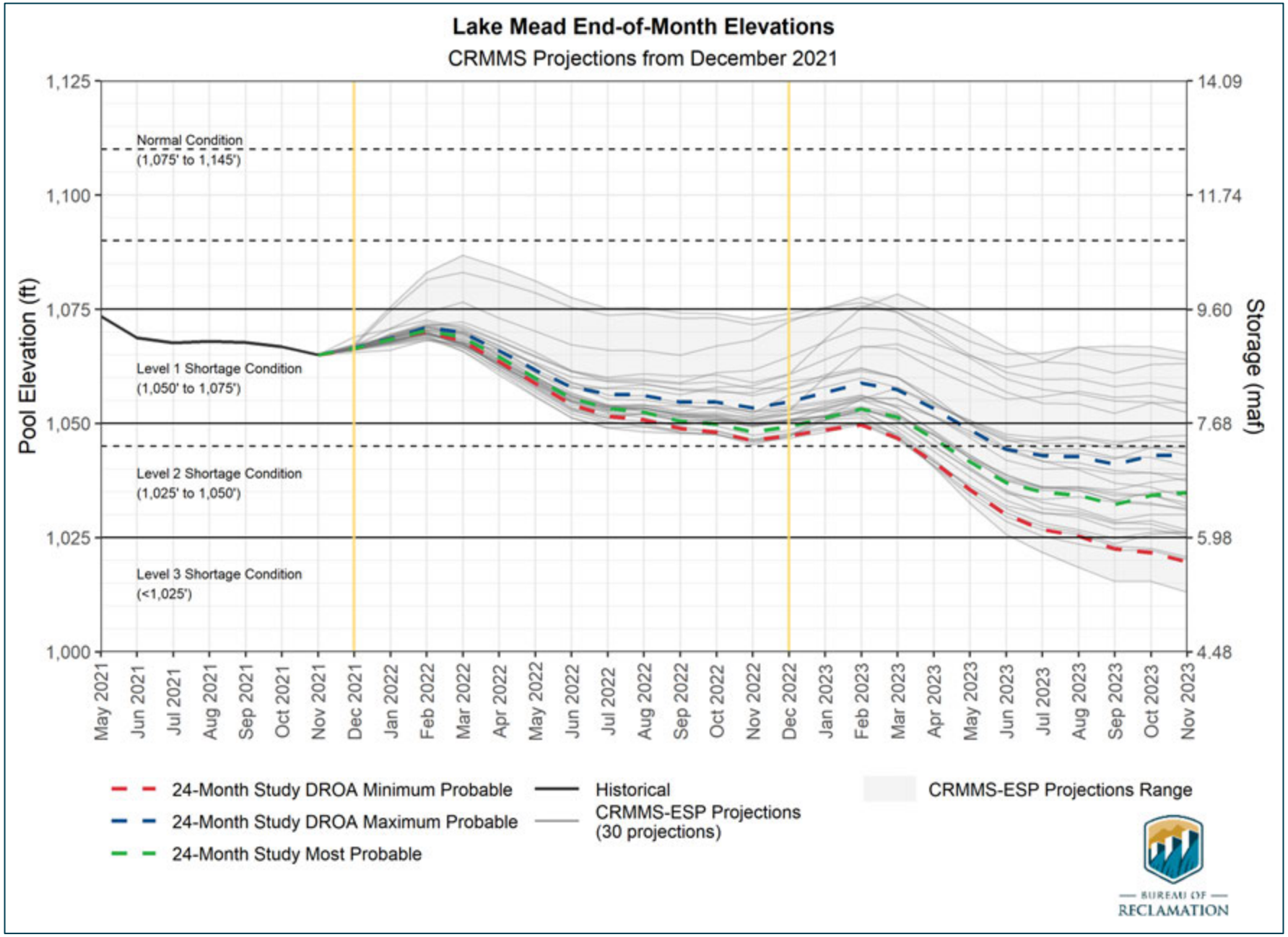
Historical Elevations

December 2021 Most Probable Inflow with a Lake Powell release of 7.48 maf in WY 2022 and 7.34 maf in WY 2023

December 2021 DROA Maximum Probable Inflow with a Lake Powell release of 7.48 maf in WY 2022 and WY 2023

December 2021 DROA Minimum Probable Inflow with a Lake Powell release of 7.48 maf in WY 2022 and 7.00 maf in WY 2023

The Drought Response Operations Agreement (DROA) is available online at: https://www.usbr.gov/dcp/finaldocs.html.



CRMMS 2-Year Probabilistic Projections are available online at: https://www.usbr.gov/lc/region/g4000/riverops/crmms-2year-projections.html

Upper Colorado Basin

Hydropower Maintenance

Glen Canyon Dam Power Plant Unit Outage Schedule for 2022

Unit Number	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022	Jul 2022	Aug 2022	Sep 2022	
1													
2													
3													
4													
5													
6													
7													
8													
Units Available	6	6	6	6	5	6	6	5	6	6	6	4	
Capacity (cfs)	18,700	18,600	11,700	18,300	11,400	11,300	17,900	14,900	15,400	18,800	18,700	11,700	DEC MOST[2]
Capacity (kaf/month)	1,150	1,110	1,110	1,160	890	1,050	1,070	970	1,100	1,180	1,150	750	DEC MOST
Max (kaf) [1]	481	500	600	723	639	675	601	599	628	709	758	567	7.48 maf
Most (kaf) [1]	481	500	600	723	639	675	601	599	628	709	758	567	7.48 maf
Min (kaf) [1]	481	500	600	723	639	675	601	599	628	709	758	567	7.48 maf
										(updated 12-14-2021)			

1 Projected release, based on December 2021 minimum, most and maximum probable inflow projections and 24-Month Study model runs.

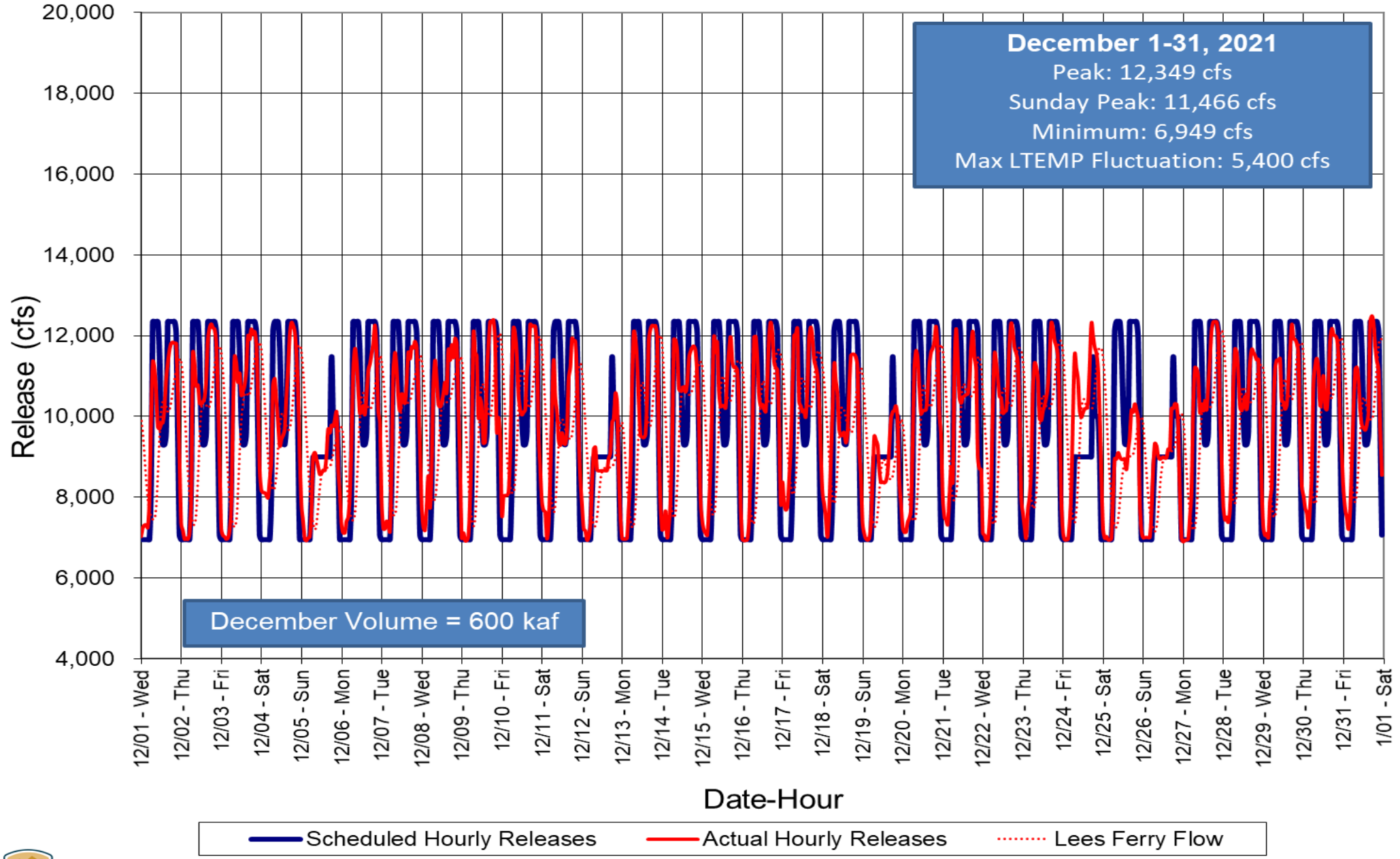
2 Dependent upon availability to shift contingency reserves, which will increase capacity by 30-40MW (3%) at current efficiency.

Glen Canyon Dam Power Plant Unit Outage Schedule for 2023

Unit Number	Oct 2022	Nov 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	Apr 2023	May 2023	Jun 2023	Jul 2023	Aug 2023	Sep 2023	
1													
2													
3													
4													
5													
6													
7													
8													
Units Available	6	6	7	8	6	7	8	7	8	8	8	6	
Capacity (cfs)	18,600	18,500	18,400	18,300	11,400	18,100	24,800	22,100	26,200	26,200	26,000	19,000	DEC MOST[2]
Capacity (kaf/month)	1,140	1,100	1,240	1,510	940	1,300	1,480	1,390	1,560	1,610	1,600	1,200	DEC MOST
Max (kaf) [1]	480	500	600	723	639	675	601	599	628	709	758	568	7.48 maf
Most (kaf) [1]	480	500	600	706	624	659	587	585	613	692	740	556	7.34 maf
Min (kaf) [1]	480	500	600	664	587	620	552	550	577	652	696	522	7.0 maf
										(updated 12-14-2021)			

1 Projected release, based on December 2021 minimum, most and maximum probable Inflow Projections and 24-Month Study model runs.
2 Dependent upon availability to shift contingency reserves, which will increase capacity by 30-40MW (3%) at current efficiency.

Glen Canyon Dam Hourly Release Pattern December 2021



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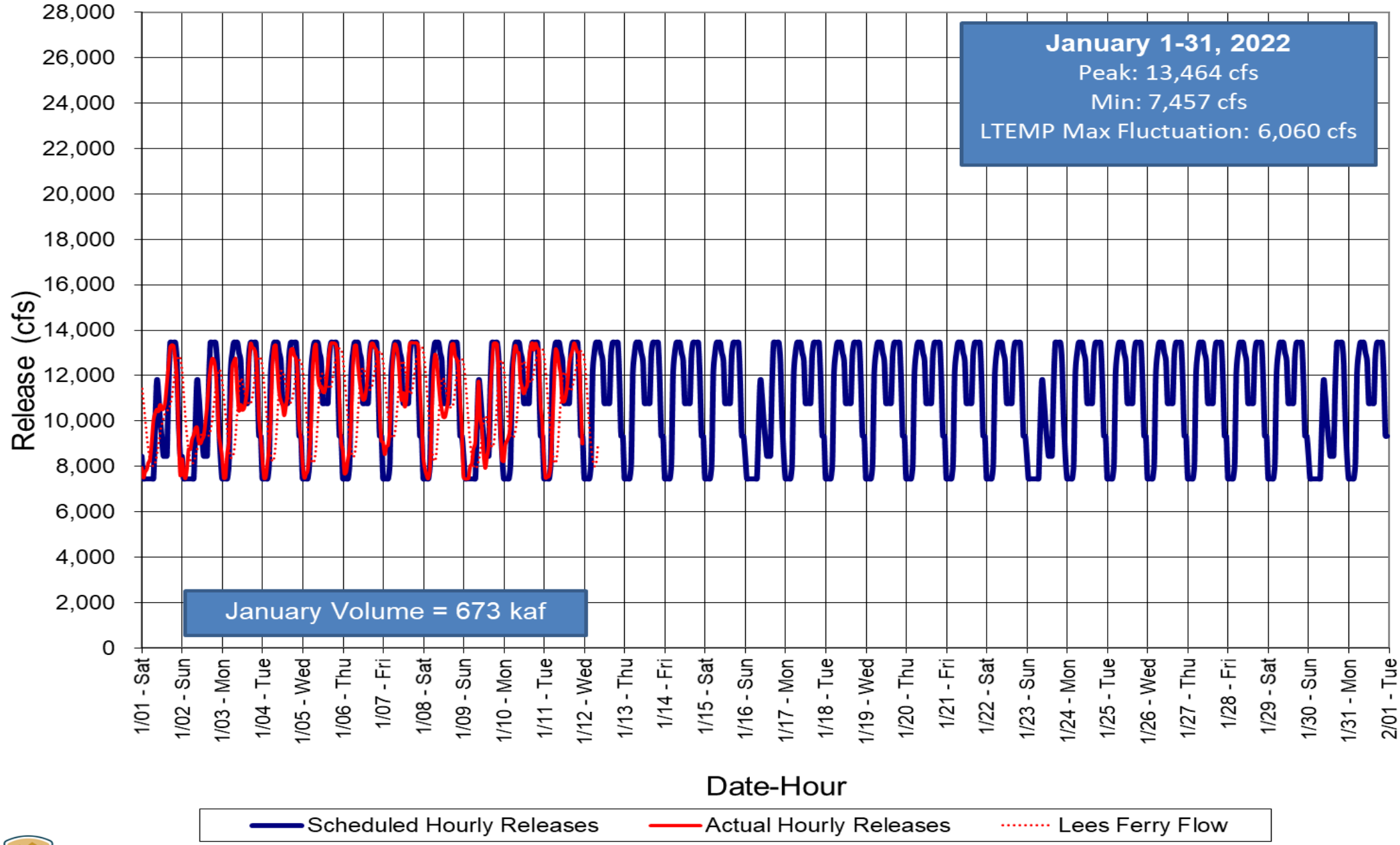
Glen Canyon Dam Hourly Release Pattern January 2022



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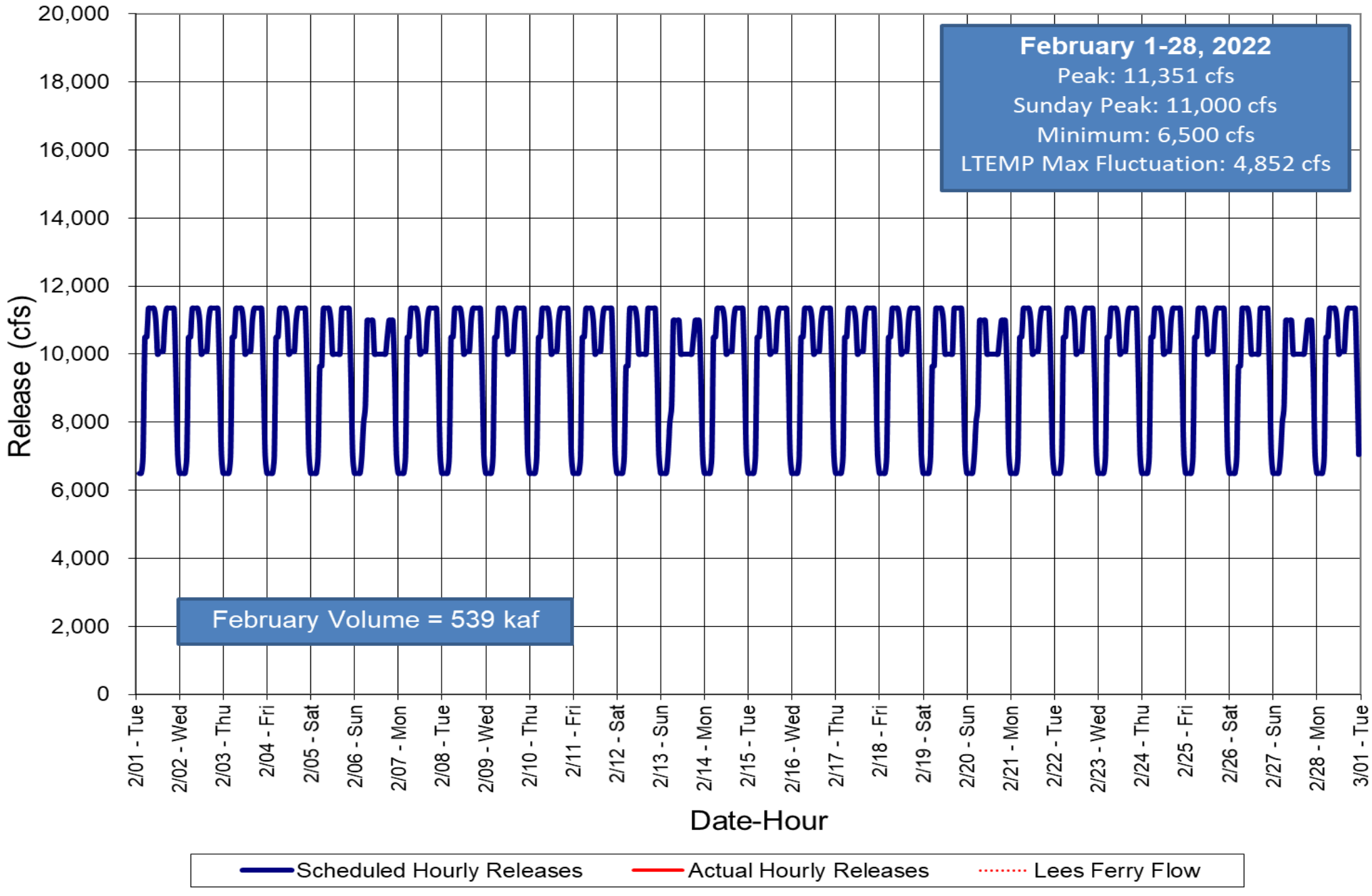
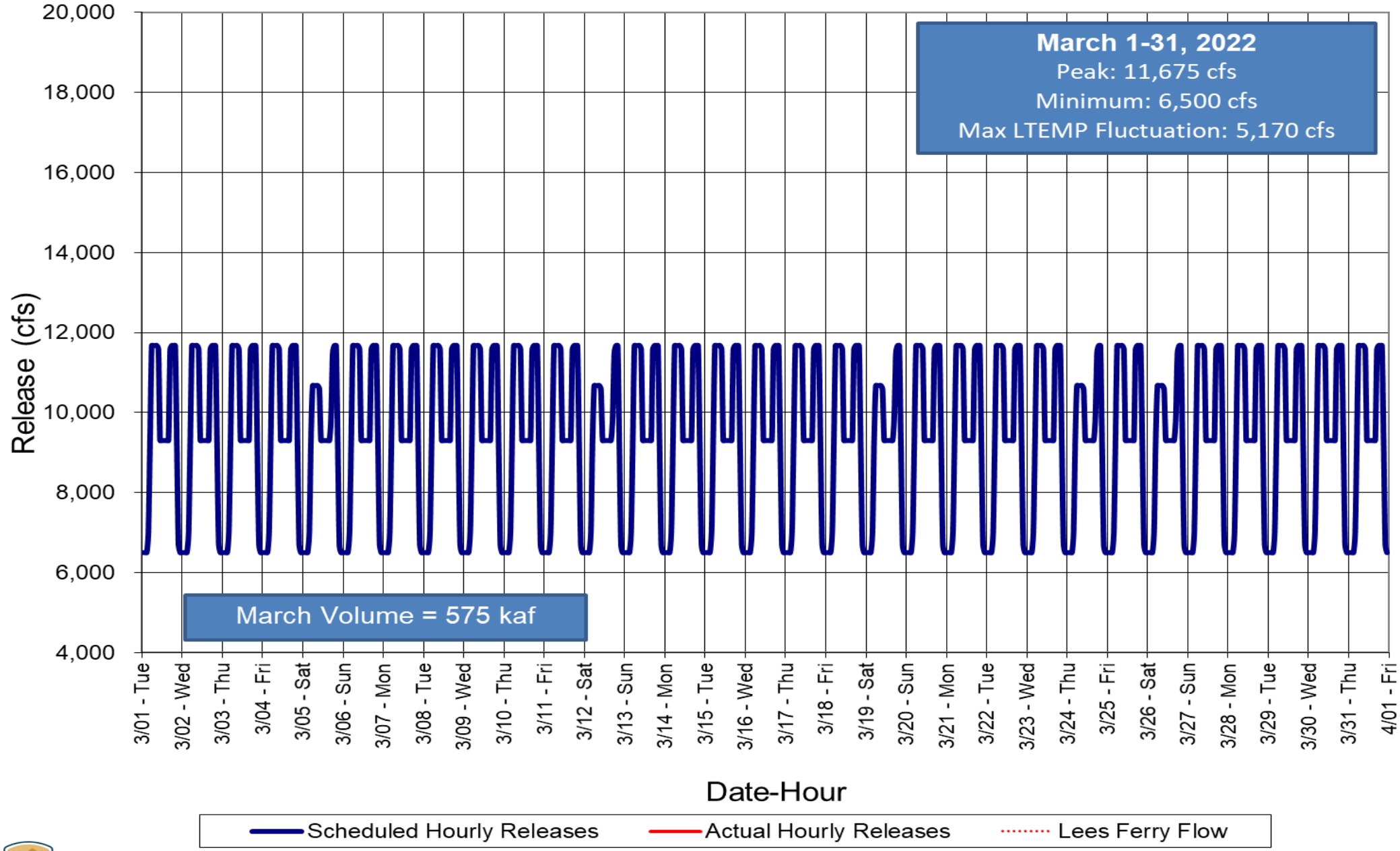
Glen Canyon Dam Hourly Release Pattern February 2022



Glen Canyon Dam Hourly Release Pattern March 2022



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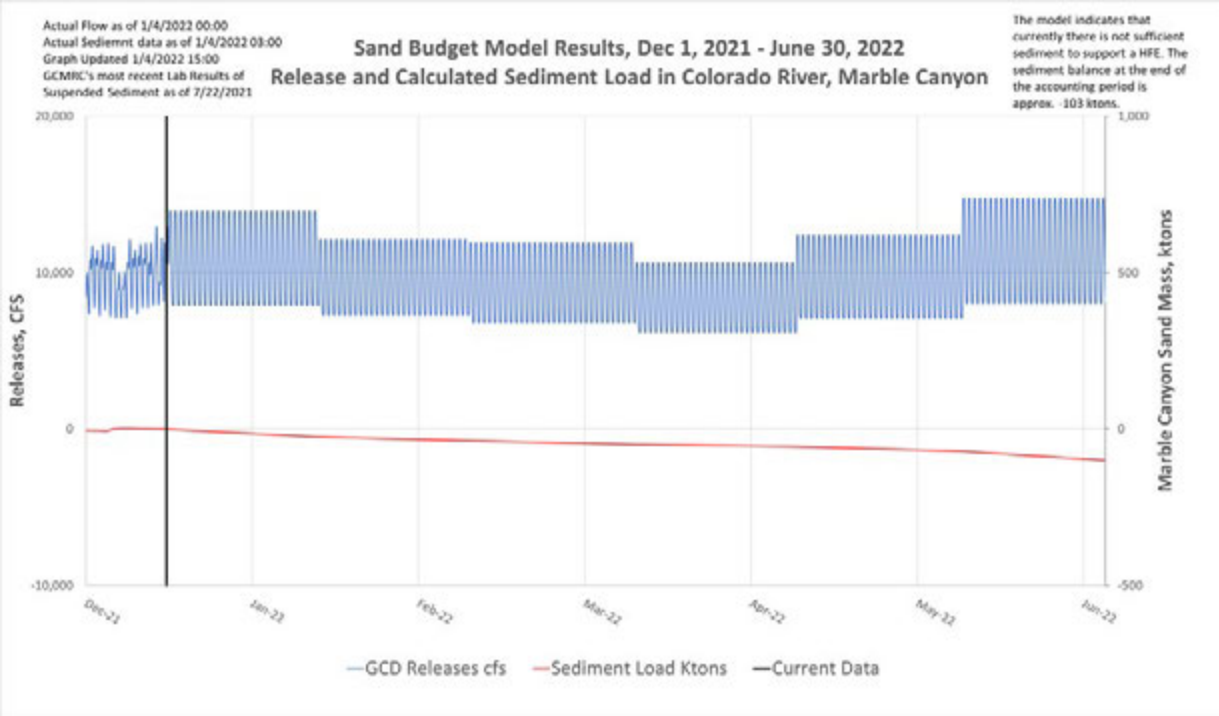
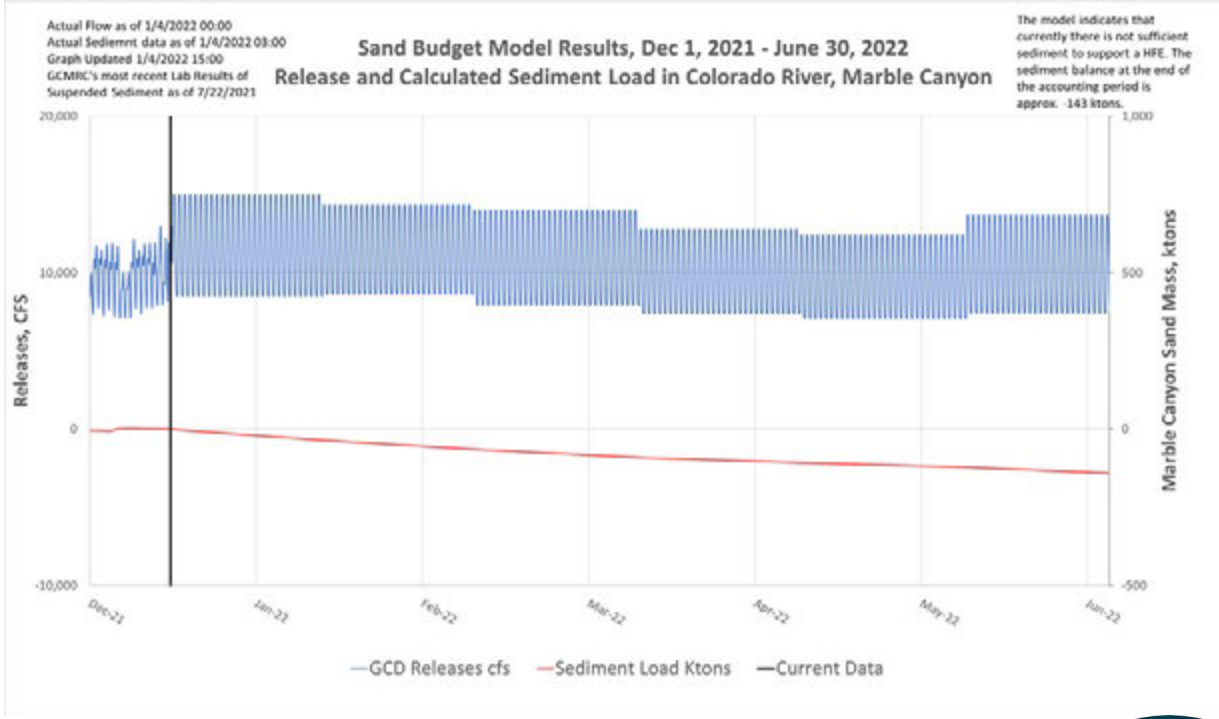
Water Quality

Spring 2022 HFE Modeling

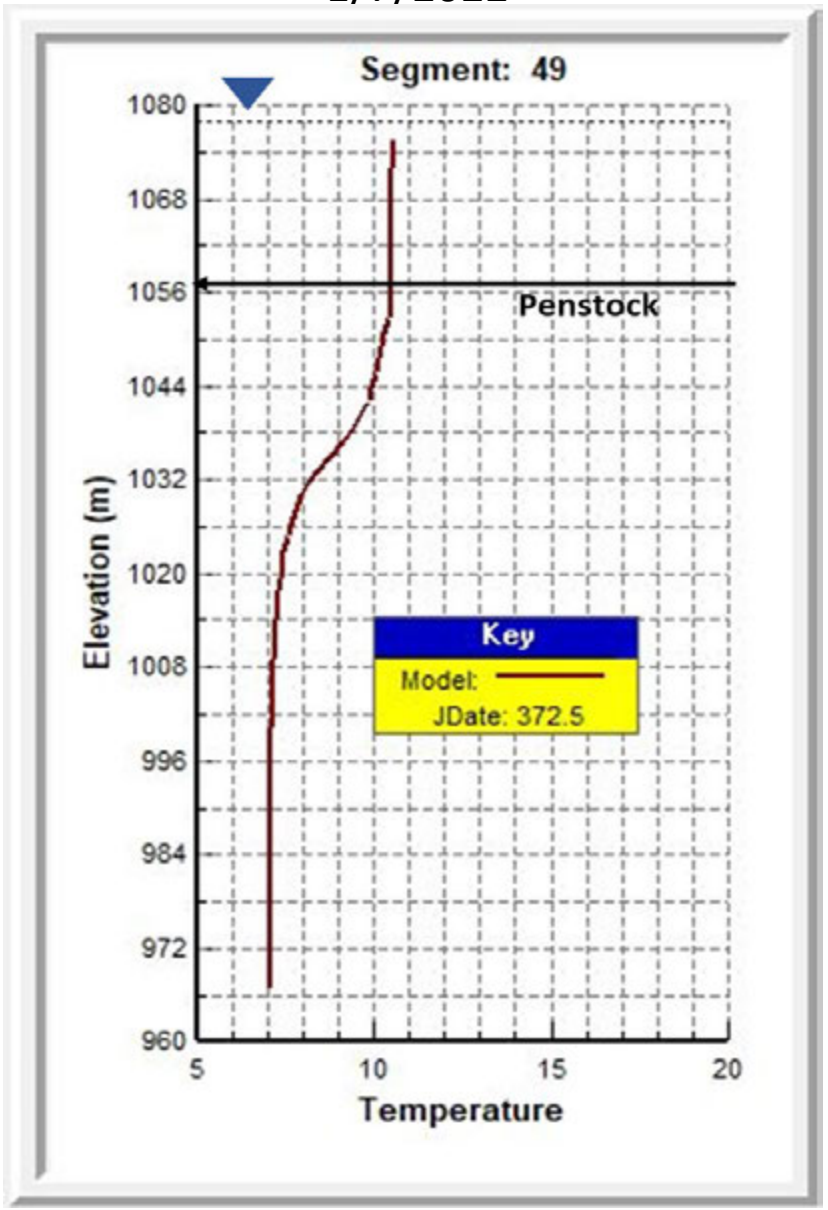
GCD Adjusted LTEMP Pattern (-103 kton)



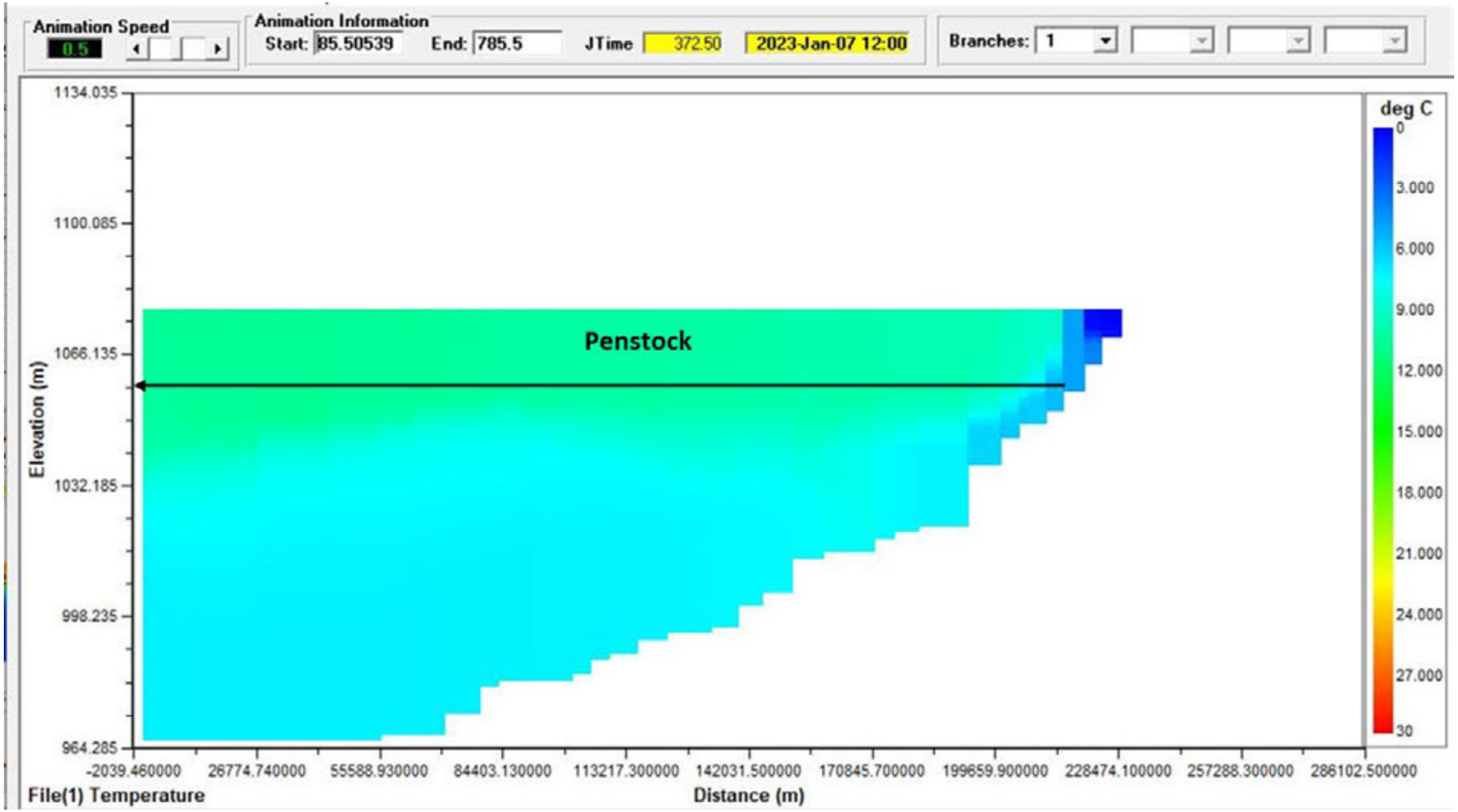
GCD Standard LTEMP Pattern (-143 ktons)



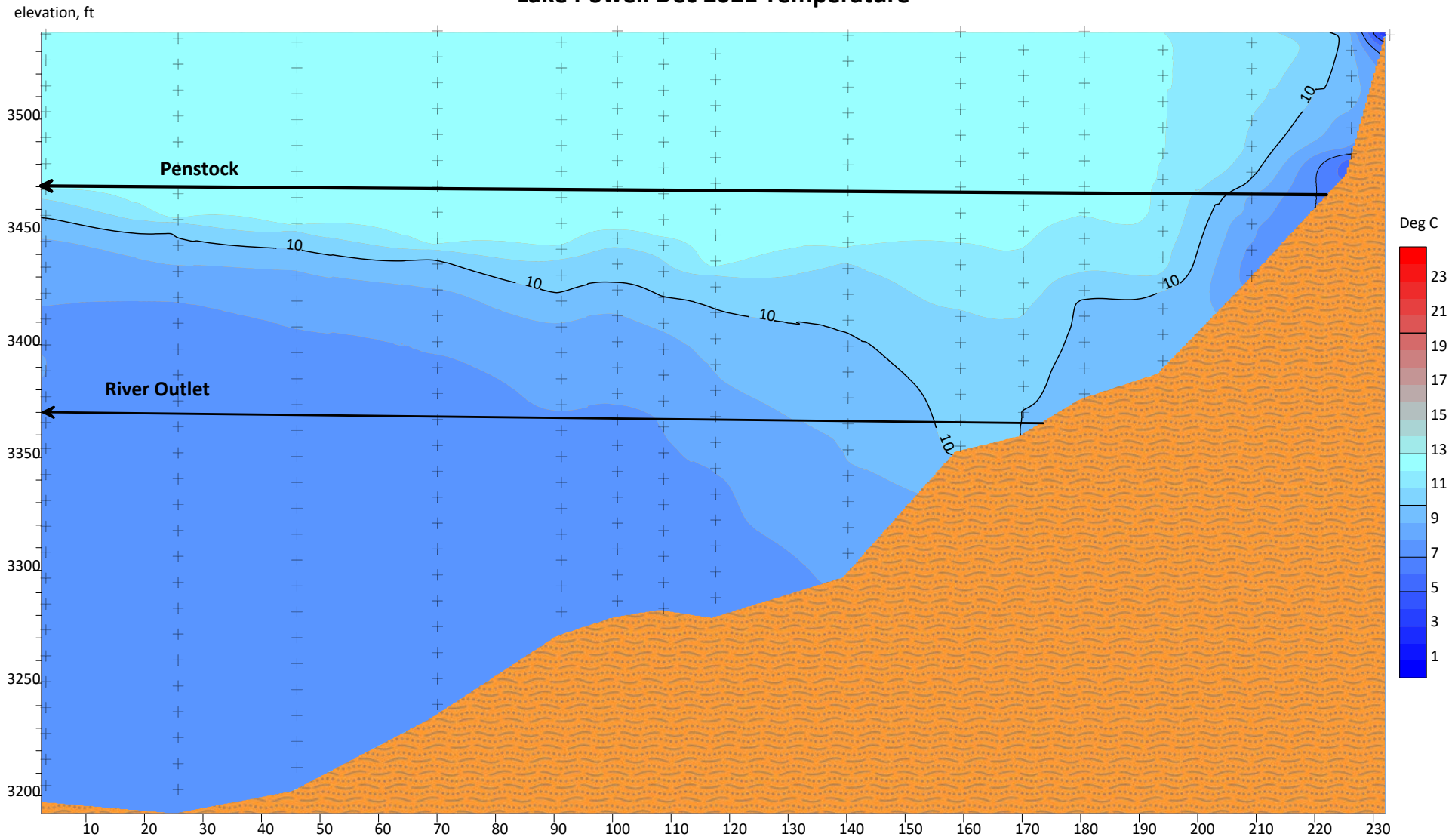
Temperature Profile of Lake Powell near Glen Canyon Dam
1/7/2022

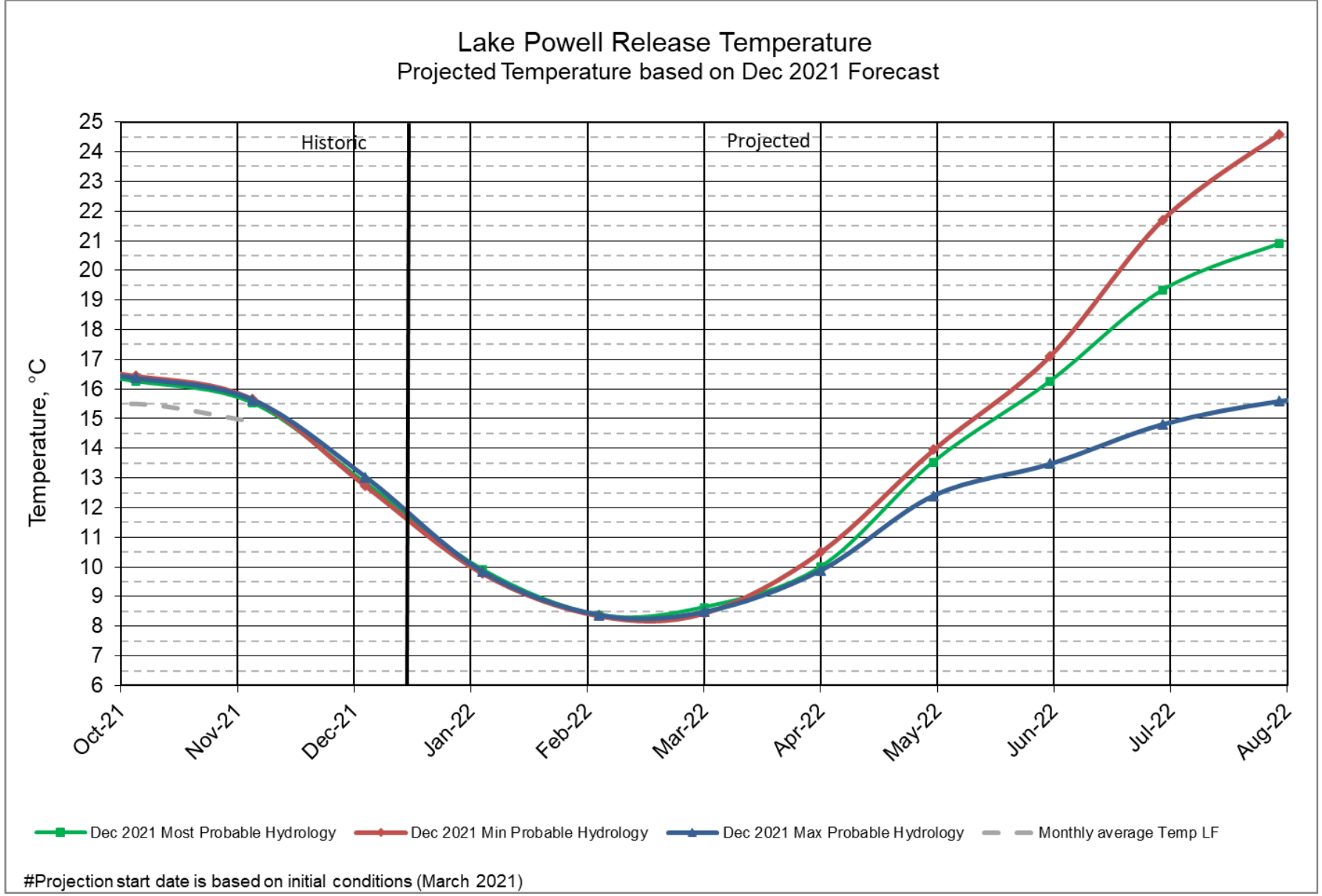


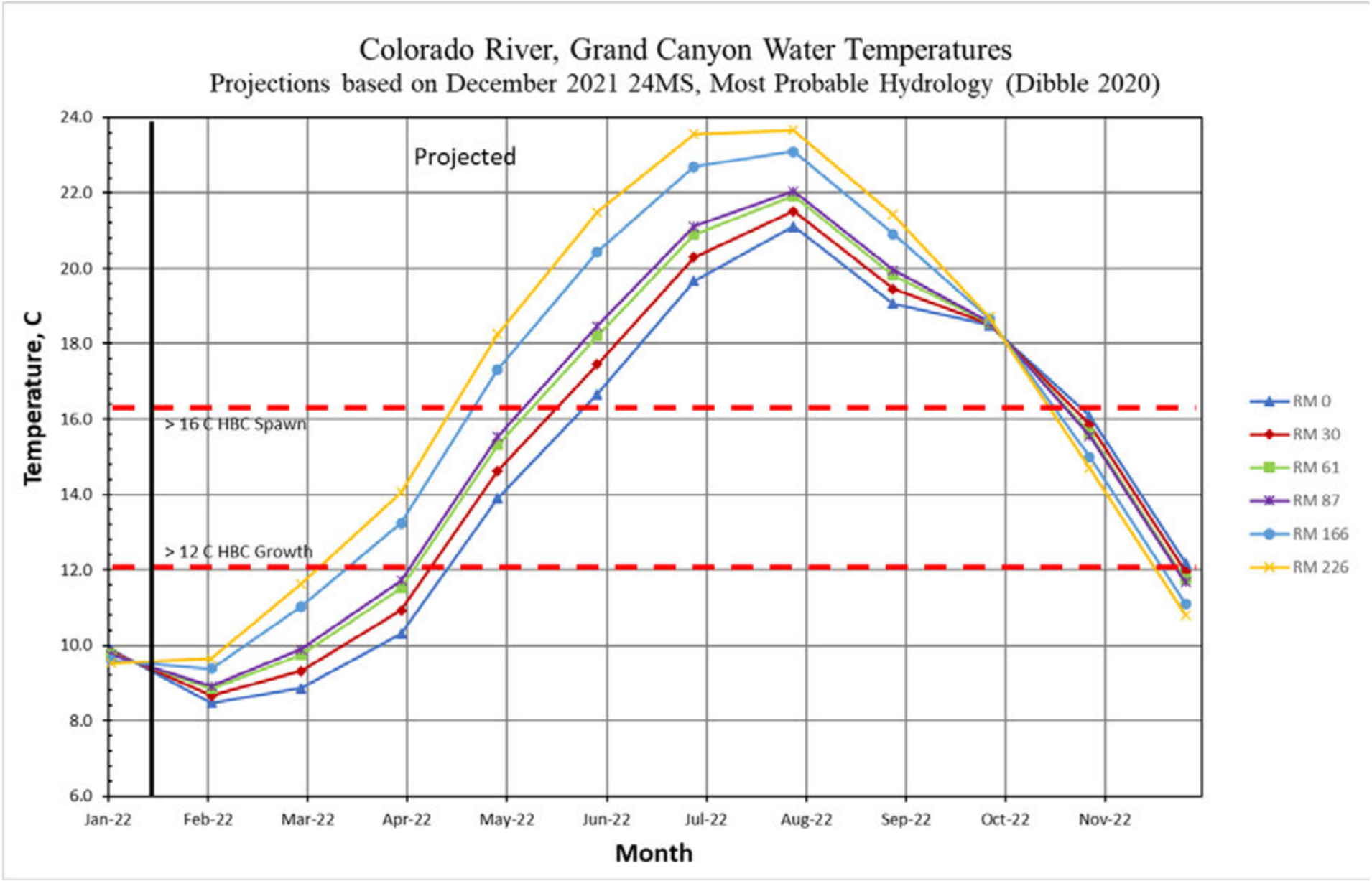
Cross Sectional Temperature Profile of Lake Powell
1/7/2022



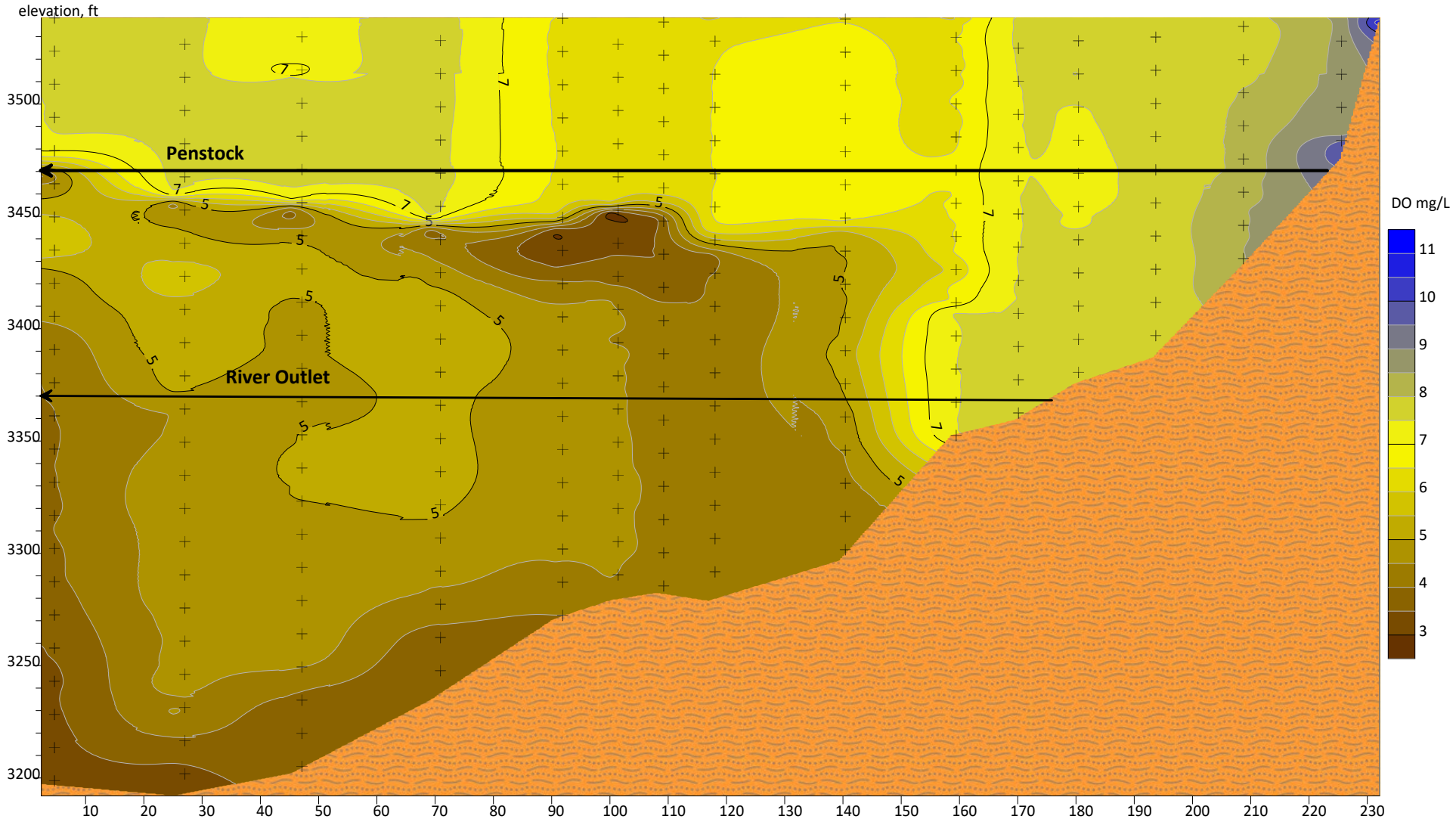
Lake Powell Dec 2021 Temperature



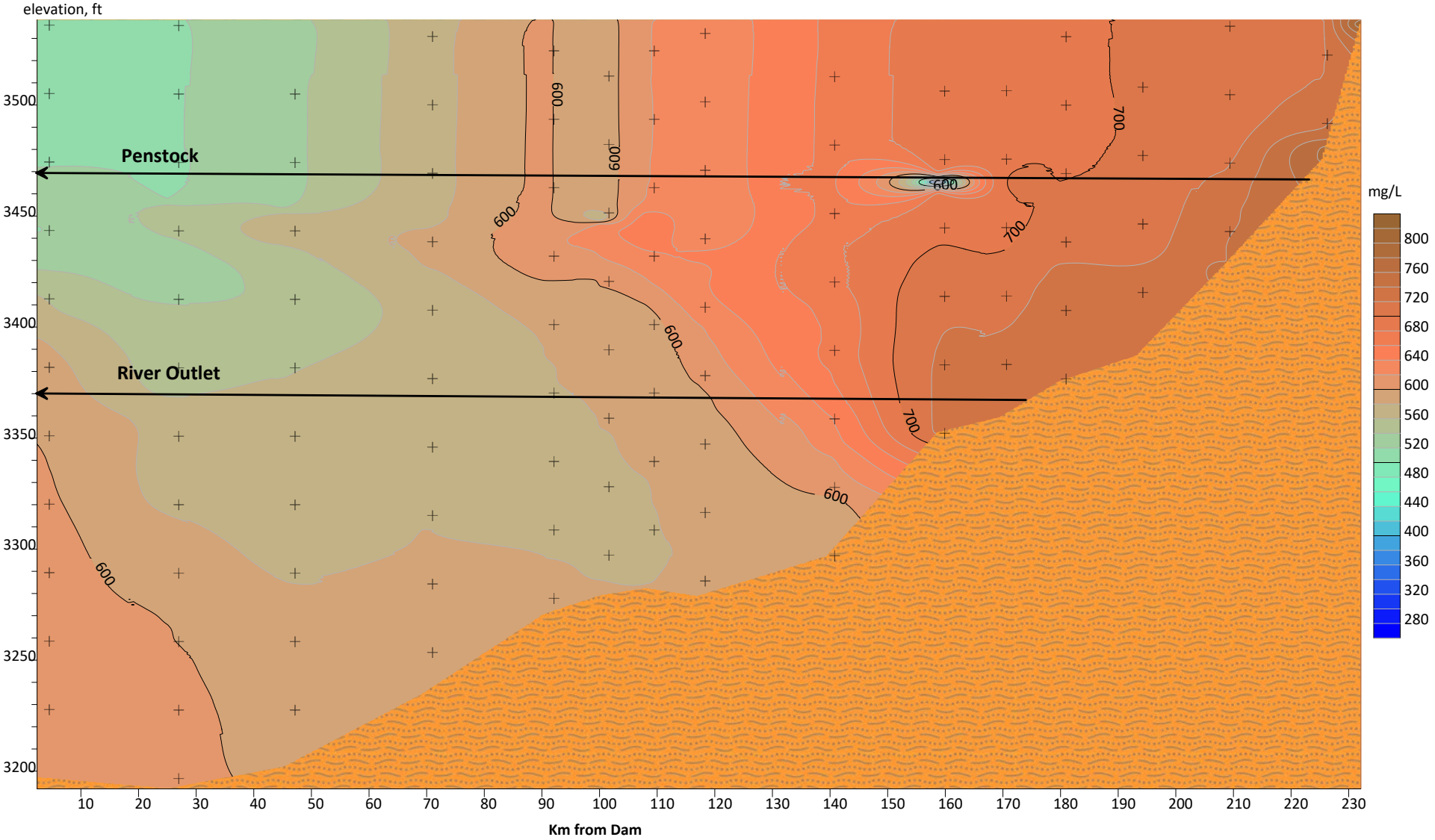

Lake Powell Release Temperature
Projected Temperature based on Dec 2021 Forecast
Historic
Projected
Temperature, °C
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
Oct-21
Nov-21
Dec-21
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Dec 2021 Most Probable Hydrology
Dec 2021 Min Probable Hydrology
Dec 2021 Max Probable Hydrology
Monthly average Temp LF
#Projection start date is based on initial conditions (March 2021)


Colorado River, Grand Canyon Water Temperatures
Projections based on December 2021 24MS, Most Probable Hydrology (Dibble 2020)
Projected
> 16 C HBC Spawn
> 12 C HBC Growth
Temperature, C
Month
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Sep-22
Oct-22
Nov-22
RM 0
RM 30
RM 61
RM 87
RM 166
RM 226

Lake Powell Dec 2021 Dissolved Oxygen



Lake Powell Dec 2021 TDS




Thank you, TWG, BOR, and Lake Powell!


Questions?
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RECLAMATION