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Glen Canyon Monthly Operations Call

Basin Hydrology and Operations

October 20, 2021

Background

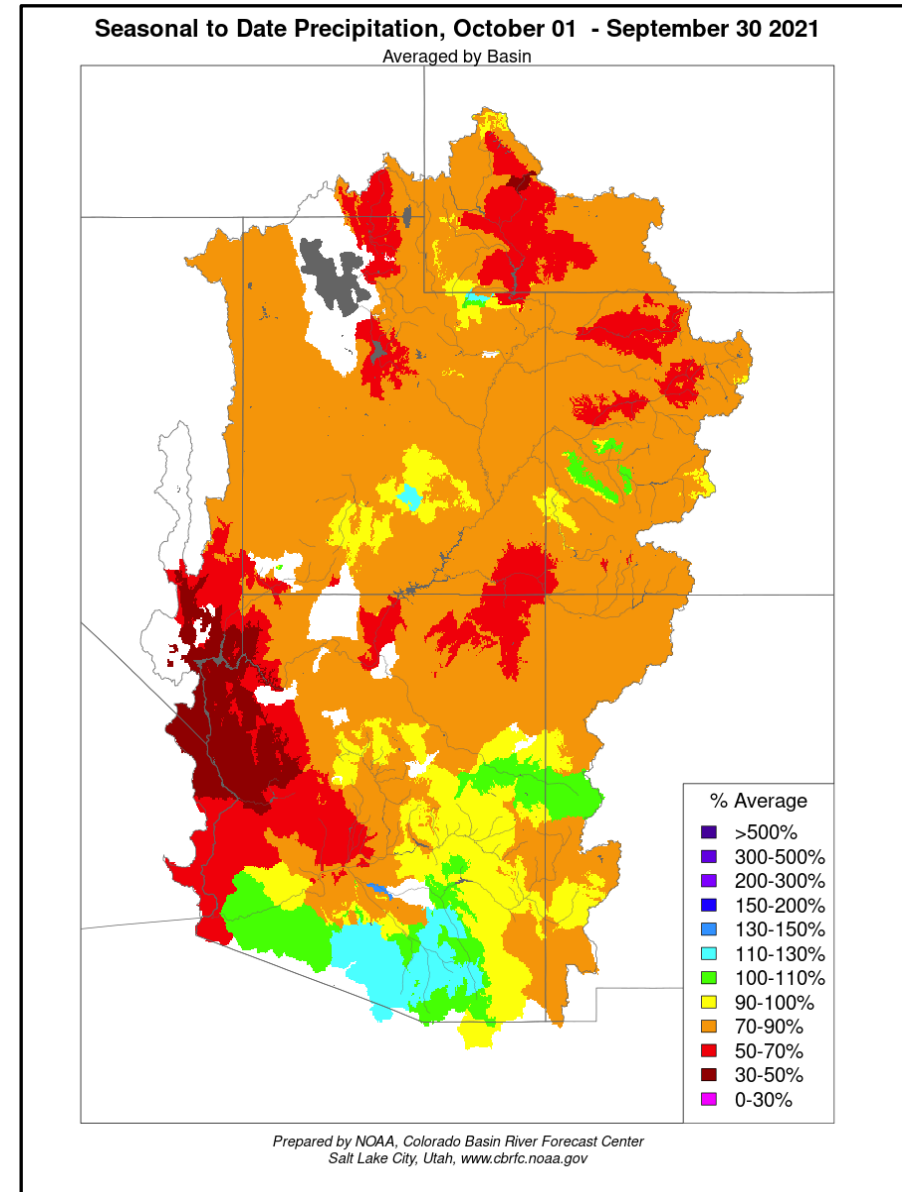
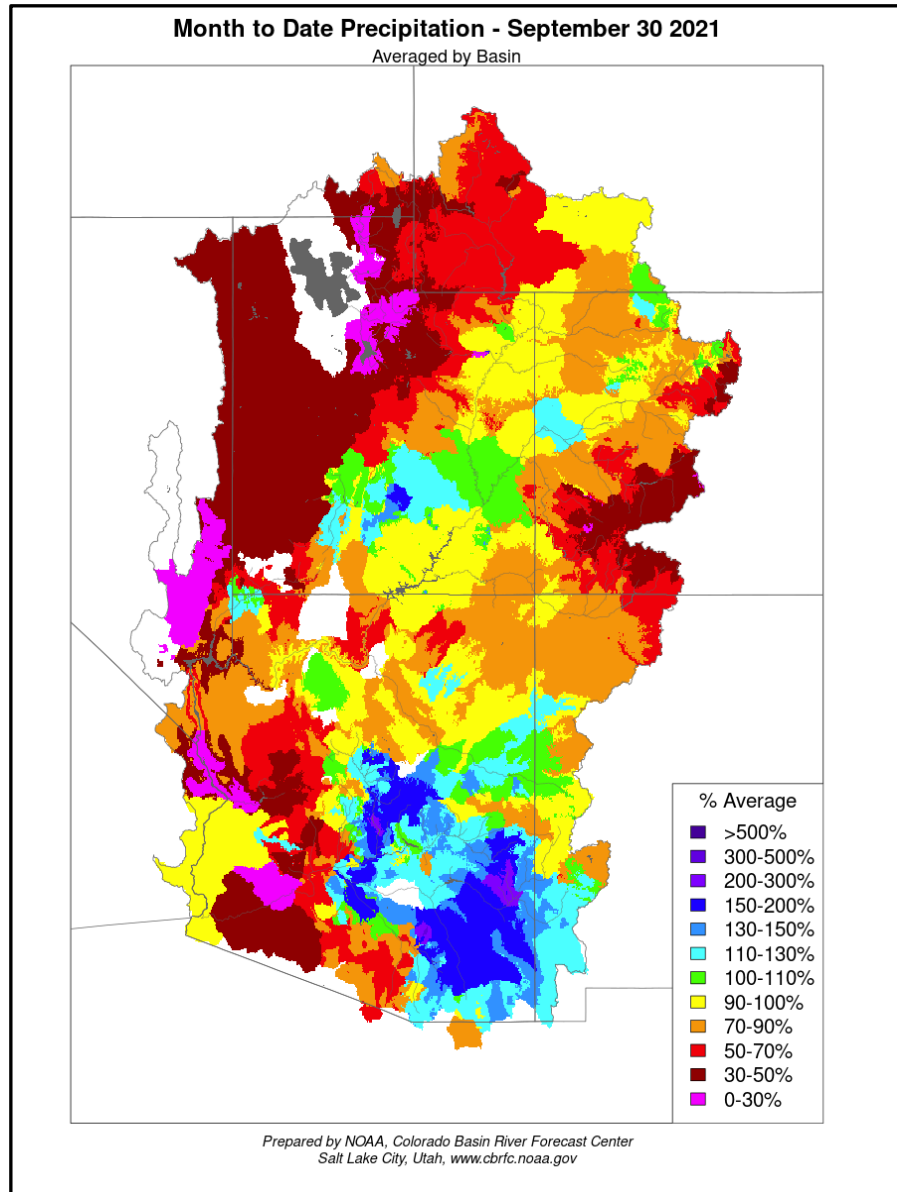
This briefing is being provided consistent with the provision in Section 1.1 of the LTEMP ROD which states:

“Annually, Reclamation will develop a hydrograph based on the characteristics above. Reclamation will seek consensus on the annual hydrograph through monthly operational coordination calls with governmental entities, and regular meetings of the GCDAMP Technical Working Group (TWG) and AMWG.

Reclamation will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (USGS, NPS, FWS, and BIA), WAPA, and representatives from the Basin States and UCRC. The purpose of these meetings or calls is for the participants to share and seek information on Glen Canyon Dam operations. One liaison from each Basin State and from the UCRC may participate in the monthly operational coordination meetings or calls.”

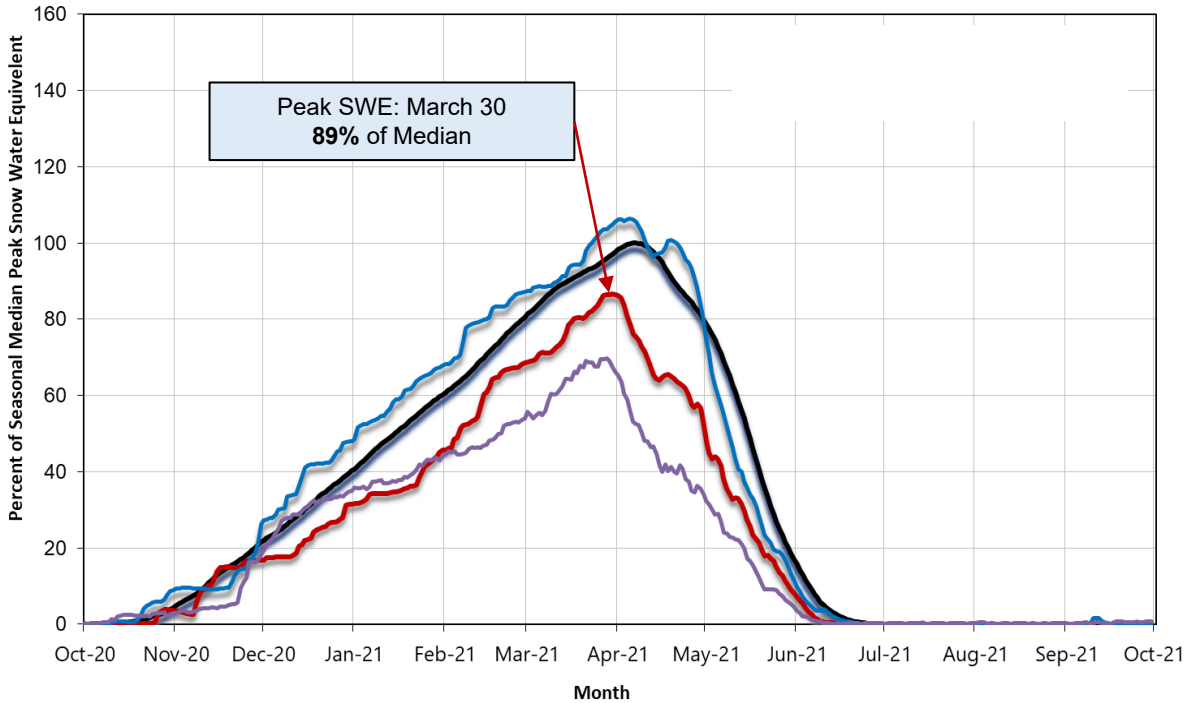


2021 Precipitation: September and Seasonal



Current SWE and Observed UC Runoff

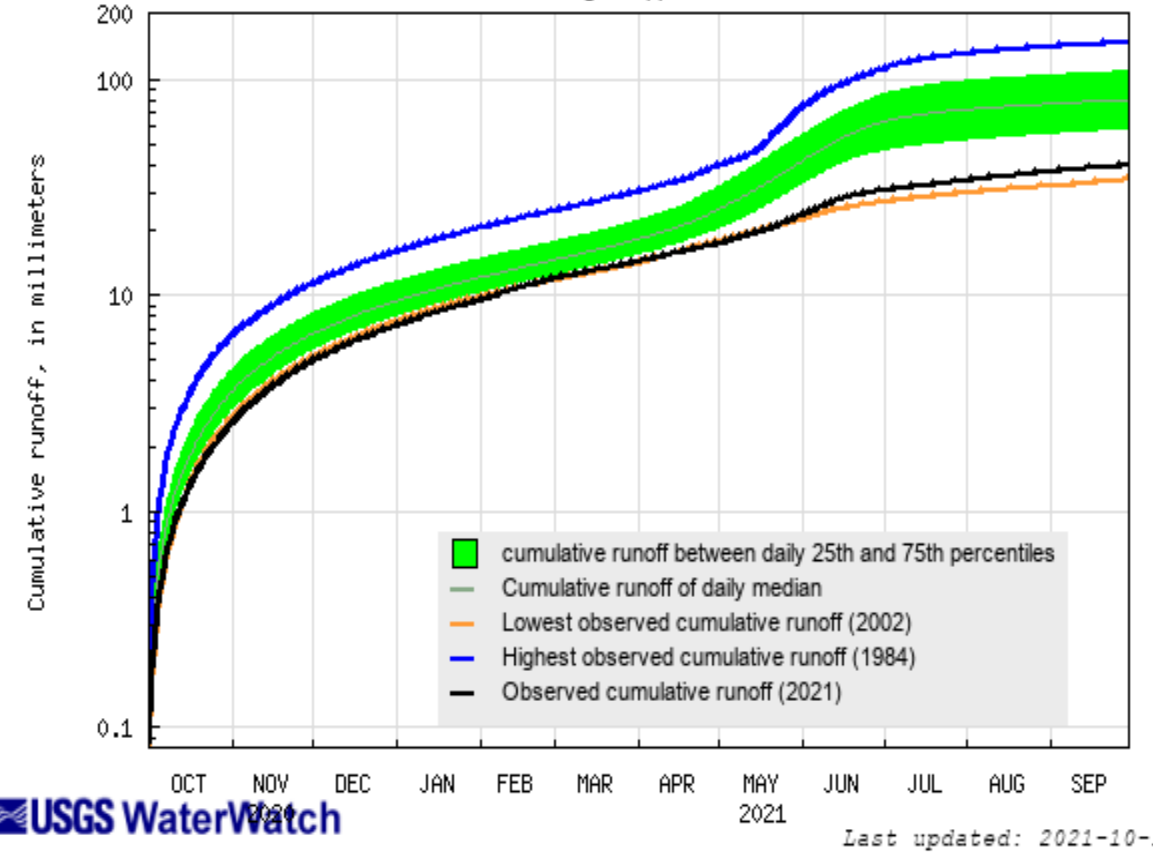
Upper Colorado River above Lake Powell Snotel Tracking



— 30 Year Median — Current WY2021 — Comparison WY2020 — Comparison WY2002

Data Provided by the Natural Resource Conservation Service

Hydrograph of cumulative 7-day average runoff for Water Resource Region Upper Colorado



USGS WaterWatch

Last updated: 2021-10-12

Available online at: https://waterwatch.usgs.gov/index.php?id=wwdur_cumrunoff



Historical Water Year 2021 Unregulated Inflows

Water Year 2021
Preliminary Observed Unregulated Inflow
as of October 11, 2021

Reservoir	Unregulated Inflow (kaf)	1981-2010 Percent of Avg
Fontenelle	561	52
Flaming Gorge	650	45
Blue Mesa	518	54
Navajo	403	37
Powell	3,502	32

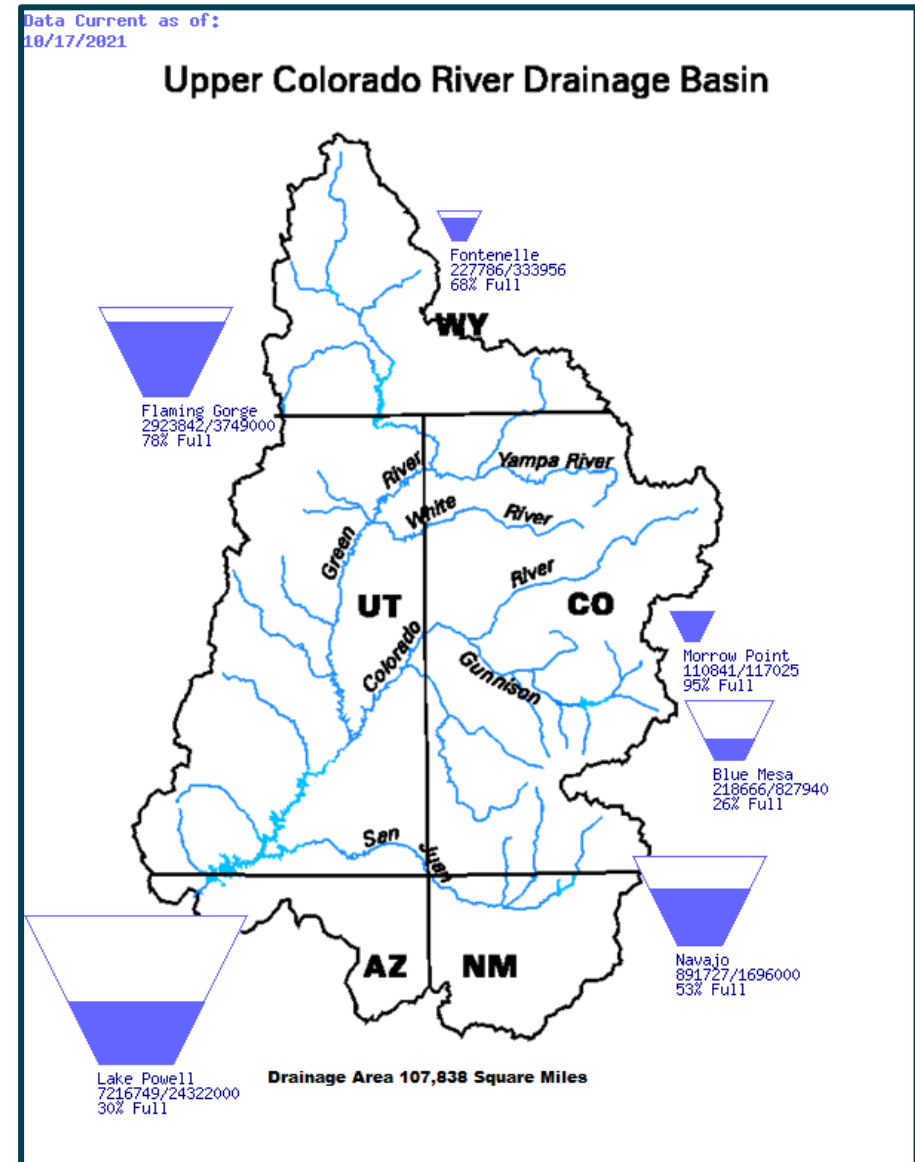
April – July 2021
Observed Unregulated Inflow
as of October 11, 2021

Reservoir	Unregulated Inflow (kaf)	1981-2010 Percent of Avg
Fontenelle	318	44
Flaming Gorge	363	37
Blue Mesa	317	47
Navajo	378	51
Powell	1,834	26

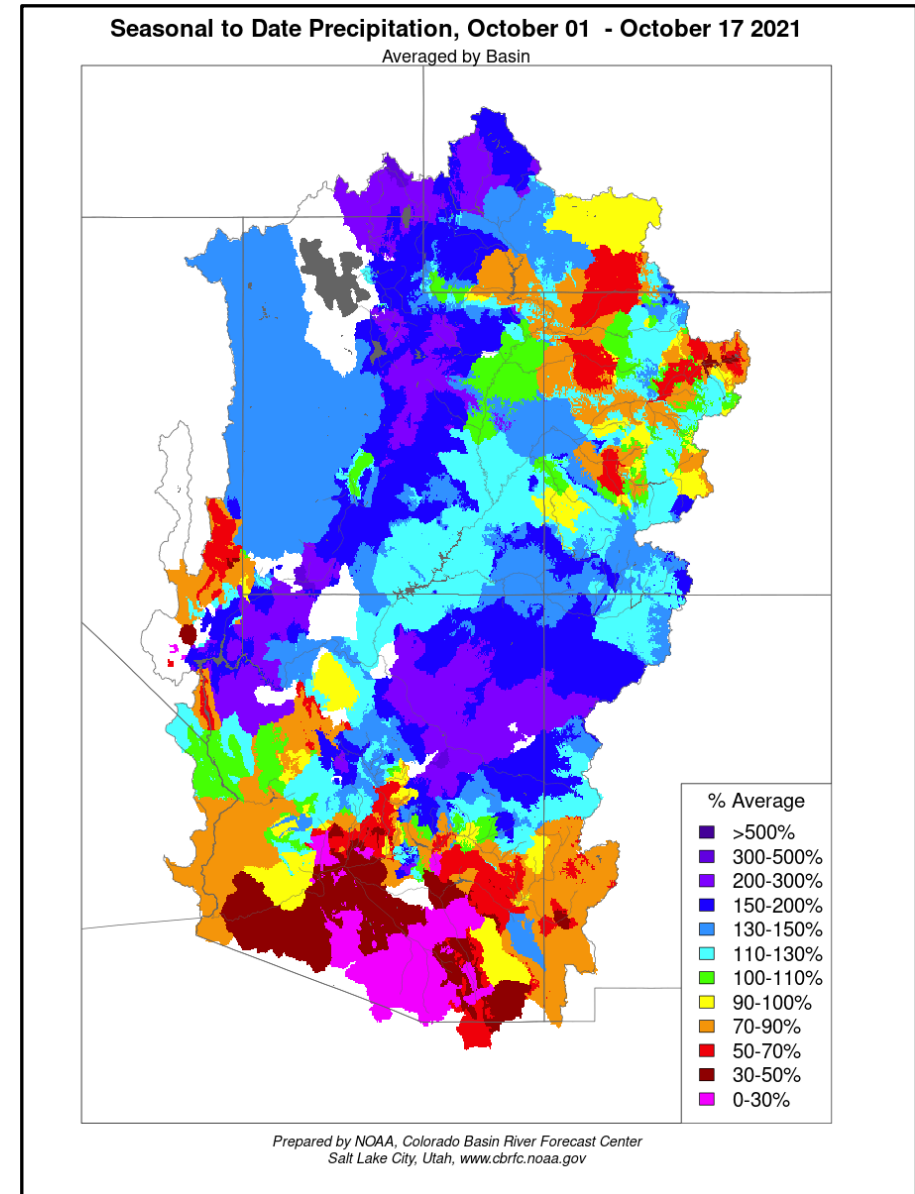
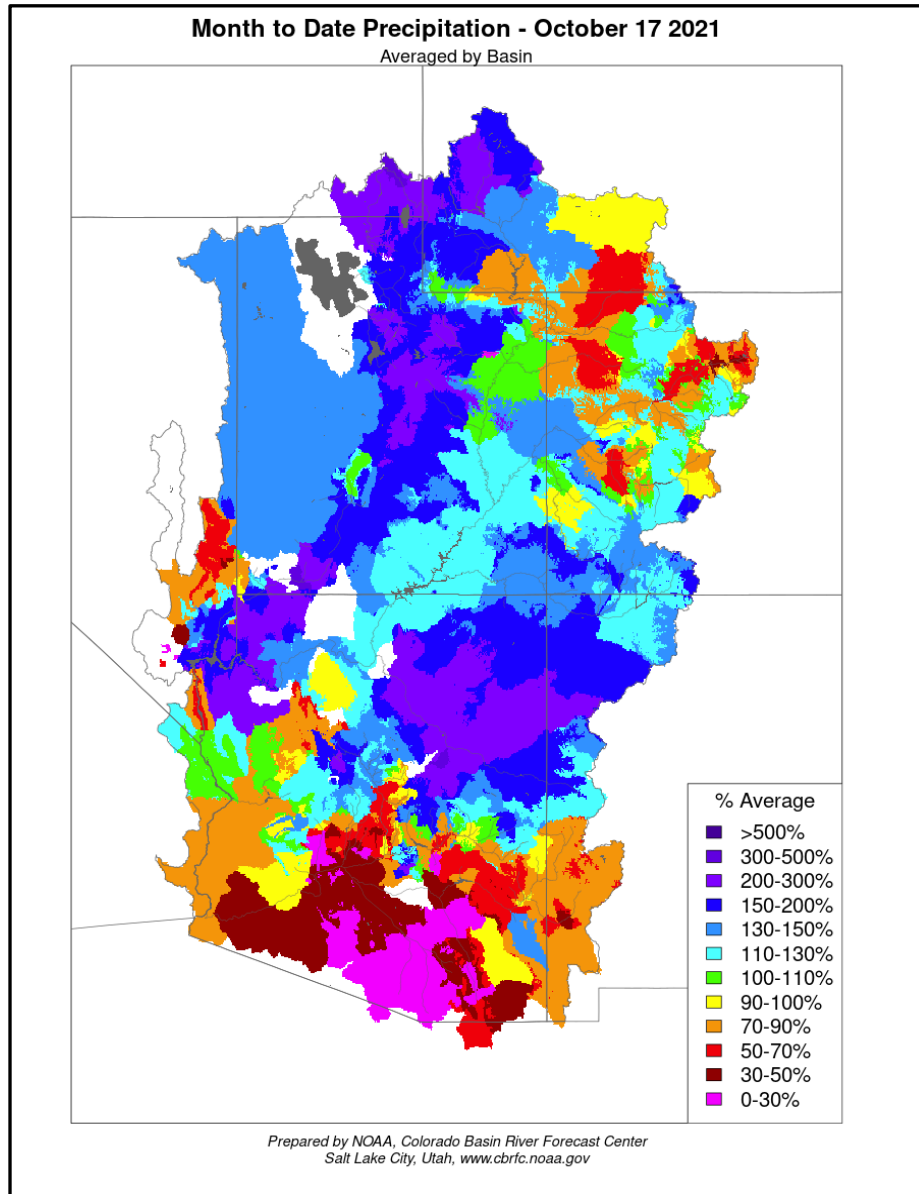


Upper Basin Storage (as of October 19, 2021)

Reservoir	Percent Current Live Storage	Current Live Storage (maf)	Live Storage Capacity (maf)	Elevation (feet)
Fontenelle	68	0.23	0.33	6,491.48
Flaming Gorge	78	2.92	3.75	6,018.41
Blue Mesa	26	0.22	0.83	7,431.32
Navajo	53	0.89	1.70	6,022.74
Lake Powell	30	7.21	24.32	3,544.67
UC System Storage	37	11.60	31.03	



2022 Precipitation: October and Seasonal



October 2021 30-Year Average Shift: 1991-2020

- CRSP Initial Unit facilities will continue to operate according to their Records of Decision
- Moving to the 1991-2020 period-of-record will provide projected reservoir operations that are more reflective of the dry conditions we are currently experiencing
 - The significant wet hydrology observed in the 1980s will be removed from the CBRFC forecast and will no longer influence/overestimate inflow forecast volumes.
 - Incorporating the last decade of record dry hydrology from 2011-2020 includes the observed higher temperatures and drier conditions that have occurred with climate change.
- Upper Green Basin has the least amount of change because of 2011 and 2017 wet hydrology
- San Juan has the greatest shift with continued dry hydrology over last decade

Reservoirs	April-July Volumes				Water Year Volumes			
	1981-2010 April-July Avg Volume (kaf)	1991-2020 April-July Avg Volume (kaf)	April-July Volume Difference (kaf)	April-July Percent Difference	1981-2010 WY Avg Volume (kaf)	1991-2020 WY Avg Volume (kaf)	WY Volume Difference (kaf)	WY Percent Difference
Fontenelle	726	735	9	1%	1,082	1,074	(7)	-1%
Flaming Gorge	979	966	(12)	-1%	1,455	1,411	(43)	-3%
Blue Mesa	676	636	(40)	-6%	955	904	(51)	-5%
Navajo	737	628	(109)	-15%	1,075	911	(165)	-15%
Powell	7,155	6,392	(763)	-11%	10,831	9,603	(1,228)	-11%

Bulletin 17B hydrologic statistics using Pearson III methodology

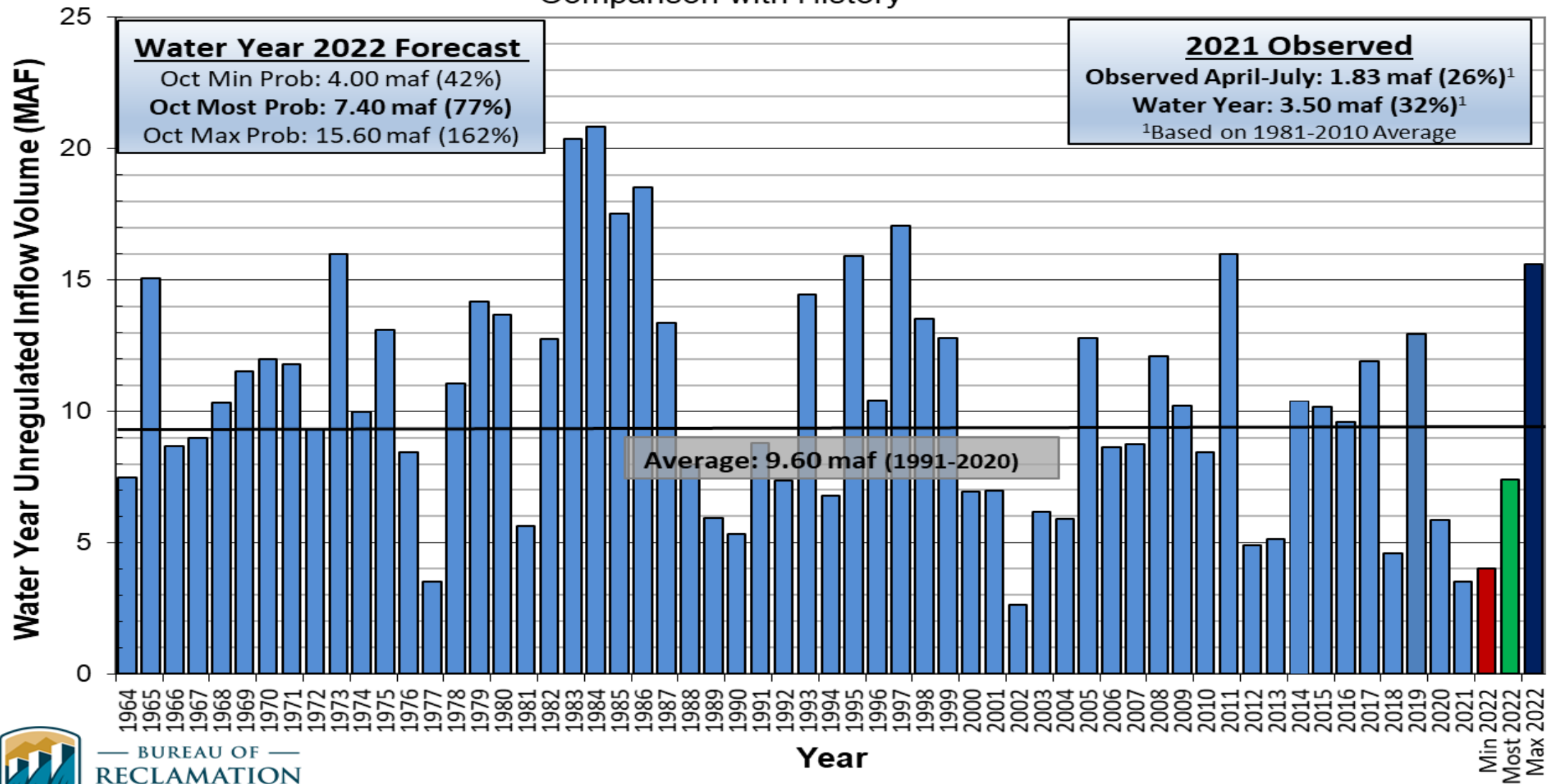
https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf



Lake Powell Unregulated Inflow

Water Year 2022 Forecast (issued October 4)

Comparison with History



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Most Probable October Forecast Water Year 2022

Water Year 2022
Forecasted Unregulated Inflow
as of October 4, 2021

Reservoir	Unregulated Inflow (kaf)	1991-2020 Percent of Avg
Fontenelle	830	77
Flaming Gorge	1,070	76
Blue Mesa	760	84
Navajo	705	77
Powell	7,400	77

April – July 2022
Forecasted Unregulated Inflow
as of October 4, 2021

Reservoir	Unregulated Inflow (kaf)	1991-2020 Percent of Avg
Fontenelle	575	78
Flaming Gorge	732	76
Blue Mesa	550	86
Navajo	518	82
Powell	5,170	81





Upper Colorado Basin

Projected Operations for Water Year 2022 Based on October 2021 Modeling



2021 DROA Timeline of Events

- **January 2021: Minimum Probable 24 Month Study run projected Powell below 3,525'**
 - Formal notification to parties
 - Enhanced monitoring and coordination
 - Monthly analysis of min/most/max
- **May 2021: Most Probable 24 Month Study run projected Powell within inches of 3,525'**
 - DROA planning formally initiated
- **July 2021: Continued declining hydrology and declining Powell**
 - Consultation and initiation of DROA releases under emergency provision of agreement



Upper Basin DROA Initial Unit Drought Response Releases that started in July 2021

- July WY2021 forecast decreased 140 kaf from the June forecast
- Continued drought conditions exacerbated already parched soil moisture conditions
- WY2022 most probable forecast decreased 1.84 maf (17%)
 - May forecast 9.97 maf (92% avg)
 - July forecast 8.13 maf (75% avg)
- Prospects of future monsoon events unknown

DROA Releases for the July 24MS Model Run

	Jul	Aug	Sep	Oct	Nov	Dec	
	(kaf)	(kaf)	(kaf)	(kaf)	(kaf)	(kaf)	Sum
Flaming Gorge	13	42	43	27	0	0	125
Blue Mesa	0	14	18	4	0	0	36
Navajo	0	0	0	0	10	10	20
Sum:	13	56	61	31	10	10	181



Lake Powell & Lake Mead Operational Table

Operating Determinations for Water Year/Calendar Year 2022

Lake Powell			Lake Mead		
Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf) ¹	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	1,220	Flood Control Surplus or Quantified Surplus Condition Deliver > 7.5 maf	25.9
3,636 - 3,666 (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	15.5 - 19.3 (2008-2026)	1,200 (approx.) ²	Domestic Surplus or ICS Surplus Condition Deliver > 7.5 maf	22.9 (approx.) ²
3,575	Mid-Elevation Release Tier Release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf	9.5	1,145	Normal or ICS Surplus Condition Deliver ≥ 7.5 maf	15.9
	3,535.40 ft		1,105		11.9
	Jan 1, 2022 Projection		1,075	1,065.85 ft	9.4
3,525	Lower Elevation Balancing Tier Balance contents with a min/max release of 7.0 and 9.5 maf	5.9	1,050	Shortage Condition Deliver 7.167 ⁴ maf	7.5
3,490		4.0	1,025	Shortage Condition Deliver 7.083 ⁵ maf	5.8
3,370		0	1,000	Shortage Condition Deliver 7.0 ⁶ maf Further measures may be undertaken ⁷	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

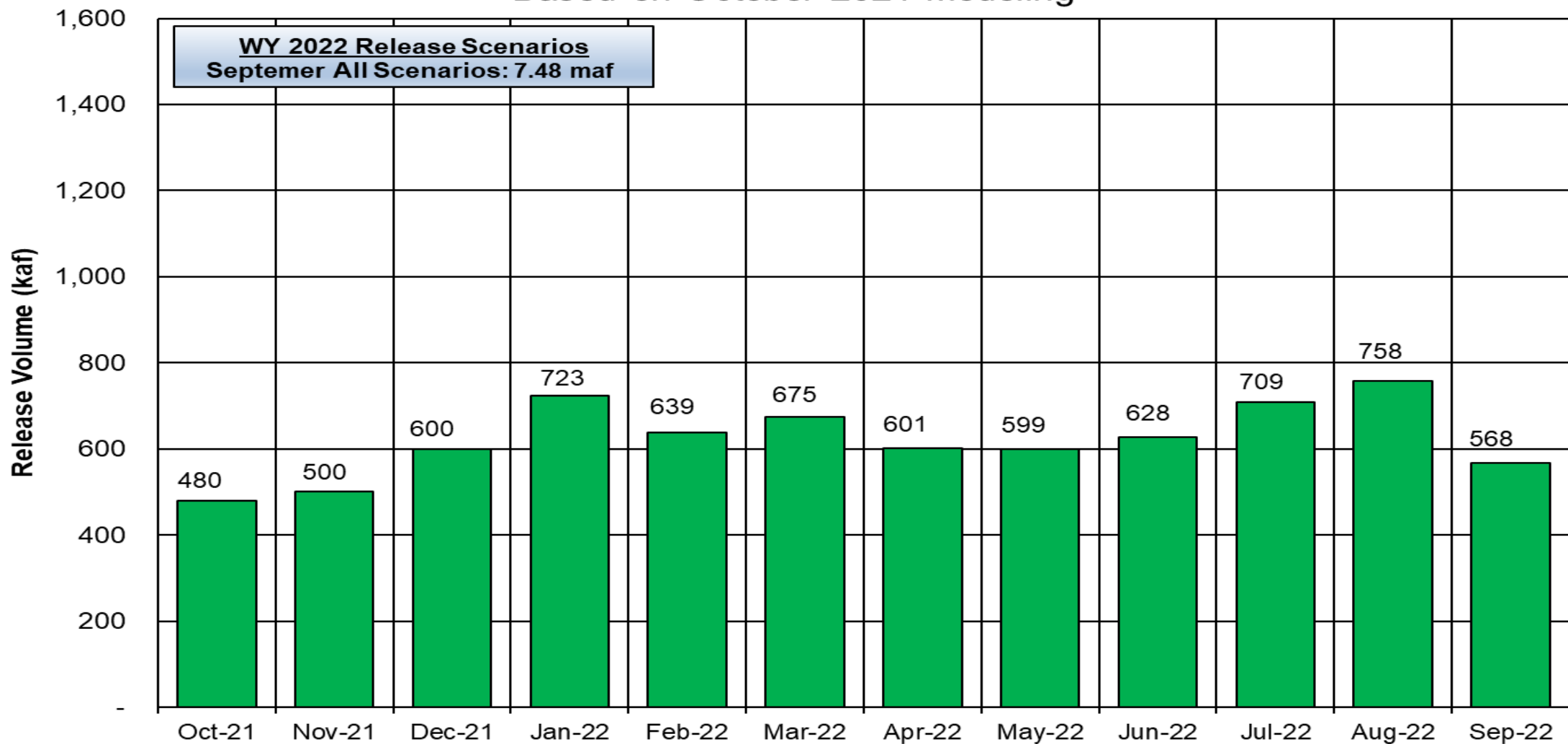
⁷ Whenever Lake Mead is below elevation 1,025 feet, the Secretary shall consider whether hydrologic conditions together with anticipated deliveries to the Lower Division States and Mexico is likely to cause the elevation at Lake Mead to fall below 1,000 feet. Such consideration, in consultation with 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 October 2021 Modeling



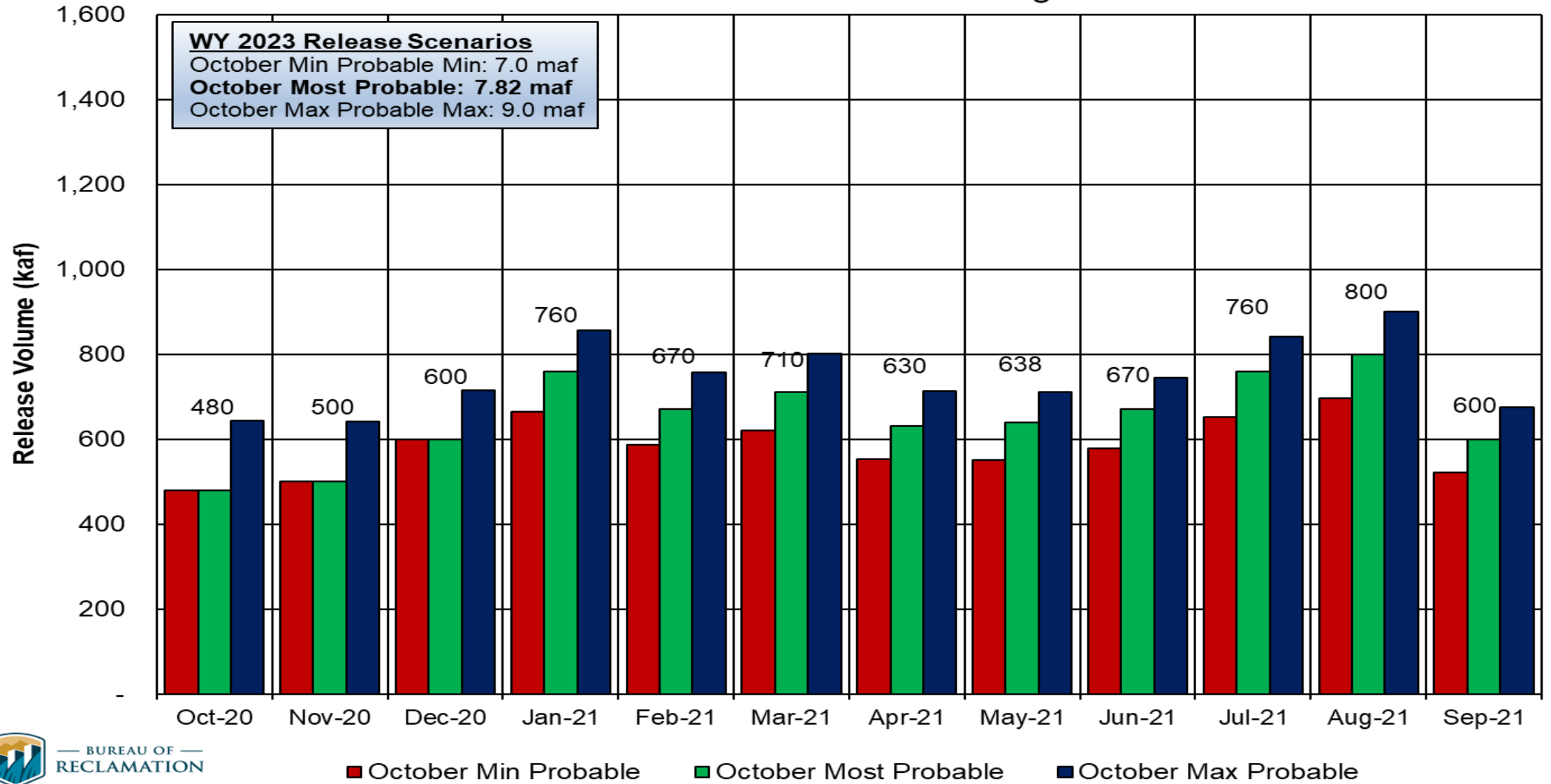
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The Drought Response Operations Agreement (DROA) can be found here: <https://www.usbr.gov/dcp/finaldocs.html>

Potential Lake Powell Monthly Release Volume Distribution

Release Scenarios for Water Year 2023

Based on October 2021 Modeling



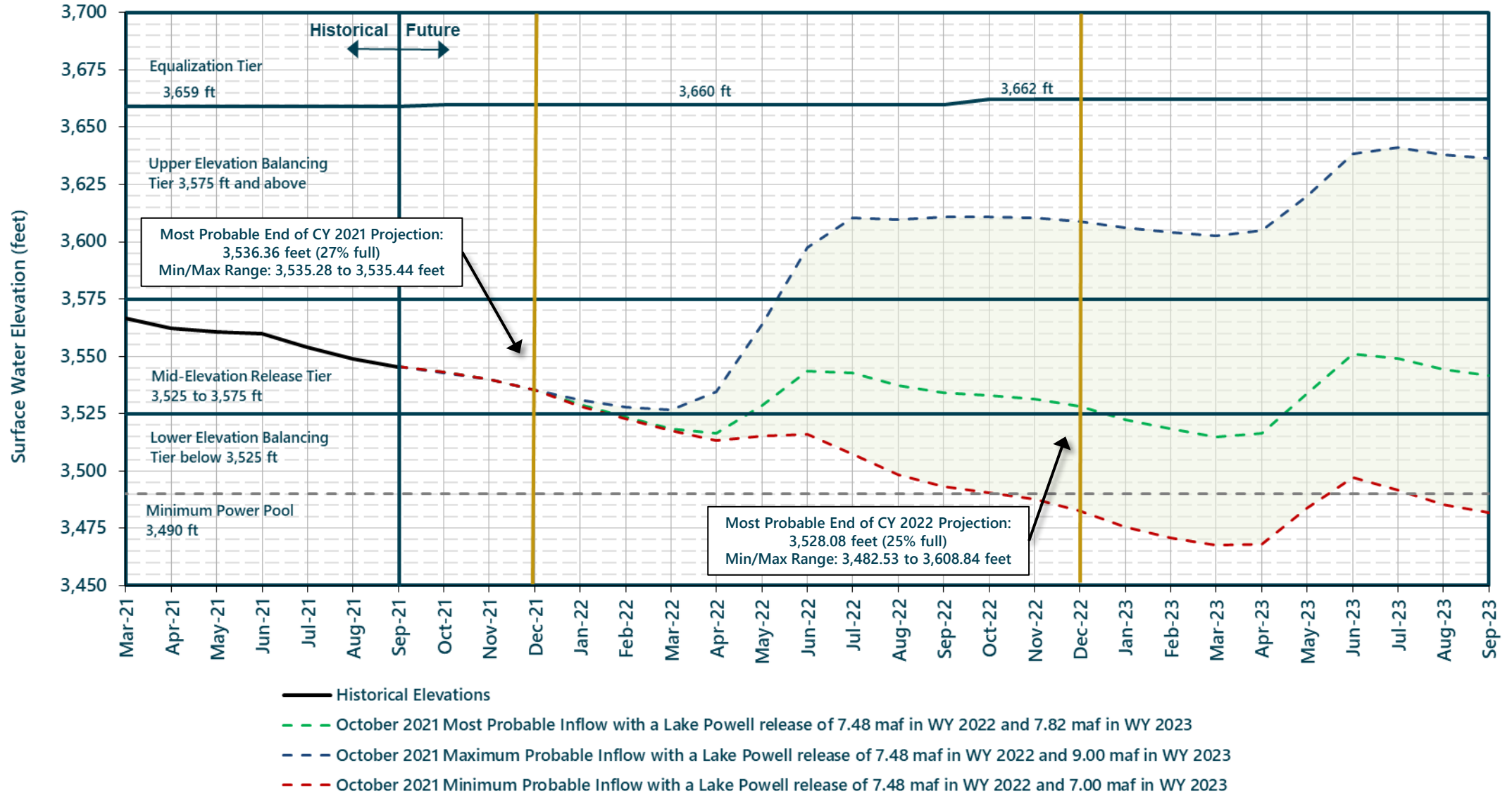
Reclamation Operational Modeling Model Comparison

	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 October 2021 24-Month Study Inflow Scenarios

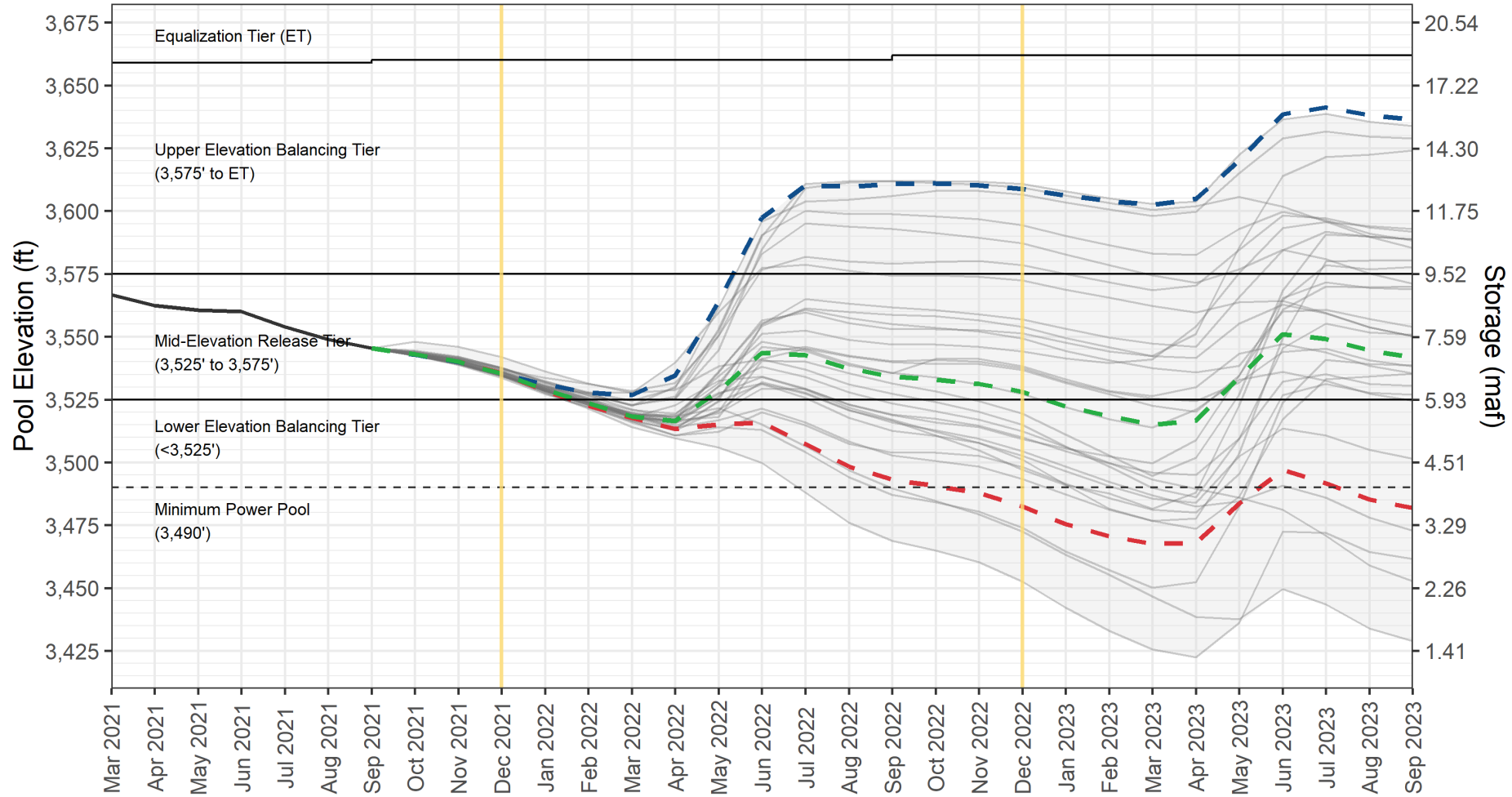


The Drought Response Operations Agreement (DROA) is available online at: <https://www.usbr.gov/dcp/finaldocs.html>.



Lake Powell End-of-Month Elevations

CRMMS Projections from October 2021

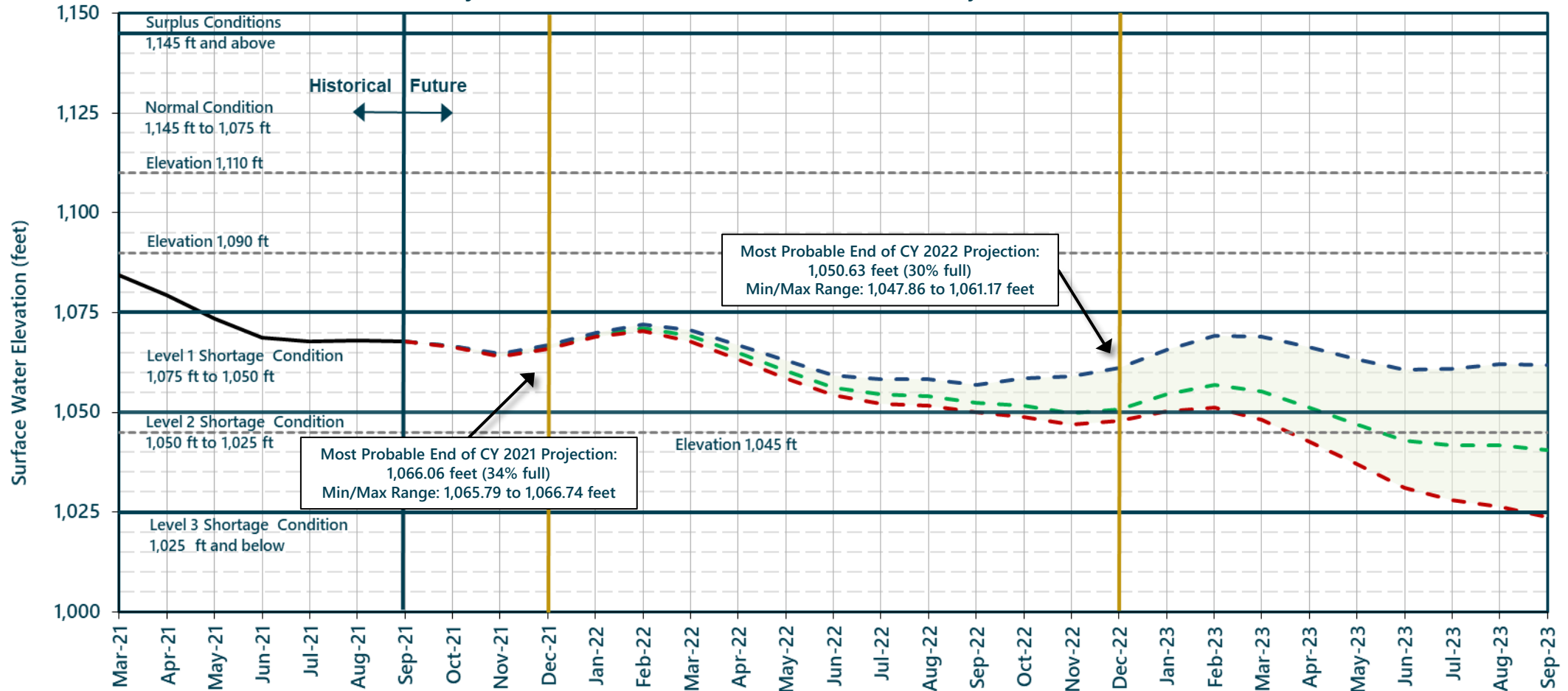


- - - 24-Month Study Minimum Probable
- - - 24-Month Study Maximum Probable
- - - 24-Month Study Most Probable
- Historical
- CRMMS-ESP Projections (30 projections)
- CRMMS-ESP Projections Range



Lake Mead End of Month Elevations

Projections from the October 2021 24-Month Study Inflow Scenarios

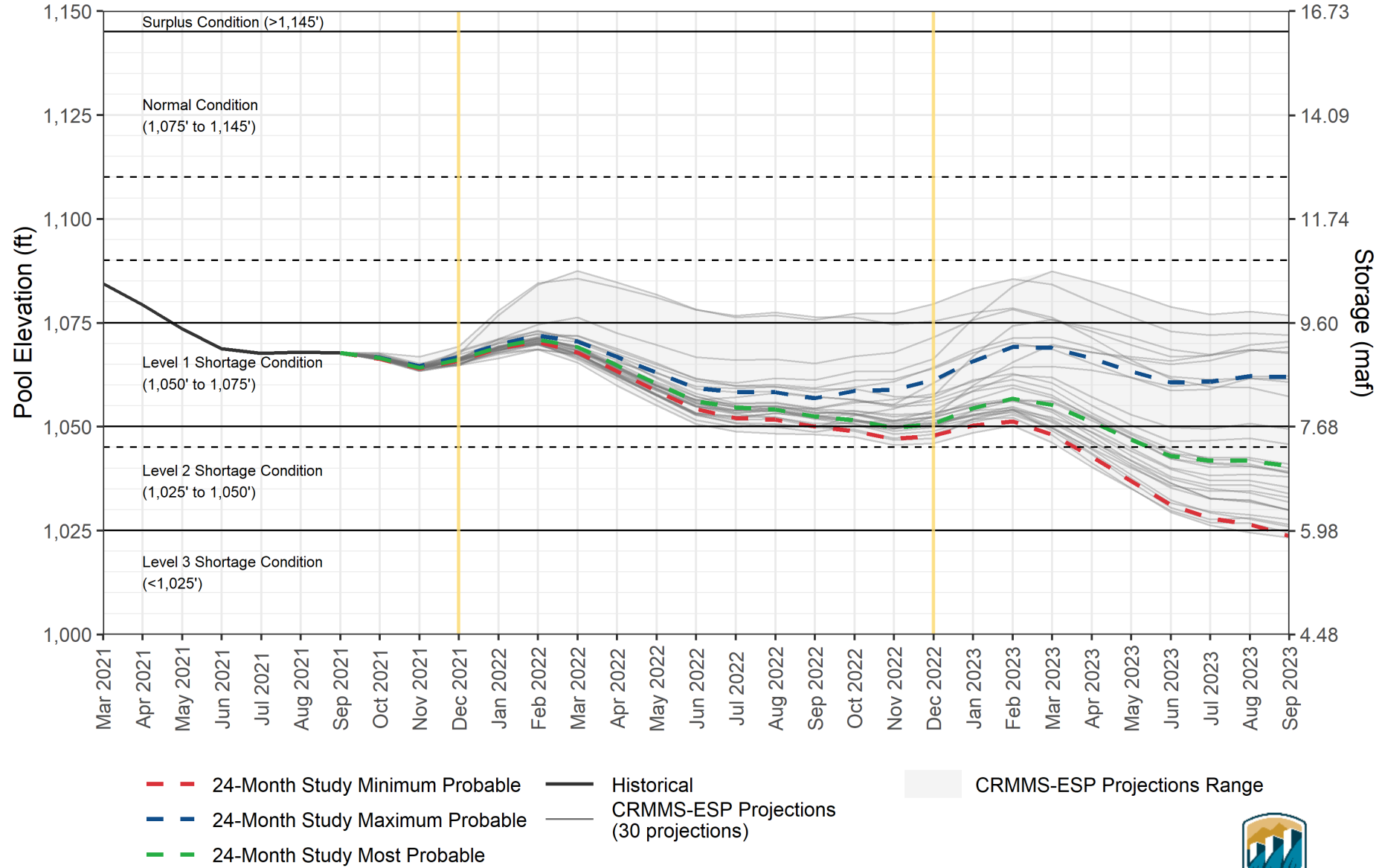


- Historical Elevations
- - - October 2021 Most Probable Inflow with a Lake Powell release of 7.48 maf in WY 2022 and 7.82 maf in WY 2023
- - - October 2021 Maximum Probable Inflow with a Lake Powell release of 7.48 maf in WY 2022 and 9.00 maf in WY 2023
- - - October 2021 Minimum Probable Inflow with 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>.



Lake Mead End-of-Month Elevations CRMMS Projections from October 2021





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	4	6	6	5	6	6	6	4	
Capacity (cfs)	18,600	18,550	18,400	18,200	11,300	17,800	17,750	14,800	18,650	18,650	18,450	11,600	OCT MOST ²
Capacity (kaf/month)	1,080	1,100	1,180	1,100	670	1,090	1,060	1,000	1,110	1,150	1,130	740	OCT MOST
Max (kaf) ¹	480	500	600	723	639	675	601	599	628	709	758	588	7.48 maf
Most (kaf) ¹	480	500	600	723	639	675	601	599	628	709	758	588	7.48 maf
Min (kaf) ¹	480	500	600	723	639	675	601	599	628	709	758	588	7.48 maf
													(updated 10-19-2021)

1 Projected release, based on October 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 2022

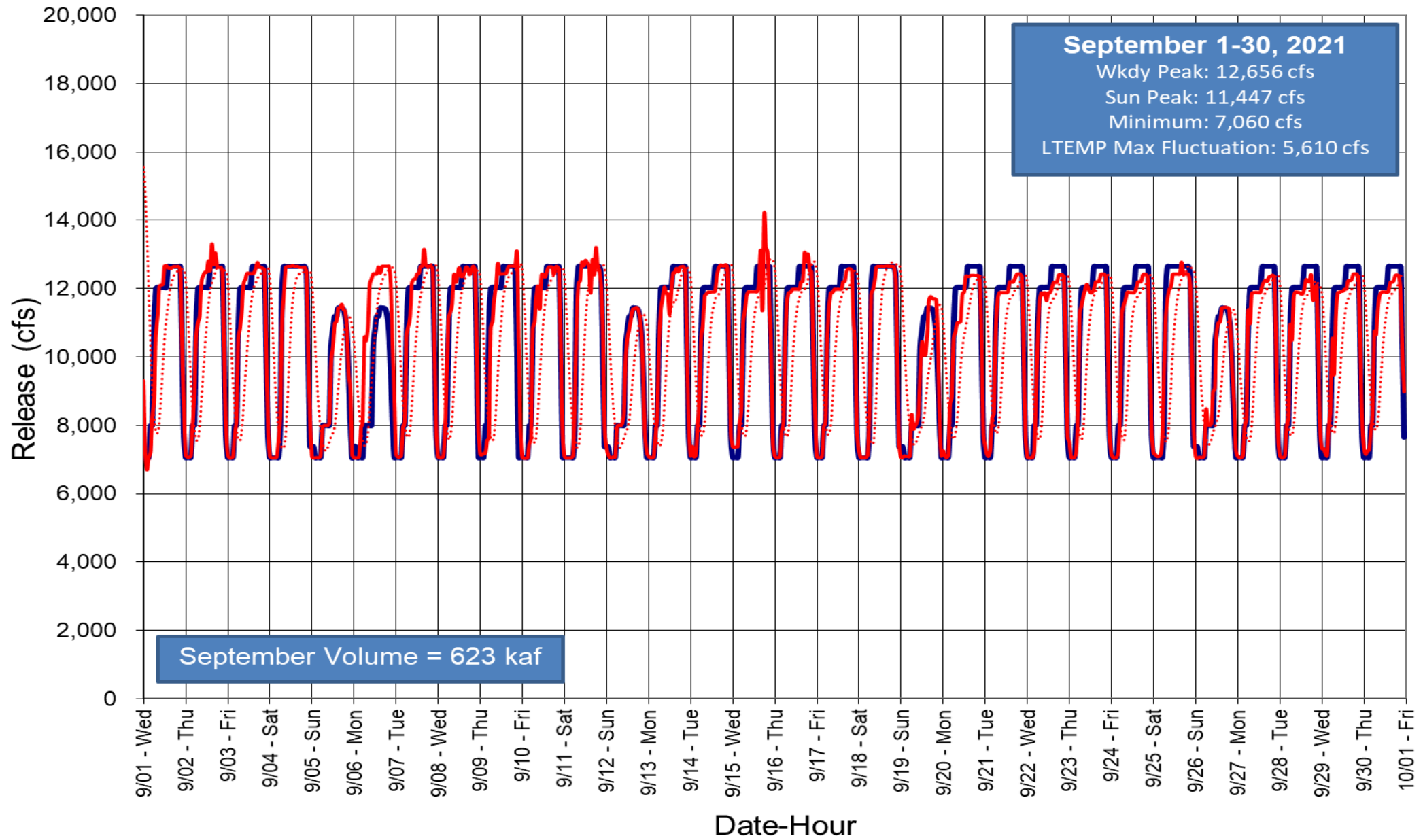
Unit Number	Oct 2022	Nov 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	Apr 2023	May 2023	Jun 2023	Jul 2023	Aug 2023	Sep 2023	
1	■												■
2	■												■
3						■		■					
4						■							
5													
6													
7	■				■								
8					■								
Units Available	7	8	8	8	6	6	8	7	8	8	8	6	
Capacity (cfs)	21,700	25,000	24,850	24,600	17,000	17,700	24,300	21,700	25,850	25,800	25,600	18,600	OCT MOST ²
Capacity (kaf/month)	1,260	1,490	1,530	1,500	1,040	1,260	1,450	1,360	1,540	1,580	1,570	1,170	OCT MOST
Max (kaf) ¹	643	642	715	857	758	801	713	710	745	842	900	674	9.0 maf
Most (kaf) ¹	480	500	600	760	670	710	630	638	670	760	800	600	7.82 maf
Min (kaf) ¹	480	500	600	664	587	620	552	550	577	652	696	522	7.0 maf
													(updated 10-19-2021)

1 Projected release, based on October 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.



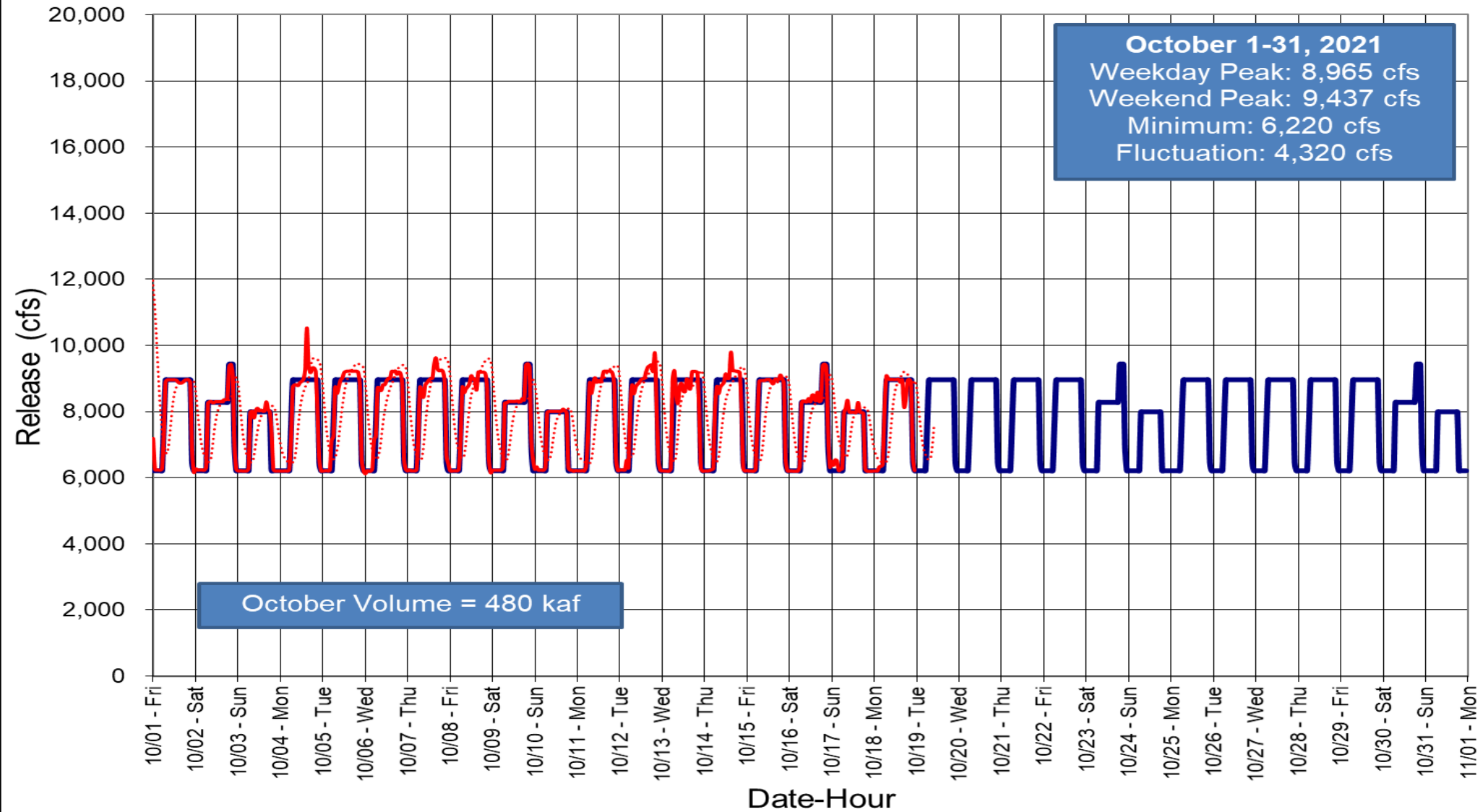
Glen Canyon Dam Hourly Release Pattern September 2021



— Scheduled Hourly Releases
 — Actual Hourly Releases
 ⋯ Lees Ferry Flow



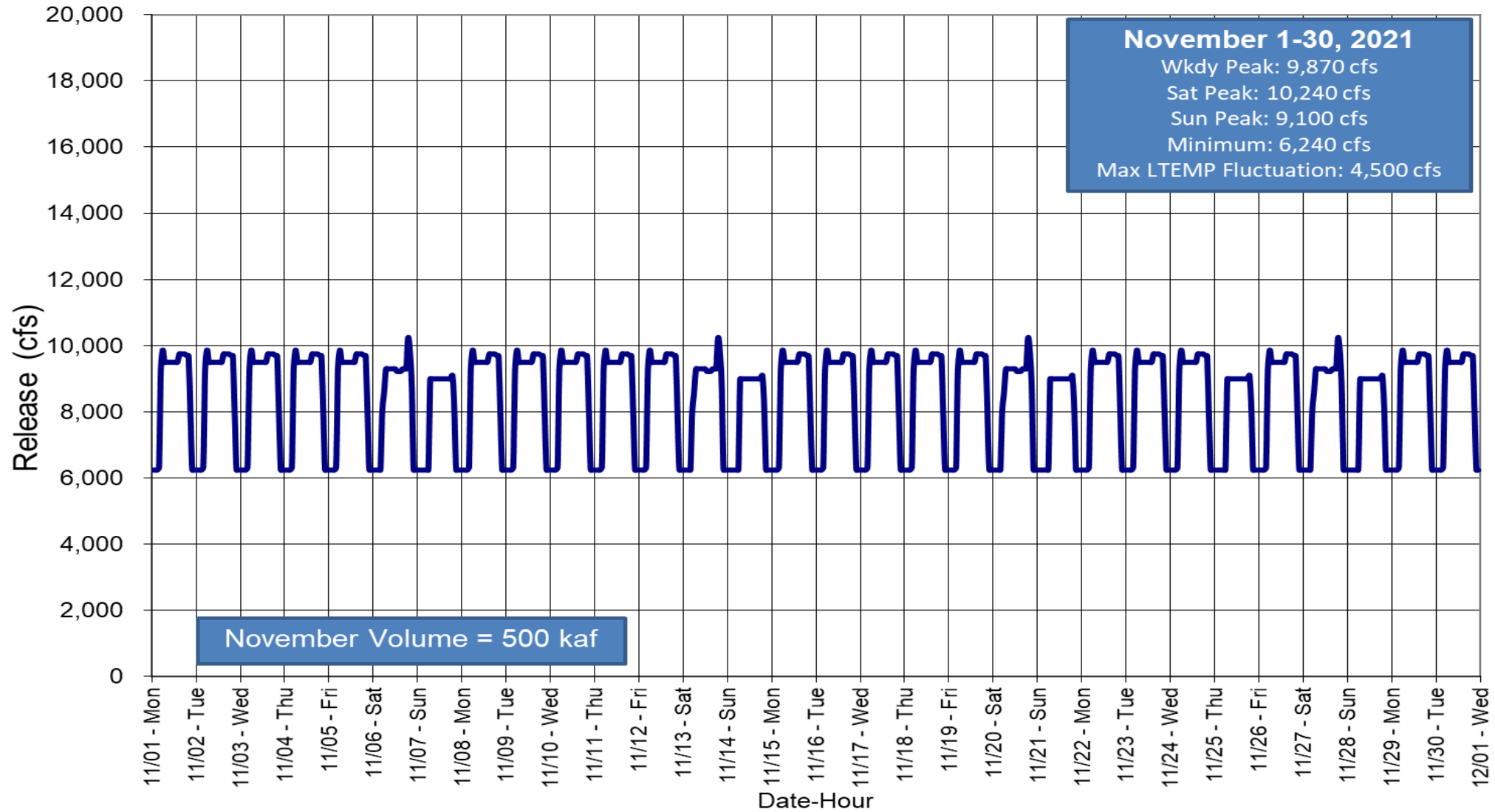
Glen Canyon Dam Hourly Release Pattern October 2021



— Scheduled Hourly Releases
 — Actual Hourly Releases
 ⋯ Lees Ferry Flow



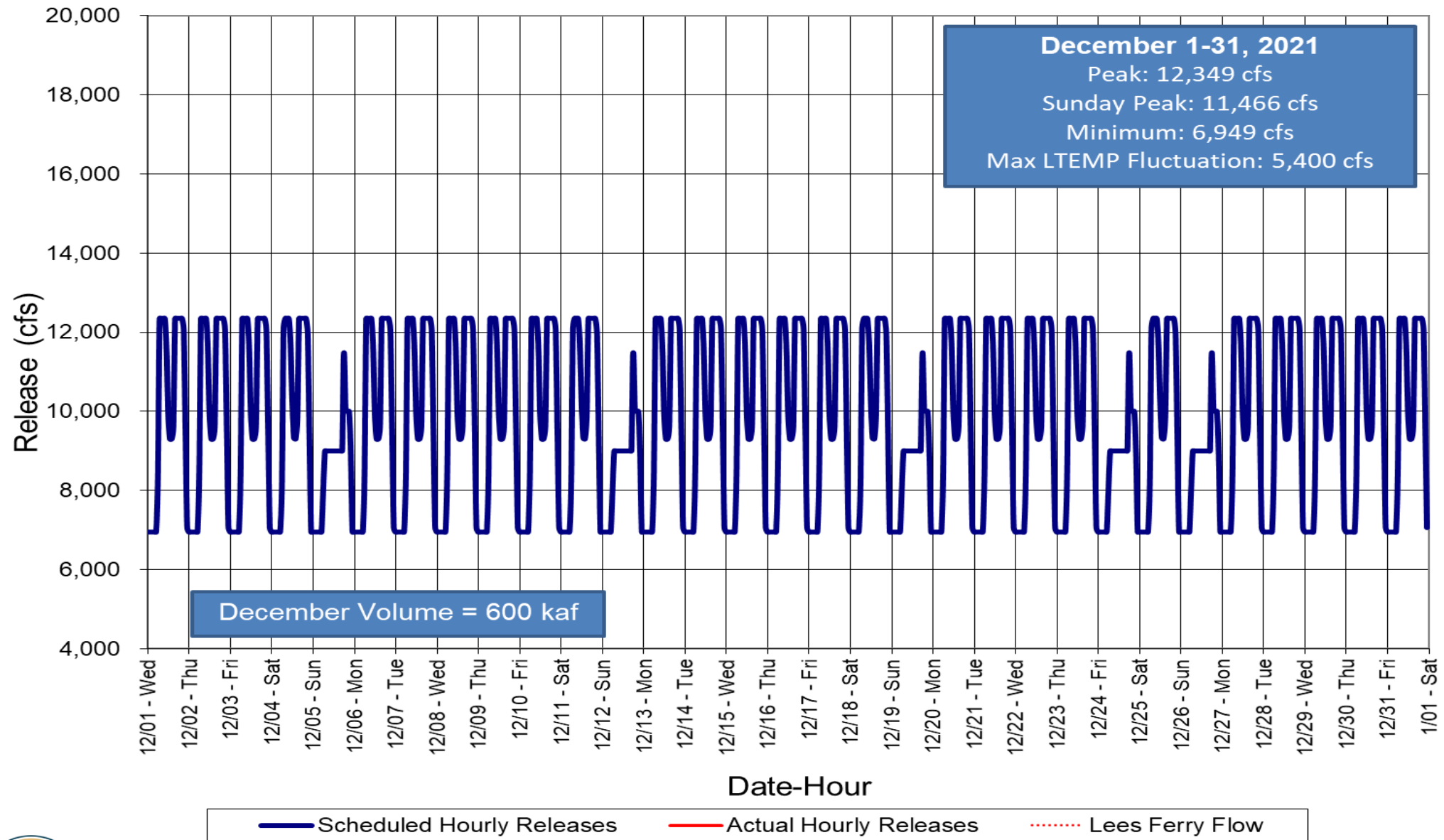
Glen Canyon Dam Hourly Release Pattern November 2021



— Scheduled Hourly Releases
 — Actual Hourly Releases
 ⋯ Lees Ferry Flow



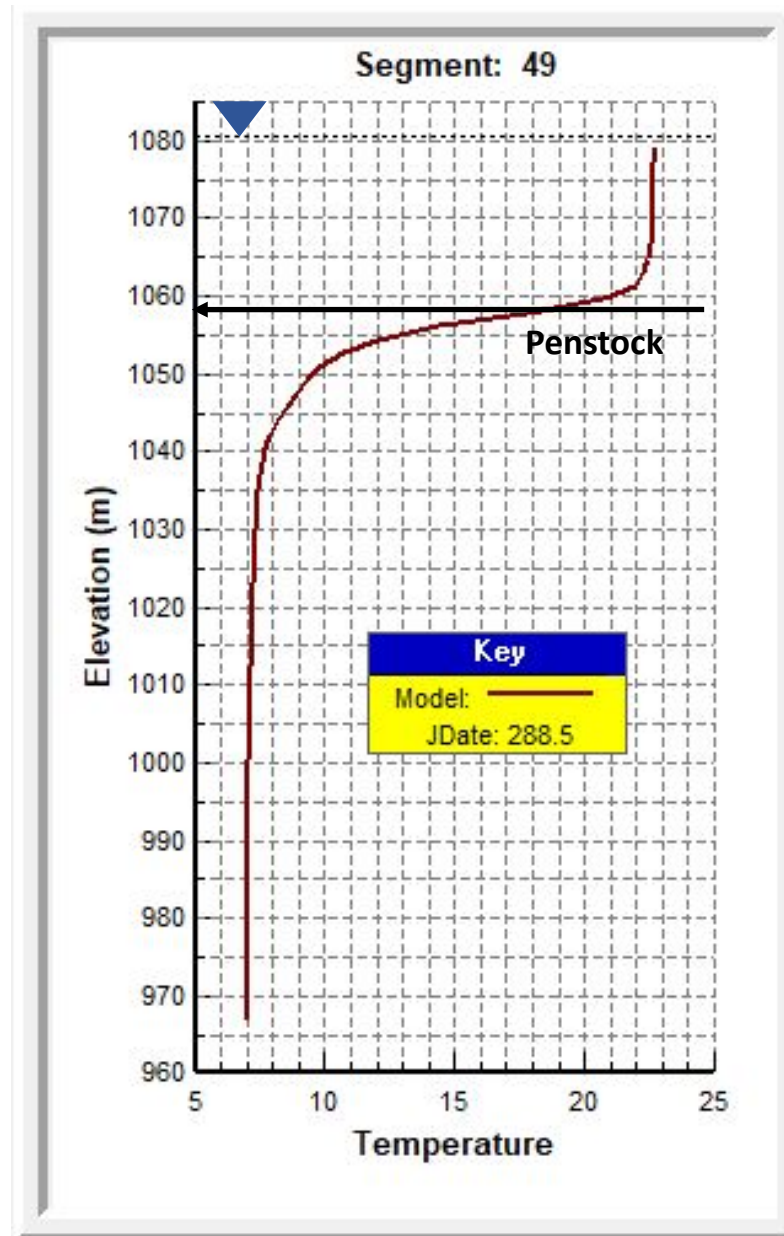
Glen Canyon Dam Hourly Release Pattern December 2021



Water Quality

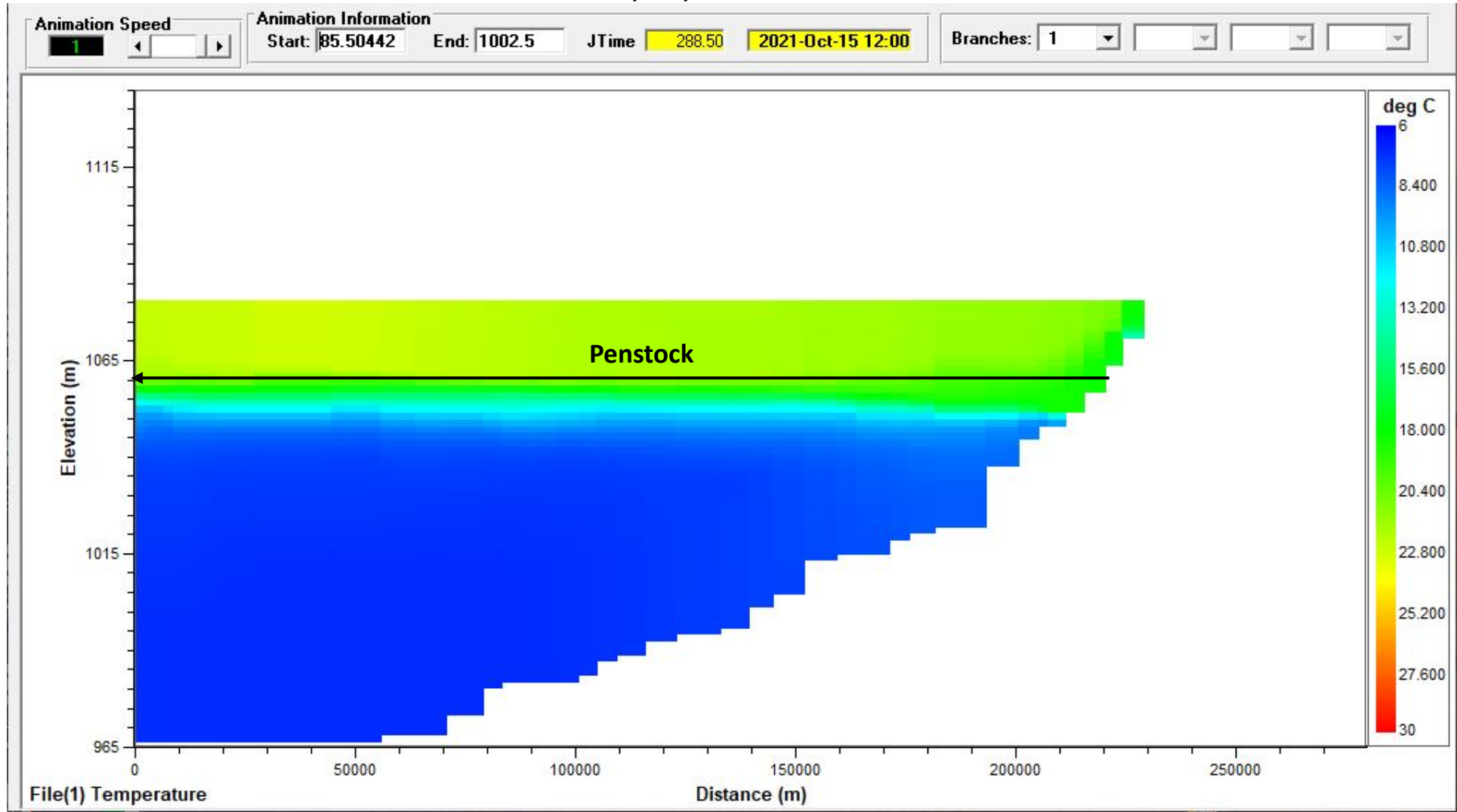


Temperature Profile of Lake Powell near Glen Canyon Dam
10/15/2021

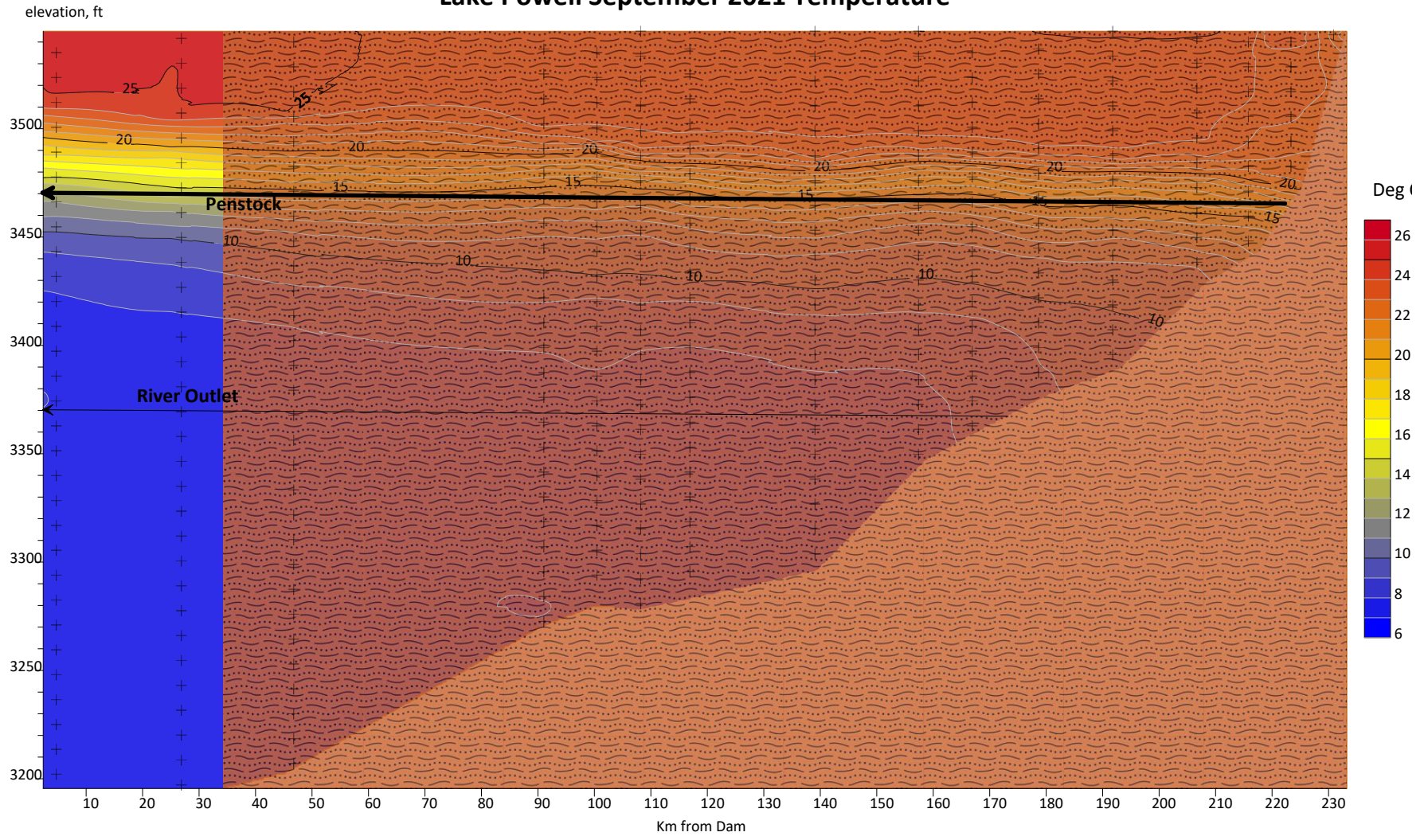


Cross Sectional Temperature Profile of Lake Powell

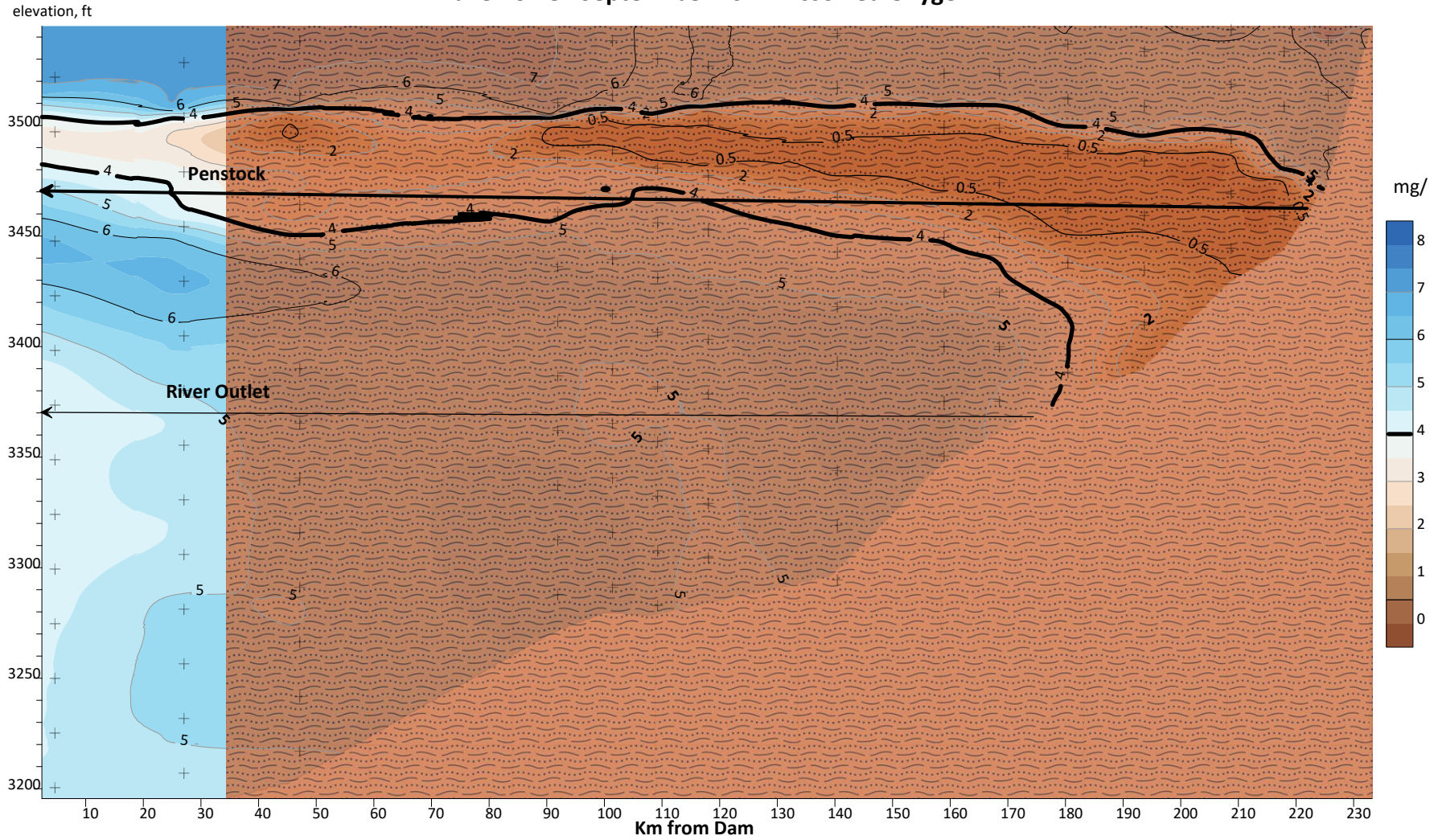
10/15/2021



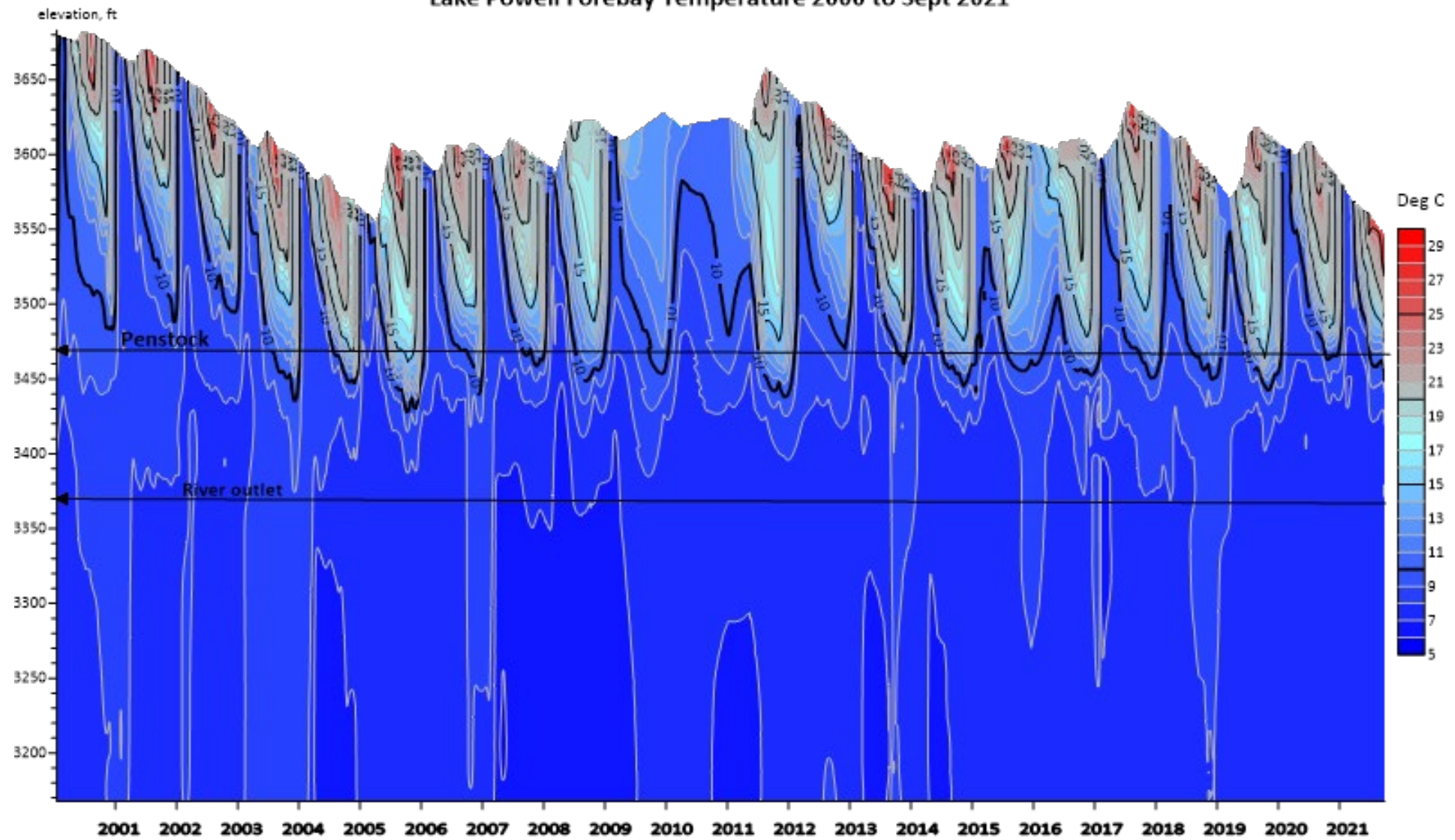
Lake Powell September 2021 Temperature



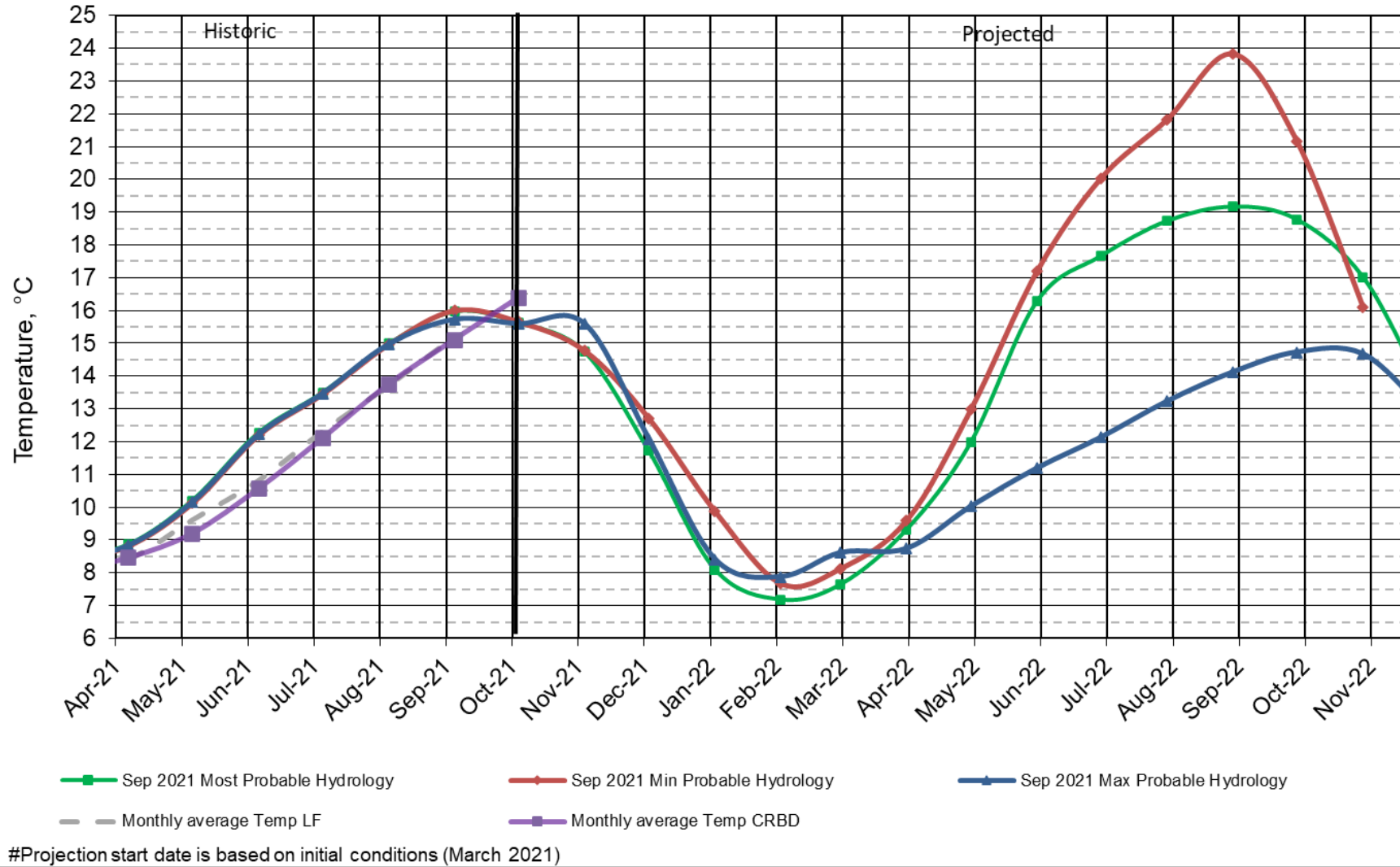
Lake Powell September 2021 Dissolved Oxygen



Lake Powell Forebay Temperature 2000 to Sept 2021

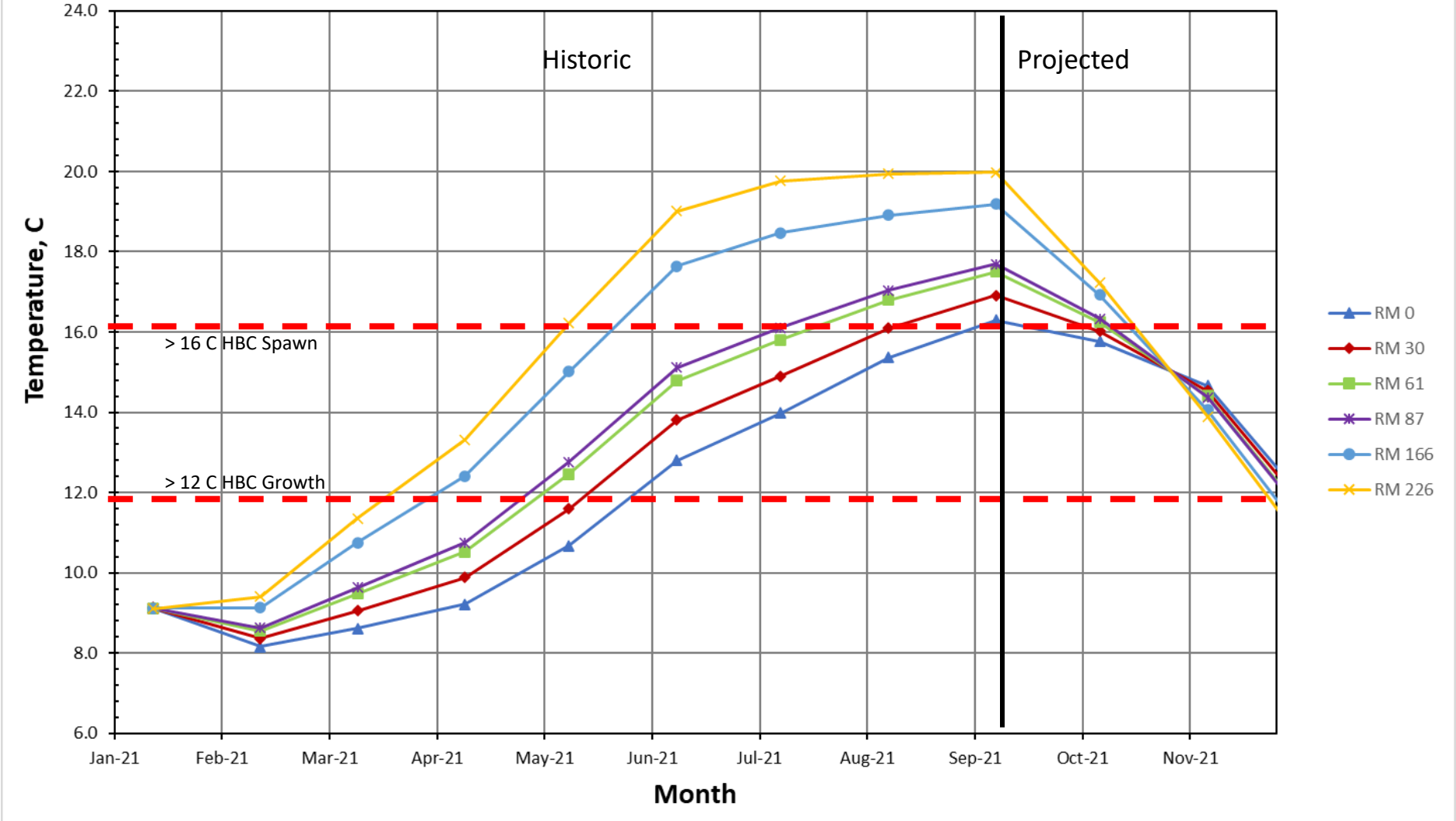


Lake Powell Release Temperature Projected Temperature based on Sep 2021 Forecast

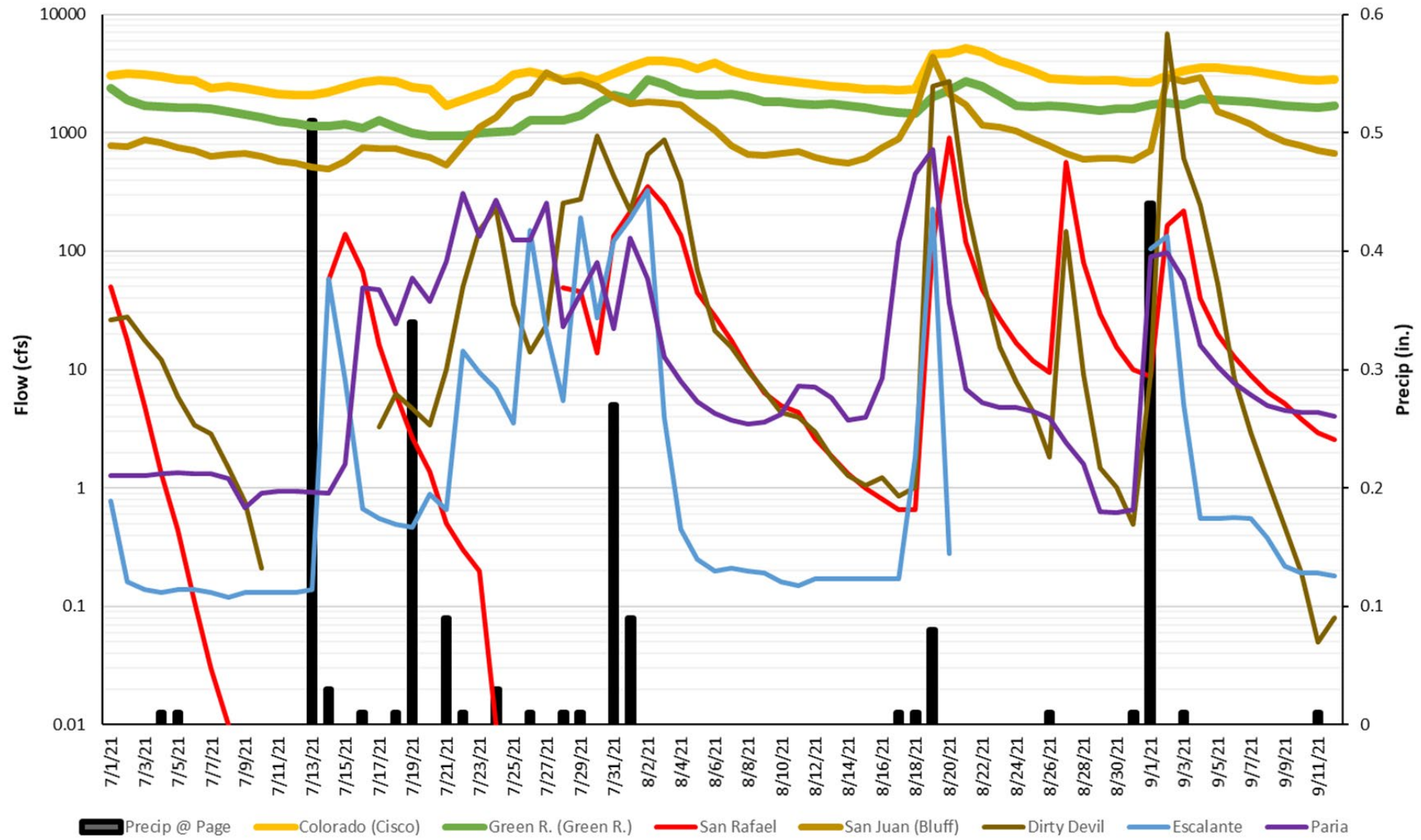


Colorado River, Grand Canyon Water Temperatures

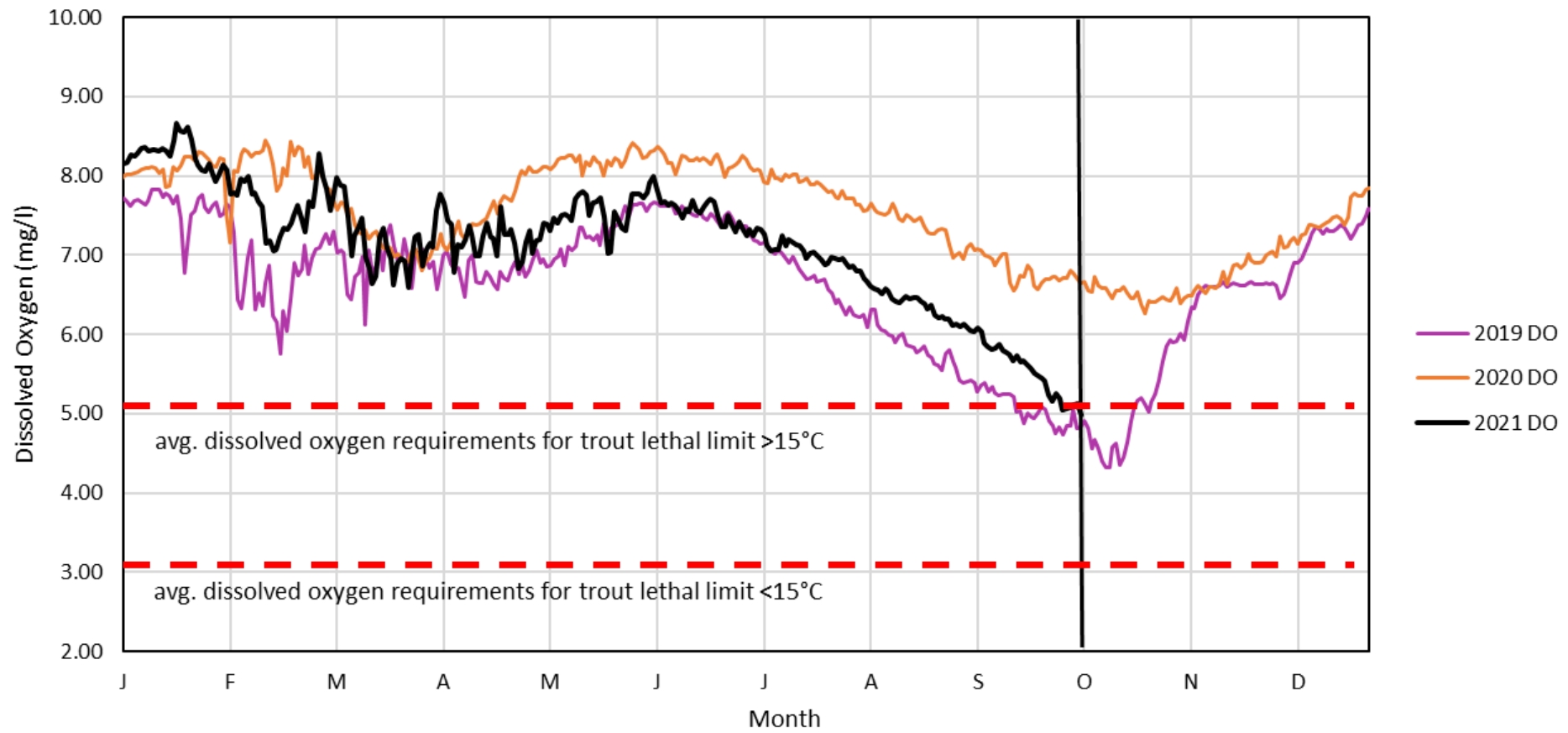
Projections based on August 2021, Most Probable Hydrology (Dibble 2020)



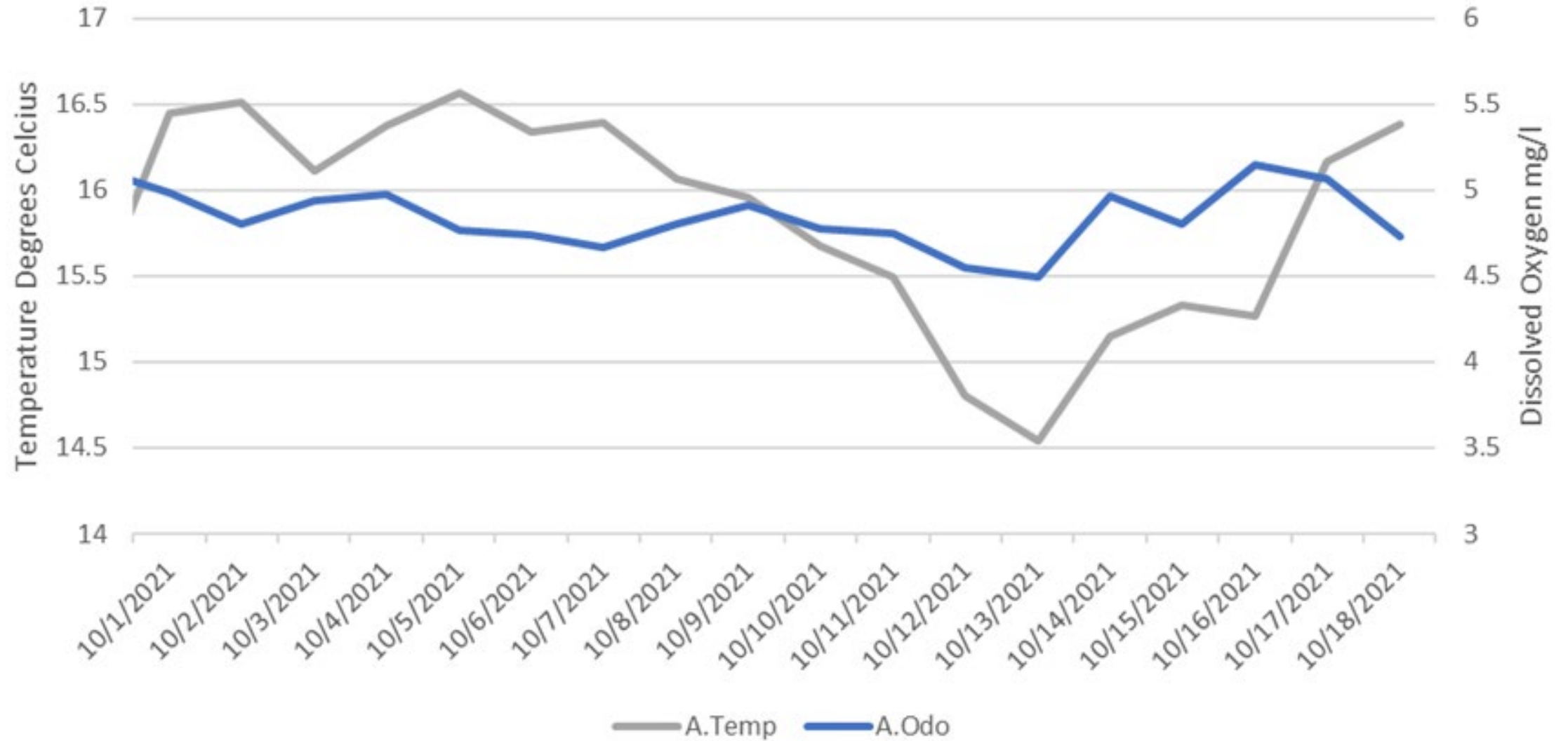
Inflows to Lake Powell (except Paria R.)



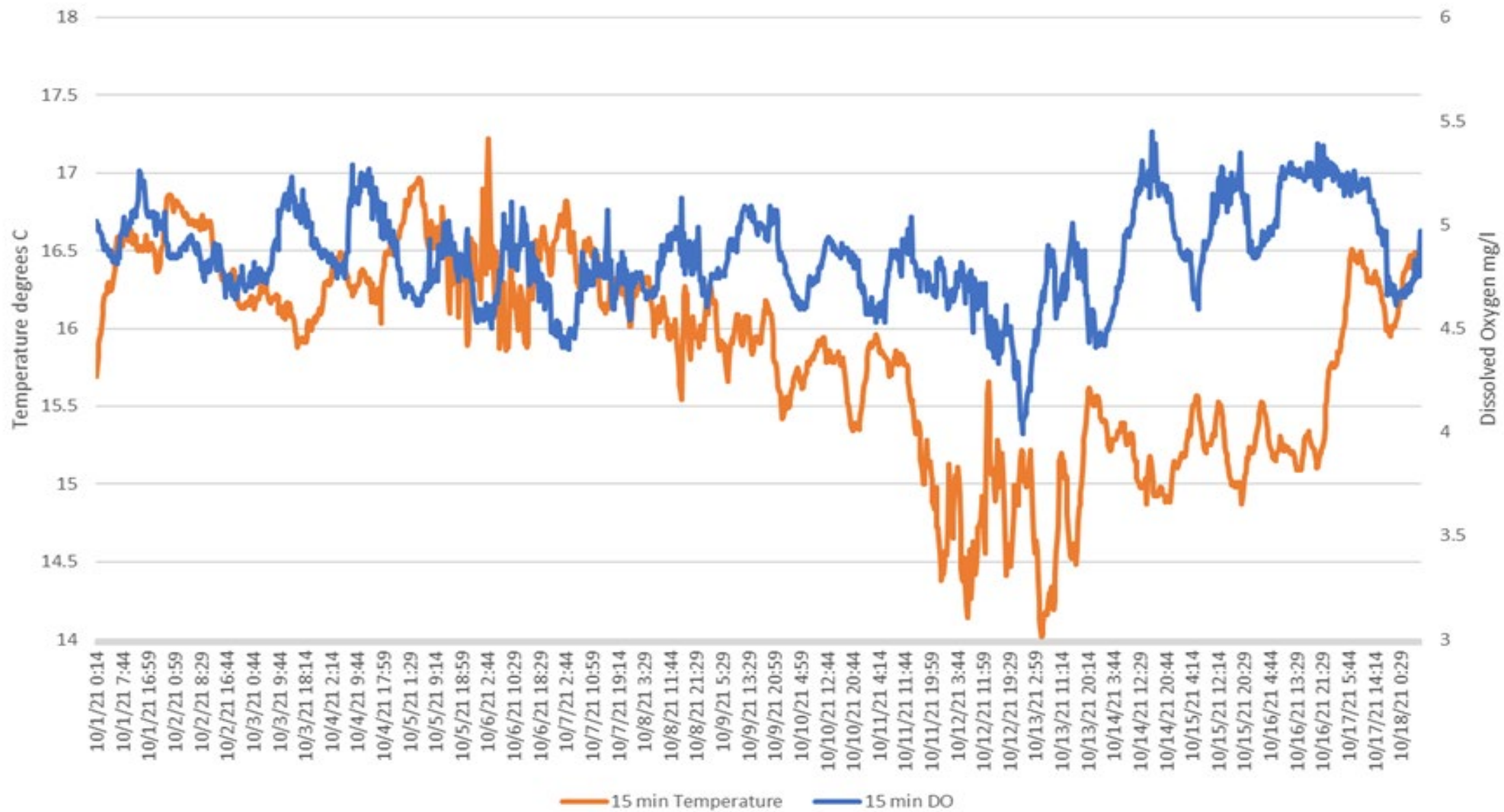
DO Concentration at Glen Canyon Dam years 2019, 2020, and 2021



Recent Changes at GCD in DO and temp



Recent Water Quality Data @ GCD



Questions?



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