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To: CRB-Info, BOR < or-sha-LCB-Info@us r.gov> b

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To the Bureau of Reclamation:

In response to your request, please see the attachment, which is my plan for addressing issues related to operations associated with the Colorado River basin during these unprecedented times. If requested, I can also provide the detailed spreadsheets on which the modeled outcomes shown in the plan are based. Please do not b hesitate if you have any questions of would like to discuss.

thanks
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The Way Forward: A Plan for Lake Powell and Lake Mead
By John Rickenbach
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In June 2022, the Bureau of Reclamation (BOR) called for an immediate 2-4 million acre-foot (maf) reduction in water use among the seven states served by the Colorado River watershed in order to avert catastrophic consequences to water and power supply within the system. Based on the recent average annual water use among the states, this call to action represents a 16-32% reduction in use from this fragile water supply.[1] If that sounds like a dramatic call to action, it is.

In an era of unprecedented drought, old assumptions and protocols for managing water supply in the Colorado River watershed no longer work. Creative, collaborative solutions are needed to ensure that the major reservoirs in the system can store sufficient water, generate power, and provide economically important recreational opportunities into the future. As recognized by the BOR, the current rate of water consumption within the system is unsustainable, at least as long as water supplies and snowpack remain generally below historic averages, a trend likely to continue into the future.

The following describes a way forward to meet this historic challenge. It involves a combination of equitably reducing water use among the affected states and Mexico, reimagining the volume and timing of water releases through the major dams, and having enough flexibility built in so that if the reservoirs begin to fill sufficiently, restrictions on water use can ease.

The key principles of this plan are these:

1. Power supply, water supply, and recreational opportunities associated with the major reservoirs in the system must be maintained in a sustainable manner, since those resources are crucial to the health, safety and economy of the West.

2. Given the current drought and extremely low levels of Lake Powell and Lake Mead, any action under this plan needs to occur immediately for the plan to be most effective.

3. Any needed water use reductions to implement this plan must be shared fairly and equitably among the states that use the water, as well as Mexico.

4. Because the entire Colorado River water supply and power system does not work unless both Lake Powell and Lake Mead are viable—actions to increase storage in both reservoirs need to be addressed simultaneously. One reservoir should not be prioritized over the other.

5. The plan must be flexible, and recognize changing conditions over time. The magnitude and duration of water use reductions are linked to the volume of water in Lake Powell and Lake Mead. If water volume in the reservoirs rises, water use reductions can ease.

[1] The average annual collective water use among the seven states from the Colorado River from 2016-20 was 12.55 million acre feet (maf), which includes the required delivery of 1.5 maf to Mexico.

Key Assumptions Under the Plan

Inflow to Lake Powell

BOR reports that the average annual inflow to Lake Powell from 1991-2020 is 9.6 million acre feet (maf). Over time, that number has been generally decreasing, but with considerable variation up and down from year to year. In 2021, unregulated inflow to Lake Powell was only 3.5 maf, the lowest amount since the reservoir came into existence.

For modelling purposes underlying this plan, the 5-year period that includes water years 2016-20 (WY 2016-20) was used to calculate a more recent realistic "average" to form the baseline for future projections. This period captured Lake Powell inflows ranging from 5.4 to 11.7 maf, encompassing relatively "good" and "bad" years. The average annual inflow during that time was 8.99 maf, slightly less than the 1991-2020 average, and thus a reasonable and conservative basis for future projections.

Inflow to Lake Mead

Inflow to Lake Mead is a function of three factors: releases through Glen Canyon Dam, inflow from the tributaries that feed the Colorado River below the dam (notably the Little Colorado and Virgin rivers), minus any evaporation between Glen Canyon Dam and Hoover Dam.

Releases through Glen Canyon Dam are highly variable, and vary based on protocols established by the BOR, depending on the surface elevation of Lake Powell and Lake Mead. This typically varies from 7.0 to 9.0 maf/year. For modeling purposes, this plan creates modified delivery protocols, depending on the surface elevation of the two reservoirs at the end of a given water year.

The average annual input from tributaries below Glen Canyon Dam from WY 2016-20 was 0.89 maf. This is also factored into calculating volume and surface elevation of Lake Mead.

Water Use

For the purpose of this plan, the baseline for calculating water use is the collective average of the seven states use in the 5-year period that encompasses Water Years (WY) 2016-20.

Upper Basin Water Use is reported in the February 2022 report entitled *Upper Colorado River Basin Consumptive Uses and Losses 2016-2020*. Upper Basin use as reported by BOR not only includes consumptive use, but evaporation from smaller reservoirs other than the large mainstem reservoirs such as Lake Powell or Flaming Gorge, which are accounted for separately. The average annual water use in the Upper Basin from WY2016-20 was 4.15 maf.

Lower Basin Water Use is reported in the annual reports issued by BOR entitled *Colorado River Accounting and Water Use Report: Arizona, California and Nevada*. The reports also include data about deliveries to Mexico, as well as releases through the smaller dams downstream of Hoover Dam. The average annual water use in the Lower Basin from 2016-20 was 6.90 maf.

Each year annual deliveries to Mexico have been consistently at or very slightly above 1.5 maf in accordance with treaty requirements between that country and the USA.

Upper Basin Reservoir Additional Storage

There are several mainstem storage reservoirs above Lake Powell, the largest of which is Flaming Gorge Reservoir. Other significant reservoirs include Lake Navajo and Blue Mesa Reservoir. These essentially function as a "bank" for water in the Upper Basin that can be later used downstream, should the need arise. Collectively, these reservoirs have a potential capacity of about 6.4 maf, nearly 60% of which is within Flaming Gorge. The reservoir levels fluctuate as downstream need or flood control dictates, but in general, these reservoirs hold about 65-90% of their collective capacity at any given time. The 5-year average from 2016-20 is 81.4%. In May 2022, these reservoirs held only about 65% of their capacity.

Upper Basin Reservoir Evaporation

"Upper Basin Reservoir Evaporation" includes reported evaporation in the mainstem reservoirs in the Upper Basin along the Colorado or Green Rivers, most notably Lake Powell itself. Of the average annual 0.47 maf evaporative loss in those reservoirs (based on WY2016-20), about 80% comes from Lake Powell, and 17% from Flaming Gorge. The remaining 3% comes from all other smaller reservoirs such as Blue Mesa and Morrow Point. Lake Navajo evaporation is not included in this dataset in the February 2022 USBR report (see Table UC-1 of that report). Although evaporated water is not technically "available" for later use, it is an important component in calculating the total water supply before any is either used or released downstream.

Lower Basin Reservoir Evaporation

"Lower Basin Reservoir Evaporation" includes reported evaporation below Glen Canyon Dam, primarily in Lake Mead, but also in the stretch of the river between the dam and Lake Mead. The figures are reported in each of USBR's 24-Month Studies, which include summarized historic data for the previous year. Evaporative loss is one of the reported numbers in that dataset. The average annual evaporative loss during the period inclusive of WY2016-20 was 0.54 maf.

Total Water Availability

In order to project future lake levels, it is first necessary to calculate the total water available in the Upper Basin watershed prior to considering any diversions, use, or evaporation. Based on existing BOR documentation, it is possible to calculate water availability in any past year using this equation:

> ***Total Water Availability in the Upper Basin =*** *Inflow to Lake Powell + Upper Basin Water Use + Upper Basin Additional Storage + Upper Basin Reservoir Evaporation*

Based on the assumptions described above, the Total Water Availability in the Upper Basin on average in the period WY2016-20 was 13.59 maf annually. This forms the "baseline" for calculations for future years, and allows for modeling hypothetical reductions or increases in precipitation for future years, if "total water availability" is used as a proxy for "total precipitation".

Baseline Surface Elevations

In June 2022 the BOR issued its latest 24-Month Study, which forecasts inflows and outflows for all reservoirs affecting the entire Colorado River watershed. The forecast is based in part on projected long-range precipitation forecasts, historic trends, and projected releases from each reservoir. The forecast extends through June 2024, or roughly midway through Water Year 2024 (WY 2024). BOR also forecasts the projected surface elevation for Lake Powell and Lake Mead during this period. For the purpose of this plan, BOR's assumption for surface elevations at the end of WY2022 (September 30) are used as the baseline for projecting future lake levels modeled under the plan. For Lake Powell, the projected elevation is 3525.79, while Lake Mead is 1037.23.

Table 1 summarizes key baseline assumptions related to the two reservoirs, water availability, and water use in the Upper Basin, Lower Basin, and Mexico.

Table 1. Key Baseline Assumptions Related to Water Availability and Use

	WY2016-20 Annual Average
Upper Basin Water Availability (prior to diversion or use)	13.59 maf
Inflow from rivers between Glen Canyon and Hoover Dam	0.89 maf
Upper Basin Water Use [1]	4.15 maf
Lower Basin Water Use	6.90 maf
Water Delivered to Mexico	1.50 maf
Upper Basin Mainstem Evaporation	0.47 maf
Lower Basin Mainstem Evaporation	0.54 maf

Sources: USBR 24-Month Studies (2010-2022); Colorado River Accounting and Water Use Report: Arizona, California and Nevada (various years); Upper Colorado River Basin Consumptive Uses and Losses 2016-2020; http://lakepowell.water-data.com; http://lakemead.water-data.com.

1. *Upper Basin Water Use also includes 0.24 maf of evaporation on non-mainstem reservoirs*

Action Plan

The following tables summarize the key aspects of the action plan for water use reductions and releases through Glen Canyon Dam to implement the key principles described at the outset of the plan, based on the previously-described assumptions. In general, required actions are based on surface elevations of Lake Powell and Lake Mead at the end of a particular water year (September 30) as reported by BOR, with water use reductions and dam releases applied to the following water year. These actions supersede any potentially conflicting protocols previously established under the 1922 Colorado River Compact and subsequent related laws, collectively known as the "Law of the River".

Table 2 shows key elevations within Lake Powell and Lake Mead that provide guidance in developing this plan, particularly regarding water use and the magnitude of releases from Glen Canyon Dam in a given year.

Table 2. Key Elevations in Lake Powell and Lake Mead		
Elevation Condition	**Lake Powell**	**Lake Mead**
Full Pool	3700	1225
Minimum elevation for all recreational facilities to be operational [1]	3588	-
Buffer elevation (35 feet above minimum power pool) [2]	3525	985
Minimum Power Pool	3490	950
Dead Pool	3370	895

1. Includes all marinas, launch ramps, access points, campgrounds, and the Castle Rock Cut
2. Provides a sufficient buffer to ensure continued power production, allowing for water levels to drop over the winter season.

Required water use reductions from the baseline 2016-20 average could range up to 30%, depending on the surface elevations of Lake Mead and Lake Powell at the end of the previous water year. Notably, water use reductions would be proportional, with an equal percentage applied to all seven states and deliveries to Mexico. Tables 3 and 4 show the required reductions by basin and by state for a water year, based on criteria related to the surface elevation of Lake Powell and/or Lake Mead at the end of the previous water year (September 30).

Table 3. Required Annual Water Use Reductions						
Annual Water Use Reduction					**When Applicable** [2, 3]	
Percentage Reduction from Baseline [1]	**Total Volume that may be used annually** [4] *(million acre feet)*				**Lake Powell**	**Lake Mead**
	Upper Basin	*Lower Basin*	*Mexico*	***Total***		
30%	2.904	4.831	1.050	**8.784**	< 3540, OR	< 1025
25%	3.111	5.176	1.125	**9.412**	> 3540 and < 3575, OR	> 1025 and < 1050
20%	3.318	5.521	1.200	**10.039**	> 3575 and < 3600, OR	> 1050 and < 1075
10%	3.733	6.211	1.350	**11.294**	> 3600 and < 3625, OR	> 1075 and < 1100
0%	4.148	6.901	1.500	**12.549**	> 3625, AND	> 1100

1. Based on average annual water use from WY2016-20, as reported by BOR.
2. Surface elevation at the end of a given Water Year (September 30). If no reduction is required, then pre-2022 usage protocols apply.
3. If the condition of one reservoir is more restrictive than the other, the higher percentage reduction of the two is required to be applied to all users in the system.
4. Reductions within each basin are allocated by State as shown in Table 4.

Table 4 shows the baseline water use for each state (average annual usage from WY2016-20), and the maximum allocation for each state depending on the percentage reduction in use required in a given year as shown in Table 3. Note that if no reduction is required in a particular year, pre-2022 water use protocols under the Law of the River would apply for that year.

Table 4. Colorado River Annual Water Use Reductions by State
(based on WY2016-20 Average, in million acre feet)

Location	Average Usage (WY2016-20)	Percentage Reduction			
		10%	20%	25%	30%
Lower Basin					
California	4.115	3.703	3.292	3.086	2.880
Arizona	2.543	2.289	2.035	1.907	1.780
Nevada	0.243	0.219	0.194	0.182	0.170
Subtotal	***6.901***	***6.211***	***5.521***	***5.176***	***4.831***
Upper Basin					
Arizona *	0.026	0.023	0.021	0.019	0.018
Colorado	2.275	2.047	1.820	1.706	1.592
Utah	1.006	0.905	0.805	0.754	0.704
New Mexico	0.420	0.378	0.336	0.315	0.294
Wyoming	0.421	0.379	0.337	0.316	0.295
Subtotal	***4.148***	***3.733***	***3.318***	***3.111***	***2.904***
Mexico	1.500	1.350	1.200	1.125	1.050
Total	**12.549**	**11.294**	**10.039**	**9.412**	**8.784**
Reduction from Baseline (maf)	*0*	*1.255*	*2.510*	*3.137*	*3.765*

Sources: Colorado River Accounting and Water Use Report: Arizona, California and Nevada (various reports); Upper Colorado River Basin Consumptive Uses and Losses 2016-2020. Both publications by BOR.

* *A small portion of Arizona is included in the Upper Basin for the purpose of calculating water consumption under the Law of the River.*

If no reduction is required, then pre-2022 usage protocols apply.

Table 5 shows the protocol for releases from Glen Canyon Dam in a given year, based on the surface elevations of both Lake Mead and Lake Powell at the end of the previous water year.

Table 5. Protocol for Releases Through Glen Canyon Dam

Required Release Through Glen Canyon Dam *(million acre feet)*	**Applicable Condition** [1]	
	Lake Powell	**Lake Mead**
5.0	< 3540 AND	> 1000
5.5	< 3540 AND	< 1000
6.0	3540-3575 AND	> 1025
6.5	3540-3575 AND	< 1025
7.0	3575-3600 AND	> 1050
7.5	3575-3600 AND	< 1050
8.0	3600-3625 AND	> 1075
8.23 minimum, or more as needed to balance the reservoirs	3600-3625 AND	< 1075
8.23 minimum, or more as needed to balance the reservoirs	> 3625	-

1. Surface elevation at the end of a given Water Year (September 30).

Possible Outcomes

Outcomes if Action is Taken Starting in WY2023

Table 6 illustrates possible 5-year outcomes of applying this plan, depending on the water availability in a given year. These tables show a range of possibilities, from 40% less than baseline average precipitation, to 20% greater than baseline average. In all cases, power generation though each dam would continue uninterrupted through this period under this plan. With the exception of an extended drought period similar in magnitude to what was experienced from 2000-04, or perhaps an extension of the historically dry year that occurred in 2021, both reservoirs would steadily recover (Lake Powell to over 3600, Lake Mead to over 1100), and in average conditions, water use reductions could be removed by 2027. However, continued water use reductions in the range 10-30% would still be required if water availability remains below average.

Crucially, this plan assumes that the seven states (and Mexico) are able to implement a 30% reduction from their current average use starting in WY 2023, and that BOR is willing to reduce flows through Glen Canyon Dam to 5.0 maf during that year. Once the reservoirs recover above critically low levels, these restrictions could be potentially eased back consistent with proposed protocols. These are challenging but necessary steps to protect the viability of the entire system, particularly if extreme drought continues, or even if WY 2023 is similarly dry as WY 2021.

Table 6. Possible Outcomes of Plan Implementation

Water Availability scenarios (WY 2023-27) [1]	Water Year	Water Use Reduction[2]	Release through Glen Canyon Dam[2] *(maf)*	Lake Powell level (Sept 30)	Lake Mead level (Sept 30)
	2022	0%	7.0	3525	1037
40% less than average (8.1 maf/yr) [3] *(similar to 2000-04)*	2023	30%	5.0	3530	1024
	2024	30%	5.0	3534	1010
	2025	30%	5.0	3531	996
	2026	30%	5.0	3528	989
	2027	30%	5.0	3525	982
20% less than average (10.9 maf/yr) *(similar to 1988-92)*	2023	30%	5.0	3565	1026
	2024	30%	6.0	3585	1031
	2025	25%	7.0	3589	1043
	2026	25%	7.0	3592	1056
	2027	20%	7.0	3593	1062
10% less than average (12.2 maf/yr) *(similar to 2003-07)*	2023	30%	5.0	3587	1028
	2024	25%	7.0	3606	1042
	2025	25%	8.0	3613	1069
	2026	20%	8.23	3615	1091
	2027	10%	8.0	3615	1100
Average (13.6 maf/yr) *(average defined as 2016-20)*	2023	30%	5.0	3609	1029
	2024	25%	8.23	3627	1063
	2025	10%	8.75	3633	1084
	2026	10%	8.75	3639	1102
	2027	0%	8.23	3645	1104
10% above average (14.9 maf/yr) *(similar to 2005-09)*	2023	30%	5.0	3631	1031
	2024	25%	9.0	3652	1077
	2025	10%	9.0	3667	1101
	2026	0%	8.23	3682	1104
	2027	0%	9.5	3688	1121
20% above average (16.3 maf/yr) *(similar to 1996-2000)*	2023	30%	5.0	3652	1032
	2024	25%	9.0	3681	1080
	2025	10%	12.0	3682	1139
	2026	0%	11.0	3687	1169
	2027	0%	11.0	3691	1194

1. Assumes a consistent level of water availability from year to year, and does not account for likely variations. Total water availability shown in parentheses is water available in the upper basin prior to its use, diversion, evaporation. The amount available for inflow to Lake Powell is considerably less, and is the remainder after Upper Basin water use, diversions, or evaporation is considered.
2. Follows protocols established in this plan.
3. Assumes that 500,000 AF is released to Lake Powell from upper basin reservoirs beyond typical release patterns in 4 of the 5 years.

What if The States and BOR Don't Take Meaningful Steps in 2023?

In June 2022, the BOR called on the seven states to find a way to reduce their collective water use by 2-4 maf, and gave them 60 days to come up with a plan. This was a sensible and necessary step to take. But even if they come to an agreement, it may be difficult to fully implement those steps in 2023. Table 7 shows what would happen if the states and BOR are not able to implement the necessary water use measures in WY 2023, and instead defer these actions until 2024. That table assumes only a modest 10% reduction in water use in 2023, and that releases through Glen Canyon Dam would be 7.048 maf as currently planned (based on the June 2022 24-Month Study published by BOR).

In general, the recovery of the reservoirs would be substantially slower than if stronger conservation measures were implemented in 2023. More importantly, power generation at Glen Canyon Dam would end in WY2023 if water availability via precipitation is 40% below normal, or a condition similar to what occurred in either 2002 or 2021. This could be avoided if releases through the dam were slowed considerably, but this would have a substantial adverse effect on Lake Mead, especially if water use reduction is only 10%, not 30% as advocated in this plan.

On the other hand, if snowpack conditions improve in the coming years, some of the most severe outcomes could be avoided, but that still assumes substantial water use reductions would be implemented starting in 2024.

Deferring immediate and decisive action is a huge gamble. It's a bet that the drought will break in 2023, or that it will at least not be as severe as it has been in years past, even as recently as 2021. Absent a significant break in the ongoing drought, and without immediate action to address its consequences, the power produced, water supplied and recreational opportunities offered by both Lake Mead and Lake Powell will eventually cease.

Table 7. Possible Outcomes of Plan Implementation (if "business as usual" in WY 2023)

Water Availability scenarios (WY 2023-27) [1]	Water Year	Water Use Reduction[2]	Release through Glen Canyon Dam[3] *(maf)*	Lake Powell level (Sept 30)	Lake Mead level (Sept 30)
	2022	0%	7.0	3525	1037
40% less than average (8.1 maf/yr) [4] *(similar to 2000-04)*	2023	10%	7.048	3484	1029
	2024	30%	5.0	3490	1016
	2025	30%	5.0	3486	1001
	2026	30%	5.0	3491	985
	2027	30%	5.0	3487	978
20% less than average (10.9 maf/yr) *(similar to 1988-92)*	2023	10%	7.048	3520	1032
	2024	30%	5.0	3570	1021
	2025	30%	6.5	3583	1034
	2026	25%	7.0	3586	1047
	2027	25%	7.0	3589	1059
10% less than average (12.2 maf/yr) *(similar to 2003-07)*	2023	10%	7.048	3541	1033
	2024	25%	6.0	3582	1032
	2025	25%	7.0	3601	1047
	2026	20%	8.23	3606	1078
	2027	10%	8.0	3606	1086
Average (13.6 maf/yr) *(average defined as 2016-20)*	2023	10%	7.048	3563	1034
	2024	25%	6.0	3616	1035
	2025	25%	8.75	3628	1077
	2026	10%	8.75	3634	1096
	2027	0%	8.23	3641	1098
10% above average (14.9 maf/yr) *(similar to 2005-09)*	2023	10%	7.048	3585	1036
	2024	25%	7.5	3629	1060
	2025	10%	9.0	3645	1085
	2026	10%	9.0	3660	1108
	2027	0%	9.5	3666	1124
20% above average (16.3 maf/yr) *(similar to 1996-2000)*	2023	10%	7.048	3606	1037
	2024	25%	9.0	3645	1085
	2025	10%	9.0	3671	1109
	2026	0%	11.0	3676	1143
	2027	0%	11.0	3681	1172

1. Assumes a consistent level of water availability from year to year, and does not account for likely variations. Total water availability shown in parentheses is water available in the upper basin prior to its use, diversion, evaporation. The amount available for inflow to Lake Powell is considerably less, and is the remainder after Upper Basin water use, diversions, or evaporation is considered.
2. Follows protocols established in this plan, except for WY 2023, where only a 10% reduction in water use is implemented (instead of 30%).
3. Follows protocols established in this plan, except for WY 2023, where BOR releases 7.0 maf through Glen Canyon Dam as previously planned (instead of 5.0 maf per updated protocol).
4. Assumes that 500,000 AF is released to Lake Powell from upper basin reservoirs beyond typical release patterns in 4 of the 5 years.