

# RECLAMATION

*Managing Water in the West*

## **The Colorado River System: Projected Future Conditions 2017-2021**

**August 2016**



U.S. Department of the Interior  
Bureau of Reclamation

# Background

- Future Colorado River system conditions were simulated using the Colorado River Simulation System (CRSS).
  - Comprehensive model of the Colorado River Basin
  - Primary long-term planning tool for studying river operations and projected development
- CRSS is implemented in the commercial river modeling software called RiverWare™ developed by the University of Colorado.
- CRSS is updated and maintained continually by Reclamation's Upper and Lower Colorado Regions.
- CRSS projections are updated at least two times annually (January and August).
- Due to uncertainties associated with future inflows into the system, multiple simulations are performed in both models to quantify the uncertainties in future conditions, and the results are expressed in probabilistic terms, e.g. “percent of futures”.

# Key August 2016 CRSS Modeling Assumptions

- Simulations begin in January 2017.
- Initial conditions based on most probable August 2016 24-Month Study projections of December 31, 2016 elevations.
  - Lake Powell: 3,605.83 feet
  - Lake Mead: 1,078.93 feet
- Future hydrology is developed by resampling the observed record of natural flows<sup>1</sup> (1906-2012), see *Figure 1*, to create 107 future hydrologic sequences using a resampling technique known as the Indexed Sequential Method.
- Lake Powell and Lake Mead operations are consistent with the 2007 Record of Decision on Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations of Lake Powell and Lake Mead (2007 Interim Guidelines), see *Figure 2*.
- Upper Basin water demands have been developed in coordination with the Upper Basin States through the Upper Colorado River Commission.
- Lower Basin water demands have been developed in coordination with the Lower Basin States and Mexico.

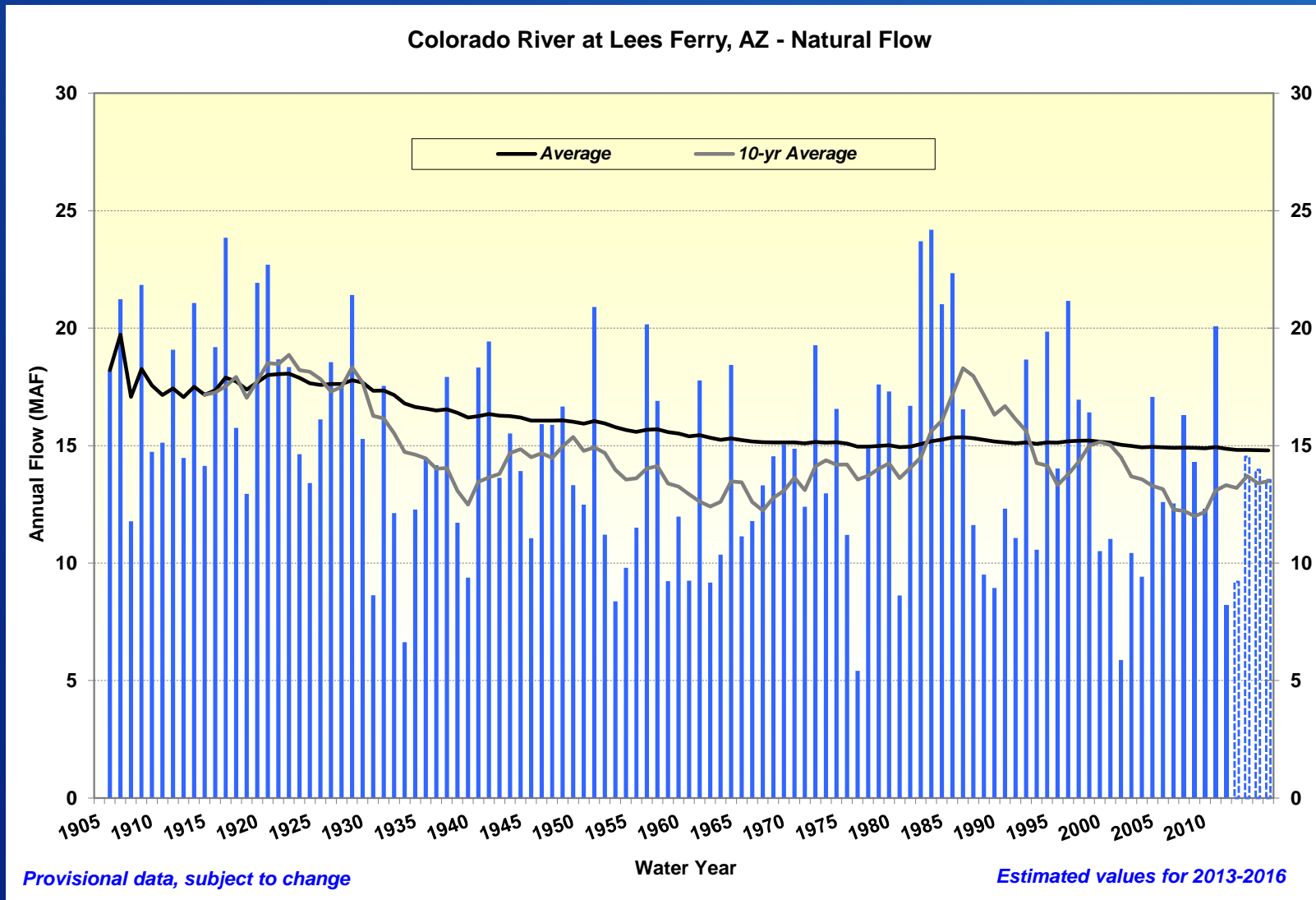
<sup>1</sup> Natural flow represents flow that would have occurred at a location had depletions and reservoir regulation not been present upstream of that location.

# Definitions of Hydrologic Terms

- Time horizon
  - Water Year: October 1 through September 30
  - Calendar Year: January 1 through December 31
- Flow “type”
  - Gaged: observed
  - Unregulated: gaged flow corrected for effects of upstream reservoirs
  - Natural: gaged flow corrected for effects of upstream reservoirs and depletions. Natural flow represents the flow that would have occurred at the location had depletions and reservoir regulation not been present upstream of that location.



# Figure 1 Natural Flow Colorado River at Lees Ferry Gaging Station, Arizona



# Figure 2 Lake Powell & Lake Mead Operational Diagrams from the 2007 Interim Guidelines

Lake Powell			Lake Mead		
Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf) <sup>1</sup>	Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf) <sup>1</sup>
3,700	<b>Equalization Tier</b> Equalize, avoid spills or release 8.23 maf	24.3	1,220	<b>Flood Control Surplus or Quantified Surplus Condition</b> Deliver > 7.5 maf	25.9
3,636 - 3,666 (2008-2026)	<b>Upper Elevation Balancing Tier<sup>3</sup></b> 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.) <sup>2</sup>	<b>Domestic Surplus or ICS Surplus Condition</b> Deliver > 7.5 maf	22.9 (approx.) <sup>2</sup>
3,575	<b>Mid-Elevation Release Tier</b> Release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf	9.5	1,145	<b>Normal or ICS Surplus Condition</b> Deliver ≥ 7.5 maf	15.9
3,525	<b>Lower Elevation Balancing Tier</b> Balance contents with a min/max release of 7.0 and 9.5 maf	5.9	1,105	<b>Shortage Condition</b> Deliver 7.167 <sup>4</sup> maf	11.9
3,490		4.0	1,075	<b>Shortage Condition</b> Deliver 7.083 <sup>5</sup> maf	9.4
3,370		0	1,050	<b>Shortage Condition</b> Deliver 7.0 <sup>6</sup> maf Further measures may be undertaken <sup>7</sup>	7.5
			1,025		5.8
			1,000		4.3
			895		0

**Diagram not to scale**

<sup>1</sup> Acronym for million acre-feet

<sup>2</sup> 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.

<sup>3</sup> Subject to April adjustments which may result in a release according to the Equalization Tier

<sup>4</sup> Of which 2.48 maf is apportioned to Arizona, 4.4 maf to California, and 0.287 maf to Nevada

<sup>5</sup> Of which 2.40 maf is apportioned to Arizona, 4.4 maf to California, and 0.283 maf to Nevada

<sup>6</sup> Of which 2.32 maf is apportioned to Arizona, 4.4 maf to California, and 0.280 maf to Nevada

<sup>7</sup> 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.

# Percent of Traces with Event or System Condition

## Results from August 2016 CRSS<sup>1,2,3</sup> (values in percent)

	Event or System Condition	2017	2018	2019	2020	2021
<b>Upper Basin – Lake Powell</b>	<b>Equalization Tier</b>	7	21	21	28	31
	<i>Equalization – annual release &gt; 8.23 maf</i>	7	21	21	27	30
	<i>Equalization – annual release = 8.23 maf</i>	0	0	0	1	1
	<b>Upper Elevation Balancing Tier</b>	93	57	57	53	45
	<i>Upper Elevation Balancing – annual release &gt; 8.23 maf</i>	89	48	43	41	35
	<i>Upper Elevation Balancing – annual release = 8.23 maf</i>	4	8	13	10	10
	<i>Upper Elevation Balancing – annual release &lt; 8.23 maf</i>	0	1	1	2	0
	<b>Mid-Elevation Release Tier</b>	0	21	20	10	16
	<i>Mid-Elevation Release – annual release = 8.23 maf</i>	0	0	0	1	1
	<i>Mid-Elevation Release – annual release = 7.48 maf</i>	0	21	20	9	15
<b>Lower Elevation Balancing Tier</b>	0	0	2	9	8	
<b>Lower Basin – Lake Mead</b>	<b>Shortage Condition – any amount (Mead ≤ 1,075 ft)</b>	0	48	60	60	56
	<i>Shortage – 1<sup>st</sup> level (Mead ≤ 1,075 and ≥ 1,050)</i>	0	48	50	41	33
	<i>Shortage – 2<sup>nd</sup> level (Mead &lt; 1,050 and ≥ 1,025)</i>	0	0	10	16	16
	<i>Shortage – 3<sup>rd</sup> level (Mead &lt; 1,025)</i>	0	0	0	3	7
	<b>Surplus Condition – any amount (Mead ≥ 1,145 ft)</b>	0	0	5	8	14
	<i>Surplus – Flood Control</i>	0	0	0	1	2
	<b>Normal or ICS Surplus Condition</b>	100	52	35	32	30

<sup>1</sup> Reservoir initial conditions based on December 31, 2016 conditions from the August 2016 24-Month Study.

<sup>2</sup> Percentages computed from 107 hydrologic inflow sequences based on resampling of the observed natural flow record from 1906-2012 for a total of 107 traces analyzed.

<sup>3</sup> Percentages shown may not be representative of the full range of future possibilities that could occur with different modeling assumptions.

# References

- RiverWare
  - <http://cadswes.colorado.edu/creative-works/riverware>
  - Zagona, E.A., Fulp, T.J., Shane, R., Magee, T.M. and Goranflo, H.M. (2001). “RiverWare: A Generalized Tool for Complex Reservoir System Modeling.” *Journal of the American Water Resources Association*, 37(4), 913-929.
- Indexed Sequential Method
  - Ouarda, T., Labadie, J.W., Fontane, D.G. (1997). “Indexed Sequential Hydrologic Modeling for Hydropower Capacity Estimation.” *Journal of the American Water Resources Association*, 33(6), 1337-1349.
- Colorado River Natural Flows
  - <http://www.usbr.gov/lc/region/g4000/NaturalFlow/index.html>
- August 2016 24-Month Study
  - [http://www.usbr.gov/uc/water/crsp/studies/24Month\\_08.pdf](http://www.usbr.gov/uc/water/crsp/studies/24Month_08.pdf)
  - <http://www.usbr.gov/lc/region/g4000/24mo.pdf>
- 2007 Interim Guidelines
  - <http://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf>



An aerial photograph of a large concrete dam and reservoir. The reservoir is filled with clear, blue-green water and is surrounded by rugged, brown mountains. The dam structure is visible in the foreground, with several spillways and a road running along its base. The sky is clear and blue.

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**For additional information and questions,  
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