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Managing Water in the West

The Colorado River System: Projected Future Conditions 2017-2021

April 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) and the Mid-term Operations Probabilistic Model (MTOM).
 - Both CRSS and MTOM are comprehensive models of the Colorado River Basin.
 - CRSS is the primary long-term planning tool for studying river operations and projected development.
 - MTOM is a risk-based planning tool for mid-term operations (within the 1 to 2 year planning window).
- CRSS and MTOM are implemented in the commercial river modeling software called RiverWare™ developed by the University of Colorado.
- CRSS and MTOM are updated and maintained continually by Reclamation's Upper and Lower Colorado Regions.
- Probabilistic model 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 April 2016 Modeling Assumptions¹

	MTOM	CRSS
Primary Use	Risk-based operational planning and analysis during mid-term time period	Long-term planning studies, operational criteria development, and risk analysis
Simulation Start Date	April 2016	January 2017
Reservoir Initial Conditions	Based on observed March 31, 2016 reservoir elevations	Based on 30 simulations of December 31, 2016 conditions using MTOM
Lake Powell and Lake Mead Operations	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) (<i>see Figure 2</i>)	
Upper Basin Inflows	Ensemble of 30 unregulated inflow forecasts dated April 5, 2016, based on observed temperature and precipitation from 1981-2010, provided by Colorado Basin River Forecast Center (CBRFC)	Resampled observed natural flows (1906-2012) (<i>see Figure 1</i>), creating 107 future hydrologic sequences using the “Indexed Sequential Method” for each of the 30 initial conditions
Lower Basin Inflows	30 possibilities based on the 30-year (1981-2010) historical record	107 possibilities based on the 107-year (1906-2012) historical record for each of the 30 initial conditions
Upper Basin Water Demand	Estimated and incorporated in the unregulated inflow forecasts provided by the CBRFC	Developed in coordination with the Upper Colorado River Commission
Lower Basin Water Demand	Developed in coordination with the Lower Basin States and Mexico	

¹ See slide 4 for definitions of hydrologic terms such as *natural flow* and *unregulated inflow*.

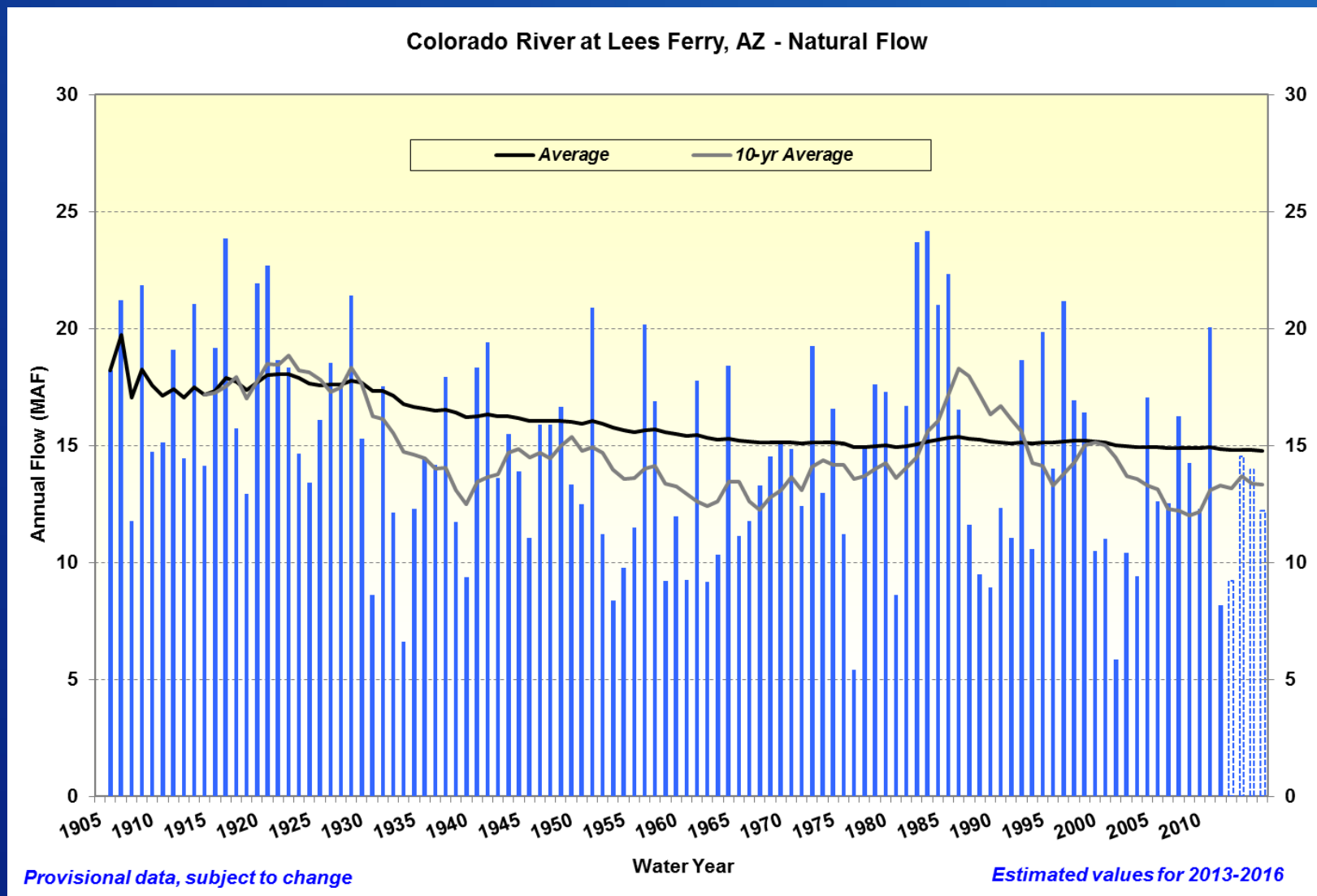
Definitions of Hydrologic Terms

- 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.



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



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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) 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 Tier³ 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			1,145	Normal or ICS Surplus Condition Deliver ≥ 7.5 maf	15.9
			1,105		11.9
	Mid-Elevation Release Tier Release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf	9.5	1,075	Shortage Condition Deliver 7.167 ⁴ maf	9.4
			1,050		7.5
3,525	Lower Elevation Balancing Tier Balance contents with a min/max release of 7.0 and 9.5 maf	5.9		Shortage Condition Deliver 7.083 ⁵ maf	
			1,025	Shortage Condition Deliver 7.0 ⁶ maf Further measures may be undertaken ⁷	5.8
3,490			1,000		4.3
3,370		0	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.

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Percent of Traces with Event or System Condition

Results from April 2016 MTOM/CRSS^{1,2,3} (values in percent)

	Event or System Condition	2017	2018	2019	2020	2021
Upper Basin – Lake Powell	Equalization Tier	5	18	20	24	28
	<i>Equalization – annual release > 8.23 maf</i>	5	18	20	24	26
	<i>Equalization – annual release = 8.23 maf</i>	0	0	0	<1	2
	Upper Elevation Balancing Tier	89	53	54	52	45
	<i>Upper Elevation Balancing – annual release > 8.23 maf</i>	77	47	44	41	35
	<i>Upper Elevation Balancing – annual release = 8.23 maf</i>	12	5	10	10	10
	<i>Upper Elevation Balancing – annual release < 8.23 maf</i>	<1	1	1	1	<1
	Mid-Elevation Release Tier	7	29	19	14	15
	<i>Mid-Elevation Release – annual release = 8.23 maf</i>	0	0	<1	1	2
	<i>Mid-Elevation Release – annual release = 7.48 maf</i>	7	29	20	13	14
	Lower Elevation Balancing Tier	0	<1	6	9	11
Lower Basin – Lake Mead	Shortage Condition – any amount (Mead ≤ 1,075 ft)	10	56	64	64	61
	<i>Shortage – 1st level (Mead ≤ 1,075 and ≥ 1,050)</i>	10	56	46	40	33
	<i>Shortage – 2nd level (Mead < 1,050 and ≥ 1,025)</i>	0	<1	18	18	18
	<i>Shortage – 3rd level (Mead < 1,025)</i>	0	0	<1	6	10
	Surplus Condition – any amount (Mead ≥ 1,145 ft)	0	<1	4	8	12
	<i>Surplus – Flood Control</i>	0	0	0	1	2
	Normal or ICS Surplus Condition	90	44	32	28	27

¹ Reservoir initial conditions based on results from 30 simulations of December 31, 2016 conditions using the Mid-term Probabilistic Operations Model.

² Each of the 30 initial conditions were coupled with 107 hydrologic inflow sequences based on resampling of the observed natural flow record from 1906-2012 for a total of 3,210 traces analyzed.

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

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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>
- Colorado River Unregulated Inflow Forecasts
 - <http://www.cbrfc.noaa.gov/outgoing/32month/>
- 2007 Interim Guidelines
 - <http://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf>

An aerial photograph of a large concrete dam and its reservoir, set against a backdrop of rugged, brown mountains. The water in the reservoir is a deep blue-green color. The dam structure is visible in the lower foreground, with a road running alongside it. The text is overlaid on the upper portion of the image.

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**For additional information and questions,
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