RECLANATION Managing Water in the West

Operation of Colorado River Reservoirs in a Changing Climate

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Operation of Colorado Reservoirs in a Changing Climate

- Overview of the Basin and Basin Hydrology
- Operational guidelines for Lake Powell and Lake Mead
- Colorado River Basin Water Supply and Demand Study
- Projections of Streamflow over Colorado River Headwater Basins

Colorado River Basin

- Operation governed by the Law of the River including:
 - Colorado River Compact (1922)
 - Boulder Canyon Project Act (1928)
 - U.S. Mexican Water Treaty (1944)
 - Colorado River Storage Project (1956)
 - Supreme Court Consolidated Decree (1964 and following)
 - Colorado River Basin Project Act (1968)
- Variable hydrology
- 60 million acre-feet of storage capacity
- System operated on a tight margin

Colorado River Basin





Annual Natural Flow at Lees Ferry Tree-ring Reconstruction (Meko et al., 2007) 25-Year Running Mean



Water Budget at Lake Mead

Given basic apportionments in the Lower Basin, the allotment to Mexico, and an 8.23 maf release from Lake Powell, Lake Mead storage declines

Inflow = 9.0 maf (release from Powell + side inflows)
Outflow = - 9.6 maf (AZ, CA, NV, and Mexico delivery + downstream regulation and gains/losses)
Mead evaporation loss = - 0.6 maf = - 1.2 maf

Data based on long-term averages

Colorado River Basin Storage (as of Apr 21, 2010)

Current Storage	Percent Full	MAF	Elevation (Feet)		
Lake Powell	56%	13.67	3619		
Lake Mead	44%	11.39	1099		
Total System Storage*	55%	32.66	NA		

*****Total system storage was **31.87** maf or **54%** this time last year



2010 Upper Colorado Projected Apr–Jul Inflow as of April 15, 2010

Flaming Gorge – 45% Blue Mesa – 74%

Navajo – 81%

- Lake Powell – 66% RECLAMATION

State of the System (1999-2010)

WY	Unregulated inflow into Powell	Powell and Mead Storage	Powell and Mead		
	% of Average	maf	% Capacity		
1999	109	47.59	95		
2000	62	43.38	86		
2001	59	39.01	78		
2002	25	31.56	63		
2003	52	27.73	55		
2004	49	23.11	46		
2005	104	27.16	54		
2006	71	25.80	51		
2007	70	24.43	49		
2008	102	26.52	53		
2009	88	26.40	53		
2010*	68	24.78	49		

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•Inflow based on latest CBRFC forecast; storage and percent capacity based on April 2010 24-Month Study

Lake Powell & Lake Mead Operational Diagrams and Current Conditions

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) 3,619	Upper Elevation Balancing Tier ³ Beleace 2.23 matri	15.5 - 19.3 (2008-2026) 13.62	(approx.) ²	Domestic Surplus or ICS Surplus Condition Deliver > 7.5 maf	(approx.) ²		
4/13/10	if Lake Mead < 1,075 feet,	4/13/10	1,145	 	15.9		
	a min/max release of 7.0 and 9.0 maf		1,105 1,100	Normal or ICS Surplus Condition Deliver ≥ 7.5 maf	11.9 11.46		
3,575	Mid-Elevation Release Tier Release 7.48 maf; if Lake Mead < 1,025 feet,	9.5	4/13/10 1,075	Shortage Condition Deliver 7.167 ⁴ maf	4/13/10 9.4		
3,525	release 8.23 maf	5.9	1,000	Shortage Condition Deliver 7.083 ⁵ maf	7.0		
	Lower Elevation		1,025		5.8		
3,490	Balance contents with a min/max release of 7.0 and 9.5 maf	4.0	1,000	Deliver 7.0 ⁶ maf Further measures may be undertaken ⁷	4.3		
3,370		0	895		0		

Diagram not to scale

Acronym for million acre-feet

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.

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

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

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

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.









Colorado River Basin Water Supply and Demand Study

- Two-year, \$2 million study cost shared by Reclamation and the Basin States
- Objectives:
 - Define current and future imbalances in water supply and demand
 - Assess the risks to Basin resources
 - Develop and evaluate adaptation and mitigation strategies
- A transparent, collaborative study with input from all stakeholders



Colorado River Water Supply & Demand



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Climate Projections

- Global Climate (or Circulation) Models (GCMs)
- Large scale, 2 degree (~200 km) gridded results
- Need for downscaling
 - Hydrologic models
 - Basin scale



Need for downscaling



Need for downscaling

Methodology to Incorporate Climate Change Information into Water Supply Projections



Preliminary Results of 112 Inflow Projections

Colorado River at Lees Ferry, AZ



Streamflow Projections over Colorado River Headwater Basins

- Utilize NWS CBRFC RFS model
- Headwater River Basins
- Account for changes in evapotranspiration due to climate change
- Part of a collaborative effort with UNLV





Methodology to Incorporate Climate Change Information into Water Supply Projections





Impact of Evaporation on Streamflow Projections in the Gunnison River Basin

Time Period



Projected Unregulated Streamflow - San Juan River Basin







Streamflow Projections by Emissions Scenarios over the San Juan River Basin

Time Period





San Juan River Basin Results

- Drying conditions along the mainstem of the San Juan River throughout the projected period
- Average decrease of 10% to 15% along the mainstem over the 2070 – 2099 period

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 Similar results over the Gunnison River Basin

Projected Unregulated Streamflow - Green River Basin





Green River Basin Results

- Wetter conditions along the mainstem of the Green River
- Average increase of 5% to 8% along the mainstem over the 2070 – 2099 period
- Results are consistent with average wetter conditions from BCSD data

Stationarity

- Use of the KS Test
- Compared each of the 30 year periods considered in this study with the 30 year period results from the CBRFC model
- Separated by emissions scenario



Stationarity

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Time Period / Emissions Scenario	Gunnison River Basin			Green River Basin			San Juan River Basin		
	A1B	A2	B1	A1B	A2	B1	A1B	A2	B1
1976 - 2005									
2010 - 2039									
2040 - 2069									
2070 - 2099									

Conclusions

- Evapotranspiration is an important consideration when considering hydrologic modeling of climate change
- Significant drying trends, but variability throughout the basin
- Evidence of nonstationarity

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Additional Information: http://www.usbr.gov/lc/riverops.html http://www.usbr.gov/lc/region/programs/ crbstudy.html