Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
February 19-20, 2014

Agenda Item
Panel on the Potential Effects of Long-Term Drought on Colorado River Operations

Action Requested
Information item only

Presenters
Rob Billerbeck, National Park Service, Moderator
Katrina Grantz, Hydraulic Engineer, Bureau of Reclamation, Upper Colorado Region
Jayne Harkins, Executive Director, Colorado River Commission of Nevada
Eric Kuhn, General Manager, Colorado River Water Conservation District
Jack Schmidt, Chief, Grand Canyon Monitoring and Research Center

Previous Action Taken
N/A

Relevant Science
The Colorado River Basin Water Supply and Demand Study
http://www.usbr.gov/lc/region/programs/crbstudy.html

Background Information
The Colorado River Basin is in the midst of a 14-year drought that is the worst in over a century of recorded history and one of the very worst in the past 1,200 years. Other areas of the west, including northern California, are also experiencing severe drought. Water managers throughout the Colorado River basin have been working to develop strategies for the long-term implications of climate change for the basin through collaborations such as the recently completed Bureau of Reclamation Colorado River Basin Water Supply and Demand Study. A more immediate need also exists to understand the near-term potential impacts to Colorado River resources – including the resources of Glen Canyon National Recreation Area and Grand Canyon National park – and to develop short and mid-term strategies and contingency plans. The panel will discuss current conditions and potential near-term projections for Colorado River operations, as well as introducing considerations for GCDAMP-related monitoring and research.

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Managing Water in the West

Potential Effects of Long Term Drought on Colorado River Operations

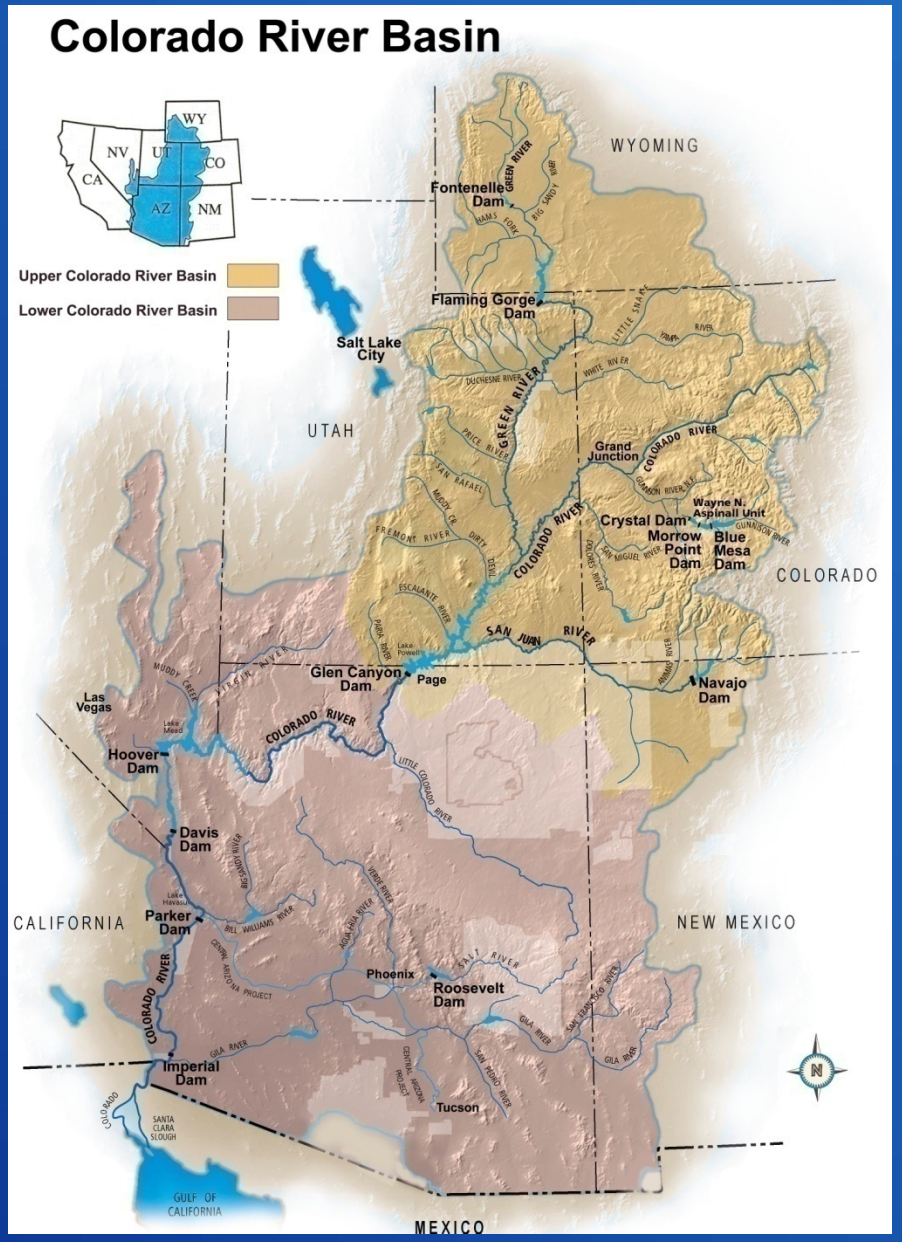
Adaptive Management Work Group

February 19-20, 2014

U.S. Department of the Interior
Bureau of Reclamation

Colorado River Basin Hydrology

- 16.5 million acre-feet (maf) allocated annually
- 13 to 14.5 maf of consumptive use annually
- 60 maf of storage
- 14.9 maf average annual "natural" inflow into Lake Powell over past 105 years
- Inflows are highly variable year-to-year



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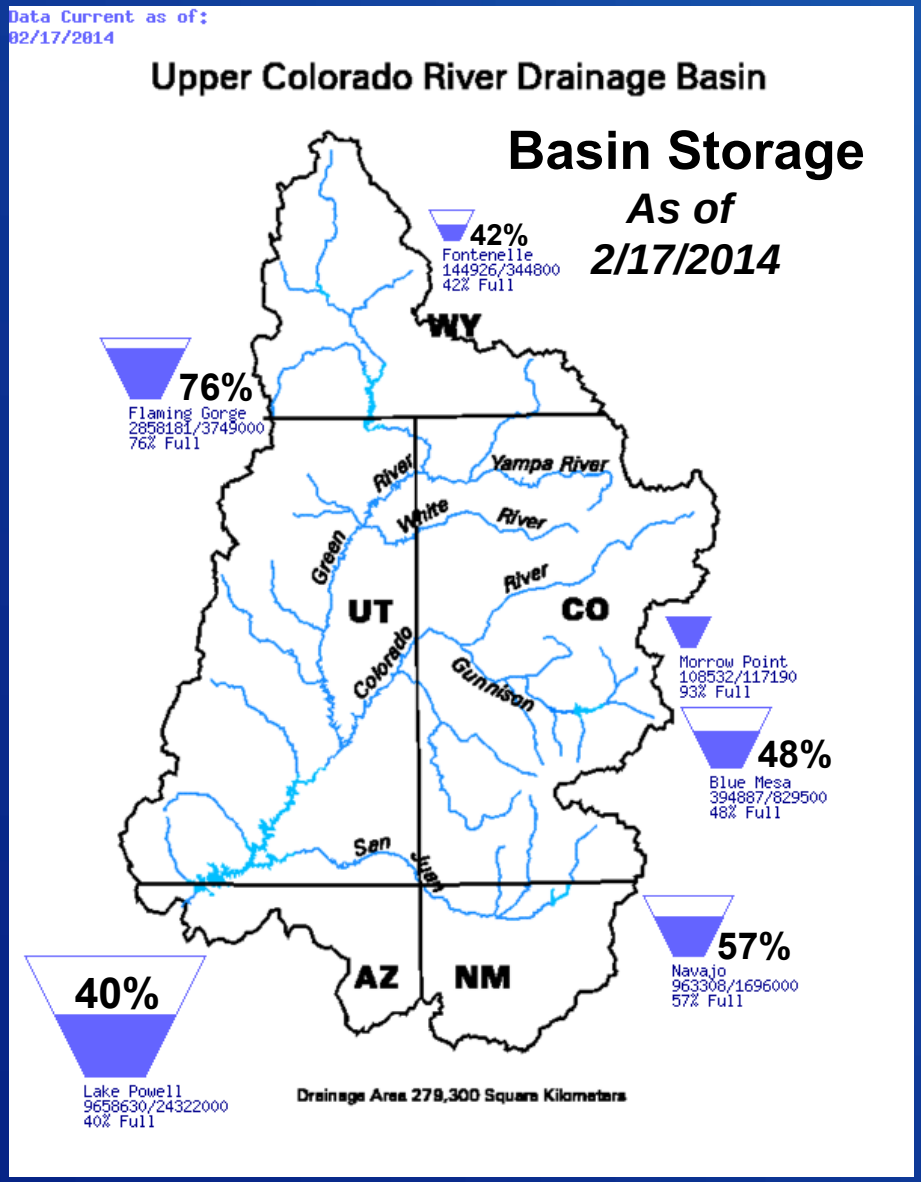

Colorado Basin Reservoir Operations Objectives

- Provide flood control and river regulation
- Meet water demands
- Generate hydropower
- Enhance and maintain ecosystem habitat
- Recover and protect endangered species
- Provide recreation

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Colorado River Drought

- 2000-2013 was the driest 14-year period in over 100 years of natural flow record
- 2012-2013 one of driest 2-year periods on record
- Tree-ring reconstructions show more severe droughts have occurred over the past 1200 years (e.g., drought in the mid 1100s)
- Reservoir System Storage at end of WY 2013 was 50%, one of lowest contents on record. (2000 was slightly less)
- The projected 2014 April through July runoff is 108% of average[1] as of February 18, 2014
- Not unusual to have a few years of above average inflow during longer-term droughts (e.g., the 1950s)

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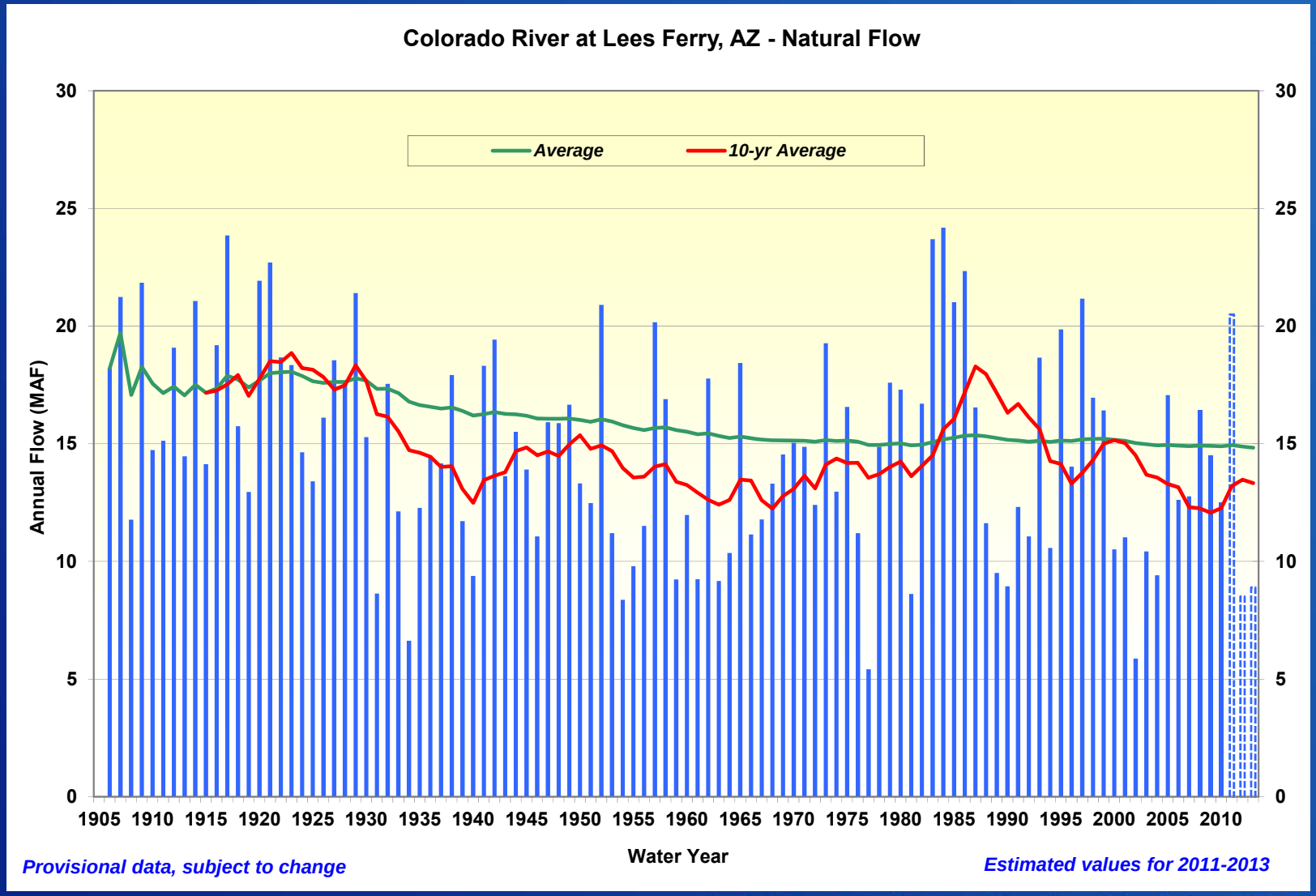
[1] Percent of average is based on the period of record from 1981-2010.

Natural Flow
Colorado River at Lees Ferry Gaging Station, Arizona
Water Year 1906 to 2013



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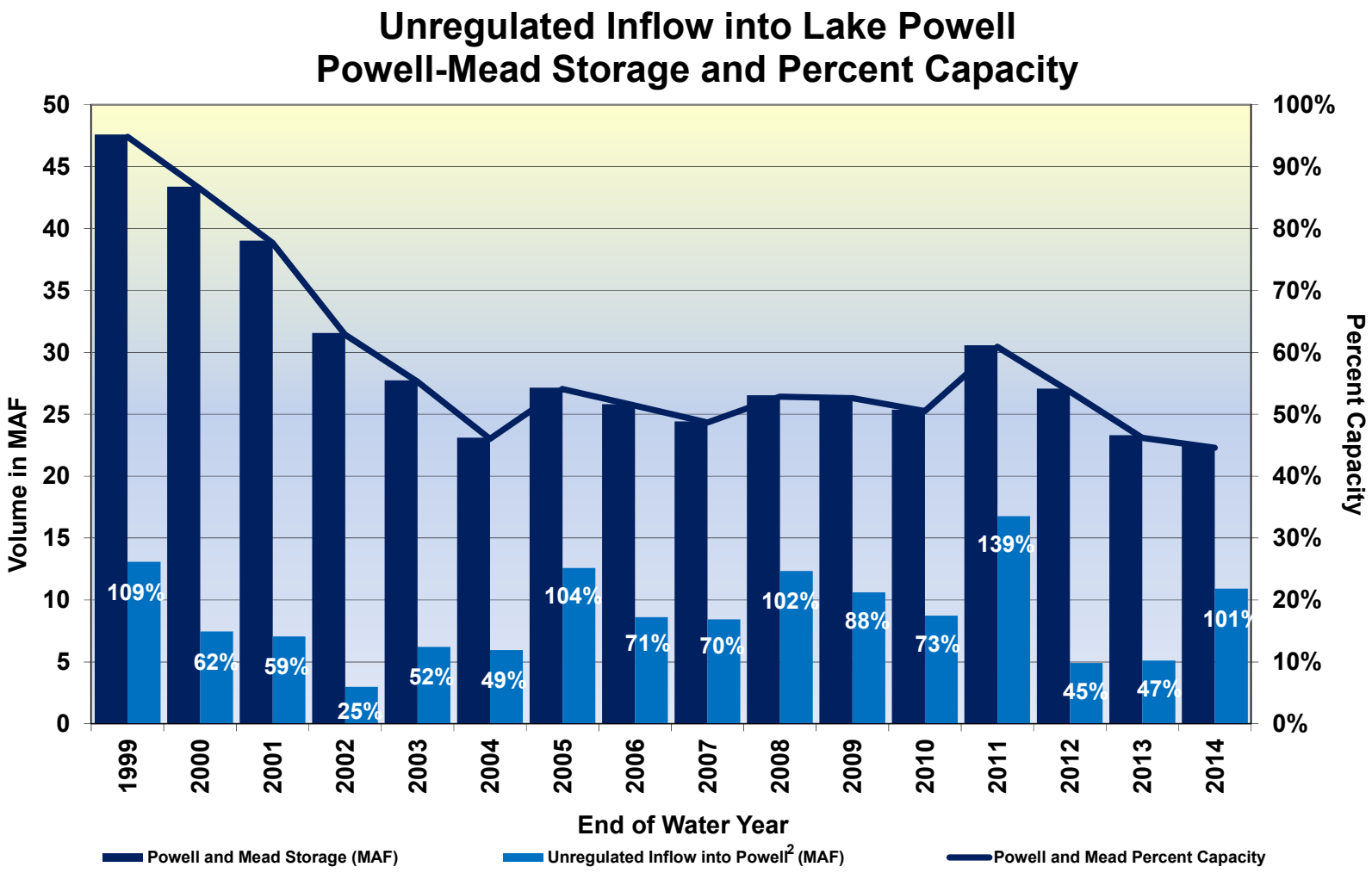
State of the System (Water Years 1999-2014)[1]



[1] Values for Water Year 2014 are projected. Unregulated inflow is based on the latest CBRFC forecast. Storage and percent capacity are based on the February 2014 24-Month Study.

[2] Percentages at the top of the light blue bars represent percent of average unregulated inflow into Lake Powell for a given water year. Water years 1999-2011 are based on the 30-year average from 1971 to 2000. Water years 2012-2014 are based on the 30-year average from 1981-2010.

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Colorado River Basin Storage
(as of February 17, 2014)

Current Storage	Percent Full	MAF	Elevation (Feet)
Lake Powell	40%	9.66	3,577
Lake Mead	48%	12.52	1,109
Total System Storage*	48%	28.86	NA

*Total system storage was 32.62 maf or 55% this time last year

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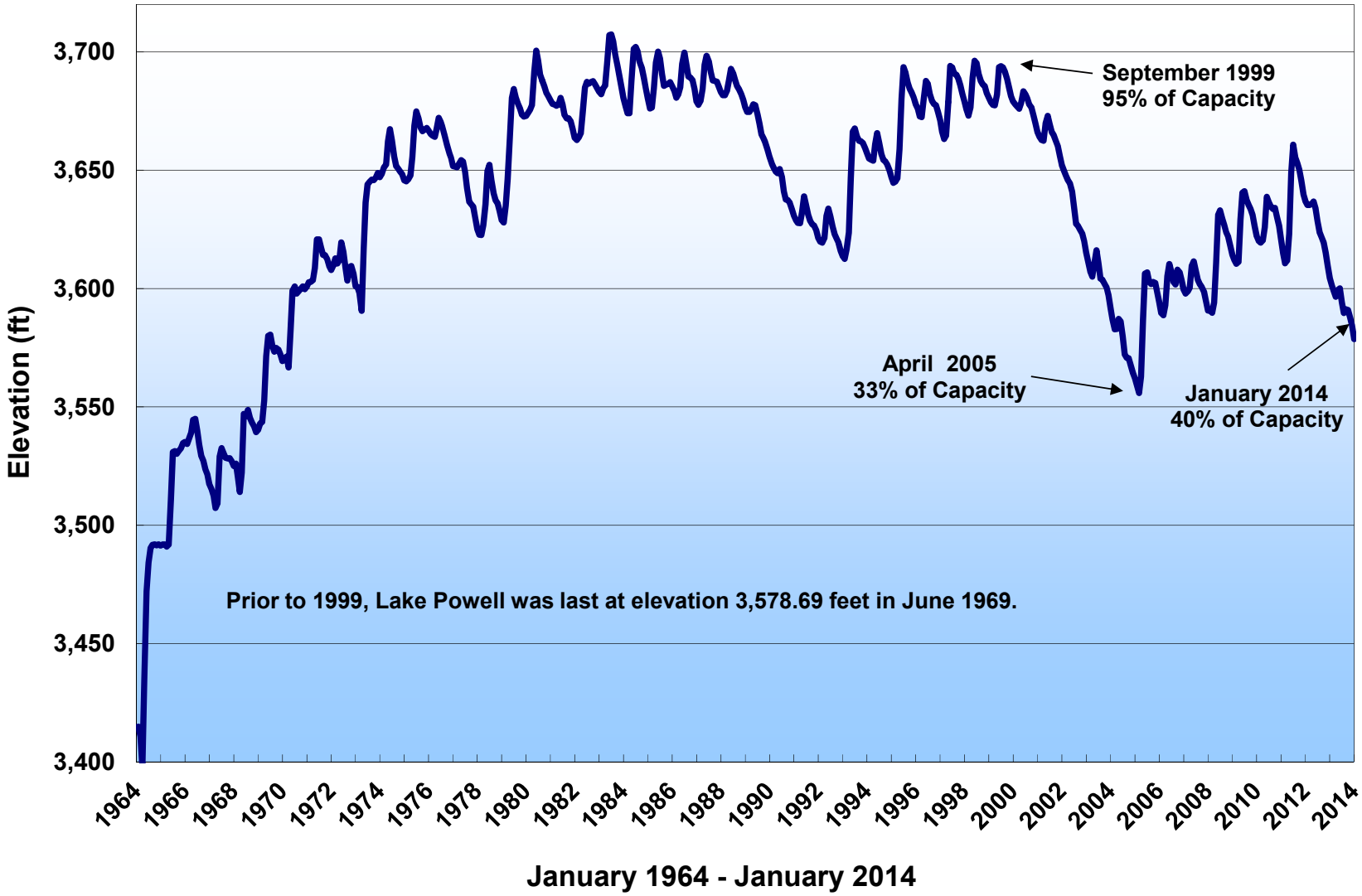
Lake Powell End of Month Elevation



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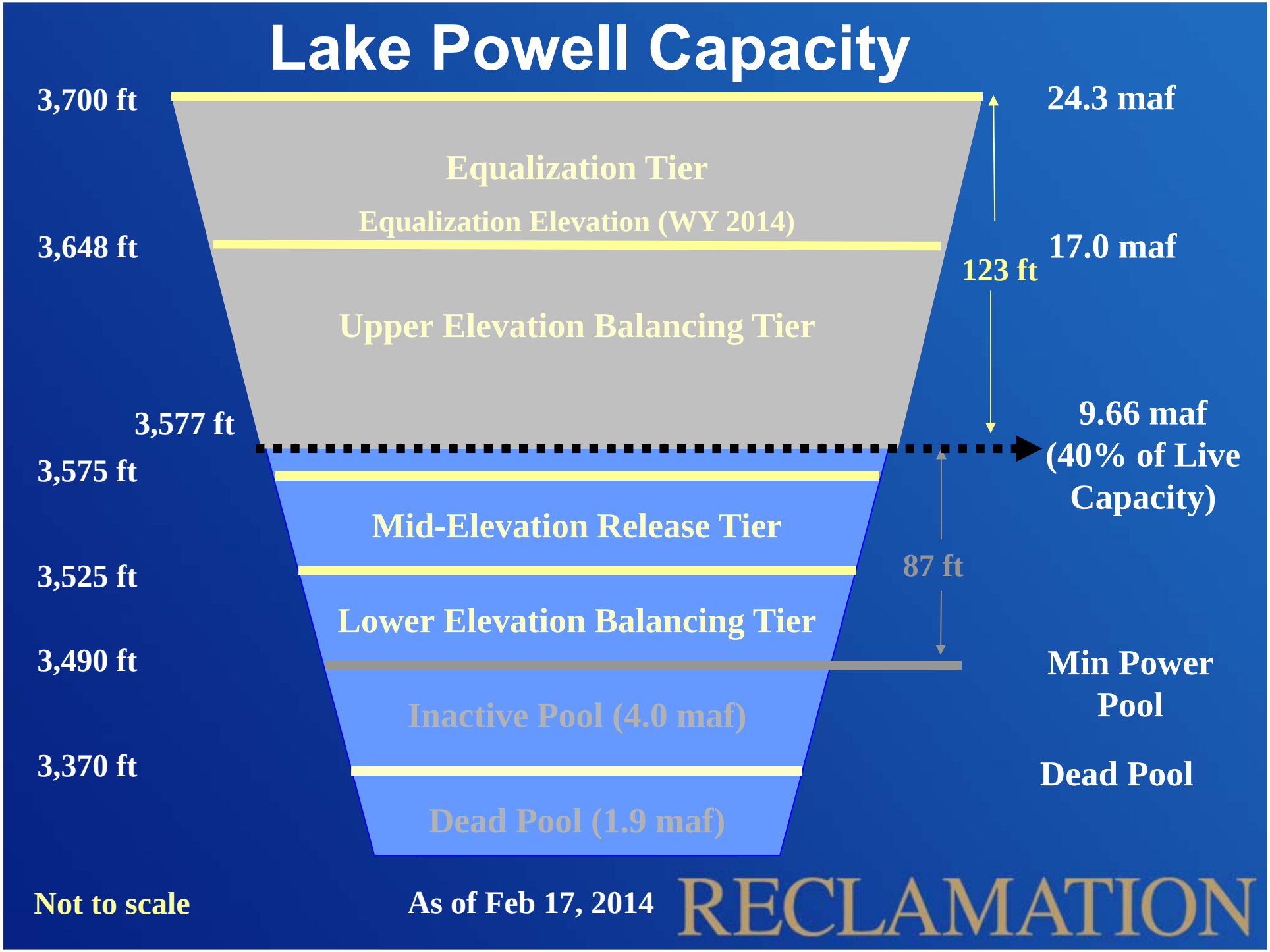
Lake Powell Capacity



Not to scale

As of Feb 17, 2014

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Glen Canyon Dam

Current Reservoir Projections

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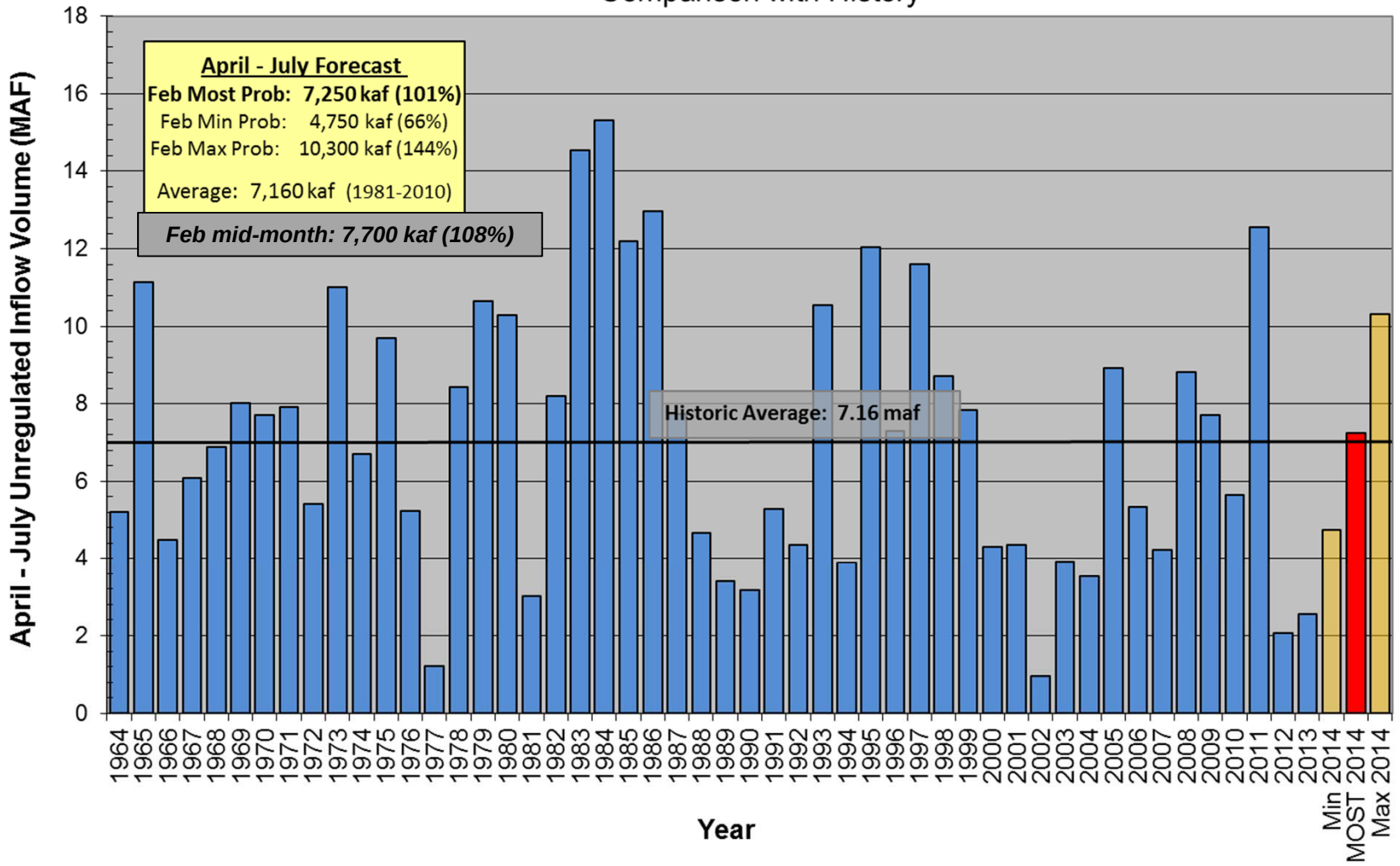
Lake Powell Unregulated Inflow

Apr - Jul 2014 Forecast *(issued Feb 4)*

Comparison with History



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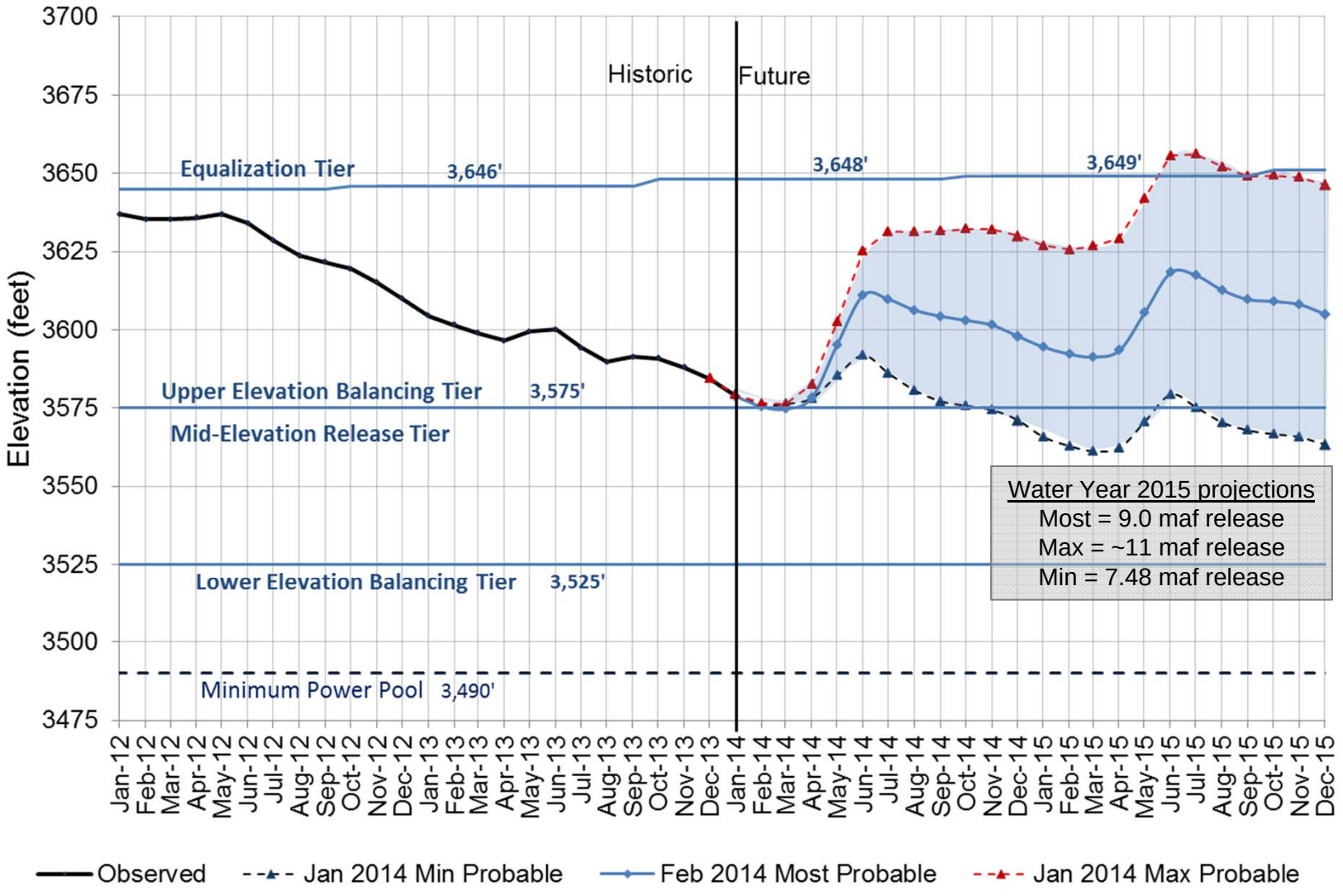
Lake Powell End of Month Elevations
Historic and Projected based on February modeling



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Percent of Traces with Event or System Condition

Results from January 2014 CRSS[1,2] (values in percent)

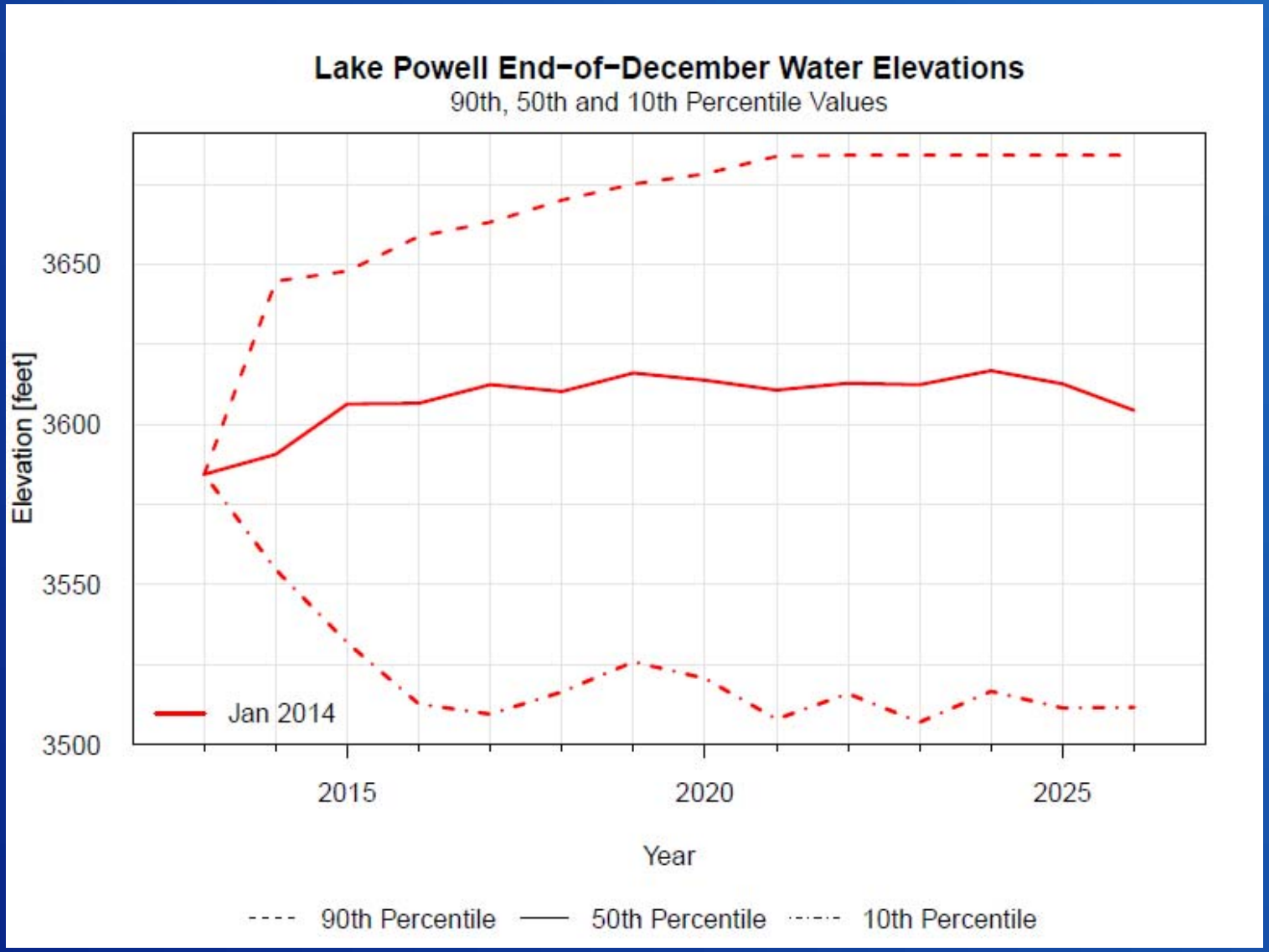
	Event or System Condition	2014[3]	2015	2016	2017	2018
Upper Basin – Lake Powell	**Equalization Tier**	**0**	**17**	**23**	**31**	**29**
	Equalization – annual release > 8.23 maf	*0*	*17*	*22*	*31*	*29*
	Equalization – annual release = 8.23 maf	*0*	*<1*	*1*	*<1*	*<1*
	Upper Elevation Balancing Tier	**0**	**50**	**51**	**45**	**42**
	Upper Elevation Balancing – annual release > 8.23 maf	*0*	*8*	*30*	*34*	*31*
	Upper Elevation Balancing – annual release = 8.23 maf	*0*	*42*	*21*	*11*	*11*
	Upper Elevation Balancing – annual release < 8.23 maf	*0*	*<1*	*<1*	*<1*	*<1*
	Mid-Elevation Release Tier	**100**	**33**	**17**	**13**	**18**
	Mid-Elevation Release – annual release = 8.23 maf	*0*	*<1*	*<1*	*1*	*1*
	Mid-Elevation Release – annual release = 7.48 maf	*100*	*33*	*17*	*12*	*17*
	Lower Elevation Balancing Tier	**0**	**<1**	**9**	**11**	**11**
Lower Basin – Lake Mead	**Shortage Condition – any amount (Mead ≤ 1,075 ft)**	**0**	**<1**	**44**	**54**	**53**
	Shortage – 1st level (Mead ≤ 1,075 and ≥ 1,050)	*0*	*<1*	*43*	*44*	*31*
	Shortage – 2nd level (Mead < 1,050 and ≥ 1,025)	*0*	*<1*	*1*	*9*	*18*
	Shortage – 3rd level (Mead < 1,025)	*0*	*<1*	*<1*	*1*	*4*
	Surplus Condition – any amount (Mead ≥ 1,145 ft)	**0**	**<1**	**4**	**7**	**13**
	Surplus – Flood Control	*0*	*<1*	*<1*	*1*	*2*
	Normal or ICS Surplus Condition	**100**	**>99**	**52**	**39**	**34**

[1] Reservoir initial conditions based on observed levels on December 31, 2013

[2] Hydrologic inflow traces based on resampling of the observed natural flow record from 1906-2010

[3] Percentages shown in 2014 are reported as '0' as 2014 operations were determined by the August 2013 24-Month Study

Lake Powell Elevation Projections through 2026



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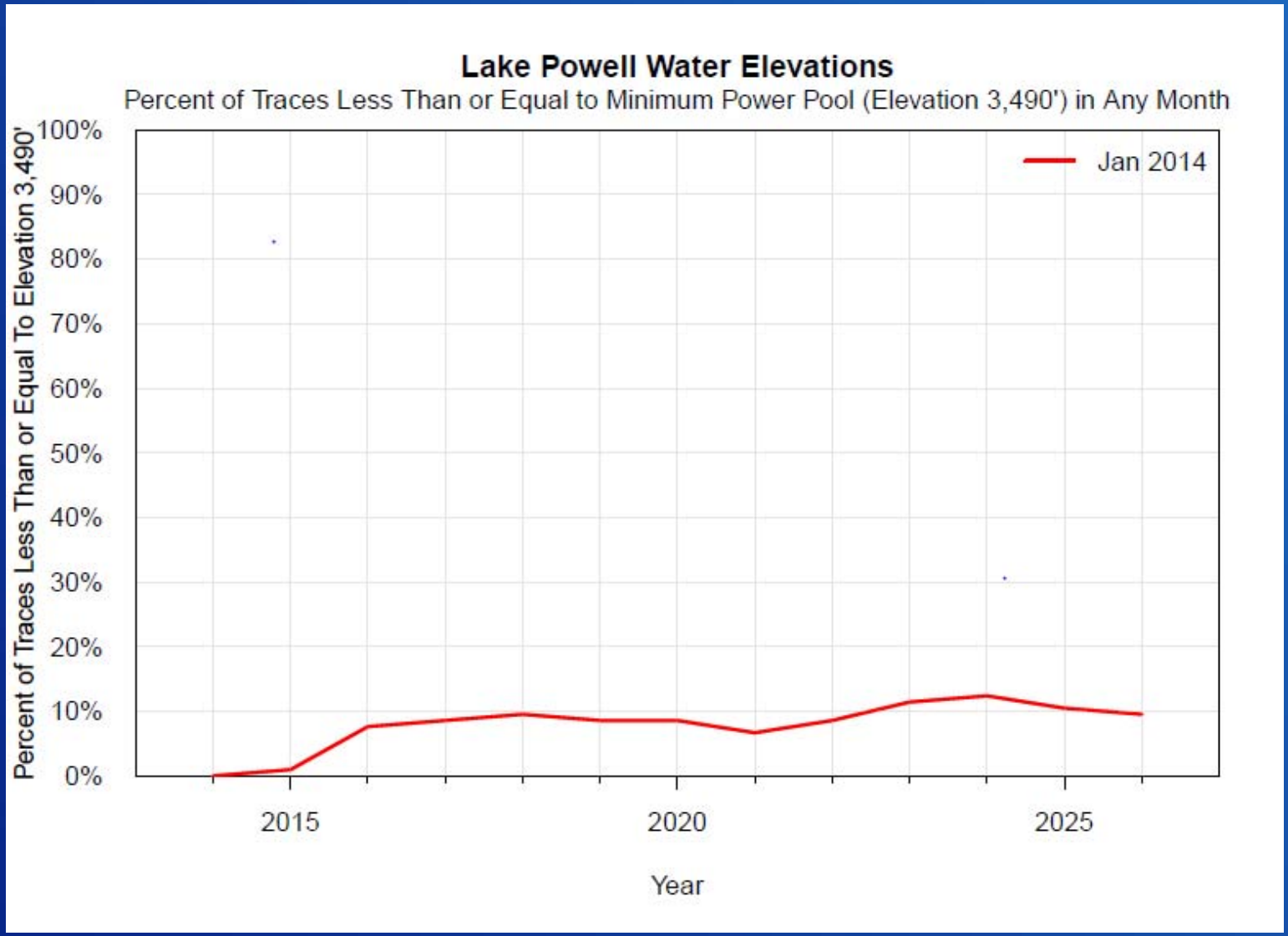
Lake Powell Min Power Pool through 2026



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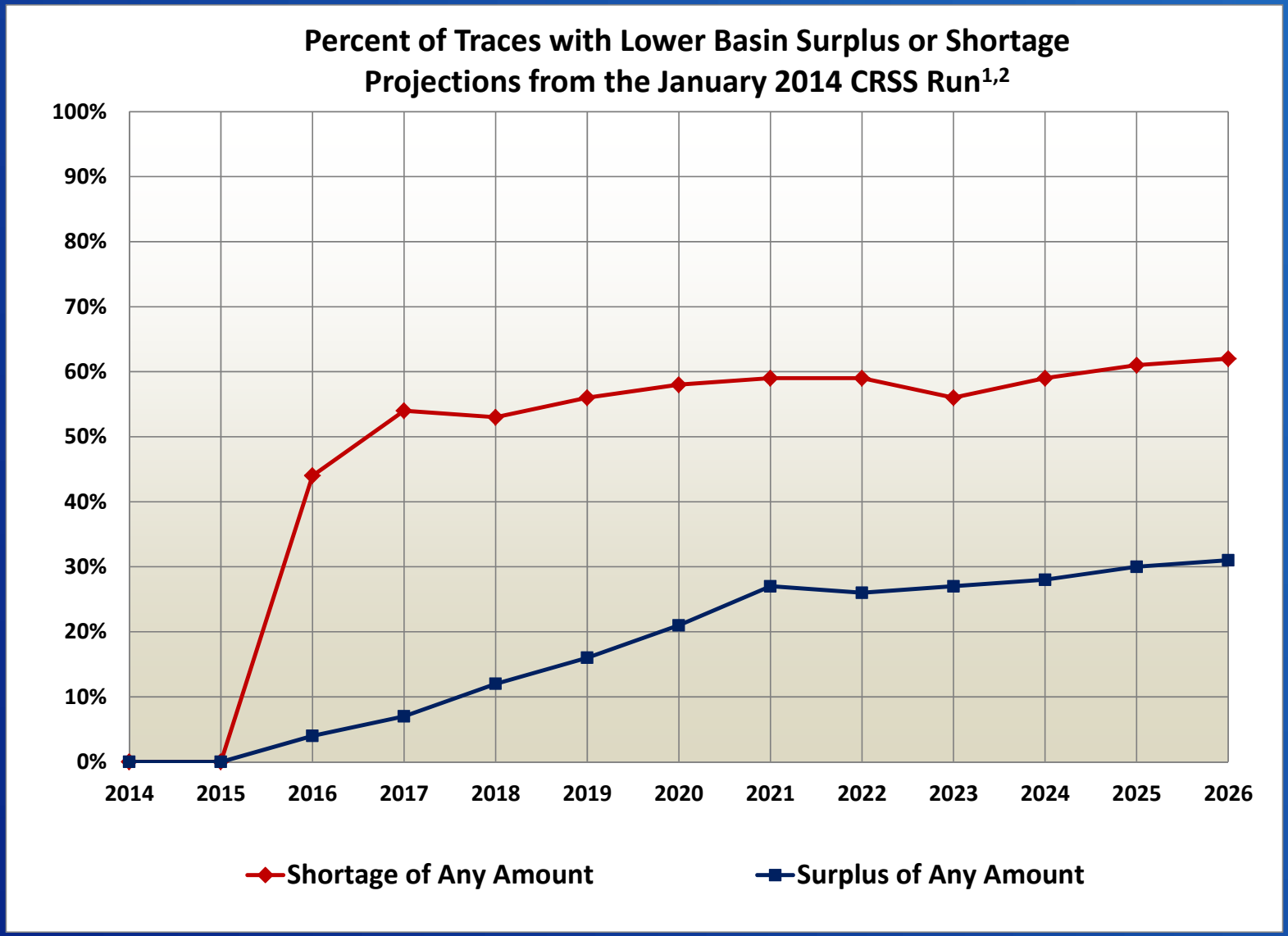
Lower Basin Surplus & Shortage through 2026



[1] Reservoir initial conditions based on observed levels on December 31, 2013

[2] Hydrologic inflow traces based on resampling of the observed natural flow record from 1906-2010.

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Glen Canyon Dam

Potential Impacts of Drought

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Operational Impacts

- More frequent releases of 8.23 maf or lower each year
- Minimum elevation for power generation is approximately 3,490 ft.
- Below 3,490 ft releases would be made through bypass tubes only
- As elevation decreases, cannot release full capacity of bypass tubes (15,000 cfs.)

3500' - 10.86 maf annually
3490' - 10.60 maf annually
3450' - 9.09 maf annually
3440' - 8.28 maf annually
3430' - 7.41 maf annually
3420' - 6.37 maf annually
3400' - 3.47 maf annually
3370' = 0 maf, dead pool

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Hydropower Impacts

- Lower inflows to Lake Powell ➔ lower releases ➔ less hydropower generation
- Lower reservoir elevation ➔less “head” (pressure) ➔ less hydropower generation
- Hydropower at Glen Canyon: ~80% of SLCA/IP total generation
  - Reductions in hydropower at Glen Canyon Powerplant significantly impact revenues available to the Upper Colorado Basin Fund
  - Glen Canyon hydropower generation pays for: reservoir and powerplant maintenance, security, salaries, environmental related costs (AMP, UCRIP, SJRIP), salinity program, and other repayment obligations
- Glen Canyon Dam cannot generate power below 3,490 ft
  - Would be a significant loss of revenue
  - could potentially affect hydropower rates (Western)

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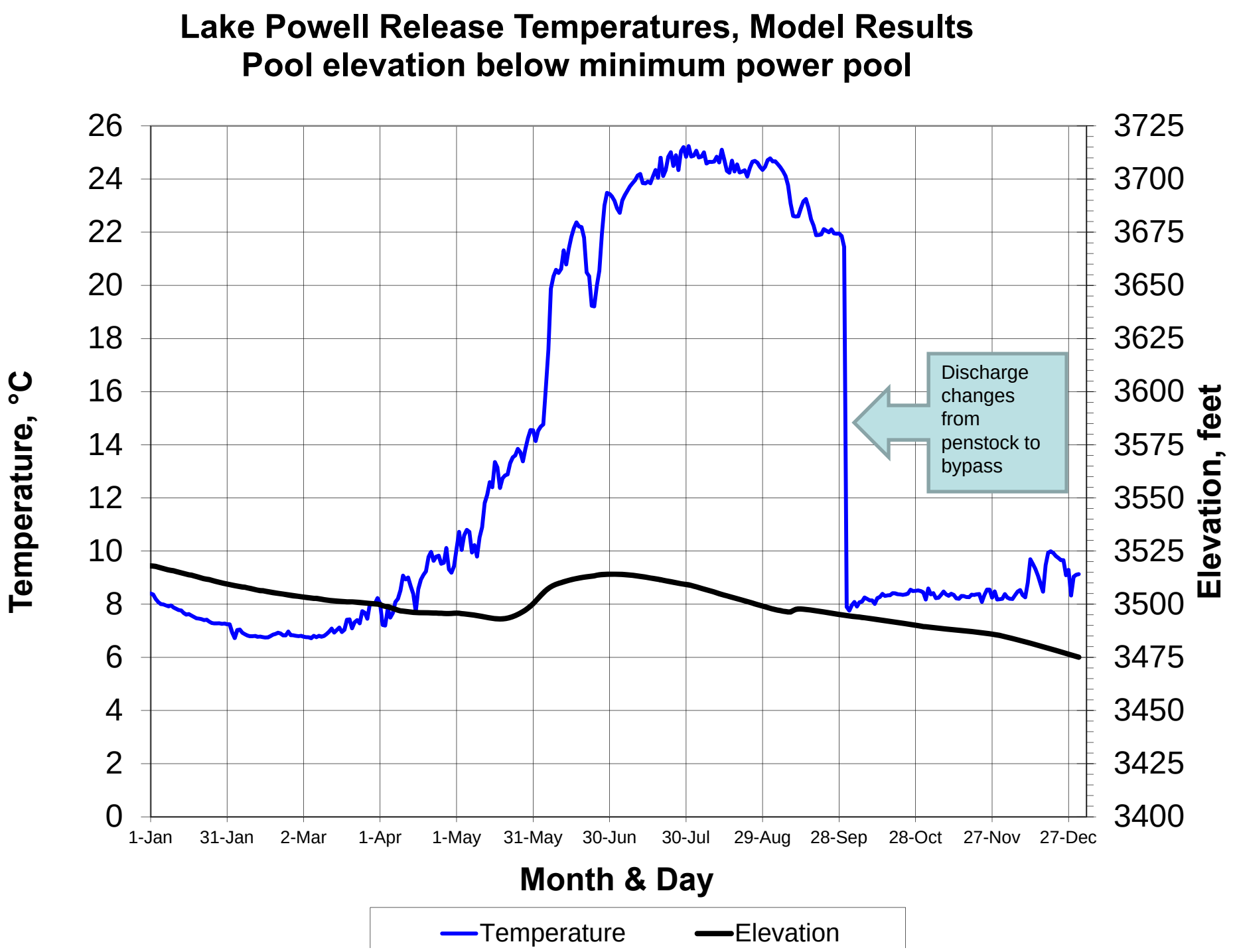
Impacts to Water Temperature

What would happen to temperature if Lake Powell were to drop below minimum power pool?

- Timing of transition from penstocks to bypass is critical:
  - Summer or early fall transition = sharp drop from warm to cold temperature (illustrated by following slide)
  - Winter or spring transition = insignificant difference in temperature
- Extended duration of bypass releases:
  - Summer/Fall peak release temperatures would be > 20°C
  - Winter/Spring minimum release temperatures would be < 7°C


Lake Powell Release Temperatures, Model Results
Pool elevation below minimum power pool
Temperature, °C
Elevation, feet
26
24
22
20
18
16
14
12
10
8
6
4
2
0
3725
3700
3675
3650
3625
3600
3575
3550
3525
3500
3475
3450
3425
3400
Discharge changes from penstock to bypass
1-Jan
31-Jan
2-Mar
1-Apr
1-May
31-May
30-Jun
30-Jul
29-Aug
28-Sep
28-Oct
27-Nov
27-Dec
Month & Day
Temperature
Elevation

Impacts to Water Quality

What would happen to water quality if Lake Powell were to drop below minimum power pool?

- Total dissolved solids concentration would increase, temporary effect
- Dissolved oxygen concentration would increase due to release through river outlets
  - Potential for supersaturation of dissolved oxygen (DO) above Lees Ferry

Summary

- Fortunate to start the drought in 2000 with nearly full system conditions
- Still early, but runoff forecast this water year is shaping up to be better than past two years
- A wide range of future outcomes is possible through 2020, including an “extended drought”
- Putting water back into the system, through a range of options, improves system resiliency and helps to avoid critical reservoir elevations

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Thank you

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Hydraulic Engineer, Glen Canyon Dam
Bureau of Reclamation

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Extra Slides

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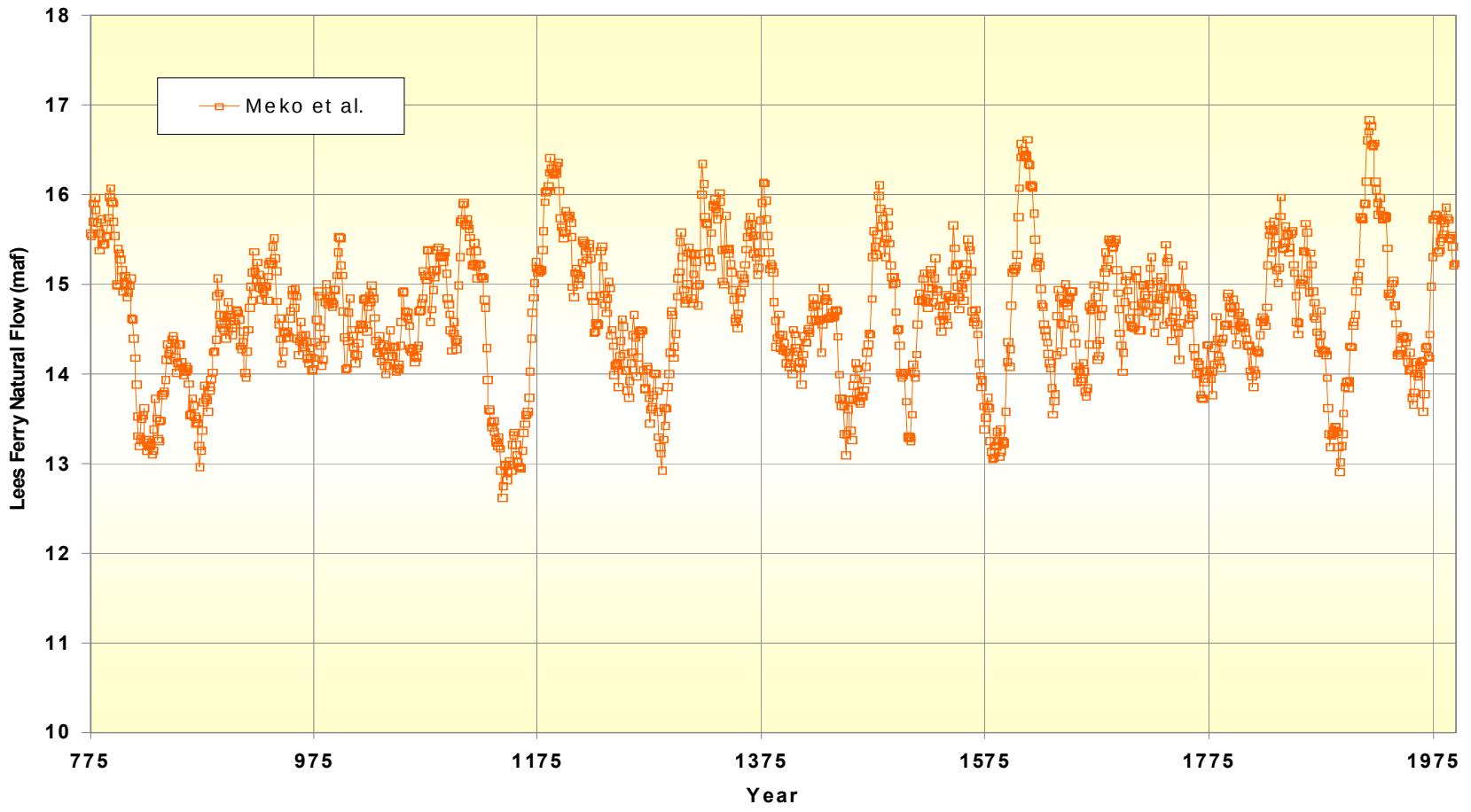
Annual Natural Flow at Lees Ferry
Tree-ring Reconstruction (Meko et al., 2007)
25-Year Running Mean



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Impetus for the Interim Guidelines

- Seven years of unprecedented drought
- Increased water use
- To date, there has never been a shortage in the Lower Basin and there were no shortage guidelines
- Operations between Lake Powell and Lake Mead were coordinated only at the higher reservoir levels “equalization”

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Interim Guidelines

- Operations specified through the full range of operation for Lake Powell and Lake Mead
- Encourage efficient and flexible use and management of Colorado River water through the ICS mechanism
- Strategy for shortages in the Lower Basin, including a provision for additional shortages if warranted[2]
- In place for an interim period (through 2026) to gain valuable operational experience
- Basin States agree to consult before resorting to litigation

1. **Issued in Record of Decision, dated December 13, 2007; available at http://www.usbr.gov/lc/region/programs/strategies.html**
2. **Mexico water deliveries are not directly affected by these guidelines**

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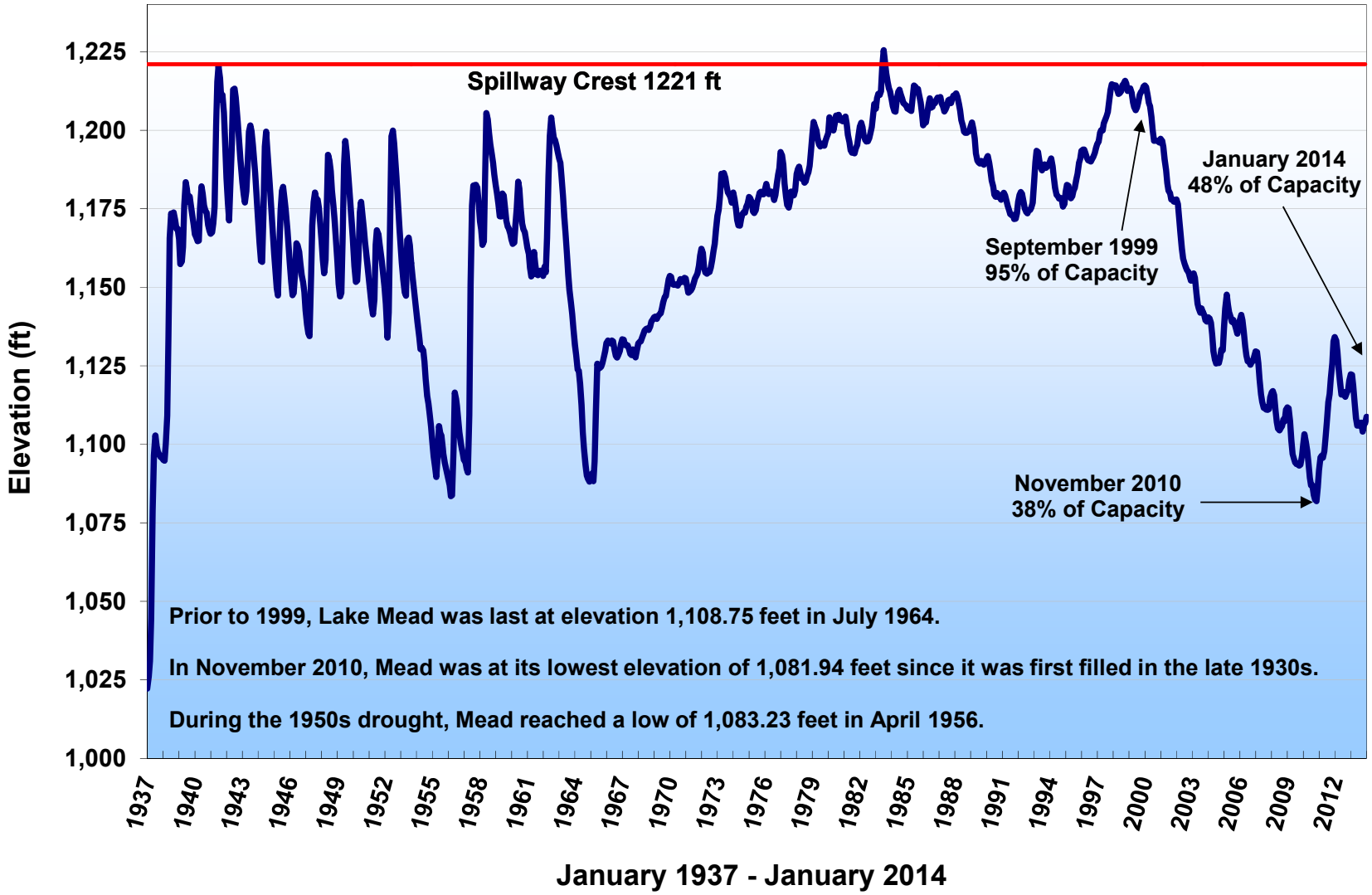
Lake Mead End of Month Elevation



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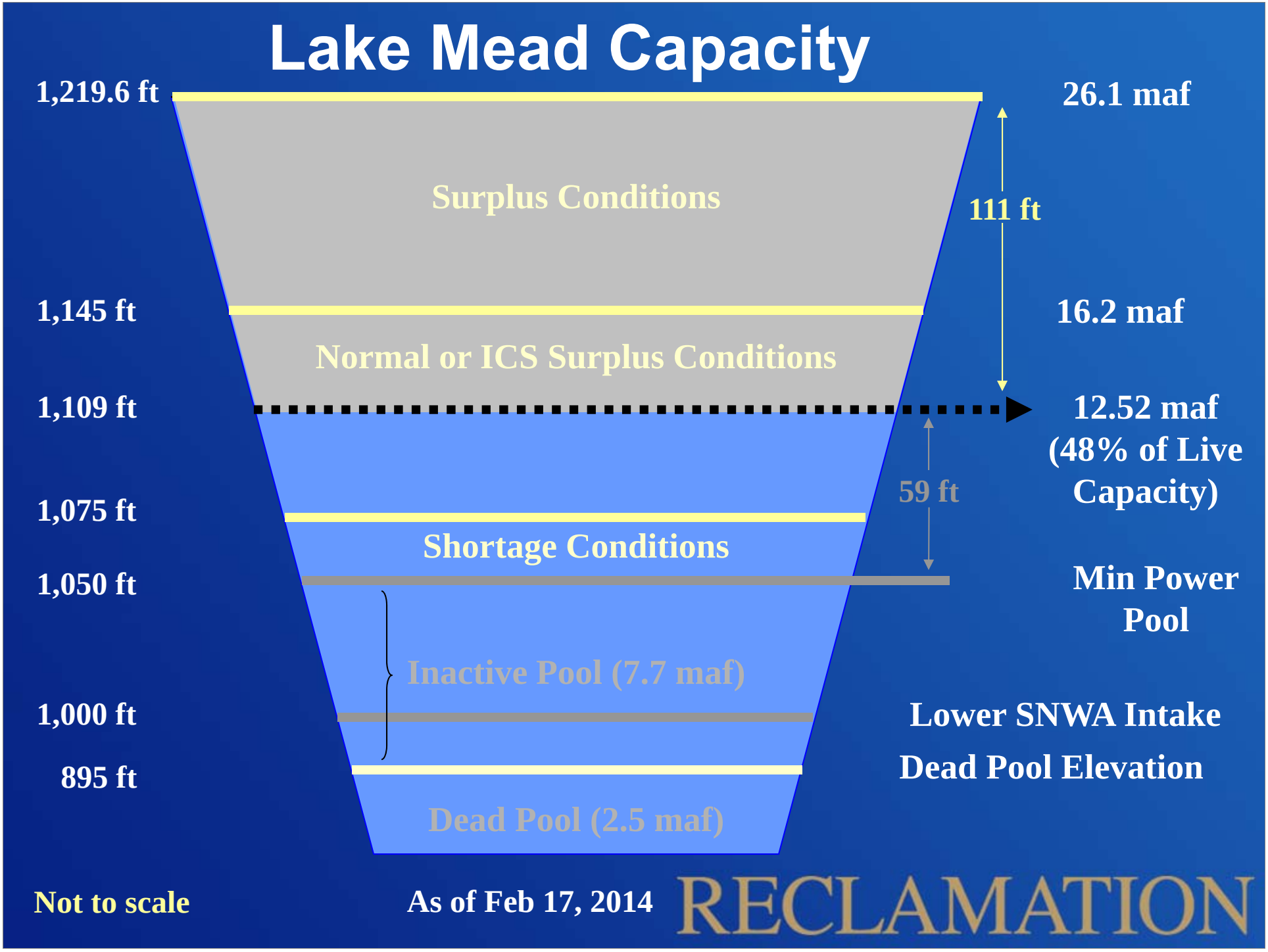
Lake Mead Capacity



Not to scale

As of Feb 17, 2014

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