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Managing Water in the West

Recent RiverWare and RiverSMART applications on the Colorado River Basin

2016 RiverWare User Group Meeting
August 24, 2016

U.S. Department of the Interior
Bureau of Reclamation

Overview of Recent RiverWare and RiverSMART applications on the Colorado River Basin

- Overview of the Colorado River Basin and Current Drought
- Overview of Colorado River Basin models
- Application of RiverSMART to facilitate combined modeling simulations

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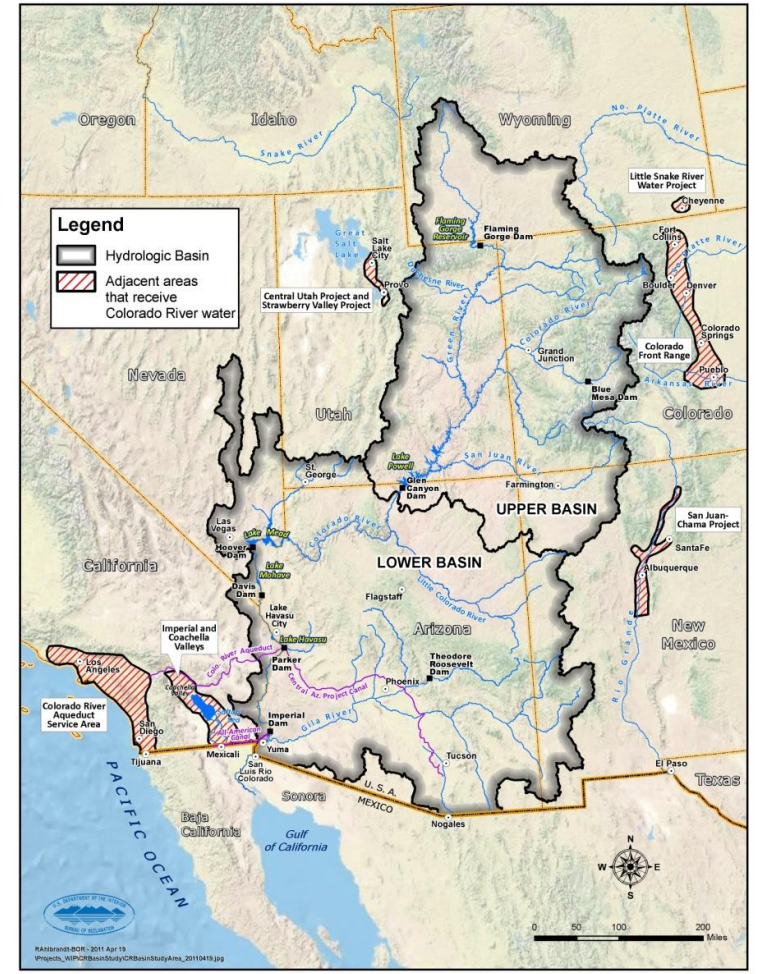
Overview of the Colorado River Basin

- 16.5 million acre-feet (maf) allocated annually
  - 7.5 maf each to Upper and Lower Basins
  - 1.5 maf to Republic of Mexico
- 13 to 14.5 maf of consumptive use on average annually
- About 16 maf average annual flow
  - 14.8 maf in the Upper Basin and 1.3 maf in the Lower Basin
  - Inflows are highly variable from year-to-year
- 60 maf of storage
  - About 4-times the annual inflow
- Operations and water deliveries governed by the “Law of the River”



Map of Colorado River Upper and Lower Basins

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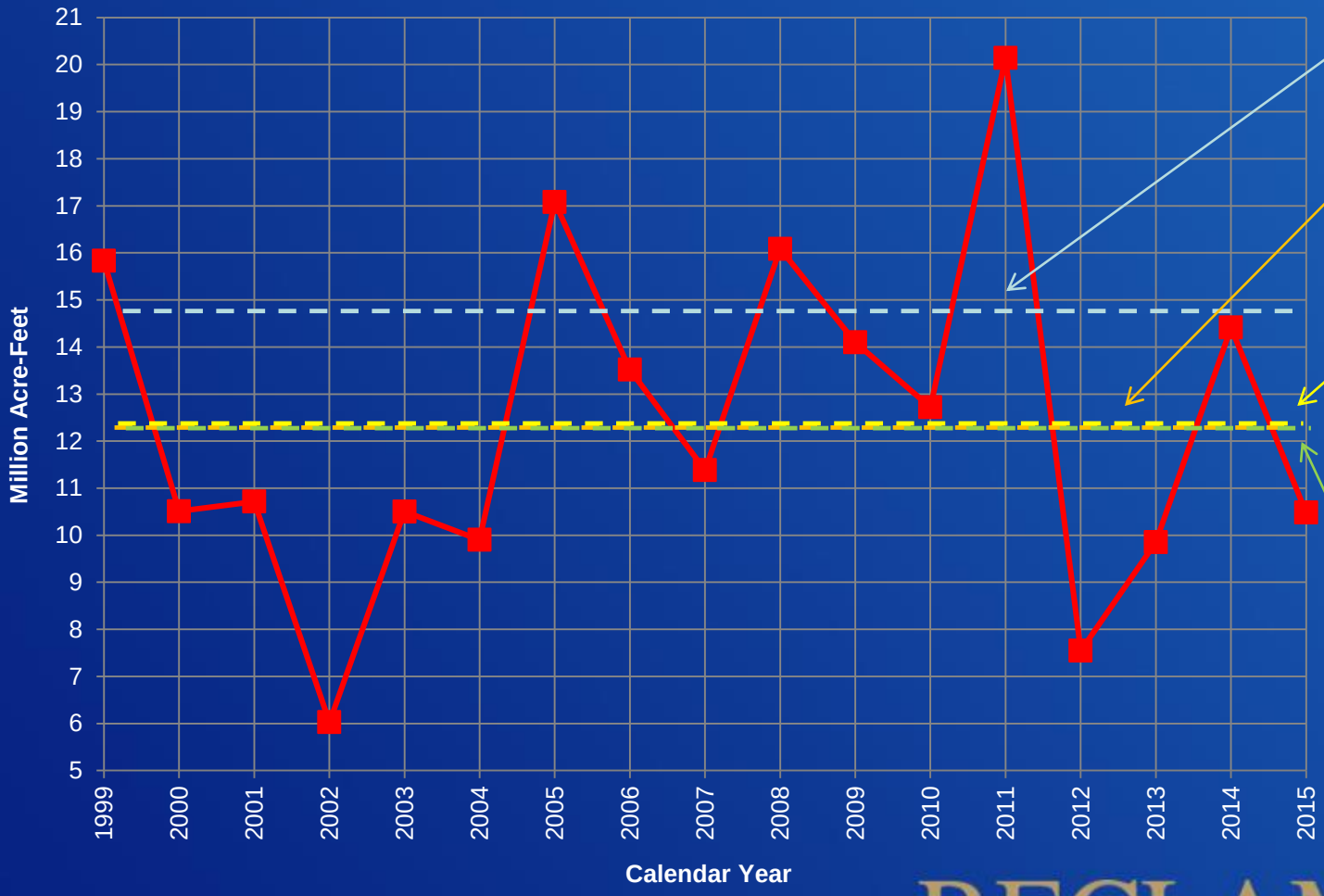
Current 16-year Drought (2000-2015)

Natural Flow at Lees Ferry



Historical Long-term Average (1906-2015*)

Current 16-year Drought Average (2000-2015)

Climate Projections (2016-2099) Approx. 25th-percentile of 16-year periods

Paleo Record (1200+ years) Lowest 16-year period

*2013-2015 natural flows are provisional

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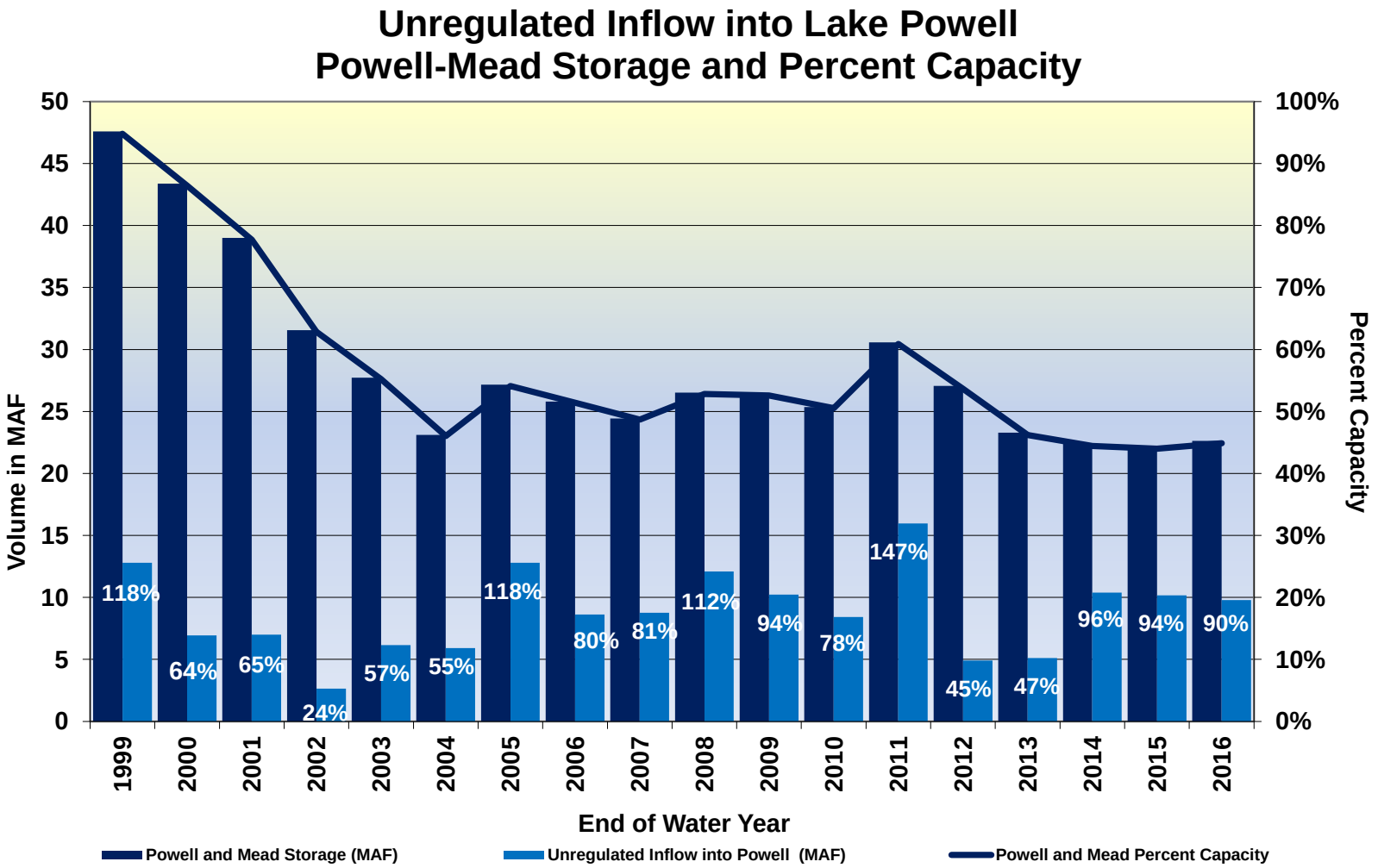
State of the System (Water Years 1999-2016)[1,2]



[1]Values for Water Year 2016 are projected. Unregulated inflow is based on the latest CBRFC forecast dated August 17, 2016. Storage and percent capacity are based on the August 2016 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. The percent of average is based on the period of record from 1981-2010.

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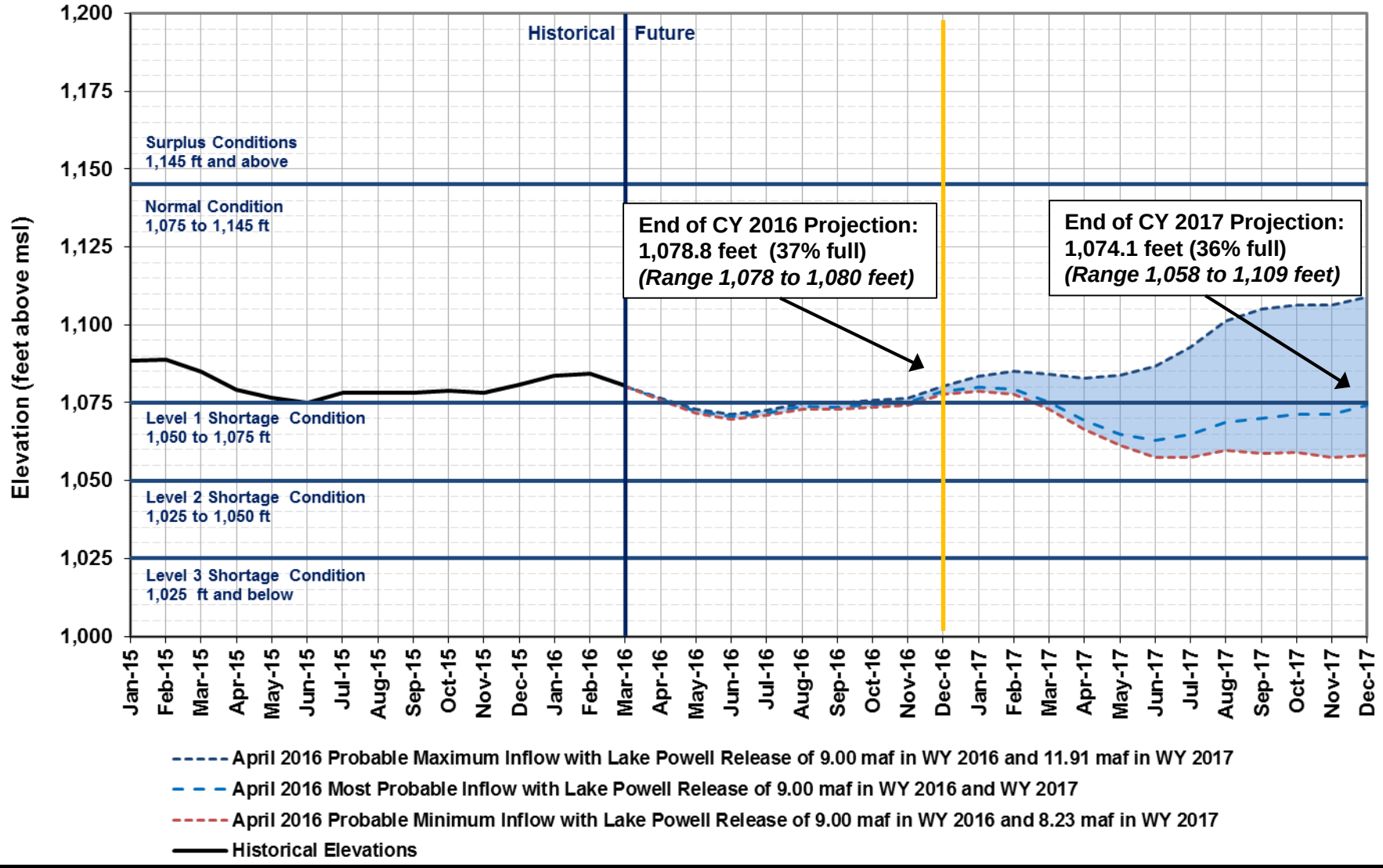
Lake Mead End of Month Elevations

Projections from April 2016 24-Month Study Inflow Scenarios



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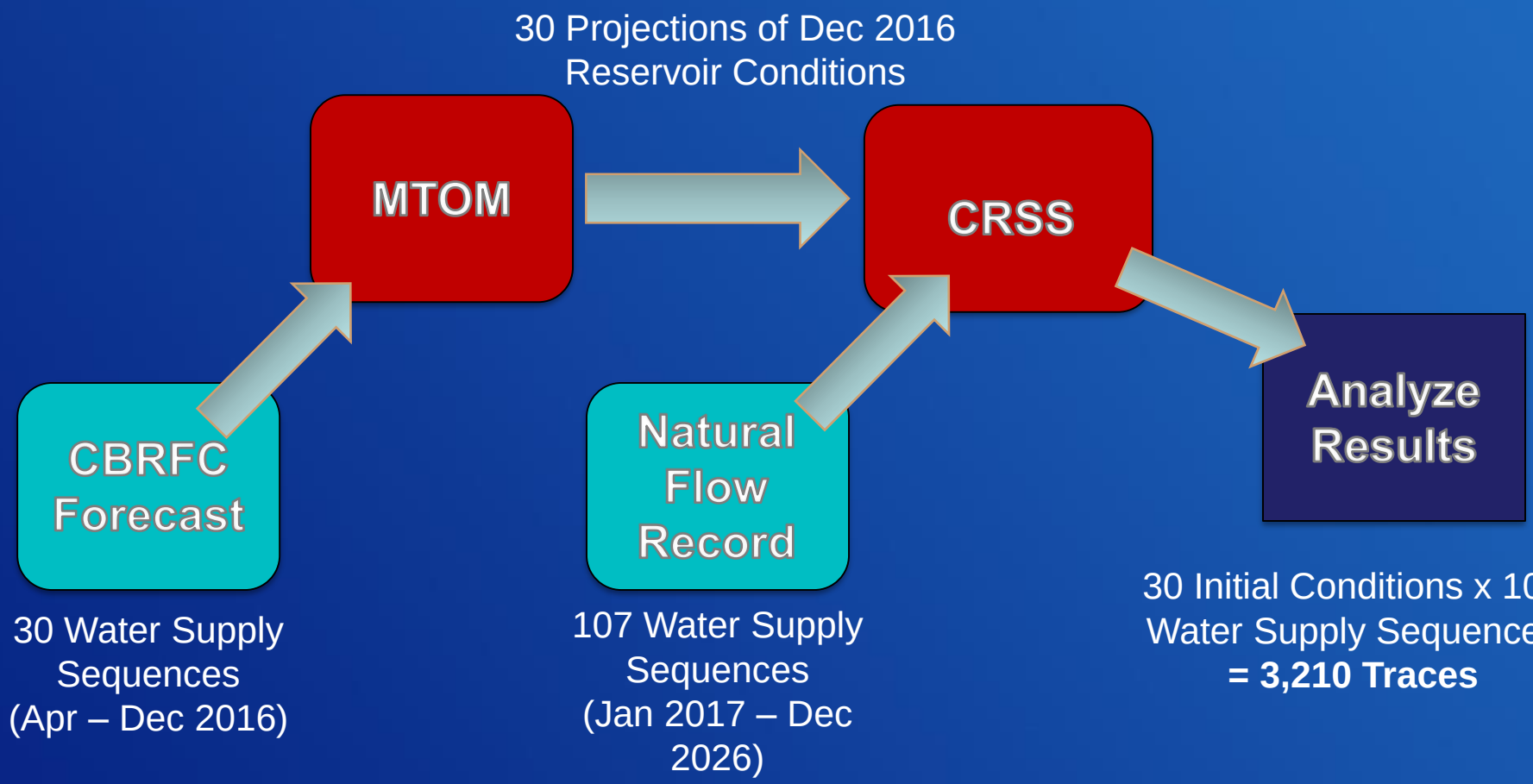
Overview of Reclamation's Mid and Long-Term Probabilistic Models

	CRSS	MTOM
Primary Use	Long-term planning studies, operational criteria development, and risk analysis	Risk-based operational planning and analysis during mid-term time period
Reservoir Initial Conditions	Based on observed or modeled December 31 conditions	Based on observed previous month reservoir elevations
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)	
Upper Basin Inflows	Resampled observed natural flows (1906-2012), creating 107 future hydrologic sequences using the "Indexed Sequential Method"	30-member ensemble of unregulated inflow forecasts, based on the period of record from 1981-2010, provided by Colorado Basin River Forecast Center (CBRFC)
Lower Basin Inflows	107 possibilities based on the 107-year (1906-2012) historical record	30 possibilities based on the 30-year (1981-2010) historical record
Upper Basin Water Demand	Developed in coordination with the Upper Colorado River Commission	Estimated and incorporated in the unregulated inflow forecasts provided by the CBRFC
Lower Basin Water Demand	Developed in coordination with the Lower Basin States and Mexico	

Combed MTOM/CRSS Simulation Approach

ex. April 2016 Simulation



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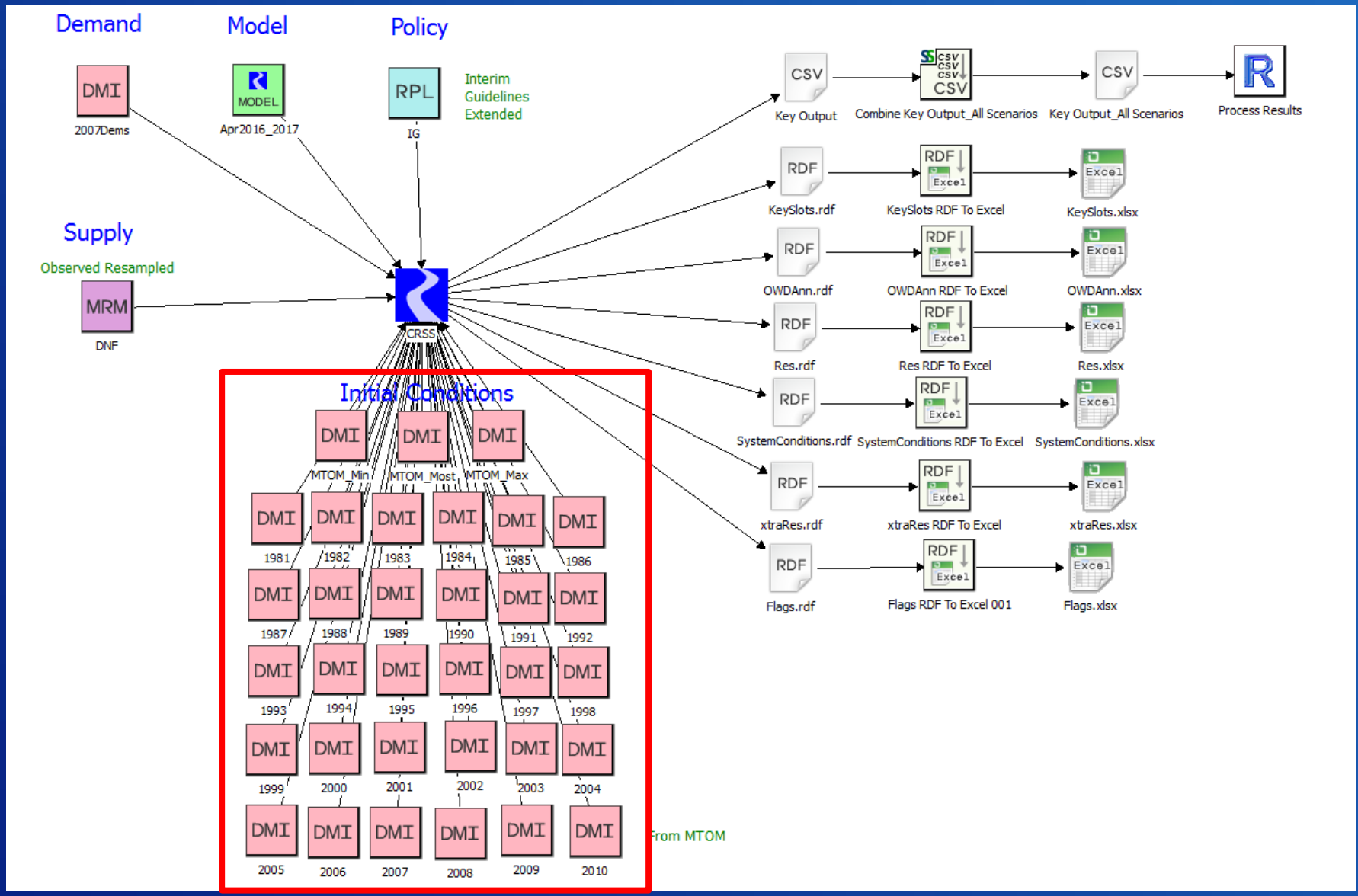
Combined CRSS/MTOM RiverSMART Layout



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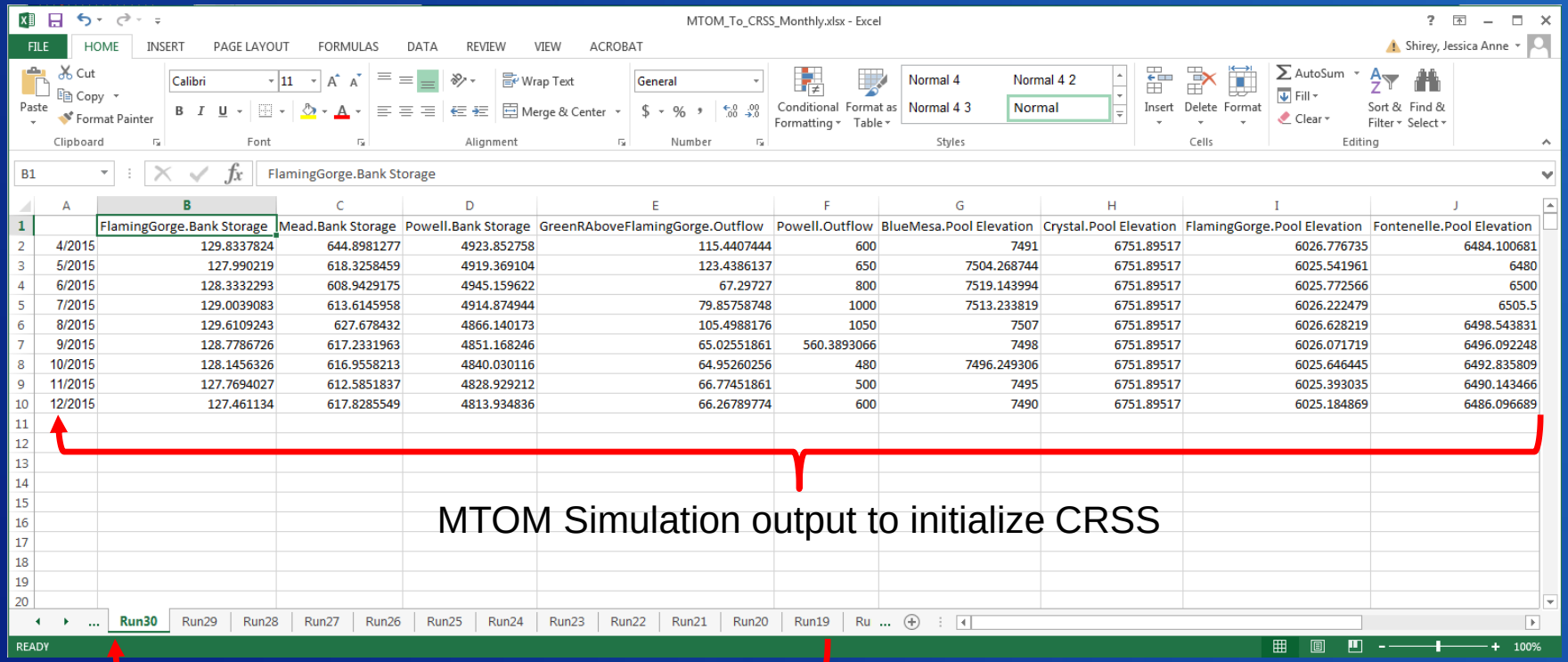
Initial Conditions DMI

- Direct to Excel Output DMI from MTOM model
- Used as Direct Connect Input DMI in CRSS



	A	B	C	D	E	F	G	H	I	J
1		FlamingGorge.Bank Storage	Mead.Bank Storage	Powell.Bank Storage	GreenRAboveFlamingGorge.Outflow	Powell.Outflow	BlueMesa.Pool Elevation	Crystal.Pool Elevation	FlamingGorge.Pool Elevation	Fontenelle.Pool Elevation
2	4/2015	129.8337824	644.8981277	4923.852758	115.4407444	600	7491	6751.89517	6026.776735	6484.100681
3	5/2015	127.990219	618.3258459	4919.369104	123.4386137	650	7504.268744	6751.89517	6025.541961	6480
4	6/2015	128.3332293	608.9429175	4945.159622	67.29727	800	7519.143994	6751.89517	6025.772566	6500
5	7/2015	129.0039083	613.6145958	4914.874944	79.85758748	1000	7513.233819	6751.89517	6026.222479	6505.5
6	8/2015	129.6109243	627.678432	4866.140173	105.4988176	1050	7507	6751.89517	6026.628219	6498.543831
7	9/2015	128.7786726	617.2331963	4851.168246	65.02551861	560.3893066	7498	6751.89517	6026.071719	6496.092248
8	10/2015	128.1456326	616.9558213	4840.030116	64.95260256	480	7496.249306	6751.89517	6025.646445	6492.835809
9	11/2015	127.7694027	612.5851837	4828.929212	66.77451861	500	7495	6751.89517	6025.393035	6490.143466
10	12/2015	127.461134	617.8285549	4813.934836	66.26789774	600	7490	6751.89517	6025.184869	6486.096689

MTOM Simulation output to initialize CRSS

30 Sets of Initial Conditions

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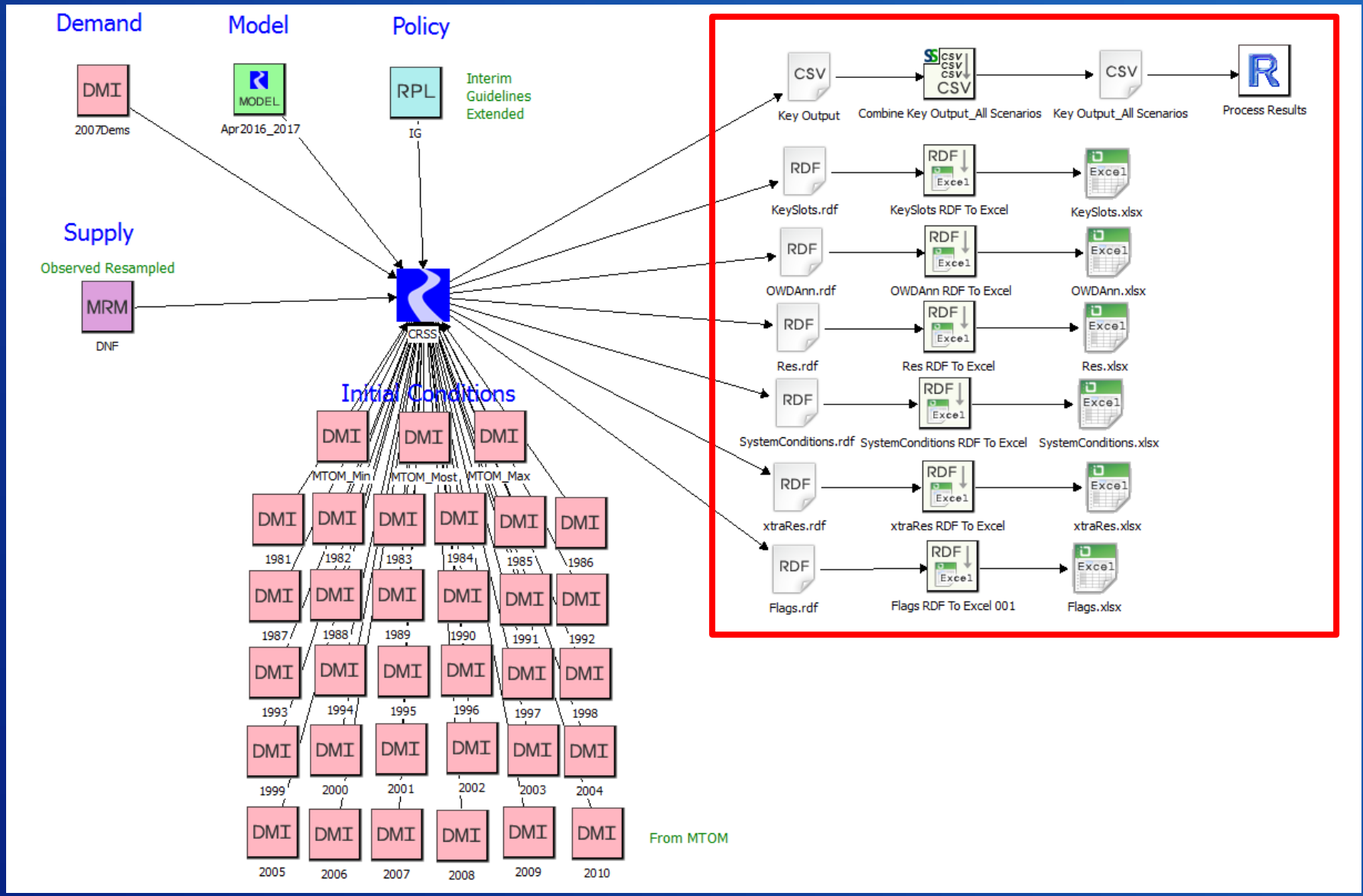
Combined CRSS/MTOM RiverSMART Layout



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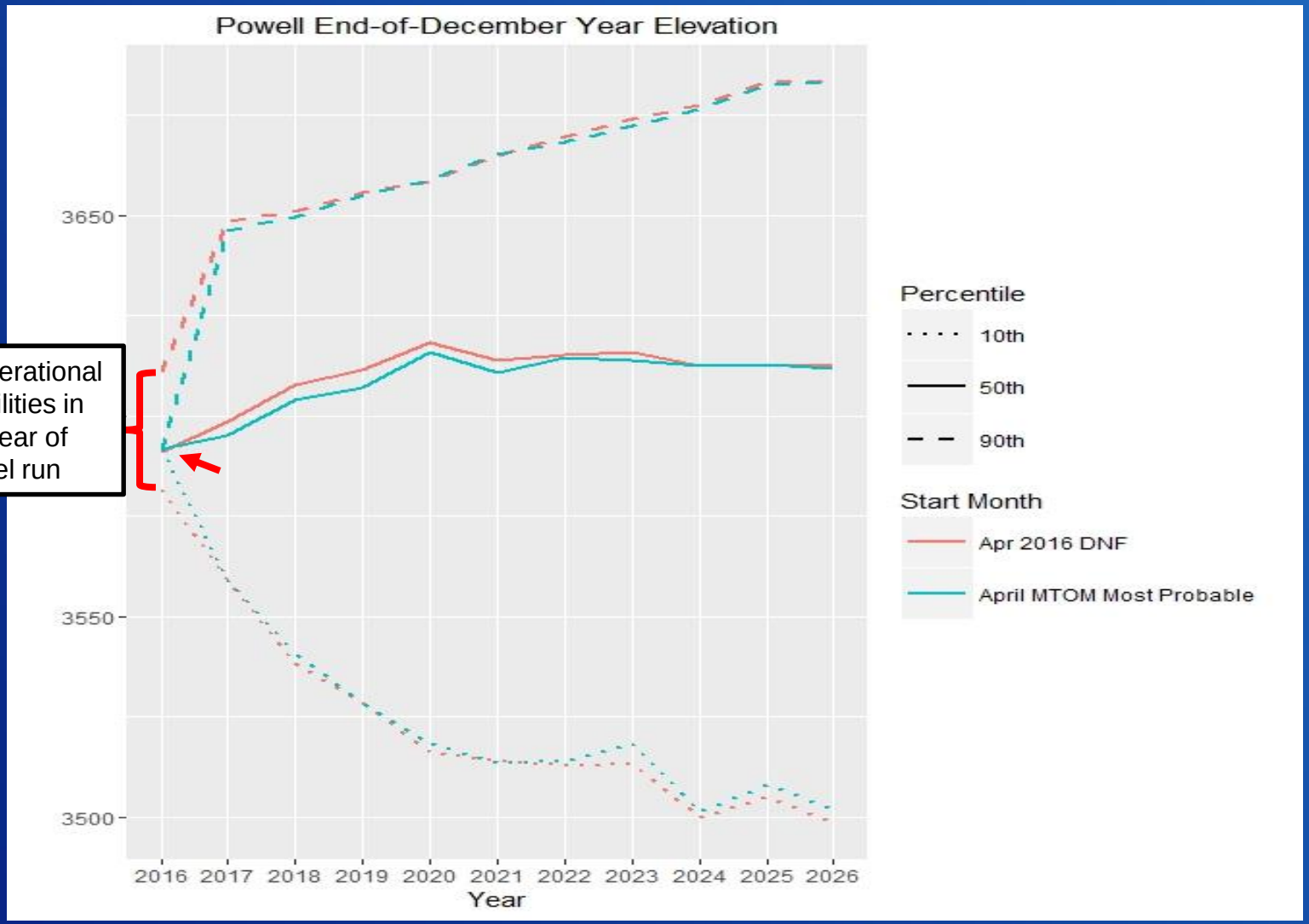
Post Processing and Sample Results



More operational possibilities in first year of model run

- *April CRSS projections generated using 30 Initial Condition sets from MTOM*
- *April CRSS projections generated using the MTOM most probable set of Initial Conditions*

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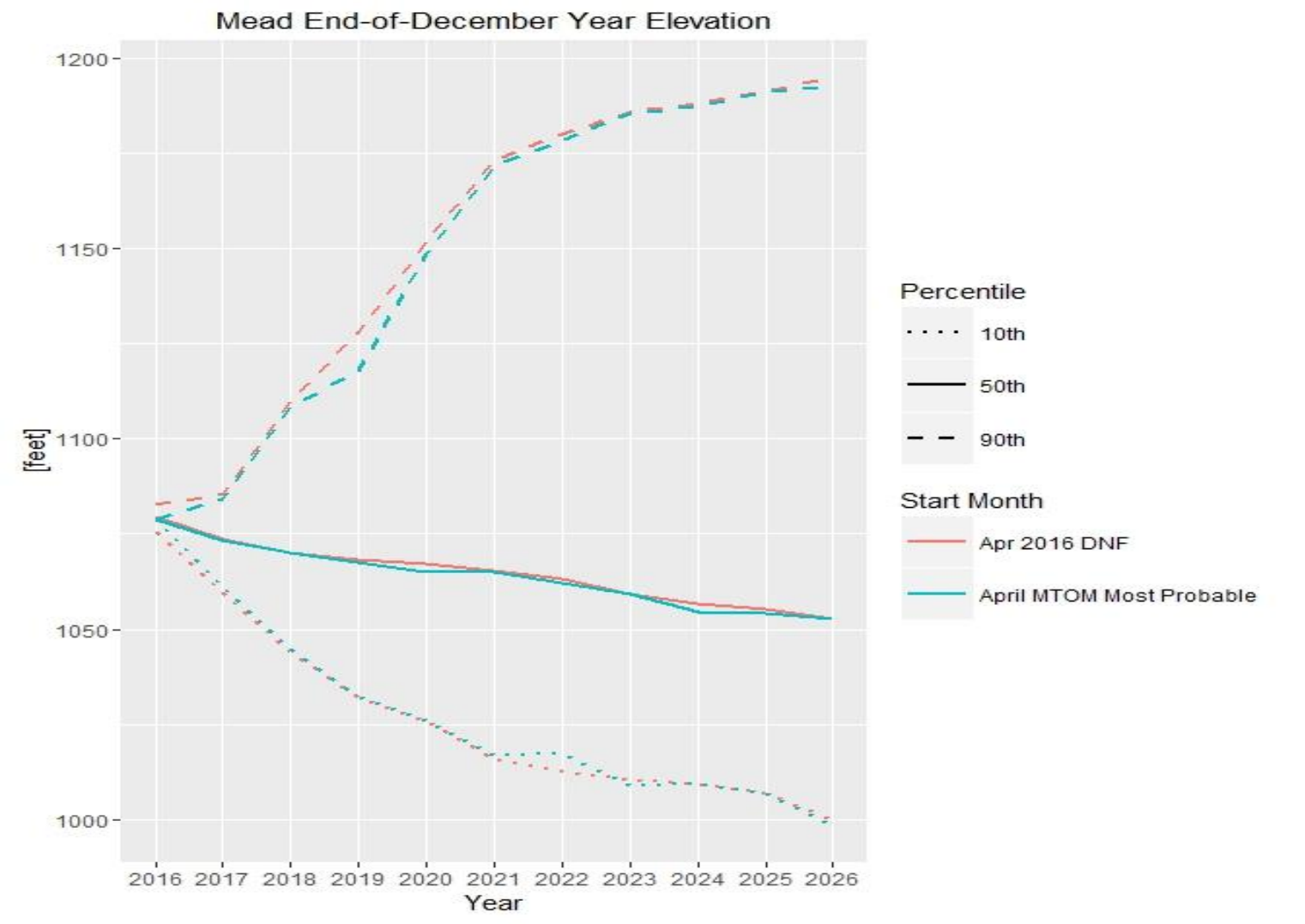
Post Processing and Sample Results



- *April CRSS projections generated using 30 Initial Condition sets from MTOM*
- *April CRSS projections generated using the MTOM most probable set of Initial Conditions*

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Post Processing and Sample Results

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**
	Equalization – annual release > 8.23 maf	*5*	*18*	*20*	*24*	*26*
	Equalization – annual release = 8.23 maf	*0*	*0*	*0*	*<1*	*2*
	Upper Elevation Balancing Tier	**89**	**53**	**54**	**52**	**45**
	Upper Elevation Balancing – annual release > 8.23 maf	*77*	*47*	*44*	*41*	*35*
	Upper Elevation Balancing – annual release = 8.23 maf	*12*	*5*	*10*	*10*	*10*
	Upper Elevation Balancing – annual release < 8.23 maf	*<1*	*1*	*1*	*1*	*<1*
	Mid-Elevation Release Tier	**7**	**29**	**19**	**14**	**15**
	Mid-Elevation Release – annual release = 8.23 maf	*0*	*0*	*<1*	*1*	*2*
	Mid-Elevation Release – annual release = 7.48 maf	*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**
	Shortage – 1st level (Mead ≤ 1,075 and ≥ 1,050)	*10*	*56*	*46*	*40*	*33*
	Shortage – 2nd level (Mead < 1,050 and ≥ 1,025)	*0*	*<1*	*18*	*18*	*18*
	Shortage – 3rd level (Mead < 1,025)	*0*	*0*	*<1*	*6*	*10*
	Surplus Condition – any amount (Mead ≥ 1,145 ft)	**0**	**<1**	**4**	**8**	**12**
	Surplus – Flood Control	*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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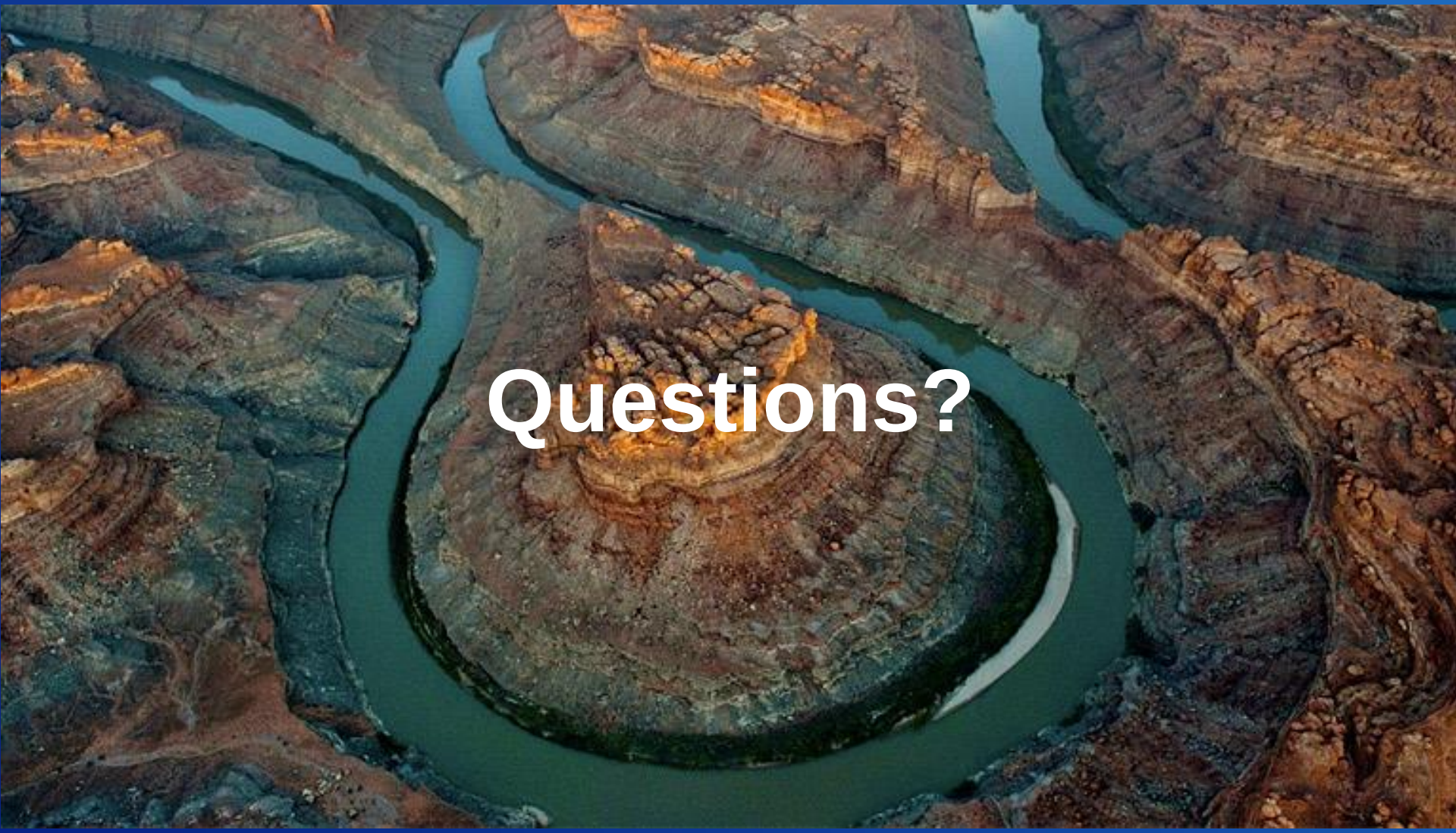
Questions?