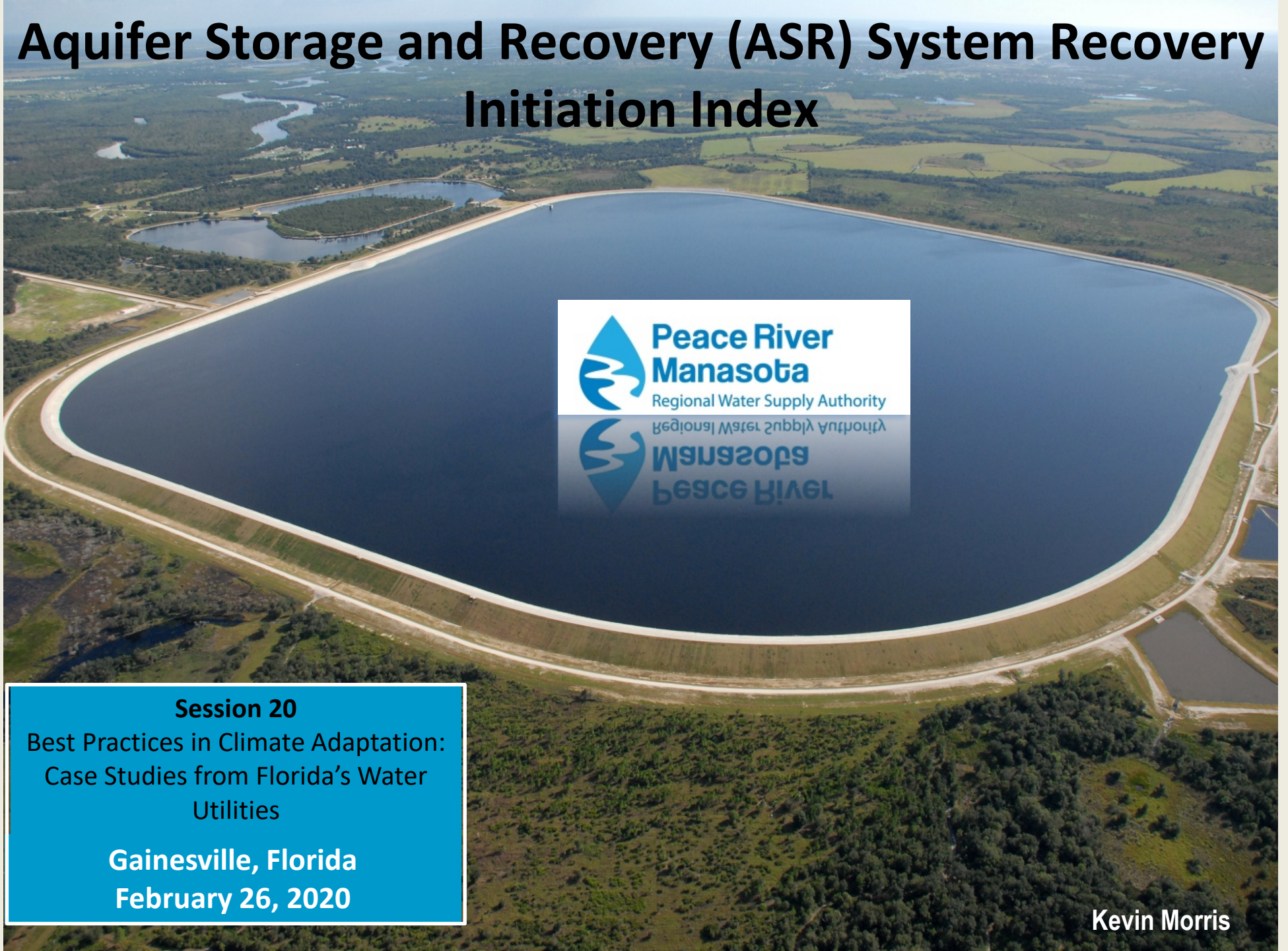
Aquifer Storage and Recovery (ASR) System Recovery Initiation Index



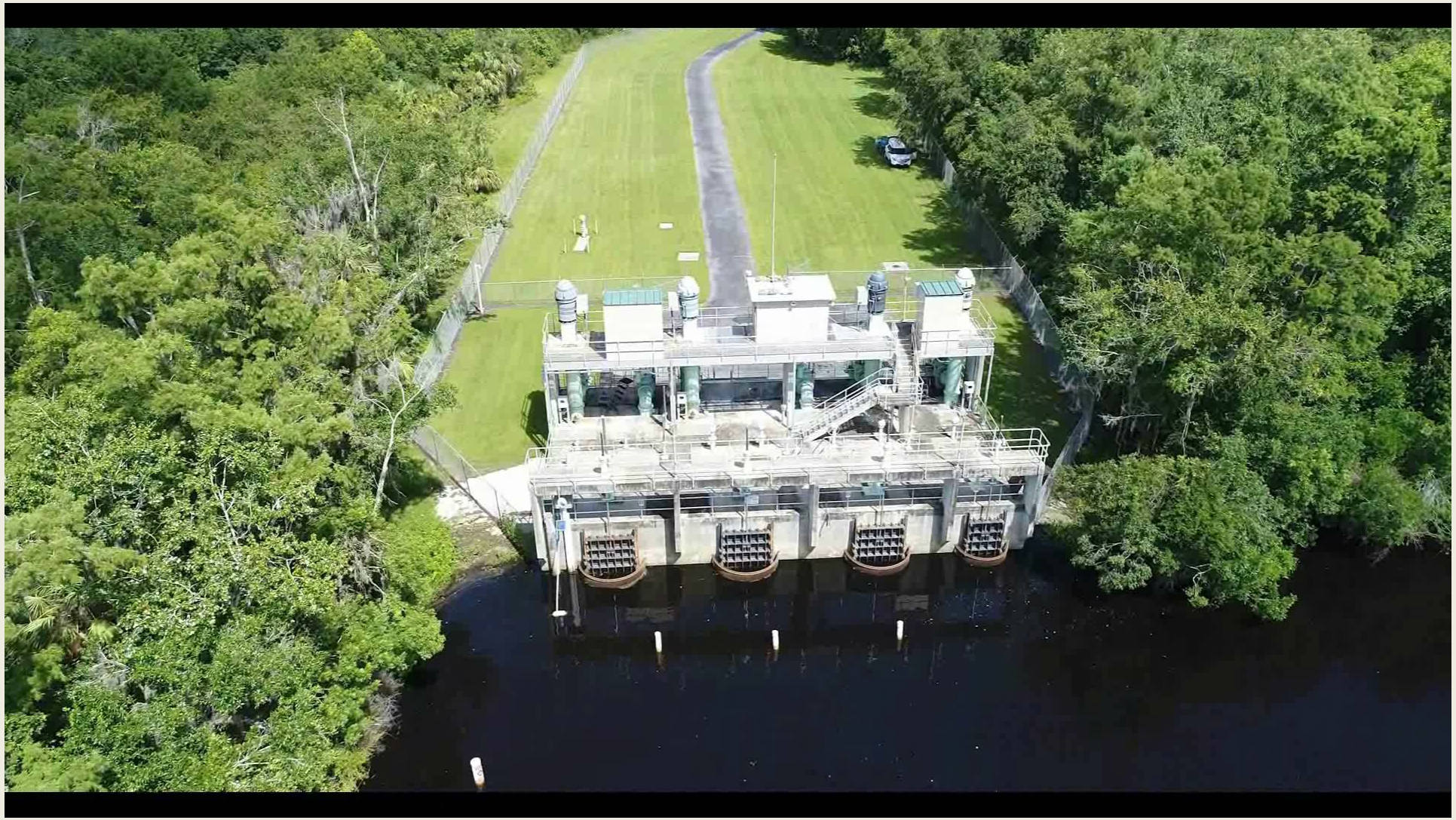
Peace River Manasota Regional Water Supply Authority

Session 20
Best Practices in Climate Adaptation: Case Studies from Florida's Water Utilities

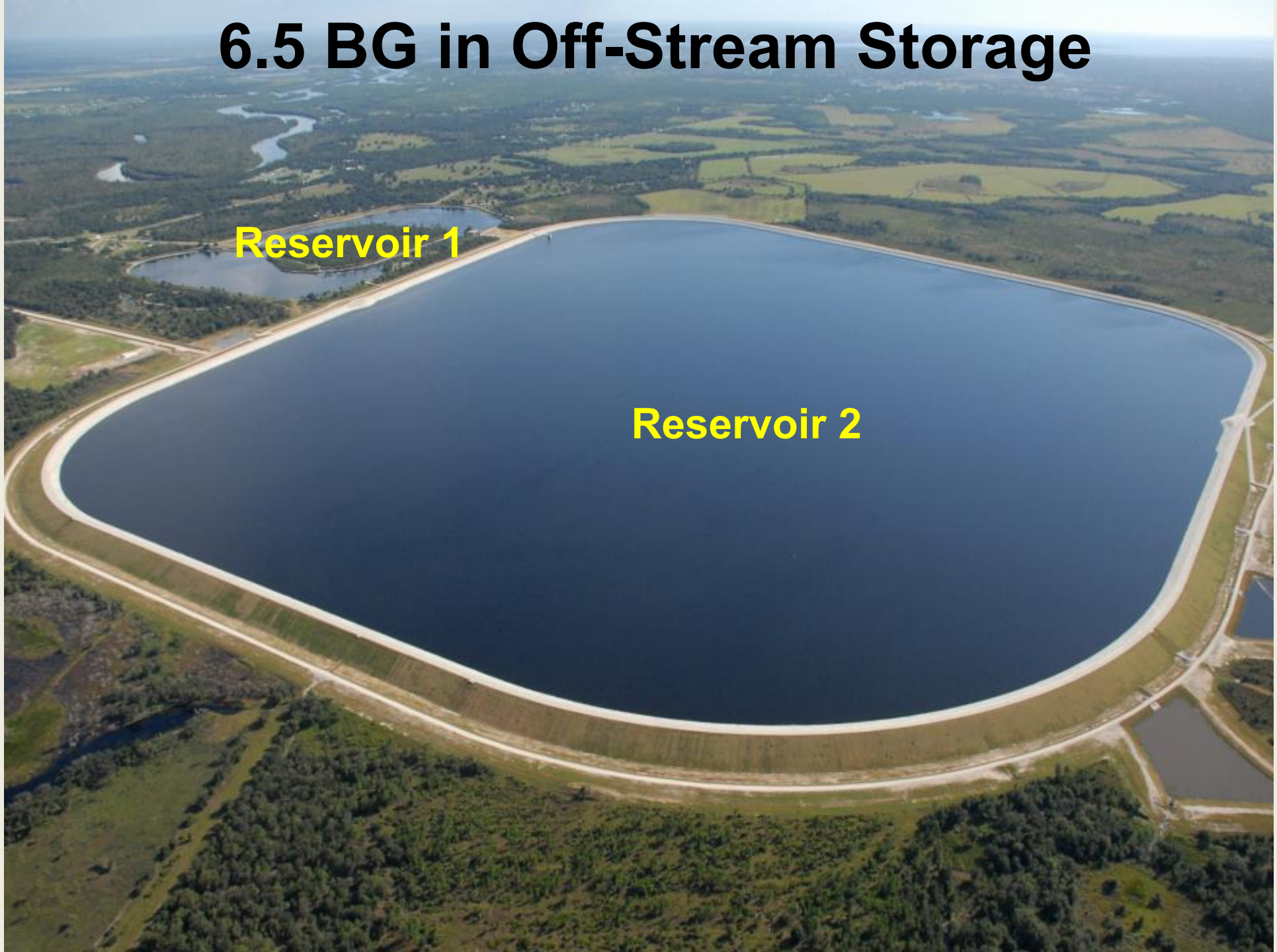
Gainesville, Florida
February 26, 2020

Kevin Morris

120 MGD River Intake Pump Station



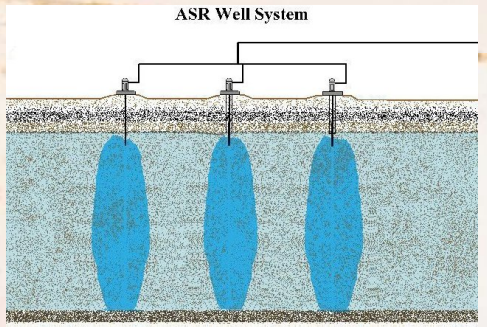
6.5 BG in Off-Stream Storage



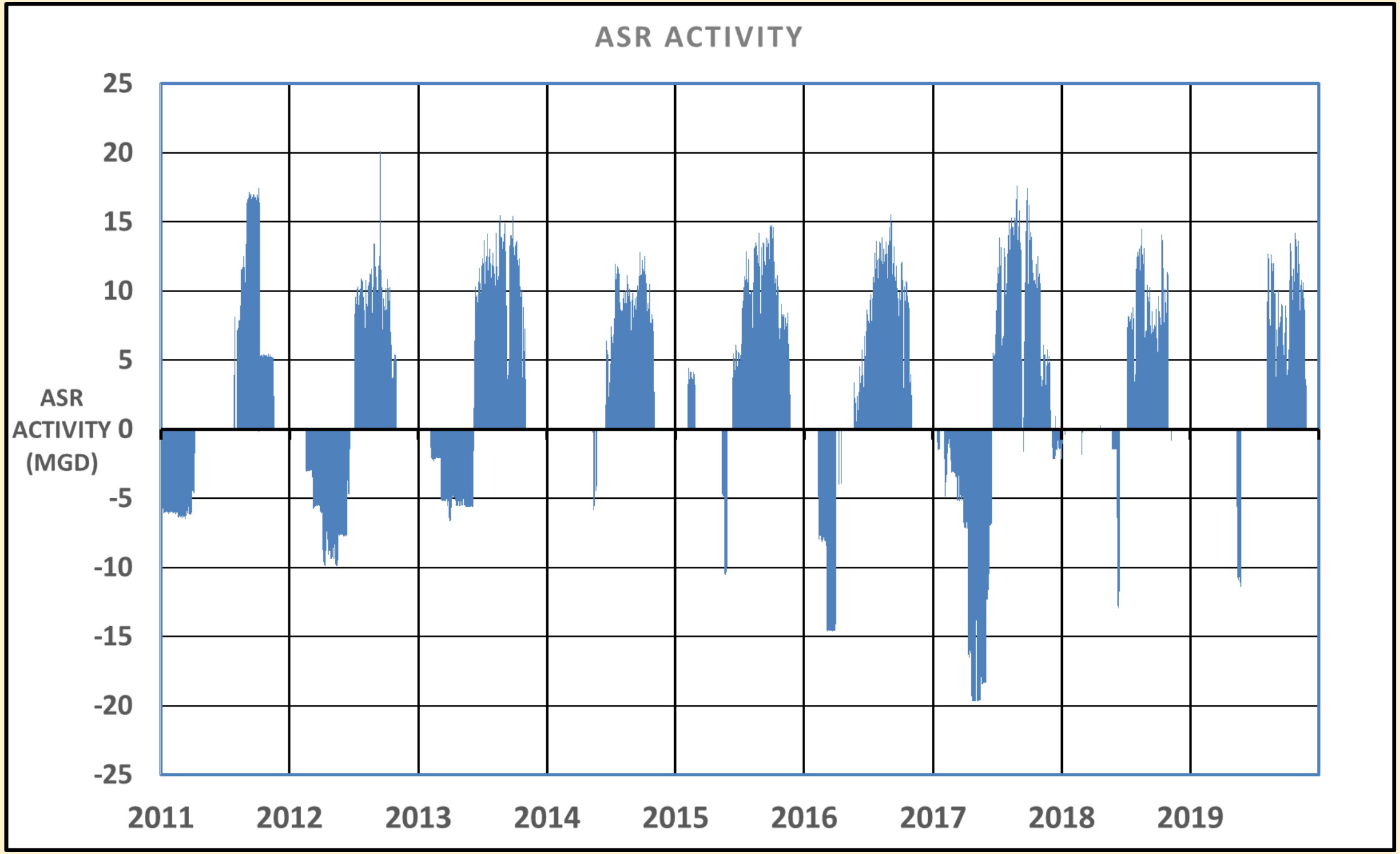
51 MGD Treatment Capacity

7 BG in Underground Storage

21 Finished Water ASR Wells



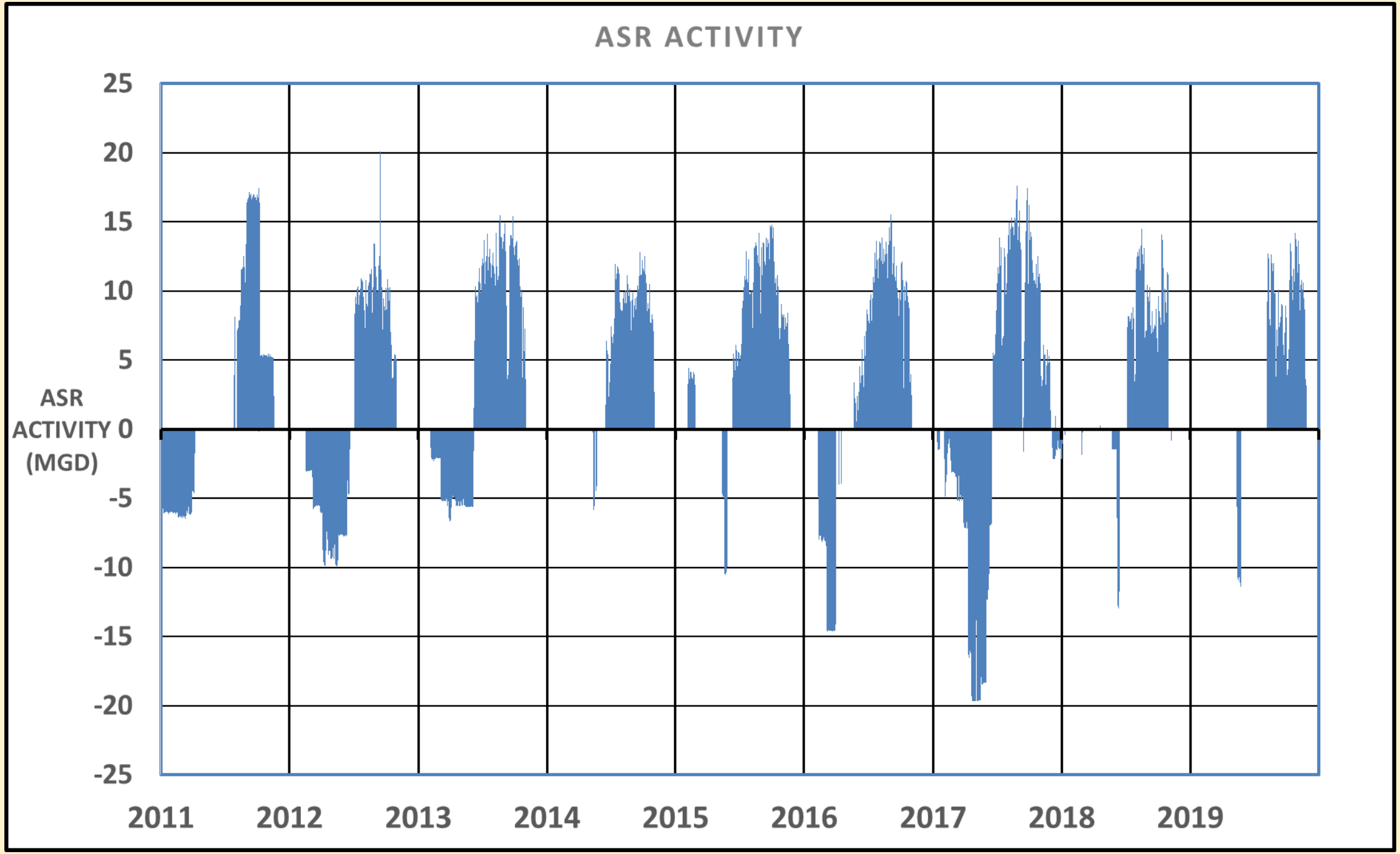

ASR RESERVES
ASR RESERVES (BG)
12
10
8
6
4
2
0
2011
2012
2013
2014
2015
2016
2017
2018
2019


ASR ACTIVITY
25
20
15
10
5
0
-5
-10
-15
-20
-25
ASR ACTIVITY (MGD)
2011
2012
2013
2014
2015
2016
2017
2018
2019

Summary of ASR Recovery Cycles 2011-2019

Year	Recovery Started	Recovery Ended	Duration (days)	Average Rate of Recovery (MGD)	Maximum Rate of Recovery (MGD)	Total Withdrawal (MG)	Major Events (> 100 days & > 500 MG)
2011	1/5/2011	4/7/2011	93	5.64	6.48	524	no
2012	2/15/2012	6/19/2012	126	6.43	9.92	810	**yes**
2013	2/4/2013	6/5/2013	122	4.35	6.70	530	**yes**
2014	5/11/2014	5/22/2014	12	2.44	5.88	29	yes
2015	5/12/2015	5/26/2015	15	7.54	10.55	113	no
2016	2/9/2016	3/30/2016	51	10.41	14.64	531	no
2017	2/1/2017	6/15/2017	135	9.72	19.71	1,312	**yes**
2018	5/22/2018	6/13/2018	23	4.82	12.95	111	no
2019	5/13/2019	5/24/2019	12	9.64	11.39	116	no

Note: does not include some off-season recoveries for testing or sampling purposes.


ASR ACTIVITY
25
20
15
10
5
0
-5
-10
-15
-20
-25
ASR ACTIVITY (MGD)
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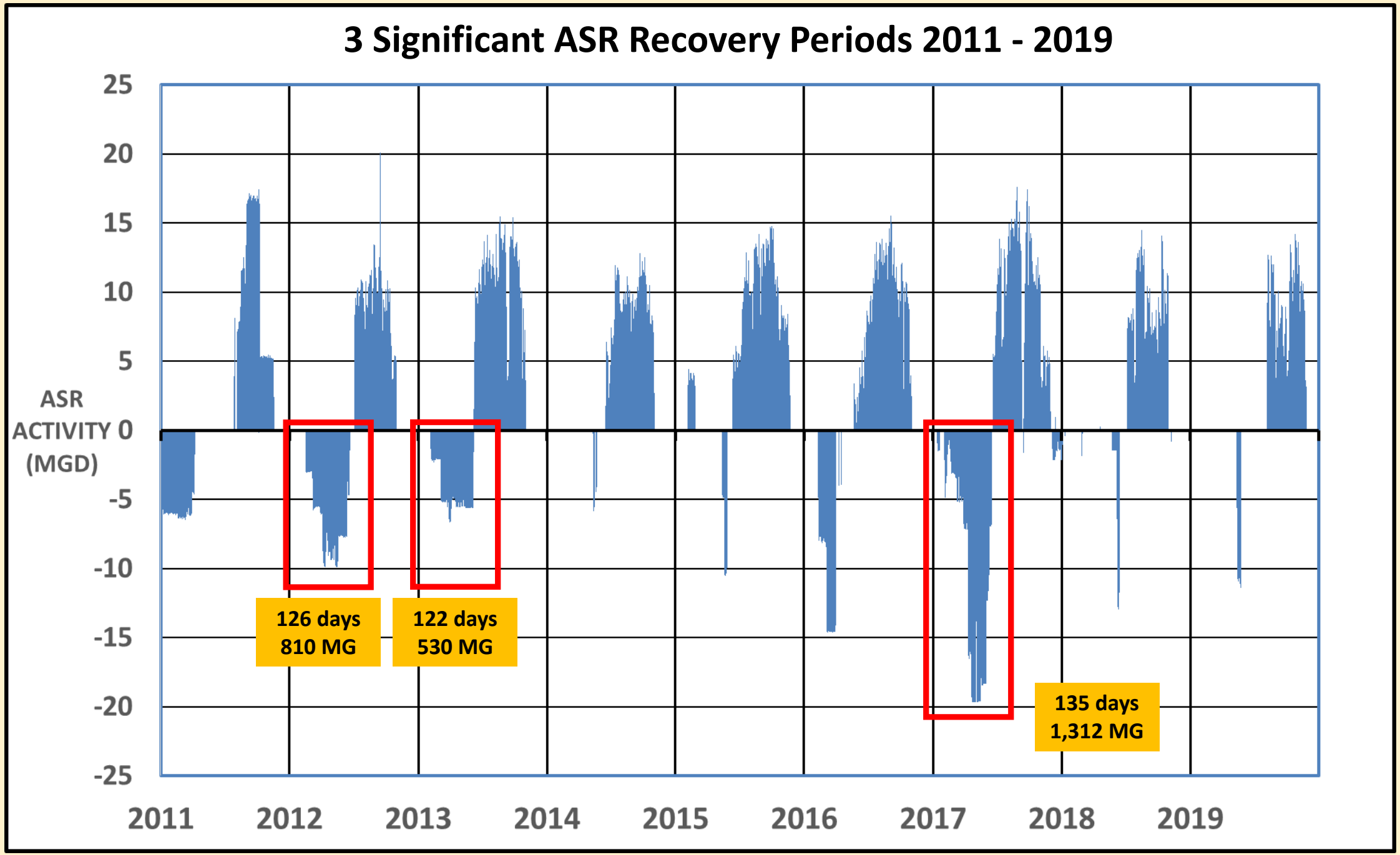
2012
2013
2014
2015
2016
2017
2018
2019


3 Significant ASR Recovery Periods 2011 - 2019
25
20
15
10
5
0
-5
-10
-15
-20
-25
ASR ACTIVITY (MGD)
2011
2012
2013
2014
2015
2016
2017
2018
2019
126 days
810 MG
122 days
530 MG
135 days
1,312 MG

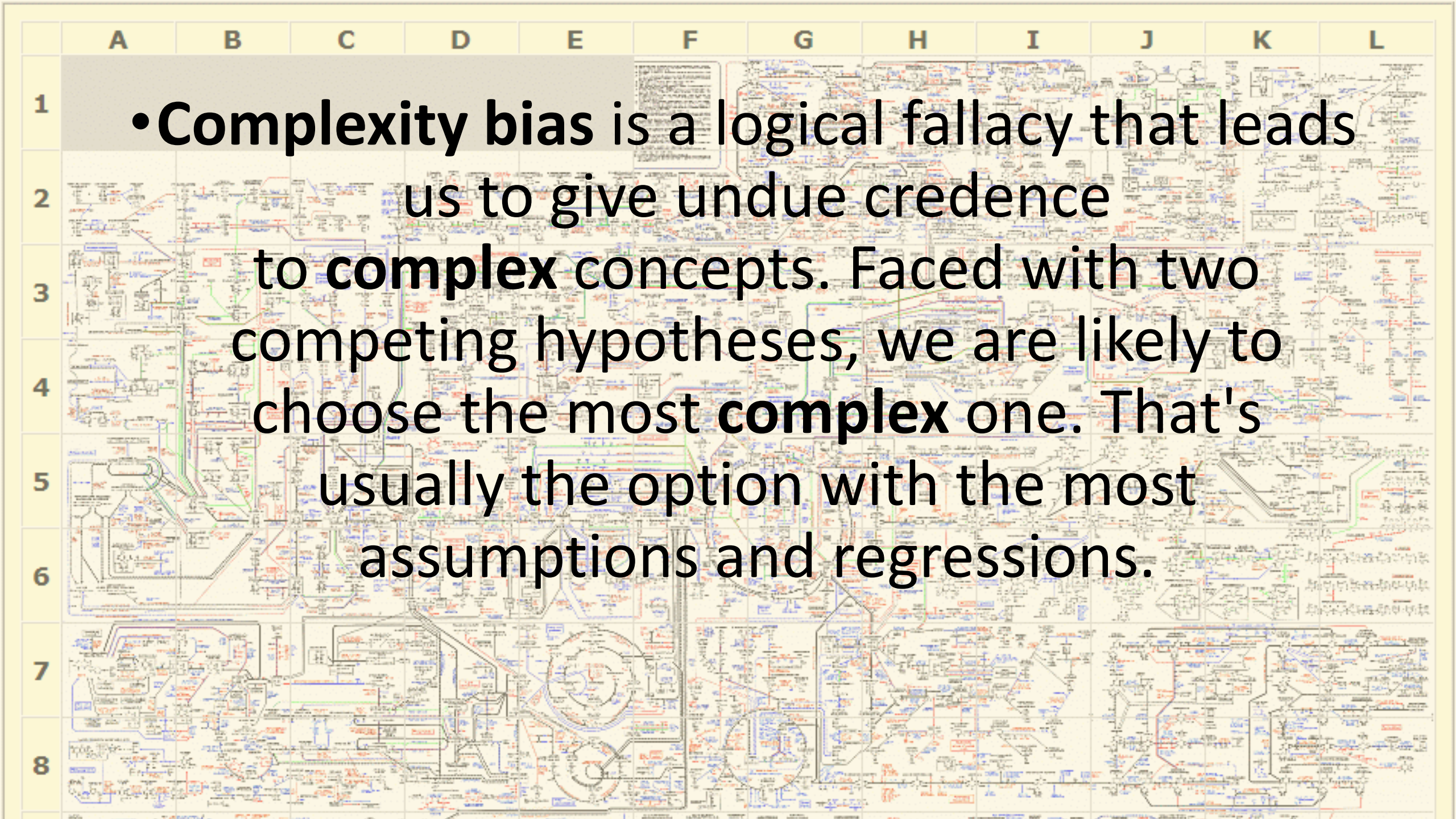
Why the Timing of ASR Recovery Matters

- **If we start too soon**
  - Added cost
  - Water quality from ASR will degrade the longer you pump
  - “Clearer” water in reservoirs increases risk of algae blooms
- **If we start too late**
  - Risk running out of water
  - May have to pump harder, can lead to upconing of saline water
  - Less surface water to dilute groundwater minerals

Balance is important

Possible Variables Considered

- River Flow
- Keech Byram Drought Index
- Time of Year (month)
- Customer Demands
- Climate Prediction Center
  - 1 Month Precip Forecast
  - 1 Month Temp Forecast
  - 3 Month Precip Forecast
  - 3 Month Temp Forecast
- Raw Water Reserves
- ASR Reserves
- Oceanic Nino Index
- Atlantic Multidecadal Oscillation


A B C D E F G H I J K L
1 2 3 4 5 6 7 8
•Complexity bias is a logical fallacy that leads us to give undue credence to complex concepts. Faced with two competing hypotheses, we are likely to choose the most complex one. That's usually the option with the most assumptions and regressions.

Only These 3 Variables Competently Predicted Need for ASR Recovery

- River Flow
- Keech Byram Drought Index
- Raw Water Reserves
- Time of Year (month)
- Customer Demands
- Climate Prediction Center
  - 1 Month Precip Forecast
  - 1 Month Temp Forecast
  - 3 Month Precip Forecast
  - 3 Month Temp Forecast
- ASR Reserves
- Oceanic Nino Index
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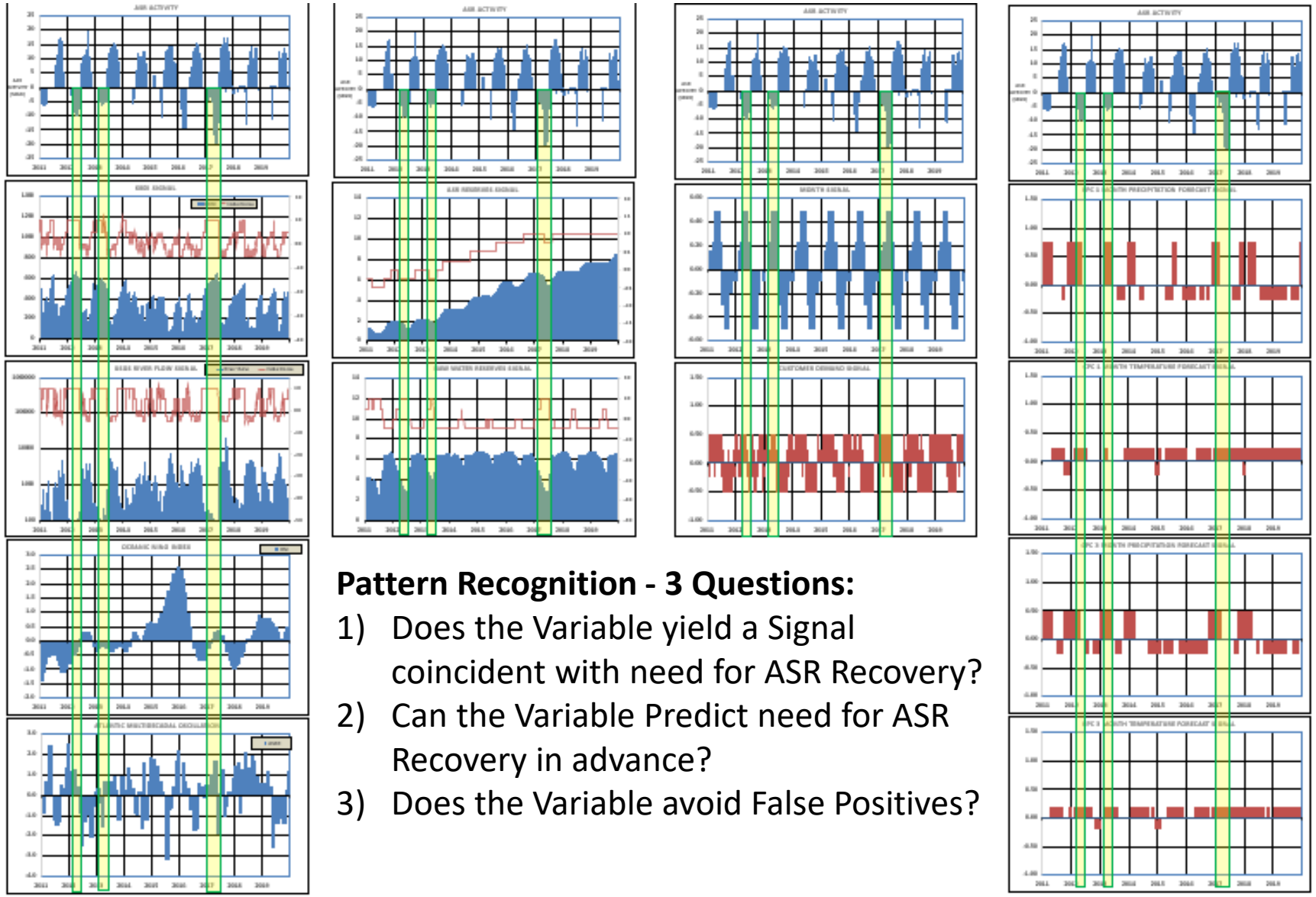


Pattern Recognition - 3 Questions:

1) Does the Variable yield a Signal coincident with need for ASR Recovery?
2) Can the Variable Predict need for ASR Recovery in advance?
3) Does the Variable avoid False Positives?

Relative Skill of Indicators

Coincident with the Need for ASR Recovery

Indicator	Recovery of 2012	Recovery of 2013	Recovery of 2017
Month	+	+	+
Customer Demands	+	+	+
CPC 3 Month Temperature Outlook	+	+	+
Raw Water Reserves	+	+	+
KBDI	+	+	+
River Flow	+	+	+
ONI	+	+	0
CPC 1 Month Temperature Outlook	+	0	+
AMO	-	+	-
CPC 1 Month Precipitation Outlook	-	-	0
ASR Reserves	-	-	-
CPC 3 Month Precipitation Outlook	-	-	-

strong agreement	+
neutral	0
disagreement	-

Making contact with the ball

swing and miss

Relative Skill of Indicators As a Predictor in Advance of the Need for ASR Recovery

Indicator	Recovery of 2012	Recovery of 2013	Recovery of 2017
Month	+	+	+
Raw Water Reserves	+	+	+
KBDI	+	+	+
River Flow	+	+	+
ONI	+	+	+
CPC 1 Month Temperature Outlook	+	0	+
CPC 3 Month Temperature Outlook	+	0	+
Customer Demands	+	-	+
CPC 1 Month Precipitation Outlook	-	0	-
ASR Reserves	-	-	-
AMO	-	-	-
CPC 3 Month Precipitation Outlook	-	-	-

strong agreement	+
neutral	0
disagreement	-

fair ball

foul ball

Relative Skill of Indicators as an Exclusive Predictor of the Need for ASR Recovery

Indicator	Recovery of 2012	Recovery of 2013	Recovery of 2017	Is the Indicator an Exclusive Predictor? (*does not yield false signals*)
Raw Water Reserves	+	+	+	+
KBDI	+	+	+	+
River Flow	+	+	+	+
Month	+	+	+	-
ONI	+	+	+	-
CPC 1 Month Temperature Outlook	+	0	+	-
CPC 3 Month Temperature Outlook	+	0	+	-
Customer Demands	+	-	+	-
CPC 1 Month Precipitation Outlook	-	0	-	-
ASR Reserves	-	-	-	-
AMO	-	-	-	-
CPC 3 Month Precipitation Outlook	-	-	-	-

strong agreement	+
neutral	0
disagreement	-

Home run

Any other outcome

A Competent Predictive Model Should be Composed of Balanced Signal Responses

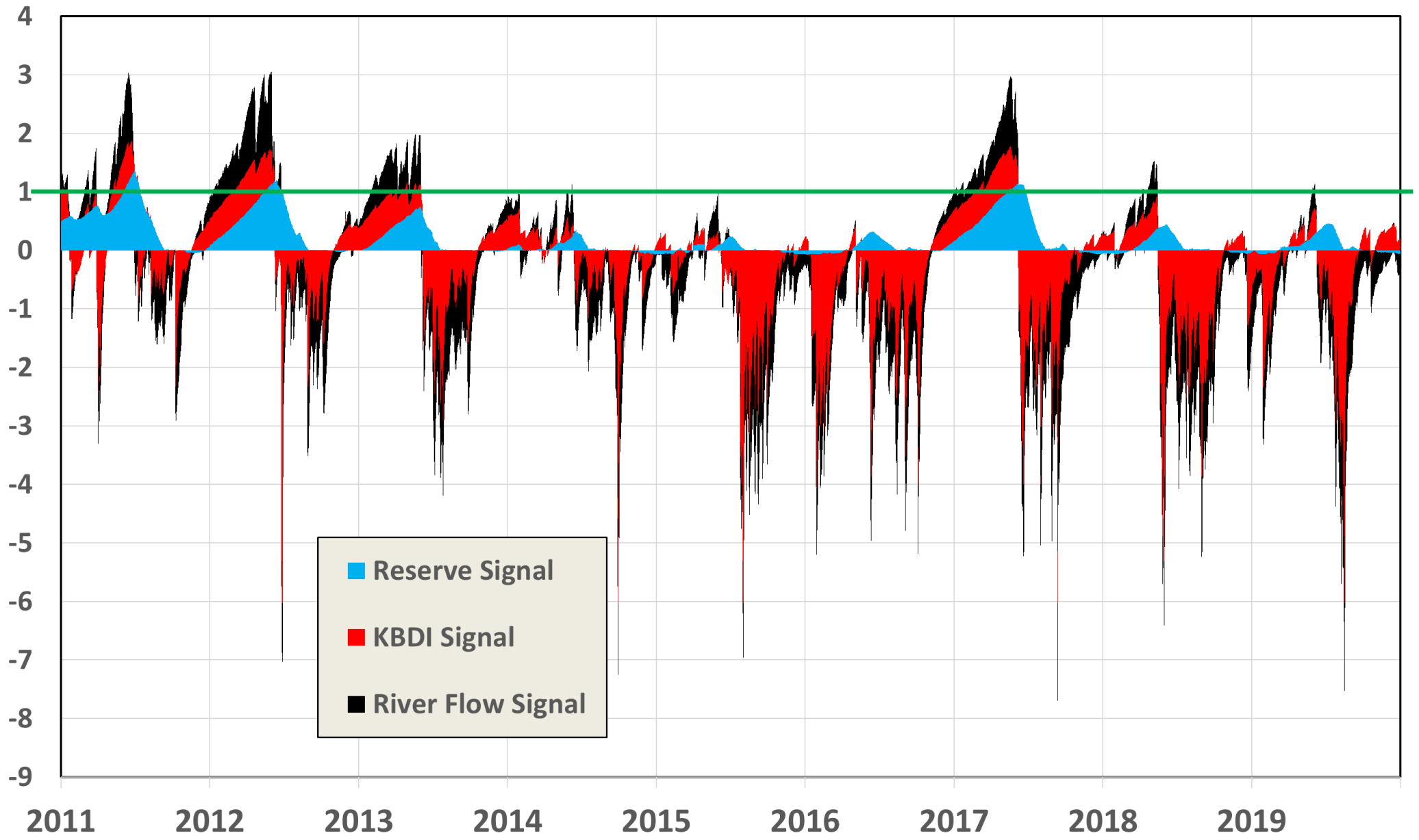
- 3 Additive Components: **River Flow$_{Signal}$** + **KBDI$_{Signal}$** + **Reserves$_{Signal}$**
- Goal = Sum of Components Signal > 1 When ASR Recovery is Needed
- **River Flow Signal**: $Flow_{river} = 1.05*\log_{10}[1/(Q_{river}/250))]$

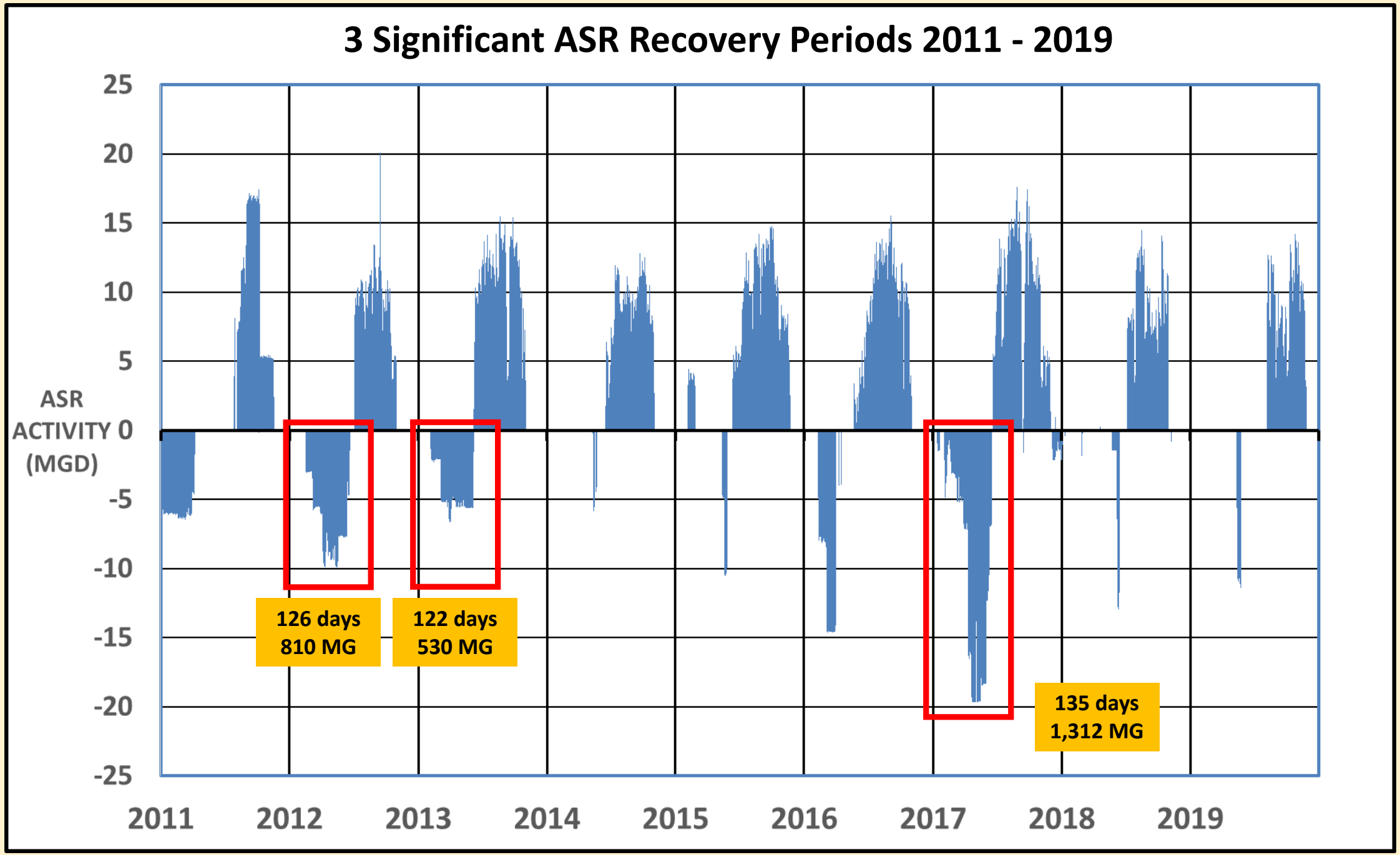
  yields 0.33 @ 122 cfs River Flow$_{USGS\ Gauge\ at\ Arcadia}$
- **KBDI Signal**: $ASR_{KBDI} = 1.2*\log_{10}[(KBDI/325)^2]$ yields

  yields 0.33 @ 445 KBDI$_{Myakka\ River\ Fire\ District}$
- **Raw Water Reserve Signal**: $ASR_{raw} = 3.0*\log_{10}[1/(Reserves/6.5)]$

  yields 0.33 @ 5.05 BG in Raw Water Reserves

ASR Recovery Index

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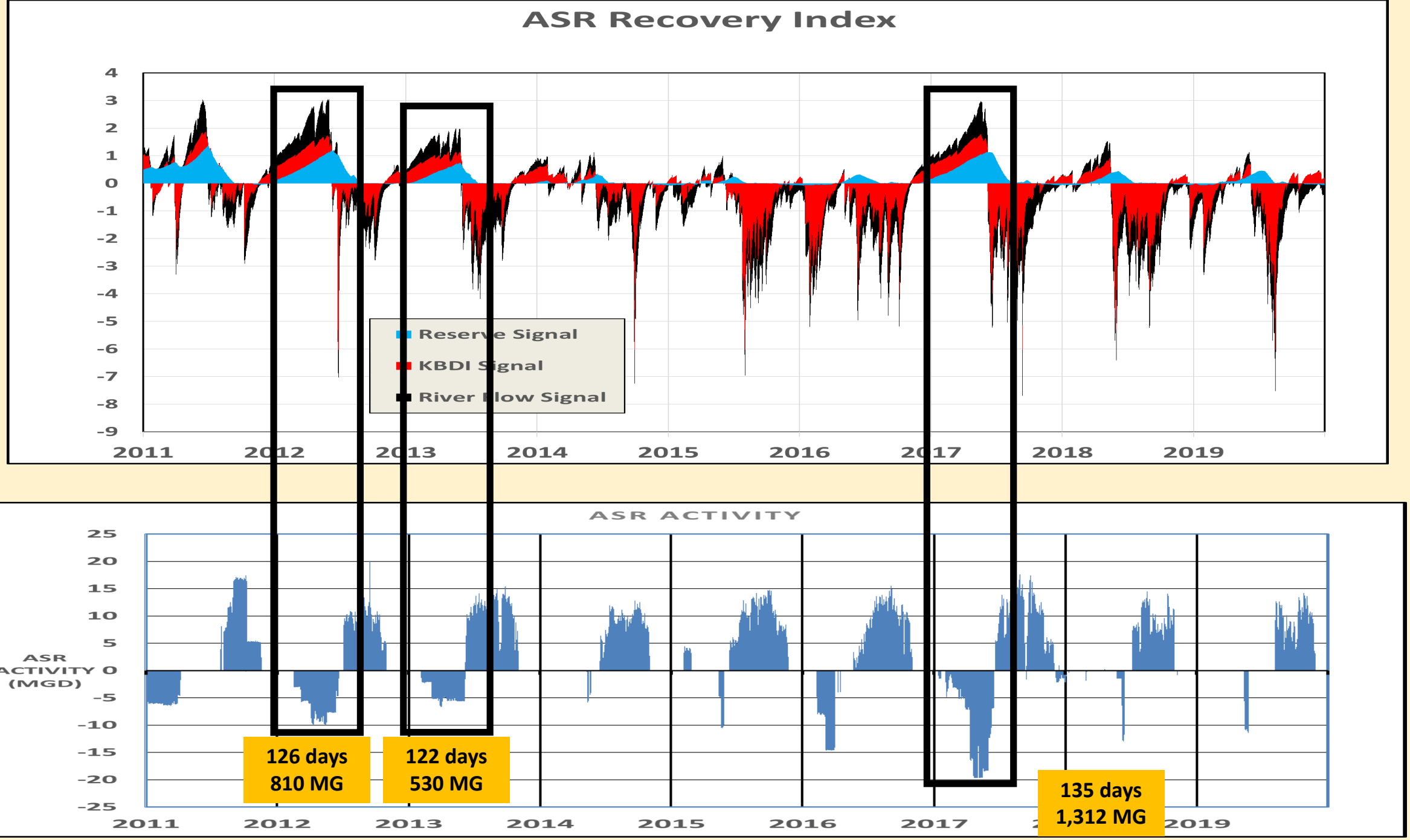
ASR Recovery Index
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
2011
2012
2013
2014
2015
2016
2017
2018
2019
Reserve Signal
KBDI Signal
River Flow Signal
ASR ACTIVITY
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20
15
10
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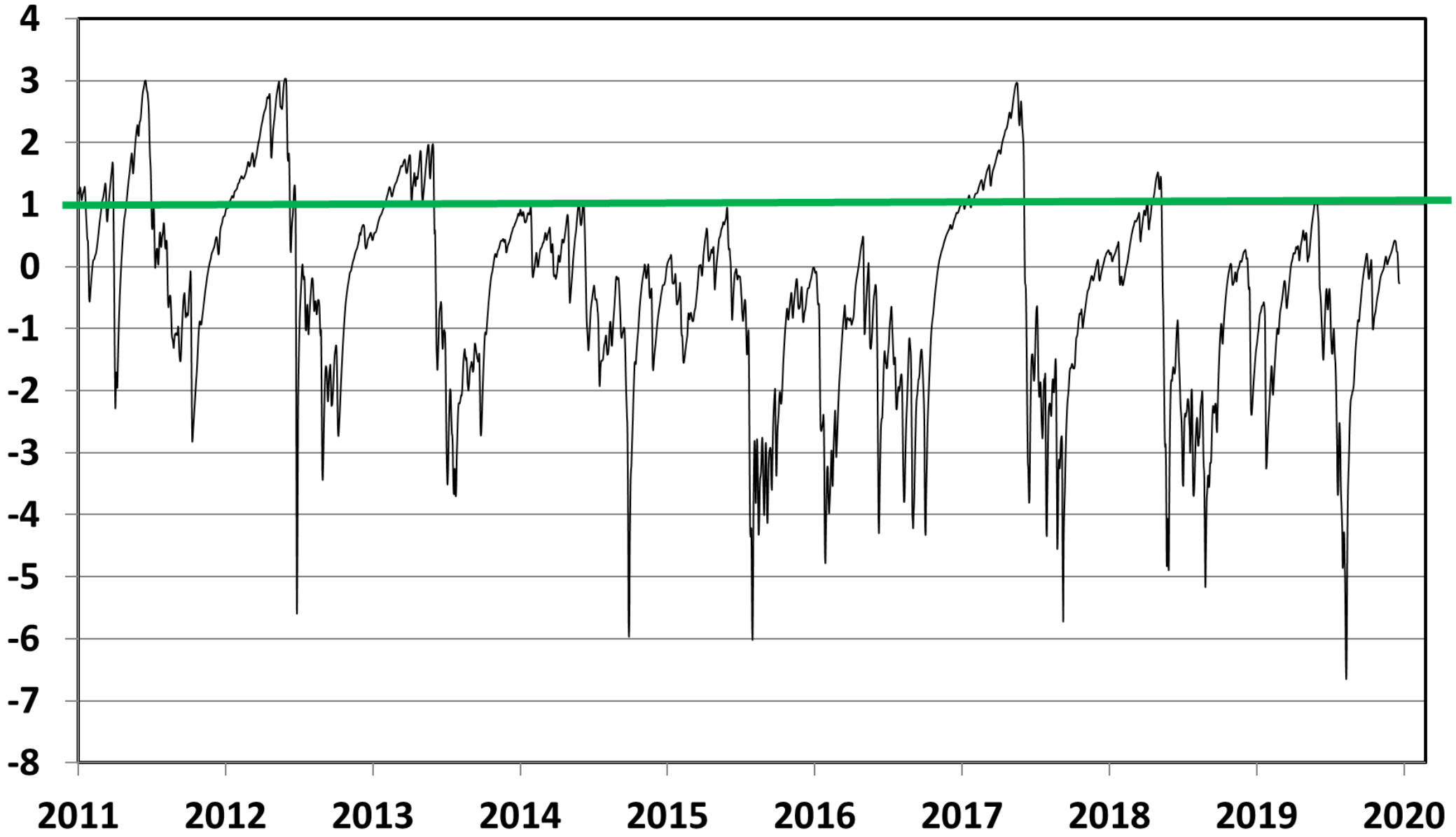
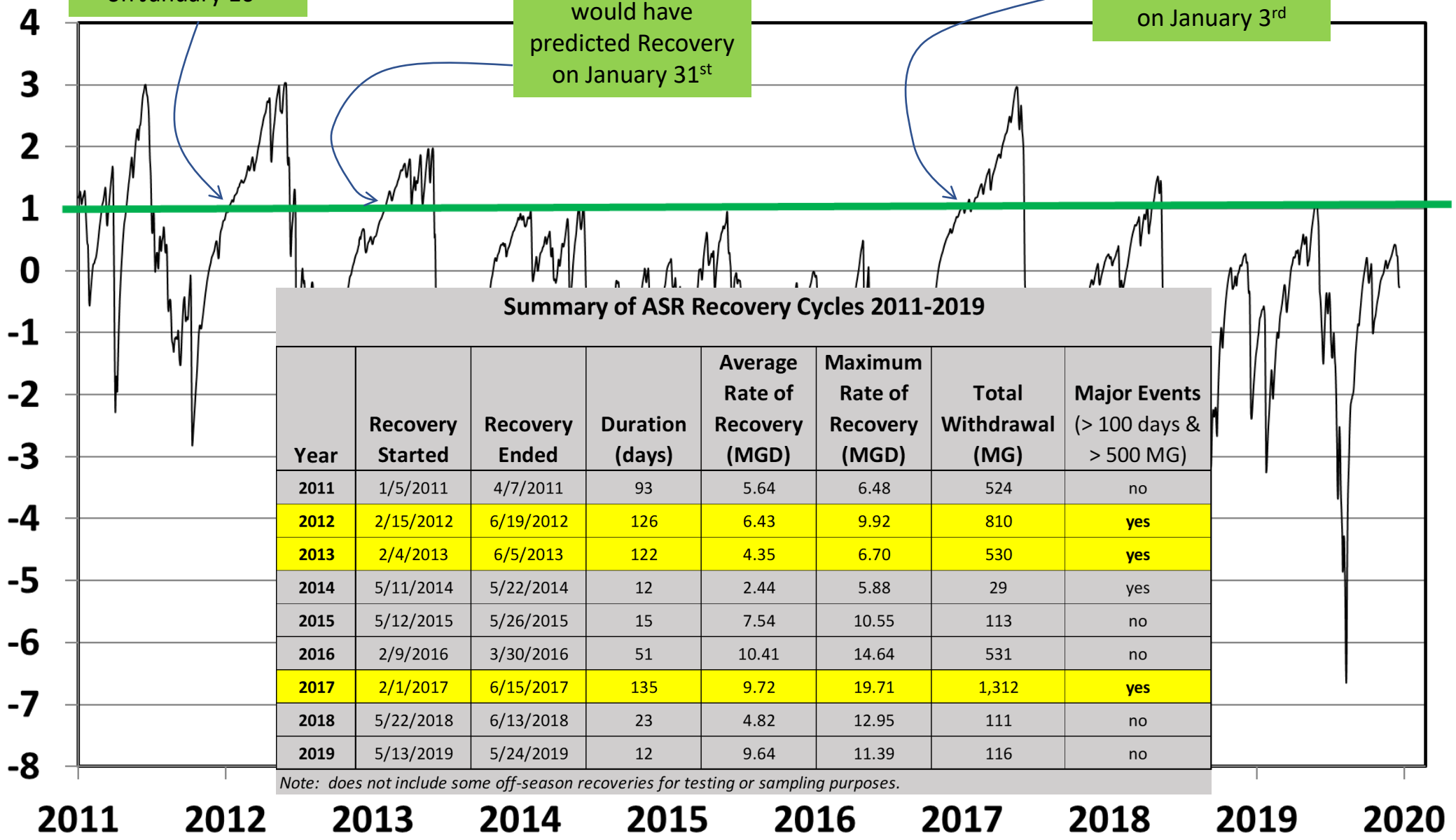


ASR Recovery Index

In 2012 ASRRI would have predicted Recovery on January 10th

In 2013 ASRRI would have predicted Recovery on January 31st

In 2017 ASRRI would have predicted Recovery on January 3rd



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Wrap Up

- Additional complexity is not always an improvement
- Not an Indictment of Accuracy for Variables excluded from ASRRI
- Thoughtfully constructed Pattern Recognition Exercises are valuable
- The ASRRI is only one Decision Support Tool
- Is there still Confirmation Bias?
- ASRRI warrants additional thought & development
- Looking forward - KBDI (Soil Moisture) via satellite measurements

Acknowledgements

- Tyler Gregan/PRMRWSA
- Brian Williams/FDACS
- Florida Water and Climate Alliance