Collaborative Modelling of the Bear River

Jake Serago, *Utah Division of Water Resources*
Connely Baldwin, *PacifiCorp*
David Hoekema, *Idaho Department of Water Resources*
Samantha Schwartz, *Wyoming State Engineer's Office*
David Neumann, *CADSWES*

RiverWare Users Workshop
2023
Boulder, Colorado

UTAH DNR WATER RESOURCES

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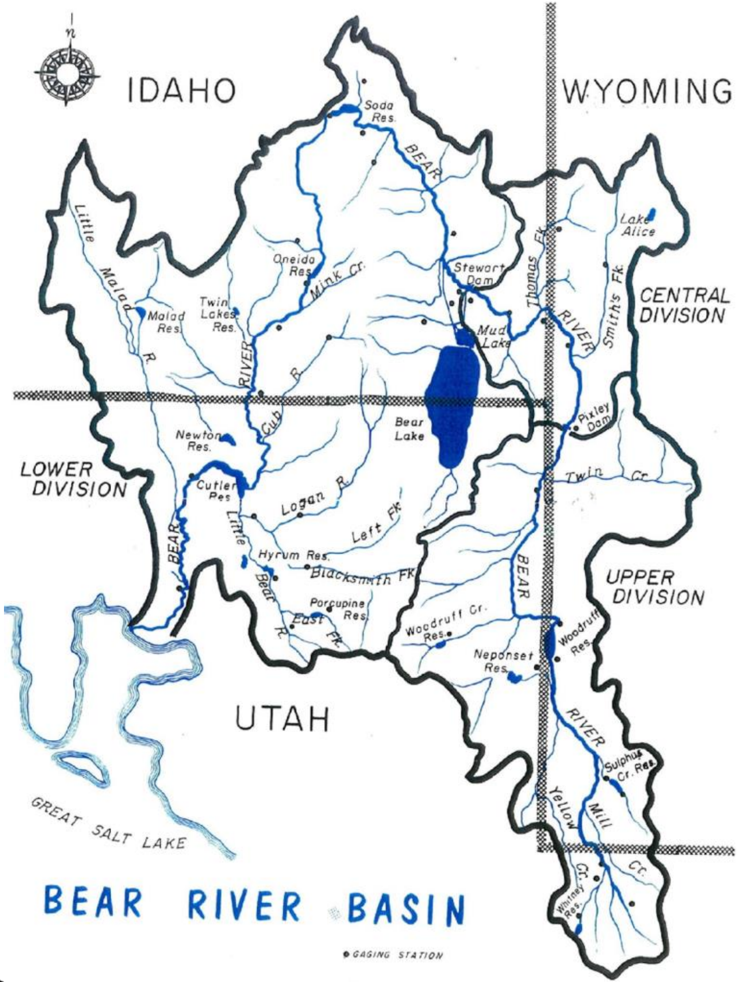

Bear River Watershed

- 7,500 mi^2 area mountain and valley lands
- 500 mi stream length
- 5 state boundary crossings
- 5 hydropower plants
- Private mainstem infrastructure
- Elevation range from 4,211 to 13,000 ft
- Annual precipitation 11 to 55 inches per
- Most precipitation falls as snow
- Largest tributary to GSL
- 150,000 acres of cropland
- Land-use:

	Range Land	48.85 %
	Agriculture	18.36 %
	Forest Land	18.02 %
	Water	10.21 %
	Wetlands	4.22 %
	Urban / Built Up Land	0.32 %
	Barren Land	0.02 %

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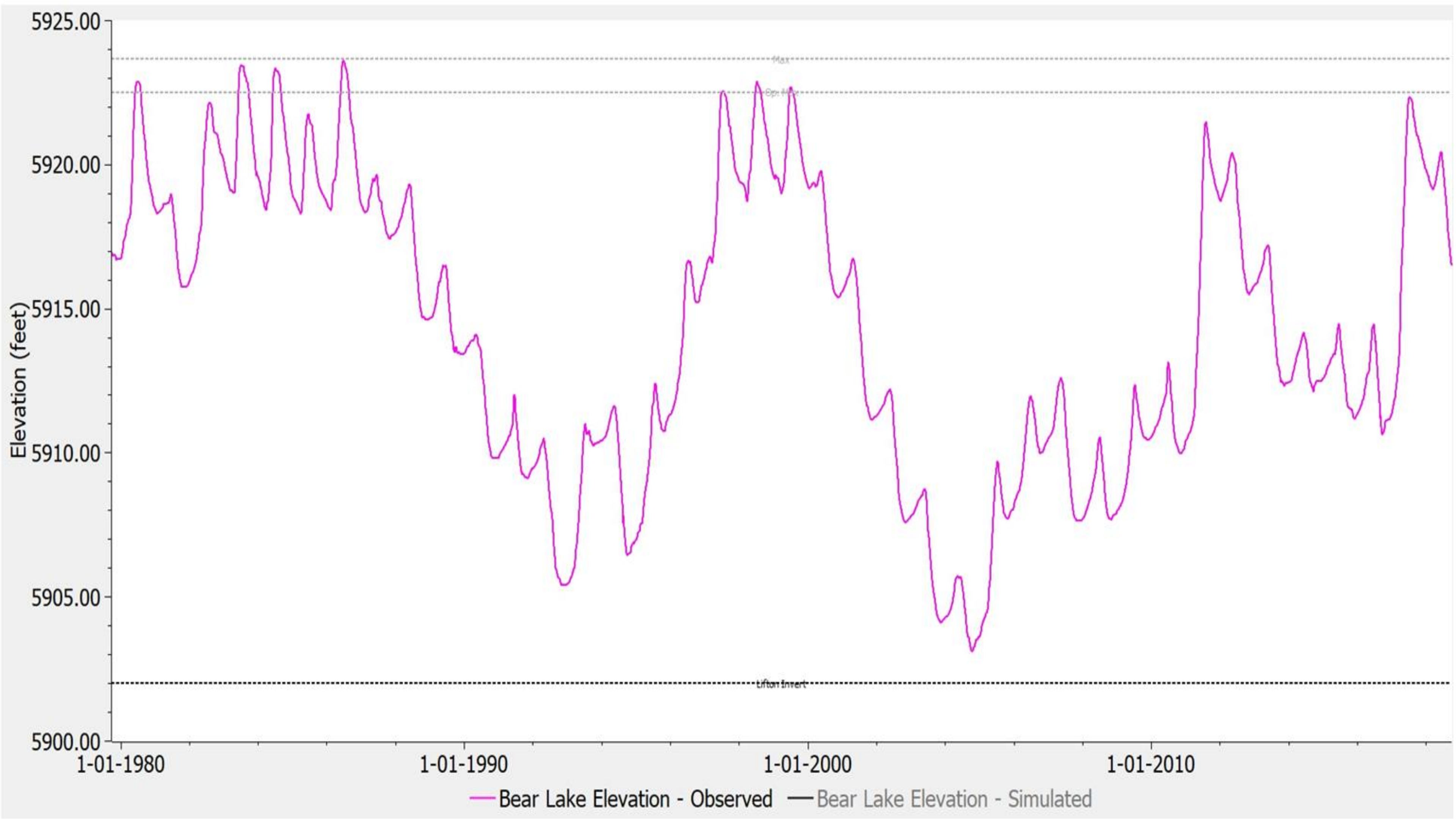
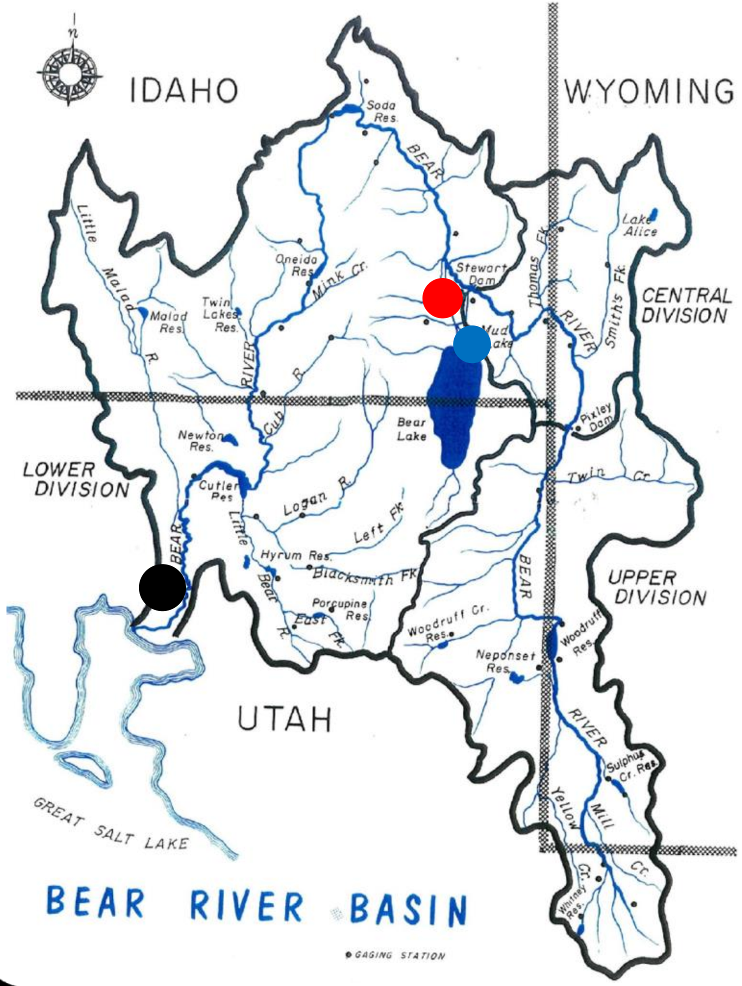
Bear Lake

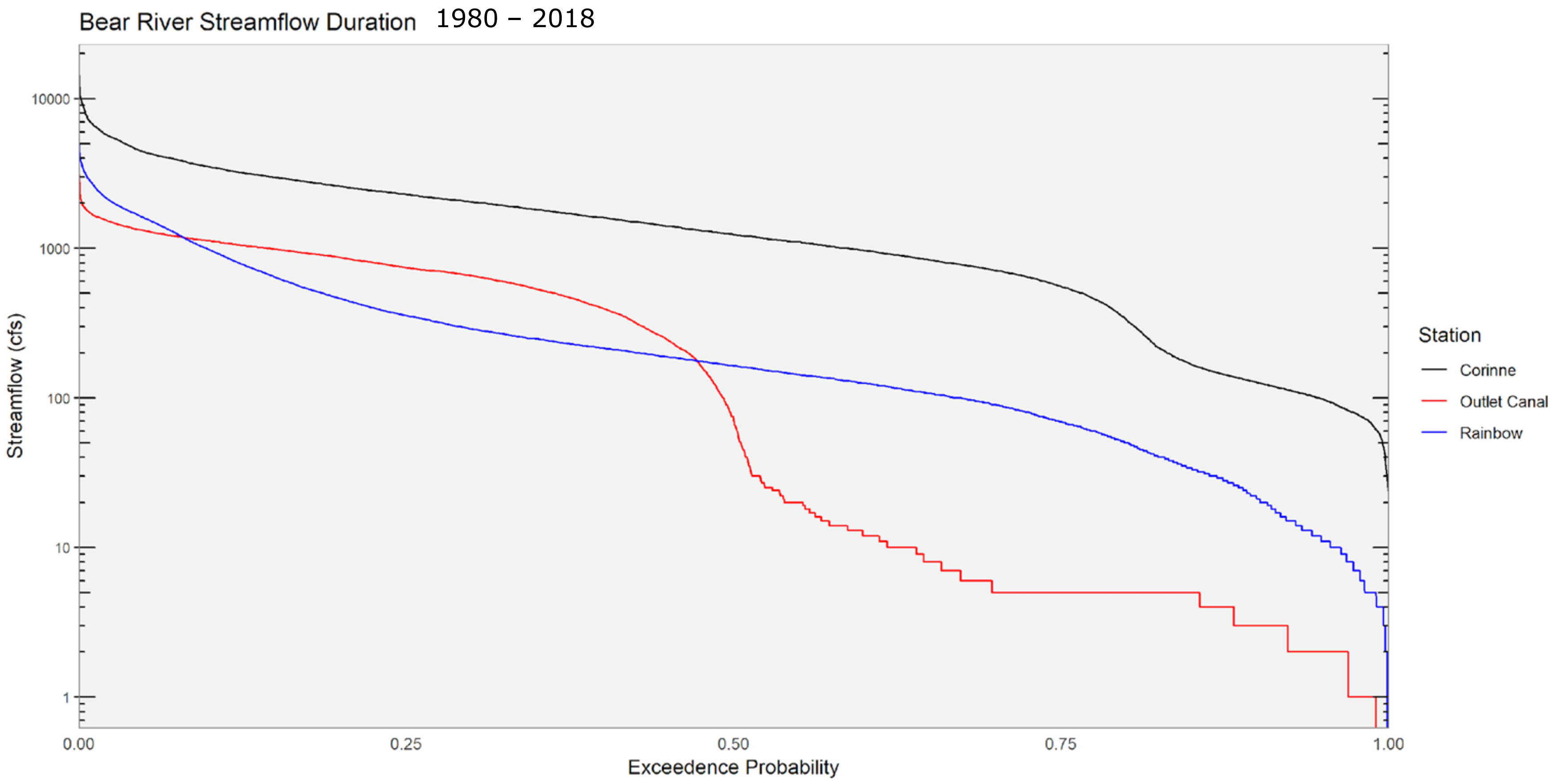
- Caribbean of the Rockies
- Natural water body
- 11,000-year disconnection
- Reconnected 1911
- Operated by private power company
- Off-stream reservoir
- Wetland flowthrough (USFWS)
- Storage contracts
- **Primary**: irrigation & flood control
- **Secondary**: hydropower
- Active operational storage range
  - 21 feet
  - 1.4 MAF

UTAH DNR WATER RESOURCES


5925.00
5920.00
5915.00
5910.00
5905.00
5900.00
Elevation (feet)
Max
Opt Max
Lifton Invert
1-01-1980
1-01-1990
1-01-2000
1-01-2010
Bear Lake Elevation - Observed
Bear Lake Elevation - Simulated

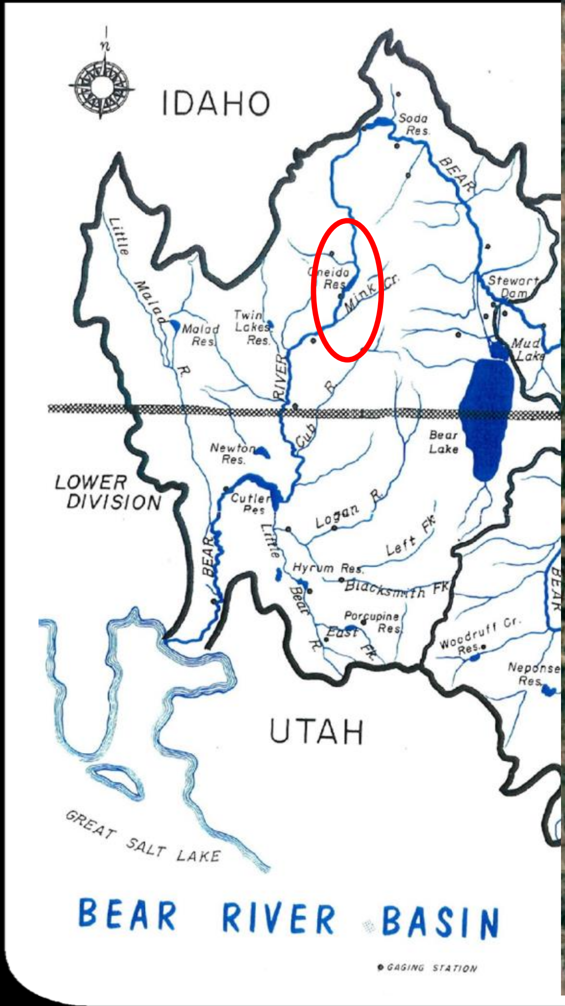
Bear River Watershed

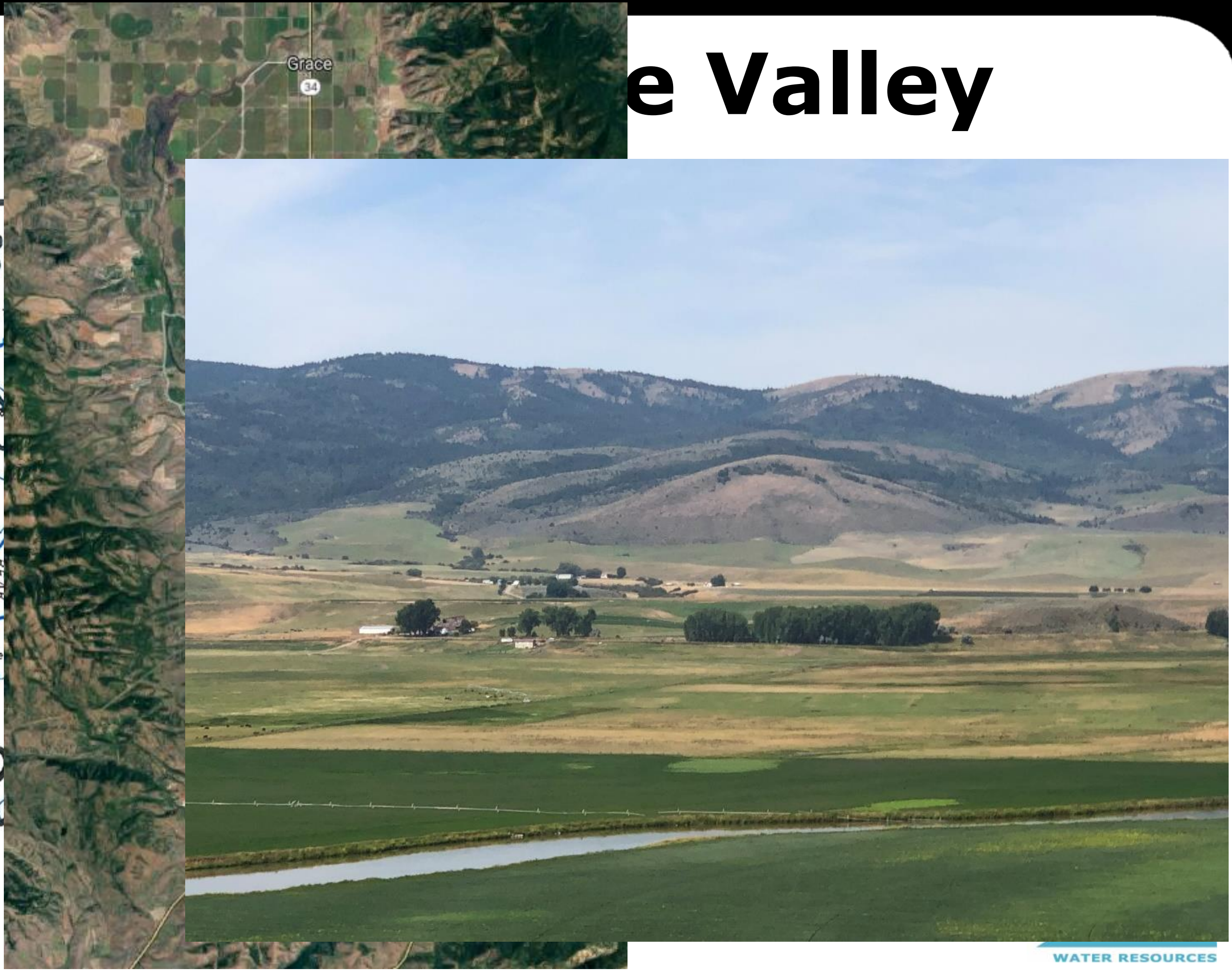




Bear River Streamflow Duration 1980 – 2018
10000
1000
100
10
1
Streamflow (cfs)
0.00
0.25
0.50
0.75
1.00
Exceedence Probability
Station
Corinne
Outlet Canal
Rainbow
WATER RESOURCES

e Valley





WATER RESOURCES

Collaboration

The cooperative nature of the various enterprises essential to settling the Great Basin was made possible by a … synthesis of the inevitable tension between self and society.

- Leonard Arrington, historian

UTAH DNR WATER RESOURCES

Compact Approach – Bear River

1946: Congress consented to tri-state negotiation

1958: Bear River Compact signed and Bear River Commission formed

UTAH DNR WATER RESOURCES

Compact Approach – Bear River

1946: Congress consented to tri-state negotiation

1958: Bear River Compact signed and Bear River Commission formed

AMENDED BEAR RIVER COMPACT

The State of Idaho, the State of Utah and the State of Wyoming, acting through their respective Commissioners after negotiations participated in by a representative of the United States of America appointed by the President, have agreed to an Amended Bear River Compact as follows:

ARTICLE I

A. The major purposes of this Compact are to remove the causes of present and future controversy over the distribution and use of the waters of the Bear River; to provide for efficient use of water for multiple purposes; to permit additional development of the water resources of Bear River; to promote interstate comity; and to accomplish an equitable apportionment of the waters of the Bear River among the compacting States.

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Compact Approach – Bear River

1946: Congress consented to tri-state negotiation
1958: Bear River Compact signed and Bear River Commission formed
1968: Bear Lake National Wildlife Refuge operations agreement
1980: Amended Bear River Compact
1995: Bear Lake Settlement Agreement
2000: Operations Agreement between PacifiCorp, UT, ID and WY
2004: Amended and Restated Bear Lake Settlement Agreement
2019: Collaborative Modelling Process

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Collaborative Modelling Process

- Questions from decision makers
- Interpret operations
- Gather data
- Bi-weekly work sessions
- Interim sharing and communication
- Model versioning
- Consider future build-out
- CADSWES

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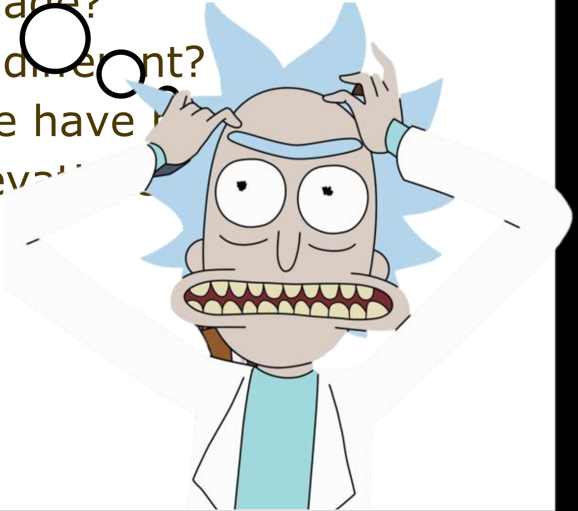
Process

CADSWES

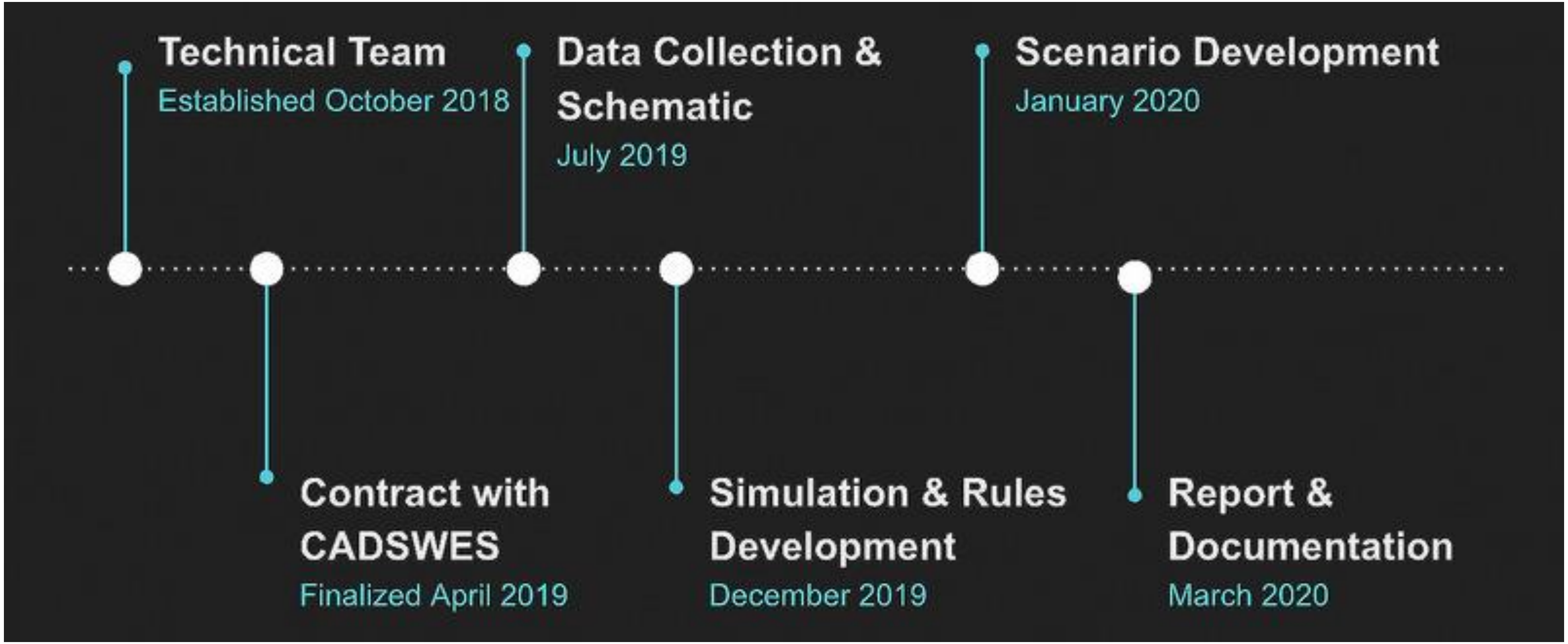
- Recommendations
- Specific Guidance
- BMP materials
- Prototyping
- Demonstrations
- Modeling foresight
- Model review
- Break up the fights

Study Objectives

- Develop a baseline condition … operations ruleset
- Change Bear Lake operation … ntify the:
  - How often could Bear Lake … er?
  - What volume of additional st… been possible?
  - What would have been the e… rage?
  - How would peak flows in Gentile … been di… nt?
  - What would the effects on inflow to Great Salt Lake have …
  - What would have been the effects on Mud Lake elev…



Schedule



Technical Team
Established October 2018
Contract with CADSWES
Finalized April 2019
Data Collection & Schematic
July 2019
Simulation & Rules Development
December 2019
Scenario Development
January 2020
Report & Documentation
March 2020

Process

Model versioning

Version	Date	Description of model/changes	Notes	Modeller	From Version	RiverWare Version
1.0.0	May 24 2019	Simulation mode entire lower division from 1996 - 2018,		JMS		7.3.2
1.0.1	May 24 2019	Rulebased using prototype rules set by DN		JMS	1.0.0	7.3.2
1.0.2	May 31 2019	Updated RiverWare version; Added object configuration for Grace power	Rulebased simulation model running. Rule 7 added to write available power diversion based on minimum downstream flow	JMS	1.0.1	7.4.4
1.0.3	Jun 7, 2019	Add Diversion and Reaches to the model	IDUT to Cutler Diversion still being added	ETG/DJH	1.0.2	7.4
1.0.4	June 6 2019	Changed object names (Bear, Mud, Outlet); added daily	Testing rules for Bear Lake. Structure of	JMS	1.0.2	7.5.0
1.0.5	June 14 2019	Updated RiverWare version; Added rules		JMS	1.0.4	7.5.0
1.0.6	June 14 2019	Added diversions and reach objects; included ID diversions		ETG	1.0.4	7.5.0
1.0.7	June 18 2019	Merged 1.0.5 and 1.0.6; updated rules	Rulebased simulation model running; rule refinement needed.	JMS	1.0.5 and 1.0.6	7.5.0
1.0.8	June 21,2019	Possible Irrigation Rules testing/exploring		CKB	1.0.7	7.5.0
1.0.9	June 24, 2019	Updated FC rules: modes, slots		JMS	1.0.7	7.5.0

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Input

- Historical streamflow observations
- Historical reservoir elevations
- Historical irrigation diversions
- April-July runoff forecasts
    - Perfect forecast
    - Blind
    - Historical NRCS water supply forecasts
- Stage-Storage tables
- Stage-Discharge index tables
- Operations

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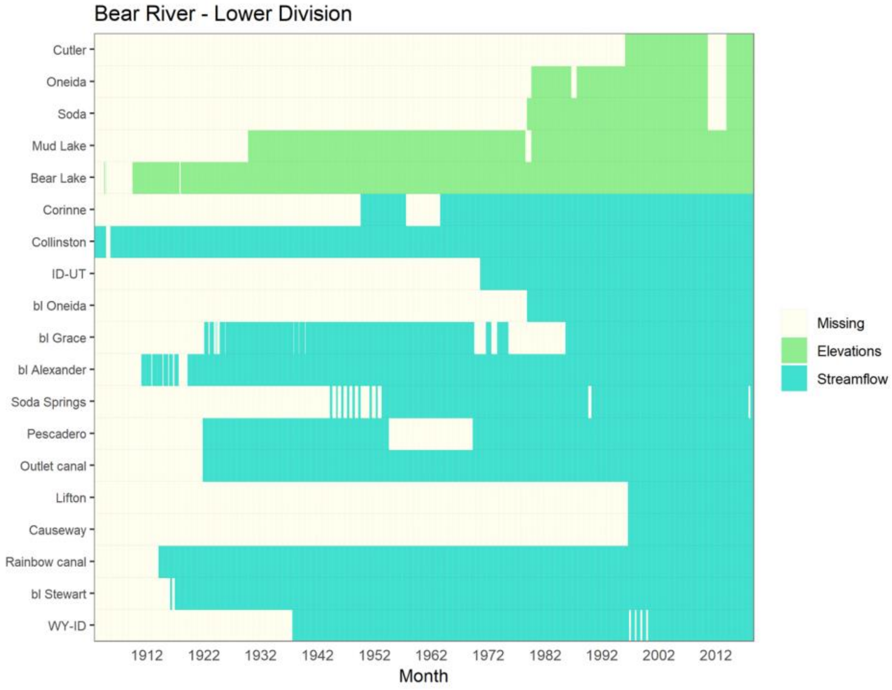
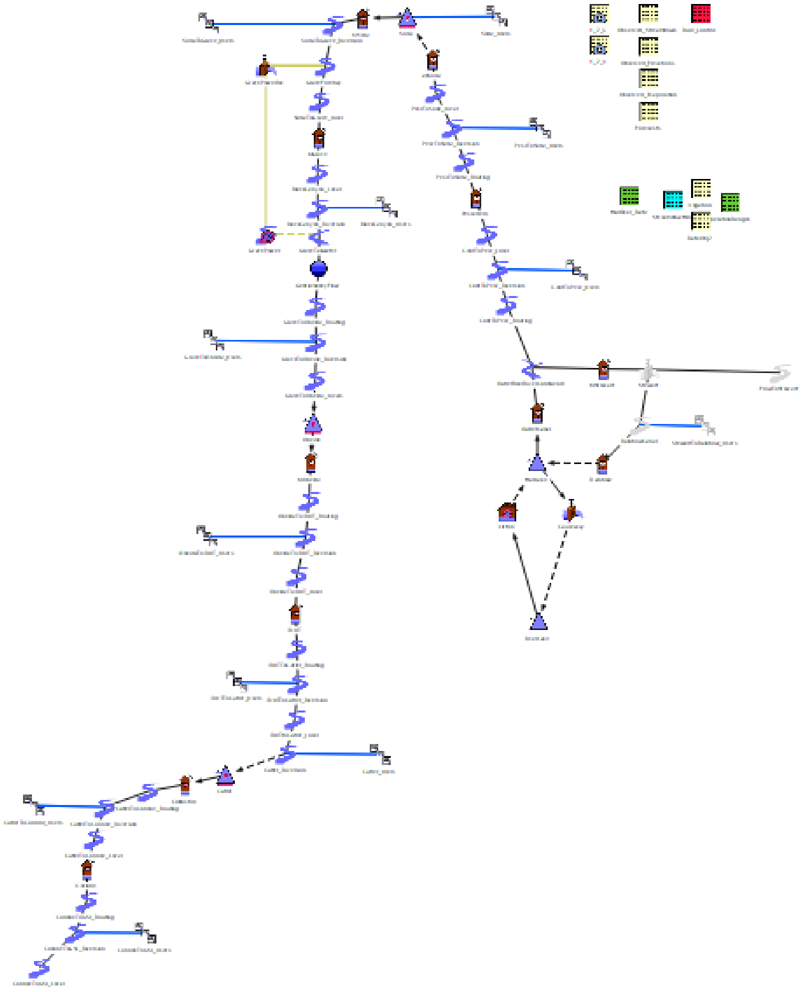
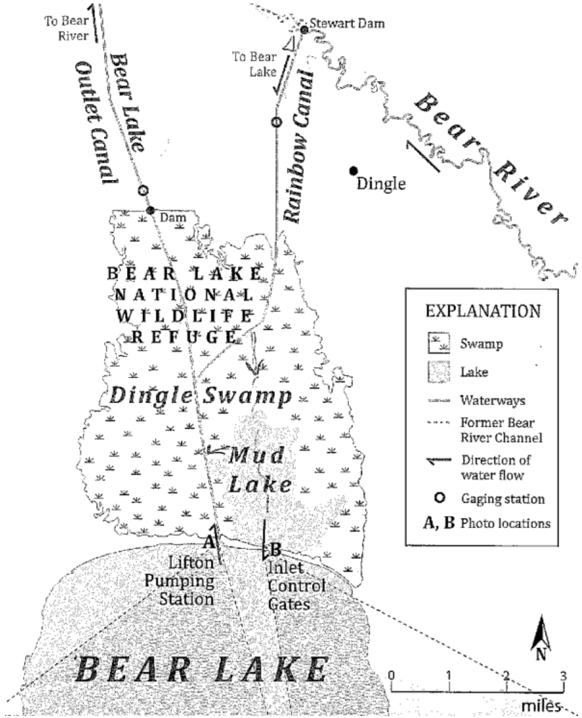
Data Timelines



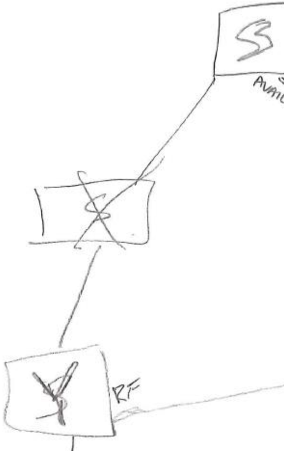


- Simulation mode
  - Historical hydrology
  - Embedded error
- Rule-based
  - Replicate operations

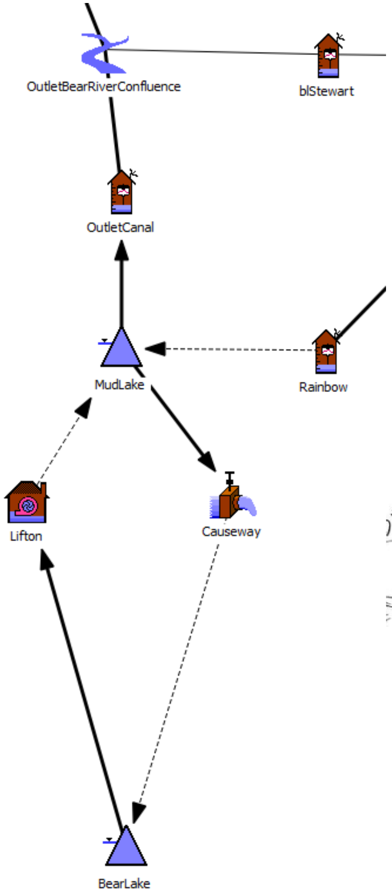
Model deve



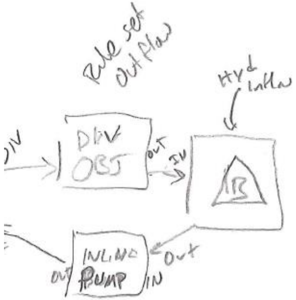
To Bear River
Outlet Canal
Bear Lake
Stewart Dam
To Bear Lake
Rainbow Canal
Bear River
Dingle
Dam
BEAR LAKE NATIONAL WILDLIFE REFUGE
Dingle Swamp
Mud Lake
A
B
Lifton Pumping Station
Inlet Control Gates
BEAR LAKE
EXPLANATION
Swamp
Lake
Waterways
Former Bear River Channel
Direction of water flow
Gaging station
A, B Photo locations
N
0
1
2
3
miles



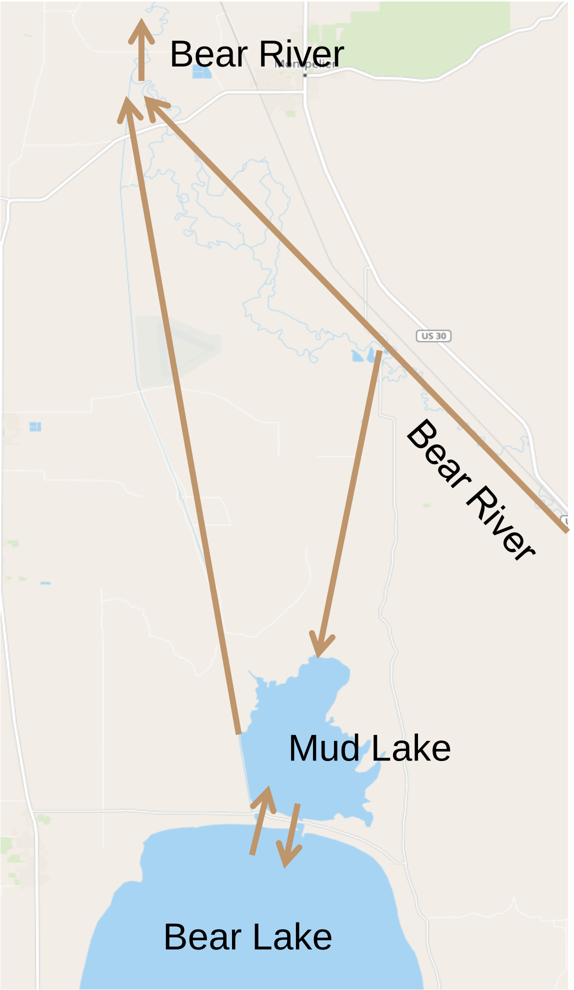
RF

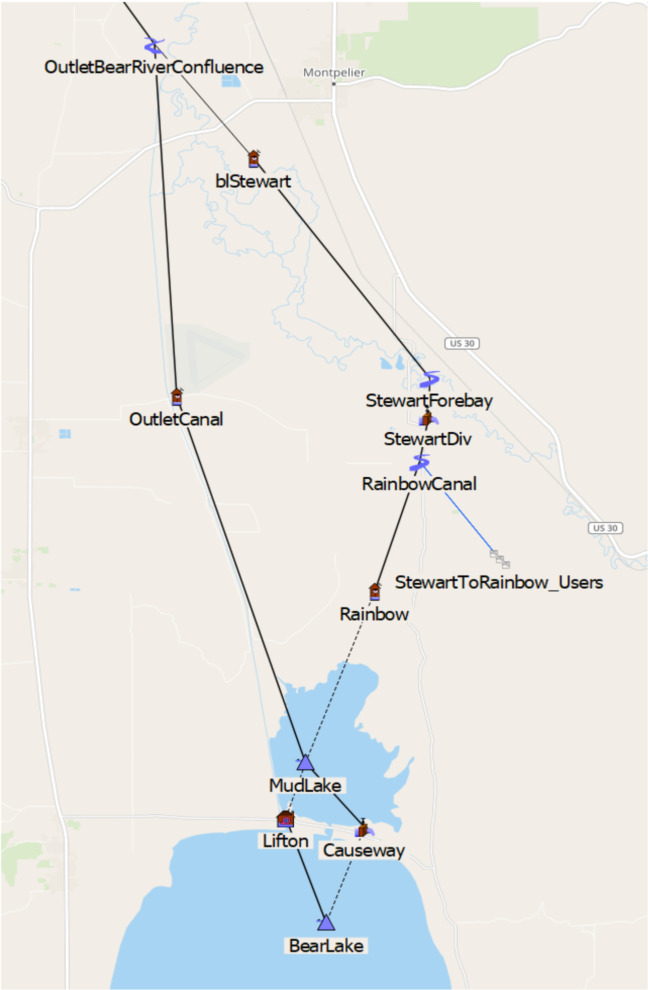


OutletBearRiverConfluence
blStewart
OutletCanal
MudLake
Rainbow
Lifton
Causeway
BearLake



Rule set Out flow
Hyd Inflow
DIV OBJ
Out
IN
INLINE PUMP





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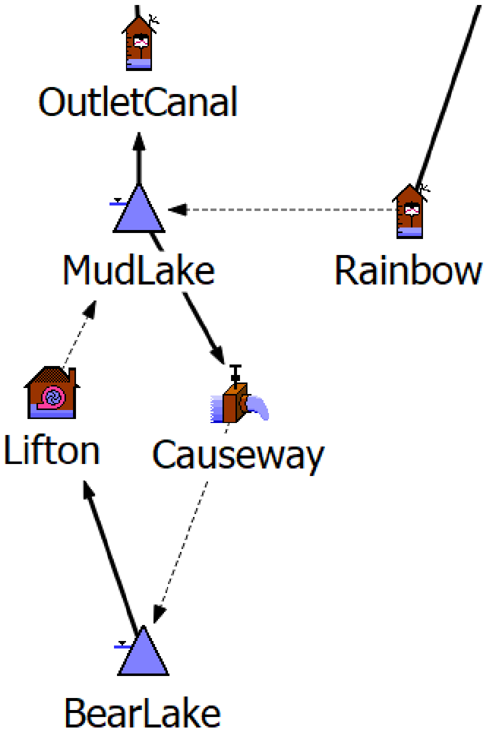
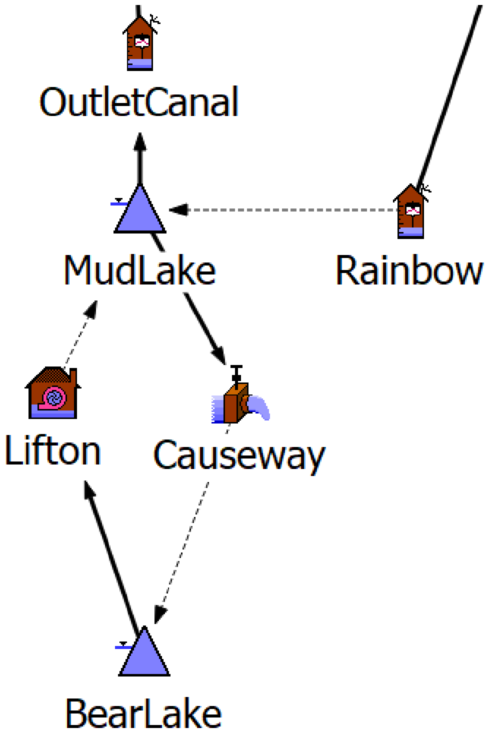
Model development



- Flows pass through Mud Lake in both directions:
  - Diversions from river (via Rainbow canal) pass through Mud to fill Bear
  - Releases or Pumping from Bear go through Mud and then downstream.
- Gravity flow based on Pool Elevation differential
- or
- Pumping through the Lifton Pumps
- This led to some complicated rules!

Model development

- **Mode 1:** move water into Mud Lake to meet a target elevation.
- **Mode 2:** moves water exclusively into Bear Lake by opening the Causeway while closing all other hydraulic works. Mud Lake must be at least 0.25 feet above Bear Lake to discharge via gravity.
- **Mode 3:** moves water into Bear Lake and Bear River by opening both the Causeway and the Outlet Canal.
- **Mode 4:** moves water from Bear Lake, through Mud Lake into the Outlet Canal, pumping if necessary.
- **Mode 5:** moves water from Mud Lake into the Outlet Canal by closing all structures except for the Outlet Canal gate.



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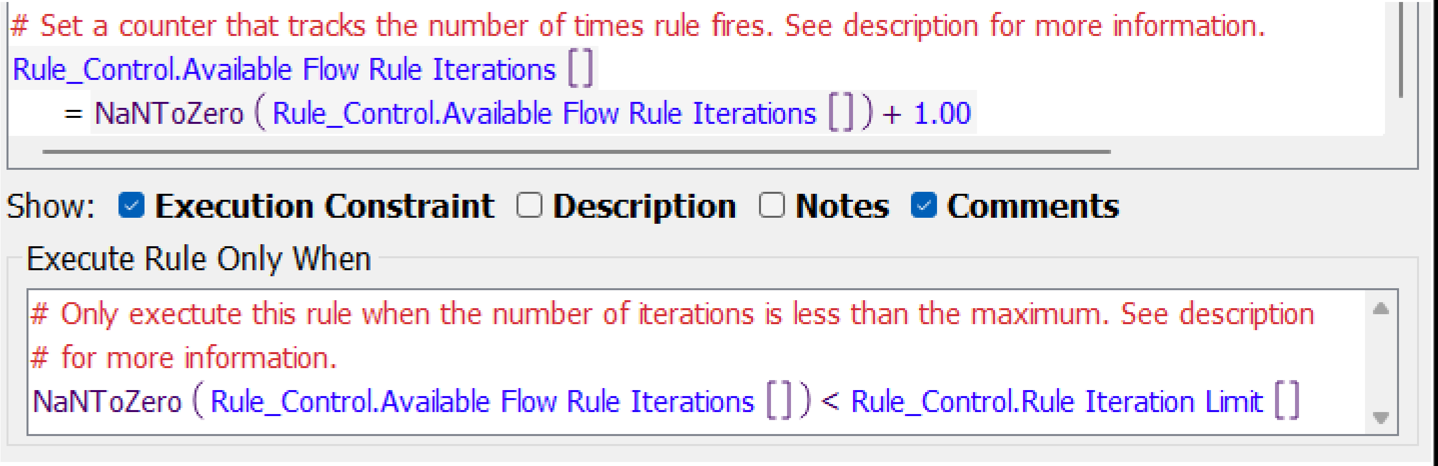
Rule Firing Process

- Determine initial Mode based on previous timestep information and/or estimates
- Operate the system to meet elevation targets and downstream demands
- Check the mode
- Iterate if necessary
- During transition periods, iterations that sometimes never converged
- Implemented rule execution limits to stop excessive iterations



Model Results

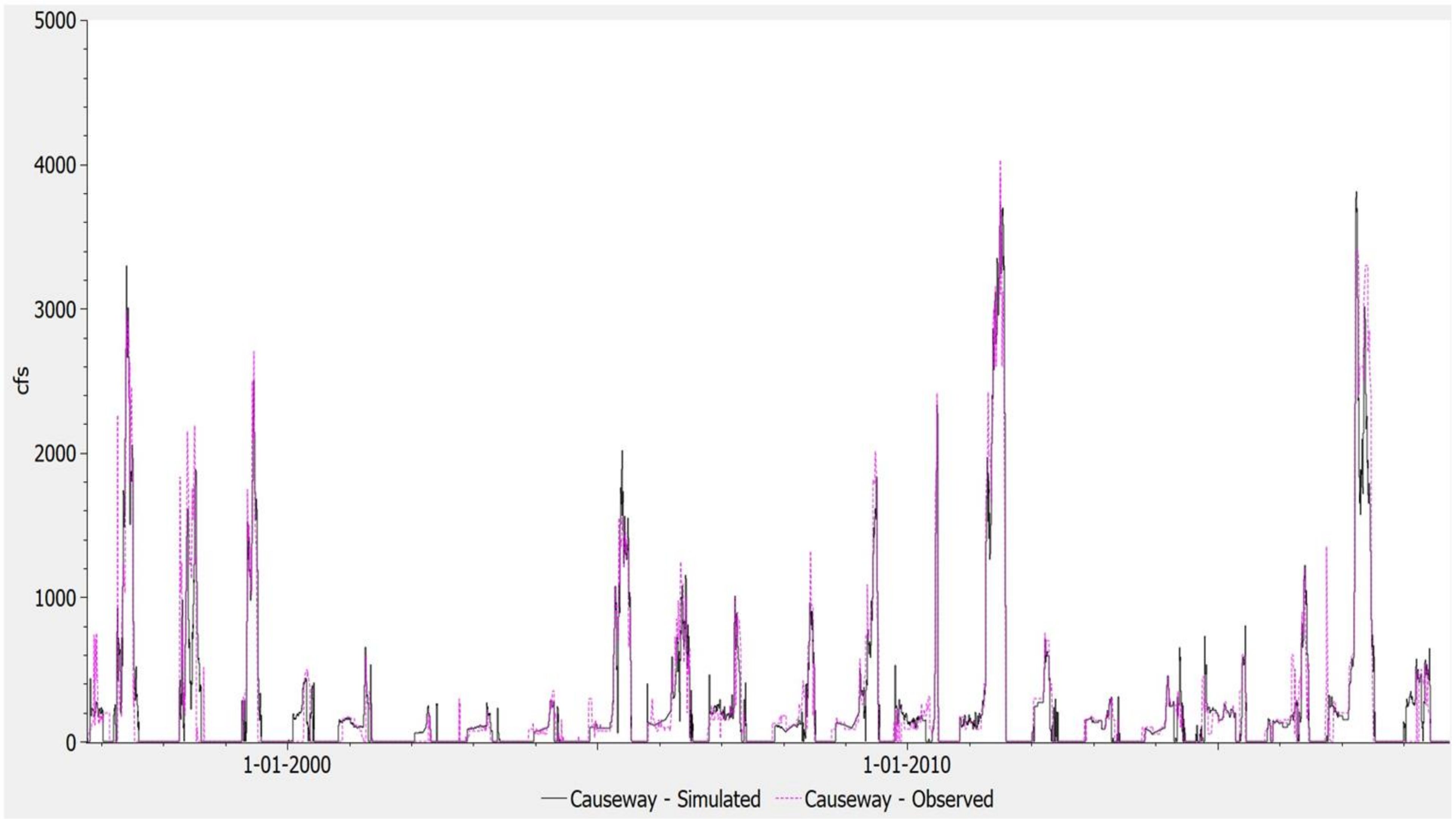

Dingle
Mud Lake


Outlet canal
looking north
into Idaho


Pump
house Bear
Lake to
Mud Lake


Causeway
inflow to
Bear Lake

WATER RESOURCES


5000
4000
3000
2000
1000
0
cfs
1-01-2000
1-01-2010
Causeway - Simulated
Causeway - Observed

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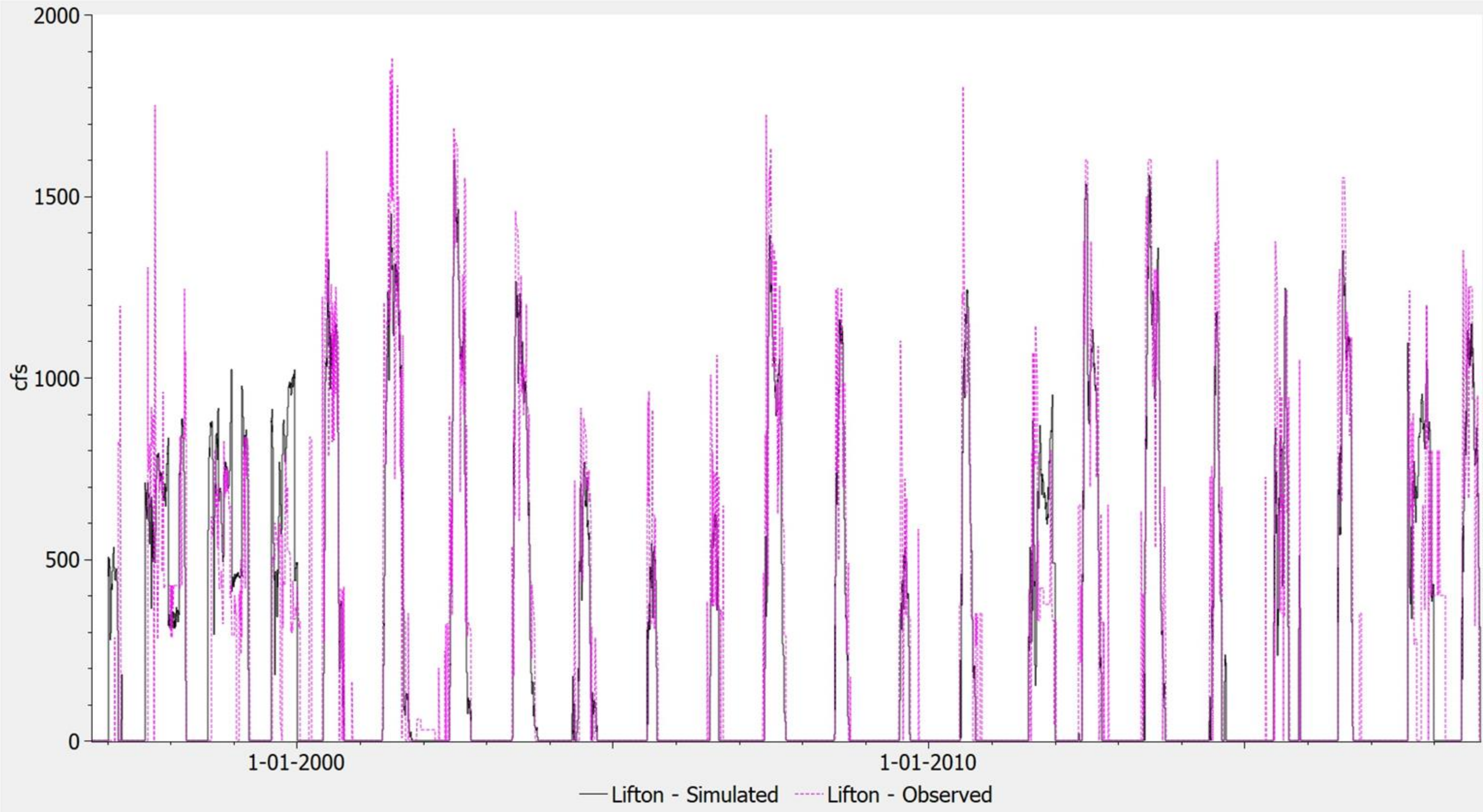
2000
1500
1000
500
0
cfs
1-01-2000
1-01-2010
Lifton - Simulated
Lifton - Observed

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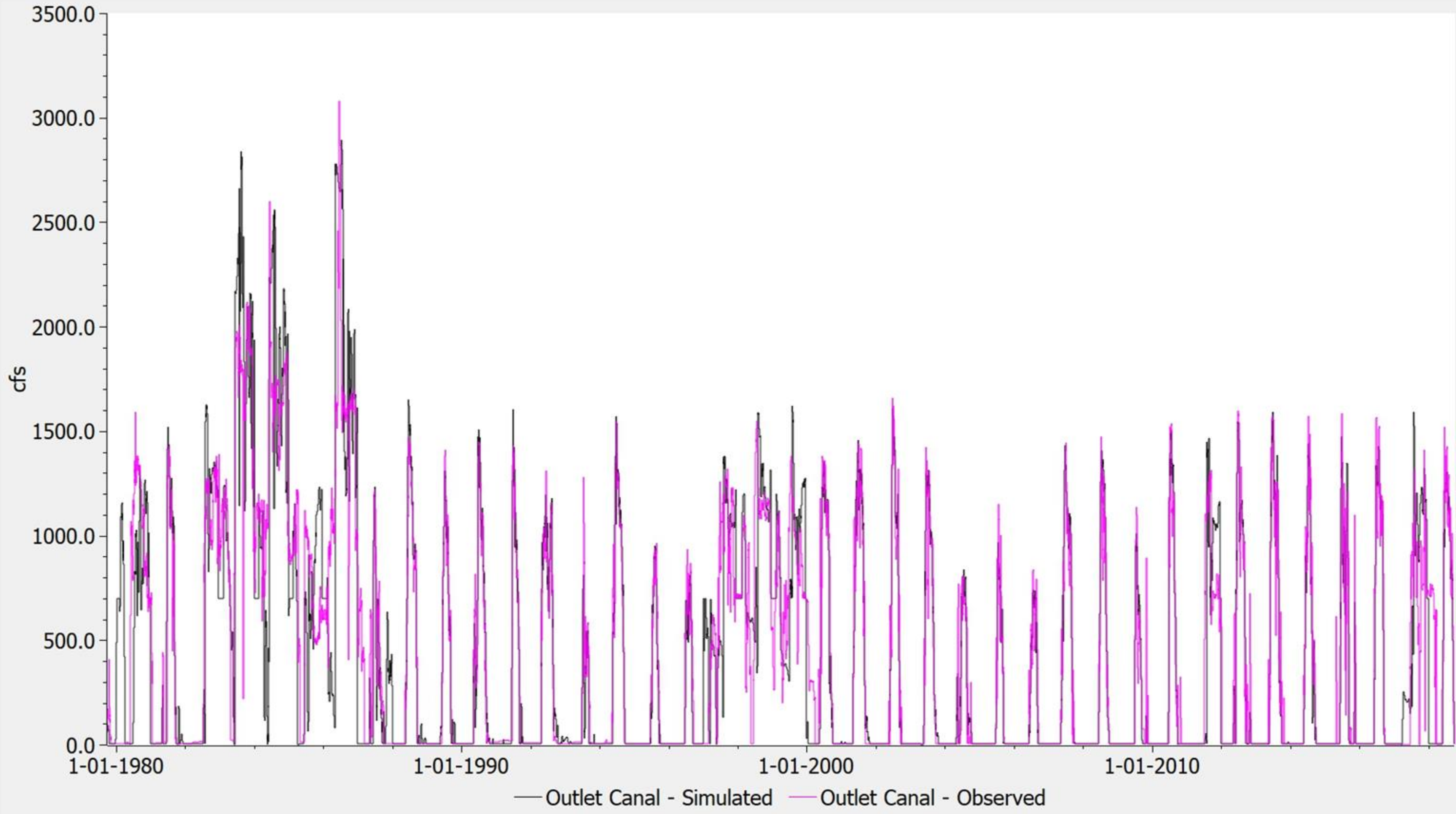
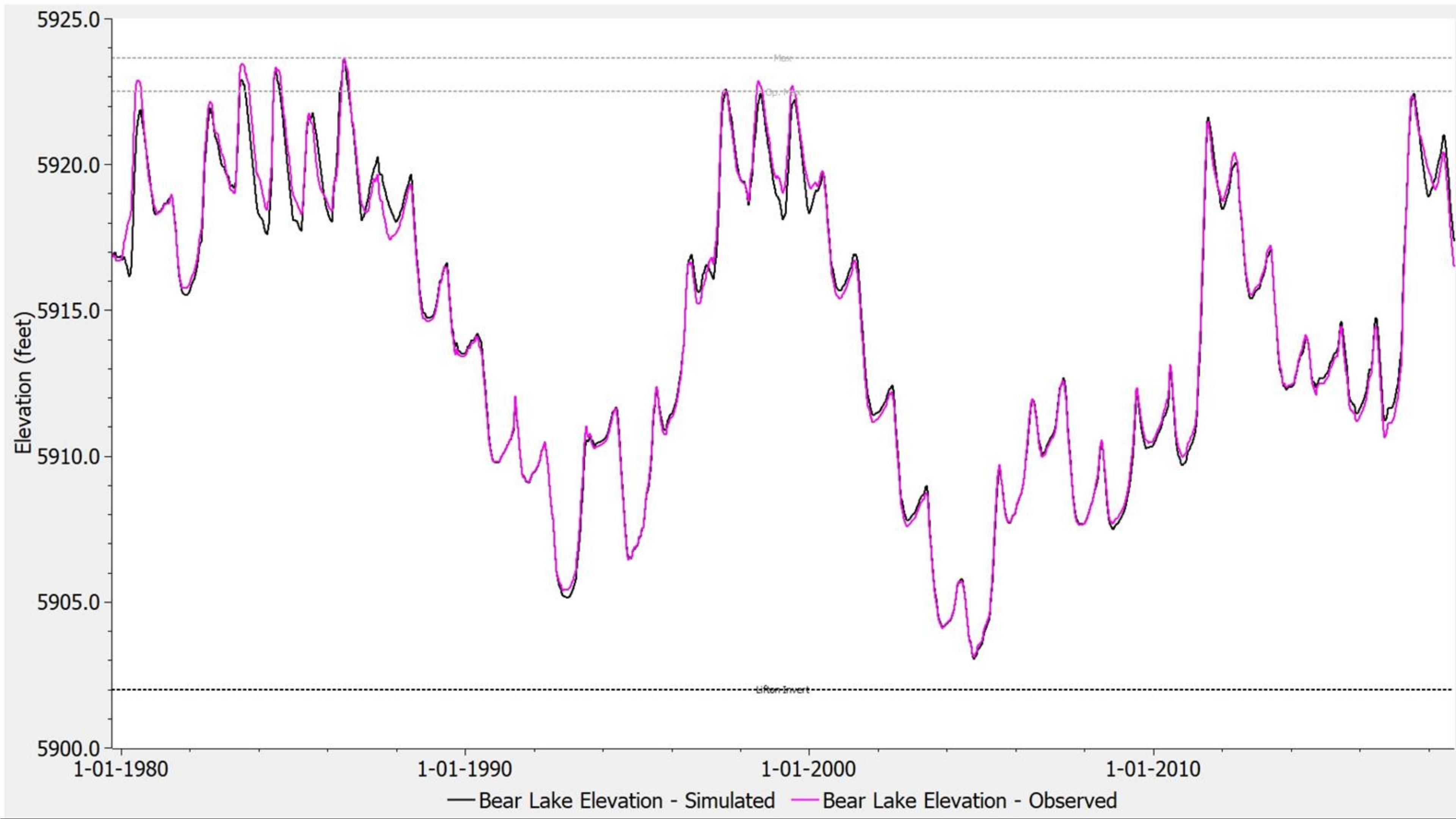

3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
cfs
1-01-1980
1-01-1990
1-01-2000
1-01-2010
Outlet Canal - Simulated
Outlet Canal - Observed


5925.0
5920.0
5915.0
5910.0
5905.0
5900.0
Elevation (feet)
Lifton Invert
1-01-1980
1-01-1990
1-01-2000
1-01-2010
Bear Lake Elevation - Simulated
Bear Lake Elevation - Observed

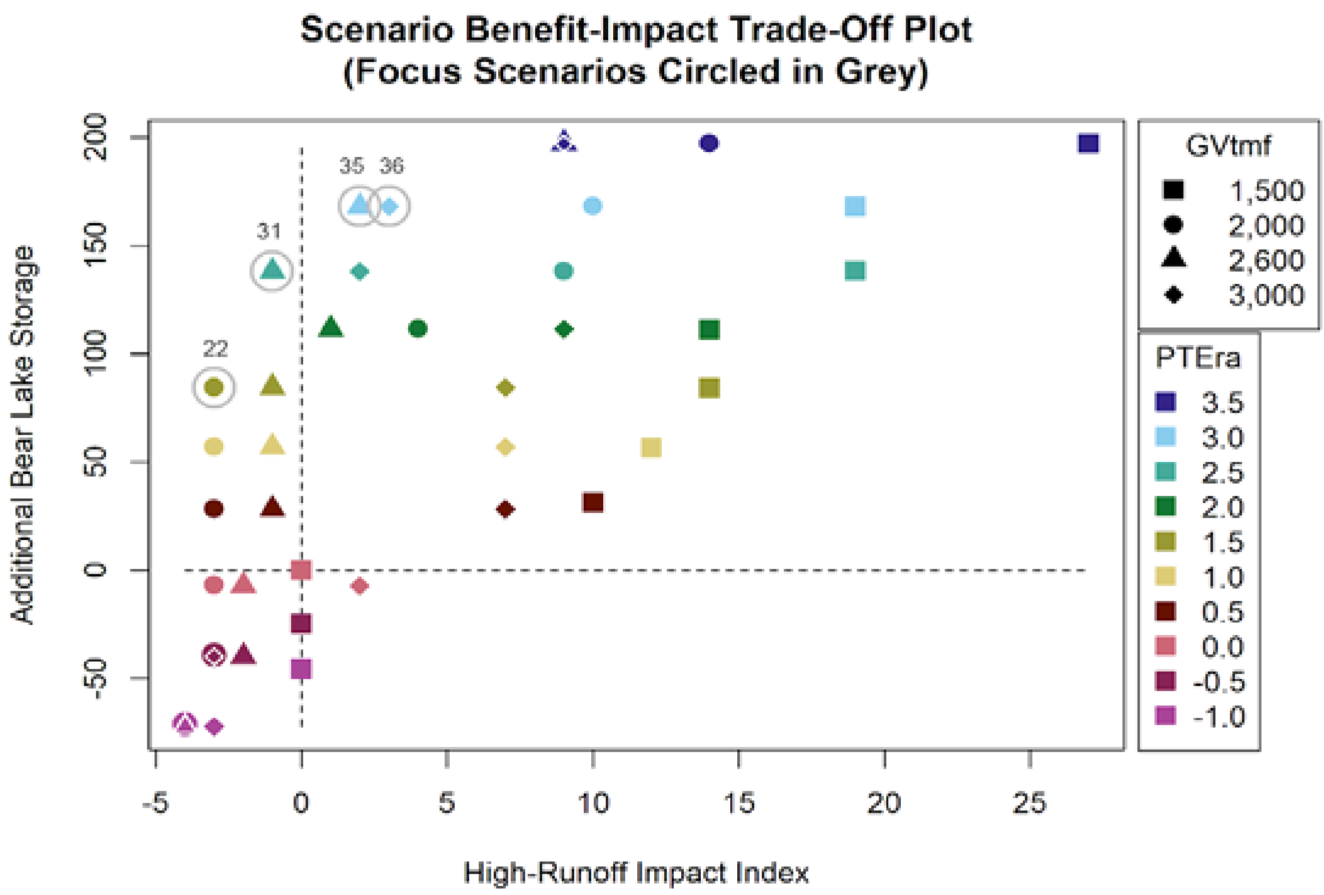
Other Model Results

- Collaboration yielded an excellent model in 6 months
- Very low expenses
- Shared understanding & knowledge base
- Communications tool to policy makers
- Focus of collaboration

Scenario Analysis

- Operational parameters

Scenario Indices					
PTEra (feet)	Scenario Default PTE	GVtmf (cfs)			
		1,500	2,000	2,600	3,000
+3.5	**5,921.5**	37	38	39	40
+3.0	**5,921.0**	33	34	**35**	**36**
+2.5	**5,920.5**	29	30	**31**	32
+2.0	**5,920.0**	25	26	27	28
+1.5	**5,919.5**	21	**22**	23	24
+1.0	**5,919.0**	17	18	19	20
+0.5	**5,918.5**	13	14	15	16
0.0	**5,918.0**	**9***	10	11	12
-0.5	**5,917.5**	5	6	7	8
-1.0	**5,917.0**	1	2	3	4



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Operations Scenario Variable Value: PTEra (+ ft)	Operations Scenario Variable Value: GVtmf (cfs)	Scenario	Performance Measure: Mean change in August 1 Bear Lake volume for carry-over years (TAF)	Change in total Bear Lake volume (TAF)	Additional years Bear Lake is above 5911	% Time above the GVtmf	High-Runoff impact index	Mean change in annual inflow to Great Salt Lake for carry-over years (TAF)	Change in total flow to Great Salt Lake (TAF)	Change in total volume through Causeway (TAF)
		Simulation Method	Yearly	Yearly	Continuous	Continuous	Continuous	Continuous	Yearly	Continuous
0.0	1500	Baseline	0	0	0	4.3%	0	0	0	0
1.5	2000	Scenario 22	84	455	4.1	2.5%	-3	-59	-458	-229
2.5	2600	Scenario 31	138	680	5.8	1.2%	-1	-96	-683	-605
3.5	2600	Scenario 35	168	1149	7.2	1.2%	2	-119	-1196	-637
3.5	3000	Scenario 36	168	1145	7.2	0.6%	3	-119	-1192	-607

Simulation methods

- No policy for additional storage use
- **Continuous Simulation-**-the additional storage is carried over from year to year
- **Yearly Simulation**--the reservoir is reset to the Baseline each August
  (removes additional storage from the reservoir)

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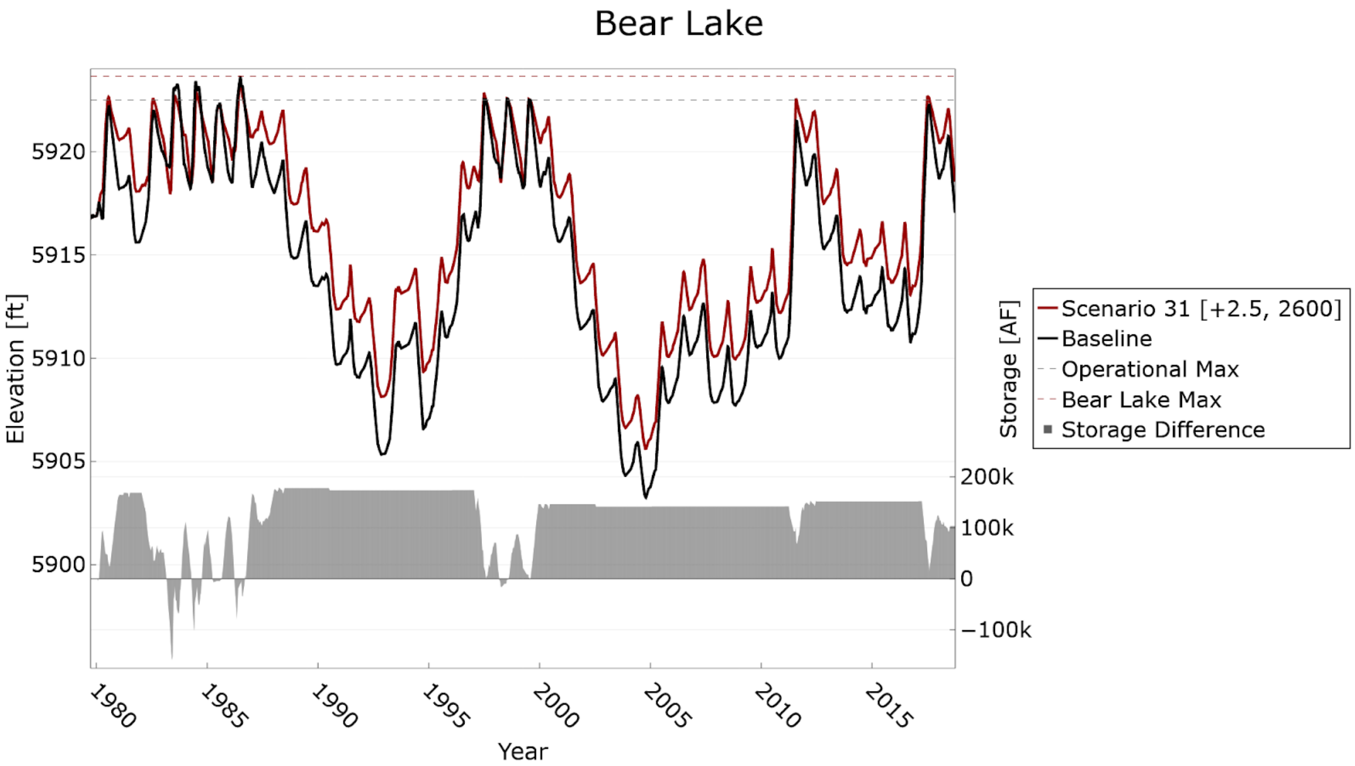
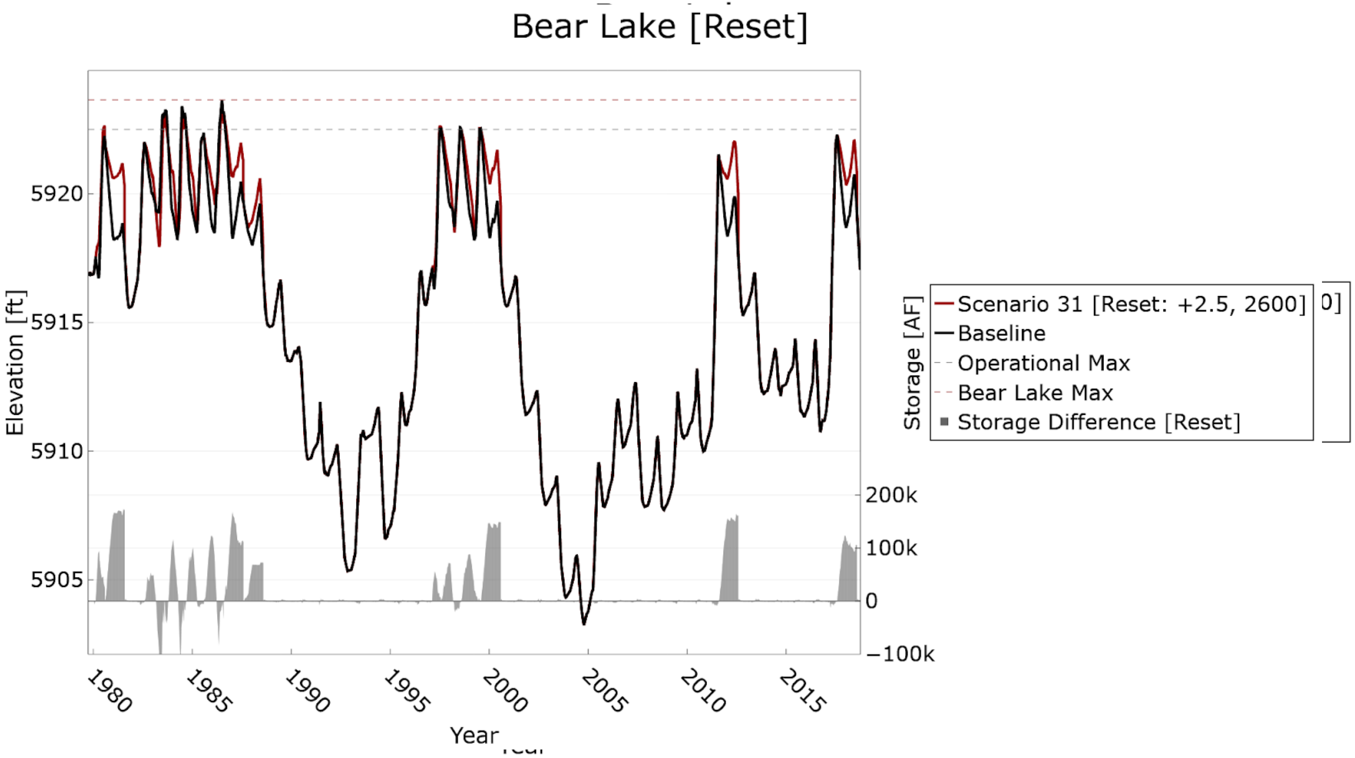
Simulation methods

- **Continuous Simulation**

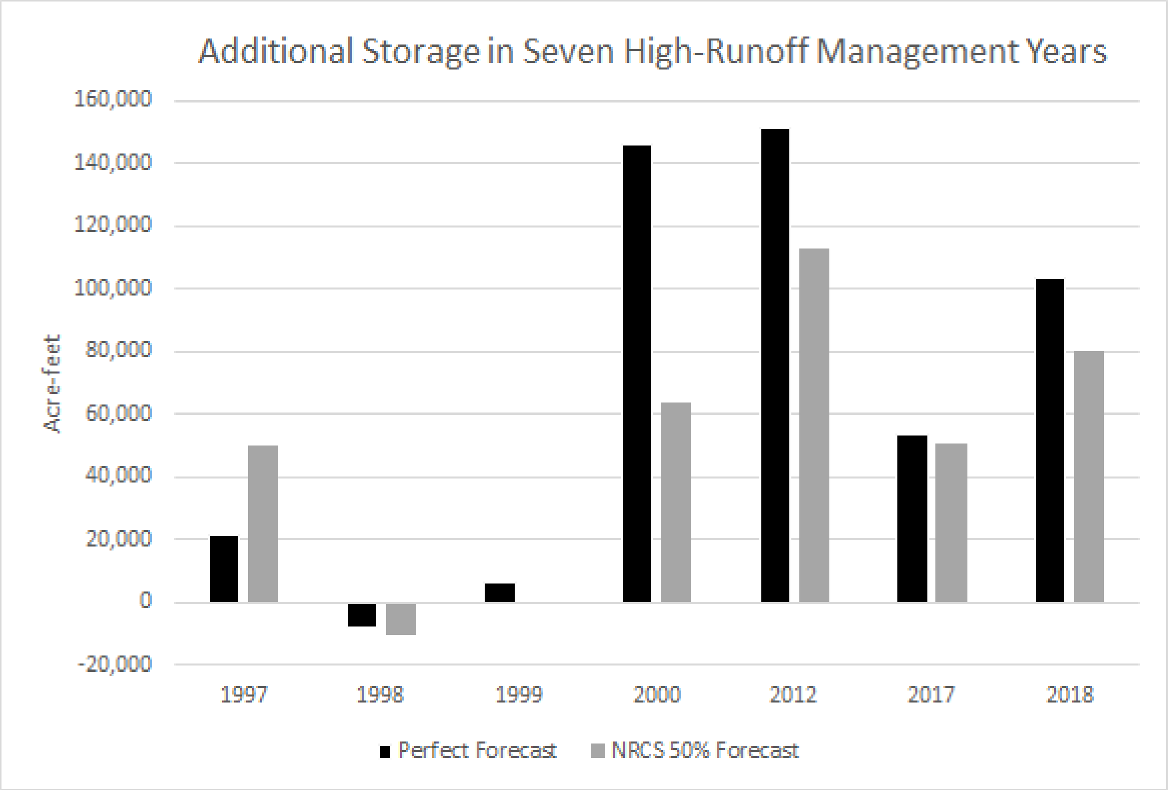


Simulation methods

- Yearly Simulation



Forecast Uncertainty



Analysis Results

- Significant additional storage available when entering a drought cycle
- Must resolve the challenge of conveyance through Gentile Valley
- Decreased inflows to Bear Lake (but higher lake levels)
- Less sediment laden water entering the lake
- Downstream effects depend on use(s) not yet modeled
- Use of additional storage would decrease flow to GSL

Recommendations

- Continue cooperative development, maintenance, and refinement
- Model updates and potential studies
- Continue stakeholder engagement

Future work

- Hydrologies
- Demands
- Operations
- Water rights accounting
- Infrastructure: Add/Remove/Modify
- Link to other models (e.g. Great Salt Lake)
- Collaborate: maintain and develop model together

Future work

Modelling Group

Policy Makers

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801-538-7283