Extended Drought Analysis Incorporating Lake Levels Important for Recreation

John Boyer

Agenda Item 4a

Resequencing Historical Flows to Investigate Potential Future Droughts

Methods

- Supply-side investigation to quantify sensitivities to hydrologic non-stationarity (aka "the past may not be a good predictor of the future")
- Each scenario constructed with repeating sequences of monthly flows and reservoir evaporation rates extracted from historical hydrology
- Used **2070 High Demand Scenario** projections
- Used current reservoir operation rules

Resequencing Historical Flows to Investigate Potential Future Droughts

Methods

Three (3) constructed scenarios:

1. Repeating 5-year drought constructed by splicing together the **five driest water years** in the hydrologic period of record with respect to mainstem total annual flow. These were **2001**, **2008**, **1981**, **1988**, and **2017**.

2. **Repeating single year drought** corresponding to the **second driest water year (2008)** and identified as the critical single year drought with respect to Lake Thurmond water supply availability.

3. **Repeating synthetic drought year** constructed by splicing together the **twelve driest calendar month flows** in the hydrologic period of record.

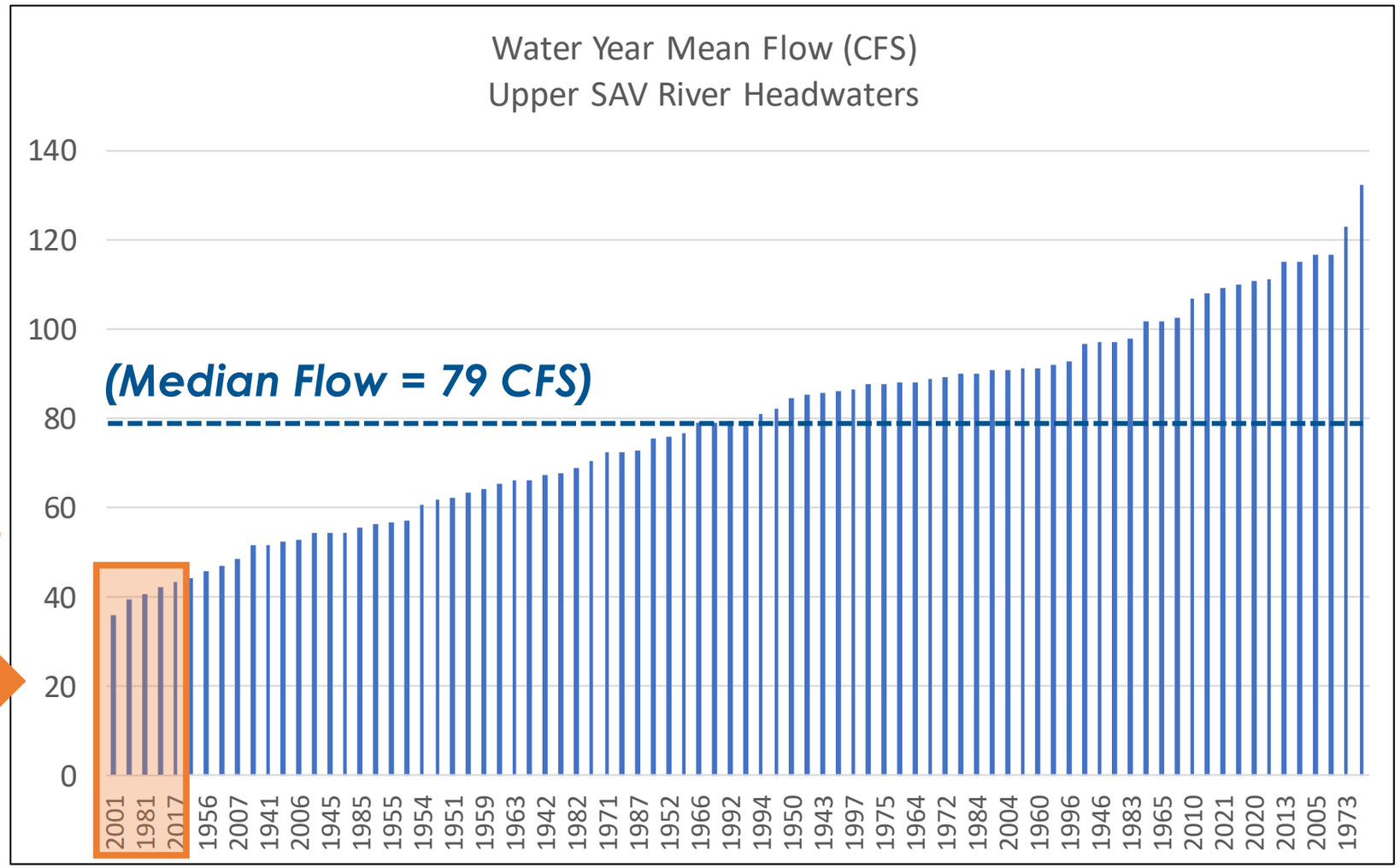
Resequencing Historical Flows to Investigate Potential Future Droughts

Methods

Ranked data based on mainstem headwater flows

5 Driest Years in terms of mainstem flow:

2001
2008
1981
1988
2017

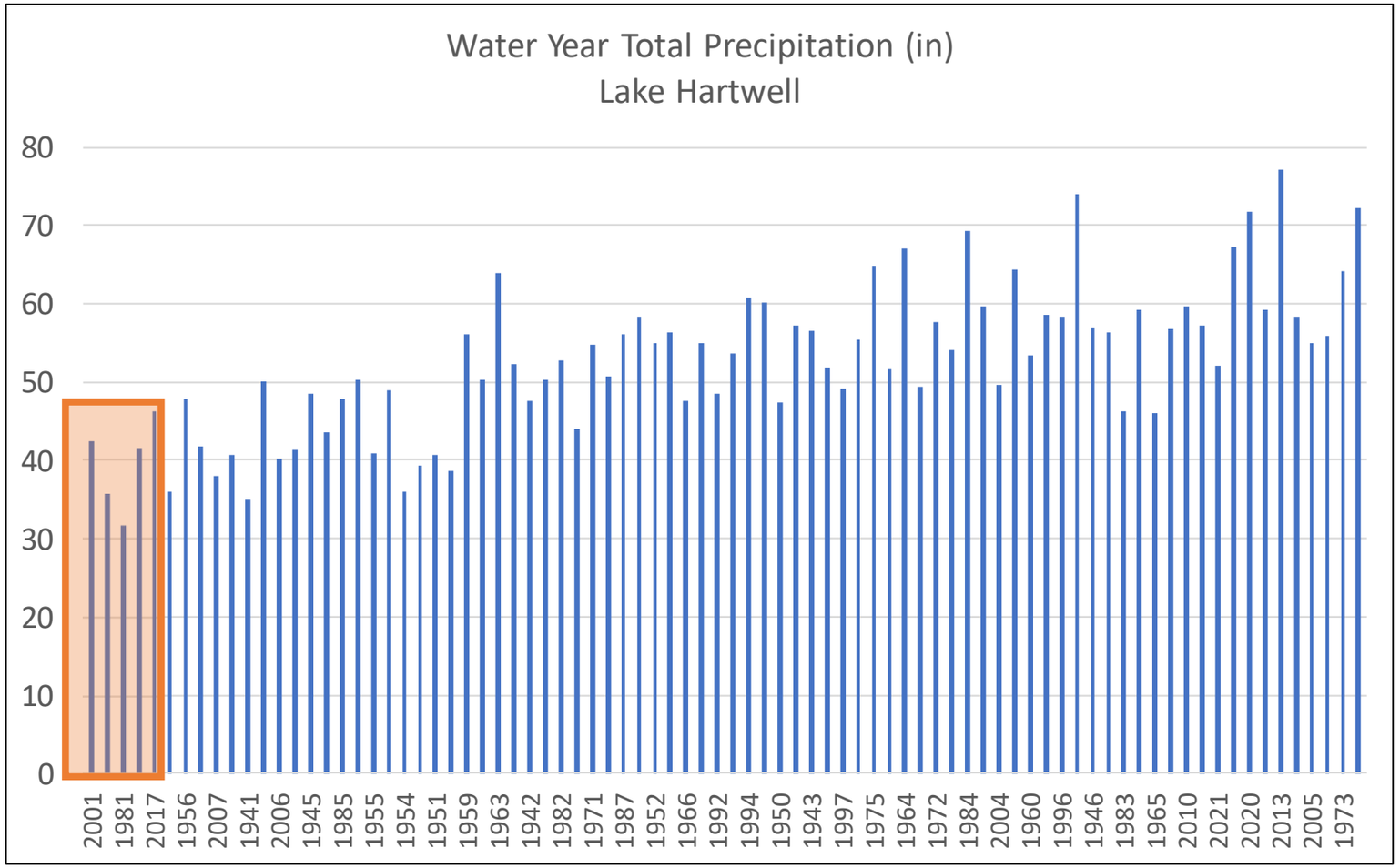


Resequencing Historical Flows to Investigate Potential Future Droughts

Methods

Reference data

Precip



Resequencing Historical Flows to Investigate Potential Future Droughts

Methods

Scenario 3: 12 driest calendar months (Mainstem headwater flow)

Mean annual flow = 22.5 CFS

Jan	1956
Feb	2017
Mar	2017
Apr	1986
May	2001
Jun	2008
Jul	2008
Aug	2007
Sep	1954
Oct	1954
Nov	2016
Dec	1955

Critical Recreational Access Levels

Reservoir	Boat Access Level (ft) *	Swimming Access Level (ft) *	Deadpool (ft)
Lake Jocassee	1,080	---	1,080
Lake Keowee	790	---	790
Lake Hartwell	**652**	**654**	625
Lake Russell	466	---	470
Lake Thurmond	**320**	**324**	312

* As defined in the 2014 Keowee-Toxaway Water Supply Study.

Boating Access
Level at which 70% of boat access points remain usable.

Swimming Access
Level at which all USACE operated swimming areas are dry.

Thurmond Lake
Boat Ramp Elevations

*** NOTE - Looking down at multiple lane ramps, ramp lanes are numbered left to right**

Area Name	Lane No.	Bottom of Ramp	Approximate lake elevation when launching becomes difficult
Leathersville Ramp	1	304.3	306.3
Dorn	3,4	306.4	308.4
Lake Springs Park	1, 2, 3	306.7	308.7
Keg Creek Ramp	1	307	309
Modoc Shores Subdivision Ramp	1	308.4	310.4
Scotts Ferry Ramp	1	308.7	310.7
Mt. Carmel Campground	1	309	311
Little River Marina	2	309.3	311.3
Winfield Campground	1	309.7	311.7
Raysville Campground	1	310.3	312.2
Hesters Ferry Campground	1	310.9	312.9
Modoc Ramp	1	311.5	313.5
Clarks Hill Park	1	311.5	313.5
Hawe Creek Campground	1	311.5	313.5
Little River Subdivison Ramp	1	311.5	313.5
Mistletoe State Park Low Water Ramp	1	311.5	313.5
Petersburg Campground	1	311.7	313.7
Mt. Carmel Picnic	1	311.7	313.7
Amity Recreation Area	3	311.8	313.8
Big Hart Recreation Area	1	311.8	313.8
Hamilton Branch State Park (Day Use)	1	312	314
Hamilton Branch State Park	1, 2	312	314
Little River Marina	1	312	314
Baker Creek State Park	1	312	314
Tradewinds Marina	1	312	314
Morrahs Ramp	2	312	314
Amity Recreation Area	2	312.3	314.3
Dorn	1,2,5,6	312.4	314.4
Little River/Hwy 378	1	312.5	314.5
Parksville Recreation Area	1	312.5	314.5
Buffalo Creek Subdivision Ramp	1	312.5	314.5
Cherokee Recreation Area	1	312.6	314.6
Gill Point Ramp	1	312.8	314.8
Ft. Gordon Recreation Area	1, 2	313	315
Plum Branch Yacht Club	1	313	315
Wildwood Park	3, 4	313	315
Bobby Brown State Park	1, 2	313	315
New Bourdeaux Subdivision Ramp	1	313	315
Holiday Park	1	313.6	315.6
Elijah Clark State Park	1, 2, 3	314	316
Landam Creek Ramp	1	314.2	316.2
Dordon Creek Ramp	1	314.2	316.2
Hickory Knob State Park	1	314.2	316.2
Wildwood Park	1, 2	315	317

Area Name	Lane No.	Bottom of Ramp	Approximate lake elevation when launching becomes difficult
Soap Creek/Hwy 220 Ramp	1	315	317
Modoc Ramp	2	315.2	317.2
Raysville Marina	1	315.6	317.6
Elbert County Subdivision Ramp	1	315.6	317.6
Amity Recreation Area	1	315.9	317.9
Soap Creek Marina	1	316	318
Cherokee Recreation Area	2	316	318
Double Branches Ramp	1	316.1	318.1
Chamberlain Ferry Ramp	1	316.33	318.33
Cherokee Recreation Area	3	316.71	318.71
Ridge Road Campground	1	317	319
Leroys Ferry Campground	1	317.5	319.5
Wildwood Park	5, 6	318	320
Maxim Subdivision Ramp	1	318	320
Wells Creek Subdivision	1	318	320
Fishing Creek/Hwy 79 Ramp	1	318.7	320.7
Bussey Point	1	319	321
Modoc Campground	1	319	321
Murray Creek Ramp	1	319	321
Parkway Ramp	1	319	321
Cherokee Recreation Area	4	319	321
Morrahs Ramp	1	319.5	321.5
Wildwood Park	5, 6	320	322
Mt Pleasant Ramp	1	320.4	322.4
Clay Hill Campground	1	321.5	323.5
Scotts Ferry (New Ramp)	1, 2	321.8	323.8
Soap Creek Park	1	322	324
Little River Quarry Ramp	1	322	324
Lakeside Subdivision Ramp	1	322	324
Mistletoe State Park	1, 2	322.2	324.2
Cherokee Recreation Area	5	322.7	324.7
Calhoun Falls Ramp	1	323	325
Broad River Campground	1	323	325
Catfish Ramp	1	323.5	325.5
Long Cane Creek Ramp	1	323.7	325.7
Hwy 28 Access Ramp	1	324	326

70% of boat access points remain usable at a lake level of 320'

30% of boat access points are unusable when lake levels drop to 320'

revised 06/21/2012

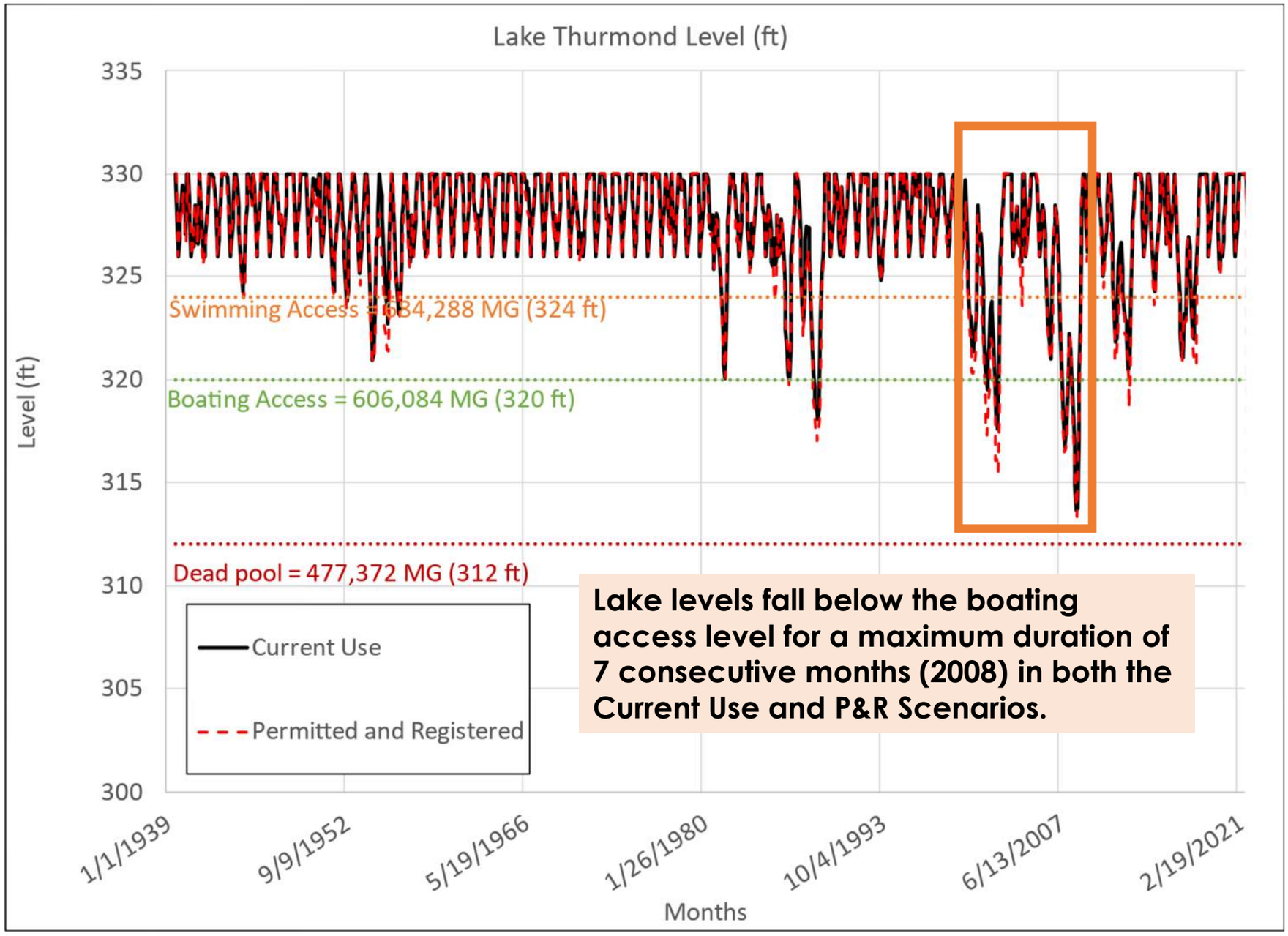
Critical Recreational Access Levels

Reservoir	Boat Access Level (ft) *	Swimming Access Level (ft) *	Deadpool (ft)
Lake Jocassee	1,080	---	1,080
Lake Keowee	790	---	790
Lake Hartwell	**652**	**654**	625
Lake Russell	466	---	470
Lake Thurmond	**320**	**324**	312

* As defined in the 2014 Keowee-Toxaway Water Supply Study.

What percentage of the simulation months does each lake drop below the recreational access levels?

	Boat Access			Swimming Access		
Reservoir	**Current Use**	**2070 HD**	**P & R**	**Current Use**	**2070 HD**	**P & R**
Lake Hartwell	**0.7%**	**3.0%**	**5.9%**	**2.7%**	**6.0%**	**8.9%**
Lake Thurmond	**2.4%**	**2.2%**	**3.3%**	**10.0%**	**11.1%**	**12.4%**

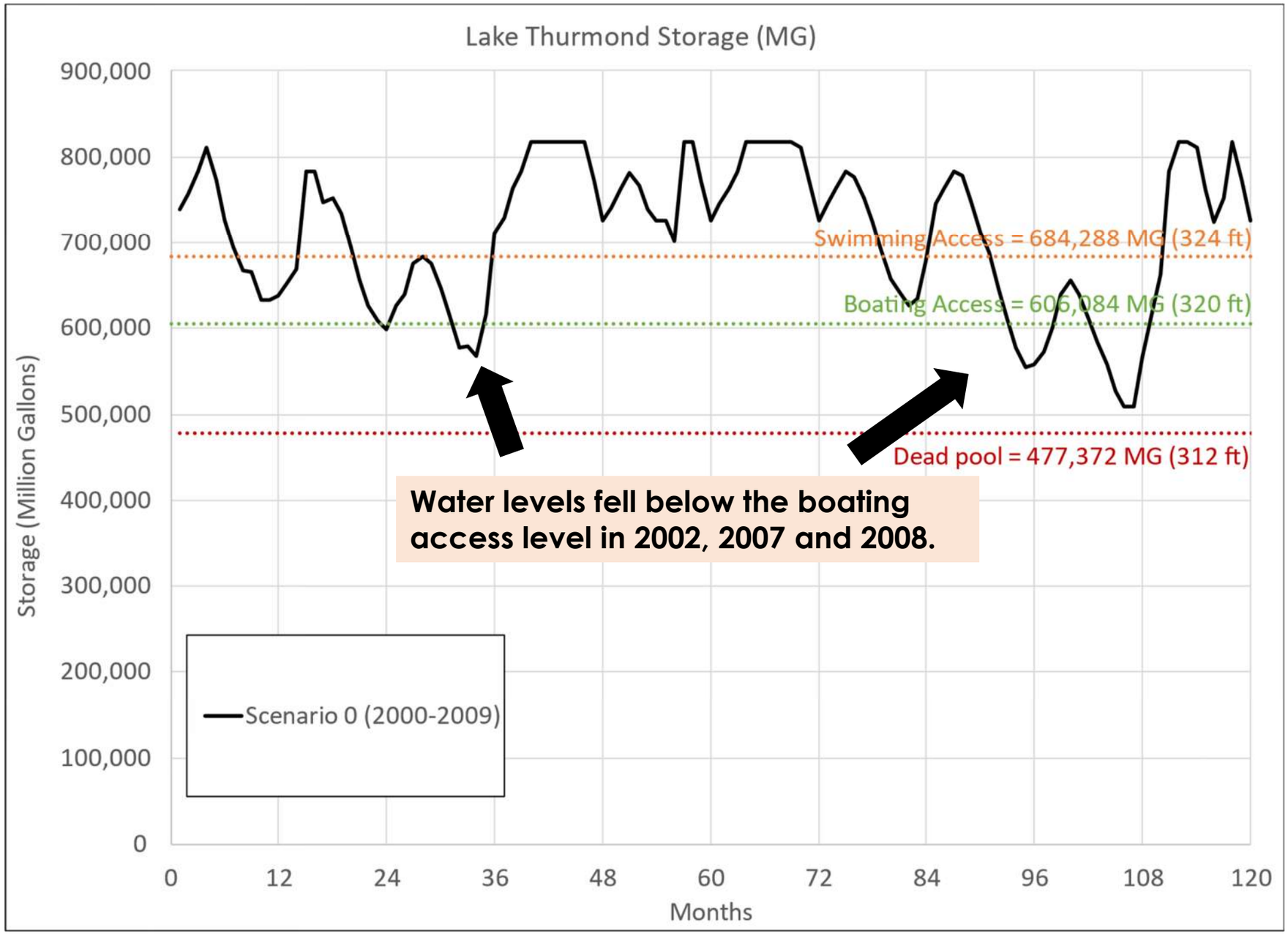


Lake levels fall below the boating access level for a maximum duration of 7 consecutive months (2008) in both the Current Use and P&R Scenarios.

Recreational Access Levels for the Current Use and Permitted and Registered Scenarios

Swimming Access = Level at which all USACE operated swimming areas are dry.

Boating Access = Level at which 70% of boat access points remain usable.



Resequencing Historical Flows to Investigate Potential Future Droughts

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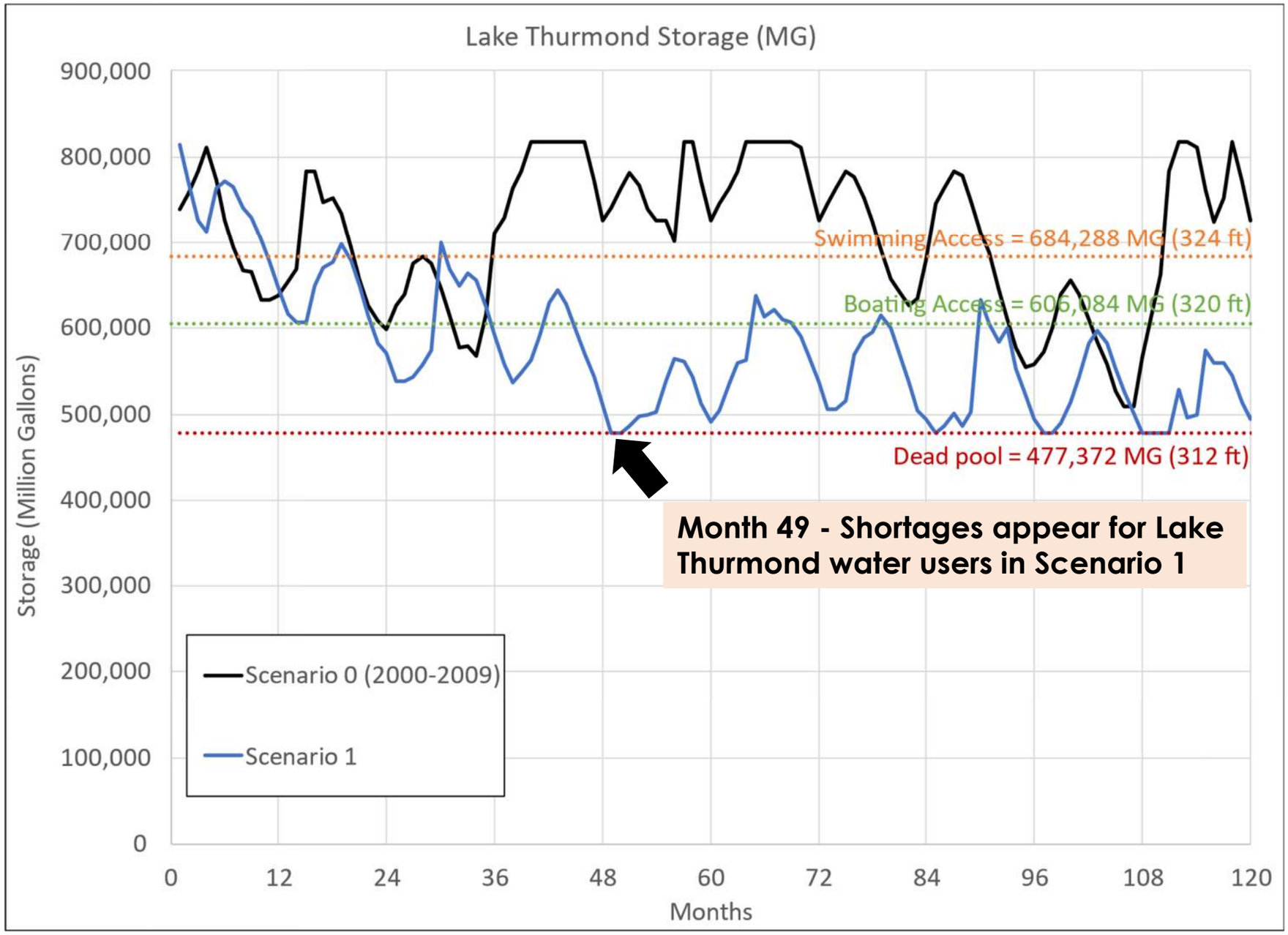
Scenario 0 is the 2070 High Demand Scenario



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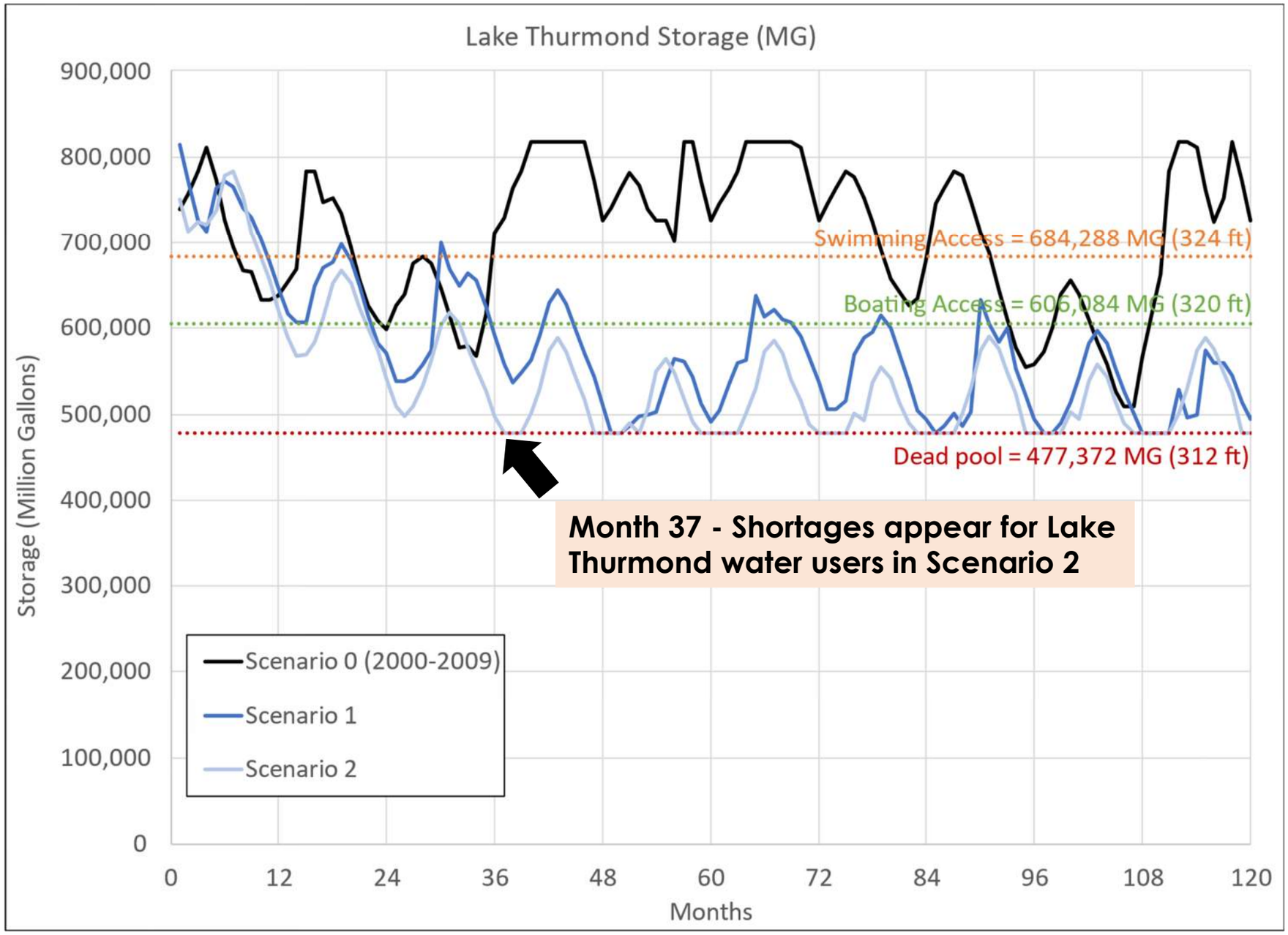

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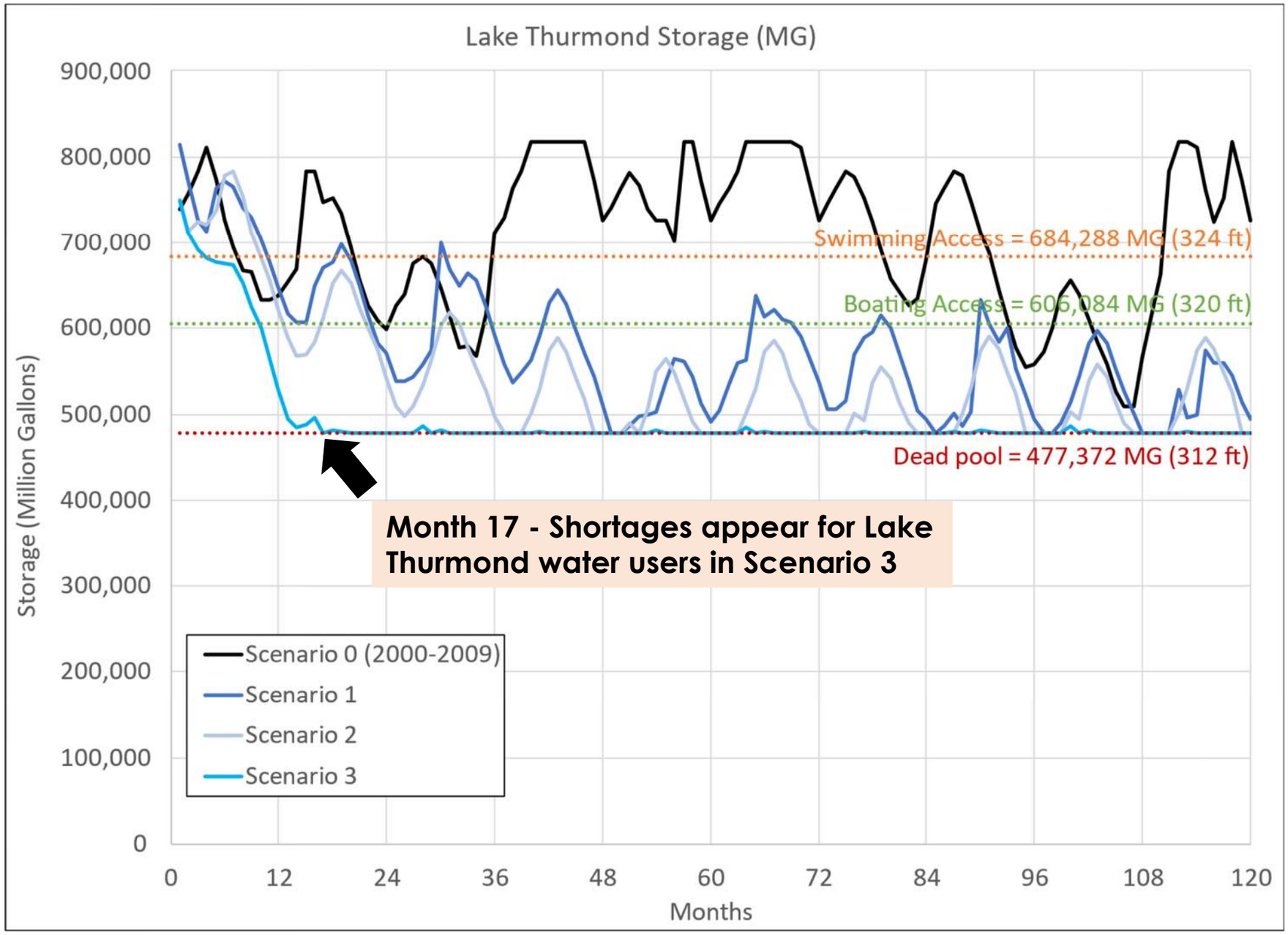

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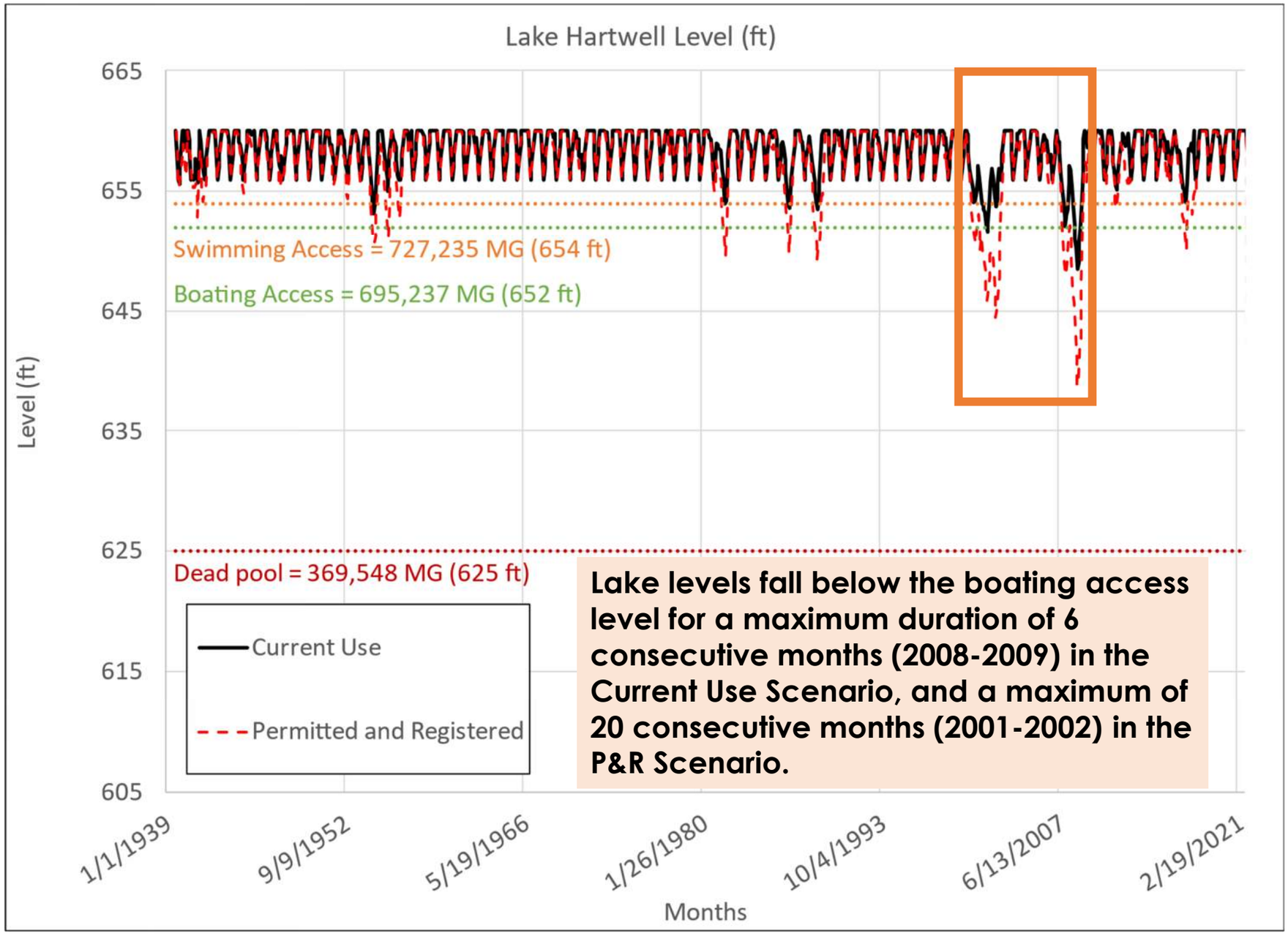

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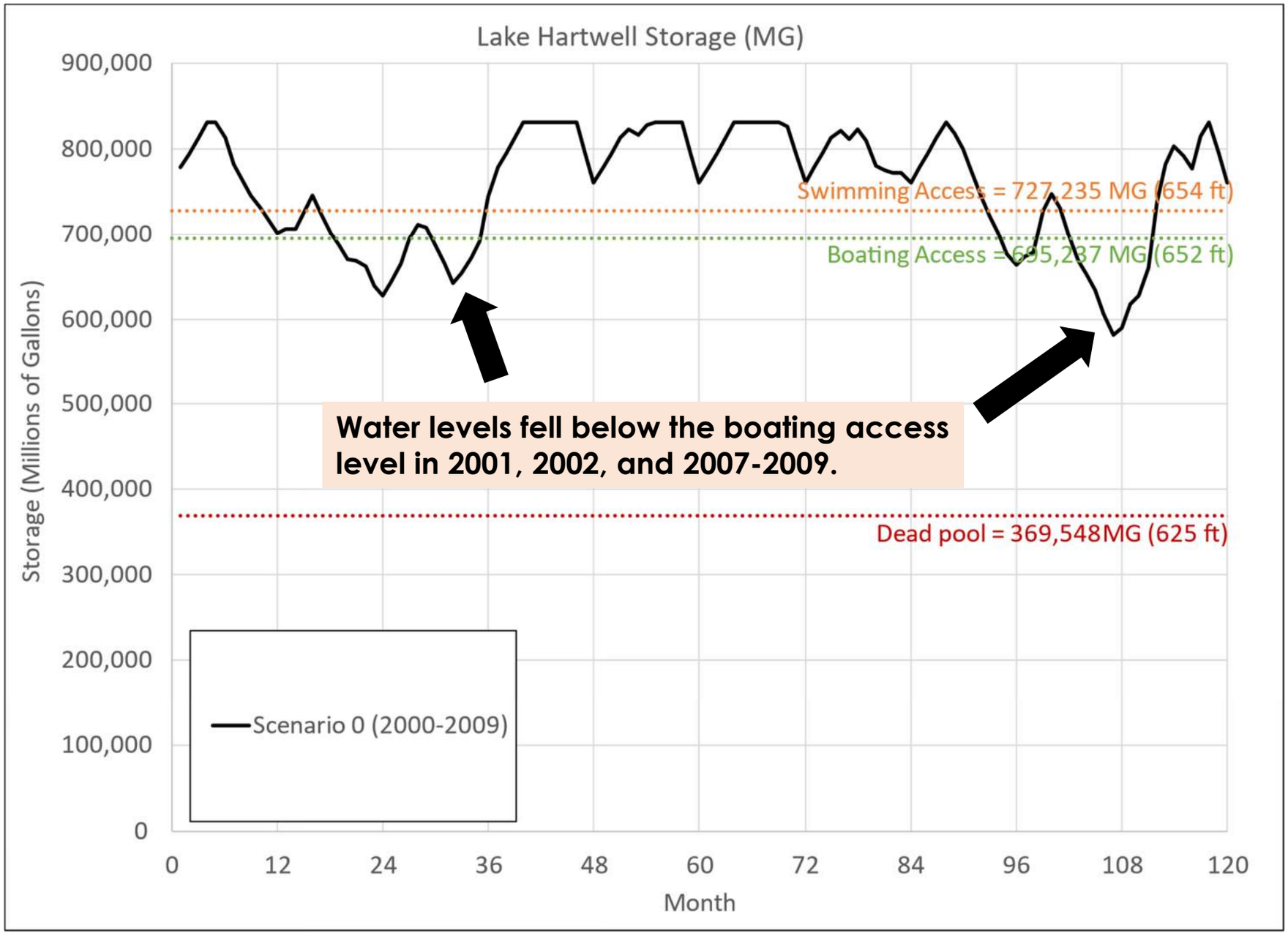

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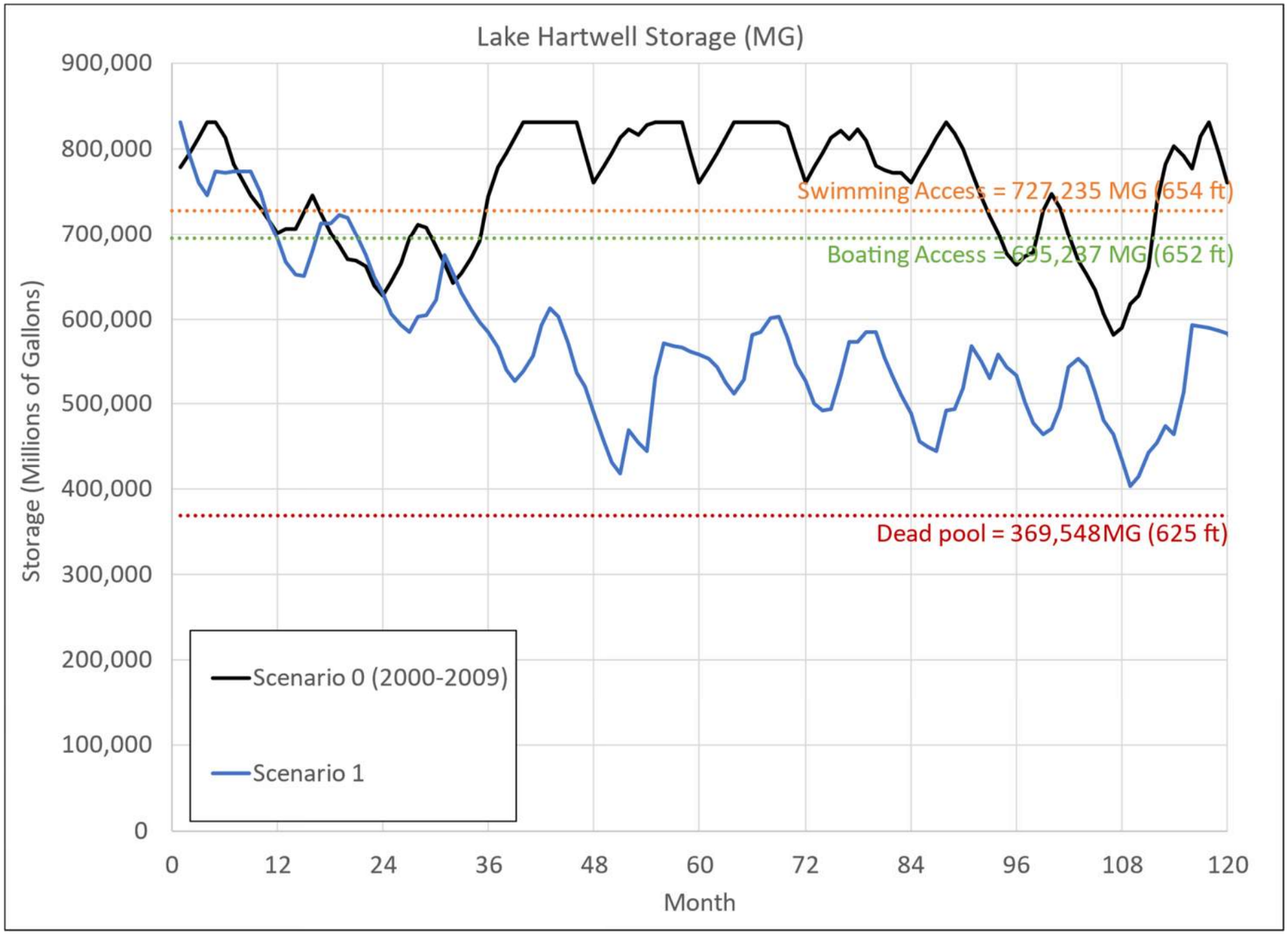

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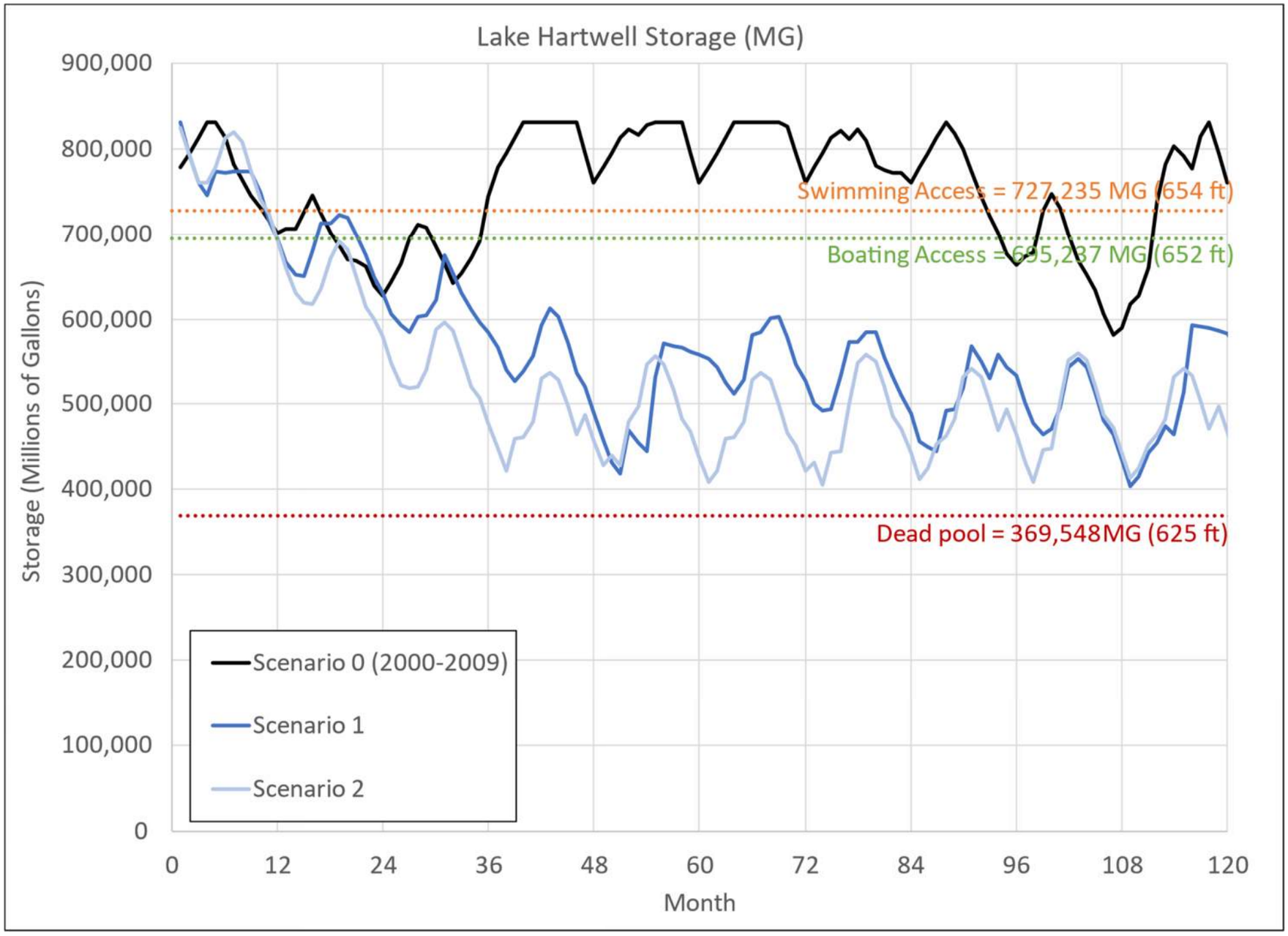

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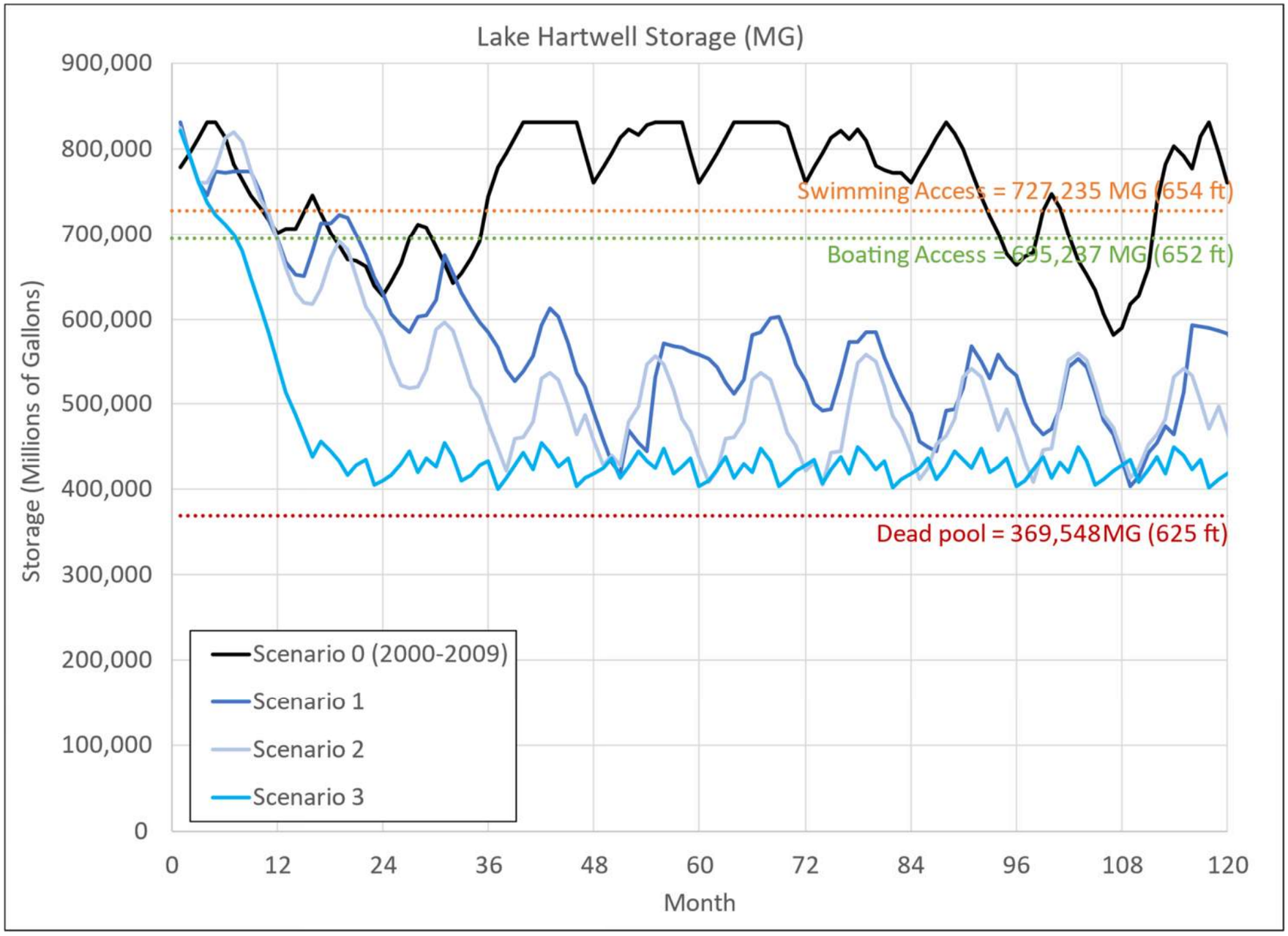

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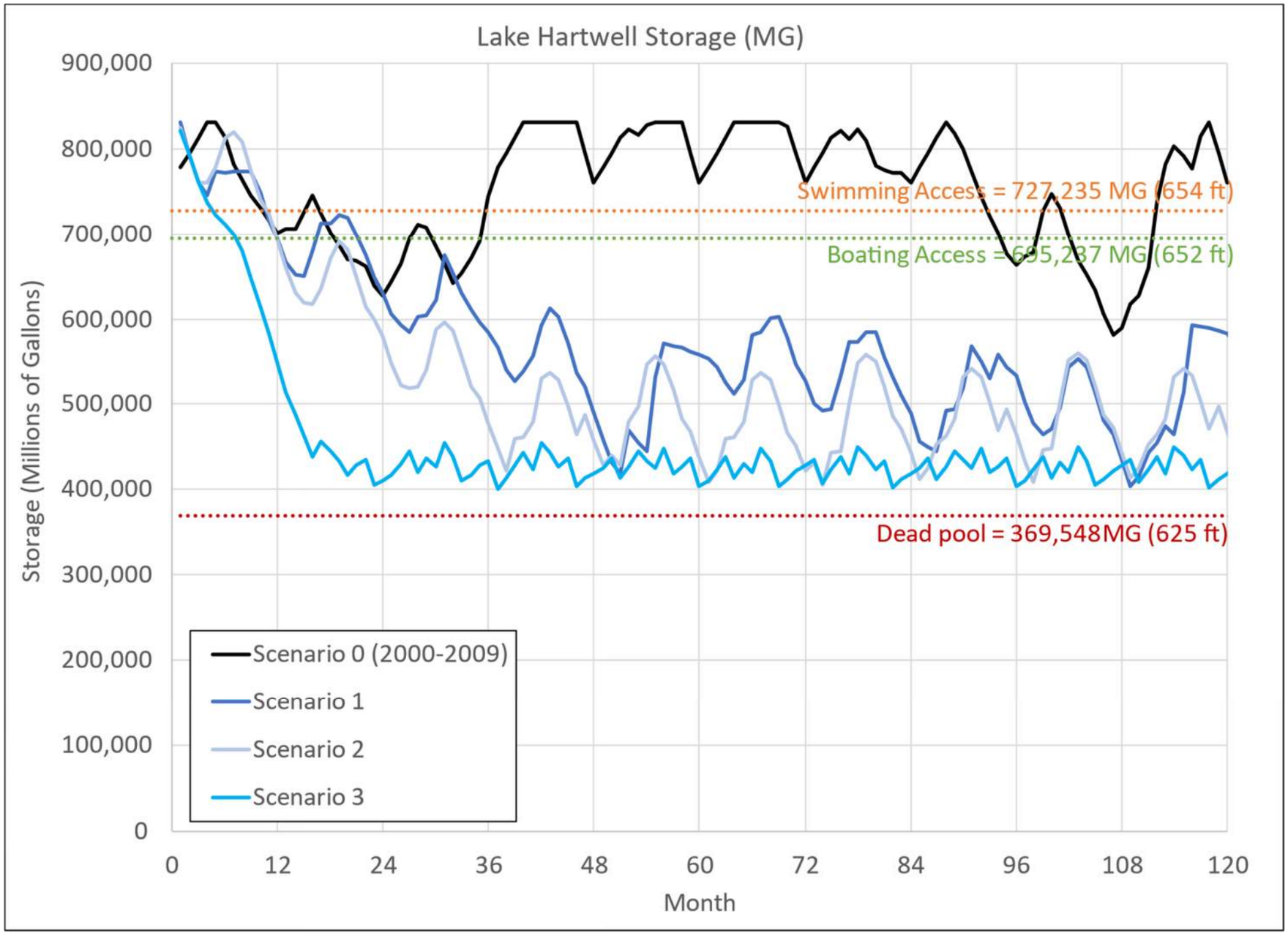

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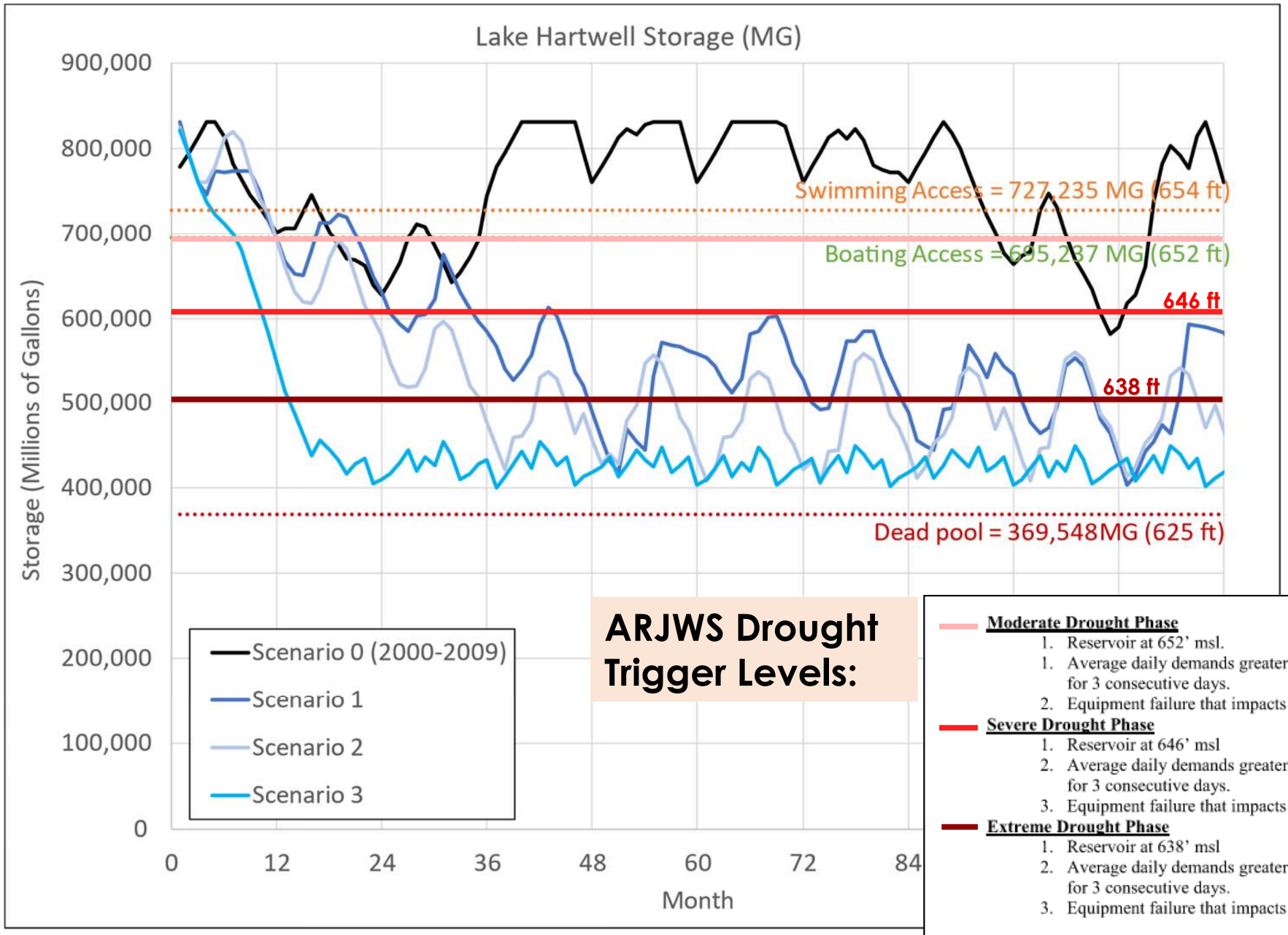

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ARJWS Drought Trigger Levels:

Moderate Drought Phase

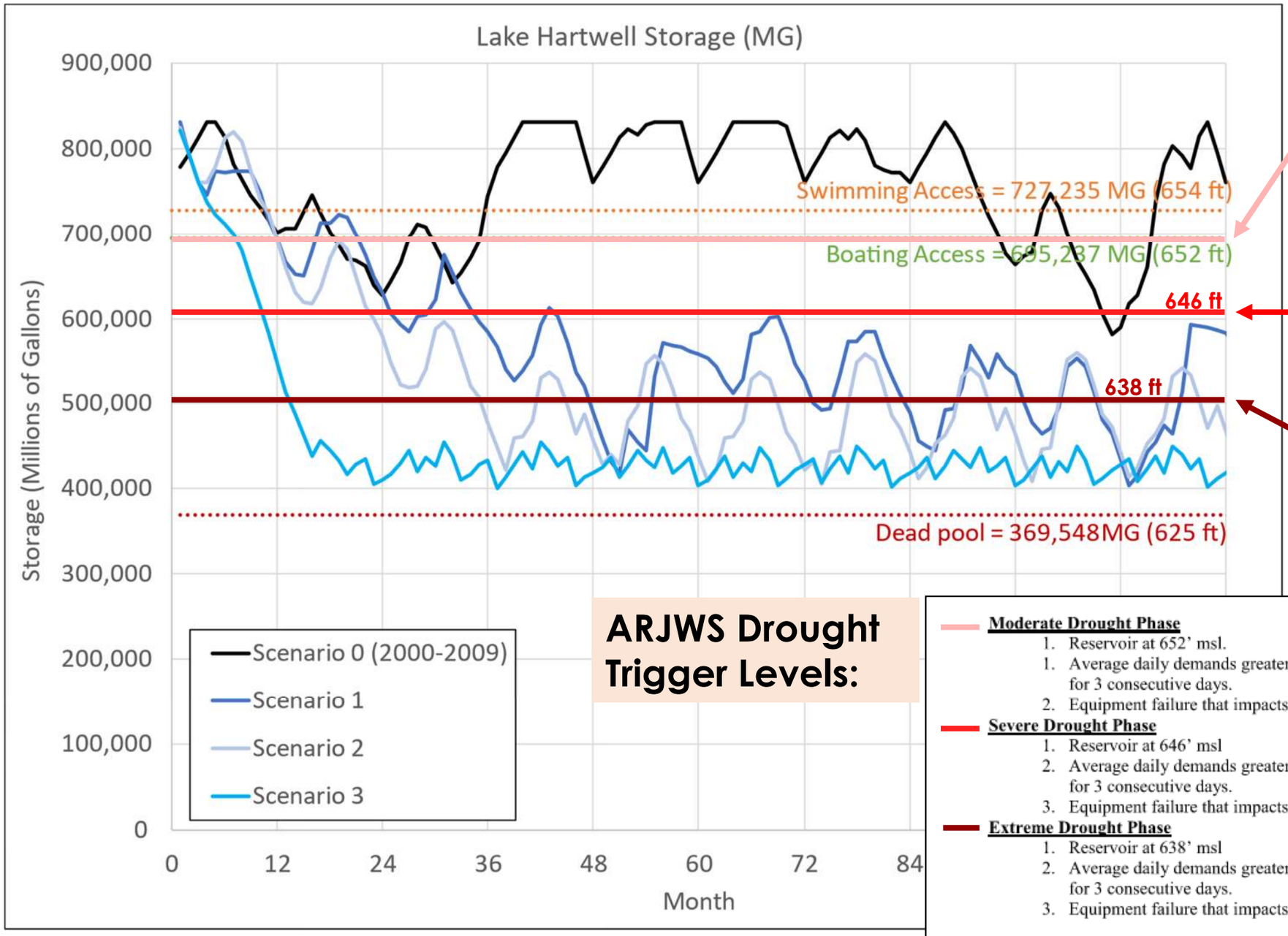
1. Reservoir at 652' msl.
1. Average daily demands greater than 80% of rated treatment capacity for 3 consecutive days.
2. Equipment failure that impacts 10% of plant capacity.

Severe Drought Phase

1. Reservoir at 646' msl
2. Average daily demands greater than 90% of rated treatment capacity for 3 consecutive days.
3. Equipment failure that impacts 15% of plant capacity

Extreme Drought Phase

1. Reservoir at 638' msl
2. Average daily demands greater than 95% of rated treatment capacity for 3 consecutive days.
3. Equipment failure that impacts 25% of plant capacity



ARJWS Drought Response Ordinance Calls for:

Voluntary restrictions

Voluntary restrictions and Mandatory restrictions on non-essential water use, with goal of 10% reduction in demand

Mandatory restrictions on, with goal of 20% reduction in demand

ARJWS Drought Trigger Levels:

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Extreme Drought Phase

1. Reservoir at 638' msl
2. Average daily demands greater than 95% of rated treatment capacity for 3 consecutive days.
3. Equipment failure that impacts 25% of plant capacity

Example Drought Plan Triggers

Water Supplier	Year	Water Source	Drought Indicator / Trigger Types
Abbeville Public Water System [2]	2003	Surface Water - **Lake Russell**	**Lake Russell is 4.5 feet, 7 feet, or 10 feet below full pool.** The upper water intake screen at Raw Water Pump Station is only partially submerged, the upper raw water intake is completely out of the water, or the lower raw water intake is only partially submerged. Average daily flow is greater than 4.5 MGD for 3, 10, or 14 consecutive days. Reservoir is completely full. There are 3 days or 1 day of supply remaining.
Anderson Regional Joint Water System (ARJWS)	2008	Surface Water - **Lake Hartwell**	**Reservoir at 652, 646, or 638 feet mean sea level (msl).** Average daily demands greater than 80%, 90%, or 95% of rated treatment capacity for 3 consecutive days. Equipment failure that impacts 10%, 15%, or 25% of plant capacity.
McCormick Commission of Public Works (CPW)	2003	Surface Water and Groundwater - **Strom Thurmond Reservoir**, 630-foot deep well	**Strom Thurmond Lake is 5, 10, or 15 feet below full pool.** Average daily flow is greater than 2.0 MGD for 3, 10, or 14 consecutive days. Reservoir is completely full. Two feet of water above all raw water intakes at Lake Thurmond, one raw water intake inlet above lake level, or two raw water intake inlets above lake level.
Seneca Light and Water [3]	2008	Surface Water - **Lake Keowee**	**Storage falls below 35 percentage of capacity.** Average daily use greater than 12 MGD for 2 consecutive days. Reservoir at 15 feet or 20 feet below full.

Typical Drought Ordinance

Moderate Drought Phase Goal of 15% Overall Reduction in Water Use

✓ Request voluntary conservation measures

Severe Drought Phase Goal of 20% Overall Reduction in Water Use

✓ Request more stringent voluntary conservation measures enact some mandatory restrictions

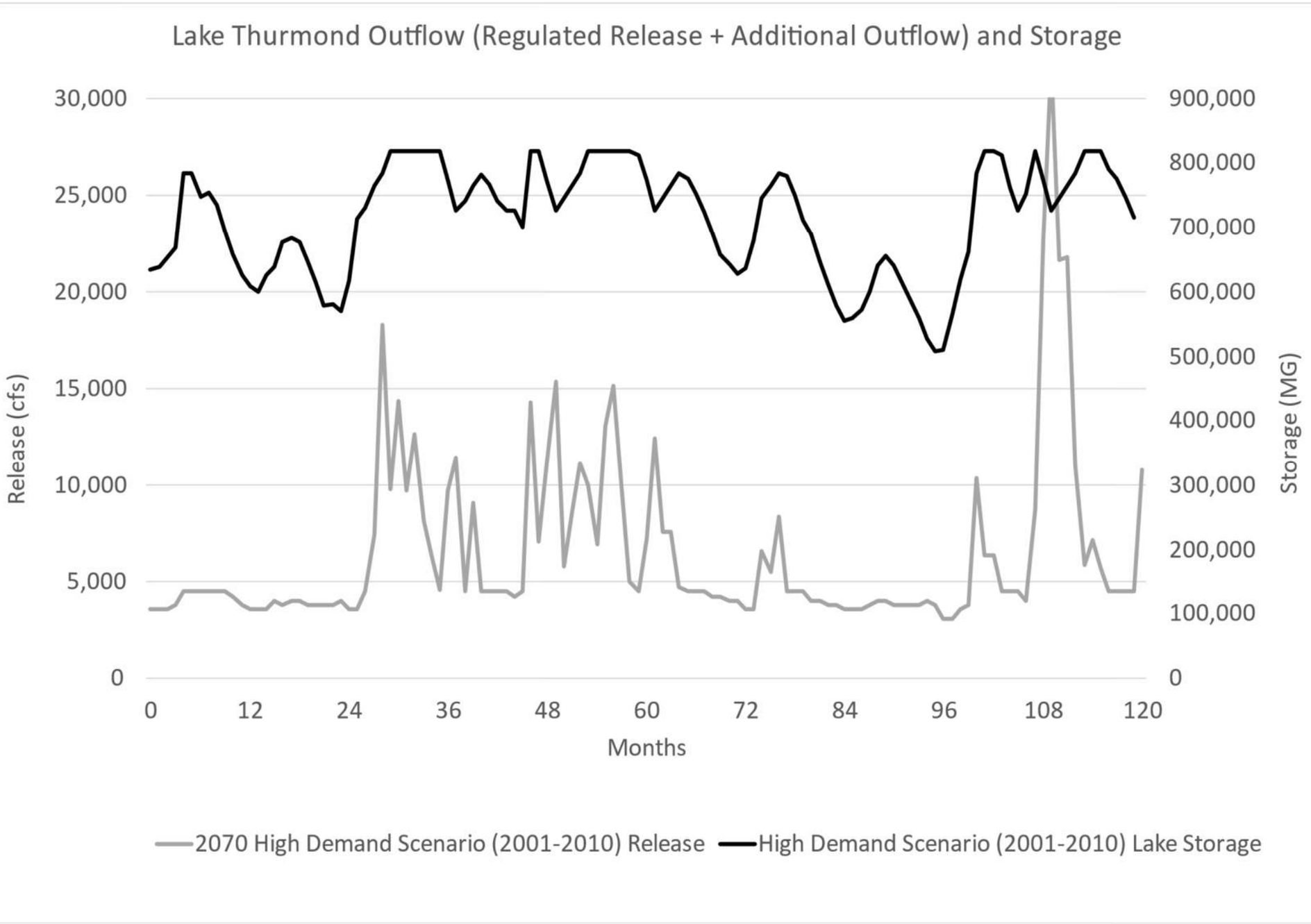
Extreme Drought Phase Goal of 25% Overall Reduction in Water Use

✓ Enact additional mandatory restrictions, impose excessive use rate schedule

Would the RBC like to request any additional analysis, such as?

- Testing the effectiveness of the **existing drought plans** in maintaining water availability and reducing impacts to recreation (i.e. lake levels) on the Current Use, Moderate, or High Demand Planning Scenarios and/or the Synthetic/Extended drought scenarios?
- Testing the effectiveness of **different drought plan triggers and/or demand reduction goals** in maintaining water availability and reducing impacts to recreation (i.e. lake levels) on the Synthetic/Extended drought scenarios?
- Other analyses?

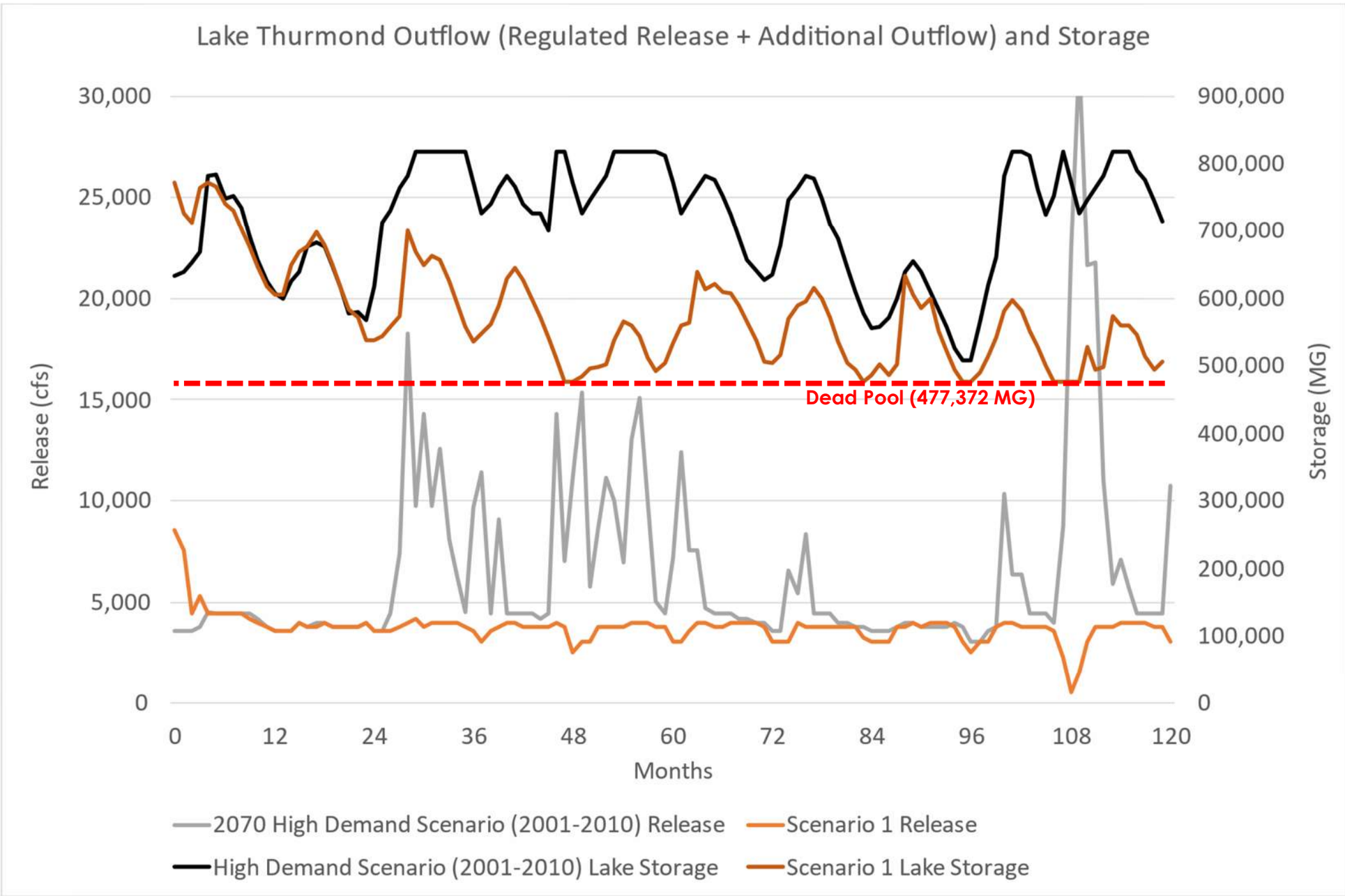
What are the impacts to the Lower Savannah River under the Synthetic/ Extended Drought Scenarios?



Resequencing Historical Flows to Investigate Potential Future Droughts

This graph plots Lake Thurmond storage and releases (monthly timestep)

2070 High Demand Scenario
For years 2001 – 2010



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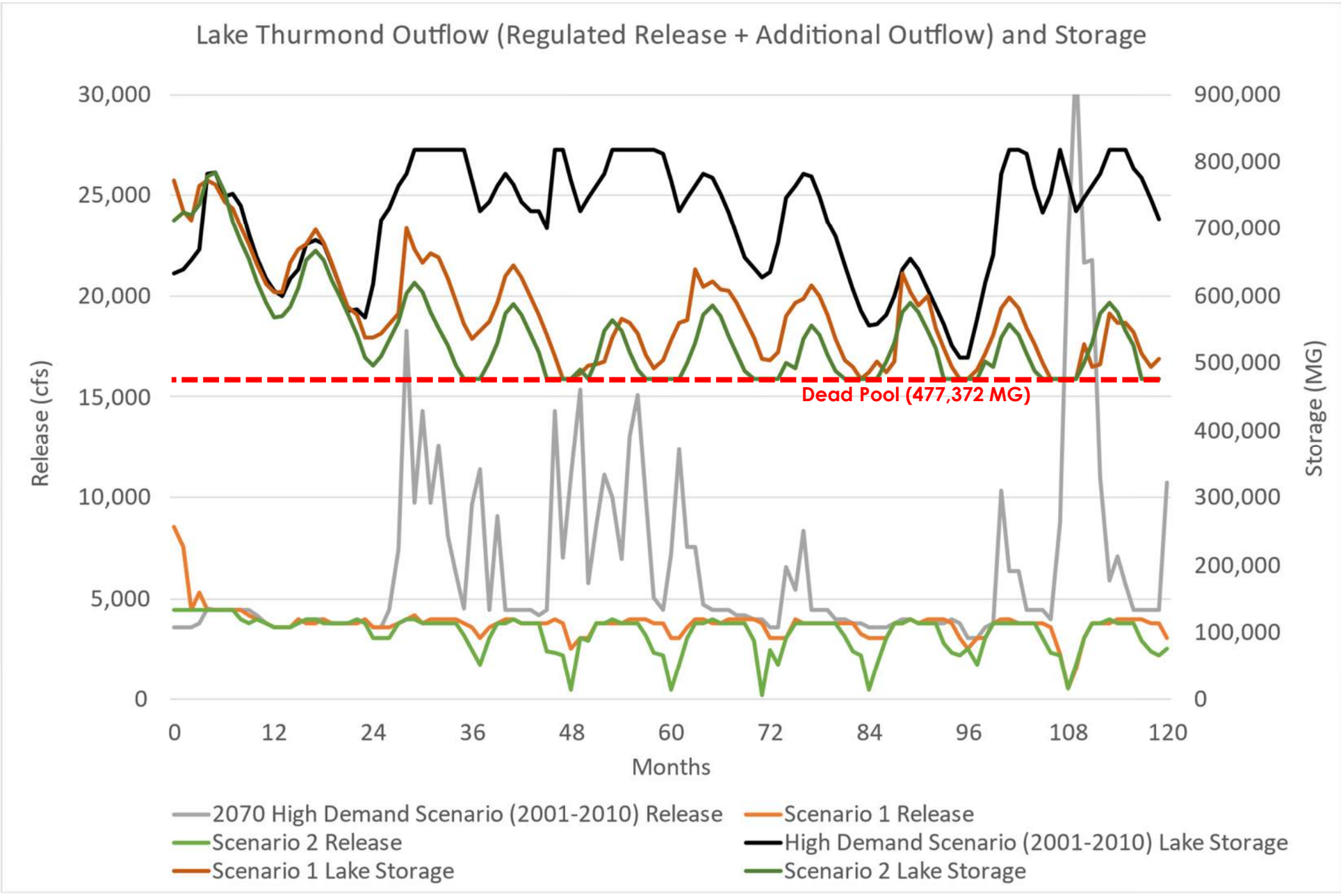
Drought Scenario 1



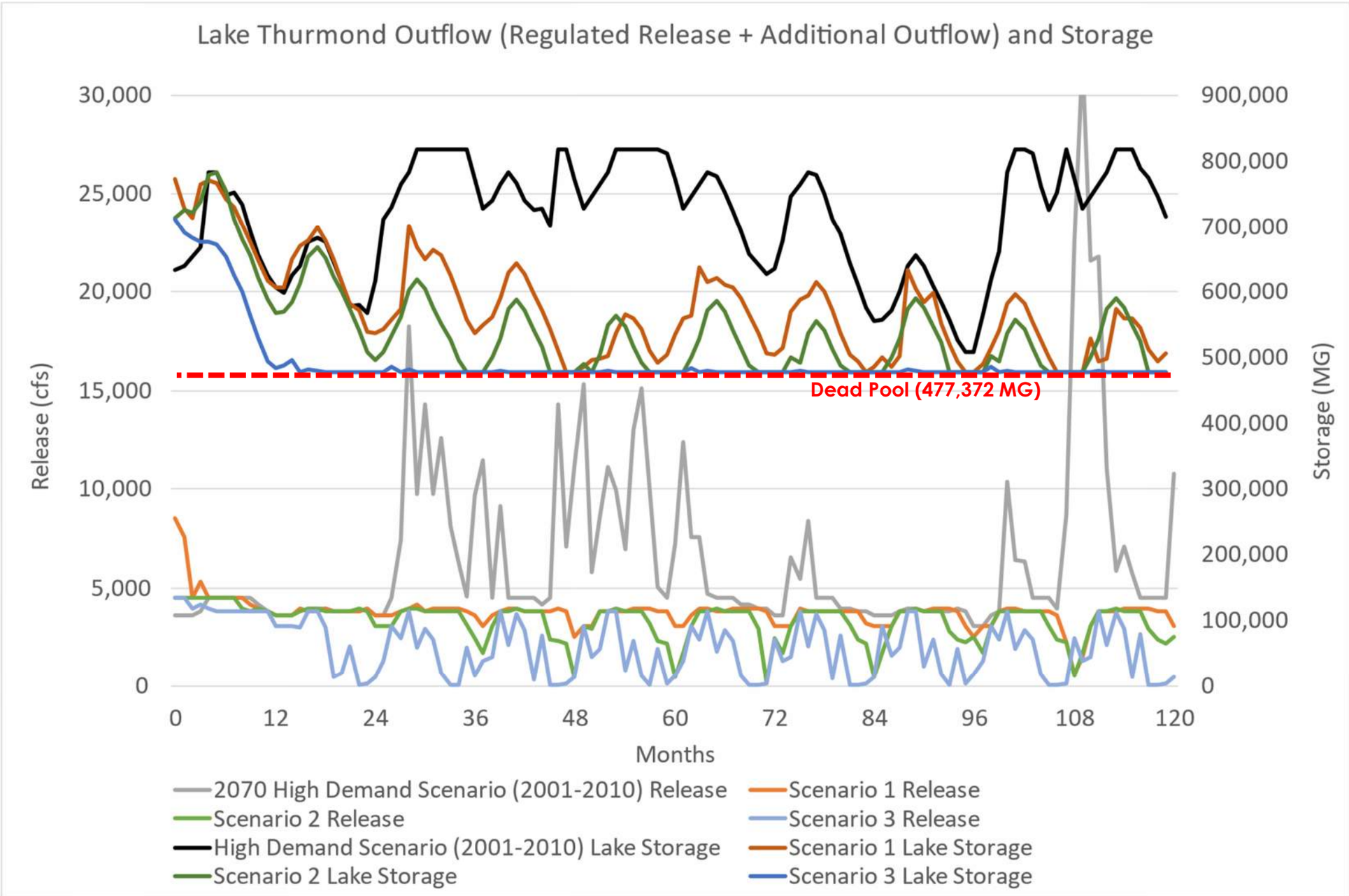
Resequencing Historical Flows to Investigate Potential Future Droughts

This graph plots Lake Thurmond storage and releases (monthly timestep)

2070 High Demand Scenario
For years 2001 – 2010

Drought Scenario 1

Drought Scenario 2



Resequencing Historical Flows to Investigate Potential Future Droughts

This graph plots Lake Thurmond storage and releases (monthly timestep)

2070 High Demand Scenario
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Drought Scenario 1

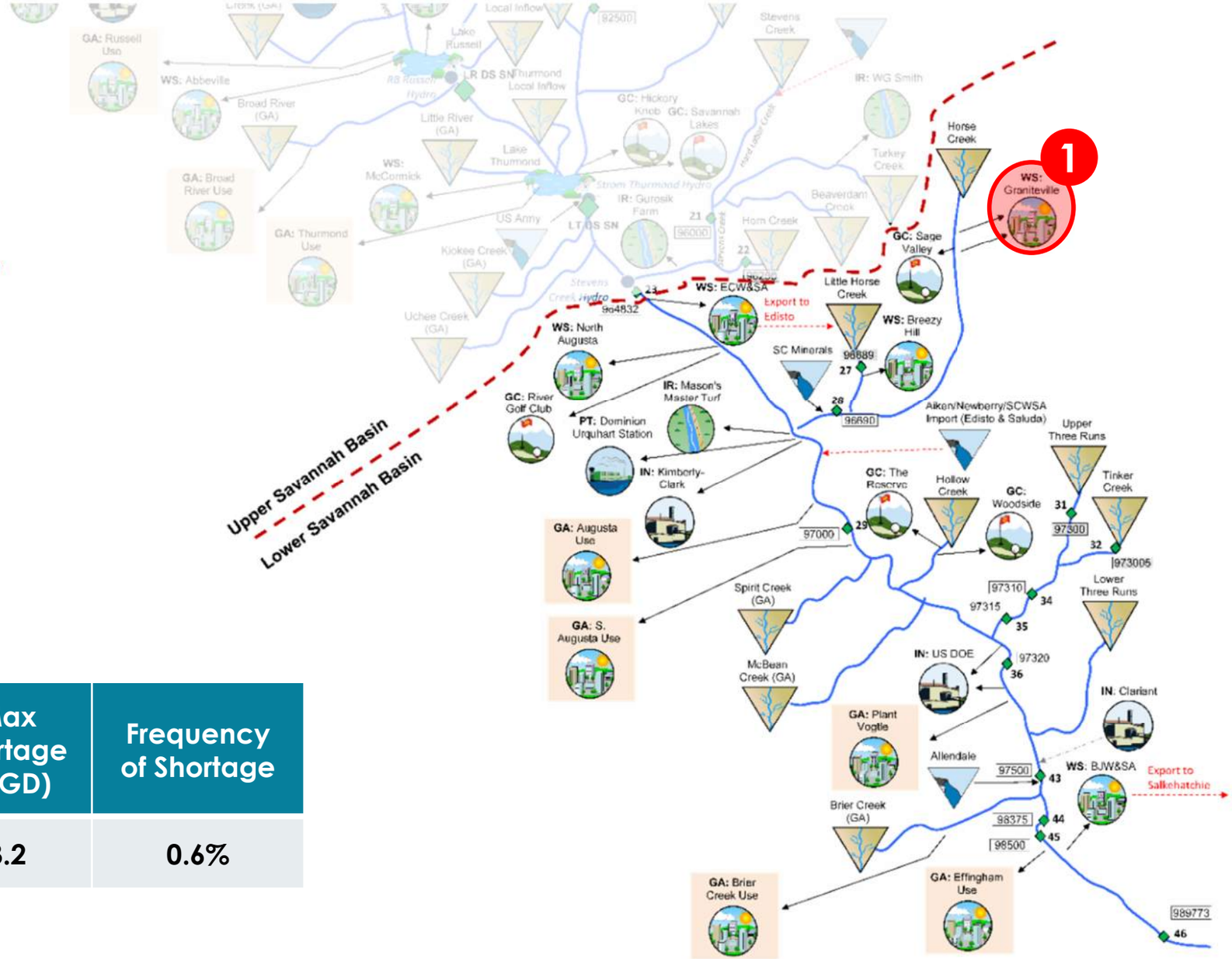
Drought Scenario 2

Drought Scenario 3

Lower Savannah River Basin

Drought Scenario 1

(uses 2070 High Demand Scenario demands)



1 **Physical Shortage**

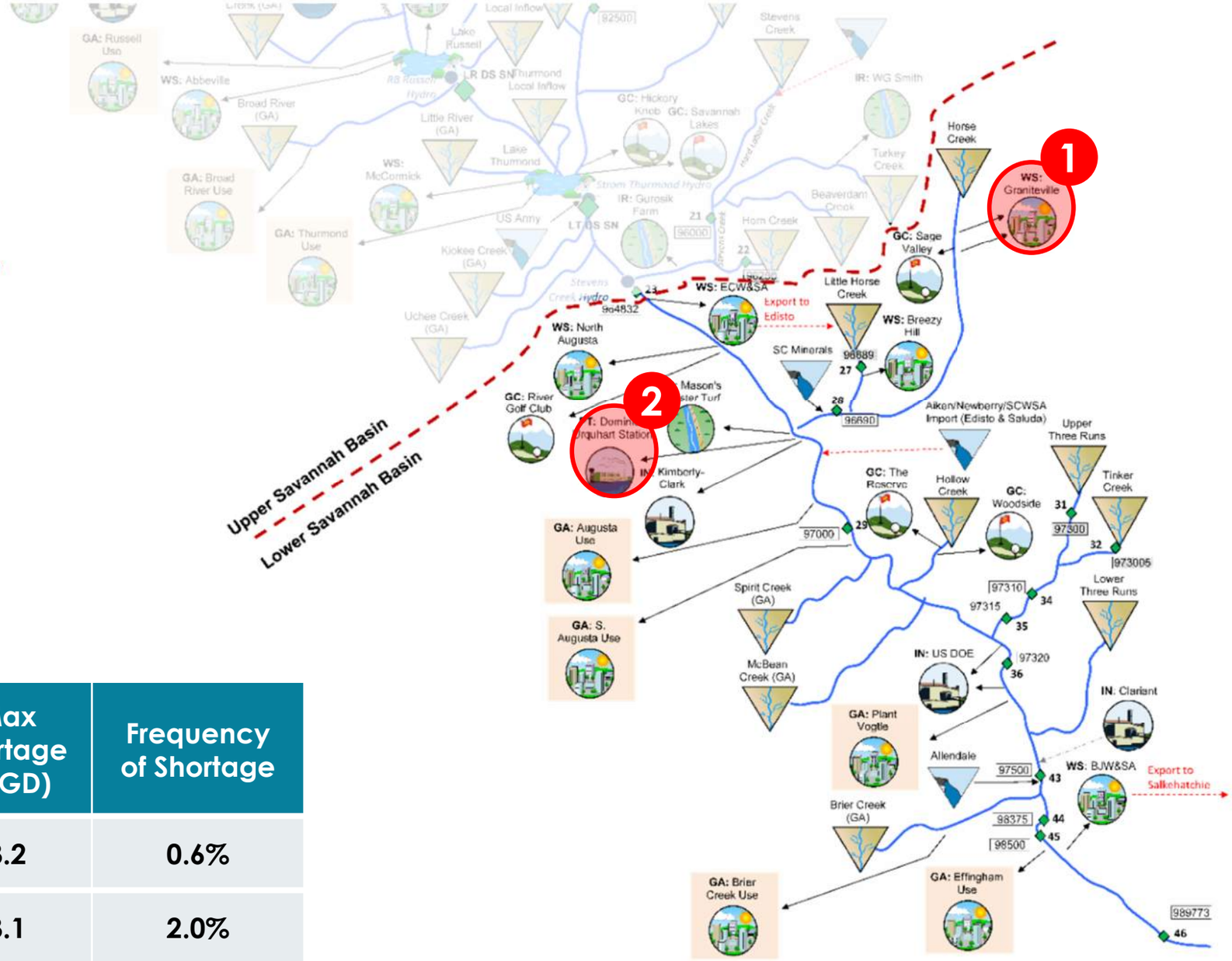
Surface Water Shortage Table

Map ID	Water User	Average Demand (MGD)	Max Shortage (MGD)	Frequency of Shortage
1	WS: Graniteville	19.5	3.2	0.6%

Lower Savannah River Basin

Drought Scenario 2

(uses 2070 High Demand Scenario demands)



1 Physical Shortage

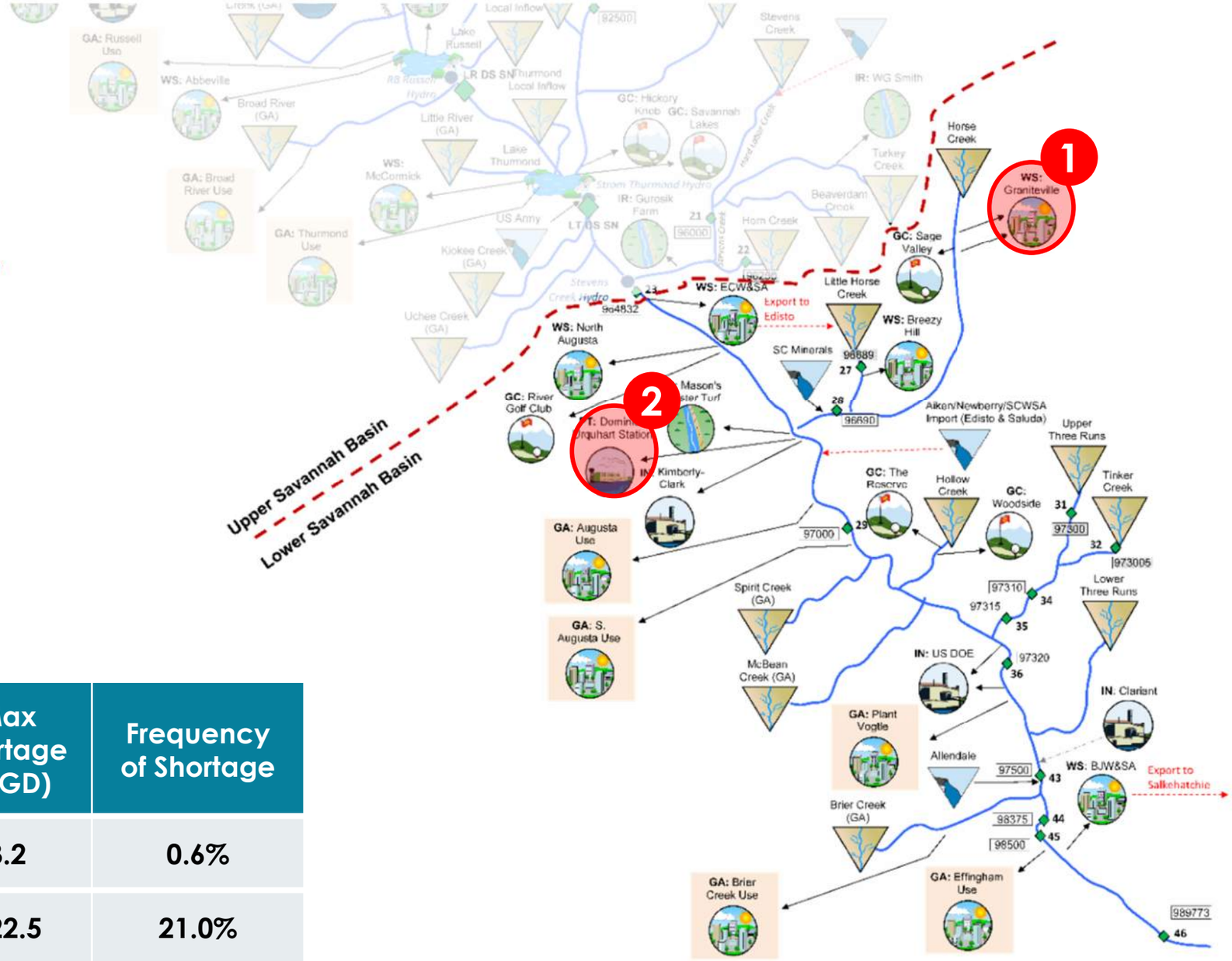
Surface Water Shortage Table

Map ID	Water User	Average Demand (MGD)	Max Shortage (MGD)	Frequency of Shortage
1	WS: Graniteville	19.5	3.2	0.6%
2	PT: Dominion Urquhart Station	149.8	3.1	2.0%

Lower Savannah River Basin

Drought Scenario 3

(uses 2070 High Demand Scenario demands)



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2	PT: Dominion Urquhart Station	149.8	122.5	21.0%

Resequencing Historical Flows to Investigate Potential Future Droughts

Discussion & Limitations

- USACE Drought Contingency Plan drought triggers conditioned upon flow in the Broad River (BR Index) would have some impact on the results, but the inability to meet release targets would still exist.

Trigger Level	Time of Year	Drought Response
1	Jan 1 - Dec 31	IF BR index >10%, Target 4200 cfs (daily average) release at Thurmond Dam IF BR index <10%, Target 4000 cfs (daily average) release at Thurmond Dam
2	Feb 1 - Oct 31	IF BR index >10%, Target 4000 cfs (daily average) release at Thurmond Dam IF BR index <10%, Target 3800 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31	Target 3600 cfs (daily average) release at Thurmond Dam
3	Feb 1 - Oct 31	Target 3800 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31 (Feb 1 – Feb 28 w/NMFS approval)	Target 3100 cfs (daily average) release at Thurmond Dam
4	Feb 1 - Oct 31	Target 3600 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31 (Feb 1 – Feb 28 w/NMFS approval)	Target 3100 cfs (daily average) release at Thurmond Dam

Resequencing Historical Flows to Investigate Potential Future Droughts

Discussion & Limitations

- Reservoir operations play a role, primarily with respect to the *location* of shortages
    - Altered operational rules could, at least partially, mitigate shortages
- No attempts have been made to directly incorporate future hydrologic or climate projections (e.g. increased evap)
- Neglects changes in groundwater-surface water interactions (e.g. reduced baseflow due to aquifer depletions)