Meeting Summary

GREAT SALT LAKE SALINITY ADVISORY COMMITTEE NOVEMBER 30, 2023

This meeting was held in person on November 30, 2023, at the Utah Department of Natural Resources with some members attending remotely via GoogleMeet. The following represents a summary of key points of discussion. It is not intended to represent meeting minutes. The meeting recording may be viewed at https://www.youtube.com/watch?v=U1XtiFCN6ms .

ATTENDEES

Leila Ahmadi/ Division of Water Resources (WRe)
Danyal Aziz/ WRe
Bonnie Baxter/Westminster University*
Carly Bieduhl/Westminster University**
Jennifer Biggs/Division of Forestry, Fire & State Lands (FFSL)
Thomas Bosteels/GSLBSC*
Phil Brown/GSLBSC
Lynn DeFreitas/FRIENDS of Great Salt Lake
Jeff DenBleyker/Jacobs
Ryan Doherty/Cargill**
Rob Dubuc/FRIENDS of Great Salt Lake
Keith Hambrecht/FFSL
Jim Harris/DWQ* (co-chair)
Joe Havasi/Compass Minerals *
Tim Hawkes/GSLBSC**
Elliott Jagniecki/Utah Geological Survey (UGS)**
Bill Johnson/University of Utah (UofU)*
John Luft/Division of Wildlife Resources (DWR)*
Mark Reynolds/US Magnesium**
Ryan Rowland/USGS*
Christine Rumsey/USGS**
Andrew Rupke/UGS*
Ben Stireman/FSL* (co-chair)
Kyle Stone/DWR**
Laura Vernon/WRe
Marisa Weinberg/FFSL**

* Salinity Advisory Committee (SAC) member
** SAC member alternate

OBJECTIVES

A key objective of the Salinity Advisory Committee (SAC) is to advise the State of Utah regarding how the salinity of Great Salt Lake (GSL) can best be managed and, more specifically, how the new Union Pacific causeway bridge may influence lake salinity. The objective of this meeting was to discuss lake conditions, evaluate current and forecasted salinity in the South Arm, and discuss recommendations for modifying the berm.

SUMMARY

A quorum was present for the meeting. Jeff DenBleyker opened the meeting with a review of the agenda for the meeting and facilitated introductions of people attending in person and online. Joe Havasi made a motion to approve the summary of the October 26, 2023, meeting; Thomas Bosteels seconded the motion. The motion was passed unanimously.

SALINITY CONVERTER WIDGET

The Division of Water Resources (WRe) has developed a salinity converter widget to help clarify the calculation and comparison of salinity vs density vs percent salinity. WRe would like to post to their website for public use and requested feedback and approval from the SAC to do so.

Ben Stireman thought it was easy to use and very helpful. Ryan Rowland indicated that USGS had reviewed the widget and thought the approach was correct. Jeff DenBleyker noted that the units for density were a little different than the SAC's Standard Operating Procedure (SOP) for salinity calculations. The consensus was that kg/L is correct but that g/cm^3 is more commonly used in this context, used on the Anton Paar meter, and is what is in the SOP. Kyle Stone asked that a comment be added that this method cannot be used directly with refractometer results. The widget should also reference the SOP and equation of state documents. Brine mass concentration should include "(salinity)" in the title and brine mass percentage should include "(% salinity)" in the title for clarity. The SAC asked to have the widget posted to UDNR's GSL website and USGS Hydromapper for GSL.

Thomas Bosteels made a motion to approve the widget for publication with the above changes; Mark Reynolds seconded the motion. The motion passed unanimously.

Update on Lake Conditions

Christine Rumsey provided an overview of lake conditions. South Arm water level is at 4192.3ft, slightly higher since last month. North Arm water levels have also increased by 0.1 feet since last month. There is still a 3.0ft difference between the water level in the North Arm and South Arm.

Inflow volume water year to date (October 1, 2023, through today) from the Bear River is at the median of historical values. Weber River inflows are near the all-time high year to date. Farmington Bay outflow is near the median value. Goggin Drain inflows are near the 75th percentile value.

South to North flows through the new breach was measured at 817 cfs on November 3 and 695 cfs on November 14. There is no discernable North to South flow. The change in flow may be because most of the flow is now through the v-notch of the berm.

The salinity of the South Arm was measured on November 6 as 136-144 g/L across all sites with 140-144 g/L more representative of the South Arm. Salinity was similar at different depths. These salinities are about 41-46 g/L lower than November 2022. The current salinity is within the target salinities in the berm protocol that the SAC previously developed.

Salinity Approximations for 2024

Christine Rumsey provided an overview of the calculations she completed as requested by the SAC. She had previously illustrated that the salinity at the bridge could be 10-30% lower due to freshwater influence from the Bear River. She had been asked to investigate how the cumulative flux may have changed throughout the season with and without Bear River influence and how that might influence the salinity of the South Arm. See her attached slides.

Using estimated flow through the bridge and discrete measurements of salinity at various locations, the estimated cumulative flux for April – July (2023) may have been 8-12% higher if the South Arm was fully mixed (ie, water with a higher salinity flows to the north), versus the lower salt flux that was observed through the bridge due to unmixed Bear River water. Using the salt mass balance and data from 2023, Christine estimated the Bear River can swing the salinity of the South Arm up to 20 g/L (if the Bear River does not mix with the South Arm at all vs if it fully mixes with the South Arm). She estimated that about 63% of the Bear River mixed with the South Arm in 2023. If 100% of the Bear River had mixed in 2023, the salinity might have been 6.6 g/L lower. She estimated that only 25% of the Bear River mixed in 2022 but conditions were different in that runoff was much lower and the berm was largely not restricting flow to the North Arm. She estimated that if 100% of the Bear River had mixed in 2022, the salinity may have been 4.2 g/L lower.

Joe Havasi asked how the berm may have influenced the observed salt flux and salinity. Christine thought that given the short-circuiting we have observed that the berm does improve mixing within the South Arm. The amount of water that is mixed within the South Arm appears to have more influence on its salinity than the salt flux through the bridge.

She also estimated salinity for the South Arm in spring 2024. If she assumes that the Bear River and other inflows are fully mixed into the South Arm, then the salinity could range from 123-124 g/L. If only 60% of the Bear River mixes with the South Arm, then the salinity could be 131-132 g/L. The unmixed forecast is at or above the target spring salinity per the protocol. This again illustrates the importance of capturing the inflow and mixing it with the South Arm to dilute the salinity. The SAC thanked Christine for her work.

Joe Havasi and Thomas Bosteels discussed how the ability to store, mix and dilute water in the South Arm and use the North Arm as a sink is a benefit. Joe explained that maintaining connectivity is important, the berm is temporary. Ben Stireman noted that we need to move water to the North Arm to control salinity in the South Arm, thus agreed that the berm should be temporary. Maximum flexibility is needed until we fully understand the system's dynamics; adaptive management has been critical for our success so far. We need to be creative in how we manage the salinity of the South Arm. Bill noted that we will need to carefully consider the options.

Ideas for Mixing Inflow in the South Arm

Jeff DenBleyker provided an overview of the goal, observations, and options the SAC has discussed to better mix South Arm water. Ideas were as follows:

1. Redirect Bear River flow to the south and east of Fremont Island. The Willard Spur area (southeast of Fremont Island) is near an elevation of +4194ft, thus a dike would likely be needed from Promontory Point to Fremont Island or a channel would need to be dredged to convey Bear River water to the south. Bill Johnson agreed that an engineered solution could be explored, notably a channel east and south of Fremont Island. John Luft said that we don't want to pool freshwater up

in Ogden Bay due to the potential for botulism so a channel is probably best; also need to consider sedimentation. Thomas Bosteels added that we don't know how these freshwater lenses benefit/impact artemia hatching. We don't want to simply eliminate that.

2. Dike to Divert Bear River inflow to the South. Numerous possible configurations are possible depending upon lake flow patterns. This solution is permanent, result isn't clear at this point, possible navigation hazard, and we do not understand the impact of mixing the freshwater upon Artemia.
3. Floating Boom to Divert Inflow to the South. Numerous possible configurations are possible depending upon lake flow patterns. This option is targeted more at the surface flows we want to mix. Less permanent and cheaper, result isn't clear at this point, possible navigation hazard, and we do not understand the impact of mixing the freshwater upon Artemia. Bill noted that the Bear River inflow is not only at the surface of the South Arm but extends down at depth.

Jeff summarized lake circulation patterns as illustrated in Rich 2002 (published in "Great Salt Lake, An Overview of Change", 2002, edited by Wally Gwynn). Field studies have generally observed a counter-clockwise gyre in Carrington Bay and separate counter-clockwise gyres in both northern and southern Gilbert Bay. Bill Johnson added that there are many factors that create these gyres. Jeff suggested that the flows we are seeing at the bridge may not only be influenced by Bear River inflows but also by Farmington Bay inflows. The SAC noted that there are also other factors such as changing bathymetry, phragmites, and even flow patterns in the lake. Bill said he had some publications that might also be useful. Key questions that remain: is this only a Bear River mixing issue? What impact will these ideas have upon lake flow patterns and ecology? Will it accomplish what we intend? Are there other unintended consequences?

4. Berm Management per Recommended Protocol. Do we want to lower the berm now? then raise the berm and allow the South Arm to fully mix? And then lower the berm in July/August to flush water/salt to the North Arm? It is important to discuss this now to take advantage of winter inflows.

Ben Stireman suggested we should consider how much water we can export if we lower the berm now to an example elevation of 4187 feet. There was discussion about lowering it too far such that North-to-South flow can occur; there was concurrence that we do not want that. Jeff estimated that the difference between 500cfs and 1000 cfs for 60 days is approximately 60,000-acre feet – that assumes that is the actual change in flow. Ben's concern is that we do not know what the inflow will be from this winter. There was general agreement that opening the berm now or waiting to raise the berm will result in lost benefit in moderating the salinity of the South Arm. Joe Havasi said that opening the berm now would be very beneficial for the North Arm; it is not just about the salinity of the North Arm, but it would help export salt to the North Arm. Ben suggested that we evaluate the benefit of opening the berm on salinity to inform investment of the available money in managing the berm. How will we get the most benefit? Christine estimated that exporting 60,000 AF for these few months will only reduce the salinity by 0.2g/L. The best benefit appears to be from storing and mixing the South Arm water.

Thomas Bosteels made a motion to raise the berm to 4196 feet as soon as possible and then lower the berm this summer to maximize export of water/salt after spring runoff. John Luft seconded the motion. Joe Havasi made a motion to amend the original motion to lower the berm to 4189 now and then raise it again in February. Ben's concern is that water managers may be releasing water from reservoirs now, we lose the benefit of mixing and only lower the salinity by 0.2 g/L. He is also concerned about whether Union Pacific will be willing to make too many changes. He suggested leaving the berm as is and then raise the berm. John and Thomas were concerned about waiting too late to raise the berm. Christine Rumsey noted that we may be able to move more water to the North Arm by lowering the berm to 4189 when the South Arm water level is at its peak after runoff. There was not a second to Joe's proposed amendment and the group reverted back to the original motion above. Of the 9 eligible voters, 1 voted no, 1 abstained, 1 was not present, and 6 voted in favor of the motion. The motion passed. Jeff will send an email to DWQ and FFSL with that recommendation.

MINERAL EXTRACTION IMPACT ON SALINITY

Mark Reynolds provided some background on US Magnesium's request to evaluate the impact that the mineral extraction industry is having upon the lake. He noted that we need this information to make informed decisions. He summarized the key tasks he thinks need to be completed by an independent third party:

1. Evaluate the salt balance in the South Arm due to salt removal, mineral returns, and stored salt in evaporation ponds.
2. Evaluate water level effects due to mineral extraction in both the South and North arms.
3. Compare mineral extraction effects on salinity and surface elevation with the current berm management protocol to export water and salt to the North Arm.

4. Estimate the advantages and disadvantages of directing South Arm mineral extractors to source brine extraction to a North Arm source.

Ben Stireman supported the proposal and clarified that he wanted to make sure the study also evaluates what happens if lake levels rise and dissolve the salt in the evaporation ponds. He urged that we make sure the study addresses the right question; that is what the GSL Advisory Council is asking for. Andrew Rupke agreed that this is an important study. Bill Johnson added that we should also consider the salt cap that is proposed on US Magnesium's closure plan. Jeff added that DWRe's gap analysis identified a similar gap and need. A key first step is to improve the salt balance and then evaluate different scenarios. Tim Hawkes suggested the SAC identify a process to develop the questions.

A subcommittee was identified consisting of Mark Reynolds, Ben Stireman, Joe Havasi, Thomas Bosteels, Andrew Rupke, Jim Harris, and Christine Rumsey. Jeff will work with this group to schedule a virtual meeting to discuss further. Marisa Weinberg asked that the committee also identify what they cost might be; that would also be helpful for the GSL Advisory Council.

The meeting was adjourned.

ACTION ITEMS

- Jeff DenBleyker will summarize the motion to raise the berm and send to DWQ and FFSL.
- Jeff will work with FFSL to develop a folder for the SAC to share files on.
- Jeff will work with the subcommittee to schedule a meeting.

Next meeting: January 25, 2023, 10:00am – 12:00pm.

Great Salt Lake Update

View from Gilbert Bay, Great Salt Lake, October 2018

Discussion Topics…

- Lake elevation and discharge/velocity data
- Salinity update
- SAC questions

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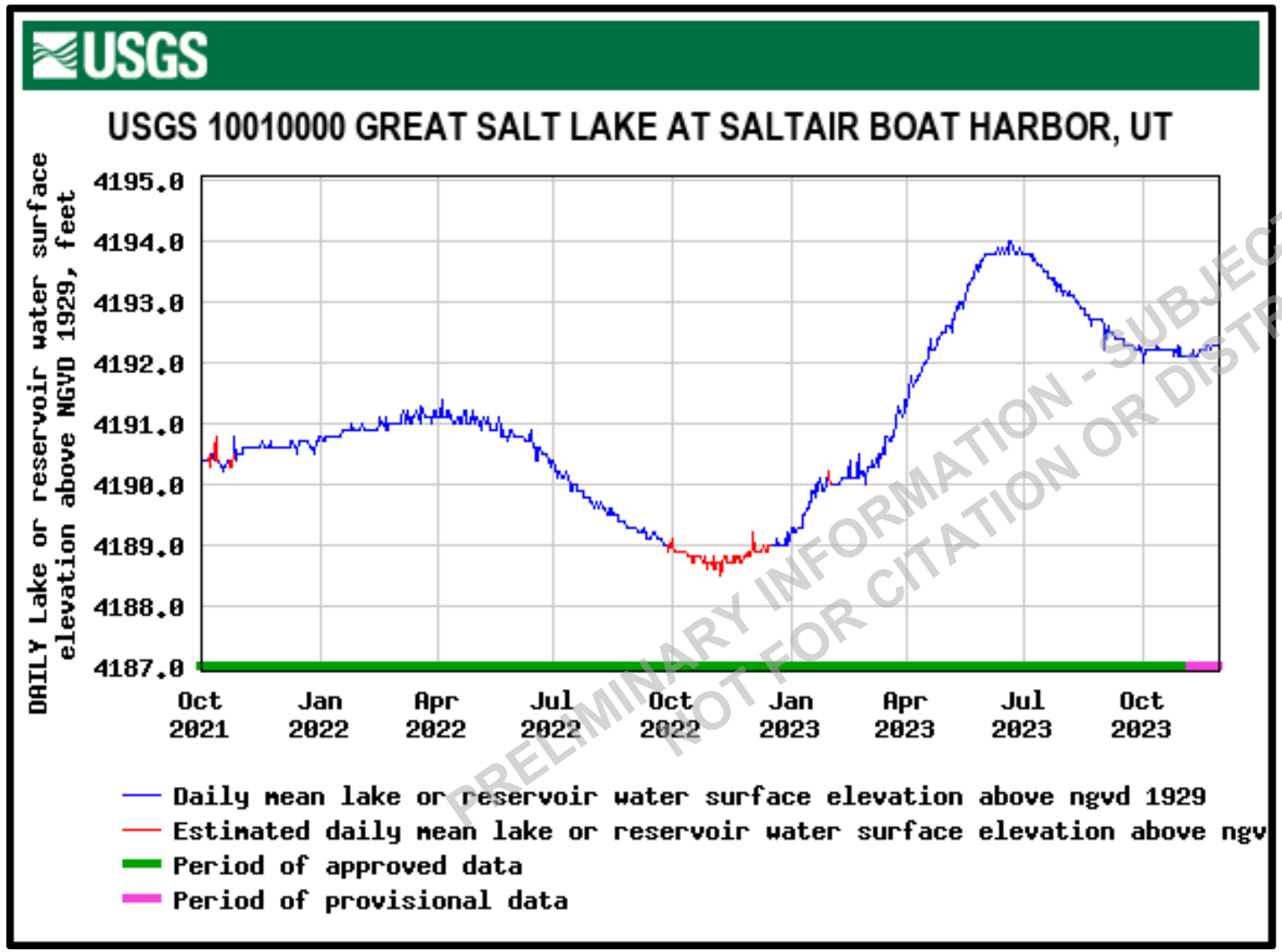
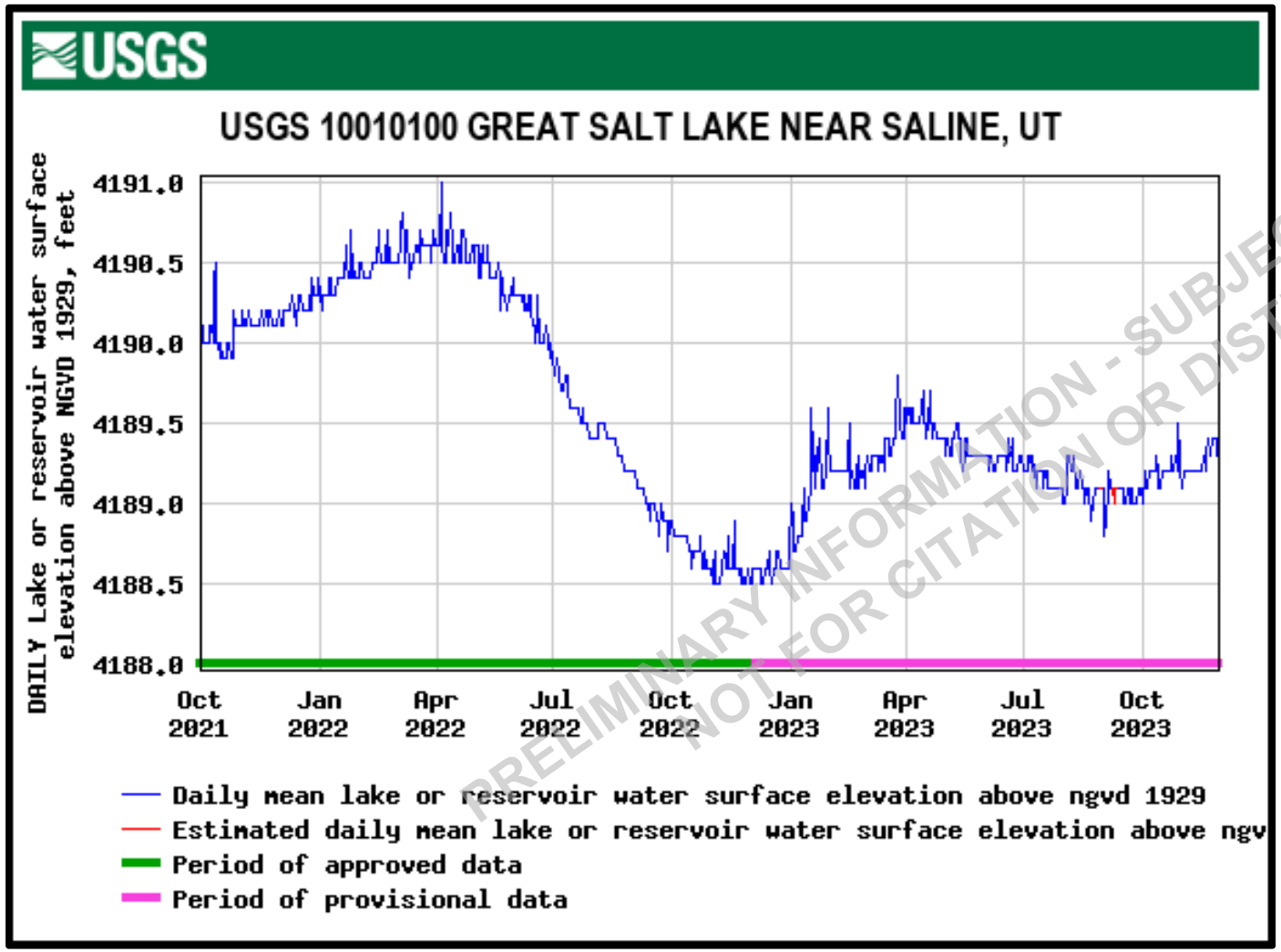
Lake Surface Elevation – South Arm



- Daily value 11/28/2023 = 4,192.3’
- Spring high = 4194.0’ on 6/19 and 6/20/2023
- Down 1.7’ since June

Lake Surface Elevation – North Arm



- Daily value 11/28/2023 = 4,189.3’
- Spring high = 4189.8’ on 3/24/2023
- Down 0.5’ since March

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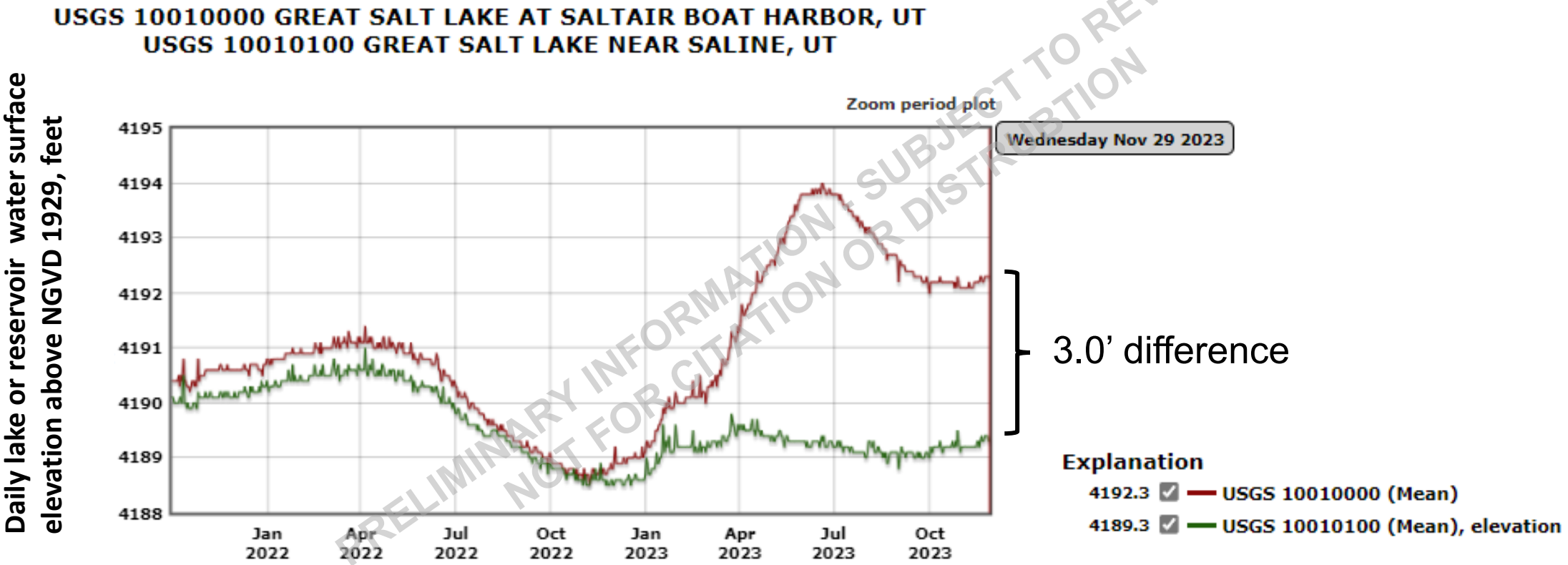
Lake Surface Elevation



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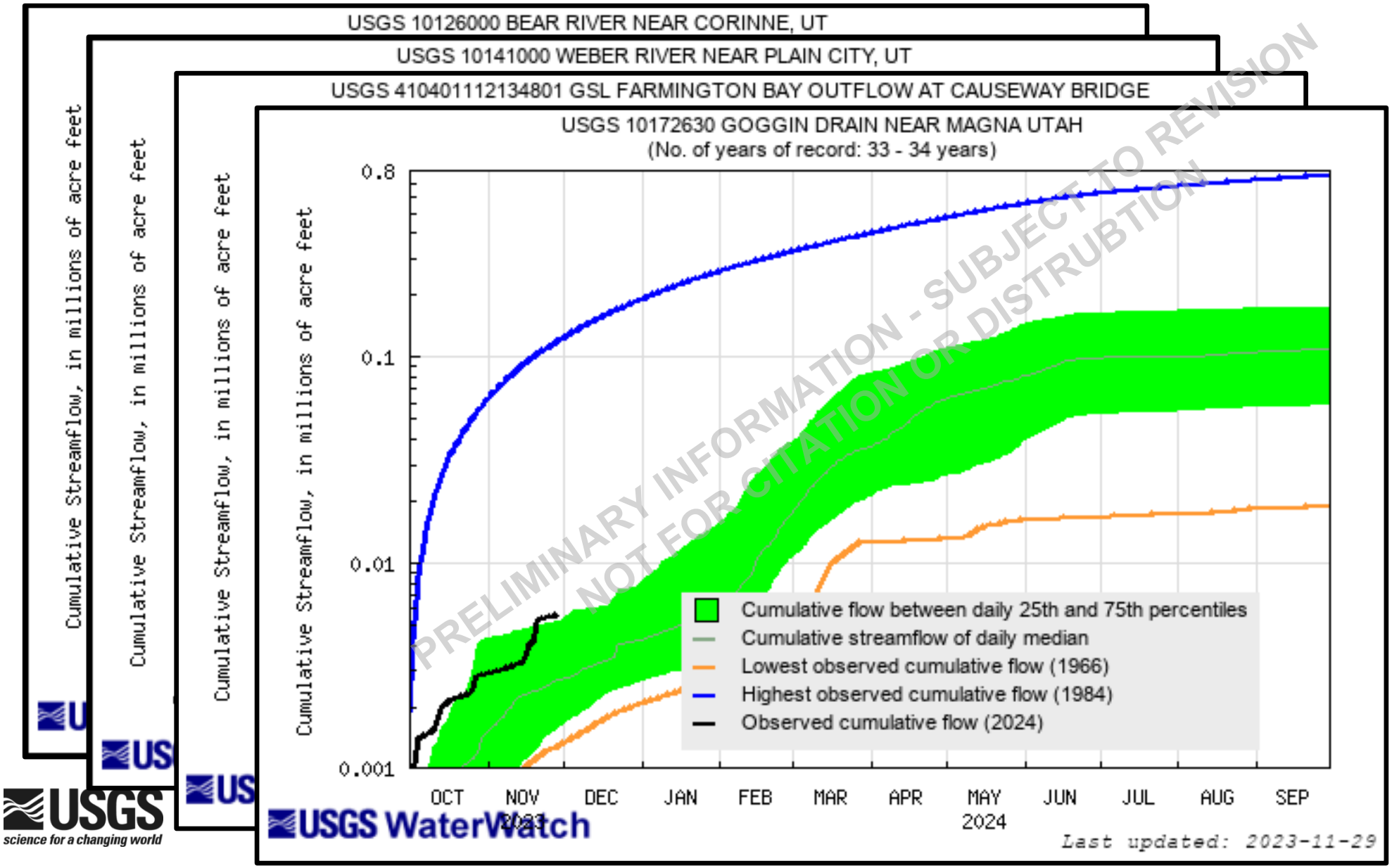
Major Surface Water Inflow Gages



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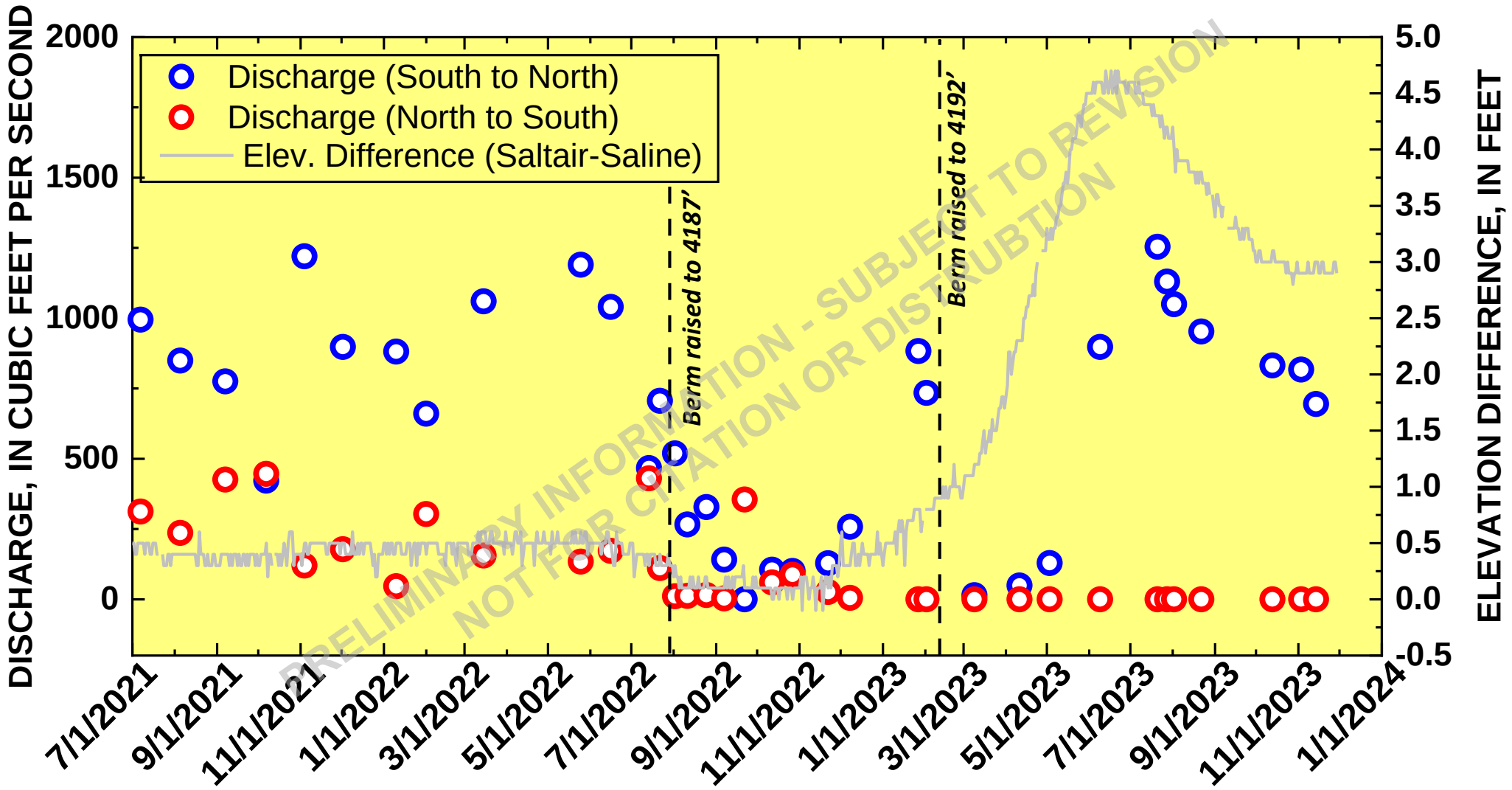
Preliminary information-subject to revision.
Not for citation or distribution.

New Breach Flows



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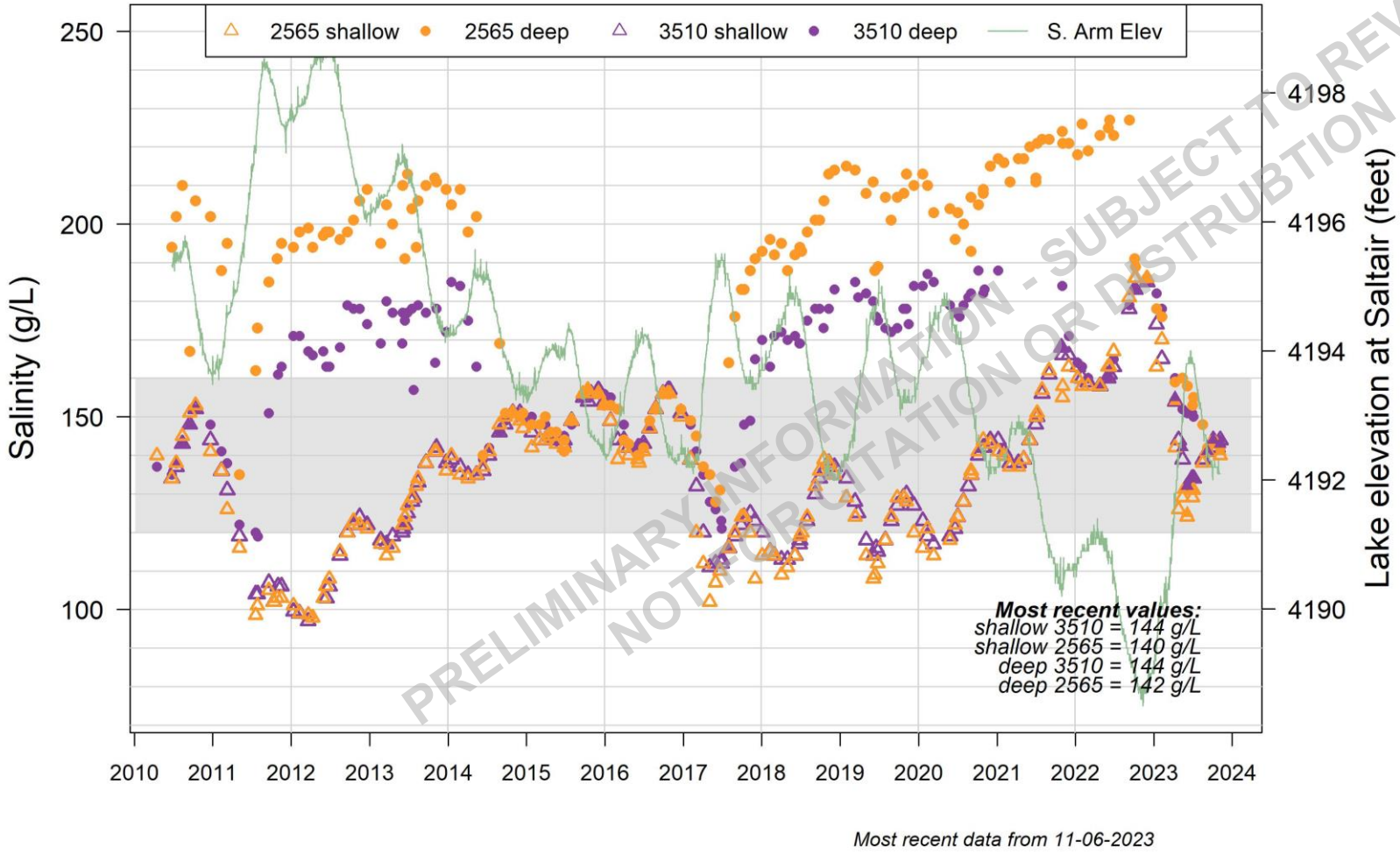
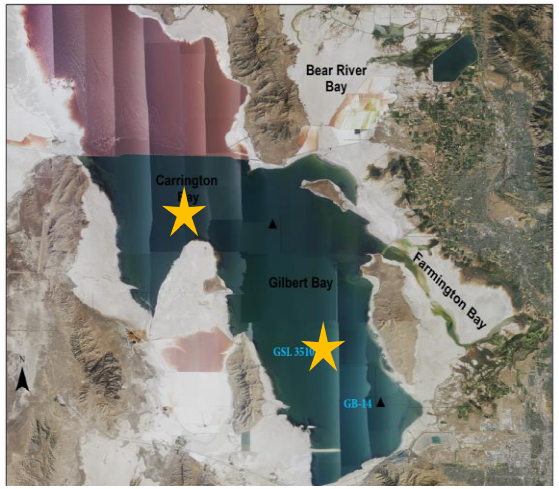
Current conditions: Salinity at 2 GSLEP sites





Other recent shallow salinities:

- ***New Breach, 10-13-23 142 g/L (S to N)***
- ***Saltair, 10-10-23 143 g/L***
- ***UGS Saltair, 11-11-23 137 g/L***

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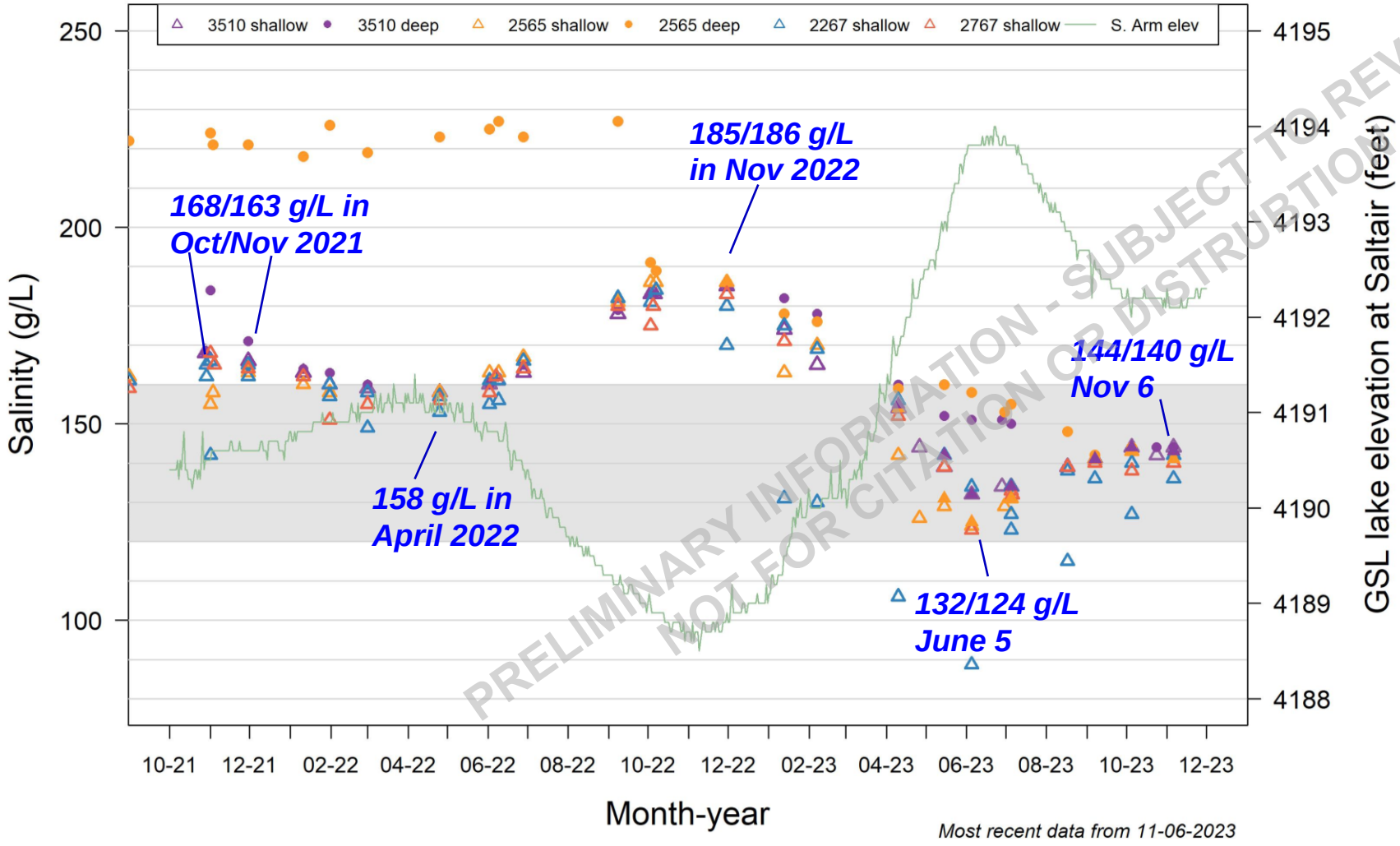
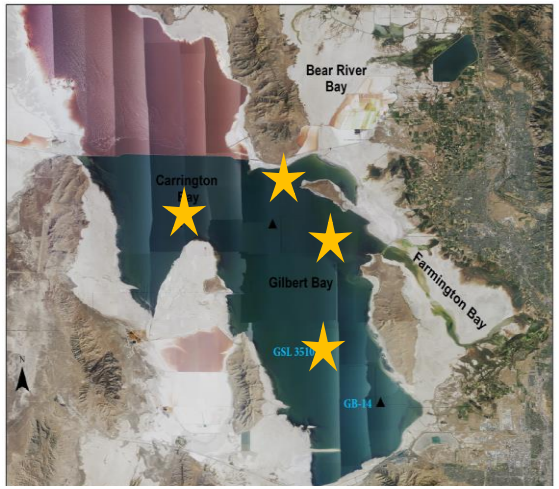
Current conditions: Salinity at 4 GSLEP sites





Nov. 2022 to Nov. 2023:

3510: Δ = -41 g/L

2565: Δ = -46 g/L

<u>November 6, 2023 shallow salinities:</u>

3510, 0.5/3 m = 144/143 g/L

2565, 0.5/3 m = 140/141 g/L

2267, 0.5 m = 136 g/L

2767, 0.5 m = 140 g/L

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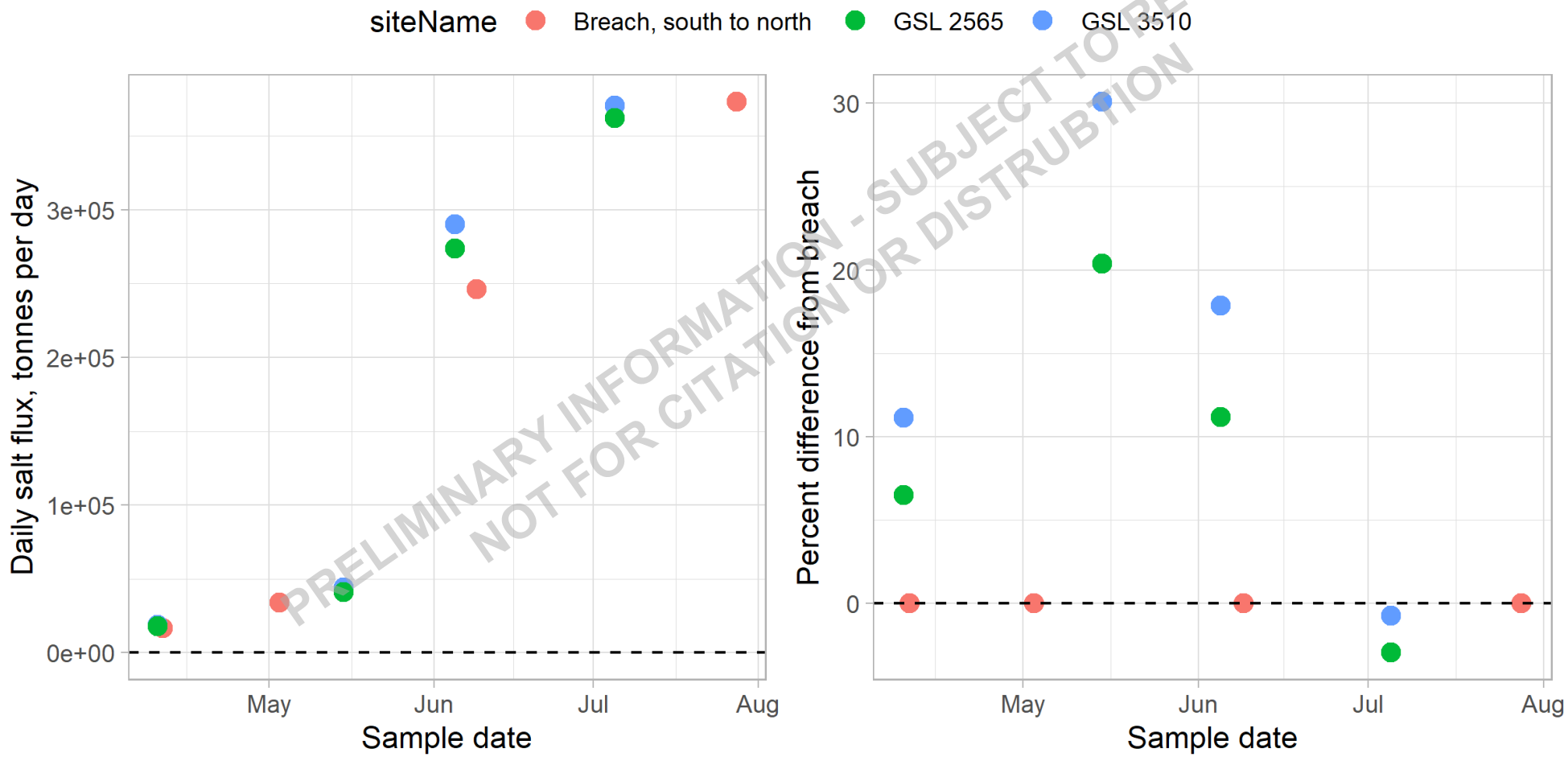
Estimating the effect of Bear River water on salt flux at the breach



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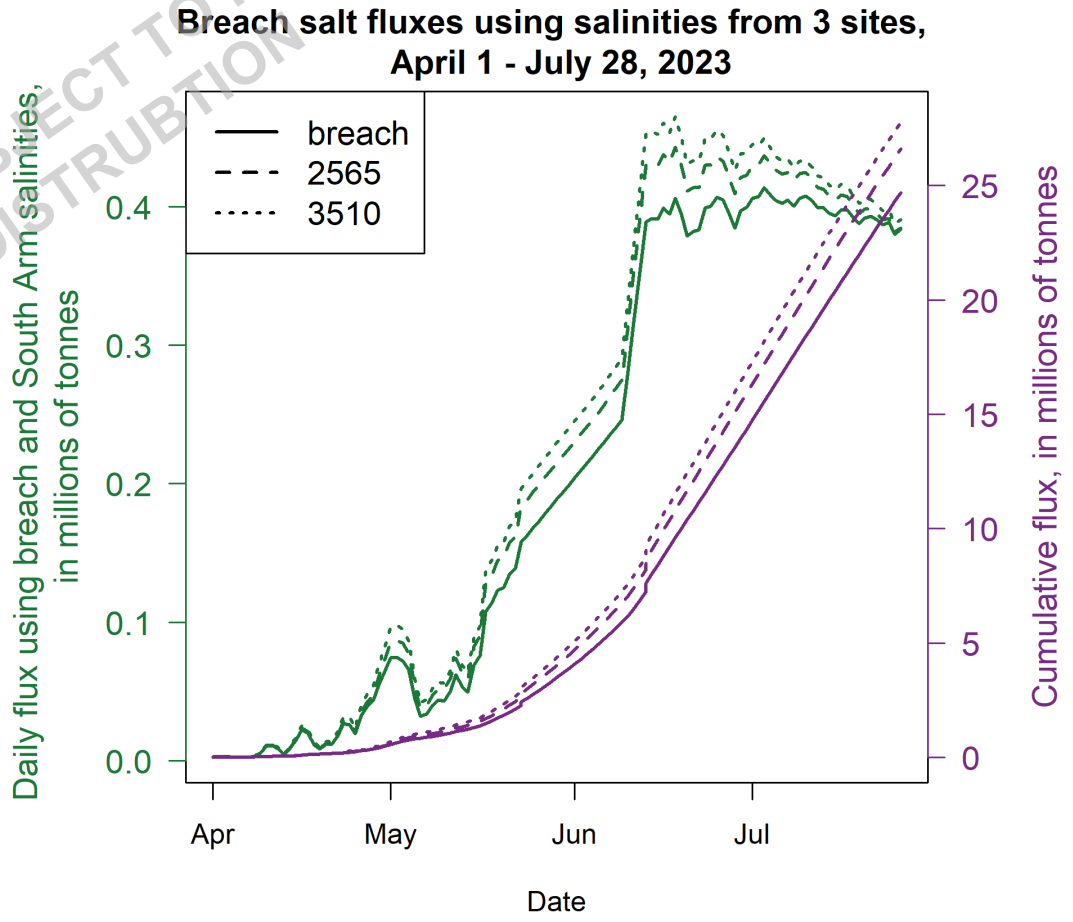
What is the cumulative salt load that would be exported with and without Bear River impact? Can we evaluate what the difference would be this year?

- Estimated cumulative salt flux at the breach using salinities from 3 different sites representative of South Arm conditions:

Salinity site	Cumulative salt flux, millions of tonnes (**April 1 – July 28, 2023**)	Percent difference in cumulative flux relative to breach measurements (%)	Cumulative flux relative to South Arm salt mass (%)
Breach (Bear River impact)	24.7	----	2.2
2565 (some Bear River impact)	26.6	7.7	2.4
3510 (minimal Bear River impact)	27.8	12.4	2.5



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Estimating the effect of Bear River on South Arm salinities

- **Governing equations used to estimate the fraction of Bear River that mixed in the South Arm in spring 2023 (Feb 7 to June 30):**

1) Salt mass balance:

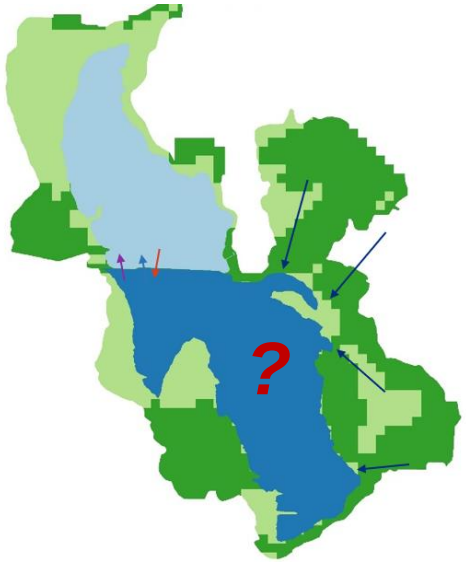
$$C_{Feb}V_{Feb} - \sum C_{in,other}V_{in,other} + C_{Bear}V_{Bear} * f_{mix} - C_{Breach}V_{Breach} = C_{June}\,V_{June}$$

- $C_{Feb}V_{Feb}$: *Initial South Arm salt mass, Feb 7, 2023*
- $\sum C_{in,other}V_{in,other}$: *Mass in from Farmington Bay, Weber River, and Goggin Drain*
- $C_{Bear}V_{Bear}$: *Mass in from Bear River*
- f_{mix}: *Fraction of Bear River mass that mixes in the South Arm*
- $C_{Breach}V_{Breach}$: *Mass out from West Crack Breach*
- $C_{June}\,V_{June}$: *Resulting South Arm salt mass, June 30, 2023*

2) Water balance:

$$V_{June} = V_{Feb} + V_{in,other} + V_{Bear} * f_{mix} - V_{Breach}$$

- f_{mix}: *Fraction of Bear River volume that mixes*



Note: evaporation and precipitation terms are not included and assumed to be equal.

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Estimating the effect of Bear River on South Arm salinities

Solving for f_{mix}, spring 2023 conditions (Feb 7 – June 30):

$$f_{mix} = \frac{(C_{Feb}V_{Feb} + \sum C_{in,other}V_{in,other} - C_{Breach}V_{Breach} - C_{June}(V_{Feb} + V_{in,other} - V_{Breach}))}{(C_{June}V_{Bear} - C_{Bear}V_{Bear})}$$

- Initial condition = Feb. 7, 2023 (C_{Feb} = 169 g/L; V_{Feb} = 6.31e9 m^3)
- Use observed June 30, 2023 concentrations to estimate f_{mix} (C_{June} = 133 g/L)
- Assumptions
  - Inflow mass and water volume mix completely in the South Arm over the analysis period (February through June)
  - Evaporation rate is equal to direct precipitation (cancel out in mass balance)
  - There are no other sources of salt coming in or out of the South Arm
  - Bear River at Corinne is a good approximation of Bear River discharge entering the South Arm
  - Volume-weighted average of salinities at sites 2565 and 3510 are representative of South Arm salinity

Estimating the effect of Bear River on South Arm salinities

- **Solving for f_{mix}, spring 2023 conditions (Feb 7 – June 30):**

$$f_{mix} = \frac{(C_{Feb}V_{Feb} + \sum C_{in,other}V_{in,other} - C_{Breach}V_{Breach} - C_{June}(V_{Feb} + V_{in,other} - V_{Breach}))}{(C_{June}V_{Bear} - C_{Bear}V_{Bear})}$$

$$f_{mix} = 0.63$$

- From Feb. 7 to June 30, 2023, it is estimated that ~63% of the Bear River inflow mixed into the South Arm

Estimating the effect of Bear River on South Arm salinities

- Predict June 30 salinity (C_{June}) for range of f_{mix} scenarios, spring 2023 conditions (Feb 7 – June 30):

$$C_{June} = \frac{(C_{Feb}V_{Feb} + \sum C_{in,other}V_{in,other} + C_{Bear}V_{Bear} * f_{mix} - C_{Breach}V_{Breach})}{(V_{Feb} + V_{in,other} + V_{Bear} * f_{mix} - V_{Breach})}$$

How does Bear River mixing affect South Arm salinity?

Vary from 0 to 1

f_{mix} = 0; no Bear River water mixes in the South Arm

f_{mix} = 1; 100% of Bear River water mixes in the South Arm

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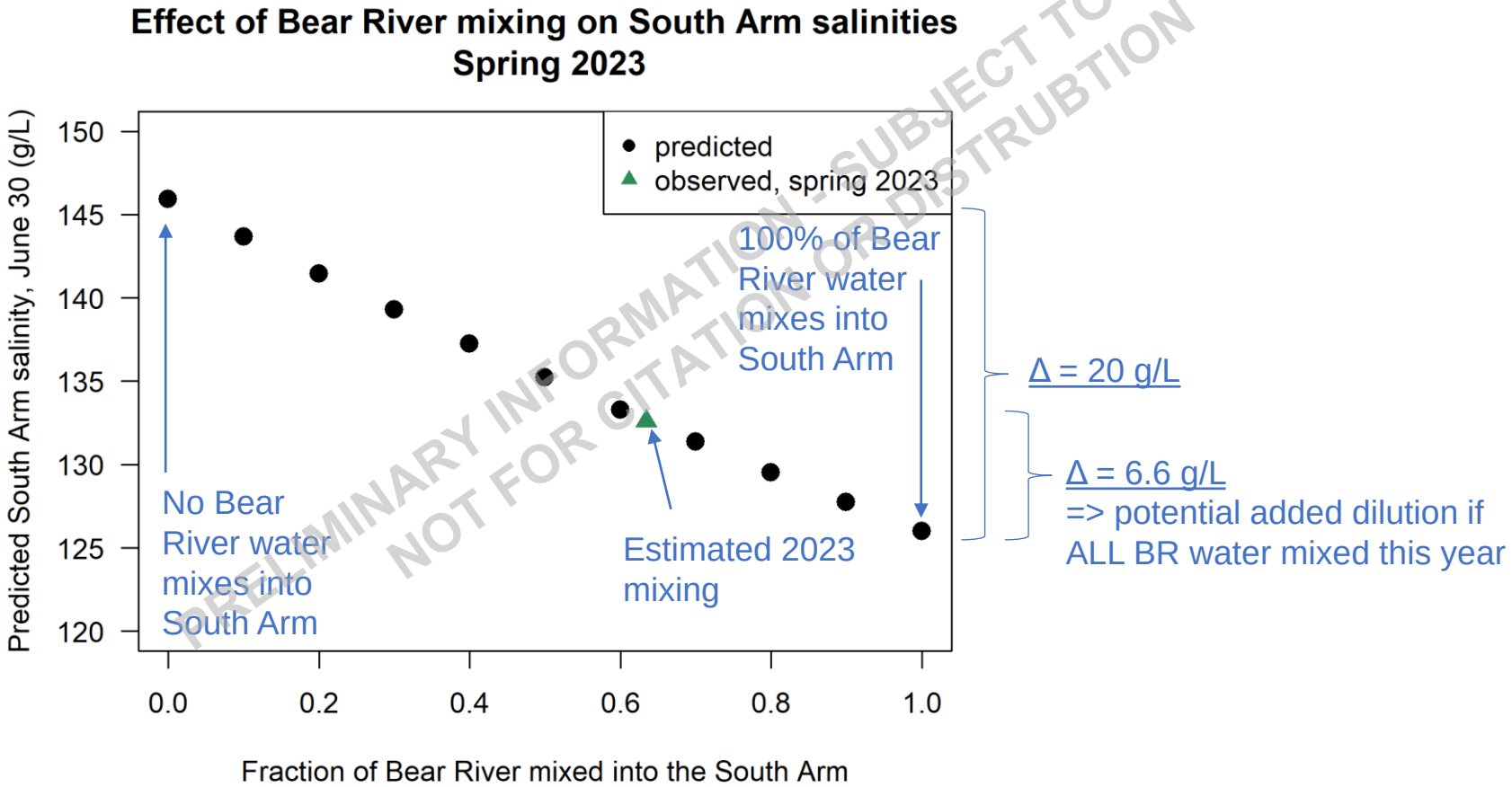
Estimating the effect of Bear River on South Arm salinities, 2023

- Predict South Arm salinity (June 30) for a range of f_{mix} :



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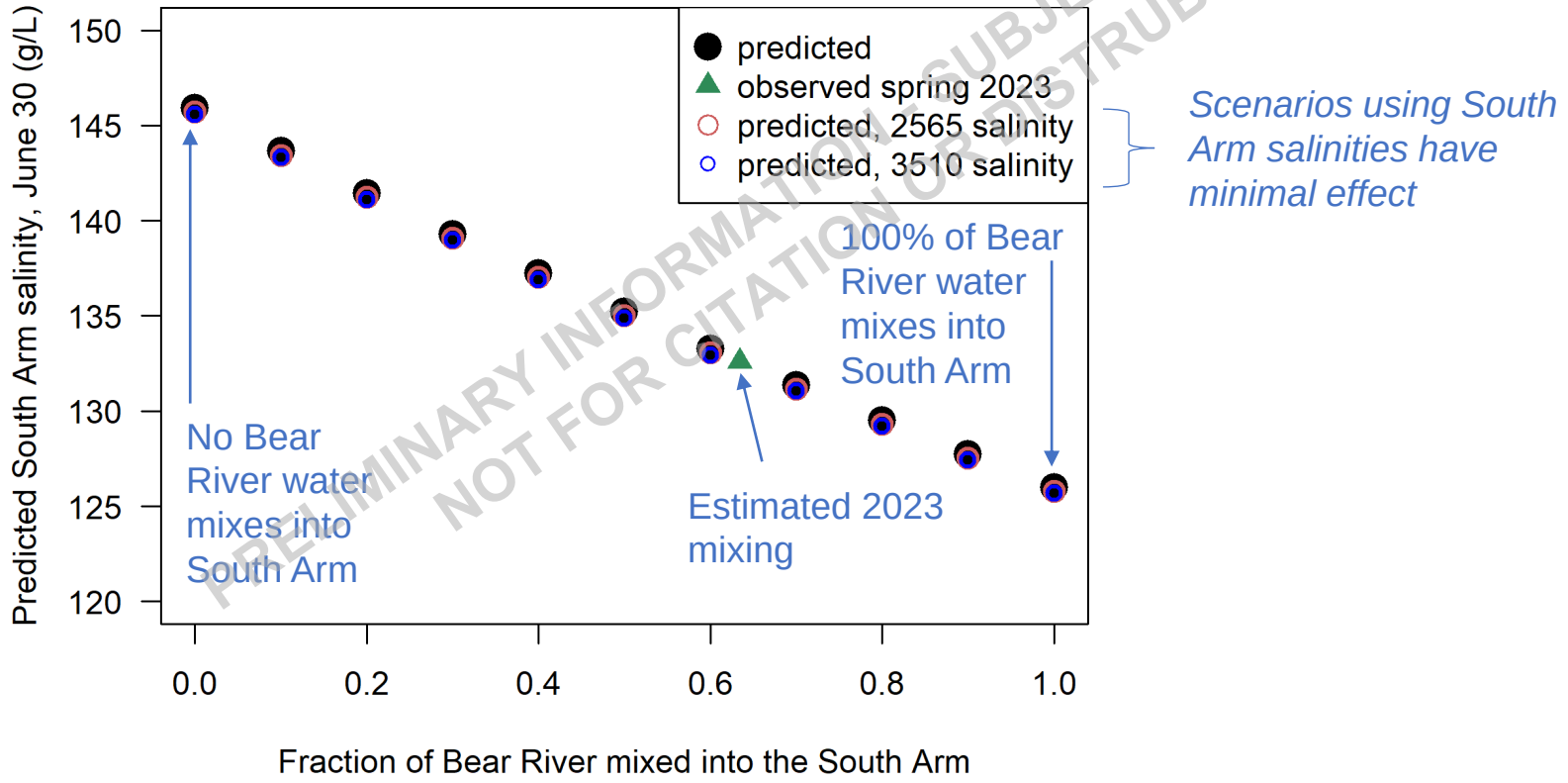
Estimating the effect of Bear River on South Arm salinities, 2023

- Predict South Arm salinity (June 30) for a range of f_{mix} and include effect of different salt fluxes at breach:



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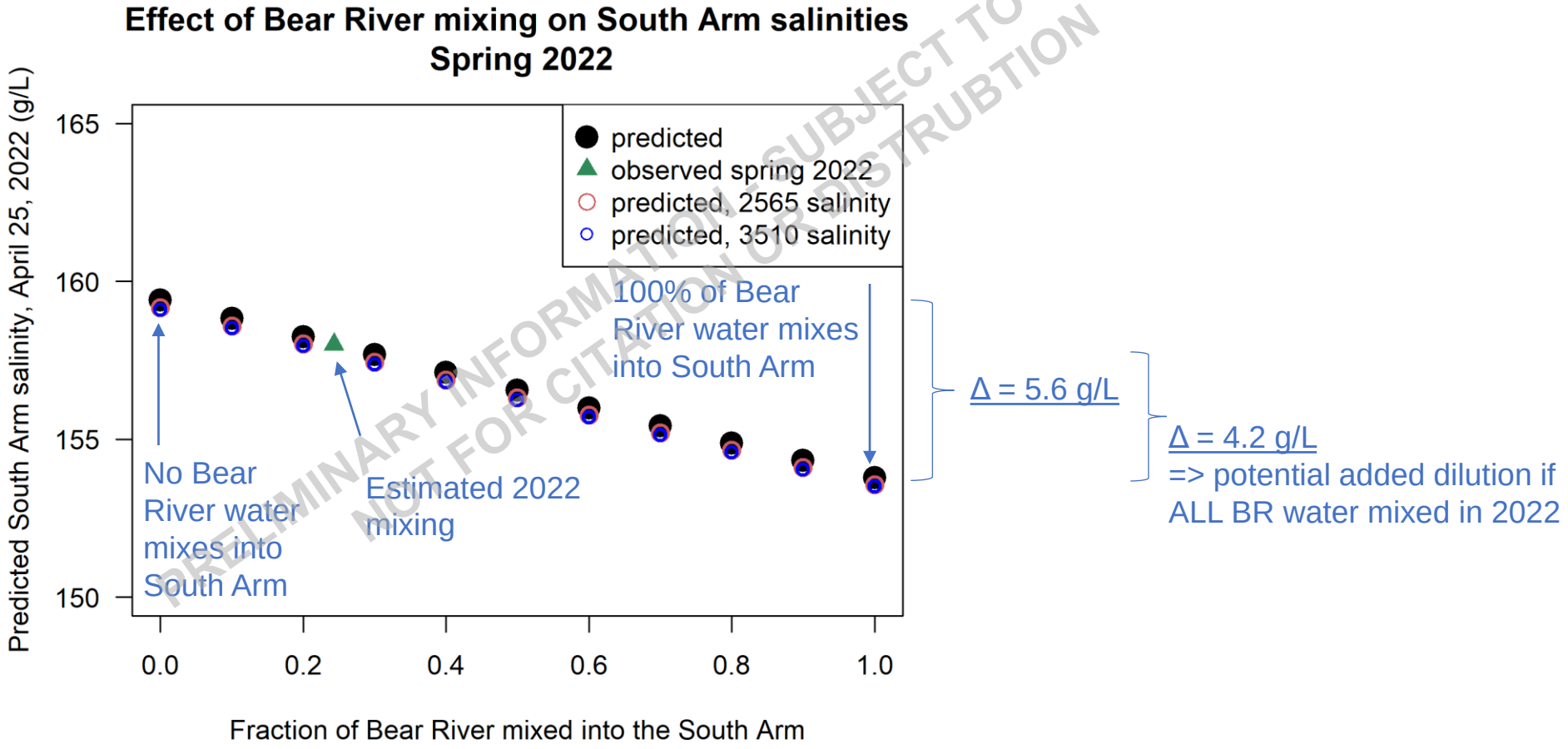
Estimating the effect of Bear River on South Arm salinities, 2022

- Predict South Arm salinity (April 25, 2022) for range of f_{mix} :



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Salinity forecast using mean monthly precipitation, evaporation, and inflows to estimate spring 2024 salinities

- **Mass balance equation used to estimate South Arm salt concentration, spring 2024:**

$$\underbrace{C_{fall}(V_{fall})}_{\text{Fall condition}} - \underbrace{C_{StoN}(V_{StoN})}_{\text{Export to north}} + \underbrace{C_{inflow}(V_{inflow})}_{\text{Surface water inflows}} = \underbrace{C_{spring}(V_{spring})}_{\text{Spring condition}}$$

$$V_{spring} = V_{fall} - V_{StoN} - V_{evap} + V_{precip} + V_{inflows}$$

- Initial condition = fall 2023 (C_{fall} = 142 g/L; V_{fall} = 5.92 maf)
- Use mean monthly precipitation, evaporation, and inflows from 2012-2022
- Assumptions
  - Assume South Arm surface area is constant for direct precipitation and evaporation
  - Assume export volume is constant (e.g. 1000 cfs)
  - Assume salinity for export is constant and instantaneous
  - Assume inflow salinity is 4 g/L
  - Assume berm is raised in February and south to north flow is zero starting February 15

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Estimated spring 2024 salinities

- Uses average climate and inflow data from 2012 - 2022

				Predictions for June 30, 2024				
Climate condition	Berm scenario - affects salt export and Bear River mixing	Percent of Bear River mixed into South Arm (assumed value)	South to north discharge thru breach, when open (cfs; assumed)	Cumulative south to north volume exported (af)	Cumulative south to north salt mass exported (Mt)	S. Arm volume (af)	S. Arm elevation (ft)	S. Arm salinity (g/L)
2012-2022 average	berm raised Feb 15	100	1000	200,335	35	6,605,052	4193.8	123.8
	berm raised Feb 15	100	1300	260,435	46	6,544,952	4193.7	123.6
	berm not raised	60	1300	611,120	107	5,795,038	4191.8	130.7
	berm not raised	60	1500	705,138	123	5,701,020	4191.5	130.5

- For reference, Nov. 6, 2023 South Arm volume was 5.92 maf, salinity was 142 g/L, and salt mass was 1037 Mt.

Spring salinity objective:
< 130 g/L in upper oxic layer

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Contact Information

View from Gilbert Bay, Great Salt Lake, October 2018

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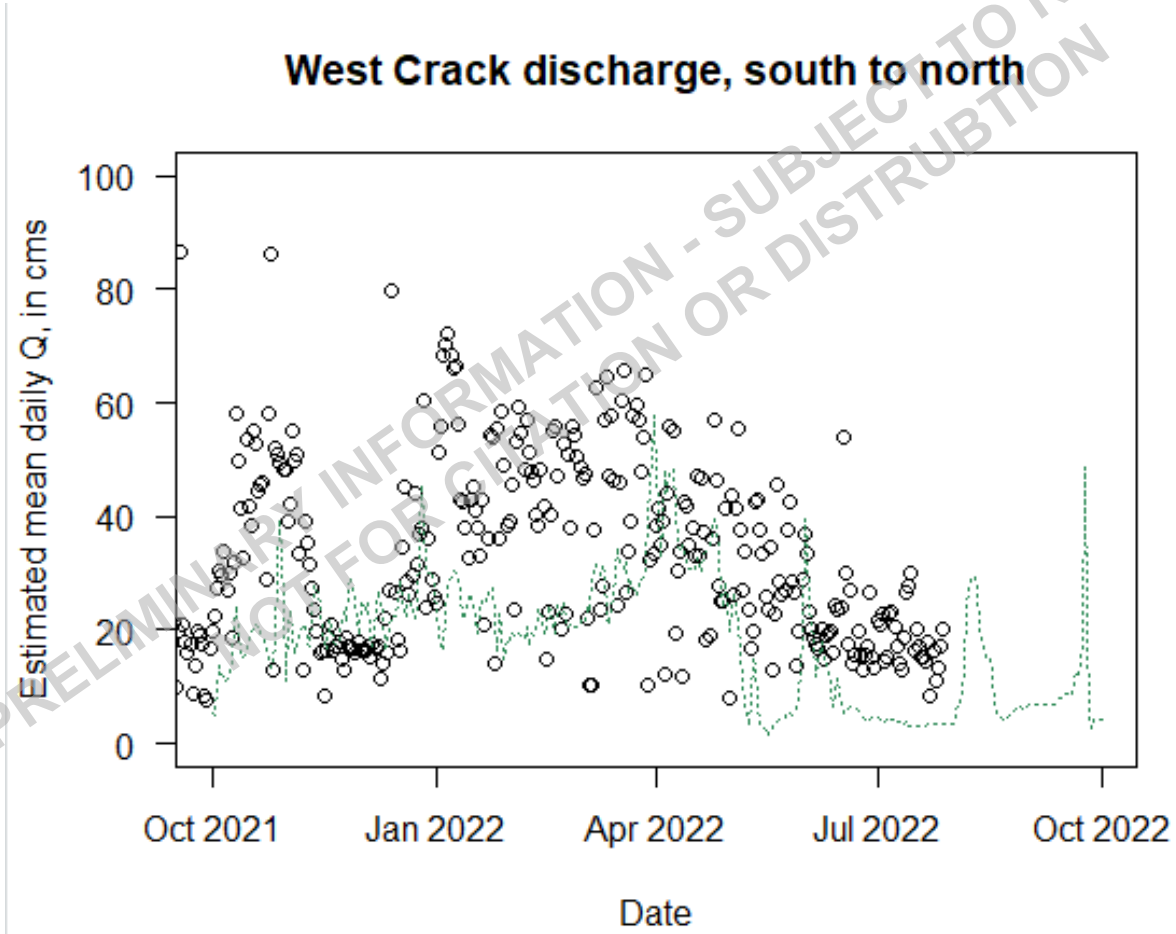
A few notes:

- **How might the South Arm salinity be affected if we were exporting the average South Arm salinity rather than the Bear River influenced (lower) salinity?**
  - **From my understanding, this question involves comparing predictions of South Arm salinities for different salt flux export scenarios at the Breach. We can do this with information on slide 10, however the effect of varying salt fluxes is small. The real issue is how much freshwater is trapped in the South Arm for dilution, i.e. how much Bear River water is mixed in the South Arm.**
- **How much does mixing of the South Arm influence the salinity of the South Arm?**
  - **Slides 11-13 estimate the fraction of Bear River water that mixed in the South Arm in 2023. Then I predict South Arm salinities using a range of mixing scenarios.**
- **The general approach for these calculations is to try and predict observed June 30, 2023 salinities using a mass balance approach with measurements taken on February 7, 2023 as a starting condition. This brackets the runoff season and the period when we have South Arm salinity measurements (no measurements were made in March). Basically, can we recreate June salinities via a mass balance starting in February, and what does that tell us about mixing and dilution influence of the Bear River?**
  - **Note, I leave out precipitation and evaporation terms. I acknowledge this introduces error, but I think the relative differences shown will still illustrate what we're after. Happy to add these terms/complexity if we think it's necessary.**

WY 2022 West Crack and Bear River inflow



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