Utah Lake Water Quality Study

ULWQS Management Goals: Science Panel Responses to Steering Committee Questions

November 13, 2020

The Science Panel (SP), commissioned by the Utah Lake Water Quality Study (ULWQS) Steering Committee (SC), is providing this document in response to the SC's request to evaluate and answer a series of questions related to the ongoing effort to develop management goals for Utah Lake. The questions were presented to the SP during Science Panel Call #16 on October 21, 2020. Following the call, the SP worked to reference the content of existing work products in addition to available Utah Lake-specific data and literature to inform response development.

The SP is drawing upon existing work products and data to determine the relevancy of the goals, measures, and targets in the process of developing numeric nutrient criteria (NNC) for Utah Lake. Specifically, the following SP work products and information were referenced in the process of responding to the questions from the SC:

- ***ULWQS Conceptual Model Report*** (SP and SC approved) – The models in the Conceptual Model Report visually demonstrate the SP's understanding of the causal pathways that connect nutrient sources to designated beneficial uses, the expected relationships between variables, and the modifying factors. The conceptual models specifically include the management goals and measures defined by the SC, and describe how they are responsive to nutrient inputs;
- ***ULWQS NNC Technical Framework*** (Draft) – The Technical Framework defines the expected stressor response variables to be used for developing NNC in addition to the associated empirical and mechanistic modeling methods;
- ***ULWQS Data Analysis Report*** (Draft) – The Data Analysis Report describes relationships between important nutrient-related variables. This analysis was specifically designed to address the Initial High Level Charge Questions developed by the SC to the SP;
- ***ULWQS Strategic Research Plan (SRP)*** (SP approved, SC review pending) – The SRP identifies knowledge gaps that limit the SP's ability to develop responses to the Initial Charge and prioritizes research activities to address the gaps;
- ***Assessment of Utah Lake nutrient and HAB data*** – The Utah Lake chemistry and harmful algal bloom dataset was evaluated to inform answers to questions 2e and 2f; and
- ***Literature from similar lake systems*** was evaluated to identify analytical methods and to provide context for our responses to questions.

Question 1. Assessment of the relevance of the management goals to the ULWQS purpose.
The SP views the development of management goals as the primary responsibility of the SC. As a result, to answer question 1 we first assessed the responsiveness and quantifiability of individual measures and targets to nutrient interactions in the lake as described in our evaluation of questions 2, 3, 4 and 5. Based on the level of responsiveness of individual measures, we then assessed the relevance of each goal. We also included an evaluation of the quantifiability of each goal, given the evaluation of the component measures for each management goal. Through this evaluation we determined that most of the management goals are relevant to the project purpose, noting that some are less directly relevant than others (See Attachment A, pages 3-4).

Question 2, 3, 4, and 5 (excluding 2e and 2f). Assessment of measures' and targets' responsiveness to nutrients, and evaluation of available data and assessment methods.

To evaluate questions 2, 3, 4, and 5 we reviewed existing SP products (as described previously) to identify relevant data, determine data resolution, and draw upon previous SP findings to determine responsiveness of each measure to nutrients. We also considered both our ability to quantify future targets and consider the most appropriate methods for evaluating current conditions.

Our responses for each question are presented in Attachment A, pages 5-13. Significant findings include:

- Are measures responsive to nutrients? (question 2)
    - The majority of the measures are known to be defensibly responsive to nutrients. Exceptions include: annual visitation to Utah Lake (likely responsive), measures from recreation survey to assess user experiences related to water quality (likely responsive), carp population density (not responsive), and percent change in non-algal turbidity associated with carp bioturbation (not responsive).
- Are measures readily quantified with existing information? (question 2a)
    - Many of the measures can be readily quantified using existing data. Exceptions include: cylindrospermopsin concentration, saxitoxin concentration, annual visitation to Utah Lake, measures from recreation survey to assess user experiences related to water quality, fish tissue algal toxin concentrations, mollusk diversity/abundance, percent change in non-algal turbidity associated with carp bioturbation, percent change in macrophyte density and distribution, percent cover of *Phragmites* on Utah Lake shoreline, percent cover of emergent and submergent macrophytes in littoral waterfowl and shorebird habitat areas, maximum # of days at each of littoral habitat exceeding TBD HAB threshold, and the maximum percent of littoral habitat area exceeding TBD HAB threshold..
- What additional efforts are required to quantify measures? (questions 2b, 2c & 2d)
    - If a measure can be quantified with existing information (question 2a), then additional efforts are not required to address the specific measure. This results in a not applicable (NA) result for questions 2b, 2c and 2d.
    - If a measure cannot be quantified with existing information, then additional efforts associated with SP analyses, WQ modeling, studies, or monitoring are required. See Attachment A for the proposed efforts (2b, 2c and 2d) required to quantify the specific measures.
- What measures are infeasible to assess or very difficult to develop targets? (question 3)
    - Most measures can be assessed, and targets can be developed. Exceptions include: annual visitation to Utah Lake (difficult), measures from recreation survey to assess user experiences related to water quality (difficult), carp population density (not related to nutrients), and percent change in non-algal turbidity associated with carp bioturbation (not related to nutrients).
    - The caveat to question 3 is that the ULWQS effort may not have the funding nor the time to quantify each and every measure provided by the SC in Attachment A. Careful consideration of the measures relevant to the development of in-lake numeric nutrient criteria is required to successfully move the ULWQS effort forward.

- How to calculate current conditions and predict future scenarios? (questions 4, 4a and 4b)
    - See Attachment A.
- What additional measures should be considered? (question 5)
    - See Attachment A for suggestions to improve quantification and reduce uncertainty for the SC proposed measures.

Question 2e and 2f. Relationships between nutrients and cyanobacterial density and between cyanobacterial density and toxin concentrations in Utah Lake.

Tetra Tech provided a technical memo under the direction of the SP to explore preliminary relationships between nutrients, cyanobacteria cell counts, and cyanotoxins to inform questions 2e and 2f. After comments and discussion regarding additional analyses and the exploration of various covariates, the SP decided that additional effort is warranted to answer questions 2e and 2f. Based on the feedback provided by the SP members, we intend to continue investigating these questions in the ongoing ULWQS Data Analysis Report in more detail. In addition, the Bioassay study commissioned by the SP is investigating phytoplankton responses to increased and reduced nutrient concentrations. This study will be finalized in the near future and is expected to provide Utah Lake-specific information relevant to questions 2e and 2f. These questions are instrumental to developing numeric nutrient criteria to manage HABs in Utah Lake and additional exploration will improve our understanding and certainty with these relationships.

Sincerely,

ULWQS Science Panel

- Janice Brahney, Utah State University
- Soren Brothers, Utah State University*
- Greg Carling, Brigham Young University
- Mitch Hogsett, Forsgren Associates, Science Panel Chair
- Ryan King, Baylor University
- James Martin, Mississippi State University
- Michael Mills, June Sucker Recovery Program
- Hans Paerl, University of North Carolina*

* Indicated they could live with the package

NOTE: the following two members approved the Table on the November 4 call, however have not yet responded to the request for final review of the package:

- Michael Brett, University of Washington
- Theron Miller, Wasatch Front Water Quality Council

Attachment A: Science Panel Evaluation of Steering Committee Questions (Not Including 2e and 2f)

Contents

Steering Committee Questions to the Science Panel

The SP can provide important scientific feedback on defensible assessment endpoints, measures, targets and target development to evaluate progress towards management goals. Important questions to convey to the SP with the table include:

Management Goals

1. Please share your thoughts on the direct relevancy of the Management Goals to the ULWQS purpose of developing in-lake nitrogen and phosphorus criteria.

Measures and Targets

2. Are these measures defensibly responsive to nutrients?
    a) Which of these measures can be readily quantified using existing information?
    b) Which measures and targets will be quantified by ongoing Science Panel analyses or the existing water quality model and therefore available for consideration of nutrient reduction scenarios?
    c) Which of the measures may require additional studies (monitoring, modeling, etc.) and what are the requirements for that?
    d) Of those that might not be quantifiable, are there other approaches (modeling or empirical) by which targets can be derived?
    e) Is there a direct correlation between cyanobacteria cell counts and nutrients?
    f) Is there a relationship between cyanobacteria cell counts and toxins?
        - Specifically, can and how do you predict change in toxin concentrations under different scenarios?
        - The EPA 2019 document (Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin) is read by some to say no relationship between toxins and recreational use, is that your understanding?

3. Are there measures that will be infeasible to assess or for which target development will be difficult?

4. What methods should be used to calculate current conditions for each measure?
    a) Can these methods be applied using modeling (empirical or mechanistic) to predict change under future scenarios?
    b) How should we group monitoring sites in evaluating current and future conditions?

Other considerations

5. Are there potential measures or targets not included that should be considered by the SC?

Responses to Steering Committee Questions

Steering Committee Question 1.

Table 1. Assessment of Steering Committee Question 1.

Management Goal	Assessment Endpoint	Please share your thoughts on the direct relevancy of the Management Goals to the ULWQS purpose of developing in-lake nitrogen and phosphorus criteria?		
		Relevant?	Currently Quantifiable?	Overall
2A. Primary contact recreation use (human health, Recreation experience, Lake aesthetics)				
Harmful algal blooms (HAB) will not create toxins that threaten public health.	Algal toxin concentrations	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures (except cylindrospermopsin) are readily available and can be quantified.
HAB occurrence is limited in spatial extent and infrequent to support robust recreational industry and community.	Magnitude, frequency, and duration of algal blooms.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures are readily available, and can be quantified.
Improve submersible recreation (swimming, paddle boarding, water skiing, etc.) experience.	Magnitude, frequency, and duration of algal blooms.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures are readily available, and can be quantified.
Swimming beaches and shoreline access locations are open all summer without nuisance algae or public health advisories.	Magnitude, frequency, and duration of algal blooms.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures are readily available, and can be quantified.
Recreation water quality standards are supported	Support of 2A Recreational Use Standards	Yes	Unknown since these are narratives.	Science Panel presumes that numeric targets developed for other category 2A management goals are already being used to interpret the narrative water quality standards.
Increase recreational opportunities and experiences.	Lake visitation and satisfaction statistics.	Likely	No	This goal is likely relevant to nutrient criteria development in that it is important to understand the effect of nutrient pollution on recreation. However, visitation targets do not exist, visitation data are limited to one location, and relationships of algal indicators to visitation measures have yet to be quantified.
Improve public perception of Utah Lake water quality.	Lake visitation and satisfaction statistics.	Likely	No	This goal is likely relevant to nutrient criteria development in that it is important to understand the effect of nutrient pollution on recreational use perception, but user perception data or targets have still to be developed. This measure has shown relevance and utility in other lake nutrient criteria development efforts.
Sport fish are safe for human consumption.	Fish tissue algal toxin concentrations.	Yes	No	This goal is directly relevant to nutrient criteria development. However, data are not available, and therefore this measure cannot currently be quantified.
3B. Warm water fishery use				
Warm water fishery is robust and healthy.	Water quality conditions	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for water quality condition assessment endpoint measures are readily available and can be quantified.
	Food abundance and diversity	Yes	Yes, but limited	This goal is directly relevant to nutrient criteria development, data for food (zooplankton, macroinvertebrate, and mollusk) abundance and diversity assessment endpoint measures are also available and can be quantified but are more limited.

Management Goal	Assessment Endpoint	Please share your thoughts on the direct relevancy of the Management Goals to the ULWQS purpose of developing in-lake nitrogen and phosphorus criteria?		
		Relevant?	**Currently Quantifiable?**	**Overall**
HAB toxins do not cause fish mortality.	Algal toxin concentrations	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures (except cylindrospermopsin) are readily available and can be quantified.
Warm water fishery can support reproductive populations of June Sucker.	Water quality conditions	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures are readily available, and can be quantified
Macrophyte habitat can support June sucker recovery and early life stages of other ecologically or recreationally important fish species.	Macrophyte abundance and distribution in Provo Bay, Utah Lake Littoral Zones, and Provo River delta.	Yes	Yes, but limited	This goal is directly relevant to nutrient criteria development. Data for assessment endpoint measures are available, and can be quantified, but are relatively limited.
Carp population does not inhibit June sucker recovery.	Carp density and water quality indicators related to carp activity.	Mixed	Mixed	Carp density and change in turbidity associated with carp bioturbation are not considered responsive or are of unknown responsiveness to nutrients so are of limited relevance to nutrient criteria development, but percent change in macrophyte density and distribution are responsive to nutrient and are directly relevant to nutrient criteria development. Data on carp density are available, but data on carp-induced non-algal turbidity and macrophyte density and distribution across the lake are not; so only carp density can be readily quantified, even though it is of limited relevance.
3D. Waterfowl, shorebirds, and other water-oriented wildlife				
Sufficient percentage cover of native and desirable nonnative littoral plant species.	Nonnative plant abundance, diversity, and distribution. Macrophyte abundance, diversity, and distribution.	Yes	No	This goal is directly relevant to nutrient criteria development, however data for assessment endpoint measures are not readily available and cannot be readily quantified.
Macroinvertebrates provide a diverse and sufficient food source to birds that use the open water and shorelines of Utah Lake.	Invertebrate abundance, diversity, and distribution.	Yes	Yes, but limited	This goal is directly relevant to nutrient criteria development, data for invertebrate abundance, diversity, and distribution assessment endpoint measures are also available and can be quantified but are more limited.
HAB toxins do not threaten waterfowl and shorebirds and do not cause bird mortality.	Algal toxin concentrations.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures (except cylindrospermopsin) are readily available and can be quantified.
HAB spatial and temporal extent supportive of healthy waterfowl and shorebird habitat.	Harmful algal bloom magnitude and duration.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures are readily available, and can be quantified
4. Agricultural Water Use				
Water used to irrigate crops will not present health risk.	Algal toxin concentrations.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures (except cylindrospermopsin) are readily available and can be quantified.
Water used to water livestock will not pose health risk to animals.	Algal toxin concentrations.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures (except cylindrospermopsin) are readily available and can be quantified.
Water used for secondary water does not clog or impede irrigation systems.	Algal and cyanobacteria density/biomass.	Yes	Yes	This goal is directly relevant to nutrient criteria development, data for assessment endpoint measures are readily available, and can be quantified.

Steering Committee Questions 2, 3, 4, and 5

Table 2. Assessment Steering Committee Questions 2, 3, 4, and 5.

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
2A. Primary contact recreation use (human health, Recreation experience, Lake aesthetics)												
Microcystin concentration	8 ug/L	HAB monitoring dataset 388 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Cylindrospermopsin concentration	15 ug/L	Insufficient data Fewer than 20 samples from HAB monitoring program	Yes	No	No	Yes, add analysis to HAB monitoring program	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Anatoxin concentration	15 ug/L	HAB monitoring dataset 285 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Annual number of lake closures due to HABs	• Microcystin: 2,000 ug/L • Anatoxin: 90 ug/L • Cyanobacteria density: 10M cells/mL	HAB advisory dataset 13-18 weeks monitored annually, 2016-2019 Locations: main basin (N, middle, S), Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	Cylindrospermopsin
Duration/frequency: Percent of recreation season with algal biomass exceeding health and nuisance thresholds at each monitoring site and target recreation site (e.g. marinas, beaches).	• Cyanobacteria density: TBD • Cyanobacteria relative abundance: TBD • Chlorophyll-a: TBD	HAB monitoring dataset Cyano density: 359 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas Routine monitoring dataset Cyano density and relative abundance: 715 samples, 2015-2019 Chlorophyll: 30 samples,	Yes	Yes	NA	NA	NA	No	Temporal interpolation	Yes	PB, GB, marinas, beaches, open water	Toxigenic cyanobacteria density and relative abundance Cyanobacteria biovolume

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
		2015-2019 Locations: main basin, Goshen Bay, Provo Bay										
Extent: Maximum % of lake surface exceeding algal biomass nuisance thresholds (reported separately for Provo Bay, Goshen Bay, and Open Water regions).	• Cyanobacteria density: TBD • Cyanobacteria relative abundance: TBD • Chlorophyll-a: TBD	HAB monitoring dataset Cyano density: 359 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas Routine monitoring dataset Cyano density and relative abundance: 715 samples, 2015-2019 Chlorophyll: 30 samples, 2015-2019 Locations: main basin, Goshen Bay, Provo Bay	Yes	Yes	NA	NA	NA	No	Spatial interpolation	Yes	PB, GB, marinas, beaches, open water	Toxigenic cyanobacteria density and relative abundance Cyanobacteria biovolume
Magnitude: Maximum seasonal algal biomass (collected as integrated water column sample) at each monitoring site and target recreation site (e.g. marinas, beaches).	• Cyanobacteria density: TBD • Cyanobacteria relative abundance: TBD • Chlorophyll-a: TBD	HAB monitoring dataset Cyano density: 359 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas Routine monitoring dataset Cyano density and relative abundance: 715 samples, 2015-2019 Chlorophyll: 300 samples, 2015-2019 Locations: main basin, Goshen Bay, Provo Bay	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	Toxigenic cyanobacteria density and relative abundance Cyanobacteria biovolume
pH	6.5 – 9	Buoy dataset 189,919 samples at 15-min intervals, 2016-2019 Locations: 3 stations in main basin, 1 station in Provo Bay	Yes	Yes	NA	NA	NA	No	Evaluate diurnal fluctuations; Use EFDC model	Yes	PB, GB, marinas, open water	No

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
Narrative water quality standards.	See targets above	NA	Science Panel presumes that numeric targets developed for category 2A are already being used to interpret the narrative water quality standards									
Annual visitation to Utah Lake.	TBD	Visitation counts for Utah Lake State Park 2003-2019 Does not address all lake access points	Likely	No	No	Additional visitation surveys	Determine target	Feasible but will require substantial effort	Additional visitation surveys and/or extrapolate state park visitation to whole lake	Yes	PB, GB, marinas, beaches, open water	Number of person-days per season or year
Measures from recreation survey to assess user experiences related to water quality.	TBD	TBD	Likely	No	No	Recreation survey	Determine target	Feasible but will require substantial effort	Recreation survey	Yes	PB, GB, marinas, beaches, open water	User perception
[Fish Tissue] Algal toxin concentrations TBD.	TBD	EPA/FWS	Yes	Unknown	No	Yes, fish tissue analysis	NA	No	Fish tissue analysis	Yes	PB, GB, marinas, open water	If data indicate mollusk consumption consider mollusk tissue
3B. Warm water fishery use												
Minimum dissolved oxygen	3.0 mg/L	Buoy dataset 193,588 samples at 15-min intervals, 2016-2019 Locations: 3 stations in main basin, 1 station in Provo Bay	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, open water	No
7-Day average dissolved oxygen	4.0 mg/L	Buoy dataset 193,588 samples at 15-min intervals, 2016-2019 Locations: 3 stations in main basin, 1 station in Provo Bay	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, open water	Super-saturations
30-Day average dissolved oxygen	5.5 mg/L	Buoy dataset 193,588 samples at 15-min	Yes	Yes	NA	NA	NA	No	See current conditions	Yes	PB, GB, marinas,	Super-saturations

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
		intervals, 2016-2019 Locations: 3 stations in main basin, 1 station in Provo Bay							assessment		open water	
pH	6.5 – 9	Buoy dataset 189,919 samples at 15-min intervals, 2016-2019 Locations: 3 stations in main basin, 1 station in Provo Bay	Yes	Yes	NA	NA	NA	NO	Evaluate diurnal fluctuations; Use EFDC model	Yes	PB, GB, marinas, open water	No
Ammonia	pH and Temperature dependent (mg/L)	Routine monitoring dataset 467 samples, 2015-2019 Locations: Main basin, Goshen Bay, Provo Bay	Yes	Yes	NA	NA	NA	No	See current assessment	Yes	PB, GB, marinas, open	No
Zooplankton diversity/abundance.	TBD	June Sucker Recovery Implementation Program, WFWQC	Yes	Yes	NA	NA	NA	No	Select diversity and richness metrics	Yes	PB, GB, marinas, open water	Composition
Macroinvertebrate diversity/abundance	TBD	June Sucker Recovery Implementation Program, WFWQC	Yes	Yes	NA	NA	NA	No	Select diversity and richness metrics	Yes	PB, GB, marinas, open water	Composition
Phytoplankton diversity and abundance	TBD	Routine monitoring dataset 715 samples, 2015-2019 Locations: main basin, Goshen Bay, Provo Bay	Yes	Yes	NA	NA	NA	No	Select diversity and richness metrics	Yes	PB, GB, marinas, open water	Composition
Mollusk diversity/abundance	TBD	WFWQC	Yes	No	No	Mollusk survey	NA	No	Select diversity and richness metrics	Yes	PB, GB, marinas, open water	Composition
Microcystin concentration	TBD	HAB monitoring dataset 388 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Cylindrospermopsin concentration	TBD	Insufficient data	Yes	No	No	Yes, add analysis to	NA	No	See current conditions	Yes	PB, GB, marinas,	No

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
		Fewer than 20 samples from HAB monitoring program				HAB monitoring program			assessment		beaches, open water	
Anatoxin/saxitoxin concentration	TBD	HAB monitoring dataset Anatoxin: 285 samples, 2017-2020 Saxitoxin: no data Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Minimum dissolved oxygen in Provo Bay and Provo River delta from July – September.	5.0 mg/L	Buoy dataset 6,494 samples at 15-min intervals, 2018 Location: 1 station in Provo Bay	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, open water	No
7-Day dissolved oxygen in Provo Bay and Provo River delta from July – September.	6.0 mg/L	Buoy dataset 6,494 samples at 15-min intervals, 2018 Location: 1 station in Provo Bay	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, open water	No
Primary productivity (chl a/ algal turbidity) supportive of macrophyte re-establishment in target areas.	• Light compensation point: TBD • Chlorophyll a: TBD • Percent algal turbidity: TBD	Routine monitoring dataset Chlorophyll: 300 samples, 2015-2019 Light: 39 profiles, 2019 Locations: main basin, Goshen Bay, Provo Bay	Yes	Yes	Yes, Analysis Report	Yes, add light profiles to routine monitoring program	NA	No	Define target areas, colonization depth goals, and target species	Yes	TBD based on target areas	Clarity (e.g., K_d, Secchi depth)
Carp population density	TBD	June Sucker Recovery Implementation Program	No	Yes	NA	NA	NA	Feasible to assess but measure not related to nutrients	Surveys from June Sucker Recovery Implementation Program	Yes	See June Sucker Recovery Implementation Program	No
Percent change in non-algal turbidity associated with carp bioturbation.	TBD	Insufficient data Total non-algal turbidity known, but carp contribution	No	No	No	Consider use of mesocosm	NA	Feasible to assess but measure not related to	Mesocosm experiment and extrapolatio	Yes	See June Sucker Recovery Implementat	No

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
		is unknown				experiments		nutrients	n to whole lake		ion Program	
Percent change in macrophyte density and distribution.	TBD	June Sucker Recovery Implementation Program Targeted, non-representative macrophyte surveys	Yes	No	No	Whole-lake macrophyte survey	NA	No	Whole-lake macrophyte survey	Yes	Determine littoral habitat zones	Composition
3D. Waterfowl, shorebirds, and other water-oriented wildlife												
Percent cover of Phragmites on Utah Lake shoreline.	TBD	June Sucker Recovery Implementation Program Targeted, non-representative macrophyte surveys	Yes	No	No	Whole-lake macrophyte survey	NA	No	Whole-lake macrophyte survey	Yes	Determine littoral habitat zones	No
Percent cover of emergent and submergent macrophytes in littoral waterfowl and shorebird habitat areas.	TBD	June Sucker Recovery Implementation Program Targeted, non-representative macrophyte surveys	Yes	No	No	Whole-lake macrophyte survey	NA	No	Whole-lake macrophyte survey	Yes	Determine littoral habitat zones	Composition
Primary productivity (chl a/ algal turbidity) supportive of macrophyte re-establishment in target areas.	TBD	Routine monitoring dataset Chlorophyll: 300 samples, 2015-2019 Light: 39 profiles, 2019 Locations: main basin, Goshen Bay, Provo Bay	Yes	Yes	Yes, Analysis Report	Yes, add light profiles to routine monitoring program	NA	No	Define target areas, colonization depth goals, and target species	Yes	TBD based on target areas	Clarity (e.g., K_d, Secchi depth)
Invertebrate index or density samples (and see 3B).	TBD	June Sucker Recovery Implementation Program, WFWQC	Yes	Yes	NA	NA	NA	No	Select diversity and richness metrics	Yes	PB, GB, marinas, open water	Composition
Microcystin concentration	TBD	HAB monitoring dataset 388 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Cylindrospermopsin concentration	TBD	Insufficient data Fewer than 20 samples from HAB monitoring program	Yes	No	No	Yes, add analysis to HAB monitoring	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches,	No

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
						program					open water	
Anatoxin concentration	TBD	HAB monitoring dataset 285 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
Maximum # days at each of littoral habitat exceeding TBD HAB threshold.	TBD	Insufficient data	Yes	No	No	Yes, develop method to determine littoral areas and extrapolate unsampled days from sampled days	NA	No	See 2c	Yes	By TBD littoral habitat units	No
Maximum percent of littoral habitat area exceeding TBD HAB threshold.	TBD	Insufficient data Method to determine littoral areas and extrapolating unsampled days from sampled days not developed	Yes	No	No	Yes, develop method to determine percent littoral area	NA	No	See 2c	Yes	By TBD littoral habitat units	No
4. Agricultural Water Use												
[Irrigated Crops] Microcystin, cylindrospermopsin, saxitoxin, anatoxin concentrations	TBD	HAB monitoring dataset Microcystin: 388 samples, 2017-2020 Anatoxin: 285 samples, 2017-2020 Cylindrospermopsin: insufficient data Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes, for microcystin and anatoxin	NA	Additional analysis through HAB monitoring program for anatoxin and saxitoxin	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
[Livestock] Microcystin, cylindrospermopsin, saxitoxin, anatoxin concentrations	TBD	HAB monitoring dataset Microcystin: 388 samples, 2017-2020 Anatoxin: 285 samples, 2017-	Yes	Yes, for microcystin and anatoxin	NA	Additional analysis through HAB monitoring	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No

Toxins	Phytoplankton	Chemistry	Biology	Human

Measures	Targets	Metadata	Q. 2 (Y/N)	Q. 2a	Q. 2b	Q. 2c (Describe)	Q. 2d (Describe)	Q. 3 (Y/N)	Q.4 (Describe)	Q. 4a (Y/N)	Q. 4b (Describe)	Q.5 (Describe)
		2020 Cylindrospermopsin and saxitoxin: insufficient data Locations: main basin, Provo Bay, beaches and marinas				program for anatoxin and saxitoxin						
Maximum seasonal cyanobacteria cell count and chlorophyll- a concentration at Utah Lake outlet.	TBD	Routine monitoring dataset Seasonal maximum (n = 5 for each variable), 2015-2019	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	Open water near lake outlet	Toxigenic cyanobacteria density and relative abundance Cyanobacteria biovolume
Downstream Uses												
[Drinking Water] Microcystin concentration	TBD	HAB monitoring dataset 388 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
[Drinking Water] Cylindrospermopsin concentration	TBD	Insufficient data Fewer than 20 samples from HAB monitoring program	Yes	No	No	Yes, add analysis to HAB monitoring program	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
[Drinking Water] Nitrate concentration	10 mg/L	Routine monitoring dataset 119 samples, 2015-2019 Locations: Main basin, Goshen Bay, Provo Bay	Yes	Yes	NA	NA	NA	No	See 2a	See 2a	Open water near lake outlet	See ammonia
Organic matter load (%)	38% reduction	Jordan River TMDL Water Quality Study (2013)	Yes	Yes	NA	NA	NA	No	See JR TMDL	Yes	Open water near lake outlet	No
[Secondary water use] Microcystin concentration	Presumed to be protective if recreational thresholds are achieved within Utah	HAB monitoring dataset 388 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No

Toxins	Phytoplankton	Chemistry	Biology	Human								
Measures	**Targets**	**Metadata**	**Q. 2 (Y/N)**	**Q. 2a**	**Q. 2b**	**Q. 2c (Describe)**	**Q. 2d (Describe)**	**Q. 3 (Y/N)**	**Q.4 (Describe)**	**Q. 4a (Y/N)**	**Q. 4b (Describe)**	**Q.5 (Describe)**
	Lake.											
[Secondary water use] Cylindrospermopsin concentration	Presumed to be protective if recreational thresholds are achieved within Utah Lake.	Insufficient data Fewer than 20 samples from HAB monitoring program	Yes	No	No	Yes, add analysis to HAB monitoring program	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No
[Secondary water use] Anatoxin concentration	Presumed to be protective if recreational thresholds are achieved within Utah Lake.	HAB monitoring dataset 285 samples, 2017-2020 Locations: main basin, Provo Bay, beaches and marinas	Yes	Yes	NA	NA	NA	No	See current conditions assessment	Yes	PB, GB, marinas, beaches, open water	No