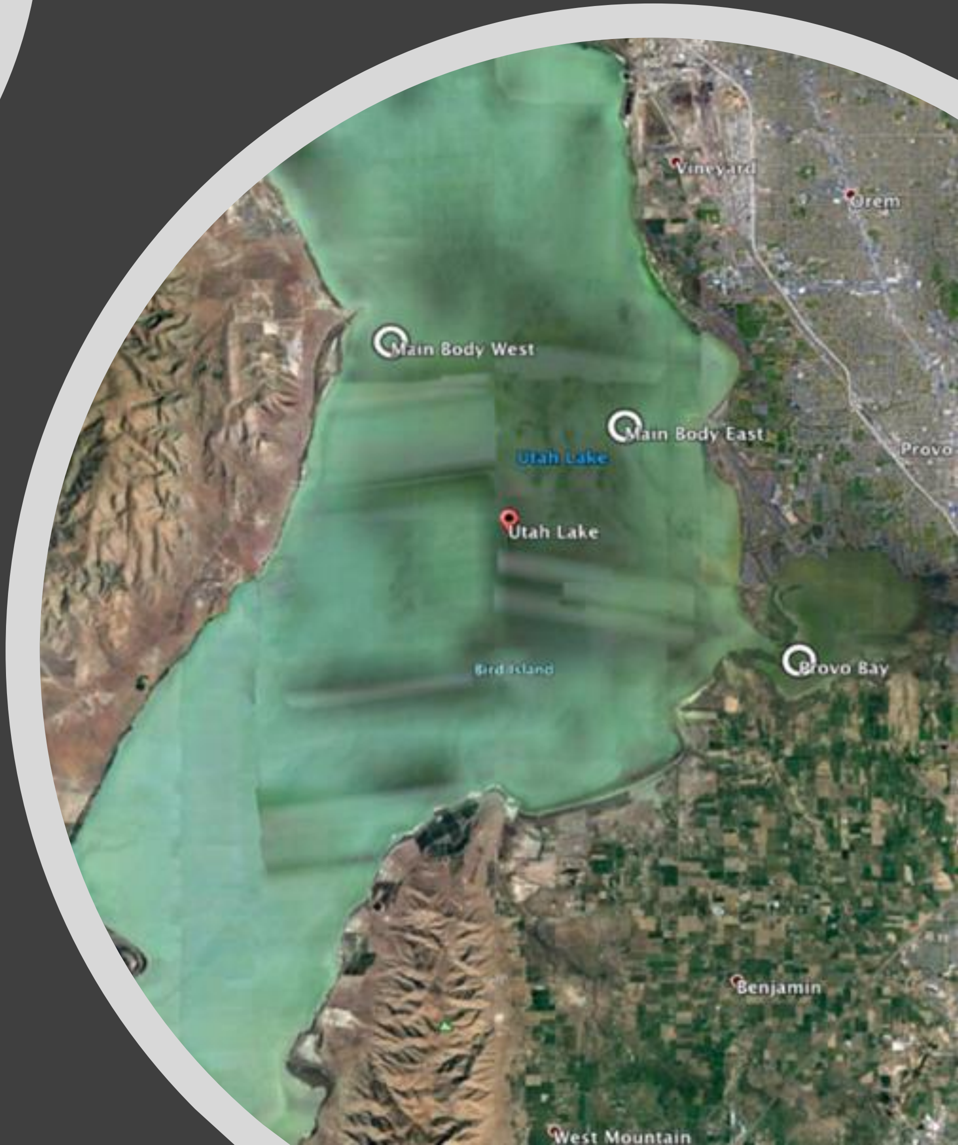


We completed the spring bioassay (4th-8th May) in the three lake locations and started the nutrient dilution bioassays yesterday (27th May). To date, we have completed four of the five bioassays with the last bioassay (early summer) scheduled for June 15th. We are adding a zooplankton addition trial to the early summer bioassay. We added N_2 fixation rates to all 2020 bioassays.

Figure 1 The ratio of N and P delta R limitation response ($\log_{10}$ ratio of a given nutrient treatment growth relative to the control per day) for combined chlorophytes (including Cyanobacteria and a limited number of diatoms, Chlorophyll-a = Exo sonde measurement) cyanobacteria (Phycocyanin = Exo sonde measurement). Values above 1 (dashed gray line) indicate increasing N limitation and values below the line indicate an increasing P limitation.

Findings Similar to other shallow lake systems, chlorophytes and to a lesser extent Cyanobacteria in the East and West location of Utah Lake transitioned from being P-limited earlier in the HAB season to N-limited later in the season.

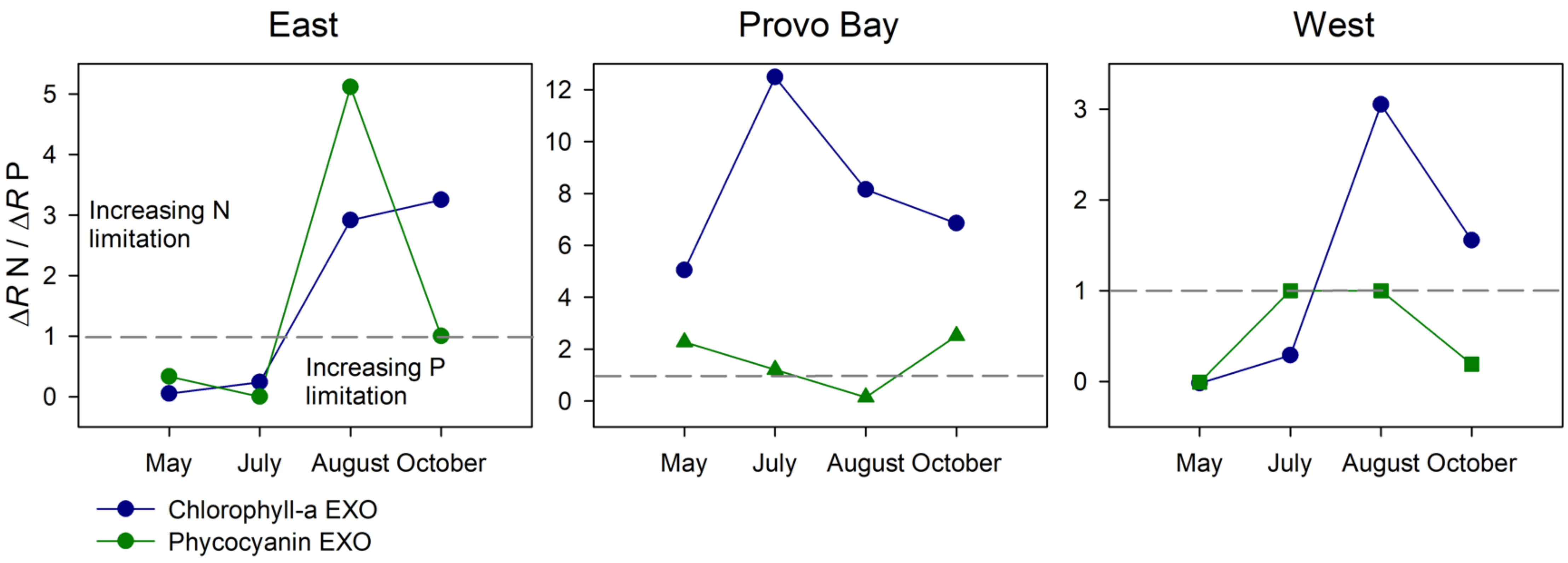


Table 1. Seasonal shifts in Cyanobacterial species by out three locations. Seasonal abbreviations include spring = SP, early summer = ES, summer = S, late summer = LS, and fall = F. Data and counts are from Utah Division of Water Quality for years 2018-2019.

	EAST						WEST						PROVO BAY					
	counts (#)	richness = 18					counts (#)	richness = 15					counts (#)	richness = 12				
Species		SP	ES	S	LS	F		SP	ES	S	LS	F		SP	ES	S	LS	F
Aphanizomenon flosaquae	47,463-234,076						5,466-81,833						100,476-344,058					
Aphanocapsa grevillei	728																	
Aphanocapsa holsatica	3,528																	
Aphanocapsa planctonica	1,568-10,662						314-627											
Aphanocapsa species	2,394-10,591						532-8,512						1,862-46,075					
Calothrix species	157																	
Chroococcus species							62											
Chrococcus dispersus													3,240					
Chroococcus limeticus	101												101					
Coelosphaerium species							45						1,440					
Cyanodictyon planctonicum	336-2,688						2,520						2,700-54,000					
Dolichospermum circinalis	645-74,650						946-3,830						1,125-630,157					
Dolichospermum species													6,413					
Gomphosphaeria aponina	5,018																	
Leptolyngbya species	3,928-9,565						3,007						7,515-17,763					
Merismopedia glauca	3,472-48,288						5,555						6,535-65,596					
Microcystis aeruginosa	686						392											
Microcystis species	2,688-3,584						6,272						12,600					
Phormidium species	1,456-2,058						2,464						1,456-12,555					
Phormidium species 3	168-8,623																	
Planktothrix species	826-19,936						9,390-15,680						5,376-36,000					
Pseudanabaena species	162-1,217						324-1,966						1,620-3,035					
Snowella lacustris	784						2,867											

RFP: UTAH LAKE SEDIMENT CALCITE PHOSPHORUS BINDING

Utah Lake Water Quality Study
Science Panel Webshop
May 28, 2020

GOALS

- Review Calcite-P RFP
- Obtain feedback to continue development

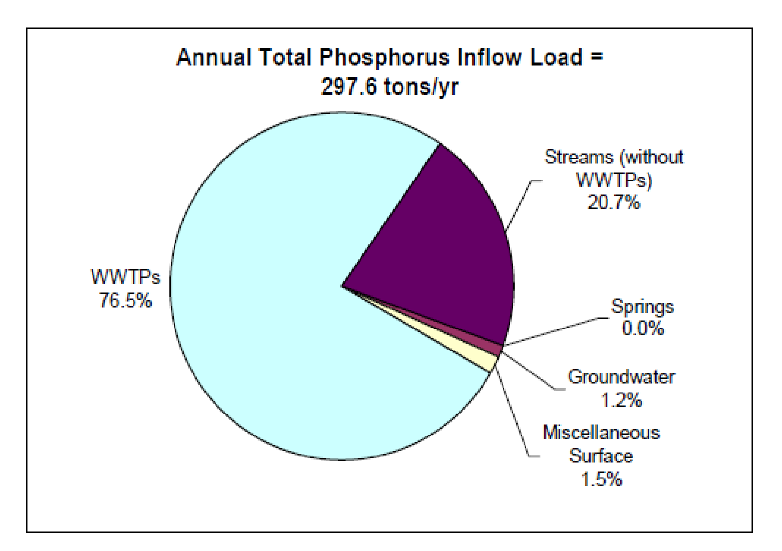
PHOSPHORUS BINDING IN UTAH LAKE

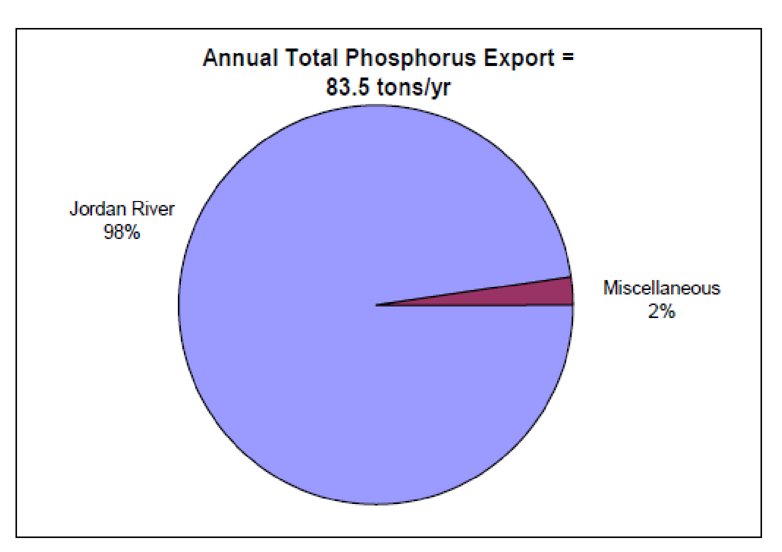
Utah Lake retains large majority of external P loads

Mechanism: P uptake by sediments

Sorption of P onto various cations

- Acidic: Al and Fe
- Alkaline: Ca and Mg





CALCITE BINDING

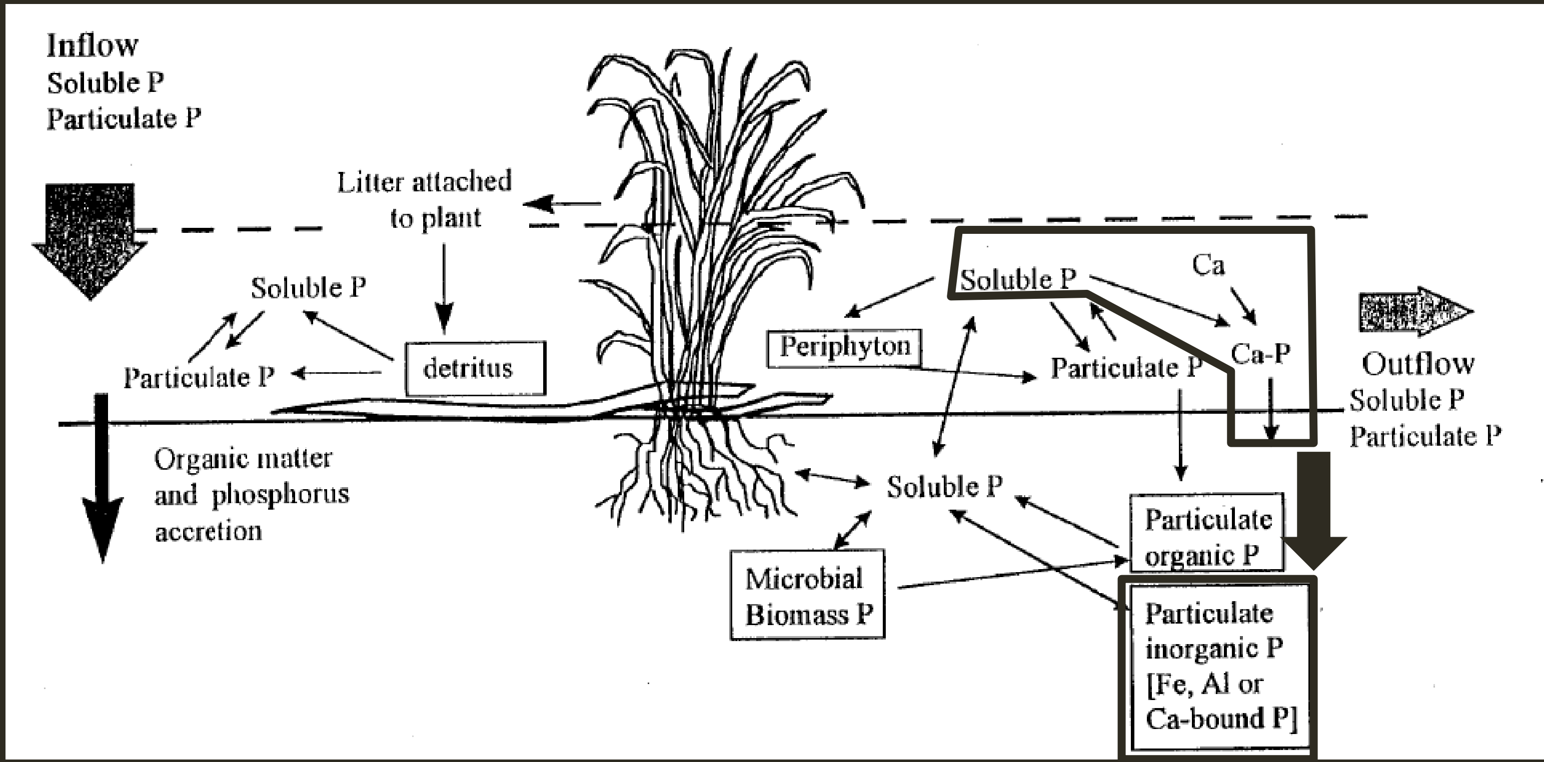
P adsorbs to calcite → precipitates

Favorable conditions

- High pH
- High [Ca^{2+}]
- High [P]

Inorganic reaction, but PP and R affect pH

May be semi-permanent sink in lakes with high Ca and alkalinity



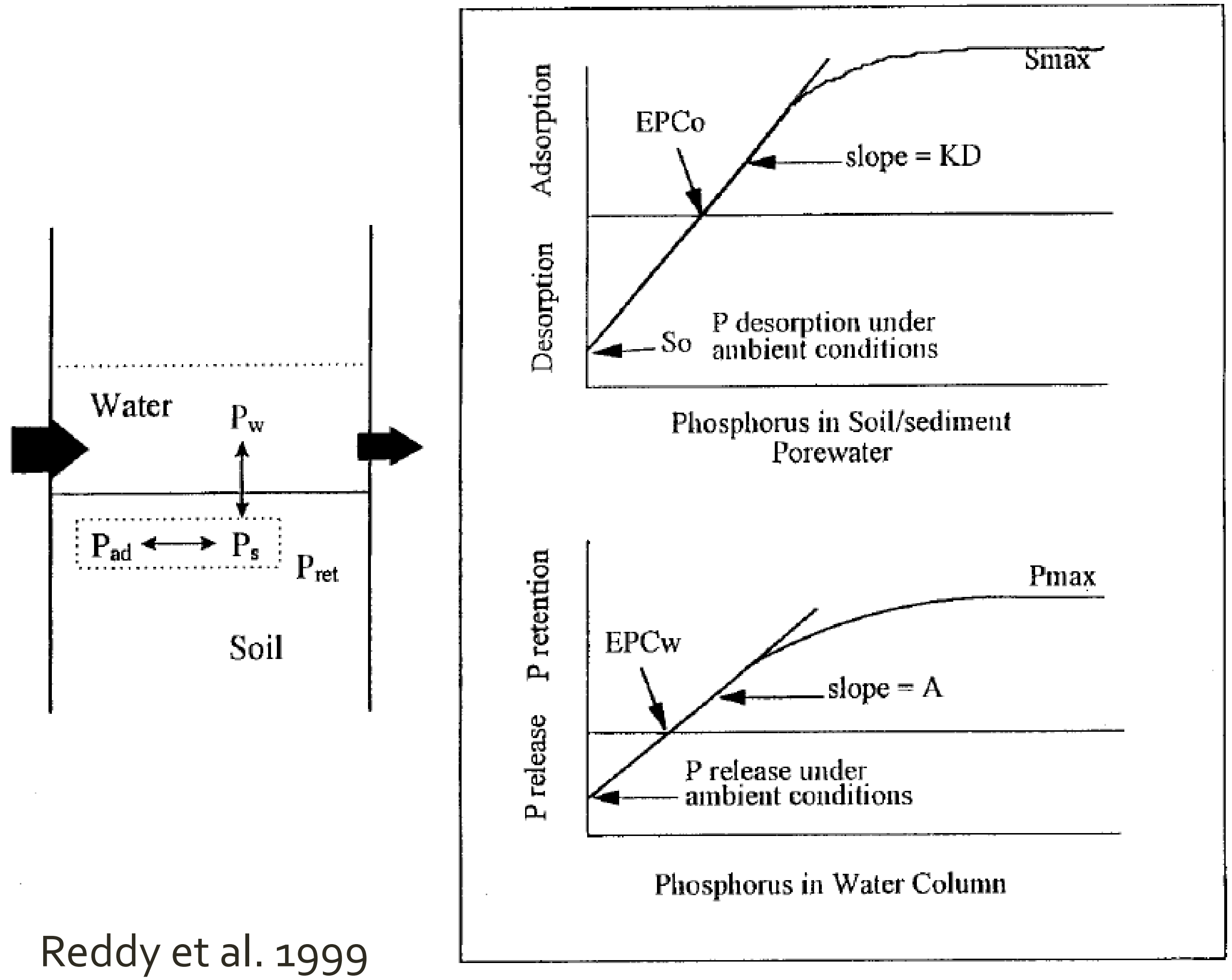
Reddy et al. 1999

SEDIMENT-WATER EQUILIBRATION

Utah Lake sediments may change from sink to source in response to lowered P loads

Timescale of equilibration depends on
- Gradient in water vs. sediment
- Amount and chemical forms of P

Needs: characterize quantities and mechanisms of P binding



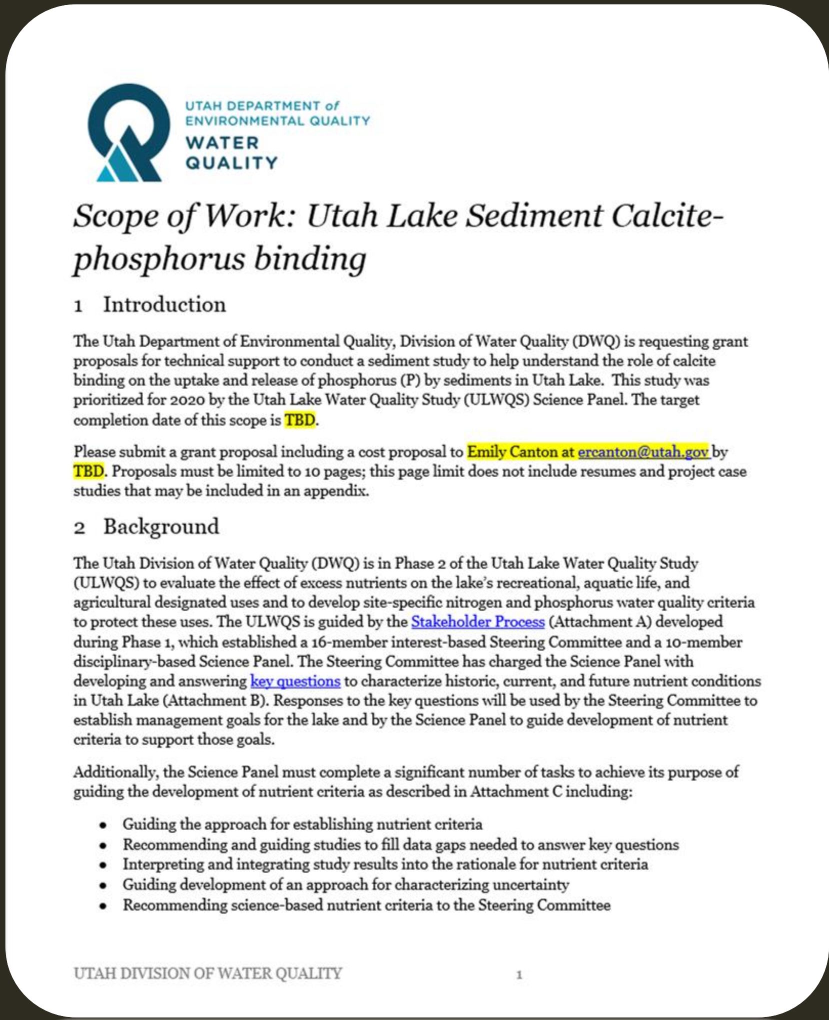
Reddy et al. 1999

RFP OBJECTIVES

1. Quantify the importance of calcite binding as a P sink
2. Parse the mechanisms of sediment P binding (and release)
3. Define the environmental conditions under which calcite binding is favorable, including the spatial and temporal extent of these conditions
4. Characterize the amount and chemical forms of water column and sediment P, including bioavailable and mineral bound forms
5. Measure the bioavailability of P forms in the water column
6. Predict the impact of changing P inputs on the binding and release of sediment P

RFP TASKS

1. Review existing literature and data
2. Analyze existing data
3. Develop sampling and analysis plan (SAP)
4. Experiments with sediment cores and/or mesocosms
5. Algal assays for P bioavailability
6. Quantify role of calcite P binding in Utah Lake
7. Prepare technical report



UTAH DEPARTMENT of ENVIRONMENTAL QUALITY
WATER QUALITY

Scope of Work: Utah Lake Sediment Calcite-phosphorus binding

1 Introduction

The Utah Department of Environmental Quality, Division of Water Quality (DWQ) is requesting grant proposals for technical support to conduct a sediment study to help understand the role of calcite binding on the uptake and release of phosphorus (P) by sediments in Utah Lake. This study was prioritized for 2020 by the Utah Lake Water Quality Study (ULWQS) Science Panel. The target completion date of this scope is TBD.

Please submit a grant proposal including a cost proposal to Emily Canton at ercanton@utah.gov by TBD. Proposals must be limited to 10 pages; this page limit does not include resumes and project case studies that may be included in an appendix.

2 Background

The Utah Division of Water Quality (DWQ) is in Phase 2 of the Utah Lake Water Quality Study (ULWQS) to evaluate the effect of excess nutrients on the lake's recreational, aquatic life, and agricultural designated uses and to develop site-specific nitrogen and phosphorus water quality criteria to protect these uses. The ULWQS is guided by the Stakeholder Process (Attachment A) developed during Phase 1, which established a 16-member interest-based Steering Committee and a 10-member disciplinary-based Science Panel. The Steering Committee has charged the Science Panel with developing and answering key questions to characterize historic, current, and future nutrient conditions in Utah Lake (Attachment B). Responses to the key questions will be used by the Steering Committee to establish management goals for the lake and by the Science Panel to guide development of nutrient criteria to support those goals.

Additionally, the Science Panel must complete a significant number of tasks to achieve its purpose of guiding the development of nutrient criteria as described in Attachment C including:

- Guiding the approach for establishing nutrient criteria
- Recommending and guiding studies to fill data gaps needed to answer key questions
- Interpreting and integrating study results into the rationale for nutrient criteria
- Guiding development of an approach for characterizing uncertainty
- Recommending science-based nutrient criteria to the Steering Committee

UTAH DIVISION OF WATER QUALITY 1

RFP TASKS: OVERLAPS WITH PALEOLIMNOLOGICAL STUDY

1. Review existing literature and data (*Paleo: M. Devey Thesis*)
2. Analyze existing data
3. Develop sampling and analysis plan (SAP)
4. Experiments with sediment cores and/or mesocosms *(Paleo: Calcite – P binding experiments; Sediment characterization)*
5. Algal assays for P bioavailability
6. Quantify role of calcite P binding in Utah Lake *(Paleo: Reconstructing Ca-binding)*
7. Prepare technical report

→ *Potential to expand Janice Brahney's work and/or delay RFP to incorporate results*

OUTSTANDING QUESTIONS

How can this RFP be amended (focus, timeline) to take advantage of paleo study?

Should the scope be broadened to address other P binding mechanisms? *(Potential opportunity: evaluate additional pathways → holistic picture of P binding and release)*

Does the RFP adequately address the forms of P in the water column and sediment?

STRATEGIC RESEARCH PLAN

Utah Lake Water Quality Study

Science Panel Call

May 28, 2020

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY

GOALS

- Update on SRP development, next steps and timeline
- Get any/all feedback on proposed projects/content

Utah Lake Water Quality Study—Strategic Research Plan

DRAFT

May 22, 2020
Version 4.1

PRESENTED TO

Utah Department of Environmental Quality
Division of Water Quality
PO Box 144870
Salt Lake City, UT 84114

PREPARED BY

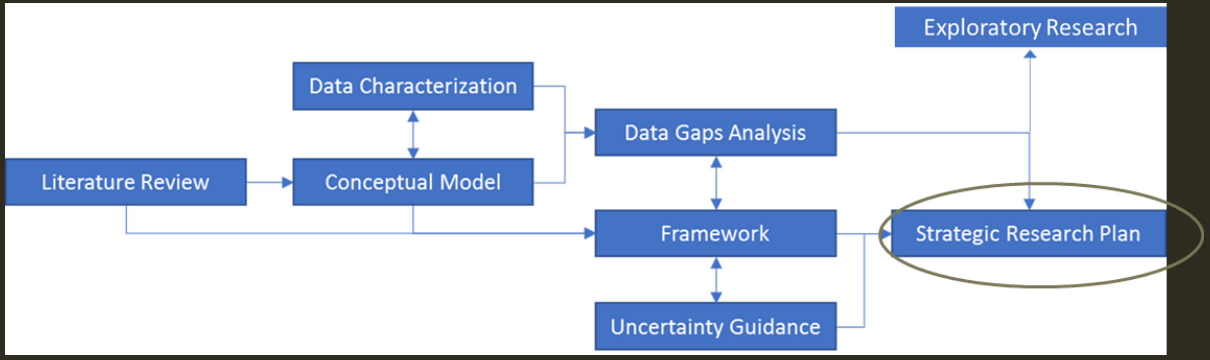
Tetra Tech
1 Park Drive, Suite 200
Research Triangle Park, NC 2709

STRATEGIC RESEARCH PLAN: PAST AND PRESENT

- Workplan (Task 6)
- Develop SRP to:
  - Fill knowledge gaps
  - Identify studies to address initial charge questions and strengthen conceptual model
  - Include problem statement, objectives and approaches
- Exploratory Research Plan: First three RFPs – ignite research actions
- SRP: Current RFPs (Littoral Sediment, CNP Budgets and Calcite P) and Future Work

RESEARCH PLAN REMINDER

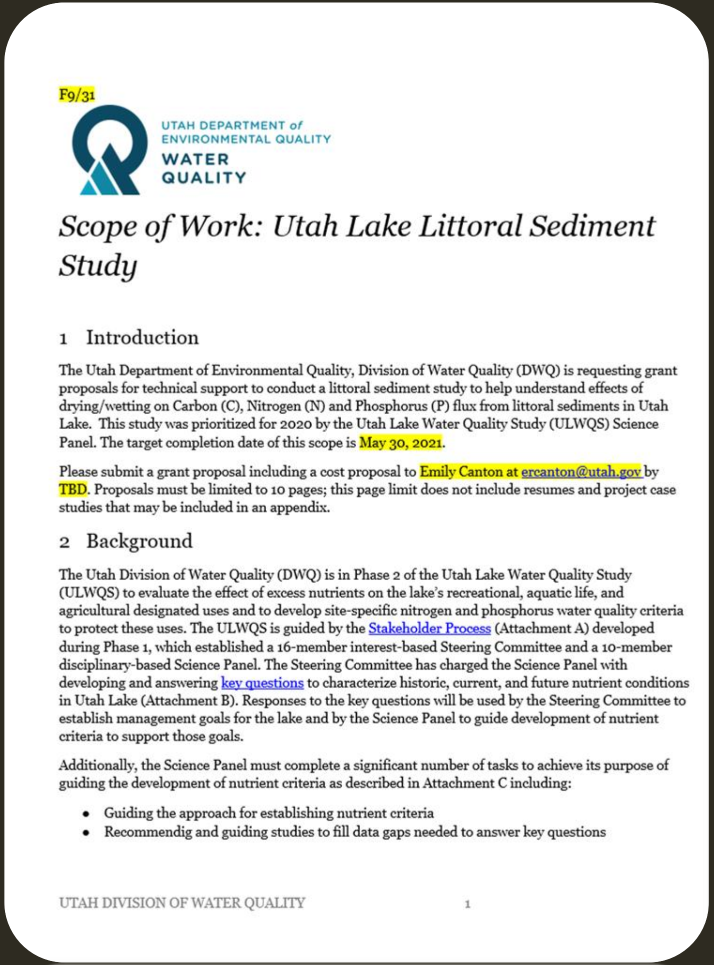
- Introduction: Process, ongoing research
- Mapped charge questions and NNC development needs to existing work
- Summarized research needs
- Laid out research priorities
- Voted to rank – then moved to RFPs



Questions	Being addressed
1.1. What does the diatom community and macrophyte community in the paleo record tell us about the historical trophic state and nutrient regime of the lake?	Partially
i. Can diatom (benthic and planktonic) and/or macrophyte extent or presence be detected in sediment cores? And if so, what are they?	Paleo RFP
ii. What were the environmental requirements for diatoms and extant macrophyte species?	No
iii. How have environmental conditions changed over time?	Data analysis
1.2. What were the historic phosphorus, nitrogen, and silicon concentrations as depicted by sediment cores? (add calcium, iron, and potentially N and P isotopes)	Paleo RFP
1.3. What information do paleo records (eDNA/scales) provide on the population trajectory/growth of carp over time? What information do the paleo records provide on the historical relationship between carp and the trophic state and nutrient regime of the lake?	No
1.4. What do photopigments and DNA in the paleo record tell us about the historical water quality, trophic state, and nutrient regime of the lake?	Paleo RFP

RFP DEVELOPMENT

- Littoral Sediment C, N and P stock and flux
- C, N, and P mass balance: external and internal
- Calcite – P binding
- N-fixation – working with Aanderud lab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UTAH DEPARTMENT of ENVIRONMENTAL QUALITY
WATER QUALITY

Scope of Work: Utah Lake Littoral Sediment Study

1 Introduction

The Utah Department of Environmental Quality, Division of Water Quality (DWQ) is requesting grant proposals for technical support to conduct a littoral sediment study to help understand effects of drying/wetting on Carbon (C), Nitrogen (N) and Phosphorus (P) flux from littoral sediments in Utah Lake. This study was prioritized for 2020 by the Utah Lake Water Quality Study (ULWQS) Science Panel. The target completion date of this scope is May 30, 2021.

Please submit a grant proposal including a cost proposal to Emily Canton at ercanton@utah.gov by TBD. Proposals must be limited to 10 pages; this page limit does not include resumes and project case studies that may be included in an appendix.

2 Background

The Utah Division of Water Quality (DWQ) is in Phase 2 of the Utah Lake Water Quality Study (ULWQS) to evaluate the effect of excess nutrients on the lake's recreational, aquatic life, and agricultural designated uses and to develop site-specific nitrogen and phosphorus water quality criteria to protect these uses. The ULWQS is guided by the Stakeholder Process (Attachment A) developed during Phase 1, which established a 16-member interest-based Steering Committee and a 10-member disciplinary-based Science Panel. The Steering Committee has charged the Science Panel with developing and answering key questions to characterize historic, current, and future nutrient conditions in Utah Lake (Attachment B). Responses to the key questions will be used by the Steering Committee to establish management goals for the lake and by the Science Panel to guide development of nutrient criteria to support those goals.

Additionally, the Science Panel must complete a significant number of tasks to achieve its purpose of guiding the development of nutrient criteria as described in Attachment C including:

- Guiding the approach for establishing nutrient criteria
- Recommendig and guiding studies to fill data gaps needed to answer key questions

UTAH DIVISION OF WATER QUALITY 1

PROCESS TO FINALIZE

- Complete identifying projects (DONE)
- Draft RFP elements (DONE)
- We fill out RFP components – iterate with you
  - SP Finalizes RFPs (Littoral, CNP done; Calcite doing)
  - SP Finalizes SRP (This effort)
- Complete RFPs/SRP
  - RFPs to SC for approval (Littoral, CNP done, Calcite doing)
  - RFPs out for bid (Littoral CNP soon, Calcite later)
  - SRP to SC for approval (Summer)

Utah Lake Water Quality Study—Strategic Research Plan

DRAFT

May 22, 2020
Version 4.1

PRESENTED TO

Utah Department of Environmental Quality
Division of Water Quality
PO Box 144870
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PREPARED BY

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Research Triangle Park, NC 2709

REMAINING PRIORITIES

- Remember our priorities – we've pursued RFPs for the highest priority elements and littoral sediments
- The rest?
- Wanted to "close the loop" on the remainder within the SRP
- As a reference for future RFP planning and development

	Research ideas	Mean Ranking - Feb 2020
1	**How large is internal vs external loading (how long would recovery take?)**	**2.3**
2	**Sediment budgets (C, N, and P; nutrient flux chambers)**	**3.6**
3	**Calcite scavenging (how bioavailable is SRP – does bioassay address?)**	**4.3**
4	**Adding modules to the WQ models (sediment diagenesis, calcite scavenging)**	**4.3**
5	Carp effects on nutrient cycling	7.3
6	Lake level (effect on macrophytes)	9.2
7	Bioassays that incorporate sediment (next phase mesocosms)	9.4
8	Macrophyte recovery potential (Provo Bay demo)	10.0
9	Lake-level effects on biogeochemistry and nutrient cycling	10.2
10	Environmental controls on toxin production	11.1
11	Turbidity effect on primary producers	11.2
12	Resuspension rates from bioturbation	11.7
13	Carp effects on zooplankton (and does this influence algal response)	11.8
14	Carp effects on macrophytes	12.1
15	Toxin Production and N Species	13.7
16	Recreational surveys	13.8
17	Macrophyte role (to biogeochemistry)	14.0
18	Additional atmospheric deposition data	14.6
19	Alternative models (PCLake – cyano/macrophyte state change)	14.9

SRP SECTION 4.2 – SPECIFIC RESEARCH PROJECTS

- Lays out strategic research elements for the 19 research priorities
  - Problem Statement
  - Existing Data and Information
  - Objectives
  - Expected Outcome/Outputs
  - Capacity to Address with Mesocosms

- Does not include approach – to be determined when they become future RFPs

MESOCOSM OPPORTUNITIES

- Mesocosms could address many areas
  - Calcite Binding
  - Carp Effects – turbidity, zooplankton, macrophytes
  - Macrophyte recovery/effects – turbidity, biogeochemistry
  - Lake Level
  - Bioassay Gen 2
  - Turbidity effects on primary producers
  - Toxin controls

- To help with TSSD planning

- Highlighted in SRP

NEXT STEPS: FINALIZING SRP

- Review SRP (Section 4.2 especially)
- Captured all the priorities?
- Characterized elements correctly?

- Provide a Record for future RFP planning and development