Utah Lake Sediment–Water Nutrient Interactions
Detailed work plan

Utah Lake Science Panel

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Objectives and rationales

- Understanding the cycling of Phosphorus within Utah Lake will help describe the current state of the lake with respect to nutrients and ecology
- Sediments are an important component of the nutrient cycling within the lake
- The overall objectives of this collaborative project are:
  - (1) to understand the role of anoxia in nutrient release and sediment dynamics over a range of phosphorus concentrations,
  - (2) to understand the role of pH in water column–sediment interactions and nutrient releases and how does the equilibrium phosphorus concentration change over a range of water column pH and,
  - (3) to estimate the sediment oxygen demand and nutrient release from sediments under current conditions. Four different tasks will complement these aforementioned objectives identified by the Science Panel in the recently released RFP.

Experimental Tasks

Task 1. Develop sampling and analysis plan (SAP) (Drs. Goel and Carling and graduate students)

Sub task 1.1: Project kick off meeting

Sub task 1.2: Develop sampling and analysis plan (SAP)

Task 2. Collect sediment cores from Utah Lake (Both labs)

Sub-task 2.1: Coordination with UDWQ and BYU for sediment core collection

Sub-task 2.2: Collecting sediment cores:

Task 3. Perform sediment core experiments and laboratory analysis

Sub-task 3.1: Nutrient spike experiments under aerobic conditions (University of Utah)

Sub-task 3.2: Column experiments under anaerobic conditions (University of Utah)

Sub-task 3.3: P spiking column experiments under ambient conditions (neutral pH) (BYU)

Task 3. Contd-

Sub-task 3.4: P spiking column experiments under elevated pH condition (pH=9.5) (BYU)

Sub-task 3.5: Sediment oxygen demand determination (University of Utah)

Sub-task 3.6: Statistical analysis

Task 4: Prepare technical report

Task 1: Experimental Plan

- Sub task 1.1: Project kick off meeting
  - Discuss project milestones, assign duties in terms of SOPs and QAPP writing
  - Discuss about the lab infrastructure in each key personnel's lab and the overall time frame of experiments

- Sub task 1.2: Develop sampling and analysis plan (SAP)
  - Develop QAPP and SAP documents, and coordinate with UDWQ
  - Submit all necessary QAPP and SAP documents to the Utah Lake science panel/UDWQ.

Task 2:Coordination with UDWQ and BYU for sediment core collection

- Sediment cores will be collected from one site in Provo Bay and one site in the open water of Utah Lake (perhaps mouth of Goshen Bay)
- A hand driven PVC corer, SCUBA diving or a percussion corer fitted with 60 cm long and 5 cm internal diameter core tubes will be applied
- A total of 36 cores (39 if SOD conducted in the lab) will be collected per site
- Cores will be preserved in the dark and on ice during transport to the lab
- The utilization of sediment cores will be detailed in Task 3.

Question: Do we process all cores simultaneously or conduct experiments in batches over 2~3 days or we collect cores in batches, finish experiments and then go back and collect more from the same site?

Note: Sediment corer will be borrowed from UDWQ/BYU

Core collection will be performed in coordination with UDWQ

Absolutely no plans to do anything before the contract is in place

Sub-task 3.1: Nutrient spike experiments under aerobic conditions (University of Utah)

- 12 sediment cores from each site
  - Each core will be equipped with a 5~10 mm diameter aeration stone connected to an aquarium pump
  - Three cores at ambient P concentrations
  - Triplicate cores at 0.5x, 2x, and 4x ambient P concentrations

  Question: Spiking equivalent to Total ambient P or total dissolved or total reactive
- Water samples collected during the experiment
  - *Samples collected at mid-depth in the water column at 6-, 12-, 24-, 48-, and 72-hours (total of 60 samples)
  - Samples analyzed for total dissolved P, SRP, nitrate, nitrite, and ammonia
  - Subset of samples analyzed for metals

  * Based on Spears et al., 2007 paper (suggested in RFP)

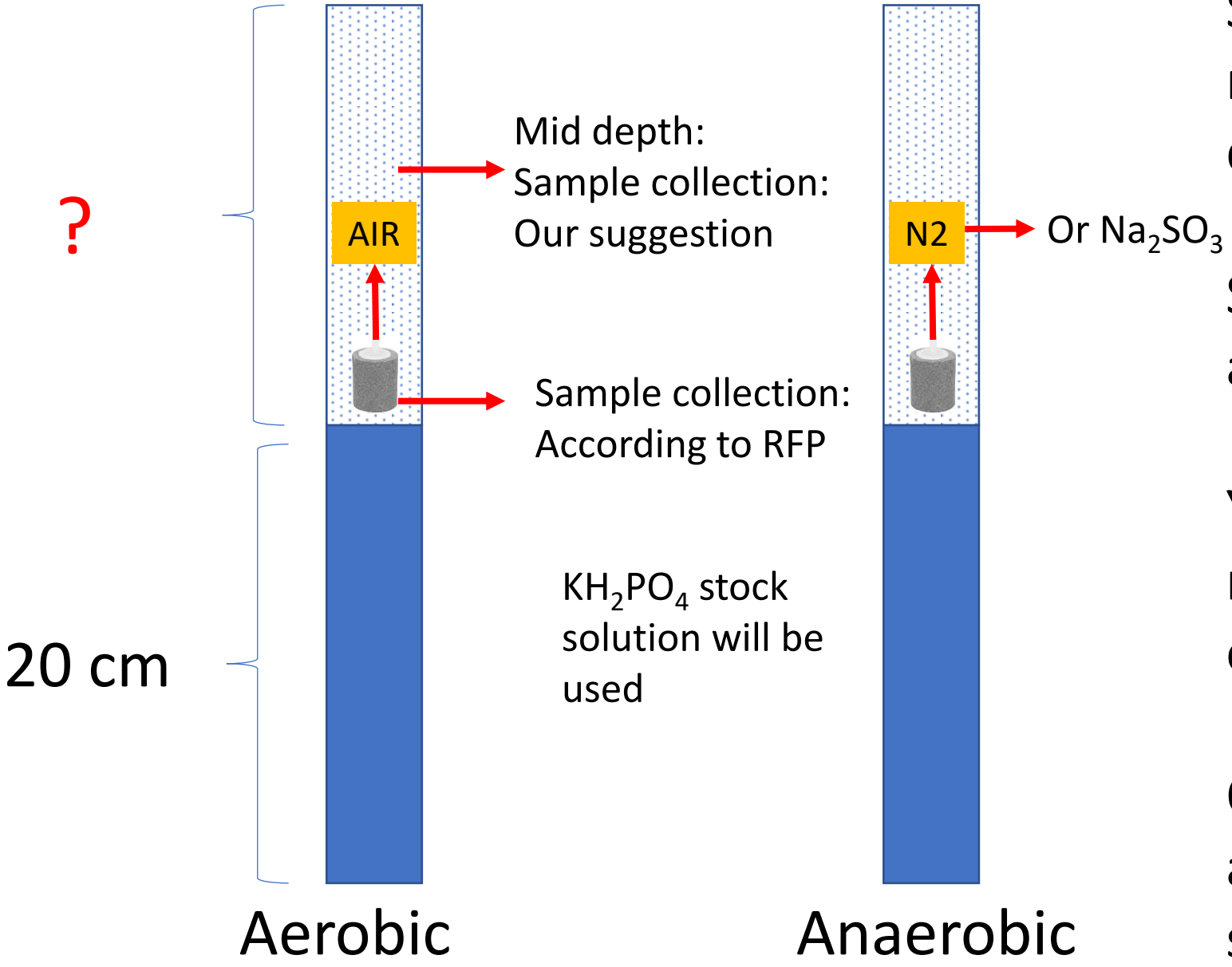
Sub-task 3.2: Column experiments under anaerobic conditions (University of Utah)

- 12 sediment cores from each site
  - Sodium **sulfite** containing trace amount of **cobalt chloride** will be added to each column (**or N2 will be purged**) to create anaerobic conditions
  - Three cores at ambient P concentrations
  - Triplicate cores at 0.5x, 2x, and 4x ambient P concentrations

- Water samples collected during the experiment
  - Samples collected at mid-depth in the water column at 6-, 12-, 24-, 48-, and 72-hours (total of 60 samples)- (**Spears et a., 2007 collected at 9 and 72 hours)**
  - Samples analyzed for total dissolved P, SRP, nitrate, nitrite, and ammonia
  - Subset of samples analyzed for metals

$$2Na_2SO_3+O_2 = 2Na_2SO_4$$

Experimental Schematic



Spears et al., 2007 did not mention about sediment core depth

Spears et al., 2007 did not agitate or create turbulence

Yu et al., 2019 used a mud:water ratio of 2:3 for similar experiments

Other concern: continuous aeration or N2 purging might strip off CO_2

Sub-task 3.3: P spiking at neutral pH (BYU)

- 12 sediment cores from each site
  - Filtered and sterilized Utah Lake water adjusted to pH 7 using 0.5 N H_2SO_4 added to each core
  - Three cores at ambient P concentrations
  - Triplicate cores at 0.5x, 2x, and 4x ambient P concentrations

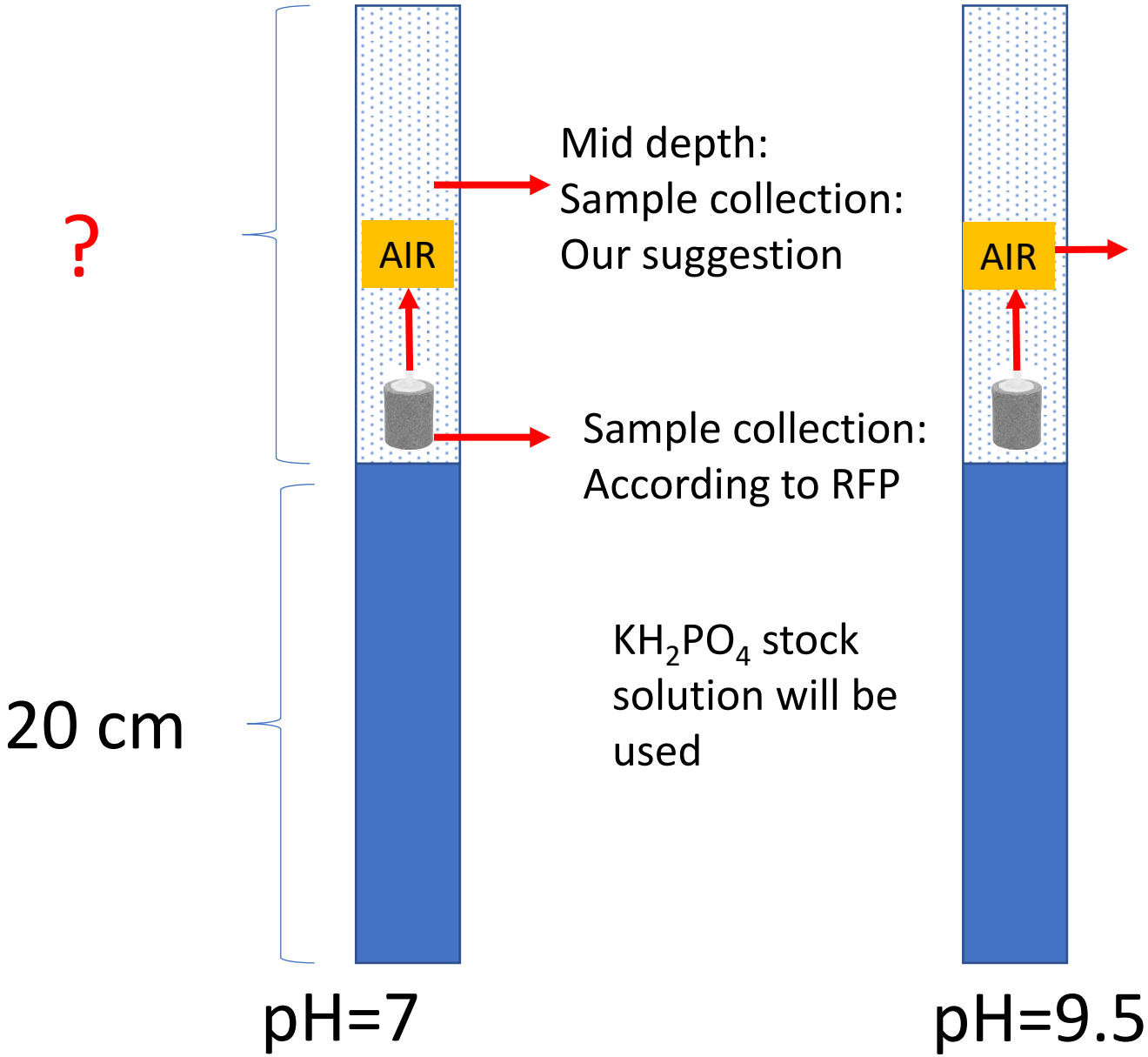
- Water samples collected during the experiment
  - Samples collected at mid-depth in the water column at 6-, 12-, 24-, 48-, and 72-hours (total of 60 samples)
  - Samples analyzed for total dissolved P, SRP, nitrate, nitrite, and ammonia
  - Subset of samples analyzed for metals

Sub-task 3.4: P spiking at elevated pH (BYU)

- 12 sediment cores from each site
  - Filtered and sterilized Utah Lake water adjusted to pH 9.5 using 0.5 N NaOH added to each core
  - Three cores at ambient P concentrations
  - Triplicate cores at 0.5x, 2x, and 4x ambient P concentrations

- Water samples collected during the experiment
  - Samples collected at mid-depth in the water column at 6-, 12-, 24-, 48-, and 72-hours (total of 60 samples)
  - Samples analyzed for total dissolved P, SRP, nitrate, nitrite, and ammonia
  - Subset of samples analyzed for metals

Experimental Schematic- pH manipulation



Spears et al., 2007 did not mention about sediment core depth

Spears et al., 2007 did not agitate or create turbulence

Yu et al., 2019 used a mud:water ratio of 2:3 for similar experiments

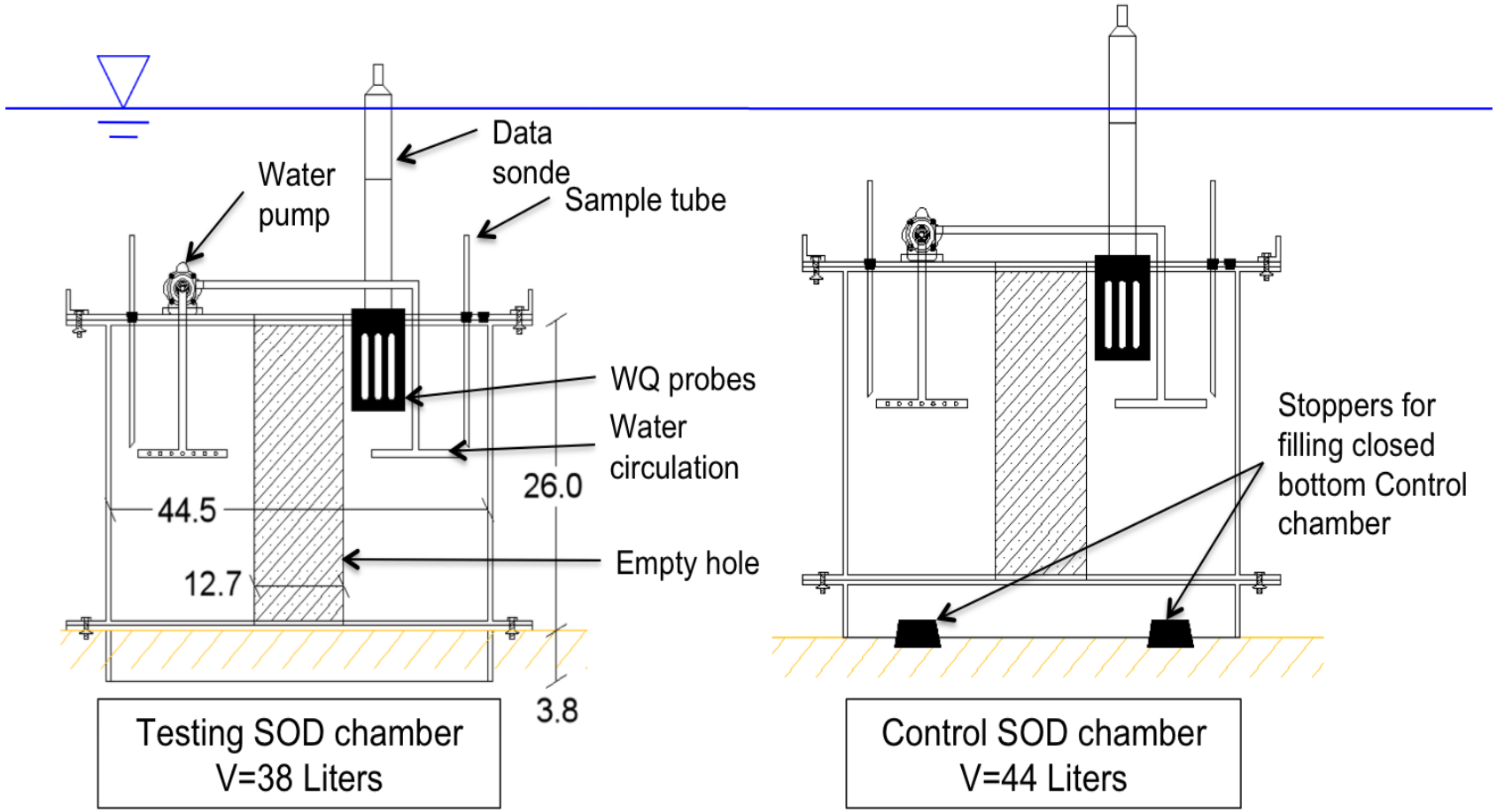
Other concern: Ammonia stripping might occur at high pH

Sub-task 3.5: Sediment oxygen demand determination (University of Utah)

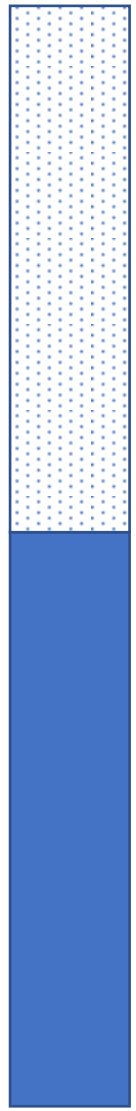
- In-situ SOD chamber
  - Shallow sites with accessibility will be applied
  - One control and two experimental chambers will be applied
  - Continuous measurement of DO is applied using DWQ SONDE
  - water samples will be collected every 20~30 minutes to determine nutrient fluxes

- In-lab measurement
  - When deep site is not assessable
  - DO consumption will be measured in triplicated sediment cores

SOD chambers



OR



Question: Do we internally circulate water inside chambers/ agitate columns in lab sediment core

Lab sediment core

Sub-task 3.6: Statistical analysis

- We will use the **R package** to conduct all the statistical analysis. We will use t-tests for more direct tests and comparison between data sets.
- Significance levels (p values) will be reported to levels of 0.05, and 0.01. For small sample sizes, we will also report p values between 0.05 and 0.10.
- Two-tailed Pearson correlation analysis will be used to determine the correlations between different parameters between different treatments.
- Principal component analysis will be used to evaluate interdependency of different parameters.

Analytical methods for ambient and spiked water

20 cm of water and sediment

Phosphate measurement

Otho-P (reactive P)	Total P	Organic P
Hach PhosVer® 3 Phosphate Reagent	Hach USEPA PhosVer® 3 with Acid Persulfate Digestion Method	Total P-otho-P

Note: All water parameters will be filtered through 0.45 um filters

Parameter/s	Method	Comments if any
All anions including nitrate, nitrite, phosphate (dissolved P and SRP) and sulfate	Ion chromatography (supplemental with acid extraction as needed for total P)	The IC is available in PI and CO-PI's labs.
Ammonium and nitrogen	HACH or CHEMetrics kit	Widely used method by ecologists and engineers with high accuracy
Metals	ICP-MS	Available at the University of Utah core facility
Turbidity	Turbidity meter	Available in the PI's lab.

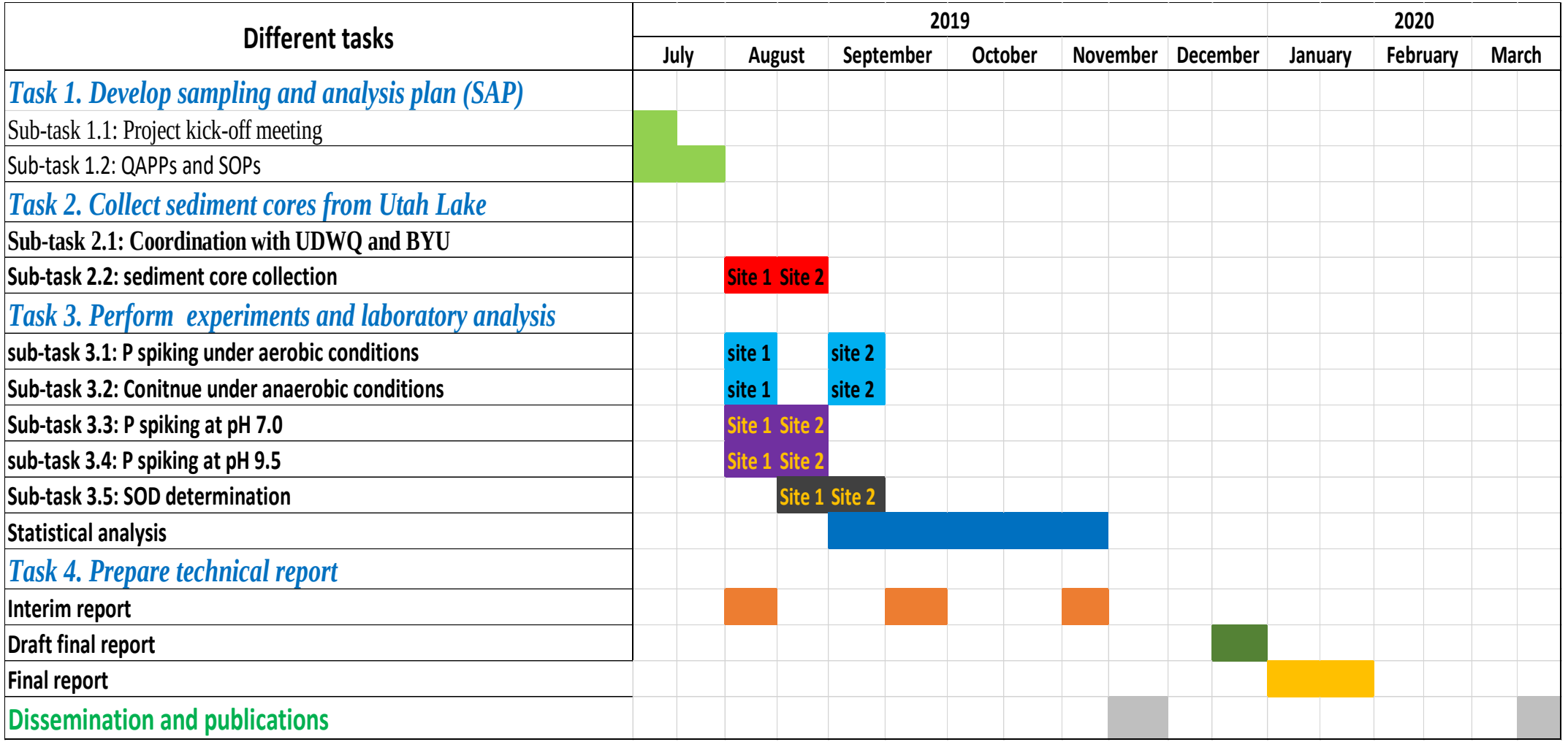
Task 4: Prepare technical report

- First, we will periodically present results at in-person meetings with UDWQ personnel and the Science Panel to inform about project progress and to seek input on future research direction.

- Secondly, we will submit a synopsis of preliminary analysis within one week from the date of experiments in the form of interim reports.

- Lastly, we will submit draft and final project reports containing all analyzed data, project rationale, future recommendations.

Project Milestones



Assuming contract is in place by July 15th

Questions

Questions for the Science Panel

- We have proposed to shake sediment cores intermittently in task 3 experiments. We think this reflects the true hydrodynamics in Utah Lake because continuous mixing does not take place in lakes (even if shallow) except during seasonal turnovers. Hence, in this work plan (pending discussion with the Science Panel), we have proposed manual intermediate mixing rather than continuous agitation/shaking of sediment cores during various experiments in task 3.
- 2. We included a water depth of 20 cm over sediments in lab scale column experiments. This may not reflect the true water column height especially for the deep open water site.
- 3. Water sampling at regular intervals in lab scale column experiments will reduce the volume of overlying water. Shall we replace the volume of water equivalent to the sampled water volume?

Task 3: sediment core experiments and laboratory analysis

Parameter/s and experiments	Rationale
Set 1: Sediment core P spiking in the water column under aerobic conditions, no spiking (control), 0.5, 2 and 4 times the ambient P concentration. (12 cores)	To determine the fate of dissolved P present in the overlying water column when the water column is in constant contact with sediments. Different concentration ranges reflect low, medium and high end of spiking.
Set 1 continuation: Sediment core P spiking in the water column under aerobic conditions, no spiking (control), 0.5, 2 and 4 times the ambient P concentration and then create anaerobic conditions after an equilibrium has been established under previous aerobic conditions. (Same 12 cores from ambient aerobic spiking experiments)	To determine the fate of dissolved P present in the overlying water column when the water column is in constant contact with sediments under oxygen free conditions. This experiment is a continuation from the previous set of experiments under aerobic conditions.
Set 2: Sediment core P spiking in the water column under aerobic conditions at a pH of 7.0, no spiking (control), 0.5, 2 and 4 times the ambient P concentration. (12 cores)	To determine the fate of dissolved P present in the overlying water column when the water column is in constant contact with sediments at neutral pH. Different concentration ranges reflect low, medium and high end of spiking.
Set 3: Sediment core P spiking in the water column under aerobic conditions at a pH of 9.5, no spiking (control), 0.5, 2 and 4 times the ambient P concentration. (12 cores)	To determine the fate of dissolved P present in the overlying water column when the water column is in constant contact with sediments at a slightly alkaline pH. Different concentration ranges reflect low, medium and high end of spiking.