Understanding Phosphorus Loading, Speciation and Ecological Effects: 2015 Studies to Support the Utah Lake TMDL Process

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Introduction

The Utah Division of Water Quality has resumed efforts to complete a phosphorus TMDL for Utah Lake. Typically, when phosphorus has been listed as the cause of impairment, it has been linked to numeric standard violation such as low DO or elevated pH. Utah Lake was added to Utah's 303(d) list approximately 8 years ago which became the only lake in Utah listed as impaired based only on the fact that P concentrations are exceeding its narrative standard of 0.025 mg/L. Indeed, neither DO concentrations nor pH values have exceeded their respective standards, despite chlorophyll a values that often suggest eutrophic conditions. More perplexing, chlorophyll levels have been predicted to be as much as 10X to 15X greater than actual measured values. Also, cyanobacteria populations have been found to occasionally dominate the phytoplankton community at some locations during the fall at a frequency of every 2-4 years. Yet, despite these limited blooms, Utah Lake remains a productive and diverse fishery, supporting several species of warmwater game fish as well as the endangered June Sucker, and the forage fish and invertebrates that comprise their foodchain.

Such observations have raised questions as to the bioavailability of phosphorus and the percentage of total P that actually promotes primary production and higher levels of the food web. Secondly, the occasional blooms of nitrogen-fixing cyanobacteria suggest that nitrogen may be limiting typical and non-hazardous green algae populations. Utah Lake has experienced elevated TDS and alkalinity in recent decades as a result of increased diversions, reduced inflows and concomitant increased retention time and evaporation. It is likely that these chemical changes have affected nutrient balances, P speciation and nitrogen loss. In the case of P, there are known chemical interactions/coprecipitation with calcium carbonate, iron hydroxides and other alkaline minerals that occur under high pH/alkaline conditions.

Another concern of stakeholders with the TMDL are the actual loading and sources of P to Utah Lake. Earlier estimates by Utah DWQ claim that the three major POTWs (Provo, Orem and Timpanogos Special Service District contribute 75% of P to Utah Lake. However, P and flow measurements in several tributaries have not been performed. Further, those that were assessed were sampled several miles upstream from the actual outlet to Utah Lake. In addition, nutrient loading from the Provo and Orem POTWs were only measured at the point of discharge to Mill Race and Powell Slough respectively. These discharge points are several kilometers upstream from Utah Lake; hence ignoring potential considerable assimilation throughout these slow-moving wetland channels.

Loading sources and quantities, as well as in-lake chemical and ecological responses to nutrient loading is paramountl to the need to prepare an accurate, comprehensive model of these myriad variables and processes.

The performance of these different projects is critical toward understanding P speciation, bioavailability and determining whether nutrient loadings are degrading ecological and beneficial use conditions. Secondly, it is unknown whether P reduction in POTW discharges will change algal production or diminish the occasional cyanobacterial blooms.

The initial effort of our Utah Lake studies includes four tasks:

Task 1. Understanding phosphorus speciation and chemistry

Task 2. Determine the sources and loadings of nutrients

Task 3. Characterize major components of the Utah Lake ecosystem and their relationship to nutrients and basic chemical characteristics

Task 4. Develop a predictive model that links the physical, chemical and nutrient characteristics and provides the ability to simulate different lake level and nutrient loading scenarios.

Task 1. Characterizing Phosphorus Mineralogy, Chemistry, and Speciation in Utah Lake Sediments

This Project is being performed by Dr. Greg Carling, Assistant professor of Geology at BYU. It is focused on understanding chemical transformations that involve P that is discharged to the lake. Ultimately, we will understand the speciation, ultimate fate and the proportion ortho-P that is available for algal production. Year 1 of this project is attached.

Task 2. Determining the various sources, forms and associated quantities of P and N that enter Utah Lake.

We have begun and intensive sampling effort to identify and quantify loading of P and N from all significant sources of surface water to Utah Lake. Because of limited accessibility by land, we have enlisted the assistance of a DNR air boat and operator. In this manner we have “combed” the eastern and northern shoreline of Utah Lake to identify and measure nutrient inputs. This effort has included biweekly sampling through October, 2015 and monthly sampling thereafter. Sampling is also being performed at the nearest road crossing upstream in order to understand the potential for nutrient assimilation/reduction that occurs between traditional sampling locations and methods and the actual entry point to the lake. This may ease future efforts in understanding nutrient loads without the extra time and expense of measurements at actual inflow points. We anticipate that this effort will continue for 3-4 years to understand seasonal and annual variability in flows and loadings. Total and dissolved fractions of P and N are being determined as well as nitrate-nitrate, TKN and ammonia fractions. These analyses are being performed in the Timpanogos Special Service District laboratory, a NELAC certified laboratory. In addition, because of the shallow holomictic/polymictic characteristic of Utah, even gentile winds can resuspend or maintain continually suspend newly formed phosphorus precipitates and sustain a high level of turbidity (Secchi depths range from 20 to 30 cm). Therefore the standard manor of sample collection includes collecting an integrated sample from the photic zone. This is performed by inverting and submersing the sample bottle to elbow depth. At that point the bottle is repositioned upright and slowly brought to the surface, allowing it to completely fill by the time the bottle reaches the lake surface.

Table 1. Locations of open-water sampling sites used to characterize chemical and ecological relationships between nutrients, pH, DO, salinity and phytoplankton, zooplankton and benthos.

Lindon Marina	40°19'35.41"N	111°46'1.96"W
Pleasant Grove Mar.	40°20'35.43"N	111°48'13.71"W
Utah Lake Outlet	40°21'31.96"N	111°53'39.68"W
Transect Point 4	40°19'38.30"N	111°48'2.75"W
Transect Point 3	40°19'37.60"N	111°49'58.41"W
Transect Point 2	40°19'32.11"N	111°51'48.49"W
Transect Point 1 (near Saratoga Springs)	40°19'36.29"N	111°53'38.72"W
1/3 Down Lake	40°15'29.22"N	111°48'13.47"W
2/3 Down Lake	40°11'19.53"N	111°48'48.71"W
Goshen Bay	40° 5'23.90"N	111°53'20.70"W

Task 3. Understanding nutrient dynamics and its relationship to phytoplankton and zooplankton and benthic macroinvertebrate populations.

Open water sampling is being performed at several locations throughout the lake to understand basic limnological processes and linkages between basic water quality, nutrients, phytoplankton and zooplankton. Sampling is performed at the locations identified in Task 2. Sampling is being performed biweekly from September through October and monthly thereafter until ice cover. Biweekly to monthly sampling will resume in Spring of 2016 in order to characterize the growing season and will occur on a biweekly basis during the September-October period when the possibility of cyanobacterial blooms increases.

Task 4. Develop a suitable mass balance and predictive models

We currently envision the need for two models; one will be an update of the Utah Lake LKSIM model first prepared by Dr. LaVere Merritt approximately 25 years ago. That model continues to be the only model developed to estimate mass balance of inflows and outflows of water and nutrients. We will update this model with current flow and water quality data. In turn, this model will be used as the baseline model for supplementing a more complex simulation model. This model needs to be capable of simulating chemical and ecological processes associated with nutrient loading, phosphorus loading and on a seasonal basis. The Division of Water Quality has suggested several models, including those that are recommended by EPA. The short list includes WASP and PCLakes. These models can simulate: Primary production, secondary production, nutrient cycling, oxygen dynamics, and sediment diagenesis (PCLakes); and multiple algal species, nutrient cycling, oxygen dynamics and sediment diagenesis (WASP). Our effort will focus on PCLake and WASP, in order to evaluate their ability to simulate algal species, but will also focus on the CAEDYM, which is a hybrid coupling the DYRESM (1-D) or with ELCOM (3-D) model. The CAEDYM model will be evaluated for its ability to simulate the unique chemistry, associated with P speciation and mineralization and subsequent bioavailability that occurs in Utah Lake. The ability to simulate P speciation and bioavailability and their connection to algal growth, community dynamics and development of cyanobacteria blooms is of paramount importance in the modelling effort.