Barr Lake and Milton Reservoir Watershed Association Limnocorral Studies for 2011

Study Plan

(Draft: 01-25-11)

Goal

The goal for the 2011 studies is to better understand internal loading and the linkages between total phosphorus (TP), chlorophyll-a (chl-a), alkalinity (Alk), and pH in Barr Lake (Barr). Since TP has never been below 100 ug/L during the growing season (June – September), it is unclear how chl-a, alk, and pH will responsed. According the to phased pH TMDL for Barr, the pH standard of 9.0 will be met if the summer time TP maximum is 100 ug/L with an average TP between 40-60 ug/L. This is based on empirical models, not actual data.

Internal loading has been estimated several times using mass balance approaches. To better understand the magnitude of internal loading of phosphorus, the limnocorrals can provide a direct measurements of how much phosphorus enters the water column from the sediments. There is also a question of how internal loading rates will change when water column TP is below 100 ug/L.

In order to observe and document the responses to a lower TP concentration and measure internal loading, large-scale limnocorrals (3 meters in diameter and 10 meters in length) will be used to isolate a column of reservoir water from the surface to the sediments. These mesocosms will be tested with alum and with aeration. These in-situ field tests will allow an opportunity see actual reservoir results without having to experiment on the entire body of water.

General Approach

Once the limnocorrals are installed (three test and one control) in May of 2011, several tests will be conducted followed by intensive monitoring of each corral and the actual reservoir. The control variable, TP, will need to be reduced from about 600 ug/L down below 100 ug/L. The best way to strip the water column of phosphorus is to use small dosages of aluminum sulfate (alum). A small aeration system will then be used to pump small, micro bubbles of air to a diffuser that will be on the reservoir bottoms. The rising bubbles will create enough mixing force to destratifity the water column in each corral.

The response variables that will be closely monitored will include chl-a, alk, Secchi depth, and pH. The hypothesis is that at some lower TP concentration, the pH standard will be achieved, and the appropriate chl-a concentration and Secchi depth will then be known.

Phosphorus Water Column Stripping with Aluminum Sulfate

Phosphorus water column stripping is one application that aluminum sulfate (alum) is used for in lake and reservoir management. This method tends to have limited effectiveness and duration and is sensitive to external and internal phosphorus loading. The impacts of alum will be isolated and short lived, but will provide an opportunity to observe the response variables during lower TP conditions (100 ug/L, 50 ug/L, and <20 ug/L).

Alum ($Al_2(SO_4)_3$) quickly dissassociates in water and forms an aluminum hydroxide precipitate ($Al(OH)_3$). This flocculation process then does two things: the hydroxide floc binds with phosphorus by adsorbtion, and secondly it physically entraps particulate material within the precipitant. The settling floc then sweeps the entire water column, removing phosphorus and particles and storing the material in the sediments.

The aluminum phosphate precipitate ($AlPO_4$) is stable and will remain in the sediments regardless of sediment redox potential or oxygen level. Alum will lower the pH because of the formation of sulfuric acid but small dosages and the high alkalinity will maintain a pH of 7.0 or higher throughout the study. The lowering of pH will be on the order of hours so chemical impacts will not mask the lower TP impacts to pH.

The first test will require an average water column TP of 100 ug/L. Then observations of chl-a, alk, and pH will be observed for two weeks. These response variables will also be monitored outside of the corral as a control (reservoir control). Then alum will be used again to lower the TP to 50 ug/L and two more weeks of observations will be recorded. Finally, the TP will be lowered below 20 ug/L to observe how the response variables react to a low level of phosphorus.

Dose determination will be based on jar testing of reservoir water. Precipitation of phosphorus will be measured when various amounts of liquid alum are applied to a liter of reservoir water. pH and TP will be analyzed with each jar test. Once the desired TP result is achieved, the ratio of alum volume to test water volume will be applied to each 70 m^3 corral.

Preliminary calculations indicate the amount of liquid alum to be used is on the order of gallons per corral. If the starting TP concentration is 600 ug/L, then approximately 1.5 gallons of liquid alum will need to be added to each corral to reduce the TP below 100 ug/L. The highest aluminum application rate would be 2-4 mg of Al/L.

Due to unforseen issues with reducing TP concentrations to 100 ug/L, 50 ug/L, and <20 ug/L, additional liqud alum may be applied based on further jar testing. It will be critical to lower the TP to the three various concentrations to see how the response variables react.

Internal Loading Estimates
Alum will not be used to treat internal loading within the corrals. The low dosages of alum will treat only the phosphorus in the water, not within the sediments. With extra thick floats and a weighted skirt on the bottom of each corral, the only phosphorus that can enter the corrals is from direct deposition and exposure to the sediments. With the know area of exposed sediments within each corral, TP measurements will be collected to calculate aerial phosphorus loading and rate. The control corral that will not be treated with alum will be important in estimating the internal loading of TP. Alum that is applied to the other corrals may have some adsorption capabilities at the sediments. Weekly and monthly estimates of internal loading will be calculated for each corral.

It is assumed that the internal loading rate will increase when the water TP concentration is reduced below 100 ug/L. Observations in the three treated corrals will confirm this and provide actual measurments on how the internal release will change.

Destratification with Microporous Diffusers
Once a good understanding of how the reservoir water will respond to lower TP levels, aeration will be used inside the corrals to document how continuous destratification will impact water quality in addition to alum use. A continuous laminar flow inversion system has been purchased to fully mix the water column in 2 of the 4 limnocorrals. A microporous ceramic diffuser will be placed in the center of each limnocorral, on top of the sediments. The aerators will be used to mix the water column to see if continuous mixing helps control planktonic algal growth.

For 2011, the limnocorrals will remain in one location during both tests, alum and mixing. Throughout the mixing study, there will be a reservoir control, limnocorral control, two corrals with with alum but no mixing, and two corrals with alum and mixing.

The destratification study will occur during the peak growing season when reservoir depth decreases the most do to reservoir releases for agricultural use. During this period (July through August), internal loading seems to build up within the bottom water and entrainment of the internal phosphorus quickly disperses to the surface cause by periodic mixing.

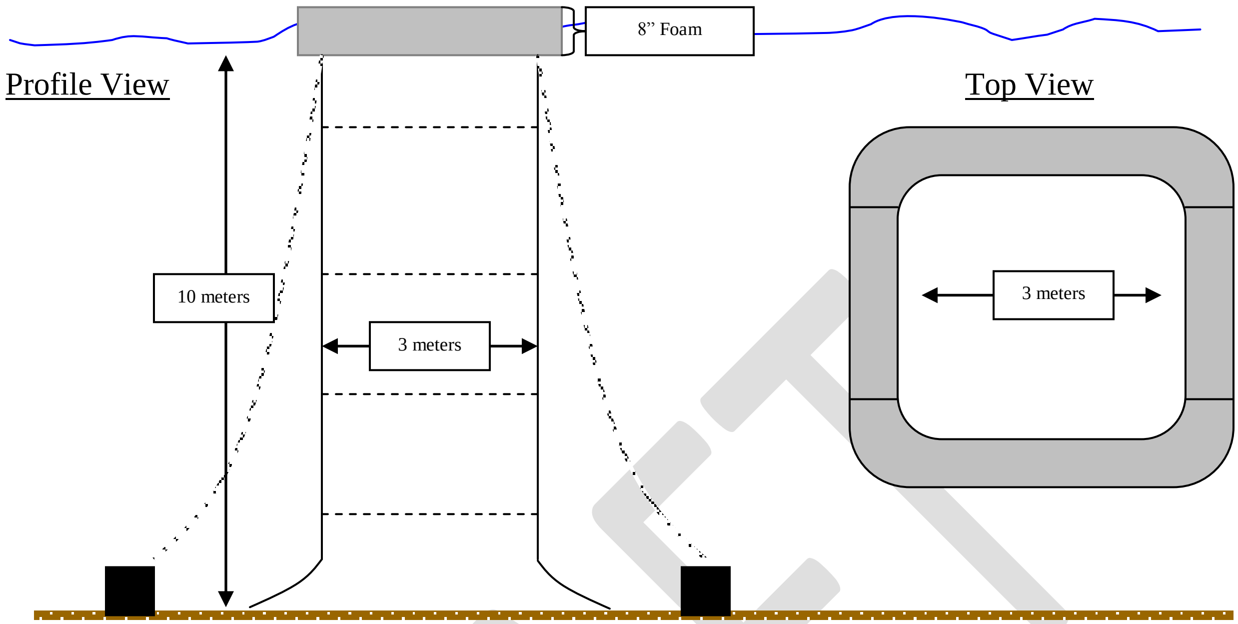
While the first part of the study is to observe the response variables and to estimate internal loading rate, the second part of the 2011 studies is to see if full water column mixing can lower pH by controlling cyanobacteria populations during the peak growing season.

Limnocorrals

Each corral is approximately 3 meters in diameter and 10 meters in length. The volume of water in each corral is approximately 70 m^3. The fabric material is made from a poly vinyl plastic that is impervious. The seems have been double sticked and welded to guaratee water tightness.

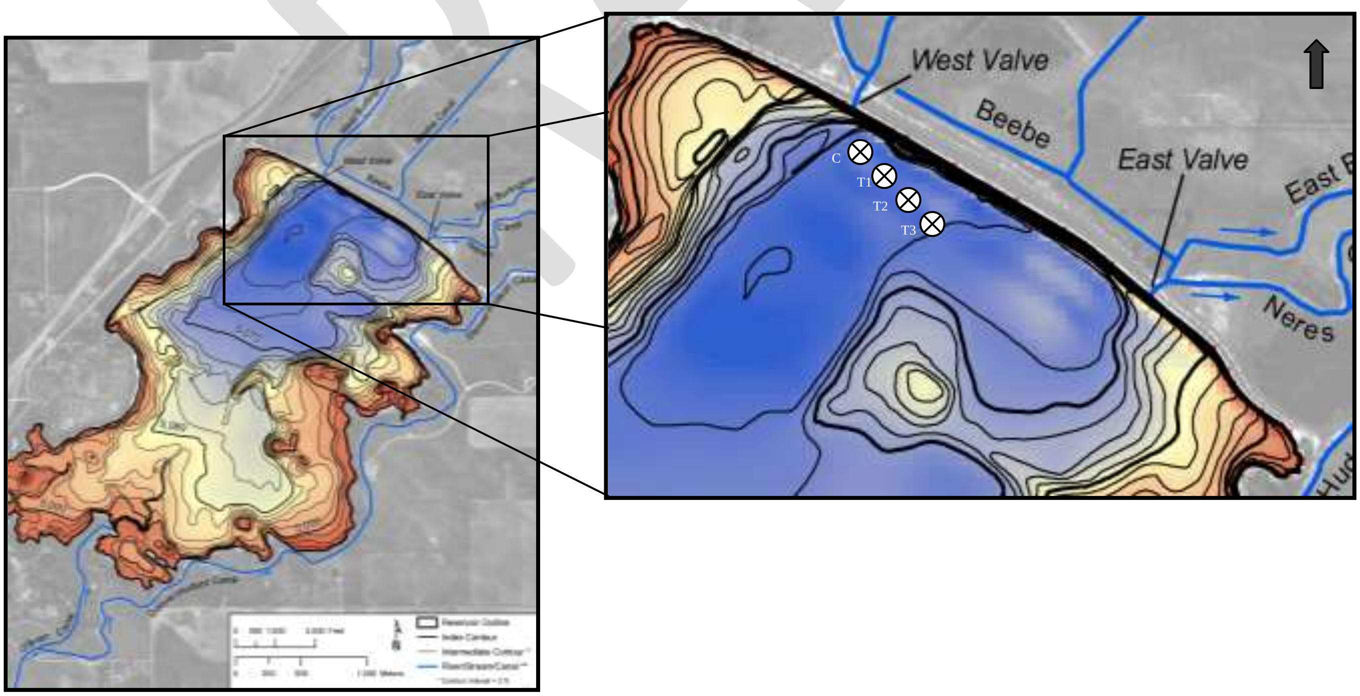
Limnocorrals will be used to isolate a section of the water column by using an impervious curtain. The limnocorrals will seal off the bottom by using a weighted skirt. Plastic piping will be used to form hoops that will shape the corral into a 3-meter diameter circle every 2-3 meters. At the surface, an eight inch foam buoy frame will keep wave action from spilling into the corral and maintain proper buoyancy (Figure 1).

Figure 1. Schematic profile and top view of a limnocorral



The limnocorrals will be anchored in series in the deepest section of the Barr Lake next to the dam (Figure 2). Barr Lake has two outlets, and the corrals will be located between them.

Figure 2. Bathymetric map of Barr Lake



The corrals will be assembled on shore and deployed from a pontoon boat. The aeration system will be connected to a power source near one of the dam outlet structures. The weighted airlines will be lowered to the reservoir bottom and each diffuser will be lowered from a boat with a float attached to it for easy retrieval.

The corrals will be barged to the proper location. The corrals will be lowered into the water with the diffuser buoy in the center of each test corral. Each corner of the corral will be securely fastened to a 50-lb anchor to avoid lateral movement.

If deployed correctly, there will be no need for underwater inspections. However, a local fire department maybe available to provide divers to inspect the bottom of each corral to assure that they are completely sealed off from the rest of the reservoir.

Monitoring

Water quality and sediment monitoring will occur before, during and after the addition of alum in each coral. Profile data and water samples will be collected weekly during the experiment. Two control sites will be compared to the test corrals; the open water sampling site and a designated limnocorral that will not be tested with alum (Table 1).

Sampling Location	Location Code	Sample Depths	Parameters	Profile Data*
Open Water	BL03	1-m, 1-m from sediment	TP, SRP, TDP, SD, NH3, NO2, NO3, TKN, Chl-a, and Alk	√
Corral 1	C1	1-m, 1-m from sediment	TP, SRP, TDP, SD, NH3, NO2, NO3, TKN, Chl-a, and Alk	√
Corral 2	T1	1-m, 1-m from sediment	TP, SRP, TDP, SD, NH3, NO2, NO3, TKN, Chl-a, and Alk	√
Corral 3	T2	1-m, 1-m from sediment	TP, SRP, TDP, SD, NH3, NO2, NO3, TKN, Chl-a, and Alk	√
Corral 4	T3	1-m, 1-m from sediment	TP, SRP, TDP, SD, NH3, NO2, NO3, TKN, Chl-a, and Alk	√

* Temp, D.O., pH, Turbidity, Specific Conductivity collected every 0.5 meter from surface to bottom

Profile data will be collected at all five locations on a weekly basis. Temperature, dissolved oxygen, percent dissolved oxygen, specific conductivity, pH, and turbidity will be recorded from the surface to the bottom at 0.5 meter intervals.

Water samples will be collected from 1 meter from the surface and 1 meter from the sediments. Samples will be analyzed for total phosphorus, total dissolved phosphorus, soluble reactive phosphorus, ammonia, nitrite, nitrate, TKN, chl-a (1-meter depth), and alkalinity.

Algae and zooplankton samples will be collected once a month for identification.

Schedule

Limnocorrals and aeration system will be assembled and installed in Barr in early May once the reservoir is at full pool and the water column temperature is above 15.0 C^0. Alum will be added once baseline data have been collected. Monitoring (profiles and water samples) will occur weekly from June to September. June and July will focus on studying the response variables to the different TP concentrations below 100 ug/L and estimating internal loading. Impacts to mixing and destratification will occur in August and September. Limnocorrals will be removed, cleaned, and stored in October followed by further refinement and additional study plans for 2012.

In early May, PVC piping and other material will be purchased to build the framing for each corral. It will take 2-3 days to assemble the corrals and install the aerator. Once the aerator is installed, it will be tested. Then it will take 2-3 days to anchor corrals over the aeration system and to inspect them. Once the corrals are in place by late May, alum will be applied to three of the corrals to strip the TP out of the water column. The goal will be to achieve an average water column TP of 100 ug/L.

The first two weeks of June will be focused on monitoring the response variables. Then during the third week of June, additional alum will be applied to the same three corrals to achieve a TP of 50 ug/L. The corrals will be monitored weekly for the rest of June.

The average TP will be lowered to less than 20 ug/L for the month of July, and the response variables will be monitored weekly. The control corral will not be treated with alum at anytime. The internal loading estimates will be calculated weekly as well as at the end of July by comparing the initial and final TP concentrations in the control corral. A rate of internal loading will be based on the length of time of isolation from any external phosphorus inputs other than minor aerial deposition and wave action that might splash over the flotation frame.

The aeration system will be turned on August 1st. There will be one diffuser in each of the two corrals that were treated with alum. The corrals will be monitored weekly through August and September. During this period, Barr typically experiences sever cyanobacteria blooms, internal loading of TP, and is nitrogen limited. Estimates of internal TP loading in all of the corrals will be calculated on a weekly basis as well as at the end of each month.

All of the corrals and the aeration system will be removed, cleaned, and stored in early October. The corrals will be power washed and dried to remove all organic material. Barr will be monitored twice in October and once in November and December to end the regular monitoring for 2011.

May		
Week	**Activity**	**Monitoring**
5/2-6	Purchase supplies, confirm dam power source, organize volunteers	
5/9-13	Assemble corrals, Regular bi-monthly monitoring	√
5/16-20	Install and test aeration system	
5/23-27	Install corrals, inspection, Regular bi-monthly monitoring	√
5/30-6/3	Strip TP from 3 of the corrals (100 ug/L TP), Corral Sampling Before	√
June		
6/6-10	Corral Sampling, TP to determine desired concentration	√

6/13-17	Regular bi-monthly monitoring, Corral Sampling, Strip TP to 50 ug/L	√
6/20-24	Corral Sampling, Zooplankton/Phytoplankton Collection	√
6/27-7/1	Regular bi-monthly monitoring, Corral Sampling	√
July		
7/4-8	Corral Sampling, Strip TP to <20 ug/L	√
7/11-15	Regular bi-monthly monitoring, Corral Sampling	√
7/18-22	Corral Sampling, Zooplankton/Phytoplankton Collection	√
7/25-29	Bi-monthly monitoring, Corral Sampling, Calculate Internal Loading	√
August		
8/1-5	Turn on Aeration System, Corral Sampling	√
8/8-12	Regular bi-monthly monitoring, Corral Sampling	√
8/15-19	Corral Sampling, Zooplankton/Phytoplankton Collection	√
8/22-26	Regular bi-monthly monitoring, Corral Sampling	√
8/29-9/2	Corral Sampling	√
September		
9/5-9	Corral Sampling	√
9/12-16	Regular bi-monthly monitoring, Corral Sampling	√
9/19-23	Corral Sampling, Zooplankton/Phytoplankton Collection	√
9/26-30	Regular bi-monthly monitoring, Corral Sampling	√
October		
10/3-7	Remove, clean, and store inside	
10/10-14	Regular bi-monthly monitoring	√
10/17-21		
10/24-28	Regular bi-monthly monitoring	√