Pigeon Lake Workshop Summary

Investigating Solutions for In-Lake Treatment

Prepared for:

Association of Pigeon Lake Municipalities

In-Lake Technical Committee

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Prepared by:
Aquality Environmental Consulting Ltd.
#204, 7205 Roper Road NW
Edmonton, AB, Canada, T6B 3J4

Aquality Environmental Consulting Ltd.

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Signature Page

Authored by:

Elynne Murray, RMOT, BComm.
Aquatic Technologist

Reviewed by:

Erin Rodger, B.Sc.
Aquatic Biologist & Project Manager

Approved by:

Jay S. White, M.Sc. P.Biol, QWAES
Principal

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1 Introduction

Pigeon Lake, located within the Counties of Leduc and Wetaskiwin, is one of the most popular recreational lakes in all of Alberta. The lake lies within the Battle River watershed of the North Saskatchewan River basin and has a drainage area of 187 km^2. Due to its unprecedented popularity, the lake has become highly developed over the years. Pigeon Lake is plagued with numerous problems, but much of the public focus is on prolific cyanobacterial blooms, beach advisories, lake levels and fish kills. The demand for integrated management of the lake and surrounding watershed is high, and continues to grow each year. This demand is spearheaded not only by the public, but numerous summer villages and stewardship associations around the lake. While the Pigeon Lake State of the Watershed Report was produced in 2008, a Watershed Management Plan to guide management initiatives around the lake has not yet been finalized.

The purpose of this project is to determine an ecologically and economically feasible method of in-lake treatment for Pigeon Lake with the goal of improved water quality. The project will use a systems thinking approach to tackle this complex problem. Systems thinking is the process of understanding how individual components of a system influence and interact with one another and as a whole[1]. In relation to this project, consideration will be given to all of the processes influencing water quality and examine how these processes work together to define the overall water quality of Pigeon Lake. By approaching the problem of poor water quality with systems thinking, we will better understand the problem and therefore reach a more effective solution.

[1] See http://en.wikipedia.org/wiki/Systems_thinking for more information.

2 Purpose

The Pigeon Lake Restoration Action Plan is an initiative of the Association of Pigeon Lake Municipalities (APLM) In-Lake Technical Committee. The APLM has engaged Aquality to bring together an expert team of professionals to find and implement the best possible solution for the in-lake treatment of Pigeon Lake. The Pigeon Lake Watershed Association (PLWA) is working in conjunction with the APLM and is responsible for spearheading the Pigeon Lake Watershed Management Plan (PLWMP) with a focus on controlling nutrient inputs from the surrounding watershed.

The work plan for the in-lake treatment of Pigeon Lake will consist of a series of phases, Phase I entailed a two day workshop which was held in Edmonton on February 18 and 19, 2014. The purpose of the workshop was to discuss the state of knowledge of Pigeon Lake and potential in-lake management treatment options. A panel of experts (Appendix C) were invited to the workshop to bring their knowledge and expertise to the workshop discussions. The experts and workshop invitees were chosen based on their extensive experience pertaining to the problem of water quality at Pigeon Lake or due to their expertise with in-lake treatment options. Participants included professionals from The Alberta Lake Management Society, Department of Fisheries and Oceans and the University of Alberta; please see Appendix A for a complete listing of attendees. Questions addressed included: What is the goal of in-lake treatment? How do we choose an appropriate method? How will we measure success? What regulatory, ecological and social obstacles will the project face? Consensus decision making was then used to determine the top three most appropriate in-lake treatment methods. The one of the goals of this project is for the project serve as a pilot that will guide others in the process of deciding on options of in-lake treatment. The science and research involved with this project is just one of the necessary steps in determining an appropriate in-lake treatment option for Pigeon Lake, the research itself is not considered part of the pilot.

During discussions it was agreed upon by all attending experts, stakeholders and participants that there is no magic bullet solution to the problems facing Pigeon Lake; in-lake treatment on its own will not solve the water quality problems. The addition of nutrients to the lake via the surrounding watershed is a key component to the success and longevity of in-lake treatment options and therefore this project recognizes that moving forward will require a multi-pronged approach focusing on both in-lake treatment and watershed management planning and controls.

3 Day One: Presentations and Setting Measures of Success

Day one of the workshop consisted of presentations by each of the attending experts with the goal of providing background information that would later help to frame measures of success. The following section will include a break down, by presenter, of key concepts covered. Please see Appendix B and C for a schedule of presentations and abstracts for each of the presenters.

3.1 Pigeon Lake by the Numbers and Groundwater Overview, Jay White

The focus of this presentation was to provide a high level summary of Pigeon Lake in order to make sure participants were on the same page moving forward with the workshop. Key points to note are the large size of the lake (96.7 km ^{2}) and small size drainage basin (187 km^2). In addition, Pigeon Lake has a long residence time of approximately 100 years. Pigeon Lake is shallow, with an average depth of 6.1 m and a maximum depth of 9.1 m and like many shallow Alberta lakes, this leads to high water temperatures during the summer months. In the past, Pigeon Lake has experienced significant fish kills, particularly of white fish. Pigeon Lake also has frequent and prolonged blue-green algae blooms resulting in yearly beach advisories posted by Alberta Health Services. The first and most significant bloom to-date occurred in 2006 and while not as severe, blooms have typically occurred annually since, including this past year's bloom which occurred on August 14, 2013. Phosphorus is believed to be the limiting nutrient in the lake and many believe it might be considered the number one pollutant of Alberta lakes. Sources of phosphorus to the lake come from internal and external loading from both natural and human sources, including nutrient rich soils, natural species shifts, atmospheric decomposition, agricultural run-off, point source pollution and leaking septic tanks. Internal release of phosphorus from the sediments is deemed to be a major contributor of phosphorus, resulting in high levels of internal nutrient loading; but this has not been quantified.

Pigeon Lake has been monitored for over 40 years by a variety of groups including the University of Alberta (U of A), Alberta Environment and Sustainable Resource Development (AESRD), Alberta Lake Management Society (ALMS) and Aquality. We know that due to its large size, shallow depths and prevailing winds that Pigeon Lake is well mixed and does not stratify for the majority of the open water season. An even distribution of temperature and oxygen levels throughout the water column can have implications for in-lake treatment options, as there is no thermocline to prevent mixing between the upper and lower portions of the water column. From a fisheries standpoint, a well-mixed lake typically means dissolved oxygen levels remain consistent throughout the water column in sufficient quantities to sustain healthy aquatic ecosystems. Pigeon Lake is subject to large fluctuations in both total phosphorus and Chlorophyll-a and despite an increase in bloom formation, both these parameters have remained relatively consistent throughout the long term monitoring data. Further questions need to be answered in regards to what is occurring in the lake and it will be important to also consider trends in Dissolved phosphorus. A better understanding of the relationship between total phosphorus, total dissolved phosphorus and orthophosphorus is needed for Pigeon Lake. Paleolimnology work was also identified as a requirement for further study. Data exists on each of these parameters and is currently being analyzed by Chris Teichreb from AESRD as part of his work on the Pigeon Lake nutrient budget.

A brief overview on groundwater and bedrock geology of the Pigeon Lake area was also provided. Citing the Worley Parsons (2010) report "Hydrological Assessment of Pigeon Lake". Very little data exists on the sustainable yield, water quality and nutrient contents of groundwater in the area. Groundwater samples were collected in 2013 as a part of the nutrient budget and further sampling is scheduled for 2014.

3.2 Sound Science, Sound Decisions: An Overview of Pigeon Lake Chemistry by Chris Teichreb

Chris Teichreb is a Professional Biologist and Limnologist with the Government of Alberta, Chris authored "Lake and Watershed Management Options for the Control of Nuisance Blue-Green Algal Blooms in Pigeon Lake" in 2012. Chris has been working on Pigeon Lake for over ten years and his presentation provided some key background information into his experience with the lake. Pigeon Lake has always been a productive and eutrophic lake and long-term limnological trend- has not shown any statistically significant trend in total phosphorus or secchi disk depth. The frequency of past monitoring initiatives may limit analysis; but regardless of the numbers, residents and the public still want action. It is because Pigeon Lake is such a large lake that very small changes in total phosphorus can result in large changes in total phosphorus estimates. A parameter that has been steadily increasing over time is total dissolved solids, which are inorganic salts and organic matter dissolved within the water column. These originate from natural sources, sewage, agricultural run-off and domestic run-off.

The subject of fish kills and any possible relationship to cyanobacteria blooms arose leading to further questioning into the age category of fish and causes of death. Both Chris Teichreb and Jason Cooper, Senior Fisheries Biologist with AESRD, note that the kills tend to affect large whitefish of the same age class and while first thought to be related to cyanobacteria blooms, further studies indicate that this is unlikely. Fish kills often occur in advance of cyanobacteria blooms and whitefish tissue samples have been analyzed but were not found to contain microcystin toxins. While more research needs to be done, fish kills are likely a result of temperature stress to a sensitive species during the increasingly warm summer months.

In 2012 Chris began work on the Pigeon Lake nutrient budget, in partnership with the Alberta Lake Management Society. The first year of the budget included stream sampling and the program was expanded in 2013 to include weekly stream, weekly lake sampling, sediment and paleolimnology work, algae sampling and groundwater sampling. Past sampling initiatives have focused heavily on water chemistry, but have not addressed the sources of nutrients into the lake. The nutrient budget will serve to provide consistent baseline data, identify major sources of nutrients entering the lake and identify areas of concern which can then be targeted for management initiatives. The budget will take into account run-off (using a 20 year monthly water balance model), atmospheric deposition (precipitation and dust fall), groundwater analysis, surface inflows and outflows, available sewage census data and water diversions.

Preliminary findings estimate that approximately 50% of the phosphorus supply is as a result of internal loading and 50% a result of external loading. External inputs are broken down as follows: 1%

groundwater, 2% sewage, 7% point source inflows, 37% dust fall and precipitation and 53% diffuse inflows. More work still needs to be conducted in order to complete the nutrient budget prior to releasing the report, including complete predictive water quality modelling. The report is expected to be released later in 2014.

In summary, the focus needs to be on reduction on nutrients, deciding on management initiatives and then monitoring these initiatives to determine success, keeping in mind that it may take numerous years before changes are detected.

3.3 Cyanobacteria in Alberta Lakes, Ron Zurawell

Ron Zurawell is also a Limnologist and Water Quality Specialist with the Government of Alberta and a Professional Biologist. This presentation provided a run-down on the characteristics of cyanobacteria, the cyanobacteria communities present in Pigeon Lake and how the Province is working with Alberta Health Services to address public health risks. Alberta's lakes are naturally alkaline and typically have high levels of pH and as such are well suited to cyanobacteria species. Cyanobacteria are typically pelagic species, have a superior ability to uptake carbon and are highly skilled fixers of atmospheric nitrogen. Additionally, cyanobacteria can control their buoyancy by using gas vesicles to adjust their position in the water column, allowing the selection of an optimal reproductive environment. Predation on these species is also limited due to the few species which feed on them; as well as, their resistance to digestion. Snails which ingest cyanobacteria have been found to excrete undigested cells back into the water column.

While blooms may appear as a rapid growth of cyanobacteria occurring overnight, bloom formation is a result of changes in conditions which cause a sudden surface bloom formation to develop. Conditions which typically precede a bloom consist of periods of high wind, followed by a calm period, wherein the cyanobacteria migrate to the surface. A variety of factors can influence bloom appearance including but not limited to life stage, degree of dispersion and pigmentation.

The major health concern related to cyanobacteria is the toxins they produce, which are most commonly hepatoxins which affect the liver, neurotoxins resulting in disruption of the nervous system and occasionally dermotoxins which cause red eyes and skin irritation. The new recreational water quality guidelines are based on two measures; total cyanobacteria cells counts measuring greater than 100,000 cells/mL or microcystin levels in excess of 20 µg/L. The cell count speaks mostly to contact recreation and not to the overall toxicity of the bloom.

The Alberta Health Services (AHS) Beach Monitoring Program was initiated in 2010 and focuses its monitoring on beaches with heavy public use. Currently, the program is a work in progress and AHS and ESRD are working together to address the need for portable, in-situ technologies with the goal of more timely and objective processing of data. In 2013, 36 advisories were posted across the province, with the majority occurring in northern Alberta. Most the advisories were a result of elevated cell counts and not microcystin concentrations, with only two of these lakes recording microcystin levels exceeding the recreational guidelines. It is important to note that AHS does not "close" lakes, they are simply advising the public of the health risks. However, the public typically does not view AHS postings this way.

In 2005, microcystin sampling was added to the ESRD sampling program. Sampling results have indicated that the amount of microcystin in lakes is highly variable, typically with greater concentrations occurring along the shorelines. Pigeon Lake does have high numbers of cyanobacteria; however, the species present (*Gloeotrichia, Aphanizomenon and Anabaena*) typically produce very low levels of toxins, with microcystin levels falling around 0.5 µg/L. The species present at Pigeon Lake form a diverse cyanobacteria community, which is not typical of other lakes in Alberta.

3.4 Pine Lake Restoration Project, Al Sosiak

In 1990, after experiencing years of persistent and severe cyanobacteria blooms, the Pine Lake Restoration Society embarked upon the Pine Lake Restoration Program with a goal to return Pine Lake to its natural level of productivity. The lake was deemed to have naturally been a mesotrophic system, based on sediment core research conducted by the University of Alberta. In 1992, a phosphorus budget was conducted for the lake which revealed that over 60% of the phosphorus supply to Pine Lake was coming from internal loading from sediments. Eight best management practice (BMPs) projects were developed to address phosphorus, and critical areas established for restoration. In addition, three sewage treatment projects ran between the years of 1993-1999. The project also included one major in-lake treatment initiative and considered options including chemical treatments, dredging, aeration, oxygen injection and flushing. A hypolimnetic withdrawl system was chosen as the most viable alternative to deplete nutrients in the sediments over time; this option was also the most cost effective at approximately $500,000. The system was installed in 1998 along with a treatment wetland.

The withdrawl system was a gravity-fed, 22 inch pipeline which required no pumping. Typically the system operates from May 1 to September 1 and has not been proven to have any adverse effects on downstream water quality or the stratification of the lake, even after 15 years of operation. Pine Lake also has a history of fish kills and overall the system has helped to moderate changes in dissolved oxygen levels, reducing the frequency and severity of fish kills.

Since the installation of the system, changes in the algal community have occurred and up until 2003 levels of chlorophyll-a were declining. However, following a number of wet years, the lake once again experienced algal blooms. In 2007, a basin sampling program took place to assess the benefit of various BMPs within the watershed. It was discovered that while the withdrawl system was effective at removing phosphorus, surface run-off was contributing four times the amount of total phosphorus that the pipe was removing each season; dissolved phosphorus was declining but not by enough. Currently, chlorophyll-a concentrations have approached the initial goal of the restoration project, but the lake still experiences cyanobacteria blooms in wet years.

A key lesson learned from this project is to use community enthusiasm while it lasts, once the situation of the lake improves it is hard to maintain momentum with watershed management planning and controls. It is also important to note that it is critical to let a phosphorus budget guide your efforts for in-lake treatment strategies. Peer-reviewed case studies and detailed analysis of existing water chemistry data are also critical to choosing an approach. It is important to note that a hypolimnetic withdrawl system is not an option for Pigeon Lake. As previously mentioned, Pigeon is a well-mixed lake, lacking stratification throughout the open water season and therefore, the Pine Lake Restoration Project is meant to serve solely as an example of the process and execution of a successful in-lake treatment initiative in Alberta.

3.5 Why, When and What to Use to Manage Your Lake's Eutrophication, Harry Gibbons

Reducing phosphorus is key to managing eutrophication and it is critical to gain a solid understanding of the *quantity* and *timing* of phosphorus availability within the lake. This presentation touched on possible in-lake treatment options and explored different routes of phosphorus in-activation. Once again it was stressed that you must never forget the watershed; any in-lake treatment will only work if the faucet is turned off; however, it is also critical to remove the internal sources of phosphorus. The problem at Pigeon Lake is tied closely to the long residence time resulting in the retention of phosphorus. Concepts discussed included redox potential and dissolved oxygen levels. When phosphorus is released, is calcium storing it deep down in the sediments? We do not yet have enough detailed sediment work to characterize this relationship. While dredging is the ultimate way to directly remove phosphorus from the lake, considerations need to be made as to where in the lake dredging should occur, if certain "hot spots" can be identified and targeted this can provide a more targeted approach. Another important consideration is the depth of dredging; as sediment sampling revealed at Pigeon Lake this past season, there is little difference in nutrient concentrations in the top 10 cm of sediment versus lower the 10 - 20 cm begging the question-how deep does sediment removal need to be? It was also noted that it can take anywhere from 2 - 10 years for a new balance to be reached after dredging. In addition, high costs are associated with the actual operation and removal.

In Harry's experience, dilution did result in successful nutrient reduction in lakes; however, only if water supply used has very low levels of phosphorus. In addition, the volume required is in the amount of 2-15% of the water volume of the lake per day. For Pigeon Lake it has already been determined that potential diversion from the North Saskatchewan River would not work as this supply had much higher levels of phosphorus than the lake. Similar findings occurred with groundwater studies, which revealed a lack of volume and relatively high levels of phosphorus. Aeration and circulation can be a good option in lakes that are not well mixed as the purpose is to increase the depths of algae in the water column to inhibit photosynthesis. However, Pigeon is large, shallow and mixes consistently on its own; therefore it is not likely that a benefit would be offered.

Phosphorus inactivation is a very effective method, but one which is often done incorrectly. There are a number of strategies used to inactivate phosphorus including (1) interception: removing it from all inflow streams and collecting all surface run-off; (2) water column stripping: use flocking agents to knock phosphorus down into the sediment (requires periodic reapplication); and (3) inactivation: stripping the water column by adding either, aluminum, iron, calcium or lanthanum or a chemical combination to bind to the phosphorus (requires periodic reapplication).

Aluminum typically works best in a 1:1 ratio but it is not yet known how it reacts in the long term with organic sediments. Factors to consider include: redox sensitivity, pH and calcium levels. Aluminum sulphate (Alum) is the most common compound added, as it is not as costly as other options and is widely available in western Canada. It has been used in the United States for over 40 years and as many as 180 peer-reviewed studies exist on its use. If Alum is it be used it needs to be buffered during application, for example with the use of sodium in a 2:1 ratio. However the solution must be delivered to exact specifications and if it falls even 5% off of the target dose the solution can drastically affect pH levels in a matter of hours, posing short term, but lethal implications for aquatic organisms. This type of treatment typically lasts 8-12 years and is treated as an on-going solution not a one-time activity.

To date many believe Alum is the most effective in-lake treatment across the board and relies less heavily on the level of watershed management in reducing phosphorus concentrations and harmful algal blooms. This treatment may work best at Pigeon Lake utilizing spot treatment at inflows and wind mixing to distribute throughout the lake and water column.

3.6 In-lake Treatment Strategies for Cyanobacteria Blooms, Our Experiences over the Past 40 Year, Terry McNabb

While new to Western Canada, in-lake treatment has been widely practiced in the United States for over 40 years. As will be the case in Canada, these applications are subject to regulatory considerations. Currently in the United States all algaecides must be registered before they become available for sale and all organizations purchasing these products must be certified permit holders. There are three basic types of algaecides which are registered, the first of which being copper based and used in 0.2 mg/L application rates. No water use restrictions apply to this type of product and the most commonly used compound is copper sulphate. While the most cost effective method, copper sulphate is insoluble causing it to sink in the water column. Ideally it would be most effective dispersed throughout the water column where it can target algae. Therefore, this option often requires increased number of applications however recent studies are underway experimenting with the addition of elements such as carbon in efforts to reduce number of treatments needed. The second commonly used algaecide is a product known as Seaklear which also uses a copper based approach and has similar shortcomings. Lastly, is a product called PAK 27 which is a peroxide-like substance which uses an oxidization process to release hydrogen peroxide into the water column and destroys algal cell membranes. Benefits of PAK 27 include quick dispersion; the peroxide will be gone within hours and is good for area-specific spot treatments such as along beaches or areas of the lake experiencing significant bloom formation. These treatments all lack experience with larger size lakes; although, new trials are underway and experiments are occurring at various lakes throughout the United States.

In addition to Alum, an element known as lanthanum is also growing in popularity as a method of nutrient inactivation. Modified bentonite clay fixed with lanthanum has a 300 times affinity to fix phosphorus. This is the active chemical used in the product Phoslock which has been used primarily in Europe to treat small waterbodies. However, the product is being scaled up to test on larger lakes, which can be successful if well thought out and a large budget exists. In 2010, Orange County, California signed a $500,000 annual management contract with Phoslock for 9 regional parks and 15 lakes. A benefit of this product is that it does not possess the ability to create large fluctuations in pH and therefore has is very unlikely to possess any toxicity to aquatic life. A major limitation of Phoslock is the lake of peer-review studies, larger lake case studies and long-term data.

With any method of in-lake treatment it is important to consider whether or not whole lake treatment is necessary, versus spot treatments targeting specific areas for application. Also, with large lakes a large production volume is required for treatment, so it is important to consider where these products are produced and what the transportation costs involved will be. For example, how are you going to get the product to where you need it? Boat travel, material handling, delivery, staging, etc are all important questions to ask. In summary, there are technologies that can work for larger lakes; however, the regulatory environment must support their use. Budget is often a limiting factor and whatever in-lake treatment is chosen needs to be part of an integrated watershed management plan.

3.7 Defining Measures of Success for Pigeon Lake

At the end of day one the question was posed “How do we define success for Pigeon Lake?” Participants provided their feedback on what, in their opinion would constitute success for the lake. It became clear that critical information is needed to define and understand the relationship between Total Phosphorus (TP), Total Dissolved Phosphorus (TDP) and Soluble Reactive Phosphorus (SRP) in Pigeon Lake. The relationship could provide options for quantifying measures of success such as lowering SRP to below 10 µg/L or reducing TP below 30 µg/L. Reducing the frequency of algal blooms was also defined as a possible indicator in addition to a reduction in the number of days beach advisories are posted for the lake. Questions arose in regards to the N:P ratio and cyanobacteria species present in Pigeon Lake in relation to a success measure of lowering bloom toxicity. Pigeon Lake’s blooms historically produce low levels of toxicity and altering this ratio could potentially create an environment suited to more toxic species. Measures of success may also be different from a public perspective than that of the committee, residents are primarily concerned with recreation, esthetic values and the number of days they can use the lake; not the levels of TP, TDP and SRP. A point form summary of all the responses and measures discussed is listed in Appendix D. While many possible measures were identified, no measure(s) of success were decided upon. Setting and clearly defining these measures will be critical to the progression of the project in the future.

4 Day Two: Brainstorming, Group Breakout Sessions and SWOT Analysis

The focus of day two was on absorbing the information from day one and applying it to various options for in-lake treatment that may be viable at Pigeon Lake. The morning consisted of brainstorming and group breakout sessions targeting answering the question "What is the most feasible in-lake treatment method for Pigeon Lake?" The afternoon session gave groups the opportunity to present their findings, engage in a SWOT analysis with the whole room, address missing information and provide input into the development of a concrete and timely plan for what the next steps of this project will be.

4.1 Group Breakout Sessions

During the breakout sessions the room was divided into two groups and each of the groups were asked to focus on a hypothetical situation of removing 50,000 kg of phosphorus from Pigeon Lake and determining the top three most effective options to do so. Once the groups had narrowed down their options a SWOT Analysis was performed on each, outlining strengths, weaknesses, opportunities and threats.

The over-reaching theme of this discussion was that we have heard a lot about what we do know, but there are still a lot of unknown variables which will be necessary to review in order to move forward with this project.

4.2 Data Gaps

4.2.1 Understanding Lake Sediments

While sediment cores and paleolimnology work was collected during 2013, more sampling needs to occur in order to gain a clear picture of sediment composition and dispersion throughout the lake. Moving forward it was recommended that further sediment sampling occurs at specific intervals across the entire lake using a transect grid, with a starting point of 15-20 cores. The focus would be to identify "hot spots"; classified as areas of sediment holding large amounts of phosphorus. Once identified, further sampling would occur in these areas to provide more information as to sediment composition, phosphorus distribution within sediments and locational boundaries of accumulations. Further sediment sampling is critical in order to maximize efficiency of potential treatments and to help reduce costs and efforts expended. With this piece of the puzzle also comes the importance of understanding seasonality; when and where in the internal nutrient loading occurring? These details will need to be identified in order to effectively plan a lake treatment program.

4.2.2 The Food Chain in Pigeon Lake

Another aspect which requires more research is the trophic cascade within the lake which would entail using a fisheries management perspective to alter the aquatic communities within the lake. Dr. Rolf Vinebrooke from the University of Alberta and Dr. Ron Zurawell of ESRD have experience with this concept and expressed that the high abundance of phytoplankton and low numbers of herbivorous zooplankton along with the shallow and moderately nutrient-rich conditions of Pigeon Lake are all conditions that suggest that biomanipulation is a potential strategy for improving water quality.

Dr. Vinebrooke explained that biomanipulation works by increasing the effect of a top predator (Walleye) on the rest of the food web by raising its annual stocking density. If the food-web structure of the lake is relatively linear (i.e. chain-like), then an increased Walleye population should result in greater suppression of their primary prey item, namely smaller forage fish (e.g., Minnows). Consequently, less forage fish result in less consumption of zooplankton, which therefore would increase in abundance.

Ideally Dr. Vinebrooke and Dr. Zurawell note that more zooplankton would then be able to consume phytoplankton, potentially suppressing blue-green algae and improving water clarity. Thereafter, greater water clarity would enable more light to reach submerged aquatic plants, thereby stimulating their growth along the bottom of the lake. These plants would then help block internal loading of phosphorus via uptake of nutrients from, and oxidation of, the sediments - thereby, helping maintain the improved water clarity. However both expressed that a better understanding of the exact nature of food-web dynamics and players (i.e. species present) in Pigeon Lake is essential to reliable prediction of whether biomanipulation is a solid prospect for improving the state of the lake.

ESRD currently has an extensive archive of zooplankton and phytoplankton samples taken from Pigeon Lake, however these would need to be analyzed in detail moving forward. Further collaboration with fisheries experts would also be required in order to determine how the fish population in Pigeon Lake has been changing over the years.

4.2.3 Gull Populations

A new concept which was brought up during group discussions was the large gull population that the lake experiences throughout the open water season. To-date no data has been collected on the gull population at Pigeon Lake. The ratio of gulls to humans in regards to phosphorus contributions is typically 3:1. A few hundred gulls may not pose a problem; whereas, thousands of gulls can have a much bigger impact on the phosphorus levels in the lake. Harry Gibbons has seen gull populations contribute anywhere from 2 - 65% of phosphorus loadings, depending on multiple factors including diet. Moving forward, gull population information should be included in the nutrient budget including counts, location, daily migrations as well as potential food sources.

5 Brainstorming Session: Viable In-Lake Treatment Options

Due to the need for balancing political and scientific agendas with the desire for immediate action, the treatment process will need to entail both short and long term approaches. Short term initiatives may help to demonstrate to the public that initiatives are underway while providing short-term esthetic solutions whereas long-term initiatives will focus on the inactivation of phosphorus in Pigeon Lake. It is important to keep in mind that at this time there is no single solution available and further studies are required for all potential initiatives.

5.1 Short Term Treatment Options: Esthetic Solutions

5.1.1 Mechanical Harvesting

As a short-term, esthetic solution algal harvesting may be a potential option. The goal would be to remove algae from the water column therefore providing mainly an esthetic response. The logistics of mechanical removal can be complex, especially on large, well-mixed lakes; how much algae must the harvester remove in order to have the desired effect? The key to this strategy would be a high intensity and timely operation in order to stay ahead of the reproduction process of the blooms.

5.1.2 Oxidants

Oxidization is another potential short-term option for esthetic purposes and is one which can be relatively specific to cyanobacteria. This process works by disrupting cellular function and can provide rapid control of algal blooms or mats. It may be possible to apply this strategy to areas of the lake or shoreline during a bloom in order to kill off the algae, providing short-term visual relief from the problem. This process is not well known in Alberta and also carries the potential for toxic effects on aquatic biota and would not address the issues of nutrients in Pigeon Lake. Further testing would be required from a scientific and regulatory perspective.

5.1.3 Biomanipulation

The concept of using fisheries management to alter the food chain was discussed in detail (Section 4.2.2) and was suggested as a possible means of action while long-term in lake treatments are further explored. This option may also serve as a way to convey to the public that action is being taken. The benefits of a successful trophic cascade could provide positive results in a matter of months and if this option does not work, there are not high risks of adverse results. More information is still needed from a fisheries standpoint in relation to population dynamics within the lake.

5.2 Long Term Treatment Options: phosphorus Inactivation

5.2.1 Aluminum Sulphate (Alum)

Both groups agreed Alum as a strong potential candidate for in-lake treatment, likely with some form of Calcium addition (dependent on further sediment core chemistry results). It was deemed that injection treatments of Alum administered to pre-determined hot spots, spread out over multiple years might be the most effective in terms of results as well as cost effectiveness. Getting the timing and injection sites right are critical to receiving maximum benefit. As mentioned previously, the major drawback with Alum is the potential for toxicity caused by increased pH levels if not done correctly. This would be considered the number one concern from the government's perspective. Moving forward, an expert in this field would calculate the suggested dose; keeping in mind the goal is not to remove all the phosphorus from the lake but to decrease the N:P ratio creating more favorable conditions for non-cyanobacteria species.

5.2.2 Phoslock (Lanthanum)

From an application standpoint there is little lake-to-lake variation with the application of the product Phoslock. The same concept is used as in Alum treatments and entails stripping the water column of phosphorus. Since both products are similar it was deemed neither option should be eliminated until further information is available. A major benefit offered by this treatment option the lack of toxicity to aquatic biota, which greatly decreases the risk associated with application. Drawbacks include the lack of peer-reviewed studies and long term data in addition to a lack of experience with large lake treatments. The cost associated with treatment may be potentially double that of Alum and availability is also be an important factor to consider. This appears to be a viable option; however, one which may be better suited for pilot projects at smaller Alberta lakes until more is known about the product.

5.3 The Role of Mesocosms

Mesocosms, known as experimental water enclosures, may be a part of the process in moving forward with the long-term in lake treatment initiatives discussed, as it is critical avoid is spending a large amount of resources on one entire lake application and risk a failure. These types of experiments also don't require the intensive approvals needed for whole lake treatment, are a good way to measure the impacts, provide a clear visual demonstration of how a product works and can be slowly scaled upwards if proving to have the desired effects. From a financial standpoint, mesocosms may be a potential motivator for rate-payers in the event that the project is financially dependent upon their contributions to an in-lake treatment; but only if success is experienced. Problems to consider with mesocosms include short comings in terms of the size of Pigeon Lake; they are not typically conducted on large lakes, due to high wind and wave action. Wind fetch can be so dynamic that you may lose the "whole" aspect of the lake, resulting in either over-prediction or under-prediction of results. With time of the essence, the question in regards to timing of these experiments arose and a desire was expressed for them to begin as soon as possible, ideally curtaining off an area for 6-7 weeks to experiment with applications. The purpose would not only be for a visual dynamic but would entail important research. Section 35 of the *Fisheries Act* would apply to this process in regards to the review of SADD (Serious Harm, Alteration, Disruption or Destruction of fish habitat). Rodderick Drummond from DFO estimated the application process would likely take 60 days for a decision to be reached and another 90 to receive authorization.

6 Public Education

Along with moving forward with in-lake treatment as well as watershed management planning it is critical to include a major public education campaign in order to demonstrate that the APLM is taking action, momentum is strong and things are happening. The education piece needs to be tied to measures of success for the public, addressing the gap in understanding as to managing the esthetics of blue green algae blooms versus managing the cause. The Alberta Lake Management Society stresses the need to also set timelines for watershed planning; not focusing solely on waterfront residents but on all non-point sources of nutrients. If reductions in the amount of phosphorus from these sources are not occurring within a certain time frame then do we still move forward with in-lake treatment? How do we create buy-in at all levels and avoid taking the focus away from watershed management planning while also demonstrating action with in-lake treatments? A fine balance will need to be struck between collecting more data and information while also formulating a plan with concrete steps and a timeline in order to create buy-in and a sense of security among the community.

7 Proposed Timeline

7.1 2014

Moving forward, the in-lake treatment project will be broken down and executed in a number of phases, including both aforementioned short and long term initiatives. Further studies need to be undertaken, timelines set and cost of treatment options quantified. Immediate actions taken this season will include the collection of sediment cores needed to provide further information into sediment chemistry, phosphorus distribution and define hot spots around the lake. This project will include mapping of critical areas as well as distribution and seasonality of phosphorus availability. The collection of these cores should take approximately two days and can potentially be completed by ESRD. The APLM would like to move forward with collection of these cores as soon as possible, potentially while the lake is still under ice cover due to ease of collection. This may not be possible due to the timing of ESRD's year-end but would also be an option during the open water season and it will be a top priority to collect this information during the 2014 season.

- Additional work that could be initiated in 2014 is that of biomanipulation of the lake. ESRD currently has archived samples of both zooplankton and phytoplankton which could be analyzed in efforts to produce a clearer picture of the food chain in Pigeon Lake. Work could be done with Fisheries experts in order to introduce apex predators such as Walleye into the lake, potentially as soon as the 2014 open water season.

- Immediate work can also begin on costing out options for short term initiatives such as oxidants and mechanical harvesting and working out logistical details which may or may not rule out these as short term solutions.

7.2 2015-2016

- Due to regulatory approval timelines and a fast approaching open water season, it is likely that mesocosms conducted with either Alum or Phoslock will not be conducted until the 2015 or 2016 season. However, this allows time to collect missing data, complete the needed approvals and regulatory support, confirm sources of funding and increase the likelihood of getting the most out of these experiments.

8 Closing Remarks

In addition to the timelines above, on-going work must also be conducted in regards to public education campaigns, watershed management planning and controls as well as the evolution of Alberta Health Services Beach Monitoring Program; including objectiveness and timeliness of postings and the wording of health advisories. Moving forward proposals could be provided to the APLM which will outline the process moving forward, including timelines, deliverables and goals for each phase.

Sincerest thanks to all whom participated, offered your feedback, thoughts, and shared their expertise. The in-lake treatment at Pigeon Lake will be a learning experience for all and the project will move forward with calculated direction and timeliness while encompassing both scientific and political agendas in order to ensure the best possible results for Pigeon Lake.

9 Appendices

Appendix A - Workshop Attendance

Workshop Invitees:

Allan Olson: APLM In-Lake Technical Committee
Peter Pellatt: APLM In-Lake Technical Committee
Ernie Elko: APLM In-Lake Technical Committee
Ralph Johnston: APLM In-Lake Technical Committee
Michael Gaian: APLM In-Lake Technical Committee
Kim Sturgess: WaterSMART
Ryan Bjornsen: WaterSMART
Curtis Brock: Alberta Environment and Sustainable Resource Development (AESRD)
Chris Teichreb: AESRD Limnologist and Water Quality Scientist
Ron Zurawell: AESRD Limnologist and Water Quality Scientist
David Trew: North Saskatchewan Watershed Alliance
Melissa Logan: North Saskatchewan Watershed Alliance
Arin Dyer: Alberta Lake Management Society
Bradley Peter: Alberta Lake Management Society
Darcy MacDonald: AESRD
Jason Cooper: AESRD Senior Fisheries Biologist
Dr. Rolf Vinebrooke: University of Alberta
Alex Wolfe: University of Alberta
Greg Goss: University of Alberta
Bill Patterson: Alberta Conservation Assocation
Terry Mc Nabb: Aquatechnex Principal
Harry Gibbons: Tetra Tech Lead Applied Limnologist
Al Sosiak: Limnologist
Michael Hunka: Department of Fisheries and Oceans (DFO)
Michael Sullivan: ESRD
Roderick Drummond: DFO Fisheries Protection Biologist
Lorne Taylor: WaterSMART

Day One Participants:

Allan Olson: APLM In-Lake Technical Committee
Ralph Johnston: APLM In-Lake Technical Committee
Chris Teichreb: AESRD Limnologist and Water Quality Scientist
Ron Zurawell: AESRD Limnologist and Water Quality Scientist
Terry Mc Nabb: Aquatechnex Principal
Harry Gibbons: Tetra Tech Lead Applied Limnologist

Al Sosiak: Limnologist
Arin Dyer: Alberta Lake Management Society
Bradley Peter: Alberta Lake Management Society
Jason Cooper: AESRD Senior Fisheries Biologist
Roderick Drummond: DFO Fisheries Protection Biologist
Dr. Mark Graham: University of Alberta
Lorne Taylor: Alberta WaterSMART
Doris Bell: Councillor, Summer Village of Crystal Springs
Erin Rodger: AqualityAquaitc Bioloist
Jay White: Aquality Principal
Elynne Aquality: Aquatic Technologist

Day 2 Participants:

Ernie Elko: APLM In-Lake Technical Committee
Ralph Johnston: APLM In-Lake Technical Committee
Chris Teichreb: AESRD Limnologist and Water Quality Scientist
Ron Zurawell: AESRD Limnologist and Water Quality Scientist
Terry Mc Nabb: Aquatechnex Principal
Harry Gibbons: Tetra Tech Lead Applied Limnologist
Roderick Drummond: Department of Fisheries and Oceans Fisheries Protection Biologist
Arin Dyer: Alberta Lake Management Society
Bradley Peter: Alberta Lake Management Society
Dr. Rolf Vinebrooke: University of Alberta
Dr. Mark Graham: University of Alberta
Roderick Drummond: DFO Fisheries Protection Biologist
Lorne Taylor: Alberta WaterSMART
Doris Bell: Councillor, Summer Village of Crystal Springs
Jay White: Aquality Principal
Elynne Aquality: Aquatic Technologist

Could Not Attend Due to Other Commitments:

Peter Pellatt APLM In-Lake Technical Committee
Michael Gaian APLM In-Lake Technical Committee
David Trew: North Saskatchewan Watershed Alliance
Melissa Logan: North Saskatchewan Watershed Alliance
Kim Sturgess: WaterSMART
Ryan Bjornsen: WaterSMART
Curtis Brock: Alberta Environment and Sustainable Resource Development
Darcy MacDonald: Alberta Environment and Sustainable Resource Development
Alex Wolfe: University of Alberta

Greg Goss: University of Alberta
Bill Patterson: Alberta Conservation Association
Michael Hunka: Department of Fisheries and Oceans

Appendix B – Workshop Schedule

Workshop Schedule Day 1

Day 1: Tuesday, February 18, 2014	
9:00 - 9:15	Welcome, Introductions and Workshop Purpose – Jay White
Guest Presentations	
9:15 – 10:00	Jay White – Pigeon Lake Background and Groundwater Overview
10:00 – 10:15	Coffee Break
10:15 – 11:00	Chris Teichreb – Sound Science, Sound Decisions: An Overview of Pigeon Lake Chemistry
11:00 – 11:45	Ron Zurawell - Cyanobacteria in Lakes
Lunch (11:45 - 12:45)	
12:45 – 1:30	Al Sosiak – Pine Lake Restoration Project
1:30 – 2:15	Harry Gibbons – Why, When and What to Use to Manage Your Lake's Eutrophication
2:15 – 2:30	Coffee Break
2:30 – 3:15	Terry McNabb – In-lake Treatment Strategies for Cyanobacteria Blooms, Our Experiences Over the Past 40 Years
3:15 – 4:45	Discussion - Setting Goals and Measuring Success for Pigeon Lake
4:45 – 5:00	Day 1 Closing Remarks – Jay White

Workshop Schedule Day 2

9:00 – 9:15	Overview of Day 1 and Goals for Day 2 – Jay White
9:15 – 10:30	Group In-Lake Treatment Methods Brainstorming
10:30 – 10:45	Coffee Break
10:45 - 12:00	Breakout Group Discussions - Most Feasible In-Lake Treatment Method
Lunch (12:00 – 1:00)	
1:00 – 2:30	Groups Presentations – Most Feasible In-Lake Treatment Option
2:30 -2:45	Coffee Break
2:45 - 4:30	SWOT Discussion on Options
4:30 – 5:00	Next Steps and Workshop Closing Remarks – Jay White

Appendix C - Expert Panel Presenters

Pigeon Lake by the Numbers and Groundwater Overview
Jay S. White, M.Sc., P.Biol.
Aquality Environmental Consulting, Principal

Jay White is an Aquatic Scientist and Professional Biologist with a B.Sc. from University of Western Ontario; where he conducted an honors project focused on limnology in Northern Ontario. His M.Sc. degree in Ecology from the University of Alberta focused on Ducks Unlimited Canada's largest wetland restoration project at Frank Lake in High River, Alberta. Following graduation, he worked as a research associate at the University of Alberta's Sustainable Forest Management Network, where he managed all of the lake research projects for the Western Aquatic Group. In 2000, he left to form Aquality Environmental Consulting Ltd. Aquality's focus areas include wetland assessments and restoration, riparian restoration and management, riparian and wetland policy development, freshwater ecology including surface water quality testing, limnology, water resource management and watershed management planning. Jay is involved with several innovative watershed management projects across Alberta, from lakes to large basins. He has long been involved with the Alberta Lake Management Society, North American Lake Management Society and Society of Wetland Scientists. He currently sits on the Executive of the Alberta Water Council and represents the Lake Environment Conservation in the Non-Government Organizations Sector. Water governance, education and sustainability are his current topics of interest and he has presented state of the environment reports to audiences at all levels throughout Alberta.

Pigeon Lake is located about 80 km southwest of Edmonton in the Counties of Wetaskiwin and Leduc and is one of the largest and most popular recreational lakes in Alberta. In recent years the effects of agriculture, development and recreational use have led to increased nutrient loading, blue-green algae blooms and decreased water quality of the lake. Jay will be providing a high level summary of Pigeon Lake, introducing key concepts such as: watershed land use, sources of eutrophication, surface water quality, monitoring initiatives and in-lake control options for blue-green algae. Jay will also be presenting a brief overview of groundwater within the Pigeon Lake area including well distribution, bedrock geology of the Paskapoo Formation as well as groundwater quality and yields.

Sound Science, Sound Decisions: An Overview of Pigeon Lake Chemistry

Chris Teichreb, M.Sc., P.Biol.
Alberta Environment and Sustainable Resources Development, Limnologist and Water Quality Specialist

Chris Teichreb has been a limnologist with Alberta Environment and Sustainable Resource Development for ten years. He has worked extensively with lake groups in order to bring forward the science required to understand water chemistry and support strategies to maintain or improve water quality conditions. His work at Pigeon Lake extends back to 2005, working closely with the Pigeon Lake Watershed Association and the Association of Pigeon Lake Municipalities. This work included the release of the report "Lake and Watershed Management Options for the Control of Nuisance Blue-Green Algal Blooms in Pigeon Lake, Alberta" in 2012.

In order to make sound decisions on management options for the control of nuisance blooms in Pigeon Lake, a fundamental understanding of the chemistry and ecology of the lake is required. Pigeon Lake has historically been monitored for the purposes of characterization but in more recent years, data has been collected to support efforts to look at watershed and in-lake management of nutrients. Historical and recent data including an overview of the Pigeon Lake nutrient budget will be discussed. Use of this data in long-term trend assessments as well as examples of how the data can be used to assess potential in-lake management options will also be presented.

Cyanobacteria in Alberta Lakes

Ron Zurawell, Ph.D., P.Biol.
Alberta Environment and Sustainable Resources Development, Limnologist and Water Quality Scientist

Dr. Ron Zurawell is a Limnologist/Water Quality Specialist with the Water Policy Branch of Alberta Environment and Sustainable Resource Development where he coordinates the Province's surface water quality monitoring program and manages the joint provincial lake monitoring program. Ron began studying cyanobacteria as an undergraduate student 20 years ago and he continues to lead research and monitoring for toxic cyanobacteria on behalf of the Government of Alberta. Also, Ron is currently serving his second term as Regional Director for the North American Lake Management Society.

For today's presentation Dr. Zurawell will be discussing cyanobacteria in Alberta lakes. Cyanobacterial blooms resulting in lake water advisories are becoming more common across Alberta. In the summer of 2012 alone, there were 18 cyanobacterial advisories on Alberta lakes, subsequently "closing" the lake for the remainder of the summer. The majority of these water advisories occurred on popular lakes that are used for a range of recreational activities. It is well known that most species of cyanobacteria produce liver or neurological toxins, the most common of which are the microcystins. While open water blooms may have concentrations of microcystin toxins that are below the Guidelines for Canadian Recreational Water Quality, blooms that occur near shore areas, such as beaches, have a much higher concentration of microcystin toxin. These blooms have resulted in lake closures, loss of recreational opportunities and economic losses for communities that depend on recreational users. The presentation will discuss in more detail why cyanobacteria blooms occur in lakes and why they pose such a serious problem.

Pine Lake Restoration Project

Al Sosiak, M.Sc., P. Biol.
Sosiak Environmental Services, Partner

Al Sosiak retired from the Alberta government in 2010, where he worked on lake and watershed restoration programs, water quality monitoring, fisheries management, and impact assessment studies since 1982. Before the Alberta government he worked as a fisheries biologist with Montreal Engineering. He now provides consulting services in these fields. He is a Past President of the North American Lake Management Society, and current Editor for the scientific journal Lake and Reservoir Management. Today he will speak about the Pine Lake Restoration Program.

Pine Lake is a small intermittently-stratified, eutrophic lake (surface area = 3.98 km2; mean depth 5.3 m) southeast of Red Deer, Alberta. Pine Lake was subject to severe cyanobacterial blooms. Public concern over deteriorating water quality prompted the Alberta government to initiate a model lake restoration program in 1991. The Pine Lake Restoration Society, an organization with representatives from the farming, commercial resort, and cottage communities, implemented a four-year work plan of watershed projects and in-lake treatment that addressed nutrient loading from all sources in 1995. To remove phosphorus released from lake sediments, a hypolimnetic withdrawal system was installed in 1998. A monitoring program to assess the benefits of the watershed projects and hypolimnetic withdrawal system began in 1999. A detailed watershed monitoring program that assessed changes in the basin since 1992 was completed in 2007.

Total dissolved phosphorus has generally decreased in Pine Lake since 1996, and cyanobacterial blooms were reduced during years with low to average precipitation. In 2000 alone, chlorophyll a approached the goal of the restoration program, a natural level of algal productivity. Flow-weighted dissolved phosphorus levels were greatly reduced in two of the three streams with major watershed projects, and did not change in one reference stream. Dissolved oxygen concentrations have improved in winter. However, cyanobacterial blooms have continued to occur during wet years. Factors that could explain these persistent blooms include increased phosphorus export over time from certain streams in the basin, increased runoff over time, and changes in the ice-free period of Pine Lake.

This presentation will conclude with some key lessons from the Pine Lake Restoration Program that can guide work at other lakes in Alberta.

Why, When and What to Use to Manage Your Lake's Eutrophication

Harry Gibbons, Ph.D.
Tetra Tech, Lead Applied Limnologist

Dr. Harry Gibbons is the lead applied limnologist for Tetra Tech, Inc. and has 40 years of experience in limnology; that includes lake/reservoir, river, stream, watershed, and wetland management/restoration. Harry has specifically planned/designed management and restoration programs for over 250 lakes/reservoirs and 40 stream and river systems. His expertise includes lake and watershed management, lake restoration, cyanobacteria bloom prevention, integrated aquatic plant management, aquatic invasive species (AIS) management, stream assessment, fish passage, aquatic habitat assessment, wetland restoration and stormwater management. Harry is a recognized leader in the development and implementation of in-lake activities for techniques like phosphorus inactivation (alum), dredging, hypolimnetic aeration, aeration and circulation, hypolimnetic withdrawal, dilution and biocontrols. Harry has served as President of the North American Lake Management Society and the Washington State Protection Association and was a charter member of both organizations.

Primary production and related water quality is a direct function of nutrients, such as nitrogen and phosphorus, and light availability. However, to manage or reduce excess productivity in a lake it is important to understand phosphorus availability, both in terms of when and how much. For many lakes that have experienced excess phosphorus loading in their past, it is not the source of phosphorus that is important but rather the quantity and timing of phosphorus availability within the lake that is the driver toward poor water quality and algal blooms. In order to maintain the beneficial uses of lakes that have experienced long-term watershed abuses causing increased phosphorus loading, in-lake activities are necessary. Many in-lake approaches have been successfully implemented but it is the understanding why a specific approach works that is the key to selecting the best action or activities to promote and obtain the desired quality of your lake, regardless of external controls because of the time it take for a lake to recover. In-lake management activities will be discussed relative to their application and effectiveness of success. The following activities will be presented: dredging, phosphorus inactivation, aeration, circulation, dilution, and hypolimnetic withdrawal.

In-lake Treatment Strategies for Cyanobacteria Blooms, Our Experiences over the Past 40 Years

Terry McNabb, CLM
Aquatechnex LLC, President, Aquatic Biologist and Certified Lake Manager

Terry McNabb is a graduate of Michigan State University with a degree in Water Resource Management and operates Aquatechnex, LLC. Aquatechnex is a lake and aquatic plant management firm with over 40 years of experience assisting lake associations and government deal with lake water quality issues. The firm is a recognized expert in the management of invasive aquatic species such as Eurasian Milfoil, Hydrilla, Flowering Rush and Brazilian Elodea. The firm is also a recognized expert in the in lake treatment of algae as well as nutrient inactivation. Terry is a past president of the international Aquatic Plant Management Society (www.apms.org) and the current president of the North American Lake Management Society (www.nalms.org).

Eutrophic lakes throughout the world often experience cyanobacteria blooms. These “Blue Green Algae” are thought to have a competitive advantage in nutrient rich lake systems. If the lake in question is an important recreational resource, bloom conditions can have a severe economic impact as well as pose a human health threat.

There have long been two approaches to in-lake management of problem algae blooms. The first approach for in-lake treatment are reactive in nature. US EPA has evaluated and registered a number of algaecides for use in lakes and potable water reservoirs. These technologies can play an important role. They provide relief from bloom conditions rapidly and in many cases are very cost effective. Treatment programs will have a monitoring component and action thresholds established based on the water body in question. When thresholds are reached, applications are made. Targeted algae are affected rapidly, die and drop out of the water column. There is often a release of nutrients from this biomass that triggers another round of bloom conditions so ongoing monitoring and treatment response is a necessary component of these programs.

Chelated copper algaecides are the primary tool used in these efforts. Copper sulfate is not stable in many lakes and loses its algaecidal effect rapidly. Chelated products are designed to remain stable in the water column to increase exposure and uptake by the target organism. Many of these are designed to infuse the cells and carry the copper into the system.

Endothall based algaecides are also very effective. This molecule is made up of carbon, oxygen and hydrogen and leaves nothing behind.

The newest registrations of algaecides are peroxygen based products such as PAK 27. These materials oxidize algae cells and break down into oxygen and water.

On larger lake systems, many of these materials can be applied using aerial application technologies and this can be a very cost effective delivery system.

In lake preventative treatment strategies focus on sequestering nutrients critical to algae growth. Algae are single celled organisms and must obtain the nutrients they need to function from the water column.

Limiting the amount of key nutrients present in the water column can limit the carrying capacity of the lake to produce algae blooms.

Our first experience with nutrient inactivation occurred in the 1970's when the US EPA Clean Lakes Program developed a number of technologies to help restore lake systems impacted by Eutrophication. We performed some of the first Aluminum Sulfate treatments in Indianan and Michigan. Aluminum has the ability to capture and sequester phosphorus when applied to form a floc in the upper portion of the water column. The floc can also settle to the lake sediments and capture release from that source.

Alum has been the go to technology for inlake treatment of phosphorus since it was developed under the Clean Lake Program in the 70's. Two projects we are currently implementing in the Western United States are the Canyon Lake TMDL treatment program and the Lake Stevens phosphorus Mitigation Project. Results will be presented from these treatments.

A newer technology has emerged over the past decade. Phoslock is a phosphorus sequestering agent that was developed by the Australian National Science Academy. This technology provides excellent phosphorus sequestration and overcomes many of the potential drawbacks to Alum technology. The receiving water quality does not impact the effectiveness of phosphorus sequestration as can be the case with Alum treatments. In addition, the addition of Phoslock does not change key water quality parameters in the receiving water as Alum treatments can. We will provide data from ongoing projects with Phoslock.

Both of these technologies can be used as whole lake recovery treatments, treatments that strip out phosphorus over time or maintenance treatments or can be focused on the deeper anoxic areas of the lake if those sediments are the major contributor. A blend of these treatment strategies can also be used. Both Phoslock and Alum applications can have pose a significant logistical challenge that can impact results. Material handling can be the most challenging part of the treatment protocol on large lake systems. Securing shoreline staging areas at key locations around the water-body can insure that application vessels are minimizing down time traveling to obtain material and maximize the time they are applying it. Getting the material in the water as rapidly as possible often required a substantial number of application vessels and teams.

The presentation will focus and expand upon these subjects.

Appendix D – Pigeon Lake Success

Defining Measures of Success for Pigeon Lake: Participant Input

- Prior to 2006 ESRD received no calls about water quality concerns at Pigeon Lake, nor were any received throughout the 1980's-1990's: if we can reproduce the situation of the lake prior to 2006 most people would be happy
- Optimizing the recreational value of the lake, using in-lake treatments to ensure no health advisories are posted and that people are not afraid to use the lake, focus on a quick an effective way to treat blooms when they occur
- Fish kills are likely un-related to nutrients in the lake; therefore, they may not need to be tied to an indicator of success
- We do not yet know enough from a fisheries standpoint, so there is still the possibility of reducing fish kills as being one of a number of indicators of success, how can we assure the two are not connected?
- Using numbers such as total phosphorus, chlorophyll-a concentrations, secchi disk depth, numerical frequencies or intensity of blooms
- The key is having specific standards to monitor: DO, pH, species of algae, TDP, TP, Chlorophyll-a
- Need for results from paleolimnological work in order to categorize Pigeon Lake pre-human development, then work toward this standard
- Focus on maintaining beneficial use of the lake in compromise with what is politically and financially acceptable
- Need for a balance between technical goals and perceptions of the public: we will need more than one measure of success in order to appeal to different audiences
- Stress related to Alberta Health Services monitoring program-can we monitor in a more efficient manner, media language is causing disconnect with the public, can we change the public's perception?
- What amount of phosphorus are we going to attribute to human causes? Quantify this number and work towards reducing it