Big Roche-A-Cri Lake District

Phase I Lake Study Report

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1 Executive Summary

Foth & Van Dyke was retained by the Big Roche-A-Cri Lake Protection and Rehabilitation District (District) to conduct a water quality evaluation of Big Roche-A-Cri Lake. The District received a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) which provided funding up to $10,000 for this project with in-kind services and matching funds of 25% provided by the District.

This evaluation and report focused on the evaluation of the current trophic status, including water quality data generation, the recharge/discharge relationship of groundwater flowing into or out of Big Roche-A-Cri Lake, an evaluation of the on-site wastewater systems around the lake, and the relationship to the land use practices in the Big Roche-A-Cri Lake watershed to the water quality of the lake.

Water Quality

A water quality sampling program was implemented to determine the lake's water quality and trophic status. Big Roche-A-Cri lake can be described as a eutrophic lake based on the high nutrient concentrations of phosphorus and nitrogen The high levels of phosphorus and nitrogen have led to excessive weed growth and algae blooms in the lake. Other parameters such as dissolved oxygen and chlorophyll *a* were more typical of mesotrophic lakes.

Groundwater Recharge/Discharge

Piezometers (groundwater wells designed to evaluate flow direction) were installed in various locations around the lake to determine the extent, if any, of groundwater contribution to Big Roche a Cri lake. There were two locations which consistently had groundwater higher than the lake level. At those locations, groundwater flows into the lake. At one location the lake level and the groundwater level were nearly identical indicating little groundwater movement. Finally, at one location, groundwater was lower than the lake level indicating lake water flowed into the groundwater.

This data is beneficial in evaluating potential pollution sources such as septic systems. Septic systems discharge to groundwater carrying nutrients into the groundwater. In the case of Big Roche-A-Cri lake, groundwater flows into the lake on the east end of the lake and flows out of the lake on the west end of the lake.

Sanitary Survey

A sanitary survey was completed as a part of the Phase I project. All residents were mailed a sanitary survey form. Many residents filled out the form and returned it to the District board. Foth & Van Dyke also conducted field work throughout much of the lake district to obtain generalized information about septic systems. Data was collected from about 50% of the systems on the lake. The data collected showed most systems had the disposal field over 100 feet from the lake. The disposal field was typically greater than 10 feet above the lake level. This indicates the on-site systems have adequate soil above groundwater and are located away from the lake to enable the wastewater to be well treated before it enters the groundwater or the lake. The data collected shows most on-site systems have little impact on the lake water quality.

Watershed Analysis

The phosphorus loading to the lake from the watershed is estimated at 826 pounds per year. The existing lake contains about 150 pounds of phosphorus. The goal for long term management should strive to limit phosphorus coming into the lake to the amount that is removed each year. At Big Roche A Cri, phosphorus is removed through deposition on the lake bottom, weed cutting, and the outlet stream. The phosphorus deposited on the lake bottom acts as a nutrient source for rooted plants, promoting excess growth. The sediment can also release phosphorus back into the surface water under certain conditions.

Agricultural land use is the largest category in the watershed and makes up 31% of the total land use. Residential land use makes up 2%. The largest impact land use is discharging the greatest mass of phosphorus to the lake. The agricultural category provided 56% of the phosphorus to Big Roche A Cri Lake. Any work done to reduce phosphorus loading should begin on the agricultural areas in the watershed.

Septic systems currently have more than 550 pounds per year of phosphorus discharged to the soil. Where septic systems do discharge to groundwater that enters the lake, there is a potential for this phosphorus to reach the lake. However, the sanitary survey found septic systems in general to be well designed and not a likely source of phosphorus discharges.

Recommendations

It is recommended that the Big Roche-A-Cri Lake Protection and Rehabilitation District proceed with the following:

- Complete a Lake Management Plan directed toward maintaining and protecting the water quality of Big Roche A Cri Lake.

- Evaluate methods of reducing phosphorus loading to the lake.

- Evaluate lake dredging to remove accumulated sediment and phosphorus, thereby reducing excessive weed growth

2 Introduction

Big Roche-A-Cri Lake is located in north central Adams County. The lake covers an area of 205 acres, has 6.1 miles of shoreline, a maximum depth of 20 feet, and an average depth of 9 feet. Development has occurred on all developable lots around the lake, and these areas currently are not serviced by public sanitary sewer. All developments adjacent Big Roche A Cri Lake have private, on-site septic systems.

In May, 1999 the District was awarded a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) to conduct a study of the water quality of Big Roche-A-Cri Lake. This study was completed in the summer of 2000.

2.1 Authorization

The District authorized the consulting firm of Foth & Van Dyke to complete Phase I of the lake study for Big Roche-A-Cri Lake, and to prepare a report identifying the results. The study resulted in a collaborative effort among Foth & Van Dyke, the District, and WDNR personnel.

2.2 Purpose

The purpose of the Phase I lake study was to address the following areas.

- Obtain water quality data to establish the existing water quality of Big Roche-A-Cri Lake,
- determine the extent to which groundwater is a feeding source for the lake,
- determine the impact of septic systems on lake water quality, and
- to complete an analysis of the land use and associated phosphorus runoff in the lake's immediate watershed.

The results of this study will be used to provide the District with a sound understanding of the water quality of Big Roche-A-Cri Lake and potential sources of pollution to the lake. This report will also provide the District with alternatives to protect and preserve the water quality of Big Roche-A-Cri Lake based on the findings of the studies.

2.3 Project Study Area

Map No. 1 illustrates the project study area, including the two water quality sampling locations and the locations where groundwater piezometers were installed.

3 Water Quality

The water quality of a lake is dependent upon a number of factors and lake characteristics. Every lake possesses a unique set of physical and chemical characteristics that may change over time. The chemical changes occur on a daily basis, while physical changes (such as plant and algae growth) occur on a seasonal basis. Seasonal changes in the physical characteristics of a lake are common because factors such as surface runoff, groundwater inflow, precipitation, temperature and sunlight are variable. A lake's water quality will vary with the seasonal changes, therefore data must be gathered over a period of time to accurately determine if a lake is experiencing significant changes in water quality and to distinguish between natural variability and human activity impacts.

To determine the water quality and trophic status of Big Roche-A-Cri Lake, a sampling program was devised which included testing numerous characteristics of the lake. The following section explains the sampling program and its components, presents the results and analysis of the sampling conducted, and provides conclusions about the water quality of Big Roche-A-Cri Lake. First however, it is important to identify the natural aging process experienced by lakes (eutrophication), and the source of the lake's water supply as this contributes to the factors which effect the quality of its water supply. In addition, identification of the water source allows for sound management practices to be selected which reflect the specific characteristics of the lake.

Eutrophication - The Aging Process

The process of eutrophication is a natural aging process which occurs in all lakes whereby a lake progresses from a more oligotrophic (young lake) to a more eutrophic (old age) state. When nutrients such as phosphorus and nitrogen wash into a lake with stormwater or by soil erosion, they fertilize the lake and encourage algae and larger plants to grow. As plants and the animals that feed on them die and decompose, they accumulate on the lake bottom as organic sediments. After hundreds or thousands of years of plant growth and decomposition, the character of a lake may more closely resemble a marsh or a bog.

However, lakes also obtain nutrients from various human activities which can literally make a lake old before its time. This accelerated transition is commonly termed "cultural eutrophication", whereby changes that would normally take centuries may occur over/within one person's lifetime. Nutrients from agriculture, stormwater runoff, urban development, lawn and garden fertilizers, failing septic systems, land clearing, construction site runoff, municipal and industrial wastewater, and recreational activities contribute to the accelerated eutrophication or enrichment of lakes.

Trophic Status Indicators

The trophic state of a water body is an indicator of the nutrient levels and water clarity in a lake. Lakes can be divided into three categories based on their trophic state which include oligotrophic, mesotrophic, and eutrophic. The following provides a description of each trophic state:

Oligotrophic: Young lakes with low productivity which are generally clear, cold, deep, and free of weeds or large algae blooms. Oligotrophic lakes are low in nutrients and therefore do not support plant growth or large fish populations, however are capable of sustaining a desirable fishery of large game fish.

Mesotrophic: These lakes are in an intermediate stage between the oligotrophic and eutrophic stages. They are moderately productive, supporting a diverse community of native aquatic plants. The bottoms of mesotrophic lakes lack oxygen in late summer months or winter periods which limits cold water fish and causes phosphorus cycling from sediments. Overall however, mesotrophic lakes support good fisheries.

Eutrophic: Lakes which are high in nutrients and support a large biomass are categorized as eutrophic. These old age lakes are usually weedy and/or experience large algae blooms. Most often they support large fish populations, however are also susceptible to oxygen depletion which limits fishery diversity. Rough fish are common in eutrophic lakes.

The trophic state of a lake can be determined by observing three lake characteristics including total phosphorus concentration (Total-P) which indicates the amount of nutrients present which are necessary for algae growth, Chlorophyll *a* concentration which is a measure of the amount of algae actually present, and Secchi disc readings which is an indicator of water clarity. As expected, low levels of Total P are related to low levels of Chlorophyll *a*, which are related to high Secchi disc readings.

To determine the trophic state of the lake, the Wisconsin Trophic State Index (WTSI) can be applied to each of the above noted factors. The WTSI converts the actual measurement into a value which is representative of one of the trophic states. Values less than or equal to 39 indicate oligotrophic conditions, values from 40-49 indicate mesotrophic conditions, and values equal to or greater than 50 represent eutrophic conditions.

General Characteristics of Big Roche-A-Cri Lake

Big Roche-A-Cri Lake is classified as an impoundment lake: an impoundment lake is a man made lake created by damming a stream. In this case, Big Roche-A-Cri Lake was created by damming Big Roche-A-Cri Creek. The creek enters the lake on the east end and flows over a dam on the west end of the lake. Impoundment lakes have their water level primarily maintained by flow from the inlet creek. Groundwater and direct precipitation are minor water source to the lake when compared to the stream flow. Water quality is most impacted by the inlet stream which is impacted by the drainage basin and the land use in that basin.

Big Roche-A-Cri Lake has a surface area of 205 acres with an average depth of 9 feet and a maximum depth of 20 feet. It is a long, narrow lake with a shoreline of 6.7 miles. There are two boat landings on the lake. The watershed associated with Big Roche-A-Cri Lake covers 45,445 acres, a relatively large watershed.

3.1 Sampling Program

The sampling program used to determine the water quality of Big Roche-A-Cri Lake was conducted over approximately a one year time period, beginning in May of 1999, and concluding in April, 2000. This sampling program provided information to evaluate the current water quality of the lake. Sampling was conducted on six separate occasions including:

- May, 1999
- June, 1999
- August, 1999
- September, 1999
- February, 2000 (ice on)
- April, 2000 (ice off - spring turnover)

Big Roche-A-Cri Lake District staff and Foth & Van Dyke personnel performed the water sampling, while laboratory analysis of the samples was completed by the State Laboratory of Hygiene. It was important to obtain samples with ice on, ice off, and in summer months to obtain data representative of the seasonal changes which affect water quality.

Numerous factors were considered in the sampling program, including:

Dissolved Oxygen (D.O.)	Temperature	Chlorophyll *a*
Total Phosphorus	Orthophosphate	pH
Ammonia Nitrogen	Nitrate plus Nitrite Nitrogen	
Total Kjeldahl Nitrogen	Secchi Disc readings	

These factors were measured at both sample locations. At sample point 2, one sample was collected near the surface (2A) and one sample was collected near the lake bottom (2B). Temperature and D.O. were measured at various depths in the lake ranging from surface to subsurface. Samples for the nitrogen compounds were taken on the first and last sample dates at surface and sub-surface levels, however all factors were not sampled on the four other dates. As the primary objective of this study was to determine the trophic status of Big Roche-A-Cri Lake, the factors which contribute to making this determination were sampled more frequently than most other factors. These factors include total phosphorus (Total P), Chlorophyll *a*, and Secchi Disc readings. For the purposes of this study, orthophosphate, dissolved oxygen, pH, and temperature were also sampled more frequently, including all sample dates.

The following section provides the results of the sampling program, highlighting the temperature profile, dissolved oxygen levels, those factors which contribute to the determination of the lake's trophic state,

3.2 Results and Analysis

The complete results of the sampling program conducted on Big Roche-A-Cri Lake are displayed in Appendix A. The following section provides a more detailed discussion of the sampling results of temperature, dissolved oxygen levels, trophic status indicators including total phosphorous concentrations, Chlorophyll *a* concentrations, and Secchi disc readings.

Temperature

Temperature exerts a major influence on biological activity and growth. To a point, the higher the water temperature, the greater the biological activity. Temperature also governs the kinds of organisms that can live in a lake. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the survival of individual species may be limited or eliminated.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it is more difficult to maintain enough oxygen in warm water for survival of aquatic life.

Stratification: Layers of a Lake

Stratification is a layering effect produced by the warming of the surface waters in many lakes during summer, during which time lake water separates into layers of distinctly different temperature. Upper waters are progressively warmed by the sun and the deeper waters remain cold. Because the layers don't mix, they develop different physical and chemical characteristics, often resembling two different lakes. As a result, oxygen in the bottom waters may become depleted. In autumn, as the upper waters cool to about the same temperature as the lower water, stratification is lost and the whole lake mixes again. This process is called fall turnover. Many lakes experience stratification in winter because ice covers the lake surface. In spring, as ice melts, the water temperatures once again equalize and mixing occurs, a process called spring turnover. As summer progresses, the temperature difference (and density difference) between surface and bottom water becomes more distinct, as mentioned previously, and most lakes form three layers. The upper layer, the epilimnion, is characterized by warmer (less dense) water and is the zone of light penetration, where the bulk of productivity or biological growth occurs. The next layer, the metalimnion or thermocline, is a narrow band where the transition from warmer surface waters goes to the cooler bottom layer. This transition zone helps to prevent mixing between the upper and lower layers. The bottom layer, the hypolimnion, has much colder water. Plant material either decays or sinks to the bottom and accumulates in this isolated layer. During fall turnover, surface waters cool until the waters from top to bottom have an equal temperature and density. Wind action then mixes the lake waters, balancing the lake's chemistry.

A shallow lake or an impoundment lake, however, is more likely to be homogeneous from top to bottom. The water is well-mixed by the wind and current, and physical characteristics such as temperature (and oxygen) vary little with depth. Because sunlight reaches all the way to the bottom, photosynthesis and growth occur throughout the water column. As in a deep lake, decomposition in a shallow lake is higher near the bottom than the top simply due to the fact that when plants and animals die they sink. It is also likely that a larger portion of the water in a shallow lake is influenced by sunlight, and that photosynthesis and plant growth are proportionately higher.

Temperature Profile of Big Roche-A-Cri Lake

Temperature profiles of Big Roche-A-Cri Lake were taken from Sample Point #2 at different depths. The data collected shows that the lake experienced slight stratification during the summer months from June through early September with a 6.4° C variation, as was expected given the lakes relatively small size and shallow maximum depth of approximately 20 feet. The water remained relatively "mixed", or at approximately the same temperature from top to bottom, throughout the remaining months. Overall, the water in Big Roche-A-Cri Lake remains mixed almost year-round, therefore distributing oxygen throughout the lake.

Dissolved Oxygen (D.O.) Concentration

The presence of oxygen in lake water determines where organisms such as fish and zooplankton are found. When water is well-mixed, such as in spring, oxygen is usually present at all depths, thus organisms may be distributed throughout the lake. However, under stratified conditions, little or no oxygen is produced in the hypolimnion. Available oxygen is consumed through decomposition of plant and animal material, and oxygen levels become too low for fish which then must move to the top layer, or epilimnion. If these conditions are prolonged and the upper waters become too warm, cold-water fish such as trout may become stressed and eventually die. In the fall, the lake layers break down and turnover replenishes oxygen to the bottom waters. The formation of ice in water reduces the supply of oxygen to the lake from the overlying air. If oxygen levels fall too low, fish and other aquatic life may die.

The concentration of dissolved oxygen (D.O.) present in a lake is important as it supports aquatic life. The solubility of oxygen depends on the temperature of the water - colder water holds more oxygen than warmer water. The amount of D.O. present in lakes at different times of the day, and at different depths, is largely determined by the processes of photosynthesis and respiration. Oxygen is produced when green plants grow (photosynthesis), and is consumed through respiration. Therefore, D.O. levels tend to be higher during daylight hours (when photosynthesis occurs), and lower at night/early morning. In addition, lake depths which are below the reach of sunlight may experience oxygen depletion. Oxygen depletion is especially apparent in winter months where snow cover prevents sunlight from penetrating the water, stopping photosynthesis and causing plants to die; this is termed "winter kill" and occurs in many eutrophic lakes.

In warm water, the water quality standard for D.O. is 5 mg/l, which represents the minimum amount needed for the survival and growth of warm water fish species. D.O. concentrations between 8 mg/l and 10 mg/l indicate saturation.

The D.O. levels in Big Roche-A-Cri Lake remained fairly consistent among the varying sample dates and depths ranging from approximately 5 mg/l to 11 mg/l, with the exception of depletion at the lower depths in August. This level of D.O. is adequate for fish growth and survival.

Trophic Status Indicators

Total Phosphorus Concentration (Total P)

Phosphorus is the key nutrient which influences plant growth in over 80% of the lakes throughout Wisconsin. Excess phosphorus promotes excessive aquatic plant growth. In most lakes, phosphorus is the least available nutrient, so it's abundance, or scarcity, controls the extent of algae growth. For that reason, phosphorus is typically referred to as the limiting nutrient. If more phosphorus is added to the lake from septic tanks, urban or farmland runoff, lawn or garden fertilizers, sewage treatment plants, or other watershed or outside resources, or even if it is released from phosphorus-rich lake bottom sediments, that limitation is taken away and more weeds and algae will grow. Under certain conditions, especially when oxygen is absent from bottom waters, phosphorus is released from bottom sediments into the overlying water. In turn, algae clouds water clarity and decreases the depth of light penetration.

Algae and weeds are a source of food and energy for fish and other lake organisms, and are a vital part of all lakes. However, excessive amounts or nuisance types of algae or weeds can interfere with lake uses by inhibiting the growth of other plants by clouding the water so that it shades them, contributing - as the decay - to oxygen depletion and fish kills, and causing taste and odor problems in water and fish. In addition, it can interfere with the aesthetic environment of the lake causing unsightly algal blooms which float on the lake surface forming scums. The regular occurrence of visible algal blooms often indicates that nutrient levels, especially phosphorus, are too high.

Aquatic plants may also limit many lake uses. Although aquatic plants (macrophytes) serve a vital function for the lake by providing cover, habitat, and even food for fish and other wildlife, an overabundance of rooted and floating plants can limit swimming, fishing, skiing, sailing, and boating activities, and aesthetic appreciation. Excessive plant growth can physically prevent mixing of oxygen through the water.

Two types of phosphorus analyses can be conducted which include soluble reactive phosphorus (orthophosphate) and total phosphorus; total phosphorus is a better indicator of the nutrient status of a lake because its levels remain more stable. The concentrations of Total P detected at the sample points and the corresponding WTSI values are presented in Table 3-1.

Table 3-1
Total Phosphorus Levels
Big Roche -A-Cri Lake

Sample Point	1	2A	2B
Average Total P ug/l	35	24	44
Range Total P ug/l	29 - 43	13 - 37	25 - 109
Average WTSI	56	53	58

The total phosphorus data indicates that Big Roche-A-Cri Lake is in a eutrophic category for lakes. The phosphorus concentrations in the upstream sample point (1) are similar to or larger than the sample point near the lake discharge. This points out that there is little or no negative impact of the immediate lake shore area on phosphorus concentrations in Big Roche-A-Cri Lake.

The WDNR guide Understanding Lake Data shows that an average total phosphorus concentration for impoundments is 65 ug/l. This guide also states that total phosphorus should be maintained below 30 ug/l for impoundment lakes in order to prevent nuisance algae blooms. As indicated in Table 3-1, the total P concentrations in Big Roche-A-Cri Lake exceeded 30 ug/l for all samples points at some time of the year. The total phosphorus concentrations in Big Roche-A-Cri Lake are lower than the average impoundment.

Chlorophyll a Concentration

Chlorophyll *a* is a green pigment which is present in all plant life and is necessary for photosynthesis. The amount of chlorophyll *a* present in a lake is dependent upon the amount of algae present, and is therefore used as a common indicator of water quality. It is also one of three characteristics used to determine the trophic state of a lake. Table 3-2 identifies the concentration of Chlorophyll *a* detected in Big Roche-A-Cri Lake and the corresponding WTSI status.

Table 3-2
Chlorophyll *a* Levels
Big Roche -A-Cri Lake

Sample Point	1	2A	2B
Average Chl. a - ug/l	2.6	6.99	3.38
Range Chl. a - ug/l	1.0 - 3.55	2.0 - 15	1.13 - 6
Average WTSI	42	50	44

Based on the results of the Chlorophyll *a* samples, the trophic status of Big Roche-A-Cri Lake was identified as being mesotrophic on average.

Secchi Disc Reading

A Secchi disc reading is a measure of water clarity; it is not a direct measure of water quality related to chemical and physical properties. However, water clarity is often indicative of a lake's overall water quality, especially the amount of algae present. Secchi disc readings are taken by lowering an 8 inch disc into the water, and taking the average of the depth where the disc disappears from sight and where it becomes visible again when raised. The Secchi disc reading can be used to determine the trophic state of a lake. Table 3-3 shows the average Secchi disc readings in Big Roche-A-Cri Lake and the corresponding WTSI status.

Table 3-3
Secchi Depth
Big Roche -A-Cri Lake

Sample Point	1	2
Average Secchi Depth - Ft.	4.75	6.9
Range Secchi Depth - Ft.	4 - 5	5 - 9.5
Average WTSI	55	49

Table 3-3 shows water clarity was much higher at sample point 2 compared to sample point 1. This is due to the shallow depth at sample point 1 which limited the depth that the Secchi depth could be lowered. The data from sample point 2 is more characteristic of the actual water clarity in the lake. These readings indicate the lake's water quality is in the mesotrophic range.

Non-Trophic Status Indicators

Orthophosphate

This chemical parameter is a measurement of the soluble phosphorus available for algae and weed growth. The concentration of ortho-phosphate will vary during the season in response to algae growth. When algae growth is at its peak, ortho-phosphate concentrations will be at a minimum.

Orthophosphate was measured in samples collected in all samples. The concentrations were relatively low in all samples and ranged from 5 ug/l to less than 2 ug/l. The highest concentrations occurred in June and the lowest concentrations occurred in September.

Nitrogen (Ammonia, NO2+NO3, and TKN)

Nitrogen is an important plant nutrient. While phosphorus is typically the limiting nutrient for algae growth, nitrogen can be limiting under some circumstances. Nitrogen compounds are present in lakes as inorganic or organic. The inorganic forms are ammonia and nitrite/nitrate ($NO_2 + NO_3$) and these forms are available to plants for growth. The organic form is included in Total Kjeldahl Nitrogen. This form is found in plant and animal tissues.

The data shows relatively high values for nitrogen compared to natural lakes. The value for nitrite/nitrate was 2.5 mg/l or higher for all samples. Total nitrogen exceeded 3.0 mg/l for all samples. Most values for natural lakes are less than 1.0 mg/l.

3.3 Conclusions

Temperature

The lake does not have strong stratification characteristic and has demonstrated a somewhat mixed condition for most of the year, meaning that the temperature of the water remains relatively stable from the top to the bottom of the lake. This is expected as the maximum depth of the lake is approximately 20 feet. Because the lake remains mixed, oxygen is distributed rather evenly throughout the lake for most of the year, as concluded from the D.O. concentrations. There are times, during the summer periods when some weak stratification has been seen. This is more evident in the DO readings than temperature.

Dissolved Oxygen

Typical of mesotrophic lakes, DO concentrations were lower at the bottom of the lake in summer and winter. At no time was the DO completed depleted even at the lowest depth. The DO concentrations were adequate for fish and other aquatic organism survival although fish likely moved out of the deepest areas when the DO was low.

Total Phosphorus

Concentrations of Total P were consistently in the eutrophic range. This was in contrast to the Chlorophyll a and Secchi disk readings which were consistently in the mesotrophic range. One potential reason for this is the large amount of weed growth in Big Roche-A-Cri Lake. Excessive weed growth shades the water, limiting the amount of light available to algae. Phosphorus is also used by the weeds rather than the algae.

Chlorophyll a

Measurements of chlorophyll a were in the mesotrophic range and tended to increase from the upstream portion of the lake to the downstream area of the lake. As indicated above, algae growth may be inhibited by the excessive weed growth in the lake. The measurement of chlorophyll a may not be a true representation of the water quality because of the weed growth.

Secchi Disc

The Secchi disc measurements were also in the mesotrophic range. Water clarity improves with a decrease in algae growth which is inhibited by the excessive weed growth.

Orthophosphate

Concentrations of orthophosphate were relatively low throughout the year and were below the level of detection in some samples in fall and winter.

Nitrogen

Inorganic and organic nitrogen compounds are relatively high in Big Roche-A-Cri Lake. This may be another reason for the excessive weed growth in the lake. The larger weeds are more dependent on nitrogen for their growth than algae are and the high nitrogen levels may account for the excessive weed growth.

Summary

The water quality parameters showed Big Roche-A-Cri Lake to be a eutrophic lake for phosphorus but mesotrophic for parameters measuring algae. The largest lake problem as identified by local residents is weed growth. The phosphorus and nitrogen concentrations are both high enough to encourage the excessive weed growth currently occurring in the lake. Adequate D.O. for fish and other aquatic life is available all year except for a short period in summer in the deepest part of the lake.

4 Groundwater Recharge/Discharge and Lake Level

4.1 Groundwater Recharge/Discharge

Most lakes are influenced to some degree by groundwater. Big Roche-A-Cri Lake is classified as an impoundment lake in which water levels are maintained by an inlet stream. The lake has a large tributary area and a relatively short detention time. Groundwater will typically have a minor impact on the lake water quality for an impoundment lake. This study collected data to determine the potential impact groundwater has on the lake.

Foth & Van Dyke installed groundwater piezometers along the lakeshore in four locations (See Map No. 1). These piezometers were monitored weekly over the summer months in 1999. The results are shown in Appendix B. The purpose of the piezometers was to determine groundwater flow direction. If the piezometer has a water level in the well lower than the adjacent lake level, then groundwater is flowing out of the lake at that point. If the piezometer has a higher water level than the adjacent lake level, then groundwater is flowing into the lake at that point.

The piezometer measurements showed a significant variation along the lake. At the east end of the lake, the groundwater is close to the level of the inlet creek. Here the groundwater flows into the lake. At the west end of the lake, the dam causes the lake level to be artificially high and is typically above the groundwater. The piezometer readings from the west end of the lake showed lake water flowing into the groundwater.

The practical application for this data is that septic systems around the lake do not necessarily discharge to the lake. On the west end of the lake, groundwater generally moves away from the lake and septic systems have little impact on the lake water quality. On the east end of the lake, groundwater moves into the lake when groundwater is high as evidenced by the data collected during 1999. Improvements to septic systems should focus on the east end of the lake.

Many residences have septic systems between the lake and their drinking water well. Since the groundwater flows away from the lake in most conditions, it is likely that the septic system effluent travels toward the well. This situation may contribute to nitrate and/or coliform bacteria in drinking water wells.


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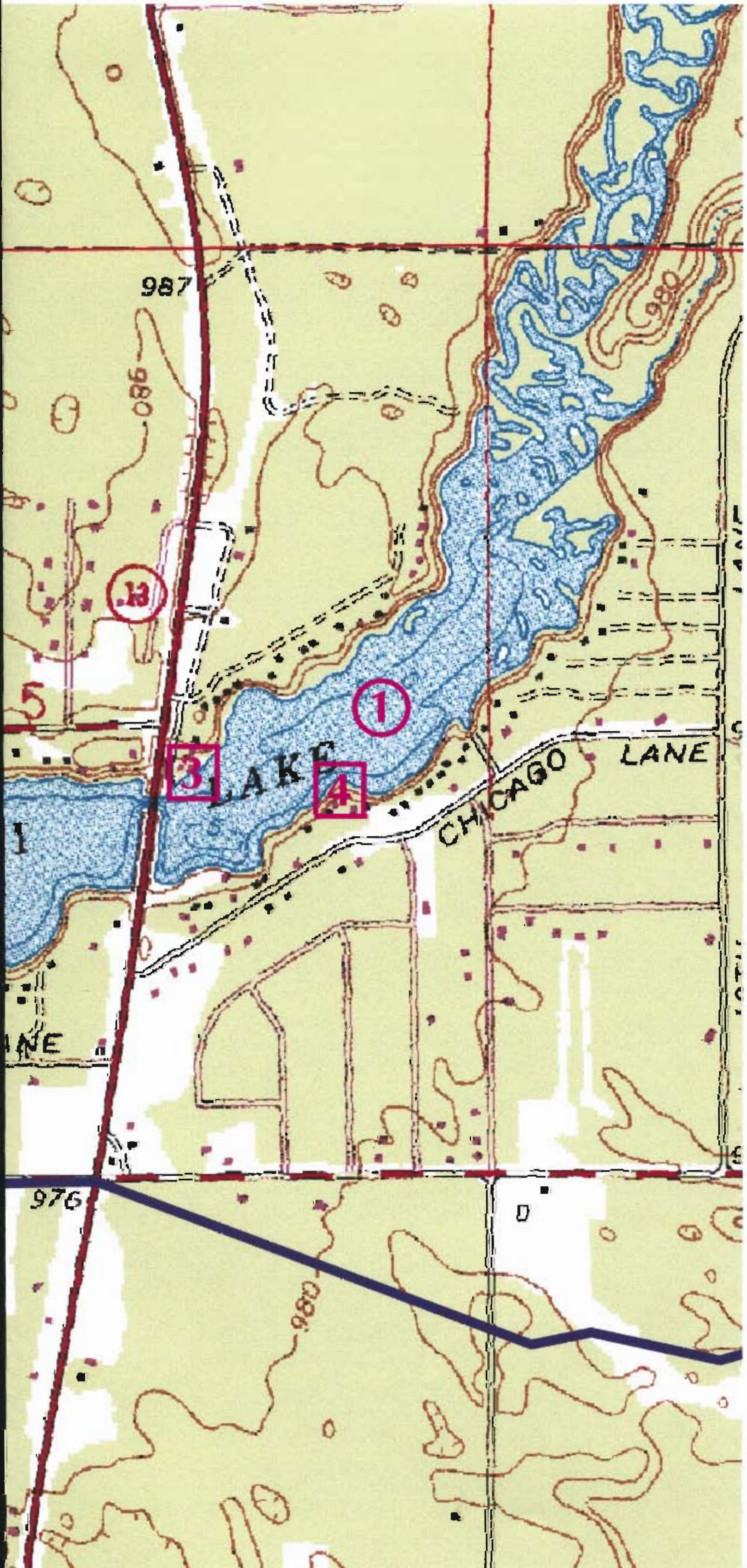
MAP 1
SAMPLING LOCATION PIEZOMETER WELL LOCATION
Big Roche a Cri Lake Watershed
Adams and Waushara Counties, Wisconsin



State of Wisconsin

- Big Roche a Cri Lake Watershed
- Minor Civil Division Boundaries
- (1) Sample Points
- [1] Piezometer Well

This drawing is neither a legally recorded map nor a survey and is not intended to be used as one. This drawing is a compilation of records, information and data used for reference purposes only.

Source: U.S.G.S. 7.5-minute topographic quadrangles - Arkdale NE, Coloma, Hancock, Roche a Cri (1984); Coloma, Coloma SW, Plainfield (1968).

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Foth & Van Dyke
consultants · engineers · scientists

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5 Sanitary Survey

A sanitary survey was distributed to all property owners within the District June, 1999, as part of the Phase I lake study. The purpose of the survey was to collect input regarding private wastewater systems to aid in evaluating the potential impact of private sanitary systems on the water quality of Big Roche-A-Cri Lake. All residences located along the lakeshore are currently equipped with private, on-site septic systems, almost all septic tanks and fields. Private septic systems can potentially have a negative impact on the water quality of the lake if they are improperly installed (including poor location selection) or maintained. The waste products of these systems contain nutrients which promote nuisance plant and algae growth. If these waste products enter the lake, the process of eutrophication can be accelerated and water quality may decrease.

The overall results of the survey and on-site observations are highlighted in this section.

5.1 1999 Sanitary Survey and On-Site Observation Results and Analysis

Sanitary survey responses were received from nearly 50% of all property owners of land along the Big Roche-A-Cri Lake shoreline. Results were collected by having residents fill out the survey form and return to the District and by Foth & Van Dyke doing a visual inspection of the site. Each form requested information on the type and age of the septic system, septic system problems, and the location of the septic system in relation to the lake. The complete results of the sanitary survey are included in Appendix C.

Based on the data collected from the sanitary survey and the observations from the field study, the following conclusions can be drawn:

- Most lots had homes located about 20 feet above the lake. Septic systems were located between the home and the road, well away from and above the lake. These systems appeared properly installed and would have little impact on lake water quality.
- On the northwest end of the lake, lots are lower and only 5 to 10 feet above the lake. Most septic systems are located 100 feet away from the lake. This situation describes about 20 homes. This area, however, has groundwater lower than the lake level and septic system discharges flow away from the lake.
- All survey respondents indicated that no problems were experienced with their systems, however they may not be educated on how to detect wastewater discharging to the surface or discharging indirectly.

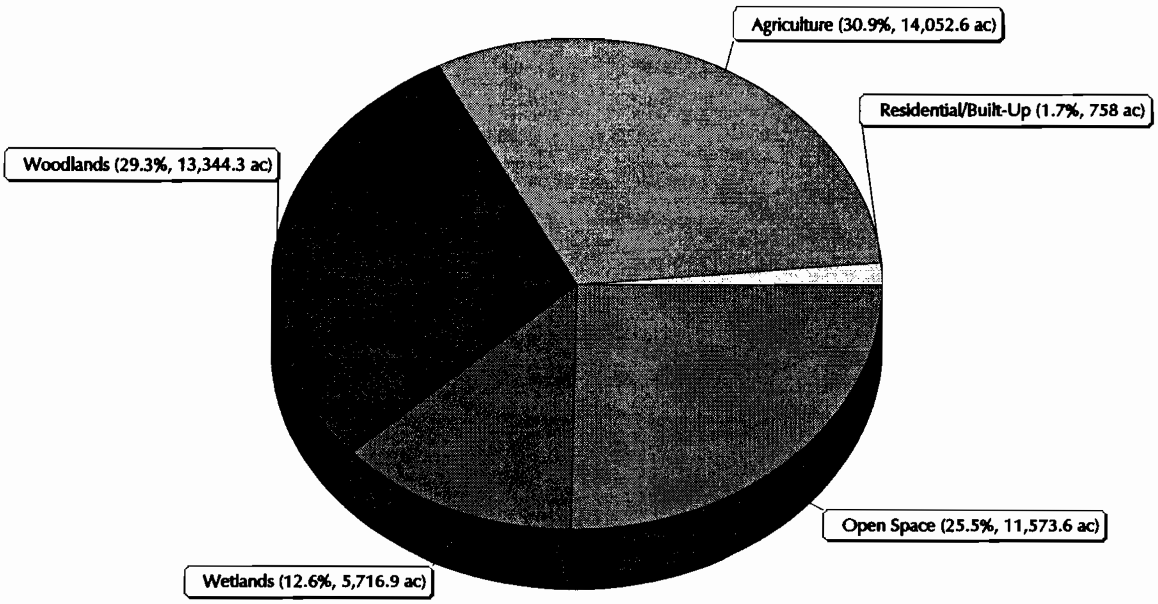
Based on this analysis, the on-site septic systems around Big Roche-A-Cri Lake are installed in appropriate locations (generally well above and away from the lake) for proper treatment. No failing systems or problem systems were identified. Therefore, on-site systems do not appear to be a significant source of pollutants to Big Roche-A-Cri Lake.

6 Watershed Analysis

A watershed is an area of land in which water drains to a common point, such as a stream, lake or wetland. A lake reflects its watershed because the watershed contributes both the water required to maintain a lake, and the majority of pollutants which enter the lake. Therefore, effective lake management programs must include watershed management practices, as lake problems generally cannot be solved without controlling the sources in the watershed. Managing the watershed to control nonpoint pollutants such as nutrients, soil, and other substances which originate over a relatively broad area is essential to protecting water quality. Water running over the land picks up these materials and transports them to the lake, either directly in runoff or through a tributary stream, drainage system, or groundwater. Water running off a lawn or driveway during a heavy rain is an example of nonpoint source runoff. Land uses such as agriculture, construction, and roadways contribute higher nonpoint pollutant loads than other land uses such as forests. Controlling nonpoint pollution sources can usually be achieved by implementing best management practices. However, it must be noted that nonpoint pollution sources are harder to identify, isolate, and control than point sources (distinct sources such as a wastewater treatment plant or an industrial facility). Controlling the water that runs from the land's surface into the lake is important as lakes receive water directly from drainage of the surrounding land (watershed) and precipitation.

The watershed, or land area, which drains ***into*** Big Roche A Cri Lake was delineated by the Wisconsin Department of Natural Resources (WDNR) and Foth & Van Dyke, and is illustrated on Map No. 2. The map was prepared using LandSat imagery which is made available by the WDNR. Figure 6-1 summarizes the land use classifications within the watershed and the total acreage and percentage of land use each comprises.

Figure 6-1
Generalized Existing Land Cover
Big Roche A Cri Lake Watershed, Adams & Waushara Counties



Source: WDNR LANSAT satellite imagery mapper from 1991, 1992, 1993; Foth & Van Dyke, 2000.

The watershed of Big Roche-A-Cri Lake is relatively large, and is situated within Adams and Waushara counties. The lake is fed by Big Roche-A-Cri Creek which runs through the towns of Preston, Big Flats, and Leola in Adams County, and the town of Plainfield in Waushara County. In addition, Dry Creek, which runs through the towns of Preston and Colburn in Adams County and the town of Hancock in Waushara County, flows into Big Roche-A-Cri Creek. Overall, the watershed of Big Roche-A-Cri Lake comprises a land area of 45,445.4 acres, while the lake itself comprises approximately 205 acres of surface water. Therefore, the watershed to lake area ratio is about 222:1. The larger the ratio, the more the watershed will have an impact on the lake through nutrient, pesticide, and soil runoff. It is typical for impoundment ratios to average ratios of more than 100:1.

According to the generalized land cover map of the watershed (See Map 2), agricultural land uses comprise the greatest amount of acreage, totaling about 31% of the watershed. Woodlands and Open Space areas follow close behind, comprising 29% and 25.5%, respectively. Wetland areas occupy nearly 13% of the watershed's total area. Residential uses (or other "developed" land) comprise under 2% of the land uses in the watershed. Within the watershed, residential land uses are concentrated in the area immediately surrounding Big Roche A Cri Lake. In fact, the majority of the 6.1 mile lake shoreline is developed residentially, leaving little room for public access. The only areas around the lake without development include near the western shore dam, the eastern inlet area, and the private summer campground located along the north shore of the lake.

Not all areas of the watershed are equal pollutant contributors. By identifying those critical areas that contribute excessive amounts of soil and nutrients to the lake, the most effective controls can be developed. For example, agricultural runoff carrying animal wastes, soil, and nutrients can be a critical pollutant contributor. Urban runoff from lawns, gardens, streets, and rooftops may be significant sources of sediment, oils and greases, nutrients, and heavy metals to lakes. Construction and forestry activities can provide significant quantities of sediments, especially during rainstorms. In small watersheds, lakeside residential activities may be more critical pollutant contributors. However, in large watersheds, the contributions from urban, forestry, and agricultural areas are generally more significant than those from lakeshore homes.

An estimation of phosphorus loading to Big Roche-A-Cri Lake was calculated based on the existing land uses illustrated in Map No. 2. Unit area loads by land use type in lbs/acre/year for phosphorus were provided by the WDNR. The unit area load by land use type was then multiplied by the total acreage The results of the calculation are identified in Table 6-1.

Table 6-1
Existing Phosphorus Loading (in lbs/yr)
Big Roche-A-Cri Lake Watershed

Land Use Class	Acreage	Phosphorus (lbs/yr)	% of Total
Residential/Built-Up	758.0	68.0	3.0%
Agriculture	14,052.6	1,265.0	56.2%
Open Space	11,573.6	347.0	15.4%
Woodlands	13,344.3	400.0	17.8%
Wetlands	5,716.9	172.0	7.6%
Total	**45,445.4**	**2,252.0**	**100.0%**

Source: Wisconsin Department of Natural Resources, Bureau of Watershed Management, Unit Area Loads by Land Use (lbs/acre/year); Foth & Van Dyke, 2000.

The table identifies the estimated existing phosphorus loadings for the Big Roche-A-Cri Lake watershed. Clearly, agricultural land use has the greatest impact on the lake's water quality based on the amount of phosphorus it contributes to the lake. As identified in the table, agricultural uses contribute approximately 56% of the phosphorus which enters the lake on an annual basis. There are some common "Best Management Practices" (BMP's) which can be used to help protect the lake's water quality from pollutants/nutrients. These BMP's are available from WDNR or local county extension offices.

In addition, however, Wetlands, Woodlands, and Open Space land uses also impact the lake's water quality, contributing roughly 40% of the phosphorus load to the lake annually. These contributions must also be considered but reductions in phosphorus load are difficult due to the more natural type of land use.

Another significant phosphorus source is from domestic wastewater. The potential phosphorus from this source can be estimated based on the following:

240 lakeshore homes (source: 1996 Big Roche A Cri Lake District Plan)
2.5 people per home
½ full-time occupancy average per home
0.006 lbs phosphorus/person

Total phosphorus from wastewater is estimated at 657 lbs/year. Of this amount, about 15% is removed in the septic tanks. The remaining 558 pounds is discharged to the soil for treatment and disposal. Phosphorus is generally removed efficiently by soil through the process of adsorption on soil particles. All soils have a finite capacity for retaining and adsorbing phosphorus. When that capacity is reached, phosphorus will pass through the soil to the groundwater and potentially discharge into the lake. Providing good wastewater treatment and keeping this source of phosphorus out of the lake should be part of a long term lake management plan. At this time, on-site systems appear to be removing phosphorus before it enters the lake. Also, many of these systems are located in an area where the groundwater flows away from the lake.

Big Roche A Cri Lake contains about 600 million gallons of water. With an average total phosphorus concentration of 30 ug/l, the average amount of phosphorus in the water is 150 pounds. The watershed evaluation identified an annual phosphorus load of 2,252 pounds with a potential additional load from septic systems. Each year phosphorus is removed by plant uptake, weed harvesting, sedimentation, and discharge from the outlet stream. Due to the large impact the inlet stream and watershed have on phosphorus entering the lake, any phosphorus removal measures done in the lake itself will have little impact on the phosphorus concentration in the lake.

7 Alternatives for Water Quality Improvements

The following presents some alternatives which may be implemented to improve the water quality of Big Roche-A-Cri Lake, and to slow the process of eutrophication. Alternatives include educating District property owners on ways they can contribute to improving the lake's water quality, improvements that can be made to sanitary systems, weed harvesting, and dredging.

7.1 Education

There are numerous ways individual landowners can contribute to maintaining or improving the water quality of Big Roche-A-Cri Lake through various land practices. Land owners should be provided with educational material explaining proper land practices and the benefits of them. While residential land use contributes minor amounts of nutrients to the lake, any improvements will be beneficial.

A number of human activities add nutrients to the water which promote excessive plant growth. The best long-term solution to control/prevent excessive plant and algae growth and improve water quality then is to prevent surplus nutrients and sediments from entering the water. Surface water runoff is a major source of nutrients and sediments in lakes. It should be noted, however, that variations in the natural environment (i.e., temperature, weather conditions, etc..) can also cause excessive plant growth.

This section identifies the ways in which private landowners can help to improve the lake's water quality by reducing surface water runoff and controlling soil erosion:

Landscaping Along the Waterfront

Landscaping along the shoreline is best kept in its natural state and provides several benefits which include:

- Protecting the water quality of the lake by filtering nutrients and pollutants from runoff before reaching the lake.
- Preserving the beauty of the shoreline by preserving the natural appearance and screening development from view.
- Providing wildlife habitat.
- Protecting the shoreline from erosion.
- Shading lakeshore water minimizing aquatic plant growth near shore.
- Low-maintenance care.

These benefits can be achieved by doing the following:

- Preserve Natural Shoreline Buffers: Leave the shoreline in a natural state if it has not yet been altered. In areas where the land slopes to the water, construct a berm back from the shore to detain runoff, allowing time for infiltration and evaporation of water.(local zoning regulations restrict shoreline vegetation removal).

- Restore Shoreline Buffer Areas: Leave a strip of unmowed grass, preferably 20 feet wide or more, along the shoreline; native flowers, shrubs and grasses will naturally grow in this area. Native species, including trees, may also be planted in these areas to add variety and provide more immediate results without requiring the use of fertilizers. The wider the buffer area, the greater the benefits.

- Shoreline Paths: Create pathways to the shoreline which follow natural contours rather than descend straight downslope to minimize erosion. Use wood chips or gravel for paving so runoff is not directed into the lake.

- Limit paved or impermeable areas. Dominating the landscape with driveways, patios, decks, and roofs increases the amount and velocity of runoff, carrying sediments and nutrients which cause nuisance plant growth, damage aquatic habitat, hinder recreational activities, and speed the eutrophication of the lake. Reduce the amount of runoff from driveways and patios by constructing them with porous paving bricks, and diverting water to areas where it can evaporate or soak into the soil.

- Minimize land slopes. Keeping the land as flat as possible reduces erosion. Terracing should be used to flatten areas of steep slope, such as those along the east shore of Big Roche-A-Cri Lake.

Lawn/Garden Care

It was observed during the field study that much of the lake is surrounded by well-kept lawns. The fertilizers and pesticides frequently used to maintain these laws and gardens can reach the water and negatively affect the water quality of the lake. A minimal amount of lawn area is recommended to maintain good water quality; ideally, native, low-maintenance groundcovers should be planted in place of lawn. There are ways however, to care for lawns and gardens which will preserve the water quality of the lake, including:

- Proper use of fertilizers and pesticides, including the use of no- or low-phosphorus containing fertilizers. Use fertilizer only if there is a nutrient deficiency present as shown by a soil test. For pesticides, avoid application 1) if rain is likely, 2) near the shoreline, and 3) near a well, do not dispose of them down a toilet or drain, do not mix different pesticides, and carefully follow the directions on the label.

- Choose a grass type or groundcover that is appropriate for your site and soils which requires minimal maintenance, fertilizer and pesticide application.

- Leave grass clippings on the lawn. This will provide up to one-half of the nitrogen the lawn needs. Do not burn grass clippings and leaves near the shore or rake them into the water.

- Do not mow more than ⅓ of the height of grass blades. Set the mower blade to 2-2½".

- Locate gardens away from the shoreline.

- Control garden pests by using natural controls and pest predators rather than pesticides.

- Add nutrients to gardens by composting aquatic weeds.

- Divert runoff from waterways. Downspouts should be directed to areas where infiltration can occur and not to areas of steep slope. Planting beds are a good location to direct downspout runoff.

- During construction, minimize soil disturbance and revegetate bare areas as soon as possible.

7.2 Sanitary System Improvements

Properly functioning sanitary systems are designed to remove the majority of disease-causing organisms and some nutrients and chemicals from household water and wastewater, keeping them from entering surface water and groundwater. However, these systems are not designed to treat many water-soluble pollutants. It is necessary, therefore, to take extra care in the maintenance of private sanitary systems, especially those located near surface waters or where groundwater is close to the surface. Malfunctioning, unmaintained, or improperly installed sanitary systems can result in the release of nutrients such as phosphorus which encourage nuisance weed and algae growth in the lake.

The following provides improvements that can be made to upgrade malfunctioning or improperly installed/located sanitary systems, and also identifies ways in which property owners can reduce the risk of a malfunctioning sanitary system through proper maintenance and waste reduction practices.

Based on the sanitary survey results and on-site observations presented in Section 5 there are no failing systems at this time. As the septic systems age and the risk of malfunctioning systems discharging wastewater into Big Roche-A-Cri Lake increases, some improvements to on-site systems should be made. These improvements may include:

- Relocate drainage fields on sites away from the lake, especially in areas of steep slope (i.e. uphill/across street from property if possible).

- Construct a cluster system with a number of other residents whereby one sanitary system has the capacity to be shared by multiple households. This is especially encouraged in areas where many small lots are grouped together and sufficient room is not available for individual systems.

- Change from conventional septic systems to holding tanks in areas of steep slope, where small lots are grouped together, and in low areas. Holding tanks can be successful if properly maintained.

- The District could develop ordinances allowing them to keep records of septic, mound and holding tank pumping frequencies for all systems in the District. This would encourage proper system maintenance.

In addition to sanitary system improvements, several recommendations are identified for properly maintaining private sanitary systems, whereby increasing the life of the system, reducing the chances of system malfunction, and more importantly reducing the incidence of allowing pollutants and nutrients to enter the lake (and groundwater):

- Decrease the amount of water used. There are several ways this can be achieved including using water-efficient appliances and flow restrictors, not letting faucets run unnecessarily, do dishes/laundry only when needed (full loads), etc.

- Use no- or low-phosphate laundry detergents and minimize the use of fabric softeners and water additives which contain phosphates. Detergents with less than 0.5% phosphate are considered low phosphate; usually liquid detergents are free of phosphates. Do not use detergents which contain fillers.

- Do not dump/pour products which contain contaminants, including pesticides, household chemicals, and solvents, or oil or grease down drains, on the ground, or down the driveway. Try to use products that are non-hazardous or less-hazardous.

- Divert discharge from wash water and water softeners from the lake; direct this water to the sanitary system.

- Avoid the use of garbage disposals.

- Don't drain sump pump water into the sanitary system, as this could increase the chance of a system overload.

- Have conventional and mound system tanks pumped at least once every year or every other year. Have holding tanks pumped upon alarm.

Malfunctioning sanitary systems can be detected by the following:

- Backup of sewage in drains or basement.
- Wet areas or ponded water over the drain field.
- Grass over the drain field is bright green (indicates effluent at the surface).
- An increase in aquatic plant growth along property's shoreline.
- Drains or toilets drain slowly.
- Sewage odors.
- Bacteria or nitrates detected in a nearby well water test.
- Biodegradable dye flushed through the system is detectable in the lake.

7.3 Weed Harvesting

The District currently conducts mechanical weed harvesting to control aquatic plants by remove (excess) plant materials from the lake which impair recreational and aesthetic opportunities. This should be continued on a regular basis.

7.4 Dredging

Sedimentation is caused by upstream erosion and from biological activity in the lake. This is a common occurrence in impoundment lakes. The sediment contains rich topsoil and decayed organic matter and provides a wonderful environment for growing weeds. With excessive weed growth being the major water quality problem in Big Roche-A-Cri Lake, dredging should be an alternative to consider for further study and implementation.

7.5 Water Level Drawdown

Many lakes lower water levels in winter. This allows sediments to be exposed and kills weeds. Regular drawdowns may reduce the weed growth in exposed areas.

7.6 Agricultural Runoff Reduction

This effort must involve state and local agencies. County land conservation agents and WDNR staff should be contacted to develop a strategy for runoff reduction.

8 Recommendations

This section provides recommendations which the District should implement to maintain and protect the water quality of Big Roche-A-Cri Lake.

8.1 Lake Management Plan

It is recommended that the District prepare a Lake Management Plan. A Lake Management Plan identifies the plan of action to be taken towards maintaining and protecting the water quality of a lake, including determining needs, setting goals, gathering and analyzing information, and developing alternative courses of action. Activities which could be included in the plan are:

- Water Testing
- Educational Programs for Lake Residents
- Develop Management and Implementation Plans for Lake Protection
- Evaluating and Developing Ordinances Related to Sanitation, Zoning, or Pollution Control

8.2 Evaluate Methods of Reducing Phosphorus Loading to the Lake

Phosphorus concentrations are consistent with other impoundment lakes and can potentially cause excessive weed growth. Methods of reducing phosphorus loading to the lake, or removing phosphorus from the lake, should be considered and included in the Lake Management Plan. Some methods include:

- Weed harvesting, including extensive fall harvesting.
- Implement a public outreach program to inform residents on ways to reduce phosphorus at home.
- Consider controlling/managing boating practices that may cause erosion or sediment disturbance
- Land use planning to minimize land use impacts on the lake.
- Cooperative efforts with agricultural land owners in the watershed reduce agricultural runoff and phosphorus loading to the lake.

The significant sediment deposits in the lake are also sources of sediment phosphorus. This source is available to water weeds during the growing season. When water flow is at a maximum in the creek, sediments may be eroded and phosphorus re-introduced to the water. Removing sediment will reduce this sediment source.

8.3 Lake Dredging

Dredging is an option to remove sediment and reduce weed growth. This option should be studied thoroughly before considering implementation. This option should be considered as part of a Lake Management Plan.

8.4 Water Level Management

This option should be considered as part of a Lake Management Plan. Lowering water levels in winter can reduce weed growth in summer.

9 Implementation

The Big Roche-A-Cri Lake District can begin the process of implementing the recommendations provided in Section 8 by applying for grants to assist with costs, sending out educational flyers to the property owners throughout the District, and proceeding with development of a lake management plan.

Lake Management Planning Grants are available from the Wisconsin Department of Natural Resources which provide cost sharing for the development of lake management plans and related activities. There are two application cycles to apply for these grants which include February 1 and August 1 of each year.

In addition, Lake Management Protection Grants are also available to assist in with the costs of implementing the recommendations of a lake management plan. The development of local regulations and ordinances, and lake improvement activities may be funded through these grants. Applications are accepted on May 1 of every year.

Educational flyers should be distributed to all property owners within the Big Roche-A-Cri Lake District, identifying ways they can contribute to the protection of Big Roche-A-Cri Lake's water quality.

Appendix A

Water Quality Data

Big Roche a Cri Lake
Water Quality Data

Date	Depth M	D.O. mg/l	Temp Deg. C	pH SU	Ammonia mg/l	NO3/NO2 mg/l	TKN mg/l	Redox Potential	Chl -a ug/l	Total P mg/l	Ortho-P mg/l	Secchi ft.
May 24, 1999												
Sample Point 1	0	8.74	11.8	8.33	0.016	3.4	0.69	281		0.029	0.005	4
Sample Point 2A	0	8.09	15.9	8.74	0.019	2.63	0.77	285		0.024	0.002	5
Sample Point 2B	5	5.63	15.6	8.79	0.027	2.54	0.76	292		0.026	0.002	5
June 28, 1999												
Sample Point 1	0	5.1	20.4	8.3				289	3.3	0.043	0.004	5.5
Sample Point 2A	0	6.6	25	9.3				270	4	0.013	0.003	9.5
Sample Point 2B	5	6.3	18.6	8.7				281	3	0.034	0.003	9.5
August 2, 1999												
Sample Point 1	0	7.4	18.7	7.7				97	1	0.037	0.01	5
Sample Point 2A	0	9.5	26	8.4.				98	15	0.037	0.003	5.5
Sample Point 2B	5	1.6	21.6	7.5				136	1.13	0.043	0.015	5.5
September 7, 1999												
Sample Point 1	0	7.28	15.17	9.15					3.55	0.03	0.002	5
Sample Point 2A	0	9.95	21.54	9.59					1.96	0.017	ND	9
Sample Point 2B	5	6.8	18.63	8.85					.6	0.025	ND	9
February 14, 2000												
Sample Point 1	0	10.7	0.6	7.2				337		0.036	0.004	4
Sample Point 2A	0	11	0.6	7.5				339		0.03	ND	5.5
Sample Point 2B	5	9.4	1.2	7.5				344		0.028	0.003	5.5
April 24, 2000												
Sample Point 1	0	8.8	10.9	8.2	0.03	2.48	0.51	360		0.035	0.003	5
Sample Point 2A	0	10.6	11	8.5	0.016	2.87	0.24	419		0.022	ND	7
Sample Point 2B	5	10.5	10.6	8.5	0.023	2.81	0.84	405		0.109	0.003	7

Big Roche a Cri Lake
Water Quality Data

Date	Total P ug/l	Total P TSI	Chl -a ug/l	Chl-a TSI	Secchi ft.	Secchi M	Secchi TSI
May 24, 1999							
Sample Point 1	29	54			4	1.2192	57
Sample Point 2A	24	53			5	1.524	54
Sample Point 2B	26	53			5	1.524	54
June 28, 1999							
Sample Point 1	43	57	3.3	44	5.5	1.6764	53
Sample Point 2A	13	48	4	45	9.5	2.8956	45
Sample Point 2B	34	56	3	43	9.5	2.8956	45
August 2, 1999							
Sample Point 1	37	56	1	35	5	1.524	54
Sample Point 2A	37	56	15	55	5.5	1.6764	53
Sample Point 2B	43	57	1.13	36	5.5	1.6764	53
September 7, 1999							
Sample Point 1	30	55	3.55	44	5	1.524	54
Sample Point 2A	17	50	1.96	40	9	2.7432	45
Sample Point 2B	25	53	6	48	9	2.7432	45
February 14, 2000							
Sample Point 1	36	56			4	1.2192	57
Sample Point 2A	30	55			5.5	1.6764	53
Sample Point 2B	28	54			5.5	1.6764	53
April 24, 2000							
Sample Point 1	35	56			5	1.524	54
Sample Point 2A	22	52			7	2.1336	49
Sample Point 2B	109	65			7	2.1336	49

Appendix B

Piezometer Readings

Big Roche - A - Cri Lake Water Quality Management Plan - Phase 1
Piezometer Readings

Date	Well No.	Distance To Lake Level - Ft.	Distance To Water Level - Ft.	Relative Piez level Ft.
May 24	1	1.52	1.65	-0.13
June 1		1.46	1.45	0.01
June 7		1.42	1.44	-0.02
June 13		1.5	1.55	-0.05
June 21		1.52	1.6	-0.08
June 28		1.47	1.54	-0.07
July 6		1.61	1.62	-0.01
July 12		1.54	1.64	-0.1
July 19		1.32	1.15	0.17
July 26		1.18	1.14	0.04
August 2		1.57	1.37	0.2
August 9		1.41	1.28	0.13
August 16		1.52	1.47	0.05
August 23		1.38	1.36	0.02
August 30		1.38	1.34	0.04
Sept. 7		1.39	1.32	0.07
Sept. 13		1.48	1.47	0.01
Sept. 20		1.44	1.44	0
Sept. 27		1.42	1.47	-0.05
Oct. 4		1.5	1.47	0.03
Oct. 11		1.53	1.5	0.03
Oct. 18		1.43	1.43	0

Date	Well No.	Distance To Lake Level - Ft.	Distance To Water Level - Ft.	Relative Piez level Ft.
May 24	2	1.5	1.22	0.28
June 1		1.43	1.29	0.14
June 7		1.38	1.15	0.23
June 13		1.49	1.24	0.25
June 21		1.52	1.28	0.24
June 28		1.43	1.24	0.19
July 6		1.58	1.31	0.27
July 12		1.52	1.35	0.17
July 19		1.35	1.14	0.21
July 26		1.18	0.68	0.5
August 2		1.53	1.06	0.47
August 9		1.38	0.87	0.51
August 16		1.54	1.13	0.41
August 23		1.36	1.03	0.33
August 30		1.38	1.05	0.33
Sept. 7		1.38	0.83	0.55
Sept. 13		1.44	1.14	0.3
Sept. 20		1.44	1.12	0.32
Sept. 27		1.42	1.12	0.3
Oct. 4		1.48	1.18	0.3
Oct. 11		1.52	1.23	0.29
Oct. 18		1.42	1.17	0.25

Date	Well No.	Distance To Lake Level - Ft.	Distance To Water Level - Ft.	Relative Piez level Ft.
May 24	3	1.52	1.48	0.04
June 1		1.48	1.46	0.02
June 7		1.38	1.39	-0.01
June 13		1.54	1.49	0.05
June 21		1.53	1.48	0.05
June 28		1.47	1.43	0.04
July 6		1.59	1.5	0.09
July 12		1.55	1.5	0.05
July 19		1.33	1.27	0.06
July 26		1.18	1.13	0.05
August 2		1.54	1.49	0.05
August 9		1.4	1.33	0.07
August 16		1.55	1.48	0.07
August 23		1.38	1.3	0.08
August 30		1.38	1.3	0.08
Sept. 7		1.4	1.35	0.05
Sept. 13		1.46	1.39	0.07
Sept. 20		1.42	1.39	0.03
Sept. 27		1.42	1.36	0.06
Oct. 4		1.47	1.43	0.04
Oct. 11		1.53	1.46	0.07
Oct. 18		1.42	1.35	0.07

Date	Well No.	Distance To Lake Level - Ft.	Distance To Water Level - Ft.	Relative Piez level Ft.
May 24	4	1.37	1.16	0.21
June 1		1.38	1.2	0.18
June 7		1.25	1.1	0.15
June 13		1.4	1.23	0.17
June 21		1.43	1.29	0.14
June 28		1.35	1.15	0.2
July 6		1.46	1.26	0.2
July 12		1.42	1.25	0.17
July 19		1.21	0.79	0.42
July 26		1.42	0.64	0.78
August 2		1.42	1.02	0.4
August 9		1.28	0.95	0.33
August 16		1.42	1.18	0.24
August 23		1.25	1.01	0.24
August 30		1.26	1.01	0.25
Sept. 7		1.26	1	0.26
Sept. 13		1.33	1.08	0.25
Sept. 20		1.33	1.08	0.25
Sept. 27		1.29	1.14	0.15
Oct. 4		1.38	1.13	0.25
Oct. 11		1.38	1.19	0.19
Oct. 18		1.31	1.08	0.23