INTRODUCTION

Since its inception in 1976, the Lake Redstone Protection District (LRPD), formerly the Lake Redstone Management District, has worked tirelessly to improve and protect Lake Redstone. The district has focused on building and maintaining valuable partnerships with Sauk and Juneau counties, the Wisconsin Department of Natural Resources (WDNR), watershed agricultural producers, consultants, and the United States Geological Survey (USGS). Through these partnerships, the LRPD has facilitated multiple studies and surveys, amassed data from the lake and its watershed, and implemented several projects aimed at improving water quality and habitat. A pinnacle accomplishment of the district is the completion of the Lake Redstone Nine-Key Element Plan (9KE) in 2022. The implementation of that plan began in 2022 and continues to this day.

The primary objective of the LRPD and the 9KE plan is to improve water quality in Lake Redstone. Through the work of the LRPD, its partners, and the development of the 9KE plan, a great deal of water quality data, from several sites, has been collected over the years. Much of that data has been analyzed and summarized in multiple reports. Still, questions remain in the minds of the active district members regarding possible recent trends in water quality, algae blooms, sources of nutrients, and possible remedies. The objective of this report, and the work leading to it, is to answer some of these questions. For the questions that cannot be answered at this time, discover gaps in the available data and information that may lead to an answer, and where possible, provide a preliminary project design and timeline of the collection of that data.

It is not the intent of this report to provide summaries of the data that were reviewed or to deeply discuss the results and conclusions found in the reports and datasets reviewed. Further, specific project scopes and designs are not included here, nor are the estimated costs for completing those projects. It is up to the LRPD to determine the projects they would like to sponsor and solicit specific project designs and proposals for that work.

INFORMATION REVIEW AND DATA GAP DETERMINATION

Several sources were utilized to discover the available data and information regarding Lake Redstone, its watershed, and the work that has been completed to improve and protect them. These sources include communications with Ken Keegstra beginning in May 2024, information and datasets provided by Ken, numerous communications between the district, agency staff, and consultants. Data were also reviewed on the WDNR SWIMS site and Surface Water Viewer. The primary sources of information and data included the 2017 Strategic Lake Management Planning Review Lake Redstone and the 2022 9KE Plan. Much of the information in the 9KE Plan was supplied by the former document or an updated version of the information supplied in that document. The development of the 9KE Plan utilized information for the Wisconsin River Total Maximum Daily Load (TMDL) developed by the WDNR and approved by the Environmental Protection Agency in 2019. Additional information was provided by a memorandum written by Patrick Oldenburg in April 2021 describing updated modeling he had completed for Lake Redstone and some additional information on potential nuisance algal bloom frequencies that could result following successful TMDL implementation.

POTENTIAL PROJECTS

This list of potential projects below is not in any particular order. There is no priority to the list, and it is very likely incomplete because new questions will arise as current questions are answered. Further, our understanding of lakes and methods for collecting and interpreting data change, and new stressors on lakes continually come into play.

Water Quality Summary Report

The 9KE plan includes water quality data spanning the late-1980s through 2020. Analysis completed by Oldenburg found a slight trend of increasing phosphorus at the deep-hole site from 1988-2019, but he stated that the increase is likely attributable to aging of the flowage as opposed to increases in external loading over that timeframe. Natural lakes age through the process of eutrophication, which is essentially a slow increase in nutrients within the lake that increases primary production in the lake over time. Eutrophication is Mother Nature's way of filling in a lake, which is started from the day it is created. In natural lakes, this processes can take millennia and can be unnoticeable in a human lifespan. In flowages, the eutrophication process is greatly accelerated as Mother Nature works to return the man-made lake to its natural form of a stream. In many cases, long-term residents of flowages observe the eutrophication in real-time as their lake supports more and more plant biomass and fills in with organic and inorganic sediments over time. Therefore, Oldenburg's comment on the increased trend in phosphorus concentrations from 1988-2019 is reasonable. Oldenburg's analysis also found that there was not a significant trend in phosphorus from 2006-2019 at the deep-hole site.

As described above, the LRPD has worked to monitor and improve water quality in Lake Redstone for decades. Their concerns were heightened in summer 2024 when very high levels of chlorophyll-*a* and very low water clarity were measured during volunteer sampling. Questions were raised regarding the causes and particularly about the sources of nutrients driving the algal blooms. In lakes, unique or rare occurrences of phenomenon, like intense algae blooms, fishkills, or loss of vascular plant life, are never the result of a single event, stressor, or impact, they are the result of a cumulation of events, stressors, and impacts.

Lake Redstone's phytoplankton population is limited by the amount of phosphorus available to the algae (see Section 4.3 in 9KE Plan). Infrequently, this may not be the case as nitrogen may be the limiting factor. Nitrogen limitation would not be brought about by an under abundance of nitrogen in the system, but by a temporary overabundance of phosphorus in the system. The overwhelmingly dominant source of phosphorus in Lake Redstone, and in most flowages for that matter, are external to the lake and arrive via surface water flows. This is made clear in the 9KE Plan and the reasoning that the majority of the work in that plan is slated to occur in the watershed. All other sources, like geese feces, sediment resuspension brought on by powerboats, wake boats, and carp, and internal nutrient loading all add to the available phosphorus for algae growth, but if addressed individually or even in combination, may not bring about a significant decrease in algae blooms. The LRPD's thoughts on high spring flows, followed by possibly higher than normal summer temperatures, is likely the bulk of the cause behind the high chlorophyll-*a* readings collected in August 2024. A pulse of nutrients followed by warm water temperatures often leads to algae blooms. Again, the other in-lake sources certainly add to the availability of phosphorus, but individually, or in combination, likely do not control it.

The water quality summary should focus on the trophic parameters from Lake Redstone through the most recent data available. The trophic parameters include total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Each parameter should be discussed separately, including trends in the long-term dataset and in more recent years, similar to how Oldenburg presented total phosphorus trends in in 2021 memo. Trophic state index values should also be calculated and discussed.

The more recent data could also be compared to flow and loading data collected by the USGS from 2020-2024. It is important to note that increases and/or decreases in trophic data over the last five or so years may not be the start of a trend in a certain direction but just cycles as seen throughout the long-term dataset (see Figure 9 in 9KE Plan).

Oldenburg compared means from the four most sampled lake sites, the deep-hole, lower, middle, and upper sites. He determined that the lower and deep-hole sites are statistically the same, but the deep-hole is different from the middle site. The middle, upper, and lower sites are statistically the same. He concluded that supplementary monitoring, if completed, would only need to include the deep-hole site and the middle site. For this reason, the water quality summary should focus upon the deep-hole and middle sites.

Canada Goose Control

Studies have shown that geese and other waterfowl can add phosphorus to waterbodies through their feces. High populations of geese can leave massive quantities of aesthetically unpleasing waste behind as well as damage valuable native plants, landscaping, and agricultural crops. Estimates vary widely, but it is certain that the geese, if in large numbers, can add phosphorus to a lake. In Lake Redstone, the amount added to the lake's annual phosphorus budget may be insignificant when compared to external sources, but a decrease in overall inputs, especially as the watershed plan is implemented, would be a positive in the long-run.

Some lake groups conduct or sponsor large-scale goose control in and around their lakes. This includes oiling eggs (addling) and the physical removal and euthanasia of geese. The control requires training and a permit through the US Fish and Wildlife Service and WDNR. Lake Iola Lake District has conducted goose control since 2015 and may be willing to provide information. The Lake Iola Lake District email address is listed as iolalakedistrict@gmail.com on the Village of Iola website.

Near-Shore (Residential) Load Reduction

The 9KE Plan includes discussion and some estimates of phosphorus loading from the developed properties around the lake. Table 7 in the 9KE Plan includes estimates of potential loading from these areas that were developed with the WI Lake Modeling Suite (WiLMS). WiLMS is a screening level suite of models that works well to provide a general overview of how watershed land uses impact the phosphors budget of a lake. Narrowing the focus to a single component, like a small section of land, or the immediate shoreline of a lake, sheds light on that area's impact, but the calculated loading estimate may not be very accurate.

Creating a more detailed estimate of how the implementation of different best management practices (BMPs) on developed near-shore properties can reduce phosphorus loading to Redstone

Lake may be useful in convincing property owners to initiate projects. This could lead to meeting some of the objectives in Section 6.2 of the 9KE Plan. Dr. Paul McGinley, Professor and Director of the Center for Watershed Science and Education at UW-Stevens Point, presented work he and others have completed on developing a model for determining the impacts of installing different types of BMPs on lake shore properties (https://www3.uwsp.edu/cnr-ap/UWEXLakes/Documents/programs/convention/2024/Friday/McGinleyandFerris_ModelingPhosphorusReductions.pdf). The model is based upon the EPA Storm Water Management Model (SWMM) and includes the input of impervious surface area, characterization of slope, infiltration rate, and buffer existence between the developed portion of the property and the lake. The model will estimate a range of possible shoreland phosphorus runoff loads, then certain BMPs can be added, such as a raingarden or an infiltration trench, and a range of percent reductions is calculated.

Dave Blumer, the lead author of the 9KE Plan, digitized a 300-ft band surrounding Lake Redstone in 2019. Impervious surface, lawns, forested, and wetland areas were digitized. These data, along with slope data developed with county LiDAR, and data collected during the shoreland assessment completed in 2018, could be used to model the most impactful properties on Lake Redstone to determine the possible phosphorus loading reduction that could be achieved with the installation of appropriate BMPs. An appropriate starting point would be the red and orange properties discussed in Section 3.2.1.1 and shown in Figure 18.

The first step in this project would be to contact Dr. McGinley to determine if the correct data are available to populate the model. Further, Dr. McGinley would be able to shed light on the effort necessary to complete the modeling assessment and the usefulness of the results.

Phytoplankton Community Survey

Lake Redstone supports frequent algae blooms with some, like those that occurred during late-summer 2024, being intense and raising concern among district members. Cyanobacteria (blue-green algae) are likely present, but their abundance, species composition, and tendency to produce cytotoxins is unknown.

Cyanobacteria ecology is complicated, and scientists and agencies are studying cyanobacteria around the globe. So, even if cyanobacteria do exist and possibly produce toxins in Lake Redstone, it would be unrealistic to assume that studies can be completed to determine the specific factors driving cyanobacteria growth in the lake in hopes of discovering a solution to prevent the growth. Ultimately, better understanding the algae community in Lake Redstone, specifically the occurrence and field-identification of cyanobacteria blooms, would have the end goal of protecting human and pet health around the lake. In general, reducing phosphorus loading will result in reduced algae growth, including cyanobacteria.

Gina LaLiberte (Gina.LaLiberte@wisconsin.gov), Water Resource Management Specialist-Advanced, with the WDNR is an algae expert. Ms. LaLiberte may be able to direct the LRPD in developing a volunteer-based monitoring program. The volunteer samples could be viewed by Ms. LaLiberte, or possibly the Wisconsin Laboratory of Hygiene (WSLH) to determine algal community structure. The volunteers could also be trained to recognize cyanobacteria blooms and collect samples for cyanotoxin analysis by the WSLH Environmental Toxicology Dept. In time, the volunteers would be able to recognize blooms that may require inspection by the Sauk County Health Department, which may lead to water contact warnings.

Internal Nutrient Loading Study

All lakes have some level of internal nutrient loading occurring within them. Internal nutrient loading is simply the recycling of nutrients between the sediments and the biota of the lake. In some lakes, especially those that were subjected to unusually high external sources of nutrients, internal loading makes up a significant portion of the lake's annual nutrient budget. After the external sources are minimized, the internal loading can continue to drive nuisance algae blooms. In most cases, the nutrient of concern is phosphorus.

In the presence of oxygen, phosphorus binds with iron and is settled to the bottom of the lake and taken out of the biological side of the cycle. In dimictic lakes, those lakes that stratify during the summer and winter and turnover (mix) during the spring and fall, the bottom layer of water (hypolimnion) can be come anoxic. This causes the iron and phosphorus to dissolve back into the overlaying water. The density gradient between the hypolimnion and the upper layers (metalimnion and epilimnion) prevents the phosphorus from entering the upper layers and being utilized by algae. However, a large portion of the phosphorus is mixed into the full water column of the lake during fall turnover. Often, the water is too cold at that time to allow for algae blooms to develop, but in some cases, the increased phosphorus concentrations persist through the winter and spur algae blooms in the spring. Under winter ice in some lakes, the hypolimnion, which now contains the warmest water in the lake (inverse stratification), becomes anoxic, bringing about high phosphorus levels which are subsequently mixed into the water column during spring overturn. Again, these high phosphorus concentrations can drive algae blooms throughout the spring and into the summer.

Internal loading is occurring in Lake Redstone to some degree. John Panuska completed a water quality modeling exercise for Lake Redstone during 1995-97 (see Strategic Planning Review). He concluded that internal phosphorus loading may account for up to 29% of the lake's annual phosphorus budget. He concluded that internal loading did not significantly contribute to algal growth in the lake.

Panuska's estimate of 29% is high – it's nearly a third of the lake's budget; however, just because the phosphorus is recycled into the water column does not mean it is utilized by algae. A portion of it, as soon as it is exposed to oxygen, is bound with iron and returns to the sediment. This cycle of binding and unbinding between phosphorus and iron is the "ferrous" wheel discussed by Richard Lathrop in several communications with the district. Some of it likely goes over the dam that fall and during the winter. During the spring, when the lake turns over and potentially mixes high concentrations from the winter hypolimnion into the water column, the flows are typically the highest of the year, so much of that phosphorus is likely exiting the lake. By the time the water warms and starts to stratify another portion is bound to iron and taken out of the biological portion of the cycle and settles to the bottom. Then the cycle begins again.

The concept of internal phosphorus loading is straight forward; however, understanding how that recycling of phosphorus impacts algal production is complicated. If internal loading does not foster algae blooms, it is not an issue and would likely go unnoticed. If it does drive nuisance algae blooms, then there is an issue, and it is surely noticeable by lake users.

A complete internal loading study includes two primary components: 1) an intense and extended water quality sampling program, and 2) sediment core collection and analysis. The former tracks phosphorus mass in the different water layers throughout the growing season, fall, winter, and spring. The latter determines the amount of phosphorus in the first 5-10 cm of sediment that is the available for internal loading (phosphorus fractionalization analysis) and what the potential phosphorus release rate is under anoxic and oxic conditions. The fractionalization analysis is also useful in determining an alum dosing rate if that technique is determined to be appropriate.

Water quality collections would occur over a three-year period and include temperature, dissolved oxygen, and phosphorus profiles throughout the summer and winter periods. During the summer months, the lake would be sampled every two weeks and during the winter on a monthly basis or as ice cover allows. Sampling would also occur following ice-out to the start of stratification and would include frequent temperature and dissolved oxygen profiles and infrequent phosphorus sampling. Less frequent sampling would be completed following fall turnover to ice-on. In all of these cases, except the summer, the exact frequency of sampling would need to be determined. The sampling would be completed by a mix of volunteers and professionals.

The objective of the sampling program would be to determine the rate of phosphorus build-up in the hypolimnion during summer stratification, and to the best extent possible, during winter stratification. The spring and fall sampling would be used to determine where the phosphorus goes following spring and fall turnover. The sampling would also lead to a better understanding of how much phosphorus is persisting through the winter following fall overturn. If the USGS continues to monitor flow at the dam, those data could be tied with surface phosphorus concentrations to determine how much phosphorus exits the lake. This would be most important in determining how much of the phosphorus that is brought up from the hypolimnion during turnover events ends up going over the dam.

The study could also include periodic sampling of iron concentrations in East and West Big Creek to determine if Richard Lathrop's thoughts on an alum treatment reducing iron levels through sulphate binding should be a real concern if an alum treatment were ever to be completed. This is not typically considered in an alum treatment plan, but additional data collection could be included if the district believes it is warranted.

Sediment cores would be collected from the lake early in the growing season and likely include several cores within the deepest part of the lake. The sediment cores would be sent to the Center for Limnological Research and Rehabilitation at UW-Stout for phosphorus fractionalization analysis and sediment phosphorus release analysis.

While internal nutrient loading is currently a great concern of the district, these studies should not be carried out until the watershed phosphorus loads are minimized to the greatest extent possible. This is a slight deviation from what is discussed in the 9KE Plan in Section 5.3.1. The external loads to the lake are surely the major force driving water quality of Lake Redstone. Completing these studies now would likely indicate that internal nutrient loading is occurring in the lake. And even if there are high amounts of phosphorus being recycled, its role in the lake's nuisance algal bloom frequency is likely small compared to the external loads. It may not be insignificant, but like goose droppings, wake boats, power boats, and carp, preventing its load is likely not going to be apparent in the lake's water quality until the external loads are controlled to the best extent possible. Further if the internal phosphorus load was found to be highly significant, in the order of 50% of the total load, completing an alum treatment before the external loads are minimized would be futile. It would be like shoveling a driveway before the snow stopped falling. At the current level of external phosphorus loading, the benefits of a successful alum treatment may last only a few years. Alum treatments typically cost hundreds of thousands of dollars, so if one is going to be completed, the benefits should be seen for at least 15 years or more.

Continued Water Quality Monitoring

The 9KE Plan spans from 2022 to 2032. It will take time to see the benefits of the work in the watershed. This is why continued water quality monitoring is important. Continued trophic parameter collections should occur under the Citizens Lake Monitoring Network at the deep-hole, and if possible, at the middle site. These collections can be enhanced by temperature and dissolved oxygen profile collections and hypolimnetic phosphorus determinations during July and August from the deep-hole site.

While the yearly results may be interesting, the trends over the long-term should be considered the most important because they indicate what is truly happening in the lake. All lakes have good years and bad years, and as described above, it is a cumulation of many factors that drive a lake's water quality. So, trying to determine exactly why a lake had poorer than normal water clarity one year in an attempt to make sure it does not happen again is very likely a waste of time. Focusing on the long-term water quality trends is the best way to determine if the implementation of the 9KE Plan is having a positive impact on the lake. If after a decade or so the benefits are not being seen, then it may be time to reassess and create a new plan. Please note, this is what the 9KE Plan calls for in the management of Lake Redstone.

SUMMARY

- **Water Quality Report**: Summarize existing data on total phosphorus, chlorophyll, and Secchi depth, especially incorporating data from recent years. Relate recent levels of trophic parameters to loadings from the watershed as monitored by the USGS.
- **Geese**: This is likely a minor contributor to the overall phosphorus input, but actions are available to reduce the impact of the deposition of geese feces.
- **Shoreland runoff**: Dr. Paul McGinley of UW-Stevens Point has developed a model which estimates phosphorus runoff from shoreline residences and potential reductions in phosphorus runoff with various BMPs.
- **Phytoplankton**: Determine the dominant algae during blooms and monitor levels of cyanobacteria toxins.
- **Internal Loading**: Estimating the amount of phosphorus from this source should not be undertaken until there has been a significant reduction in phosphorus input from the watershed.
- **Water Quality Monitoring**: Continue to monitor key water quality indicators such as total phosphorus, chlorophyll, and water clarity (Secchi disc depth).