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FINAL REPORT

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Preliminary Design Report Engineering Services for Wastewater System in Browntown, Wisconsin

CIVIL ENGINEERING 578 – SENIOR CAPSTONE DESIGN
GEOLOGICAL ENGINEERING 479 – GEOLOGICAL ENGINEERING DESIGN

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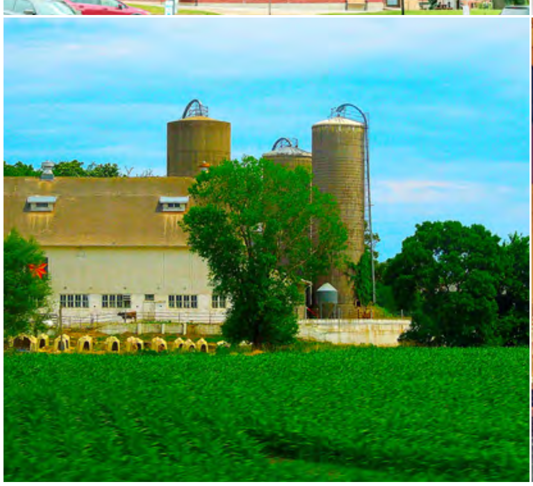

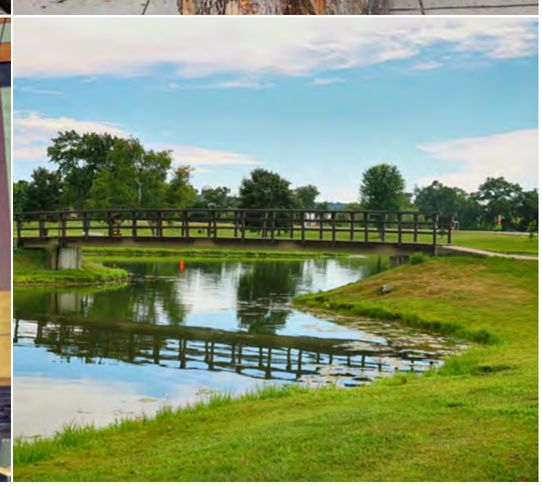

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Preliminary Design Report Engineering Services for Wastewater System in Browntown, Wisconsin

Prepared For:
Village of Browntown, WI

Prepared By:
M.M. C.R.B. Consultants

April 6th, 2021

M.M. C.R.B. Consultants
1415 Engineering Drive
Madison, WI 53706

April 6, 2021

TO:
Jan Kucher, PE Adjunct Professor
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

RE: Preliminary Design Report
Engineering Services for Wastewater System Phosphorus Removal Village of Browntown, WI

Dear Professor Kucher,

M.M. C.R.B. Consultants appreciates the opportunity to submit a Preliminary Design Report for Phosphorus Removal in the Village of Browntown's Wastewater Treatment Facility. In this report, our team presents issues being faced by the facility and solutions to those issues. Our team has studied project details and constraints outlined in the proposal and has met with the facility manager and associated consultants. In-depth research and calculations have been completed on multiple solutions for the problem.

In this report, we also explore current site conditions and regulations that are applicable to each alternative. Several engineering disciplines are considered, including environmental, geotechnical, structural, construction, hydraulic and hydrological engineering. A cost analysis for each option and a decision matrix is included as well. With this analysis comes our team's recommended design alternative for the Wastewater Treatment Facility.

We appreciate your time and consideration and look forward to the opportunity to provide a proper solution. If you have additional questions or concerns, please feel free to contact me.

Sincerely,

Project Manager
M.M. C.R.B. Consultants

Disclaimer

The concepts, drawings and written materials provided here were prepared by students in the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison as an activity in the course Civ Engr 578 – Senior Capstone Design/GLE 479 – Geological Engineering Design. These do not represent the work products of licensed Professional Engineers. These are not for construction purposes.

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1. Executive Summary

The Village of Browntown Wastewater Treatment Facility (WWTF) treats wastewater for the village of 280 people. The scope of treatment includes treating for mostly residential households, a few small businesses, and a one large industrial facility. The WWTF includes two aerated lagoons with a primary and secondary cell and then a chlorination disinfection tank. After the water is treated, it is discharged to Skinner Creek.

The purpose of this project is to reduce phosphorus levels in the effluent of the WWTF to comply with upcoming interim discharge limits in the WWTF's Wisconsin Pollution Discharge Elimination System (WPDES) permit. The target effluent total phosphorus (TP) levels need to be below 2 milligrams phosphorus per liter (mg-P/L). Along with this issue, the client would like to help reduce leakage that is witnessed into the WWTF as well. The proposed solution must follow the triple bottom line in order to be socially, environmentally, and economically sustainable. The recommended solution must be adaptable in order to meet future standards set by the Wisconsin Department of Natural Resources (DNR). Along with these requirements, the firm must design a system that falls within the requested budget presented by the Village.

Within this project, there have been multiple constraints that need to be considered in order for the project to be successful. The first constraint is the budget set by the client. Considering the size of the Village, the overall cost needs to be reasonable and have a low annual budget. This includes the maintenance level of the recommended solution. The staff for the WWTF is small and mostly limited to one person. Therefore, the solution needs to be adaptable and efficient to maintain throughout the year. Another constraint the project is facing is the space. There is a limited area of land available for expansion near the facility which means that the solutions have mostly been limited to the current set up with advancements made in terms of technology or processes used.

For the Village, four alternatives have been analyzed in terms of reducing the phosphorus levels to meet the DNR requirements. The first option is tertiary treatment with chemical polishing. This alternative involves adding a chemical treatment to the lagoon system and then implementing a filter system to help remove phosphorus to further treat the remaining phosphorus. This alternative would need little land for new structures and would be highly efficient. The second alternative would be chemical precipitation. A chemical solution would be added to the system to help facilitate the removal of phosphorus. This option would be low cost and low maintenance for high efficiency operations. The next option is a recycled concrete aggregate (RCA) bed implemented to help separate phosphorus from the system. This alternative uses recycled material and the design is quite simple. However, it would have a large annual cost mainly due to material usage. The final alternative is the construction of a nearby wetland. This option needs a large land base and therefore would require larger capital costs than most. However, it needs little maintenance and has a low environmental impact. A decision matrix further reiterating these ideas can be seen in Table 1.1. As shown in the table, six factors were used to compare the alternatives. Each alternative was weighted on a scale of 1-4 with 1 being the worst score and 4 being the best score. The weights were then multiplied by the score and totaled in order to determine the weighted total.

Table 1.1 Decision Matrix of Preliminary Design Alternatives

Factor	Weight	Filtration with Chemical Polishing	**Score**	Chemical Precipitation	**Score**	Concrete Bed	**Score**	Constructed Wetland	**Score**
Efficiency	24%	4	.96	4	.96	3	.72	2	.48
Maintenance	18%	3	.54	3	.54	2	.36	4	.72
Sustainability	18%	3	.54	3	.54	3	.54	4	.72
Land Required	15%	3	.45	4	.6	3	.45	1	.15
Annual Cost	15%	3	.45	4	.6	1	.15	2	.30
Capital Cost	10%	1	.1	4	.4	3	.3	2	.2
Weighted Totals			3.04		**3.64**		2.52		2.57

As seen in Table 1.1, chemical precipitation has the highest weighted score and is therefore the most effective option. This alternative is recommended as it will not only lower phosphorus concentrations to below 2.0 mg-P/L, but will also offer low operating costs and flexibility. The chemical precipitation alternative can be adjusted easily with changes to site selection, chemical selection, and amount of treatment. This alternative is also quite common amongst other treatment facilities for these reasons. If the Village selects this alternative, the project will move into the final design phase and then towards construction of the alternative.

M.M. C.R.B. Consultants look forward to continuing to work with the Village of Browntown and hope we have provided adequate design alternatives for the WWTF. Details on all four alternatives, site selection, cost estimation, and scheduling can be found in this remainder of this report. We hope to implement a sustainable and cost effective alternative that will remain beneficial to the community for years to come.

2. Introduction

The Village of Browntown (Village) in Wisconsin has tasked M.M. C.R.B. Consultants with evaluating, designing, recommending, and implementing updates to their wastewater treatment facility (WWTF). Currently, the facility is facing an issue with the phosphorus levels being too high due to current limit alterations and issues with leakage from high inflow and infiltration. By completing a thorough evaluation of the WWTF design and solutions, four possible alternatives have been presented in detail in this report.

2.1 Project Background

The Village of Browntown is located in Green County in south-central Wisconsin, which is shown in Figure 2.1. In 1890, the Village was officially incorporated. Home to industry and residential areas, the Village connects Wisconsin natives to the Tri-County Cheese Trail along with an ATV and snowmobile trail. The WWTF is responsible for treating wastewater for the entire community. This includes roughly 280 people along with local businesses and facilities. However, to help plan for future population growth in the next 20 years, a population of 335 will be used as an estimate for design. The last major update to the WWTF was completed in 1979. Currently, the Village will require upgrades to meet upcoming effluent phosphorus discharge requirements. There have also been issues with infiltration and inflow (I&I) into the Village's sewer system.

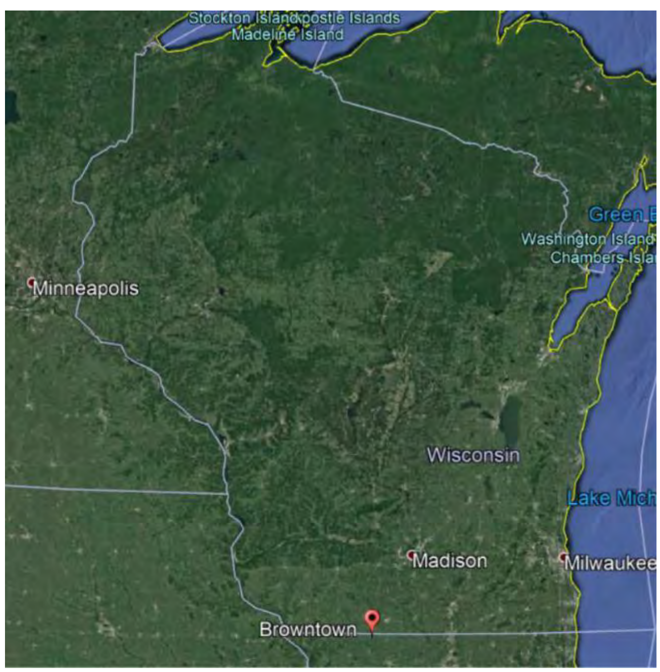


Figure 2.1 Location of Browntown, Wisconsin

Before wastewater reaches the treatment facility, it is collected via the sewer system network and directed to the pumping station, which is located southwest of the facility. A comminutor that precedes the pumping station grinds up large solids to prevent clogging and backups in the treatment systems, and then the wastewater is pumped to the WWTF. The treatment facility uses an aerated lagoon treatment system. Within the aerated lagoon treatment process, there is a primary and secondary cell, which can be seen in the aerial view of the facility in Figure 2.2. Sewage is pumped to the primary cell which contains four aerators. This facilitates aerobic digestion of solids and organic matter. Then the wastewater continues to flow through to the secondary cell for further digestion and solids settling. After this stage, the water is disinfected by the chlorination and dechlorination processes before it is discharged to Skinner Creek. The existing process flow diagram of the facility summarizes what was described above and is shown in Figure 2.3.

Figure 2.2 Aerial View of Browntown WWTF

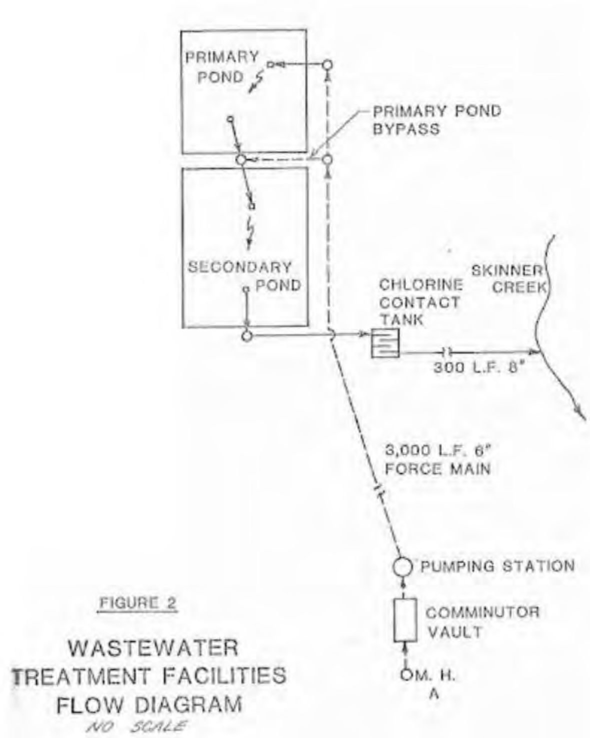


Figure 2.3 Browntown WWTF Existing Process Flow Diagram

2.2 Project Needs

In order for this project to be successful, multiple aspects have been taken into consideration. To begin, the project must fall within the required budget set by the Village and follow the philosophy of the triple bottom line which strives to meet a goal of sustainability in terms of the economy, the environment, and the social aspect. The method chosen and implemented must reduce the effluent phosphorus discharge concentration down to at least 2.0 mg-P/L. The solution must be easy to maintain due to the limited staff at the WWTF. Finally, the solution should not have a large expansion involved due to the limited amount of space at the facility. The lands surrounding the facility are privately owned and henceforth mean the general physical layout and location of the plant need to stay the same.

2.3 Existing Conditions

The effluent limits for the Browntown WWTF listed in the WPDES permit are shown in Table 2.1 below.

Table 2.1 Browntown WPDES Permit Effluent Limits

Parameter	Limit Requirements
Biochemical Oxygen Demand (BOD_5)	30 mg/L monthly average 45 mg/L weekly average
Total Suspended Solids (TSS)	60 mg/L monthly average
pH	Daily Maximum: 9 su Daily Minimum: 6 su
Total Phosphorus	6.4 mg/L monthly average (current) 2.0 mg/L monthly average (after July 1, 2022)
Ammonia Nitrogen	108 mg/L monthly average 108 mg/L weekly average
Total Residual Chlorine	38 ug/L daily max (May-September)
Fecal Coliform	400# / 100 mL weekly max (May-September)

Exhibit 1 in Appendix A includes the WWTF effluent flow and influent and effluent phosphorus concentrations from January 2018 to December 2020 as reported to the Wisconsin DNR. A summary of the effluent flow and phosphorus data collected during this time period is provided in Table 2.2 below.

Table 2.2 Summary of Effluent Flow and Phosphorus Data from 2018-2020

Flow	Daily Average Flow (DAF): 0.0225 MGD
	Daily Maximum Flow (DMF): 0.2272 MGD
Total Phosphorus	Monthly Average Concentration: 4.17 mg/L Monthly Average Loading: 0.560 lbs/day
	Monthly Max Concentration: 8.14 mg/L Monthly Max Loading: 0.923 lbs/day

As previously stated, the WWTF is experiencing high phosphorus concentrations that are exceeding the anticipated regulatory limits to be enforced by the Wisconsin DNR. Per the facility's last permit, it was expected that the facility would meet a 0.075 mg-P/L phosphorus water-quality based effluent limit (WQBEL) in the coming years. However, the Village pursued an Individual Economic Variance for Municipal Discharges as listed under Wisconsin Statute 217.19 of 2 mg-P/L in July 2017 as it was deemed economically infeasible for the Village to meet the phosphorus WQBEL at the time. In the Village's newest permit effective as of April 2020, the facility has a current monthly average phosphorus limit of 6.4 mg-P/L until July 2022. At this time, the facility will then be held to the individual phosphorus limit of 2 mg-P/L. The Discharge Monitoring Report (DMR) data for the WWTF from the time period of January 2018 through December 2020 has been extensively analyzed. It was determined that the monthly average phosphorus concentration during this time was about 4.2 mg-P/L. This average concentration is sufficient for the phosphorus limit currently in place for the Village (6.4 mg-P/L), but further reduction is required for the upcoming 2 mg-P/L limit effective July 2022.

The DMR data has also been analyzed for the purpose of addressing the I&I issue. Calculations for projected flows provided in Appendix B demonstrate that the current design capacity of the facility (0.0405 MGD) suffices for the anticipated flow at the facility over the next 20 years (0.02345 MGD). Because the design capacity of the facility is 0.01705 MGD larger than the expected future flow, there is additional treatment allowance for any I&I that reaches the facility. In addition, the effect the I&I has had on phosphorus effluent concentrations was also considered. It was determined through effluent loading data that spikes in influent flow due to I&I in the system do not contribute to higher concentrations and loadings of phosphorus in the effluent. This suggests that the I&I flows affect the phosphorus removal efficiency very little. Due to these findings on I&I flow into the treatment facility and the large costs required for replacing sections of the sewer network, it was deemed that pursuing sewer and piping replacement would not be feasible for the Village at this time.

2.4 Scope of Work

The services provided by M.M. C.R.B. Consultants have included a preliminary design. This includes analyzing the project from each engineering consideration: civil, environmental, hydrological, hydraulic, structural, geotechnical, and construction. As a result, the preliminary report has further examined the needs of the client and how to complete this project successfully. After careful consideration, a decision matrix of possible solutions and a recommendation have been made to the clientele. With the decision being made by the client, the team has then moved onto finalizing documents, drawings and design preparation, and cost estimations.

2.5 Design Matrix

A decision matrix was created in order to analyze the most important factors and their weight for each alternative that the firm researched. Therefore, the six most important factors for the proposed solutions were included each with a corresponding weight determined by the importance to the clientele and the firm. The factors include efficiency of phosphorus removal, ease of operation, sustainability, land required, annual cost, and capital cost. The alternatives were scored on a range of 1 to 4 with 1 indicating least favorable and 4 indicating most favorable. As a result, chemical precipitation had the highest weighted total. The Decision Matrix can be found in the Executive Summary as Table 1.1.

2.6 Regulatory Codes

The following codes and regulations will be abided by in regards to municipal wastewater discharge:

Environmental Protection Agency (EPA) Clean Water Act Law 92-500, amendments 1342 and 1383; This section of the Clean Water Act further describes the actions that must be taken to discharge a certain amount of a pollutant. These sections reiterate the permit process and requirements for a pollutant to be discharged. Overall, this section clarifies the standards that administrators must follow.

Code of Federal Regulations 122 and 133; Wisconsin Department of Natural Resources (WDNR) NR216 code; Along with pollutant discharge limits, the NR216 code verifies that sites are performing at an acceptable level. It also establishes which facilities require WPDES storm water permits.

Wisconsin Pollutant Discharge Elimination System (WPDES) statutes 283 and 284; These statutes cover standards of performance, effluent levels, permit requirements, and the enforcement of these regulations.

Green County Codes 9-2-18 and 1-13-11. These codes describe the contamination and hazardous waste cleanup that is required for communities within Green County along with the requirements for construction sites in operation within the county.

Through the Wisconsin Pollutant Discharge Elimination System (WPDES), the Wisconsin DNR implements regulatory permits for municipal and industrial dischargers to surface waters and groundwater. The Village operates under WPDES Permit No. WI-0032051-07-0.

2.7 Project Constraints

There are several constraints that M.M. C.R.B. Consultants have been considered throughout further design of the alternatives to produce a successful solution for the treatment facility's problems.

2.7.1 Economic

The Village has a limited budget for the impending project of $1,500,000 and operates on a total annual budget of $175,000. Therefore, the design for the facility upgrade project is constrained by the initial project budget as well as the annual budget for operation and maintenance costs. It must also be considered that the Village has additional annual budget items that do not pertain to the WWTF.

2.7.2 Environmental

The WWTF currently has a higher rate of discharging phosphorus into Skinner Creek than is deemed acceptable by the Wisconsin DNR under the Village's future WPDES Permit. As mentioned earlier, the average monthly effluent phosphorus concentration from January 2018 to December 2020 was about 4.2 mg-P/L, which is more than double the future permit limit of 2.0 mg-P/L to be effective July 1, 2022. This future discharge limit is set in place by the Wisconsin DNR to protect the quality of the water bodies downstream from the outfall of the treatment facility. Therefore, the phosphorus treatment system to be developed at the facility must perform adequate removal of the nutrient amidst the limited budget mentioned previously.

2.7.3 Social

Skinner Creek feeds into the Pecatonica River and eventually the Rock River, which is a major stream that flows through both Wisconsin and Illinois. Many recreational activities occur on or near these streams including fishing, kayaking, and hiking. It is essential that the effluent discharge from the WWTF does not jeopardize the enjoyment or quality of these activities. Due to the fact that this WWTF is the only operating facility for the Village, it is also important that the recommendations and construction portion of the project work in a timely manner in order to not impact the daily operations of the community too much. The water needs of the people who reside and work within the Village need to be taken into consideration when planning.

2.7.4 Health and Safety

While phosphorus itself is not harmful or toxic, excess phosphorus in water bodies can cause eutrophication, which promotes algae growth and depletes dissolved oxygen levels. This can generate harmful conditions, especially in the case of toxic cyanobacteria. In addition, the potential construction sites are located near the lagoons for the WWTF so adequate protection including barriers, soil traps, and fall protection must be provided to protect the construction workers and the lagoons.

3. Site Selection

The soil at the potential sites were tested using standard penetration test (SPT) borings and classified using the Unified Soil Classification System (USCS). The different soil layers can be seen in the adjacent Figure 3.1 with a small layer of lean clay (CL)/top soil on top. Below the topsoil is a 4.75 foot layer of sandy silt (SM) followed by a fine sand (SP) layer, and finally a loose/medium Silt (ML). Blow count (N) was determined for each of the soil layers using ASTM D2216 and is seen in the adjacent figure. A cohesion of 1800 psf and a friction angle of 32 degrees were calculated based on the soil layer. It is also important to note that the groundwater was found close to the surface at a range of 2 to 3 feet from the surface.

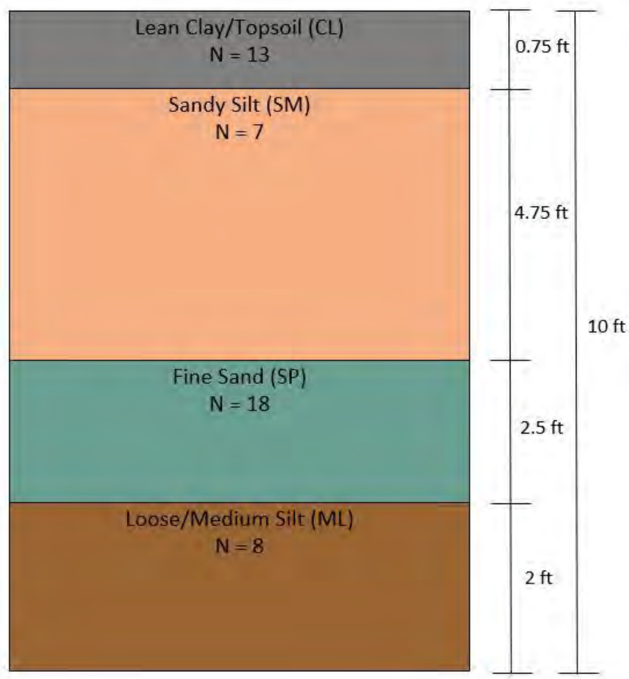


Figure 3.1 Soil Profile of Potential Sites at WWTF

The most important consideration when choosing a selection site for any of the alternatives is proximity to the lagoon. More specifically, the site should be at a convenient location for piping and interception of effluent between the second lagoon and the disinfection tank. Looking at Figure 3.2, the second lagoon collects the treated wastewater from the southwest side and pumps it to the disinfection tank located almost ten feet to the southeast. Since every alternative must intercept the wastewater before reaching disinfection, a selection site in this area is the most convenient. Hydraulic gradation calculations have also been performed to determine the feasibility of these sites. This is explained further in Appendix B.

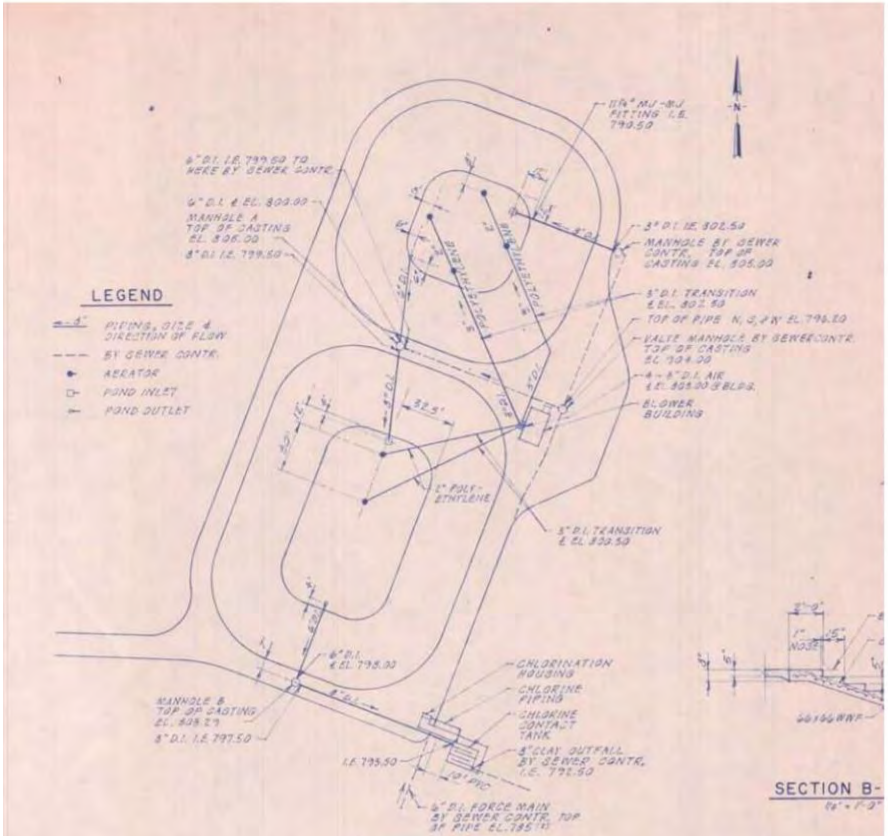


Figure 3.2 Existing Piping Plan of Facility

While the constructed wetland requires a vast amount of area, site selection for that alternative will not be considered in this section due to its large size. This is further explained in Section 4. The next largest alternative, RCA Bed, requires almost 4000 square feet of space. As seen in Figure 3.3, Site 1 fits the alternative adequately and is in close proximity to the disinfection influent piping on the southern side of the secondary lagoon. Site 2 is located just north of the existing blower building and would be a potential location for the chemical storage building for the chemical precipitation alternative. The proposed building would only require 120 square feet, so placing it in close proximity to the ponds and the manhole located between the ponds is preferred. This allows for short piping distance as well as flexible usage in the future. Figure 3.3 also shows the facility's property lines as denoted by the area that has a green hue.

Figure 3.3 Property Lines of Facility

Seen in Figure 3.3 is also the layout of the main road leading to the WWTF and the overhead view. The facility also has secondary access to County Highway M to the west. The construction crew will be able to enter the site shown on the far east side with ample room. Considering the limited staff for the facility, the parking lots directly next to the lagoon system will be able to store construction materials. With a small town population and a large amount of land space, the construction vehicles should face little traffic and difficulty when transporting materials. If any obstacles are encountered, the secondary access road can be used.

4. Analysis of Design Alternatives

Further research has been performed on the four design alternatives initially proposed as solutions to current issues at the WWTF. The four design alternatives include filtration with chemical polishing, chemical precipitation, a recycled concrete aggregate bed, and a constructed wetland.

4.1 Alternative 1: Filtration with Chemical Polishing

The option to install a filtration system in cooperation with a chemical polishing system is a common tertiary treatment method for further removal of nutrients at wastewater treatment facilities. The chemical feed system and filter would both be new installations to be incorporated into the existing lagoon treatment system. The chemicals to treat phosphorus would be administered into the aerated lagoons in order to increase the settling out of phosphorus from the process wastewater. The filter would then further remove particulates that did not settle out in the lagoons. In the order of the process flow, the filtration system would be implemented after the biological treatment in the aerated lagoons and prior to disinfection in the chlorine contact tank. The proposed location for the filter and chemical system at the WWTF is explored in Section 3: Site Selection. Three filter types, including cloth media, sand, and membrane filters, were extensively researched and compared in order to determine which would be the best fit for the clientele. It was decided by the design team for this alternative that the cloth media filter would be the optimum choice for the facility based on its existing conditions and needs. The decision matrix for the filter choice can be found in Table 4.1 below.

Table 4.1 Decision Matrix for Tertiary Filter Choice

Factor	Weight	Cloth	**Score**	Sand	**Score**	Membrane	**Score**
Efficiency	30%	4	1.2	3	.9	3	.9
Capital Cost	20%	3	.6	2	.4	2	.4
Infrastructure Required	20%	2	.4	4	.8	2	.4
Chemical usage	15%	3	.45	2	.3	1	.15
Maintenance	15%	4	.6	3	.45	1	.15
Weighted Totals			**3.25**		2.85		2.00

The cloth media filter technology developed in the early 1990s is vertically oriented and therefore has a smaller footprint than most. The disk also has six easy to remove segments making the design low maintenance. An overview of the cloth media filter can be seen below in

Figure 4.1. The filter is installed in a concrete or steel tank, and therefore can be implemented in a new or retrofit system. Once the filter is installed and a direction of flow is chosen, the solids can be removed via a backwash method. This method involves reversing the flow and increasing the velocity to push the solids out of the clogged filter pores. In order for this method to be effective, a timer or a manual switch of the flow is needed. The cloth filter needs to be replaced approximately every 10 years. According to a design report received from tertiary filtration manufacturer Aqua-Aerobic Systems, it is recommended that two filter units with one disk per unit are implemented at the Village WWTF. The total filter area provided based on these conditions would be roughly 22 square feet, and each filter would be housed in its own steel tank to be supplied by Aqua-Aerobic Systems. The manufacturer recommends its AquaDisk package model with an OptiFiber media cloth type that is chlorine resistant. Additionally, this system would have an automatically operated vacuum backwash and solids removal system (Chycota, 2021).

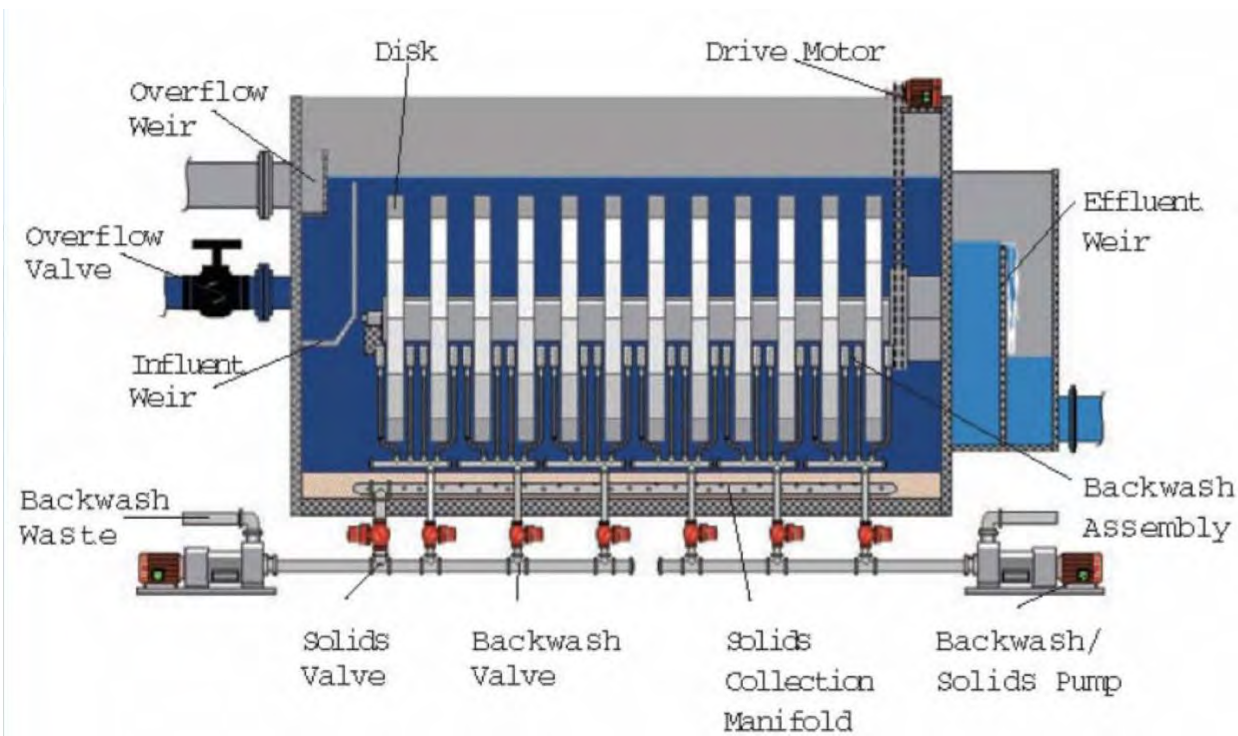


Figure 4.1 Example of Cloth Media Filtration System

4.1.1 Assessment of Sustainability

Economic

A WWTF typically operates all day long every day of the year. As a result, the methods chosen for the facility must be able to run efficiently throughout the lifetime period. For the proper filter to be chosen, efficiency, changes in filter media, and sterilization need to be considered. Maintenance costs for the filter system would incur intermittently depending on the performance of the filter media over the course of a few years. In terms of facility lifetime, the filter system would most likely need to be replaced further down the line. Newer technologies often offer a better efficiency rate and help cut costs which would be beneficial to the Village.

Environmental

Depending on the type of filter, manufacturer, and innovation of the technology, practices with the environment in mind are implemented for filtration. For example, backwashing is a common filter cycle needed to clean the solids from the device intermittently to prevent backups and minimize head loss within the wastewater treatment system. Some filters are described as having a low backwash rate in order to be cognizant of the water used for this process. The chosen cloth media filter has a low backwash rate and therefore uses less water than other filters. This design is also sustainable in terms of greenhouse gas emissions as large amounts of materials do not need to be delivered and no measurable emissions are generated. In excess, nutrients such as nitrogen and phosphorus have an adverse effect on the quality of water in the environment. Ecosystems can be severely damaged and organisms killed by persistent high concentrations of nutrients. The installation of a phosphorus removal system with chemical treatment and filtration would have a sustainable impact on the environment due to the decreased concentrations of nutrients discharged into downstream water bodies.

Social

A top priority of this alternative is to discharge clean and safe water back into the environment. Discharging properly treated wastewater back into water bodies ultimately affects the potable water people use. This option is socially sustainable because it will assist in providing a healthy water distribution system which will support the families and businesses of the Village.

Health and Safety

The goal of filtration and chemical treatment of wastewater is to reduce the amount of contaminants being discharged back into water bodies. On top of harming ecosystems as mentioned previously, excess nutrients also jeopardize the health of people and animals because of decreased water quality. Implementing a chemical phosphorus removal system in conjunction with tertiary filtration would largely improve water quality in and downstream of the Village, which would protect the health and safety of people, animals, and other organisms.

4.2 Alternative 2: Chemical Precipitation

Chemical precipitation is a common method used in wastewater treatment to precipitate excess phosphorus. Ferric chloride ($FeCl_3$) and aluminum sulfate ($Al_2(SO_4)_3$) are chemicals commonly used for precipitating the phosphorus. Ferric chloride and aluminum sulfate perform an ionic reaction when mixed with wastewater influent leading to the iron (ferric) and aluminum binding with the phosphate and creating a precipitate the sinks to the bottom. The chemical would be fed into the existing manhole where flow is either diverted to the primary pond or to the secondary pond by utilizing the primary pond bypass. Under normal operating conditions, all of the flow at the facility is directed toward the primary pond first. Therefore under normal operation, the chemical would be introduced into the primary pond first and then the secondary pond to allow for maximum coagulation and settling out of phosphorus. The chemical would be well distributed through mixing with the influent into the ponds and further mixing action within the ponds. Chemical must be stored on site in a ventilated and heated building. The presence of a chlorine storage building on the southeast side of the facility offers an existing storage location, but due to the age of the building, the team recommends constructing a new storage building that is within Federal and State building and safety codes. The proposed design for the building was drawn in AutoCAD as seen in Exhibit 4 and Exhibit 5 in Appendix A. This building would be located in between and to the east of the primary and secondary ponds, which can be seen in Section 3 Figure 3.3. A proposed process flow diagram illustrating the described system was drawn in AutoCAD and is provided in Appendix A as Exhibit 2. When calculating the amount of aluminum sulfate and ferric chloride needed, a variety of things need to be considered including percent strength and the ratio of moles of phosphorus to moles aluminum or iron. Using the calculations provided in Appendix B, required amounts of aluminum sulfate and ferric chloride can be obtained. Dredging will need to be done to prevent sedimentation of the lagoon. The costs for these services are outlined in Appendix B.

4.2.1 Assessment of Sustainability

Economic

The following costs comparisons can be made between aluminum sulfate and ferric chloride:

- Price for Chemical
  - -Aluminum Sulfate: $2.33/gallon or $2,900/year
  - -Ferric Chloride: $7.22/gallon or $4,900
- Price for Dredging (based on sludge generation calculations in Appendix B)

-Aluminum Sulfate: $18,100/year
-Ferric Chloride: $8,600/year

These rates were obtained from Fehr Graham (Buholzer, 2021). Detailed calculations on how these amounts were obtained as well as Present Worth calculations for both chemicals can be found in Appendix B. If chemical precipitation is used, then dredging would be a necessity to prevent sedimentation from occurring and would be performed consistently on a determined time interval. Cost of dredging needs to be added to the cost of chemical precipitants. Cost of acquiring resources is fairly cheap and using this alternative would be under the given budget. It should be noted that a preliminary assessment of the current sludge levels will be performed by the operator in Spring of 2021. If the levels indicate a need, the Village plans to coordinate a full assessment as well as removal for the current sludge in the lagoons.

Environmental

Use of chemical precipitation would reduce the phosphorus levels to below DNR requirements. This is important because reducing phosphorus levels prevents eutrophication of the lagoons and leads to a healthier ecosystem for the organisms to reside in. Dredging would be important to prevent metal contamination into the ecosystem, and dredged material should be deposited in a designated site. Disposal of contaminated sediments should follow EPA and DNR regulations. Energy usage for this method is present via the pumping of chemicals with the wastewater influent leading to greenhouse gas emissions. Use of aluminum sulfate is recommended over the use of ferric chloride to prevent orange colored staining of equipment, which comes from iron reacting with oxygen.

Social

A top priority of this alternative is to discharge clean and safe water back into the environment. Discharging properly treated wastewater back into water bodies ultimately affects the potable water people use. Testing will ensure that regulations are met as well as ensure that the water is safe for all of the people of Browntown to consume.

Health and Safety

The goal of the Chemical Precipitation method is to reduce the amount of phosphorus being discharged back into water bodies. On top of harming ecosystems as mentioned previously, excess phosphorus also jeopardizes the health of people and animals because of decreased water quality caused by eutrophication. Implementing chemical precipitation would largely improve water quality in and downstream of the Village, which would protect the health and safety of people, animals, and other organisms. However, the use of aluminum sulfate is highly recommended for the safety of the people and animals due to ferric chloride creating hydrogen chloride gas when reacting with the atmosphere.

4.3 Alternative 3: Recycled Concrete Aggregate (RCA) Bed

Bed Filters have been a widely used method for wastewater treatment. Traditionally, these filters have been placed after initial treatment methods such as settling and digestion, but have also been used in mine waste treatment. The lime (or Calcium Oxide, CaO) in limestone and concrete aggregates causes phosphate absorption, thus removing phosphorus from wastewater. After sufficient absorption, the concrete aggregate is replaced with a new bed. The drainage from this bed can then move on to disinfection or other facility processes. These filters also have the capability to be run intermittently or full time, allowing for significant removal rates and effluent concentrations below established limits. Recent studies have shown that "recycled concrete aggregate (RCA) removed more than 90% of P from effluent when at pH 5" (Deng et. al 2018). While results generally declined as pH increased, phosphorus removal rates were still around 75% on the lower end of performance. In addition, recycled concrete aggregate and limestone are quite abundant and once saturated with phosphorus and collected, can be used as fertilizer supplement. Using Filtration Bed calculations outlined in Appendix B, potential sizing of the RCA was obtained. These calculations are subject to change after lab scale testing is completed to determine the phosphorus adsorption capacity of the RCA to be used. The size of the bed can be changed as needed, but our team recommends a bed of 60 feet in length, 45 feet in width, and 3 feet in depth. The proposed locations of the bed have been further explored in Section 3: Site Selection. A high density polyethylene liner will be used on the sides and bottom of the RCA bed, while a lightweight protective cover will be placed on the top. Between the RCA and the HDPE liner, there will be a protective layer to protect the liner and reduce the porosity of the soil and velocity of the flow to protect the HDPE liner . The geotechnical team has recommended a layer of sand with a thickness of 1 foot below the RCA bed. Both the RCA and sand layer require a void ratio of 0.25 and will be compacted until this void ratio is reached. The sand layer will be sloped to a center point in order for all wastewater to be collected and piped to the chlorine tank to be treated. A soil profile drawing can be found in Appendix A as Exhibit 3.

4.3.1 Assessment of Sustainability

Economic

The RCA material is in abundance and cheaper sources than those outlined in this report can be utilized. The phosphorus saturated material also has potential to be sold and used in fertilizer, however a client and profit for this idea is yet to be determined. The initial capital investment is within the Village's budget, and while the annual operating cost is larger than other alternatives, the capabilities and durability of the RCA Bed are significant.

Environmental

Concrete accounted for 381.8 million tons of waste in 2015. By using RCA as a phosphorus filtration method, we hope to promote the use of this technology and perhaps reduce the amount of concrete waste produced. In addition, the phosphorus saturated RCA can potentially be used in fertilizers, thus reintroducing phosphorus into agricultural soils and promoting healthy crop growth. While this is on several scales larger than the footprint of the WWTF, we hope to set an example for others to follow in environmental engineering sustainability. It should be noted, however, that if not used for fertilizer, phosphorus saturated RCA will have to be disposed of in landfills or waste sites. In addition, the amount of RCA material required every year is significant and requires transportation. This increases the WWTF's carbon footprint and reduces the sustainable aspect of the alternative.

Social

A top priority of this alternative is to discharge clean and safe water back into the environment. Discharging properly treated wastewater back into water bodies ultimately affects the potable water people use. However, lab scale testing will be done to ensure that minimal leaching occurs from hydraulic loading on the RCA. It would be counterproductive to implement an alternative that treats phosphorus, but introduces a different contaminant to the water and environment.

Health and Safety

The goal of this RCA Filtration Bed is to reduce the amount of phosphorus being discharged back into water bodies. On top of harming ecosystems as mentioned previously, excess phosphorus also jeopardizes the health of people and animals because of decreased water quality caused by eutrophication. Implementing a filtration bed would largely improve water quality in and downstream of the Village, which would protect the health and safety of people, animals, and other organisms.

4.4 Alternative 4: Constructed Wetland

An option to remove excess phosphorus is the use of a constructed wetland. Influent to the constructed wetland will come from the effluent of the lagoon wastewater treatment plant. A constructed wetland will utilize the vegetation to clean the water. The vegetation acts as a biofilter which removes sediments, chemicals and metal contaminants from the lagoon effluent through chemical reactions. A depth of at least 6 feet was also recommended so that during the winter, the vegetation could still perform the reactions to remove phosphorus from the water. The determined area of the wetland was determined to be 1 acre. An RCA bed can be attached for polishing if sufficient phosphorus removal does not occur. This alternative was analyzed with the assumption that one would not be required.

4.4.1 Assessment of Sustainability

Economic

Wetlands initially will need a lot of funds to construct, but in the long run, there could be minimum costs. Wetlands need very little maintenance and only rely on natural cycles and processes to stay functional. However, the issue is acquiring land which can be costly depending on how much land is needed as well as the location of the land. If the constructed wetland is used however, money can be made back through tourism. Costs will be varied based on the type of media used and vegetation used for the wetland.

Environmental

Use of a constructed wetland would potentially reduce the phosphorus levels to below DNR requirements. This is important because reducing phosphorus levels prevents eutrophication of the lagoons and leads to a healthier ecosystem for the organisms to reside in. Asides from reducing phosphorus levels, constructed wetlands also provide habitats for a variety of organisms. Another benefit is that less energy is needed to maintain the wetland leading to less of an impact on the greenhouse effect.

Social

A top priority of this alternative is to discharge clean and safe water back into the environment. Discharging properly treated wastewater back into water bodies ultimately affects the potable water people use. Asides from practical uses however, constructed wetlands can also be a tourist destination and attract people to the Village by the construction of nature walkways or parks on top of or near the constructed wetland.

Health and Safety

The goal of the constructed wetland method is to reduce the amount of phosphorus being discharged back into water bodies. On top of harming ecosystems as mentioned previously, excess phosphorus also jeopardizes the health of people and animals because of decreased water quality caused by eutrophication. Implementing a constructed wetland would largely improve water quality in and downstream of the Village, which would protect the health and safety of people, animals, and other organisms.

5. Design Standards

It is important to assess each of the design alternatives with a multidisciplinary approach in order to ultimately choose the best recommended design for the Village. Critically evaluating the design alternatives from the perspectives of different disciplines allows for a broader and more comprehensive view of each of their advantages and disadvantages. The disciplines that have been considered below for the evaluation of each alternative include environmental, geotechnical, structural and construction, and hydraulic and hydrologic.

5.1 Alternative 1: Filtration with Chemical Polishing

Environmental

A filter and chemical polishing system requires a careful selection of chemicals used in order to ensure proper functionality of the lagoon system. The chemicals used would likely either be aluminum sulfate or ferric chloride. The filter and chemical choice requires that there is a low environmental impact on the plant life nearby. The cloth media filter that was chosen as optimal by the team treats to yield small phosphorus concentrations to be discharged in the effluent, which protects the water quality of downstream water bodies.

Geotechnical

The installation of a filter and chemical feed system would require loadings of the equipment to be determined to verify that the soil is stable in supporting these small yet important structures. At this point in time, the estimated loadings of the filtration and chemical polishing system are unknown for a geotechnical analysis to be performed. Geotechnical analysis includes calculation of settlement, allowable bearing pressure, and bearing capacity.

Structural and Construction

A filter and chemical feed equipment would likely necessitate the construction of a concrete pad and a small structure to house and protect the systems from the outdoor elements. Until exact sizing and model parameters have been determined, the structural and construction needs can only be estimated.

Hydraulic and Hydrologic

Hydraulic modeling of the filter and chemical polish system would be necessary to ensure alternative design adequately handles flows and constituent loadings, while also channeling wastewater properly through the treatment system. Hydraulic analysis for any piping and pump systems are also required. No hydrologic analysis is required.

5.2 Alternative 2: Chemical Precipitation

<u>Environmental</u>

A chemical precipitation system requires a careful selection of chemicals used in order to ensure proper functionality of the lagoon system. Common chemicals used are aluminum sulfate, ferric chloride, and calcium carbonate. The chemical choice requires that there is a low environmental impact on the plant life nearby. Phosphorus adsorption capacity and price of chemical is a priority when selecting the proper chemical for treatment. Lastly, sludge generation from chemical precipitation must also be considered. Copious amounts of sludge will require frequent dredging of treatment lagoons, which can become costly.

<u>Geotechnical</u>

This alternative does not require geotechnical analysis.

<u>Structural and Construction</u>

This alternative does not require structural engineering and requires minimal construction, only. Excavation and placement of piping is needed.

<u>Hydraulic and Hydrologic</u>

Hydraulic modeling of the chemical precipitation system would be necessary to ensure alternative design adequately handles flows and constituent loadings, while also channeling wastewater properly through the treatment system. Hydraulic analysis for any piping and pump systems are also required. No hydrologic analysis is required.

5.3 Alternative 3: RCA Bed

<u>Environmental</u>

RCA Beds operate on the basis of experimentally derived phosphorus adsorption capacity. Lab scale testing must be completed to determine actual phosphorus adsorption capacity of RCA used. Until then, adsorption capacity from scientific literature must be used to size the RCA bed. Potential pollutant seepages will also be determined from lab scale testing.

<u>Geotechnical</u>

Geotechnical analysis includes calculation of settlement, allowable bearing pressure, and bearing capacity. Excavation of bed and consolidation of RCA with a void ratio of approximately 0.25 is required.

Structural and Construction

No structural analysis is required for this alternative. Excavation of bed and placement of liner, piping, and pumps is required.

Hydraulic and Hydrologic

Hydraulic loading of the RCA Bed must be determined in order to prevent overloading and flooding of the filtration bed. Hydraulic gradient line and profile for pumps and piping must also be determined. Hydraulic modeling of the bed would be necessary to ensure alternative design adequately handles flows and constituent loadings, while also channeling wastewater properly through the filtration bed and retaining a 12 hour hydraulic retention time.

5.4 Alternative 4: Constructed Wetland

Environmental

Phosphorus adsorption capacity of wetland must be determined and selection of wetland parameters such as media and vegetation must be made to optimize this adsorption. Sizing of the wetland can then be determined based on this adsorption capacity.

Geotechnical

Constructed wetlands require significant land usage, therefore demanding extensive criteria for site selection. Proposed site must be investigated for current soil conditions so that excavation and media placement can be determined. No further geotechnical analysis is required as the constructed wetland does not have significant loading or bearing pressure.

Structural and Construction

Based on current soil conditions, extensive excavation and placement of wetland media and vegetation may be required. This would demand construction oversight and planning. No structural analysis is required.

Hydraulic and Hydrologic

Hydraulic loading of the wetland must be determined in order to prevent overloading and flooding of the wetland. Hydraulic gradient line and profile for pumps, piping, and gradation of wetland must also be determined. Hydraulic modeling of the bed would be necessary to ensure alternative design adequately handles flows and constituent loadings, while also channeling wastewater properly through the wetland and, if required, to an attached RCA bed.

6. Opinion of Probable Costs

An estimation of costs has been prepared for the various design alternatives. The current costs listed are subject to change with further review of the technical and economic information of the equipment for the designs. Costs have been divided into the capital costs for initial installation of the design (Table 6.1), annualized costs for operation and maintenance of the alternatives (Table 6.2), and the Present Worth of each alternative (Table 6.3). A further breakdown of calculations and documentation for these costs can be found in Appendix B.

Capital Costs

Table 6.1 Summary of Capital Costs for Design Alternatives

Description	Filtration with Chemical Polishing	Chemical Precipitation	RCA Limestone Bed	Constructed Wetland
Capital Cost of Equipment/Materials	$200,700	$35,000	$134,300	$507,000
Construction Costs	--	$5,000	$69,600	--
Engineering/PM Costs	$110,000	$110,000	$110,000	$110,000
Contingency (20%)	$40,140	$8,000	$40,800	$101,000
Total	**$350,840**	**$158,000**	**$354,700**	**$718,000**

Annual Operation and Maintenance Costs

Table 6.2 Summary of Annual Costs for Design Alternatives

Description	Filtration with Chemical Polishing	Chemical Precipitation	RCA Limestone Bed	Constructed Wetland
Operation Costs				
Energy	$3,000/year	--	--	--
Material	$4,200/year	$2,900/year	$37,000/year	--
Subtotal	$7,200/year	$2,900/year	$37,000/year	--
Maintenance Costs				
Inspections	$3,000/year	--	--	$3,000/year
Repairs	$12,000/year	$15,300/year	$6,700/year	--
Subtotal	$15,000/year	$15,300/year	$6,700/year	$3,000/year
Total	**$22,200/year**	**$18,200/year**	**$43,600/year**	**$3,000/year**

Salvage Value

No Salvage Value is available for any of the alternatives. All alternatives intercept treated wastewater before reaching disinfection while the Constructed Wetland would replace the direct discharge to Skinner Creek; therefore no equipment is to be replaced or removed from the facility.

Life Cycle Cost Analysis

All alternatives have been designed and evaluated based on 20 year projections (up through 2040). Assuming a discount rate of 3%, the Present Worth of each alternative can be calculated using the methods outlined in Appendix B. Table 6.3 summarizes the Present Worth of each alternative, showing that Chemical Precipitation is the least expensive option at $428,770.

Table 6.3 Present Worth of Each Alternative

Description	Filtration with Chemical Polishing	Chemical Precipitation	RCA Bed	Constructed Wetland
Total Present Worth of Costs	$681,120	$428,770	$1,003,400	$763,100

7. Uncertainties in Design

Due to the design of the WWTF still being in progress, uncertainties remain that will likely alter the design at a later point. Even as the preliminary design progresses into the final design, there will still be unknowns that will pose challenges. Uncertainties that are not considered or addressed can create potentially large problems in performance and safety relating to the WWTF and the downstream water bodies. Therefore, M.M. C.R.B. Consultants will be closely looking into possible uncertainties and assessing their risk to the project in order to mitigate potential repercussions in the future. Data-based and knowledge-based uncertainties in the design that are understood by the team are described in more detail below.

Data-Based Uncertainties

Influent and effluent flow and loading data is consistently collected at the Browntown WWTF and reported to the Wisconsin DNR for the purposes of monitoring facility performance. Some data that is gathered includes flows, BOD concentrations, TSS concentrations, ammonia-nitrogen concentrations, and total phosphorus concentrations. This data is collected by means of flowmeters, automatic samplers, and laboratory tests. With all of these methods of data collection comes uncertainties in measurements, which creates some variance from the true measurement. Additionally, there were some values reported to the DNR and summarized in the DMR data that the team believed to be incorrect because they were large outliers compared to the remainder of the data. The team was aware of these values during analysis of flows and loadings and omitted these obvious outliers from the remainder of the data sets. Including these outlier values would have altered the analysis of the existing conditions greatly. Ultimately, this would have also likely affected some design choices made by the team that could have led to poor consequences in performance, financials, and safety.

In addition to the uncertainties in the data collected at the Browntown WWTF, there are also some data-based unknowns in the specifications received by the team from equipment vendors. More specifically, a design for a tertiary treatment cloth media filtration system was requested from Aqua-Aerobic Systems, Inc. The data that was provided to the vendor from the team contributed to some uncertainty because the vendor likely needed to make assumptions in their calculations and design parameters. This results in some potential error as to what extent this proposed filtration system design would treat phosphorus, although its overall impact on the treatment system and environment is likely minuscule.

Knowledge-Based Uncertainties

The Village currently has a limit variance of 2 mg-P/L of phosphorus taking effect July 2022. However, progressing climate change and consequential eutrophication of water bodies will continue to evoke more stringent limits in the future. Therefore, the facility will need to be periodically reviewed and most likely redesigned to ensure that the phosphorus limits are being met, since it is unknown exactly how and when these permit limits will be altered.

Although the Wisconsin Department of Administration projects population for the next 20 years, there is uncertainty in exactly how much the Village's population will increase in the coming years. This will affect the flows and loadings that the Browntown WWTF experiences, and may require an expansion of the facility to accommodate increased flows. However, with the current population and the future population estimate, the impact of these changes is expected to be small.

Additionally, the design alternatives that are proposed have uncertain phosphorus removal efficiencies. It can be estimated how much phosphorus will likely be removed based on the conditions at the facility and capabilities of the alternative, but the exact effluent concentrations for phosphorus from the WWTF into the outfall at Skinner Creek will be unknown until the design is constructed and measurements are taken. The effluent concentrations are also subject to fluctuation due to the constant changes in influent flow due to rain events and consequent runoff that carries nutrient loadings.

8. Final Recommendation

With an understanding of the different design alternatives that have been proposed to solve the high phosphorus concentration in the effluent of the WWTF, a decision matrix was created to determine the most favorable option for the Village. As seen in Table 1.1, all the alternatives were evaluated using a range of different topics from efficiency to cost that factor into choosing the best option that the Village should move forward with. A ranking system was used in the decision matrix with 1 being the least favorable outcome, and 4 being the most favorable rating that an alternative can receive. Finally the weighted totals were summed up, and the alternative with the highest ranking was deemed to be the best choice.

Table 1.1 Decision Matrix of Preliminary Design Alternatives

Factor	Weight	Filtration with Chemical Polishing	**Score**	Chemical Precipitation	**Score**	Concrete Bed	**Score**	Constructed Wetland	**Score**
Efficiency	24%	4	.96	4	.96	3	.72	2	.48
Maintenance	18%	3	.54	3	.54	2	.36	4	.72
Sustainability	18%	3	.54	3	.54	3	.54	4	.72
Land Required	15%	3	.45	4	.6	3	.45	1	.15
Annual Cost	15%	3	.45	4	.6	1	.15	2	.30
Capital Cost	10%	1	.1	4	.4	3	.3	2	.2
Weighted Totals			3.04		**3.64**		2.52		2.57

It was determined by the design team that chemical precipitation is the most favorable option for the Village WWTF. This was determined by several factors. The first was on the land it would require to operate this alternative. The recommended chemical, alum, is added to the lagoons which combines with the attracted phosphorus and settles to the bottom of the lagoon as a sludge. A different chemical such as ferric chloride can be used as well. Additional hardware that would be needed is a pumping system to add the chemical into the lagoons and a storage facility to hold excess chemical on site. Secondly, due to the limited amount of equipment needed to run this alternative and the low cost of the chemical, both the annual cost and the capital cost to construct this option would be low.

M.M. This brings the cost of this design alternative lower than the other alternatives which require more extensive capital and annual costs. Finally chemical precipitation is one of the most efficient options to remove phosphorus with the filtration and chemical polishing being similar in efficiency. As the removal of phosphorus is the main objective for these design alternatives, this was considered the most critical factor in evaluating these four options. Any alternative that was ranked the highest among the design options was further considered versus options that ranked lower. Due to other considerations like cost, chemical precipitation was determined to be the most viable option. With these considerations, M.M. C.R.B. Consultants recommended that the chemical precipitation design alternative be implemented at the village WWTF to remove phosphorus most efficiently from the discharge water.

8.1 Project Schedule

Figure 8.1 Schedule of Construction for Final Design

Final Design Submission……………………………………………………………..April 2021
Permitting…………………………………………………………………………..June 2021
Bidding and Contract Award…………………………………………………............July 2021
Design Documents for Interim Report…………………………………………….January 2022
Complete Construction for Interim Limit…………………………………………….April 2022
Collect and Analyze Baseline Data…………………………………………………..January 2023
Final Inspection…………………………………………………………………....April 2023

Shown in Figure 8.1 is the schedule for the final design and construction after the final design alternative is selected by the Village. Final Design Submission will occur in April 2021 with permitting documentation submitted to the DNR and other required agencies shortly afterwards. After permits have been accepted, bidding for the construction of the design alternative will begin and the contract will be awarded in July of 2021 with construction following. Construction will conclude in the spring of 2022 in which data will start to be collected to determine the efficiency of the design alternative to remove phosphorus. The collected data will be analyzed and sent to the Wisconsin DNR to receive approval to the permit that was given to the Village to reduce the phosphorus concentration levels by July 2022. While the Wisconsin DNR approves of the phosphorus concentration levels in the discharge water, flow data as well as sludge generation data will be continuously collected and analyzed. Once the DNR approves of the discharge, a final inspection will occur and the finalized project will be turned over to the Village by spring 2023. These dates are approximate and subject to change.

APPENDICES

Appendix A

Exhibit 1 Historical Effluent Data

Date	Influent			Effluent				
	Flow (MGD)			Flow (MGD)		BOD (mg/L)		TSS (mg/L)
	Average	Maximum	Annual Average Design Flow (MGD)	Average	Maximum	Weekly Average	Monthly Average	Monthly Average
Jan-18	0.0093	0.0172	0.0405	0.0087	0.0222	12.00	9.40	13.60
Feb-18	0.0107	0.0330	0.0405	0.0165	0.0478	16.00	10.50	17.25
Mar-18	0.0098	0.0167	0.0405	0.0063	0.0116	34.00	27.50	21.00
Apr-18	0.0090	0.0129	0.0405	0.0059	0.0125	38.00	24.25	19.00
May-18	0.0094	0.0145	0.0405	0.0082	0.0179	39.00	22.00	15.20
Jun-18	0.0114	0.0231	0.0405	0.0110	0.0496	11.00	6.66	6.66
Jul-18	0.0097	0.0173	0.0405	0.0087	0.0360	4.00	2.60	3.40
Aug-18	0.0136	0.0475	0.0405	0.0107	0.0381	17.00	6.50	4.25
Sep-18	0.0208	0.0471	0.0405	0.0206	0.0770	14.00	7.75	5.00
Oct-18	0.0256	0.0440	0.0405	0.0245	0.0533	14.00	11.00	6.20
Nov-18	0.0172	0.0236	0.0405	0.0148	0.0244	11.00	8.75	6.20
Dec-18	0.0143	0.0235	0.0405	0.0125	0.0256	14.00	12.20	12.50
Jan-19	0.0165	0.0250	0.0405	0.0145	0.0257	16.00	15.67	15.00
Feb-19	0.0173	0.0344	0.0405	0.0209	0.0313	14.00	13.33	13.33
Mar-19	0.0167	0.0774	0.0405	0.0305	0.0883	16.00	13.50	14.25
Apr-19			0.0405					
May-19	0.0252	0.0351	0.0405	0.0198	0.0299	26.00	25.75	19.00
Jun-19	0.0253	0.0353	0.0405	0.0156	0.0226	17.00	11.67	21.33
Jul-19			0.0405					
Aug-19			0.0405					
Sep-19			0.0405					
Oct-19			0.0405					
Nov-19	0.0261	0.0327	0.0405	0.0178	0.0242	10.00	7.00	8.00
Dec-19	0.0221	0.0279	0.0405	0.0150	0.0228	20.00	16.50	19.75
Jan-20			0.0405					
Feb-20	0.0553	0.0558	0.0405	0.0125	0.0125	24.50	24.50	34.00

Mar-20	0.0565	0.0573	0.0405	0.0097	0.0126	44.00	44.00	69.33
Apr-20	0.0356	0.0447	0.0405	0.0139	0.0249	39.75	39.75	17.75
May-20			0.0405			37.75	37.75	26.25
Jun-20	0.0437	0.2272	0.0405	0.0199	0.0358	22.25	22.00	22.20
Jul-20	0.0321	0.0372	0.0405	0.0182	0.0392	9.50	9.50	6.00
Aug-20	0.0268	0.0396	0.0405	0.0113	0.0259	6.25	6.25	5.00
Sep-20	0.0270	0.0535	0.0405	0.0151	0.0336	5.00	5.60	7.20
Oct-20	0.0220	0.0331	0.0405	0.0097	0.0318	8.25	8.25	5.25
Nov-20	0.0250	0.1793	0.0405	0.0183	0.0999	8.75	8.75	6.75
Dec-20	0.0179	0.0215	0.0405	0.0083	0.0303	12.25	11.80	10.80
6 mo avg	0.0251	0.0607		0.0135	0.0435	8.33	8.36	6.83
yr avg	0.0342	0.0749		0.0137	0.0347	19.84	19.83	19.14
3 yr avg	0.0225	0.0461		0.0145	0.0347	18.71	15.69	15.05
Max	0.0565	0.2272	0.0405	0.0305	0.0999	44.00	44.00	69.33

Date			
	Total Ammonia Nitrogen (mg/L)		**Phosphorus (mg/L)**
	Monthly Average	**Daily Max**	**Monthly Average**
Jan-18		20.64	5.40
Feb-18		24.50	5.68
Mar-18		22.12	4.64
Apr-18		18.29	4.90
May-18		10.78	4.28
Jun-18			6.49
Jul-18		0.82	5.88
Aug-18		3.28	8.14
Sep-18		9.53	5.09
Oct-18		1.15	4.59
Nov-18		3.32	2.73
Dec-18		8.60	3.14
Jan-19		13.71	3.52
Feb-19		23.45	4.01
Mar-19		34.92	3.14
Apr-19			
May-19		10.01	3.68
Jun-19		4.44	4.27

Jul-19			
Aug-19			
Sep-19			
Oct-19			
Nov-19		2.77	2.89
Dec-19			2.64
Jan-20			
Feb-20	13.86	15.48	3.58
Mar-20	16.03	16.56	4.29
Apr-20	8.01	11.44	3.22
May-20	4.51	5.24	3.46
Jun-20	0.17	0.27	2.95
Jul-20	0.55	1.16	3.75
Aug-20	4.01	4.89	4.25
Sep-20	5.98	6.44	4.50
Oct-20	2.58	4.00	3.60
Nov-20	2.40	2.98	3.17
Dec-20	80.40	84.00	3.32
6 mo avg	15.99	17.25	3.76
yr avg	12.59	13.86	3.64
3 yr avg	12.59	13.03	4.17
Max	80.40	84.00	8.14

Exhibit 2 Proposed Process Flow Diagram for Chemical Precipitation

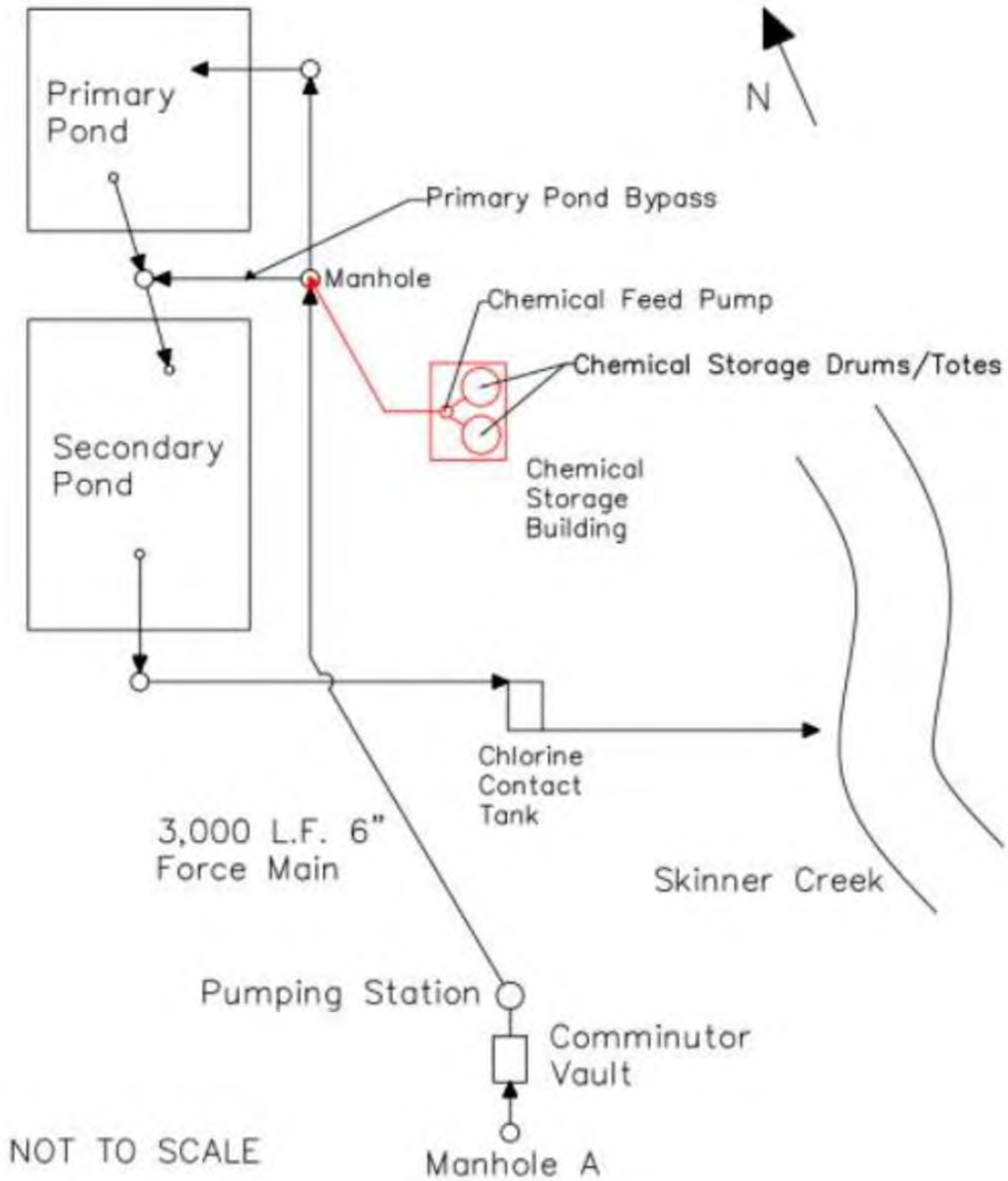


Exhibit 3 Soil Profile Drawing for RCA Bed

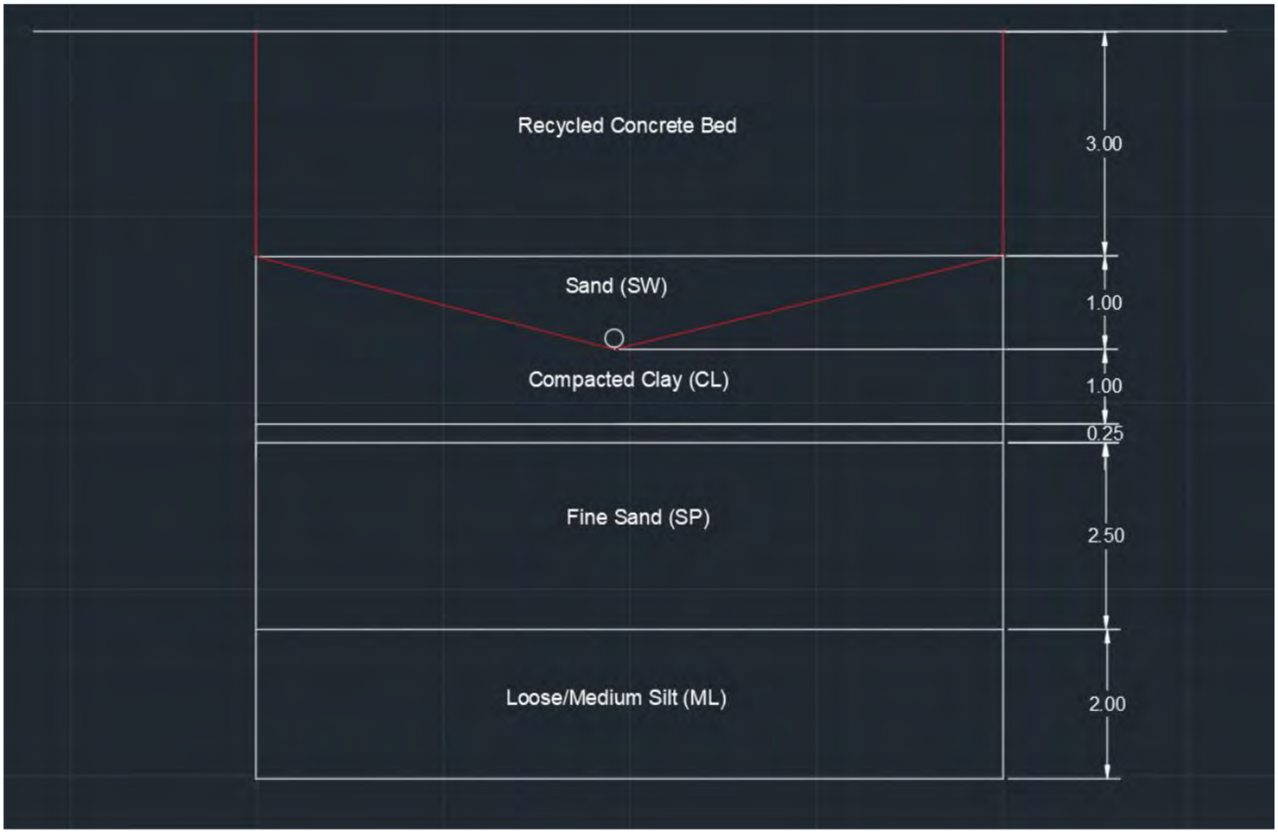


Exhibit 4 Front and Side View of the Proposed Storage Building with Chemical Totes

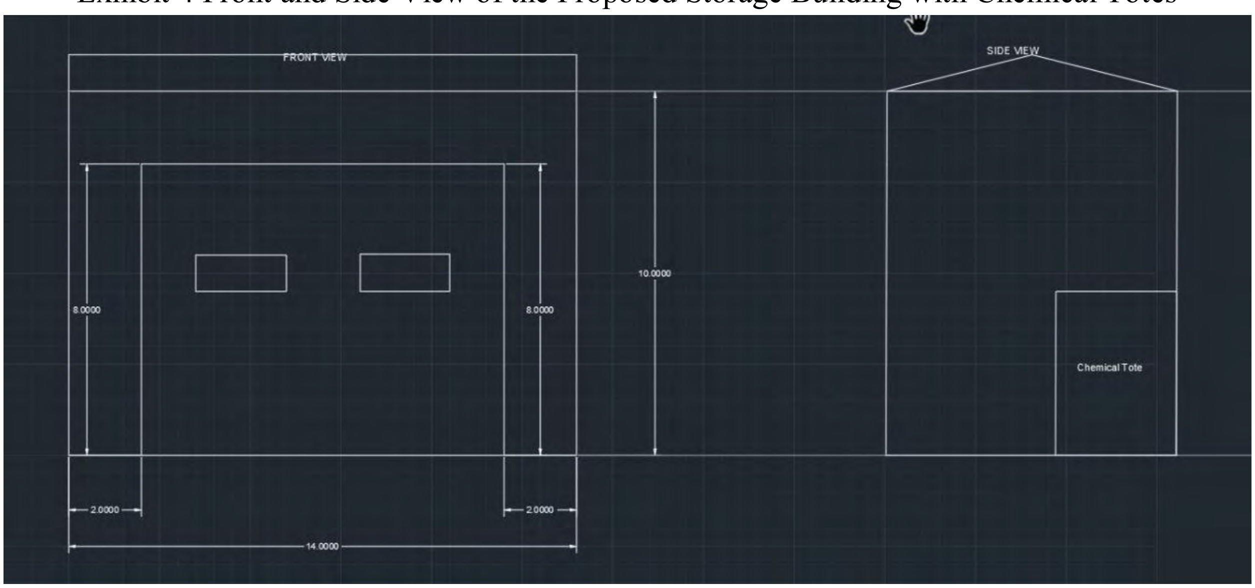
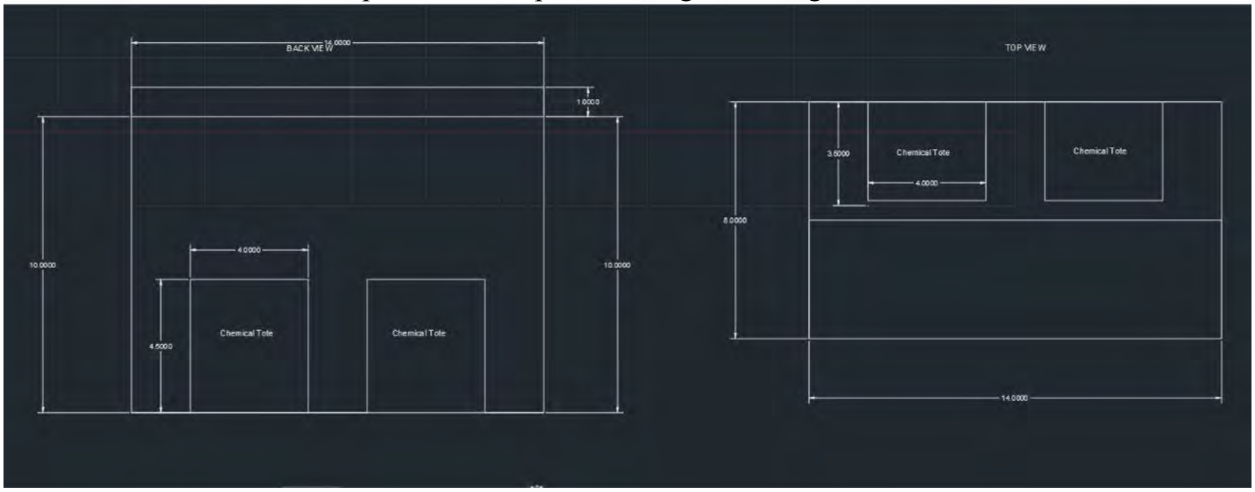


Exhibit 5 Back and Top View of Proposed Storage Building with Chemical Totes Inside



Appendix B

Calculations

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: **Projected Flow Calculations**		
PREPARED BY: **MacKenzie Phillips**	DATE: **3/3/2021**	FINAL ☐
CHECKED BY: **Rahim Ansari**	DATE: **3/7/2021**	REVISION ☐

PROJECTED FLOW CALCULATIONS

Purpose:

To assess the existing flow capacity for the Browntown Wastewater Treatment Facility based on the projected population for the next 20 years.

Methodologies:

In assessing the existing conditions at the Browntown Wastewater Treatment Facility (WWTF), there are updates that must be made in order to improve the wastewater treatment operations. Improved phosphorus removal is necessary at the facility due to more stringent permit limits to be implemented in the coming years. Since populations within municipalities constantly fluctuate, it is necessary for the flow capacity of the Browntown WWTF to be re-evaluated based on the anticipated future conditions. The Wisconsin Department of Administration performs population projections to be used as reference for the expected population changes in Browntown in the next 20 years. The Browntown WWTF also has problems with infiltration and inflow (I&I) into the Village's sewer network, so analysis of the current design capacity may also indicate whether the I&I issue requires immediate action. If the current design flow capacity for the Browntown WWTF is lower than the forecasted flow for this future time period, further investigation and design will be required to expand the facility's treatment capabilities, as well as potentially addressing the sources of I&I into the system.

Assumptions:

The following assumptions were used to calculate the anticipated flow for the Browntown WWTF:

- The current population for the Village of Browntown is based on data collected from the 2010 Census.
- The future population projections made by the Wisconsin Department of Administration are assumed to be an accurate depiction of the growth in population for Browntown, Wisconsin.
- The lifetime of the impending facility upgrade is assumed to be roughly 20 years, which therefore yields the design population year to be 2040.
- The base flow per person is 70 gallons per capita per day (gpcd) based on NR 110 standards.

Calculations:

Current Annual Average Design Flow = 0.0405 MGD

Current Population for the Village of Browntown = 280 people

2040 Population Projection (given by the Wisconsin DOA) = 335 people

Base Flow per Person = 70 gallons/person/day

Projected Flow for Design Year 2040 = 335 people * 70 gallons/person/day

Projected Flow for Design Year 2040 = 23,450 gallons/day = 0.02345 MGD

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: **Projected Flow Calculations**		
PREPARED BY: **MacKenzie Phillips**	DATE: **3/3/2021**	FINAL ☐
CHECKED BY: **Rahim Ansari**	DATE: **3/7/2021**	REVISION ☐

0.02345 MGD < 0.0405 MGD
2040 Projected Flow < Current Annual Average Design Flow

0.0405 MGD - 0.02345 MGD = 0.01705 MGD extra capacity

Results:
As demonstrated in the calculations section above, the projected flow for the 2040 design year is expected to be less than the current annual average design flow of the facility. This indicates that the current flow capacity for the treatment facility is sufficient for handling the anticipated flows for the next 20 years. From this analysis, the design of the facility for the impending upgrade does not necessitate an expansion for treating higher flow volumes. It also suggests that immediate action for I&I problems may not be required. However, I&I will also be further analyzed by its effect on treatment efficiency within the facility.

References:

State of Wisconsin Department of Administration. MCD and Municipal Population Projections, Prepared by David Egan-Robertson. December 2013. https://doa.wi.gov/Pages/LocalGovtsGrants/Population_Projections.aspx

Wisconsin State Legislature Administrative Code. Department of Natural Resources: NR 110, Sewerage Systems. Register No. 774, updated June 2020. https://docs.legis.wisconsin.gov/code/admin_code/nr

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: RCA Filtration Bed Sizing and Cost		
PREPARED BY: Rahim Ansari	DATE: 3/17/2021	FINAL ☐
CHECKED BY: Michael Liu	DATE: 3/17/2021	REVISION ☐

RCA Filtration Bed Sizing and Cost Calculations

Purpose:

To size and estimate cost of the Recycled Concrete Aggregate (RCA) Filtration Bed for treatment of wastewater at the Village of Browntown Wastewater Treatment Facility (WWTF) according to projected loadings for the next 20 years.

Methodologies:

Filtration beds are designed to receive wastewater after primary treatment. This wastewater has already settled and removed a majority of BOD, TSS, and various nutrients. Filtration beds offer additional removal to assist in meeting desired concentrations and regulatory requirements. Treated wastewater filters vertically through the bed and collects at the bottom, draining out for further treatment such as disinfection. Beds can be adjusted to prioritize removal of the target constituent. In this case, Recycled Concrete Aggregate (RCA) is used to adsorb phosphorus based on findings by Deng et al 2018 and guidelines for filtration beds (Metcalf and Eddy, 2002). It should be noted that this technique varies case to case (2-5mm sized RCA was used in Deng et al 2018) and initial lab scale testing would need to be performed in order to determine the exact performance of locally-sourced RCA. Once exact performance characteristics are determined, calculations can be run again through the in-house spreadsheet. This spreadsheet takes into account Daily Average Flow, Phosphorus Concentrations, Phosphorus Adsorption, among others. It should be noted that a target phosphorus concentration of 1.0 mg/L was used in order to provide flexibility and permit space for the facility. It is possible that extensive phosphorus loading on a given occasion may not yield sufficient removal, so 1.0 mg/L was used. Cost estimation for this sizing is also included on the spreadsheet. Cost estimates include material costs, O/M costs, construction costs, and engineering costs. Material costs for RCA and Fill Sand were based on quotes obtained from Wingra Stone and Todd’s Redi Mix, both of which are Wisconsin stone and aggregate suppliers. Considering lab scale testing is yet to be performed to determine the preferred aggregate properties, a high-end estimate of $50/ton RCA was used. This cost includes crushing RCA to approximately 5mm particles and additional loading charges. It should be noted that delivery charges are presented as a separate cost below (based on 45 miles to the WWTF from Wingra Stone). O/M costs were calculated using a study done by the University of New Hampshire on sand filters (Collins et al 2000). Construction costs were estimated using a report published by the EPA also on sand filters (Lesikar et al 1999). RCA Bed Filtration for phosphorus removal does not have sufficient literature to support costs estimates so literature on sand filters were used due to the similarities in the technologies. Since both of these studies are over 20 years old, an adjustment rate of 48.47% was applied to both O/M and construction costs to account for inflation (Webster, 2021). All of these costs are then presented cumulatively as a Present Worth cost using a discount rate of 3% (Matthews, 2014).

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: RCA Filtration Bed Sizing and Cost		
PREPARED BY: Rahim Ansari	DATE: 3/17/2021	FINAL ☐
CHECKED BY: Michael Liu	DATE: 3/17/2021	REVISION ☐

Assumptions:

The following assumptions were used to design the RCA Filtration Bed:

- A Phosphorus Adsorption of 0.75 mg P/mg RCA (Deng et al 2018)
- RCA Density of 1506 kg/m^3 (Wingra Stone)
- Maximum Hydraulic Load of 15 gallons/day/ft^2 (Metcalf and Eddy 2002)
- $50.00/ton RCA (Wingra Stone, High Estimate)
- $11.50/ton Fill Sand (Wingra Stone)
- $10.00/ft PVC Pipe (Lesikar et al 1999)
- O/M of $6,700/year (Collins et al 2000)
- Construction cost of $69,600 (Lesikar et al 1999)
- Discount rate of 3% (Matthews, 2014)

Calculations:

Factor Of Safety = FoS
Daily Average Flow = DAF
Phosphorus = P

FoS = Design DAF/Projected DAF
FoS = 40,500 gpd/23,450 gpd = 1.7
Round up to 2.0

Daily P Adsorption = FoS x (Influent [P] - Target [P]) x Projected DAF
Daily P Adsorption = 2 x (4.2 mg/L - 1 mg/L) x (23,450 gpd) x 3.78541
L/gallons Daily P Adsorption = 568,114.3 mg P/day

RCA Weight = (Daily P Adsorption/P Adsorption Rate) x 365 days/year
RCA Weight = (568,114.3 mg P/day) x (1 g RCA/0.75 mg P) x 365 days/year x
(1kg/1000g) RCA Weight = 276,482.3086 kg RCA/year

RCA Volume = RCA Weight x 1/RCA Density
RCA Volume = (276482.3086 kg RCA/year) x (1 m^3/1506 kg)
RCA Volume = 183.5871903 m^3 RCA/year

Total Bed Volume = Volume of Voids + Volume of RCA
Total Bed Volume = (Void Ratio x Volume of RCA) + Volume of RCA
Total Bed Volume = (0.25 x 183.5871903 m^3/year) + 183.5871903 m^3/year
Total Bed Volume = 229.4839879 m^3

Dose Volume = FoS x Projected DAF/Dosing Frequency
Dose Volume = (2 x 23,450 gallons/day)/(48 times/day)
Dose Volume = 977.0833333 gallons/dose

Orifices Per Lateral = (Dose Volume/Orifice Flow)/(Number of Laterals)

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: RCA Filtration Bed Sizing and Cost		
PREPARED BY: Rahim Ansari	DATE: 3/17/2021	FINAL ☐
CHECKED BY: Michael Liu	DATE: 3/17/2021	REVISION ☐

Orifices Per Lateral = [(977.0833333 gallons/dose)/(1.5 gallons/orifice)]/(8 Laterals)
Orifices Per Lateral = 81.42361111 = 82

Minimum Lateral Length = (Orifices Per Lateral + 1) x Orifice Spacing
Minimum Lateral Length = (82 + 1) x 8 inches x (1 ft/12 inches)
Minimum Lateral Length = 55.33333333 ft
Round up to 60 ft for Total Bed Length
Total Bed Width = Total Bed Volume/(Bed Depth x Total Bed Length)
Total Bed Width = (229.4839879 m^3 x 35.3147 ft^3/m^3)/(3 ft x 60 ft)
Total Bed Width = 45 ft

Lateral Spacing = Total Bed Width/(Number of Laterals + 1)
Lateral Spacing = 45 ft/9 Laterals = 5 ft

Height of Drain Area = Drain Slope x (Total Bed Width/2)
Height of Drain Area = 0.045 x (45ft/2) = 1.0125 ft

Volume of Drain Area = ½ x Height of Drain Area x Width x
Length Volume of Drain Area = ½ x 1.0125 ft x 45 ft x 60 ft
Volume of Drain Area = 1366.875 ft^3

Weight of Drain Area = Volume of Drain Area x Density of Drain
Material Drain Material = Fill Sand
Density of Drain Material = 1631 kg/m^3 = 101.82 lbs/ft^3
Weight of Drain Area = 1366.875 ft^3 x 101.82 lbs/ft^3 = 13,9318 lbs = 69.66 tons

Max Daily Hydraulic Load = Max Hydraulic Load x Surface
Area Max Daily Hydraulic Load = 15 gallons/day/ft^2 x (60 ft x 45
ft) Max Daily Hydraulic Load = 40,500 gallons/day
As long as Max Daily Hydraulic Load is equal to or greater than Design DAF, then adequate design

Cost:
Weight of RCA = 304.77 tons
Cost of RCA per ton = $50.00/ton
RCA Cost = 304.77 tons x $50.00/ton = $15,238.46

Weight of Drain Material = 69.66 tons
Cost of Drain Material per ton = $11.50/ton
Drain Material Cost = 69.66 tons x $11.50/ton = $801.08

Delivery charges are $4.75/Ton for the first five miles and $0.80 per/Ton for each additional mile. Delivery Distance = 45 miles
Delivery Cost = $4.75/ton x (Total Weight in Tons) x 5 miles + $0.80/ton x (Total Weight in Tons) x 40 miles
Delivery Cost = $4.75/ton x (304.77 + 69.66) x 5 miles + $0.80 x (304.77 + 69.66) x 40
miles Delivery Cost = $20,874.37

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: RCA Filtration Bed Sizing and Cost		
PREPARED BY: Rahim Ansari	DATE: 3/17/2021	FINAL ☐
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Total PVC Length = Length of Laterals x Number of Laterals + Length of Flow Splitters x Number of Laterals + Distance of Piping to and from RCA Bed
Total PVC Length = 53.3 ft x 8 Laterals + 3 ft x 8 + 170ft = 636.67 ft
PVC Cost per foot = $10.00/ft
Total PVC Cost = $10.00/ft x 636.67 ft = $6366.67

Pump Cost = $1,500
Materials Capital Cost
= (RCA Cost + Drain Material Cost + Delivery Charge + PVC Cost + Pump Cost) x
Multiplier Multiplier = 3
Materials Capital Cost = ($15,238.46 + $801.08 + $20,874.37 + $6,366.67 + $1,500) x
3 Materials Capital Cost = $134,341.71
Construction Costs = $69,600
Capital Costs = Materials + Construction
Capital Costs = $203,941.71
Engineering Costs = $110,000
Contingency = .20 x Capital Costs
Contingency = .20 x $203,941.71
Contingency = $40,788.34
Total Capital Costs = Capital Costs + Engineering Costs + Contingency
Total Capital Costs = $203,941.71 + $110,000+ $40,788.34
Total Capital Costs = $354,700

Annual Material Costs = RCA Cost + Drain Material Cost + Delivery
Charge Annual Material Costs = $15,238.46 + $801.08 + $20,874.37 Annual
Material Costs = $36,913.90

Total Annual Costs = Annual Material Costs + Annual O/M Costs
Total Annual Costs = $36,913.90 + $6,700 = $43,613.90

P/A Factor = (1-(1+i)^-n)/i
i = discount rate = 3%
n=number of years = 20
P/A Factor = (1-(1.03^-20))/.03 = 14.8774748605 Present
Worth = Capital Cost + Annual Cost x P/A Factor Present
Worth = $354,700 + ($43,613.90 x 14.8774748605)
Present Worth = $1,003,357

<table>
<tr><td colspan="2">PROJECT / PROPOSAL NAME / LOCATION: Browntown WWTF / Village of Browntown, WI</td><td rowspan="2">PROJECT / PROPOSAL NO.</td></tr>
<tr><td colspan="2">SUBJECT: RCA Filtration Bed Sizing and Cost</td></tr>
<tr><td>PREPARED BY: Rahim Ansari</td><td>DATE: 3/17/2021</td><td>FINAL ☐</td></tr>
<tr><td>CHECKED BY: Michael Liu</td><td>DATE: 3/17/2021</td><td>REVISION ☐</td></tr>
</table>

Results:

A total of 276,482.3086 kg RCA are required every year. This RCA will become saturated with Phosphorus after one year and will need to be replaced. The saturated RCA must be removed and hauled away, and then can be used for downstream purposes such as a fertilizer ingredient. New RCA will need to be bought, delivered, and placed. The RCA will fill an approximately 60 foot by 45 foot bed that is 3 feet deep. Below the RCA will be a Drain Area filled with sand that is approximately 1 foot deep at the center with a 4.5% slope towards the center from both sides. A 0.1% slope can be designed along the length of the bed in order to promote drainage. A total of 8 2-inch laterals will be placed with 82 quarter-inch orifices placed every 8 inches along the more than 55 foot long laterals; spacing will be approximately 5 feet apart. Many of these parameters can be adjusted, but recalculation would need to be completed in order to ensure proper treatment. A total Present Worth of $1,003,357 was calculated using a discount rate of 3%. Given that this is an estimate, this number will be rounded to $1,003,400.

References:

Wastewater Engineering: Treatment and Reuse George Tchobanoglous, Franklin L. Burton, H. David Stensel (4th edition, 2002). Metcalf and Eddy.

H. Scott Matthews,Chris T. Hendrickson, and Deanna Matthews, Life Cycle Assessment: Quantitative Approaches for Decisions that Matter, 2014.Open access textbook,retrieved from https://www.lcatextbook.com/

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Collins, M. R., & Montel, A. (2000). Costing Summaries for Selected Water Treatment Processes (Rep.). Durham, NH: University of New Hampshire Department of Civil Engineering.

Lesikar, B. J., Lindbo, D. L., Tarquin, A., & Vehuizen, D. (1999). Decentralized Systems Technology Fact Sheet Recirculating Sand Filters (Rep. No. EPA 832-F-99-079). Washington, D.C.: United States Environmental Protection Agency.

Webster, I. (2021, March 13). Inflation rate BETWEEN 2000-2019: Inflation calculator. Retrieved March 17, 2021, from https://www.officialdata.org/2000-dollars-in-2019?amount=100

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: Constructed Wetland Cost		
PREPARED BY: Rahim Ansari	DATE: 3/7/2021	FINAL ☐
CHECKED BY: Michael Liu	DATE: 3/15/2021	REVISION ☐

Constructed Wetland Cost Calculations

Purpose:

To estimate the cost of the Constructed Wetland for treatment of wastewater at the Village of Browntown Wastewater Treatment Facility (WWTF) according to projected loadings for the next 20 years.

Methodologies:

The wetlands expert at Jacob's engineering used their in-house design tool to create an estimate of cost for the proposed wetland. All costs are then presented cumulatively as a Present Worth cost using a discount rate of 3% (Matthews, 2014). A RCA filtration bed may be added for additional phosphorus removal if needed. Costs for this addition are outlined in RCA Bed Sizing and Cost.

Assumptions:

- Discount rate of 3% (Matthews, 2014)

Calculations:

Estimate from Jacob's Engineering
$500,000 for earthwork, vegetation, piping
$7,000 for 1 acre land
Capital Cost = $507,000
Engineering Cost = $110,000
Contingency = Capital Cost x 0.20
Contingency = $507,000 x 0.20
Contingency = $101,400
Total Capital Cost = Capital Cost + Engineering Cost + Contingency
Total Capital Cost = $507,000 + $110,000 + $101,400 = $718,400

P/A Factor = (1-(1+i)^-n)/i
P/A Factor = (1-(1.03^-20))/.03
P/A Factor = 14.8774748605

Annual costs = Inspections and Repairs = $3,000/year
Present Worth = Total Capital Costs + Annual Costs x P/A Factor
Present Worth = $718,400 + ($3,000 x 14.8774748605)
Present Worth = $718,400 + $44,632.42
Present Worth = $763,032.20

Results:

The Present Worth for the constructed wetland is $763,032.20. Since this is an estimate, the Present Worth is rounded to $763,100.

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: Constructed Wetland Cost		
PREPARED BY: Rahim Ansari	DATE: 3/7/2021	FINAL ☐
CHECKED BY: Michael Liu	DATE: 3/15/2021	REVISION ☐

References:

Wastewater Engineering: Treatment and Reuse George Tchobanoglous, Franklin L. Burton, H. David Stensel (3rd edition, 1991). Metcalf and Eddy.

Simpkin, T., & Fitzgerald, C. (2021). Constructed Wetland Cost Estimate (Cost Estimate). Englewood, CO: Jacobs.

H. Scott Matthews,Chris T. Hendrickson, and Deanna Matthews, Life Cycle Assessment: Quantitative Approaches for Decisions that Matter, 2014.Open access textbook,retrieved from https://www.lcatextbook.com/

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: **Projection of Alum Amount and Cost**		
PREPARED BY: **Michael Liu**	DATE: **3/3/2021**	FINAL
CHECKED BY: Rahim Ansari	DATE: 3/15/2021	REVISION

Projection of Alum and Ferric Chloride Amount and Cost

Purpose:

To assess the projected amount of liquid Alum needed to precipitate phosphorus from the influent of wastewater and project the costs for acquisition.

Methodologies:

The main method to calculate the amount of liquid Alum and liquid ferric chloride needed was the use of stoichiometry. Mole ratios between alum and phosphorus alongside molar ratios between ferric chloride and phosphorus were used to determine the gallons of the solution in terms of gallons per day. Stoichiometry ratios were also used to determine the amount of sludge created by chemical precipitation. Calculations were performed via an excel spreadsheet.

Assumptions:

Several assumptions need to be made in order to determine the amount of liquid Alum needed:

- The amount of aluminum required to precipitate phosphorus is a 1.38:1 ratio (MOP 8)
- The projected average daily flow for 2040 is 0.02345 MGD
- Target Phosphorus concentration is 1 mg/L and average effluent phosphorus concentration is 4.2 mg/L
- The molar weight of phosphorus (P) is 30.97 g/mol (Metcalf and Eddy)
- The molar weight of aluminum (Al) is 26.98 g/mol (Metcalf and Eddy)
- The molar weight of aluminum sulfate (*18H_2O) (Alum) is 594.37 g/mol (Metcalf and Eddy)
- The molar weight of iron (Fe) is 55.85 g/mol (Metcalf and Eddy)
- The molar weight of ferric chloride (Ferric) is 162.5 g/mol (Metcalf and Eddy)
- Unit conversion for mg of chemical to lbs of chemical per day is 8.34 lb/(MG*mg/L) (Metcalf and Eddy) (Simpkin and Fitzgerald, 2021)
- Chemical costs and concentrations are from Hawkins Water Treatment Group (Ruppert, 2021)
- The Ferric solution is 35% strength while Alum solution is 49% strength (Ruppert, 2021)
- The density of alum solution (lbs/gal) is 11.09 (Simpkin and Fitzgerald, 2021)
- The density of ferric solution (lbs/gal) is 11. 68 (Simpkin and Fitzgerald, 2021)
- The price of aluminum sulfate is $4.47/gal (Simpkin and Fitzgerald, 2021)(Ruppert, 2021)
- The price of ferric chloride is $7.22/gal (Simpkin and Fitzgerald, 2021)(Ruppert, 2021)
- Dredging costs are from Triplepoint Environmental. The price of dredging is $350 per dry ton (Hill, 2020)
- The Capital Costs are approximately $57,000 (Buholzer, 2021)

Calculations:

Factor Of Safety = FoS
Daily Average Flow = DAF
Phosphorus = P

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: **Projection of Alum Amount and Cost**		
PREPARED BY: **Michael Liu**	DATE: **3/3/2021**	FINAL ☐
CHECKED BY: Rahim Ansari	DATE: 3/15/2021	REVISION ☐

MW= Molar weight
Alum=Aluminum sulfate
FoS = Design DAF/Projected DAF
FoS = 40,500 gpd/23,450 gpd = 1.7
Round up to 2.0

Alum calculations:
Mg metal required/L= P/(Phosphorus MW)*(mol Al/mol P)*(Al MW)
Mg metal required/L=(3.2 mg/L)/(30.97 g/mol)*((1.38 mol Al)/(1 mol P))*(26.98 g/mol Al)=3.85 mg Al/L

Mg chemical required/L=(Mg metal required/L)/(Al MW)/2*(Alum MW)
Mg chemical required/L= (3.85 mg Al/L)/(26.98 g/mol)/2*(594.37 g/mol)=42.4 mg Alum required/L

Lb Chemical/day= mg chemical required/L* (8.34 lb/(Mgal*mg/L))*DAF
Lb Chemical/day= 42.4 mg alum required/L*(8.34 lb/(Mgal*mg/L))*0.02345 Mgal/day=8.29 lb Alum/day

Lb Alum solution/day=lb chemical/day/ Alum strength
Lb alum solution/day= 8.29 lb Alum/day/0.49=16.91 lb alum solution/day

Gal solution/day= lb alum solution/day/density of alum solution
Gal solution/day= 16.91 alum solution/day/11.09 lb/gal=1.52 gal Alum/day

Ferric Chloride calculations:
Mg metal required/L= P/(Phosphorus MW)*(mol Fe/mol P)*(Al Fe)
Mg metal required/L=(3.2 mg/L)/(30.97 g/mol)*((1 mol Fe)/(1 mol P))*1.38*(55.85 g/mol Fe)= 7.96 mg Fe/L

Mg chemical required/L=(Mg metal required/L)/(Fe MW)*(Fe MW)
Mg chemical required/L= ((7.96 mg Fe/L)/(55.85 g/mol))*(162.5 g/mol)= 23.16 mg ferric chloride required/L

Lb Chemical/day= mg chemical required/L* (8.34 lb/(Mgal*mg/L))*DAF
Lb Chemical/day= 23.16 mg ferric chloride/L*(8.34 lb/(Mgal*mg/L))*0.02345 Mgal/day)=4.53 lb ferric chloride/day

Lb Ferric Chloride solution/day=lb chemical/day/ Alum strength
Lb Ferric Chloride/day= 4.53 lb ferric/day/0.35=12.94 lb ferric chloride solution/day

Gal solution/day= lb alum solution/day/density of ferric chloride solution
Gal solution/day= 12.94 lb ferric chloride solution/day/11.68 lb/gal=1.11 ferric chloride gal/day

The annual amount of Alum solution needed: 1.52 gal Alum/day*365 days=556.66 gal Alum/year

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: **Projection of Alum Amount and Cost**		
PREPARED BY: **Michael Liu**	DATE: **3/3/2021**	FINAL ☐
CHECKED BY: Rahim Ansari	DATE: 3/15/2021	REVISION ☐

The annual amount of Ferric Chloride Solution needed: 1.11 gals ferric chloride/day*365 days= 405.15 gals ferric chloride/year

Annual amount Alum incorporating FoS= 2*556.66 gal Alum/year =1113.32 gal Alum/year
Annual amount Ferric Chloride incorporating FoS=2*405.15 gal Ferric chloride/year=810.3 gal Ferric chloride/year

Sludge Calculations:

Aluminum Sulfate:

Mass of aluminum (lb Al/day)= Mass of Aluminum required *(8.34 lb/(Mgal*mg/L))*DAF
Mass of aluminum (lb Al/day)=(3.85 mg Al/L)*(8.34 lb/(Mgal*mg/L))*0.02345=0.753
Mass of PO4 (lb PO4/day)=(average effluent phosphorus-target phosphorus concentration)/Phosphorus MW*Phosphate MW*DAF
Mass of PO4 (lb PO4/day)=((4.2-1)/30.97)*94.966*(8.34 lb/(Mgal*mg/L))*0.02345=1.92 lb PO4/day Total mass of Sludge/day=1.92 lb PO4/day +0.75 Aluminum/day=2.67 lb/day
Total tons of sludge/year=2.67 lb Sludge/day*(365 days/year)/2000 lbs/ton=0.49 tons

Ferric Chloride:

Mass of iron (lb Al/day)= Mass of iron required *(8.34 lb/(Mgal*mg/L))*DAF
Mass of aluminum (lb Fe/day)=(7.96 mg Fe/L)*(8.34 lb/(Mgal*mg/L))*0.02345=1.56 lb Fe/day
Mass of PO4 (lb PO4/day)=(average effluent phosphorus-target phosphorus concentration)/Phosphorus MW*Phosphate MW*DAF
Mass of PO4 (lb PO4/day)=((4.2-1)/30.97)*94.966*(8.34 lb/(Mgal*mg/L))*0.02345=1.92 lb PO4/day Total mass of Sludge/day=1.92 lb PO4/day +1.56 lb Fe /day=3.48 lb/day
Total tons of sludge/year=3.48 lb Sludge/day*(365 days/year)/2000 lbs/ton=0.64 tons

Price Calculations:

The annual price for alum solution:1113.32 gal Alum/year*$4.47/gal=$4,976.54 /year
The annual price for ferric chloride solution:810.3 gal Ferric Chloride/year*$7.22/gal=$5850.37/year
The annual price for dredging Alum sludge: $350/dry ton*0.49 tons Alum sludge=$171.50/year
The annual price for dredging Ferric sludge: $350/dry ton*0.64 tons Ferric sludge=$224/year

The total annual price for using alum: $4976.54/year + $171.50/year=$5148.04/year
The total annual price for using ferric: $5850.37/year +$224/year=$6074.37/year

Capital Costs = Cost of Equipment/Initial Material + Cost of Construction + Engineering Cost + Contingency
Capital Costs = $35,000 + $5,000 + ($110,000) + ($40,000 x 0.20) = $158,000

PROJECT / PROPOSAL NAME / LOCATION: **Browntown WWTF / Village of Browntown, WI**		PROJECT / PROPOSAL NO.
SUBJECT: **Projection of Alum Amount and Cost**		
PREPARED BY: **Michael Liu**	DATE: **3/3/2021**	FINAL ☐
CHECKED BY: Rahim Ansari	DATE: 3/15/2021	REVISION ☐

P/A Factor = (1-(1+i)^-n)/i
i = discount rate = 3%
n=number of years = 20
P/A Factor = (1-(1.03^-20))/.03 = 14.8774748605 Present
Worth = Capital Cost + Annual Cost x P/A Factor
Present Worth of Alum solution = $158,000 + ($5148.04/year x 14.8774748605)=$234,590
Present Worth of Ferric solution=$158,000 + ($6074.37/year x 14.8774748605)=$248,370

Results

The annual price of an alum solution was calculated to be $5148.04 while the annual price of a ferric solution was estimated to be $6074.37. With dredging costs considered, and a 3% discount rate, the Present Worth of alum is $234,590 and the Present Worth of ferric is $248,370. Given that these are estimates, the costs will be rounded to $235,000 and $249,000 respectively. With ferric costing $14,000 more than alum over 20 years, M.M. C.R.B Consultants recommend using alum due to the oxidative nature of ferric, which will cause staining and usage of dissolved oxygen.

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M.M. C.R.B. Consultants
1415 Engineering Drive
Madison, WI 53706

April 6, 2021

TO:
Jan Kucher, PE Adjunct Professor
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

RE: 100% Geotechnical Report for Wastewater Treatment Facility in Browntown, Wisconsin

Dear Professor Kucher,

M.M. C.R.B. Consultants have completed the initial geotechnical report for the Village of Browntown's Wastewater Treatment Facility project. With the help from our drilling team and geotechnical engineer, data has been collected on soil properties, hydrology, geology, and stratigraphy. With this data, accurate design alternatives can be constructed safely and efficiently.

Using the collected data from the geotechnical investigation, recommendations can be provided to the preliminary design of phosphorus removal for the Browntown WWTF. This report includes the following: site investigation using soil borings, subsurface conditions around the treatment facility, and M.M. C.R.B. Consultants' final engineering recommendations for the geotechnical aspects of the design alternatives as the project progresses.

We appreciate your time and look forward to seeing the project progress. If you have additional questions or concerns, please feel free to contact me at rahim.ansari125@gmail.com or 608-335-1049.

Sincerely,

Rahim Ansari
Project Manager
M.M. C.R.B. Consultants

100% Geotechnical Report
Engineering Services for Wastewater System in Browntown, Wisconsin

Prepared For:
Village of Browntown, WI

Prepared By:
M.M. C.R.B. Consultants

April 6th, 2021

Disclaimer

The concepts, drawings and written materials provided here were prepared by students in the Department of Civil & Environmental Engineering at the University of Wisconsin-Madison as an activity in the course Civ Engr 578 – Senior Capstone Design/GLE 479 – Geological Engineering Design. These do not represent the work products of licensed Professional Engineers. These are not for construction purposes.

Introduction

M.M. C.R.B. Consultants have completed the geotechnical investigation and report for the Wastewater Treatment Facility (WWTF) in Browntown requested by the Village of Browntown located in Green County, Wisconsin. The Village of Browntown has requested design alternatives to reduce the phosphorus concentrations in their discharge water from the WWTF, so any additional structures above or below the surface that achieve this objective will be investigated. This report includes all the geological conditions and soil properties that factor into the WWTF additions in the area to properly construct on the current surface conditions. After the investigation has been completed, recommendations will be given on how to reduce the impact on the site and limit the settlement when constructing design alternatives.

Project Description

Site History:

The Village of Browntown WWTF was designed in 1978 by Strand Associates Consulting Engineers and constructed in 1979. Strand Associates designed the facility as a lagoon treatment system with dual lagoons to process wastewater. Once wastewater has gone through the two lagoons, the wastewater is treated with a chlorine tank for disinfection. Finally the disinfected effluent is pumped back into Skinner Creek to be reintroduced to the watershed. Currently on site, there are two lagoons, a pump station, and a chlorine treatment structure to handle all of the Village of Browntown's wastewater. The WWTF has not seen any major updates or renovations since its construction in 1979.

Features of Proposed Designs:

M.M. C.R.B. Consultants are proposing several design alternatives to remove phosphorus from the wastewater in Browntown. One design alternative is a crushed concrete bed or recycled concrete aggregate (RCA) bed that has high concentrates of limestone. Wastewater will be pumped through this RCA bed and phosphorus in the wastewater will be adsorbed to the limestone within the concrete and be removed from the wastewater. Another design option is using a filtration method to process out any phosphorus in the wastewater. A third design option is proposed using a chemical precipitate that binds with the phosphorus within the lagoons and creates a sludge. Periodically this sludge will need to be removed from the lagoons. Chemical precipitation will need a new building constructed in order to store the aluminum sulfate used in the process so a new foundation will be designed by the geotechnical team. Finally a fourth design alternative was considered by the project team, a constructed wetland. For this alternative, additional land would need to be purchased and more geotechnical data would need to be collected with borings to provide a complete recommendation to construct this wetland.

Scope of Work

The scope of this geotechnical report includes: boring of future sites for design alternatives with boring logs which include soil and rock samples, evaluation of foundations required for RCA bed and slab on grade structures that house phosphorus removal hardware, mapping of local water table levels and bedrock within Green County, and analysis of bearing capacity and settlement for geological design of design alternatives.

All borings performed on site will be used to determine soil extent and thicknesses, properties of soil types to accurately design foundations and footings for design alternatives and water table levels to determine saturation. This geotechnical report will include relevant information on local geology, groundwater and saturation levels, soil types and conditions to excavate and construct on, expected bearing capacity, allowable bearing capacity, settlement estimates, foundation recommendations for selected design alternatives, and issues in regards to construction of any designs.

Scope of Subsurface Exploration

Type of Exploration:

To determine soil strata and variation, two standard penetration test (SPT) borings were performed at the WWTF. These borings were performed on October 16th, 2020, by M.M. C.R.B. Consultants' geotechnical team and analyzed by their geotechnical engineer. These SPT borings were performed for exploration and structural analysis to determine soil properties while designing bearing capacity and allowable bearing pressure for any design alternatives for the removal of phosphorus. M.M. C.R.B. Consultants' geotechnical team performed these borings using a MA-13 SPT Autohammer by TMG Manufacturing mounted to a pickup truck to perform borings with 2-¼ inch hollow stem augers to a depth of 10 feet. The location of these borings can be seen in Figure 2 of Appendix A.

Site Description

Regional Geology:

The Village of Browntown has two primary rock groups in the region, the Ancell (Oa) and Sinnipee (Os) groups. The Ancell group is made up of primarily sandstone. It is found as the local bedrock in Browntown and can also be found at low ridges or outcrops in the surrounding area. The sandstone in this group is included in two rock formations, the Glenwood and the Saint Peter formations. The second group, Sinnipee, is predominately made up of dolomite with fossils commonly within the dolomite. This group can be found as the bedrock but also appears at ledges or piles of eroded rubble piles. The Sinnipee dolomite is within two rock formations, the Platteville and Glenwood formations. Both of these rock groups are found as bedrock and are relatively close to the surface as soil cover is thin. The bedrock of the Village of Browntown can be seen in Figure 3 of Appendix A.

Surface Characteristics:

The Village of Browntown is on the boundary between the driftless and glaciated zones. The driftless zone was not affected by glaciers so the topography of the Village of Browntown changes constantly with many hills and slopes surrounding the local area. This is also the cause of the thin soil cover over the bedrock. This thin soil cover is local to the area and causes many outcrops of the sandstone and dolomite bedrock to be exposed as erosion occurs. South of the Village of Browntown is the boundary of the glaciated zone where glaciers moved through southern Wisconsin. As these glaciers recessed north, they dropped additional sediment and rocks. This can be seen as these areas are full of sandy loams and multiple layers of soil types.

Significant Lab Test Results:

All soil boring samples collected during the boring testing were examined by the geotechnical engineer following ASTM D1586 standards. Using ASTM D2216, the number of blows required to get through the soil type were accounted for on the boring logs. This can be seen in Appendix B, under the column labeled N. A range of N values were found between 4 and 23 with Boring 1 having an average N value of 9 and Boring 2 having an average of 14. With these N values, the cohesion and friction angle of each of the soil types can be determined which is seen in Table 3 of Appendix C. Cohesion of 1800 psf and a friction angle of 32 degrees will be used for further analysis. Also in the laboratory, using the Unified Soil Classification System (USCS), soil types were determined and can be seen in Figure 4 of Appendix A.

Groundwater Conditions:

The depth of groundwater was found to be relatively close to the surface. This is due to the location of the WWTF. Groundwater data can be seen in Table 1 of Appendix C. It is close to Skinner Creek which merges with the Pecatonica River. Being so close to Skinner Creek, groundwater was found to be 5 feet from the surface when the borings were drilled, however typically groundwater is found to be 2 to 3 feet from the surface. As the Village of Browntown is located in the driftless zone, the ground elevation changes constantly with large slopes, which change the direction of groundwater frequently. Groundwater recharge typically comes from precipitation and snowmelt, and groundwater flow leads this recharge to Skinner Creek. Due to the low groundwater table and changing directions of groundwater, contamination is at a higher risk from the WWTF if spillage occurs or manure and fertilizer enter the facility from nearby pastures and farm fields.

Another issue with the high groundwater table will be found during construction. Excavation and installation of the RCA bed will require water to continually be removed and maintained from the construction site. The usage of sump pumps will be required until the geotextile layer around the RCA bed is installed to reduce the risk of contamination. When the RCA bed is in use, collected wastewater will be pumped to the chlorine treating station at the WWTF.

Environmental Issues and Impacts:

There are several sources of environmental issues that arise from this geotechnical investigation. The first would be the impact that potentially could occur to the ground and surface water. Due to how close this WWTF is located to Skinner Creek and how high the groundwater table is, the risk for contamination is increased. This increase comes from the WWTF and any construction that occurs on site. Spillage from the facility could potentially spread rapidly from the groundwater into Skinner Creek which connects with larger bodies of water until it reaches the Rock River which then flows into the Mississippi River. During any construction on the WWTF, heavy equipment will be used to excavate soil. These heavy pieces of equipment like bulldozers or excavators use diesel and other petroleum-based fluids to operate, and any quantity could contaminate the groundwater.

Another environmental issue is with the use of recycled crushed concrete. Metals and other pollutants from the concrete could leach out of the concrete as it is being used to filter the wastewater for phosphorus and potentially contaminate the wastewater even more. Lab scale testing will need to be performed in order to determine if this may occur. Also, this concrete will need to be replaced once per year to continually filter for phosphorus. During the removal of concrete, all of the concrete must be safely removed and either used for downstream purposes such as fertilizer or disposed of properly. Finally the treated wastewater that is filtered through the RCA bed must be completely recollected as it still must be treated using chlorine to kill any remaining bacteria before it can reenter the groundwater. The RCA bed must be designed to reduce any seepages into the soil and effectively drain the treated wastewater at the bottom of the filter bed.

Discussion and Recommendations

Introduction:

All of the design alternatives at this point are still being considered until a final decision is made on the best design alternative to remove phosphorus from the WWTF, however geotechnical services will only be needed to construct the RCA bed, and the new foundation for the storage facility for chemical precipitation. This is due to the consideration that the other design alternatives require additional infrastructure requirements and data analysis which will proceed to be collected if that preliminary design is chosen.

Site Selection:

As seen in Appendix 1, Figure 2, there are two viable location options for the RCA bed to be constructed at the WWTF. Boring data has been collected from both sites. This data shows that the soil characteristics are ideal at both sites and an RCA bed can be constructed there. Due to the depth requirements, both potential sites will hit the groundwater table and will need adequate equipment to remove water during construction. Costs associated with site preparation will be relatively the same as both sides are similar in the aspects of demolition and soil removal. When the final design is made, the project team will recommend a preferred site and will be accounted for.

Site Preparation:

To prepare the site for construction, barriers will need to be constructed around the lagoons in order to protect them from any spillage of removed materials or fluids. This can be done using a combination of all purpose 3 foot tall ultra containment wall sections and silt fences. All topsoil, trees, and debris must be removed. All preparation for construction including installation of protective barriers is under the responsibility of the soil moving contractor.

Foundation Recommendations:

The RCA bed will be designed to be 3 feet thick starting at the surface and reaching a depth of 3 feet as a shallow foundation bed. A high density polyethylene liner will be used on the sides and bottom of the RCA bed, while a lightweight protective cover will be placed on the top. Between the RCA and the HDPE liner, there will be a protective layer to protect the liner and reduce the porosity of the soil and velocity of the flow to protect the HDPE liner . The geotechnical team recommends a layer of sand with a thickness of 1 foot below the RCA bed. This layer requires a void ratio of 0.25 and will be compacted until this void ratio is reached. The sand layer will be sloped to a center point in order for all wastwater to be collected and piped to the chlorine tank to be treated. A downhill slope of 4.5% to the center point must be achieved.

The final additional layer for the RCA layer will be a 1 foot thick layer of clay to reduce the porosity and increase protection to the groundwater. This layer will have a slope of 0% and be compacted to 95% in order to provide adequate protection. Design of this RCA bed can be seen in Figure 5 of Appendix A.

Chemical precipitation requires a new storage facility to be constructed to hold the aluminum sulfate used to reduce the phosphorus concentration. The foundation recommended by the geotechnical team at M.M. C.R.B. Consultants is a shallow foundation constructed as a slab on grade concrete deck. Due to the low load anticipated for the storage facility, footings will not be necessary with the slab on grade having a thickness of 6 inches. The sides of the facilities foundation are sloped to increase thickness to a minimum depth of 24 inches with a width of 3 feet. A generalized foundation example was provided below.

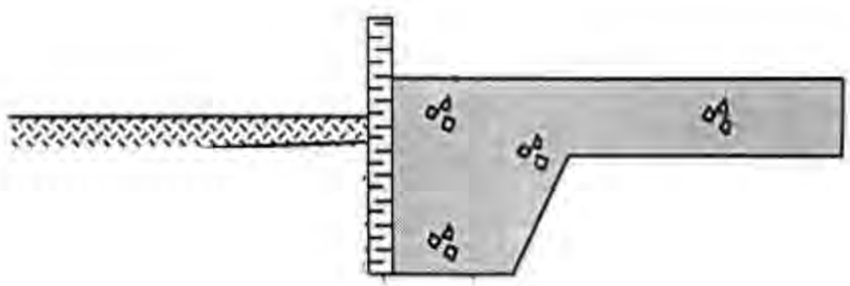


Figure 1: Generalized example of shallow slab on grade foundation.

Bearing Capacity and Allowable Bearing Pressure:

Bearing capacity and the allowable bearing pressure for structures built at the potential site were calculated with the boring data that was calculated. Using Terzaghi's bearing capacity theory, a bearing capacity was calculated to be 88,915 pounds per square foot and can be seen in Appendix C. Using the calculated bearing capacity and a factor of safety of 3, the allowable bearing pressure was calculated to be 29,638 pounds per square foot and can also be seen in Appendix C. With this information, the structural engineer can confirm that soil at the potential sites will withstand the weight of the RCA bed. Bearing capacity was calculated to be 67,788 pounds per square foot and an allowable bearing pressure was determined to be 22,596 pounds per square foot for the newly constructed storage facility.

Settlement:

Settlement from the RCA bed will be negligible as there is no load on top of the crushed concrete bed and the load. Calculations were done on the settlement and can be seen in Appendix C. Anticipated soil settlement from the RCA bed and storage facility is 0.08 inches which is within standards set by M.M. C.R.B. Consultants.

Settlement for the chemical precipitation storage facility was calculated to be 1.26 inches. To further reduce the settlement from the load of this storage facility, the M.M. C.R.B. Consultants geotechnical team recommends that the construct site be covered in a gravel bed and it be compacted to 95% compaction. With this compacted gravel layer, the settlement will be reduced to below 1 inch which is within the standard set of M.M C.R.B. Consultants. These can all be seen in table 5 of Appendix C.

Lateral Earth Pressure Coefficients

Using soil descriptions and data collected from the boring logs that were performed, lateral earth pressure coefficients were calculated for the potential construction sites at the WWTF. With an internal friction angle of 32 degrees, an active lateral earth pressure was calculated to be 0.013, a passive lateral earth pressure was calculated to be 0.633, and for an at rest lateral earth pressure 0.47 was calculated. Due to the high saturation of the soil sites that are located near Skinner Creek, an active or at rest condition are the most frequent lateral earth pressures to occur. Table 4 in Appendix C shows the calculated values for lateral earth pressure coefficients.

Limitations:

There are some limitations when it comes to this geotechnical report. The first is that the RCA bed was calculated to not hold any load on top of it. Any additional structures above the RCA bed pose a threat to the structural integrity of the design and are not recommended without further analysis. Secondly, all analysis and calculations were performed with the soil sample data as it was collected. If soil conditions change due to saturation levels or other characteristics, further calculations will need to be performed in order to construct a safe facility and RCA bed.

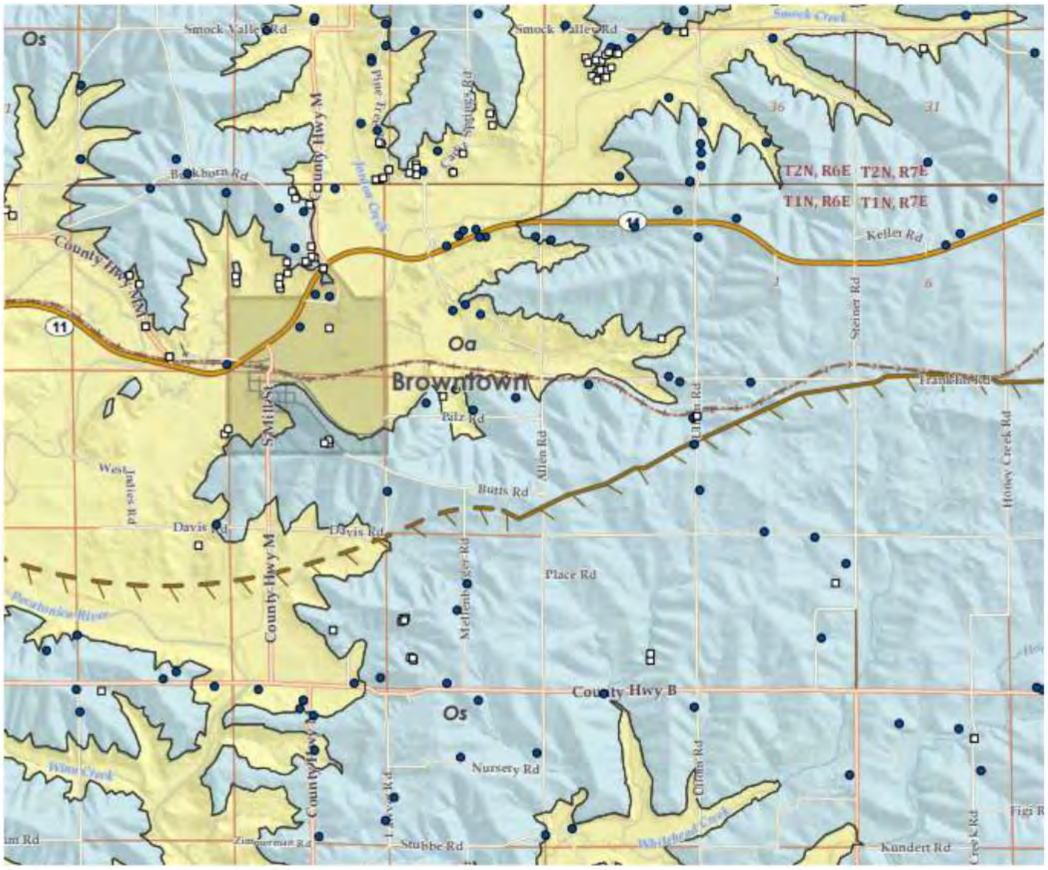
Conclusion:

The WWTF has two viable locations to construct a RCA bed to filter phosphorus out of the wastewater discharge. Both locations have adequate soil properties and groundwater conditions to support a structure. A bearing capacity was calculated to be 88,915 pounds per square foot. Using the bearing capacity and a factor of safety of 3, the allowable bearing pressure was calculated to be 29,638 pounds per square foot. An estimated settlement of 0.08 inches was calculated after the RCA bed is calculated. For chemical precipitation, a constructed storage facility bearing capacity was calculated to be 67,788 pounds per square foot and using this with a factor of safety of 3, an allowable bearing pressure will be 22,596 pounds per square foot. With this in mind, a settlement of less than an inch will be achieved by using a compacted gravel layer underneath the storage facility.

Appendix A:

Figure 1: Map of the Village of Browntown's Wastewater Treatment Facility

Figure 2: Map of Boring locations and Potential Sites



BEDROCK GEOLOGY FEATURES

- Bedrock Outcrop or Exposure
- Private Well with Logged Bedrock Geology
- Well Location with Detailed Geologic Log

BEDROCK GEOLOGIC

Sinnipee Dolomite (Os)
Os
Thw Sinnipee Group includes dolomitic rock formations, including the Galena, Decorah, and Platteville formations. For this map only the geologic

Ancell Group (Oa)
Oa
The Ancell Group includes shale and sandstone rock formations, including the Glenwood and St. Peter formations. For this map only the geologic group is

Figure 3: Bedrock of the Village of Browntown

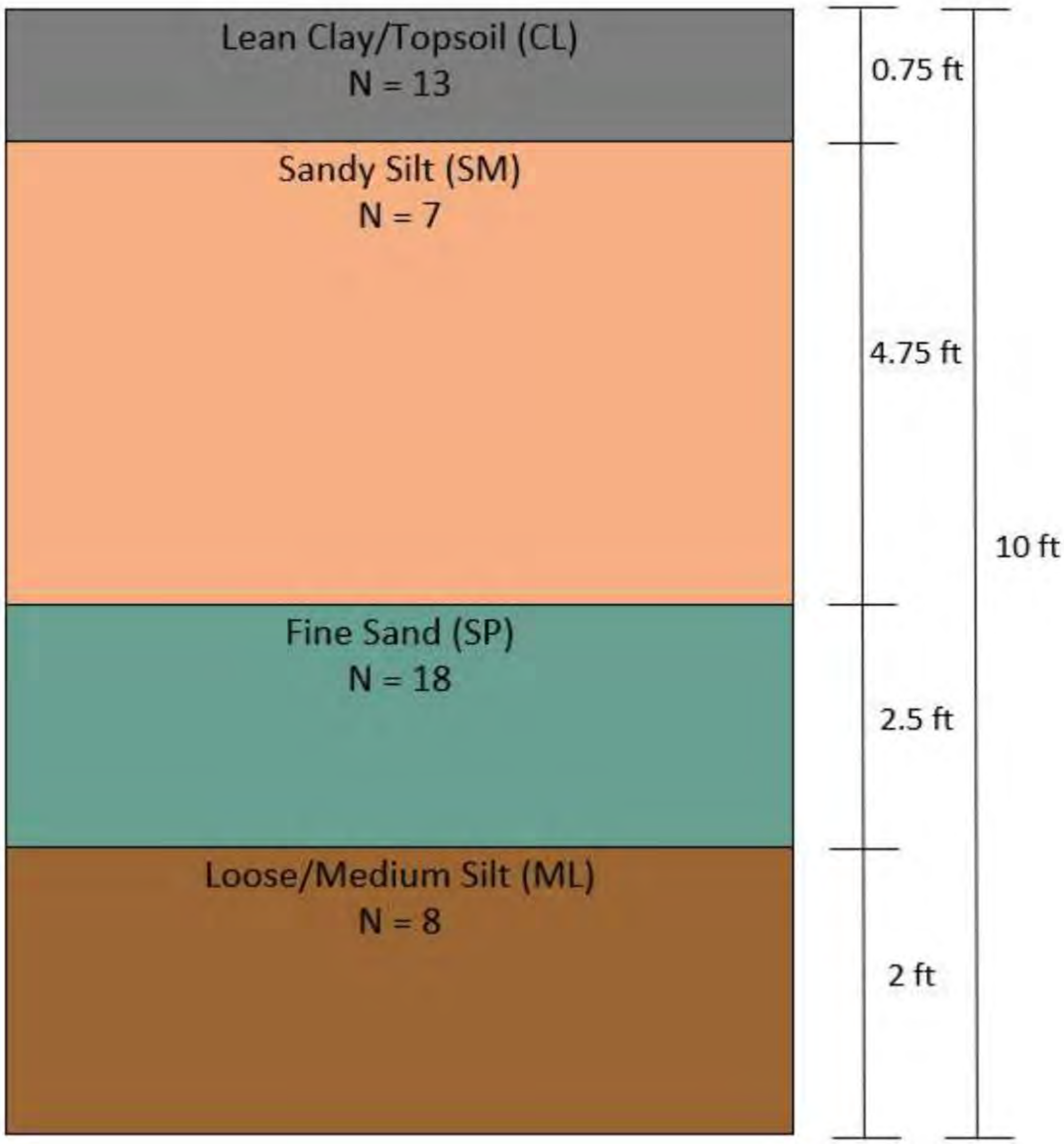


Figure 4: Soil Cross Section of Boring Logs

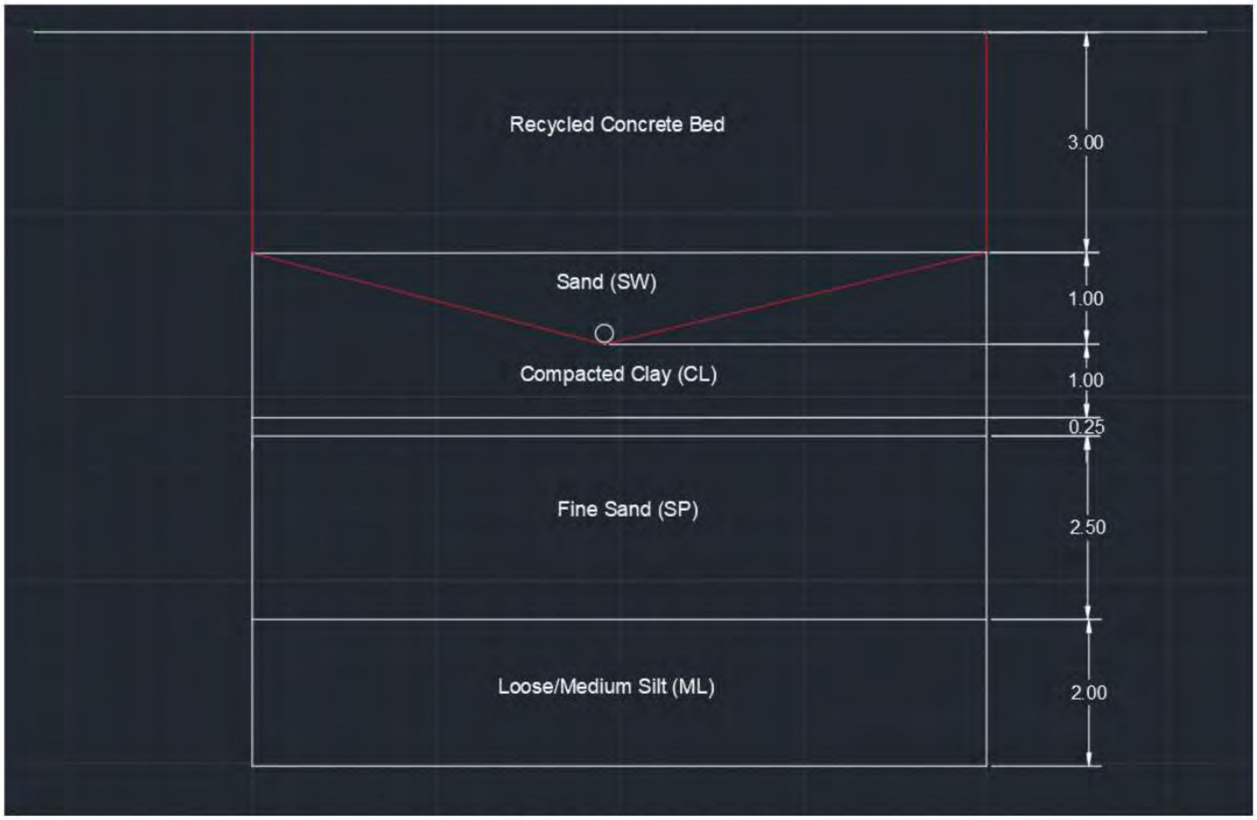


Figure 5: Design of RCA Bed

Appendix B:

LOG OF TEST BORING

M.M. C.R.B.

Project: Wastewater Treatment Facility
M.M. C.R.B. Consultants
Location: Browntown, WI

Boring No. 1
Surface Elevation (ft) 851.4 ft
Job No.
Sheet 1 of 1

SAMPLE No.	Rec (in.)	Moist	N	Depth (ft)	VISUAL CLASSIFICATION and Remarks	qu (qa) (tsf)	W	LL	PL	LI
					FILL: Dark Brown Lean Clay (Topsoil) to 0'8"					
1	12	M	13		Dark Brown to Black Sandy Silt, Little Wood, Glass, Cinders and Gravel to 5'6"					
2	6	M	4	5						
3	18	W	13		Medium Dense, Gray Fine SAND, Trace Silt and Gravel (SP)					
4	0	M	6	10	Medium Stiff, Gray Sandy Lean CLAY, Trace Gravel (CL)					
				15	End Boring at 10 ft Borehole backfilled with bentonite chips					

This boring log has been prepared for a UW Capstone Engineering Class for educational use ONLY. It does not represent actual conditions and should NOT be used for any other purpose.

WATER LEVEL OBSERVATIONS

While Drilling	▽ 5.5'	Upon Completion of Drilling			3.0'
Time After Drilling					3/4 hr
Depth to Water					2.0 ▼
Depth to Cave in					

The stratification lines represent the approximate boundary between soil types and the transition may be gradual.

GENERAL NOTES

Start 10/16/20	End 10/16/20	
Driller AD	Chief WP	Rig CME-45
Logger TO	Editor SB	
Drill Method 2 1/4" HSA		

M.M. C.R.B.

LOG OF TEST BORING

Project: Wastewater Treatment Facility
M.M. C.R.B. Consultants
Location: Browntown, WI

Boring No. 2
Surface Elevation (ft) 847.3 ft
Job No.
Sheet 1 of 1

SAMPLE No.	Rec (in.)	Moist	N	Depth (ft)	VISUAL CLASSIFICATION and Remarks	qu (qa) (tsf)	W	LL	PL	LI
					FILL: Dark Brown Lean Clay (Topsoil) to 0'9"					
1	18	M	13		Dark Brown to Black Fine Sand, Trace Gravel to 3'0"					
2A/B	18	M/W	10	5	Dark Brown to Black Lean Clay, Sand and Topsoil, Some Glass and Gravel to 5'6"					
3	18	W	23		Medium Dense, Gray Fine SAND, Trace to Little Silt (SP-SP/SM)					
4	18	W	10	10	Loose to Medium Dense, Brown SILT, Little Sand (ML)					
				15	End Boring at 10 ft Borehole backfilled with bentonite chips					

This boring log has been prepared for a UW Capstone Engineering Class for educational use ONLY. It does not represent actual conditions and should NOT be used for any other purpose.

WATER LEVEL OBSERVATIONS

While Drilling ▽ 5.0' Upon Completion of Drilling 4.5'
Time After Drilling 1/4 hr
Depth to Water 3' ▼
Depth to Cave in

The stratification lines represent the approximate boundary between soil types and the transition may be gradual.

GENERAL NOTES

Start 10/16/20 End 10/16/20
Driller AD Chief WP Rig CME-45
Logger TO Editor SB
Drill Method 2 1/4" HSA

LOG OF TEST BORING

General Notes

Descriptive Soil Classification

GRAIN SIZE TERMINOLOGY

Soil Fraction	Particle Size	U.S. Standard Sieve Size
Boulders	Larger than 12"	Larger than 12"
Cobbles	3" to 12"	3" to 12"
Gravel: Coarse	3/4" to 3"	3/4" to 3"
Fine	4.76 mm to 3/4"	#4 to 3/4"
Sand: Coarse	2.00 mm to 4.76 mm	#10 to #4
Medium	0.42 to mm to 2.00 mm	#40 to #10
Fine	0.074 mm to 0.42 mm	#200 to #40
Silt	0.005 mm to 0.074 mm	Smaller than #200
Clay	Smaller than 0.005 mm	Smaller than #200

Plasticity characteristics differentiate between silt and clay.

GENERAL TERMINOLOGY

Physical Characteristics
Color, moisture, grain shape, fineness, etc.
Major Constituents
Clay, silt, sand, gravel
Structure
Laminated, varved, fibrous, stratified, cemented, fissured, etc.
Geologic Origin
Glacial, alluvial, eolian, residual, etc.

RELATIVE DENSITY

Term	"N" Value
Very Loose	0-4
Loose	4-10
Medium Dense	10-30
Dense	30-50
Very Dense	Over 50

RELATIVE PROPORTIONS OF OF COHESIONLESS SOILS

Proportional Term	Defining Range by Percentage of Weight
Trace	0%-5%
Little	5%-12%
Some	12%-35%
And	35%-50%

CONSISTENCY

Term	q_u-tons/sq. ft.
Very Soft	0.0 to 0.25
Soft	0.25 to 0.50
Medium	0.50 to 1.0
Stiff	1.0 to 2.0
Very Stiff	2.0 to 4.0
Hard	Over 4.0

ORGANIC CONTENT BY COMBUSTION METHOD

Soil Description	Loss on Ignition
Non Organic	Less than 4%
Organic Silt/Clay	4-12%
Sedimentary Peat	12-50%
Fibrous and Woody Peat	More than 50%

PLASTICITY

Term	Plastic Index
None to Slight	0-4
Slight	5-7
Medium	8-22
High to Very High	Over 22

The penetration resistance, N, is the summation of the number of blows required to effect two successive 6" penetrations of the 2" split-barrel sampler. The sampler is driven with a 140 lb. weight falling 30" and is seated to a depth of 6" before commencing the standard penetration test.

SYMBOLS

DRILLING AND SAMPLING

CS–Continuous Sampling
RC–Rock Coring: Size AW, BW, NW, 2"W
RQD–Rock Quality Designator
RB–Rock Bit
FT–Fish Tail
DC–Drove Casing
C–Casing: Size 2 1/2", NW, 4", HW
CW–Clear Water
DM–Drilling Mud
HSA–Hollow Stem Auger
FA–Flight Auger
HA–Hand Auger
COA–Clean-Out Auger
SS–2" Diameter Split-Barrel Sample
2ST–2" Diameter Thin-Walled Tube Sample
3ST–3" Diameter Thin-Walled Tube Sample
PT–3" Diameter Piston Tube Sample
AS–Auger Sample
WS–Wash Sample
PTS–Peat Sample
PS–Pitcher Sample
NR–No Recovery
S–Sounding
PMT–Borehole Pressuremeter Test
VS–Vane Shear Test
WPT–Water Pressure Test

LABORATORY TESTS

q_p–Penetrometer Reading, tons/sq. ft.
q_u–Unconfined Strength, tons/sq. ft.
W–Moisture Content, %
LL–Liquid Limit, %
PL–Plastic Limit, %
SL–Shrinkage Limit, %
LI–Loss on Ignition, %
D–Dry Unit Weight, lbs/cu. ft.
pH–Measure of Soil Alkalinity or Acidity
FS–Free Swell, %

WATER LEVEL MEASUREMENT

∇ –Water Level at time shown
NW–No Water Encountered
WD–While Drilling
BCR–Before Casing Removal
ACR–After Casing Removal
CW–Caved and Wet
CM–Caved and Moist

Note: Water level measurements shown on the boring logs represent conditions at the time indicated and may not reflect static levels, especially in cohesive soils.

UNIFIED SOIL CLASSIFICATION SYSTEM

COARSE-GRAINED SOILS

(More than half of material is larger than No. 200 seive size.)

GRAVELS More than half of coarse fraction larger than No. 4 sieve size		**Clean Gravels** (Little or no fines)
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		Gravels with Fines (Appreciable amount of fines)
	GM^{d}_{u}	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS More than half of coarse fraction smaller than No. 4 sieve size		**Clean Sands** (Little or no fines)
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
		Sands with Fines (Appreciable amount of fines)
	SM^{d}_{u}	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures

LABORATORY CLASSIFICATION CRITERIA

GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} X D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} X D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for SW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

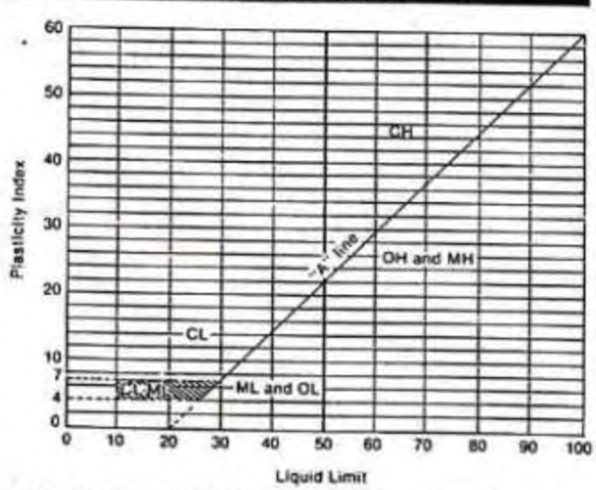
Less than 5 per cent . . . . GW, GP, SW, SP
More than 12 per cent . . . . GM, GC, SM, SC
5 to 12 per cent . . . . Borderline cases requiring dual symbols

FINE-GRAINED SOILS

(More than half of material is smaller than No. 200 sieve.)

SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit greater than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

PLASTICITY CHART

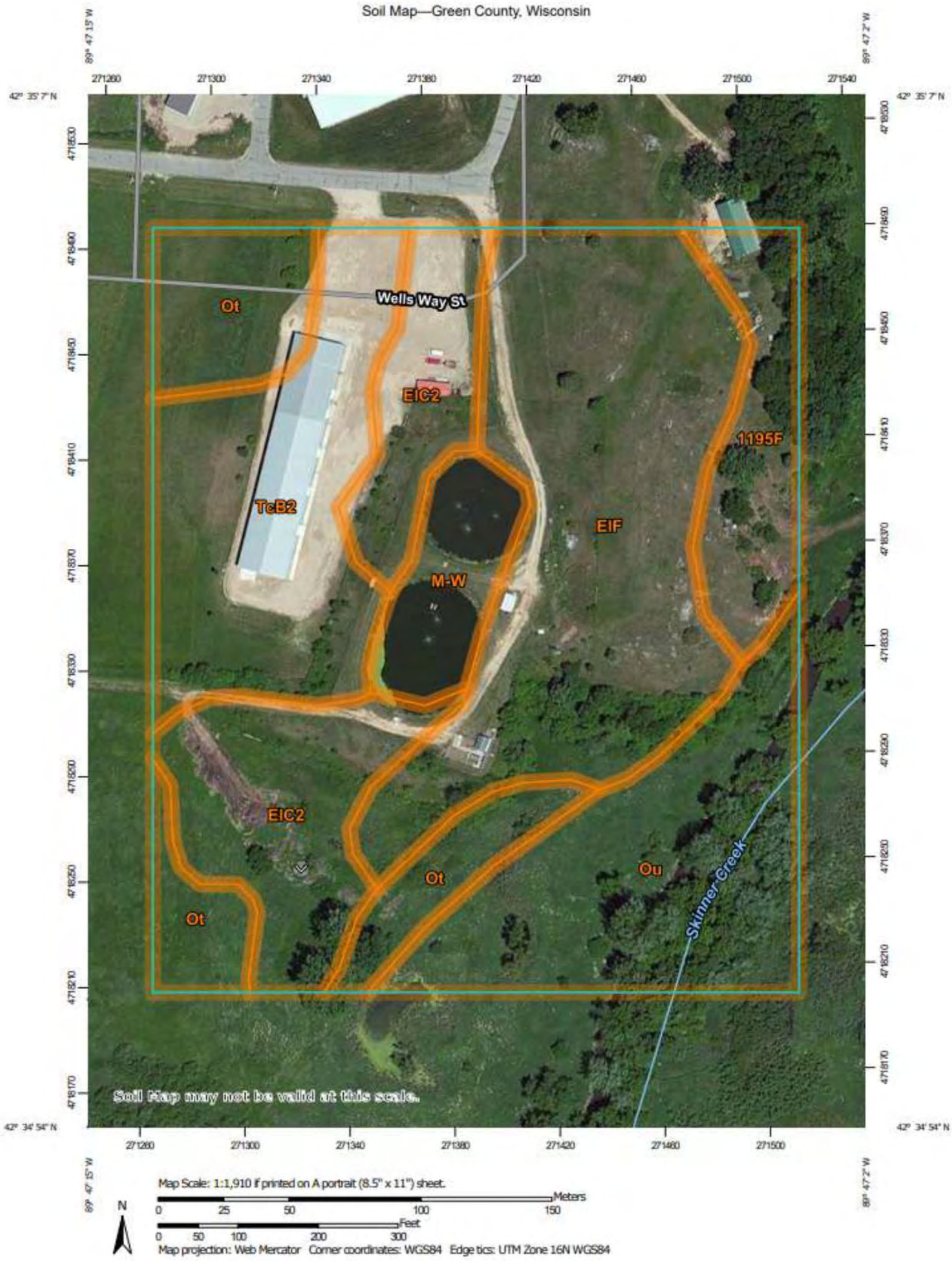


For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg Limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line: PI = 0.73 (LL - 20)

Soil Map—Green County, Wisconsin



Map Scale: 1:1,910 if printed on A portrait (8.5" x 11") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:12,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Green County, Wisconsin
Survey Area Data: Version 21, Jun 8, 2020

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 29, 2011—Jun 13, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1195F	Elkmound-Northfield complex, 30 to 60 percent slopes, very rocky	1.2	6.9%
ElC2	Elkmound sandy loam, 6 to 12 percent slopes, moderately eroded	2.9	16.2%
ElF	Elkmound sandy loam, 30 to 45 percent slopes	4.9	27.6%
M-W	Miscellaneous water	0.9	4.9%
Ot	Ossian silt loam, occasionally flooded	2.0	11.3%
Ou	Otter silt loam, frequently flooded	3.0	16.7%
TcB2	Tell silt loam, 2 to 6 percent slopes, moderately eroded	2.9	16.5%
Totals for Area of Interest		**17.7**	**100.0%**

Appendix C

Laboratory Testing Results:

Table 1: Groundwater Conditions

	Boring 1	Boring 2
Surface Elevation	851.4 ft	847.3 ft
Depth to Groundwater	5 ft	5.5 ft
Groundwater Elevation	846.4 ft	841.8 ft
Total Boring Depth	10 ft	10 ft
Date Performed	10/16/2020	10/16/2020

Table 2: N Values from Borings

	Boring 1	Boring 2
Average N Value	9	14

Table 3: Soil Data

Soil Type (USCS)	Cohesion	Friction Angle	N_C	N_q	N_y
CL	1800 psf	30^o	30.1	18.4	15.67
SM	850 psf	33^o	38.9	26.0	26.07
SP	0 psf	32^o	36.0	23.2	22.05
ML	650 psf	35^o	40.4	33.5	37.39

Table 4: Lateral Earth Pressure Coefficients

Soil Type (USCS)	Internal Friction Angle (Φ)	Cohesion (psf)	Earth Pressure Coefficient at rest (K_o)	Earth Pressure Coefficient Active (K_a)	Earth Pressure Coefficient Passive (K_p)
CL	30^o	1800 psf	0.500	0.017	0.589
SM	33^o	850 psf	0.455	0.011	0.656
SP	32^o	0 psf	0.470	0.013	0.633
ML	35^o	650 psf	0.426	0.008	0.704

Table 5: Bearing Capacity, Allowable Bearing Pressure, and Settlement

	Bearing Capacity	Allowable Bearing Pressure	Factor of Safety	Settlement
RCA Bed	88,915	29,638	3	0.08
Chemical Pre. Storage Facility	67,788	22,596	3	1.26

Analysis Calculations:

Terzaghi Bearing Capacity (Q_u) Theory:

$$Q_u = (c * N_c) + (g * D * N_q) + (0.5 * g * B * N_y)$$

$c =$ Cohesion of soil
$g =$ Effective unit weight of soil
$D =$ Depth of footing
$B =$ Width of footing

Terzaghi's Bearing Capacity Factors

$N_c = 36$
$N_q = 23.2$

$N_y = 22.05$

$Q_u = 1{,}800\ \frac{lb}{ft^2} * 36 + 37.6\ \frac{lb}{ft^2} * 3\ \text{ft} * 23.2 + 0.5 * 37.6\ \frac{lb}{ft^2} * 51.86\ \text{ft} * 22.05$

$Q_u = 88{,}915\ \frac{lb}{ft^2}$

Allowable Bearing Pressure (Q_{all}):

$Q_{all} = Q_u / FS$

$Q_u =$ Bearing Capacity
$FS =$ Safety Factor

$Q_{all} = 88{,}915\ \frac{lb}{ft^2}\ /\ 3$

$Q_{all} = 29{,}638\ \frac{lb}{ft^2}$

Settlement:

$\delta = ((0.68 * q' * B_r) / (N_{60} * \sigma_r * K_d)) * (B / B + B_r)^2$

$q' =$ Net Bearing Pressure
$B_r =$ Reference Width
$N_{60} =$ Average N value
$\sigma_r =$ Reference Stress
$K_d =$ Depth Factor
$B =$ Footing Width

$\delta = ((0.68 * 226.94 psf * 1 ft) / (11.5 * 2000 psf * 1.019)) * (51.86 ft / 51.86 ft + 1 ft)$

$\delta = 0.00646 ft$ or $0.08\ in$

Lateral Earth Pressure Coefficients

$K_a = tan^2(\frac{45-\Phi}{2})$

$K_p = tan^2(\frac{45+\Phi}{2})$

$K_o = 1 - sin(\Phi)$

Φ = Internal Friction Angle

$K_a = tan^2(\frac{45-32}{2})$

$K_a = 0.013$

$K_p = tan^2(\frac{45+32}{2})$

$K_p = 0.633$

$K_o = 1 - sin(32)$

$K_o = 0.47$

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About UniverCity Year

UniverCity Year is a three-phase partnership between UW-Madison and communities in Wisconsin. The concept is simple. The community partner identifies projects that would benefit from UW-Madison expertise. Faculty from across the university incorporate these projects into their courses, and UniverCity Year staff provide administrative support to ensure the collaboration's success. The results are powerful. Partners receive big ideas and feasible recommendations that spark momentum towards a more sustainable, livable, and resilient future. Join us as we create better places together.

GREEN COUNTY WISCONSIN

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