Community Waterwater Treatment Park Report
College of Engineering

THE UNIVERSITY OF IOWA
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

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In partnership with the City of Iowa City

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THE UNIVERSITY OF IOWA IOWA INITIATIVE FOR SUSTAINABLE COMMUNITIES

CITY OF IOWA CITY

THE UNIVERSITY OF IOWA College of Engineering

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UNIVERSITY OF IOWA
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
CEE: 3084:0001 Project Design & Management

Final Design Report

IOWA SMALL COMMUNITY WASTEWATER TREATMENT PARK

GREENWASH ENGINEERING CONSULTING INC.
3225 Seamans Center
103 Capitol Street
Iowa City, IA 52242

Deadline for Submittal: May 6, 2016

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EXECUTIVE SUMMARY

The Iowa Small Community Wastewater Technology (WW Tech) Park was designed to explore the use of a Submerged Attached Growth Reactor (SAGR) for wastewater treatment in Iowa communities with less than 5,000 people. Final designs were established according to standards defined by the Iowa Department of Natural Resources and Wastewater Engineering (Metcalf & Eddy, 2003). The final designs for the WW Tech Park were generated based on the advisement of Tim Wilkey, operators at the Iowa City Wastewater Treatment Plant (IC WWTP), environmental engineering faculty at the University of Iowa, and local environmental engineering professionals.

The WW Tech Park is designed to treat degritted, raw wastewater. A maximum of 0.25 MGD influent will be pumped to a headerbox that controls the flow rate of influent to the WW Tech Park. For the current SAGR system, a V-notch weir will allow 50,000 gpd (0.05 MGD) to enter the lagoon system. A network of PVC pipe will direct the influent flow from the headerbox to the series of lagoons, including a primary aerated lagoon and two secondary settling lagoons, by gravity. A blower system was designed to properly aerate the primary lagoon for biological oxygen demand (BOD) digestion and SAGR cells for comprehensive treatment. After BOD and total suspended solids are both reduced to less than 50 mg/L in the secondary lagoon effluent, water will flow to one of the two SAGR cells in parallel for final treatment. 20 horsepower positive displacement blowers, through 3 inch HDPE piping, aerate the primary lagoon and SAGR cells. Primary lagoons and SAGR cells will be aerated with fine bubble diffusers and coarse bubble diffusers, respectively. Aeration within the SAGR cells is designed to allow airflow to be varied for the creation of an oxic or anoxic environment in the cells. This variation in oxygen concentration allows for possible denitrification. After water is treated in the SAGRs, the effluent will be sent to an adjacent wastewater drain line that flows water to the beginning of the IC WWTP for complete treatment.

Our design is efficient, effective, and sustainable. The layout has been optimized to fit on the land available at the IC WWTP for development. Based on construction and material expenses, Greenwash Engineering Consulting Inc. estimates a total cost of $446,060 and 60 days for the construction of the Small Iowa Community WW Tech Park. The following report further explains the system design, design considerations, and cost analysis.

Section I: Introduction

Greenwash Engineering Consulting Inc. is a small engineering firm focused on sustainability and water resource design located at 3225 Seamans Center, 103 Capitol Street in Iowa City. The design team at Greenwash Engineering Consulting Inc. is presenting design considerations to the City of Iowa City for a Small Community Wastewater Technology (WW Tech) Park. This WW Tech Park will test the effectiveness of Submerged Attached Growth Reactors (SAGR) in Iowa's climate for communities with populations of less than 5,000 people. This facility will be built at the Iowa City South Wastewater Treatment Plant (IC WWTP) located at 4366 Napoleon Street SE, Iowa City, IA 52240 shown in Figure 1.

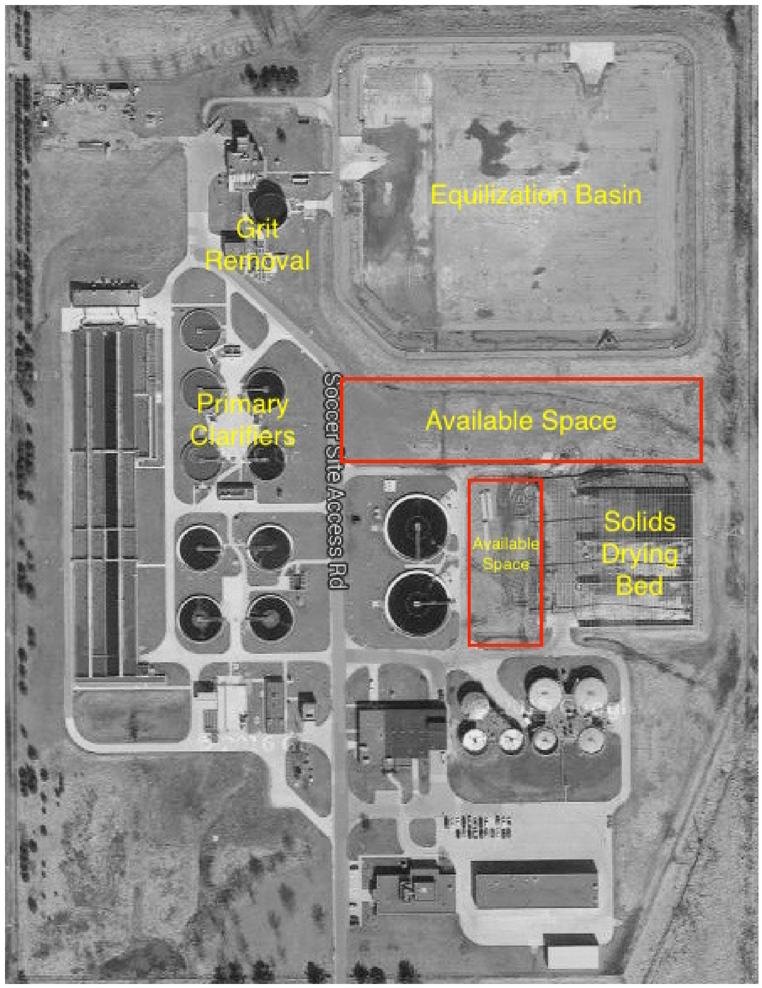

Figure 1: Satellite Image of Iowa City Wastewater Treatment Plant located south of Iowa City, IA.

The City of Iowa City has set aside a 1.6-acre plot of land south of the equalization basin located in the NE portion of the plant. An additional 1-acre plot was also provided for construction east of the solids drying bed on site. The design team at Greenwash Engineering Consulting Inc. consists of Kathryn Langenfeld as project manager, Bruce McWilliams as report developer, Daniel Salgado as design and report assistant, and Alexandro Colon as technical support. All members of the design team at Greenwash are senior engineering students at the

University of Iowa with years of classroom education and a diverse array of project design experience that benefitted the design of the Iowa Small Community WW Tech Park. This report details the design process that preceded the final selection by describing our objectives, approaches, constraints, and challenges. The report also covers the impacts this project has on the local community and the state, and the benefits of this project. Lastly, the final design is described in detail and cost estimations for final design conclude this report.

<u>Section II:</u> Problem Statement

Design Objectives

The Iowa Small Community WW Tech Park is designed to explore the feasibility and effectiveness of experimental wastewater treatment technologies for Iowa communities less than 5,000 people. Iowa's economy is based on the strong presence of agriculture in the state. In 2015, the USDA reported that 24,655,000 acres of land were used to plant field crops in the state (USDA, 2015). Iowa is the largest producer of pork in the nation, and 21,714,000 head of hogs were reported in Iowa in 2015 almost seven times the state's population (USDA, 2015). Agriculture is the largest contributor to water pollution in the state, and over 72% of surface water in Iowa is considered to be in very poor, poor, or fair condition (USDA, 2015). Nitrate and ammonia are discharged into Iowa surface water daily from agricultural operations statewide. Agricultural run-off is the main contributor to Iowa's poor water quality. Nutrients from Iowa agriculture eventually flow into the Mississippi River and then discharge into the Gulf of Mexico. These nutrients cause large algal blooms, which create an anoxic environment that is the largest contribution to the growing dead zone in the Gulf of Mexico. The goal of this design is to create an effective plant layout to test if a SAGR minimizes cost, while also effectively reaching Iowa Department of Natural Resources (DNR) nutrient discharge standards to lower the impact small Iowa communities have on the environment.

Design Approaches

The Research Project will be constructed at the existing IC WWTP located south of the city. A hydraulic system will be designed to receive a maximum of 0.25 million gallons per day (MGD) of degritted, raw wastewater and maintain a maximum flow rate of 50,000 gallons per day (gpd) to the SAGR system. This flow rate was requested by our client and will model a town of approximately 500 people. This flow rate is based on the EPA estimation that a person has a daily water usage of 100 gpd and allow flexibility for future additions and amendments to the WW Tech Park (EPA, 2014). The IC WWTP has established 1.6 acres of land for construction of the WW Tech Park. Optimization of the available space for the lagoon system and pipe networks to accommodate the design flow and hydraulic loading of the wastewater is a top priority. Design considerations were determined based on the required hydraulic loading of the system and hydraulic retention time based on influent data provided by the IC WWTP. The Iowa DNR establishes design constraints for the depths of primary and secondary lagoons, as well as the lagoon length to width ratios. These specifications will dictate the sizing of the lagoon system, and be instrumental in optimizing layouts to fit the build site. Pipe network designs will be determined by the design flow rate and dictated by the elevations at the site to utilize gravitational flow. This system is also aerated, and blower designs will depend upon aerator spacing and biological oxygen demand (BOD) concentrations of wastewater influent.

Constraints

The Small Community WW Tech Park will be built on a portion of land not currently being used for treatment processes at the plant. The land available for this project, is a flat 325-feet by 120-feet plot (39,000 square feet) north of the plant office and is bordered by the equalization basin and solids drying bed as well as a smaller southern section between the solids drying bed and secondary clarifiers (Figure 2 & 3). According to the United States Department of Agriculture Soil Survey, the soil composition is primarily silty loam and silty clay loam with a rare chance for flooding events (NRCS, 2016). The land is currently owned and operated by the City of Iowa City. There should be no foreseeable obstacles with construction, but proper soil cores should be taken prior to construction.

The purpose of the project is to determine the effectiveness of a SAGR in Iowa's climate. To maximize the effectiveness of the WW Tech Park and the proposed land use, the system will be optimized to fit according to design standards and DNR specifications. Since the project is focusing on wastewater treatment for small Iowa communities, the design flow in the treatment system is based on a maximum population of 500 people. The EPA and USGS estimate that a single person uses about 100 gallons of water a day with peak water use occurring in the morning and evening of everyday (USGS, 2016). The project will be designed to accommodate a maximum flow rate of 0.25 MGD. Degritted, raw wastewater will be used in the WW Tech Park. A primary aerated lagoon and secondary lagoons will reduce the concentration of BOD and TSS in the wastewater. After the water is treated in the WW Tech Park, the effluent will be discharged into the main waste line running through the WWTP to ensure all wastewater meets treatment standards. For the treatment in the WW Tech Park to be deemed effective for small Iowa communities, the effluent must reach standards for water quality defined by the Iowa DNR, Iowa Water Environment Association, and the Iowa Nutrient Reduction Strategy. Upon implementation in small Iowa communities, these techniques will mitigate the possibility of discharging water that does not meet discharge standards.

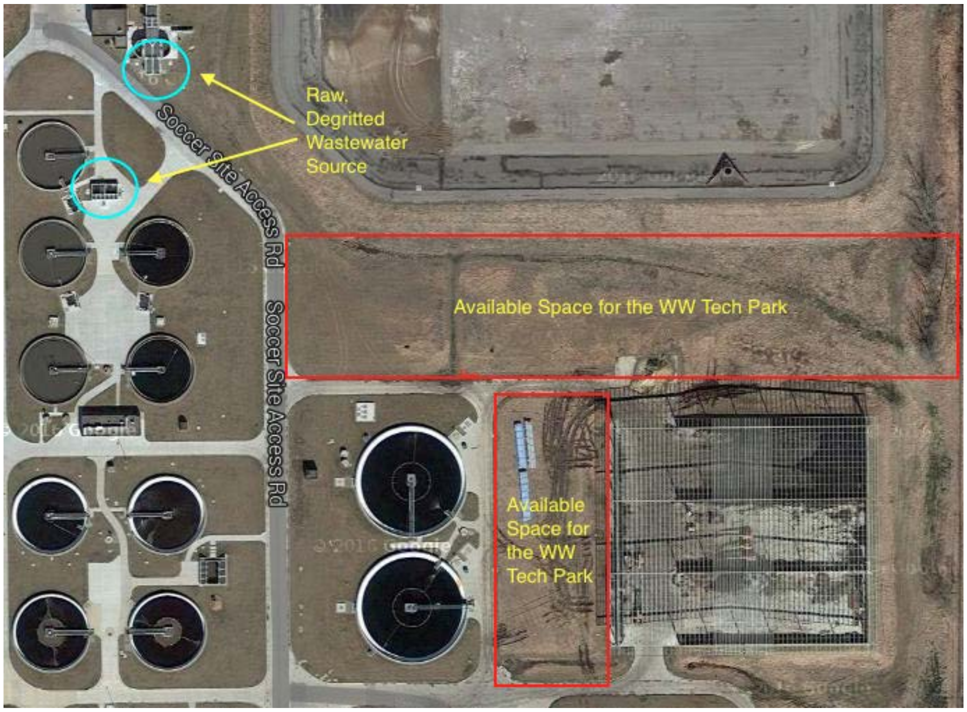

Figure 2: An aerial view of the WW Tech Park site at the IC WWTP.

Figure 3: Onsite assessment of proposed build location looking northwest. The equalization basin is on the left side and the solids drying bed is on the right side of the image.

The 0.25 MGD of raw wastewater is pumped to an elevation of 645ft to a V-notch weir, which allows 50,000 gpd (0.05 MGD) to spill over to the lagoon system for treatment. This is to ensure that there is ample water available to reach the flow rate desired for each technology. The goal of this project is to determine the effectiveness of treatment technologies and appropriately size them according to the population serviced to reduce system costs. The final layout is designed in a way that the technologies can be easily replaced while simulating a community ranging in population from 500 to 5,000 people.

SAGR cell influent must have less than a 50 mg/L concentration of BOD and TSS to be properly treated. The manufacturer, Nelson Engineering, defined the influent specifications and these concentrations are the treatment goal of the primary and secondary lagoons. The final design is flexible enough to allow the client to replace the technologies once SAGR testing is complete and the Iowa DNR has made a decision on the SAGR's effectiveness.

Challenges

One challenge of this project is to ensure that proper water chemistry is achieved throughout the treatment process to ensure the SAGR cells are receiving water that meets manufacturing specifications. In addition, the SAGR technologies that are installed must be constructed so they can be deconstructed and replaced once the end of their testing period is reached. This includes installing certain equipment that can be used universally by more than one type of technology, such as blowers, to reduce cost and amount of materials and construction of future amendments to the WW Tech Park.

Another challenge facing this design is its location on the property of a functioning WWTP that services wastewater produced by a population of over 73,000 people. The project must be designed in a way that does not hinder the treatment of wastewater at the plant. The installation of this project will mesh fluidly with the existing infrastructure of the treatment process. The design must also be spaced accordingly, so that the SAGR cells and lagoons fit within the available space, and work to the best of their ability to preserve the project's objective of serving as a testing facility. Iowa City is also home to a soap manufacturing plant owned by Proctor & Gamble (P&G). This plant discharges a large amount of industrial wastes into the wastewater such as zinc and detergents. The wastewater produced from P&G cannot be avoided in our design, but proper defoaming agents and chemicals are added in the degritting process to the water to ensure that it does not affect the treatment process. These high concentrations of zinc and detergents will not be present in the wastewater of small communities in the state. While these challenges may prove difficult, they can easily be overcome to make sure the project and plant runs as smoothly as possible.

Societal Impacts

Iowa's economy is based on the strong presence of agriculture in the state. In 2015, the USDA reported that 24,655,000 acres of land were used to plant field crops in the state (NASS, 2015). Iowa is the largest producer of pork in the nation. 21,714,000 head of hogs were reported in Iowa in 2015, which is almost seven times the state's population (NASS, 2015). Agriculture is the largest contributor to water pollution in the state, and over 72% of surface water in Iowa is considered to be in very poor, poor, or fair condition (NASS, 2015). Iowa is also the largest contributor to the dead zone in the Gulf of Mexico due to the high amount of nitrate production from non-point source pollution. Manure from livestock and fertilizer applied to fields runs off and reaches the Mississippi River causing adverse environmental and ecological effects once the polluted water reaches the Gulf of Mexico. Excess nutrients cause massive algal blooms to grow and die once their life cycle is complete. Microbes in the ocean use available oxygen to decompose the biomass of dead algae, which lowers the dissolved oxygen concentration to hypoxic conditions. Iowa has a water quality issue that not only affects water in its own borders, but also crosses state and national lines. This problem must be addressed and curbed before it reaches an extreme level that cannot be contained.

The Small Community WW Tech Park will be a multi-year effort with the possibility to positively impact 867 communities in all 99 counties benefiting 648,821 Iowans. Within two years, this project has the potential to save over $250,000 in expense for a single community of approximately 1,500 people (Just, 2015). In the longer-term, much smaller Iowa communities and individual households could benefit financially from the Small Communities WW Tech Park. Exploring and evaluating different cost-effective wastewater treatment options will help small communities save money and reduce the amount of nutrients discharged. Walker, Iowa recently installed SAGR to treat wastewater and have been shown to successfully meet ammonia discharge requirements year-round. Based on the performance of the Walker plant, SAGR systems are being proposed that are 30% smaller and can be used for small Iowa communities. The Walker project cost $2,535,515 ($3200/person), and the city could have saved an estimated $150,000 if the system would have been sized correctly. There are over 267 Iowa communities larger than Walker, but smaller than 5,000 people (Just, 2015). This gives the Small Community WW Tech Park the opportunity to save millions of dollars for Iowans.

Additional Information

The Iowa DNR requires that all wastewater lagoons be lined with geosynthetic bed liners, such as clay or bentonite, to prevent the infiltration of untreated water into ground water sources. All ground will be compacted to reduce the porosity and hydraulic conductivity of soil to prevent this from occurring. Earthen dikes or berms will be constructed around the wastewater lagoons to prevent confined water from exiting the embankment. Berms will be using 2 feet of freeboard to prevent leakage. The Iowa DNR also requires a 10-foot buffer zone around the treatment technologies to prevent them from infringing upon other technologies in the plant, and public roads and land (DNR). Lagoons will be constructed using common wall designs to limit the surface area they occupy and ensure they are in compliance with this standard.

Section III: Preliminary Development of Alternative Solutions

Lagoon System Design

The SAGR is a clean stone bed reactor that is fully aerated using a blower system, water flows horizontally or vertically through the reactor, and the surface is covered by a layer of insulating mulch to prevent the formation of ice. This allows the technology to treat wastewater that is near freezing. The SAGR system can treat an influent with a maximum BOD_5 concentration of 50 mg/L and a TSS concentration of 50 mg/L. The design requires a system of lagoons to decrease the BOD_5 and TSS of the wastewater so the SAGR cells can treat them appropriately. The size and number of primary aerated cells and secondary quiescent cells were determined based on the qualities of the wastewater, shown in Figure 4 below.

For 2015, the IC WWTP had an annual influent BOD_5 concentration of 303.2 mg/L and an annual average TSS concentration on 302 mg/L. in order to achieve the required influent standard for the SAGR system, a lagoon system including a primary BOD digestion lagoon and two secondary settling lagoons were designed. An image of a wastewater treatment lagoon is displayed in Figure 4. The effluent from the secondary lagoons feeds the SAGR cells and meets the 50 mg/L concentration of BOD and TSS. The required hydraulic retention time for BOD digestion in the primary aerated lagoon was calculated, and a sample calculation is displayed in Appendix I.

Figure 4: A wastewater treatment lagoon with submerged aerators

The required retention time to reach 50 mg/L of BOD in the primary cell was calculated to determine the volume of the primary lagoon. This calculation is shown in Appendix I. A reaction coefficient of 0.06 day^{-1} was used in the calculation for a temperature of $1^{o}C$ to simulate cold weather conditions. Using the hydraulic retention time of 36.7 days and a design flow of 50,000 gpd, the volume of the primary lagoon was determined based on the maximum depth of 6 feet as specified by the DNR. The total volume of the primary lagoon was determined to be 245,320.8 cubic feet. This value was divided by the maximum depth of 6 feet for primary lagoon cells, which determined that the lagoon would have a surface area of 40,886.81 ft^2. The Iowa DNR requires a minimum length to width ratio of 2:1 and a maximum ratio of 5:1. Optimizing the proposed design area based on the calculated surface area, length of the primary lagoon was determined to be 372 feet by a width of 110 feet.

Effluent from the primary lagoon is piped to a splitter box between the primary and secondary lagoons. This splitter box allows for sampling of the primary lagoon effluent to be analyzed on site at the IC WWTP water lab to ensure that BOD_5 requirements are reached. The splitter box then diverts water to the two secondary settling lagoons where TSS will be lowered to achieve the 50 mg/L maximum required by the SAGR cells. Since design flow is set at 50,000 gpd, it is assumed that both secondary lagoons will receive a flow of 25,000 gpd. The Iowa DNR requires secondary settling lagoons, of a three part controlled discharge, to have a minimum 30 day hydraulic retention time. Total volume of the secondary lagoons was calculated and a sample calculation is provided in Appendix I. The total volume of a single secondary lagoon was determined to be 100,267.4 cubic feet. Since the DNR specifications require a maximum depth of 8 feet for settling lagoons, the total volume was divided by a depth of 8 feet to determine the total surface area of a secondary lagoon to be 12,533.4 ft^2. Optimizing the secondary lagoon dimensions by DNR sizing specifications, length was found to be 216.5 feet and width was 58 feet based on available space. These dimensions were used for both secondary settling lagoons that were designed to create the three cell controlled discharge pond system.

Effluent from the two secondary settling lagoons is then be piped to a splitter box between the SAGR cells. This splitter box allows the two effluents to mix, and provides an area for water samples to be taken for analysis in the water lab to ensure proper concentration of BOD and TSS is reached before water enters the SAGR cells. The cross sectional area of the SAGR cells, based on width and depth, was calculated using the equation provided by the Iowa DNR. Cross sectional area was calculated using a $CBOD_5$ concentration of 25 mg/L and a design flow of 0.025 MGD. A sample calculation is shown in Appendix I.

As defined by the SAGR manufacturer Nelson Engineering and studies conducted by the Iowa DNR, SAGR cells require a minimum 24 hours of retention time and a minimum depth of 4 feet, excluding the liner and mulch surface. Based on previous installations of SAGR technologies, average depth of existing cells is 8 feet. Dividing the calculated value for the SAGR cross sectional area by an assumed depth of 8 feet, the width of the SAGR cell was determined to be 26 ft. Since the SAGR is an aerated, stone bed cell, a porous aggregate must be used to allow adequate aeration. The DNR specifications require a minimum porosity (η) of .38 for the aggregate used. This value affects the required volume of the SAGR cells due to the effect of aggregate porosity on aeration as defined in Appendix I. Based on a design flow of 25,000 gpd to each SAGR cell, the total volume was calculated to be 8,795.4 ft^3 for a single SAGR cell. Dividing the total volume by an assumed depth of 8 feet, total surface area is calculated to be 1,099.4 ft^2. The surface area of the SAGR was then divided by a calculated width of 26 feet. This determined the length of the SAGR to be 42.3 feet, satisfying the 2:1 length to width ratio required by the DNR. The system was organized according to DNR specifications and the available space to develop. A summary of the overall dimensions and layout of the system are shown in Table 1 and Figure 5.

Table 1: Dimensions of the SAGR system cells

Component	# of Cells	Length (ft)	Width (ft)	Depth (ft)	Volume (ft^3)	Surface Area (ft^2)
Primary Lagoon	1	372	110	6	245320	40890
Secondary Lagoon	2	216	58	8	100270	12530
SAGR Cell	2	42.3	26	8	8795	1010

Figure 5: Final Design Layout of Lagoon and SAGR System

Piping Network Design Development

Four pipe design alternatives were considered to deliver raw, degritted wastewater to the WW Tech Park. The alternatives are described in the subsequent sections.

Piping Network Design Option 1

The first piping network design option is shown in Figure 6. The piping path is shown in red. The piping network begins at the capped end of the 24-inch diameter pipe leaving the primary splitter box. Two pumps operating in parallel will be located at the transition point between the 24-inch diameter pipe and the smaller PVC pipe for the WW Tech Park. The PVC pipe turns 45-degrees until it goes under the road, and then bends 45-degrees to run along the side of the road until it reaches the northwest corner of the WW Tech Park site location.

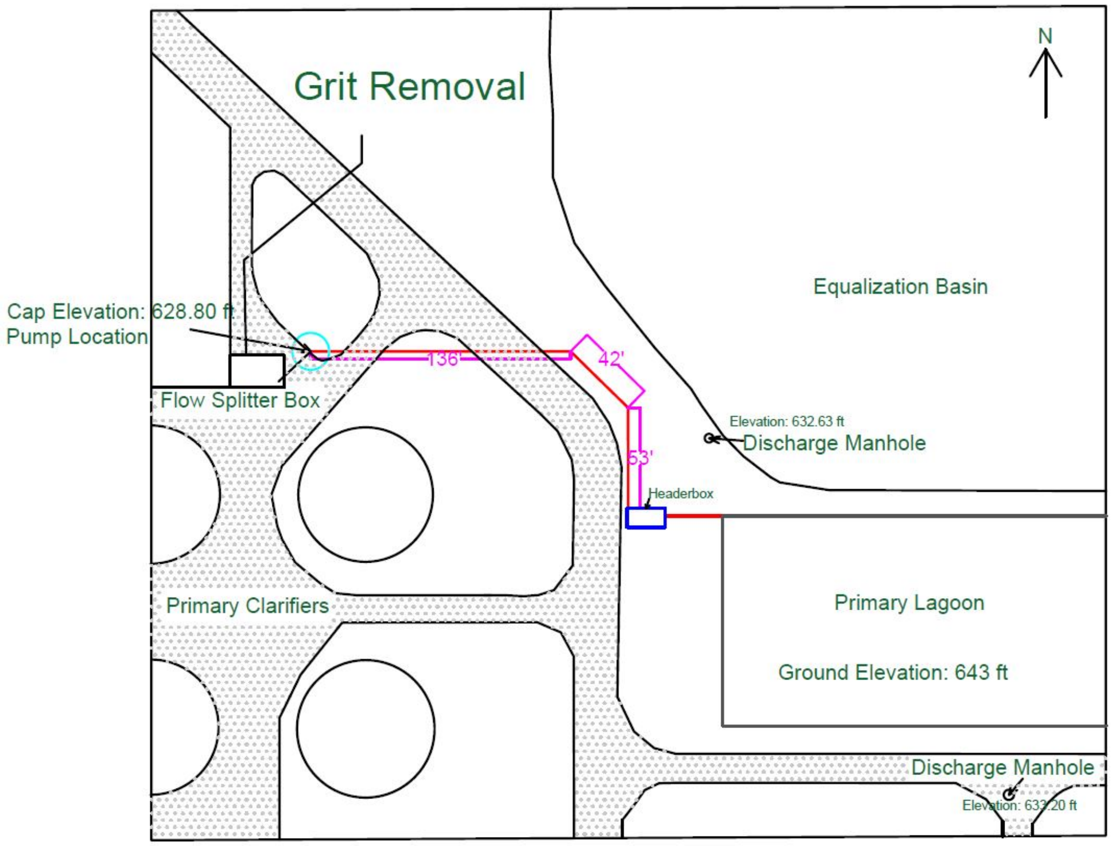

Figure 6: The piping network design option 1 layout. The pipes are shown in red, the light blue circle indicate the starting point and pump location, and the magenta lines are length measurements. The headerbox is the royal blue rectangle.

The pipes are designed to carry 0.25 MGD of degritted influent wastewater to the headerbox of the WW Tech Park. Pumps will be located at the start of the piping network to pump the water from the initial elevation of 628.80 feet to 645 feet at the headerbox location. Using the energy equation, the necessary pump head requirements were determine for 4-inch, 6-inch, and 8-inch PVC pipes as 19.6 feet, 16.7 feet, and 16.3 feet, respectively. Head losses due to friction and pipe bends were taken into account. A set of sample calculations for the energy equation can be found in Appendix I. The AMT 1-1/2”x1-1/4” centrifugal pump operating at 2 horsepower and 230 Volts (Gorman-Rupp, Royersford, PA) was selected for the system. For a flow rate of 86.6 GPM, half of the 0.25 MGD flow, the pump provides approximately 30 feet of head. A cost comparison was performed to determine the optimal diameter of pipe for this layout located in Appendix II. Based on the cost analysis, a 4-inch diameter pipe size is the most cost efficient option.

Piping Network Design Option 2

The second piping network design option is shown in Figure 7. The piping path is shown in red. The piping network begins at the currently capped end of the 24-inch diameter pipe leaving the primary splitter box. Two pumps operating in parallel will be located at the transition point between the 24-inch diameter pipe and the smaller PVC pipe for the WW Tech Park. The PVC pipe continues in the same trajectory as the capped pipe under the road, and then bends 90-degrees to run along the side of the road until it reaches the northwest corner of the WW Tech Park site location.

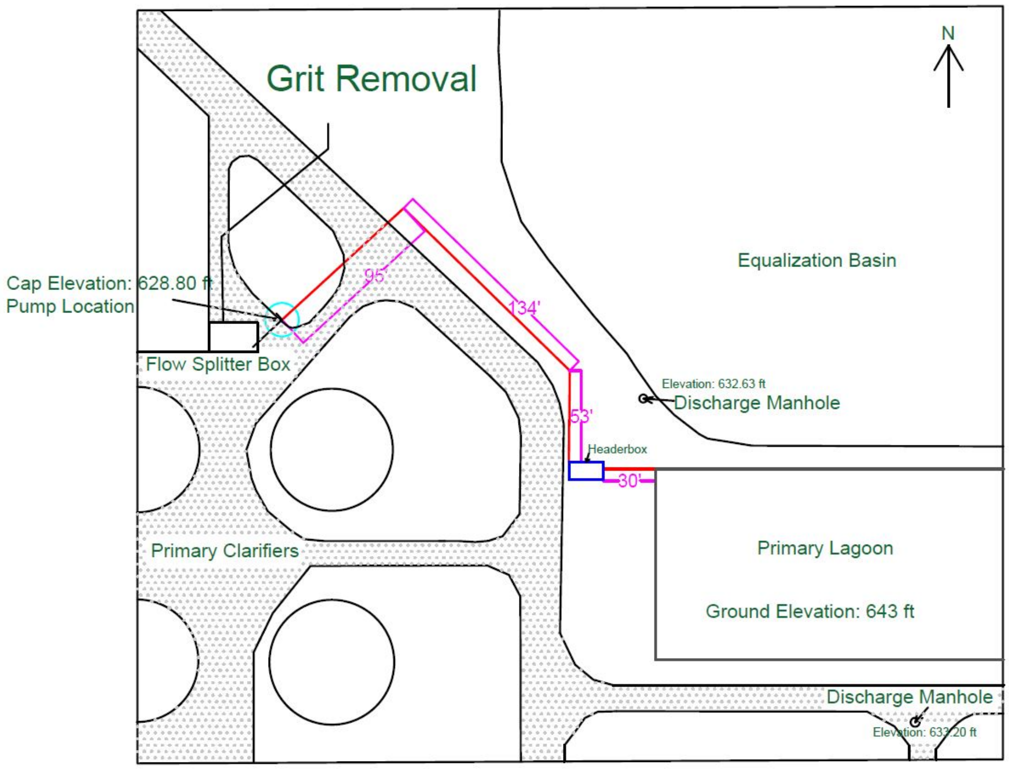

Figure 7: The piping network design option 2 layout. The pipes are shown in red, the blue circles indicate the starting point and pump location, and the magenta lines are length measurements. The headerbox is the royal blue rectangle.

The pipes are designed to carry 0.25 MGD of degritted influent wastewater to the headerbox of the WW Tech Park. Pumps will be located at the start of the piping network to pump the water from the initial elevation of 628.80 feet to 645 feet at the headerbox location. Using the energy equation, the necessary pump head requirements were calculated for 4-inch, 6-inch, and 8-inch PVC pipes as 20.4 feet, 16.8 feet, and 16.4 feet, respectively. Head losses due to friction and pipe bends were taken into account using the same methodology described in the previous pipe design layout. The AMT 1-1/2”x1-1/4” centrifugal pump operating at 2 horsepower and 230 Volts (Gorman-Rupp, Royersford, PA) was selected for the system. For a flow rate of 86.6 GPM, half of the 0.25 MGD flow, the pump provides approximately 30 feet of head. A cost comparison was performed to determine the optimal diameter of pipe for this layout located in Appendix II. Based on the cost analysis, a 4-inch diameter pipe size is the most cost efficient option.

Piping Network Design Option 3

The third piping network design option is shown in Figure 8. The piping path is shown in red. The piping network begins at the currently capped end of the 24-inch diameter pipe leaving the primary splitter box. Two pumps operating in parallel will be located at the transition point between the 24-inch diameter pipe and the smaller PVC pipe for the WW Tech Park. The pipe line immediately turns 90-degrees and runs under a roadway. Then, the PVC pipe continues along the road until it is across the road from the WW Tech Park headerbox. At that point, the pipe line turns 90-degrees and goes under the road to the northwest corner of the site location.

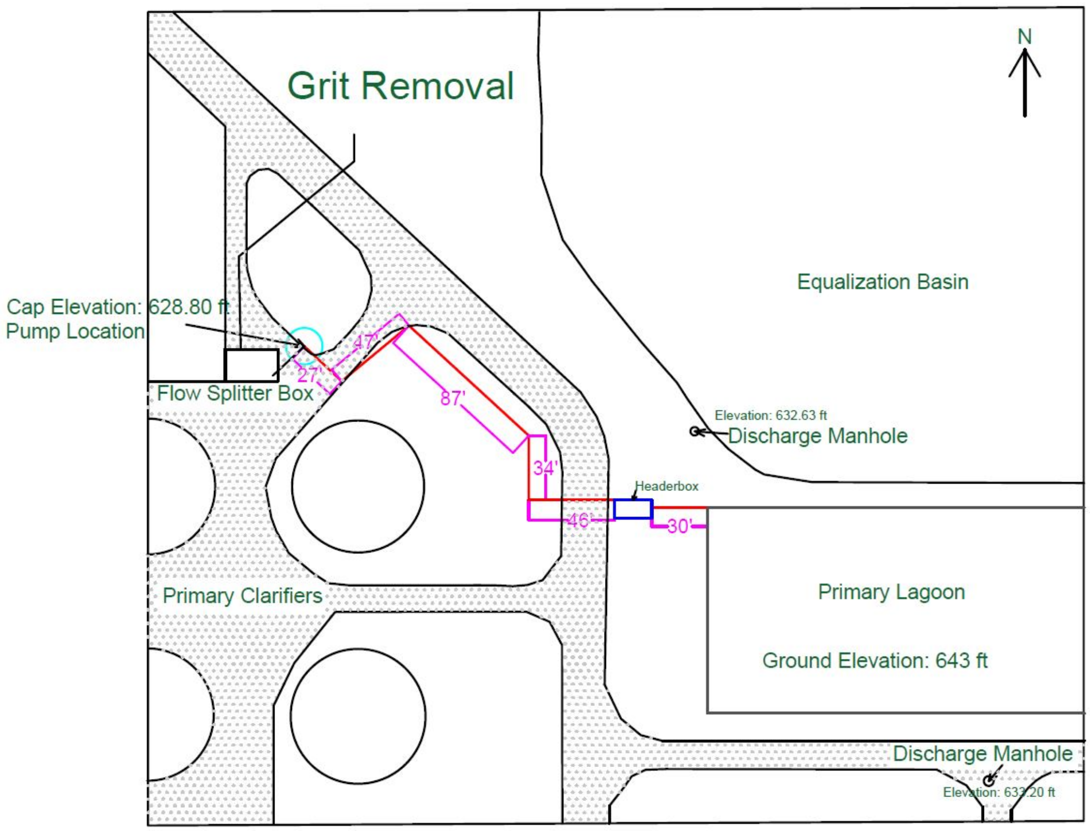

Figure 8: The piping network design option 3 layout. The pipes are shown in red, the blue circles indicate the starting point and pump location, and the magenta lines are length measurements. The headerbox is the royal blue rectangle.

The pipes are designed to carry 0.25 MGD of degritted influent wastewater to the headerbox of the WW Tech Park. Pumps will be located at the start of the piping network to pump the water from the initial elevation of 628.80 feet to 645 feet at the headerbox location. Using the energy equation, the necessary pump head requirements were determined for 4-inch, 6-inch, and 8-inch PVC pipes as 19.9 feet, 16.8 feet, and 16.3 feet, respectively. Head losses due to friction and pipe bends were taken into account using the same methodology described in the previous pipe design layout. The AMT 1-1/2”x1-1/4” centrifugal pump operating at 2 horsepower and 230 Volts (Gorman-Rupp, Royersford, PA) was selected for the system. For a flow rate of 86.6 GPM, half of the 0.25 MGD flow, the pump provides approximately 30 feet of head. A cost comparison was performed to determine the optimal diameter of pipe for this layout and the results are located in Appendix II. Based on the cost analysis, a 4-inch diameter pipe size is the best option for this piping layout.

Piping Network Design Option 4

The fourth piping network design option is shown in Figure 9. The piping path is shown in red. The piping network begins at a curve in the 36-inch diameter pipe coming directly from the degritting vortex chamber end. Two pumps operating in parallel will be located at the transition point between the 26-inch diameter pipe and the smaller PVC pipe for the WW Tech Park. The PVC pipe runs parallel along the road until it reaches the northwest corner of the WW Tech Park site location.

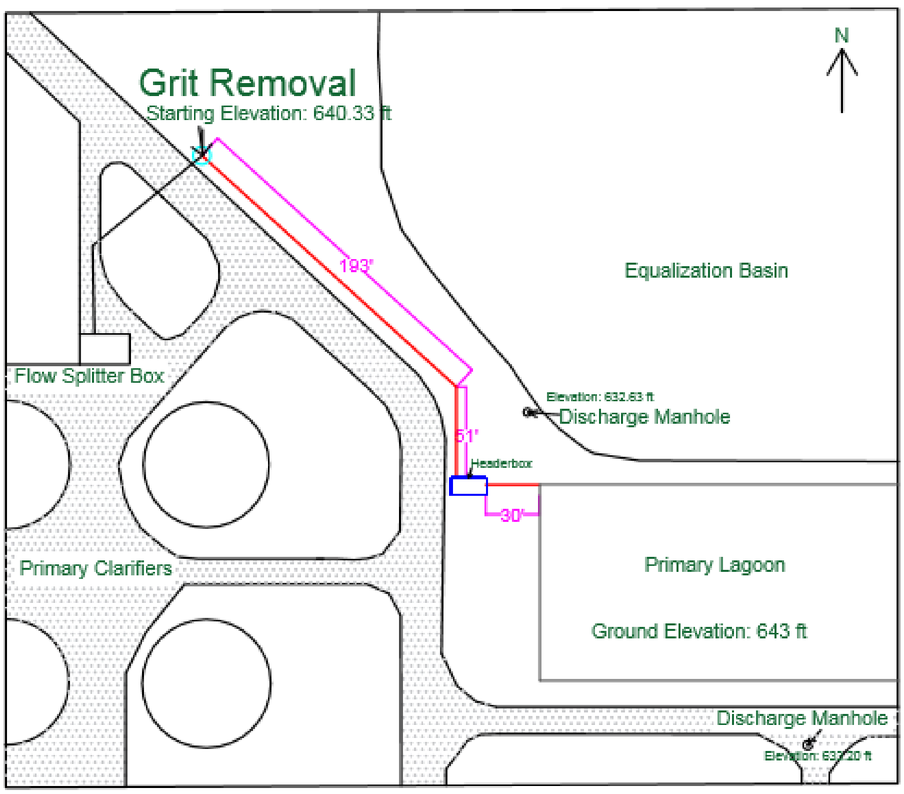

Figure 9: The piping network design option 4 layout. The pipes are shown in red, the blue circles indicate the starting points, and the magenta lines are length measurements. The headerbox is the royal blue rectangle.

The pipes are designed to carry 0.25 MGD of degritted influent wastewater to the headerbox of the WW Tech Park. Pumps will be located at the start of the piping network to pump the water from the initial elevation of 640.33 feet to 645 feet at the headerbox location. Using the energy equation, the necessary pump head requirements were determined for 4-inch, 6-inch, and 8-inch PVC pipes as 8.7 feet, 5.2 feet, and 4.8 feet, respectively. Head losses due to friction and pipe bends were taken into account using the same methodology described in the previous pipe design layout. The AMT 1-1/4”x1” centrifugal pump operating at 2 horsepower and 115 to 230 Volts (Gorman-Rupp, Royersford, PA) was selected for the system. For a flow rate of 86.6 GPM, half of the 0.25 MGD flow, the pump provides approximately 10 feet of head. A cost comparison was performed to determine the optimal diameter of pipe for this layout located in Appendix II. Based on the cost analysis, a 4-inch diameter pipe size is the most cost efficient option.

Aeration System Development

Two types of blowers, centrifugal and positive displacement, were considered to supply air to the primary lagoon and the SAGR cells. Images of the two types of blowers are displayed in Figure 10 below. Pipe materials considered for transporting the air were PVC, HDPE, and metal. Lastly, fine and coarse bubble diffusers were considered to aid in transferring oxygen to the water. The diffusers come in a variety of styles, including disk, dome, tube, and plate diffusers.

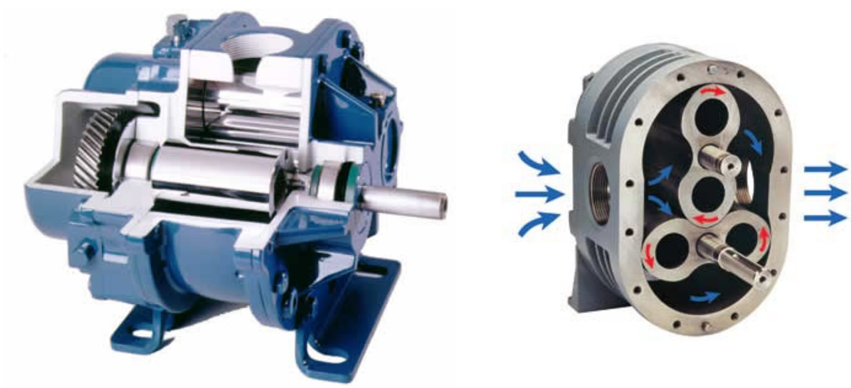

Figure 10: Centrifugal blower (left) and a positive displacement blower (right)

The design for the aeration system was dependent on the most efficient way to transfer oxygen to the primary lagoon and the two SAGR Cells. The aeration design for the primary lagoon was based off of the common methods of lagoon aeration for standard wastewater treatment. The required materials included blowers to force air into the water, piping including all appropriate valves and fittings, and diffusers to generate bubbles of a controlled size to dissolve oxygen into the water. The guidelines for the design were set by the aeration requirements laid out in the Iowa DNR Design Standards for aerated lagoons in section 18C, the Iowa DNR Technology Analysis No. 11-1 on the SAGR system, and Wastewater Engineering (Metcalf & Eddy, 2003). These standards set the minimum dissolved oxygen content of the lagoon and SAGR at 3 mg/L with at least 2 blowers for both the primary lagoon and the SAGR cells as well as requiring that a single blower meet the aeration requirements of each lagoon. The overall blower design layout is shown in Figure 11 below.

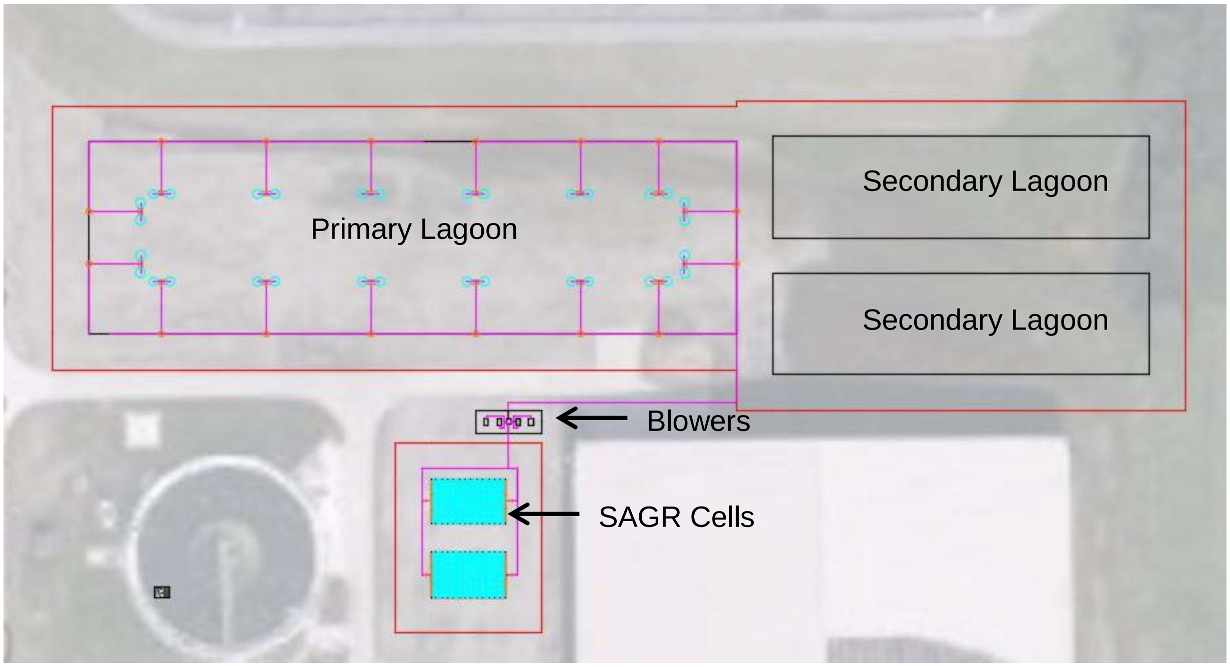

Figure 11: Overall Blower System Layout

In the SAGR cells, the diffusers are in a one square foot grid along the bottom of each cell. The concentrated diffusion pattern is necessary because of the reduced aeration effectiveness due to the aggregate bed porosity that bacteria grow on. Aeration equipment must be easily retrievable to maintain the blower system. The known pump power of 20 horsepower was used to calculate the mass of oxygen needed to adequately aerate the cells and find the air flow rate.

PVC, HDPE, and metal pipe material were considered and evaluated based on cost and strengths. Pipe sizes of 12 inches, 6 inches, 4 inches, 3 inches and 2 inches were considered by calculating the friction losses in the pipe to determine how much head would be lost The friction head loss in the 12 inch pipe was 0.04 feet, in the 6 inch pipe 0.03 feet, in the 4 inch pipe 13.4 feet, in the 3 inch pipe 42.3 feet, and in the 2 inch pipe 214.3 feet. When head loss of pipefittings such as valves, tees, and diffusers was considered, head loss was 9.5 feet for the primary lagoon and 18.6 feet for the SAGR system.

The selection process of the diffusers focused on the two main categories of diffuser: coarse bubble and fine bubble. Coarse bubble diffusers offer greater mixing and less head loss, but sacrifice oxygen transfer with a standard oxygen transfer efficiency (SOTE) of 6-8%, while fine bubble diffusers provide a SOTE of about 12%. A range of diffusers can be used such as dome, plate, membrane and tube diffusers made from a wide range of materials. Different traits can be generalized to each diffuser type. Plate diffusers are specialized to each scenario, offer the greatest efficiency at about 20% SOTE but are the most expensive option. The dome and tube diffusers offer an approximate SOTE of 10-15%, but they lack the ability to remove fouling without removing them from the lagoon. Fouling is the formation of a biofilm on a diffuser that decreases the aeration efficiency and must be removed to maintain dissolved oxygen concentration. The technique referred to as “bumping” rapidly throttles the flow rate to flex the membrane and knock off biofilms without requiring that each diffuser be brought up and cleaned.

<u>Section IV:</u> Selection Process

Lagoon System Selection

The lagoon system was designed according to Iowa DNR specifications for the primary and secondary lagoons. Manufacturing dimensions defined by Nelson Engineering and suggestions from HR Green were used to design the SAGR cells. Since the City of Iowa City provided us with limited space to build the WW Tech Park on, multiple design layouts were not an option due to the necessary volumes for the lagoons and restrictions on depth. Since these are wastewater lagoons, contaminated water infiltration from the lagoons is a serious problem. This requires the installation of synthetic and geosynthetic bed liners for prevention. A decision matrix was used to determine the best option between clay and bentonite clay as a geosynthetic liner, and 30 and 60 mil HDPE bed liner for a synthetic liner. Geosynthetic liners are installed at the base of the excavated lagoons and compacted to lower hydraulic conductivity and porosity of the soil and were evaluated based on material needed. Bentonite clay and standard clay have different absorption characteristics due to their different chemical compositions. Bentonite has free ions like calcium and potassium that absorb potential pollutants from wastewater better than clay. Synthetic liners were also evaluated based on material needed, and infiltration resistance due to liner thickness. 60 mil HDPE is twice as large as 30 mil HDPE, which makes 60 mil more effective than 30 mil at preventing infiltration. Since bentonite clay and 60 mil HDPE have better infiltration resistance than their opposing options, they also have a higher cost per unit which was considered in the material decision. Options were ranked in Table 2, with a low score indicating the better option. A score of 1 shows that the liner was the best option with regard to that parameter while a score of 2 means that it was the less preferred option. The scores for each category were summed and the option with the lowest sum is the best.

Table 2: Decision Matrix for Synthetic and Geosynthetic Bed Liners

Parameter	**Geosynthetic**		**Synthetic**	
	Clay	**Bentonite Clay**	**30 mil HDPE**	**60 mil HDPE**
Cost per Unit	1	2	1	2
Required Compaction	1	1	NA	NA
Infiltration Resistance	2	1	2	1
Material Needed	1	1	1	1
Total	**5**	**5**	**4**	**4**

Based on the decided factors displayed in the matrix, both options for geosynthetic liners and synthetic liners were equally suited for the WW Tech Park. Bentonite clay is more expensive than standard clay, but it is the most effective bed liner for wastewater treatment lagoons. A 1.5 foot layer of material is required for each option and both must be compacted by 15%. It was concluded that the water retention benefits of bentonite outweigh the increased cost. Bentonite will be used over standard clay as a geosynthetic liner. A similar decision was made for our synthetic liner as well, and decided that the benefits of 60 mil HDPE liner outweigh the cost of 30 mil. Both synthetic liners will require the same amount of material since they will separate the wastewater from the exposed earth. 60 mil HDPE liner will be used as a synthetic liner in our lagoon system.

Pipe Network Layout Selection

A decision matrix to aid in selecting the best preliminary design has been created. The three parameters considered are the number of road or path crossings required to reach the headerbox, capital cost, and annual operating and maintenance (O&M) costs. The number of road or path crossings for the pipe network to reach the headerbox was decided to be an important parameter because it correlates to the amount of interference construction of the pipeline will have on the WWTP operators. The rankings were created by designating the best with a score of one, the next best design with a score of two, the score of three, and the worst design with a score of four for each of the selection parameters. The decision matrix is shown in Table 3. Based on the decision matrix, the fourth pipeline design is the best option.

Table 3: The decision matrix for each of the pipeline designs. The designs were ranked from the best design receiving the fewest points to the worst design receiving the most points.

Parameter	**Design 1**	**Design 2**	**Design 3**	**Design 4**
Number of Road/Path Crossings	3	2	4	1
Capital Cost	3	2	4	1
O&M Cost	1	4	2	3
Total	**7**	**8**	**10**	**5**

Aeration System Selection

The decision matrix to aid in selecting the type of blower to use for aeration is shown in Table 4. The rankings were created by designating the best with a score of one and the worst option with a score of two for each of the selection parameters. Positive displacement blowers will be used instead of standard centrifugal blowers because the required air pumping does not require a large head and positive displacement blowers are more efficient. Positive displacement blowers transport a constant volume of air through tubing without adding a significant amount of pressure. This is preferred because a high pressure is unnecessary for diffusion into the cells.

Table 4: Decision matrix for the blower pumps

Parameter	Positive Displacement	Centrifugal
Cost	2	1
Efficiency	1	1
Total	**3**	**2**

Using the pump power equation, the mass flow rate and velocity to maintain a minimum dissolved oxygen (DO) concentration of 3 mg/L was calculated based on the density of air at different temperatures. Some wastewater treatment plants use pure oxygen to aerate lagoons, but pumping air is more economical and safer in the system and requires additional diffusers to meet the oxygen requirements. PVC, HDPE, and metal were considered as piping material. A decision matrix is shown in Table 5. The metal piping was quickly rejected due to the high material cost, large thermal expansion and contraction, and risk of corrosion. HDPE was favored due to its low cost and flexibility, which will aid in retrieving the diffusers for maintenance. Pipe sizes were evaluated based on system head loss and material cost. The head losses for 2 –inch, 3-inch, and 4-inch diameter pipes were calculated using the energy equation and determined to be 233 feet, 61 feet, and 32 feet, respectively. The 3-inch diameter pipe was selected for design due to its low material cost and minimal energy loss.

Table 5: Decision matrix for the aeration pipe material

Parameter	PVC	HDPE	Metal
Cost	2	1	3
Durability	1	1	3
Temperature Resistance	1	2	3
Total	**4**	**4**	**9**

The diffusers considered were coarse bubble and fine bubble. Coarse bubble diffusers encourage mixing and have a lower head loss, but have a lower oxygen transfer rate. Fine bubble diffusers are more efficient at transferring oxygen, but increase the head loss in the system. Fine bubble diffusers were selected for the primary lagoon because a higher oxygen transfer rate is required to reduce the BOD to less than 50 mg/L before entering the SAGR cells. SAGR cells will use coarse bubble diffusers to increase the mixing between aggregate and the high density of diffusers required in the small area. The fine bubble diffusers considered were plate diffusers, tube diffusers, and circular membrane diffusers. A decision matrix is shown in Table 6. The plate diffusers have the greatest oxygen transfer efficiency, but required custom designs for each scenario and therefore are much more expensive. Tube diffusers are common in wastewater treatment applications, but are not the best option for this system compared to membrane fine bubble diffusers. Membrane fine bubble diffusers were selected because it is the most effective at removing fouling via bumping.

Table 6: Decision matrix for the fine diffusers to be used in the primary lagoon

Parameter	Circular Membrane	Plate	Tube
Cost	1	3	2
Oxygen Transfer	2	1	3
Maintenance	1	3	2
Total	**4**	**7**	**7**

Section V: Final Design Details

Degritted, raw wastewater will be directed south of the existing equalization basin at the IC WWTP to the WW Tech Park. Once the degritted wastewater reaches the WW Tech Park, all 0.25 MGD of flow will enter a headerbox at an elevation of 645 feet. The headerbox will divide the flow to an overflow channel or the WW Tech Park. An image of the headerbox design is shown in Figure 12. The headerbox is 15 feet wide, 35 feet long, and 4 feet tall with the bottom at an elevation of 643 feet. For safety and accessibility, a removable metal grate will cover the headerbox. This will allow for the flow rate to be manually controlled and influent data to be collected.

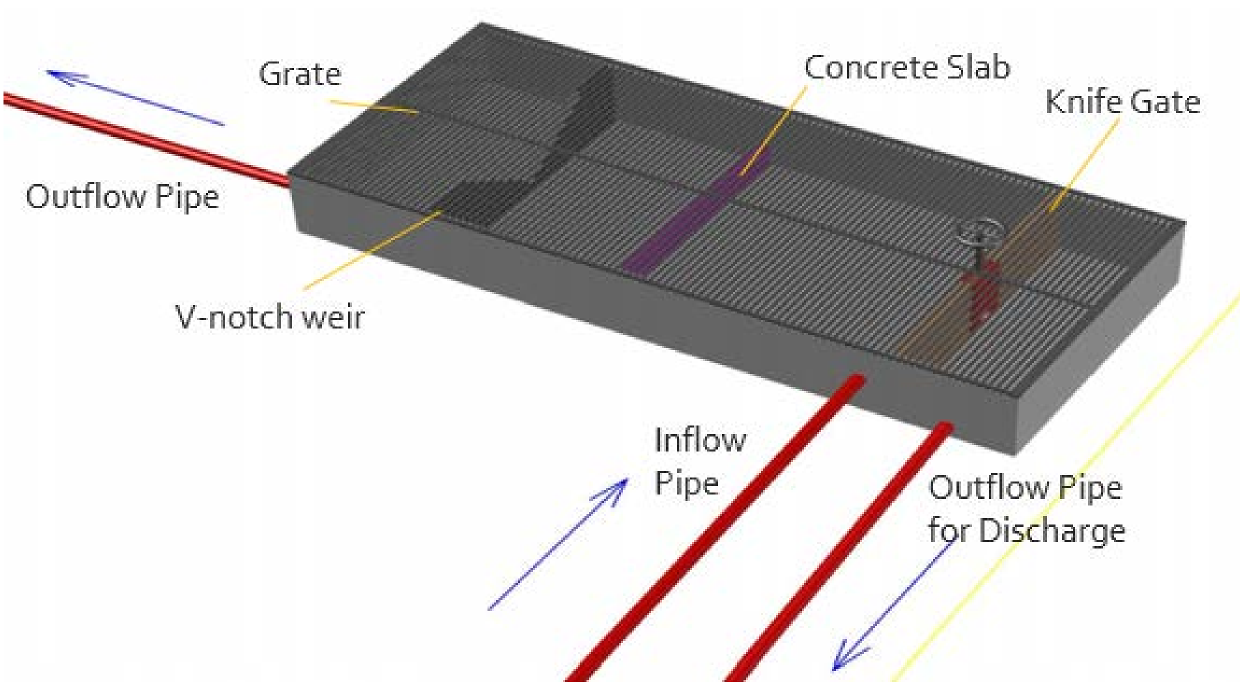

Figure 12: Headerbox

The water first enters a space that will allow the flow to calm. On the west side, there will be a wall with a 6-inch diameter knife gate that will allow the excess flow to be routed to the start of the WWTP. The overflow line will start at the northwest corner of the headerbox at an elevation of 643.5 feet and travel north, then bend 90-degrees and run east until it reaches a manhole for the waste line that runs through the WWTP to the head of the plant. An image of the pipe layout is shown in Figure 14. The overflow line is designed to be able to divert all of the incoming flow, or 0.25 MGD, in case the SAGR system is taken off line. Based on the energy equation, the optimal pipe diameter for the headerbox overflow line is 3-inches.

On the east side of the influent pipe, a wall that is 1.5 feet high and 14 feet from the inlet will act to reduce the turbulence of the water before the water reaches a V-notch weir. The V-notch weir is 22 feet away from the headerbox inlet. The purpose of the V-notch weir is to increase the control of the flow rate to the WW Tech Park. After the water flows over the V-notch weir, it will reach the opening for a pipeline that will lead to the primary lagoon. The pipeline is sized to carry a maximum flow of 50,000 gpd. The pipeline starts along the eastern edge of the headerbox at an elevation of 643.5 feet and travels east until it reaches the northwest corner of the primary lagoon as shown in Figure 14. The optimal pipe diameter for this pipe segment is 2.5-inches based on the energy equation. A ball valve will be located at the start of the pipeline in order to stop the flow to the entire system.

Primary lagoon influent will be sufficiently aerated by an extensive blower system to decrease the BOD. The primary lagoon has a maximum depth of 6 feet, length of 341 feet, and width of 120 feet. These dimensions give the primary aerated lagoon a volume of 245,320 cubic feet. The BOD concentration entering the lagoon is on average 303.2 mg/L and will be reduced to less than 50 mg/L with a minimum hydraulic retention time of 36.7 days. Microorganisms within the lagoon will reduce BOD by consuming the bioavailable organic carbon and respiring the oxygen provided by the aeration system.

From the primary lagoon, the pipeline to the secondary lagoons splits at a tee-intersection allowing for half of the flow to enter one secondary lagoon and the other half to enter the other secondary lagoon. The initial pipe leaving the primary lagoons will be 3.5-inches in diameter and each segment leading to the secondary lagoons will be 2-inches in diameter. Figure 5.3 shows the pipe layout from the primary lagoons to the secondary lagoons. In each of the 2-inch diameter pipes leading to the secondary lagoons, there will be a compact PVC ball valve that will allow each lagoon to be taken off line for maintenance at any time without stopping the flow in the entire system. Flow will enter two non-aerated lagoons with a maximum depth of 8 feet, length of 217 feet, and width of 58 feet. This gives each secondary lagoon a volume of 100,270 cubic feet. Since the design flow will be split, each lagoon will receive 25,000 gpd. The minimum hydraulic retention time for settling lagoons in three part systems is 30 days to reduce TSS from 302 mg/L to less than 50 mg/L.

From the secondary lagoons, the entire flow will rejoin to enter a splitter box located east of the SAGR cells. The pipeline will run from the eastside of the primary lagoons, join at a tee-intersection directly east of the south secondary lagoon and run west along the south side of the south secondary lagoon before crossing under the road and entering the splitter box. Figure 14 shows the pathway of the pipeline. Based on the energy equation, all of the pipes will be 3-inches in diameter.

The splitter box will receive the secondary lagoon effluent and provide an area for water quality sampling. The splitter box will be 20 feet long, 10 feet wide, and 6 feet tall. The splitter box will allow for physical sampling of SAGR influent to ensure it has a maximum of 50 mg/L of BOD and TSS. A removable metal grate will cover the box to allow for sampling to occur. An image of the splitter box is shown in Figure 13. After entering the splitter box, there will be two exits for the water. Each exit will lead to a different SAGR cell. Along the pipeline to each SAGR cell, a compact PVC ball valve will allow the flow to either SAGR to be taken off line for maintenance without disrupting the flow to the other SAGR cell. Each pipeline will be 2-inches in diameter based on the energy equation and will carry 25,000 gpd.

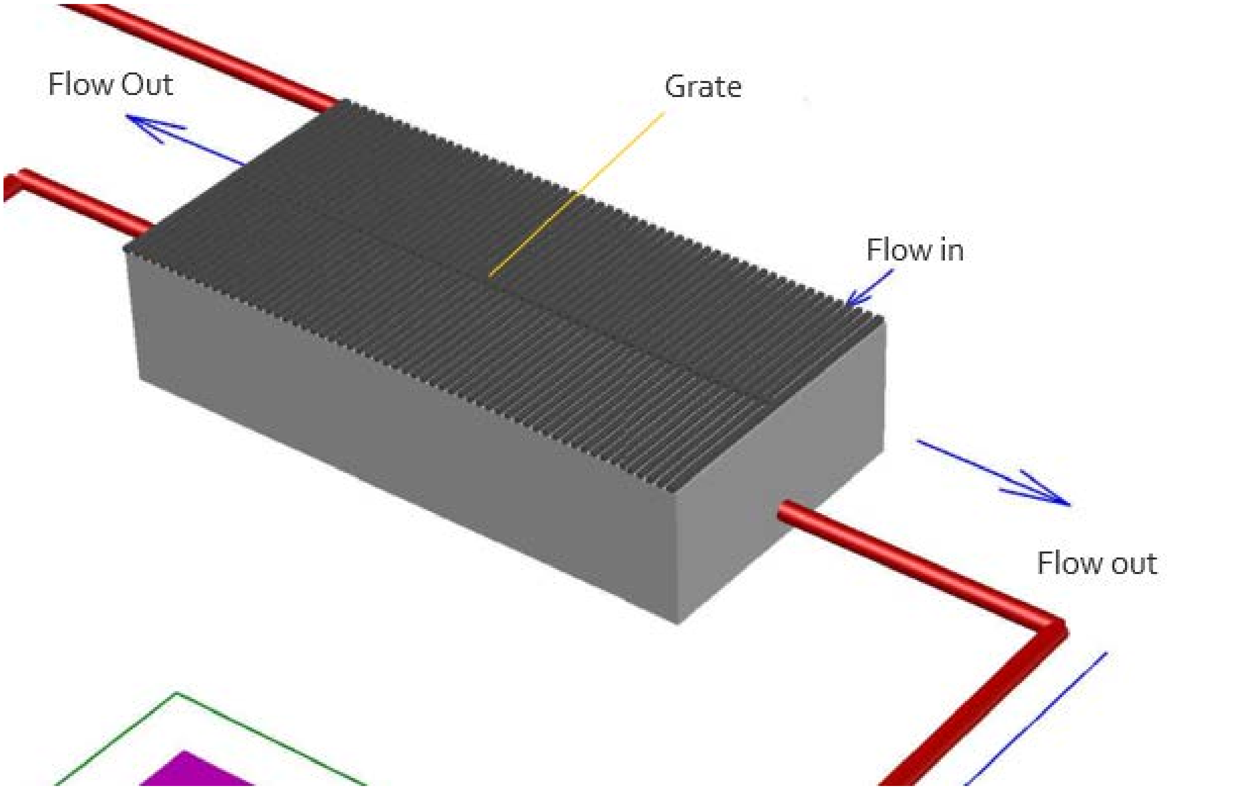

Figure 13: Splitter box

Influent will enter each SAGR cell at a maximum flow rate of 25,000 gpd where it will be aerated through an aggregate bed for treatment. Based on recommendations from HR Green in Cedar Rapids, the design depth of the SAGR cells is 8 feet. The cells will be 42.3 feet in length and 26 feet in depth. This gives each individual SAGR cell a volume of 8,795 cubic feet with a minimum hydraulic retention time of 24 hours. The SAGR effluent will enter into a pipeline to be taken to a nearby manhole that is a part of the pipeline where the headerbox overflow line was ejected. The pipeline from the SAGRs will be 1.5-inches in diameter to carry 25,000 gpd, then join at a tee-intersection west of the north SAGR cell. The pipeline will expand at the intersection to a diameter of 2-inches and travel north, then turn 90-degrees and head west until intersecting with the manhole location. From there the SAGR effluent will be taken to the head of the plant. Figure 14 shows the pipe layout.

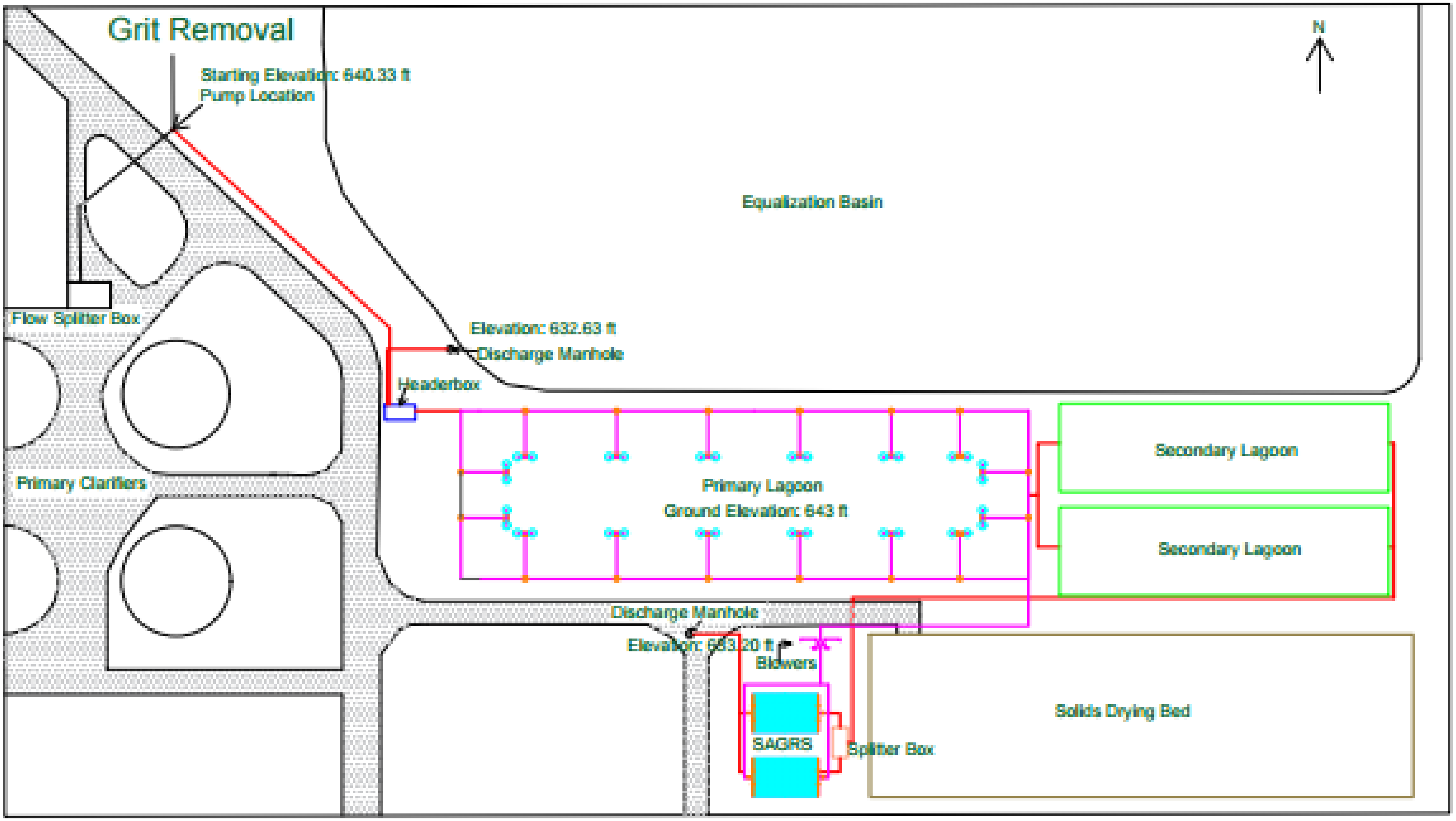

Figure 14: Final Pipe and Lagoon Design

The aeration system is designed to use the least amount of pipe and minimize crossing roads to avoid unnecessary costs. The HDPE piping was selected for the final design due to low material costs, temperature resistance, and material flexibility. Energy losses were calculated based on friction and pipe fittings such as elbows and valves. After energy losses were determined in the final system, 20 hp blowers were selected to aerate the primary lagoons and the SAGR cells. The system requires an air mass flow rate of 0.91 lb per second to meet aeration requirements in all aerated components based on the pump power equation. Air is assumed to be 21% oxygen in concentration, giving the total system an oxygen supply rate of 0.19 lb per second. The aeration system will include a total of four positive displacement blowers. One blower supplies oxygen to the primary lagoon and another will supply both of the SAGR cells. The DNR requires each blower to have a backup blower in the event of failure because of this two additional blowers are included in the final design. The HDPE piping leads from each individual blower into a manifold which allows the four blowers to supply air to either the primary lagoon or SAGR cells. The 3 inch piping is fitted with a variety of different fittings to allow for different aspects of the aeration to be altered. Check valves are installed in each diffuser line to allow air to flow into the lagoons, but block water from flowing into the piping when the blowers are turned off. Isolation Butterfly valves are installed on the end of each diffuser line in the primary lagoon to allow the flow for each set of diffusers to be reduced or turned off, and divide the aeration grid in the SAGR cells into thirds to allow for different aeration conditions in each cell. The different DO conditions of the SAGR cells will create aerobic or anaerobic which will allow different microbes to grow and alter the degree of nitrate removal. Elbow fittings and tee fittings divert the flow to different sections of the aeration system.

The entire SAGR system requires approximately 3,168 feet of piping. 1,742 feet for the primary lagoon, 1,367 feet for the SAGR cells, and 58 feet for the blower house. Total maximum friction head losses including valves, diffusers and other fittings were 52 feet for the primary lagoon and 61 feet for the SAGR cells. Despite the moderately high head loss it is still more economical than purchasing a larger pipe. Fine and coarse bubble membrane diffusers were selected so that the “bumping” function can be performed for ease of maintenance. Diffusers and HDPE pipe lines will be weighted down using small concrete footings to keep them at the bottom of the cells. The concrete footings will be placed at intervals of 25 feet and keep the diffusers half a foot off of the cell bottom to ensure they do not become buried under sediment or waste. The design requires 32 fine bubble diffusers and 2,050 coarse bubble diffusers to ensure proper aeration. The number of pipe fittings is 34 butterfly valves, 116 check valves, 29 90˚ elbows, and 128 tee splitters. These all come together to form the complete aerator design for the SAGR system and will provide enough oxygen to allow the SAGR system to remove nutrients at its optimum efficiency as well as allow the airflow to be altered to provide conditions for a variety of water treatment bacteria.

<u>Section VI:</u> Cost and Construction Estimates

Cost estimation based on construction and required materials were completed for the final lagoon, pipe network, and aeration design. Table 7 shows the final cost estimate for the entire Small Community WW Tech Park. Values in this table were condensed and simplified from the cost estimation tables found in Appendix II.

Table 7: Final Design Overall Cost Estimation

Component	Estimated Cost
Primary Lagoon	$ 181,610.00
Secondary Lagoons	$ 136,160.00
SAGR Cells	$ 20,000.00
Headerbox	$ 11,540.00
Splitter Box	$ 4,910.00
Blower System	$ 82,820.00
Piping and Pumping System	$ 9,020.00
Total	**$ 446,060.00**

Material costs, including construction, as well as excavation and compaction estimates were made based on RSMeans 2015 data. Prices for pumps, blowers, and HDPE piping and fittings were based on current market value using information from USA bluebook. A detailed cost estimation for the WW Tech Park is shown in Appendix II. The total overall project cost was estimated to be $446,060.

<u>Section VII:</u> Construction Timeline

The Iowa Small Community WW Tech Park will be constructed in approximately 60 days beginning with excavation and ending with system start up procedures. Construction will begin by excavating soil needed to construct each component of the lagoon system and install pipes between each component. Excavation will be ongoing during the beginning of construction and will be scheduled according to the progress of the pipe installation. Pipe installation begins once soil has been trenched to lay sections of pipe. Pipe Installation has an estimated start date of two days after excavation begins and concludes after 50 days. Berms will be constructed 14 days after the project start date and will be built around the lagoon system to prevent water from spilling over the lagoon boundary. To reduce cost, soil excavated to build the lagoons will be used to construct the berms. Soil excavated for the construction of the primary lagoon, secondary lagoons, and SAGR Cells, as well as soil used for berms, must be compacted to lower soil porosity. A bentonite clay bed liner will also be installed in the bottom of the lagoons, and must be compacted to prevent leaching of contaminants in wastewater. Compaction will begin 21 days from the start of construction and will conclude, after the clay bed liner is installed, in six days. The construction of the header box, splitter box, and blower house will start on day 31, and will conclude after 14 days, 8 days, and 10 days respectively. Construction for these components will begin simultaneously to avoid using multiple cement trucks and allow the concrete ample time to set. Pumps will be installed once the previous three components are completed. Pump installation will last five days and will begin 45 days after construction starts. Synthetic liners will also be installed in the lagoons to provide a barrier between bare soil and contaminated wastewater. These liners will be installed beginning on day 46 and will be completed in two days. The SAGR cells will be the final step of the construction process and will begin on day 48 and will take seven days to complete. Once all construction has concluded, the system will undergo start up procedures to grow necessary bacteria for treatment and allow time for the technologies to fill with water. Startup procedures will be conducted for six days until the entire system is ready to treat wastewater after 60 days from the start of construction. A Gantt chart displays the construction schedule in Appendix III.

<u>Section VII:</u> Conclusion

The Iowa Small Community WW Tech Park is designed to explore the feasibility and effectiveness of SAGR treatment technologies for Iowa communities with less than 5,000 people. Using a design flow of 50,000 gpd, lagoon dimensions, pipe networks, and aeration systems were designed according to specifications defined by the Iowa DNR and the manufacturer Nelson Engineering. Lagoons were designed to lower concentrations of BOD and TSS from averages of 303.2 mg/L and 302 mg/L, respectively, to less than 50 mg/L before entering the SAGR cells. Lagoons and SAGR cells were optimized to fit in the provided space, and a pipe network was designed to efficiently carry 50,000 gpd of wastewater to the system. The pipe design was used gravity to provide flow with minimal pumping required initially. The system flow rate will be controlled by a V-notch weir located in a headerbox at the start of the system. Effluent will be drained to a manhole that directs effluent back to the beginning to the IC WWTP.

An aeration system was constructed to provide the primary lagoon and SAGR cells with sufficient DO to complete their treatment processes. HDPE pipes will be deliver aeration using positive displacement blowers. Coarse bubbling diffusers will be used in the SAGR cells and circular membrane diffusers will be used in the primary lagoon. The diffusers should provide enough DO to lower BOD in the primary lagoon in order to reach Iowa DNR effluent standards for BOD and TSS in the SAGR effluent. The total cost estimation of the Small Community WW Tech Park is estimated to be $446,060 and construction is estimated to last two months.

<u>Section VI:</u> Bibliography

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Section VII: Appendices

Appendix I: Sample Calculations

Lagoon Design

Hydraulic Retention Time:

$$t = \frac{E}{2.3K_1(100-E)}$$

Where:

$$E = Percent\ of\ Total\ BOD\ removed\ by\ aerated\ cell\ (\%)$$
$$K_1 = \ Reaction\ coeffcient\ for\ 1^oC\ (day^{-1})$$
$$t = Hydraulic\ retention\ time\ (days)$$

Calculations:

$$E = \frac{(303.2\frac{mg}{L} - 50\ \frac{mg}{L})}{303.2\frac{mg}{L}} = 83.51\%$$

$$t = \frac{83.51}{2.3(.06)(100-83.51)} = 36.7\ days$$

Volume:

$$t = \frac{V}{Q}$$

Where:

$$t = Hydraulic\ retention\ time\ (days$$
$$V = Volume\ of\ Cell\ (ft^3)$$
$$Q = Design\ Flow\ (gpd)$$

Primary:

$$V = Q(t) = 36.7\ days\ (50{,}000\ gpd) = 1{,}835{,}000\ gallons\ x\ \frac{1\ ft^3}{7.48\ gal}$$

$$\underline{\underline{V = 245{,}320.8\ ft^3}}$$

Secondary:

$$V = Q(t) = 30\ days(25{,}000\ gpd) = 750{,}000\ gallons\ x\ \frac{1\ ft^3}{7.48\ gal}$$

$$\underline{\underline{V = 100{,}267.4\ ft^3}}$$

SAGR Design

Cross-Sectional Area (SAGR):

$$2.5\ \frac{lb - CBOD_5}{100\ ft^2 - day} = \frac{Q(25\frac{mg}{L})(8.34)(100)}{A_x}$$

Where:

$$A_x = Cross - Sectional\ Area\ (ft^2)$$
$$Q = Peak\ Flow\ (MGD)$$

Calculation:

$$A_x = \frac{.025\ MGD\left(25\frac{mg}{L}\right)(8.34)(100)}{2.5\ \ \frac{lb - CBOD_5}{100\ ft^2 - day}} = 208.5\ ft^2$$

Volume:

$$t = \frac{V(\eta)}{Q}$$

Where:

$$\eta = Aggregate\ Porosity$$
$$Q = SAGR\ Design\ Flow\ (gpd)$$
$$V = Volume\ (ft^3)$$
$$t = Hydraulic\ retention\ time$$

Calculation:

$$V = \frac{Q(t)}{\eta} = \frac{25{,}000\ gpd\ (1\ day)}{.38} = 65{,}789\ .5\ gallons\ x\ \frac{1\ ft^3}{7.48\ gal}$$

$$\underline{\underline{V = 8{,}795.4\ ft^3}}$$

Pipe Design

Energy Equation:

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{L}{D}\frac{V^2}{2g} + n_{90}K_{L,90}\frac{V^2}{2g} + n_{45}K_{L,45}\frac{V^2}{2g}$$

Where:

$$p_1 = pressure\ at\ beginning\ of\ pipeline$$
$$p_2 = pressure\ at\ end\ of\ pipeline$$
$$\gamma = specific\ weight$$
$$V_1 = velocity\ at\ beginning\ of\ pipeline$$
$$V_1 = velocity\ at\ beginning\ of\ pipeline$$
$$g = acceleration\ of\ gravity\ \left(32.2\frac{m}{s^2}\right)$$
$$z_1 = elevation\ at\ beginning\ of\ pipeline\ (ft)$$

$$z_2 = elevation\ at\ end\ of\ pipeline\ (ft)$$
$$h_p = pump\ head\ (ft)$$
$$f = friction\ factor$$
$$L = pipe\ length\ (ft)$$
$$D = pipe\ diameter\ (ft)$$
$$n_{90} = number\ of\ 90 - degree\ pipe\ bends$$
$$n_{45} = number\ of\ 45 - degree\ pipe\ bends$$
$$K_{L,90} = head\ loss\ constant\ for\ 90 - degree\ bend$$
$$K_{L,45} = head\ loss\ constant\ for\ 45 - degree\ bend$$

Assumptions:

$$p_1 = p_2, V_1 = V_2$$
$$z_1 = 628.8\ ft$$
$$z_2 = 645.0\ ft$$
$$Q = 250{,}000\frac{gal}{d} = 0.387\ cfs$$
$$\frac{r}{d} = 2\ \therefore K_{L,90} = 0.19, K_{L,45} = 0.09$$
$$\nu = 1.21 \times 10^{-5} ft^2/s$$

Where:

$$Q = flow\ rate\ (cfs)$$
$$\frac{r}{d} = \frac{pipe\ turn\ radius}{pipe\ diameter}$$
$$\nu = kinematic\ viscosity\ (\frac{ft^2}{s})$$

Simplified Energy Equation:

$$h_p = (z_2 - z_1) + f\frac{L}{D}\frac{V^2}{2g} + n_{90}K_{L,90}\frac{V^2}{2g} + n_{45}K_{L,45}\frac{V^2}{2g}$$

Supporting Equations:

$$A = \frac{\pi}{4}D^2$$
$$V = \frac{Q}{A}$$
$$Re = \frac{VD}{\nu}$$

Where:

$$A = pipe\ area\ (ft^2)$$
$$Re = Reynold's\ number$$

Moody Diagram:

Determine friction factor (*f*) using the smooth pipe curve and Reynolds' number (Re) on the Moody Diagram (Figure 7.1).

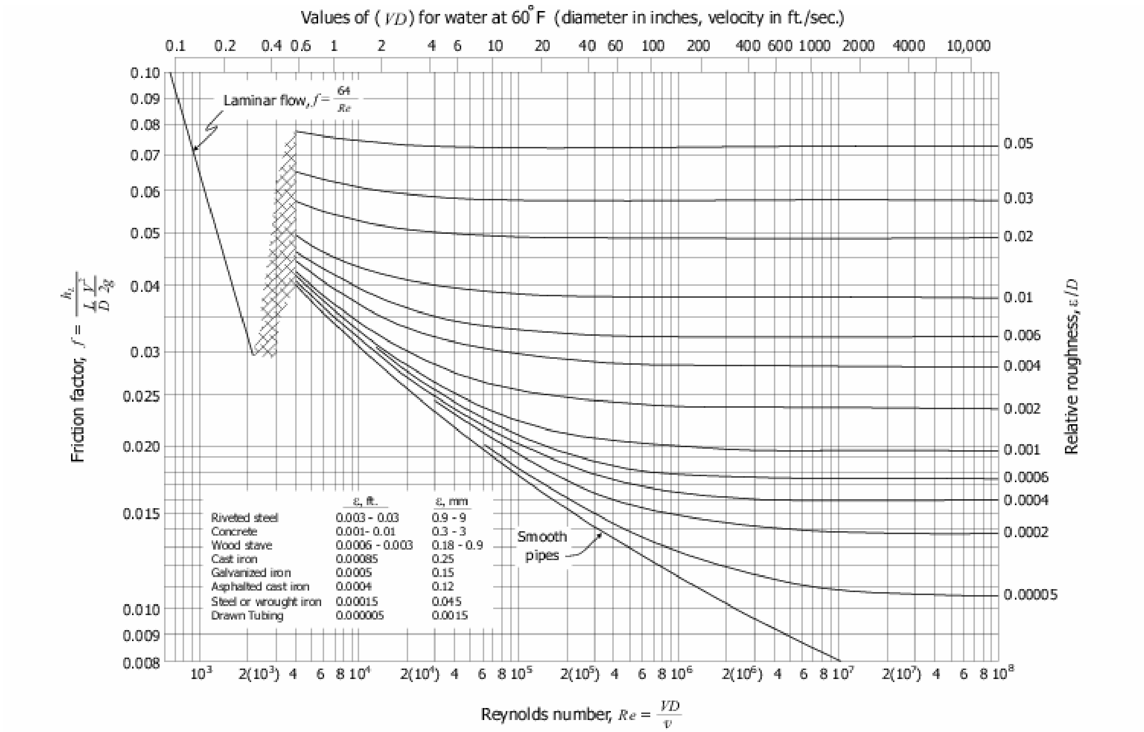

Figure 15: Moody diagram used to determine f by following the smooth pipes curve for different Re values.

For the 4-inch diameter pipe in design 1:

$$h_p = (645.0\,ft - 628.8\,ft) + 0.017\,\frac{211\,ft}{0.33\,ft}\,\frac{\left(4.43\,\frac{ft}{s}\right)^2}{2\left(32.2\,\frac{ft}{s^2}\right)} + (0)(0.19)\,\frac{\left(4.43\,\frac{ft}{s}\right)^2}{2\left(32.2\,\frac{ft}{s^2}\right)} + (3)(0.09)\,\frac{\left(4.43\,\frac{ft}{s}\right)^2}{2\left(32.2\,\frac{ft}{s^2}\right)}$$

$$\underline{\underline{h_p = 19.6\,ft}}$$

Blower Design

Pump Power Equation:

$$P_w = \frac{w * R * T_1}{550 * n * e} * \left(\frac{p_2}{p_1}\right)^{0.283} - 1$$

$$w = \frac{20}{\frac{563.67 * 53.3}{550 * 0.283 * 0.8} * ((\frac{20}{14.7})^{0.283} - 1)} = 0.91\,lb\,\frac{air}{s}$$

Variables:

P_w- Pump power (hp)

w- mass flow rate of air (lb O_2/h)

R- Ideal Gas Constant (ft-lbf/(lb mol-°R)

T_1- Temperature of water (°R)

P_1-pressure at the free surface of the lagoon (psi)
P_2-pressure at the bottom of the lagoon (psi)
e- Pump efficiency (%)

Assumptions:

P_w= 20 hp
R=53.3 $\frac{ft*lb}{lb\ air*R}$
N=0.283
e= 80%=0.8

Supporting Equations:

p_2= $p_{atmosphere}$ + $p_{hydrostatic}$= 14.7 p.s.i. + (γ*D(ft))* 1ft/144 in^2

$$p2 = 14.7\ p.s.i. + \left(62.4\ \frac{lb}{ft^3} * 6ft\right) * \frac{1\ ft^2}{144\ in^2} = 17.3\ psi$$

Variables:

$P_{atmosphere}$- atmospheric absolute pressure (at sea level) (psi)
γ- Specific weight of fluid (lb/ft^3)
D-depth of lagoon (ft)

Assumptions:

p_1=p_{atm}=14.7 psi

$$Q = \frac{w}{\gamma(air)} = \frac{0.91\ lb\frac{air}{s}}{0.074\frac{lb}{ft^3}} = 12.93\frac{ft^3}{s}$$

Variables:

Q- Volumetric flow rate (ft^3/s)

Head Loss Equation:

$$h_L = f * \frac{L\ ft * V^2}{D\ ft * 2 * g} * F.S.$$

$$h_L = \frac{730.25\ ft * (4.39\frac{ft}{s})^2}{0.25\ ft * 2 * 32.2\ ft/s^2} * 1.1 = 42.33\ ft$$

$$h_L(minor) = \frac{\sum K_L * \left(V\frac{ft}{s}\right)^2}{2 * g\frac{ft}{s^2}}$$

$$h_L(minor) = \frac{25.45 * (4.39)^2}{2 * 32.2} = 9.5\ ft$$

Variables:

h_L- head loss (ft)
f-Friction factor

L-length of pipe (ft)
V- Velocity of fluid (ft/s)
D-diameter of pipe (ft)
g-Acceleration of gravity (ft/s^2)
F.S. –Factor of Safety
K_L- Loss coefficient of pipe fittings

Supporting Equations:

$$A = \frac{\pi}{4} D^2$$

$$A = \frac{\pi}{4} (\frac{3\ in}{12})^2 = 0.05\ ft^2$$

$$V = \frac{Q}{A}$$

$$V = \frac{12.93 \frac{ft^3}{s}}{\frac{\pi}{4} * \left(3\ in * \frac{1\ ft}{12\ in}\right)^2} = 4.39 \frac{ft}{s}$$

$$Re = \frac{VD}{\nu}$$

$$Re = \frac{0.25 ft * 263 \frac{ft}{s}}{1.81 * 10^{-4} \frac{ft^2}{s}} = 3.64 * 10^5$$

Variables:

A-area of pipe (ft^2)
Re- Reynold's number
v-Kinematic viscosity of fluid (ft^2/s)

Actual Oxygen Transfer Rate Equation:

$$AOTR = SOT * \left(\frac{\beta * C_{s-,T,H} - C_L}{C_{s,20}}\right) * (1.024^{T-20}) * \alpha * F$$

$$AOTR = 1.6 \frac{kgO_2}{h} * \left(\frac{0.95 * 4.91 \frac{mg}{L} - 3 \frac{mg}{L}}{9.08 \frac{mg}{L}}\right) * (1.024^{20-20}) * 0.6 * 0.75 = 0.132 \frac{kg\ O_2}{h}$$

Variables:

AOTR- Actual Oxygen Transfer Rate (kg O_2/h)
SOT-Standard Oxygen Transfer (kg O_2/h)
β- Correction factor
$C_{s-,T,H}$- Concentration of dissolved oxygen at Temp and elevation (mg/L)
C_L-Desired dissolved oxygen concentration (mg/L)
$C_{s,20}$- Dissolved oxygen content at standard conditions (mg/L)
T-temperature (K)

α- Correction factor
F-Fouling Factor

Assumptions:

$$SOT = 1.6 \frac{kgO_2}{h}$$
$$\alpha = 0.6$$
$$\beta = 0.95$$
$$C_{s,T,H} = 9.08 \frac{mg}{L}$$
$$O_t = 19\%$$
$$C_L = 3 \frac{mg}{L}$$
$$C_{s,20} = 9.08 \frac{mg}{L}$$
$$F = 0.75$$

Supporting Equation:

$$C_{s-,T,H} = C_{s,T,H} * \frac{1}{2} * (\frac{P_d}{P_{atm,H}} + \frac{O_t}{21})$$

$$C_{s-,T,H} = 9.08 \frac{mg}{L} * \frac{1}{2} * \left(\frac{17.93\ kPa}{101.3\ kPa} + \frac{19}{21}\right) = 4.91 \frac{mg}{L}$$

Appendix II: Cost Estimations

Degritted Wastewater to Headerbox Pipeline Designs

Project:	**Iowa Small Community WW Tech Park**						
Design Component:	**WW to Tech Park Pipe Design 1**						
Point of Contact:	**Kathryn Langenfeld**						
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**4-inch Diameter Subtotal**	**6-inch Diameter Subtotal**	**8-inch Diameter Subtotal**
Piping Materials							
4" White PVC Schedule 40 Pipe	ft	$ 5.92	235	$ 1,391.20	$ 1,391.20		
6" White PVC Schedule 40 Pipe	ft	$ 10.82	235	$ 2,542.70		$ 2,542.70	
8" Gray PVC Schedule 40 Pipe	ft	$ 16.75	235	$ 3,936.25			$ 3,936.25
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	0	$ -	$ 1,391.20		
6" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 135.66	0	$ -		$ 2,542.70	
8" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 349.37	0	$ -			$ 3,936.25
4" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 55.86	3	$ 167.58	$ 1,558.78		
6" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 137.29	3	$ 411.87		$ 2,954.57	
8" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 330.15	3	$ 990.45			$ 4,926.70
Pumping Materials							
AMT 1-1/2x1-1/4 Centrifugal Pump							
2HP/230V/1PH CI Case	unit	$ 539.95	2	$ 1,079.90	$ 2,638.68	$ 4,034.47	$ 6,006.60
4" Socket PVC Valve With EPDM O-Ring	unit	$ 233.08	4	$ 932.32	$ 3,571.00	$ 4,966.79	$ 6,938.92
4" White PVC Schedule 40 Pipe	ft	$ 5.92	16	$ 80.96	$ 3,651.96	$ 5,047.75	$ 7,019.88
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	4	$ 34.72	$ 3,686.68	$ 5,082.47	$ 7,054.60
4" DWV Sanitary Tee	tee	$ 57.40	2	$ 21.96	$ 3,708.64	$ 5,104.43	$ 7,076.56
Material Sub-Total					**$ 3,708.64**	**$ 5,104.43**	**$ 7,076.56**

Project:	**Iowa Small Community WW Tech Park**						
Design Component:	**WW to Tech Park Pipe Design 2**						
Point of Contact:	**Kathryn Langenfeld**						
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**4-inch Diameter Subtotal**	**6-inch Diameter Subtotal**	**8-inch Diameter Subtotal**
Piping Materials							
4" White PVC Schedule 40 Pipe	ft	$ 5.92	290	$ 1,716.80	$ 1,716.80		
6" White PVC Schedule 40 Pipe	ft	$ 10.82	290	$ 3,137.80		$ 3,137.80	
8" Gray PVC Schedule 40 Pipe	ft	$ 16.75	290	$ 4,857.50			$ 4,857.50
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	1	$ 43.10	$ 1,759.90		
6" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 135.66	1	$ 135.66		$ 3,273.46	
8" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 349.37	1	$ 349.37			$ 5,206.87
4" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 55.86	1	$ 55.86	$ 1,815.76		
6" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 137.29	1	$ 137.29		$ 3,410.75	
8" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 330.15	1	$ 330.15			$ 5,537.02
Pumping Materials							
AMT 1-1/2x1-1/4 Centrifugal Pump							
2HP/230V/1PH CI Case	unit	$ 539.95	2	$ 1,079.90	$ 2,895.66	$ 4,490.65	$ 6,616.92
4" Socket PVC Valve With EPDM O-Ring	unit	$ 233.08	4	$ 932.32	$ 3,827.98	$ 5,422.97	$ 7,549.24
4" White PVC Schedule 40 Pipe	ft	$ 5.92	16	$ 80.96	$ 3,908.94	$ 5,503.93	$ 7,630.20
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	4	$ 34.72	$ 3,943.66	$ 5,538.65	$ 7,664.92
4" DWV Sanitary Tee	tee	$ 57.40	2	$ 21.96	$ 3,965.62	$ 5,560.61	$ 7,686.88
Material Sub-Total					**$ 3,965.62**	**$ 5,560.61**	**$ 7,686.88**

Project: Iowa Small Community WW Tech Park
Design Component: WW to Tech Park Pipe Design 3
Point of Contact: Kathryn Langenfeld

Material Expenses	Unit	Unit Price	Quantity	Cost	4-inch Diameter Subtotal	6-inch Diameter Subtotal	8-inch Diameter Subtotal
Piping Materials							
4" White PVC Schedule 40 Pipe	ft	$ 5.92	245	$ 1,450.40	$ 1,450.40		
6" White PVC Schedule 40 Pipe	ft	$ 10.82	245	$ 2,650.90		$ 2,650.90	
8" Gray PVC Schedule 40 Pipe	ft	$ 16.75	245	$ 4,103.75			$ 4,103.75
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	4	$ 172.40	$ 1,622.80		
6" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 135.66	4	$ 542.64		$ 3,193.54	
8" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 349.37	4	$ 1,397.48			$ 5,501.23
4" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 55.86	1	$ 55.86	$ 1,678.66		
6" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 137.29	1	$ 137.29		$ 3,330.83	
8" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 330.15	1	$ 330.15			$ 5,831.38
Pumping Materials							
AMT 1-1/2x1-1/4 Centrifugal Pump 2HP/230V/1PH CI Case	unit	$ 539.95	2	$ 1,079.90	$ 2,758.56	$ 4,410.73	$ 6,911.28
4" Socket PVC Valve With EPDM O-Ring	unit	$ 233.08	4	$ 932.32	$ 3,690.88	$ 5,343.05	$ 7,843.60
4" White PVC Schedule 40 Pipe	ft	$ 5.92	16	$ 80.96	$ 3,771.84	$ 5,424.01	$ 7,924.56
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	4	$ 34.72	$ 3,806.56	$ 5,458.73	$ 7,959.28
4" DWV Sanitary Tee	tee	$ 57.40	2	$ 21.96	$ 3,828.52	$ 5,480.69	$ 7,981.24
Material Sub-Total					**$ 3,828.52**	**$ 5,480.69**	**$ 7,981.24**

Project: Iowa Small Community WW Tech Park
Design Component: WW to Tech Park Pipe Design 4
Point of Contact: Kathryn Langenfeld

Material Expenses	Unit	Unit Price	Quantity	Cost	4-inch Diameter Subtotal	6-inch Diameter Subtotal	8-inch Diameter Subtotal
Piping Materials							
4" White PVC Schedule 40 Pipe	ft	$ 5.92	270	$ 1,598.40	$ 1,598.40		
6" White PVC Schedule 40 Pipe	ft	$ 10.82	270	$ 2,921.40		$ 2,921.40	
8" Gray PVC Schedule 40 Pipe	ft	$ 16.75	270	$ 4,522.50			$ 4,522.50
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	0	$ -	$ 1,598.40		
6" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 135.66	0	$ -		$ 2,921.40	
8" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 349.37	0	$ -			$ 4,522.50
4" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 55.86	2	$ 111.72	$ 1,710.12		
6" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 137.29	2	$ 274.58		$ 3,195.98	
8" Schedule 40 White PVC Socket 45° Elbow	elbow	$ 330.15	2	$ 660.30			$ 5,182.80
Pumping Materials							
AMT 1-1/4"x1" Centrifugal Pump 2HP/115-230V/1PH, CI/316SS	unit	$ 539.95	2	$ 1,079.90	$ 2,790.02	$ 4,275.88	$ 6,262.70
4" Socket PVC Valve With EPDM O-Ring	unit	$ 233.08	4	$ 932.32	$ 3,722.34	$ 5,208.20	$ 7,195.02
4" White PVC Schedule 40 Pipe	ft	$ 5.92	16	$ 80.96	$ 3,803.30	$ 5,289.16	$ 7,275.98
4" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 43.10	4	$ 34.72	$ 3,838.02	$ 5,323.88	$ 7,310.70
4" DWV Sanitary Tee	tee	$ 57.40	2	$ 21.96	$ 3,859.98	$ 5,345.84	$ 7,332.66
Material Sub-Total					**$ 3,859.98**	**$ 5,345.84**	**$ 7,332.66**
Indirect Expenses							
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	21	$ 221.55	$ 221.55	$ 221.55	$ 221.55
Indirect Sub-Total					**$ 221.55**	**$ 221.55**	**$ 221.55**
Total					**$ 4,081.53**	**$ 5,567.39**	**$ 7,554.21**

Headerbox and Related Pipe Networks

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Headerbox**				
Point of Contact:	**Alexandro Colon**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Structure Materials					
Concrete	cubic yd	$ 110.00	20	$ 2,200.00	$ 2,200.00
0.5 in x 10 ft long steel rebar	unit	$ 5.25	440	$ 2,310.00	$ 4,510.00
3 ft x 20 ft Galvanized Iron Grate	unit	$ 495.00	12	$ 5,940.00	$ 10,450.00
6"Knife Gate Valve Lug Metal Seats 316SS Body	unit	$ 999.95	1	$ 999.95	$ 11,449.95
Material Sub-Total					**$ 11,449.95**
Indirect Expenses					
Compaction- Riding, vibrating roller, 6" lifts, 2 4 passes	cubic yd	$ 0.79	117	$ 92.43	$ 92.43
Indirect Sub-Total					**$ 92.43**
Total					**$ 11,542.38**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Overflow Pipeline from Headerbox to Manhole**				
Point of Contact:	**Kathryn Langenfeld**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Piping Materials					
3" White PVC Schedule 40 Pipe	ft	$ 4.54	75	$ 340.50	$ 340.50
3" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 25.25	1	$ 25.25	$ 365.75
Material Sub-Total					**$ 365.75**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	13.1	$ 138.21	$ 138.21
Indirect Sub-Total					**$ 138.21**
Total					**$ 503.96**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Pipeline from Headerbox to Primary Lagoon**				
Point of Contact:	**Kathryn Langenfeld**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Piping Materials					
2.5" White PVC Schedule 40 Pipe	ft	$ 3.95	35	$ 138.25	$ 138.25
2-1/2" TB Series PVC Safe Lockouts with Valve, Socket w/EPDM O-rings	valve	$ 194.71	1	$ 194.71	$ 332.96
Material Sub-Total					**$ 332.96**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	0.3	$ 3.17	$ 3.17
Indirect Sub-Total					**$ 3.17**
Total					**$ 336.13**

Lagoons, Splitter Box, SAGR Cells, and Related Pipe Networks

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Primary Lagoon**				
Point of Contact:	**Bruce McWilliams**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Primary Lagoon					
Bentonite Liner	cubic yd	$ 6.00	2614	$ 15,684.00	$ 15,684.00
HDPE Liner	square ft	$ 0.70	40887	$ 28,620.90	$ 44,304.90
Material Sub-Total					**$ 44,304.90**
Indirect Expenses					
Excavation- Minimum labor/ equipment charge				$ 750.00	$ 750.00
Excavation- 300' haul, sandy clay & loam	cubic yd	$ 11.50	11770	$135,355.00	$ 136,105.00
Compaction- Riding, vibrating roller, 6" lifts, 2 4 passes	cubic yd	$ 0.79	1514	$ 1,196.06	$ 137,301.06
Indirect Sub-Total					**$ 137,301.06**
Total					**$ 181,605.96**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Pipeline from Primary Lagoon to Secondary Lagoons**				
Point of Contact:	**Kathryn Langenfeld**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Piping Materials					
4" White PVC Schedule 40 Pipe	ft	$ 5.92	5	$ 29.60	$ 29.60
2" White PVC Schedule 40 Pipe	ft	$ 3.19	110	$ 350.90	$ 380.50
2" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 12.62	2	$ 25.24	$ 405.74
4" x 2" DWV Reducer Coupling	coupling	$ 9.21	1	$ 9.21	$ 414.95
2" DWV Sanitary Tee	tee	$ 17.45	1	$ 17.45	$ 432.40
Hayward® QVC Series Compact PVC Ball Valves Socket White 2"	valve	$ 6.35	2	$ 12.70	$ 445.10
Material Sub-Total					**$ 445.10**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	0.9	$ 9.50	$ 9.50
Indirect Sub-Total					**$ 9.50**
Total					**$ 454.60**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Secondary Lagoons**				
Point of Contact:	**Bruce McWilliams**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Secondary Lagoons					
Bentonite Liner	cubic yd	$ 6.00	1601	$ 9,606.00	$ 9,606.00
HDPE Liner	square ft	$ 0.70	33835	$ 23,684.50	$ 33,290.50
Material Sub-Total					**$ 33,290.50**
Indirect Expenses					
Excavation- Minimum labor/ equipment charge				$ 750.00	$ 750.00
Excavation- 300' haul, sandy clay & loam	cubic yd	$ 11.50	8816	$101,384.00	$ 102,134.00
Compaction- Riding, vibrating roller, 6" lifts, 2 4 passes	cubic yd	$ 0.79	930	$ 734.70	$ 102,868.70
Indirect Sub-Total					**$ 102,868.70**
Total					**$ 136,159.20**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Pipeline from Secondary Lagoons to Splitter Box**				
Point of Contact:	**Kathryn Langenfeld**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Piping Materials					
3" White PVC Schedule 40 Pipe	ft	$ 4.54	590	$ 2,678.60	$ 2,678.60
3" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 25.25	4	$ 101.00	$ 2,779.60
3" DWV Sanitary Tee	tee	$ 35.30	1	$ 35.30	$ 2,814.90
Material Sub-Total					**$ 2,814.90**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	9.8	$ 103.39	$ 103.39
Indirect Sub-Total					**$ 103.39**
Total					**$ 2,918.29**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Splitter Box**				
Point of Contact:	**Alexandro Colon**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Structure Materials					
Concrete	cubic yd	$ 110.00	4	$ 440.00	$ 440.00
0.5 in x 10 ft long steel rebar	unit	$ 5.25	268	$ 1,407.00	$ 1,847.00
3 ft x 20 ft Galvanized Iron Grate	unit	$ 495.00	4	$ 1,980.00	$ 3,827.00
Material Sub-Total					**$ 3,827.00**
Indirect Expenses					
Excavation- Minimum labor/ equipment charge				$ 750.00	$ 750.00
Excavation- 300' haul, sandy clay & loam	cubic yd	$ 11.50	26	$ 299.00	$ 1,049.00
Compaction- Riding, vibrating roller, 6" lifts, 2 4 passes	cubic yd	$ 0.79	45	$ 35.55	$ 1,084.55
Indirect Sub-Total					**$ 1,084.55**
Total					**$ 4,911.55**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Pipeline from Splitter Box to SAGR Cells**				
Point of Contact:	**Kathryn Langenfeld**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Piping Materials					
2" White PVC Schedule 40 Pipe	ft	$ 3.19	65	$ 207.35	$ 207.35
2" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 12.62	2	$ 25.24	$ 232.59
Hayward® QVC Series Compact PVC Ball Valves Socket White 2"	valve	$ 6.35	2	$ 12.70	$ 245.29
Material Sub-Total					**$ 245.29**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	0.6	$ 6.33	$ 6.33
Indirect Sub-Total					**$ 6.33**
Total					**$ 251.62**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**SAGR Cells**				
Point of Contact:	**Bruce McWilliams**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
SAGR Cells					
Bentonite Liner	cubic yd	$ 6.00	130	$ 780.00	$ 780.00
HDPE Liner	square ft	$ 0.70	4385	$ 3,069.50	$ 3,849.50
Aggregate	cubic yd	$ 7.40	81.5	$ 603.10	$ 4,452.60
Mulch	cubic ft	$ 2.62	2200	$ 5,764.00	$ 10,216.60
Material Sub-Total					**$ 10,216.60**
Indirect Expenses					
Excavation- Minimum labor/ equipment charge				$ 750.00	$ 750.00
Excavation- 300' haul, sandy clay & loam	cubic yd	$ 11.50	774	$ 8,901.00	$ 9,651.00
Compaction- Riding, vibrating roller, 6" lifts, 2 4 passes	cubic yd	$ 0.79	163	$ 128.77	$ 9,779.77
Indirect Sub-Total					**$ 9,779.77**
Total					**$ 19,996.37**

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Pipeline from SAGR Cells to Manhole**				
Point of Contact:	**Kathryn Langenfeld**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Piping Materials					
1.5" White PVC Schedule 40 Pipe	ft	$ 2.65	50	$ 132.50	$ 132.50
1.5" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 10.86	1	$ 10.86	$ 143.36
2" White PVC Schedule 40 Pipe	ft	$ 3.19	60	$ 191.40	$ 334.76
2" Schedule 40 White PVC Socket 90° Elbow	elbow	$ 12.62	1	$ 12.62	$ 347.38
2" X 1-1/2" x 1-1/2" DWV Sanitary Reducing Tee	coupling	$ 17.45	1	$ 17.45	$ 364.83
Material Sub-Total					**$ 364.83**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yard	$ 10.55	10.4	$ 109.72	$ 109.72
Indirect Sub-Total					**$ 109.72**
Total					**$ 474.55**

Blower System

Project:	**Iowa Small Community WW Tech Park**				
Design Component:	**Blower System**				
Point of Contact:	**Daniel Salgado**				
Material Expenses	**Unit**	**Unit Price**	**Quantity**	**Cost**	**Subtotal**
Primary Lagoon					
HDPE Flexible Piping	ft	$ 3.25	1745	$ 5,671.25	$ 5,671.25
Butterfly Valve	valve	$ 147.00	16	$ 2,352.00	$ 8,023.25
Check Valve	valve	$ 90.73	16	$ 1,451.68	$ 9,474.93
90-degree Elbow	elbow	$ 46.95	5	$ 234.75	$ 9,709.68
Tee	tee	$ 30.95	33	$ 1,021.35	$ 10,731.03
12-inch Fine Diffuser	unit	$ 34.00	32	$ 1,088.00	$ 11,819.03
SAGR Cells					
HDPE Flexible Piping	ft	$ 3.25	2340	$ 7,605.00	$ 19,424.03
Butterfly Valve	valve	$ 147.00	12	$ 1,764.00	$ 21,188.03
Check Valve	valve	$ 90.73	100	$ 9,073.00	$ 30,261.03
90-degree Elbow	elbow	$ 46.95	12	$ 563.40	$ 30,824.43
Tee	tee	$ 30.95	95	$ 2,940.25	$ 33,764.68
5-inch Coarse Diffuser	unit	$ 9.25	2050	$ 18,962.50	$ 52,727.18
Blower House					
HDPE Flexible Piping	ft	$ 3.25	43	$ 139.75	$ 52,866.93
90-degree Elbow	elbow	$ 46.95	6	$ 281.70	$ 53,148.63
Blower Manifold	unit	$ 550.00	1	$ 550.00	$ 53,698.63
Positive Displacement Blower	unit	$ 7,268.00	4	$ 29,072.00	$ 82,770.63
Material Sub-Total					**$ 82,770.63**
Indirect Expenses					
Excavation- 4'-6' deep, 1/2 C.Y. excavator w/ trench box	cubic yd	$ 10.55	5	$ 52.75	$ 52.75
Indirect Sub-Total					**$ 52.75**
Total					**$ 82,823.38**

Appendix III: Gantt Chart

Iowa Small Community Technology Park

TASK	START DAY	TASK DURATION
Excavation	1	30
Berm Construction	14	7
Compaction	21	6
Clay Liner	24	3
Pipe Installation	3	50
Headerbox Construction	31	14
Splitter Box Construction	31	8
Blower House Construction	31	10
Pump Installation	45	5
Lagoon Liner Placement	46	2
SAGR Installation	48	7
Site Start Up	55	6

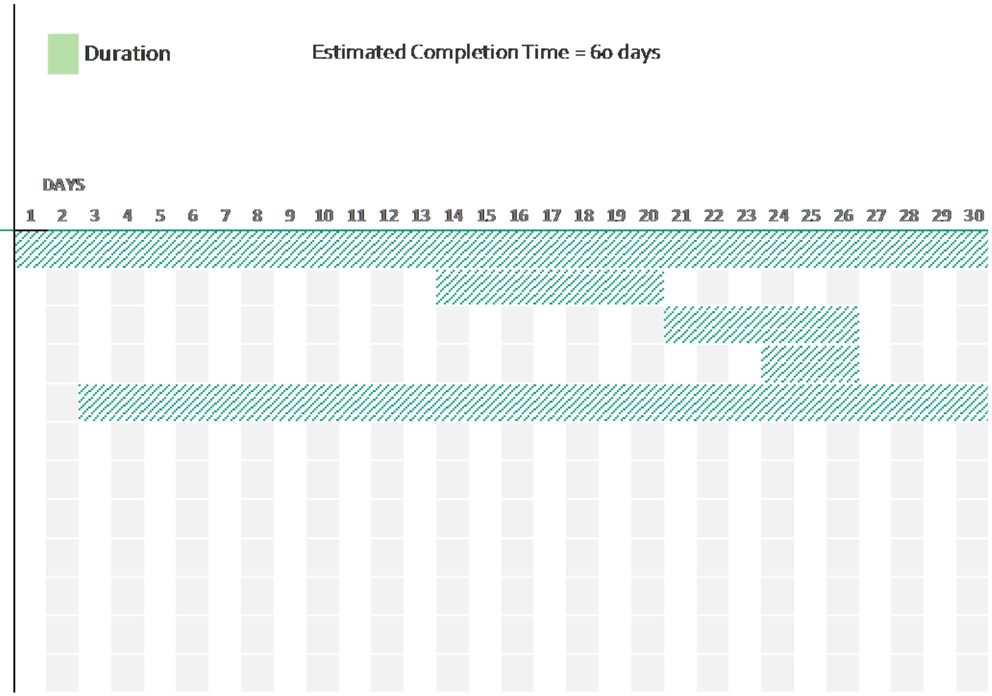

Figure 16: Gantt chart of the first 30 days of estimated time of construction for the SAGR System

Iowa Small Community Technology Park

TASK	START DAY	TASK DURATION
Excavation	1	30
Berm Construction	14	7
Compaction	21	6
Clay Liner	24	3
Pipe Installation	3	50
Headerbox Construction	31	14
Splitter Box Construction	31	8
Blower House Construction	31	10
Pump Installation	45	5
Lagoon Liner Placement	46	2
SAGR Installation	48	7
Site Start Up	55	6

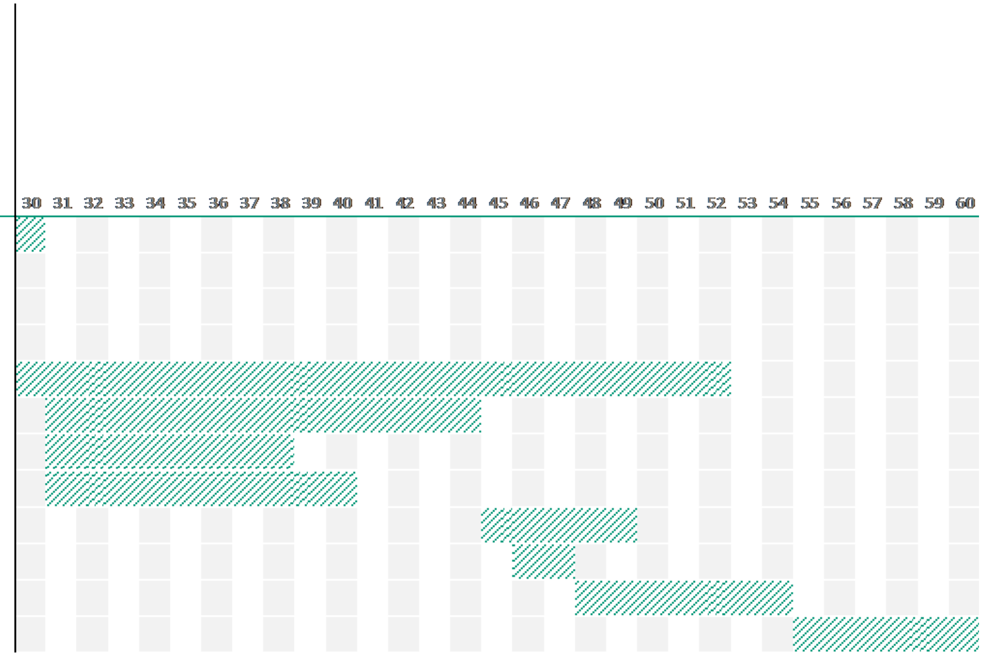

Figure 17: Gantt chart of the last 30 days of estimated time of construction for the SAGR System