2022

Final Design Report: Cave Creek Water Reclamation Plant Rehabilitation Project

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List of Abbreviations

CCWRP- Cave Creek Water Reclamation Plant
WRP – Water Reclamation Plant
MGD- Million Gallons per Day
CWA – Clean Water Act
SDWA – Safe Drinking Water Act
EPA – Environmental Protection Agency
NPDES – National Pollutant Discharge Elimination System
AZDEQ – Arizona Department of Environmental Quality
NTU - Nephelometric Turbidity Units
BOD - Biological Oxygen Demand
AWT – Advanced Water Treatment
IPR - Indirect Potable Reuse
DPR – Direct Potable Reuse
CASP - Conventional activated sludge process
UASB - Upflow anaerobic sludge blanket reactor
ADWR – Arizona Department of Water Resources
TCE – Trichloroethylene
PFOS – Perfluorooctane Sulfonate
PFOA – Perfluorooctanoic Acid
RAS – Return Activate Sludge
MBBR – Moving Bed Biofilm Reactor
TBL– Triple Bottom Line
GHG–Greenhouse Gas
TSS – Total Suspended Solids

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Jeffrey Heiderscheidt, PhD: Technical Advisor and Grading Instructor

Senior Lecturer of Civil Engineering, Construction Management, and Environmental Engineering at Northern Arizona University.

1.0 Project Introduction

1.1 Project Description

The Cave Creek Water Reclamation Plant (CCWRP) is one of the three water reclamation facilities in the City of Phoenix, AZ. It was constructed to support development north of the Central Arizona Project canal, delivering water from the Colorado River. The project was previously commissioned in 2002 and then closed in 2009 due to a decline in projected population and development reductions north of the 101 Beltline Freeway. The current design project focuses on the rehabilitation of the CCWRP. The purpose is to reduce the impact of growth-related flows on the old existing infrastructure, produce Class A+ reclaimed water for irrigation, and recharge the service area. Figure 1.1 shows the location of the plant in relation to the city of Phoenix and in relation to the state of Arizona in the bottom left corner [1]. Some exclusion for this project includes the team will not be taking any sampling for lab analysis.

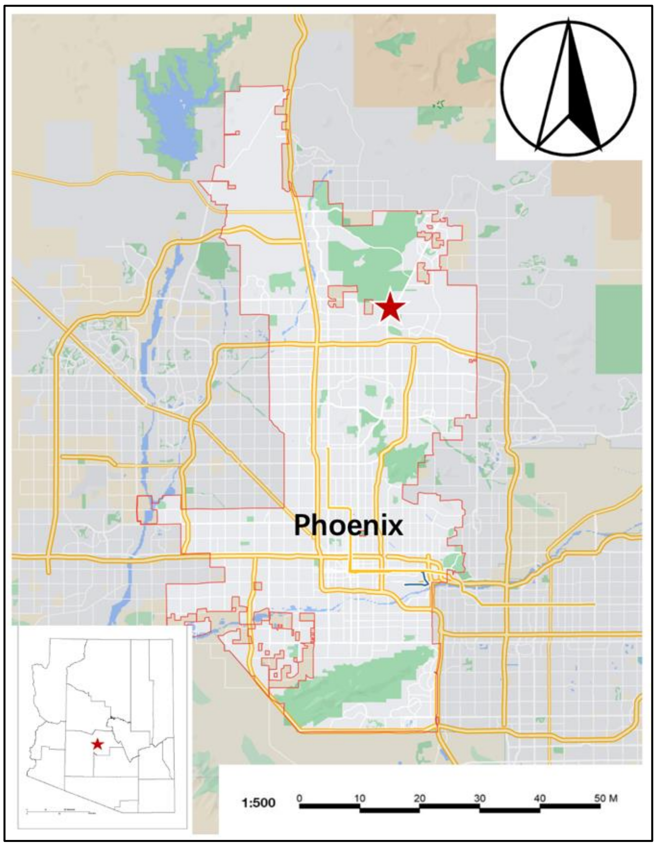

Figure 1. 1 Map of Location Relative to Phoenix [2]

The CCWRP has a treatment capacity of 8 million gallons per day (MGD) [1]. The existing processes at this plant include a bar screen, primary clarifier, aeration basin, secondary clarifier, tertiary filters, and UV disinfection [2]. These processes can be seen in Figure 1.2 through the aerial view of the plant. The existing treatment was lacking in grit removal and a determined use for the effluent produced from the plant.

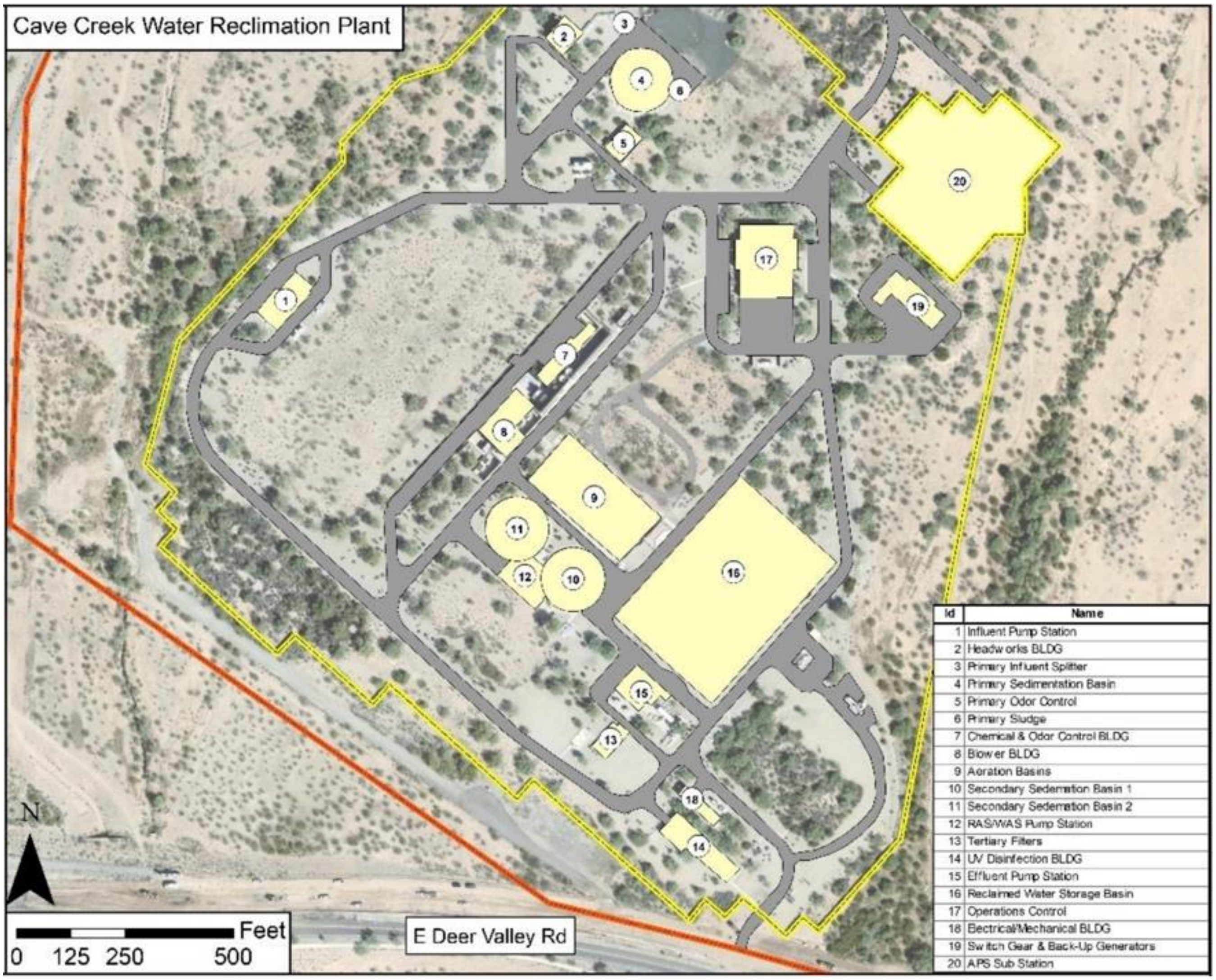

Figure 1. 2 Aerial View of Plant [2]

1.2 Constraints

In the Clean Water Act (CWA), under Title 18 Environmental Quality Chapter 11: Department of Environmental Quality – Water Quality Standards Section R18-11-303, expresses the requirements needed for the treated water to be classified as Class A+ reclaimed water. Under Subsection B of R18-11-303, all requirements are stated with the main requirements being that reclaimed water must undergo secondary treatment, filtration, nitrogen removal treatment and disinfection. As well as it being required to add coagulants or polymers that react with the effluent before disinfection within the 24-hour turbidity criterion. The turbidity criterion states that the 24-hour average turbidity of filtered effluent must be equal to or less than 2 NTU, or filtered effluent does not exceed 5 NTU at any time.

In addition, the plant needs to comply with the CWA, Compliance Monitoring [3], and accreditation of laboratories that complete analysis of drinking water samples and are necessary to ensure compliance with regulations [4].

The treatment plant is in Maricopa County, and its government, Water Supply, and System Facts' requirements for water quality mention that water quality requirements are set and regulated by the EPA [8]. The Drinking Water Program regulates public water systems to ensure they comply with Safe Drinking Water requirements of the Water Law. Although the treatment plant produces class A+ reclaimed water for irrigation and recharge in the service area, it is also subject to EPA regulations and oversight.

1.3 Major Objectives

The major objectives of this project include the following:

- Analysis of historic flow characteristics, existing treatment process, and proposed treatment alternatives
- Projection of population in the service area
- Reviewing related water quality regulations and making recommendations for effluent use
- Evaluation of proposed treatment processes/technologies and proposed plant layout
- Evaluation of effluent use options
- Estimation of the cost of the improvements

2.0 Site Investigation and Existing Conditions

CCWRP produces class A+ reclaimed water which is the highest standard of reclaimed water. The plant closed in 2009 due to slow population growth. However, the current growth in population has led to the reopening [5]. When the plant closed, it was treating 8 MGD. The influent wastewater came from pumping sewers located on Cave Creek Road and Deer Valley Road [6]. The plant consists of preliminary, primary, secondary, tertiary, and disinfection processes. Figure 1.2 expresses a site map for the CCWRP based on the 2019 WEF Student Design Team's site visit as the 2022 team was unable to visit the site. The key expresses the current technologies that were operating at the plant.

Figure 2.1 expresses the process flow diagram for the existing CCWRP. When in operation, the plant had issues with large amounts of grit in the system which wears out pumps. The lack of grit removal caused overloading with the primary sedimentation basin, issues with the UV system due to operation and maintenance, high salinity, and lack of redundancy within the plant thus causing shutdowns for maintenance [2].

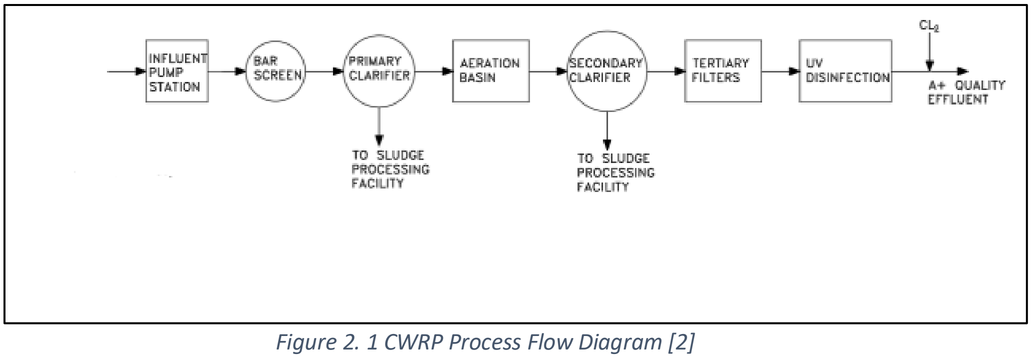

Figure 2. 1 CWRP Process Flow Diagram [2]

3.0 Population Estimation

To fully be able to design a water reclamation plant (WRP), the current population and expected future population needs to be known so that the plant can operate efficiently for the entire plant lifecycle. The current population served for this treatment plant has been estimated at 40,000 people due to the plant most likely receiving wastewater from the surrounding cities of Cave Creek, Carefree, and Anthem. The projected population is computed through the year 2070 because 50 years is the typical life expectancy of a water reclamation plant, and the rehabilitation process is occurring in 2022 [7].

The growth rate was calculated based on Equation 3.1 shown below and utilizing past populations from the Census in the years of 2010 and 2020 which had populations of 1,445,632 and 1,608,139 respectively [8]. The growth rate begins at 1.12% as that is the estimated growth rate for Phoenix currently and the cities that will be utilizing this plant which surrounds Phoenix. The future growth rates were then estimated based on the phases of the plant and the nature of population growth. Therefore, in phase 1 there is a steady increase in the growth rate because Phoenix is still growing rapidly as it is seen as a good place to retire, warm weather, and no major natural disasters to deal with. However, phases 2 and 3 have a decrease in growth rate because Phoenix is entering a Tier 1 drought and the effects of this may be felt by 2037. Along with that, the city of Phoenix will not be able to withstand the constant growth and people will begin to leave as space and resources become scarcer due to the increasing population.

Equation 3. 1 Growth Rate [9]

$$r = \left(\frac{(P_2 - P_1)}{P_1}\right) \times 100\%$$

With the variables defined as:

r – Growth Rate
P_2 – Current Population
P_1 – Initial Population

Using the growth rate values described above, this value was plugged into Equation 3.2 to calculate the future population as seen in Appendix A-1 in the tabulated calculations. The calculation conducted uses the current population, the time that the plant is expected to operate efficiently for, and the rate of increase for population growth. The growth rate is expressed as a decimal representing the change in population size as a factor of time [9]. The projected population was then used as the current population for the next year and the trend continued.

Equation 3. 2 Population Growth [12]

$$P = P_0 e^{rt}$$

With the variables defined as:

P= Number of People at a Future Date
P_0= Present Population of People
r= Rate of Increase as a Decimal
t= Time Period (yr)

The population will increase over the next 50 years; however, the growth rate will decrease starting in 2040 to account for limiting factors that are expected to occur when reaching such a high increase in population per year. The growth rate begins to decrease again when it reaches the maximum growth of 1.14%. Overpopulation and a limited source of water and resources considering the cities and water sources are not built to handle this population. Table 3.1 below displays the projected population that the WRP will serve for the next 50 years in increments of 10-year spans. Because of this projection, the plant will be built to accommodate approximately 70,000 people. Appendix A shows the calculations for each year from 2021 to 2070 for projected populations based on Equations 3.1 and 3.2 shown above.

Table 3. 1 Projected Population per 10 Year Increments

Year	Projected Population
2030	44275
2040	49599
2050	55525
2060	62097
2070	69377

4.0 Effluent Usage

4.1 Overview of Effluent Use Needs

In 2022, the Federal Government declared a Tier 1 water shortage for the Colorado River, meaning states including Arizona will receive reduced water supplies. Specifically, there will be a reduction for agricultural users [10]. Additionally, the years 2000 to 2021 were the driest 22-year period since the year 800 and will likely continue through 2022 [11]. These events influence the use of effluent from water reclamation plants as reusing reclaimed water can lessen the demand for potable water and can be used in agriculture to offset the decrease in available water from the Colorado River. Since the plan must also incorporate future issues, it is essential that the reclaimed water will not only be available for agricultural purposes but also drinking water through indirect and/or direct potable reuse. The CCWRP produced Class A+ water for irrigation and groundwater recharge within the area of service [2]. Class A+ reclaimed water is the highest standard of reclaimed water meaning the initial wastewater underwent secondary treatment, filtration, nitrogen removal treatment, and disinfection [12].

4.2 Decision Matrix

To analyze the options for effluent use, the environmental, social, and economic impacts were examined. The team examined multiple options for the most efficient effluent use based on a set of design criteria. The decision was made based on the option that scored highest.

The design criteria were determined based on what the team saw as most important and included environmental impact, social impact, and life cycle cost.

- The environmental impact was seen as important due to a decrease in water availability. Therefore, this impact has a weight of 40% in the decision matrix. As discussed previously, there is a water shortage, so the reuse of effluent is only becoming more significant to be able to have a water source.
- The other impact of social impact weighs 35% and was chosen because reusing wastewater can be controversial as citizens see it as unsanitary and do not feel that the effluent is clean enough for their exposure. Therefore, the way that effluent use is presented to society is a very important factor in approval.
- The last criterion is life cycle cost which weighs 25% as cost will always be a factor to design and it will play a factor how expensive each implementation will cost.

These criteria were scored on a scale of one to five with one being that it does not meet the criteria and five being that it exceeds the criteria. A score of 2 is given when the use meets some of the criteria that is given. A three is awarded to effluent uses that just meet the criteria and a four is given when the criteria somewhat exceed the criteria listed. The effluent uses that were rated based on the decision criteria are discussed in the following sections.

4.3 Direct Potable Reuse

In 2018, Arizona updated its rules for recycled water to allow for direct potable reuse (DPR). However, AZ is still developing rules for permitting and regulating a DPR system. DPR treats wastewater or reclaimed water using AWT, thus creating potable water. DPR differs from IPR in that there is no environmental buffer, the water goes straight to the potable delivery system as shown in the figure below. A DPR system can be made as an entirely new AWT facility or additional technology can be added to the existing WRP.

The environmental and social advantages of DPR are that it offsets the demand for raw water from ground or surface water sources and offers the community a reliable way to obtain safe drinking water. However, since it is a newer technology, there is a public perception hurdle. In addition, in terms of both social and economic impacts, DPR has the potential to raise water rates to help contribute to the cost of advanced treatment. For environmental impacts, DPR lessens the need for other natural sources of water such as pulling from aquifers or surface water. Additionally, for life cycle costs DPR has a high upfront cost as there are recommended testing periods, pilot studies, design, and the creation of either a new advanced water treatment (AWT) plant or an addition to the existing WRP. However, once DPR is implemented it offers a continuously available source of potable water. Figure 4.1 shows a DPR flow diagram of how water from upper Lake Mary is treated for the community of Flagstaff, Arizona.

It is encouraged for the plant to plan for DPR in the future as the need for a drought resilient water source increase. This may include becoming involved in groups such as WaterReuse Arizona and staying up to date on upcoming bills such as the Water Infrastructure Modernization Act which allocates money to ADEQ to begin developing regulations for DPR.

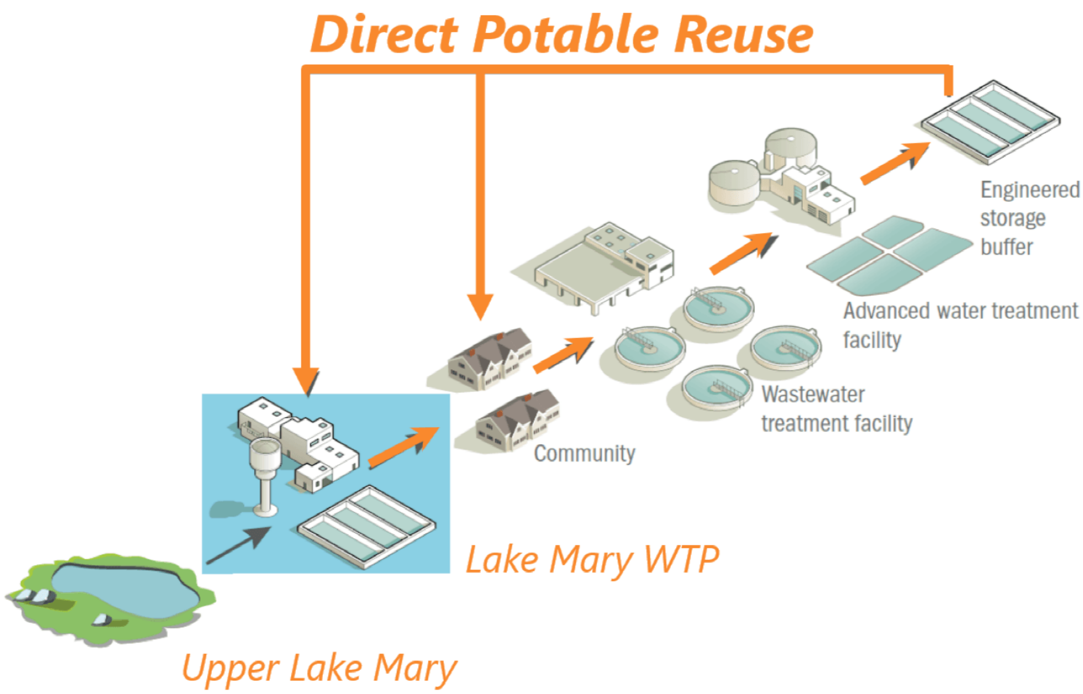

Figure 4. 1 Direct Potable Reuse [13]

4.4 Expanding Reclaimed Delivery

When reviewing current reclaimed users, there was reclaimed delivery to golf courses and for agriculture. With the existing reclaimed water delivery, one of the options for the effluent is to expand the delivery to other areas such as parks, restaurants, and to individuals.

Reclaimed water delivery is seen to have a highly positive impact on the environment because it can be utilized for non-potable uses such as irrigation, toilets, golf courses, parks, and agriculture. This allows water to be recycled and used for other services. With the location being in a drought, using reclaimed water for non-potable usage decreases the chances of using other finite water resources and can promote maintaining other main water resources such as groundwater and water from local rivers and streams [14]. Due to this aspect, reclaimed delivery was rated a four and one of the main reasons that it did not receive the highest rating of a five is due to it being non-potable and in cases where the water is used for public parks and irrigation, if the water is not treated correctly, it could lead to contamination exposure to the surrounding wildlife and/or the residents. When reviewing the social impact of using reclaimed delivery, one of the main social benefits is the decrease in water billing due to fresh water not being needed for appliances such as toilets and irrigation systems. Along with this benefit, a large amount of the public in the Phoenix metropolitan area, as much as 49%, are willing to try and use reclaimed water with 38% being neutral on the use of reclaimed water [15]. With this survey, there was 13% of the public that refused to use reclaimed water [15]. Due to this small amount of disapproval, the social impact of using reclaimed water for effluent use was rated at four.

4.5 Indirect Potable Reuse

In addition to DPR, the team also analyzed three forms of indirect potable reuse (IPR). IPR for aquifer recharge is currently legal in Arizona and plants can obtain recharge credits through the Arizona Department of Water Resources (ADWR) by meeting certain recharge guidelines. De facto reuse is currently done all over the state of Arizona meaning reclaimed effluent is unintentionally aiding in recharging the aquifer; however, through streambed recharge or groundwater injection wells the discharge of reclaimed water can be more intentional and aid in additional aquifer recharge. IPR uses an environmental buffer unlike DPR and in the case of streambed recharge, the stream acts as an environmental buffer and in both cases the effluent travels down through the vadose zone which aids in the potential removal of contaminants. IPR can be done with or without AWT, for the purpose of this design the team decided to only examine IPR without AWT as AWT is not required. Lastly, for all IPR options there is a potential for the release of unregulated contaminants and therefore the team recommends conducting sampling analysis to determine if the plant wishes to use AWT to treat for additional unregulated contaminants. The figure below expresses the cycle of treatment for IPR.

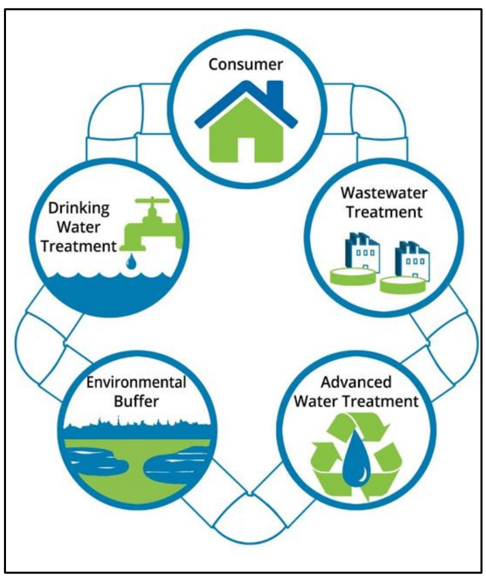

Figure 4. 2 Indirect Potable Reuse [19]

4.5.1 IPR through Surface Water Blending

This method of IPR takes the A+ reclaimed effluent and releases it into bodies of surface water. The requirements for this type of effluent use are to ensure the water maintains Class A+ reclaimed water. This is an important regulation as the surface water that is being blended could be released to lakes or rivers that also have a recreational use and must be safe for both humans and the environment [16]. When analyzing this usage for the decision matrix, it was rated as exceeding the criteria for the environmental impact because this method of IPR increases water levels which can positively impact the ecosystem and aid in not overusing the supply. The social impact met the criteria as everything that is being done is safe and good for the society, but some people may have an issue with wastewater effluent being discharged into lakes where they swim even when it is Class A+ reclaimed water. Lastly, the cost of surface water blending exceeded criteria as it is a cheaper option and does not require significant changes to the current system however, a pipeline would need to be built to transport the reclaimed water to the source. Lastly, the cost of surface water blending accounted for the need for a pipe to distribute the water and the permitting associated with this [16]. Overall, indirect potable reuse of surface water blending is a viable option to look at for effluent use but is not as impactful as streambed recharge.

4.5.2 IPR through Groundwater Injection

Well injection may be a viable option as well due to the plant having pre-existing wells [17]. This allows for less construction and reduces the negative social and environmental impacts. Another benefit of well injection is that this method is less time consuming than infiltration through the streambed into the aquifer [18]. The water still travels to the aquifer through the vadose zone, which is a natural environmental buffer that further cleans reclaimed water before it mixes with the natural raw water in the aquifer. The disadvantage of well injection is that wells require backwashing, which increases the life-cycle cost [2]. Figure 4.3 below expresses an example of IPR through groundwater injection.

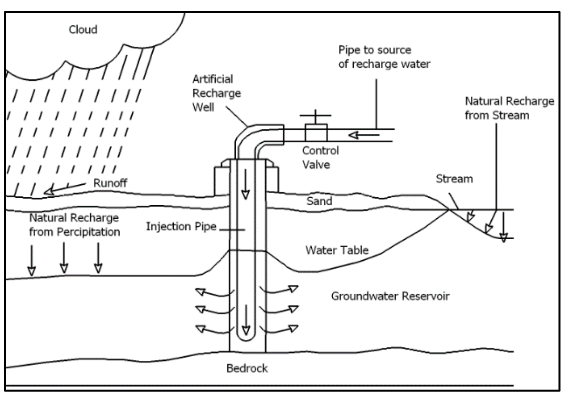

Figure 4. 3 Groundwater Injection [3]

4.5.3 IPR through Streambed Recharge

Another type of IPR that was reviewed for the effluent design was streambed recharge. When reviewing the different reclaimed discharges that CCWRP utilizes now, there are two main discharge uses that were identified, as mentioned earlier, one to the Cave Creek Wash and the other to the Galloway Wash. There are a few economic benefits of streambed recharge including maintaining groundwater levels, agricultural benefits, pumping costs for public use are reduced, and waterlogging being minimized. Within Arizona, one of the primary sources of water is groundwater, with over 40% being used for local rivers and streams [22]. The groundwater allows local rivers and streams to maintain their riparian environments that often promote growth in riparian vegetation and wildlife [22]. By using streambed recharge for this design, one will be able to promote more stable flows within local rivers and streams along with promoting the growth of riparian environments. For the social impact, some benefits consist of there being no limitations on groundwater usage and due to streambed recharge maintaining the groundwater levels, there will be a decrease in the cost of pumping groundwater for local communities and farmers. Due to Cave Creek having a large amount of farming and agriculture, maintaining the groundwater level is a large economic benefit for the local farms and can promote agricultural expansion. Figure 4.4 expresses an example of how streambed recharge works.

Due to the plant currently using groundwater recharge, there is little to no infrastructure impact and the process could continue with no new construction. Because of these factors, the life cycle costs are one of the highest ratings, a five.

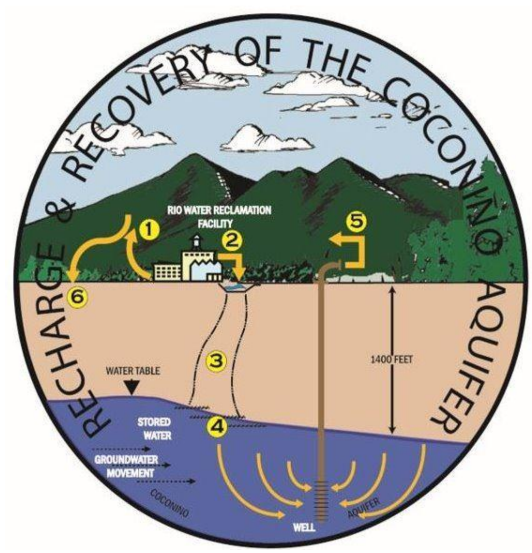

Figure 4. 4 Groundwater Recharge [19]

4.6 Final Decision

After analyzing all the options for effluent reuse, it was found that streambed recharge scored the highest based on Table 4.1 below. Streambed recharge meets all the criteria for the environmental impact, somewhat exceeds the criteria for the social impact and exceeds criteria of the life cycle cost as it is a cheaper way to reuse effluent. However, it is possible for the effluent to have multiple uses. Therefore, the team's final recommendation is to continue supplying reclaimed water to current reclaimed users in addition to streambed recharge to recharge the aquifer. The team recommends that the plant does a seepage study to determine if there are better discharge areas for the reclaimed water compared to the current effluent discharge sites such as the Cave Creek Wash and the Galloway Wash.

The reclaimed water at the current plant is chlorinated in the final step before being released into the system. For the reclaimed water to be used for streambed recharge, the water must be dechlorinated to remove residual chlorine from the treated water. Dechlorination also helps to reduce the toxic effects of disinfection byproducts [20]. Therefore, with the use of dechlorination, streambed recharge will be implemented as the effluent usage.

Table 4. 1 Decision Matrix for Effluent Use

Parameter	Weight (%)	IPR- Surface Water Blending	DPR	IPR - Streambed Recharge	IPR - Well Injection (Aquifer Recharge)	Reclaimed Delivery
Environmental Impact	40	3	4	3	3	4
Social Impact	35	4	4	4	4	4
Life Cycle Cost	25	3	3	5	3	3
Total	100	3.35	3.75	3.85	3.35	3.75

5.0 Process Selection

5.1 Decision Matrix

The proposed design is made up of many different processes that are needed to run a WRP and with each process comes a decision on what technology is to be used. The design must be evaluated at each step in the process to ensure that the best treatment process is selected. Alternatives were analyzed for screening, grit removal, equalization basin, primary settling, biological treatment, activated sludge, secondary settling, advanced treatment, and disinfection.

5.2 Decision Criteria

The decision criteria that were utilized when making choices for the water reclamation plant included efficiency, sustainability, maintenance and operation, staffing, feasibility, life cycle costs, and social and environmental impacts. The criteria were a combination of what the team values and what the CCWRP values. Aspects such as feasibility, lifecycle costs, maintenance and operation, staffing and efficiency were criteria that were provided as significant factors through the problem statement. In addition to these, the team felt it was also important to investigate sustainability and social and environmental impacts to evaluate how each process may be used in other ways to benefit the world.

For evaluating technologies, these criteria have been defined as the following:

- Efficiency is present when technology is decreasing energy use and head loss while increasing the quality of treatment as compared to the plant's current efficiency.
- Sustainability is defined as sustainably sourced materials where products can be reused, recycled, or limit harm to the environment.
- Maintenance and operation were analyzed by factoring in processes that will need updates and maintenance, short- and long-term upgrade and maintenance needs in which factors into staffing for the number of staff needed to operate the plant.
- Staffing is based on the amount of additional operator training, certification requirements, and the number of staff needed to run the plant.
- Feasibility and constructability are rated based on the use of innovative technology, reliability of the technology based on history of use in the U.S., ease to construct technology and obtaining materials.
- Lifecycle costs are rated highest when limiting the amount of the technology cost for implementation along with the technologies economic impact being considered and the need to pay for staffing, maintenance, and local community costs.
- Social and environmental impacts include reducing the short- and long-term impacts on environmental health, materials used, and cradle-to-grave impacts. It also examines how the project will positively or negatively impact the surrounding community.

The rating system used to score the decision criteria was based on a one to five scale with five being the highest ranked for each category. When evaluating the decision matrix, a technology received a one in the category if it was said to not meet the criterion and definitions given above. A two would be administered if the technology somewhat meets the criterion. Once the technology was able to only meet the criterion, it was given a three for satisfying all things listed in the definition. A four was received when the technology somewhat exceeded the criterion. Lastly, a five was awarded for the technology that truly exceeded the criterion and was able to go beyond expectations for a given process. It was also crucial to weigh each criterion as some are more important than others to the final design. In that way, it was decided that efficiency would be the most important criterion and would represent 25% of the score for each technology. After efficiency, the factors of sustainability, feasibility, and lifecycle cost were all determined to be 15% of the rating weight for each of the technologies because these were seen as important to the construction of the plant but less so than the efficiency. Following those criteria includes maintenance and operation, staffing, and social and environmental impacts which carry the weight of 10% for each technology. With all the ratings and the weights of the criteria, the decision matrix is scored by multiplying each weight by each rating and summing them together to create a score out of 5. In the end, the higher the score, the better the technology was for the design.

5.3 Screening

The first stage of the water reclamation plant is screening, which removes objects from the influent stream before entering the plant for further treatment. Three bar screen options were analyzed as follows: the continuous bar screen, hand cleaned coarse bar screen, and fine bar screen. Screening is identified as the first step in a wastewater treatment plant and serves the purpose of removing all objects that have ended up in the flow of water including hygiene products, flushable wipes, trash, large objects, and more.

5.3.1 Coarse Bar Screen

One of the bar screens that were looked at included a hand cleaned coarse bar screen, but this did not meet the criteria as well in areas like maintenance and operation and social and environmental impacts because hand cleaned bar screens require maintenance by the staff and are only a coarse bar screen which removes larger objects but allows finer substances to pass through. The large openings in a coarse bar screen can be seen in the figure below.

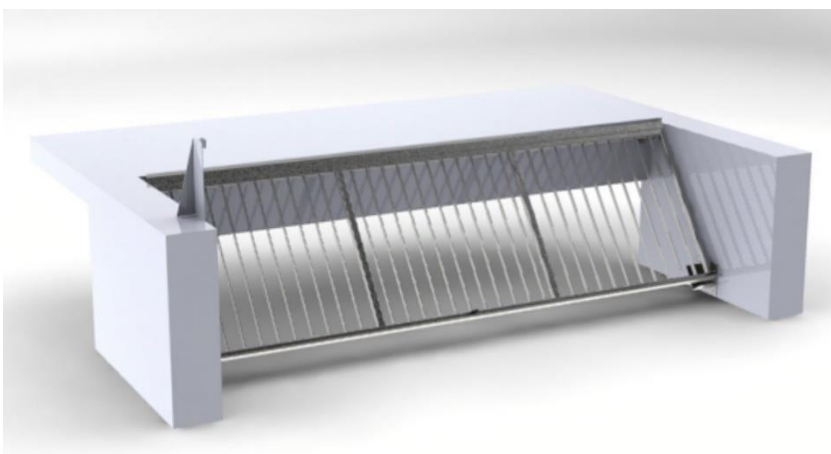

Figure 5. 1 Coarse Bar Screen [21]

5.3.2 Fine Bar Screen

The other viable option was Fine Bar Screen which would be able to stop all large and small objects from getting through but was not as efficient in categories such as maintenance and operation and feasibility due to the fact that the screens are fine and are more likely to get clogged, causing more maintenance and a lesser likelihood for a large treatment plant. The fine bar screen can be seen below where the fine screens can be observed.

Figure 5. 2 Fine Bar Screen [22]

5.3.3 Continuous Bar Screen

The continuous belt bar screen will be a very efficient option as it is always moving and separating objects out of the incoming flow. The continuous belt bar screen is described as ultra-high tech while still being functional and efficient with both fine and coarse solids [23]. With this technology having multiple rakes moving continuously, it has been decided as the most sustainable technology and scored the highest in sustainability, maintenance and operation, and social and environmental impacts. Figure 5.3 shows this technology below where the continuous belt design is pictured.

Figure 5. 3 Continuous Belt Bar Screen [24]

5.3.4 Final Decision

Therefore, the final decision for the screening process is the belt bar screen because it scored the highest based on the decision matrix shown below in Table 5.1. The continuous belt bar screens will be the best design for this reclamation plant because there are multiple rakes allowing faster screening while still being able to remove large and finer objects that have been flushed and enter the plant.

Table 5. 1 Screening Decision Matrix

		Screening		
Parameter	Weight (%)	Hand Cleaned Coarse Bar Screen	Continuous Belt Bar Screen	Fine Bar Screens
Efficiency (Process Improvements)	25	3	3	4
Sustainability	15	1	4	1
Maintenance and Operation	10	1	4	1
Staffing	10	4	2	4
Feasibility/ Constructability	15	4	2	1
Process Life Cycle Costs	15	4	2	4
Social and Environmental Impacts	10	2	4	4
Total	100	2.8	2.95	2.8

5.4 Grit Removal

The second stage of the water reclamation plant is grit removal, which acts to remove the grit and particles. The team analyzed three options for grit removal and these technologies looked at include an aerated grit chamber, detritus grit chamber, and horizontal flow grit chamber. Grit removal is the second process in a treatment plant and has the purpose of removing finer particles from the flow after all large objects have been removed by the bar screens.

5.4.1 Detritus Grit Chamber

The Detritus Grit Chamber was analyzed but it was decided that this technology was not satisfactory with the design criteria as it did not meet the criteria for efficiency and sustainability because these chambers have been known to let more grit through than normal and do not allow the water flow to be controlled [25]. This would be an issue since the Equalization Basin in the final design is placed after the grit removal. A figure of the Detritus Grit Chamber can be seen below in Figure 5.4.

Figure 5. 4 Detritus Grit Chamber [26]

5.4.2 Horizontal Flow Grit Chamber

A Horizontal Flow Grit Chamber was also investigated, but it was found that these types of chambers are not sufficient in the sustainability and maintenance and operation aspects of the decision matrix because they also have difficulty in controlling flow and all their equipment is placed inside the chamber with water which can cause them to wear out quicker and not be as sustainable [25]. A schematic of a Horizontal Flow Grit Chamber can be seen below.

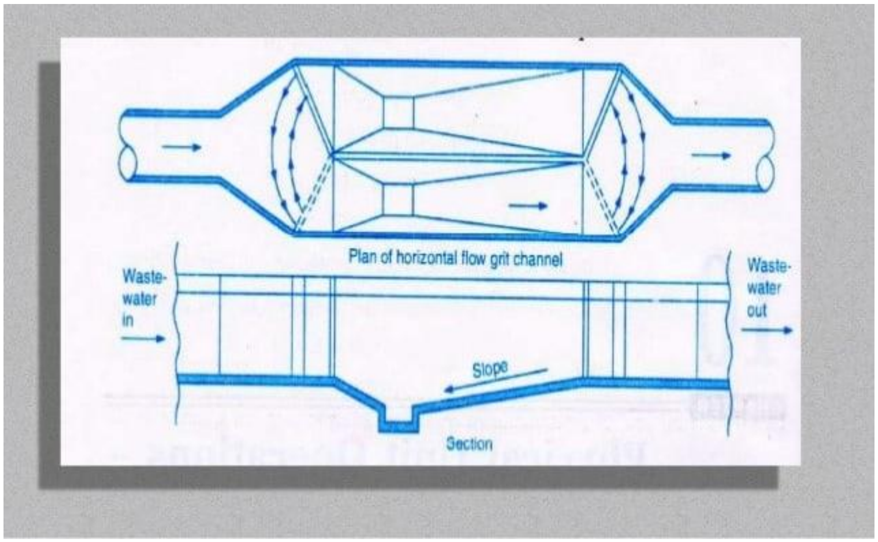

Figure 5. 5 Horizontal Flow Grit Chamber Diagram [27]

5.4.3 Aeration Grit Chamber

Therefore, the best design for grit removal is an Aeration Grit Chamber because it allows for various flow rates as needed before the Equalization Basin. Additionally, chemicals can be added to the grit chamber and the chamber will increase the efficiency of the treatment plant. An example of an aerated grit chamber can be seen below in Figure 5.6 where the aeration can be observed through the picture.

Figure 5. 6 Aerated Grit Chamber [28]

5.4.4 Final Decision

After analyzing these options, the Aeration Grit Chamber was decided on for the final design as it scored the highest on the decision matrix shown below in Table 5.2. The aeration grit chamber allows for chemicals to be added into the system and allows different flows which makes this chamber sustainable, easy to operate and maintain, and the best overall technology.

Table 5. 2 Grit Chamber Decision Matrix

		Grit Chamber		
Parameter	Weight (%)	Aerated Grit Chamber	Detritus Grit Tank	Horizontal Flow Grit Tank
Efficiency (Process Improvements)	25	3	2	3
Sustainability	15	4	3	1
Maintenance and Operation	10	4	3	1
Staffing	10	3	4	4
Feasibility/ Constructability	15	4	5	5
Process Life Cycle Costs	15	4	4	3
Social and Environmental Impacts	10	4	4	3
Total	100	3.65	3.4	2.9

5.5 Equalization Basin

The next step of the water reclamation plant is an equalization basin which is installed to neutralize the incoming flow. The team analyzed two options for the equalization basin and those were an in-line equalization basin and a side-line equalization basin. An equalization basin is needed to aid in reducing fluctuations in flows throughout the day. For example, the basin can hold a volume of the peak flow from the day and distribute it at night when the overall influent flow is lower. An equalization basin helps to control the flow and releases it steadily into the rest of the treatment processes.

5.5.1 Side-Line Equalization Basin

A side-line equalization basin serves the purpose that was previously discussed to normalize the flow except it only takes the overflow that the treatment process cannot handle. The extra flow goes off to the side to be held by the equalization basin until it is needed. This process can be seen below in the schematic of Figure 5.7. When analyzing the side-line equalization basin, it seemed less feasible and had larger social and environmental impacts than the in-line equalization basin. This is because the entire flow cannot pass through the side-line equalization basin as it only takes what cannot be handled by the plant, but this creates extra piping and spacing needed to build a basin on the side of the main treatment train [29]. The side-line basin only taking the overflow also does not help when the treatment plant is operating for a maximum of 8 MGD but is receiving half of that due to the time of day thus wasting energy.

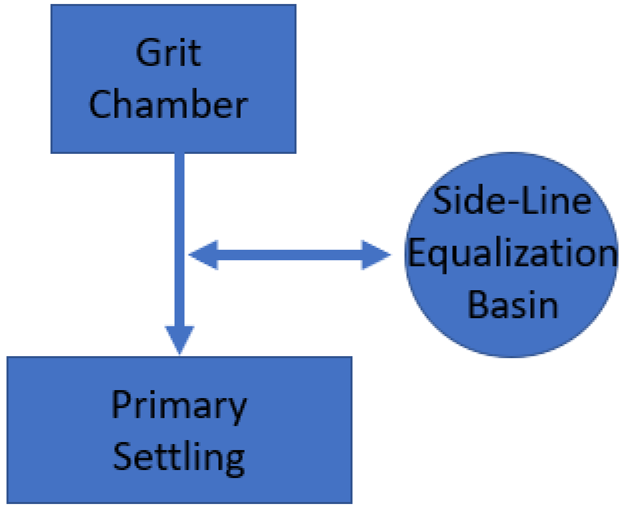

Figure 5. 7 Side-Line Equalization Basin Schematic

5.5.2 In-Line Equalization Basin

Unlike the side-line equalization basin, the in-line equalization basin stays in the treatment train and regulates all flow that enters the treatment plant. This basin holds the extra inflow when needed and releases it when there is a decrease in the flowrate. The schematic of an in-line equalization basin can be seen below in Figure 5.9. An in-line equalization basin is most efficient because it can handle the entire flow of the influent and helps to dampen the concentration and mass of the flow. With the entire flow going through the equalization basin as part of the treatment, there is no need for extra equipment and space because it can be built into the process train. The entire flow going through the basin also helps save energy because if the flow is minimal the basin will hold it until there is enough flow for the treatment process to remain efficient. An in-line equalization basin can be seen in the figure below for reference as they usually appear as a large tank that will hold the flow until it needs to be released.

Figure 5. 8 In-line Equalization Basin [30]

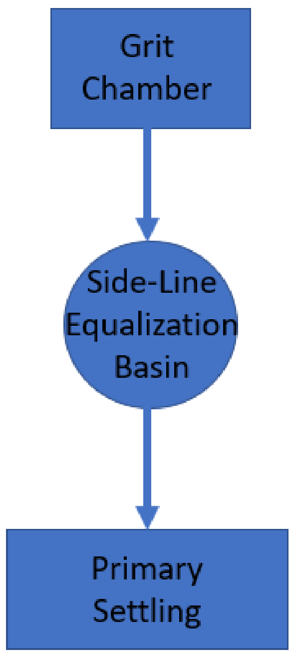

Figure 5. 9 In-Line Equalization Basin Schematic

5.5.3 Final Decision

In the decision matrix, both a side-line and an in-line equalization basin were analyzed, and it was found that an in-line equalization basin would be most efficient for this treatment plant. The schematics above express how the equalization basin would be placed within the treatment train. As shown in Table 5.3 below, the in-line equalization basin is more feasible for this plant and has more beneficial social and environmental impacts than the side-line equalization basin.

Table 5. 3 Equalization Basin Decision Matrix

		Equalization Basin	
	Weight (%)	Side-line Equalization Basin	In-line Equalization Basin
Efficiency (Process Improvements)	25	4	3
Sustainability	15	1	1
Maintenance and Operation	10	3	3
Staffing	10	5	5
Feasibility/ Constructability	15	2	5
Process Life Cycle Costs	15	4	3
Social and Environmental Impacts	10	2	4
Total	100	3.0	3.4

5.6 Primary Settling

The first clarifier of the water reclamation plant is the primary clarifier which is the physical process of removing inorganic solids. There were two options analyzed for the primary clarifier that were a traction clarifier and the other clarifier was a column support clarifier. When moving into the clarifying of the treatment process, a primary clarifier is needed to remove solids that remain in the water but are not objects or grit captured from previous processes but more substances such as Biological Oxygen Demand (BOD) and sludge.

5.6.1 Column Support Clarifier

One of the primary clarifiers that was researched was a column support clarifier which is used for larger tanks but lacks the criteria needed in areas like efficiency and social and environmental impacts because it is made for larger flows but is less efficient when handling the flows and could impact the environment and society if the inorganic solids are not removed [31]. The figure below shows a column support clarifier where the arms can be seen. This clarifier is less efficient than the traction clarifier as it does not collect any solids that float throughout the clarifier but instead only collects what is settled at the bottom. It can be seen that the arms of the column support are shorter than the traction clarifier making it not as effective at the treatment.

Figure 5. 10 Column Support Clarifier [32]

5.6.2 Traction Clarifier

The primary clarifier of the Traction Clarifier is much better for this treatment plant as this technology is highly efficient and the skimmer in the tank extends to the end of the tank which will clean all the water better. Although these clarifiers can be similar in some ways, the traction clarifier is adjustable to the size of the tank. This clarifier is also known to be more efficient with the removal of BOD and sludge than the column support clarifier. As observed in Figure 5.11, the traction clarifier has an arm that extends the whole length of the tank and skimmers that hang from this arm and skim through the water to best clarify the incoming flow by removing particles and biological sludge.

Figure 5. 11 Traction Primary Clarifier [33]

5.6.3 Final Decision

Different types of primary clarifiers were looked at and the decision matrix table 5.4 below found that a traction primary clarifier is the most efficient type of clarifier to use. The traction clarifier was rated very high in efficiency due to the mechanisms discussed previously with the arm and skimmers that cover the entire tank. It also ranks well when it comes to social and environmental impacts because it is the most efficient clarifier for this process. Overall, the traction clarifier is a better design for this treatment plant and will be the most sustainable and efficient way to remove biological sludge and floating particles

Table 5. 4 Primary Clarifier Decision Matrix

		Primary Clarifier	
Parameter	Weight (%)	Column Support Clarifier	Traction Clarifier
Efficiency (Process Improvements)	25	2	5
Sustainability	15	3	3
Maintenance and Operation	10	4	1
Staffing	10	4	3
Feasibility/ Constructability	15	5	5
Process Life Cycle Costs	15	3	2
Social and Environmental Impacts	10	4	5
Total	100	3.35	3.65

5.7 Biological Treatment

The team analyzed four biological treatment methods for secondary treatment: Membrane Bioreactor, Trickling Filter, Rotating Biological Reactor, and Moving Bed Biofilm Reactor [34].

5.7.1 Membrane Bioreactor

The Membrane Bioreactor (MBR) treats water with high clarity because contaminants and salts are separated near the electrodes. Membrane filtration technology makes the process easy to operate. However, the frequent occurrence of clogging and membrane contamination leads to a low score in maintenance and operation. Figure 5.12 shows an example of membrane bioreactor.

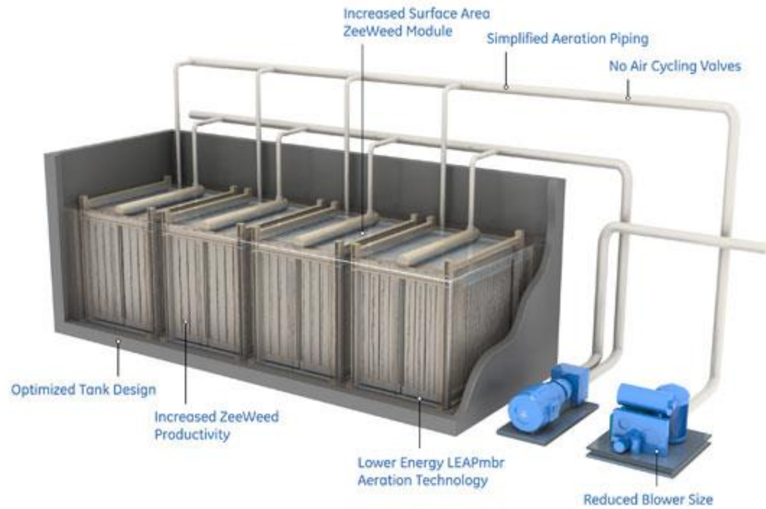

Figure 5. 12 Membrane Bioreactor [35]

5.7.2 Trickling Filter

One of the advantages of the Trickling filter is that the membranes are less likely to clog, so maintenance costs are very low. A major disadvantage of the Trickling filter is the poor clarity of the water, which requires subsequent tertiary treatment. The treatment plant produces unpleasant odors, making it score low in terms of environmental and social impacts. Figure 5.13 shows an example of trickling filter.

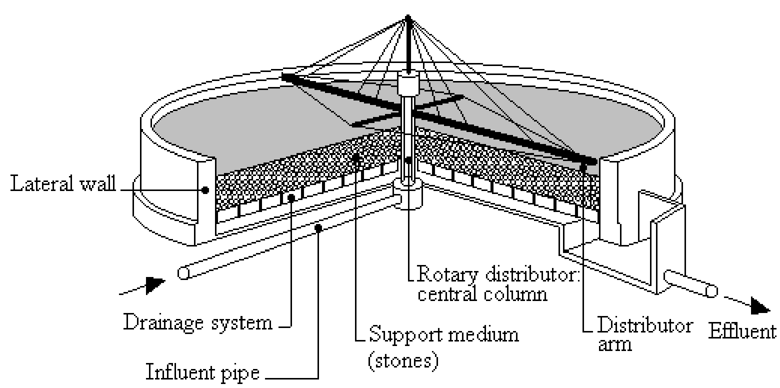

Figure 5. 13 Trickling Filter [36]

5.7.3 Rotating Biological Contactor

The Rotating Biological Contactor (RBC) is inexpensive and easy to install and operate. The continuous rotation of the shaft helps metabolize the organic components of the wastewater, greatly reducing the BOD and improving the recovery of phosphate from the wastewater. However, the clarity of the treated water is poor and must undergo subsequent tertiary treatment. Figure 5.14 shows an example of RBC reactor.

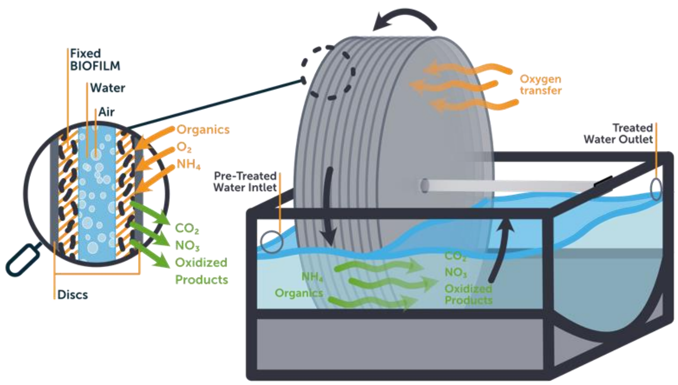

Figure 5. 14 Rotating Biological Reactor [37]

5.7.4 Moving Bed Biofilm Reactor

Moving Bed Biofilm Reactor (MBBR) is an efficient process as it requires less time to treat the wastewater. Another advantage of using this system is that it requires less space and is cost effective compared to other processes. Clogging is also less likely in the case of MBBR due to the presence of an aeration system. However, MBBR is a manual process that requires a lot of manual work, so this technology scores low on staffing. Another disadvantage of it is that the biofilm present on the hexagonal carrier attracts insects.

5.7.5 Final Decision

According to the decision matrix, the Rotating Biological Reactor is selected as the final solution. The Rotating Biological contactor somewhat exceeds the criteria on maintenance and operation, staffing, feasibility, and life-cycle cost. Although the efficiency and the water quality are low for this process, the water will further go through tertiary treatment process so this will not be a big problem.

Table 5. 5 Biological Treatment Decision Matrix

Parameter	Weight (%)	Biological Treatment: Membrane Bioreactors	Trickling filters	Rotating Biological contactors	Moving bed biofilm reactors
Efficiency (Process Improvements)	25	4	2	3	3
Sustainability	15	3	3	3	4
Maintenance and Operation	10	2	4	4	3
Staffing	10	4	5	4	2
Feasibility/ Constructability (reliability)	15	3	4	4	3
Process Life Cycle Costs	15	3	5	4	3
Social and Environment Impacts	10	3	2	3	2
	Total:	3.25	3.4	3.5	2.95

5.8 Activated Sludge

The Activated Sludge process works as a part of the biological process to produce the biogas and other bioproducts to support the energy generation of the plant and the gas collection system for this process will have a positive environmental impact. The team looked at Conventional activated sludge process (CASP) and Upflow anaerobic sludge blanket (UASB) reactor [28].

5.8.1 Conventional Activated Sludge Process

CASP is a conventional continuous flow system that is widely used throughout the country. Because the prepared sludge is reused in the process, no additional space is required to degrade the sludge. The CASP process requires very little time, and its output water has very low turbidity and BOD levels. Some of the disadvantages of CASP are that it is a costly process and requires well-trained personnel to handle the process. Sludge expansion is the main operational problem encountered in CASP. The reactor tanks used for CASP are often quite large and the larger sludge volume means higher costs associated with disposal.

5.8.2 Upflow Anaerobic Sludge Blanket

The main advantage of using UASB is no aeration system is required, as the process is anaerobic. After treatment, the BOD of the treated effluent is considerably reduced. The process produces less sludge waste, reducing the burden of sludge disposal compared to conventional methods. However, it takes 2-8 months for the anaerobic bacteria to develop on the anaerobic blanket, making the treatment time much longer. The upward flow of wastewater through the anaerobic sludge layer and the movement of gases facilitates the water agitation process. Therefore, no additional energy is used for agitation. However, the temperature control used to maintain anaerobic bacterial growth consumes most of the energy. The figure below shows UASB reactors from AQUANOS.

Figure 5. 15 UASB Reactor [38]

5.8.3 Final Decision

According to the decision matrix, the UASB is selected as the final solution. This process is more energy saving and it produces a large amount of biogas (methane and CO_2), which is collected by a collection hood and can be used as an energy source to run the plant.

Table 5. 6 Activated Sludge Decision Matrix

		Activated Sludge	
Parameter	Weight (%)	Conventional Activated Sludge Process	Upflow Anaerobic Sludge Blanket
Efficiency (Process Improvements)	25	3	5
Sustainability	15	2	4
Maintenance and Operation	10	4	3
Staffing	10	3	4
Feasibility/ Constructability (reliability)	15	2	3
Process Life Cycle Costs	15	2	2
Social and Environmental Impacts	10	3	4
	Total:	2.65	3.7

5.9 Secondary Settling

Some of the solids collected in the secondary clarifier (return activated sludge) are sent back to the aeration tank to treat more wastewater and the excess (waste activated sludge) is pumped to another location in the plant for further treatment. The clean water that flows out the top of the clarifier is sent along for advanced treatment and disinfection.

5.9.1 Spiral Scraper Clarifier

The team considered three approaches for the Secondary Clarifier. The first is the Spiral Scraper Clarifier. The size and porting of the inlet center column of the spiral scraper clarifier both prevents settling and systematically reduces the inlet velocity. The flow of water to the surface ensures that the full volume of the flocculation well is used for gentle mixing and flocculation of the biosolids [46]. The opposing gates are arranged so that the incoming water stream hits itself, effectively dissipating the incoming energy and eliminating concentrated streams that may enter the clarification zone. This means that nothing can "clog" underwater. Regardless of the solids load, the settled sludge will be transported to the settled sludge pit and/or rotating sludge manifold. At the same time, the transport time of settled sludge is significantly reduced. Many consider a spiral blade clarifier to be a fast solids removal clarifier [47]. This can be seen below in Figure 5.16 of the Spiral Scraper Clarifier.

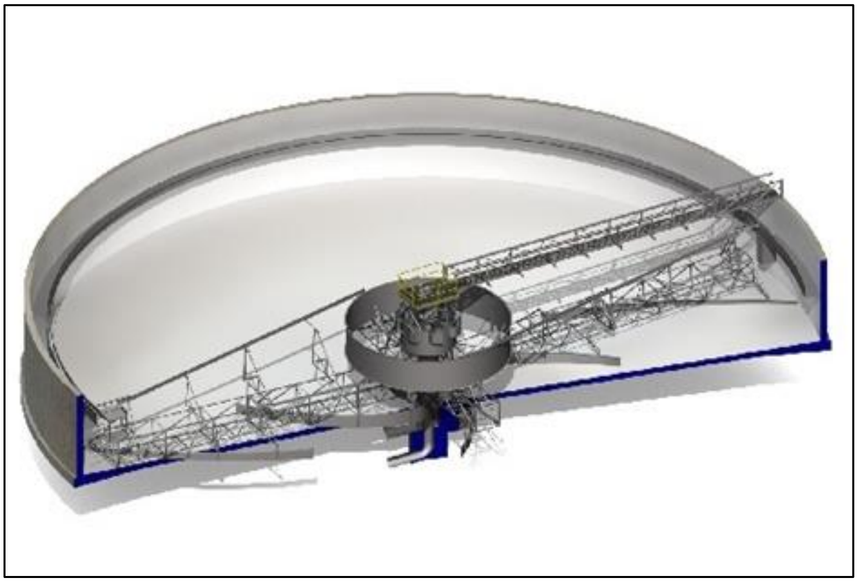

Figure 5. 16 Spiral Scraper Clarifier [46]

5.9.2 Up-flow Clarifier

Then there is the Up-flow clarifier, it is often advantageous to employ high solids contact zone for better quality effluent. This is done in an up-flow clarifier, so-called because the water flows up through the clarifier as the solids settle to the bottom. Most up-flow clarifiers are either solid contact clarifiers or sludge bed clarifiers. Both types have an inverted cone inside the clarifier, where there is a rapid mixing zone and a high solids concentration zone. However, its installation and maintenance costs will increase, and it requires a larger area for the clarifier and more helical blades [48]. A diagram showing the process involved in the Up-flow clarifier can be seen below.

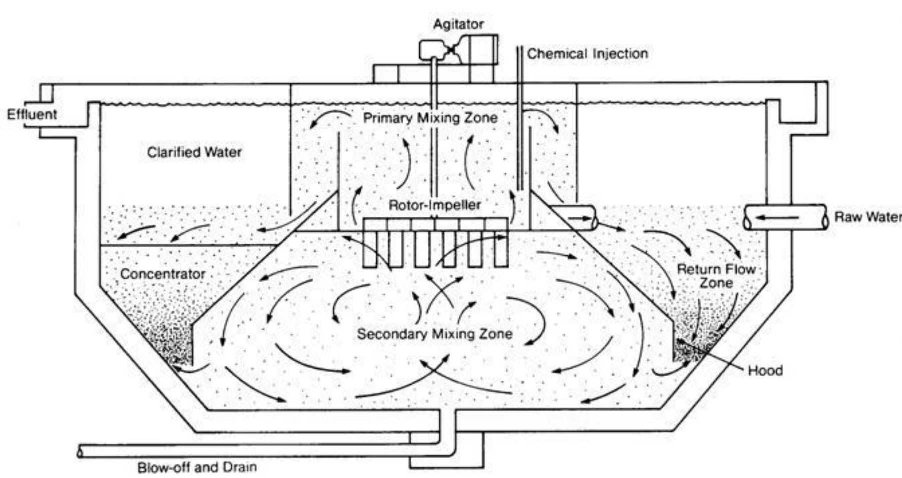

Figure 5. 17 Up-flow Clarifier [39]

5.9.3 Suction Header Clarifier

Last is the Suction Header Clarifier. Its principle is that one or two circular or square tapered headers extend radially from the manifold through the bottom of the clarifier. The differently sized and spaced orifices located at the leading edge of the suction header are designed to draw settled sludge into the entire bottom of the tank with a uniform removal rate. By the process of pumping or differential pressure, settled solids are drawn into the manifold through headers and discharged from the clarifier. However, at low RAS removal rates, the suction header holes may be blocked. If the actual RAS flow is different from the design, the headers may draw solids at the bottom of the pool at an uneven rate. A seal must be maintained between the rotating manifold, the clarifier center column, and the tank bottom. A figure showing the different parts of this clarifier that have been discussed can be seen below. A high head differential in the suction header can cause the seal to collapse or suck in, rendering it useless. This also increases life cycle costs as seals must be replaced approximately every 5 to 7 years [49]. Figure 5.18 shows an example of a suction header clarifier.

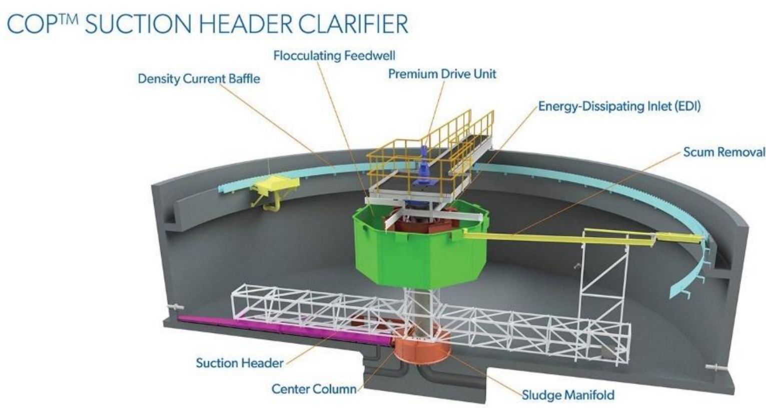

Figure 5. 18 Suction Header Clarifier [40]

5.9.4 Final Decision

After studying three different types of Secondary Settling, the Spiral Scraper Clarifier was found to be the most suitable type of clarifier among them through the decision matrix shown in Table 5.7. Its biggest advantage is high efficiency. Such as, it can effectively prevent sedimentation and reduce the inlet velocity. Due to the mechanism of the opposing gates discussed earlier, it can dissipate the incoming energy to the greatest extent and eliminate the concentrated water flow that may enter the clarification zone, and at the same time, it can effectively save the transportation time of sludge. It also excels in maintenance and operation and staffing. Overall, the Spiral Scraper Clarifier is currently the best option for the plant and the most stable and efficient technology for sludge removal and subsequent transport.

Table 5. 7 Secondary Clarifier Decision Matrix

		Secondary Clarifier		
Parameter	Weight (%)	Spiral Scraper Clarifier	Upflow clarifier	Suction Header Clarifier
Efficiency (Process Improvements)	25	5	4	3
Sustainability	15	2	3	5
Maintenance and Operation	10	4	3	3
Staffing	10	4	3	4
Feasibility/ Constructability (reliability)	15	3	4	3
Process Life Cycle Costs	15	3	3	2
Social and Environmental Impacts	10	3	4	5
	Total:	3.55	3.5	3.45

5.10 Advanced Treatment

In the final stages of treatment, a filter is used to remove any remaining particulate matter. Additionally, disinfection is completed to neutralize any remaining pathogens. For this stage in the treatment train, the team considered sand and membrane filters and UV, chlorine, peracetic acid and microalgae disinfection.

5.10.1 Sand Filter

Sand filters operate by removing remaining particulate matter from the partially treated wastewater stream as water percolates down the filter. Sand filters contain granular media in which large particles are unable to pass through. Absorption also occurs which removes particles through the pores in the sand [41]. Sand filters are energy efficient as they use gravity to move the flow from the top of the filter to the bottom. Additionally, they can provide high quality effluent. Sand filters are also sustainable and have been proven as efficient over years of use within the U.S.

For the filter media, if sand is not feasible there are other media options that can be locally sourced thus improving the local economy and aiding in the sustainability of the practice as the transportation of the media over a large distance is not required in addition the media can be found locally. Sand filters do require regular maintenance and the possible clogging of filter media can cause increased costs and maintenance requirements [43]. Due to the cost effectiveness, feasibility, and social and environmental impacts the sand filter scored higher than the membrane filter. Figure 5.19 expresses an example of a sand filter diagram and set up.

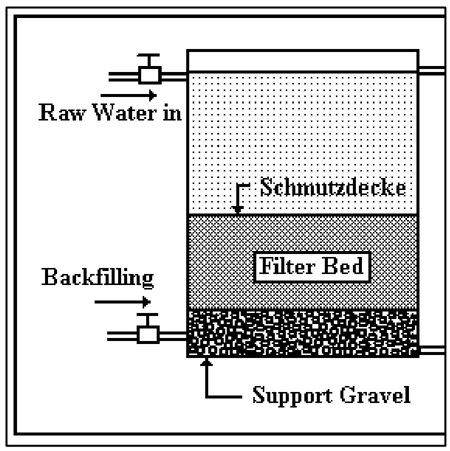

Figure 5. 19 Sand Filter [42]

5.10.2 Membrane Filter

A membrane filter uses mechanical and chemical sieving of particles and macromolecules [44]. Membrane filtration as a tertiary treatment process is known to have a smaller footprint compared to the activated sludge process, and the process also delivers a higher final effluent water quality. This is due to the fact that it relies heavily on the isolation of the microorganisms.

A membrane filter does require more maintenance and operation than other methods due to membrane fouling occurring. Membrane fouling is a process where the membrane pores are congested with contaminants which decreases filtration efficiency [45]. On average, after 21 years, the membrane filter can be a victim of membrane fouling and will need to be replaced. To prevent membrane fouling, it is required to have maintenance on the membrane filter and monitoring of the system. Due to these concerns, maintenance and operation of this technology was scored a three. The feasibility of a membrane filter is high due to the process not needing a large amount of space in the water treatment facility. The process is a common treatment method due to its effectiveness and is a well-known and approved method in water treatment. Membrane filtration as a tertiary treatment is a cost-effective method for wastewater. Most of the cost-effective means have come from technological improvements such as higher fluxes, longer membrane lifetimes, and lower aeration requirements. Membrane filtration is most effective in places where land acquisition is expensive. Also, due to the process being faster than other technologies and saturation can be reused, membrane filtration is seen to be highly efficient. Figure 5.20 below expresses an example of membrane filter technology and treatment.

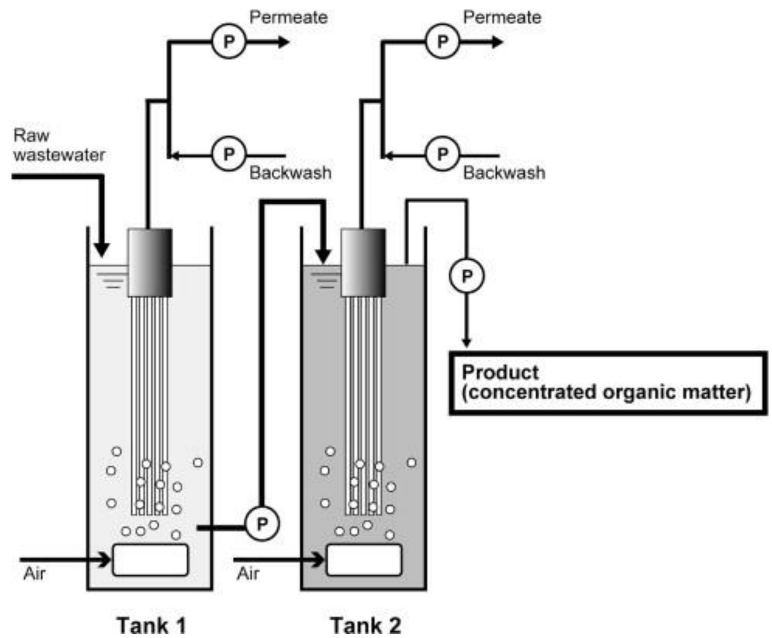

Figure 5. 20 Membrane Filter Schematic [46]

5.10.3 Filter Final Decision

Table 5.8 below shows the decision matrix where both a sand filter and a membrane filter were analyzed. It was found that the sand filter scored a 3.9 compared to the membrane filter which scored a 3.45. The sand filter overall scored better in efficiency and impacts but was relatively comparable to the membrane filter in other areas. Based on the decision matrix table shown below, the sand filter will be implemented into the final design.

Table 5. 8 Filter Decision Matrix

Parameter	Weight (%)	Membrane Filter	Sand Filter
Efficiency (Process Improvements)	25	3	4
Sustainability	15	4	4
Maintenance and Operation	10	2	3
Staffing	10	4	4
Feasibility/Constructability	15	4	4
Process Life Cycle Costs	15	4	4
Social and Environmental Impacts	10	3	4
Total	100	3.45	3.9

5.11 Disinfection

Disinfection is the final step in the treatment plant before the A+ reclaimed effluent is released for reclaimed delivery and streambed recharge. Disinfection is crucial in removing and killing remaining pathogens in the treated water. This can include pathogens such as those that cause cholera in addition to bacterial, viral, and parasitic diseases [47]

5.11.1 Ultraviolet (UV)

UV disinfection was the most energy efficient process and has been proven to provide proper disinfection through years of use within the U.S. Chlorine disinfection, while also common, did not score as high in other areas such as sustainability due to the need for further dechlorination to remove potentially toxic effects from disinfection, there are no known disinfection byproducts from UV [48]. UV disinfection was the most energy efficient process and has been proven to provide proper disinfection through years of use within the U.S. There are also no known disinfection byproducts from UV [48]. An example of UV disinfection can be found in the following image.

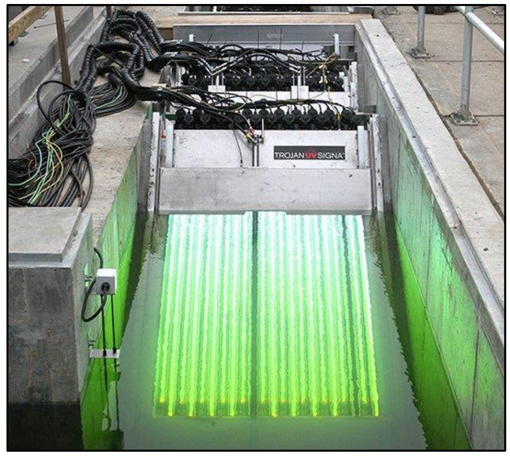

Figure 5. 21 UV Disinfection [49]

5.11.2 Chlorine

Chlorine disinfection is also a commonly used practice within the U.S. and therefore scored highly in the feasibility and constructability criteria. However, as mentioned above, chlorine disinfection produces disinfection byproducts which have potentially toxic effects and therefore scored lower in social and environmental impacts. Additionally, due to the need for dechlorination, chlorine received a lower score for sustainability. A schematic for this alternative can be seen below in Figure 5.22.

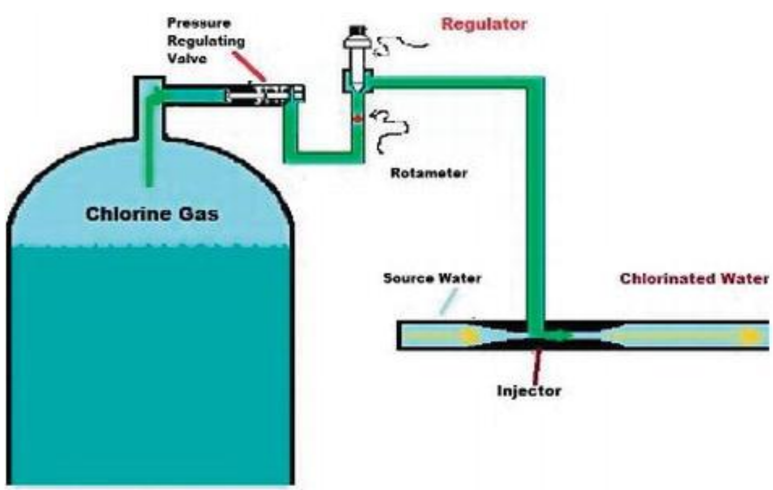

Figure 5. 22 Chlorine Disinfection Schematic [50]

5.11.3 Peracetic Acid

Peracetic acid is up and coming, however, did not score well for feasibility and constructability compared to the other alternatives. Additionally, UV costs less than peracetic acid over time even though UV is expensive to install [51]. The plant currently has UV disinfection. However, upgrades will still be made to the existing system to allow for the treatment of the additional effluent. UV disinfection works by affecting the DNA of the microorganisms therefore damaging the DNA and prohibiting the microorganism from reproducing and causing infection [48]. Figure 5.23 can be seen below which shows the technology needed for peracetic acid.

Figure 5. 23 Peracetic Acid Technology [52]

5.11.4 Microalgae

Microalgae is an efficient way to be used for tertiary treatment for wastewater, however, the strain of microalgae and its growth conditions will vary depending on how efficient it is. Due to this, efficiency was rated as three. Microalgae is a new sustainable technology that can be used for tertiary treatment. It is seen to be sustainable due to it creating a by-product of bioenergy. This biogas can be used as a resource for energy and in some cases can be either sold or used to power the treatment plant. Because microalgae rely on photosynthesis as its main growth process, the staffing needed for microalgae is low compared to other treatment methods. Microalgae as a treatment method has a low initial cost, minimal maintenance cost, and low operational cost. Figure 5.24 below expresses various microalgae treatment uses for wastewater.

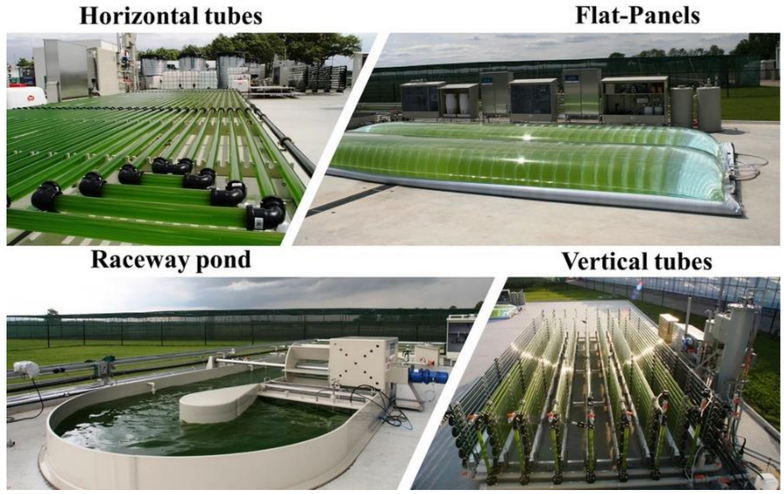

Figure 5. 24 Microalgae Disinfection Examples [53]

5.11.5 Disinfection Final Decision

Based on the decision matrix shown in Table 5.9 it was found that UV disinfection scored the highest and will therefore be used in the final design. UV scored best overall for efficiency, cost, feasibility, and sustainability. Additionally, UV is the current disinfection technology at the plant, thus the implementation of this into the final design will be for an upgrade of the current system.

Table 5. 9 Disinfection Decision Matrix

Parameter	Weight (%)	UV	Chlorine	Peracetic Acid	Microalgae
Efficiency (Process Improvements)	25	5	3	4	3
Sustainability	15	4	3	3	4
Maintenance and Operation	10	2	3	4	3
Staffing	10	4	4	3	5
Feasibility/ Constructability (reliability)	15	5	5	3	2
Process Life Cycle Costs	15	5	5	3	4
Social and Environment Impacts	10	4	3	4	5
	Total:	4.35	3.7	3.45	3.55

5.12 Biogas Production

An up flow anaerobic sludge blanket reactor is used within the treatment process to remove organics from wastewater and sludge [54]. During this process, anaerobic microorganisms produce biogas which is made up primarily of methane and carbon dioxide which is a renewable source of energy. This biogas can be collected in a collection hood where it can be used to produce electricity for the plant. This process would require a cogeneration engine to produce electricity from the biogas [55]. This electricity can then be used to power the plant operations thus lowering the methane emissions from the plant and offering cost savings on energy use for the entire treatment plant.

6.0 Solids Handling

6.1 Decision Matrix

The last step in a wastewater treatment process is to decide what needs to be done with the solids that have been produced. Through the processes conducted, there will be sludge produced every day that needs to be taken care of cautiously as it could contain many different contaminants. The process of solids handling is important for the CCWRP as it needs to be properly disposed of and aesthetics should be considered as well.

6.2 Decision Criteria

When analyzing the different options for solid handling, the three main aspects that were considered in the decision matrix were the environmental impact, social impact, and life cycle cost. The team examined multiple options for the most efficient solid handling based on a set of design criteria. The decision made was to calculate what option would be best overall depending on these different factors.

The design criteria were determined based on what the team sees fit and the areas of importance included environmental impact, social impact, and life cycle cost.

- The environmental impact is seen as important because the way that waste is handled is very important, and it would be best to implement a way where the waste can be disposed of without harming the environment. Therefore, this impact has a weight of 40% in the decision matrix. As waste is being disposed of, there are many environmental factors that can be impacted based on how it is handled.
- The other impact of social impact weighs 35% and was chosen because the aesthetics of different solid handlings can create negative social impacts for the surrounding community looking at the waste.
- The last criteria are life cycle cost, which weighs 25% as cost will always be a factor to design and it will play a factor in how expensive each solids handling will cost. The different techniques listed below have various costs included in the process like transportation.

These criteria will be scored on a scale of one to five with one being does not meet the criteria and five being that it exceeds the criteria. A score of 2 is given when the design meets some of the criteria that is given. A three is awarded to effluent uses that just meet the criteria and a four is given when the criteria somewhat exceed the criteria listed. The solid handlings that were rated based on the decision criteria are discussed in the following sections.

6.3 Landfill

While researching the environmental impacts and social impacts of a landfill, there were numerous negative impacts such as when waste decomposes, methane gas is created in the process, which is known to be a greenhouse gas harmful to the environment and continues to promote global warming [56]. Another negative impact is the creation of landfills which eliminate natural habitats of animals, where the average size of a landfill is 600 acres. As for landfills' negative social impacts, it has been observed that on average, landfills decrease the land value that is adjacent to the landfill. With large landfills, the land value decreases by 12.9% and smaller landfills decrease by 2.5% [56]. Along with the decrease of land values, there are multiple negative social impacts that affect the local community's aesthetic including but not limited to hazardous odors, noise, bugs, smokes, and hazard of water supply contamination which is a priority within Cave Creek due to the large population using groundwater [57].

6.4 Incineration

Another option that was analyzed was the process of incineration where all the solids are burned through thermal treatment and turned into ash and flue gas. Incineration implementation has a large capital cost. However, it is known to be much better for the environment than putting solids in a landfill because it is turned into ash instead of just buried into the environment. The social impact is rated as a three because it is not horrible for society, but it also does not promote the idea of recycling waste and could even increase waste production since it is not building up in a landfill for people to see [58]. As mentioned previously, it would cost a lot for an incineration chamber to be built and therefore received a one in life cycle cost and is likely to be the reason it was not chosen for the final design.

6.5 Land Application

The final option that was discussed was the possibility of using land application for solid handling which consists of the spreading of biosolids on the soil surface or incorporating or injecting biosolids into the soil [59]. Some of the environmental impacts of using this process include to establish sustainable vegetation, reduce the bioavailability of toxic substances often found in soils, control soil erosion, and regenerate soil layers at sites that have damaged soils especially at reclaiming sites [60] [57]. Although these are all beneficial to the environment, there have been cases of biosolids creating contaminated runoff during large storm events. Biosolids have also been seen to be used as fertilizer and help promote vegetation growth or as mentioned before, regenerating soil layers. Due to these benefits, once the biosolids have degraded and neutralized through nutrients being absorbed, the soil can be sold as fertilizer or can be used for various projects. In this case, it is not only good for the environment as the waste is being reused but it is also beneficial to the social impact and cost as fertilizer is being sold. This is a major advantage for the treatment plant to make money for selling this fertilizer to the farmers. Some areas where biosolids are used in industry include forestry and agriculture. This could be highly beneficial to the farming that is done around the treatment plant and helps land application come off as a good option for the final design.

6.6 Final Decision

The option that was seen to be the final choice due to it getting the highest rating when compared to incineration and landfills was the land application. The land application was decided as the best handling technique for the environmental impact and life cycle cost. It also will be good for the social impact. Therefore, the overall rating for land application was shown to be the best as expressed in Table 6.1 and will be implemented into the final design after treatment has taken place.

Table 6. 1 Solid Handling Decision Matrix

Parameter	Weight (%)	Landfill	Incineration	Land Application
Environmental Impact	40	2	3	4
Social Impact	35	2	3	3
Life Cycle Cost	25	2	1	3
Total	100	2	2.5	3.4

7.0 Hydraulic Design

7.1 Existing Flow Data

The CCWRP was constructed originally for a flow capacity of 8 MGD. As the population increases, the wastewater produced, and flow will increase as well. The data for contaminants and loadings in the wastewater have been analyzed in the following sections and include concentrations of BOD, COD, and TSS [2].

7.2 Future Projected Flow Data

As explained in Section 3.0 Population Estimation, the population served is growing for this treatment plant and the projected population has been calculated. Using the current population and the given flow rate, the flow rate can be averaged to a per capita basis and then will be multiplied by the future populations to see how the flow rate will grow with population. This calculation is made with the assumption that people will continue to use the same amount of water. With this assumption, the population will use around 200 gallons per day per capita or 0.0002 MGD per capita. Using this average, the future flows can be estimated by multiplying by the population each year as shown in Table 7.1 below split according to the proposed phases. Therefore, if the plant is to operate until 2070, the plant will need to be built to treat roughly 14 MGD.

Table 7. 1 Project Flow Rate

	Year	Population	Flow Rate (MGD)	Flow Rate (GPCPD)
Phase 1	2021	40000	8.00	200
	2036	47396	10.00	200
Phase 2	2037	47939	10.00	200
	2053	57426	12.00	200
Phase 3	2054	58073	12.00	200
	2070	69377	14.00	200

7.3 Hydraulic Analysis

The main hydrologic analysis consisted of identifying the hydrology for the effluent pump. This process consisted of using calculations based on Darcy's Law. For more specifics on the calculations see Appendix C. The main calculations consisted of finding the total dynamic head loss which is the sum of the major head loss the minor head loss, and the change in elevation. The total dynamic head loss is the amount of head that the pump will have to overcome to properly pump the influent. A major factor in finding the major head loss is identifying the friction factor within the system. The friction factor was found using Swamee Jain's Equation 7.1. All four equations can be found below. These calculations were used to create a system curve. The system curve shows the required pump head that is needed to move the designated fluid through the piping system at different flows. Therefore, when the system curve for this design intersected with a manufacturer's pump curve, this means that the pump will be appropriate for the design and will overcome the head loss occurring.

Equation 7. 1 Swamee Jain Equation

$$f = \frac{0.25}{\left(\left(\log\left(\frac{K_s}{3.7D} + \frac{5.74}{R_e^{0.9}}\right)\right)^2\right)}$$

Variables:

f = Darcy Weisbach Friction Factor
D = Diameter (ft)
K_s = Pipe roughness
R_e = Reynold's Number

Equation 7. 2 Major Head Loss

$$h_{L_f} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

Variables:

h_{Lf} = Friction Loss (ft)

V = Velocity (ft/s)
g = Gravitational Constant (ft/s^2)

Equation 7. 3 Minor Head Loss

$$h_{L_m} = K\left(\frac{V^2}{2g}\right)$$

Variables:

h_{Lm} = Minor Headloss (ft)
K = Minor Loss Coefficient

Equation 7. 4 Total Dynamic Head Loss

$$TCH = h_{L_f} + \sum h_{L_m} + \Delta Elev.$$

Variables:

TDH = Total Dynamic Head (ft)
$\Delta Elev$ = Change in elevation (ft)

After completing the calculations, two options were discussed for the pump design; one was to design a pumping station with two large slurry pumps, and the other was to design the pump station to have four smaller slurry pumps. Multiple manufacturers were reviewed, but due to the large flow rate and total design head loss, the team used Gould Water Technologies. Due to having four slurry pumps being more cost efficient than having two large pumps, with the cost difference averaging to $22,618 US, the team decided to continue with the multiple pump design. Four pumps for this design were chosen with the concept of the fourth pump being only in use for emergency maintenance while the three other pumps will be running throughout the year. Each pump will have a knife gate valve to easily turn off or on each pump depending on the need for use throughout the three phases.

The type of pump that was chosen was the Gould abrasive slurry pump, model SRL-CM, size 10 x 8-21. An image of the selected pump can be seen below. The type of model is based on the material used to create the pump which is a soft natural rubber blend that is resistant and resilient to abrasive and corrosive sewage. Slurry pumps are a type of centrifugal pump that is made to handle tough and abrasive duties and is often used to move liquid and solid mixtures [61]. Below is a figure showing the Slurry pump.

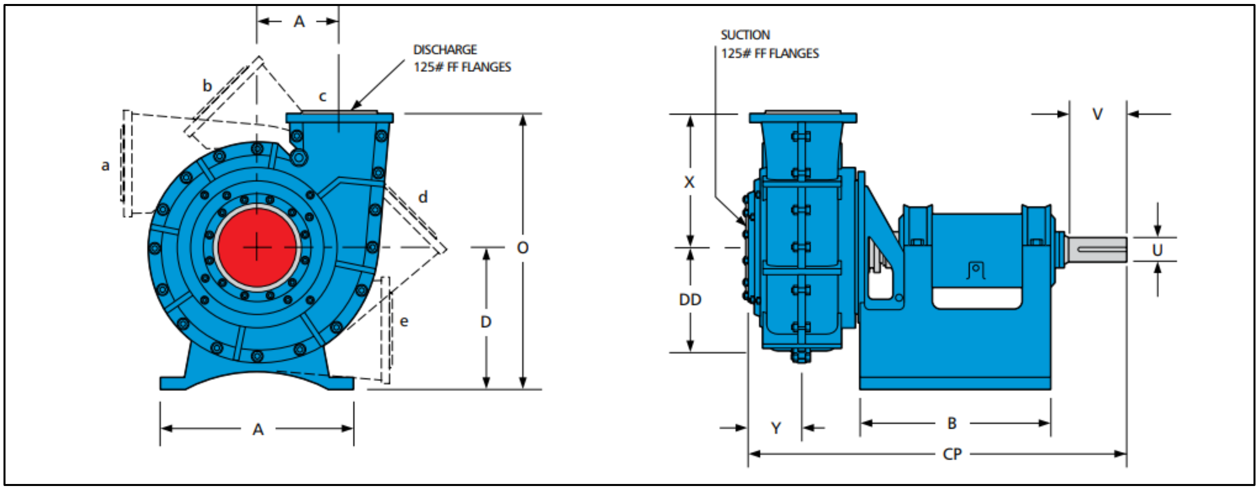

Figure 7. 1 Image of the Slurry Pump SRL-CM [66]

These types of pumps have been seen to be used for various industrial work such as mine drainage, dredging of settling lagoons, and pumping of drilling mud [61]. The Slurry pump SRL-CML model is a submersible pump which is due to the submersible model having multiple benefits compared to the non-submersible pumps. Submersible pumps do not require support structures, occupy less space, easy installation, low noise levels, or in some cases there is silent operations, motors are easily cooled by surrounding liquid, along with flexible installation with multiple installation modes that are all categorized as portable or semi-permanent [61]. Another aspect that was analyzed for the hydrologic pump design was the pump performance. It is important to identify that Slurry pumps differ from regular centrifugal pumps due to the number of solid particles in the slurry [61]. Since there are more solid particles within the slurry pump than a regular centrifugal pump transporting clean water, there will be an increase in power and a decrease in total dynamic head and efficiency. Upon completion of the pump calculations and deciding on this pump, a hydraulic grade line can be seen below in Figure 7.2 as this will be the elevation of each process based on the pump and its' starting elevation.

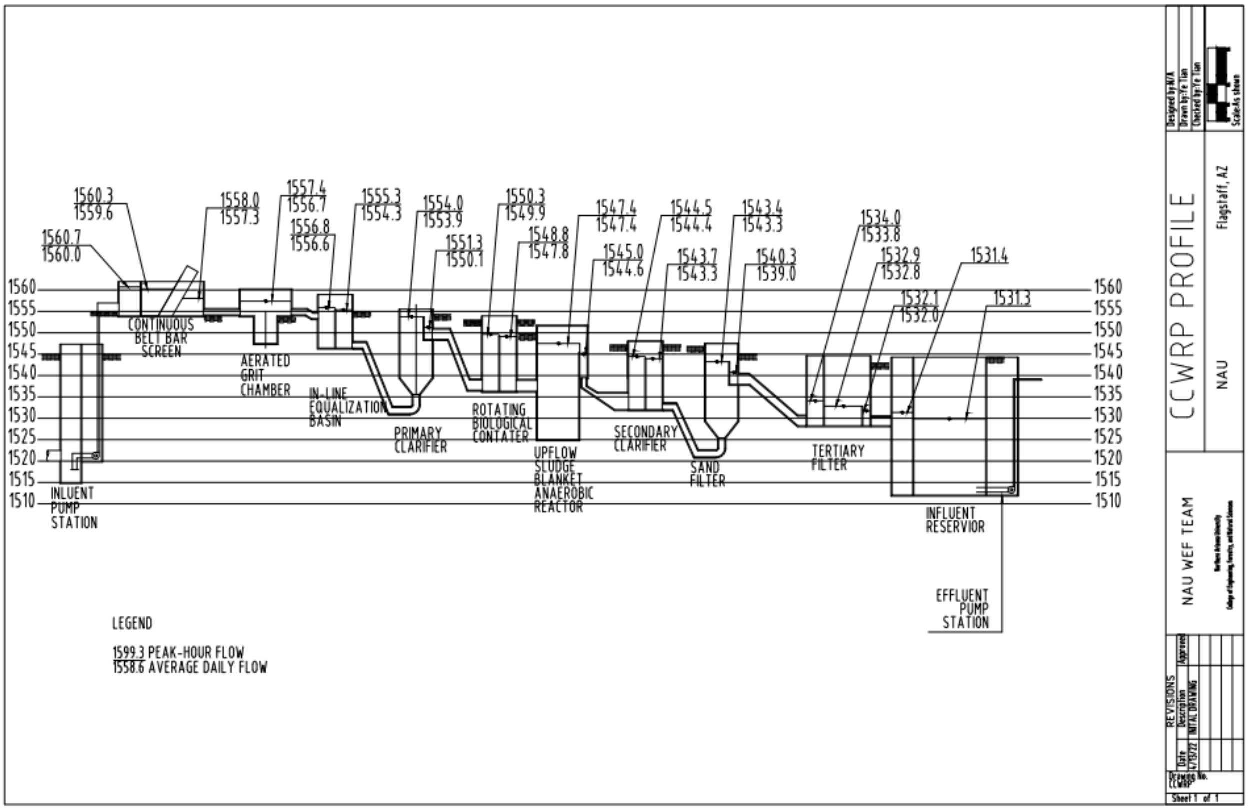

Figure 7. 2 Hydraulic Grade Line

8.0 Final Design Recommendations

Based on the decision matrices, the final design will include the treatments in the following order, belt bar screen, aerated grit chamber, in-line equalization basin, traction primary clarifier, rotating biological contactor, upflow anaerobic sludge blanket reactor, spiral scraper secondary clarifier, sand filter, and UV disinfection. Design calculations were conducted for each technology for phase 1, 2, and 3. Layout plans for these different phases can be found in Appendix E. An assumption was made that the influent values such as BOD and TSS would remain the same for each phase as the influent characteristics are not changing such as an increase in industrial or recreational influent. The main influent loading criteria can be found in Table 8.1 below. The team did not receive site information regarding the specific technologies therefore for the purpose of the project, the team assumed that any existing technology that will be reused in the design is the same size as determined by the calculations.

Table 8. 1 Influent Loading and Design Information

Phase	**Year**	**Population**	**Design Flow**	**COD**	**BOD**	**TSS**
Number	Range	Range	MGD	mg/L	mg/L	mg/L
1	2021-2036	40000-47396	10	474.97	287.73	264.10
2	2037-2053	47939-57426	12	474.97	287.73	264.10
3	2054-2070	58073-69377	14	474.97	287.73	264.10

Phase one of the design is for 10 MGD for 2021-2036. The design flow was rounded up from 9.47 MGD to 10 MGD to account for any error in the population change in addition to ensuring that all needs are met. Phase two of the design accounts for an additional 2 MGD for a total of 12 MGD for 2037-2053. Phase three of the design accounts for another additional 2 MGD for a total of 14 MGD.

The solids produced from the treatment process can be used in land application. Additionally, to aid in cost savings and lessening environmental impacts the biogas produced from the UASB process will be used to generate electricity for the plant. Any excess from this can also be sold back into the grid for profit.

The final effluent use recommendation is to continue to serve current reclaimed users in addition to expanding the use of indirect potable reuse through streambed recharge. It is recommended that in order to achieve the best recharge rates, a seepage study is conducted to determine additional sites to release the A+ reclaimed water. The expectation for the effluent is that it will meet or be below the required limits outlined in various regulations. The water will also be Class A+ reclaimed water meaning it has undergone extra processes of secondary treatment, filtration, nitrogen removal treatment, and disinfection. With these extra processes, the wastewater will be cleaned to Class A+ and be able to be redistributed into the community. The exact amount of each effluent contaminant that is expected is listed in Appendix C where the calculations of removal are listed in tables and these concentrations are under regulations due to treatment removal processes.

With these updates and phases, the CCWRP will become more efficient than before and will be able to handle 14 MGD by 2070 to accommodate an increasing projected population. The overall project cost will be approximately $407,472,342.

The technology and number of units for each phase can be found in Table 8.2 below. The additional units account for the increase in influent flowrate in addition to aiding in redundancy within the system.

Table 8. 2 : Phase 1-3 Treatments

Treatment Type	Phase	Number of Units	Phase	Number of Units Added	Number of Units Total	Phase	Number of Units Added	Number of Units Total
Belt Bar Screen	1	2	2	2	4	3	1	5
Aerated Grit Chamber		2		1	3		1	4
In-Line Equalization Basin		1		1	2		0	2
Traction Primary Clarifier		2		1	3		1	4
RBC		4		2	6		1	7
UASB Reactor		2		1	3		1	4
Spiral Scraper Secondary Clarifier		2		1	3		1	4
Sand Filter		4		2	6		2	8
UV		36 Banks		8 Banks	44 Banks		6 Banks	50 Banks

The Belt Bar Screen was designed utilizing the values and equations found in Appendix C-1 below. The main design values can be found in the table below. This table summarizes the main parameters needed to design the technology which includes the number of screens, numbers of bars, and the dimensions that are involved for the design of this technology. The complete design can be seen in Appendix C where all equations and calculations can be shown fully. The continuous belt bar screen that will be utilized in CCWRP will be the Noggerath® Continuous Belt Screen, Model BS-XL. With the implementation of this model, the bar screen will be a mechanical technology that will collect objects on a moving belt as the influent flows through it.

Table 8. 3 Belt Bar Screen Design Dimensions

Belt Bar Screen		
Parameter	**Units**	**Value**
Number of Units	(-)	2.00
Bar Spacing	(m)	0.04
Bar Width	(m)	0.01
Bar Thickness	(m)	0.03
Depth of Channel	(m)	0.02
Width of the channel	(m)	1.00
Number of bars, N	(-)	10.00

After the bar screen, two aerated grit chambers will be placed in the treatment train to remove any grit that is in the influent which will help the efficiency of the plant as there will be less erosion affecting the following treatments. There will be two chambers placed for redundancy in case one needs to go offline for maintenance. The main calculations needed to design the aerated grit chamber are shown below where the number of chambers, dimensions, and percent removal for COD and TSS are found. The complete calculations and equations used are found in Appendix C to show the complete design process. After the calculations are completed, the SPIRAC® Technology Grit Chamber will be implemented as the dimensions specified.

Table 8. 4 Aerated Grit Chamber Dimensions

Aerated Grit Chamber		
Parameter	**Units**	**Value**
Number of Chambers	(-)	2.00
Volume (V)	(m^3)	39.43
Depth (D)	(m)	2.00
Width (W)	(m)	3.00
Length (L)	(m)	6.57
Opening Under Baffle/Slot Height (d_b)	(m)	0.65
Grit		
Volume of Grit (V_{grit})	(m^3)	3.79
Depth of Grit Channel ($D_{grit\ channel}$)	(m)	0.63
Percent Removal		
TSS Removal	(%)	45.00
COD Removal	(%)	40.00

The In-Line Equalization basin for phase one was designed for an excess of 25% in order to account for unexpected changes in flow. Additionally, this will allow for only one more equalization basin needed as with the excess volume the two equalization basins will be able to handle the design flow of 14 MGD for phase three. The main design parameters for the basin can be found below. It is assumed that for each additional basin added per phase, the values and parameters will be the same to aid in ease of constructability. The complete calculations and equations can be found in Appendix C. The specific In-Line Equalization basin used will be the AIRE-O2 TRITON ®, Model TR Series 2.0. This model consists of an aerator and mixer with a swing arm. The swing arm aids in O&M as it is considered maintenance friendly [62]. A full manufacturer description of the basin can be found in Appendix C.

Table 8. 5 In-Line Equalization Basin Dimensions

In-Line Equalization Basin		
Parameter	**Units**	**Value**
Number of Basins	(-)	2.00
Storage Volume	(m^3)	2412.74
Height	(m)	23.50
Radius	(m)	8.00
Diameter	(m)	16.00

The primary clarifier utilized in the CCWRP will be a traction primary clarifier that will also have two tanks for redundancy for if one needs to go offline for certain reasons. The number of tanks will increase by one for each phase as the flowrate will increase and more clarifiers will be needed to keep the treatment plant efficient. The parameters shown below include the number of tanks, dimensions, launder information, weir information, and percent removals. The rest of the calculations and the equations used to find these parameters can be found in Appendix C. The model selected for the primary clarifier is the Peripheral Traction Clarifier with weirs, baffles, and mechanical mechanisms also known as the Model PTP12.

Table 8. 6 Primary Clarifier Dimensions

Traction Primary Clarifier		
Parameter	**Units**	**Value**
Number of Tanks, N	(-)	2.00
Width, W	(m)	9.00
Length, L	(m)	45.72
Side Water Depth, D	(m)	3.00
Depth of tank, D_t	(m)	22.86
Launders		
Number of Launders, N_L	(-)	1.00
Launder Length, L_L	(m)	22.86
Weir		
Weir Length, L_W	(m)	45.72
Percent Removal		
BOD Percent Removal	(%)	55.00
TSS Percent Removal	(%)	40.00

The RBC is implemented in the CCWRP as the biological treatment that takes place after primary clarifying. The RBC has important design parameters such as the number of trains, number of contactors per train, surface area and the percent removal for BOD and COD. The equations utilized to find these parameters can be found in Appendix C-5 along with the rest of the calculations completed for this technology. The Napier-Reid’s RBC with Bio-Rotor™ Technology will be installed into the treatment plant in phase 1 with 4 trains needed. Phase 2 will include an installment of two more trains for a total of six and phase 3 will have one more rotating biological contactor needed. By the end of all the phases, the plant will need to have seven Napier-Reid's RBC with Bio-Rotor™ to be able to biological treat the 14 MGD of flow coming in.

Table 8. 7 RBC Dimensions

Rotating Biological Contactor		
Parameter	**Units**	**Value**
Number of Trains	(-)	4
Number of Contactors/Train	(-)	6
Contactor Surface Area	(ft^2/contactor)	190000
BOD removal	(%)	88
COD Removal	(%)	86

The Upflow Anaerobic Sludge Blanket Reactor contains a gas liquid separator (GLS) which is one of the most important parts of the UASB design [63]. The GLS is above the sludge blanket and separates solid particles from the mixture which allows for the gas and liquid effluent to leave the reactor [64]. Phase one contains two reactors and one reactor is added in phase two and three to account for the increase in influent wastewater in addition to adding redundancy to the system. The dimensions of the reactor can be found in the table below. The full design parameters, calculations, and equations can be found in Appendix C. The specific technology is the ANUBIX™-B UASB System which is known for not needing additional sludge and gas storage, low O&M due to minimized moving parts, minimal sludge loss and more [65].

Table 8. 8 UASB Dimensions

Upflow Anaerobic Sludge Blanket Reactor		
Parameter	**Units**	**Value**
Number of Reactors	(-)	2.00
Reactor Volume (V)	(m3)	7097.65
Height (H)	(m)	10.80
Diameter (D)	(m)	28.93
Sludge Bed Height	(m)	2.00
Sludge Bed Volume	(m3)	2839.06
TSS Removal	(%)	75.00
COD Removal	(%)	80.00
BOD Removal	(%)	67.00
Gas Liquid Separator (GLS)		
GLS Volume	(m^3)	1774.41
GLS Upflow Velocity	(m/hr)	2.00
GLS Height	(m)	2.70
Diameter of Separator	(m)	18.29

The Spiral Scraper Secondary Clarifier is a cylindrical tank with a feedwell and sludge hopper. The table below expresses the general design dimensions, and a full design table can be found in Appendix C along with the calculations and specific manufacturer information. The COP™ Spiral Blade Clarifier by WesTech is designed for rapid solids removal. The flow enters at the top of the clarifier where mixing and flocculation then occur [66]. The clarifier creates a well-flocculated mixed liquor that is able to spread throughout the clarifier without disturbing the solids located on the bottom of the basin [66]. Phase one includes two clarifiers with an additional clarifier being added in the following phases to account for the increase in flow and to add redundancy within the system.

Table 8. 9 Spiral Scraper Dimensions

Spiral Scraper Secondary Clarifiers		
Parameter	**Units**	**Value**
Number of Tanks, N	(-)	2.00
Diameter of Tank (Dt)	(m)	21.95
Volume (V)	(m3)	1514.16
Depth of tank, dt	m	4.00
BOD Percent Removal	(%)	55.00
TSS Percent Removal	(%)	40.00
COD Removal	(%)	55.00
Feedwell		
Depth of feedwell	(m)	3
Volume	(m^3)	270.39
Area of Cylinder	(m^2)	25.13
Diameter of Feedwell	(m)	8.00
Sludge Hopper		
Angle of Sidewall	(degree)	50
Width of bottom	(m)	0.60
Diameter	(m)	10.00
Height	(m)	2.00
Volume	(m^3)	4.35

The Sand Filter is made up of rectangular beds. The dimensions for the sand filter can be found in the table below, for the full design parameters and equations, and the manufacturer information please see Appendix C. The sand filter is a Super Sand WesTech filter; the flow enters in at the bottom of the tank and the water floats up through the media bed, this differs from traditional sand filters where the flow enters through the top. Sand filter also includes a backwash system that is performed continuously when the filter is processing flow [67]. Phase one consists of four beds with an additional two beds being added in each phase following to account for the increase in influent and to aid in redundancy within the system.

Table 8. 10 Sand Filter Dimensions

Sand Filter		
Parameter	**Units**	**Value**
Number of Beds	(-)	4.00
Area of Bed (A)	(m^2/filter bed)	19.72
Width of one cell (W)	(m)	3.00
Length (L)	(m)	3.29
Gullet Width	(m)	0.60
Number of Troughs (N)	(-)	3.00
Trough Spacing	(m)	1.10
Depth of Trough (D_T)	(m)	0.54
Depth of Expanded Bed (D_e)	(m)	0.70
Depth of Unexpanded Bed (D)	(m)	0.50
Filter Backwash Volume (V)	(m^3)	182.37
Backwash Tank Volume	(m^2)	364.74
TSS Removal	(%)	86.00
COD Removal	(%)	86.00
BOD Removal	(%)	68.00

The UV disinfection system is the final treatment step. The basic design dimensions can be found in the table below with a more detailed table located in Appendix C in addition to the relevant equations and manufacturer fact sheet. The Trojan UV Sigma Bank will be used, it is known for low lamp count but high overall electrical efficiency. Additionally, to aid in O&M the system has automatic lamp sleeve cleaning which also aids in reducing membrane fouling. Medium pressure systems require approximately 460-560 kWhr/MG therefore 216 lamps and 6 banks are required for phase 1 of the plant [68].

Table 8. 11 UV Disinfection Dimensions

UV Disinfection		
Parameter	**Units**	**Value**
Bank Type	(-)	6 Rows
Number of Banks	(-)	44
Number of Lamps	(-)	264
Wattage Per Lamp	(Watts)	1000

9.0 Cost Analysis

9.1 Construction Cost

The construction cost is comprised of the cost for each technology process needed and all the cost that goes into getting the treatment plant up and running. The average construction values and the prices for each unit were determined from RS means [69]. Estimations for excavation and concrete were calculated based on the area and volume needs of the units. Length of pipe and electrical connections were estimated to be 30% and 35% of the total unit cost respectively [2]. The future worth of each unit was calculated with a recommended interest rate of 0.5% from the US Federal Reserve [70]. A summary of the capital costs of each process is displayed in Table 9.1 below.

Table 9. 1 Summary of Capital Cost

Unit	2021 Capital Cost	2037 Capital Cost	2054 Capital Cost
Influent Pump Station	$ 1,010,000	$ -	$ -
Screen System	$ 891,891	$ 975,981	$ 525,729
Grit Removal	$ 470,993	$ 255,059	$ 282,929
Equalization Basin	$ 309,375	$ 268,060	$ -
Primary Clarifiers	$ 1,244,100	$ 625,474	$ 680,820
Aeration Basins	$ 188,100,000	$ 98,288,707	$ 68,081,956
Secondary Clarifiers	$ 1,402,500	$ 536,120	$ 583,560
Sand Filter	$ 13,406,250	$ 7,186,245	$ 7,822,130
UV Disinfection	$ 2,003,100	$ 16,500	$ 369,600
Biogas	$ 10,125	$ 56,585	$ 61,592

Permitting cost was estimated based on the 2007-2008 values. The contingency cost was calculated as 3% of the capital cost. The summary of CCWRP construction cost can be seen in Table 9.2, the full unit cost line-item sheet can be seen in Appendix D.

Table 9. 2 Summary of CCWRP Construction Cost

Summary of CCWRP Estimated Construction Cost	
Capital Cost	$ 395,465,381
Permitting	$ 143,000
Contingency	$ 11,863,961
Total	$ 407,472,342

9.2 Operation and Maintenance Cost

The operation and maintenance cost that is accounted for this treatment plant includes the cost for training employees, updating processes with new versions, and maintaining the treatments by fixing technologies when they go offline. The operation and maintenance cost for each unit were estimated to be 5.5% of the initial capital cost with an estimated increase for each year after the 1st year of service due to the age of the equipment [71]. The interest rates are 8%, 8.5%, 9% for the three phases and these numbers are assumed constant during each phase. The estimated operations and maintenance cost for each unit can be seen in Table 9.3 below.

Table 9. 3 Estimated Operations and Maintenance Cost

CCWRP Yearly Operation & Maintenance Cost						
Unit	Yearly Initial Maintenance (2021-2036)		Yearly Phase2 Maintenance (2037-2053)		Yearly Phase3 Maintenance (2054-2070)	
Influent Pump Station	$	35,640	$	38,669	$	42,150
Screen System	$	85,810	$	93,103	$	101,483
Grit Removal	$	36,323	$	39,411	$	42,958
Equalization Basin	$	20,788	$	22,555	$	24,585
Primary Clarifiers	$	91,814	$	99,618	$	108,584
Aeration Basins	$	12,760,944	$	13,845,624	$	15,091,730
Secondary Clarifiers	$	90,798	$	98,516	$	107,383
Sand Filter	$	1,015,502	$	1,101,819	$	1,200,983
UV Disinfection	$	86,011	$	93,322	$	101,721
Biogas	$	5,645	$	6,125	$	6,676
Total $/yr	$	14,229,275	$	15,438,764	$	16,828,252

9.3 Expected Life Cycle Cost

In this project, the life-cycle cost is estimated as the total cost of the initial construction value and the present value of the operation and maintenance, minus the present residual value. The life span is 50 years. Equation 9.1 is used to calculate the life-cycle cost. The estimated life-cycle cost can be seen in Table 9.4.

Equation 9. 1 Equation for Life-Cycle Cost

$$\begin{aligned} Life\ Cycle\ Cost \\ &= Initial\ Cost + O\&M\ Cost\left(\frac{A}{G}, 8\%, 50\right) \\ &- Residual\ Value\left(\frac{P}{A}, 8\%, 50\right) - Saving\ Cost \end{aligned}$$

Table 9. 4 Estimated Life-Cycle Cost

Life-Cycle Cost		
Particulars	Cost	
Construction Cost	$	407,472,342
O&M Cost	$	729,711,379
Sampling&Laboratory	$	11,303,289
No. of Years		50
Interest Rate		8%
Residual Value	$	101,868,086
Life-Cycle Cost	$	9,425,626,729

9.4 Cost Saving

As a result of the implementation of the cogeneration engine on site to convert the biogas from the aeration process to electrical output, the project yearly electrical savings for Phase 2 and Phase 3 are $934,692 and $1,869,384 respectively. There will be no cogeneration engine installed for the first phase so the cost saving start from phase 2. From Phase 2, two cogeneration engines will be put into use to generate energy for the plant daily running, and two additional cogeneration engines will be used at the start of Phase 3. Table 9.5 lists the general parameters of the cogeneration engine.

Table 9. 5 General Parameters of the Cogeneration Engine

Criteria	**Phase 2**	**Phase 3**
Number of Cogeneration Engine	2	4
Efficiency	39.40%	39.40%
Electrical Output/Engine, kW	1067	1067
Hours of Operation, hr/day	12	12
kWh/day	25608	51216
kWh/yr	9346920	18693840
$/yr	$ 934,692	$ 1,869,384

10.0 Impacts Analysis

The processes by which water reclamation facilities produce effluent may have intentional or unintentional impacts on society, the environment, and the economy. These impacts may occur throughout the water treatment plant process and may be related to the actual characteristics and impacts of effluent usage, biological treatment, and related processes or clarification processes. A single technology or process may have multiple impacts that are also influenced by factors unrelated to the product or process. The tool chosen to analyze the impact analysis is Triple Bottom Line (TBL) which evaluates each impact based on the factors discussed below.

10.1 Economic Impacts

Innovations related to water treatment technology provide opportunities for new production processes. In addition to identifying these innovations as important parameters of impact, the changing demand for products will also have some impact. Growing population needs lead to increased demand for water usage, and possibly increasing plant construction and maintenance costs as well. However, this impact also depends on the local population and products that the CCWRP needs. The increased demand for water due to population growth will lead to increases in corresponding costs such as expanding factories, increasing staff, etc. At the same time, the CCWRP may also change production methods, productivity, and processing to achieve a better economic process.

The cost of electricity consumption, chemical consumption, sludge transportation, final disposal of dewatered sludge, and the benefits of biogas are considered when looking at the economic aspects. Economic data is divided into three categories: capital costs, operating costs, and economic benefits. Capital costs were estimated by summing up construction, mechanical instrumentation, and consulting costs obtained from the CCWRP. The major operating costs of electricity and chemical consumption, sludge treatment, and transportation costs are considered for this plant. The methane content in the biogas is 60%, and the heat from sludge incineration is recovered in the form of steam, which accounts for 65-75% of the total heat demand [72]. The power generation efficiency of biogas and steam is estimated at 33%. Additional biogas production in the integrated system reduces sludge disposal costs. Overall, the integrated sludge management alternative can reduce total sludge treatment costs by approximately 6.1%. As the CCWRP was developed to meet Class A+ standards, the extensive use of reclaimed water enables landscape irrigation and toilet flushing at discrete sites which reduces the amount of potable water distributed to those sites, the amount of fertilizer required, and the amount of wastewater generated, transported, and treated by wastewater treatment facilities. In other words, reuse of water saves water, energy, and money.
The entire cycle of wastewater management is a key component to water conservation from source to distribution, collection, and treatment to disposal and reuse, including water, nutrient, and energy recovery. A circular economy is one that creates products to last and be recycled which aims to close resource cycles and extend the lifespan of resources and materials through longer use, reuse, and remanufacturing [73]. Resource recovery and reuse can help close resource cycles and provide sustainable alternatives to extracting new resources. The CCWRP takes one step closer to having the option to be a circular economy with the implementation of this design.

10.2 Social Impacts

Most wastewater research focuses on technical aspects and improvements in water quality, as well as minimizing environmental and health impacts, without adequate attention to its underlying social and sustainability aspects. Where treatment cannot keep up with population growth and where environmental pollution threatens public health, the social impact of wastewater management becomes apparent.

Even with advanced technologies to treat wastewater, careful treatment, and control of health risks, the social perception remains an aspect of the success or failure of wastewater reuse programs, regardless of all scientific evidence. Depending on public perceptions, impressions, and attitudes, the development of wastewater programs can be supported or limited. Negative public perception can hinder well-planned projects from moving forward. On the other hand, positive public perception leads to greater acceptance and is a key factor in the successful implementation of water reclamation uses.

From the planning stage to full implementation, developing an effective public engagement strategy leads to greater acceptance and facilitates the process of implementing a wastewater reuse program. Effective public engagement begins with early participation from potential users and stakeholders which can involve education, public awareness programs, the formation of advisory committees, and holding public workshops to discuss the benefits and risks of reuse. Therefore, it is necessary to weigh the different goals of recycling, along with the acceptance and preferences of people or users. The selection of the streambed recharge for recycling water seemed most likely to be accepted by the community and will be implemented.

As climate change and prolonged drought continue to affect the Colorado River, the federal government first announced in August 2021 that one of the river's major reservoirs, Lake Mead, triggered a Tier 1 shortage. This would deprive low-priority users of some of their water use. Arizona will lose 18 percent of its river allocation in 2022, meaning that it will lose 512,000 acre-feet of its allocation. Due to the prominence of drought, this has raised awareness of the need to find new sources of water. The importance of the CCWRP is highlighted at this time, and while the public inevitably resists reclaimed water, the willingness to overcome this inherent aversion increases if people believe that the use of recycled water will help with the larger issues like climate change and drought adaptation. As the population of the surrounding communities served by the CCWRP grows and the threat of a drought increases, the use of recycled water will continue to rise.

10.3 Environmental Impacts

The main objective of conventional wastewater treatment plants is to clean wastewater and minimize water pollution. However, they also contribute to air pollution, such as greenhouse gas (GHG) emissions, which have been identified as a major negative impact on wastewater treatment plant operations. In addition, WWTP effluent is considered a major point source of micro-pollutants released into the water cycle. Compounds in water treatment plant effluent can be divided into two categories based on their impact on ecosystems: those that promote biological activity and those that damage or hinder their activity. One of the functions of the CCWRP is to reduce the concentration of pollutants that damage biological activity compounds to acceptable levels. Therefore, the role of WWTPs is no longer limited to protecting the water environment or assessing effluent quality but includes an emphasis on overall environmental impacts beyond the aquatic environment.

In addition to providing a reliable, locally controlled water supply for the reclaimed water produced, The CCWRP offers substantial environmental benefits. By providing an additional source of water through reclamation, the water cycle can help find ways to reduce water transfer in sensitive ecosystems. Other benefits include reducing wastewater discharge, reducing pollution, or possibly preventing it. After the water needs of surrounding communities are met, excess reclaimed water can also be used to create or improve wetlands and riparian habitats in the future.

At the same time, plants, wildlife, and fish depend on adequate water flow to their habitats to survive and reproduce. Inadequate flows due to drainage for agricultural, urban, and industrial uses can lead to deterioration of water quality and ecosystem health. Using reclaimed water to supply part of people's needs can help reduce reliance on water in the environment and increase flows to important ecosystems. Reclaimed water will reduce the discharge of pollutants into the ocean, rivers, and other bodies of water, along with reducing the pollutant load of water bodies in the environment. Additionally, recycled water may contain higher levels of nutrients such as nitrogen which can be used for agriculture and landscape irrigation to provide an additional source of nutrients and reduce the need to use synthetic fertilizers.

11.0 Summary of Engineering Work

11.1 Staffing and Budget

There was no specific budget for this project as the design was to be innovative and sustainable, which can involve utilizing more expensive and efficient technologies. However, there was an estimate for the hours of staffing which is compared to the actual hours of staffing that were used to complete this. In Table 11.1 below are the proposed staffing hours, which can be compared to Table 11.2 of the actual staffing hours that took place during the completion of the project.

Table 11. 1 Proposed Staffing Summary

Task	SENG (hr)	ENG (hr)	EIT (hr)	TECH (hr)	INT (hr)	Total (hr)
Task 1: Initial Project Preparation	1	7	9	10	12	39
Task 2: Site Investigation	0	8	9	9	8	34
Task 3: Evaluation of Site Investigation Data	2	6	12	8	8	36
Task 4: Population Estimation	2	9	13	4	11	39
Task 5: Analyze Applicable Regulations	0	12	18	0	12	42
Task 6: Treatment Design	19	103	80	47	78	327
Task 7: Lifecycle Cost Analysis	6	9	16	6	20	57
Task 8: Impacts Analysis	2	2	12	0	6	22
Task 9: Deliverables	10	36	52	30	60	188
Task 10: Project Management	24	32	32	28	32	148
Total Hours	66	224	253	142	247	932

Table 11. 2 Actual Staffing Summary

Task	SENG (hr)	ENG (hr)	EIT (hr)	TECH (hr)	INT (hr)	Total (hr)
Task 1: Initial Project Preparation	2	5	5	2	7	21
Task 2: Site Investigation	1	6	7	5	15	34
Task 3: Evaluation of Site Investigation Data	6	10	6	9	4	35
Task 4: Population Estimation	0	3	2	1	7	13
Task 5: Analyze Applicable Regulations	0	3	4	0	3	10
Task 6: Treatment Design	27	64	52	32	36	211
Task 7: Lifecycle Cost Anaylsis	10	3	7	3	8	31
Task 8: Impacts Analysis	3	2	6	3	6	20
Task 9: Delieverables	51	85	95	37	83	351
Task 10: Project Management	31	49.5	55.5	14	39.5	189.5
Total Hours	131	230.5	239.5	106	208.5	915.5

The main difference between the total hours was due to the reduction of Task 2 as unfortunately the client was unable to allow the time for the site investigation to occur, so these hours are based on time spent researching. Some other major differences would include the change in total hours for the different positions listed. For example, the proposed staffing summary predicted that the technician would need to be paid for a total of 142 hours when in reality they only need to be paid for 106 hours because there was no site visit, and the evaluation of this data was less intensive than anticipated. Therefore, the technician's main work consisted of drafting the AutoCAD work in the computer lab, working on the website, and completing certain calculations needed. The breakdown of each subtask with its allocated hours can be seen in Appendix B which gives a more detailed look at Table 12.1 for the proposed cost.

11.2 Schedule and Time Management

The Gantt chart shown in Appendix B was initially created during the proposal stage before the team found out there would not be a competition or site visit and that the data would not be received until late March. Therefore, there are some big changes to the Gantt chart since parts of the schedule could not be completed and the whole project was momentarily postponed. Task 2 Site Investigation was never completed but instead the team researched previous data on the plant. In addition to this, Task 3 Evaluation of Site Investigation Data was pushed back and not done by February 2nd like the schedule stated because the site data was not received until March 18th. The team then had to work additional time on the project to make up for the lack of data and time for the design. The final design is still to be completed on time by April 20th. The data coming later than expected just pushed back some milestones such as completing Task 6 treatment design as the data is needed to complete this. Overall, the project will be completed on time, but certain milestones and tasks were pushed back due to the circumstances

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12.0 Summary of Engineering Cost

The proposed engineering cost is shown below in Table 12.1, which was established before the project took place. In the actual engineering cost, the cost of this project decreased significantly with the cancellation of all travel expenses. Without the site visit or the competition occurring, there was a decrease of just over $1,000 from just these two factors.

Table 12. 1 Proposed Engineering Cost

Personnel	Classification	Hours	Rate, $/hr	Cost, $
	SENG	66	180	$11,880
	ENG	224	100	$22,400
	EIT	253	80	$20,240
	TECH	142	55	$7,810
	INT	247	25	$6,175
Personnel Cost				$68,505
Travel			**Cost Per, $**	**Cost, $**
Site Visit Rental Van	1 Van 2-Day Trip		44/day	$88
Competition Rental Van	1 Van 2-Day Trip		44/day	$88
Site Visit Mileage	550 mi Roundtrip		0.23/mi	$127
Competition Mileage	300 mi Roundtrip		0.23/mi	$69
Site Visit Hotel	3 Rooms 1 Night		119/night	$357
Competition Hotel	3 Rooms 1 Night		94/night	$282
Site Visit Per Diem	5 People 2-Day		33.75/day	$338
Competition Per Diem	5 People 2-Day		33.75/day	$338
Total Travel Cost				$1,011
Supplies			**Cost Per, $**	**Cost, $**
	Computer Lab, 10 days		100/day	$1,000
Total Project Cost				$70,516

Table 12. 2 Actual Engineering Cost

Personnel	Classification	Hours	Rate, $/hr	Cost, $
	SENG	131	180	$23,580
	ENG	230.5	100	$23,050
	EIT	239.5	80	$19,160
	TECH	106	55	$5,830
	INT	208.5	25	$5,213
Personnel Cost				$76,833
Travel			**Cost Per, $**	**Cost, $**
	N/A			$0
Total Travel Cost				$0
Supplies			**Cost Per, $**	**Cost, $**
	Computer Lab, 5 days		100/day	$500
Total Project Cost				$77,333

Some of the other changes in cost came with the fluctuation of hours each position worked and the estimated time needed in the lab compared to the actual time it took to complete the AutoCAD layout. In reality, the staffing cost increased due to certain tasks needing higher positions of the Senior Engineer and Engineer however the plans conducted in the lab only took 5 days instead of 10 days. Therefore, with the total hours put into this project, the total project cost is $77,333 which is a little more than proposed because there was more technical work done by higher positions than anticipated.

13.0 Conclusion

In the end, the final design that was found to be the best for the CCWRP includes the treatments in the following order, belt bar screen, aerated grit chamber, in-line equalization basin, traction primary clarifier, rotating biological contactor, upflow anaerobic sludge blanket reactor, spiral scraper secondary clarifier, sand filter, and UV disinfection. The design will be split into three phases throughout the expected life until 2070 so the plant does not initially need to be constructed to treat the total 14 MGD that will be coming in by the end of the plant's life. The total capital cost to complete this design will cost $9,425,626,729 once the whole design is implemented.

The effluent produced from the CCWRP will be given to the suppliers who were already buying it for the agricultural and recreational uses as before. In addition to providing it to former customers, the plant will also begin streambed recharge which will introduce another type of indirect potable reuse. A seepage study should be completed before beginning this effluent use to find out more sites that could release A+ reclaimed water.

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Appendices

Appendix A: Population

Appendix A: Population

Table A. 1 Projected Population Table

	Year	Current Population (people)	Population Growth (%)	Time Difference (years)	Population (people)
Phase 1	2021	40000			40000
	2022	40000	1.12	1	40452
	2023	40452	1.13	1	40910
	2024	40910	1.13	1	41373
	2025	41373	1.13	1	41842
	2026	41842	1.13	1	42317
	2027	42317	1.13	1	42797
	2028	42797	1.13	1	43284
	2029	43284	1.13	1	43776
	2030	43776	1.13	1	44275
	2031	44275	1.13	1	44779
	2032	44779	1.13	1	45290
	2033	45290	1.14	1	45807
	2034	45807	1.14	1	46330
	2035	46330	1.14	1	46860
	2036	46860	1.14	1	47396
Phase 2	2037	47396	1.14	1	47939
	2038	47939	1.14	1	48486
	2039	48486	1.14	1	49040
	2040	49040	1.13	1	49599
	2041	49599	1.13	1	50164
	2042	50164	1.13	1	50735
	2043	50735	1.13	1	51313
	2044	51313	1.13	1	51896
	2045	51896	1.13	1	52485
	2046	52485	1.13	1	53081
	2047	53081	1.13	1	53682
	2048	53682	1.13	1	54290
	2049	54290	1.13	1	54904
	2050	54904	1.12	1	55525
	2051	55525	1.12	1	56152
	2052	56152	1.12	1	56786
	2053	56786	1.12	1	57426
Phase 3	2054	57426	1.12	1	58073
	2055	58073	1.12	1	58727
	2056	58727	1.12	1	59387
	2057	59387	1.12	1	60054
	2058	60054	1.12	1	60728
	2059	60728	1.12	1	61409
	2060	61409	1.11	1	62097
	2061	62097	1.11	1	62792
	2062	62792	1.11	1	63494
	2063	63494	1.11	1	64204
	2064	64204	1.11	1	64920
	2065	64920	1.11	1	65645
	2066	65645	1.11	1	66376
	2067	66376	1.11	1	67115
	2068	67115	1.11	1	67861
	2069	67861	1.11	1	68616
	2070	68616	1.10	1	69377

Appendix B: Staffing and Scheduling

Appendix B: Proposed Staffing Tasks

Table A. 2 Proposed Staffing Table

Task	SENG (hr)	ENG (hr)	EIT (hr)	TECH (hr)	INT (hr)
Task 1: Initial Project Preparation	1	7	9	10	12
Task 1.1 Application for WEF	0	1	2	2	2
Task 1.2: Review WEF Rules and Criteria	1	2	3	3	3
Task 1.3: Additional Treatment Research	0	4	4	5	7
Task 2: Site Investigation	0	8	9	9	8
Task 2.1: Field Visit	0	7	7	7	7
Task 2.2: Collect Current Data from Operators	0	1	2	2	1
Task 3: Evaluation of Site Investigation Data	2	6	12	8	8
Task 3.1: Analyze Data of Current Plant	2	3	6	4	4
Task 3.2: Review Existing Site Design and Technology	0	3	6	4	4
Task 4: Population Estimation	2	9	13	4	11
Task 4.1: Current Population of City	0	3	5	2	5
Task 4.2: Future Population Calculation	2	6	8	2	6
Task 5: Analyze Applicable Regulations	0	12	18	0	12
Task 5.1: Federal Regulations	0	4	6	0	4
Task 5.2: State Regulations	0	4	6	0	4
Task 5.3: County Regulation	0	4	6	0	4
Task 6: Treatment Design	19	103	80	47	78
Task 6.1 Determine Criteria	1	6	4	0	3
Task 6.2 Determine Water Demand	2	3	4	3	7
Task 6.3 Initial Treatment	2	16	12	6	9
Task 6.3.1 Preliminary Design of Alternatives	1	13	7	4	6
Task 6.3.2 Decision Matrix and Choose Alternative(s)	1	3	5	2	3
Task 6.4 Essential Treatment	2	17	14	8	13
Task 6.4.1 Preliminary Design of Alternatives	1	14	8	5	10
Task 6.4.2 Decision Matrix and Choose Alternative(s)	1	3	6	3	3
Task 6.5 Advanced Treatment	2	15	12	6	13
Task 6.5.1 Preliminary Design of Alternatives	1	12	8	4	9
Task 6.5.2 Decision Matrix and Choose Alternative(s)	1	3	4	2	4
Task 6.6 Disinfection	2	11	10	5	10
Task 6.6.1 Preliminary Design of Alternatives	1	8	6	3	6
Task 6.6.2 Decision Matrix and Choose Alternative(s)	1	3	4	2	4
Task 6.7 Solids Handling	2	10	7	4	9
Task 6.7.1 Preliminary Design of Alternatives	1	8	5	3	6
Task 6.7.2 Decision Matrix and Choose Alternative(s)	1	2	2	1	3
Task 6.8 Final Design Matrix	3	9	7	3	6
Task 6.9 Final Decision and Design	3	16	10	12	8
Task 7: Lifecycle Cost Analysis	6	9	16	6	20
Task 7.1 Construction Cost	2	3	5	3	8
Task 7.2 Operation and Maintenance Cost	2	3	5	3	8
Task 7.3 Expected Lifecycle Cost	2	3	6	0	4
Task 8: Impacts of Analysis	2	2	12	0	6
Task 9: Deliverables	10	36	52	30	60
Task 9.1 30% Submission	2	8	12	9	12
Task 9.2 60% Submission	2	8	12	5	12
Task 9.3 90% Submission	2	8	12	8	12
Task 9.4 100% Submission	2	8	12	4	12
Task 9.5 Competition Deliverables	2	4	4	4	12
Task 10: Project Management	24	32	32	28	32
Task 10.1: Meetings	18	18	18	18	18
Task 10.2: Schedule	4	8	8	8	8
Task 10.3: Resources	2	6	6	2	6
Subtotal	66	224	253	142	247
Total	932				

Appendix B: 2021 Gantt Chart

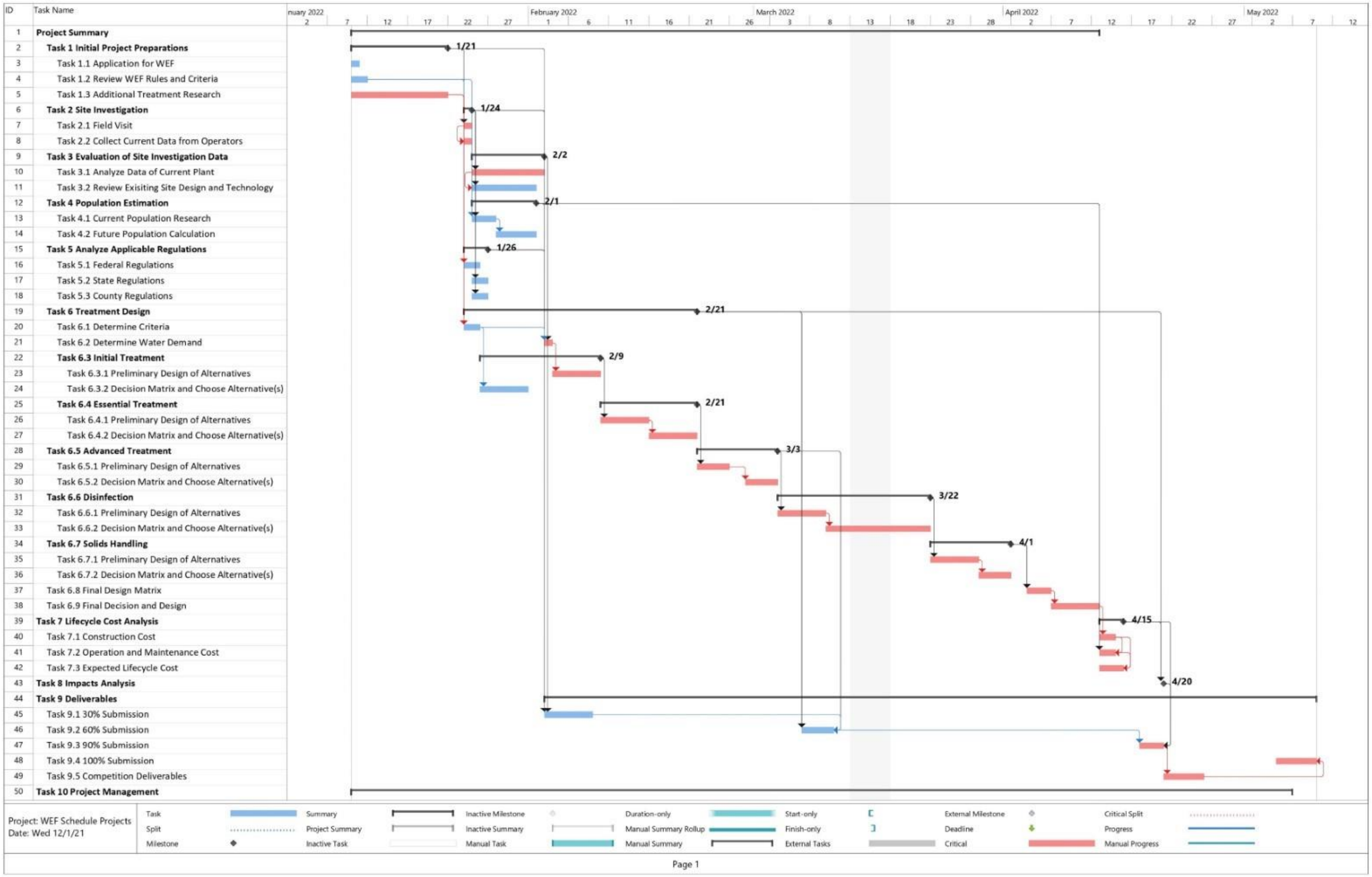


Figure B. 1 2021 Gantt Chart

Appendix B: 2022 Gantt Chart

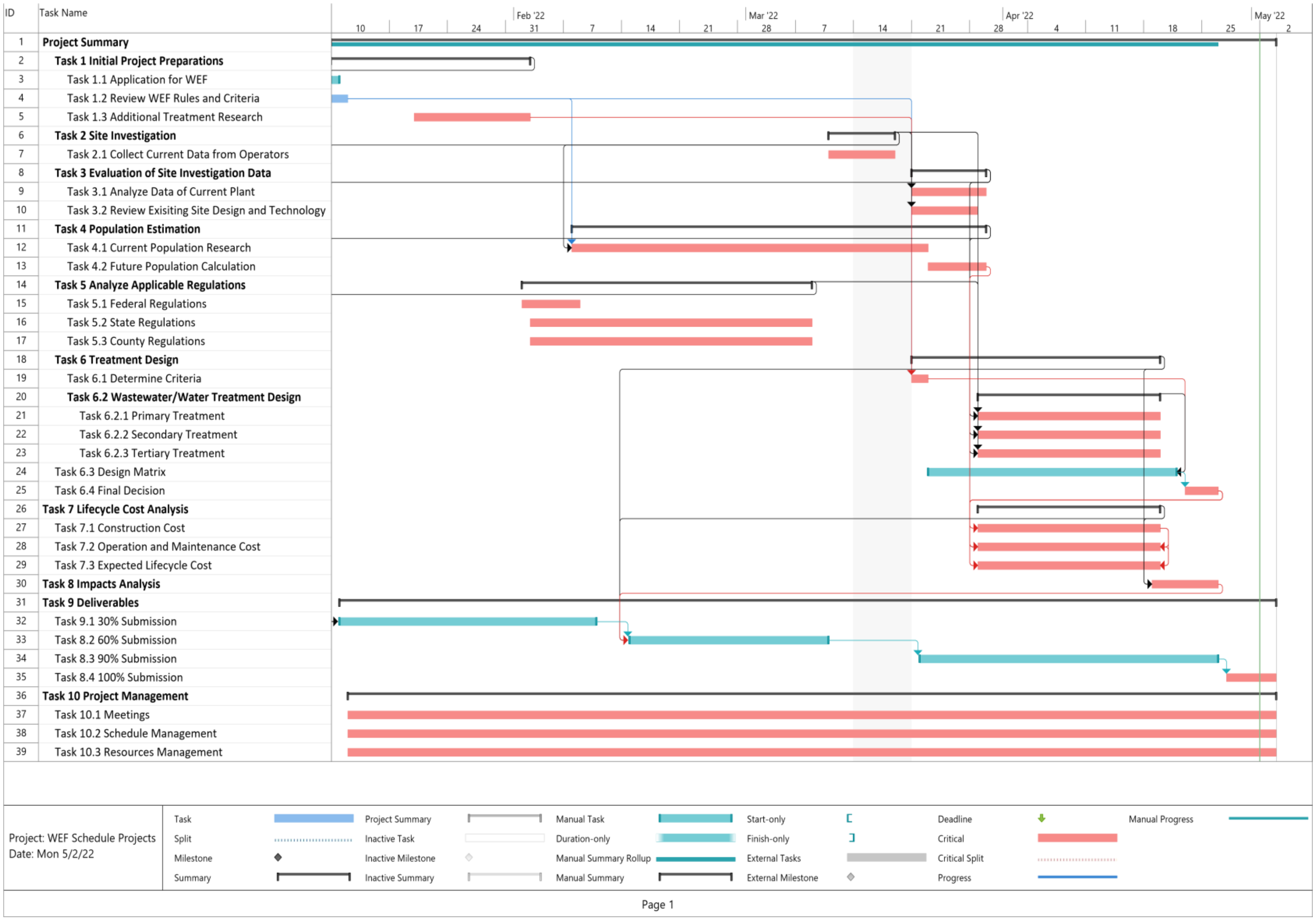
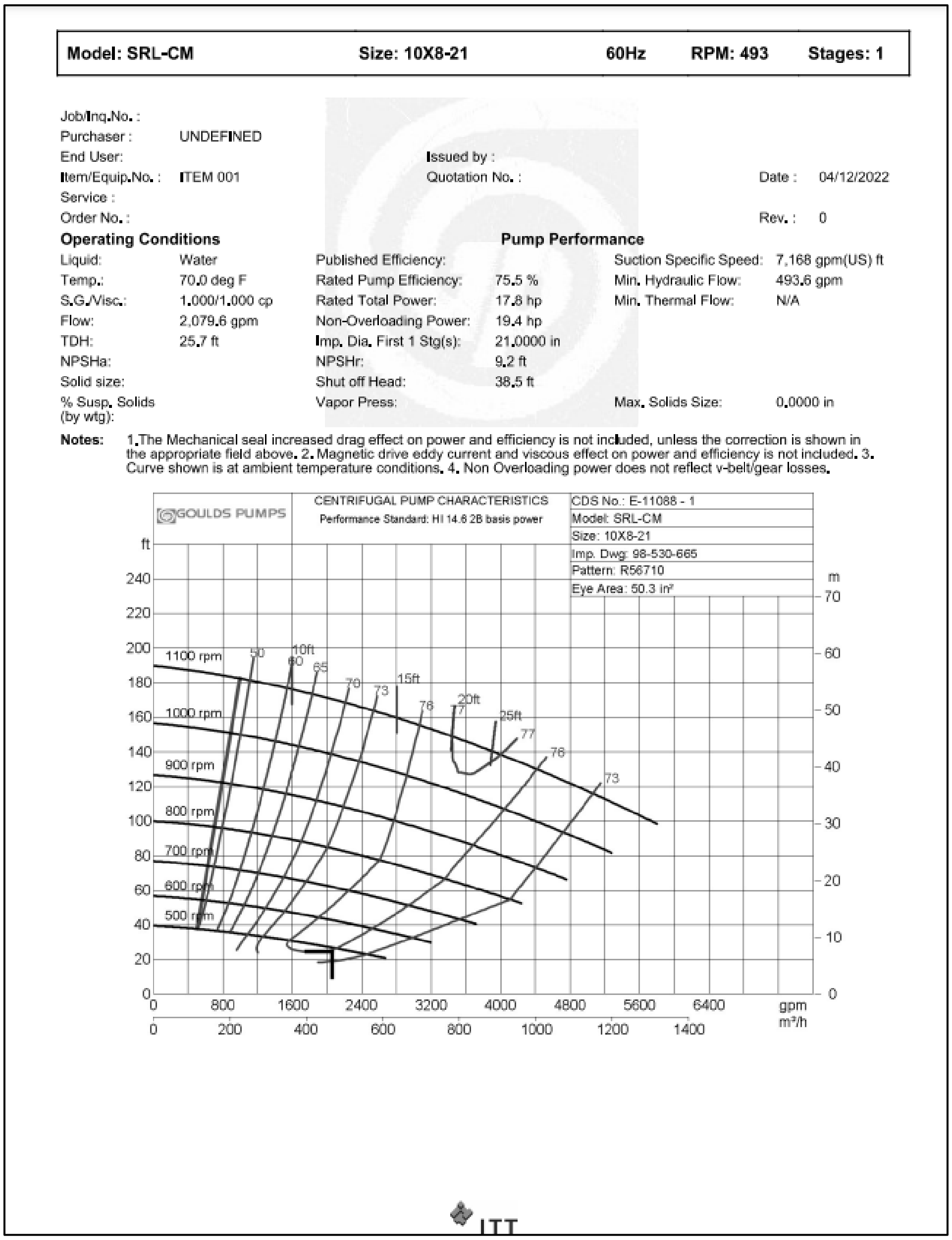


Figure B. 2 2022 Gantt Chart

Appendix C: Design Information

Appendix C: Pump Selection

Gould water technology's pump selection services created the following pump performance report.



Model: SRL-CM	Size: 10X8-21	60Hz	RPM: 493	Stages: 1

Job/Inq.No. :
Purchaser : UNDEFINED
End User:
Issued by :
Item/Equip.No. : ITEM 001
Quotation No. :
Date : 04/12/2022
Service :
Order No. :
Rev. : 0

Operating Conditions

Liquid:	Water
Temp.:	70.0 deg F
S.G./Visc.:	1.000/1.000 cp
Flow:	2,079.6 gpm
TDH:	25.7 ft
NPSHa:	
Solid size:	
% Susp. Solids (by wtg):	

Pump Performance

Published Efficiency:		Suction Specific Speed:	7,168 gpm(US) ft
Rated Pump Efficiency:	75.5 %	Min. Hydraulic Flow:	493.6 gpm
Rated Total Power:	17.8 hp	Min. Thermal Flow:	N/A
Non-Overloading Power:	19.4 hp		
Imp. Dia. First 1 Stg(s):	21.0000 in		
NPSHr:	9.2 ft		
Shut off Head:	38.5 ft		
Vapor Press:		Max. Solids Size:	0.0000 in

Notes: 1.The Mechanical seal increased drag effect on power and efficiency is not included, unless the correction is shown in the appropriate field above. 2. Magnetic drive eddy current and viscous effect on power and efficiency is not included. 3. Curve shown is at ambient temperature conditions. 4. Non Overloading power does not reflect v-belt/gear losses.

Figure C. 1 Pump Performance Data

In order to start the pump selection process, one must calculate the major and minor headloss along with finding the change in elevation which are equation 2 and 3 respectively. Before calculating the major head loss, the friction factor must be found using equation 1. After solving for the total major and minor head loss, they were summed together along with the change in elevation from the pump's influent to the entrance into the headworks, the total dynamic headloss can be calculated using equation 4. Calculations can be seen in table 1. With this total dynamic head loss being calculated a system curve can be established and compared with different pumps to find which will be able to work of the specific elevation and pressure needs. Figure 2 show the system curve plotted with the chosen pump curve.

Table C. 1 Calculation for System Curve

V	e/d	Nr	f	hf	hm		THD (ft)	q (cfs)	Q (gpm)
0	0.001286	0	0	0	1.112149		39.55912	0	0
1	0.001286	108024.7	0.023144	0.246427	1.112149		39.35858	1.069014	479.9874
2	0.001286	216049.4	0.022167	0.944104	1.112149		40.05625	2.138028	959.9747
3	0.001286	324074.1	0.021797	2.088752	1.112149		41.2009	3.207043	1439.962
4	0.001286	432098.8	0.021599	3.679629	1.112149		42.79178	4.276057	1919.949
5	0.001286	540123.5	0.021475	5.716405	1.112149		44.82855	5.345071	2399.937
6	0.001286	648148.1	0.021389	8.198891	1.112149		47.31104	6.414085	2879.924
7	0.001286	756172.8	0.021327	11.12696	1.112149		50.23911	7.483099	3359.912
8	0.001286	864197.5	0.021279	14.50053	1.112149		53.61268	8.552113	3839.899
9	0.001286	972222.2	0.021241	18.31953	1.112149		57.43168	9.621128	4319.886
10	0.001286	1080247	0.02121	22.58392	1.112149		61.69606	10.69014	4799.874
11	0.001286	1188272	0.021185	27.29364	1.112149		66.40579	11.75916	5279.861
12	0.001286	1296296	0.021163	32.44867	1.112149		71.56082	12.82817	5759.848
13	0.001286	1404321	0.021145	38.04898	1.112149		77.16113	13.89718	6239.836
14	0.001286	1512346	0.021129	44.09455	1.112149		83.2067	14.9662	6719.823
15	0.001286	1620370	0.021115	50.58536	1.112149		89.6975	16.03521	7199.81
16	0.001286	1728395	0.021102	57.52138	1.112149		96.63353	17.10423	7679.798
17	0.001286	1836420	0.021091	64.9026	1.112149		104.0148	18.17324	8159.785
18	0.001286	1944444	0.021082	72.72902	1.112149		111.8412	19.24226	8639.772
19	0.001286	2052469	0.021073	81.00061	1.112149		120.1128	20.31127	9119.76
20	0.001286	2160494	0.021065	89.71737	1.112149		128.8295	21.38028	9599.747

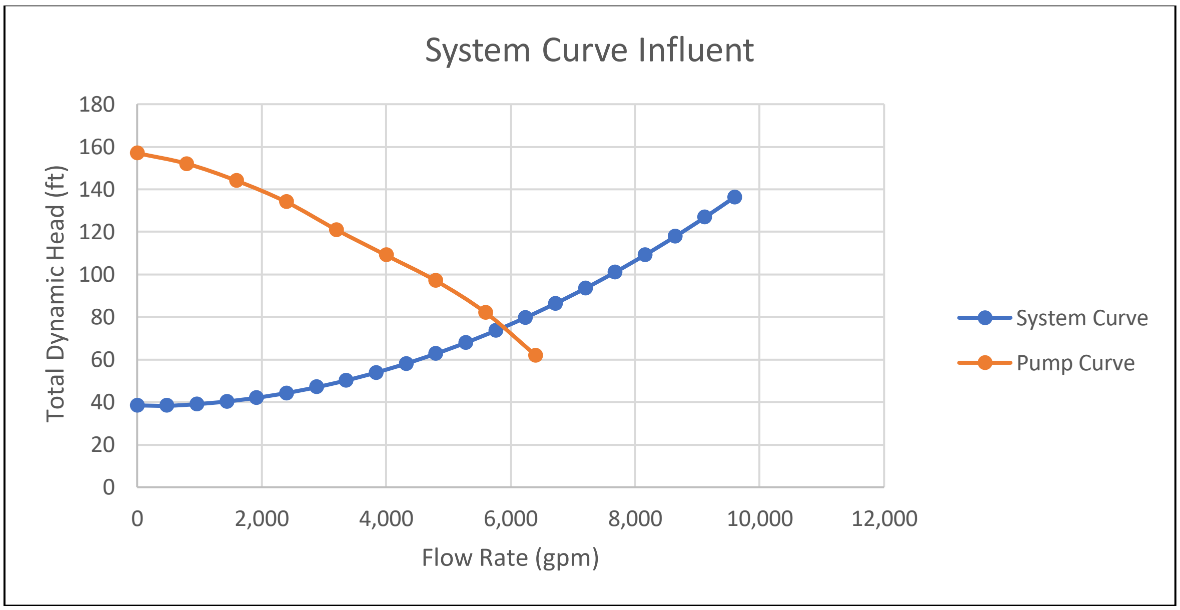


Figure C. 2 System Curve vs. Pump Curve

Appendix C: Belt Bar Screen

The Belt Bar Screen table shown below gives all the calculations that were found in order to fully design this technology. This builds off what is in the report because it includes all dimensions, areas, velocities, and the inclination angle which the bar needs to be installed at for the most efficient process possible. These calculations were performed in excel and certain parameters were found as a guidance for this specific technology. The only specific calculation for bar screens that was utilized was to calculate the number of bars which is shown below the table.

Table C. 2 Belt Bar Screen Dimensions

Belt Bar Screen		
Parameter	**Units**	**Value**
Channel Cross Sectional Area, Ac	(m^2)	0.24
Bar Spacing	(m)	0.04
Bar Width	(m)	0.01
Bar Thickness	(m)	0.03
Approach Velocity (V_A)	(m/s)	0.90
Depth of Channel	(m)	0.02
D:W Ratio	(-)	1.50
Head Loss (H_L)	(m)	0.43
Inclination Angle	(degrees)	70.00
Bar Screen Cross Sectional Area, As	(m^2)	0.31
Net Area available for flow, Anet	(m^2)	0.19
Width of the channel	m	1.00
Calculated Number of Bars, n	(-)	19.20
Actual Number of Bars per Screen (for constructability)	(-)	10.00
Velocity through openings, Vb	m/s	0.70
Number of Units	(-)	2.00

Equation C. 1 Number of Bars on Bar Screen [74]

$$N_{bars} = \frac{W_C - bar\ spacing}{W_B + Bar\ Space}$$

N_{bars} = Number of Bars
W_C = Width of the channel (m)
Bar Spacing = Bar spacing (m)
W_B = Width of bar (m)

Noggerath® Continuous Belt Screen BS-XL	
Type:	Nogco Guard XL 1000-2800-6
Max. Flow rate:	280 l/s
Screen mesh width:	6 mm
Channel depth H:	1,610 mm
Channel width W:	1,000 mm
Discharge height to channel bottom H1:	2,800 mm
Discharge height to channel top H2:	1,190 m

Figure C. 3 Belt Bar Screen Information [75]

Appendix C: Aerated Grit Chamber

The complete calculations for the Aerated Grit Chamber are shown below for Phase 1 as an example of the parameters that need to be designed for when installing each grit chamber. The additional parameters shown here that are not in the main report include preliminary calculations like flow rates, velocities, detention time and all parameters needed to calculate the settling velocity for the particles in the grit chamber. An important equation dealing with the Aerated Grit Chamber then would be the Stokes' settling velocity which is shown below the table. The SPIRAC® Technology Grit Chamber information can be found below.

Table C. 3 Aerated Grit Chamber Design Dimensions

Aerated Grit Chamber		
Parameter	**Units**	**Value**
Number of Chambers	(-)	2.00
Detention Time	(s)	180.00
Volume (V)	(m^3)	39.43
Depth (D)	(m)	2.00
Width (W)	(m)	3.00
Length (L)	(m)	6.57
W:D	(-)	1.50
L:W	(-)	2.19
Air Rate (A_F)	(m3/s*m)	0.01
Dimensional Coefficient (K)	(m*s)	0.70
Peak Flow (Q_p)	(m^3/d)	18927.06
Opening Under Baffle/Slot Height (d_b)	(m)	0.65
Submergence (S)	(m)	1.35
Velocity Across Bottom of Chamber (v_b)	(m/s)	0.19
Volume of Grit (V_{grit})	(m3)	3.79
Depth of Grit Channel ($D_{grit\ channel}$)	(m)	0.63
Particle Diameter, d	(m)	38.00
Density of Particles, ps	(kg/m3)	1030.00
Density of Wastewater, pw	(kg/m3)	1000.00
Drag Coefficient, Cd	(-)	0.11
Settling Velocity, Vs	(m/h)	11.76
Reynold's Number, Re	(-)	222.51
Kinematic Viscosity	(m^2/h)	0.01
TSS Percent Removal	(%)	45.00
TSS Out	(mg/L)	145.26
COD Percent Removal	(%)	40.00
COD Out	(mg/L)	172.64

Equation C. 2 Settling Velocity of Particles [76]

$$V_S = \sqrt{\frac{4g(\rho_s - \rho)d}{3C_D\rho}}$$

V_s = Settling Velocity of Particles (m/h)
g = Gravity (m/s^2)
ρ_s = Density of particles (kg/m^3)
ρ = Density of Wastewater (kg/m^3)
d = Particle Diameter (m)
C_D = Drag Coefficient (dimensionless)

Grit chambers can be up to 50m (160ft) in length to suit very high capacity grit settling tanks.

The Cast-in-place SS troughs are simple to install and have got a long life expectancy. The low RPM (4-6) provides low turbulence and a high torque. Grit chambers discharge into sump chambers where the rest of the grit will be removed by a grit pump. A standard bell housing provides a shaft seal up to 8m of water head.

Figure C. 4 Aerated Grit Chamber Information [77]

Appendix C: In-Line Equalization Basin

The In-Line Equalization Basin table shown below is for phase one as an example of the calculations performed. Phase 1 is designed with a 25% excess storage capacity to account for changes in flow. The calculations were performed in excel where the diurnal flow data was used over a 14-day period. The volume in and out were calculated in addition to the change in volume and overall storage. The Aire-O2 Triton ® is the model from Aeration Industries International as shown below.

Table C. 4 In-Line Equalization Basin Design

In Line Equalization Basin		
Parameter	**Units**	**Value**
Shape	(-)	Cylindrical Basin
Number of Basins	(-)	2.00
Volume per tank	(m^3)	1173.73
Storage Volume (with 25% extra capacity)	(m^3)	2347.46

Storage Volume to Design for (rounded up for construction feasibility based on height and diameter)	(m^3)	2412.74
Height	(m)	12.00
Radius	(m)	8.00
Diameter	(m)	10.00

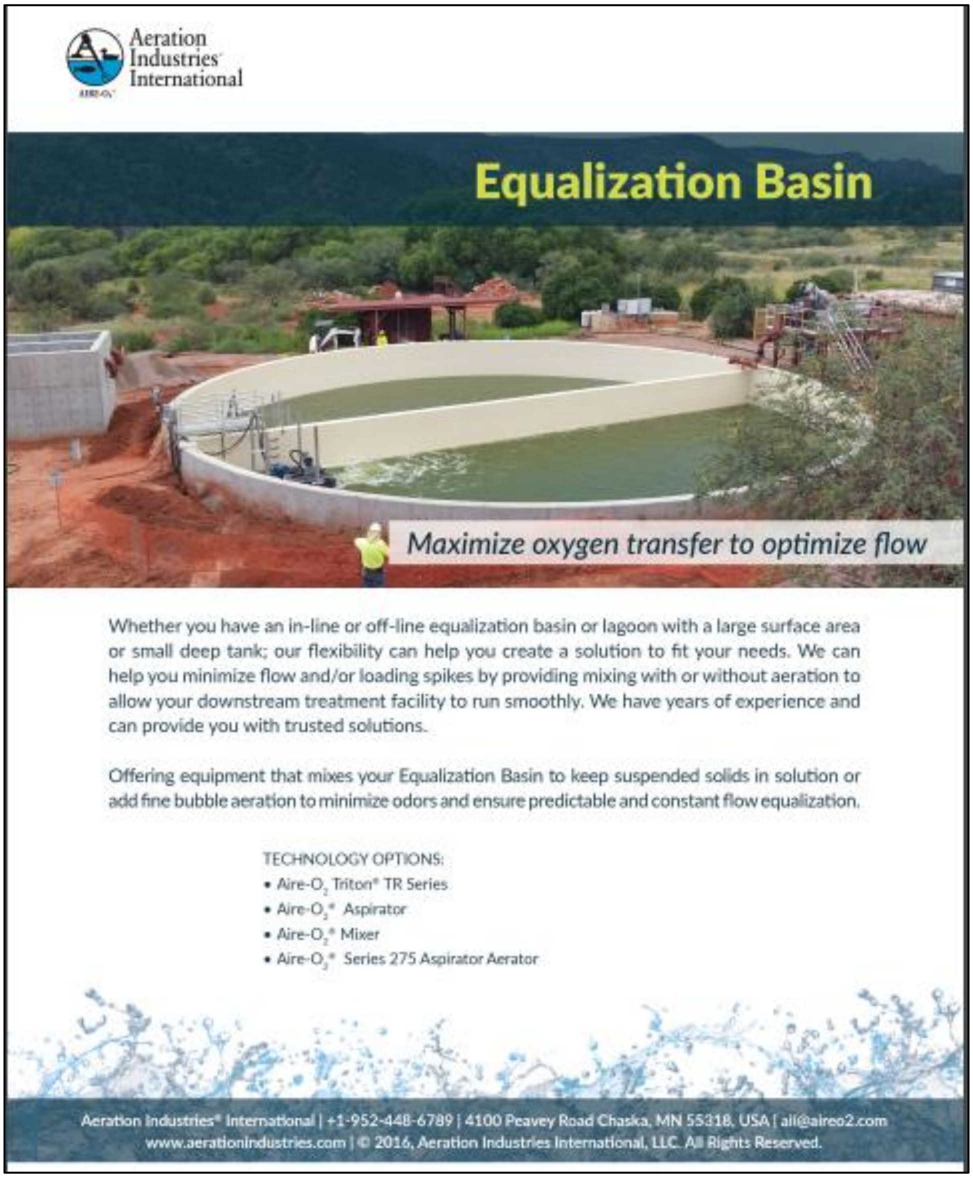


Figure C. 5 Equalization Basin Information

Appendix C: Traction Primary Clarifier

The traction primary clarifier that is used has the full calculations shown below in the table where more specific parameters such as the overflow rate, hydraulic radius, launder information and weir information. These are also important aspects to the design of the primary clarifier as the addition of these calculations allow the design to be as efficient as possible with the correct number of launders and weirs. Some of the equations used specifically for this process can be seen below the table which includes the hydraulic radius and the weir loading rate. The Peripheral Traction Clarifier information can be found below.

Table C. 5 Traction Primary Clarifier Dimensions

Traction Primary Clarifier		
Parameter	**Units**	**Value**
Overflow Rate (Avg)	($m^3/d*m^2$)	46.00
Number of Tanks, N	(-)	2.00
Tank Surface Area, As	(m^2)	411.46
Select Width, W	(m)	9.00
Length, L	(m)	45.72
Select Side Water Depth, D	(m)	3.00
Select Depth of sludge zone, Ds	(m)	1.00
Hydraulic Detention Time, t_d	(hr)	1.57
Check Fluid Velocity, V_f	(m/s)	0.01
Check Reynolds Number, Re	(-)	0.0000002
Hydraulic Radius, R_h	(m)	1.38
Check Froude Number, Fr	(-)	0.0000027
Select Number of Launders, N_L	(-)	1.00
Select Launder Length, L_L	(m)	22.86
Fraction of Tank Length	(-)	0.50

Tank Weir Length, LW	(m)	45.72
Weir Loading Rate, WL	(m^3/d-m)	207.00
Depth of tank, dt	m	4.00
BOD Percent Removal	(%)	55.00
TSS Percent Removal	(%)	40.00
BOD Out	(mg/L)	129.48
TSS out	(mg/L)	87.15

Equation C. 3 Hydraulic Radius [78]

$$R_H = \frac{W * D}{2D + W}$$

R_H= Hydraulic Radius (m)
W= Width (m)
D= Depth (m)

Equation C. 4 Hydraulic Detention Time [74]

$$t_d = \frac{W * L * D}{\frac{Q}{N}}$$

td= Hydraulic Detention Time (hours)
W= Width (m)
L= Length (m)
D= Depth (m)
Q= Flow Rate (m^3/d)
N= Number of Tanks

Features

- Available for tanks of up to 60m in diameter
- Scum removal device
- Hot dip-galvanised carbon steel / 304 L / 316 L SS

Benefits

- Quick installation
- High removal efficiency of sludge and floating matter
- Easy installation also into existing tanks

Options

- PTP Clarifier with +1/3 walkway length radius, with bottom scraper and back bottom scraper
- Double traction clarifier with diametric walkway and double scrapers
- Material: 304 L / 316 L SS / painting
- Alternative voltage and frequency
- Alternative degree of motor protection

Figure C. 6 Traction Clarifier Information [79]

Appendix C: Rotating Biological Contactor

The rotating biological contactor full calculations can be seen in the table below which is more in depth than the parameters given in the report and includes the hydraulic loading rate, organic loading rate and the organic load of BOD. This technology includes four trains in phase 1 as the report stated and the calculations shown are based off of these trains and therefore change when the trains increase for each phase. Along with these parameters needed, some important equations that were utilized are also shown below the table. The Napier-Reid's RBC with Bio-Rotor™ information can be found below.

Table C. 6 RBC Design Dimensions

Rotating Biological Contactor		
Parameter	**Units**	**Value**
# Trains	(-)	4
# Contactors/train	(-)	6
Contactor Surface Area	(ft2/contactor)	190,000
Total Surface Area of Media Surface Area	(ft2)	4,560,000
Hydraulic Loading Rate	(m3/d/ft2)	0.008301342
Hydraulic Loading Rate	(gpd/ft2)	2.192982031
Organic Load BOD	(lb/day)	10798.63826
Organic Loading Rate	(lb $SBOD_5$/day/1000ft^2)	2.368122424
Submerged Percent	%	40
Rotating Speed	rpm	1.3
BOD removal	%	88

BOD Out	(mg/L)	15.537609
COD Removal	%	86
COD Out	(mg/L)	24.169614

Equation C. 5 Organic Load [80]

$$Organic\ Load = C * Q * 8.34$$

Organic Load = Organic load BOD (lb/day)
C = Concentration of BOD (mg/L)
Q = Flow rate (MGD)
8.34 = Constant (lb/gal)

Equation C. 6 Organic Loading Rate [80]

$$Organic\ Loading\ Rate = \frac{Organic\ Load}{A}$$

Organic Loading Rate = Organic Loading Rate (lb $SBOD_5$/day/1000 ft^2)
Organic Load = Organic load BOD (lb/day)
A = Total Surface Area of Media (ft^2)

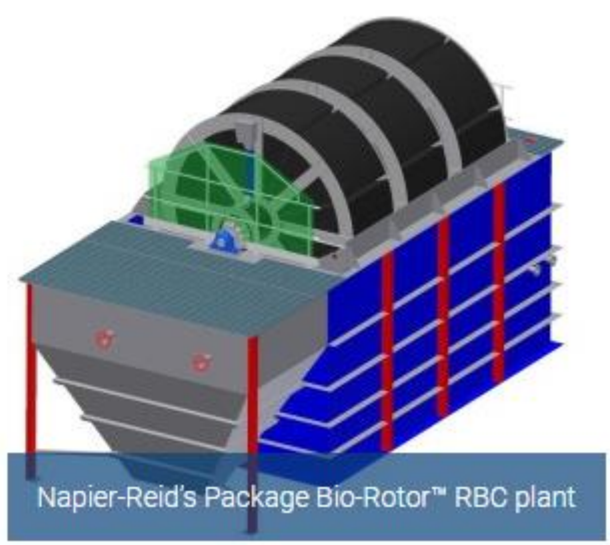


Figure C. 7 RBC Information

Appendix C: Upflow Anaerobic Sludge Blanket Reactor

The UASB design calculations are based primarily on research papers as this is an emerging technology. The design also includes the parameters and dimensions of the gas liquid separator. Additionally, the biogas production from the UASB is used to generate electricity for the plant as mentioned previously. Excess electricity can be sold back into the grid. The main equations used for the design can be found below. It was found that UASB systems can produce 8,846 kcal of methane per cubic meter of sludge [81]. The Upflow velocity is a key parameter of the design and affects the ability of the reactor to maintain granulation and to guarantee that there is enough mixing within the system [63]. More information for the ANUBIX ™ - B Global Water and Energy UASB reactor can be found below.

Table C. 7 UASB Design Calculations

Upflow Anaerobic Sludge Blanket Reactor		
Parameter	**Units**	**Value**
Number of Reactors	(-)	2.00
Reactor Volume (V)	(m3)	7097.65
Height (H)	(m)	10.80
Upflow Velocity	(m/hr)	1.20
Cross Sectional Area (S)	(m2)	657.19
Diameter (D)	(m)	28.93
Sludge Bed Height	(m)	2.00
Sludge Bed % of total Volume	(%)	40.00
Sludge Bed Volume	(m3)	2839.06
Gas Liquid Separator (GLS)		
Gas Liquid Separator % of total Volume	(%)	25.00
GLS Volume	(m3)	1774.41
GLS Upflow Velocity	(m/hr)	2.00
Ratio between Separator height and reactor height	(-)	0.25
GLS Height	(m)	2.70
Separator Angle	(degree)	50.00
Separator and deflector overlap	(m)	0.20
Deflector Angle	(degree)	45.00
Cross Sectional Area of the liquid	(m2)	394.31
Cross Sectional Area of the separator	(m2)	262.88
Diameter of Separator	(m)	18.29
HRT	(hr)	9.00
COD Load Capacity	(kg/m3*D)	1.27
Temperature	(C)	20.00
COD/SO4(2-) Ratio	(-)	20.00
Diameter of microbes	(m)	0.00
Superficial Velocity, va	(m/s)	0.00
Yield Coefficient	g VSS/g COD	0.06
Decay Coefficient	g VSS/d/g VSS	0.05
UASB methane generation	kcal/m3	8846.00
Methane Production for the plant	kcal	2511431 4.59
TSS Removal	(%)	75.00
TSS out	(mg/L)	21.79
COD Removal	(%)	80.00
COD Out	(mg/L)	4.83
BOD Removal	(%)	67.00
BOD out	(mg/L)	5.13

How does ANUBIX™ – B work?

In a typical plant, wastewater is first screened and then collected in a buffer tank equipped with an agitator. This tank is designed to allow sufficient qualitative and quantitative equalization and to acidify the wastewater partially. This allows for more stable operation and better sludge quality in the next stage: the ANUBIX™ – B anaerobic reactor. Provisions will be made for pre-settling of solids, heating, cooling, CO2 degasification, and inline neutralization if required as part of the overall process.

Raw wastewater is fed into the ANUBIX™ – B reactor through an internal influent distribution system and rises from the bottom to the top part of the reactor at a predetermined speed, after passing through a bed of active anaerobic sludge. Anaerobic digestion of organic material takes place in the ANUBIX™ – B anaerobic reactor. Organic compounds (such as sugar) are primarily degraded by anaerobic bacteria (sludge) and converted into biogas (a mixture of methane and carbon dioxide). Only a small amount of sludge growth takes place at this stage.

At the bottom of the ANUBIX™ – B reactor, the sludge becomes highly concentrated (up to 10% DS) and develops a granular structure. At sufficient hydraulic stress and under the appropriate conditions, which are created by the ANUBIX™ – B reactor, the granular structure is achieved spontaneously, without the need for additives.

Figure C. 8 UASB Information

Appendix C: Spiral Scraper Secondary Clarifier

The Spiral Scraper Secondary Clarifier is a cylindrical clarifier with a feedwell, sludge hopper, and weir. The sludge hopper is an angular hopper, the angled sides aid in lessening the accumulation of raw sludge on the sides of the hopper. The feedwell is designed to be in the center of the tank and aids in distributing the flow equally throughout the clarifier [74]. The feedwell also aids in flocculation [74]. Standard equations were used for each calculation, some of which are listed below. The WesTech COP ™ Spiral Blade Clarifier information can be found below.

Table C. 8 Spiral Scraper Secondary Clarifier Design Calculations

Spiral Scraper Secondary Clarifier		
Parameter	**Units**	**Value**
Overflow Rate	(m3/d*m2)	50.00
Number of Tanks, N	(-)	2.00
Tank Surface Area, As	(m^2)	378.54
Diameter of Tank (Dt)	(m)	21.95
Volume (V)	(m3)	1514.16
Select Side Water Depth, D	(m)	4.00
Select Depth of sludge zone, Ds	(m)	1.00
Hydraulic Detention Time, t_d	(hr)	1.92
Fraction of Tank Length	(-)	0.50
Weir Loading Rate, WL	(m^3/d-m)	301.23
Depth of tank, dt	m	4.00
Feedwell		
Detention Time	(min)	20.00
Depth of feedwell	(m)	3.00
Volume	(m^3)	270.39
Surface Area	(m^2)	90.13
Area of Cylinder	(m^2)	25.13
Velocity Through	(m/s)	0.01
Diameter of Feedwell	(m)	8.00
Sludge Hopper		
Angle of Sidewall	(degree)	50.00
Width of bottom	(m)	0.60
Diameter	(m)	10.00
Height	(m)	2.00
Volume Calculated	(m3)	4.35
BOD Percent Removal	(%)	55.00
TSS Percent Removal	(%)	40.00
BOD Out	(mg/L)	2.31
TSS out	(mg/L)	13.07
COD Removal	(%)	55.00
COD Out	(mg/L)	2.18

Equation C. 7 Weir Loading Rate [74]

$$W_L = \frac{Q}{Pi * D_{Tank}}$$

W_L – Weir Loading (m^3/d*m)
Q – Flow (m^3/d)
D_{tank} – Diameter of the Whole Tank (m)

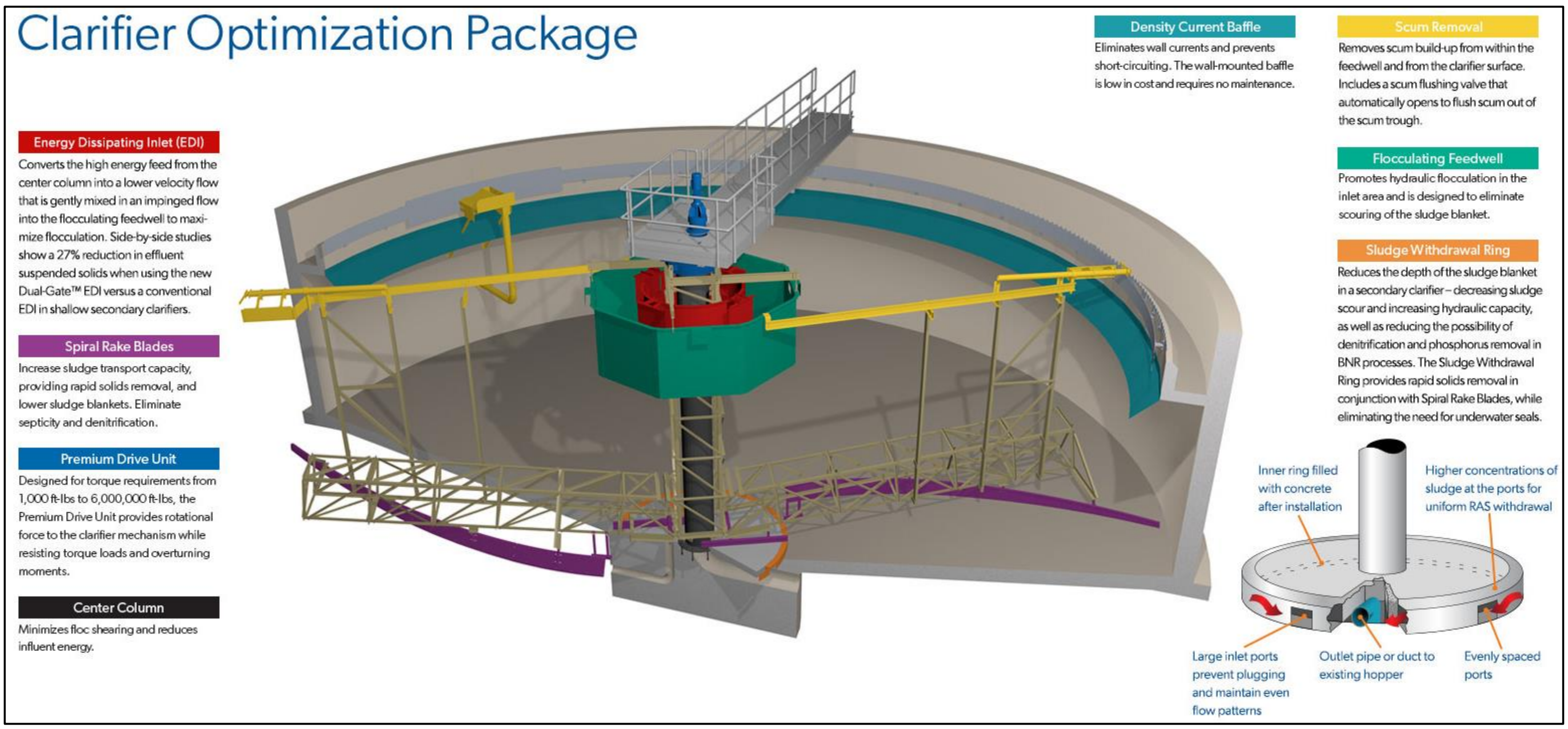


Figure C. 9 Secondary Clarifier Information

Appendix C: Sand Filter

The sand filter contains filter beds with cells, troughs, and gullets. Backwashing also takes place within the filter and was calculated for. The number of filter beds can be calculated for however, there is also a recommendation for larger plants to contain at least four beds. In order to determine the wash trough sizing the chart below was used to determine the W and Y value for design based on the flow rate. For this design a margin of safety of 0.15 was used to determine the trough elevation as shown in the equation below. The table below expresses all design calculations and considerations for the sand filter. The WesTech SuperSand ™ Continuous Backwash Filter information can be found below.

Table C. 9 Wash Trough Sizing Chart [74]

Sand Filter		
Parameter	**Units**	**Value**
Number of Beds	(-)	4.00
Number of filter beds (N)	(-)	3.79
Filtration Rate (V_f)	(m3/d*m2)	120.00
Area of Bed (A)	(m2/filter bed)	19.72
Width of one cell (W)	(m)	3.00
Length (L)	(m)	3.29
L:W Ratio	(-)	1.10
Gullet Width	m	0.60
Number of Troughs (N)	(-)	3.00
Trough Spacing	(m)	1.10
Maximum Particle Travel Distance	(m)	0.55
Backwash Velocity (V_B)	(m/hr)	37.00
Maximum Flow Rate per Trough	(m3/hr)	364.74
W	(m)	0.38
Y	(m)	0.30
Freeboard (FB)	(m)	0.05
Depth of Trough (D_T)	(m)	0.54
Depth of Expanded Bed (D_e)	(m)	0.70
Depth of Unexpanded Bed (D)	(m)	0.50
Margin of Safety (MS)	(m)	0.15
Trough Elevation	(m)	0.89
Time	(hr)	0.25
Filter Backwash Volume (V)	(m3)	182.37
Backwash Tank Volume	(m2)	364.74
TSS Removal	(%)	86.00
TSS out	(mg/L)	1.83
COD Removal	(%)	86.00
COD Out	(mg/L)	0.30
BOD Removal	(%)	68.00
BOD out	(mg/L)	0.16

Equation C. 8 Trough Elevation [78]

$$T_E = D_e - D + D_{Trough} + D_{MS}$$

T_E – Trough Elevation (m)
D_e – Depth of Expanded Bed (m)
D – Depth of Unexpanded Bed (m)
D_{MS} – Margin of Safety (m)

Equation C. 9 Number of Filters [78]

$$N = 0.0195Q^{0.5}$$

N – Number of Filter Beds
Q – Maximum Design Flow Rate (m^3/d)

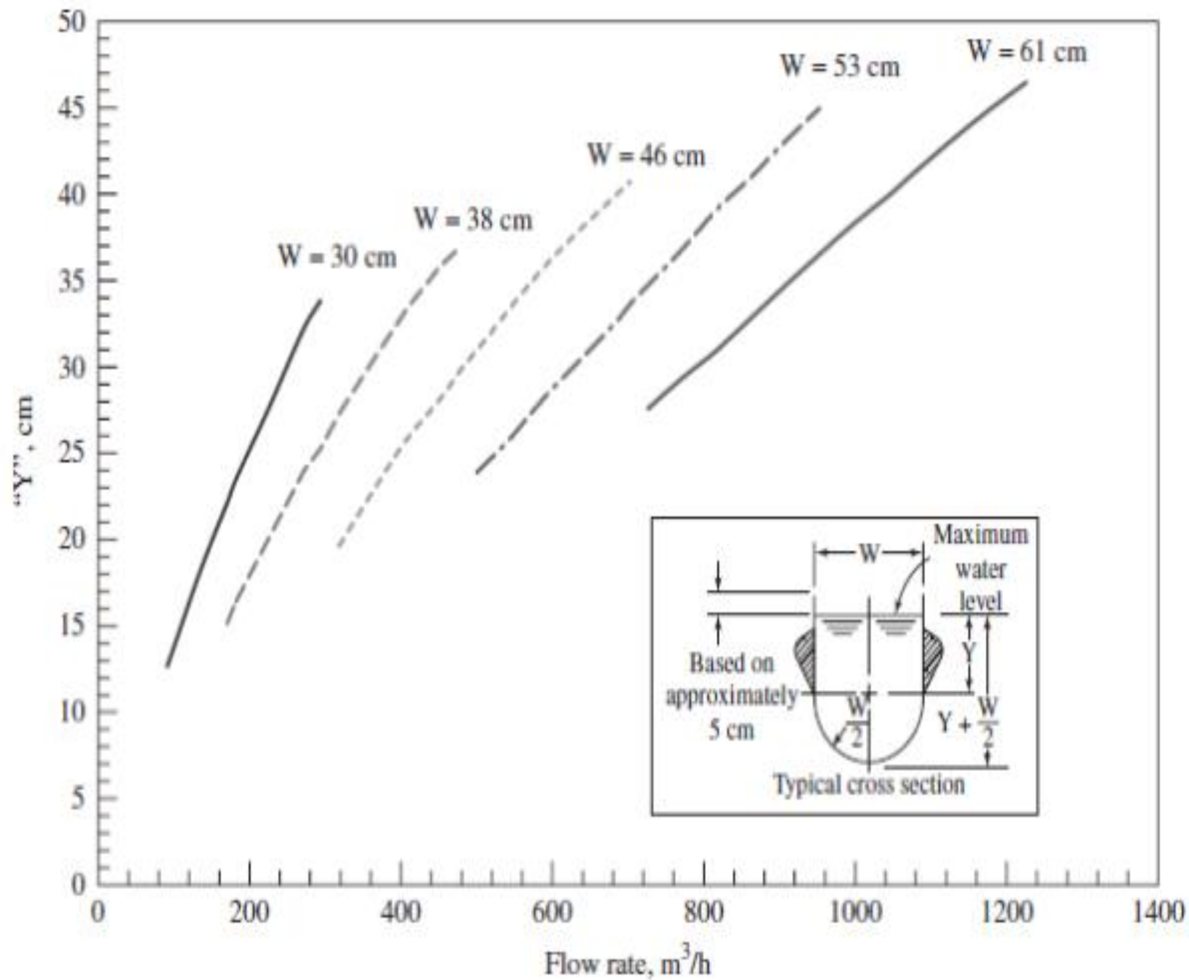


Figure C. 10 Wash Trough Sizing Information

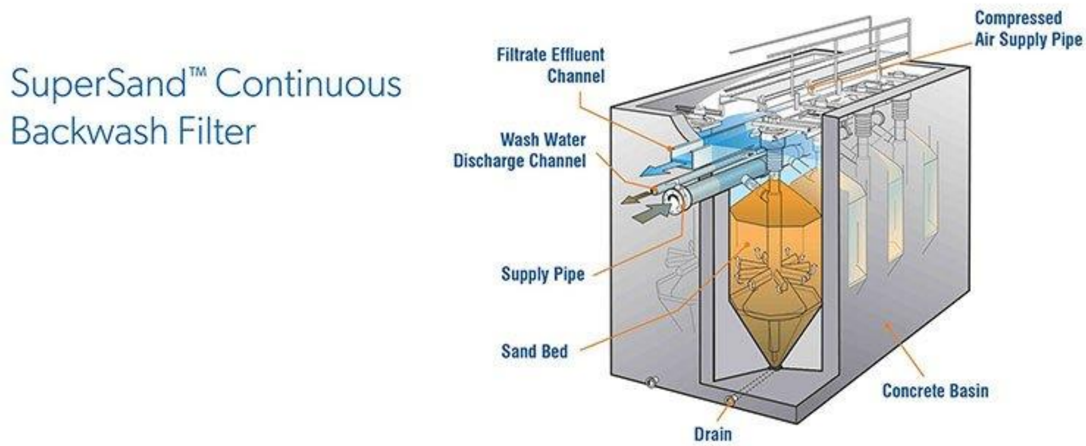


Figure C. 11 SuperSand Filter Information

Appendix C: UV Disinfection

The UV disinfection design was based primarily on the manufacturer information. Based on the specifications of the UV system and the plant requirement of 500 kWh/MG the number of lamps needed was determined for each phase. Diurnal data was used and then increased to account for increase in flow and redundancy to determine how many MG are treated per hour. Fouling is also often a design consideration as it affects lamp intensity and thus treatment, however, this is combated in the system through the automatic cleaning system. The design calculations and manufacturer information can be found below.

Table C. 10 UV Disinfection Design Calculations

UV Disinfection		
Parameter	**Units**	**Value**
Bank Type	(-)	6 rows
Number of Banks	(-)	36
Number of Lamps	(-)	216
Wattage Per Lamp	(Watts)	1000
Influent Flow	(MG/hr)	0.416667
Plant Info	(kWhr/MG)	518.4
Plant Requirements	(kWhr/MG)	500

System Specifications	
System Characteristics	**TrojanUVSigna**
Lamp Type	TrojanUV Solo Lamp (amalgam)
Lamp Driver	Electronic, high-efficiency (99% power factor)
Input Power Per Lamp	1000 Watts
Lamp Control	30 - 100% variable lamp power (1% increments)
Lamp Configuration	Staggered, inclined array (two-row, four-row or six-row)
Module/Bank Frame	Type 6P (IP67)
Ballast Enclosure	Type 4X (IP66)
Cleaning System	Automatic ActiClean chemical/mechanical
UV Intensity Sensor	1 per bank – with automatic chemical cleaning
Bank Lifting Device	1 per bank - Automatic Raising Mechanism (ARM)
Level Control Device	Fixed weir or motorized weir gate
Water Level Sensor	High and low water level sensors available (one per channel)
Installation Location	Indoors or outdoors
System Control Center	Standard color HMI, 16 digital I/O, 4 analog I/O, SCADA compatible PLC options available

Figure C. 12 TrojanUV Signa Specification

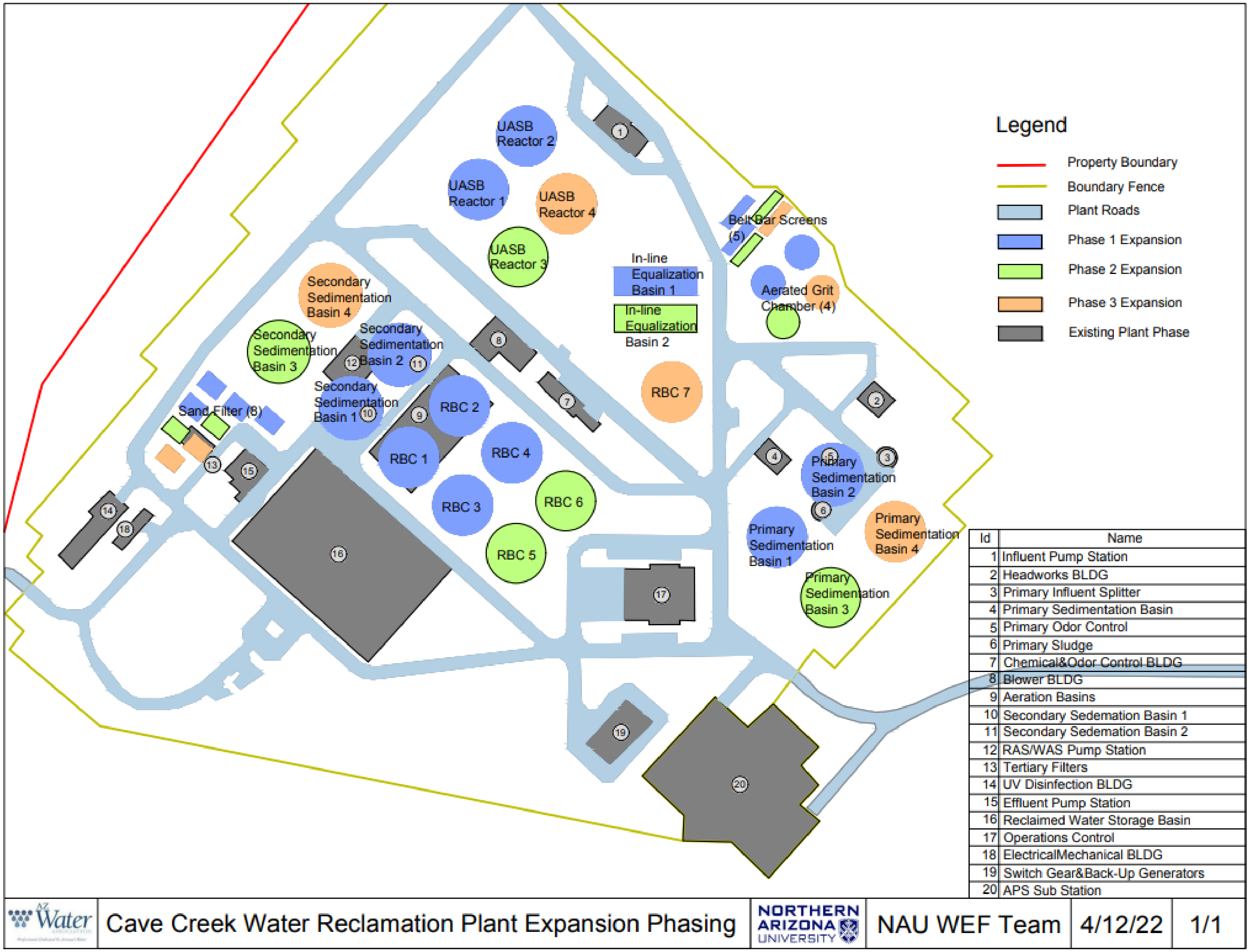
Appendix D: Cost Estimates

Table D. 1 Cost Estimates

Capital Cost Estimation

Item #	Item	Size/Description	unit	2021 Quantity	2021 cost/unit	2037 Quantity	2037 cost/unit	2054 Quantity	2054 cost/unit	2021 Capital Cost	2037 Capital Cost	2054 Capital Cost
Influent Pump Station										**$ 1,010,000.00**	**$ -**	**$ -**
1	Pump	Slurry Abrasive pump, Model 10x8-21	EA	4	$ 150,000.00	0	$ 162,460.67	0	$ 176,836.25	$ 600,000.00	$ -	$ -
2	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 180,000.00	$ -	$ -
3	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 210,000.00	$ -	$ -
4	Removal Existing	Remove existing pumps	EA	4	$ 5,000.00		$ -		$ -	$ 20,000.00	$ -	$ -
Screen System										**$ 891,891.00**	**$ 975,981.41**	**$ 525,728.87**
1	Continuous Belt Bar Screen	Noggerath® Continuous Belt Screen, Model BS-XL	EA	2	$ 267,000.00	2	$ 289,180.00	1	$ 314,768.53	$ 534,000.00	$ 578,359.99	$ 314,768.53
2	Concrete	Normal weight reinforced concrete	CY	12	$ 545.00	12	$ 590.27	6	$ 642.51	$ 6,540.00	$ 7,083.29	$ 3,855.03
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 162,162.00	$ 175,632.98	$ 95,587.07
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 189,189.00	$ 204,905.15	$ 111,518.24
5	Removal Existing	Remove existing bar screens	EA	0	$ -	2	$ 5,000.00	0	$ -	$ -	$ 10,000.00	$ -
Grit Removal										**$ 470,992.50**	**$ 255,059.19**	**$ 282,929.16**
1	Aerated Grit Chamber	SPIRAC® Technology Grit Chamber	EA	2	$ 140,000.00	1	$ 151,629.96	1	$ 165,047.17	$ 280,000.00	$ 151,629.96	$ 165,047.17
2	Concrete	Normal weight reinforced concrete	CY	10	$ 545.00	5	$ 590.27	10	$ 642.51	$ 5,450.00	$ 2,951.37	$ 6,425.05
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 85,635.00	$ 46,374.40	$ 51,441.67
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 99,907.50	$ 54,103.47	$ 60,015.28
Equalization Basin										**$ 309,375.00**	**$ 268,060.11**	**$ -**
1	In Line Equalization Basin	AIRE-O2 TRITON ®, Model TR Series 2.0	EA	1	$ 150,000.00	1	$ 162,460.67	0	$ 176,836.25	$ 150,000.00	$ 162,460.67	$ -
2	Excavation	Excavation and earthwork for installation of equalization basin	CY	750	$ 50.00	0	$ 54.15	0	$ 58.95	$ 37,500.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 56,250.00	$ 48,738.20	$ -
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 65,625.00	$ 56,861.24	$ -
Primary Clarifiers										**$ 1,244,100.00**	**$ 625,473.59**	**$ 680,819.56**
1	Traction Clarifier	Peripheral Traction Clarifier W/ weirs, baffles, and mechanical mechanisms, Model PTP12	EA	2	$ 350,000.00	1	$ 379,074.90	1	$ 412,617.92	$ 700,000.00	$ 379,074.90	$ 412,617.92
2	Excavation	Excavation and earthwork for installation of primary clarifier basin	CY	900	$ 60.00	0	$ 64.98	0	$ 70.73	$ 54,000.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 226,200.00	$ 113,722.47	$ 123,785.38
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 263,900.00	$ 132,676.22	$ 144,416.27
Aeration Basins										**$ 188,100,000.00**	**$ 98,288,706.98**	**$ 68,081,956.31**
1	Rotating Biological Reactor	Napier-Reid's RBC with Bio-Rotor™ Technology	EA	4	$ 20,000,000.00	2	$ 21,661,423.03	1	$ 23,578,166.69	$ 80,000,000.00	$ 43,322,846.05	$ 23,578,166.69
2	Upflow Anaerobic Sludge Blanket	ANUBIX™ – B reactor	EA	2	$ 15,000,000.00	1	$ 16,246,067.27	1	$ 17,683,625.01	$ 30,000,000.00	$ 16,246,067.27	$ 17,683,625.01
3	Excavation	Excavation and earthwork for installation of aeration basin	CY	80,000	$ 50.00	0	$ 54.15	0	$ 58.95	$ 4,000,000.00	$ -	$ -
4	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 34,200,000.00	$ 17,870,674.00	$ 12,378,537.51
5	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 39,900,000.00	$ 20,849,119.66	$ 14,441,627.10
5	Removal Existing	Remove existing aeration basin	EA	1	$ 5,000.00	0	$ 5,415.36	0	$ 5,894.54	$ 5,000.00	$ -	$ -
Secondary Clarifiers										**$ 1,402,500.00**	**$ 536,120.22**	**$ 583,559.63**
1	Spiral Scraper Clarifier	110' COP™ Spiral Blade Clarifier	EA	2	$ 300,000.00	1	$ 324,921.35	1	$ 353,672.50	$ 600,000.00	$ 324,921.35	$ 353,672.50
2	Excavation	Excavation and earthwork for installation of secondary clarifier basin	CY	5000	$ 50.00	0	$ 54.15	0	$ 58.95	$ 250,000.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 255,000.00	$ 97,476.40	$ 106,101.75
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 297,500.00	$ 113,722.47	$ 123,785.38
Sand Filter										**$ 13,406,250.00**	**$ 7,186,244.78**	**$ 7,822,130.48**
1	Sand Filter	Super sand tertiary system W/ 8 basins & 4 filters per basin	EA	4	$ 2,000,000.00	2	$ 2,166,142.30	2	$ 2,357,816.67	$ 8,000,000.00	$ 4,332,284.61	$ 4,715,633.34
2	Concrete Wall	Concrete Masonry Unit wall around the top of filter basin	SF	0	$ 25.00	850	$ 27.08	850	$ 29.47	$ -	$ 23,015.26	$ 25,051.80
3	Excavation	Excavation and earthwork for installation of sand filter	CY	2500	$ 50.00	0	$ 54.15	0	$ 58.95	$ 125,000.00	$ -	$ -
4	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 2,437,500.00	$ 1,306,589.96	$ 1,422,205.54
5	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 2,843,750.00	$ 1,524,354.95	$ 1,659,239.80
UV Disinfection										**$ 2,003,100.00**	**$ 16,500.00**	**$ 369,600.00**
1	Trojan UV Signa Bank	Trojan UV Signa bank with 161,000W bulbs per bank W/ controls, sluice gate, and connections	EA	14	$ 86,000.00	2	$ 5,000.00	4	$ 56,000.00	$ 1,204,000.00	$ 10,000.00	$ 224,000.00
2	Removal Existing	Remove existing UV system and controls	EA	2	$ 5,000.00	0	$ 5,415.36	0	$ 5,894.54	$ 10,000.00	$ -	$ -
3	Pipe, Valves &Fittings	Estimation of pipes, valves and fittings (30% of unit cost)								$ 364,200.00	$ 3,000.00	$ 67,200.00
4	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 424,900.00	$ 3,500.00	$ 78,400.00
Biogas										**$ 10,125.00**	**$ 56,585.05**	**$ 61,592.07**
1	Collection Hood	Hanon Gas Collection Hood, Model WD03	EA	5	$ 1,500.00	5	$ 1,624.61	5	$ 1,768.36	$ 7,500.00	$ 8,123.03	$ 8,841.81
2	Cogeneration Engine	Jenbacher Type 3 cogeneration engine	EA	0	$ 15,600.00	2	$ 16,895.91	2	$ 18,390.97	$ -	$ 33,791.82	$ 36,781.94
3	Electrical	Estimation of electrical connections and instrumentation (35% of unit cost)								$ 2,625.00	$ 14,670.20	$ 15,968.31

Appendix E: CCWRP Expansion Layout Drawing



Id	Name
1	Influent Pump Station
2	Headworks BLDG
3	Primary Influent Splitter
4	Primary Sedimentation Basin
5	Primary Odor Control
6	Primary Sludge
7	Chemical&Odor Control BLDG
8	Blower BLDG
9	Aeration Basins
10	Secondary Sedemation Basin 1
11	Secondary Sedemation Basin 2
12	RAS/WAS Pump Station
13	Tertiary Filters
14	UV Disinfection BLDG
15	Effluent Pump Station
16	Reclaimed Water Storage Basin
17	Operations Control
18	ElectricalMechanical BLDG
19	Switch Gear&Back-Up Generators
20	APS Sub Station

Figure F. 1 Treatment Plant Drawing Layout