CIV 440 Engineering
Stony Brook University, Dept. of Civil Engineering
2434 Computer Science
Stony Brook, New York 11794-4424

CIV 440 Engineering

December 7, 2020
Emailed to: reichel@townofriverheadny.gov

Town of Riverhead
200 Howell Avenue
Riverhead, NY 11901-2596
(631) 727-3069

Attention: Michael Reichel
Superintendent

Subject: Town of Riverhead Class A Biosolids Study
Our Project No: 01

Dear Superintendent Michael Reichel:

Within the attached Town of Riverhead Class A Biosolids Report, you will find information on the feasibility of achieving Class A biosolids designations utilizing the most cost effective approach to reuse treated waste sludge as a material for local businesses as well as reducing current disposal costs.

Our analysis includes researching current viable processes that can convert domestic waste activated sludge to Class A biosolids. These viable processes would take into consideration construction costs, aesthetics, odor potential, and various environmental risks. In addition to the identification of several key processes that can achieve a Class A biosolid designation, our feasibility study also details several preliminary cost calculations. Although these calculations are not final, they would gauge an understanding of the various costs associated with undertaking each process. Several local demand sources have also been identified.

Currently, our analysis details several options that have been considered to achieve Class A biosolids designations, considering each option, a list of potential advantages and disadvantages were drawn up. While each process had advantages over its neighboring process, several factors would hinder the progression of these processes from recommended to mentioned. The feasibility report attached is only 35% completed. Only three processes that have been identified would be feasible with regards to the aforementioned factors. Each process selected contains preliminary cost estimates and an evaluation of the process that is undertaken to achieve the Class A biosolid designation.

Over the course of the next few months after the acceptance of a recommended plan, our group will begin designing the chosen treatment option which will enable us to generate a comprehensive cost estimate. As part of this process, we will be investigating how to fund the installation of this process, including but not limited to tax breaks, grants, and new methods of disposal. These incentives would severely reduce the overall cost of the chosen treatment option. We will establish an environmentally acceptable plan for reusing the material for regional disposal use, along with the establishment of a project payback period.

Thank you for trusting us to complete this feasibility study for you. We appreciate the opportunity to design and make use of current processes not only to benefit a community, but as a means of recycling waste sludge for a beneficial use. Our team looks forward to working with you in the future. Please review the feasibility study and respond with your thoughts.

If you have any additional questions, feel free to contact me anytime at kumil.ali@stonybrook.edu or (646) 934-2502. I look forward to speaking with you further on this project.

Tel. No.: (646) 934-2502

Very truly yours,

CIV 440 Engineering - Stony Brook University

Kumil Ali
Project Manager

Encl.

Cc: Mr. Frank M. Russo, P.E. (w/encl.)

TOWN OF RIVERHEAD
CLASS A BIOSOLIDS STUDY

Project Team:

Kumil Ali
Robert Seaman
Stephen Okolowich
Aaron Mairzadeh
Syed Islam

Prepared for:

Superintendent Michael Reichel
Town of Riverhead
200 Howell Avenue
Riverhead, NY 11901-2596

Prepared by:

CIV 440 Engineering
Stony Brook University
Civil Engineering
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Mid-Term Report | 12/07/2020
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CIV 440 Group Number 01

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Executive Summary

The subject of this engineering report is executing a feasibility study on how an existing wastewater treatment plant located in the Town of Riverhead, New York can produce Class A biosolids with the addition of a sludge treatment option. This report also determines which treatment options available are the most cost-effective in achieving the Class A biosolids designation. It is the aim of the facility to reuse the material for local businesses and farms as a soil amendment or fertilizer to reduce disposal costs. Disposal costs are nearly $2 million per year according to Superintendent Michael Reichel, our client for this report. These disposal costs mainly derive from transporting the sludge nearly 6 hours by truck to a landfill located in Pennsylvania. By redirecting this material to more local farms and business, this facility has the opportunity to reduce these costs significantly.

This report completes a comprehensive and thorough analysis on Class A biosolids including their benefits and the methods of achieving them. This report also fully analyzes the project problem statement, recommended and not recommended design alternatives, the costs associated with those alternatives, and current facility processing. Also included in this report are the federal and state regulations encompassing pollutant restrictions, land application and storage requirements, pathogen reduction requirements, and vector-attraction reduction requirements. Information on alternate dewatering options, including the currently used belt filter press, centrifuge, filter press, and rotary drum vacuum filter can be found in this report. Odor and dust control systems including biofilters can be found in this report as well. Following these pre-treatment options are the treatment options where they are analyzed for practicality and differentiated based on their respective advantages, disadvantages, and costs. This report ends by covering the regional demand for Class A biosolids and some reuse options after treatment.

Our recommended design alternatives include thermal drying, thermal hydrolysis, and advanced alkaline stabilization (AAS). Each of these processes have their advantages and disadvantages but all meet the requirements for Class A and are viable options for the project site given the site limitations.

Significant results achieved by our group include, but are not limited to, a cost-effective analysis, an assessment of regional demand, analysis of proprietary and vastly effective treatment options and an assessment of manufacturer products and their benefits. In conclusion, our group finds that the proposed improvements listed in this report are indeed worth the extra expenditure, as they will lead to saving money on a long-term basis. These improvements, although challenging due to the unique nature of the site, are indeed possible. We reached this conclusion through completing the feasibility study listed below. It is our hope that after reading through our findings that the same conclusions can be found.

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1. BACKGROUND INFORMATION

1.1. Project Problem Statement

The Town of Riverhead owns and operates three wastewater treatment facilities: Water Resource Recovery Facility (1.6 mgd), Calverton Advanced Wastewater Treatment Facility (0.1 mgd), and the Scavenger Waste Treatment Facility (0.1 mgd). Each of these facilities produces a waste sludge from their biological treatment process that is disposed of off-site by a contract sludge hauler. Sludge removal costs per year total approximately $2 million. (The liquid sludge from the Calverton plant is directly hauled off to a regional sludge processing facility. The sludge from the Water Resource Recovery Facility / Scavenger Waste plants are blended and dewatered onsite before being hauled to another state for landfill disposal.) The purpose of this study is to determine a cost-effective method to achieve the Class A biosolids designation to be able to reuse the material for local businesses as a soil amendment or other products to reduce disposal costs.

1.2. Background on Biosolids

The treated waste sludge that is the end result of wastewater treatment is known as biosolids. There are multiple different classifications for biosolids, and they are categorized by the 40 CFR Rule put forward by the EPA (Environmental Protection Agency). The main factors for classification of biosolids (Class B, Class A, and Class A EQ) is the level of pathogens present as well as the material's properties in terms of Vector Attraction Reduction requirements as mentioned in the EPA Part 503 Rule. Class B biosolids are classified based on their level of detectable pathogens. In Class A biosolids, the detectable level of pathogens, through treatment, has been effectively reduced to zero. In Class A EQ biosolids, the treated sludge meets and also exceeds all requirements for pathogens and vector attraction reduction, making them of exceptional quality. Each classification of biosolids has benefits in terms of cost, potential use, and health. Class A EQ is the most beneficial and least restricted for reuse.

1.2.1. What is Class A Biosolids?

Class A biosolids are dewatered and heated sewage sludge that has the potential for land application uses because it meets EPA guidelines. There are three main factors that must be accounted for when considering to convert a sludge into a biosolid. These include the pollutant concentration, the vector attraction, and the pathogen concentration. Despite these three factors being extremely important, it is the pathogen concentration that separates Class A and Class B biosolids. Pathogens present in Class A biosolids are inactivated during the process of converting the sludge to Class A biosolids since these pathogens have the potential to be dangerous to any surrounding plant or animal life during land application. How the Class A biosolids are classified and used during this land application is completely dependent on how the pollutants and vector attraction in the biosolids are regulated. The federal regulations that distinguish Class A biosolids from other types of biosolids are outlined in the Code of Federal Regulations (CFR) Title 40 Part 503.

In order for treated sewage sludge to achieve Class A classification, multiple requirements must be met. Firstly, pathogens must be inactive and/or virtually undetectable through processes such as UV treatment. Aside from pathogens, Part 503 of the EPA 40 CFR Rule specifies other standards to be met, mainly vector attraction reduction, metal concentrations and odor. These factors are what set Class A biosolids apart from Class B biosolids.

1.2.2. Use and Benefits of Class A Biosolids

Class A biosolids are a classification of biosolids that are well suited for land application. Class A biosolids are more viable for land application over other classifications of biosolids since the level of dangerous pathogens in the resulting Class A biosolid sludge is reduced to virtually zero. Class A biosolids have a variety of highly effective uses, such as fertilizer for agriculture and soil rehabilitation and re-oxygenation. These uses are not only benefits, but these biosolids have the added benefit of reducing the landfill restrictions of the biosolids. For example, sludge with a Class A designation no longer needs to be hauled out of state. These biosolids can instead be sold to buyers such as farms or deposited in forest biomes to improve the soil composition. Class A biosolids, however, are mainly used in agriculture as fertilizers since they are rich in nutrients such as nitrogen, phosphorus and potassium. These biosolids also improve the soil structure, and reduce demand for synthetic fertilizers. Depending on the type of Class A biosolids produced, these biosolids can be used on larger farms or smaller personal gardens. Composting is also an option for these biosolids. When discussing these biosolids effects on forests, Class A biosolids have been found to promote rapid timber growth, thereby allowing quicker and more efficient timber harvesting or more effective forest rejuvenation. With the host of benefits that Class A biosolids provide, an increased effort needs to be made to improve the quality of the sludge being produced by the Town of Riverhead to reach the Class A threshold.

1.2.3. Biosolids Production, Use and Disposal in NY State

In 2015, there were 612 publicly-owned treatment facilities in New York State treating approximately 2,400 mgd of wastewater. The total biosolids produced at these facilities reaches approximately 1,000 dry tons of solids (DTS) per day (NYS DEC. 2018). The processes used to treat the sludge produced at these treatment facilities producing biosolids include aerobic or anaerobic digestion, heat drying, composting, and alkaline stabilization. Disposal of biosolids in New York State is primarily done by shipping and disposing the biosolids in landfills both in and out-of-state as shown in Figure 1. In 2015, an estimated 68% of the biosolids produced in New York treatment facilities were disposed of in landfills. Another 16% of the biosolids produced were incinerated in order to reduce the volume of material that was being disposed of in landfills. Only 16% of the biosolids produced in New York State were used to benefit the community or surrounding environment (NYS DEC. 2018). Landfill disposal has seen an increase mainly because it is the cheapest and easiest option for disposal and has the least number of restrictions on the biosolids. The beneficial uses of the biosolids produced at treatment facilities in New York State include direct land application, composting to enhance soil, heat drying to form a commercial fertilizer, and chemical stabilization to form a lime substitute for agriculture.

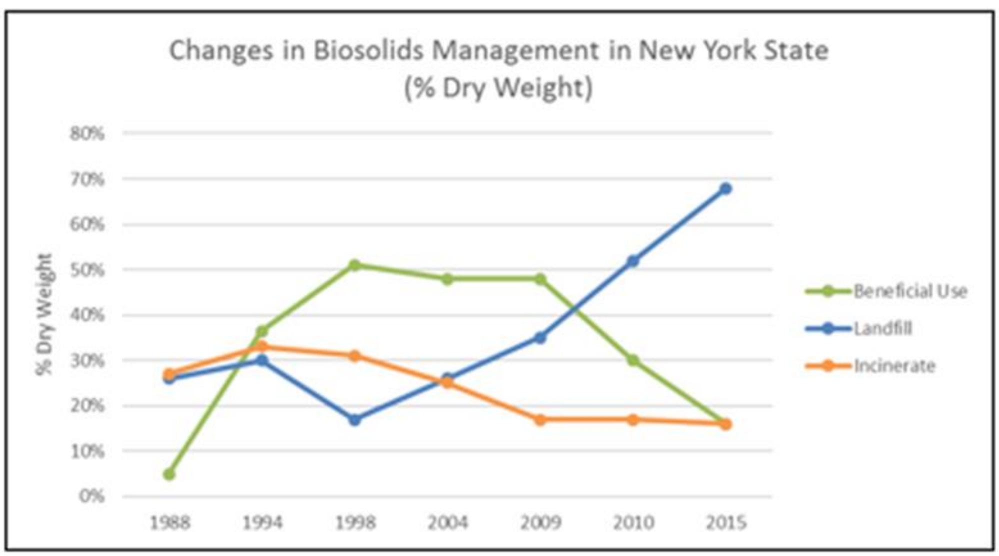

Figure 1: Graph of biosolids disposal in New York State. Source: NYS DEC, 2018

1.3. Riverhead Wastewater Treatment and Current Processes

The Town of Riverhead's Water Resource Recovery Facility (RWRRF) is where the town's wastewater is treated and the sludge is produced. The facility is located just north of the Peconic River and lies between the Indian Island Golf Course and Peconic Estuary as shown in Figure 2.

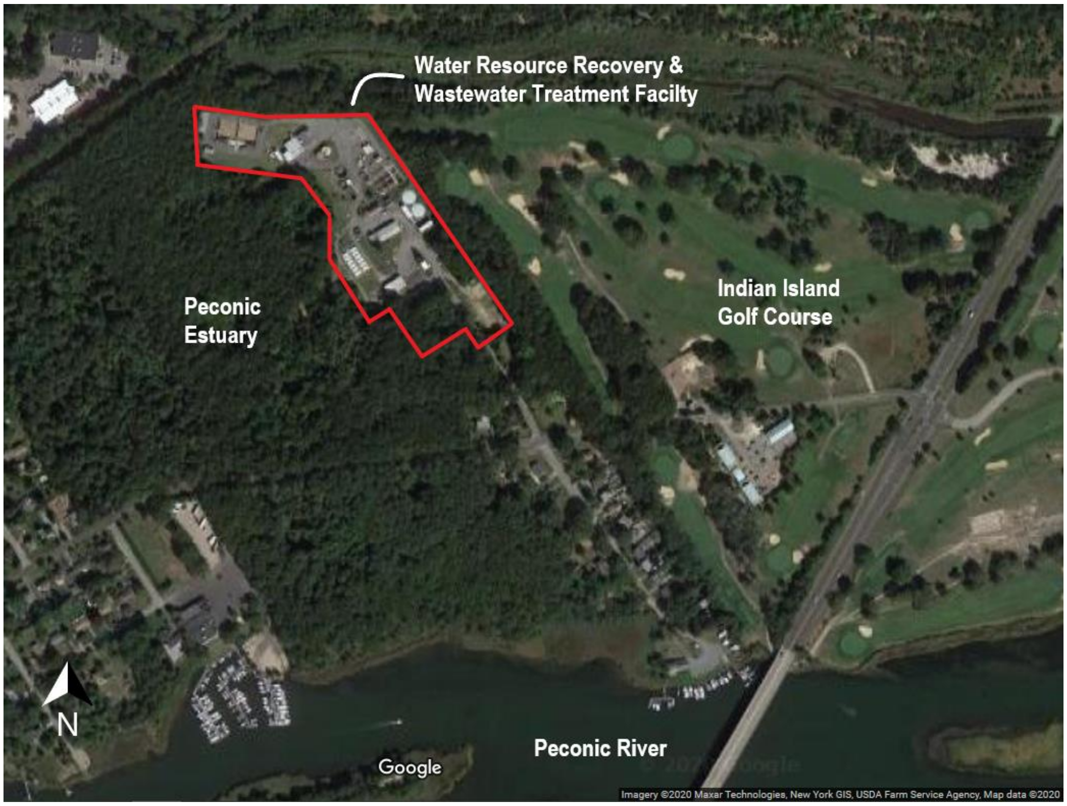

Figure 2: Aerial view of project site location.

This facility has a design flow of 1.5 mgd and is currently treating about 1 mgd of wastewater. The treatment facility primarily treats the wastewater from the Town of Riverheads sewage system. Stormwater drainage is not connected to the Town's sewer system and is therefore not treated at the treatment facility. Septic sewage delivered by septic tank delivery trucks is treated separately from the sewer wastewater before being combined with the sewage system water and further treated. The design flow for the septic sewage treatment is 0.1 mgd and currently treats about 0.047 mgd of septic sewage. Power for the facility is generated on-site using diesel generators. The fuel storage capacity for the on-site power generator is 7,900 gals. This storage capacity only lasts for 3 days and costs $500,000 annually.

1.3.1. Current Riverhead Processing

The wastewater treatment process currently used at RWRRF is shown in Figure 3. The facility is designed for redundancy so the facility does not stop running. This is to account for the sewage that never stops flowing into the facility. The main wastewater treatment facility has three stages. The first stage is the preliminary treatment of the influent from the Riverhead sewer system. This stage consists of fine screening, grit removal settling, and equalization. From the equalization tanks the wastewater is pumped to the second treatment stage, the Membrane Bioreactor (MBR) system. The MBR system first treats the wastewater in large aeration tanks where nitrification and denitrification take place. The nitrification and denitrification processes aid in removing the BOD and ammonia in the wastewater. The wastewater is then filtered through a series of 0.04 µm diameter hollow fiber membranes. The treated sludge from the MBR system is pumped to the sludge blending tanks where the sludge is combined with the sludge produced from the septic sewage treatment process and homogenized. At this point, the treated sludge contains only 0.5% solids. The blended sludge is then pumped to the third treatment stage consisting of a gravity belt thickening system and belt filter press. An emulsion polymer is added to the sludge to act as a coagulate to solidify and clump the solid sludge together. After the sludge has been thickened by the gravity belt thickener, it is pumped to the thickened sludge tank where it is temporarily stored. The thickened sludge contains approximately 2-3% solids. The thickened sludge is then pumped to the belt filter press where the sludge is thickened further and then pressed to remove water. Then the sludge is collected in an auger and loaded onto the truck to be hauled away. The final sludge product contains between 15-17% solids.

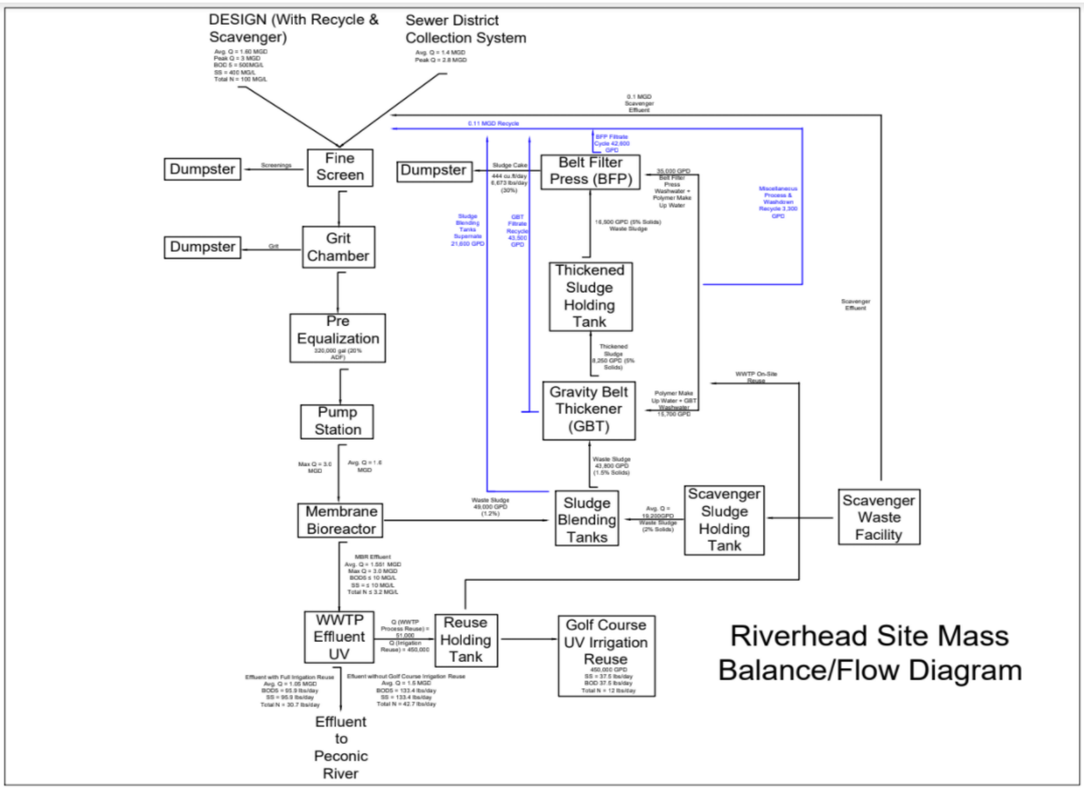

Figure 3: Flow chart/mass balance diagram of the treatment process at the RWRRF.

The scavenger waste treatment facility treats sewage from local septic collection trucks. These trucks have to register with the facility so they know where the septic sewage comes from if any problems with the sewage occur. The sewage is first sent through bar screens to remove any debris in the sewage and then into the aeration grit chamber which removes grit from the sewage. The sewage is then pumped into equalization tanks where it is aerated and mixed. From there, the sewage flow is controlled and pumped to the flocculation tank where the solid particles are attracted together and clump together. The sewage is then pumped to the primary clarifier which separates the water from the sludge. Then the sludge is thickener. First, sodium bicarbonate is added to the sludge to increase the pH to 10. Next the sludge is sent through the rotating biological clarifier (RBC) system. The RBC system treats the sludge using a fixed film media for BOD and ammonia removal. Then the sludge is pumped to the final clarifier to remove more water from the sludge. The water that is separated from the sludge in both the primary and final clarifiers are pumped to the fine screening of the primary treatment facility where the water is further treated with the other sewage. The sludge is then pumped to the gravity belt thickening and pumped to the blending tanks to be combined and mixed with the other treated sludge from the MBR system. (Information provided by RWRRF Superintendent Michael Reichel during a site visit.)

1.3.2. Current Sludge Disposal and Associated Costs

The sludge that is treated at the Riverhead Water Recovery Resource Facility is currently being hauled away to a landfill located deep in Pennsylvania. This landfill is currently the closest location that accepts the quality of sludge that is currently being generated at the RWRRF. The sludge is hauled away multiple times a week by a semi-truck with a capacity of 25 tons. There are three to four truckloads of sludge that

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are hauled away each week at the current flow of the facility. There could be as many as five to six truck loads per week at the facilities design capacity. The cost for each truck load to ship the sludge is roughly $3,000. Extrapolating that information, it means that approximately $500,000 is used just to haul away the sludge produced at the Riverhead Water Resource Recovery Facility annually. This high transportation cost is one of the driving factors behind aiming for a Class A biosolid classification for the sludge being produced by this facility.

1.4. Other Facilities with Class A Biosolid Processing and Disposal

Biosolids production has been implemented all across the country for beneficial use. Some examples of facilities currently producing biosolids from sludge are the Immokalee Water and Sewer District in Florida, City of Centralia wastewater treatment plant in Washington, Fond Du Lac Wastewater Treatment & Resource Recovery Facility in Wisconsin, Syracuse Wastewater Treatment Plant in New York, and Rensselaer County Sewer District Wastewater Treatment Facility in New York.

The Immokalee Water and Sewer District in Florida originally produced Class B biosolids containing 1-1.5% solids. This facility has a design flow of 4.0 mgd. The annual costs associated with dewatering and hauling away to landfill the produced Class B biosolids was $500,0000/yr. After 2013, they upgraded the facility to produce Class A biosolids. The new system produces Class A biosolids by first dewatering the sludge in a screw press getting the material to 16% solids. Lime and sulfamic acid is then added to the dewatered sludge and heated in a reactor for 30 to 40 minutes at 122℉. These processes were chosen since there was limited available land to expand the facility. The final product is Class A biosolids that regional agricultural areas use as a fertilizer. The facility operating costs associated with producing Class A biosolids is $130,000/yr which is considerably less than originally dewatering and hauling Class B biosolids to landfills. There was the added benefit that local farms got to use the biosolid material as a fertilizer, saving up to $50,000/yr in fertilizer costs (Trojak, 2016).

In the City of Centralia in Washington, the wastewater treatment plant was designed to produce Class A biosolids. The design flow of the facility is 10.3 mgd and uses a belt filter press for dewatering the sludge which is then treated by lime stabilization and pasteurization. After only 5 years in operation the costs of lime went up considerably and the City investigated other cheaper alternatives. They decided to switch the facility to compositing to produce Class A biosolids. The dewatered biosolids are mixed with ground woody debris and composited to produce Class A biosolids. The end product is either sold at $10/yd, donated, or used on city properties (City of Centralia, 2016).

The Wastewater Treatment & Resource Recovery Facility in Fond Du Lac, Wisconsin produces biosolids which are used for land application or disposed of in landfills. The sludge produced at the facility is first treated by anaerobic digestion and then dewatered in a centrifuge. This produces biosolids containing 26% solids. The facility produces about 30 wet tons of biosolids each day and is hauled away to regional farms to be applied and incorporated into the soil. If the biosolids produced are not used then it is disposed of in landfills (City of Fond du Lac, 2018).

The Syracuse Wastewater Treatment Plant in New York is an example of a metropolitan wastewater treatment plant that produces biosolids. This facility has a peak design flow of 126 mgd but operates at 84 mgd on average. This facility services the City of Syracuse and other areas outside of the city in Onondaga County. After primary, secondary, and tertiary treatment, a polymer is added to the sludge and is thickened by gravity belt thickeners. The thickened sludge is then blended together and treated by anaerobic digestion. Then it is heated, mixed, and dewatered in a centrifuge. The biosolids produced contain 30-35% solids. The biosolids are either recycled or disposed of in landfills (Onondaga County, 2020).

Rensselaer County's Sewer District Wastewater Treatment Facility in New York has a peak design flow of 63 mgd but operates on average at 24 mgd. Figure 4 shows the process used at this facility to produce biosolids for beneficial use.

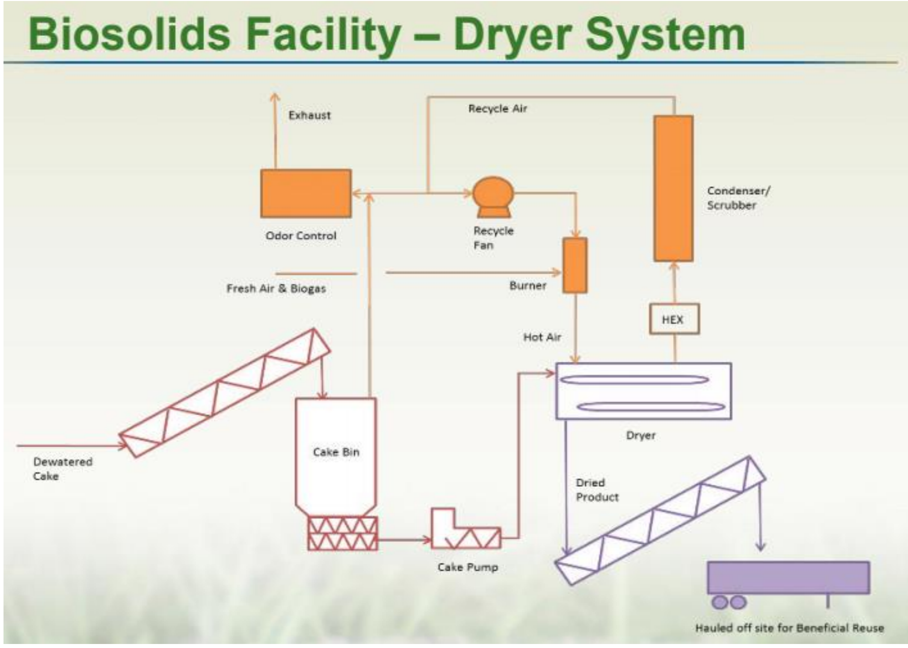

Figure 4: Schematic of Rensselaer County's Sewer District Wastewater Treatment Facility Dryer System. Source: Smith CDM, 2016

The sludge produced at this facility is treated by anaerobic digestion and is then dewatered. The resulting biosolids contain 23% solids. This dewatered biosolids is then further treated in a heat drying system. The heat drying system uses a mixture of air and biogas that is produced from the digestion process. This air/biogas mixture is then heated and used to heat and dry the biosolids. This system produces a 90+% dry product which is then hauled away or stored on site for up to 90 days. The biosolids produced at this facility are sold to help offset the cost of operation at the facility (Smith CDM, 2016).

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2. FEDERAL AND STATE REGULATIONS

2.1. Federal and State Regulation Codes

The federal biosolids regulations that must be followed were instated by the United States Environmental Protection Agency in 1993. It was established as a part of Title 40 of the Clean Water Act known as The Standards for the Use or Disposal of Sewage Sludge. The regulations specifically geared towards biosolids are outlined in Part 503 of this title. This rule details how biosolids are to be classified and the uses for those biosolids depending on their classification. This classification process depends on the concentration of pathogens and pollutants contained within. An in-depth guide to the rule published by the EPA offers suggestions on how certain concentrations of pathogens and pollutants can be achieved to reach certain biosolid classification thresholds. This rule also describes how biosolids would be used for land-application, one of the possible routes of removal for the biosolids if Class A is achieved (EPA, 1993).

The New York State regulations that must be followed are found in Title 6 CRR-NY, Chapter IV: Quality Services, Subchapter B: Solid Wastes. There are a few parts of this subchapter that are related to biosolids production, use, storage, facility operation, permits and more. Part 360 focuses on solid waste management facilities and general requirements. Part 361 focuses on the facility processes and requirements for Class A biosolids. Subpart 361-2 discusses the requirements for design and operation requirements for land application and storage. Subpart 361-3 discusses pathogen reduction, vector attraction reduction, and pollutant limit requirements to achieve Class A biosolids for use (NYS DEC, 2020).

2.1.1. Pollutant Restrictions

The pollutant restrictions described in Title 6 CRR-NY Subpart 361 section 3.9 and Title 40 CFR Part 503 Subpart C section 23 must be met. Subpart 361 section 3.9 describes the requirements that must be met if Class A biosolids are to be used for land application in New York specifically. Part 503 Subpart B section 13 details the requirements that must be met for land application to be considered anywhere in the United States. Table 1 shows the ceiling pollutant concentration limit requirements for both Federal and State regulations. As shown, the State requirements are more restrictive than the federal requirements. These state regulations will need to be met for Class A biosolids production if New York land application is to be considered.

Refer to Table 1 for a direct comparison of the state and federal regulations for biosolids pollutants. By showing a direct comparison of these ceiling requirements, it is easier to see how much stricter the restrictions are on a state level. This will be important to consider moving forward when deciding on a treatment process for disposal since it will be the state restrictions that will have to be followed (EPA, 1993).

Table 1 – Federal and State Pollutant Limit Requirements for Class A Biosolids

Parameter	Federal	State
	Maximum Concentration (mg/kg)	
Arsenic (As)	75	41
Cadmium (Cd)	85	10
Chromium (Cr-total)	3,000	1,000
Copper (Cu)	4,300	1,500
Lead (Pb)	840	300
Mercury (Hg)	57	10
Molybdenum (Mo)	75	40
Nickel (Ni)	420	200
Selenium (Se)	100	100

Zinc (Zn)	7,500	2,500

While these ceiling concentrations are important when first considering land application and reaching Class A biosolid classification, these concentrations do not consider the pollutant limits for specific land use situations. The pollutant concentrations for bulk land use are different than that for packaged and individual land use. Part 503 outlines the four main types of biosolids based on how they are used for land application. These types include Excellent Quality (EQ), Pollutant Concentration (PC), Cumulative Pollutant Loading Rate (CPLR), and Annual Pollutant Loading Rate (APLR) biosolids. These types are differentiated by their pollution level and how they are applied. Figure 5 below helps with visualizing how these types are separated based on use.

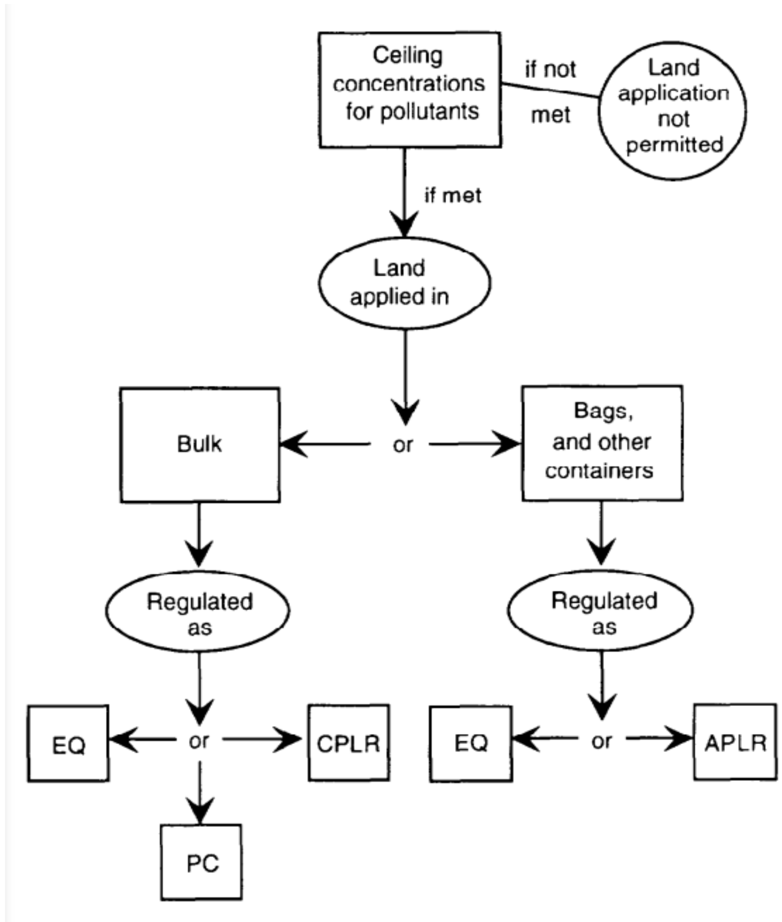

Figure 5: Types of Class A biosolids that are land applicable. Source: Cook, 1994

EQ biosolids are virtually unregulated for bulk land-application due to how strict the pollutant limits and vector attraction reduction requirements are to achieve the EQ standard. It is also possible for EQ to be bagged for commercial consumer use. These biosolids are typically the highest quality biosolid type people aim for. PC biosolids have the same pollutant limits as EQ biosolids only with less strict vector reduction requirements. PC biosolids have more restrictive management practices during the land application as well, making them slightly less desirable compared to EQ biosolids. They also are not viable for commercial bagging. The pollutant concentration limits for EQ and PC biosolids are very close to the New York pollutant limits for land application. This means that these types of Class A biosolids may be desirable when considering a land-application alternative for the biosolids. It should be noted however that the pollutant limits for Selenium in EQ and PC biosolids are a bit more restrictive than the standards set by New York state and the United States. The selenium limit set for EQ and PC biosolids is 36mg/kg while the limit set by both the state and federal government is only 100 mg/kg. Every other pollutant limit set by New York State either matches or exceeds the limits for EQ and PC biosolids (Cook, 1994).

CPLR biosolids are a bit less restrictive in their pollutant limits in comparison to the PC and EQ biosolid limits. The limit on Selenium for CPLR biosolids matches both the federal and state limit of 100mg/kg. While this option is much easier to achieve in comparison to the previous two options, there are more management practices that must be followed and pollutants that must be tracked. This puts more pressure on the biosolid applier, making it less desirable to farmers who would potentially use the biosolids for land application (Cook, 1994).

APLR biosolids are much more restrictive that any of the biosolid types previously discussed. The pollutant limits for this type of biosolid are much lower than that for the other types of biosolids. The vector attraction requirement is just as strict as the EQ requirement. The reason behind these strict pollutant limits and demanding vector attraction reduction requirements is that these biosolids are specifically catered for commercial bagging and individual use. They are not used for bulk application due to the cost of reaching such a standard of quality (Cook, 1994).

All four of these land application classifications can achieve the pathogen requirements for Class A biosolid distinction. As described, the main differences between them are the restrictions on pollutant concentrations.

Refer to Table 2 for the federal pollutant limits for these designations. This Table shows the pollutant ceiling concentration levels for all four types of Class A biosolids. By comparing these levels to those noted in Table 1, the ideal type of Class A biosolids for state land application can be found. From these tables, EQ and PC pollutant concentration levels seem to be the ones that mostly match or exceed the state requirements for these pollutants (Cook, 1994).

Table 2 – Federal Land Application Classification Requirements

Parameter	EQ and PC (mg/kg)	CPLR (kg/he)	APLR (kg/he/year)
Arsenic (As)	41	41	2
Cadmium (Cd)	39	39	1.9
Chromium (Cr-total)	1,200	3,000	150
Copper (Cu)	1,500	1,500	75
Lead (Pb)	300	300	15
Mercury (Hg)	17	17	0.85
Molybdenum (Mo)	-	-	-
Nickel (Ni)	420	420	21
Selenium (Se)	36	100	5
Zinc (Zn)	2,800	2,800	140

It should be noted that most of the pollutant limits for PC and EQ biosolids are met with the state concentration limits aside from the limit for selenium. This will be useful when considering which Class A distinction goal is recommended for the RWRRF.

2.1.2. Pathogen and Vector Attraction Reduction

The requirements for wastewater sludge to achieve Class A biosolids are outlined in regulation code Title 6 CRR-NY Subpart 361 section 3.7(a). Pathogens in the waste for Class A biosolids must either contain a fecal coliform density less than 1,000 most probable number per gram of total dry solids or the density of salmonella sp. bacteria in the biosolids is less than 3 most probable number per 4 grams of total dry solids. The reduction of pathogens in the biosolids must be met at the time it is used or disposed and must be treated by one of the alternatives described in subpart 361-3.7.

Vector attraction reduction criteria for Class A biosolids are also outlined in regulation code Title 6 CRR-NY Subpart 361 section 3.7(b). One of the methods described in that section must be achieved before the biosolids leave the facility. Vector attraction reduction must be met either after meeting the pathogen reduction requirements or at the same time the pathogen reduction requirements are met.

There are two main options when it comes to dealing with the pathogens that are present in untreated sewage. These options include high heat temperature treatment and high pH treatment. Part 503 Subpart D Section 32 outlines these processes and how these processes are to be executed based on the solids content of the influent sludge. The high temperature alternative uses high heat in order to kill any pathogens that are living within the sludge. The sludge must be heated for an extended period of time to ensure that all the sludge is properly heated and rid of any pathogens living within. For the high temperature alternative, there are calculations presented in this section that outline how high the temperature of the sludge should be raised and the amount of time that the sludge should be kept at that temperature. The equation to be used for this calculation can be found below where D is the time in days and t is the temperature above the minimum 50 degrees Celsius required for treatment. These variables, as shown in the equation below, have an indirect relationship (EPA, 1993).

$$D = \frac{131{,}7000{,}000}{10^{0.1400t}}$$

For the pH alternative, a high pH material is added to the sludge in order to kill pathogens that cannot survive in the high pH atmosphere. During this treatment method, the temperature also needs to be raised in order to improve the effectiveness of the treatment. While the duration and temperature of the heating isn’t nearly that of the first alternative, it does mean that a heating system would need to be implemented in both alternatives. The total time required for this process to be executed is 72 hours or 3 full days. An additional 12-hour heating period above 50 degrees Celsius is also required in this process. With this information, alternatives for treatment can be analyzed for their relative feasibility and effectiveness in meeting these requirements (EPA, 1993).

2.1.3. Land Application and Storage Requirements

Subpart 361-2.4-2.7 of the State regulations code Title 6 CRR-NY must be followed for land application and storage of biosolids. These subparts describe the requirements that must be met if Class A biosolids are to be used for land application or storage. The biosolids used for land application must meet all requirements stated above for pollutant limits, pathogen reduction, and vector reduction. Sections 361-2.4 and 361-2.5 must be followed for land application and include information for permit application requirements, land application criteria including nutrient loading, monitoring and recordkeeping requirements, access and crop restrictions.

If biosolids are being produced but there is no immediate use for them, the biosolids must be stored. The requirements specified in Subpart 361-2.6 and 361-2.7 must be met. These sections include information on permit application requirements, storage location in relation to site features, sampling and inspection, and construction options.

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2.1.4. Requirements for Other Disposal Options

Landfill disposal is also an option to consider for the resulting biosolids since landfill disposal has far fewer pollutant removal and stabilization requirements. Subpart C section 23 of the Part 503 rule outlines the pollutant federal limits for surface disposal. Title 6 CRR-NY Subpart 363-7.1(j) outlines the New York state requirements for disposal of biosolids in landfills. The federal and state pollutant requirements for disposal can be found in Table 3 below. These limits do not include domestic sewage as a source of sludge.

Refer to Table 3 for the ceiling concentrations for disposing of biosolids through landfill disposal. Comparing this with the ceiling concentrations for land-application, this table helps in illustrating how different the requirements are between landfill dumping and land-application. This also shows how much the treatment processes will have to achieve on this metric and it will be something to keep in mind when deciding on a treatment option.

Table 3 – Federal and State Pollutant Limit Requirements for Landfill Disposal

Parameter	Federal	State
	Maximum Concentration (mg/kg)	
Arsenic	73	41
Chromium	600	1,000
Nickel	420	200

New York State also requires that the biosolids are stabilized, dewatered to at least 20% solids, and exhibit no free liquid to be disposed of in landfills. Stabilization can be achieved either by digestion or lime stabilization. Other state requirements can be met if digestion or lime stabilization are not met at the treatment facility. These other state requirements are outlined in Title 6 CRR-NY Subpart 363-7.1(j).

3. DESIGN ALTERNATIVES

3.1. Design Considerations

There are a few design elements that we must consider in addition to which process we recommend to produce Class A biosolids. These design considerations include site limitations, dewatering techniques, odor control, and dust control. Each design alternative will need to address these appropriately.

3.1.1. Site Limitations and Proposed Facility Expansion

There are several site limitations that must be considered when choosing a process for producing Class A biosolids. On the West border of the facility site there are wetlands. Expansion of the facility near these wetlands will result in environmental concerns being accounted for. There also needs to be room for trucks to move throughout the site from River avenue on the South side of the site. One of the tanks as shown in Figure 6 is not currently being used and could be repurposed as a storage tank. The proposed site for expansion of the facility is also shown in Figure 6 and is roughly 1,500 sq. ft. This is located where the old UV disinfection treatment was but is no longer used since the facility was recently upgraded. Any underground piping and utilities will have to be considered in the costs of any construction done in the proposed area.

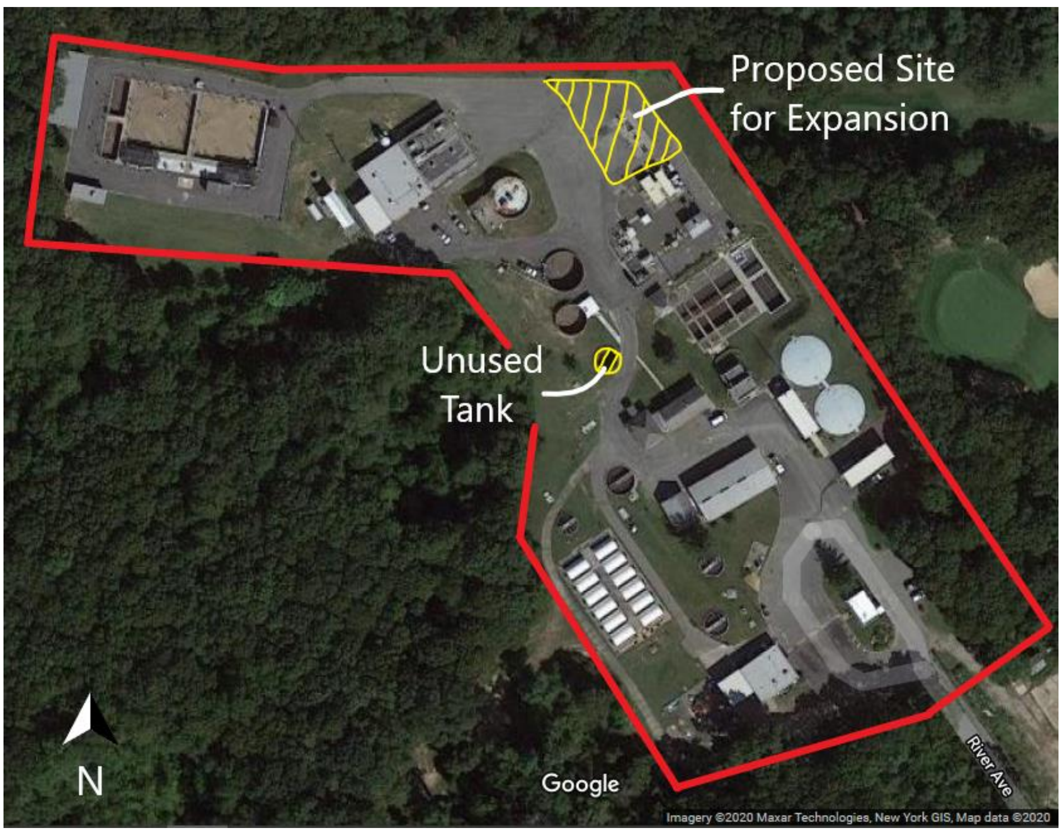


Figure 6: Aerial view of proposed site for facility expansion.

3.1.2. Dewatering Alternatives

Dewatering of the sludge produced at the RWRRF is currently done using a belt filter press as shown in Figure 7. The belt filter press has been in operation at the facility for about 12 years. This produces a dewatered sludge containing 15-17% solids. There are other options for dewatering that could increase the percent solids contained in the sludge. The cost savings for increasing the percent solids can not only apply to hauling costs but also to the processing costs for producing Class A biosolids.

Figure 7: Photos of the belt filter press at RWRRF.

3.1.2.1. Belt Filter Press

A belt filter press removes water from the sludge by applying pressure to squeeze the water out of the sludge. This is done using tensioned porous belts that pass over rollers with decreasing diameters as shown in Figure 8. The typical components of a belt filter press include the porous belts, rollers, bearings, belt tracking and tensioning system, controls and drives, and a belt washing system. The resulting dewatered cake from a belt filter press contains 15 - 25% solids (EPA, 2000).

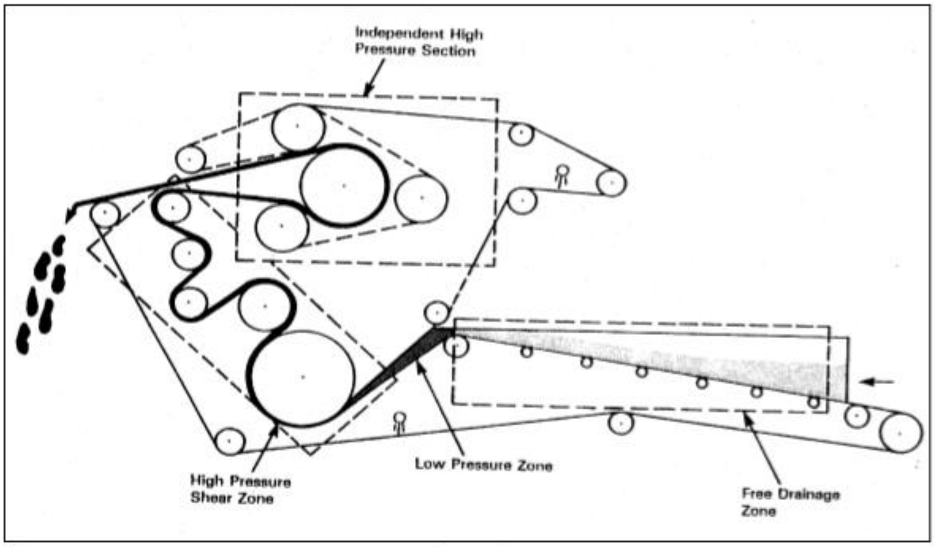


Figure 8: Diagram of a typical belt filter press. Source: EPA, 2000

Operation of a belt filter press includes monitoring polymer usage, feed volume of sludge, and dewatered cake. The tensioning on the porous belts periodically need adjustments. Also, the bearings and rollers require frequent lubrication. The belts need to be washed at the end of each day of use. After around 2,700 hours of running time the porous belts need replacement. The typical operation and maintenance (O&M) costs for a belt filter press can range from $80 - $200 per DTS. The polymer that is used in a belt filter press is dependent on the facility but on average costs about $25 per million gals. of sludge feed. Typical capital costs for a belt filter press machine range from $150,000 to $180,000 but this does not include installation and other related costs such as feed pumps (Glenn, 2001). A belt filter press uses an estimated 80 kWh/DTS of electricity during operation. The advantages and disadvantages of a belt filter press are as follows:

Advantages

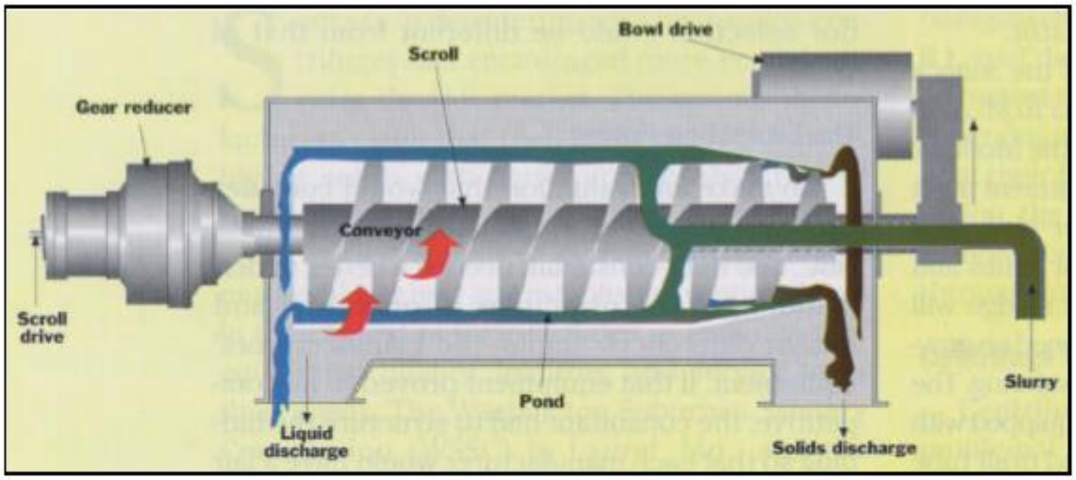
- Low staff requirements to operate.
- Simple and inexpensive maintenance.
- Quick startup and shutdown.
- Relatively low noise when in use.

Disadvantages

- Odors could be an issue which requires odor control and a ventilation system.
- Operator attention is higher than other dewatering options.
- Belt washing is required each day of use which can be time consuming.

3.1.2.2. Centrifuge

Centrifuge is another type of dewatering machine which uses high rotational speeds of a cylindrical bowl to separate the water from the solids in the sludge. Figure 9 shows a typical cross-section diagram of a centrifuge and shows how it separates the water from the solids of the sludge. For a sludge containing 2-4% solids, 5-16 lbs. of polymer per DTS is required for operation. This produces a dewatered cake containing between 25-35% solids (EPA, 2000).



Source: Ireland and Balchunas, 1998.

Figure 9: Cross-sectional diagram of a typical centrifuge.

Centrifuges can be operated almost fully automatic while running. The tasks the operators must do is when starting up and shutting down the centrifuge and putting feed into the machine. Operators need to monitor polymer and sludge feed rate to optimize the output cake. When shutting down the centrifuge, the speed is gradually decreased then is emptied and cleaned out before fully shutdown. Required staff hours to operate one centrifuge can be between 4-8 hours per day of use but additional machines only increase the required staff hours by 2-4 hours depending on the number of additional machines. Typical O&M costs for a centrifuge range from $65 - $210 per DTS. Polymer costs are based on usage but average around $24 per million gals. of sludge feed. Capital costs range from $200,000 to upwards of $500,000 depending on the required size (Glenn, 2001). The power consumed by a centrifuge when it is running is estimated at 100 kWh/DTS. The main advantages and disadvantages to using a centrifuge for dewatering are as follows:

Advantages

- Low O&M costs relative to performance.
- Minimal operator attention when in operation.
- Easy to clean the machine out.
- Small required floor space for the machine.

Disadvantages

- High power consumption.
- Spare parts are relatively expensive.
- Generates a lot of noise while in operation.
- Startup and shutdown take about one hour to get to operation speed or to stop.

3.1.2.3. Rotary Drum Vacuum Filter

A rotary drum vacuum filter can be used to dewater liquid sludge. The sludge is pumped into a trough where a large suspended drum is partially submerged in the sludge. The drum rotates up to a speed of 2 rpm. As the drum rotates, the vacuum draws the liquid through a filter media cloth on the drum surface by using a liquid ring vacuum. The solids adhere to the drum surface as the vacuum continues to pull air through the solids and removes liquid. This dries and dewaters the cake as the drum continues to rotate. The filtrate air is pulled through the filter cloth through internal filtrate pipes that pass through the rotary valve and onto a filtrate receiver. The filtrate receiver separates the vapor and the liquid. The dewatered cake is then discharged into a conveyor or chute to be processed further or disposed of (Komline, 2020).

For a liquid sludge containing 0.5 - 5% solids, the rotary drum vacuum filter can produce a dewatered cake containing 10 - 40% solids. Figure 10 shows a typical setup of the required components for a rotary drum vacuum filter with the addition of precoat material. Precoat material is typically diatomaceous earth, diatomite, or other suitable material and is applied to the drum at a layer thickness of 1in to 6in.. Precoating is only required if the cake is slimy or sticky and binds to the filter cloth creating difficulties when trying to discharge the cake from the drum (Komline, n.d.).

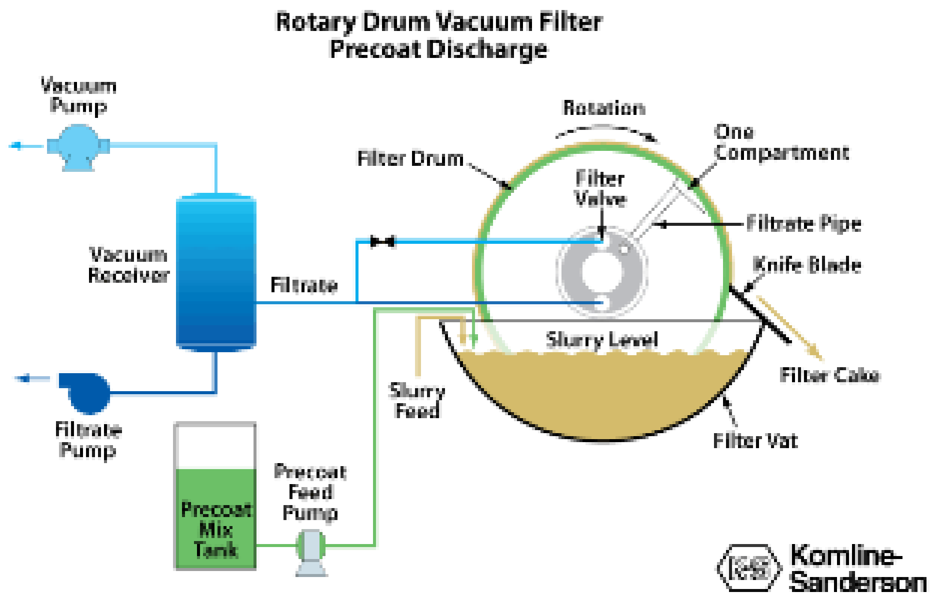


Figure 10: Schematic of a typical rotary drum vacuum filter system with a precoat discharge. Source: Komline, 2020

Operation of a rotary drum vacuum filter is almost entirely hands-off, requiring minimal operator attention. Operators monitor the level of liquid sludge in the trough and the drum's rotational speed to optimize operation. The slow rotational speed means that the rotary drum vacuum filter will run generally trouble-free with low required maintenance. Maintenance that is required includes lubricating the drives and bearing and occasionally changing the filter cloth. If a precoat is used, then it will need to be replaced every day or so depending on the layer thickness. Other maintenance includes replacing worn parts such as the cake discharge assembly and parts on the filter valve. O&M costs are comparable to operating a centrifuge and range from $60 - $200 per DTS. Power consumption is mainly due to the vacuum pump and can be as high as 300 kWh/DTS in total. Typical capital costs for a rotary drum vacuum filter are around $225,000 but this does not include costs for the additional required equipment. The total capital cost for the entire system can cost over $500,000. The main advantages and disadvantages of a rotary drum vacuum filter are as follows:

Advantages:

- Low O&M costs with minimal operator attention required while running.
- Relatively small required floor space.
- Wide ranges of sizes to accommodate needs.

Disadvantages

- High energy consumption by the vacuum pump.
- High capital costs due to requiring additional equipment to run such as the vacuum pump, filtrate pump, and receiver unit.
- May require addition of precoat material to the drum to prevent binding.
- Optimal operation is for continuous use.

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3.1.2.4. Filter Press

Another type of dewatering machine is the filter press as shown in Figure 11. This process uses pressure to dewater sludge. This process is not continuous but is done in cycles. The sludge is first chemical conditioned by mixing the sludge with a polymer. Then the sludge is pumped into pressure chambers between plates that are lined with a filter cloth as seen in Figure 12 (Hydroflux, 2019). As the pressure gradually builds in the chamber, the water is filtered through the filter cloths. The filtrate flows between ridges in the plates and is discharged. The remaining solid cake is retained between the plates and falls from the plates at the end of the cycle. Cycle times range from 1.5 to 6 hrs (Ontario, 2019). The resulting cake contains 25 - 50% solids. The resulting solids percentage is dependent on the initial sludge conditions.

Figure 11: Image of a typical filter press machine. Source: Hydroflux, 2019

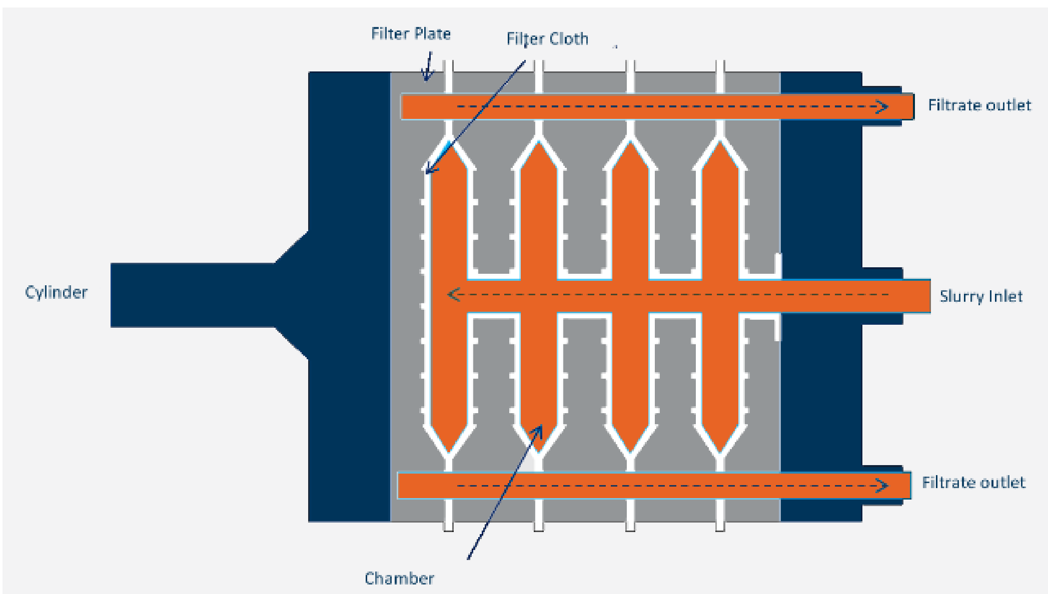

Figure 12: Diagram of the internal process of a filter press. Source: Ontario, 2019

Operation of a filter press involves startup and shutdown of the machine, monitoring sludge conditioning prior to feeding into the filter press, monitoring the feed and chamber pressure to optimize performance, removal of the cake from the filter plates as needed, and cleaning the filter plates. Maintenance of the filter press includes replacing the filter cloth and gaskets on the plates as needed and periodically replacing worn filter plates. Typical capital costs for a filter press range from $100,000 - $200,000 with O&M costs estimated to be $60 - $100 per DTS. Some of the main advantages and disadvantages of a filter press are as follows:

Advantages:

- High solids percentage of dewatered cake.
- Low operational requirements and simple maintenance
- Startup and shutdown are simple and quick

Disadvantages:

- Process is done in batches instead of continuous.
- Cake removal requires some manual assistance
- Requires large amounts of conditioning agents such as polymers

3.1.2.5. Summary

There are many dewatering techniques that can be used for dewatering sludge. The techniques previously mentioned are the most viable for use at the Riverhead Water Resource Recovery Facility.

Refer to Table 4 which shows a comparison of the resulting cake solids percentage, typical capital costs, O&M costs, relative operator attention, and estimated power consumption for the various techniques discussed. The most expensive and least feasible option from this table is the rotary drum vacuum filter. The best options, when compared to the already existing belt filter press, are the centrifuge and the filter press although both options have their advantages and disadvantages which must be considered.

Table 4 – Summary of Dewatering Techniques

Dewatering Technique	Range of Solids Percentage of Dewatered Cake	Typical Capital Costs	Typical O&M Costs (per DTS)	Relative Operator Attention	Estimated Power Consumption[1] (kWh/DTS)
Belt Filter Press	15 - 25%	$150,000 - $180,000	$80 - $200	High	80
Centrifuge	25 - 35%	$200,000 - $500,000	$65 - $210	Low	100
Rotary Drum Vacuum Filter	10 - 40%	$500,000+	$60 - $200	Low	300
Filter Press	25 - 50%	$100,000 - $200,000	$60 - $100	Moderate	100

1 Source: Ontario, 2019

3.1.3. Odor and Dust Control Systems

Part of the design considerations for treated wastewater sludge, including Class A biosolids sludge, is odor control. Odor control is an important factor for any sludge treatment. It is especially important in our case since the RWRRF is located close to a residential area. Odor control is needed however not just a concern for treatment plants in residential areas. Treated wastewater sludge needs to be assessed for odor when used for fertilizer, soil rejuvenation, compost, and etcetera. In order to control this odor, there are odor contributing factors that can be controlled, as well as several design choices for odor control options.

Odor, or nuisance odors (Biosolids and Residuals Management Fact Sheet) can affect property value, aesthetic value, and the quality of life of those in constant contact with it. All waste sludge has toxic airborne pollutants in its odors that can be extremely harmful if not controlled correctly. These odors originate from the very composition of waste sludge or biosolids, as well as their nature. It is important to remember that waste sludge originally started out as sewage or cesspool waste. Because of this, odor assessment is a required element to consider during design.

During odor assessment, there are several culprits that are responsible for the serious and offensive odors generated by waste sludge and its treatment process including, but not limited to, compounds such as sulfur, ammonia, amines, mercaptans, and organic fatty acids. Heating, aerating, and digesting, all essential steps to the treatment process, are typically responsible for the release of these odors. In odor assessment, we have been able to identify which processes are responsible for the release of different odorous compounds. Anaerobic digestion for example, although a great design choice for the achievement of Class A biosolids for certain treatment plants, produces sulfur containing gases such as hydrogen sulfide as well as methane, a gas known for its repulsive odor.

There are five main independent factors that are identified when performing an odor assessment:

1. **Intensity/pervasiveness**: a standard compound of similar concentration is compared to the original odor to gauge its strength.
2. **Character**: character can be defined as the mental associations made by people in smelling and assessing the resultant odor. For example, nobody would drink Aquafina if they advertised that their water was refined and filtered sewage water.
3. **Hedonics**: hedonics is the relative pleasing or unpleasing odor sensed by people.
4. **Detectability/quantity**: how many dilutions are required in order to reduce an odor to its minimum detectable threshold concentration? In achieving Class A biosolids, part of the goal is to ensure that pathogen levels within the solid are reduced to virtually zero, which makes detectability/quantity vital to the odor assessment process, especially considering the goal of Class A biosolids is reuse.
5. **Mass**: it is the volume of odorous air produced.

Each of the factors listed independently have their own importance as well as their own. The fifth and final factor in odor assessment is simply the associated testing methods and mitigation measures. It is important to note that for the purposes of this report, they are a vital component of the proposed design process since the ultimate goal is to reduce costs by achieving Class A classification for reuse, redistribution, and resale of biosolids sludge.

Part of the odor assessment process is something called an odor audit. In an odor audit, an air dispersion modeling is performed by a biosolids specialist/consultant. A successful odor audit completes all of the following:

1. Quantify each source responsible for individual odor emissions (point source, area source, etc.).
2. Perform an analysis of which compounds are producing which odor.
3. Determine which treatment processes are causing odors and which ones are not.
4. Of those sources listed in 1 and 3, identify the most significant sources of odor.
5. Upon completion of the air dispersion modeling, obtain the relevant data in order to determine the necessary steps to follow.
6. The specialist then completes the audit and presents the most effective and efficient odor management plan.

The odor assessment and resulting audit can be beneficial in that they will most likely lead to a significant decrease in capital expenditures and operating costs and ultimately increase effectiveness and efficiency. The information obtained from the audit can often justify several relatively low-cost design changes including but not limited to reheating to increase thermal buoyancy and dilution with ambient air. These depend on the already existing conditions for the biosolids sludge.

The other side of the coin is odor control for land application. This is important to consider taking into account the goal of this project: Achieve Class A classification for reuse/redistribution/resale. So, what responsibilities lie on the shoulders of biosolids producers, and what should be done in order to successfully work around these parameters? There are several that need to be discussed, extending beyond agreements/contracts made between producers/clients.

The biosolids producer is responsible for odor control even at land application sites where a third-party contractor was hired for transportation, storage, or delivery. Along with this, proper planning is needed from the producer's side as failsafe programming in the event that odor response is needed. These are primarily necessary in the event of odor complaints. The provider should also have the means to transport the biosolids away from the land application site if odor complaints are issued.

It is important for the provider to minimize odor for land application since the site of land application's long-term efficacy is dependent on it. Many biosolids reuse and recycling programs have been subject to local ordinances banning them due to odor complaints. The federal government does not regulate odor since there is no evidence that shows it can be detrimental to human health, however these programs have suffered due to complaints and the aforementioned local ordinances. The EPA lists several methods for odor reduction at land application sites:

- Proper stabilization, conditioning, and managing of biosolids at treatment sites prior to delivery for land application.
- Elect remote and out of sight areas for land application.
- Ensure application of well stabilized material.
- Properly clean all equipment every day.
- Application of biosolids directly into subsurface/soil.
- Effectively minimize storage time.
- Ensure the storage area is remote and out of sight.
- Consider wind conditions in land application as odors can be carried downwind.
- Take into account outdoor holidays/events such as Memorial Day and Labor Day.
- Have a failsafe odor control program including landfill.

3.1.3.1. Biofilters

One option for odor control is biofilters. Biofilters treat odor by removing the odor through adsorption and absorption into a natural media bed. In the natural media bed, microorganisms oxidize the compounds, in turn neutralizing the odors. All types of composting operations use biofilters to treat the air. There are several advantages and disadvantages to consider as follows:

Advantages:

- Reduction of odor through biofiltering is quite significant and as a byproduct, volatile organic compound emissions are also significantly reduced.
- The technology behind biofiltering is fairly simple, with very few moving parts.
- Biofiltering equipment does not require large amounts of energy.

- Biofiltering equipment is not affected by cold winter temperatures. This is important considering the climate where the Riverhead treatment plant is located.
- Biofilter equipment does not require a stack and is easily out of sight.

Disadvantages:

- A large land area is needed for installation of biofilters.
- The biofilter surface area size is directly proportional to the airflow that is to be treated - a 45 to 60 second detention time is needed.
- Biofilters can perform poorly depending on the relative humidity in the air to the moisture present in the filter media.
- Biofilters are subject to catastrophes such as short circuits, pH depression, and high temperature.
- Reduced efficiency in ammonia removal can occur if ammonia concentrations exceed 35 ppm.
- A lot of water is used in order to keep the biofilters moist.
- Leachate and condensate result from biofiltering and therefore need to be disposed of.
- Biofilters are not desirable for very strong odors.

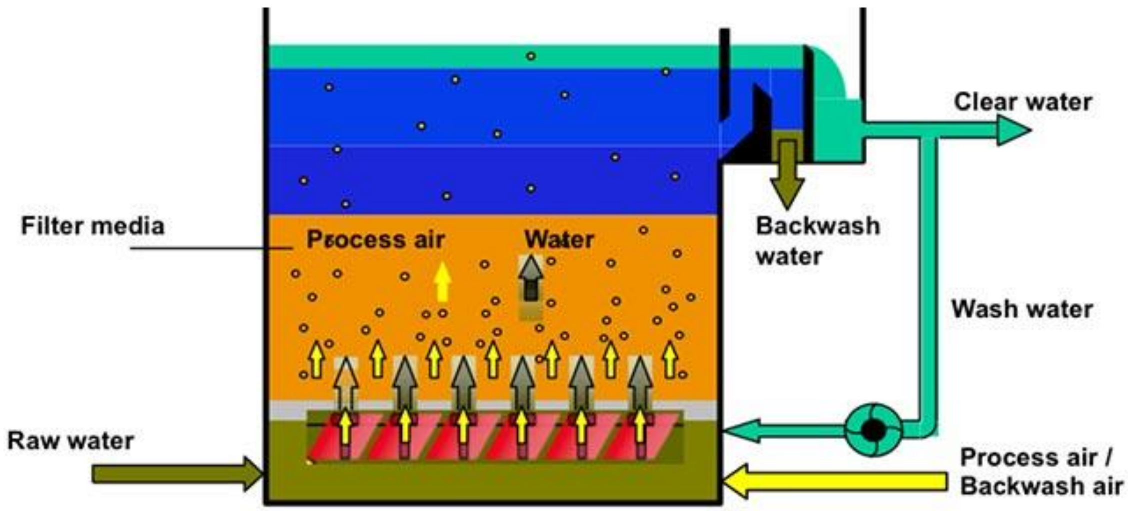

Figure 13: Biofilter Diagram

Different materials can be chosen for the porous media: they include but are not limited to bark, wood chips, yard waste, agricultural waste compost, peat moss, sand, pulverized volcanic rock, and oyster shells. Materials like oyster shells can provide pH control, whereas materials like sand are needed to ensure porosity of the media bed. An optional addition is drip piping in order to keep the media bed moist. Leachate collection and disposal is often facilitated by a layer of impermeable PVC or a similar material that lays under the gravel bed where the biofilter equipment rests.

Depending on the nature of the design, (i.e. the location it is installed whether it be a soil trench or impermeable container) it might be necessary to engineer the container in such a way that short circuiting and corrosion from acidic leachate are both avoided. All in all, biofiltering is an effective low-cost method for odor control. An estimated life expectancy of biofilters, given proper care and maintenance in terms of temperature, moisture, and so on, is roughly one to seven years, with filters being replaced every two years.

3.1.3.2. Sludge Basins

Another option for odor control is activated sludge basins. Similar to biofiltering, activated sludge basins perform odor removal through adsorption and absorption. Where they differ, however, is that activated sludge basins also remove odor through condensation and microbial oxidation (Biofiltration, Advanced Treatment). There are several advantages and disadvantages to consider as follows:

Advantages:

- Activated sludge basins are extremely cost effective (both capital and operating expenses) in facilities that operate aeration basins.
- Activated sludge basins, unlike biofilters, can treat moderate to severe odors.
- Activated sludge basins are simple and have low operating/maintenance considerations.

Disadvantages:

- Blower corrosion can be a major impeding factor in the efficiency of activated sludge basins.
- Steel inlet filters and piping are at even more risk for corrosion.
- A greasy film and/or tar-like substance can form on the internal parts of the basin, which can reduce its capacity to treat odor.

Now that the advantages/disadvantages associated with activated sludge basins have been explored, it is appropriate now to look at the design criteria and the operation/maintenance as well as the costs associated with each of them. Generally, the foul air diffuser and blower assembly for an activated sludge basin should be at the very least eight feet underground, in order to ensure maximum efficiency of odor removal. Since the components are easily subject to corrosion, they must be designed accordingly. The best materials for this, generally, are stainless steel and PVC. The volume of foul air can be reduced and/or minimized by including flat gasketed covers or individual enclosures for blending equipment. The major benefit with activated sludge basins is that if a treatment site already has and is currently using a diffused aeration system/aeration basin, a producer can expect little to no increase in cost in terms of O&M. Aside from periodic cleaning, activated sludge basins require little additional maintenance, making them a good choice for moderate to severe odor control.

3.1.3.3. Other Odor Control Options

Additional options for odor control are wet chemical scrubbers, regenerative thermal oxidizers, counteractants, neutralizing agents, and oxidizing agents. The EPA provides tables for both efficiency as well as the costs associated with each odor control option as shown below. Keep in mind, cost can vary significantly and is dependent on many factors. In order to properly assess which option is best, an odor audit needs to be conducted by a specialist as mentioned above.

Refer to Table 5 which breaks down the removal efficiencies of common methods of odor control. This table shows how effective these methods are at removing certain materials from the air. The table shows a direct comparison of the multiple methods of odor control on a numerical basis. With this information, we can decide on which method may be the most useful to use depending on which treatment option is chosen.

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Table 5 – Reported Removal Efficiencies

System	H_2S	NH_3	Odor Units (D/T)
Biofilter	>98%	>80%	>95%
Activated Sludge (Coarse Bubble)	<85%-92%	>90%	90-95%
Activated Sludge (Fine Bubble)	>99.5%	N/A	>99.5%
Wet Scrubbers	>95%	>95%	<80%-99%
RTO	N/A	N/A	>95%
Chemical Oxidants	>99%	N/A	Up to 99%
Counteractants and Neutralizing Agents	30%	30%	N/A

Source: Schiffman et,al, Williams, Ostojic & O'Brien, Giggey et al, Solomon, LeBeau & Milligan, Pisotti, Singleton et al; Vaith et al; Ficek.

Refer to Table 6 which breaks down the relative costs of the mentioned odor control technologies. While specific costs are not useful due to the extreme variety in each category, knowing the costs of these systems in relation to each other can help with choosing the most cost-effective option if a treatment option requires odor control. The breakdown of each component of cost for the odor control systems will assist in finding a preferred option.

Table 6 – Relative Costs of Odor Control Technologies

System	Overall	Capital	Operation/ Maintenance	Electrical or Fuel	Supplies/Chemicals	Effectiveness
Biofilter	Moderate	Moderate-but land area needed	Moderate	Low	Water needed	High>95%in compost
Advanced Sludge Basins	Low, if existing system	Low, if existing system	Low, if existing system, may corrode blowers	Low, if existing system and biosolids processing facility is close	Low	High 90-95% for H2S and ammonia
Wet Chemical Scrubbers	High	High-up to 50% of total plant costs	High-much high-speed equipment & instrumentation	High-must move water at high pressure	High-chemical costs and water demand	High <80-99% handles alkaline stab and all odors
Regenerative Thermal Oxidizers	High	Moderate	High-due to high temp equipment	High-tremendous heat demand	High-oil or gas	Good for organic odorants from incinerators, and heat dryers
Oxidizing Agents	Varies-moderate to high	Low	Low-just material handling issues	Low-small pumps required	High-potassium permanganate can be expensive	Varies from one plant to another
Counteractant & Neutralizing Agents	Moderate	Low-moderate	Varies from one plant to another	Low	High-usually patented compounds	Varies, but may help at end use site

Source: Hentz et al, Giggey, Ostojic and O'Brien, Pisarcyk and Rossi, Ponte, Bowker, Vaith et al, Williams, Wu.

3.1.3.4. Dust Control

In biofilters, dust control systems are typically not needed. Particulate matter builds up in the biofilter media. This issue is easily circumnavigated by simply replacing the filter, which is a cheap maintenance cost. In activated sludge basins, the addition of inlet covers allows for particulate matter buildup to be avoided. Part of the reason wet chemical scrubbers are typically less popular is that there is a high potential for emission of particulate matter from the scrubber exhaust stack. In AAS, according to the EPA, small amounts of particulate matter may be emitted by the processing facility, but these are easily mitigated.

3.2. Recommended Design Alternatives

There are a wide variety of processes that can be utilized to produce Class A biosolids from the waste activated sludge that is produced at the RWRRF. Our recommended design alternatives include thermal drying, thermal hydrolysis, and advanced alkaline stabilization (AAS). Each of these processes have their advantages and disadvantages but they meet the requirements for Class A and are viable options for the project site given the site limitations.

3.2.1. Thermal Drying

Thermal drying involves heating sludge to a high temperature for extended periods of time to dewater and kill any pathogens contained in the sludge. This process utilizes direct or indirect heat to drive water out of wastewater solids and produce a Class A biosolid with 90% or higher dry solids percentage. This process dewaters the sludge through evaporation and kills the bacteria through the high heat. Thermal drying meets state regulation requirements from Title 6 CRR-NY Part 361 Subpart 3.7 section a subsection 1-i-b for pathogen reduction. This also meets state regulation for vector attraction reduction according to Title 6 CRR-NY Part 361 subpart 3.7 section b subsection 1-viii since the resulting biosolids produced by thermal drying has a solids content higher than 90%. This process ideally works for a sludge with an already high solids content, since it requires less energy to dewater and thereby requires less time to complete. However, knowing that the common dry solids concentration averages 15%, estimates on its effectiveness can still be obtained.

The equipment necessary for a thermal drying system varies depending on the type of drying unit used but typically includes the drying unit, burner or boiler, condenser unit, and an air recycling fan (WRRF Data, 2014). In addition, the sludge cake must be transported from the dewatering machine to the drying unit using a cake pump and may require storage and mixing before the dewatered sludge is used in the dryer system. A conveyance system for the dried biosolids from the dryer unit will be required. Also, storage for the dried biosolids will be needed. An odor control and dust control system will also be required since the biosolids is a very dry material. Figure 14 shows a basic schematic of an indirect drying system with necessary equipment. This schematic is utilizing a paddle dryer unit manufactured by Komline-Sanderson (Komline, 2008).

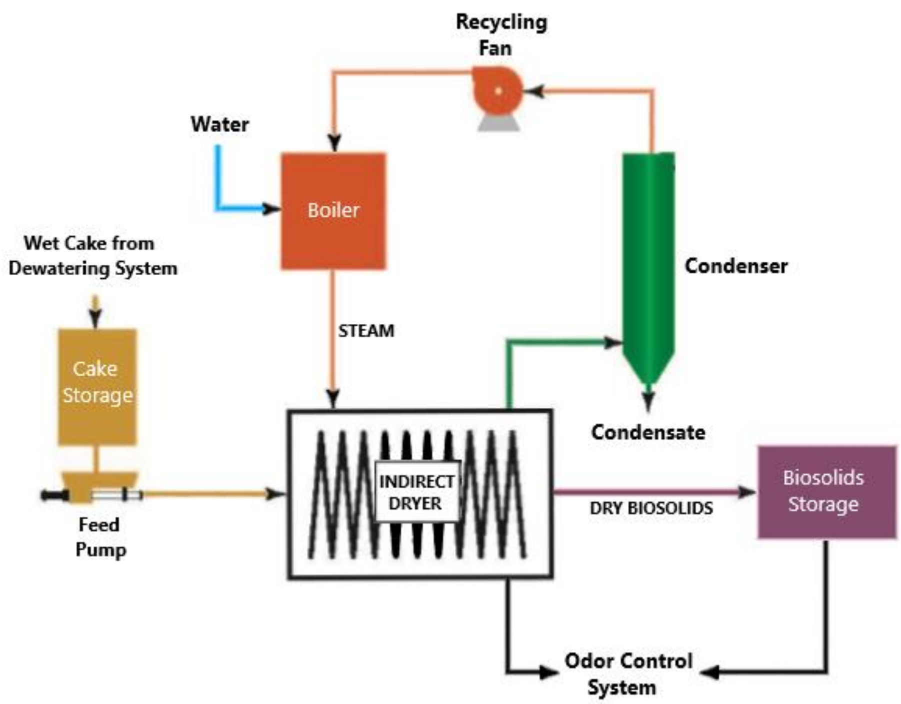

Figure 14: Schematic of an indirect drying system using a paddle dryer.
Source: WRRF Data, 2014

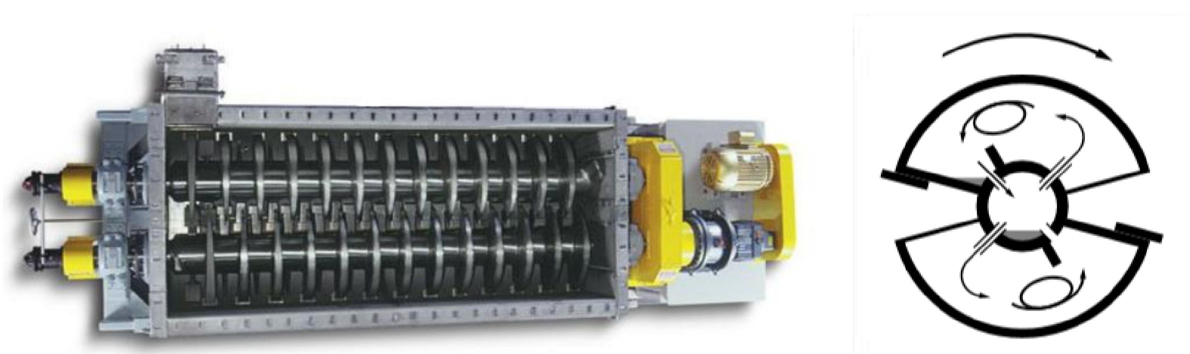

Figure 15: Image of a typical indirect paddle dryer unit manufactured by Komline-Sanderson and the flow of steam within each paddle. Source: Komline, 2008

Figure 15 shows an indirect dryer unit manufactured by Komline-Sanderson that could be utilized at the Riverhead Water Resource Recovery Facility. Reuse water at the facility would be utilized in the boiler where it is heated to create steam. That stream is sent to the indirect dryer system and is evenly distributed to the paddles through a rotary joint. The steam enters the paddles, as shown in Figure 15, and heats them up which then heats and dries the sludge cake. Any condensate within the paddles is removed as the paddles revolve as well as excess stream front the system. The steam and condensate are sent to a condenser unit where the air and water is separated (Komline, 2008). The air is then recycled back into the system by use of a recycling fan. The water can then be sent to be treated or back into the boiler to be heated again. As the sludge cake is conveyed through the drying unit the water evaporates and the sludge dries. The sludge is transferred into usable Class A biosolids by the end of the drying process. These biosolids will then be stored until they are utilized. The thermal drying process has many advantages and disadvantages as follows:

Advantages:

- Reduced weight and volume from increased percent solids and water reduction.
- Reduced weight can reduce hauling costs.
- Reduced volume decreases storage needs.
- Dried biosolids can be utilized easily in various ways.
- Installed system is compact and low maintenance.

Disadvantages:

- High Power Consumption
- High capital costs compared to other systems.
- Particulate matter and odor produced from dried biosolids.
- Equipment is complex and requires experienced operators.
- Safety issues pertaining to fire risk.

The main contributor to the O&M costs for thermal drying is the energy costs, which can account for over 50% of the total O&M costs (EPA, 2006). It takes approximately 1,450 BTUs of energy to remove 1 pound of water through the indirect drying process. The current sludge cake produced at the Riverhead Water Resource Recovery Facility contains 15% solids. This requires about 4,700 kWh of energy per DTS produced. If the initial dewatered sludge cake had a higher solids percentage than the energy consumption for the thermal drying system would be greatly reduced. The graph in Figure 16 shows how the energy consumption decreases as the percent solids of the dewatered sludge increases. This graph assumes the dried biosolids produced from the drying system contains 90% solids.

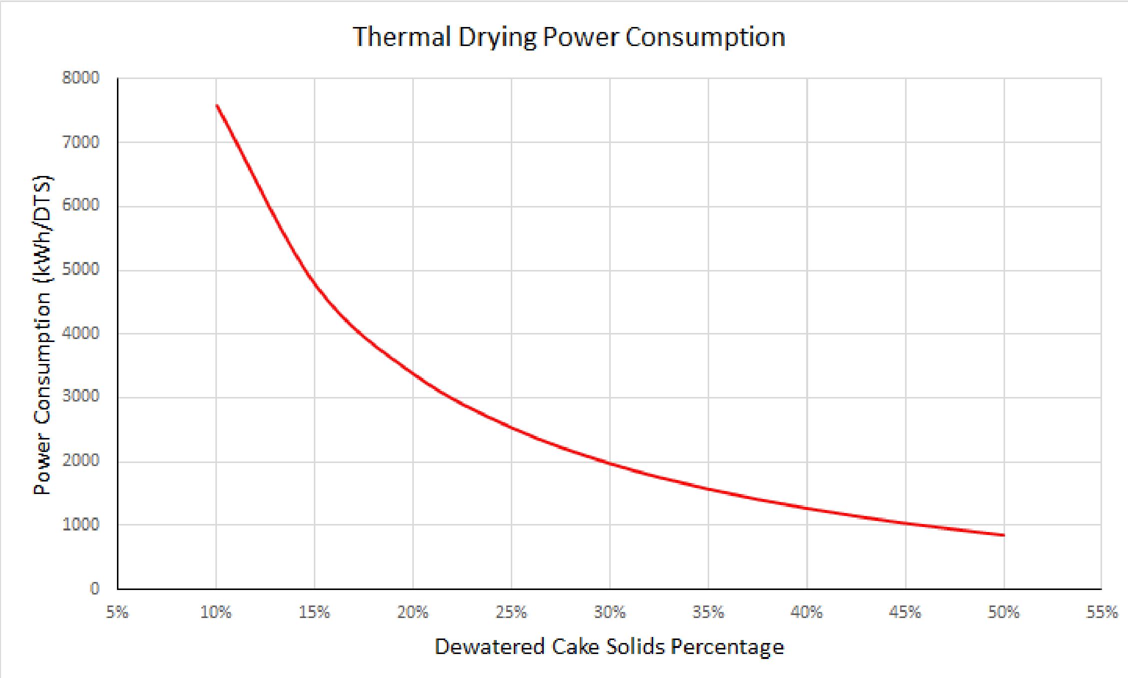

Figure 16: Graph of power consumption vs sludge solids percentage.

Total O&M estimated costs range from $300 - $700 per DTS where power consumption costs range from $100 - $500 per DTS. This leads to a yearly O&M cost ranging from $210,000 - $490,000 at current facility processing and $330,000 - $770,000 at design capacity for the facility Capital costs vary widely based on the equipment used and energy requirements for the thermal drying process. For a facility the size of RWRRF which has a total treatment capacity of 1.6 mgd, the estimated capital costs for the total thermal drying system including all required equipment ranges from $5 to $10 million. This capital cost can vary based on the type of drying system and manufacturer used. Although the O&M costs are high, the long-term benefits make this a viable option. We recommend upgrading the dewatering technique to reduce the total power consumption of the thermal drying system.

3.2.2. Thermal Hydrolysis without Anaerobic Digestion

While most thermal hydrolysis processes require anaerobic digestion to follow, there is a process offered by Lystek that only requires a thermal hydrolysis system. The information gathered for this system is based on a conversation with Lystek Business Development Manager James Dunbar. Dunbar claimed the system produces Class A biosolids without the anaerobic digestion to follow. According to Dunbar, this can be achieved because while the system does involve steam power to hydrolyze the biosolids, it also requires alkaline material that gets injected into the system to reach the required pH of 9.5 to kill harmful pathogens. The system also includes a shearing blade which helps to mix the biosolids, steam, and alkaline material in the reactor evenly. The Lystek system does its process in half batches in order to reduce the additional steam required to heat the biosolids. This means that only half of the biosolids are expelled from the system at a time. The process takes roughly 45 minutes for a full batch and requires 60 kWh/DTS. The material produced is of a liquid consistency and due to the enclosed nature of the system, does not need to worry about odor as a pressing issue. The construction space required from this system varies between 1,500 and 2,000 sq. ft., making it a compact system that could fit within the construction space restrictions. The Lystek Reactor that would be used for this option can be found broken down in Figure 17.

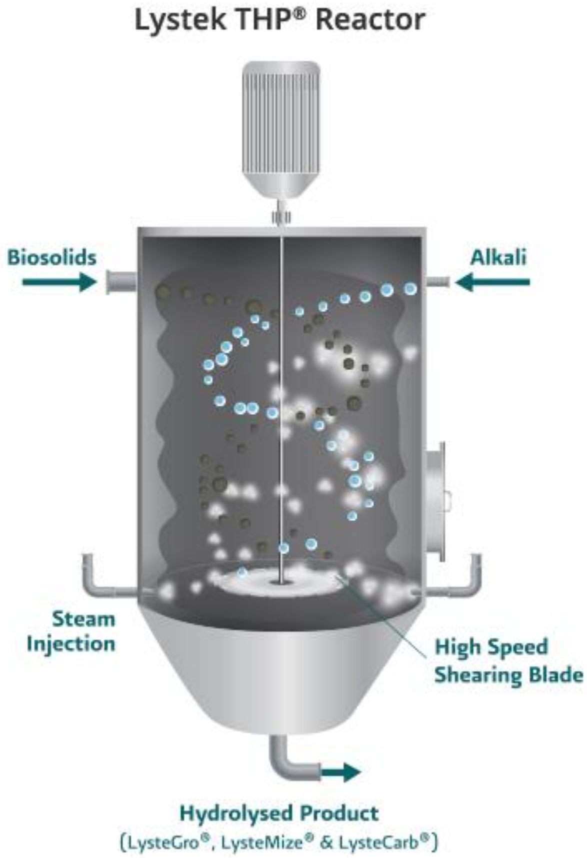

Figure 17: Lystek Reactor Breakdown as provided by the Lystek Website

An important note about this system aside from the lack of anaerobic digestion required is how the biosolids are handled after processing through the Lystek system. After processing, Lystek takes full responsibility for the solids produced. This means that the biosolids produced are a product of Lystek which go to be sold as a fertilizer called LystekGro. Transportation and disposal of the solids are handled by Lystek from that point on. This responsibility can be kept by the facility so long yearly audits are completed on Lystek's behalf. This does not mean that costs are removed, however, only they are reclassified as Lystek backend charges which account for the shipping and handling costs of the solids. These backend charges depend on how much and how often the material needs to be transported off site. Estimates on these charges have not been worked out. After shipping, the material is marketed and sold as a fertilizer product, where a portion of the profit from that product goes back to the facility. Revenue sharing from the product sales would need to be worked out later, but it is something to keep in mind for reducing the operation costs. Placement of the system within the scope of a treatment plant such as that of Riverhead Wastewater is shown in Figure 18 and is provided by Lystek on their website.

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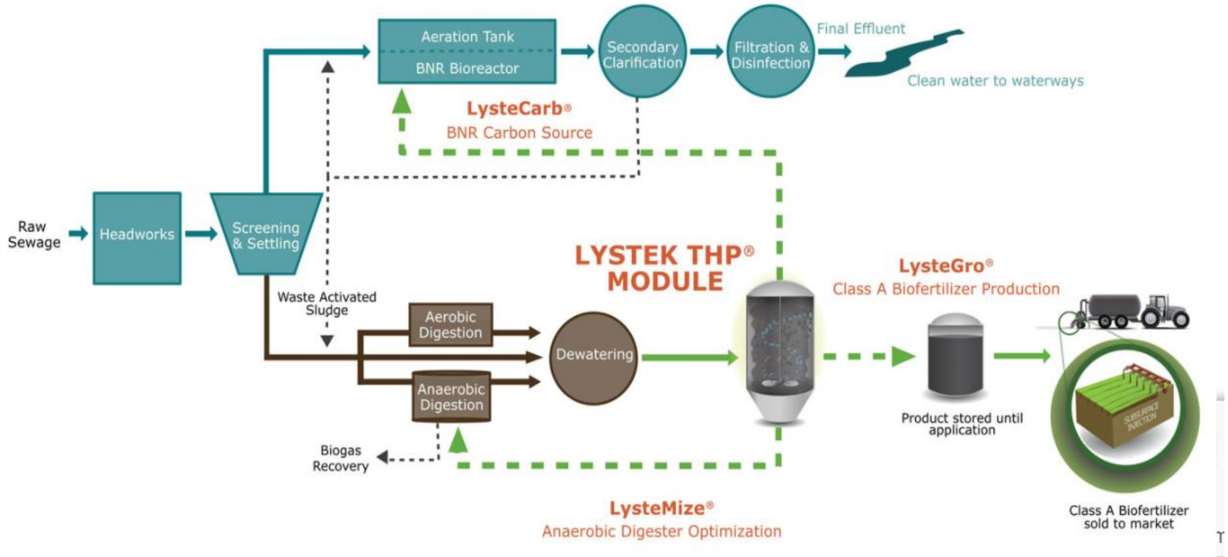

Figure 18: Placement diagram of the Lystek THP module as provided by the Lystek website.

Figure 18 shows how any treatment effluent, whether it has gone through a digestion process or not, can be treated by the THP module and produce a land-applicable Class A biosolid product. The only issue is holding the effluent long enough to where shipments can be less regularly done to decrease the transportation costs.

An idea that was considered for this option also included using the unused settling tank that has been fenced off southeast of the bench filter press. Since the biosolids produced after the thermal hydrolysis process are in liquid form, this settling tank would be perfect for storage purposes if retrofitted. The volume of the cylindrical settling tank was estimated to have a volume of nearly 8,300 c.f. based on a diameter of 23 ft and a height of 20 ft. Based on this estimate, the design wastewater capacity of the facility, and the percent dry solids of the final effluent, the biosolids would only have to be shipped out every 2 week or so.

While understanding the process can be useful, a breakdown of the advantages, disadvantages, and costs can be helpful when choosing an option. The advantages, disadvantages and costs of such a system for the RWRRF can be found below:

Advantages:

- Fully Automated and equipped with Remote Internet Access.
- Anaerobic Digestion is not required, thereby decreasing the space, capital cost, and time required for that process.
- Few permitting requirements.
- Relatively compact, only requires 1,500 - 2,000 square feet of space.
- Revenue sharing, allowing for profit off the biosolids.
- Relinquishing responsibility of the disposal of the biosolids to Lystek removes the issue of finding local interest in the biosolids for land application.
- Liquid form of biosolids allows for more storage possibilities, including the unused settling tank.
- Enclosed nature of process removes the issue of odor control.

Disadvantages:

- Needs alkaline material in the form of Potassium Hydroxide to execute the process correctly. This means that regular shipments of the material would need to be done to obtain the material.
- Loss of control of disposal and transportation may not be in best interest of the facility
- Backend costs need to be more specifically worked out, leaving the possibility of high disposal costs despite the addition of the THP
- Demand for LystekGro may be small at first meaning low incoming revenue for the first few years.

The costs of this system are broken down in the Table 7 below. The information provided in this table are based on information derived from Lystek Business Development Manager James Dunbar. Mr. Dunbar was extremely helpful in getting a lot of the cost information for this system. He was particularly helpful in getting information on the backend costs, maintenance costs, electrical demands and capital costs for the system. For that, our team is extremely grateful. The capital cost of the Lystek LY3 THP system proposed for this treatment option is, according to Dunbar, between \$2 - \$3 million depending on the availability of gas to the facility. A layout of the system cost estimates derived from Mr. Dunbar along with other sources can be found in Table 7.

Refer to Table 7 which provides a full breakdown of the yearly costs of using this process. This table can help with understanding the yearly sources of cost and in comparing the yearly costs imposed by this process to those imposed by other treatment alternatives. A summary of the costs for the three most recommended options can be found in Table 8. The electric cost rate is also based on the PSEG Long Island November 2020 rate for electricity, or \$0.114642 /kwh (PSEG Long Island, 2020).

Table 7 –Cost Breakdown for Thermal Hydrolysis without Anaerobic Digestion

Item	Cost per DTS	Yearly Cost (Current)	Yearly Cost (Design Capacity)
Electrical Costs	\$6.88/DTS	\$5,000	\$8,000
Alkaline Costs	\$700/DTS	\$490,000	\$770,000
Maintenance/Inspection Costs	\$33 - \$67/DTS	\$35,000	\$52,000
Backend Charge Cost	\$333/DTS	\$226,000	\$367,000
Annual Shear Blade Replacement	N/A	\$1,000	\$1,000
Total	**\$1,090/DTS**	**\$757,000**	**\$1,198,000**

Sources: Lystek, 2019; Industrial Chemicals Corporation; PSEG Long Island, 2020; Bulk Apothecary, 2020

3.2.3. Advanced Alkaline Stabilization (AAS)

The main process of advanced alkaline stabilization (AAS) of biosolids involves the addition of alkaline material to the dewatered sludge which raises the pH. The increase of pH of the sludge reduces favorable conditions for pathogen growth. The materials used for AAS include but are not limited to: hydrated lime, quicklime (calcium oxide), lime and cement kiln dust, lime ash, and carbide lime. The most common materials used in quicklime as it has a greater heat of hydrolysis which can reduce the number of pathogens. The other materials are utilized typically to reduce cost and due to availability.

Advanced alkaline stabilization can achieve Class A biosolids classification when the pH of the mixture is above 12 for a period of 72 hours, with temperatures remaining a constant 52 degrees Celsius for a period of 12 hours. This process satisfies state regulation code Title 6 CRR-NY Part 361 Subpart 3.7 section a.1.iii for pathogen reduction. The produced biosolids must be tested according to Title 6 CRR-NY Part 361 Subpart 3.9 to ensure they meet vector attraction reduction requirements outlined in Title 6 CRR-NY Part

361 Subpart 3.7 section b. Vector attraction reduction is achieved when the biosolids pH is above 12 and remains above 12 for 2 hours, then the pH remains at 11.5 or greater for an additional 22 hours without any additional lime added to the material. There are many processes involved as well as alternate routes a facility can take regarding alkaline stabilization. In one scenario an additional dosage of lime is applied to maintain a pH higher than 12 and to raise the temperature using a supplementary heat source. However, this procedure involves monitoring for various contaminants that may still reside in the treated biosolids. The Part 503 Rule for meeting Class A requirements requires the monitoring of viruses, and pathogens before and after treatment with alkaline stabilization.

Low lime treatment plants are considerably less efficient in phosphorus and organic removal than either high lime treatment plants or plants incorporating the use of lime with other metal salts. When centrifugation and pressure filtration are used, the use of recalcified lime has been shown to improve the dewatering of waste sludges generated in lime treatment. The use of lime allows higher surface overflow rates on sedimentation tanks than does an iron or aluminum salt, and this is an important factor for upgrading any existing treatment plants (Parker, 1975). In all cases, however, coagulant choice should be based on an engineering economic evaluation of each alternative. Lime was used in waste treatment long before the present era of "advanced waste treatment" (AWT). Quicklime does not react uniformly when applied directly to water or wastewater but must first be converted to calcium hydroxide. Hydrated lime or slaked lime is a dry powder obtained by a chemical reaction that occurs when enough water is added to quicklime to satisfy its affinity for water. Agitation is too vigorous or insufficient agitation of quicklime and water is undesirable. Some agitation is necessary. Lime can be delivered either in bags or in bulk. The choice between these two forms depends mostly on the rate of chemical use at the treatment plant. Bagged lime is delivered in truck or rail cars. Once at the treatment plant, the bags are transferred by hand truck, fork lift, or overhead crane to storage.

There are several factors that are considered when designing an AAS system. The factors that affect the equipment size include the amount of alkaline material required to add to the sludge, and the mixing time. The percent solids of the infeed and source of alkaline material must also be considered. Also, odor control and dust control of particulate matter must be considered. Figure 19 shows a basic schematic of an AAS system. The equipment required includes a sludge feed or conveyance system, lime storage silo, lime transfer conveyance, mixer, and air emission controls to minimize odors and dust.

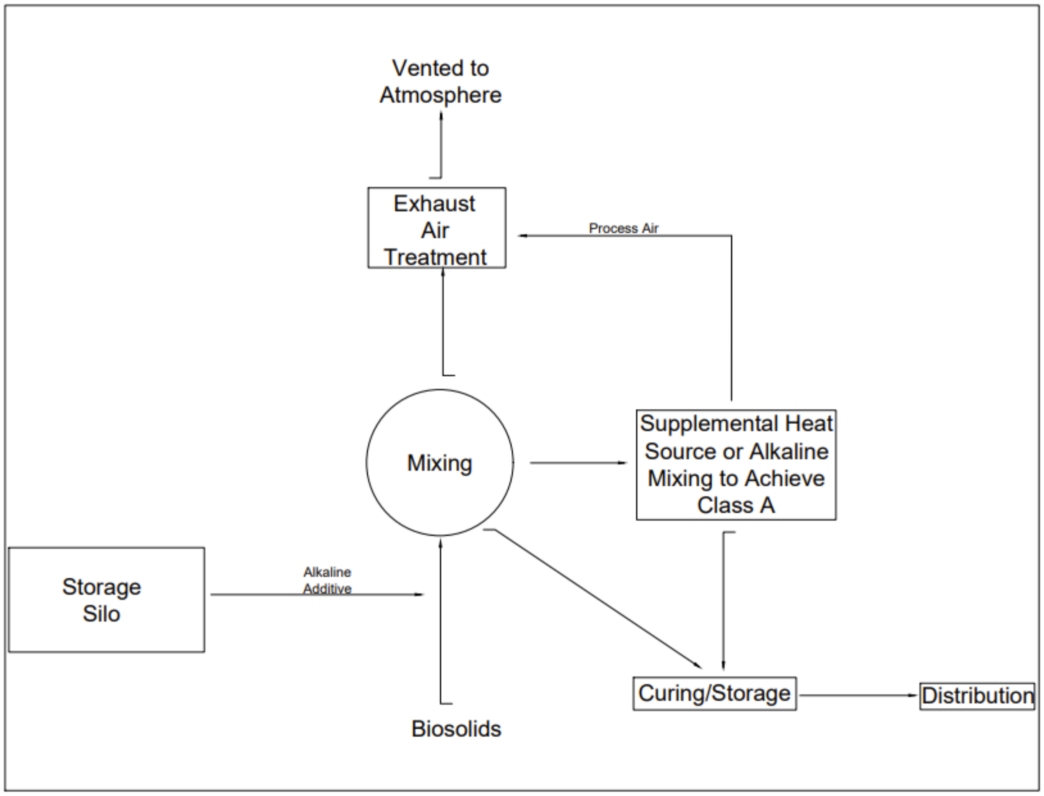

Figure 19: Schematic diagram of Advanced Alkaline Stabilization process.
Source: Parsons Engineering Science, Inc., 1999.

Class A biosolids achieved through AAS are generally more beneficial as it allows for better vegetive growth by improving soil pH, soil texture, and the water holding capacity of the soil. Alkaline stabilized biosolids can be used as a better alternative to fertilizers. Additional applications of alkaline stabilized biosolids lie in land reclamation. Sites that have degraded due to chemical contamination, poor soil, and a high amount of trace metals can be remedied using alkaline stabilized biosolids. At these sites' drainage can be improved, erosion potential can be reduced, and plant growth can be aided. The advantages and disadvantages of AAS are as follows:

Advantages:

- Suitable for Agricultural Application, Mine Reclamation, or a Landfill Cover
- Lower in Nitrogen because Nitrogen is converted to Ammonia during Processing, Contains 1-2% Nitrogen, 1 % Phosphorus
- Alkaline stabilized biosolids are typically used for pH adjustment, Nutrient benefits come secondary.
- Materials must be applied at a rate of 60 - 100 DTS/Acre, it can be used as a Daily Cover, or case by case
- Used for Regions where Soil is Acidic, higher value in those regions
- Advantages of AAS are: allows for reuse, simple to perform and achieve, ease, small land area is used in the process, as well as flexibility in performance (starting/stopping).

Disadvantages:

- Odor Issues arising due to the processing or release of Ammonia (Nuisance Issue)
- Amount of Ammonia Released depends on the Nitrogen Content and the pH levels that need to be achieved.
- Particulate Matter
- Land Application can increase concentration of trace elements in the Soil, pH conditions can be improved, land may be more fertile, alkaline stabilized biosolids will lead to metals becoming insoluble, and less likely to move towards the groundwater table.
- Not for use with soil due to high pH, up to 50% increase in volume, which affects shipping costs, potential for odor generation, potential for harmful dust.

Typical unit costs for Class A lime stabilization ($228/DTS) are significantly lower than for aerated static pile composting ($277/DTS) for a 20 mgd wastewater treatment facility. Lime transfer conveyor costs are in the range of $2,000-$5,000 (USA). Manufacturers of conveyor systems in USA: Daifuku America Corp., Regal Beloit Corporation, FLSmidth, Inc., Intelligrated, Inc., BEUMER Corporation. Manufacturers of lime storage silos: Henan Kingman M&E Complete Plant Co., LTD, VeloDyne, USA, Flyer Steel Silo. Manufacturers of Mixers in USA: Evoqua Water Technologies, MixMor, Brawn Mixer, Proquip, Inc., and Sabo Industrial Corp.

The alkaline stabilization process for producing biosolids involves the use of lime stabilization, aerated static pile composting and Thermal Drying. Alkaline Stabilization requires less space and can incur lower capital costs, the use of lime can offer various municipalities more flexibility to increase capacity of the degrees of treatment. Class A lime stabilization can cost around $228 per DTS. The use of aerated Static Pile Composting costs $277 per DTS, and thermal drying can cost $372 per DTS for a 20 mgd wastewater treatment plant.

AAS systems are relatively simple and do not require highly skilled labor. Heavy equipment laborers, maintenance personnel, and computer operators are needed due to the high caustic nature of the process. In terms of costs, estimation is difficult due to the unique nature of the preexisting Riverhead treatment facility. Estimated costs for Class A AAS range from $139 - $313 per DTS in facilities up to 60 mgd. The RWRRF operates at 1.0 mgd, with capacity up to 1.6 mgd. Capital costs in the study ranged from $1 - 4 million. Considerations for cost estimation include: equipment purchase/installation/use, curing/storage, loading, shipping, operating fees due to proprietary processes, maintenance, alkaline additives such as lime, labor, odor control, and marketing costs/revenues as well as permits.

3.2.4. <u>Summary</u>

With several treatment options analyzed in this report, there are many benefits, drawbacks and costs associated with each design alternative that need to be considered. In order to make an official decision for a design alternative, our group must speak with Superintendent Michael Reichel in order to accurately assess his vision and goals for biosolids sludge. Before speaking with Superintendent Michael Reichel, our group has chosen thermal drying as the recommended treatment option. After sharing our research results with the client, it is our hope that he agrees with our assessment. More work would need to be done beyond this to work out the specifics of such a system in the context of the RWRRF if Michael Reichel were to choose thermal drying as the preferred method of treatment.

While the advantages and disadvantages are more difficult to weight and more relative to how the client feels towards one option or another, the cost analysis can be a main factor for choosing a design alternative. Each alternative has a cost benefit and drawback. By comparing these costs, a decision on how the solids should be handled can be made.

Refer to Table 8 below to see a comprehensive table summarizing the costs for the three recommended design alternatives. The yearly cost estimates in the table are based on the design capacity of the facility treating 1.6 mgd of wastewater and producing an estimated 1,100 DTS/year of biosolids.

Table 8 –Cost Summary for Recommended Design Alternatives

Design Alternative	Volume of Material Produced	Estimated Yearly O&M Cost	Estimated Capital Cost	Estimated Power Consumption
Thermal Drying	3667 c.f./week	$330,000 - $770,000	$5 - $10 million	800 - 4700 kwh/DTS
Thermal Hydrolysis w/o Digestion	4723 c.f./week	$1,198,000	$2 - $3 million	60 kwh/DTS
Advanced Alkaline Stabilization	4010 c.f./week	$500,000 - $750,000	$1 - $4 million	350 kwh/DTS

3.3. Other Considered Design Alternatives

There are other design alternatives that, although they can produce Class A biosolids and meet State and Federal regulations, they are not feasible for this project. RTOs, Chemical Oxidants, Counteractants, and Neutralizing agents are all less popular design choices due to their associated costs, maintenance factors, feasibility, and allowable space. It is for these reasons that these are being considered less than the aforementioned alternatives. These alternatives are indeed viable, but our site and conditions do not allow for them.

3.3.1. Thermal Hydrolysis with Anaerobic Digestion

Anaerobic digestion achieves Class A biosolids with the use of bacteria that attack and destroy more harmful pathogens present in sludge waste. This process, however, has quite a few variants, one of which involves a step requiring thermal hydrolysis. This variant of anaerobic digestion is known as Anaerobic Thermophilic Digestion. Thermal hydrolysis is the use of heat and pressure via injected steam, and thermophilic anaerobic bacteria in order to jumpstart the anaerobic digestion process. This 30-minute process reduces the digestion time from 30-35 days to 9-12 days, roughly one third the original digestion time. After the thermal hydrolysis process, the sludge is stored to be digested by bacteria until the pathogens are eradicated. The thermal hydrolysis process with Anaerobic Digestion can be seen in the diagram below:

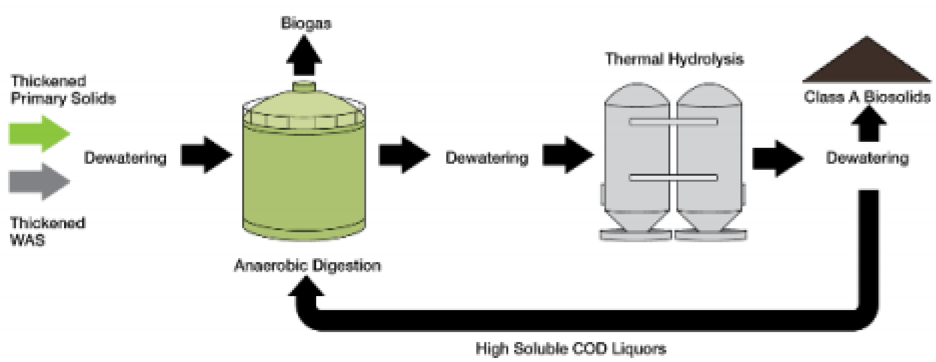

Figure 20: Schematic diagram of Thermal Hydrolysis with Anaerobic Digestion with Biogas Production. Source: Water Environment Federation 2019

The first benefit of the Anaerobic Thermophilic Digestion process is the decrease in water content. At the end of the process, a dry solids content of 40% can be achieved, thereby reducing transportation costs and the amount of sludge that would need to be stored during this process. This process also has the benefit of having very little odor. The bacteria used in digesting the sludge reduces the odors emitted by the sludge, thereby improving its marketability to local farms. Anaerobic digestion has the added benefit of producing methane gas which can be used to power digesters or other facility components. This could reduce the operating costs for this process or that of other facility components. Nearly 50% more methane is released using the thermal hydrolysis process as compared to when it was not used during mesophilic digestion. Steam used to heat the sludge can be reused in earlier stages of the process as a means of reducing energy costs. This process also avoids sludge bulking by eliminating filamentous bacteria.

The process of anaerobic digestion itself can be broken into a single step approach or a dual step approach, both of which depend on the level of treatment necessary. Various processes exist during which the sludge can be heated at varying temperatures in order to reach a desired level of reduction of total solids or sludge quantity. There exist three separate stages of anaerobic digestion, known as Hydrolysis, Volatile Acid Fermentation and Methane Formation (EPA 2006). A process of designing a system or facility involves heating the various stages at varying temperatures for different periods of time, this approach is known as Temperature Phased Anaerobic Digestion (TPAD). Utilizing this process would allow an increase in the pH levels, and controlling the different temperatures allows an optimization to the overall process. The primary purpose of utilizing a staged and separate process would allow greater control and enhancement of the overall results.

The issues concerning Anaerobic Thermophilic Digestion vary greatly. One of the most difficult issues to deal with for this process is the amount of space required to install the components of this process and the storage space required to complete this process. Regularly storing 100 to 150 tons of sewage would be difficult for this facility to maintain since there is a severe lack of storage space. It might be possible to make use of unused storage tanks currently available on facility grounds to make up for this storage shortage, but it will still prove difficult to incorporate. Capital investment is also an issue to consider for this process due to the high cost of installing so many components, including the thermal hydrolysis reactor tank, pulper tank, flash tank, digestor storage tanks, and process gas unit. The overall capital cost of installing these facilities can be upward $2.40 - $4.87 million based on estimates from a 5,000 Ton/Year capacity anaerobic digestion plant.

The feasibility of a multistage Anaerobic Digestion System depends primarily upon the Feed Solid Concentration. Varying ranges in the feed solid concentrations limit the overall feasibility of adding or retrofitting a multistage anaerobic digestion system. The overall benefits of a Multistage Anaerobic Digestion System over a Single Stage Anaerobic Digestion System lies in the ability to optimize the overall process. The advantages of a Multistage process allow for greater control, a Thermophilic Stage can achieve Class A biosolids standards and a Mesophilic Stage can achieve greater volume reduction (EPA 2006). However, there exists several drawbacks regarding a multistage anaerobic digestion system. One key reason would be a greater O&M cost, in addition to a greater overall cost due to additional reactors required.

Cambi, an industry leader in thermal hydrolysis offers a system that includes both the THP pre-treatment and anaerobic digester system. After exiting the flash tank, the sludge enters an anaerobic digester and goes through a 10-12-day digestion process. This process not only dewaters the sludge to a dry solids content of 30-40%, deodorize the sludge between 70 and 80% of its original odor content and increase the methane production of the effluent by nearly 50%, but the effluent volume decreases significantly from both the dewatering and the methane removal. This reduction in volume would even further reduce the transportation cost of depositing the solids at a local deposit station for land-application in the case of farms. Cambi also claims that the biosolids are of EQ quality, meaning that the biosolids are virtually unrestricted for reuse. This could be essential for farms looking for an easy alternative for their current fertilizer utilization. The advantages and disadvantages of this process are listed as follows:

Advantages:

- Use of methane from Anaerobic Digestion can be used for cogeneration of steam for the THP process or to power other facility processes using CHP engines.
- Increased methane production allows for better use of CHP engines and lower biosolids output.
- Biogas generated by the Anaerobic Digestion Process can be reapplied and used throughout the facility therefore reducing the energy cost.
- Other additive (Alkaline boosting) materials are not needed in processing.
- Odor is not a big issue since the majority of it is released during the digestion process.
- Digestion greatly reduces total biosolids being produced through dewatering and deodorizing, thereby reducing transportation costs.
- The Class A Biosolid is of EQ quality meaning virtually unrestricted application of the biosolids and a very marketable product that most farms would be attracted to use for land-application.
- Cambi offers for the THP process to be fully built before on-site construction, thereby greatly reducing the construction time.

Disadvantages:

- Space required for both the THP and Anaerobic Digestion Processes would be extensive. A typical area of 4,500 - 8,000 ft^2 may be required. These values may be slightly higher or lower depending greatly upon the treatment route taken.
- Anaerobic digestion requires 9-12 days to complete.
- Maintenance costs for a THP system is high, considering the large number of components involved.
- Capital costs will be high due to the implementation of both the AA digestion, THP processes and gas processing units. The capital cost alone could approach nearly $2.0 - $3.0 million for the addition of a THP Process, with roughly $2.5 - $4.0 million for an anaerobic digestion process along with respective gas units required for this process.
- The liquid sludge produced from the anaerobic digesters would have to be further dewatered to produce a cake that could be used for land application, meaning an even greater capital and electrical cost.

Overall, Thermal Hydrolysis with Anaerobic Digestion does have several advantages over other treatment processes. However, due to a large space requirement to implement this treatment process, it is ultimately not a viable option for this project. The space available at the RWRRF site would not be able to hold both an anaerobic digester and a thermal hydrolysis unit. Additional conditions for negating this process would be high capital expenditure, along with high operational costs. Ultimately while Anaerobic Digestion with Thermal Hydrolysis does achieve Class A Biosolid Standards, the disadvantages prevent this facility from installing this process.

3.3.2. Autothermal Thermophilic Aerobic Digestion (ATAD)

ATAD is a fermentation process, where the digestion of the sludge retains heat, and is placed in a reactor where the temperature rises to 70-75 degrees Celsius. Ammonia in the process is then liberated and the pH is elevated to 8.4. ATAD can operate as a tertiary sludge treatment process which utilizes the heat generated by the sludge digestion to stabilize the treated sludge, it can operate as a 1 or 2 stage process, the sludge is proceeded to thicken with a polymer addition, and the use of aeration and mixing of the thickened sludge allows the sludge to biodegrade. The heat used in this process rises from 60-75 degrees

Celsius, which helps inactivate the pathogens. The use of ATAD as a liquid fertilizer can be used for land application.

This process satisfies state regulation code Title 6 CRR-NY Part 361 Subpart 3.7 section a subsection 1-i-d for pathogen reduction. The produced biosolids must be tested according to Title 6 CRR-NY Part 361 Subpart 3.9 to ensure they meet vector attraction reduction requirements outlined in Title 6 CRR-NY Part 361 Subpart 3.7 section b. The advantages and disadvantages of the ATAD system are as follows:

Advantages:

- The treated biosolid has a unique arsenal of Enzymes, and various biodegradative capabilities
- High Ammonia Nitrogen Levels to make for an excellent liquid fertilizer
- High Degradation Capacity
- Short Treatment Period (10 days)
- Inactivation of Pathogens

Disadvantages:

- High Cost of Energy associated with Aeration and Mixing
- (The high cost of energy can be reduced utilizing Heat Recovery Processes)
- Problems with Odor, Poor Volatile Solids Reduction
- High Dewatering Costs
- Inflexible Design

The disadvantages associated with the ATAD process make it not a viable option for this project.

3.3.3. Mesophilic Anaerobic Digestion (MAD)

The Mesophilic Anaerobic Digestion (MAD) process requires the use of mesophilic anaerobic bacteria to kill harmful pathogens contained within sludge effluent. Mesophilic anaerobic bacteria thrive in room temperature settings deprived of oxygen. This process is quite simple, only requiring a storage space that can be vacuum sealed and deprived of oxygen to digest the solids to a usable Class A biosolids state. The relatively low odor and production of usable methane make it an option to consider for some facilities.

MAD, however, would be nearly impossible to incorporate in this facility due to a lack of space. While the Anaerobic Thermophilic Digestion (ATD) process would be space restricted to store 75-150 tons of biosolids regularly, it doesn't compare to the over 250 tons of sewage that would need to be stored in a MAD system. This produces a similar problem to composting as the length of time required to complete the process is far too long. While an ATD system typically requires between 9 and 12 days to complete, the MAD system typically requires 30-35 days. That combined with the reduced amount of methane available from the process and the lack of water removed from the sludge during this process to reduce transportation costs make it a much worse choice to consider than the Anaerobic Thermophilic Digestion option. For these reasons, this option is not recommended.

3.3.4. Composting

Composting is a treatment option for biosolids. Composting allows for low operating costs for processing; however, land requirement and retention is significant. Composting of biosolids is the degradation of organic matter in the Sludge that allows the solid waste water to stabilize prior to use in agriculture or land application. Stabilization of Wastewater Solids allows the destruction of pathogens, minimizes raiders, and reduces VARs (Vector Attraction). Composting of biosolids is a viable disposal option as it allows large amounts of organic matter and nutrients to enter the soil, and acts as an organic fertilizer. Composting is not a viable option for this project since the space required is not available on the project site. Also, the associated odor issues with composting sludge would be a major issue since the RWRRF is within close proximity to public places and residential and commercial areas.

4. DISPOSAL OPTIONS

The intended goal for the produced Class A biosolids is for reuse within the local farming community. There are a few ways of disposing Class A biosolids other than land application. These include landfill, composting, incineration, and forest rejuvenation or land reclamation. The disposal options available are restricted to what is available in the area. In some cases, the produced Class A biosolids would still have to be hauled away off-site or even out-of-state to be disposed of. Since we want to avoid hauling away the biosolids and eliminate the associated costs with hauling it away, land application and reuse of the Class A biosolids is preferred.

4.1. Regional Demand and Reuse Options

Between 2000 and 2010, biosolids generation within the United States has increased every year. In 2000, 7.1 million DTS were produced for use or disposal and by 2010, 8.2 million DTS had been produced. Currently about 50% of all biosolids produced in the U.S. are being used as fertilizer but only 1% of cropland has biosolids applied.

If the plant is fitted to generate Class A biosolids and send it to local farms on Long Island instead of transporting it to Pennsylvania, a lot of money can be saved. There are a total of 604 farms in Suffolk county alone covering 35,975 acres. There is demand for Class A biosolids because of its many land application uses and benefits mentioned earlier and therefore opportunity for money to be saved at the treatment plant. Below is a map and table showing the proximity of the treatment plant to local Riverhead farms, and a table showing the distances by car. By this we can see that there are many options for reuse of class A biosolids since the site is in such close proximity to farms that can make good use of the product.

Most fertilizers commonly used by farmers contain the three basic nutrients nitrogen, phosphorus, and potassium. These nutrients are also present in Class A biosolids which makes it a great substitute for traditional fertilizers. There are many farms that are in close proximity to the project site as seen in Figure 21.

Figure 21: Map of proximity to local Riverhead farms. Provided by Google Maps

These farms vary in what they produce including sod, vegetable crops, and more. These farms' relative driving distance to the RWWRF site is described in Table 9. We found that some farms on Long Island do have interest in acquiring Class A biosolids. Both Pranti farms and Brightwaters farms had shown interest. They see it as an opportunity to cut costs in terms of buying the materials used to grow the crops such as fertilizer and mulch. Therefore, a partnership with local farms would be mutually beneficial because both parties involved would save money. Also, sending Class A biosolids to local farms is good for the planet because the carbon footprint from transportation would dramatically decrease since Pennsylvania is many miles away from the treatment plants.

Refer to Table 9 which shows all the driving distances to the nearest farms in relation to RWRRF. The driving distances shown in this table were generated in Google Maps. These farms represent some of the farms where the biosolids may be reused for land application. This information can help in deciding which farms should be considered when finding a disposal location for the reuse of Class A biosolids.

Table 9 –Driving Distance of Local Farms from RWRRF.

Farm	Distance by Car (mi)	Farm	Distance by Car (mi)
G & W Farms Inc	1.5	Union Standardbred Farm	5.8
Hallock Farms	3.2	Holzman's Family Farm	5.1
Anderson's Farm Stand	3.0	Briermere Farms	4.5
Talmage Farm Agway	3.4	Wells Farm	4.9
Anderson's Potato Barn	3.1	Goodale Farms	2.1
Long Island Perennial Farm	5.4	Harbes Orchard	5.9
Karpinski Farms	6.6	Ty Llwyd Farm	6.1
Edward Zilnicki Farms	7.0	Big E Farm Inc	7.0
Schmitt's Family Farm	7.0	Bayview Market & Farms	3.6
Bison Farm	4.4	Woodside Farms	5.6
North Quarter Farm	4.3	Golden Earthworm Farm	4.2

Source: Google Maps

4.2. Other Disposal Options

If repurposing biosolids sludge is for whatever reason not viable, there are other options for managing treated wastewater sludge. Below are several options listed and their associated advantages/disadvantages, costs, and so on. Ideally, disposal is not the best option, since there are associated costs and biosolids sludge has a lot of potential that would otherwise be wasted if disposed of. Not to mention, there are also emissions regulations that need to be mitigated in order for disposal to work, making this a poor choice.

4.2.1. Landfill

Currently, RWRRF disposes of their treated biosolids sludge by transporting them to a landfill in Pennsylvania, since biosolids sludge cannot be dumped in NY due to state regulations. This makes disposal very costly. Landfills provide a safe and reliable method of disposing biosolids, however there exists several downsides with this approach. Biosolids contain a large number of nutrients and organic matter, disposing of sludge in a landfill would waste these resources. There are no landfills on Long Island that currently accept biosolids sludge, and hauling and drop off costs/fees would be significantly reduced based on water/solids content.

4.2.2. Composting

Composting is an interesting disposal option to consider but one that ends up being difficult to implement. Composting at a designated facility could theoretically make it easier to dispose of the sludge in an environmentally sound fashion while minimizing costs. The practicality of composting does not improve when used for disposal. The location of the RWRRF is too far from any composting facilities and does not have nearly enough room to hold the sludge for such a long period of time. The closest facility for composting is off of Long Island, almost far enough to where dumping in Pennsylvania might end up still cheaper. And while this may be a money cheap option if done near the facility, it is a space and time expensive one as well. The time and space required for this type of disposal near the facility would be too much to bear. Beyond even this, odor becomes an uncontrollable issue that will be an unavoidable nuisance for any nearby residents. Composting, while an intriguing option, was not a feasible option for treatment and isn't an option for disposal.

4.2.3. Incineration

Biosolids can be incinerated because incineration is a viable method when land for disposal is limited. The application of incineration leaves a small amount of residue or ash that would later be disposed of via a landfill. While the residue generated from incineration of biosolids may also contain high levels of nutrients, the high metal concentrate prevents the biosolids from being widely used. The generation of ash leads to various issues resulting in air quality and permitting issues that has made incineration less common and widely used. Incineration of biosolids accounts for 20% of the total amount of biosolids disposed of, or accounts to 1.1 million DTS (NAP 2001).

4.2.4. Forest Rejuvenation/Land Reclamation

Land reclamation sites that have degraded due to chemical contamination, poor soil, and a high amount of trace metals can be remedied using biosolids, especially biosolids produced through advanced alkaline stabilization. At these sites' drainage can be improved, erosion potential can be reduced, and plant growth can be aided. It is certainly an option that could provide huge benefits to degraded areas of natural landscape. However, while interesting, there are a number of problems that prevent this option of disposal from being an easily viable option.

The reason why this option is not viable for the RWRRF is that there are no known sites for forest rejuvenation or land reclamation currently on Long Island. This means high transportation costs for long distance disposal and therefore higher GHG emission rates. Forest rejuvenation sites in upstate New York are too far to justify traveling to them. Had there been sites on Long Island, this might be a more viable option for disposal. In this circumstance however, it is not an option worth employing.

5. STATEMENT FOR MOVING FORWARD

Moving forward, our group has many things to consider. Firstly, we learned many lessons throughout completing this report which include but are not limited to: better communication, stricter deadlines, adherence to company standards, and effective time management. On top of considerations for our group, the next steps are to put the suggested design alternatives into action, making contact with nearby farms and manufacturers, cost analysis, and so on. We look forward to furthering our work on this project, and hope that this report is found to be helpful and informative.

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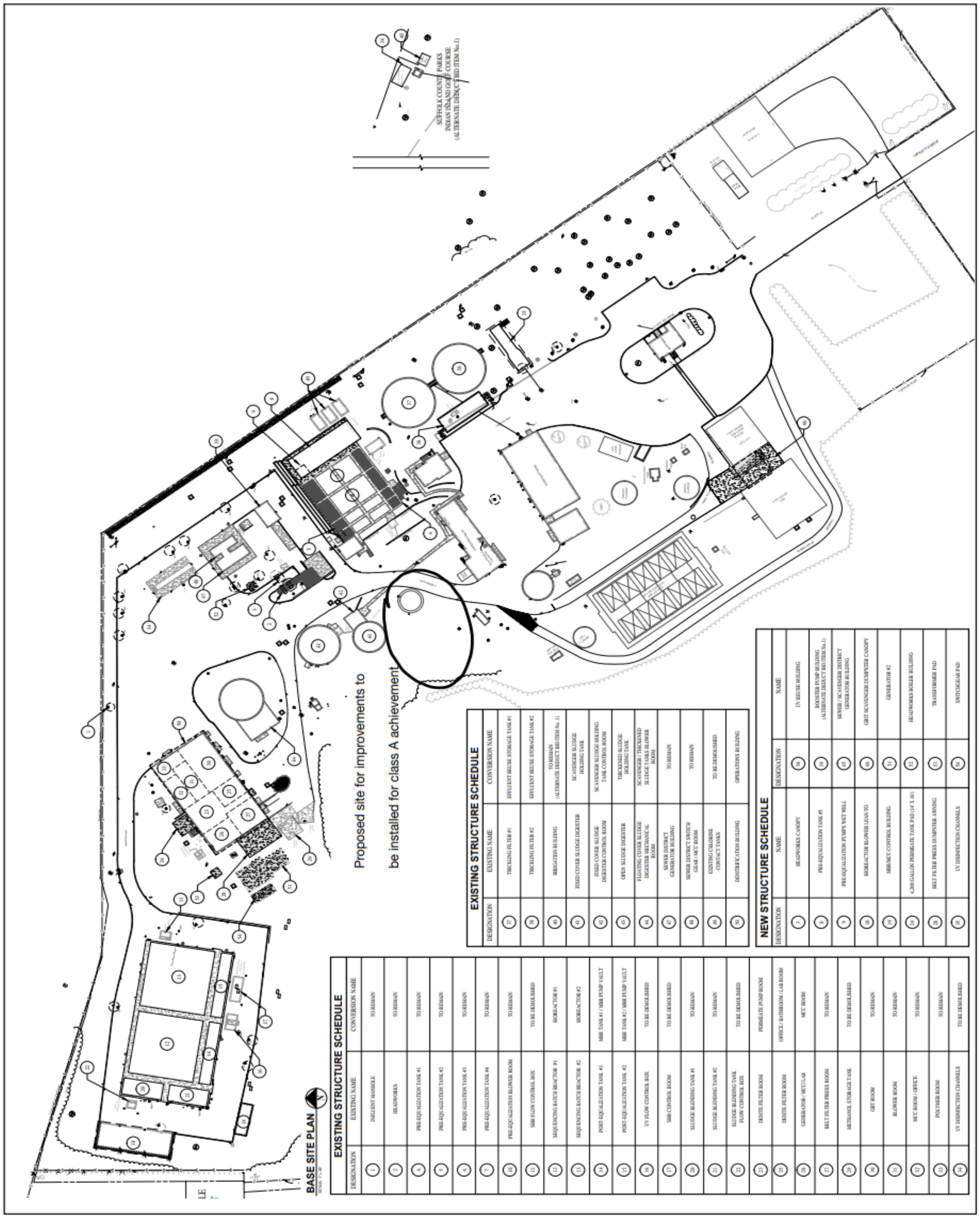
Appendix A – RWRRF Site Plans
provided by H2M Engineering

Base Site Plan



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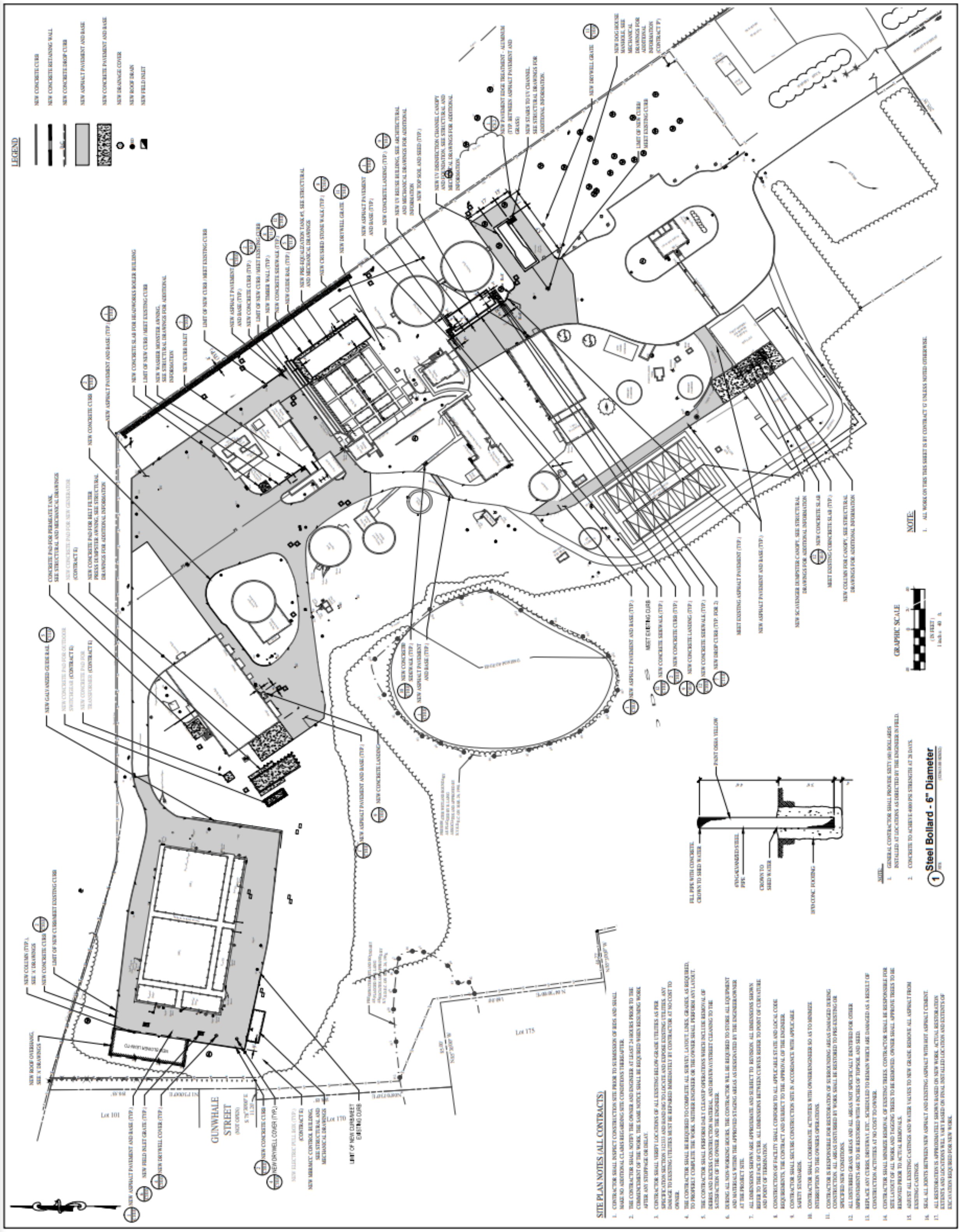
Dimensional Site Plan



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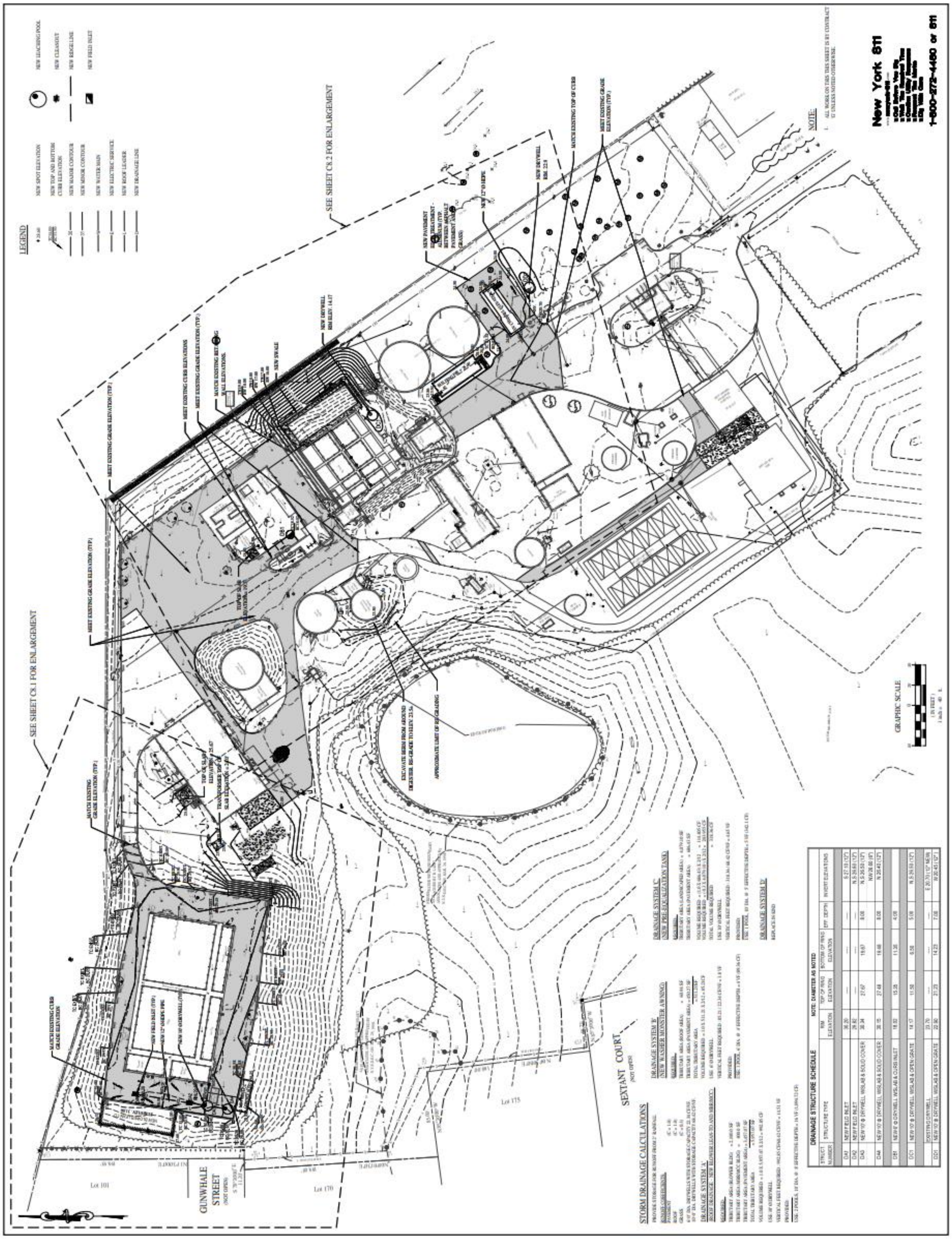
Grading and Drainage Site Plan



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Appendix B – Calculations

Sludge Volume Calculations:

- Specific Gravity of Wet Sludge assuming $GS_s = 1.4$

$$GS_{sl} = \frac{1}{\left(\frac{\%\ solids}{GS_s} + \frac{\%\ water}{GS_w}\right)}$$

Source: Sludge Volume – Weight Relationships

- ❖ Sludge at 15% solids

$$GS_{sl} = \frac{1}{\left(\frac{\%\ solids}{GS_s} + \frac{\%\ water}{GS_w}\right)} = \frac{1}{\left(\frac{0.15}{1.4} + \frac{0.85}{1}\right)} = 1.045$$

- ❖ Biosolids at 90% solids

$$GS_{sl} = \frac{1}{\left(\frac{\%\ solids}{GS_s} + \frac{\%\ water}{GS_w}\right)} = \frac{1}{\left(\frac{0.90}{1.4} + \frac{0.10}{1}\right)} = 1.346$$

- Volume of Sludge (based on 87.5 wet tons/week for current facility treatment flow)

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}}$$

Source: Sludge Volume – Weight Relationships

- ❖ Sludge at 15% solids

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}} = \frac{87.5\ tons/week(2200\ lbs/ton)}{(62.4\ lbs/ft^3)(1.045)} = 2952\ ft^3/week$$

- ❖ Biosolids at 90% solids

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}} = \frac{87.5\ tons/week(2200\ lbs/ton)}{(62.4\ lbs/ft^3)(1.346)} = 2292\ ft^3/week$$

- Volume of Sludge (based on 140 wet tons/week for current facility treatment flow)
  - ❖ Sludge at 15% solids

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}} = \frac{140\ tons/week(2200\ lbs/ton)}{(62.4\ lbs/ft^3)(1.045)} = 4723\ ft^3/week$$

- ❖ Biosolids at 90% solids

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}} = \frac{140\ tons/week(2200\ lbs/ton)}{(62.4\ lbs/ft^3)(1.346)} = 3667\ ft^3/week$$

Calculations for Design Alternatives:

- Thermal Drying Power Consumption Calculations:

Assumption: 1,450 BTUs of energy per pound of water removed

1 dry ton of biosolids (DTS) at 90% solids contains: $W_s = 0.90\ \ ton;\ W_w = 0.10\ ton$

- for 1 wet ton of sludge (WTS) at 15% solids

$$W_s = 0.15\ \ ton;\ W_w = 0.85\ ton$$

$$\frac{0.90\ ton/DTS}{0.15\ ton/WTS} = 6\ WTS/DTS$$

$$(6 \times 0.85\ ton\ water) - 0.1\ ton\ water = 5.0\ ton\ water\ removed/DTS$$

$$(5.0\ ton\ water/DTS \times 2{,}200\ lbs/ton) \times 1{,}450\ BTUs/lb\ of\ water = 15{,}950{,}000\ BTUs/DTS$$

$$Power\ Consumption = \frac{15{,}950{,}000\ BTUs/DTS}{3412.14\ BTUs/kWh} = 4674.5\ kWh/DTS$$

- for 1 wet ton of sludge (WTS) at 25% solids

$$W_s = 0.25\ \ ton;\ W_w = 0.75\ ton$$

$$\frac{0.90\ ton/DTS}{0.25\ ton/WTS} = 3.6\ WTS/DTS$$

$$(3.6 \times 0.85\ ton\ water) - 0.1\ ton\ water = 2.6\ ton\ water\ removed/DTS$$

$$(2.6\ ton\ water/DTS \times 2{,}200\ lbs/ton) \times 1{,}450\ BTUs/lb\ of\ water = 8{,}294{,}000\ BTUs/DTS$$

$$Power\ Consumption = \frac{8{,}294{,}000\ BTUs/DTS}{3412.14\ BTUs/kWh} = 2430.7\ kWh/DTS$$

- for 1 wet ton of sludge (WTS) at 35% solids

$$W_s = 0.35\ \ ton;\ W_w = 0.65\ ton$$

$$\frac{0.90\ ton/DTS}{0.35\ ton/WTS} = 2.57\ WTS/DTS$$

$$(2.57 \times 0.85\ ton\ water) - 0.1\ ton\ water = 1.57\ ton\ water\ removed/DTS$$

$$(1.57\ ton\ water/DTS \times 2{,}200\ lbs/ton) \times 1{,}450\ BTUs/lb\ of\ water = 5{,}008{,}000\ BTUs/DTS$$

$$Power\ Consumption = \frac{5{,}008{,}000\ BTUs/DTS}{3412.14\ BTUs/kWh} = 1467.8\ kWh/DTS$$

- for 1 wet ton of sludge (WTS) at 50% solids

$$W_s = 0.50\ \ ton;\ W_w = 0.50\ ton$$

$$\frac{0.90\ ton/DTS}{0.50\ ton/WTS} = 1.8\ WTS/DTS$$

$$(1.8 \times 0.85\ ton\ water) - 0.1\ ton\ water = 0.8\ ton\ water\ removed/DTS$$

$$(0.8\ ton\ water/DTS \times 2{,}200\ lbs/ton) \times 1{,}450\ BTUs/lb\ of\ water = 2{,}552{,}000\ BTUs/DTS$$

$$Power\ Consumption = \frac{2{,}552{,}000\ BTUs/DTS}{3412.14\ BTUs/kWh} = 747.9\ kWh/DTS$$

- Thermal Hydrolysis without Anaerobic Digestion – Electrical Costs:
  - Cost per DTS

    $\$0.114642/kWh \times 60\ kWh/DTS = \$6.88/DTS$
  - Current Cost per Year

    $\$6.88/DTS \times 700\ DTS/year = \$4{,}830/year$
  - Design Cost per Year

    $\$6.88/DTS \times 1{,}100\ DTS/year = \$7{,}590/year$
- Thermal Hydrolysis without Anaerobic Digestion – Potassium Hydroxide Costs:

  Given: 190-230 lbs. of 445% alkaline solution/DTS

  12.14 lbs./gal

  $2,100 per 200 L of 45% Potassium Hydroxide solution

  200 L ~ 53 gals. = 650 lbs.

  3 dry tons per $2,1000 spent
  - Cost per DTS

    $\$2{,}100\ /\ 3\ DTS \approx \$700/DTS$
  - Current Cost per Year

    $\$700/DTS \times 700\ DTS/year = \$490{,}000/year$
  - Design Cost per Year

    $\$700/DTS \times 1{,}100\ DTS/year = \$770{,}000/year$
- Advance Alkaline Stabilization Electrical Costs:
  - Cost per DTS

    $\$0.115/kWh \times 350\ kWh/DTS = \$40.25/DTS$
  - Current Cost per Year

    $\$40.25/DTS \times 700\ DTS/year = \$28{,}175/year$
  - Design Cost per Year

    $\$40.25/DTS \times 1{,}100\ DTS/year = \$44{,}275/year$
- Thermophilic Anaerobic Digestion

  (taking biogas production into consideration)

  Consider 140 wet tons of sludge per week = 20 wet tons/day
  - Consider a 1:2 Waste: Water Slurry

    $Flow\ Rate = 1(20\ wet\ tons) + 2(20\ wet\ tons) = 60\ tons = 60{,}000\ m^3/day$
  - Retention time of 8-12 days (Consider 12 days)

    $60{,}000\ m^3/day \times 12\ days\ = 720{,}000\ m^3$
  - Considering a 25% biogas layer

    $720{,}000\ m^3 + 240{,}000\ \ m^3 = 960{,}000\ m^3$ *Required Volume*

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Appendix C – References

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