



Hazen and Sawyer
804 Green Valley Road, Suite 206
Greensboro, NC 27408 • 336.292.7490



Solids Handling PER

Municipal Sewerage District of Buncombe County
Final Report

January 29, 2026
31359-001



French Broad River Water Reclamation Facility

Solids Handling PER

January 29, 2026



Hazen

804 Green Valley Road, Suite 206
Greensboro, NC 27408
C-0381

December 15, 2025

To: Metropolitan Sewerage District of Buncombe County (MSD)

From: Sharanya Ananth, Hazen
Aaron Babson, PE, Hazen
Ruth Borgmann, PE, Hazen
Michael Bullard, PE, Hazen
Jacqueline Yeh, PE, Hazen

French Broad River WRF Solids Handling PER – Executive Summary

FINAL

Table of Contents

1. Introduction	3
1.1 Existing Solids Handling Process	3
2. Solids Mass Projections	4
2.1 Flow and Population Projections	4
2.2 Primary and Secondary Solids Production	6
2.3 Condition and Capacity Assessment	8
3. Solids Redundancy Assessment	8
3.1 Redundancy Alternative: Landfill Disposal	9
3.2 Redundancy Alternative: Rehabilitation of Existing FBI	10
3.3 Redundancy Alternative: Thermal Drying	10
4. Overall Solids Management	11
4.1 Solids Management Site Planning	12
4.2 Thickening Technology Assessment	13
4.3 Dewatering Technology Assessment	14
4.4 Thermal Drying Assessment	15
4.5 Incineration Assessment	17
5. Solids Management Considerations	19
5.1 Permitting	19
5.2 Final Product Management	19
5.3 Cost Comparison	19
6. Next Steps	21
6.1 Solids Management Selection	21
6.2 Alternative Delivery Options	23
6.3 Proposed Project	23

1. Introduction

The Metropolitan Sewerage District (MSD) of Buncombe County retained Hazen and Sawyer (Hazen) to complete a Solids Handling Preliminary Engineering Report (PER) for the French Broad River Water Reclamation Facility (FBRWRF). The PER includes a condition and capacity assessment of the existing equipment, technology assessments, permitting assistance and development of a new solids handling facility concept to be seamlessly integrated into the forthcoming liquid train project.

The purpose of this executive summary is to summarize the results of the following technical memoranda and provide recommendations for the detailed design phase of the solids handling project:

- TM No. 1 – Solids Projections, Condition and Capacity Assessment
- TM No. 2a – Redundancy Assessment
- TM No. 2b – Technology Assessment
- TM No. 2c – Thermal Drying Assessment
- TM No. 2d – Incineration Assessment
- TM No. 3 – Incineration Supplement

1.1 Existing Solids Handling Process

The FBRWRF currently produces a combination of primary sludge (PS) and waste activated sludge (WAS) which are thickened, dewatered, and incinerated. Incinerator ash is managed onsite via an ash thickener and ash lagoon. The existing solids treatment process contains the following major unit process facilities:

- Gravity Thickening
- Belt Filter Press (BFP) Dewatering
- Fluidized Bed Incineration (FBI)
- Ash Handling

Figure 1-1 shows the solids process flow diagram and **Table 1-1** summarizes the design criteria for the existing solids unit processes.

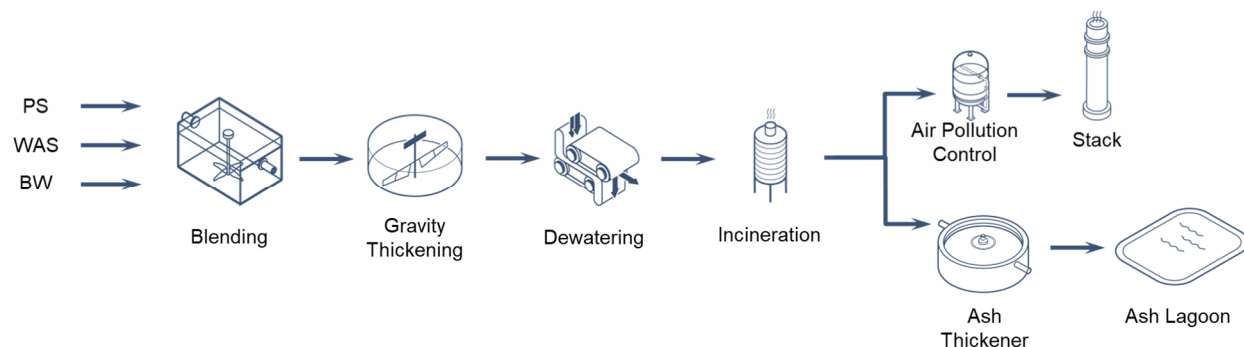


Figure 1-1: Existing Solids Handling Process Flow Diagram

Table 1-1: Summary of Existing FBRWRF Solids Infrastructure

Process Unit	Parameter	Design Criteria
Thickening	Gravity Thickeners	(2) 100-ft gravity thickeners
	Thickened Solids Pumps	(3) 150 gpm progressive cavity pumps
Dewatering	Polymer Feed	Dry polymer prep system 390-gal mix/feed tank (3) 5 gpm dilute polymer solution feed pumps
	Dewatering Equipment	(2) 2.5-meter BFPs Solids Loading Rate: 1,562.5 lb-dry/hr Hydraulic Loading Rate: 250 gpm
	Conveyance	(2) 12-in Screw Conveyors (162 cu ft/hr volumetric capacity, each)
Incineration	Cake Pumping	(2) 42 gpm Schwing Cake Pumps
	Incinerator	(1) 40 dry tons per day (dtpd) FBI, derated to 39.8 dtpd (2) 6,500 standard cubic feet per minute (scfm) fluidizing air blowers (1) primary heat exchanger (1) quencher (1) multi-venturi scrubber (2) purge air blowers (1) NPW booster pump skid
Ash Handling	Ash Slurry Pump	(2) ash slurry transfer pumps
	Ash Thickener	(1) 18-ft ash thickener
	Thickened Ash Pumps	(2) thickened ash pumps
	Ash Lagoon	9-acre lagoon

2. Solids Mass Projections

2.1 Flow and Population Projections

Hazen prepared flow projections to establish the influent flow of the FBRWRF in target year 2053 to estimate future solids handling requirements. The approach utilized the most recent traffic analysis zone (TAZ) population estimates along with unit rates and assumptions established by CDM Smith as part of a 2019 study. MSD and Hazen worked together to refine the expected area to be served over the next 30 years to ensure the flow projections are in line with general growth expectations. At the start of the study in 2022, 2023 was selected as the start year and 2053 as the 30-year projection target year.

Table 2-1 summarizes the flow projections using 2022 as the base year and projecting forward to the target year 2053. **Figure 2-1** shows the projected flow will remain under the plant's treatment capacity

when the target year is reached. However, the 80% and 90% treatment capacity will be exceeded; therefore, potential 50 and 60 mgd expansion design scenarios were also considered. These flow projections were also used to develop operations and maintenance (O&M) annual and life cycle cost estimates.

Table 2-1: Flow Projection Summary Table

	Population Growth	Per Capita GPCD	Flow (mgd)
Annual Average Dry Weather Flow 2022			20.07
Residential	76,228	58	4.42
Employee	92,931	33	3.07
Industrial & DWI			1.44
2053 Annual Average Dry Weather Flow (mgd)			29.00
2053 Annual Average (1.06x) Flow (mgd)			30.61
2053 Maximum Month (1.3x) Flow Calculation (mgd)			39.79

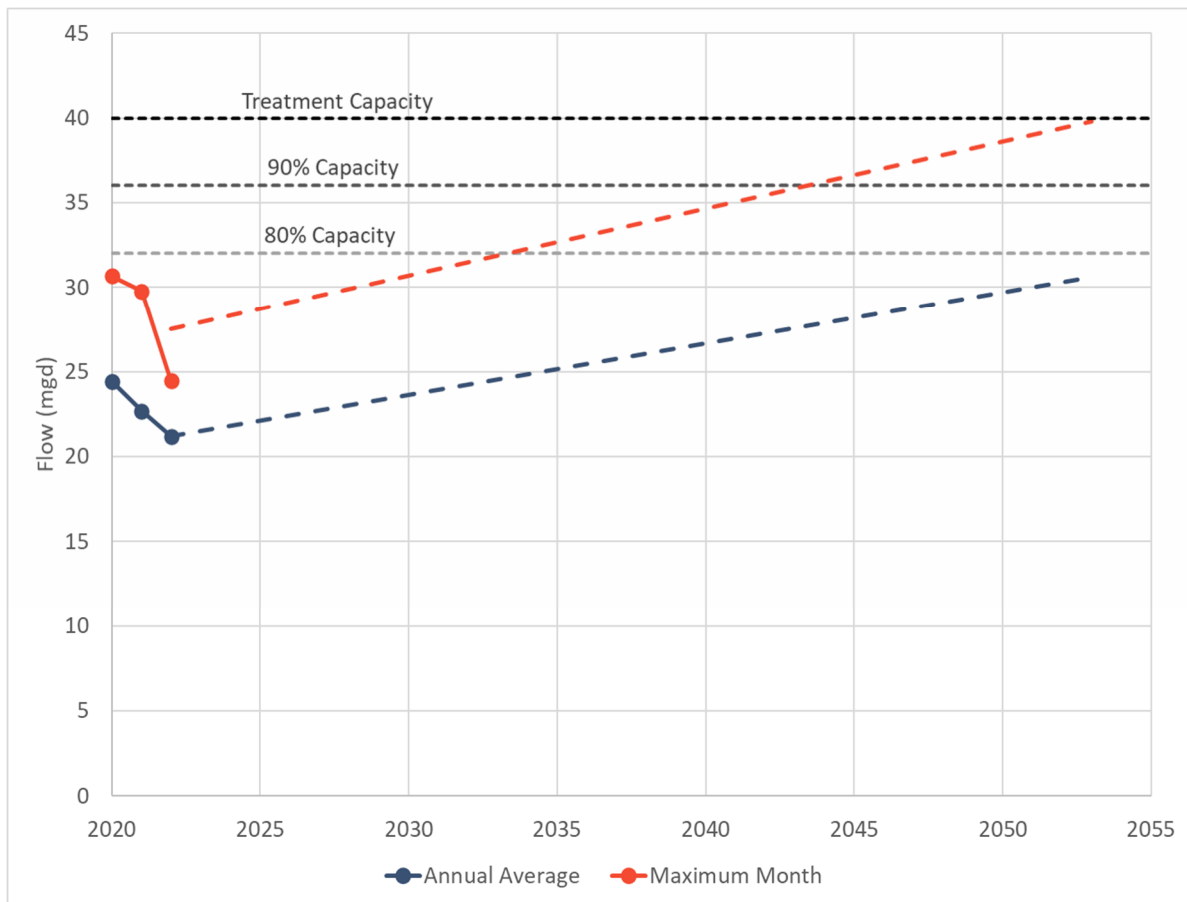


Figure 2-1: Future Flows Projection

2.2 Primary and Secondary Solids Production

The influent wastewater to the FBRWRF is composed mainly of domestic sewage. The average concentrations for influent BOD₅ and TSS were used to calculate the solids loadings. Both the influent BOD₅ and TSS concentrations are characteristic of typical medium strength domestic wastewater.

In the concurrent liquids study, the following six biological nutrient removal alternatives were evaluated:

- Aerobic Granular Sludge (AGS)
- Biological Aerated Filter (BAF)
- Densified Activated Sludge (DAS)
- Integrated Fixed-Film Activated Sludge (IFAS)
- Membrane Aerated Biofilm Reactor (MABR)
- Moving Bed Biofilm Reactor (MBBR)

Based on the evaluation completed as a part of the Biological Treatment Alternatives Evaluation, it was assumed that the recently installed high-rate primary treatment (HRPT) process would be retained with all of the secondary treatment process alternatives. Preliminary testing indicates that the HRPT system can

treat a maximum of 7.5 mgd per train (15 mgd total). Therefore, it was assumed that only 15 mgd of the influent flow would be processed through the HRPT system; the remainder of the influent flow would bypass the HRPT by gravity to the selected secondary treatment process. Additional scenarios were considered when only one HRPT train is in service to ensure that the solids processes are capable of managing increased secondary loads from increased HRPT bypass flows.

Table 2-2 provides a summary of the inputs and assumptions used for calculating annual average (AVG365), maximum month (MAX30), maximum two-week (MAX14), and maximum week (MAX07) solids production. Secondary sludge production rates were estimated as a part of the concurrent biological treatment alternatives study. For the six alternatives, Hazen coordinated with manufacturers and relied on previous modeling experience and documented yield rates to predict biomass growth and decay to develop each sludge production rate. For conservatism, the DAS alternative was carried through the solids assessments since it has the highest secondary solids production.

Table 2-2: Solids Mass Projection Assumptions

Parameter	Value			
Average Annual Influent BOD ₅	230 mg/L			
Average Annual Influent TSS	220 mg/L			
HRPT Maximum Capacity	15 mgd			
HRPT TSS Removal Efficiency	70%			
HRPT BOD ₅ Removal Efficiency	50%			
Biological Reactor Age	Coordinated with each process manufacturer / process modeling ¹			
Peaking Factors	Annual Average (AVG365)	Maximum Month (MAX30)	Maximum Two Week (MAX14)	Maximum Week (MAX07)
BOD ₅ Mass Loading Peaking Factor	1.00	1.15	1.35	1.45
TSS Mass Loading Peaking Factor	1.00	1.15	1.50	1.60

¹See FBRWRF Preliminary Evaluations TM No. 1. In TM, a MAX30 peaking factor of 1.15 and a maximum day peaking factor of 1.8 was established. MAX14 and MAX07 not defined as a part of the Biological Treatment Alternatives Evaluation.

Table 2-3 shows the sludge production loading rate for the 40 mgd design capacity for the DAS process.

Table 2-3: Total Sludge Loading Rates (lb/day) at 40 mgd

Parameter	Design	MAX14	MAX07	PS:WAS Ratio
DAS Sludge Production, lb/day	66,500	83,200	89,000	33%

2.3 Condition and Capacity Assessment

A visual, mechanical condition assessment of the existing solids handling equipment and staff interviews were conducted during a site visit in June 2023 by Hazen and its subconsultant, Chavond-Barry Engineering (CBE), to identify visible mechanical defects and deficiencies. For detailed assessments of each piece of equipment, reference TM No. 1.

Based on the rated capacity of the existing FBI of 40 dtpd, the FBI is inadequate to support estimated maximum two-week (MAX14) and maximum week (MAX07) mass peaking events for all secondary treatment alternatives under consideration at plant permitted capacity. The facility is not anticipated to reach permitted plant flows until 2053 based on the flow projections presented in Section 2.1 above. Therefore, it was determined by MSD and Hazen that installation of a new solids final management technology would be required. The dewatering equipment and polymer system are in good condition and have adequate capacity for the design scenarios, but if a new final solids management facility is constructed in a location at a distance from the existing Solids Handling Facility, conveying dewatered cake may not be a realistic assumption. Based on the age of the dewatering equipment, replacement during the construction of a new final solids handling facility is recommended.

FBRWRF currently operates the gravity thickeners with only one GT in service. With only one gravity thickener in service, the solids loading rate for the projected MAX30, MAX14, and MAX07 scenarios is within the acceptable range for gravity thickeners based on WEF MOP 8. However, with the process configurations for each of the liquid alternatives, gravity thickening presents some challenges. Both AGS and DAS include settling via gravity, through settling tanks and a hydrocyclone, respectively. Therefore, the solids that are received at thickening are not likely to settle well with further use of a gravity settling process.

The existing Sludge Blending Tank capacity of 12,000 gallons was determined to not have adequate capacity for WAS storage and blending. It is recommended that the existing tank only be used for primary sludge storage and three additional tanks adjacent to the proposed solids handling facility be added for PS/WAS and thickened solids storage.

3. Solids Redundancy Assessment

Due to the anticipated capacity issues for the 40 MGD scenario with the existing infrastructure, a redundancy assessment was conducted to evaluate biosolids management strategies that could be implemented to provide redundancy to a new FBI, be implemented during incinerator downtime, or be implemented in place of a new incinerator. The following potential alternatives were considered and presented to MSD:

- Landfill Disposal / Management with current FBI
- Rehabilitation of the existing FBI / New FBI
- Thermal Drying / FBI Rehab
- Thermal Drying – Redundant Units
- Composting
- Supercritical Water Oxidation (SCWO)

- Lime Stabilization
- Third-Party Management

The composting, supercritical water oxidation, lime stabilization and third-party management options were all ruled out for further evaluation by MSD during the Redundancy Assessment Workshop. Details regarding reasoning for the removal of these options from consideration may be found in TM2a – Redundancy Assessment.

The landfill disposal/management with current FBI, rehabilitation of the existing FBI paired with a new FBI, and both thermal drying alternatives were selected for further evaluation and will each be discussed in the following sections. MSD's primary considerations for selection of redundancy alternatives were having control of their own destiny (MSD-led or owned solids handling strategy, with no separate entity) and reduced operation and maintenance costs since the redundant strategy will only be utilized when the new incinerator or thermal dryer is offline.

3.1 Current Scenario: FBI and Wet Cake Landfill Disposal

The current redundant solids management option at the FBRWRF is hauling dewatered cake to the nearby Buncombe County Landfill. This is a short-term biosolids handling outlet. MSD has a long-standing verbal agreement with the Buncombe County Landfill for waived tipping fees for disposal of their biosolids in exchange for receiving the landfill leachate at the FBRWRF. Although this agreement is currently highly beneficial for the FBRWRF during incinerator downtime, there is no guarantee that such an agreement will be maintained in the future and without a written contract, the landfill may refuse to accept dewatered cake for a variety of reasons or impose a high tipping fee, leaving the FBRWRF with no outlet in place to dispose of their solids or a greatly increased operation cost to continue disposing of solids at the landfill. Typical landfill tipping fees at other sites in the southeast region range between \$40 and \$125 per wet ton (wT), which could become a considerable added expense to MSD, if implemented. Another challenge of this option is that the acceptance hours of the landfill do not line up with the dewatering hours required by MSD, meaning truck staging is required to continue dewatering operations when the landfill is not open to accept solids.

Currently, the FBRWRF receives approximately 100,000 to 150,000 gallons of landfill leachate per day from the Buncombe County Landfill. This leachate could represent a significant PFAS and emerging contaminant risk to the treatment facility operations. MSD is evaluating a potential PFAS mitigation system that would be located at the Buncombe County Landfill to reduce PFAS risk at the FBRWRF. Discussions to update leachate management and address PFAS concerns present an opportunity for MSD and Buncombe County Landfill to work together and sign a contract that could formalize the design, construction and operation of a remote leachate treatment system. If this option is continued as the primary mode of redundancy, it should be formalized to protect all parties with regards to PFAS risk and have defined cake hauling expectations.

3.2 Redundancy Alternative: Rehabilitation of Existing FBI with New FBI

Another redundancy option that would allow MSD to leverage existing assets would be to rehabilitate the existing incinerator and upgrade the air pollution control equipment to meet the more stringent LLLL regulations. This alternative would allow the rehabilitated incinerator to operate during times when a new incinerator is down, maintaining the existing ash lagoon as the solids management location for produced ash.

The existing incinerator would not have enough capacity to be a completely redundant alternative for the new incinerator at its current 39.8 dT per day capacity. Therefore, for a truly redundant alternative, the incinerator would need to be replaced with a larger unit in addition to the air pollution control upgrades.

The existing Solids Handling Building is space constrained and does not have room to fit an additional FBI and the associated dewatering equipment. Therefore, the new FBI would need to be located in a separate building. This further complicates this alternative as there are limited options for conveying dewatered cake over long distances which means the plant would likely need to maintain and operate two different dewatering facilities in addition to two different FBIs. Incinerators should not be cycled on and off frequently as thermal cycling can impact material longevity and incinerator startup is an involved process that takes time and significant operator attention. In order to maintain two FBIs in operation, an operational scheme to cycle each incinerator on and offline would need to be developed to balance thermal cycling concerns with maintenance demands on the equipment.

Beyond the operational concerns and siting issues, this alternative requires a significant capital investment in the existing FBI to allow it to operate as a truly redundant facility. In addition, there are potential permitting challenges with this alternative and at a minimum a lengthy permitting process to be the first FBI permitted under the more stringent LLLL rules in EPA Region 4..

3.3 Redundancy Alternative: Thermal Drying with New FBI or Existing FBI

Thermal drying is a process that uses thermal energy (heat) to evaporate a significant amount of water from sludge, resulting in volume and mass reduction of solids, to produce a high-quality Class A dried product, typically greater than 90% dry product solids (less than 10% moisture content). The high quality nature of this dried product would provide MSD with more flexibility in finding a final product outlet. Depending on market and customer development, the dried solids could potentially be a revenue source estimated to be in the range of \$5-\$20 per product ton. However, revenue potential for this project is dependent on identifying a customer, and therefore, revenue from this source will not be considered in the financial analysis. For this redundancy alternative, a thermal dryer, cake bin, dewatered cake conveyance, other ancillary equipment, and a new facility housing the thermal drying process would be required onsite at the FBWRF. Dryer sizing will be further explored in the thermal drying assessment section.

In workshops with MSD, it was noted that thermal drying as a redundancy alternative to a new incinerator presents a significant capital cost and is not the recommended usage of a dryer. In the vast majority of facilities with thermal dryers, the technology is the primary final solids management strategy. Thermal dryers are operated in campaigns to manage the solids produced per week and similar to incinerators

require significant startup effort if not used frequently. Thus, MSD determined that thermal drying would be considered alongside incineration as a primary solids management alternative. Hazen evaluated redundancy alternatives for the dryer as a primary technology option as part of the thermal drying assessment with a second thermal dryer as the redundant option.

3.4 Redundancy Alternative: Redundant Thermal Drying Units

As noted above, thermal drying is typically the primary solids management strategy for a facility and does not serve as a redundant technology to another solids processing technology. Therefore, an alternative with two thermal drying units was evaluated. For this redundancy alternative, the new facility would be sized to house a fully redundant thermal dryer train (from dewatering to pellet loadout) and dryer sizing would take into account the redundancy capabilities to help process peak loading scenarios.

As compared to the Thermal Drying and FBI alternative above, this option allows the facility to focus operations and maintenance on one solids management process alone instead of the difficulty of maintaining the ability to operate two disparate and complex processes. Because a new facility is required for the thermal dryer process, it could be adequately sized for both units and would allow all solids operations to be centralized at the FBWRF instead of having to operate two separate technologies in two separate locations. In addition, transitioning to thermal drying would simplify air permitting for the facility and allow FBRWRF to drop their Title V permit and associated annual stack and rata testing and annual compliance monitoring for the SO₂ and mercury scrubber.

4. Overall Solids Management

Based on the Redundancy Assessment workshop, both thermal drying and incineration were advanced in the evaluation as primary solids management options. For the incineration option, it was assumed that rehabilitation of the existing FBI would be included as the redundancy alternative. For the thermal drying option a redundant thermal dryer was considered. As part of the evaluation, thickening and dewatering technologies were considered with respect to each final solids management technology. The pros and cons of each thickening, dewatering, and final solids technology were assessed to determine the recommended combination of treatment options for the FBRWRF. The following process flows were considered in the development of the technology assessments.

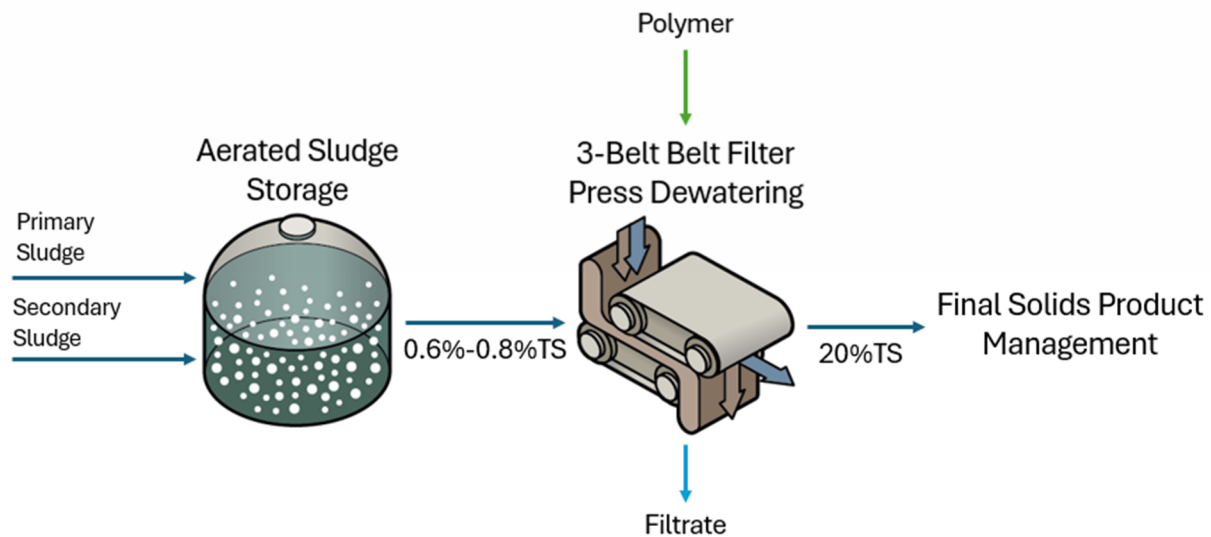


Figure 4-1: Overall Process Flow with 3-Belt BFP (Combined Thickening and Dewatering)

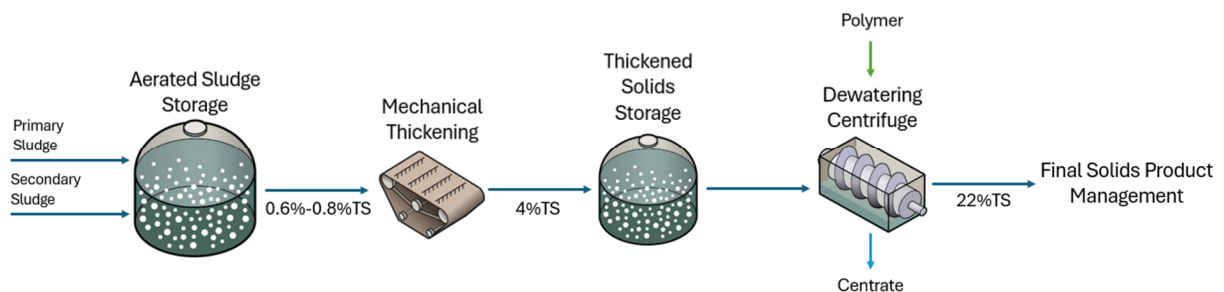


Figure 4-2: Overall Process Flow with Mechanical Thickening and Centrifuge Dewatering

4.1 Solids Management Site Planning

For a facility of the size required for solids processes and a thermal dryer or incinerator, the optimal location on the site is the space behind the former administration and training facility. This location is shown on the plant site in **Figure 4-3** marked with a white box.



Figure 4-3: New Solids Handling Facility Location

The space in this location is adequate for a facility with a maximum size of approximately 300 feet long and 100 feet wide. Per the preliminary geotechnical report commissioned by MSD, this area is suitable for a large solids handling facility. The two borings collected in the area showed deep residual soils that varied from medium to stiff density on average. A more detailed geotechnical evaluation will be required as design progresses to gather additional borings and run settlement analyses on proposed structure loading to provide final confirmation that no subgrade remediation will be required. The space below this footprint is reserved for secondary treatment improvements. Additional sitework will be required to expand this space in the northwest direction. Expansion in other directions is not recommended due to grade and potential conflicts with the ash lagoon. Space is also required around the facility for road access for truck hauling and service purposes.

4.2 Thickening Technology Assessment

The thickening technology assessment considered if the FBRWRF should maintain gravity thickening or transition to mechanical thickening, with a technology such as gravity belt thickening (GBT) or rotary drum thickening (RDT). The recommended number of thickening units was developed based on 24/7 operation, with thickening decoupled from dewatering and final solids management. A detailed comparison of the two technologies can be found in TM No. 2b as well as considerations and concerns with continuing to operate with gravity thickening.

Gravity thickening provides a wide spot between liquids processes and dewatering in the current process configuration. With a transition to mechanical thickening, sludge storage will be required to decouple the thickening process from the liquid treatment processes. Three (3) tanks are proposed to have a volume of 500,000 gallons, each, with one tank designated for each of the following:

- Primary and WAS blending
- Thickened sludge storage
- Swing (blending to thickened sludge storage)

The tanks would have piping for transfer between tanks and will be aerated and mixed.

The thickening equipment will operate in solids limited mode. Based on the breakpoint solids concentration of the equipment, DAS solids must be blended with PS to increase the feed solids concentration for solids limited loading. For layouts and cost estimates, RDTs were considered since more units and ancillary equipment are required.

4.3 Dewatering Technology Assessment

Two dewatering technologies, a belt filter press (BFP) and a dewatering centrifuge (DCEN), were evaluated for the liquid treatment alternatives. The equipment was sized by considering the required downstream solids management for the various solids loading scenarios. Equipment design criteria will be presented in the thermal drying and incineration assessment summary. The primary decision drivers for dewatering technology selection are the final solids management process and capital and O&M costs.

Because it is not recommended to dewater cake in one facility and pump dewatered cake across the site to another final solids management facility, it is not viable to maintain dewatering in the existing Solids Handling Facility. Therefore, it is assumed that a new dewatering facility would be located at the site identified in Figure 4-3. Further discussion of maintaining dewatering in the existing facility vs locating in a new solids complex can be found in TM No. 2b.

In the dewatering technology assessment, a standard 2-belt BFP was considered. However, thickening is recommended prior to BFP dewatering, which necessitates thickened sludge storage. In order to minimize the footprint of the process, a three-belt BFP was proposed following discussion of the thickening and dewatering technology assessments since it incorporates an independent gravity belt that can adapt to a thinner feed sludge without compromising solids mass throughput.

DCENs are a dewatering technology that rely on centrifugal force to separate solids from water in liquid sludge. TM No. 2b provides a more detailed technical description of how the technology works. A comparison of dewatering technologies considered is shown in **Table 4-1**.

Table 4-1: Dewatering Equipment Comparison

Parameter	Belt Filter Press	Centrifuge
Advantages	• Lower operating and maintenance costs • Lower energy demand	• Higher cake solids (optimizes thermal drying process) • Smaller equipment footprint • Fully enclosed operation (limited odor potential)
Disadvantages	• Open process (higher odor potential) • High washwater demands • Larger equipment footprint	• Requires specialized maintenance and operation • Higher power consumption • Higher noise • High rotational speeds

4.4 Thermal Drying Assessment

Thermal drying utilizes thermal energy to evaporate a significant amount of water from sludge, resulting in both volume and mass reduction of solids to produce a high-quality dried product. For MSD to produce a Class A product, the end product must be greater than 90% dry product solids, because it has undigested primary sludge in the feed. While there are multiple thermal dryer technologies, such as belt dryers and indirect paddle dryers, a rotary drum dryer is recommended for the scale of drying operation required at the 40 mgd condition for the FBRWRF. Further details on the technical theory behind a rotary drum dryer are provided in TM No. 2c – Thermal Drying Assessment.

Advantages of thermal drying as a technology include the flexibility of outlets for the dried product, as it can be pelletized and sold for valuable use. The dried end-product is of a uniform size and shape, which allows it to be marketable in a wide range of applications. However, a large-scale pellet distribution operation will require market evaluation and customer development, as well as increased operational and maintenance costs. The primary operational cost for a rotary drum dryer is the cost of the natural gas required to continually heat the drum during operation.

In the United States, the most common vendor for rotary drum dryer systems is Andritz. **Figure 4-4** shows an example installation of an Andritz rotary drum dryer, along with the required ancillary equipment.



Figure 4-4: Rotary Drum Dryer and Ancillary Equipment by Andritz

In addition to the thermal dryer, several ancillary systems are required to support the drying process. A typical Andritz rotary drum dryer system package includes the following per dryer:

- Wet Cake Receiving Bin / Cake Hopper – receive solids from dewatering
- Dewatered Cake Pumps – transfer solids from the wet cake bin to the dryer
- Regenerative Thermal Oxidizer (RTO) – optional Odor Control for exhaust gas
- Nitrogen Generator – provides nitrogen to maintain an oxygen-deficient atmosphere
- Dried Product Silo – typically 7-14 days of final product storage
- Control equipment – including MCC and VFD

In discussion with MSD, it was determined that two dryer trains would be optimal due to the redundancy present for operational flexibility. For two dryer trains, dryers can be sized such that one train manages the annual average loading at 24 hours per day for seven days a week. The second train can be brought online to manage excess loads during the maximum month or week loading conditions. In MSD's selected scenario, one dryer train would be installed in the original construction with another installed prior to reaching 40 mgd loading. The thermal dryer must be sized so that it can operate on the single dryer scheme for all loading scenarios prior to installation of the second dryer. The thermal dryer and

dewatering equipment design criteria are presented below in **Table 4-2**, for the DAS scenario with two thermal dryers.

Table 4-2: Required Drying and Dewatering Equipment

Parameter	Belt Filter Press	Centrifuge
Number of Thermal Dryers	2	2
Thermal Dryer Model, Andritz	DDS-50	DDS-40
Thermal Drying Evaporative Loading Rate, lb(water)/hr each	11,000	8,800
Recommended Number of Duty Dewatering Units per Dryer	2	1
Recommended Number of Total Duty Dewatering Units	4	2
Recommended Total Number of Dewatering Units	5	3
Dewatering Solids Loading, lb(dry)/hr per unit	1,700	3,200
Dewatering Unit Size	2.0-m (belt width)	24-25 in (bowl size)
Solids Loading Rate per Meter, lb(dry)/hr-m	850	--

Due to the higher solids content of cake produced by centrifuges, the thermal dryer can be downsized from the BFP sizing. Additionally, due to the larger processing capacity available for centrifuges, less dewatering equipment is required. Due to these factors, the layout required for a thermal drying facility with centrifuges is smaller than that required for one with BFPs. Preliminary assessment indicates that the entire solids complex could be located in the location identified in **Figure 4-3**. Detailed layouts may be found in TM2c – Thermal Drying Assessment.

There are many uncertainties with this facility design, including footprint of the selected thickening and dewatering technologies, timeline of installation of the second dryer, and required site work for the location. If thermal drying is selected, further evaluation is required to determine which layout will provide MSD with the most flexibility while being cost efficient.

4.5 Incineration Assessment

Chavond-Berry Engineering (CBE) evaluated a new Fluidized Bed Incinerator (FBI) as a primary solids management option for the FBRWRF. CBE performed an Incineration Assessment on fluidized bed incinerators (FBI) due to MSD's experience with the technology at the FBRWRF and as the more common incineration style compared to multiple hearth incinerators (MHI). This assessment included review of energy recovery systems, air pollution control measures, mercury control measures, and additional emerging contaminant considerations, namely dioxin furan and per- and polyfluoroalkyl substances (PFAS). Since the construction and permitting of the existing FBI, more stringent air pollution requirements have been placed on sewage sludge incinerators. This necessitates upgraded air pollution control (APC) equipment if a new incinerator is installed.

A design concept for a new incinerator building with solids processing, including dewatering, was developed in the new solids complex area shown in **Figure 4-3**. The following recommendations shown in **Table 4-3** were made for ancillary equipment if a new incinerator is selected. Further details on the

evaluation of each technology are provided in CBE's Asheville Air Pollution Control TM. With the recommended technologies, a minimum building with a footprint of 50 ft width and 100 ft length is recommended. Based on discussions with MSD, a larger building would be desired to provide additional maintenance and operations access to the equipment. This footprint does not include sludge storage, carbon bed, sand storage silo or ash thickening equipment.

Table 4-3: Incineration Equipment Recommendations

Parameter	Recommendation
Incinerator Type	Fluidized Bed Incinerator
Incinerator Size, dT/day	44.5
Recommended Total Number of BFPs	4
Recommended Total Number of DCENs	3
Energy Recovery Option	Primary Heat Exchanger
Air Pollution Control System	Wet Scrubber with WESP
Mercury Control Technology	Carbon Bed

Advantages of incineration include less management of the final product, as the ash produced by incineration can be processed by the ash lagoon following ash thickening, a smaller footprint than thermal drying, and a simpler 24/7 operational scheme. The primary disadvantage for a new incinerator is the permitting process, which is generally more robust than what is required for a thermal dryer. The public perception of incineration also presents a challenge for construction of a new incinerator compared to thermal drying. In addition, rehabilitation or replacement of the existing FBI would also need to be considered for redundancy. Reuse of the existing Solids Handling Building was considered to fully leverage the existing assets and reduce overall capital cost. However, this means that the facility would have to maintain two separate dewatering and incineration facilities which would be an operational burden. A centralized facility with two new FBIs was not considered due to the prohibitive cost associated with that alternative.

The same considerations for the overall solids management scheme at the FBRWRF are present for incineration as for thermal drying. Centrifuges will provide a thicker dewatered cake to the incinerator, which will require less supplemental fuel than dewatered cake from a BFP. Sludge storage is recommended to decouple the solids and liquids processes and maintain a wide spot for incinerator downtime.

5. Solids Management Considerations

5.1 Cost Comparison

Each facility concept was evaluated for capital and O&M costs. Capital costs are broken down by civil, mechanical, structural/architectural, and electrical/instrumentation costs. The following contingencies are then applied:

- Engineering Contingency: 30% (applied to Subtotal 1)
- Contractor Overhead, Profit, and Mobilization: 30% (applied to Subtotal 2)
- Owner's Allowance: 5% (applied to Subtotal 2)

The capital costs for each of the solids handling facility concepts previously laid out for the process options are shown in **Table 5-2**. The Total Construction Cost (No Redundancy) represents the cost associated with one thermal dryer and one new FBI. MSD requested a capital cost estimate for installation of a second dryer train and for replacement of the existing FBI to understand the total construction cost including redundancy. Therefore, the Total Construction Cost (Full Redundancy) below presents that cost.

Table 5-2: Opinion of Probable Construction Cost

Parameter	Thermal Drying	Incineration
Civil Cost, \$	\$11,000,000	\$8,000,000
Mechanical and Equipment Cost, \$	\$33,000,000	\$35,000,000
Structural and Architectural Cost, \$	\$20,000,000	\$18,000,000
Electrical and I&C Cost, \$	\$13,000,000	\$13,000,000
Subtotal 1: Total Capital Cost, \$	\$77,000,000	\$74,000,000
Engineering Contingency (30%), \$	\$24,000,000	\$23,000,000
Subtotal 2: Total Capital Cost including Contingency, \$	\$101,000,000	\$97,000,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$31,000,000	\$30,000,000
Owner's Allowance (5%), \$	\$6,000,000	\$5,000,000
Total Construction Cost (No Redundancy), \$	\$138,000,000¹	\$132,000,000²
Total Construction Cost for Redundant Unit, \$	\$32,000,000	\$80,000,000
Total Combined Construction Cost (Full Redundancy), \$	\$170,000,000	\$212,000,000

¹New facility sized for redundant thermal dryer train and associated ancillary equipment

²Redundant FBI to be located in existing SHB, new facility only sized for new FBI

The annual and lifecycle cost comparison of the two alternatives is shown below in **Table 5-3**. These numbers represent the O&M cost for the entire solids management train assuming mechanical thickening, centrifuge dewatering and drying or incineration.

Table 5-3: Thermal Drying and Incineration O&M Comparison

Parameter	Thermal Drying	Incineration
20-year Labor Cost (2024 \$)	\$9,000,000	\$13,000,000
20-year Operation Cost (2024 \$)	\$23,000,000	\$20,000,000
20-year Maintenance Cost (2024 \$)	\$32,000,000	\$30,000,000
20-year Hauling Cost (2024 \$)	\$13,000,000	\$10,000,000
20-year Lifecycle O&M (2024 \$)	\$77,000,000	\$73,000,000
CAPEX Cost (2024 \$)	\$170,000,000	\$212,000,000
20-year Lifecycle Cost (CAPEX + OPEX) (2024 \$)	\$247,000,000	\$285,000,000

Incineration presents a lower operating, maintenance and hauling cost compared to thermal drying, with a higher labor cost. This results in a slightly lower lifecycle O&M cost for incineration. However, when combined with the capital cost for the full 20-year lifecycle cost, the incineration option is more expensive than the thermal drying option. The incineration O&M cost does not include incinerator rehab, only maintenance of the incineration equipment and building. Rehabilitation costs may be substantial and require long shutdowns.

6. Solids Management Selection

Thermal drying and incineration both present viable options for final solids management at the FBRWRF. Both technologies have comparable capital and O&M costs. Although a fully redundant thermal drying scenario has a lower CAPEX and 20-year lifecycle cost than the fully redundant incineration option. Thermal drying will generate a marketable product, but if the market is not viable for MSD, the dried product will require disposal. Incineration ash can be managed in a similar manner to the current system at the FBRWRF, with a potential evaluation of the ash lagoon. Thermal drying will require a large footprint compared to incineration, but combining final solids management with the upstream solids processes in a large facility means that the proposed location will have adequate space for the facility layouts required for each option. Due to the existing FBI, both options will likely be permitted under Title V, with the thermal dryer as a modification to the existing permit. Despite stringent air permitting and regulatory requirements, some members of the public hold negative views of incineration due to the presence of stack emissions. By contrast, thermal drying is seen by the public as a novel, sustainable technology which does not produce air emissions and produces a useful product. Dried product as an

alternative to traditional mineral fertilizers also contributes to the sustainability of the project in the community. A summary of the advantages and disadvantages of each technology is presented in **Table 6-1**.

Table 6-1: Thermal Drying and Incineration Technology Comparison

Parameter	Thermal Drying	Incineration
Pros	- Dried product flexibility and positive public perception - Reduced regulatory burden - Greenhouse gas offset - Redundancy throughout the process with storage wide spot and future second dryer train - Potential for add-on PFAS treatment such as gasification/pyrolysis - Does not require substantial rehab as often as incineration	- Final product management onsite via ash lagoon - Smaller facility footprint
Cons	- Offsite final product management required - Larger facility footprint - Campaign operation requires increased sludge storage - Increased operational costs	- Permitting and public perception hurdles - Longer project duration due to permitting - Stringent air pollution control requirements - Increased maintenance and labor requirements - Cake hauling cost during incinerator downtime - No redundancy and high cost / difficulty to bring existing incinerator from MMMM to LLLL air pollution control standards - Operational difficulty cycling two units on and off

It was determined that site visits to operating rotary drum dryers would aid MSD in coming to a decision on final solids management. MSD visited facilities with rotary drum dryer installations in Aiken, SC, Clarksville, TN, and Nashville, TN. MSD noted preferences for a future thermal dryer facility based on these site visits, including a strong preference for a concrete frame building and wet scrubbers for dust removal. Design decisions specific to a thermal dryer facility will be further explored in detailed design. Detailed design will require evaluations of the existing plant systems to determine all the required components of the proposed solids handling improvements. These systems and facilities include, but are not limited to, the future of the existing ash lagoon and solids handling building, the non-potable water system for equipment washwater usage, and the existing natural gas supply. Looking towards the future, thermal drying will provide more flexibility, redundancy, and reliability for MSD.

6.1 Proposed Project

Based on site visits and MSD internal discussion of the advantages and disadvantages of each technology, MSD selected thermal drying as the final solids management technology and centrifuges as the dewatering technology. Preferred mechanical thickening technology will need to be selected during detailed design. Based on preliminary discussions, MSD had interest in the enclosed nature of RDTs, but was concerned about the quantity of equipment.

MSD selected a phased installation plan to have the flexibility of two dryers in the future without incurring the capital cost of two dryer trains in the present. The equipment will be installed in the following phases, with provisions for equipment life and 50/60 mgd buildout. The building sizing provided is for this phased approach, allowing FBR WRF to transition from the DDS-40s required for 40 mgd to the DDS-50s required for 60 mgd.

- Phase 1: Install 1st DDS-40 and associated train of equipment
- Phase 2: Install 2nd DDS-40 and associated train of equipment when 1st DDS-40 is not adequate to manage MAX07 load
- Phase 3: Replace original DDS-40 at end of life (anticipated to be prior to 50 mgd) with DDS-50
- Phase 4: Replace 2nd DDS-40 at end of life (anticipated to be prior to 60 mgd) with DDS-50

Figure 6-1 shows the proposed process flow diagram for the selected project alternative. Future equipment is shown with a dashed box.

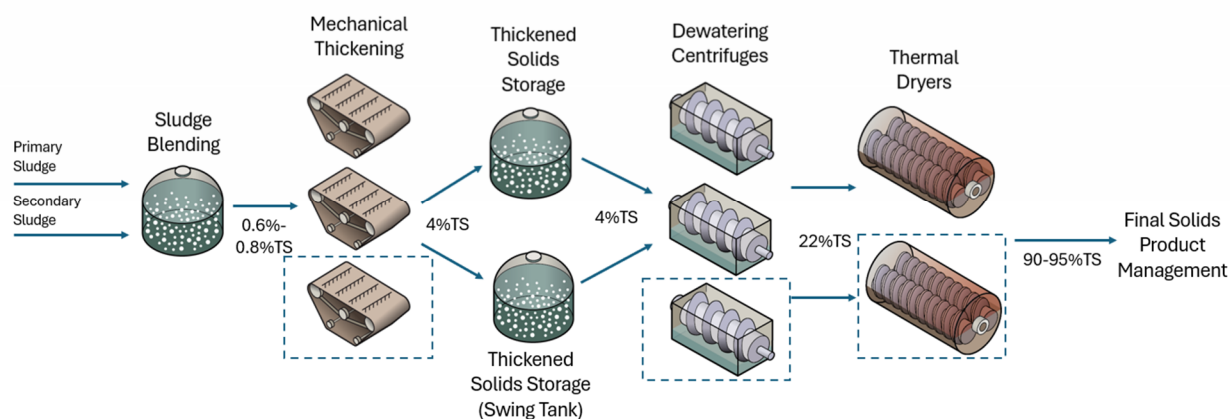


Figure 6-1: Proposed Project Process Flow Diagram

Hazen *Technical Memorandum*

Final: July 11, 2025

To: Metropolitan Sewerage District of Buncombe County (MSD)
From: Sharanya Ananth, Hazen
Aaron Babson, PE, Hazen
Ruth Borgmann, PE, Hazen
Michael Bullard, PE, Hazen
John Collett, PE, Hazen
Jackie Yeh, PE, Hazen

Technical Memorandum No. 1 – Solids Projections, Condition and Capacity Assessment

FINAL

31359-001

Table of Contents

1. Introduction	4
2. Summary of Existing Solids Handling Treatment Process	4
3. Flow Projections	6
3.1 Base WWTP Influent Flows	6
3.2 TAZ Population Estimates	7
3.3 2019 CDM Smith Flow Projections	9
3.4 Flow Peaking Factors	9
3.5 Flow Projection Summary	9
4. Solids Mass Projections	11
4.1 Influent Characteristics	11
4.2 Biosolids Projections and Loading Rates	12
4.3 Future Solids Mass Projections: 50 mgd and 60 mgd	16
5. Condition Assessment	18
5.1 Gravity Thickener Facilities	18
5.1.1 Gravity Thickeners No. 1 and No. 2	18
5.1.2 Thickened Solids Pumps	18
5.2 Dewatering Facilities	19
5.2.1 Polymer System	19
5.2.2 Belt Filter Presses	19
5.3 Incineration and Ash Handling Facilities	20
5.3.1 Schwing Cake Pumps	20
5.3.2 Ash Slurry Pumps	20
5.3.3 Ash Thickener	20
5.3.4 Ash Transfer Pumps	20
5.3.5 Incinerator and Air Pollution Control System	21
6. Capacity Assessment	21
6.1 Gravity Thickener Facilities	21
6.2 Dewatering Facilities	25
6.3 Incineration	27
7. Next Steps	27

Appendix A: Condition Assessment Field Forms

Appendix B: Record of Solids Production Updates

1. Introduction

The Metropolitan Sewerage District (MSD) of Buncombe County retained Hazen and Sawyer (Hazen) to complete a Solids Handling Preliminary Engineering Report (PER) for the French Broad River Water Reclamation Facility (FBRWRF). The PER includes a condition and capacity assessment on the existing equipment, technology assessments, permitting assistance and development of a new solids handling facility concept to be seamlessly integrated into the forthcoming liquid train project.

The purpose of this technical memorandum (TM) is to evaluate the future solids production rates at the FBRWRF using historical data analysis in conjunction with the Biological Treatment Alternatives Evaluation (See TM No. 1 – *French Broad River Water Reclamation Facility (FBRWRF) Preliminary Evaluations*, Final Submitted - 02/27/2025) and provide a condition and capacity assessment of the existing solids handling facilities.

The FBRWRF is undergoing a study to upgrade the biological treatment process from rotating biological contactors (RBCs) to an alternate process capable of meeting more stringent ammonia limits (8.5 mg/L). A high-rate primary treatment (HRPT) process was recently constructed at the FBRWRF; operation of which is still being optimized by MSD staff. The addition of the HRPT system and future modifications to the secondary process do and will impact sludge volume, quantity, and quality at the FBRWRF. Impacts on the existing solids handling system will be detailed throughout this TM.

Sludge production rates and solids loading rates were established for the 40-million gallon per day (mgd) maximum month design flow condition for each biological treatment alternative under evaluation. These solids loadings will be utilized to assess the process adequacy of existing and proposed major solids handling unit treatment processes to meet the anticipated loadings for current and future conditions. The condition assessment conducted for each component of the solids handling train includes a discussion of operations, maintenance, and current safety observations. The capacity assessment evaluates the ability of existing equipment to handle permitted (40 MGD) flow based on the established sludge production rates for the various future biological treatment alternatives.

2. Summary of Existing Solids Handling Treatment Process

The FBRWRF, owned and operated by MSD, provides wastewater treatment for the City of Asheville, Buncombe County, and portions of Henderson County. The FBRWRF currently produces a combination of primary sludge (PS) and waste activated sludge (WAS) which are thickened, dewatered, and incinerated. Incinerator ash is managed via an ash thickener and ash lagoon. The existing solids treatment process contains the following major unit process facilities:

- Gravity Thickening
- Belt Filter Press (BFP) Dewatering
- Fluidized Bed Incineration (FBI)
- Ash Handling

Figure 2-1 shows the solids process flow diagram and **Table 2-1** summarizes the design criteria for the existing solids unit processes.

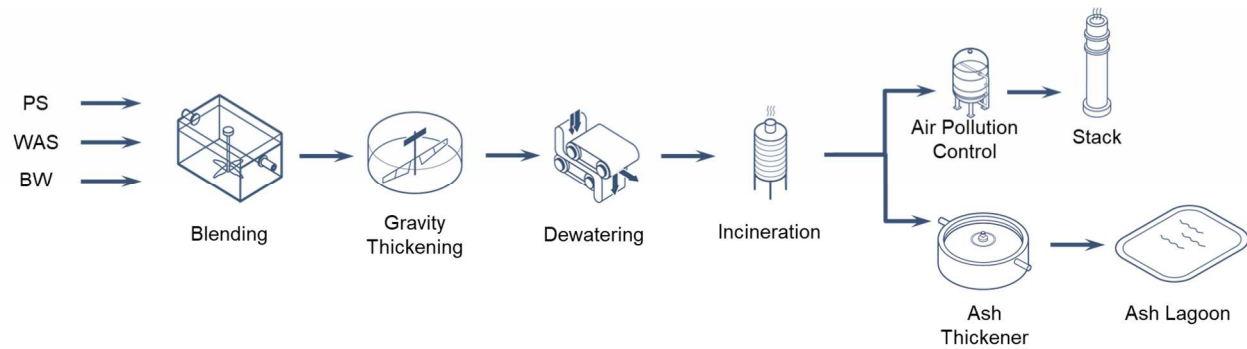


Figure 2-1: Existing Solids Handling Process Flow Diagram

Table 2-1: Summary of Existing FBRWRF Solids Infrastructure

Process Unit	Parameter	Design Criteria
Thickening	Gravity Thickeners	(2) 100-ft gravity thickeners
	Thickened Solids Pumps	(3) 150 gpm progressive cavity pumps
Dewatering	Polymer Feed	Dry polymer prep system 390-gal mix/feed tank (3) 5 gph dilute polymer solution feed pumps
	Dewatering Equipment	(2) 2.5-meter BFPs (Solids Loading Rate: 625 lb/hr/m, Hydraulic Loading Rate: 125 gpm)
	Conveyance	(2) 12-in Screw Conveyors (162 cu ft/hr volumetric capacity, each)
Incineration	Cake Pumping	(2) 42 gpm Schwing Cake Pumps
	Incinerator	(1) 40 dry tons per day (dtpd) FBI, derated to 32 dtpd (2) 6,500 standard cubic feet per minute (scfm) fluidizing air blowers (1) primary heat exchanger (1) quencher (1) multi-venturi scrubber (2) purge air blowers (1) NPW booster pump skid
Ash Handling	Ash Slurry Pump	(2) ash slurry transfer pumps
	Ash Thickener	(1) 18-ft ash thickener
	Thickened Ash Pumps	(2) thickened ash pumps
	Ash Lagoon	9-acre lagoon

A number of upgrades and repairs to the solids handling infrastructure at the FBRWRF have been completed over the years. The incinerator was initially installed in 1992. A major rehabilitation of the incinerator was completed in 2004 along with installation of two (2) new belt filter presses. Additional

air pollution control equipment (new heat exchanger, quench, venturi scrubber and mercury scrubber) was added in 2015 to meet more stringent sewage sludge incinerator emissions requirements. Finally, MSD has replaced various parts and pieces of the solids handling equipment as required.

3. Flow Projections

Hazen prepared systemwide flow projections to establish the influent flow of the FBRWRF in target year 2053 which is needed to estimate future solids handling requirements. The approach utilized the most recent traffic analysis zone (TAZ) population estimates along with unit rates and assumptions established by CDM Smith as part of a 2019 study. MSD and Hazen worked together to refine the expected area to be served over the next 29 years to ensure the flow projections are in line with general growth expectations.

3.1 Base WWTP Influent Flows

Hazen reviewed daily flow records from 2020 through 2022 for the FBRWRF and found that the average daily flow across this 3-year period was 22.77 mgd. When looking at only the most recent year of data during 2022 the average was lower, at 21.18 mgd. We compared the flows with precipitation recorded at a centrally located USGS rain gauge, as shown in **Figure 3-1**.

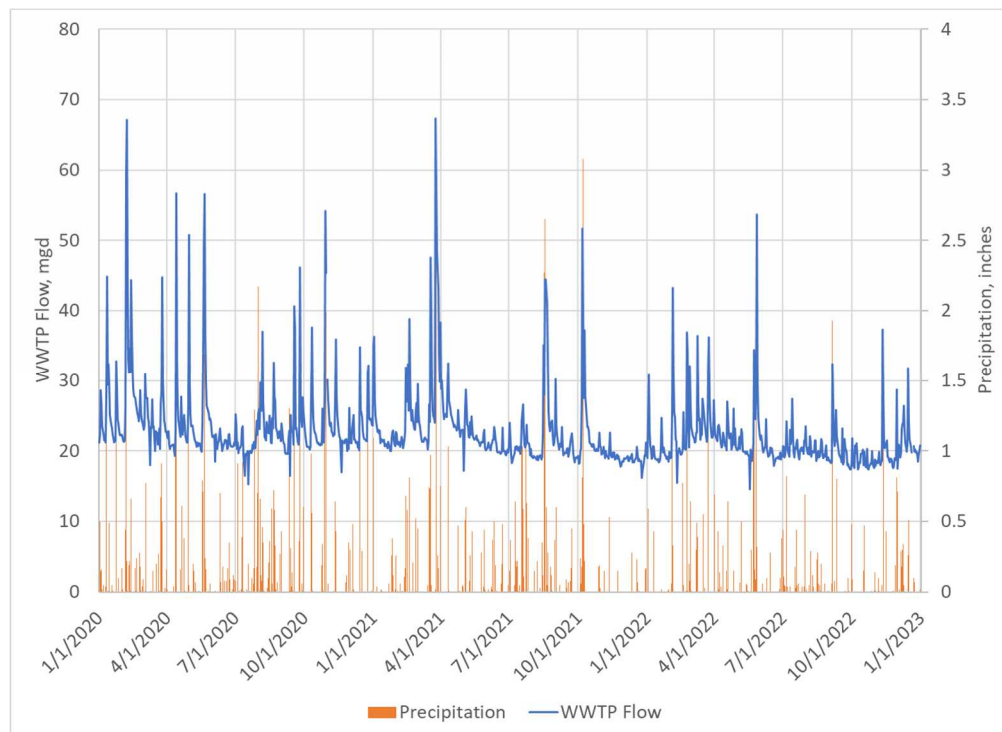


Figure 3-1: Historical WWTP Influent Daily Flow and Precipitation from 2020 – 2022

The flow projections are based on daily dry weather flow, so Hazen needed to establish the baseline flow for the existing system. Hazen processed the daily flow data by excluding flows where there was day-of and day-after precipitation. MSD and Hazen decided to use the average dry weather flow from 2022 of

20.07 mgd, as shown in **Figure 3-2**. This flow represents existing conditions to which flows from growth will be added to reach the target year flow.

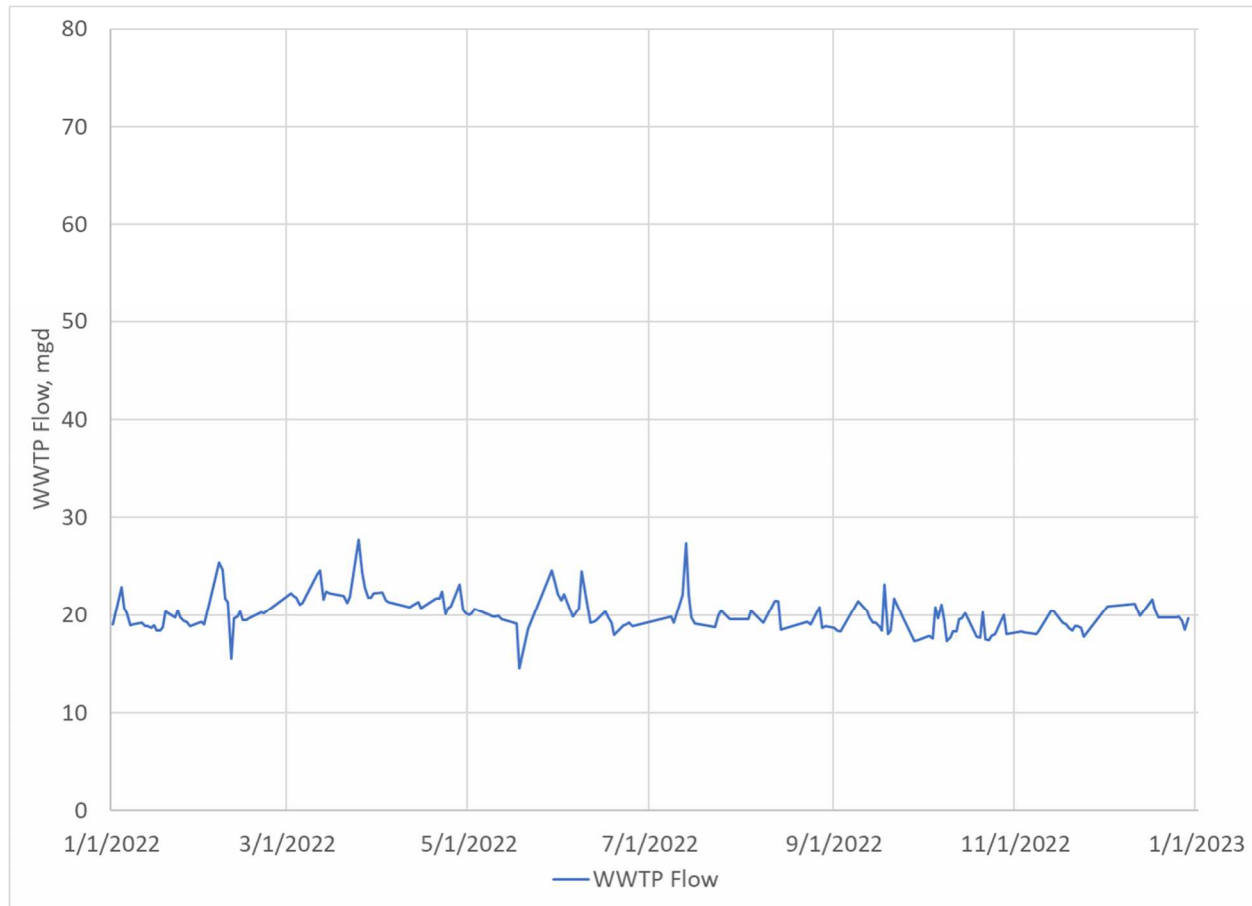


Figure 3-2: Historical WWTP Influent Daily Dry Weather Flow from 2022

3.2 TAZ Population Estimates

The area of service has a direct impact on flow projections, as Hazen assumed that the service area boundary will remain static over the planning horizon and that all growth within the service area will be captured. Initially, Hazen used a future service area boundary which was provided by MSD; however, flow projections were higher than anticipated, partially due to the expanded service area boundary. MSD instead decided to use the existing sewershed service area, expecting it to continue to be a reasonable representation of the area served for the next 29 years. **Figure 3-3** shows the existing service area in green (used for these projections) and future service area boundary in pink.

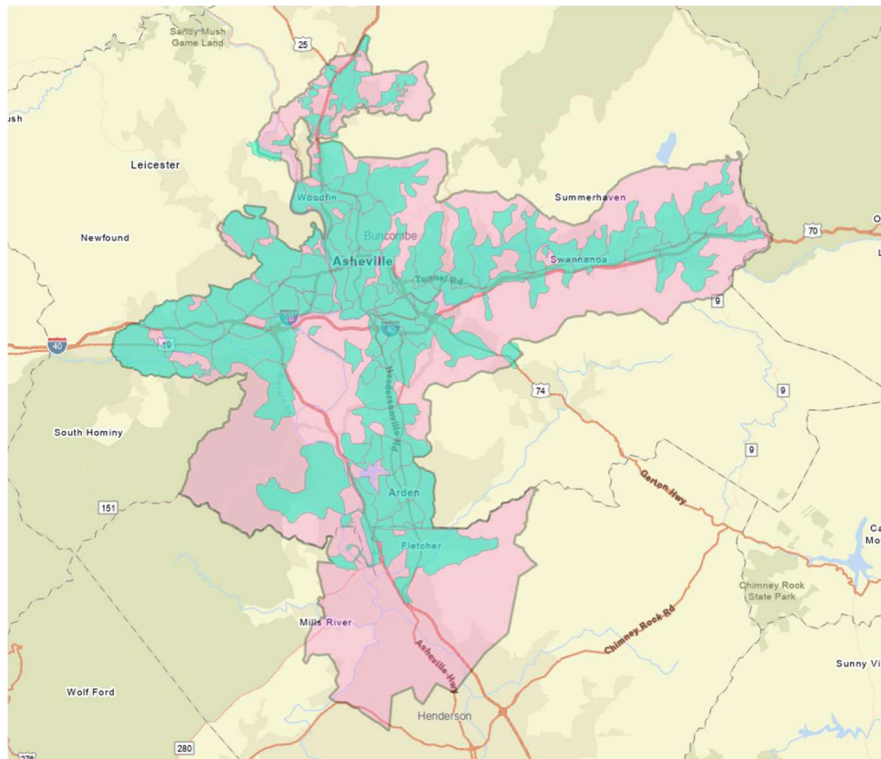


Figure 3-3: Existing and Future Service Area Boundary

The population growth was estimated from TAZ data obtained from the French Broad River MPO for years 2020 and 2045. Both datasets were trimmed to match the service area boundary. A linear growth rate was assumed and used to calculate an annual growth per year to reflect both residential and employee growth to extend the projection to the desired target year (2053). **Figure 3-4** shows the population density across the service area for both the 2020 base year and 2045 projected year.

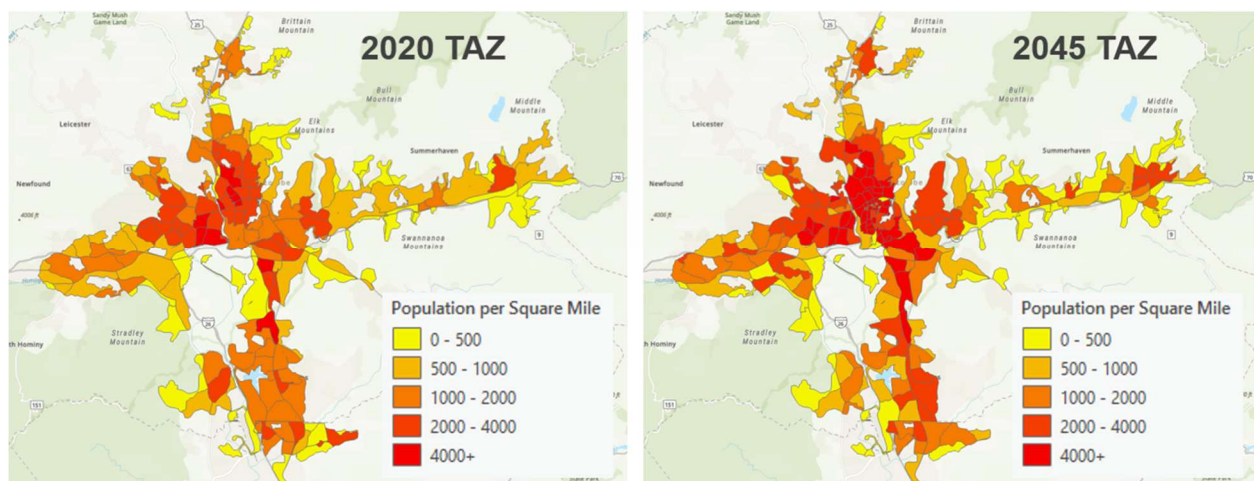


Figure 3-4: TAZ Population Density for Years 2020 and 2045

Table 3-1 shows the calculated growth per year for both residential and employee.

Table 3-1: Calculated Population Growth Per Year

	2020 Population	2045 Population	Total Population Growth	Population Growth / Year
Residential	147,046	208,520	61,474	2,459
Employee	110,859	185,803	74,944	2,998

3.3 2019 CDM Smith Flow Projections

CDM Smith prepared the *French Broad Interceptor Carrier Bridge PER* in May 2019 which provided comprehensive flow projections through year 2070 (and further buildout estimates to 2180). They projected the dry weather flow increase to 2035 using TAZ data, then performed straight-line projection to estimate 2070 flows. The projections assumed the increase in flow would occur within existing sewer sheds. The study reviewed historical population data and wastewater flows to calculate wastewater per capita rates for both residential and employee user categories. Hazen agrees with the methodology used to establish these rates and applied the same values to current TAZ population projections.

CDM Smith accounted for future dry weather inflows (DWI) by taking the ratio of the 2017 DWI to 2017 base sanitary flow, then multiplying that factor by the planning period base sanitary flow. They also accounted for future industrial flows, however these flows were described narratively then combined with the dry weather inflow value in a summary table of their report (Table 3-2). Hazen was able to use the combined total dry weather inflow and industrial flow projected in 2035 of 6.37 mgd and subtract the estimated combined flow in 2017 of 5.50 mgd to establish a total flow increase from these two components of 0.87 mgd. That equates to an annual increase of 0.048 mgd for both dry weather inflow and industrial growth. Hazen applied this annual increase over the 30-year planning horizon.

3.4 Flow Peaking Factors

High rates of precipitation cause flow peaking events at WWTPs. The average dry weather flow was used as the basis of projections, however maximum month flows are needed to inform solids handling calculations. Hazen reviewed the historical data and selected a 1.06 factor to go from annual average dry weather flow to annual average flow. A 1.30 peaking factor was selected for to go from annual average flow to maximum month flow based on a review of historical data, discussions with MSD and coordination with the design criteria outlined in the Biological Treatment Alternatives Evaluation (See TM No. 1 – *French Broad River Water Reclamation Facility (FBRWRF) Preliminary Evaluations*, Final Submitted - 02/27/2025) .

3.5 Flow Projection Summary

The flow projections use 2022 as the base year and 2053 as the target year, projecting forward 31 years. The projections are summarized in **Table 3-2**. **Figure 3-5** shows the projected flow will remain under the

treatment capacity when the target year is reached. The results reflect a compounding annual flow rate increase of 1.19%.

Table 3-2: Flow Projection Summary

	Population Growth	Per Capita GPCD	Flow (mgd)
Annual Average Dry Weather Flow 2022			20.07
Residential	76,228	58	4.42
Employee	92,931	33	3.07
Industrial & DWI			1.49
2053 Annual Average Dry Weather Flow (mgd)			29.04
2053 Annual Average (1.06x) Flow (mgd)			30.66
2053 Maximum Month (1.3x) Flow Calculation (mgd)			39.85

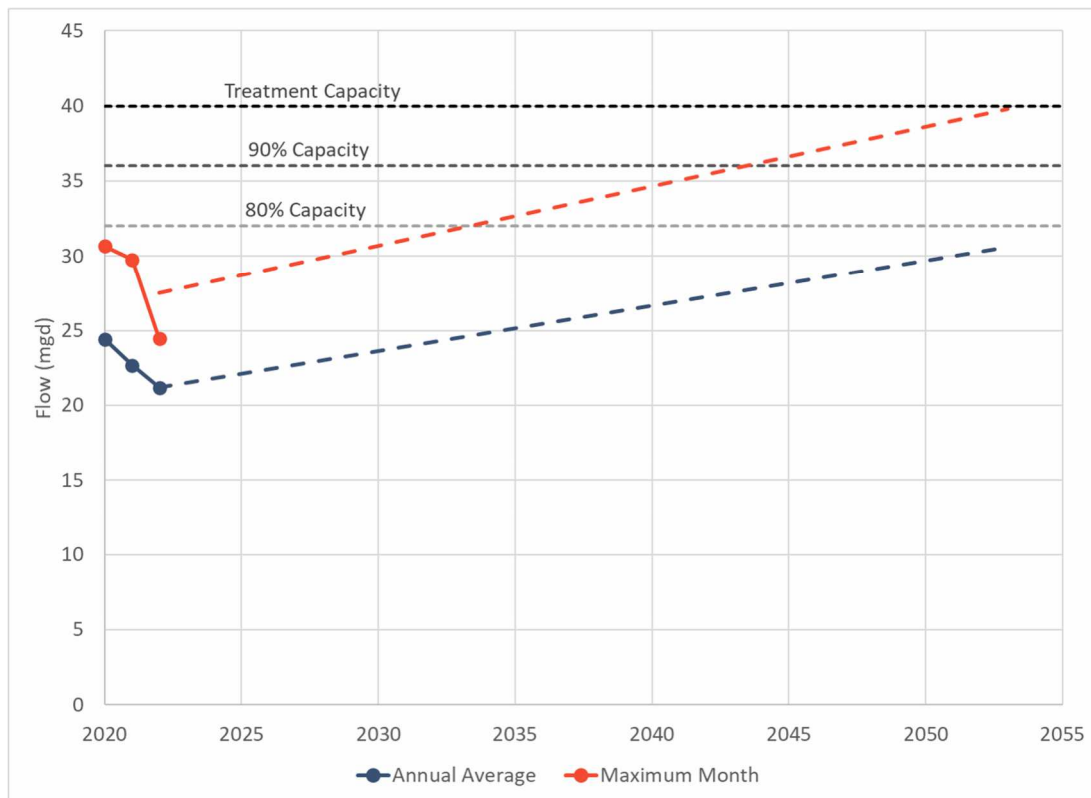


Figure 3-5: Future Flows Projection

4. Solids Mass Projections

4.1 Influent Characteristics

The influent wastewater to FBRWRF is composed mainly of domestic sewage. Influent historical data was provided for analysis from the period of January 1, 2020, through December 31, 2022. **Table 4-1** summarizes the yearly average five-day biochemical oxygen demand (BOD₅) and total suspended solids (TSS) concentrations. Mass loading values were calculated on an individual day basis for dates when both the influent mass concentration and influent flow were provided. Due to differences in the sampling frequency for the influent constituents, the annual average loading calculated for influent BOD₅ and TSS does not include the entire flow dataset. The term five-day cBOD₅ (Carbonaceous Biological Oxygen Demand) is used to identify samples that have been analyzed with a nitrification inhibitor and can be adjusted to BOD₅ by accounting for nitrification. The typical cBOD₅ to BOD₅ ratio for domestic influent wastewater is 0.85:1. For the purposes of this study, Hazen adjusted the reported cBOD₅ values to BOD₅ values using the typical ratio of 0.85.

Table 4-1: FBRWRF Influent Characteristics (January 2020 –December 2022)

Year	Annual Average Flow	Influent BOD ₅		Influent TSS	
	mgd ¹	mg/L	lb/day	mg/L	lb/day
2020	24.4	202	40,700	199	40,800
2021	22.7	238	45,000	224	42,500
2022	21.2	247	43,400	237	41,800
Average	22.8	230	43,100	220	41,700

¹ Influent flow was recorded daily, and the reported annual average flow is the average for all reported days of flow in the corresponding year.

Figure 4-1 shows the cumulative frequency curves for influent BOD₅ and TSS data. Cumulative frequency curves show the percent of the data which falls below the corresponding plotted concentration. These types of plots are useful for observing the median concentration at the 50% data point and the overall range of the raw data.

The average concentrations for influent BOD₅ and TSS (see Table 4-1) were used to calculate the solids loadings. Both the influent BOD₅ and TSS concentrations are characteristic of typical medium strength domestic wastewater.

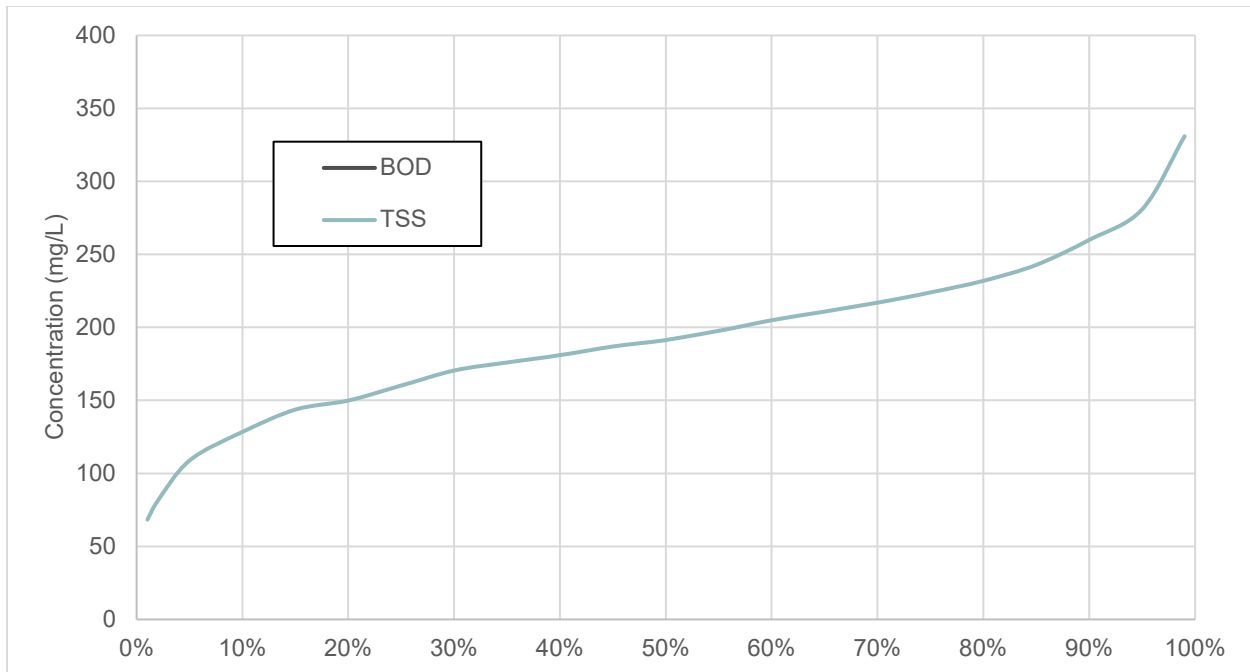


Figure 4-1: BOD₅ and TSS Cumulative Frequency Diagram

4.2 Biosolids Projections and Loading Rates

As noted previously, the FBRWRF is undergoing a study to replace the existing carbon oxidation process (RBCs) with a nutrient removal process to meet more stringent ammonia limits. The following six biological nutrient removal alternatives are being evaluated:

- Aerobic Granular Sludge (AGS)
- Biological Aerated Filter (BAF)
- Densified Activated Sludge (DAS)
- Integrated Fixed-Film Activated Sludge (IFAS)
- Membrane Aerated Biofilm Reactor (MABR)
- Moving Bed Biofilm Reactor (MBBR)

Based on the evaluation completed as a part of the Biological Treatment Alternatives Evaluation, it was assumed that the existing HRPT process would be retained with all of these secondary processes. Optimization of the recently installed HRPT is ongoing. Preliminary testing indicates that the existing HRPT system can treat a maximum of 7.5 mgd per train (15 mgd total). Therefore, it was assumed that only 15 mgd of the influent flow would be processed through the HRPT system; the remainder of the flow would be bypassed by gravity to the selected secondary treatment process.

Table 4-2 provides a summary of the inputs and assumptions used for calculating annual average (AVG365), maximum month (MAX30), maximum two-week (MAX14), and maximum week (MAX07) solids production. These assumptions are based on typical peaking factors and the FBRWRF design values of 230 mg/L influent BOD₅ and 220 mg/L influent TSS. HRPT performance assumed a TSS

removal efficiency of 70% and a BOD₅ removal efficiency of 50%. Secondary sludge production rates were estimated as a part of the Biological Treatment Alternatives Evaluation. For the six alternatives, Hazen coordinated with manufacturers and relied on previous modeling experience and documented yield rates to predict biomass growth and decay to develop each sludge production rate.

Table 4-2: Solids Mass Projection Assumptions

Parameter	Value			
Average Annual Influent BOD ₅	230 mg/L			
Average Annual Influent TSS	220 mg/L			
HRPT Maximum Capacity	20 mgd			
HRPT TSS Removal Efficiency	70%			
HRPT BOD ₅ Removal Efficiency	50%			
Biological Reactor Age	Coordinated with each process manufacturer / process modeling ¹			
Peaking Factors	Annual Average (AVG365)	Maximum Month (MAX30)	Maximum Two Week (MAX14)	Maximum Week (MAX07)
BOD ₅ Mass Loading Peaking Factor	1.00	1.15	1.35	1.45
TSS Mass Loading Peaking Factor	1.00	1.15	1.50	1.60

¹See FBRWRF Preliminary Evaluations TM No. 1. In TM, a MAX30 peaking factor of 1.15 and a maximum day peaking factor of 1.8 was established. MAX14 and MAX07 not defined as a part of the Biological Treatment Alternatives Evaluation.

Table 4-3 shows the estimated primary sludge loading rates for the HRPT process for the design, maximum two week, and maximum week conditions.

Table 4-3: Primary Sludge Loading Rates (lb/day)

Parameter	Design	MAX14	MAX07
Primary Sludge Production, lb/day	22,200	29,000	30,900

As a part of the biological process evaluation, MSD selected to shortlist AGS, BAF, and DAS, as indicated in bold. Therefore, the solids loading rates for these three technologies will be carried throughout the remainder of this TM. **Table 4-4** shows the estimated secondary sludge loading rates for the three different alternatives. As can be seen, there is wide variation in secondary sludge production depending on the selected processing alternative due to the different solids retention times associated with each biological process and different growth kinetics.

Table 4-4: Secondary Sludge Loading Rates (lb/day) at 40 mgd

Parameter	Design	MAX14	MAX07
AGS Sludge Production, lb/day	36,900	45,200	48,400
BAF Sludge Production, lb/day	49,800	61,100	65,400
DAS Sludge Production, lb/day	44,200	54,200	58,100

Table 4-5 shows the sludge production loading rates for the 40 mgd design capacity with 15 mgd baselined to the HRPT process.

Table 4-5: Total Sludge Loading Rates (lb/day) at 40 mgd

Parameter	Design	MAX14	MAX07	PS:WAS Ratio
AGS Sludge Production, lb/day	59,100	74,200	79,300	38%
BAF Sludge Production, lb/day	72,000	90,100	96,300	31%
DAS Sludge Production, lb/day	66,400	83,200	89,000	33%

Because the HRPT process will be base loaded at 15 mgd and current annual average flows to the FBRWRF exceed 15 mgd, the primary solids loading will remain constant unless the HRPT is offline for maintenance. This is not the case for the secondary solids loading rates since as flow increases, additional influent will be bypassed around the HRPT process thereby increasing the influent load to the secondary process. **Figure 4-2** shows the increased BOD₅ concentration and **Figure 4-3** shows the increased TSS concentration to the secondary process as flow increases.

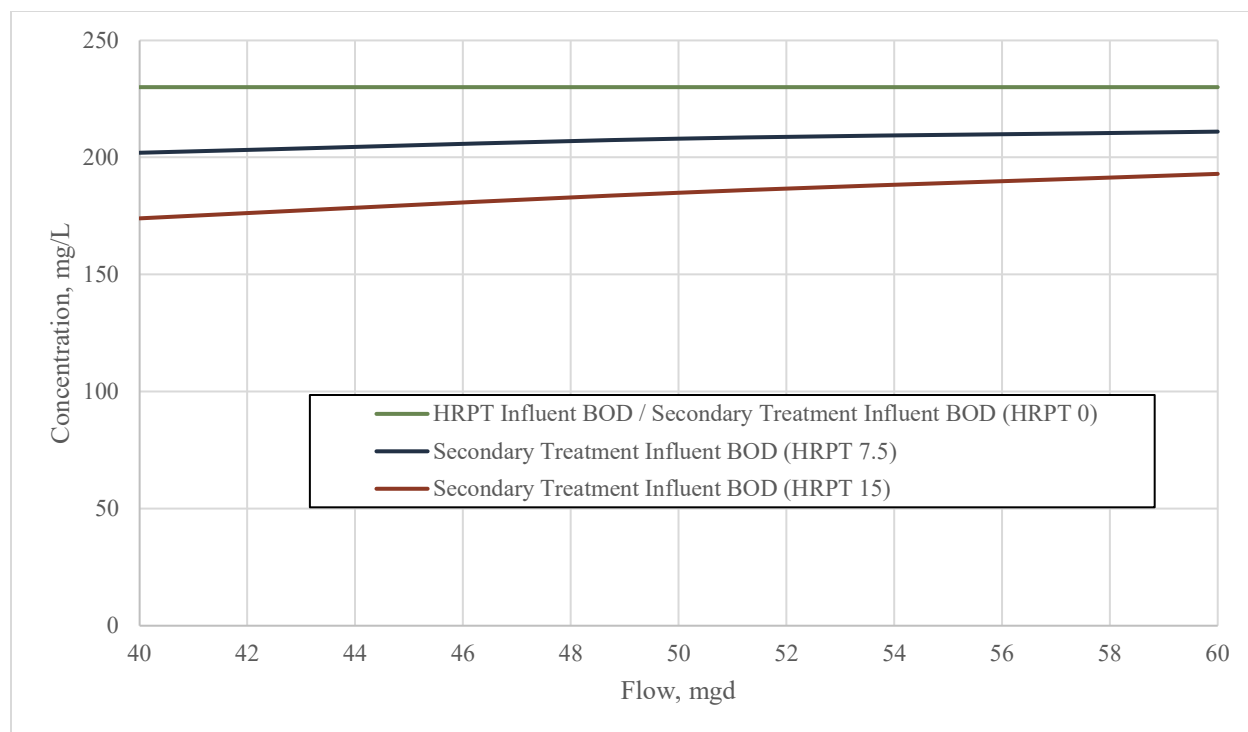


Figure 4-2: HRPT and Secondary Treatment Influent BOD₅ Concentrations

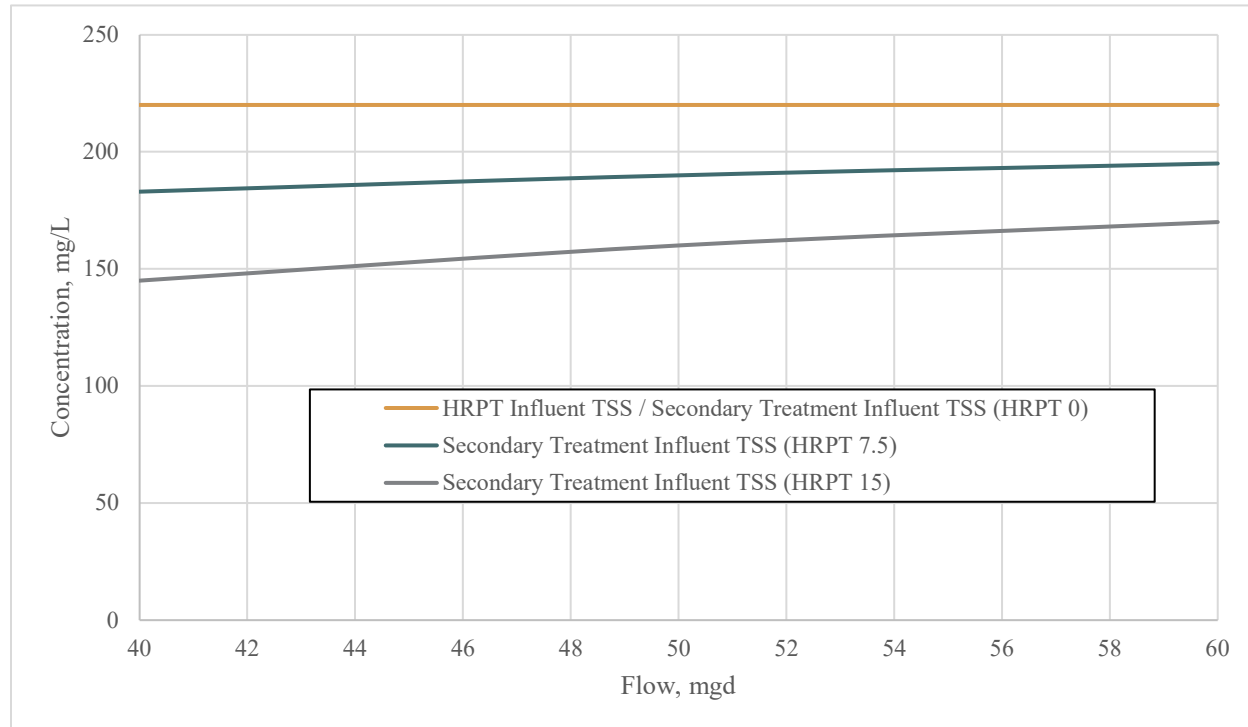


Figure 4-3: HRPT and Secondary Treatment Influent TSS Concentrations

The increased influent loading to the secondary process will result in a higher secondary solids production rate (lb/MG). Therefore, the numbers presented in **Table 4-4** cannot be scaled up by flow. Hazen understands that MSD has requested the 50 MGD and 60 MGD scenarios be developed for the three selected process alternatives (AGS, BAF and DAS). The increased solids production rate associated with these higher flows will be coordinated with the continued work of the biological process evaluation. Lastly, as additional flow is bypassed around the HRPT, the primary solids to secondary solids ratio will decrease. Primary sludge typically has an increased volatile solids ratio and results in higher dewatered cake solids. Both the volatile solids content and moisture content of the feed cake impact incinerator operations and ability to burn autogenously.

The sludge production estimates found in **Table 4-5** were used to assess the capacity of the existing solids processing equipment and will be utilized for the remainder of the Solids Handling PER.

4.3 Future Solids Mass Projections: 50 mgd and 60 mgd

To project the 50 mgd and 60 mgd influent scenarios, the annual average TSS and BOD loading and HRPT removal rates were calculated throughout the system to determine the secondary process influent loading. Using the influent BOD and TSS concentrations to the secondary process, daily mass loading of WAS was calculated, and the result of each of the methods was averaged. This was then calculated for each subsequent year based on the increased diverted flow to secondary process. A similar methodology was used to calculate annual sludge production starting in 2024 for lifecycle cost analysis. This calculation has an inherent uncertainty and was primarily used to project final solids management equipment (thermal dryer, incinerator) capacity required in the 50 and 60 mgd scenarios. That uncertainty is only compounded when the solids mass projections for these maximum month scenarios are extrapolated to AVG365, MAX14, and MAX07. Examples of the solids calculation methodology are provided in **Table 4-6** below.

Table 4-6: Secondary Sludge Projections for Future Scenarios

Parameter	40 MGD	50 MGD	60 MGD
Flow to HRPT, MGD	15		
Primary Sludge Mass, lb/day	19,300		
Primary Sludge Solids, %TS	2%		
Method 1. BOD Loading			
Influent BOD Concentration, mg/L BOD	230		
Influent BOD Loading, lb/day BOD	76,700	95,900	115,100
HRPT Influent BOD Loading, lb/day BOD	27,500		

Parameter	40 MGD	50 MGD	60 MGD
HRPT Effluent BOD Loading, lb/day BOD	14,400		
HRPT Bypass BOD Loading, lb/day BOD	48,000	67,100	86,100
Secondary Process Influent BOD Loading, lb/day BOD	62,300	81,500	100,700
DAS Production BOD Calculation, lb/day WAS	49,100	64,700	80,200
BOD Calculated Secondary Solids Production Rate, lb/MG	1,228	1,294	1,337
Method 2. TSS Loading			
Influent TSS Concentration, mg/L TSS	220		
Influent TSS Loading, lb/day TSS	73,400	91,700	110,100
HRPT Influent TSS Loading, lb/day TSS	27,522		
HRPT Effluent TSS Loading, lb/day TSS	8,257		
HRPT Bypass TSS Loading, lb/day TSS	45,900	64,200	82,600
Secondary Process Influent TSS Loading, lb/day TSS	54,100	72,500	90,800
DAS Production TSS Calculation, lb/day WAS	48,400	64,000	79,600
TSS Calculated Secondary Solids Production Rate, lb/MG	1,210	1,280	1,327
Summary			
DAS Average Secondary Solids Production Rate, lb/MG	1,219	1,287	1,332
DAS Production Average Calculation, lb/day WAS	48,800	64,300	79,900
Secondary Sludge Solids, %TS	0.55%		
Total Sludge Mass, lb/day	68,100	83,600	99,200
Primary and Secondary Solids, %TS	0.66%	0.64%	0.69%

These scenarios should be thoroughly projected when more data is available following design and construction of MSD's selected liquids and solids alternatives for the 40 MGD scenario. For the executive summary, only the 40 mgd scenario will be considered for the majority of solids technology assessments. The 50 and 60 mgd scenarios will be noted for dryer facility flexibility options.

5. Condition Assessment

A visual, mechanical condition assessment of the existing solids handling equipment was conducted during a site visit in June 2023 by Hazen and its subconsultant, Chavond-Barry Engineering (CBE), to identify visible mechanical defects and deficiencies. In addition to the visual condition assessment, staff interviews were conducted. The following summarizes the key observations for each facility during the assessment. Additional details can be found in Appendix A.

5.1 Gravity Thickener Facilities

5.1.1 Gravity Thickeners No. 1 and No. 2

Gravity Thickeners (GT) No. 1 and No. 2 were installed in 1983. Under typical conditions, only one gravity thickener is in service. Blended PS and WAS are pumped to the centerwell via waste pumps that were installed in the 2020 HRPT project. If the HRPT process is online, thickened solids concentrations can reach 5% TS. If the HRPT is offline, solids typically are in the 3% range during the summer and 4% range in the winter. Polymer is added to the WAS feed pumps during the summer to aid thickening. Operations staff tries to keep the sludge blanket below 2-feet to keep the sludge fresh. If the blanket increases above 2-feet, a decrease in solids concentration below 2.5% is experienced.

When the HRPT process is online and higher flows are pumped to the GTs, the center well is very turbulent. The feed flow hits the top of the mechanism seal causing concern for the bearing. As a part of Task 3, thickening technologies are being evaluated. If the GTs are to be maintained in the new solids handling concept, the hydraulics and feed to the GT centerwell will need to be closely reviewed.

The GT mechanism appears to be well maintained. New wipers and drives were installed within the last two years and rake arm replacement is planned.

5.1.2 Thickened Solids Pumps

Thickened Solids Pumps No. 1, No. 2 and No. 3 remove thickened solids from the bottom of the gravity thickeners and are used to feed the BFPs. Typically, only one thickened solids pump and one BFP are in operation. Solids are conveyed from the Thickened Solids Pump Station to the dewatering process through (1) 8-inch pipe. In the future, if multiple BFPs are in service, feed through a dedicated pumped line per BFP is recommended. Depending on the capacity assessment, this piping arrangement will be reviewed as a part of the larger solids handling facility concept development.

No significant operational issues were reported other than occasional air binding on the suction side of the pumps. Maintenance has seen an increase on rotor/stator wear since the HRPT process has been online; likely due to the sand carryover from that process. Pump 2 has a split casing to allow for stator tensioning adjustments, however, maintenance staff does not like this feature. No pump protections such as a high-pressure switch or high temperature switch are present on the pumps. For an added measure of protection to prevent running a pump dry or pumping against a closed valve, these pump protections could be considered. In addition, MSD can consider addressing ventilation within the room to comply with

NFPA820 classification requirements. Per NFPA 820, Table 6.2.2, Row 9a, if a sludge pumping station dry well either has no ventilation or is ventilated at less than 6 air changes per hour, the space is rated as Class I, Division 2. The MCC and electrical gear within the thickened solids pump station is not currently rated for the Class I, Division 2 environment. In order to declassify the environment, the space can be ventilated at 6 air changes per hour. Lastly, the thickened solids pumps are on VFDs, but the motors are not rated for inverter duty. Replacement of the motors with inverter duty motors could be considered.

5.2 Dewatering Facilities

5.2.1 Polymer System

A new dry polymer preparation system with mix/feed tanks and three polymer makeup units was installed by MSD in 2022. Dry polymer management and containment can be difficult and messy for some facilities, but the polymer system appeared to be in very good condition and the polymer area was very clean. No repair or replacement of the dry polymer preparation system is recommended based on condition.

5.2.2 Belt Filter Presses

BFPs No. 1 and No. 2 were installed in 2004. Typically, one press is used to feed the incinerator. The in-service press is rotated every 6 months for even wear and so that preventative maintenance can be performed on each unit.

In general, no significant operational or maintenance issues were reported. It was noted that in addition to sludge age impacting the settleability of the sludge in the gravity thickeners, it also impacts the polymer usage and dewaterability of the solids. Within 6 hours of the HRPT being online, an increase in cake solids is observed. The existing BFPs are well maintained by in-house maintenance staff. A decrease in belt life has been noted as the equipment has aged and as the HRPT has come online. The typical belt life for the facility is 6 months. When the BFPs were installed, there was a preference for a hydraulic system; however, existing maintenance staff would prefer electric motors. As noted, preventative maintenance is performed on the out of service unit on a regular basis. Bearings are purged every year and greased every 3 months. Some structural modifications could allow for increased ease for removal of rollers. MSD can consider addressing ventilation within the dewatering area to comply with NFPA820 classification requirements, but this applies to the larger Solids Handling Building structure as a whole. During discussions with MSD it was noted that ventilation of the Solids Handling Building was a concern to Buncombe County during the 2015 Incinerator Emissions Upgrade project. As a part of that project, a combustible gas detector was added to each floor to address these concerns.

As a part of Task 3, dewatering technologies are being evaluated. Due to the age of the existing BFPs, either rehabilitation or replacement will be considered if BFPs are the selected technology for the new solids handling concept. Additionally, the ventilation concerns in the existing Solids Handling Building will be considered as options are developed for the new solids handling concept.

5.3 Incineration and Ash Handling Facilities

5.3.1 Schwing Cake Pumps

The Schwing cake pumps, their associated hydraulic units and sludge piping were replaced in 2020 as a part of the HRPT project. No major operational or maintenance issues were identified based on discussions with plant staff. Plant operations staff flush the water box every eight to ten hours. Following the Schwing pump replacement the pistons were replaced at the manufacturer's expense. However, following this repair everything has been working well. No repair or replacement of the Schwing cake pumps is recommended based on condition.

5.3.2 Ash Slurry Pumps

Two (2) ash slurry pumps convey ash from the multi-venturi scrubber to the ash thickener. The ash slurry pumps are on VFDs and transfer ash to the thickener based on level. No operational or maintenance concerns were noted with the ash slurry pumps and the pumps are in good condition. Seal water is used to protect the pump seal.

5.3.3 Ash Thickener

One (1) 18-foot diameter ash thickener receives ash from the multi-venturi scrubber for thickening. Thickened ash is withdrawn from the bottom of the thickener and pumped to the ash lagoon via the ash transfer pumps. Ash thickener overflow drains by gravity back to the head of the plant. The ash thickener was installed in 1988 along with the fluidized bed incinerator. No major upgrades have been completed on the ash thickener. The overflow weir is rusted, and the metal is thin on the bottom pump well due to grit wear. The outside steel surface and main control panel appeared to be in good condition considering the age of the equipment. The piping needs to be flushed regularly due to a buildup of ash and sand. The mechanism and scrapers appear to be nearing the end of life.

5.3.4 Ash Transfer Pumps

The existing ash transfer pumps send thickened ash to the ash lagoon through a 4-inch CPVC and stainless steel forcemain. The existing ash transfer pumps are constant speed. Current flow is below the scour velocity of 3 feet per second within the forcemain, therefore flushing is required every 8 to 10 hours for about 30 minutes each time. No major maintenance issues were noted. Previous seal issues have been alleviated since seal replacement and addition of seal water. A spare impeller is stocked.

Operations staff has a desire to eliminate the ash thickener and ash transfer pumps from service and pump unthickened ash slurry to the lagoon and regain the space within the existing Solids Handling Building in lieu of reinvesting in the equipment. Review of the pump curve and level setpoints for ash slurry pump VFD control is required to determine if the existing ash slurry pumps can pump to the ash lagoon while maintaining adequate velocity in the line to prevent ash from settling and clogging the piping. This will be reviewed as a part of the new solids handling facility concept.

5.3.5 Incinerator and Air Pollution Control System

Review of the incinerator and air pollution control system was not included as a part of the condition assessment as the existing FBI and support equipment was previously evaluated by IFCO in 2020 and MSD has plans in place to complete repairs and upgrades as required to maintain operation until a new unit can be installed. However, Hazen and its subconsultant, Chavond-Barry Engineering (CBE), assessed the exterior condition of the incinerator and associated equipment to the extent practicable and discussed equipment operations with operations and maintenance staff.

From the conversations, it was determined that most equipment operates reliably with normal levels of routine maintenance. The site-specific limits (bed temperature specifically) require extra auxiliary fuel to be used. A thermal scan of the outside of the incinerator identified that the refractory appears to be in a useable condition. Serious corrosion issues were noted on the upper and lower primary heat exchanger plenums. The installation of a corrosion resistant membrane on the interior steel surface of the plenums would likely increase lifespan of the equipment substantially. Heat exchanger replacement is already planned for early 2024. For continuing operation of the incinerator, there are not many thermocouples in the incinerator so local hotspots are difficult and/or impossible to identify. Installation of more bed thermocouples could assist in limiting damage in the future. Also, there are several areas of the incinerator which would benefit from better visibility within the incinerator. Installation of several sight ports would substantially aid in diagnosing potential operational issues.

6. Capacity Assessment

Solids production rates developed in conjunction with the Biological Process Evaluation were utilized to assess the existing solids processing equipment capacity and ability to handle AVG365, MAX30, MAX14 and MAX07 conditions for the current permitted plant capacity. The capacity assessment was completed for the three technologies that were shortlisted as a part of the biological process evaluation: AGS, BAF, and DAS. The existing process units, anticipated capacity and capacity shortfalls and bottlenecks are summarized in this section.

6.1 Gravity Thickener Facilities

To assess the capacity of the existing GT facility, typical solids and hydraulic loading rates from WEF MOP 8 were utilized, see **Table 6-1** for capacity information on the existing GT.

Table 6-1: Gravity Thickener Parameters and Loading Rates (WEF MOP 8)

Parameter	Value	
Diameter, ft	100	
Surface Area, sq ft	7,854	
Feedstock	Solids Loading Rate ¹ (lb/sft-day)	Hydraulic Loading Rate ¹ (gal/sft-day)
Primary + WAS Blend	4.9 – 14.7	380 – 760
WAS Only	2.5 – 7.4	100 – 200

¹Typical loading rates from Water Environment Foundation Manual of Practice No. 8: Design of Municipal Wastewater Treatment Plants

Current practice at the FBRWRF is to keep only one GT in service and feed a blend of PS and WAS. Therefore, the capacity of the existing GTs was evaluated with only one GT in service. Solids production values from **Table 4-5** were used to establish loading rates for thickening at the plant permitted capacity. The average WAS percent solids used in the calculations were based on typical values for AGS and DAS. The thickening process was assumed to achieve 90% capture efficiency.

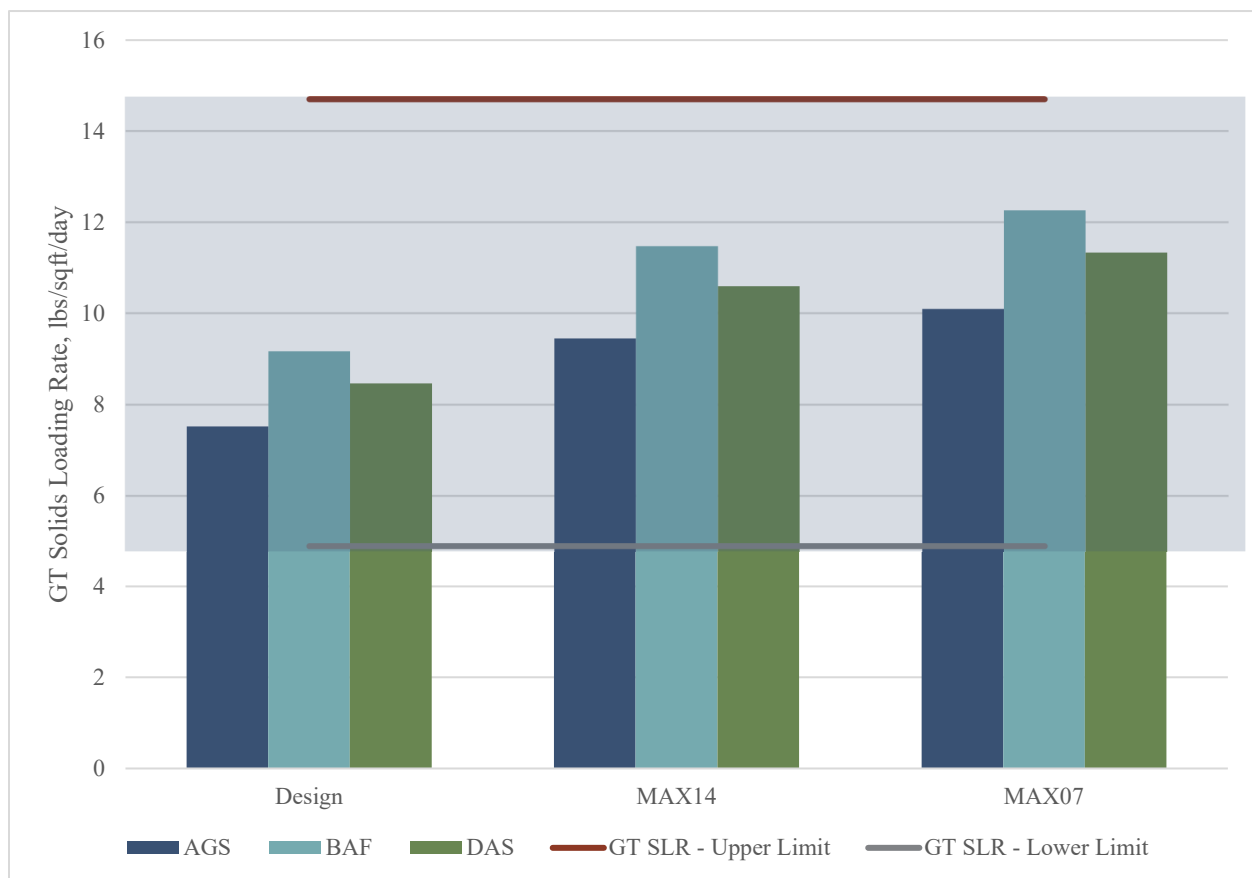


Figure 6-1: Gravity Thickener Capacity Assessment at Permitted Capacity (1 GT in Service)

As shown in **Figure 6-1** and **Table 6-2**, the solids loading rate falls within the acceptable range at the plant permitted capacity with only one gravity thickener in service for all three secondary treatment alternatives.

Table 6-2: GT Capacity Assessment at 40 MGD Permitted Capacity

Parameter	AGS Alternative			BAF Alternative			DAS Alternative		
	Design	MAX14	MAX07	Design	MAX14	MAX07	Design	MAX14	MAX07
Total Mass to Thickening, lb/day	59,100	74,200	79,300	72,000	90,100	96,300	66,400	83,200	89,000
HRPT Solids Concentration, %TS	2.00%			2.00%			2.00%		
Secondary Solids Concentration, %TS	0.80%			0.12%			0.50%		
Blended Solids Concentration, %TS	1.03%			0.17%			0.67%		
Volume to Thickening, gpd	685,900	851,300	910,700	5,109,100	6,279,000	6,720,000	1,194,200	1,473,600	1,578,500
Limiting Capacity	SLR			SLR			SLR		
SLR, lb/sf-day, 1 GT in service	7.5	9.4	10.1	9.2	11.5	12.3	8.5	10.6	11.3
SLR, lb/sf-day, All units in service	3.8	4.7	5.0	4.6	5.7	6.1	4.2	5.3	5.7
Thickened Solids, lb/day	53,200	66,800	71,400	64,800	81,100	86,700	59,800	74,900	80,100

While the loading rates indicate there is adequate capacity and redundancy with the existing gravity thickeners, a thickening assessment will be completed to evaluate continuing with gravity thickening or transitioning to a mechanical thickening process as a part of the Task 3 – Technology Assessment. It should be noted that AGS secondary solids are settled via gravity in a sludge buffer tank to 0.8 – 1.0% TS prior to being wasted to the solids train. Based on Hazen’s experience and knowledge with AGS, gravity thickening is not recommended as a reliable thickening method for AGS solids. Additionally, for the BAF process, the backwash flow removed stored solids from the process and the solids concentration in the backwash process is very thin; additional coordination is required with Veolia to better understand options to concentrate the solids from BAF and if mechanical separation is required. Veolia does not recommend gravity thickening for backwash solids and mechanical thickening presents spatial considerations due to the large volume. A cost-benefit analysis will be completed to assess the best option for MSD moving forward.

6.2 Dewatering Facilities

FBRWRF has two (2), 2.5-meter BFPs for dewatering. Thickened solids from the GTs are sent to the BFPs for dewatering. See **Table 6-3** for capacity information on the existing BFPs. As can be seen, based on provided historical data, the typical plant loading to the BFPs is higher than what was specified for performance testing. The higher historical loading rates were utilized to assess BFP capacity.

Table 6-3: Dewatering Equipment

Parameter	Existing BFPs	
Belt width, m	2.5	
Source	2004 Specification	2020 – 2022 Historical Data
Solids Loading Rate (SLR) Capacity, lb/hr/m	625	800
Hydraulic Loading Rate (HLR) Capacity, gpm	125	135
Breakeven Concentration (SLR=HLR), %TS	1.0% TS	1.2% TS
SLR Controlled Operation, lbs/day (per BFP)	37,500	48,000 ¹
HLR Controlled Operation, gpd (per BFP)	180,000	194,400

¹Based on the derated incinerator capacity of 32 dtpd (64,000 lb/day), one (1) BFP cannot support the FBI at full loading. However, (2) BFPs have more than enough capacity (96,000 lb/day) to support both the derated FBI capacity of 32 dtpd (64,000 lb/hr) and full capacity of 40 dtpd (80,000 lb/hr).

Because the thickened solids concentration is always greater than 1.2% TS, the SLR is the controlling parameter for this equipment. Solids production values from **Table 4-5** and **Table 6-2** were used to establish loading rates for thickened solids at the permitted (40.0 mgd) flows for each of the secondary processes. The dewatering process was assumed to achieve 95% capture efficiency.

Table 6-4: BFP Required Runtime, hrs/day

Parameter	Design	MAX14	MAX07	Design	MAX14	MAX07	Design	MAX14	MAX07	Design	MAX14	MAX07
No. BFPs in Operation	1			2			2			2		
BFP Processing Rate	48,000 lb/day			64,000 lb/day (32 dtpd)			80,000 lb/day (40 dtpd)			96,000 lb/day		
AGS Alternative	26.6	33.4	35.7	19.9	25.0	26.8	16.0	20.0	21.4	13.3	16.7	17.8
BAF Alternative	32.4	40.5	43.3	24.3	30.4	32.5	19.4	24.3	26.0	16.2	20.3	21.7
DAS Alternative	29.9	37.4	40.1	22.4	28.1	30.0	17.9	22.5	24.0	15.0	18.7	20.0

Typical operation at FBRWRF is to operate 1 BFP at a time to feed the incinerator; as noted above this limits the feed to the incinerator to less than the rated capacity. The second BFP could be operated at a reduced loading rate to maximize solids loading to the incinerator. BFP runtime matches the incinerator runtime and is typically continuous unless the incinerator is shut down for maintenance. A typical assumption for continuous equipment is to assume that it can process the solids mass with 85% up time or 20.4 hours plus redundancy. Values above 20.4 hours of runtime as shown in red in **Table 6-4**. The existing BFP equipment is inadequate to support solids removal for any of the three secondary treatment alternatives with only one unit in service. If the downstream limiting capacity of the incinerator is set aside, two units in service can support the loading rate for the AGS and DAS alternatives for all mass peaking scenarios and the BAF alternative at design and MAX14, but with no redundancy available.

As a part of the Task 3 – Technology Assessment, a dewatering assessment will be completed to evaluate belt filter press or centrifuge dewatering. A recommendation of whether MSD should continue to dewater with BFPs or transition to centrifuges when a new incinerator is constructed will be completed. Regardless of selected technology, the capacity shortfall will need to be addressed. The capacity of the dewatering system will be coordinated with the capacity of the FBI to ensure that the FBI can be fully loaded across all design conditions and the dewatering infrastructure does not act as a bottleneck on the solids handling system.

6.3 Incineration

FBRWRF has one (1) FBI with a rated capacity of 40 dtpd. In 2018, the capacity of the FBI was derated to 32 dtpd. Dewatered cake from the BFPs is pumped to the FBI via Scwring cake pumps. As stated above, one (1) BFP cannot support the FBI at full loading. However, (2) BFPs have more than enough capacity to support both the derated FBI capacity of 32 dtpd and full capacity of 40 dtpd.

As anticipated, the calculations in **Table 6-4** conclude that even at the design capacity, the FBI is inadequate to support mass peaking events at MAX14 and MAX07 for all secondary treatment alternatives and design loadings for BAF assuming an 85% runtime requirement. The new incinerator will need to have increased processing capacity beyond the capacity of the existing FBI. Hazen and CBE will address the capacity, air pollution control technologies and various air distribution schemes to the new incinerator as a part of Task 3 – Technology Assessment.

7. Next Steps

This TM will serve as the basis for the remainder of the Solids Handling PER. The sludge production and loading rates will be utilized in the Technology Assessments (Task 3) and the New Solids Handling Facility concept development (Task 5). Next steps include technology assessments for thickening, dewatering, incineration, and air pollution control technology to confirm the best solution for these solids handling processes for the new Solids Handling Facility concept. In addition, Hazen will conduct a redundancy assessment to evaluate biosolids management strategies that could be implemented to provide redundancy to the new FBI or be implemented during incinerator downtime.

Appendix A: Condition Assessment Field Forms

Process Unit: Gravity Thickener Facility					
Date: 6/22/2023			By: Ruth Borgmann, Barry Bickerstaff		
Equipment					
Gravity Thickener 1 & 2					
Equipment Name Plate Data					
GT1: Evoqua / Siemens Circular Drives, Siemens Gearbox & Motors, 1.5 HP					
GT2: Evoqua / Siemens Circular Drives, SEW Eurodrive Gearbox & Motors, 1.5 HP					
Equipment Installation Dates					
Installed / Age: 1980s			Normal Life: 25 years		
Equipment Run Time (if applicable)					
Hours:			Hours / Year:		
Last Major Equipment Overhaul					
Wiper and drive replacement in last 1-2 years.					
Opinion of General Overall Unit Condition					
Appears to have regular maintenace. GT1 - some aggregate exposure on channel. SST weir in good condition. GT2 - Minor corrosion on bridge. GT1&2 rake arms in need of replacement					
Condition Assessment Criteria					
In Service	Yes - GT1				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition		Minor Chipping or Bare Spots			
Corrosion		Minor Corrosion			
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition		Minor Defects			
Installation/Accessibility	Installed properly, easy to access				
Other Notes: GT1 in service at time of inspection, GT2 out of service					

Historical Maintenance, Problems and Spare Parts Availability

Rake arms in poor condition and in need of replacement. Grounding clamps in need of replacement.

Historical Operation & Problems

When HRPT is running, the feed to the centerwell is very turbulent and liquid hits the top of the seal (concern for bearing). This should be evaluated further pending selected secondary treatment process and thickening process carried forward. When running HRPT try to keep sludge levels to <2 ft. HRPT solids can get very thick, very fast. In summer feed polymer on RBCs. Typical solids concentrations: HRPT Running: 4.5-5%, RBCs Only: 3% in Summer and 4% in Winter (< 2 ft blanket), <2.5% (if high blanket)

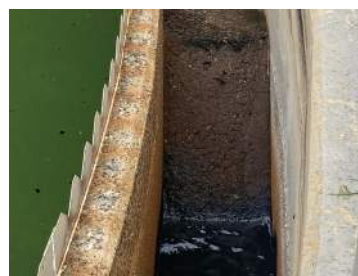
Recommended Repair / Replacement

Continue preventative maintenance as it is currently scheduled

Recommended Changes / Upgrades / Coating Systems Application

Wait on results of thickening assessment to determine if significant reinvestment in GTs is appropriate

Photos of Unit



Process Unit: Gravity Thickener Facility					
Date: 6/22/23		By: Ruth Borgmann, Barry Bickerstaff			
Equipment					
Thickened Solids Pumps					
Equipment Name Plate Data					
Seepex BN 52-6L, 15 HP					
Equipment Installation Dates					
Installed / Age: (1) 2019? (2) 12/22/2020			Normal Life: 25 years		
Equipment Run Time					
Hours:			Hours / Year:		
Last Major Equipment Overhaul					
Pumps recently replaced in last 5 years by plant maintenance staff					
Opinion of General Overall Unit Condition					
Pump station was in good condition with apparent regular maintenance					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition	Like New				
Corrosion	Like New				
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition		Minor Defects			
Installation/Accessibility	Installed properly, easy to access				
Other Notes: Pump 1 was running at the time of the assessment. Pump 3 was locked out / tagged out for maintenance. Pump 2 has a split casing for rotor/stator adjustments. Pump 3 has welded steel suction and discharge piping as opposed to flanged DIP.					

Historical Maintenance, Problems and Spare Parts Availability

Have seen increased wear on rotor/stator since HRPT has come online. Likely due to sand carryover from HRPT process. Do not like split casing on Pump 2 as adjustments do not seem to work.

Historical Operation & Problems

No significant issues reported other than occasional air binding on suction side of the pump. Typical operation is to provide manual flush water on start as no ARV or suction gauge is installed. Pump station is a clean set up with a good method for containing leaks and drains.

Recommended Repair / Replacement

Continued preventative maintenance as currently scheduled. Consider addition of suction side ARVs, pressure gauges and pump protections (pressure switch high, temperature switch high)

Recommended Changes / Upgrades / Coating Systems Application

Consider addressing ventilation within the room to comply with NFPA820 and switching to motors rated for inverter duty

Photos of Unit



Process Unit: Solids Handling Building					
Date: 6/22/23		By: Ruth Borgmann, Barry Bickerstaff			
Equipment					
Dry Polymer Preparation System					
Equipment Name Plate Data					
Equipment Installation Dates					
Installed / Age: 2022			Normal Life: 20 years		
Equipment Run Time					
Hours:			Hours / Year:		
Last Major Equipment Overhaul					
N/A - Replaced in 2022					
Opinion of General Overall Unit Condition					
In very good condition					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition	Like New				
Corrosion	Like New				
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition	Like New				
Installation/Accessibility	Installed properly, easy to access				
Other Notes: Dry polymer can be messy and difficult to manage, but very clean and well kept install					

Historical Maintenance, Problems and Spare Parts Availability

No major maintenance issues.

Historical Operation & Problems

No major operational issues.

Recommended Repair / Replacement

None

Recommended Changes / Upgrades / Coating Systems Application

None

Photos of Unit



Process Unit: Solids Handling Building					
Date: 6/22/2023			By: By: Ruth Borgmann, Barry Bickerstaff		
Equipment					
BFP 1 & 2					
Equipment Name Plate Data					
2.5-meter BDP units					
Equipment Installation Dates					
Installed / Age: 2004			Normal Life: 25 years		
Equipment Run Time					
Hours: Matches incinerator run time.			Hours / Year: Run 1 unit 6 months then switch		
Last Major Equipment Overhaul					
PM performed, belt replaced within last 6 months. No major rehab completed to date.					
Opinion of General Overall Unit Condition					
Well maintained units. Due to age, likely in need to total rehab or replacement pending results of dewatering technology evaluation					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition			Moderate Chipping or Bare Spots		
Corrosion		Minor Corrosion			
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition		Minor Defects			
Installation/Accessibility			Moderate installation problems or access obstructions		
Other Notes:					

Historical Maintenance, Problems and Spare Parts Availability

Purge bearings 1x/year and grease every 3 months as part of PM program.
Belts needs frequent maintenance. Must be replaced every 6 months of operation. Is completed in house.
Takes 1/2 day with 5 staff. Belt life noted to have decreased over time and with HRPT online.
Periodic issues with belt tracking that have been addressed with in-house maintenance

Historical Operation & Problems

Sludge age impacts settleability of solids along with BFP performance, polymer usage and incinerator NG consumption. Try to keep feeding fresh sludge to BFP to keep polymer and NG usage low and dewaterability high.

Recommended Repair / Replacement

Emergency pull cord around unit needs to be tightened

Recommended Changes / Upgrades / Coating Systems Application

Consider replacing hydraulics system with electric motors. Could add a spray/flush system to the containment area to ease cleanup. Consider addressing ventilation within the room to comply with NFPA820 (whole building issue)

Photos of Unit



Process Unit: Solids Handling Building					
6/22/2023		By: Barry Bickerstaff & Arthur White			
Equipment					
Schwing Cake Pump					
Equipment Name Plate Data					
Schwing Bioset Model PP440 / 60 HP / Weight 4200 lbs / Max hyd Pressure 1440 sys 1 and 3000 sys 2					
Equipment Installation Dates					
Installed / Age: 2019 / 3.5 years			Normal Life: 20 years		
Equipment Run Time					
Hours:			Hours / Year:		
Last Major Equipment Overhaul					
N/A - Replaced in 2020. Pistons replaced at manufacturer's expense due to improper sizing. No issues now.					
Opinion of General Overall Unit Condition					
In very good condition					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition		Minor Chipping or Bare Spots			
Corrosion		Minor Corrosion			
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition		Minor Defects			
Installation/Accessibility	Installed properly, easy to access				
Other Notes: The cake pumps consist of a hydraulic power pack for each pump as well as the pumping assembly with the piston and the poppet valve. Discharge piping for each pump has a separate line going to the incinerator as well as to truck loadout for offsite disposal					

Historical Maintenance, Problems and Spare Parts Availability

No major maintenance issues. Occasional sludge in water box / gearbox seal issue. Maintenance staff stock spare parts and is familiar with the maintenance procedures.

Historical Operation & Problems

No major operational issues. Flush water box every 8-10 hours

Recommended Repair / Replacement

None

Recommended Changes / Upgrades / Coating Systems Application

Consider addressing ventilation within the room to comply with NFPA820

Photos of Unit



Process Unit: Solids Handling Building					
6/22/2023			By: Barry Bickerstaff & Arthur White		
Equipment					
Ash Slurry Pumps					
Equipment Name Plate Data					
Equipment Installation Dates					
Installed / Age:			Normal Life:		
Equipment Run Time					
Hours:			Hours / Year:		
Last Major Equipment Overhaul					
Opinion of General Overall Unit Condition					
Appears to be in good condition. Would need performance test to check efficiency to determine where on curve pump operates					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition	Like New	Minor Chipping or Bare Spots			
Corrosion	Like New	Minor Corrosion			
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition	Like New	Minor Defects			
Installation/Accessibility	Installed properly, easy to access				
Other Notes:					

Historical Maintenance, Problems and Spare Parts Availability

No major maintenance issues. Seal water system protects the seals. Stock spare impeller

Historical Operation & Problems

No major operational issues. VFDs provide level control for pumping ash from scrubber to the ash thickener.

Recommended Repair / Replacement

None

Recommended Changes / Upgrades / Coating Systems Application

None

Photos of Unit



Process Unit: Solids Handling Building					
6/22/2023			By: Barry Bickerstaff & Arthur White		
Equipment					
Ash Thickener					
Equipment Name Plate Data					
Equipment Installation Dates					
Installed / Age: 1988			Normal Life: 20 years		
Equipment Run Time					
Hours: 24/7			Hours / Year:		
Last Major Equipment Overhaul					
None. Last condition assessment 30% of the scraper was gone and the bottom pump well was getting very thin due to grit wearing. The base metal could fail at any time					
Opinion of General Overall Unit Condition					
Nearing end of life.					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks					No
All Safety Features Present	Yes				
Coating Condition				Significant Chipping or Bare Spots	
Corrosion				Significant Metal Loss	
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition		Minor Defects			
Installation/Accessibility			Moderate installation problems or access obstructions		
Other Notes: Motor, gear drive and bearing are original equipment still working. Lifting mechanics looks good for its age. The overflow weir is rusted as well as the visible center support bracket. Outside steel painted surface and main control panel look good considering age of equipment					

Historical Maintenance, Problems and Spare Parts Availability

The pump suction well will need to be repaired/replaced in the near future. The under water mechanism and scrapers will need a detailed assessment to determine if they can be replaced or repaired and recoated as well as the overflow weir. Maintenance has not been performed since plant desire to eliminate equipment.

Historical Operation & Problems

Suction pipe and discharge pipe need to be flushed regularly due to build of ash and sand

Recommended Repair / Replacement

Plant desire to eliminate ash thickener and regain footprint.

Recommended Changes / Upgrades / Coating Systems Application

Plant desire to eliminate ash thickener and regain footprint.

Photos of Unit



Process Unit: Solids Handling Building					
6/22/2023			By: Barry Bickerstaff & Arthur White		
Equipment					
Ash Transfer Pumps					
Equipment Name Plate Data					
WEG MOTOR 480 V /58.5 A/1770 RPM					
Equipment Installation Dates					
Installed / Age: 7 years			Normal Life:		
Equipment Run Time					
Hours:			Hours / Year:		
Last Major Equipment Overhaul					
None					
Opinion of General Overall Unit Condition					
Appears to be in good condition. Would need performance test to check efficiency to determine where on curve pump operates					
Condition Assessment Criteria					
In Service	Yes				
Acceptable Level of Noise	Yes				
Acceptable Oil/Grease	Yes				
Acceptable Smell or Heat	Yes				
Acceptable Vibration	Yes				
Absence of Leaks	Yes				
All Safety Features Present	Yes				
Coating Condition	Like New				
Corrosion	Like New	Minor Corrosion			
Mounting	Securely mounted, well supported				
Electrical Cable / Conduit Condition	Like New				
Installation/Accessibility	Installed properly, easy to access				
Other Notes: These pumps are running at constant speed and the original sheaves were changed to reduce the flow. The current flow is operating below the scour velocity of 3 fps in the ash transfer forcemain. The operating personnel are stopping the system periodically and flushing it to keep the solids from building up in the system.					

Historical Maintenance, Problems and Spare Parts Availability

No major maintenance issues. Since replacing flushless seal with one with seal water, no seal issues. Spare impeller stocked.

Historical Operation & Problems

No major operational issues. Constant speed pumps are not able to maintain scour velocity above 3 fps within forcemain. Flushing is required every 8-10 hours for approximately 30 minutes of flushing.

Recommended Repair / Replacement

Plant desire to eliminate this set of pumps.

Recommended Changes / Upgrades / Coating Systems Application

Plant desire to eliminate this set of pumps.

Photos of Unit



Appendix B: Record of Solids Production Updates

The previous version of TM 1 included solids production numbers based on an assumed HRPT capacity of 20 mgd. Based on feedback from MSD at the TM 1 workshop, the HRPT capacity was updated to 15 mgd, with 7.5 mgd capacity per train. This resulted in a decrease of primary solids production and an increase in secondary solids production. A comparison of the solids production for 20 mgd and 15 mgd to HRPT is provided below. **Figure B-1** shows this update in visual form.

Figure B-1: Primary Sludge Loading Rates (lb/day) Comparison

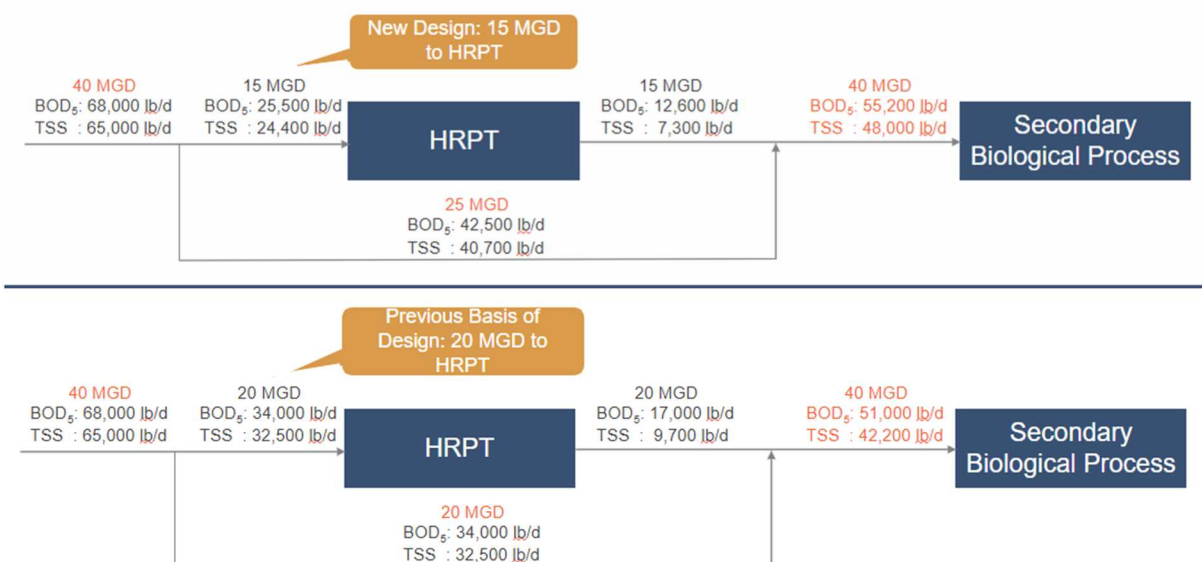


Table B-1 shows the change in primary sludge production, which scales with flow, so the reduction of HRPT capacity by 33% corresponds to a reduction in primary sludge loading of 33%.

Table B-1: Primary Sludge Loading Rates (lb/day) Comparison

Parameter	Design	MAX14	MAX07
Primary Sludge Production with 20 mgd to HRPT, lb/day	29,500	38,500	41,100
Primary Sludge Production with 15 mgd to HRPT, lb/day	22,200	29,000	30,900

Table B-2 shows the estimated secondary sludge loading rates for the six different alternatives with 20 mgd to HRPT. As can be seen, there is wide variation in secondary sludge production depending on the selected processing alternative due to the different solids retention times associated with each biological process and different growth kinetics.

Table B-2: Secondary Sludge Loading Rates (lb/day) at 40 mgd

Parameter	Design	MAX14	MAX07
AGS Sludge Production, lb/day	33,800	41,400	44,400
BAF Sludge Production, lb/day	49,500	60,700	65,000
DAS Sludge Production, lb/day	38,500	47,200	50,600
IFAS Sludge Production, lb/day	70,000	85,800	91,900
MABR Sludge Production, lb/day	31,300	38,400	41,100
MBBR Sludge Production, lb/day	55,700	68,300	73,100

The secondary sludge production does not scale with flow, due to the increase in flow bypassed around the HRPT process, as outlined in Section 4.2 of the TM. This also means that secondary sludge production does not scale with flow to HRPT, as shown in **Table B-3**. Note that secondary sludge production for IFAS, MABR, and MBBR alternatives were not developed for the 15 mgd scenario, as these alternatives had been removed from consideration prior to that update.

Table B-3: Secondary Sludge Loading Rates (lb/day) Comparison at 40 mgd

Parameter	Design	MAX14	MAX07
AGS Sludge Production with 20 mgd to HRPT, lb/day	33,800	41,400	44,400
AGS Sludge Production with 15 mgd to HRPT, lb/day	36,900	45,200	48,400
BAF Sludge Production with 20 mgd to HRPT, lb/day	49,500	60,700	65,000
BAF Sludge Production with 15 mgd to HRPT, lb/day	49,800	61,100	65,400
DAS Sludge Production with 20 mgd to HRPT, lb/day	38,500	47,200	50,600
DAS Sludge Production with 15 mgd to HRPT, lb/day	44,200	54,200	58,100

Table B-4 shows the sludge production loading rates for the 40 mgd design capacity with 20 mgd baselined to the HRPT process.

Table B-4: Total Sludge Loading Rates (lb/day) at 40 mgd

Parameter	Design	MAX14	MAX07	PS:WAS Ratio
AGS Sludge Production, lb/day	59,100	74,200	79,300	38%
BAF Sludge Production, lb/day	72,000	90,100	96,300	31%
DAS Sludge Production, lb/day	66,400	83,200	89,000	33%
IFAS Sludge Production, lb/day	99,500	124,300	133,000	30%
MABR Sludge Production, lb/day	60,800	76,900	82,200	49%
MBBR Sludge Production, lb/day	85,200	106,800	114,200	35%

Table B-5 shows the comparison of total sludge loading rates at 40 mgd with 20 and 15 mgd to HRPT. The total sludge loading rates are less with 15 mgd to HRPT due to the decreased amount of primary solids that also receive secondary treatment. The PS:WAS ratio decreased for each of the liquid treatment alternatives, which bears an impact on incinerator operation.

Table B-5: Total Sludge Loading Rates (lb/day) Comparison at 40 mgd

Parameter	Design	MAX14	MAX07	PS:WAS Ratio
AGS Sludge Production with 20 mgd to HRPT, lb/day	63,300	79,900	85,500	47%
AGS Sludge Production with 15 mgd to HRPT, lb/day	59,100	74,200	79,300	38%
BAF Sludge Production with 20 mgd to HRPT, lb/day	79,000	99,200	106,100	37%
BAF Sludge Production with 15 mgd to HRPT, lb/day	72,000	90,100	96,300	31%
DAS Sludge Production with 20 mgd to HRPT, lb/day	68,000	85,700	91,700	43%
DAS Sludge Production with 15 mgd to HRPT, lb/day	66,400	83,200	89,000	33%

A case study was conducted considering the impact of varying HRPT throughput on solids production. If one HRPT train is offline, only 7.5 mgd may be processed through the primary treatment process, increasing the bypass load to secondary treatment. This results in overall fewer total solids at the design condition, but the lower PS:WAS ratio likely decreases sludge dewaterability. **Table B-6** shows the comparison of this case to the baseline 15 mgd to HRPT scenario at the design condition.

Table B-6: Secondary Sludge Loading Rates (lb/day) Comparison at 40 mgd

Parameter	15 mgd to HRPT	7.5 mgd to HRPT
Primary Sludge Production, lb/day	22,200	11,100
Secondary Sludge Production, lb/day	41,800	47,400
Total Sludge Production, lb/day	64,000	58,500
PS:WAS Ratio	35%	19%

Hazen *Technical Memorandum*

Final: July 11, 2025

To: Metropolitan Sewerage District of Buncombe County (MSD)

From: Sharanya Ananth, Hazen
Aaron Babson, PE, Hazen
Ruth Borgmann, PE, Hazen
Michael Bullard, PE, Hazen
Jacqueline Yeh, PE, Hazen

Technical Memorandum No. 2a – Redundancy Assessment

FINAL

31359-001

Table of Contents

1. Introduction	3
2. Technologies Considered	3
2.1 Landfill Disposal/Management.....	4
2.2 Existing Incinerator Rehabilitation	5
2.3 Thermal Drying	6
2.4 Composting	8
2.5 Supercritical Water Oxidation (SCWO).....	9
2.6 Lime Stabilization.....	11
2.7 Third-Party Vendor.....	12
3. Next Steps	14

Appendix A: 374water Proposal

1. Introduction

The Metropolitan Sewerage District (MSD) of Buncombe County retained Hazen and Sawyer (Hazen) to complete a Solids Handling Preliminary Engineering Report (PER) for the French Broad River Water Reclamation Facility (FBRWRF). The PER includes a condition and capacity assessment on the existing equipment, technology assessments, permitting assistance and development of a new solids handling facility concept to be seamlessly integrated into the forthcoming liquid train project.

Specifically, this technical memorandum (TM) evaluates alternative disposal options which could provide the FBRWRF with a redundant biosolids management strategy when the incinerator is not operational. The following potential alternatives were considered and presented during the Redundancy Assessment Workshop to MSD on May 23, 2024, to discuss which options would be evaluated further by Hazen.

- Landfill Disposal/Management
- Rehabilitation of the existing Fluidized Bed Incinerator (FBI)
- Thermal Drying
- Composting
- Supercritical Water Oxidation (SCWO)
- Lime Stabilization
- Third-Party Management

2. Technologies Considered

The existing solids process at the FBRWRF includes gravity thickening, dewatering via belt filter press technology, incineration, and ash handling at an on-site ash lagoon. This process is compared to each alternative in their respective process flow diagrams, but the FBI could be exchanged for a thermal dryer or any other solids handling process as the primary solids management technology. **Figure 2-1** illustrates the existing processes.

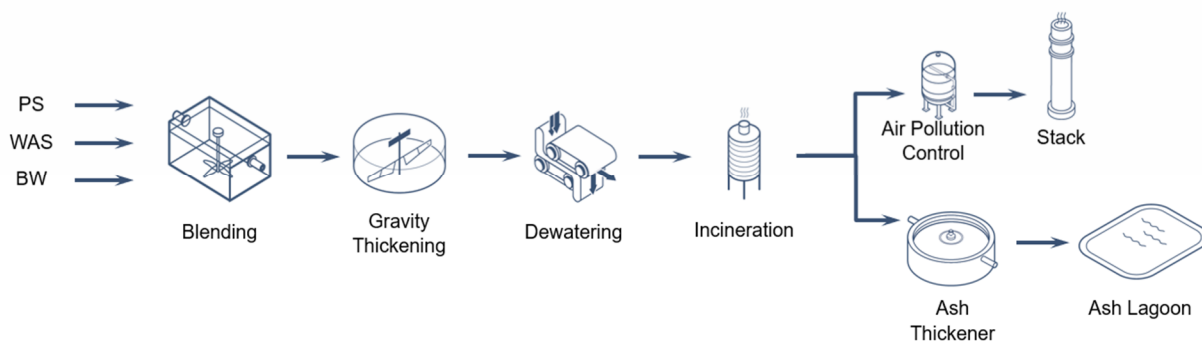


Figure 2-1: Existing Solids Handling Process Flow Diagram

The current alternative solids handling strategy during incinerator downtime or maintenance is to send dewatered cake to the Buncombe County Landfill. While the landfill could be a viable option for

continued use, there are several alternatives that could also provide a redundant solids management strategy that can be considered. The following sections will detail the alternatives examined.

2.1 Landfill Disposal/Management

During times when the MSD incinerator is down, the FBRWRF can utilize the nearby Buncombe County Landfill as a short-term biosolids handling outlet for dewatered cake. **Figure 2-2** shows the process flow associated with this alternative, with dewatered cake being trucked offsite to the landfill.

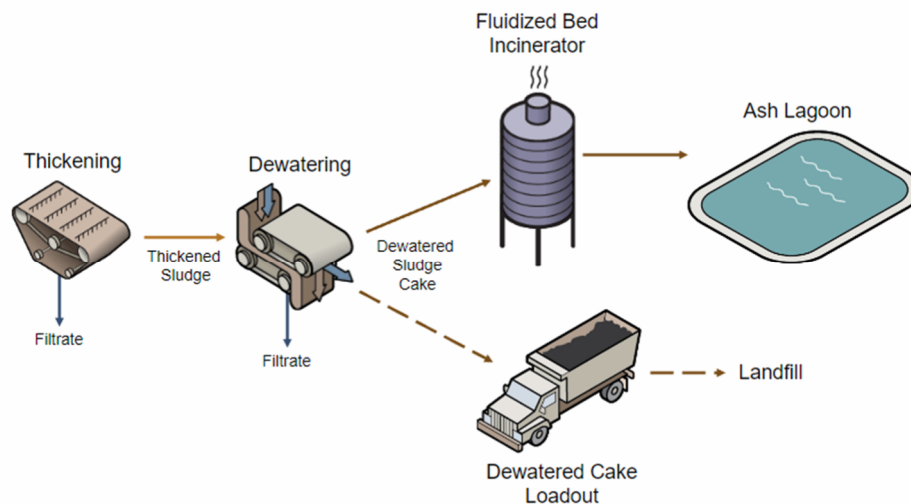


Figure 2-2: Landfill Process Flow Diagram

MSD currently has a long-standing verbal agreement with the Buncombe County Landfill for waived tipping fees for disposal of their biosolids in exchange for receiving the landfill leachate at the FBRWRF. Although this agreement is currently highly beneficial for the FBRWRF during incinerator downtime, there is no guarantee that such an agreement will be maintained in the future. Without a contract, the landfill may refuse to accept dewatered cake for a variety of reasons or impose a high tipping fee, leaving the FBRWRF with no outlet in place to dispose of their solids or a greatly increased operation cost to continue disposing of solids at the landfill. Typical landfill tipping fees at other sites in the southeast region range between \$40 and \$125 per wet ton (wT), which could become a considerable added expense to MSD, if implemented.

Another challenge of this option is that the acceptance hours of the landfill do not line up with the dewatering hours required by MSD, meaning truck staging is required to continue dewatering operations when the landfill is not open to accept solids.

Currently, the FBRWRF receives approximately 100,000 to 150,000 gallons of landfill leachate per day from the Buncombe County Landfill. This leachate could represent a significant PFAS and emerging contaminant risk to the treatment facility operations. MSD is evaluating a potential PFAS mitigation system that would be located at the Buncombe County Landfill to reduce PFAS risk at the FBRWRF.

Discussions to update leachate management and address PFAS concerns present an opportunity for MSD and Buncombe County Landfill to work together and sign a contract that could formalize the design, construction and operation of a remote leachate treatment system, FBRWRF acceptance of treated leachate and identify dewatered cake hauling guidelines during incinerator downtime to protect all parties.

Table 2-1 below shows additional considerations for the landfilling alternative.

Table 2-1: Landfill Pros and Cons

Pros	Cons
• Status quo - continued hauling of dewatered cake to Buncombe County Landfill • Low capital cost (dewatered cake loadout improvements)	• Landfill limitations: mass, cake dryness and strength requirements • Potential for future tipping fees • Logistical challenges associated with truck staging and hauling

2.2 Existing Incinerator Rehabilitation

Another redundancy option that would allow MSD to leverage existing assets first would be to rehabilitate the existing incinerator. Recent stack testing results have resulted in an updated processing capacity rating of 39.8 dT per day. This alternative would allow the rehabilitated incinerator to operate during times when a new incinerator is down, maintaining the existing ash lagoon as the solids management location for produced ash. **Figure 2-3** shows the proposed process flow including the option to send dewatered cake to either the new or rehabilitated incinerator.

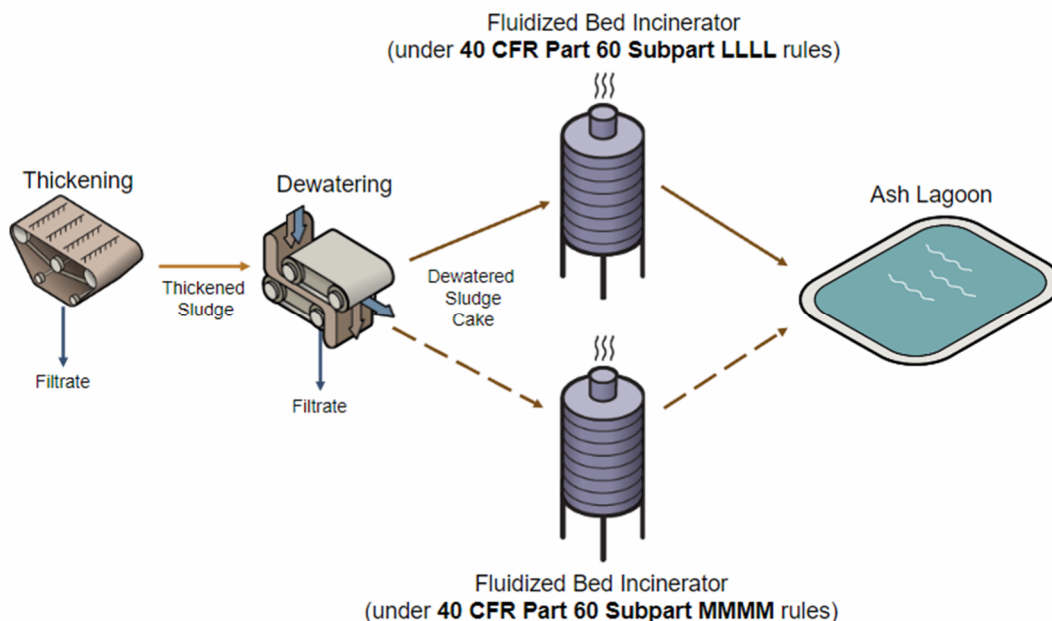


Figure 2-3: Incinerator Rehab Process Flow Diagram

Although there are no new facility footprints associated with this redundancy alternative, this alternative has funding and permitting challenges to repair and rehabilitate the existing Fluidized Bed Incinerator

(FBI). To our knowledge, no significant modifications or rehabilitations have been approved by the EPA – Region 4 for any improvements regulated under the Routine Maintenance, Repair and Replacement (RMRR) requests. The Asheville - Buncombe Air Quality Agency would be required to comply with the minimum standards from the EPA, thus an RMRR authorization would be required. The following multi-factor policy questions were developed by the EPA to determine whether a project meets the RMRR requirements and to approve the existing incinerator rehabilitation:

- Does the project extend the life of the incinerator beyond the planned retirement date?
- Will the cost of the project be drastically higher than the normal O&M annual budget?
- How long will the outage occur to complete the planned repairs?
- How many workers are projected to be needed to complete the proposed project?
- How much amount or percentage work is to be performed by an outside entity and how much work will be performed by plant staff?
- Have other sewage sludge incinerators in the US undergone this type of project?

Additionally, the existing incinerator would not have enough capacity to be a completely redundant alternative for the new incinerator. If the existing incinerator were in operation as a redundant solids handling strategy, dewatered solids in excess of the 39.8 dT per day capacity would still need to be directed to a secondary outlet such as the landfill. Additional considerations for the rehabilitation option are shown in **Table 2-2**.

Table 2-2: Existing Incinerator Rehabilitation Pros and Cons

Pros	Cons
• No offsite disposal of biosolids or ash • Completely MSD owned and operated • Familiar system for operators	• Challenging permitting requirements • Maintaining two complex systems with different emission standards • Continued landfilling when sludge production is >39.8 dT per day capacity • Maintaining operability of redundant FBI with limited use • High capital cost

2.3 Thermal Drying

Thermal drying is a process that uses thermal energy (heat) to evaporate a significant amount of water from sludge, resulting in volume and mass reduction of solids, to produce a high-quality dried product, typically greater than 90% dry product solids (less than 10% moisture content). The high quality of this dried product would provide MSD with more flexibility in finding a final product outlet. Depending on market and customer development, the dried solids could potentially be a revenue source estimated to be in the range of \$5-\$20 per product ton. However, revenue potential for this project is dependent on identifying a customer, and therefore, revenue from this source will not be considered in the financial analysis. For this redundancy alternative, a thermal dryer, cake bin, dewatered cake conveyance, other ancillary equipment, and a new facility housing the thermal drying process would be required onsite at the FBWRF. **Figure 2-4** shows the proposed solids handling process flow diagram with thermal drying as the redundant pathway.

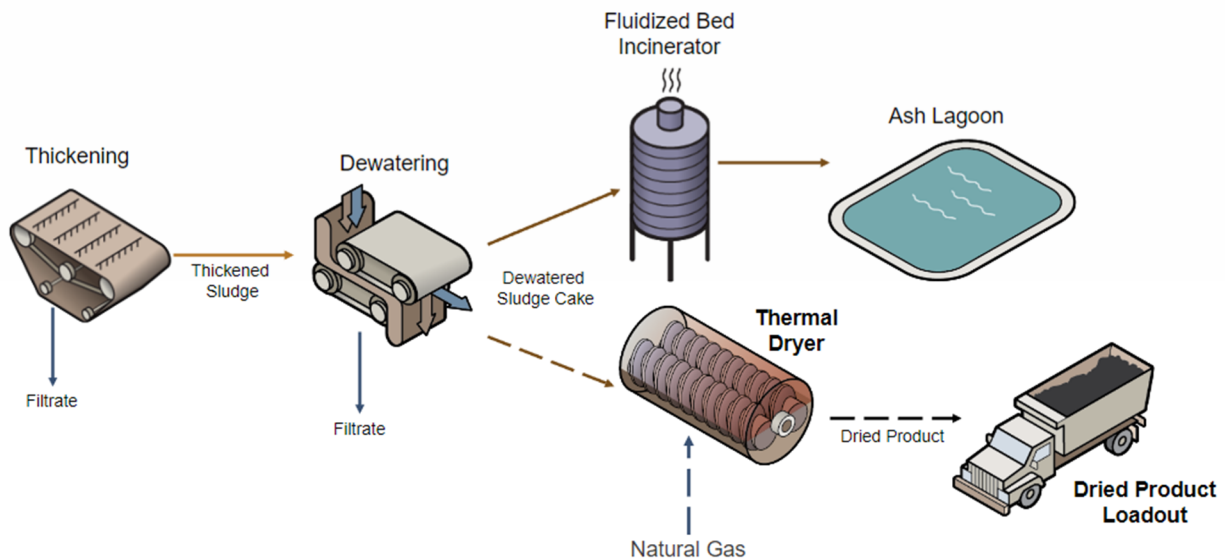


Figure 2-4: Thermal Drying Process Flow Diagram

There are two different methods of thermal drying – direct drying and indirect drying.

- **Direct drying:** Also described as convection drying, this type of drying allows the heat source, typically hot air, to come into contact with the material being dried. As an example, a drum dryer is a direct dryer, as are some forms of belt dryers.
- **Indirect drying:** Also described as conduction drying, where the heat source does not come into direct contact with the material being dried. Indirect dryers include rotating chamber, paddle dryers, and some forms of belt dryers.

A few different drying technologies are available on the municipal market, including drum dryers, belt dryers, and paddle dryers. Rotary drum dryers have many benefits and are one of the most proven forms of drying technology. Belt dryers produce the lowest quality of product, require more time to dry, and have the largest footprint of the three options. Due to the limited footprint available for additional processes at the FBRWRF, a belt dryer would not be recommended. Paddle dryers are a type of indirect dryer and result in a granular product that has a wide size distribution and are slightly more complex drying systems to operate. Though it is the most complex type of thermal drying, drum drying would be the recommended thermal dryer technology for MSD due to the size of the facility and high quality of the final product.

For the expected solids production of the liquid treatment process alternatives still under consideration, a preliminary dryer size would be the Andritz DDS-60 which has an evaporation capacity of 13,200 lb(water) per hour at an assumed feed solids concentration of 20%TS.

Table 2-3 shows additional considerations for using a thermal dryer as a redundant technology option.

Table 2-3: Thermal Drying Pros and Cons

Pros	Cons
• Class A material • Significantly reduced final product to manage • Flexibility of outlets for final product • Potential for revenue from final product	• High capital cost • Maintaining operability of complex system with limited intended use • Large footprint • High O&M (natural gas cost) • Requires market research and customer development

2.4 Composting

Composting is a process which allows organic matter to be decomposed under controlled aerobic conditions to produce a humus-like soil that can be used for agricultural purposes. The composting process includes a series of steps: mixing dewatered biosolids with a bulking agent, a period of active composting, screening, and curing. During active composting, the temperature of the material increases between 122°F and 131°F for between 21 and 30 days, allowing the process to meet the USEPA 503 guidelines for pathogen reduction and vector attraction reduction.

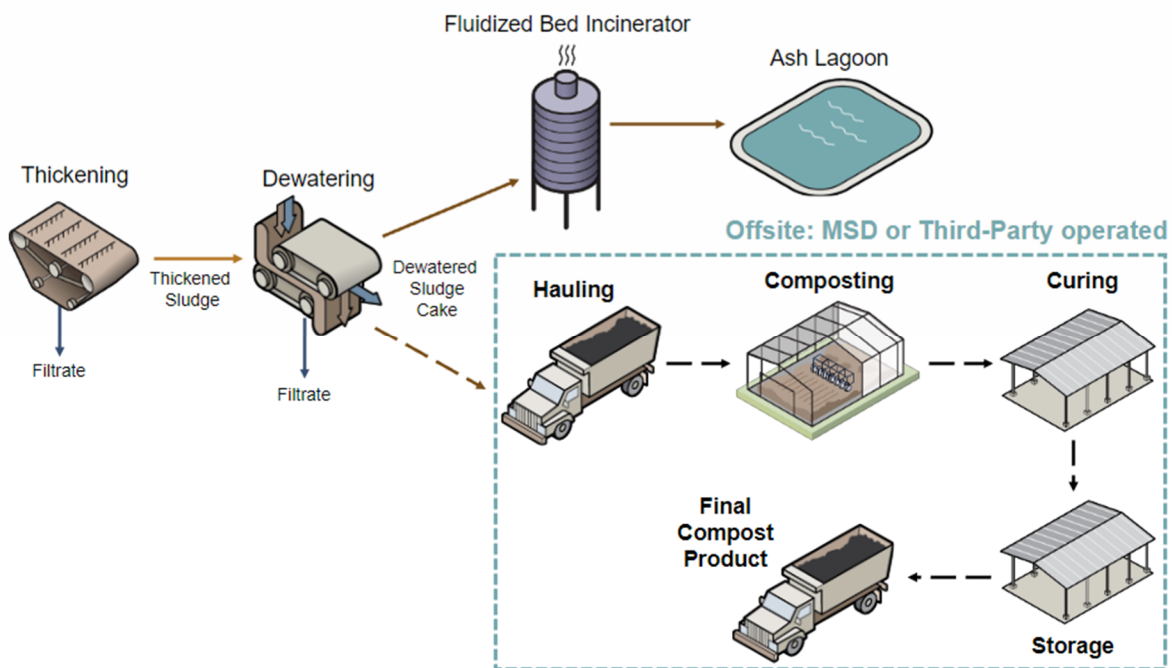


Figure 2-5: Composting Process Flow Diagram

Figure 2-5 shows a proposed process flow diagram for how a composting alternative would fit into the solids handling process at the FBRWRF. Although the composting process is a viable alternative for solids handling, the FBRWRF does not have enough footprint to build an onsite composting facility that could be owned and operated by MSD. If this alternative is considered as a redundant solids handling alternative, this process would need to occur at an offsite location or MSD would need to enter a partnership with a third-party operated composting facility. For the MSD-owned option, a relatively close

parcel of land would need to be procured to be developed into a composting facility. This option would require MSD to load dewatered biosolids at the FBRWRF and haul the cake to the composting facility as well as source a bulking agent. At 40 mgd plant capacity, the FBRWRF would be estimated to produce 135-165 wT per day of biosolids (See TM No. 1) that could be redirected to a composting facility when the new incinerator is offline. Finding an appropriately sized and zoned parcel of land would likely be challenging. See Section 2.7 for additional discussion of the third-party vendor alternative. **Table 2-4** shows additional considerations for an MSD-owned composting alternative.

Table 2-4: Composting Pros and Cons

Pros	Cons
- Fundamentally simple process - Produces a valuable and marketable product - Relatively fewer restrictions to end use application compared to another Class A biosolids	- Requires at least an equivalent amount of bulking agent to the processed biosolids - Large area requirement to implement composting facility - Challenging to find appropriately sized and zoned land - Labor intensive process - Requires an odor control system or large buffer between facility and neighbors - Requires some minimum weekly baseline of dewatered cake (especially if third-party operated)

2.5 Supercritical Water Oxidation (SCWO)

Supercritical Water Oxidation (SCWO) utilizes a special phase of water that occurs above 374°C and above 218 atm where the water exhibits characteristics of both liquid-like and gas-like properties. **Figure 2-6** shows the water phase chart and location of the supercritical phase. In the presence of an oxidizing agent, such as oxygen, organic material is fully oxidized. Above the supercritical threshold, most organic components are soluble, oxygen is fully miscible, and salts are insoluble. Thus, at the end of the SCWO treatment, the dewatered cake fed into the system becomes distilled water, mineral salts, and carbon dioxide. Due to the complete oxidation of the organic material, the SCWO process greatly reduces the amount of final product to be managed. The SCWO process has lower temperatures than traditional combustion technologies, though the process occurs at significantly elevated pressures. Figure 2-7 shows a proposed process flow diagram for how SCWO would fit into the FBRWRF solids handling process as an alternative to sending dewatered biosolids to the new incinerator. The primary SCWO vendor in the municipal industry, 374Water, designs their SCWO process to fit within a standard shipping container, allowing for a modular design for layout flexibility and to add additional SCWO trains.

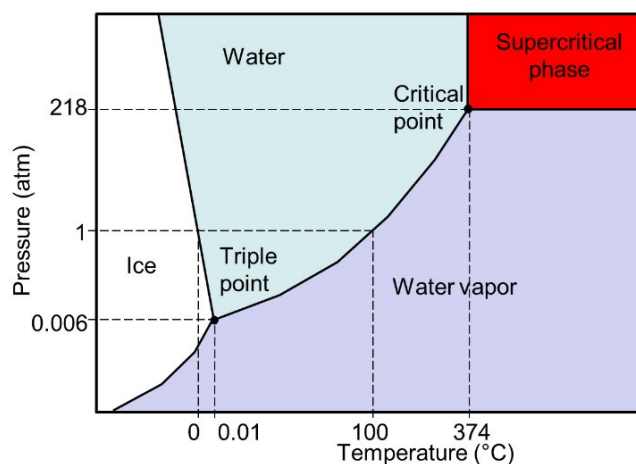


Figure 2-6: Water Phase Diagram (SCWO)

Recent studies by the EPA on SCWO have shown promising results regarding PFAS destruction in the liquid phase of feed streams. The study was performed on the SCWO treatment of aqueous firefighting foam, showing greater than 99% destruction of total PFAS (including PFOS and PFOA) removal in the liquid phase. While the results of this study show great results for PFAS removal from the liquid phase, additional research is needed to see if any of those PFAS compounds or precursors are transferred to the gas phase and released as part of the emissions stream.

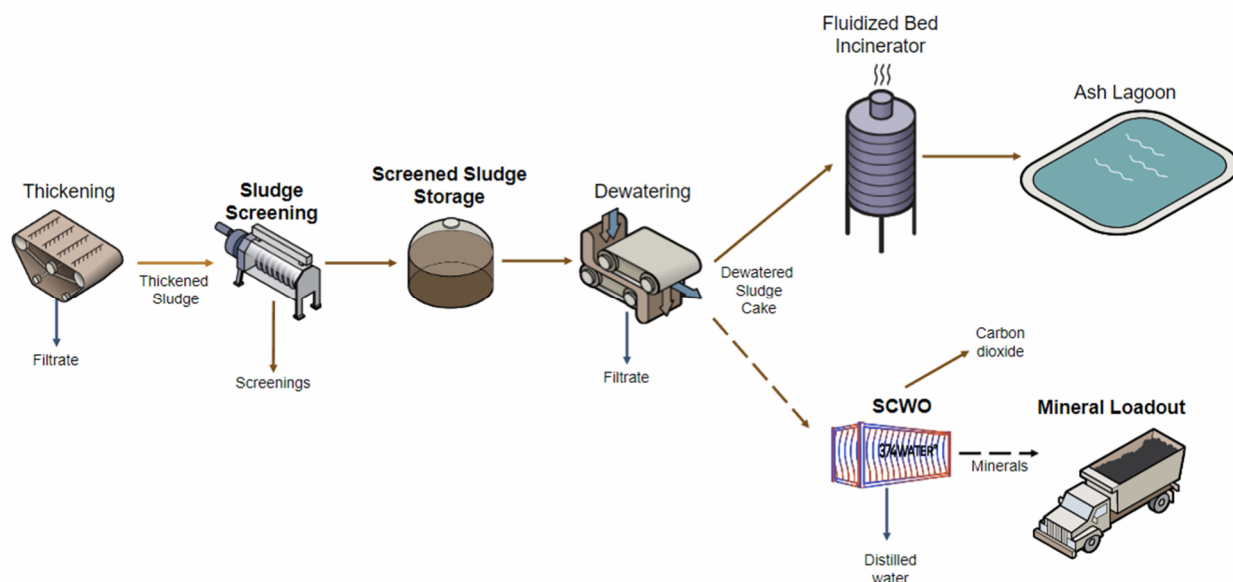


Figure 2-7: SCWO Process Flow Diagram

Although the SCWO process has been proven for its original purpose of treating hazardous waste, it is still an emerging technology for the wastewater industry and several of the units proposed by 374Water are conceptual only, with no units installed for continuous service at this time. **Table 2-5** shows the

current size options developed by 374Water. Hazen’s first SCWO project with the Orange County Sanitation District in California is anticipated to be onsite and operational by the Fall of 2024.

Table 2-5: 374Water AirSCWO Sizes

	AirSCWO-6	AirSCWO-30	AirSCWO-200
Capacity, wT/day	6	30	200
Implementation Level	Commercial	Currently in Design	Pending Design

All units sized assuming 15%TS feed solids concentration.

Based on MSD dewatered cake production, a minimum of six AirSCWO-30 trains or a single AirSCWO-200 unit would be required for the 40 MGD plant permitted capacity. The AirSCWO-6 is currently the only commercial size offered; however, this is not a reasonable size for a redundant solids handling technology at the FBRWRF. Additional considerations for SCWO are shown in **Table 2-6**.

Table 2-6: SCWO Pros and Cons

Pros	Cons
• Significantly reduced final product to manage • High PFAS destruction efficiency • Lower footprint requirements	• Emerging technology, not developed at size and scale required • Sludge screening and screened sludge storage required • Maintaining operability of complex system with limited use • High capital cost

During the SCWO presentation in the redundancy assessment workshop, MSD noted interest in a pilot of the smallest SCWO unit to test its efficacy in removing PFAS from MSD’s sludge. MSD’s assumed primary source of PFAS is leachate accepted from the landfill, so a SCWO pilot treating a combination of sludge and landfill leachate was of particular interest to test the technology’s potential for PFAS removal at FBR WRF. According to 374water, this would require pretreatment to concentrate the leachate into foamate, and is very dependent on the heat value of the sludge. The proposal submitted by 374water is attached in Appendix A. Due to the nature of SCWO as an emerging technology, this may be considered in the future when more installations can be observed and the technology becomes more cost effective.

2.6 Lime Stabilization

Lime stabilization is a process in which calcium oxide (lime) is blended with dewatered cake to raise the pH of blended material to meet pathogen and vector attraction reduction standards. MSD has prior experience with Lime Stabilization and does not consider this to be a viable option for their uses. This alternative is ideal for facilities that may utilize land and agricultural application of solids. Per the EPA CFR Part 503 Rule, lime stabilization can be used to meet either Class A or Class B standards. To meet standards for Class B, lime stabilization is required to raise pH above 12 for a short period of time and can be completed within five minutes of mixing. To meet Class A standards, the mixture of biosolids and lime must be held above a pH of 12 for at least 72 hours, in addition to requiring an elevated temperature of 52°C for at least 12 hours of the total time or above 70°C for 30 or more minutes. The increased temperature may be achieved by overdosing the added lime or through a supplemental heat source.

Figure 2-8 shows a proposed process flow diagram for where the lime stabilization process could be added as a redundant solids handling process alternative.

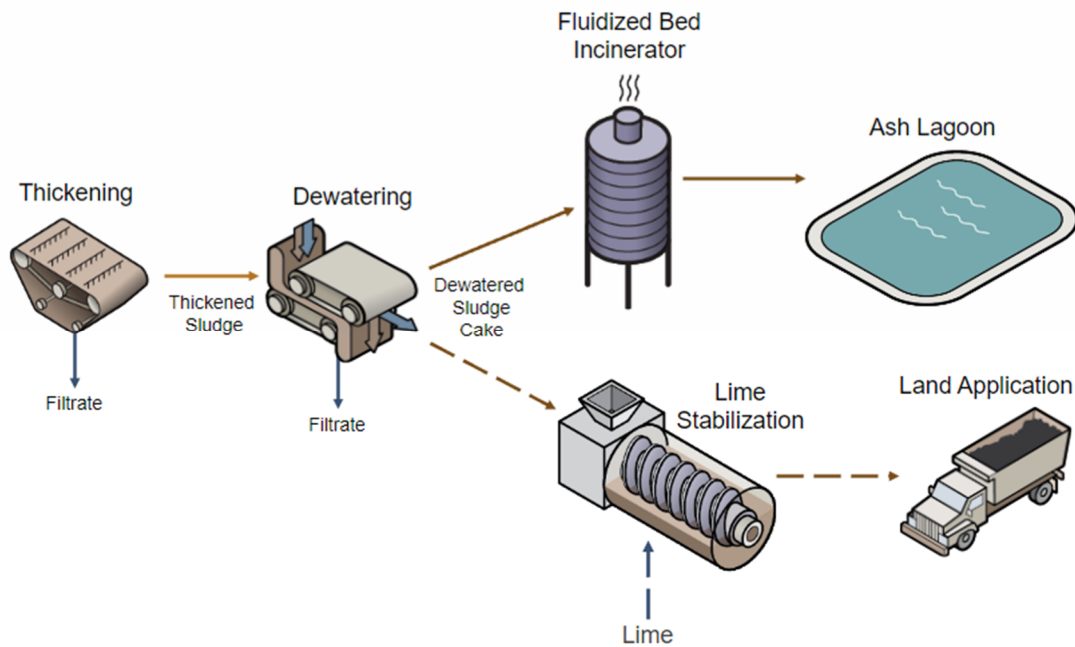


Figure 2-8: Lime Stabilization Process Flow Diagram

Due to the small footprint requirements of a lime stabilization process, this alternative would be relatively easy to locate and construct onsite at the FBRWRF. Though simple in operation, this alternative would be increasing the amount of final product that would need to be managed, resulting in increased hauling requirements. This is an obstacle MSD experienced when practicing lime stabilization in the past. Marketing research would be needed to select suitable end users for this product. **Table 2-7** shows a summary of considerations for using lime stabilization as a redundant solids handling technology at the FBRWRF.

Table 2-7: Lime Stabilization Pros and Cons

Pros	Cons
• Simple operation • Flexibility to produce a Class A or B product	• Requires offsite hauling • Increased mass for final product management • Chemical cost • Elevated pH can result in high ammonia odor • Requires market research and customer development

2.7 Third-Party Vendor

For the third-party vendor alternative, dewatered cake from FBRWRF would be hauled offsite to a stand-alone processing facility which would perform its own operation and management. In this alternative,

MSD would form a partnership with the third-party vendor for the vendor to receive dewatered biosolids, stabilize, and handle final product management. Known third-party vendors in the region include McGill, Synagro, and Denali. Of the existing third-party owned facilities, the McGill composting facility in New Hill, NC is the nearest third-party location to the FBRWRF, though it is a significant distance of 250-miles one-way, from the facility which would incur significant hauling costs for MSD. Another McGill location is being investigated in Anson County, slightly closer at 180-miles for a one-way trip, however this facility is currently in the permitting phase. **Figure 2-9** shows how hauling of dewatered cake to a third-party vendor facility would fit in with the existing solids handling process at the FBRWRF.

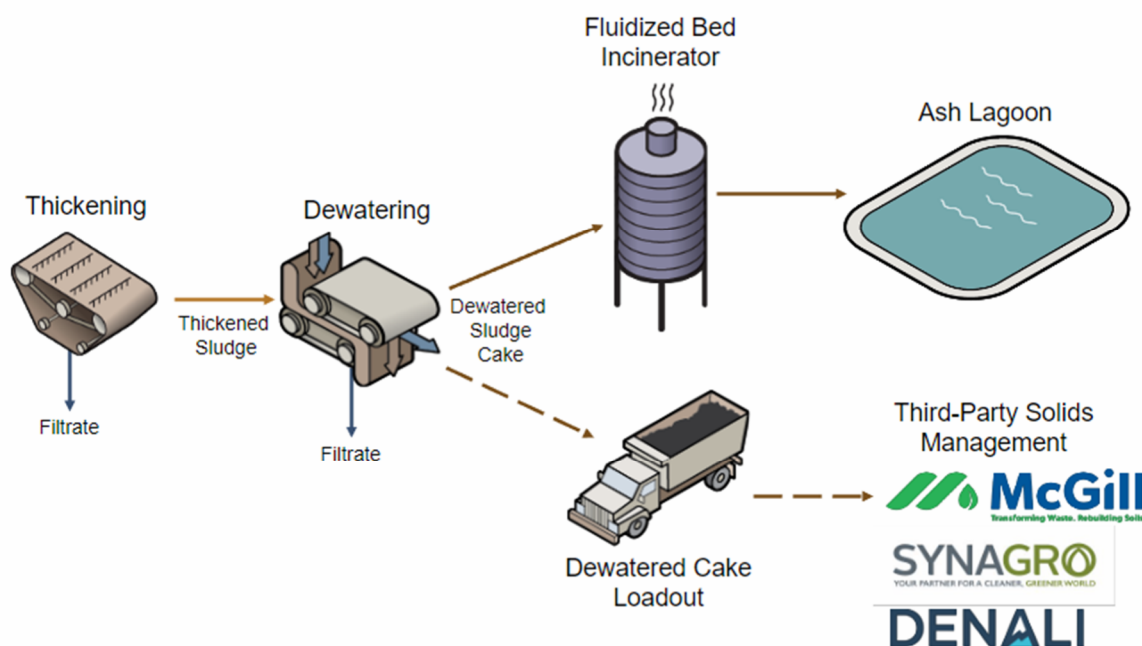


Figure 2-9: Third Party Management Process Flow Diagram

To ensure consistency in operation, third-party vendors typically prefer to develop a stable, long-term contract with clients, including a guarantee of minimum solids that will be sent to the third-party facility. For example, a typical contract might require a minimum of three loads of dewatered biosolids per week with a \$50 per wT tipping fee. As a redundant solids handling alternative only to be implemented when the selected alternative is offline, this requirement does not match MSD's intended typical operation strategy.

The hauling and tipping costs will be a significant ongoing expense to transfer dewatered biosolids to a third-party vendor processing facility location. Although there are minimal impacts to the current dewatered cake loadout operations at the FBRWRF, MSD would be logistically limited to only being able to send dewatered cake during the third-party vendor's hours of operation and may need to purchase trailers to stage on site to allow for longer dewatering hours. Having MSD-owned trailers would allow for the onsite dewatering process to be decoupled from the third-party vendor's acceptance hours. **Table 2-8** shows additional considerations for use of a third-party vendor as a redundant solids handling strategy at the FBRWRF.

Table 2-8: Third-Party Vendor Pros and Cons

Pros	Cons
- Limited additional onsite biosolids processing required - Meets sustainability/beneficial use requirements - Low capital cost	- Significant hauling distance - Significant hauling and tipping costs - Limited third-party facility hours of operation that do not match 24/7 intended dewatering strategy - No 'control of the utility's own destiny'

3. Next Steps

Each alternative under consideration offers benefits and drawbacks as summarized in **Table 3-1**. After discussing each of the options with MSD, it was decided that the following alternatives would be carried forward and developed further for consideration:

- Landfill
- Incinerator rehabilitation
- Thermal drying (as a primary solids management option)

Table 3-1: Potential Redundancy Alternatives Summary

Alternative	Capital Cost	Footprint	Permitting Challenges	Quantity of Final Product for Management	Other Important Considerations
Landfill	■	■	■	■	Not a reliable long-term option
Incinerator Rehab	■	■	■	■	Capacity will not match new FBI
Thermal Drying	■	■	■	■	High O&M cost
Composting	■	■	■	■	Offsite land requirements
SCWO	■	■	■	■	Emerging Technology
Lime Stabilization	■	■	■	■	Land application clients needed
Third-Party Vendor	■	■	■	■	Hauling distance

Note: Green icons indicate a relatively positive impact, compared to the other alternatives. Yellow indicates the feature does not lean positive or negatively in the consideration. Red indicates significant challenges are associated with the corresponding alternative and feature.

Composting was removed from consideration because both the land requirements and initial capital costs were considered excessive for an option that would be a backup to the new incinerator and not in use for the majority of the year. While SCWO is considered beneficial and an important emerging technology due to the current studies on PFAS removal, this option will not currently be considered as a full-scale redundant backup to the incinerator due to its lack of installations in the municipal space. MSD may consider working with the Buncombe County Landfill to examine if SCWO may be an option for PFAS treatment of leachate if action is required by new PFAS regulations. Lime stabilization was removed from consideration due to previous MSD experience with alkaline stabilization and the increased mass of

the final product due to the addition of lime. The third-party vendor option was removed from consideration due to the long hauling distances and associated costs. If another composting facility in closer proximity to the FBRWRF is opened in the future, this option may be reconsidered at such time.

MSD's primary considerations for selection of redundancy alternatives were having control of their own destiny (MSD-led or owned solids handling strategy, with no separate entity) and reduced operation and maintenance costs since the redundant strategy will only be utilized when the new incinerator is offline. The remaining alternatives continuing forward reflect these preferences of MSD. Hazen will carry forward the three selected redundancy options and develop a detailed assessment of the viability of each at the FBRWRF.

Appendix A: 374water Proposal

374WATER^o

To: [Sharanya Ananth, Hazen and Sawyer](#)
Subject: [MSD Buncombe Leachate](#)
Project Location: [Buncombe County, NC](#)
Date: [3/19/2025](#)

AirSCWO OVERVIEW

AirSCWO utilizes the power of supercritical water oxidation (SCWO) to treat wet organic wastes like dewatered wastewater sludge. It is a transformative technology that utilizes the unique properties of water above its critical point 705°F (374°C) and 3200 psi (221 bar). At these conditions, in the presence of oxygen, organics are rapidly converted to water, non-haz/inert solids and gases, and reusable heat with >99.9% conversion of carbon to energy.

PRODUCT OFFERING

374Water is pleased to propose 1 x AirSCWO 06 system(s) for this project.

The footprint for the system(s) is roughly 1 x 40' x 8' x 9.5' + with a surrounding work perimeter(s).

The system design is based on the information listed in the following tables and will be supplied according to 374Water design standards.

SCWO INPUTS

SOURCE	GIVEN VALUES		ADJUSTED VALUES	
	VOL. (WTPD)	CONC. (% DS)	VOL. (WTPD)	CONC. (% DS) / HHV (MJ/kg)
Sludge (WAS/RAS)	4.00	20.0%	4.87	18% / 2.34
Foamate	0.11	1.0%	0.21	1% / 0.02
Trim fuel (co-fuel)	----	----	0.02	100% / 46
COMBINED	---	---	5.10	17% / 2.42

SCWO OUTPUTS

Electricity	Generates roughly 734 kWh/day of electrical energy with the heat to electric recovery unit add-on option.
Heat	Generates roughly 3,399 kWh th/day of thermal energy that is reused in the SCWO process.
Minerals	Produces roughly 0.15 metric dry tonnes of phosphorus rich minerals each day with the mineral separation add-on option.
Non-potable water	Produces roughly 5 cubic meter of non-potable clean water each day with the mineral separation add-on option.

Note: Without the heat recovery add-on option, no electricity is generated. Without the mineral separation add-on option, the effluent volume will be ~100% of the feed volume and contain ~ 1-3% inert solids <4mm.

CAPITAL COSTS

		Summary
1 x AirSCWO 06	system	\$4,500,000
(Add-on) Pretreatment skid	system	\$19,971
(Add-on) 2 Post-treatment mineral separation containers	system	\$44,000
(Add-on) Heat to electric recovery unit	-	NOT INCLUDED
One-time project fees**	service	\$450,000
Consultancy engineering and design fees	-	NOT INCLUDED
Permits and regulatory compliance costs	-	NOT INCLUDED
TOTAL CAPITAL COSTS		\$5,013,971

Note: One time project fees are estimated for civil engineering, installation, startup, commissioning, and training + associated travel.

Note: Each mineral separation container will add a footprint of 20' x 8' x 3.5' (LxWxH) with a surrounding 10' work perimeter.

ANNUAL OPERATING COSTS

		Summary
AirSCWO System Maintenance*	per 1 year	\$67,304
(Add-on) Pretreatment skid system maintenance	per 1 year	\$499
(Add-on) Post-treatment mineral separation filters	per 1 year	\$5,000
(Add-on) Heat to electric recovery unit system maintenance	-	NOT INCLUDED
Electricity costs for using 2750 kWh/day @ \$0.15/kWh	per 1 year	\$137,363
Fuel for 24 startups/shutdowns per year @ \$5.5 USD/gal	per 1 year	\$1,196
Trim fuel @ \$5.5 USD/gal	per 1 year	\$9,677
Labor costs for 1 FTE	-	NOT INCLUDED
TOTAL OPERATING COSTS		\$221,039

* Estimate for possible replacement/repair of specialized pumps, replacing wear equipment/rotating parts, change out of instrumentation, calibrations of analyzers, allowance for field service tech, contingency for (planned and any unplanned) shutdowns and associated waste disposal costs.

Please note that the above pricing is expressly contingent upon the items in this proposal and are subject to Standard Terms of Sale. Due to current market conditions for fabricated metal items this price is subject to change based on actual fabrication costs at time of order placement. This pricing is FOB (Orlando, FL). This pricing does not include any sales or use taxes. In addition, pricing is valid for ninety (90) days from the date of issue.

CONTACT

[Naomi Senehi](#)
[Sunny Viswanathan](#)

Technical Solutions Lead, Municipal & Global Access | 1 (301) 461-4491
Vice President, Municipal and Industrial | 1 (919) 800-9221

Hazen *Technical Memorandum*

Final: July 11, 2025

To: Metropolitan Sewerage District of Buncombe County (MSD)
From: Sharanya Ananth, Hazen
Aaron Babson, PE, Hazen
Ruth Borgmann, PE, Hazen
Michael Bullard, PE, Hazen
Jacqueline Yeh, PE, Hazen

Technical Memorandum No. 2b – Thickening and Dewatering Technology Assessment

FINAL

31359-001

Table of Contents

1. Introduction	3
2. Thickening Technology Assessment.....	3
2.1 Sludge Blending and Storage	6
2.2 Gravity Thickening	9
2.3 Mechanical Thickening	12
2.3.1 Gravity Belt Thickener	12
2.3.2 Rotary Drum Thickener.....	16
2.4 Comparative Evaluation and Recommendation	20
3. Dewatering Technology Assessment.....	22
3.1 Belt Filter Press.....	23
3.2 Dewatering Centrifuge	27
3.3 Comparative Evaluation and Recommendation	31
4. Site Plan	32
5. Conclusions	36

1. Introduction

The Metropolitan Sewerage District (MSD) of Buncombe County retained Hazen and Sawyer (Hazen) to complete a Solids Handling Preliminary Engineering Report (PER) for the French Broad River Water Reclamation Facility (FBRWRF). The PER includes a condition and capacity assessment on the existing equipment, technology assessments, permitting assistance and development of a new solids handling facility concept to be seamlessly integrated into the forthcoming liquid train project.

The purpose of this technical memorandum (TM) is to evaluate potential thickening and dewatering treatment technologies based on the future solids production rates for each Biological Treatment Alternative. Two different thickening technologies were evaluated: (1) continuing with gravity thickening; or (2) transitioning to a mechanical thickening process, such as a gravity belt thickener (GBT) or rotary drum thickener (RDT). Two dewatering technologies were also evaluated: (1) a belt filter press (BFP); and (2) a dewatering centrifuge (DCEN). Both technology assessments considered the condition and capacity of the existing thickening and dewatering processes on site, as detailed in TM No. 1 – *Solids Projections, Condition and Capacity Assessment* (Submitted - 02/29/2024). Sludge production rates and solids loading rates established in TM No. 1 for the 40-million gallon per day (mgd) maximum month design flow condition for each biological treatment alternative were utilized to assess the process adequacy of proposed thickening and dewatering processes to meet the anticipated design loading.

2. Thickening Technology Assessment

Thickening technologies were evaluated for each of the liquid biological treatment alternatives under consideration:

- Aerobic Granular Sludge (AGS)
- Biological Aerated Filtration (BAF)
- Densified Activated Sludge (DAS)

Solids production rates were developed for each of the secondary process scenarios and are presented in **Table 2-1**. The design flow scenario is the maximum month (MAX30) loading at 40 mgd, with the HRPT process receiving full loading, assumed to be 15 mgd. Additional information on development of primary and secondary solids production rates is provided in TM No. 1.

Table 2-1: Total Solids Production Rates assuming 15 mgd to HRPT

Parameter	Design (MAX30)	MAX14	MAX07	PS:WAS Ratio
Total Sludge Production (AGS Secondary Process), lb/day	59,100	74,200	79,300	38%
Total Sludge Production (BAF Secondary Process), lb/day	72,000	90,100	96,300	31%
Total Sludge Production (DAS Secondary Process), lb/day	66,500	83,200	89,000	33%

The assumed solids concentrations for the waste streams used in the thickening technology assessment are summarized in **Table 2-2**. The AGS and BAF solids concentrations were determined based on manufacturer proposals, while the DAS solids concentration was estimated based on BioWin™ modeling.

- Secondary solids from the AGS process will be processed through a sludge buffer tank before being sent to the solids processing train. Following a period of settling, the contents of the tank are removed from the bottom of the tank by pumping. Once the solids concentration is below 0.8% (8,000 mg-TSS/L), the wasted material is returned to the head of the AGS treatment process.
- For the BAF process, the secondary solids are the backwash from the filters. This is a high volume, thin backwash that is routed to a mudwell to provide equalization and then to thickening.
- For the DAS process, the modeled scenario was the sludge densification process followed by a hydrocyclone, which is a type of gravity separator that separates particles by weight, so the solids received at thickening will be thinner and those that will not settle well.

Table 2-2: Assumed Waste Stream Solids Concentrations

Waste Stream	Solids Concentration
Primary Sludge, %TSS	2.00%
AGS Secondary Sludge, %TSS	0.80%
BAF Secondary Sludge, %TSS	0.12%
DAS Secondary Sludge, %TSS	0.50%

Due to the HRPT flow remaining at 15 mgd as the plant flow increases, the ratio of primary sludge (PS) to waste activated sludge (WAS) will decrease over time. Thus, the blended solids concentration to thickening cannot be assumed to be constant and will decrease with increasing plant flow as increasing secondary sludge mass continues to exert a dilution influence on the blended sludge stream.

The volume of sludge that must be processed at thickening varies greatly with each liquid process alternative, as shown in **Table 2-3**. The design maximum month and maximum week conditions are provided.

Table 2-3: Sludge Volume to Thickening

Parameter	AGS		BAF		DAS	
	Design (MAX30)	MAX07	Design (MAX30)	MAX07	Design (MAX30)	MAX07
Total Primary Sludge Volume, gal/day	133,100	185,300	133,100	185,300	133,100	185,300
Total Secondary Sludge Volume, gal/day	552,800	725,400	4,976,000	6,534,800	1,061,100	1,393,300
Total Sludge Volume to Thickening, gal/day	685,900	910,700	5,109,100	6,720,100	1,194,200	1,578,600

The sludge volume and characteristics are taken into consideration in the thickening technology assessment, which compares gravity thickening and mechanical thickening. Each thickening technology is evaluated based upon the following criteria:

- Solids Feed Rate (lb-dry TSS/hr)
- Thickened Solids Content (% TSS)
- Electrical Consumption (kW-hr)
- Polymer Consumption (lb(active)/dT solids)
- Footprint
- Capital Cost (\$)
- Operation and Maintenance (O&M) Cost (\$)
- Operational Complexity
- Thickened Sludge Storage Requirements
- Impact on Dewatering Operation and FBI (if any)

In the O&M cost evaluation, the following assumptions shown in **Table 2-4** were used for the thickening and dewatering technology assessments.

Table 2-4: O&M Cost Assumptions

Parameter	Assumed Value
Electrical Power Unit Cost, \$/kWh	\$0.058
Emulsion Polymer Unit Cost, \$/lb active	\$2.35
Electrical Utilization Factor	70%
Fully Loaded FTE Labor Cost, \$/year-FTE	\$88,000
Inflation Rate, %/year	3%

Parameter	Assumed Value
Discount Rate, %/year	5%
Real Discount Rate, %/year	1.9%

The electrical power unit cost was updated from \$0.09 to \$0.058 based on recent invoices from MSD's electric utility and upgrade to large general service tier. Additionally, labor assumptions were updated following the development of the incineration O&M for the Executive Summary. The methodology used for the liquid train assessment referencing the Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants was applied to this TM and costs were updated with the number of FTEs supported by this report. A further explanation of the guide is provided in the Executive Summary. **Table 2-5** presents the updated labor assumptions used in this TM.

Table 2-5: Labor Requirement Assumptions

Process	Annual Hours	FTEs Required
Gravity Thickening	365	0.25
Mechanical Thickening and Sludge Storage	1,460	1.00
Belt Filter Press	5,840	4.00
Dewatering Centrifuge	2,920	2.00

These are labor requirements only for the specified process, not any upstream or downstream processes like sludge storage or incineration.

2.1 Sludge Blending and Storage

Blending of PS and WAS upstream of thickening is recommended to maintain a homogenous feedstock and provide a wide spot between primary and secondary solids processes and mechanical thickening.

Figure 2-1 demonstrates the proposed solids process flow with mechanical thickening and sludge blending and storage.

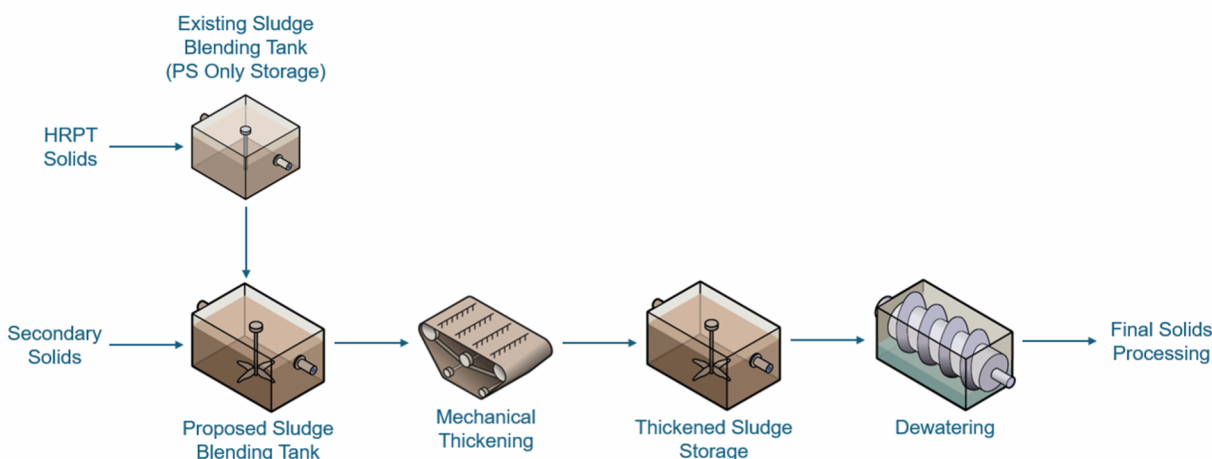


Figure 2-1: Proposed Solids Process Flow Diagram

The existing primary and secondary solids Sludge Blending Tank that was installed as part of the HRPT project has an approximate active volume of 12,000 gallons. Based on the sludge volumetric flow rate to thickening at the 40 mgd maximum month design scenario, this tank will provide the hydraulic retention times (HRTs) shown in **Table 2-6** for each liquid process alternative.

Table 2-6: Existing Sludge Blending Tank Hydraulic Retention Times

Parameter	AGS		BAF		DAS	
	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Blend Tank HRT, minutes	25	19	3.4	2.6	14	11

Due to the range of WAS volumes for the liquid process alternatives, the existing sludge blending tank would not provide adequate blending time to be effective. To achieve a homogenously blended sludge, 1-3 hours of HRT is recommended. Thus, usage of this tank for only PS storage was considered for all mechanical thickening scenarios. At the maximum month design condition, the tank will store PS for approximately 2 hours. Under this operating scenario, an additional tank would be required for PS and WAS blending. Due to secondary treatment improvements, new WAS pumps are proposed for all scenarios, so repurposing the existing blending tank for PS only storage is recommended.

In addition to sludge blending, thickened sludge (TS) storage is recommended. This will allow for a wide spot between thickening and dewatering and decouple the two processes. Based on preliminary site planning, the following configuration of sludge storage tanks is recommended:

- One (1) PS and WAS blend tank
- One (1) TS storage tank
- One (1) swing tank to be used for pre-thickening blending or post-thickening storage

These tanks would be adjacent to a new mechanical thickening building. The swing tank would be located between the blend tank and TS storage tank with piping and valving configuration so that it can be used for blending or TS storage. The standard mode of operation will be for the swing tank to be used for blending, as there will be a larger volume of sludge prior to thickening. All tanks will be mixed with a vertical mixer. The proposed tank geometry for each tank is shown in **Table 2-7**.

Table 2-7: Sludge Storage Tank Geometry, Each Tank

Parameter	Criteria
Number of Tanks	3
Tank Depth, ft	20
Tank Width, ft	20
Tank Length, ft	30
Tank Volume, gallons	89,760

These tanks would provide the HRTs shown in **Table 2-8**, making for a more reliable wide spot prior to thickening than the existing sludge blending tank.

Table 2-8: Recommended Sludge Blending Tank Hydraulic Retention Times

Parameter	AGS		BAF		DAS	
	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Sludge Blend Tank HRT, hours	3.1	2.4	0.4	0.3	1.8	1.4
Sludge Blend Tank and Swing Tank HRT, hours	6.3	4.7	0.8	0.6	3.6	2.7

The TS storage tank will provide the HRTs shown in **Table 2-9**. As detailed in the following thickening assessment, a GBT is expected to produce 5% thickened solids, while an RDT is expected to produce 4% thickened solids. The difference between the concentration of the solids produced for a GBT and an RDT means that the processes will produce a differing volume of thickened sludge. Therefore, the TWAS storage tank will provide different HRTs for each mechanical thickening technology alternative.

Table 2-9: Recommended TS Storage Tank Hydraulic Retention Times

Parameter	AGS		BAF		DAS	
	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Gravity Belt Thickener TS (5%) Tank HRT						
GBT TS Storage Tank HRT, hours	16.0	11.9	13.1	9.8	14.2	10.6
GBT TS Storage Tank and Swing Tank HRT, hours	32.0	23.8	26.3	19.6	28.5	21.2
Rotary Drum Thickener TS (4%) Tank HRT						
RDT TS Storage Tank HRT, hours	12.8	9.5	10.5	7.9	11.4	8.5
RDT TS Storage Tank and Swing Tank HRT, hours	25.6	19.1	21.0	15.7	22.8	17.0

The swing tank will not typically be used for thickened sludge storage. However, in case of dewatering equipment or incinerator/thermal dryer downtime, the extra volume provided by the swing tank will allow around a day of storage at the design condition.

2.2 Gravity Thickening

Gravity Thickeners (GT) No. 1 and No. 2 were installed in 1983. Under typical conditions at current flows and loads, only one GT is in service. The capacity of the existing GTs is provided in TM No. 1. For the AGS and DAS scenarios, only one GT is required to be in service and it will operate in solids limited loading rate mode. For the BAF scenario, the GT will operate on the breakpoint of the solids loading and hydraulic loading rates.

Based on Hazen's experience and knowledge with AGS, gravity thickening is not recommended as a reliable thickening method for AGS solids. AGS secondary solids are settled via gravity in a sludge buffer tank to 0.8-1.0% TSS (8,000 to 10,000 mg-TSS/L). Further usage of a settling technology, such as gravity thickening, is not expected to be as effective as mechanical thickening. Similar concerns are expected for the DAS scenario due to the proposed hydrocyclone upstream of thickening.

The recommended BAF process configuration according to Veolia is backwash return to primary treatment followed by mechanical thickening. Veolia does not recommend gravity thickening for BAF solids and does not operate the process in that configuration at any of their current installations.

While gravity thickening is not recommended for any of the proposed liquid treatment processes, the evaluation below was included for comparative purposes to the mechanical thickening alternative.

Additional facilities are not required for operation of the GTs for AGS, BAF or DAS, so the gravity thickening option does not require any additional footprint on the site. The plant staff is very familiar with operation of the GT, but process optimization due to the HRPT is ongoing. When the HRPT process is online and higher flows are pumped to the GTs, the center well is very turbulent. The feed flow hits the top of the mechanism seal causing concern for the bearing. If the GTs are to be maintained in the new solids handling concept, a new feed point from the new WAS pumps will be required. The proposed modification of the existing sludge blending tank to a PS only storage tank will allow the existing pumps from the HRPT blending well to be maintained and should reduce the turbulence in the center well since those pumps will operate at the reduced PS only flow. Blending PS and WAS upstream of the GTs is not required.

Gravity thickening is a technology with minimal labor, operation, and maintenance costs. Thickened sludge storage is not required prior to dewatering, as the GT can operate as a wide spot for storage. It is noted that there is a limit to the blanket level that plant staff feels comfortable maintaining in the GT before seeing downstream dewatering performance impacts. The electrical consumption is low, as the primary power requirement is the GT mechanism, which runs at a low speed. Currently, polymer is added to the WAS feed pumps during the summer to aid thickening. This seasonal polymer addition was estimated to be 4 active lbs per dry ton of sludge over the course of a year, per WEF Solids Process Design and Management, Section 4.2.7.

Per the condition assessment presented in TM No. 1, the GT mechanism is in good condition and well maintained. However, for the 40 mgd design scenario, mechanism replacement is recommended and included in capital costs. In the future, replacement of the thickened solids pumps will present capital costs, but this was not included due to the recent replacement of these pumps. Estimated capital costs for a thickening facility with GBTs are provided in **Table 2-10**. For all capital cost summaries, the engineering contingency is added to the subtotal cost of the facility. Then, contractor overhead, profit, and mobilization and the owner's allowance are applied for the total project cost.

Table 2-10: Gravity Thickener Capital Costs

Parameter	Cost
Mechanical and Equipment Cost, \$	\$4,800,000
Subtotal 1: Total Capital Cost, \$	\$4,800,000
Engineering Contingency (30%), \$	\$1,440,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$6,240,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$1,872,000
Owner's Allowance (5%)	\$312,000
Total Project Cost, \$	\$8,424,000

Generally, annual equipment maintenance costs are assumed to be 3% of capital costs. For the GT option, an annual maintenance cost of \$100,000 was assumed, representing a sizeable annual cost that is still less than that of mechanical thickening options. O&M costs were evaluated for the annual average DAS solids production scenario for comparative purposes only as gravity thickening is not considered optimal for AGS, BAF or DAS. A summary of the O&M costs associated with gravity thickening is shown in **Table 2-11**.

Table 2-11: Gravity Thickener O&M Costs

Parameter	Cost
Installed Horsepower, HP	72
Power Cost, \$/dT	\$0.65
Polymer Dose ¹ , lb(active)/dT	4
Polymer Cost, \$/dT	\$9.40
Operating Cost, \$/dT (2024)	\$10.05
Annual Operation Cost, \$/year (2024)	\$66,000
Full-Time Employees	0.25
Annual Labor Cost, \$/year (2024)	\$22,000
Annual Maintenance Cost, \$/year (2024)	\$100,000
GT Annual OPEX Cost (2024)	\$188,000
¹ This polymer dosage is only applied in the summer to aid thickening. Six months of polymer dosage was assumed.	

The operation, labor, and maintenance costs considered for the 20-year lifecycle of 2024-2043 are shown in **Table 2-12** in present value 2024 dollars.

Table 2-12: Gravity Thickening Lifecycle Cost

Parameter	Cost
GT CAPEX Cost (2024)	\$8,424,000
20-year Labor Cost	\$369,000
20-year Operation Cost	\$1,217,000

Parameter	Cost
20-year Maintenance Cost	\$1,676,000
20-year Total OPEX Cost	\$3,262,000

If the HRPT process is online, thickened solids concentrations can reach 5% TSS. If the HRPT is offline, solids typically are in the 3% TSS range during the summer and 4% TSS range in the winter. To maintain conservatism of design, a thickened solids concentration of 3% TSS was assumed from the GTs. Even at 3% TSS, the evaluated dewatering equipment would operate in solids limited mode and does not impact the number of pieces of equipment required for the dewatering process. It is likely that dewatering a gravity thickened sludge will produce wetter cake than mechanically thickened sludge, impacting the operation of the incinerator and the potential for autogenous operation (or throughput capacity of a thermal dryer).

2.3 Mechanical Thickening

Two technologies were considered for the mechanical thickening evaluation – a GBT and RDT. While gravity thickening relies on settling of solids, mechanical thickening separates sludge from water, generally achieving higher solids concentrations. Both processes will produce a filtrate that will be routed to the head of the plant, similar to gravity thickener overflow in the existing scenario.

For the BAF process, the backwash flow removes stored solids from the process using a large volume of effluent so the solids concentration in the backwash process is very thin. Due to the large volume of dilute backwash waste, mechanical thickening directly downstream of BAF wasting is not a reasonable solution due to the significant amount of equipment required. Veolia recommends returning BAF wasting to primary treatment to concentrate the solids with primary sludge, followed by a mechanical thickening process.

2.3.1 Gravity Belt Thickener

GBTs use a moving belt through which solids are filtered by gravity. Solids are conditioned with polymer prior to distribution on the belt, as flocculation of sludge is critical to gravity separation of liquids and solids. The belt can be driven by a variable speed or constant speed drive, which is configured like a roller and imparts torque on the belt through friction. Some advantages to GBTs include the high solids capture rate, low speed and low energy demand, and relatively low maintenance costs. GBTs also have a significantly smaller footprint than gravity thickeners. Disadvantages include high odor potential due to open nature of the equipment, high washwater usage, and larger footprint requirements.

GBTs were installed in the original 1988 construction of the Solids Handling Building. MSD requested an investigation into why these were eventually abandoned in the 2004 Sludge Handling Improvements project. Documentation of this decision was not found, but the reason was likely the cost efficiency of combining both mechanical thickening and dewatering processes with a three-belt BFP, which has a gravity (GBT) section and a press (BFP) section.

Based on the solids production rates at 40 mgd, a GBT with the design criteria shown in **Table 2-13** was considered.

Table 2-13: Gravity Belt Thickener Design Criteria

Parameter	Value
GBT Operating Width, meters	2.0
Solids Loading Rate, lb(dry)/hr	1,800
Hydraulic Loading Rate, gpm	600
Breakpoint Solids Concentration, % TS	0.6%

Based on the feed solids concentration for each of the liquid process alternatives, GBTs would operate in solids limited mode for the AGS and DAS scenarios and in hydraulic limited mode for the BAF scenario. Considering the limiting loading rates, the number of duty GBTs required for each liquid process alternative was estimated. The number of recommended GBTs shown in **Table 2-14** is based on the maximum of the following:

- Number of GBTs required with one unit out of service at the design maximum month (MAX30) loading condition; or
- Number of GBTs required with all units in service at the maximum week (MAX07) loading condition

A 24/7 operational schedule with 85% equipment up time was assumed to match the existing incinerator operation.

Table 2-14: Gravity Belt Thickener Operational Units

Parameter	AGS		BAF		DAS	
	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Required Solids Processing Rate, lb(dry)/hr	2,460	3,300	3,000	4,010	2,770	3,710
Required Hydraulic Processing Rate, gpm	480	630	3,550	4,670	830	1,100
Operating Mode	Solids Limited		Hydraulic Limited		Solids Limited	
Number of duty GBTs required	1.6	2.2	7.0	9.2	1.8	2.4
Number of GBTs, all units in service	2	3	7	10	2	3
Number of GBTs, one unit out of service	3	4	8	11	3	4

Parameter	AGS		BAF		DAS	
	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Recommended number of GBTs	3		10		3	

For the purposes of cost estimation, the AGS and DAS recommended mechanical thickening scenarios were considered as the same, as both require three (3) GBTs. The number of recommended GBTs for the BAF scenario demonstrates the unsuitability of mechanical thickening without any upstream form of solids concentration, such as primary treatment, also as recommended by Veolia. Since GBTs are not recommended for BAF, other mechanical thickening options, such as a dissolved air flotation thickener (DAFT) should be considered.

Based on Hazen experience with GBTs, a capture efficiency of 95% and thickened sludge concentration of 5% TSS were assumed. This results in a slightly higher mass of sludge passed to dewatering (90% capture for GT), but significantly less volume (3% TSS) compared to gravity thickening. Thickened sludge storage is recommended to decouple thickening from dewatering, as discussed in Section 2.1. The cost of the blend tank and thickened sludge storage tank and electrical consumption was included in the GBT cost estimate.

The AGS and DAS mechanical thickening scenario with three (3) GBTs was considered for the GBT cost estimate. Per recent equipment quotes and cost estimates, one 2.0m GBT was estimated to be \$851,400, including labor and materials. The following ancillary equipment was included in the capital cost estimate:

- Thickening Feed Pump, one (1) per GBT
- Washwater Booster Pump, one (1) per GBT
- Thickened Solids Pump, one (1) per GBT
- Polymer Makeup Unit, one (1) per GBT
- Sludge Storage Tank Mixers, one (1) per tank
- Bulk Polymer Storage

Due to the larger footprint of a GBT, a two-story building of approximately 8,500 square feet was estimated based on previous Hazen thickening facility designs. Estimated capital costs for a thickening facility with GBTs are provided in **Table 2-15**.

Table 2-15: Gravity Belt Thickener Capital Costs

Parameter	Cost
Civil Cost, \$	\$1,600,000
Mechanical and Equipment Cost, \$	\$4,512,000
Structural and Architectural Cost, \$	\$6,158,000

Parameter	Cost
Electrical and I&C Cost, \$	\$2,667,000
Subtotal 1: Total Capital Cost, \$	\$15,000,000
Engineering Contingency (30%), \$	\$4,500,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$19,500,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$5,850,000
Owner's Allowance (5%)	\$975,000
Total Project Cost, \$	\$26,325,000

O&M costs were evaluated for the annual average AGS and DAS solids production scenario. The DAS scenario, which has a slightly higher cost due to increased solids processing requirements, is presented in **Table 2-16**. Annual maintenance costs were estimated as 3% of mechanical costs and 1% of building costs. The polymer dose was estimated based on values from WEF MOP 8 for the range of PS:WAS blend.

Table 2-16: Gravity Belt Thickener O&M Costs

Parameter	Cost
Installed Horsepower, HP	305
Power Cost, \$/dT	\$3.90
Polymer Dose, lb(active)/dT	10
Polymer Cost, \$/dT	\$23.50
Operating Cost, \$/dT (2024)	\$27.40
Annual Operation Cost, \$/year (2024)	\$189,000
Full-Time Employees	1.0
Annual Labor Cost, \$/year (2024)	\$88,000
Annual Maintenance Cost, \$/year (2024)	\$240,000
GBT Annual OPEX Cost (2024)	\$517,000

The operation, labor, and maintenance costs considered for the overall 20-year lifecycle costs of mechanical thickening with a GBT from 2024-2043 are shown in **Table 2-17** in present value 2024 dollars.

Table 2-17: Gravity Belt Thickener Lifecycle Cost

Parameter	Cost
GBT CAPEX Cost (2024)	\$26,325,000
20-year Labor Cost	\$1,475,000
20-year Operation Cost	\$3,504,,000
20-year Maintenance Cost	\$4,017,000
20-year Total OPEX Cost	\$8,996,000

Operation of a GBT is more complex than operation of a GT, which is reflected in the increased labor, operation, and maintenance costs of the mechanical thickening option. Mechanical thickening will produce a thicker sludge than gravity thickening, which will ensure SLR limited operation and allow for maximizing capacity in dewatering.

2.3.2 Rotary Drum Thickener

RDTs use a flocculation tank and internally fed rotary drum screen. Solids are conditioned with polymer and coagulated before they enter the process drum, where free water is released through a rotating screen drum. The solids are flocculated in the low-shear floc tank through a small mixer and the drum is typically rotated by a variable speed motor. **Figure 2-2** provides an example of how a rotary drum thickener operates.

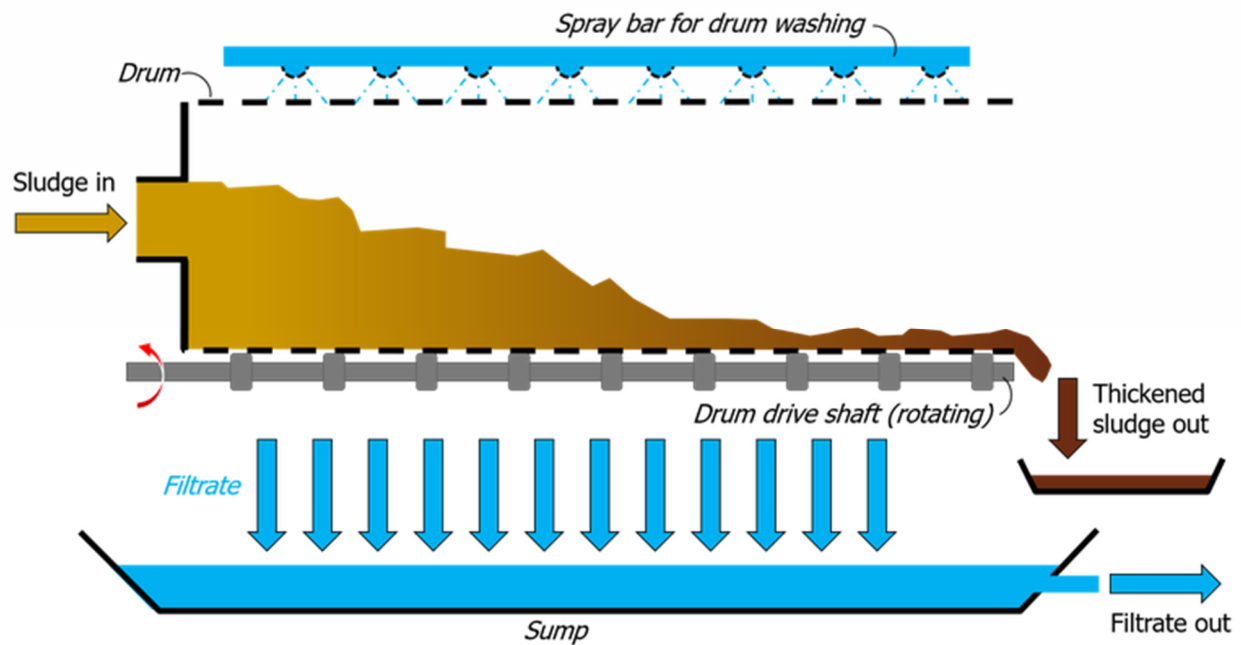


Figure 2-2: Rotary Drum Thickener Equipment

Since RDTs are fully enclosed, they have a smaller footprint and present less of an odor concern than GBTs. RDTs also have a high solids capture rate, low speed and low energy demand, and relatively low maintenance costs. RDTs also have a significantly smaller footprint than gravity thickeners. Disadvantages include a higher polymer dosage and power rate than required for GBTs, as well as a lower throughput, resulting in more required units and associated ancillary equipment. Based on the solids production rates at 40 mgd, the RDT design criteria shown in **Table 2-18** was considered.

Table 2-18: Rotary Drum Thickener Design Criteria

Parameter	Value
Solids Loading Rate, lb(dry)/hr	1,500
Hydraulic Loading Rate Capacity, gpm	400
Breakpoint Solids Concentration, % TS	0.75%

RDTs would operate in solids limited mode for the AGS and DAS scenarios and in hydraulic limited mode for the BAF scenario. Considering this loading rate, the number of duty RDTs required was estimated. The number of recommended RDTs shown in **Table 2-19** is based on the maximum of the number of RDTs required with one unit out of service at the maximum month loading condition or the number of RDTs required with all units in service at the maximum week loading condition. A 24/7 operational schedule with 85% equipment up time was assumed to match the incinerator operation.

Table 2-19: Rotary Drum Thickener Operational Units

Parameter	AGS		BAF		DAS	
	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Required Solids Processing Rate, lb(dry)/hr	2,460	3,300	3,000	4,010	2,770	3,710
Required Hydraulic Processing Rate, gpm	480	630	3,550	4,670	830	1,100
Operating Mode	Solids Limited		Hydraulic Limited		Solids Limited	
Number of duty RDTs required	1.9	2.6	10.4	13.7	2.4	3.2
Number of RDTs, all units in service	2	3	11	14	3	4
Number of RDTs, one unit out of service	3	4	12	15	4	5
Recommended number of RDTs	3		14		4	

Similar to the analysis conducted for GBTs, RDTs are not a viable option for BAF due to the large number of units required. The footprint and operational demand of such a thickening facility is not reasonable. As mentioned previously, other thickening technologies, such as DAFT, must be considered to manage the large backwash volume from the BAF process.

Based on Hazen experience with RDTs, a capture efficiency of 95% and thickened sludge concentration of 4% TSS were assumed. As with GBTs, this results in a higher mass of sludge passed to dewatering, but less volume compared to gravity thickening. Thickened sludge storage is recommended to decouple thickening from dewatering, as discussed in Section 2.1 The cost of both the blend tank and thickened sludge storage tank and associated electrical consumption was included in the RDT cost estimate.

For the purposes of cost estimation, the AGS scenario of three (3) RDTs and the DAS scenario of four (4) RDTs were considered. Per recent quotes and cost estimates, one RDT was estimated to be \$985,400, including labor and materials. The following ancillary equipment is required for each of the RDTs:

- Thickening Feed Pump, one (1) per RDT
- Washwater Booster Pump, one (1) per RDT
- Thickened Solids Pump, one (1) per RDT
- Polymer Makeup Unit, one (1) per RDT
- Sludge Storage Tank Mixers, one (1) per tank
- Bulk Polymer Storage

A two-story building was estimated based on previous Hazen thickening facility designs, which was smaller than that for the GBTs due to the smaller footprint of the RDTs. Estimated capital costs for a

thickening facility with RDTs are provided in **Table 2-20**. The capital costs for RDT equipment were adjusted based on an updated quote from a manufacturer after the submittal of the draft TM in 2024.

Table 2-20: Rotary Drum Thickener Capital Costs

Parameter	Alt 1 (AGS): 3 RDTs	Alt 2 (DAS): 4 RDTs
Thickening Facility Area, sq ft	5,600	7,000
Civil Cost, \$	\$1,205,000	\$1,617,000
Mechanical and Equipment Cost, \$	\$3,158,000	\$4,973,000
Structural and Architectural Cost, \$	\$4,878,000	\$5,810,000
Electrical and I&C Cost, \$	\$2,009,000	\$2,696,000
Subtotal 1: Total Capital Cost, \$	\$9,900,000	\$13,000,000
Engineering Contingency (30%), \$	\$2,970,000	\$3,900,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$12,870,000	\$16,900,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$3,861,000	\$5,070,000
Owner's Allowance (5%)	\$644,000	\$845,000
Total Project Cost, \$	\$17,375,000	\$22,815,000

O&M costs were evaluated for the annual average AGS and DAS solids production scenarios. Annual maintenance costs were estimated as 3% of capital costs. The polymer dose was estimated based on values from WEF MOP 8 for the range of PS:WAS blends. Estimated RDT O&M costs are summarized in **Table 2-21**.

Table 2-21: Rotary Drum Thickener O&M Costs

Parameter	Alt 1 (AGS): 3 RDTs	Alt 2 (DAS): 4 RDTs
Installed Horsepower, HP	300	380
Power Cost, \$/dT	\$5.70	\$5.50
Polymer Dose, lb(active)/dT	14	
Polymer Cost, \$/dT	\$32.90	

Parameter	Alt 1 (AGS): 3 RDTs	Alt 2 (DAS): 4 RDTs
Operating Cost, \$/dT (2024)	\$38.60	\$38.40
Annual Operation Cost, \$/year (2024)	\$248,000	\$265,000
Full-Time Employees	1.0	
Annual Labor Cost, \$/year (2024)	\$88,000	
Annual Maintenance Cost, \$/year (2024)	\$176,000	\$250,000
RDT Annual OPEX Cost (2024)	\$512,000	\$603,000

The operation, labor, and maintenance costs considered for the overall RDT 20-year lifecycle from 2024-2043 are shown in **Table 2-22** in present value 2024 dollars.

Table 2-22: Rotary Drum Thickener Lifecycle Cost

Parameter	Alt 1 (AGS): 3 RDTs	Alt 2 (DAS): 4 RDTs
RDT CAPEX Cost (2024)	\$17,375,000	\$22,815,000
20-year Labor Cost	\$1,475,000	
20-year Operation Cost	\$4,558,000	\$4,907,000
20-year Maintenance Cost	\$2,944,000	\$4,198,000
20-year Total OPEX Cost	\$8,977,000	\$10,580,000

Operation of an RDT is more complex than operation of a GT, which is reflected in the increased operation and maintenance costs of the RDT option. Mechanical thickening will produce a thicker sludge than gravity thickening, which will ensure SLR limited operation and allow for maximizing capacity in dewatering.

2.4 Comparative Evaluation and Recommendation

Gravity thickening and mechanical thickening each have their own advantages. Gravity thickening has an existing footprint onsite and the operators are familiar with the process. It also does not require as much polymer conditioning as mechanical thickening and does not have washwater requirements. Mechanical thickening produces thicker solids and has a higher capture rate, across GBTs and RDTs. However, for each of the liquid process alternatives under consideration, only certain thickening technologies are

viable, as summarized in **Table 2-23**. While GT is viable for DAS, it is not recommended or preferable, which must be considered when viewing the cost comparison.

Table 2-23: Thickening Technology Viability Summary

Thickening Technology	AGS	BAF	DAS
Gravity Thickening	No	No	Yes ¹
Mechanical Thickening	Yes	No ²	Yes

¹Not recommended with the use of hydrocyclones.
²While traditional mechanical thickening technologies such as GBT and RDT are not recommended, a DAFT may be viable.

The selected thickening technology is dependent on the selected liquid process alternative. Considering site layout, the existing gravity thickeners represent a space on the site that can be utilized for solids handling or liquid processes. If mechanical thickening is preferred, further evaluation in the design process can determine if a combined solids thickening and dewatering facility is viable, which will require a smaller footprint than two separate facilities.

Based on this evaluation, BAF is not recommended without further evaluation of alternate thickening technologies, such as DAFT. With no primary treatment for the backwash solids, DAFT is a possible thickening technology that can be applied, as it can handle a large volume of thin feed. Sludge is conditioned with polymer and fed to a dissolved air tank. The sludge will flocculate and float at the top of the tank by attaching to the air bubbles. DAFT works by utilizing buoyant force rather than gravity settling, and can thus process a higher SLR/HLR compared to a GT.

An option for accommodating DAFT at the FBRWRF is to convert the existing GTs to DAFTs. The existing surface area can process at the recommended design solids loading rate for DAFTs with one unit out of service. However, operation of DAFTs will require more ancillary equipment than is currently used for the GT process. The DAFT process requires an air tank, air compressor, recirculation pump, and additional ancillary equipment that will not fit in the footprint of the existing GT pump room, presenting a site planning concern.

For the AGS and DAS scenarios, the capital and operational costs of the viable thickening options are compared below in **Table 2-24**.

Table 2-24: Thickening Lifecycle Cost Comparison

Liquid Process Alternative	AGS		DAS		
	GBT	RDT	GT	GBT	RDT
Units Required	3	3	2	3	4

Liquid Process Alternative	AGS		DAS		
Parameter	GBT	RDT	GT	GBT	RDT
Footprint	8,500	5,600	8,000	8,500	7,000
CAPEX Cost (2024 \$)	\$26,325,000	\$17,375,000	\$8,424,000	\$26,325,000	\$22,815,000
20-year Total OPEX Cost (2024 \$)	\$8,746,000	\$8,977,000	\$3,262,000	\$8,996,000	\$10,580,000
20-year Lifecycle Cost, CAPEX + OPEX (2024 \$)	\$35,071,000	\$26,352,000	\$11,686,000	\$35,321,000	\$33,395,000

While gravity thickening presents clear cost savings in the short and long term, mechanical thickening can optimize the solids handling process through a higher rate of solids capture and may be necessary depending on the liquid process alternative that is ultimately selected. Transition to mechanical thickening is recommended due to viability for multiple liquid process alternatives, increased process efficiency through higher solids capture and higher thickened solids content to dewatering, and smaller solids processing footprint compared to gravity thickening.

During the workshop reviewing this TM, MSD inquired if the filter backwash flow at the design condition of 40 mgd will have any impact on GT operation. At this flow, approximately 0.8-1.6 mgd of filter backwash flow is anticipated to be routed to the GTs. This additional flow will not have a major impact on the GTs as they can still be operated in solids limited mode with one GT in service. However, this flow will dilute the load to mechanical thickening and require additional units to accommodate. If mechanical thickening is selected, filter backwash flow is recommended to be sent to the secondary treatment process, which can be coordinated with the liquid train design. The increased solids load to thickening following secondary treatment will not require additional equipment once the volume is processed in the secondary process.

3. Dewatering Technology Assessment

Two dewatering technologies, BFPs and DCENs, were evaluated for each of the three liquid biological treatment alternatives. For each liquid process alternative, the viable thickening technologies prior to dewatering were also considered in development of dewatering sludge loading rates. Since the same capture rate was assumed for mechanical thickening (MT) with GBT and RDT technologies, both processes have the same solids loading to dewatering, shown in **Table 3-1**. As discussed in the thickening assessment, the GBT is expected to produce 5% TSS and the RDT is expected to produce 4% TSS. Due to the uncertainty with thickening for the BAF scenario, a conservative assumption of 2.5% TSS thickened solids and 90% capture efficiency was applied.

Table 3-1: Solids Loading to Dewatering

Liquid Process Alternative	AGS		BAF		DAS	
Parameter	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
GT Sludge Mass to Dewatering, lb(dry)/day	N/A	N/A	N/A	N/A	59,800	80,100
MT Sludge Mass to Dewatering, lb(dry)/day	56,100	75,300	64,800 ¹	86,700 ¹	63,100	84,600

¹As previously discussed, the only mechanical thickening option that is viable for the BAF alternative is DAFT.

The above daily solids loading rates were used to determine the size and number of units of dewatering equipment required for each scenario. Each dewatering technology is evaluated based upon the following criteria:

- Solids Feed Rate (lb-dry/hr)
- Cake Dryness (% total solids)
- Electrical Consumption (kW-hr)
- Polymer Consumption (lb(active)/dT solids)
- Footprint
- Capital Cost (\$) (including structural implications of centrifuges)
- Operation and Maintenance Cost (\$)
- Historical Operating Performance (Owner References)
- Impact on Cake Pumps and FBI Operation (and energy expended at FBI)

3.1 Belt Filter Press

The existing BFPs No. 1 and No. 2 were installed in 2004. Typically, one press is operated to feed the incinerator. **Table 3-2** provides the design criteria considered for the BFPs, which matches that of the existing BFPs.

Table 3-2: Belt Filter Press Design Criteria

Parameter	Value
Solids Loading Rate, lb(dry)/hr	2,000
BFP Operating Width, meters	2.5
Hydraulic Loading Rate Capacity, gpm	400
Breakpoint Solids Concentration, % TS	1.0%

For all AGS, BAF and DAS scenarios, the BFPs will operate in solids limited mode. **Table 3-3** shows the number of BFP units for each liquid process alternative and the recommended thickening equipment. Similar to thickening equipment, a recommendation for the number of BFPs is based on the maximum of:

- Number of BFPs required with one unit out of service at the maximum month (MAX30) condition; or
- Number of BFPs required with all units in service at the maximum week (MAX07) condition.

A 24/7 operational schedule with 85% equipment up time was assumed to match the existing incinerator operation.

Table 3-3: Belt Filter Press Operational Units

Liquid Process Alternative	AGS - MT		BAF - DAFT		DAS - GT		DAS - MT	
Parameter	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Required Solids Processing Rate, lb(dry)/hr	2,340	3,140	2,700	3,610	2,500	3,340	2,630	3,530
Required Hydraulic Processing Rate, gpm	100	130	220	290	170	220	110	140
Operating Mode	Solids Limited		Solids Limited		Solids Limited		Solids Limited	
Number of duty BFPs required	1.4	1.8	1.6	2.1	1.5	2.0	1.5	2.1
Number of BFPs, all units in service	2	2	2	3	2	2	2	3
Number of BFPs, one unit out of service	3	3	3	4	3	3	3	4
Recommended number of BFPs	3		3		3		3	

For all scenarios, the installation of one additional BFP is recommended for redundancy.

If a new incinerator is selected as the final solids management process, the BFPs must operate at a schedule that can meet the rated capacity of the incinerator. Based on Hazen's experience and current

plant operations, the BFPs produce a dewatered cake at 18-20% TSS. The incinerator will be sized based on the range of dewatered cake mass for the liquid process alternatives and solids concentrations.

For all liquid process scenarios, 3 BFPs were considered for the BFP cost estimate. Per recent quotes and cost estimates, one BFP was estimated to be \$760,000, including labor and materials. While the existing BFPs are in good condition, due to the time since their installation, replacement of the BFPs for 40 mgd is recommended. Replacement of ancillary equipment is also recommended. The following ancillary equipment was included in the capital cost estimate:

- Dewatering Feed Pump, one (1) per BFP
- Washwater Booster Pump, one (1) per BFP
- Dewatered Cake Conveyor, one (1) for third BFP
- Polymer Makeup Unit, one (1) for third BFP

The existing dewatering building contains space for a third BFP on the third floor as shown in **Figure 3-1**, so there are no footprint considerations associated with the BFP option.

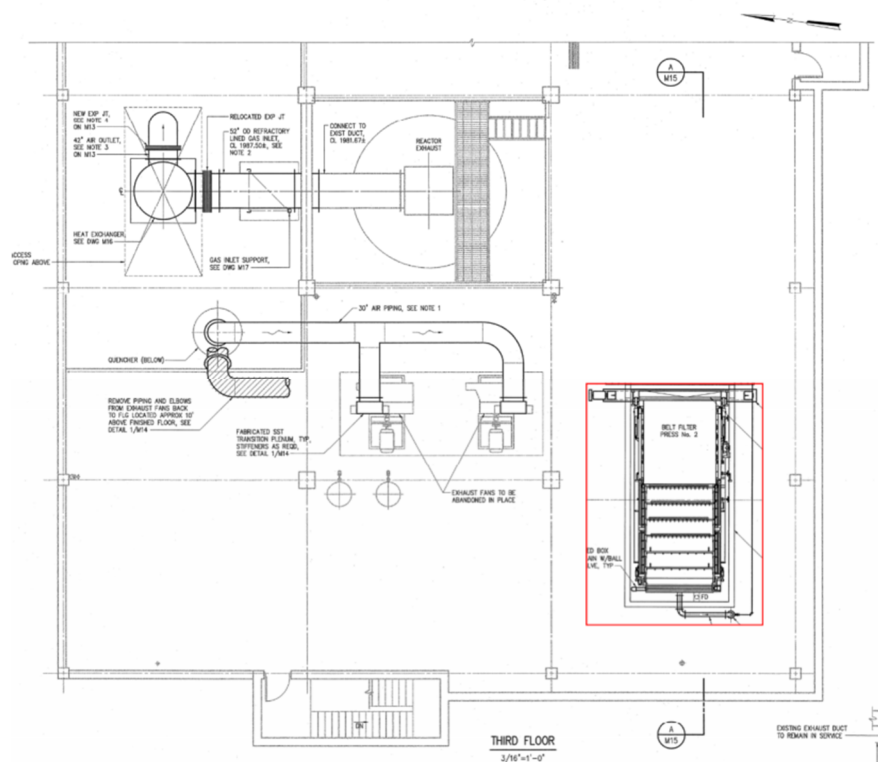


Figure 3-1: Proposed Additional BFP Location

However, continued usage of this building will require HVAC improvements to meet NFPA 820 and structural and architectural improvements to reinforce the building for a third BFP and meet IBC. Estimated capital costs for an upgraded facility with BFPs are provided in **Table 3-4**.

Table 3-4: Belt Filter Press Capital Costs

Parameter	Cost
Civil Cost, \$	\$0
Mechanical and Equipment Cost, \$	\$6,041,000
Structural and Architectural Cost, \$	\$1,088,000
Electrical and I&C Cost, \$	\$1,646,000
Subtotal 1: Total Capital Cost, \$	\$8,800,000
Engineering Contingency (30%), \$	\$2,640,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$11,440,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$3,432,000
Owner's Allowance (5%)	\$572,000
Total Project Cost, \$	\$15,444,000

O&M costs were evaluated for the annual average AGS, BAF and DAS solids production scenario. The DAS mechanical thickening scenario, which has a slightly higher cost due to increased solids processing requirements, is presented below in **Table 3-5**. Maintenance costs were estimated as 3% of mechanical equipment costs and 1% of building costs. The polymer dose was estimated based on values from WEF MOP 8 for the range of PS:WAS blends.

Table 3-5: Belt Filter Press O&M Costs

Parameter	Cost
Installed Horsepower, HP	200
Power Cost, \$/dT	\$2.90
Polymer Dose, lb(active)/dT	25
Polymer Cost, \$/dT	\$58.75
Operating Cost, \$/dT (2024)	\$61.65
Annual Operation Cost, \$/year (2024)	\$378,000

Parameter	Cost
Full-Time Employees	4.0
Annual Labor Cost, \$/year (2024)	\$352,000
Annual Maintenance Cost, \$/year (2024)	\$209,000
BFP Annual OPEX Cost (2024)	\$939,000

The total operation, labor, and maintenance costs considered for the BFP 20-year lifecycle of 2024-2043 are summarized in **Table 3-6** in present value 2024 dollars.

Table 3-6: Belt Filter Press Lifecycle Cost

Parameter	Cost
BFP CAPEX Cost (2024)	\$15,444,000
20-year Labor Cost	\$5,901,000
20-year Operation Cost	\$6,957,000
20-year Maintenance Cost	\$3,496,000
20-year Total OPEX Cost	\$16,354,000

Since BFPs generally produce a wetter cake than DCENs, selection of a BFP as the dewatering technology will require evaluation of impacts on the incinerator and its autogenous operation. Additional energy must be expended at the existing cake pumps and incinerator to manage this wetter cake.

3.2 Dewatering Centrifuge

DCENs spin at a high speed to separate solids from water in liquid sludge. The feed tube introduces polymer conditioned sludge to the center of the rotating bowl. The scroll spins inside the bowl at a slight differential speed and moves the dewatered sludge to the solids discharge. The centrate is discharged at the opposite end of the machine over an adjustable weir plate. **Figure 3-2** provides an example of how a dewatering centrifuge operates.

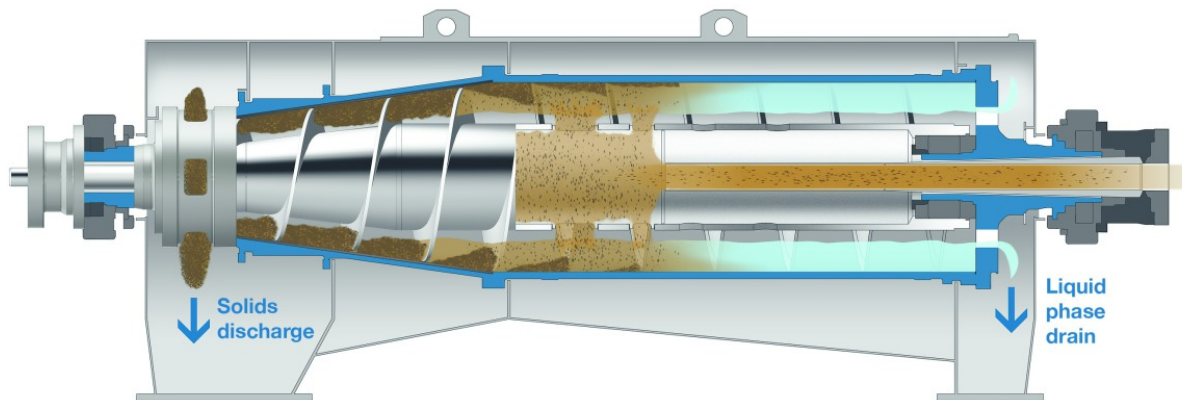


Figure 3-2: Dewatering Centrifuge Equipment

DCEN centrate would be routed to the head of the plant, similar to existing BFP filtrate management. Advantages of a DCEN include generally higher cake solids content, a compact equipment footprint, high solids capture rate, and fully enclosed operation, limiting the odor potential. Some disadvantages include the need for specialized maintenance and operation, higher power consumption, higher noise, and the high rotational speeds, which present a structural design consideration. **Table 3-7** provides the design criteria considered for the DCENs.

Table 3-7: Centrifuge Design Criteria

Parameter	Value
Solids Loading Rate, lb(dry)/hr	2,400
Hydraulic Loading Rate Capacity, gpm	240
Breakpoint Solids Concentration, % TS	2.0%

During the redundancy assessment workshop, MSD noted that a fraction of sand and gritty material from the HRPT process is currently conveyed to the thickening and dewatering processes. For high-speed processes, such as centrifuges, increased grit is expected to result in increased wear on the equipment. Increased wear may not be expected on low speed thickening technologies discussed in this report or BFPs, but any pumps associated with these processes can anticipate impacts from sand and grit.

For all liquid process scenarios, the DCENs will operate in solids limited mode. **Table 3-8** shows the number of DCEN units for each scenario and the recommended equipment. A recommendation for the number of DCENs is based on the maximum of the number of DCENs required with one unit out of service at the maximum month loading condition or the number of DCENs required with all units in service at the maximum week loading condition. A 24/7 operational schedule with 85% equipment up time was assumed to match the existing incinerator operation.

Table 3-8: Centrifuge Operational Units

Liquid Process Alternative	AGS - MT		BAF - DAFT		DAS - GT		DAS - MT	
Parameter	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07	MAX30	MAX07
Required Solids Processing Rate, lb(dry)/hr	2,340	3,140	2,700	3,610	2,500	3,340	2,630	3,530
Required Hydraulic Processing Rate, gpm	100	130	220	290	170	220	110	140
Operating Mode	Solids Limited		Solids Limited		Solids Limited		Solids Limited	
Number of duty DCENs required	1.1	1.5	1.3	1.8	1.5	2.0	1.3	1.7
Number of DCENs, all units in service	2	2	2	2	2	2	2	2
Number of DCENs, one unit out of service	3	3	3	3	3	3	3	3
Recommended number of DCENs	3		3		3		3	

Similar to the BFPs, if a new incinerator is selected as the final solids management process, the DCENs must operate at a schedule that can meet the rated capacity of the incinerator. Based on Hazen's experience, DCENs will produce a dewatered cake greater than 20% TS. For the same feedstock, DCENs typically produce a cake that is 10% higher in cake solids than that of a BFP (i.e. from 20% to 22%).

The AGS and DAS scenario of 3 DCENs was considered for the DCEN cost estimate. Per recent quotes and cost estimates, one DCEN was estimated to be \$750,000, including labor and materials. The following ancillary equipment was included in the capital cost estimate:

- Dewatering Feed Pump, one (1) per DCEN
- Dewatered Cake Conveyors, one (1) per DCEN
- Polymer Makeup Units, one (1) per DCEN
- Bulk Polymer Storage

The existing building contains adequate space for three DCENs on the second and third floors. However, DCENs present a structural concern due to the level of vibration generated. In order for a retrofit of this building to accommodate DCENs, a thorough structural evaluation of this building is required. More structural improvements may be required to use this building for DCENs rather than BFPs. The same HVAC improvements to meet NFPA 820 requirements discussed in the BFP section would also be required.

During the workshop reviewing this TM, MSD noted that the BFP replacement project may have included a comparative evaluation of BFPs and DCENs. If there was such an evaluation, it would have included a structural assessment of the building. This evaluation was not found in the record documents.

If MSD wishes to use the existing solids handling building, a structural assessment is still recommended due to any potential wear and changes in the building in the last 20 years.

The structural evaluation must be undertaken to determine if a new building is required. However, costs for a new dewatering building with DCENs were estimated. The size of the existing dewatering building was matched in order to have space for a new incinerator. Estimated capital costs for a dewatering facility with DCENs are provided in **Table 3-9**.

Table 3-9: Centrifuge Capital Costs

Parameter	Cost (Existing Building)	Cost (New Building)
Civil Cost, \$	\$0	\$1,904,000
Mechanical and Equipment Cost, \$	\$6,188,000	\$6,188,000
Structural and Architectural Cost, \$	\$1,397,000	\$6,506,000
Electrical and I&C Cost, \$	\$1,756,000	\$3,173,000
Subtotal 1: Total Capital Cost, \$	\$9,400,000	\$17,800,000
Engineering Contingency (30%), \$	\$2,820,000	\$5,340,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$12,220,000	\$23,140,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$3,666,000	\$6,942,000
Owner's Allowance (5%)	\$611,000	\$1,157,000
Total Project Cost, \$	\$16,497,000	\$31,239,000

O&M costs were evaluated for the annual average AGS, BAF, and DAS solids production scenario. The DAS mechanical thickening scenario, which has a slightly higher cost due to increased solids processing requirements, is presented below in **Table 3-10**. Annual maintenance costs were estimated as 3% of mechanical equipment costs and 1% of building costs, for which the new building option was selected to maintain conservatism. The polymer dose was estimated based on values from WEF MOP 8 for the range of PS:WAS blends and is notably higher than the dosage required for BFPs.

Table 3-10: Centrifuge O&M Costs

Parameter	Cost
Installed Horsepower, HP	410

Parameter	Cost
Power Cost, \$/dT	\$4.90
Polymer Dose, lb(active)/dT	40
Polymer Cost, \$/dT	\$94.00
Operating Cost, \$/dT (2024)	\$98.90
Annual Operation Cost, \$/year (2024)	\$606,000
Full-Time Employees	2.0
Annual Labor Cost, \$/year (2024)	\$176,000
Annual Maintenance Cost, \$/year (2024)	\$301,000
DCEN Annual OPEX Cost (2024)	\$1,083,000

The total operation, labor, and maintenance costs considered for the DCEN 20-year lifecycle of 2024-2043 are shown in **Table 3-11** in present value 2024 dollars.

Table 3-11: Centrifuge Lifecycle Cost

Parameter	Cost
DCEN CAPEX Cost (2024)	\$31,239,000
20-year Labor Cost	\$2,950,000
20-year Operation Cost	\$11,155,000
20-year Maintenance Cost	\$5,053,000
20-year Total OPEX Cost	\$19,158,000

3.3 Comparative Evaluation and Recommendation

Both a BFP and DCEN are viable options for dewatering technologies at FBRWRF. Each technology presents advantages and disadvantages related to polymer and electrical consumption, footprint, structural considerations, and cost. While the capital cost for BFPs is less than that for DCENs, cost savings as shown in **Table 3-12** compared to the BFP option may not be as much as expected due to the necessity of BFP and ancillary equipment replacement. Through process optimization, a DCEN will produce drier

cake than a BFP, which will increase the efficiency of the incinerator or selected final solids management process.

Table 3-12: Dewatering Capital Cost Comparison

Parameter	BFP (Existing Building)	DCEN (Existing Building)	DCEN (New Building)
Units Required	3	3	3
CAPEX Cost (2024 \$)	\$15,444,000	\$16,497,000	\$31,239,000

Table 3-13 presents the lifecycle cost comparison for BFPs and DCENs for the liquid process AGS and DAS scenarios.

Table 3-13: Dewatering Lifecycle Cost Comparison

Liquid Process Alternative	AGS - MT	DAS - GT	DAS - MT
BFP 20-year Total CAPEX + OPEX Cost (2024 \$)	\$31,797,000	\$31,936,000	\$32,330,000
DCEN 20-year Total CAPEX (Existing Building) + OPEX Cost (2024 \$)	\$35,656,000	\$35,878,000	\$36,510,000
DCEN 20-year Total CAPEX (New Building) + OPEX Cost (2024 \$)	\$50,398,000	\$50,620,000	\$51,252,000

Selection of a dewatering technology is more dependent on owner preferences and cost analysis than selection of a thickening technology. For all liquid process scenarios, BFPs and DCENs are viable. The primary benefit of a DCEN over a BFP is the increased cake solids produced by a DCEN. This will have downstream efficiency and operation impacts on the final solids process management technology. Selection of an incinerator or thermal dryer will inform selection of a dewatering technology. The results of the structural evaluation will also influence this decision.

4. Site Plan

For both the AGS and DAS liquid process alternatives, a site plan was developed to support the assumptions made in the cost estimates. Separate thickening and dewatering buildings are proposed. For maintenance of plant operations (MOPO), the thickening building is proposed to be located at the site of the gravity thickeners. Only one GT is required to be in service under current and 40 mgd flows and loads, so demolition of the second GT and construction of the thickening building in its location will maximize the use of the site footprint. The thickening building shown is the GBT thickening building, which is larger than either of the RDT options. The space between the thickening building and the surge tank will be the location of the pre-thickening and post-thickening sludge storage tanks, as well as the filtrate pump station. The thickened solids will be pumped across the site to the proposed dewatering and incineration building. This building will be located adjacent to the existing building so that existing piping can be utilized.

The site plan shows the most conservative scenario. Though the existing dewatering building may be utilized for BFP and/or DCEN dewatering, a new building could be required based on the results of the structural evaluation. In order to keep the existing incinerator in service, an additional building for the new incinerator or other final solids management process would be required. **Figure 4-1** shows the site plan for the AGS scenario. **Figure 4-2** shows the site plan for the DAS scenario. Through coordination with the liquid train design, the solids buildings are proposed in the same location for each scenario.



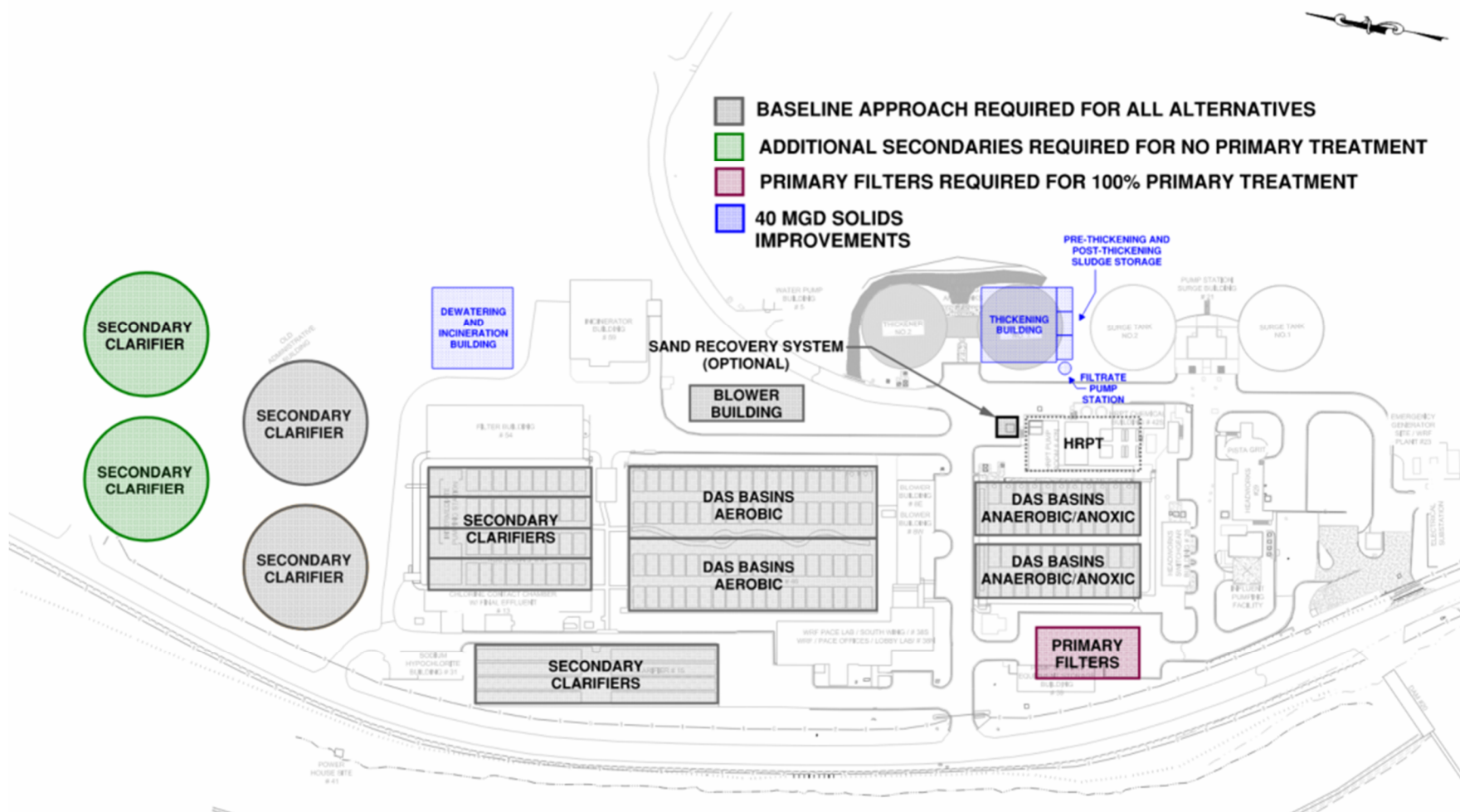


Figure 4-2: DAS Scenario Solids Site Plan

5. Conclusions

Certain combinations of thickening and dewatering technologies are more efficient, either in terms of solids processing or cost, or both. **Table 5-1** presents the sum capital and operation costs of each thickening and dewatering technology combination for the AGS scenario. This represents the conservative scenario of new thickening and dewatering buildings as shown on the site plan. **Table 5-2** presents the same for the DAS scenario.

Table 5-1: AGS Thickening and Dewatering Lifecycle Cost Comparison

Selected Thickening + Dewatering Technology	GBT + BFP	RDT + BFP	GBT + DCEN	RDT + DCEN
CAPEX Cost (2024 \$)	\$41,769,000	\$32,819,000	\$57,564,000	\$48,614,000
20-year Total OPEX Cost (2024 \$)	\$25,100,000	\$25,340,000	\$27,910,000	\$28,140,000
20-year Lifecycle Cost, (2024 \$)	\$66,869,000	\$58,158,500	\$85,474,000	\$76,753,500

Table 5-2: DAS Thickening and Dewatering Lifecycle Cost Comparison

Selected Thickening + Dewatering Technology	GT + BFP	GBT + BFP	RDT + BFP	GT + DCEN	GBT + DCEN	RDT + DCEN
CAPEX Cost (2024 \$)	\$23,868,000	\$41,769,000	\$38,259,000	\$39,663,000	\$57,564,000	\$54,054,000
20-year Total OPEX Cost (2024 \$)	\$19,760,000	\$25,890,000	\$27,470,000	\$22,650,000	\$29,010,000	\$30,600,000
20-year Lifecycle Cost, (2024 \$)	\$43,628,000	\$67,659,000	\$65,729,000	\$62,313,000	\$86,574,000	\$84,654,000

Except for options in which one or both of the existing technologies on site, gravity thickening and belt filter presses, are maintained, significant cost savings are not apparent for any of the scenarios. The primary consideration for selection of a thickening technology is site planning. If thermal drying is selected as the final solids management technology, the location of the existing GTs could be a desirable site for a thermal dryer facility, due to its required footprint. An incinerator building is anticipated to be smaller than a thermal dryer building, so footprint is not as significant of a driver.

A decision on incineration or thermal drying is also necessary to determine the dewatering technology selection. The incinerator or thermal dryer will be sized based on the post-dewatering solids mass. The drier cake produced by a DCEN compared to a BFP presents efficiency benefits for both incineration and thermal drying. However, the cost benefit analysis for each final solids management process must be considered for a cumulative solids process assessment and dewatering technology recommendation.

Hazen *Technical Memorandum*

Final: July 11, 2025

To: Metropolitan Sewerage District of Buncombe County (MSD)
From: Sharanya Ananth, Hazen
Aaron Babson, PE, Hazen
Ruth Borgmann, PE, Hazen
Michael Bullard, PE, Hazen
Jacqueline Yeh, PE, Hazen

Technical Memorandum No. 2c – Thermal Drying Assessment

FINAL

Table of Contents

1. Introduction	3
2. Thermal Dryer Technology Assessment	3
2.1 Thermal Dryer Technology Description	3
2.2 Thermal Dryer Design Criteria	5
3. Process Option: Belt Filter Press and Thermal Drying	11
3.1 AGS Thermal Dryer Sizing	11
3.2 DAS Thermal Dryer Sizing	12
3.3 Sludge Storage Sizing	14
3.4 Belt Filter Press Sizing	15
4. Process Option: Thickening, Dewatering Centrifuge and Thermal Drying	16
4.1 Sludge Blending and Mechanical Thickening	16
4.2 AGS Thermal Dryer Sizing	17
4.3 DAS Thermal Dryer Sizing	19
4.4 Thickened Sludge Storage	21
4.5 Dewatering Centrifuge Sizing	22
5. Site Planning	24
5.1 Belt Filter Press	25
5.2 Dewatering Centrifuge	26
6. Cost Estimate	29
6.1 Opinion of Probable Construction Cost	29
6.2 Operation and Maintenance Cost	33
6.3 Lifecycle Cost Estimate	38
7. Conclusions	39

1. Introduction

The Metropolitan Sewerage District (MSD) of Buncombe County retained Hazen and Sawyer (Hazen) to complete a Solids Handling Preliminary Engineering Report (PER) for the French Broad River Water Reclamation Facility (FBRWRF). The PER includes a condition and capacity assessment on the existing equipment, technology assessments, permitting assistance and development of a new solids handling facility concept to be seamlessly integrated into the forthcoming liquid train project.

The purpose of this technical memorandum (TM) is to evaluate thermal drying as the final solids management technology and regulatory compliance process. Thermal drying is assessed based on the future solids production rates for each Biological Treatment Alternative, Aerobic Granular Sludge (AGS) and Densified Activated Sludge (DAS). Biological Aerated Filtration (BAF) was not considered as it has been removed from consideration by MSD as a biological treatment alternative.

Thermal drying was evaluated considering two different dewatering technologies: (1) a three-belt belt filter press (BFP), capable of both thickening and dewatering sludge; and (2) a dewatering centrifuge (DCEN), which would require upstream mechanical thickening. Further evaluation of thickening and dewatering technologies was completed in TM No. 2b – *Thickening and Dewatering Technology Assessment*. Sludge production rates and solids loading rates established in TM No. 1 – *Solids Projections, Condition and Capacity Assessment* for the 40-million gallon per day (mgd) maximum month design flow condition for each biological treatment alternative were utilized to size the thermal drying equipment and requisite thickening and dewatering equipment.

2. Thermal Dryer Technology Assessment

2.1 Thermal Dryer Technology Description

Thermal drying utilizes thermal energy to evaporate a significant amount of water from sludge, resulting in both volume and mass reduction of solids to produce a high-quality dried product. Dewatered cake contains approximately 75-80% water by weight. This water content represents the typical limit for mechanically separating water from biosolids. For MSD to achieve a high-quality dried product, which achieves Class A status under the EPA 40 CFR 503 regulations, the end product must be greater than 90% dry product solids, or less than 10% moisture content, because it has undigested primary sludge in the feed.

While there are multiple thermal dryer technologies, such as belt dryers and indirect paddle dryers, a rotary drum dryer is recommended for the scale of drying operation required at the 40 mgd condition for FBRWRF. This is due to the required evaporative loading rate, the parameter by which thermal drying equipment is sized. Rotary drum drying is one of the most advanced thermal drying technologies available and is the most common high evaporation rate dryer type found in the United States.

In this type of dryer, dewatered cake is fed to an enclosed, rotating drum. Heated gas enters the drum between 800°C and 1,000°C. As the drum rotates with the solids and heated gas, water is evaporated out of the solids. The constant, slow rotation of the drum creates a hard and nearly spherical granule. At the

end of the drum, vibrating screens sort the dried pellets by size, allowing the equipment to recycle over- and under-sized pellets back to the dryer to create a more uniform product, typically in the range of 0.5 to 4.0 mm. Biosolids are typically dried to between 92% and 95% TS. Rotary drum dryers typically have a startup time of approximately 30 to 40 minutes and a cool down period of 45 minutes.

Advantages of thermal drying as a technology include the flexibility of outlets for the dried product, as it can be pelletized and sold for valuable use. The dried end-product is of a uniform size and shape, which allows it to be marketable in a wide range of applications. However, a large-scale pellet distribution operation will require market evaluation and customer development, as well as increased operational and maintenance costs. The primary operational cost for a rotary drum dryer is the cost of the natural gas required to continually heat the drum during operation.

In the United States, the most common vendor for rotary drum dryer systems is Andritz. **Figure 2-1** shows an example installation of an Andritz rotary drum dryer, along with the required ancillary equipment.



Figure 2-1: Rotary Drum Dryer and Ancillary Equipment by Andritz

The Andritz drum dryer is a triple-pass drum in which the sludge is dried by convection. The final product is homogenous and stable, dust-free, low odor, and can achieve 90-95% TS dryness. Safety

provisions include explosion suppression systems, dust control, and maintenance of an oxygen-deficient atmosphere. Andritz has many installations of rotary drum dryers across the US and globally.

In addition to the thermal dryer, several ancillary systems are required to support the drying process. A typical Andritz rotary drum dryer system package includes the following per dryer:

- Wet Cake Receiving Bin / Cake Hopper – receive solids from dewatering
- Dewatered Cake Pumps – transfer solids from the wet cake bin to the dryer
- Odor Control for exhaust gas – regenerative thermal oxidizer (RTO) recommended for rotary drum dryers
- Nitrogen Generator – provides nitrogen to maintain an oxygen-deficient atmosphere
- Dried Product Silo – typically 7-14 days of final product storage
- Control equipment – including MCC and VFD

The wet cake bin is required to decouple the dewatering and drying processes. This wet cake bin is relatively small and not intended to be used for long-term storage. In general, dewatering operates on the same schedule as drying, so the wet cake bin provides sufficient storage if dewatering is temporarily offline and to provide flexibility during equipment startup. In addition to operational flexibility, the wet cake bin allows for a more consistent feed to the dryer.

The ancillary equipment may be purchased separately, but that is generally not found to be economical. Additionally, Hazen's design standard is an integrated system for optimal process control and ensures a single source of responsibility. For the thermal drying evaluation presented in this report, dryer sizes manufactured by Andritz were the primary drying system considered. A dried product loadout facility and storage silos can also be provided depending on final product management strategy and can be designed by the engineer or the manufacturer based on owner preference and estimated cost.

2.2 Thermal Dryer Design Criteria

Thermal dryers are sized based on evaporative loading rate, which is based on the amount of water removed from the dewatered cake. All supporting equipment, including dewatering equipment, is sized such that under a variety of potential cake conditions, the dryer can be fed at a rate which will utilize the full evaporative capacity of the dryer. The cake was assumed to be dried to 90% TS final product, which meets the minimum dryness requirement for the EPA 40 CFR 503 vector attraction reduction standard. The required evaporation rate for a drying system can be calculated as shown below:

$$\text{Evaporation Rate} \left[\frac{\text{lb water}}{\text{hr}} \right] = \text{Cake Loading} \left[\frac{\text{dry lb}}{\text{day}} \right] \times \left[\frac{7 \text{ days}}{\text{week}} \right] \times \left(\frac{1}{\% \text{ TS (wet cake)}} - \frac{1}{\% \text{ TS (dry product)}} \right) \div \text{Dryer Runtime} \left[\frac{\text{hr}}{\text{week}} \right]$$

Additionally, plant staff communicated that two dryer trains would be optimal due to the redundancy present for operational flexibility. Rotary drum dryers are typically run in campaigns where they are started up once per week, operating continuously to process all solids for the week, and then shut down. This mode of operation minimizes unnecessary shutdown and startup cycles and is more energy efficient than multiple operational cycles per week. Additionally, the dryer downtime allows for required routine preventative maintenance activities. The operational scheme for one dryer train and two dryer trains would differ.

For one dryer train, thermal dryers are generally operated in the following scheme:

- 24 hours per day for four days per week (96 hrs/week) at annual average loadings
- **24 hours per day for five days per week (120 hrs/week) at maximum month loadings**
- 24 hours per day for six days per week (144 hrs/week) at maximum two-week loadings
- **24 hours per day for seven days per week (168 hrs/week) at maximum week loadings**

The dryer sizing for one dryer train scenarios was based on the maximum month and maximum week loading operational hours. For the annual average and maximum two-week loading conditions, hours can be increased to meet the solids loading.

For two dryer trains, the dryers are sized such that one train can manage the average annual loading through continuous, 24 hours per day for seven days per week operation. The second train can be brought online to manage excess loads during the maximum month or week transient loading conditions. This means that the two dryer train design will call for two smaller dryers than the size required for one dryer to manage required loading. While this lends redundancy and flexibility, two dryer trains will require more supporting equipment and ultimately present higher capital costs.

Due to the importance of the cake solids content to the evaporative loading rate, the upstream process flow, particularly the dewatering process, is critical for the dryer sizing. Based on the thickening and dewatering technology assessment, the following process flow options were considered: (1) a three-belt belt filter press (BFP), capable of both thickening and dewatering sludge; and (2) a dewatering centrifuge (DCEN), which would require upstream mechanical thickening. For each dewatering technology, one and two dryer train scenarios were considered. The BFP option process flow is shown in **Figure 2-2**.

The DCEN option process flow is shown in **Figure 2-3**. Mechanical thickening is recommended so that the centrifuges could operate in solids loading rate limited mode. Operating in solids loading rate limited mode allows for fewer pieces of dewatering equipment (and associated ancillary equipment). Gravity thickening was not considered viable for the AGS or DAS scenarios due to footprint constraints and inherent sludge characteristics from these liquid treatment processes.

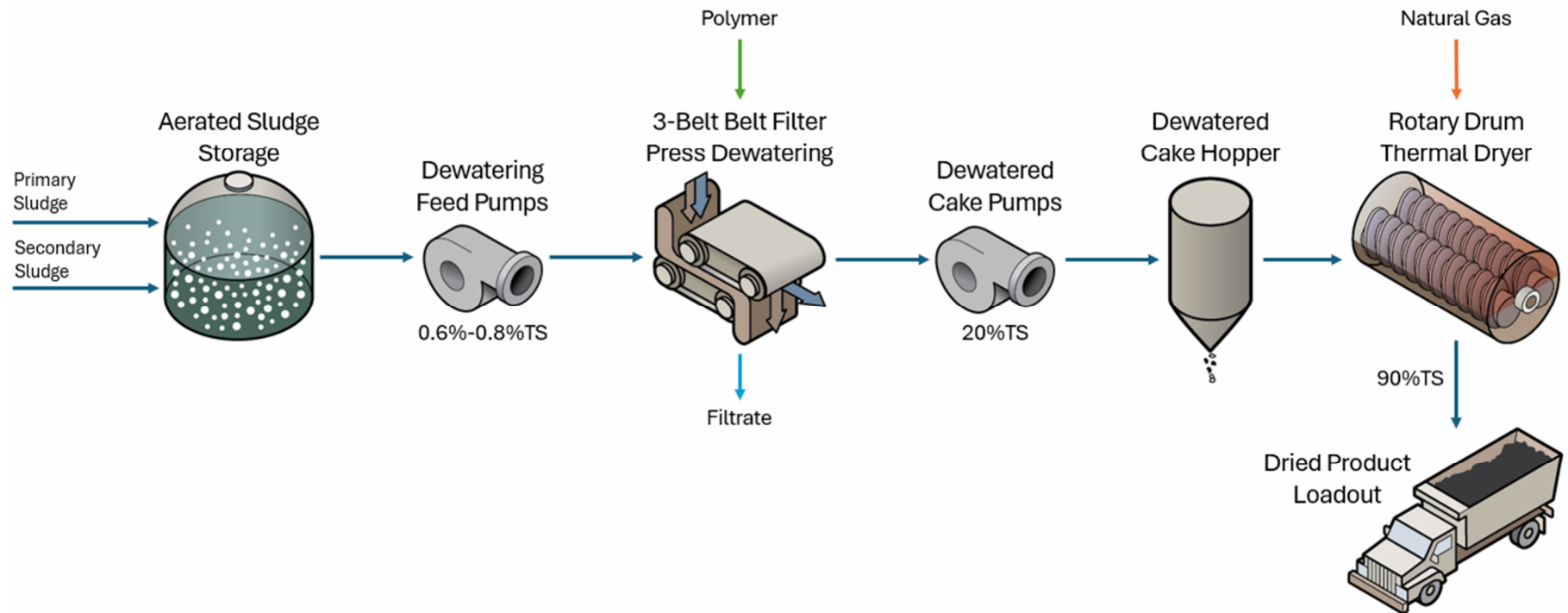


Figure 2-2: Belt Filter Press Dewatering and Thermal Drying Process Flow

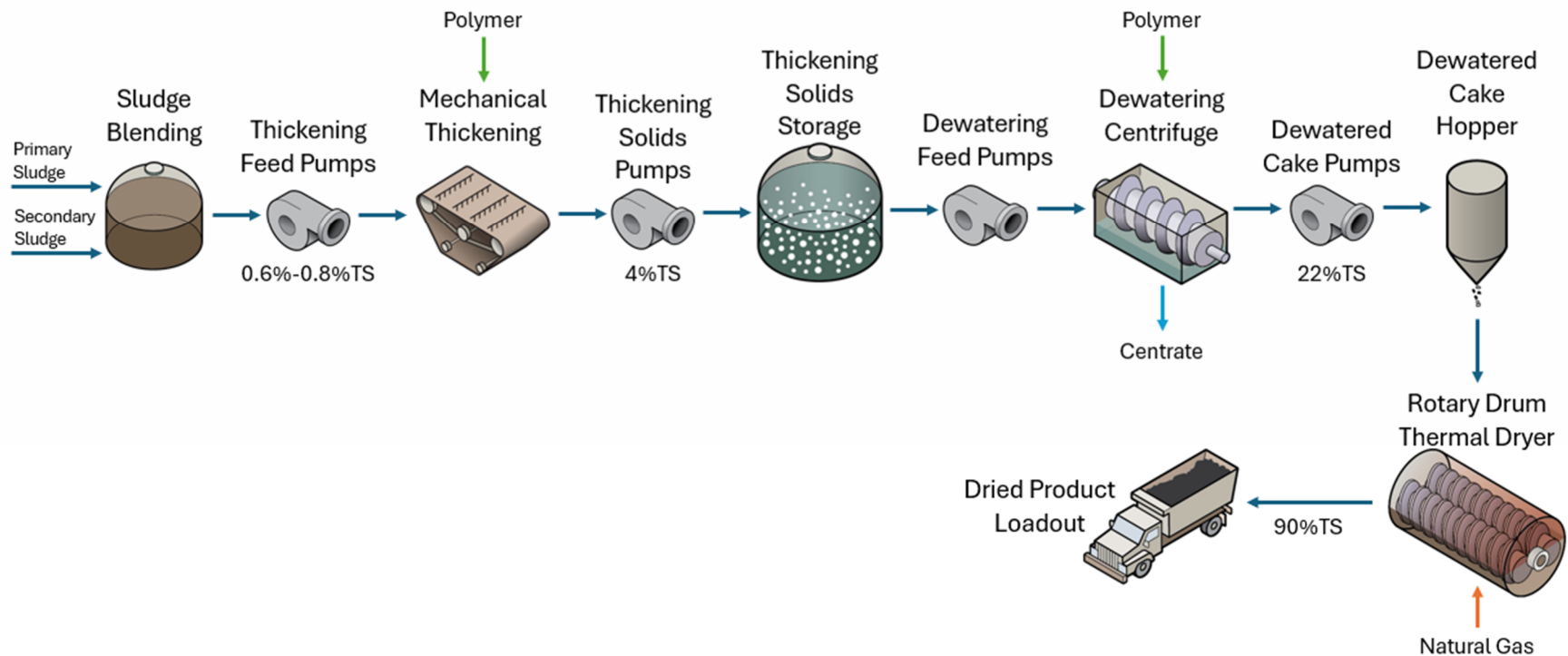


Figure 2-3: Centrifuge Dewatering and Thermal Drying Process Flow

At the 40 mgd maximum month flow design condition, the following dewatered sludge production rates are anticipated for the AGS and DAS alternatives. Dewatered cake mass routed to the dryer was estimated using a typical 95% capture efficiency in the dewatering process. The DCEN option process flow includes mechanical thickening, for which a 95% capture efficiency was also applied resulting in a slightly lower mass to post-dewatering solids management.

Table 2-1: Post-Dewatering Sludge Mass Production

Parameter	AGS		DAS	
	MAX30	MAX07	MAX30	MAX07
BFP Post-Dewatering Sludge Mass, lb(dry)/day	56,100	75,300	63,100	84,600
BFP Post-Dewatering Sludge Mass, dT/day	28	38	32	42
DCEN Post-Dewatering Sludge Mass, lb(dry)/day	53,300	71,600	60,000	80,300
DCEN Post-Dewatering Sludge Mass, dT/day	27	36	30	40

Each dewatering scenario was considered separately for thermal dryer sizing, as the dewatered cake mass will impact the required evaporative loading rate. For the BFP scenario, 20% TS dewatered cake was assumed and for the DCEN scenario, 22% TS dewatered cake was assumed. These conservative assumptions were applied due to the uncertainty of the future sludge quality and based on the currently produced dewatered cake solids content. Due to the variety of factors influencing thermal dryer design criteria, the following scenarios will be considered for thermal dryer sizing, site planning, and cost estimating:

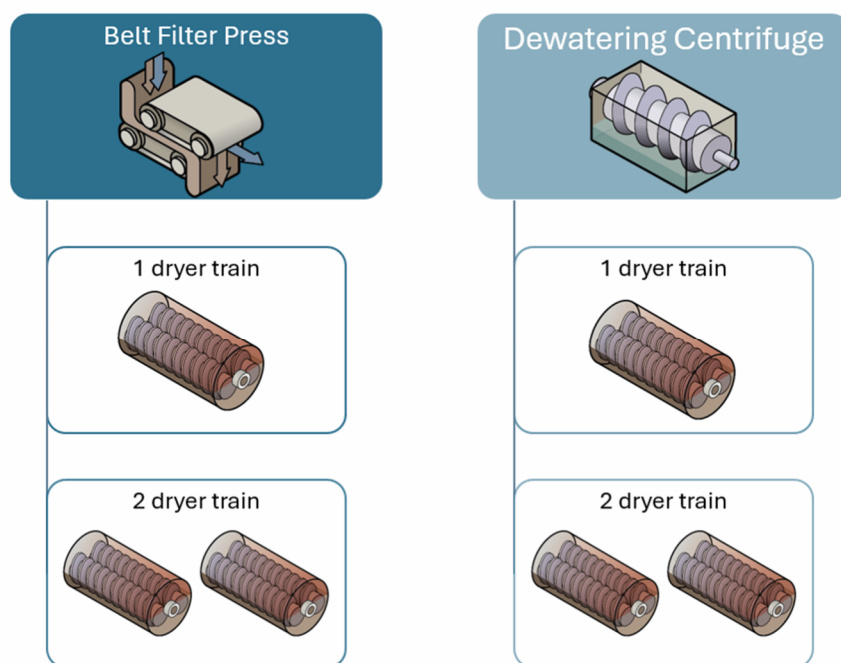


Figure 2-4: Thermal Drying Design Scenarios

Each of the four scenarios combining dewatering technologies and number of dryer trains was also evaluated for the AGS and DAS liquid process alternatives. Thus, eight process scenarios will be considered. The following drum dryer sizes are manufactured by Andritz for this range of operation.

Table 2-2: Andritz Drum Dryer Sizes

Dryer Model	Dryer Evaporative Loading Rate, kg(water)/hr	Dryer Evaporative Loading Rate, lb(water)/hr	Dryer Solids Feed Rate at 20% Cake Solids, lb(dry)/hr ¹	Dryer Solids Feed Rate at 22% Cake Solids, lb(dry)/hr ¹	Dryer System Equipment Cost
DDS-40	4,000	8,800	2,263	2,562	\$15,500,000
DDS-50	5,000	11,000	2,829	3,203	\$16,500,000
DDS-60	6,000	13,200	3,394	3,844	\$18,000,000
DDS-70	7,000	15,400	3,960	4,484	\$18,500,000

¹Assuming 90% dred product solids.

Sections 3 and 4 will show the thermal dryer sizing for each of these scenarios, organized by dewatering technology. Dewatering equipment and all supporting processes were designed based on the required feed to the dryer.

3. Process Option: Belt Filter Press and Thermal Drying

BFPs continuously dewater solids using at least two moving belts and a series of rollers to perform the conveying, pressing and dewatering functions. The sludge is conditioned with polymer to coagulate and flocculate the solids prior to dewatering on the belt press and water is removed through the belt filter fabric through gravity drainage and compression. A 3-belt BFP was evaluated based on the results of the thickening technology assessment. On a 3-belt BFP, an independent gravity belt can adapt to a thinner feed sludge without compromising solids mass throughput and the optimized configuration has a gravity deck for easy operator access and an elevated discharge for conveyance.

Since there is no separate mechanical thickening in this process option, as shown in **Figure 2-2**, sludge storage prior to dewatering is required to maintain independent operation of the dewatering and drying system from the liquid process wasting.

3.1 AGS Thermal Dryer Sizing

The required dryer sizing and dryer feed rate calculated based on an estimated 20% TS cake solids content produced by a 3-belt BFP are shown in **Table 3-1**. The bolded values show the criteria used to select the thermal dryer size.

Table 3-1: AGS Thermal Dryer Sizing

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing				
Dryer Operating Schedule, days/week	4	5	6	7
Dryer Operating Schedule, hrs/week	96	120	144	168
Minimum Dryer Feed Rate, lb(dry)/hr	3,559	3,274	3,427	3,139
Minimum Dryer Evaporation Rate, lb(water)/hr	13,839	12,733	13,326	12,207
2 Dryer Train Sizing				
Dryer Operating Schedule, days/week	7	7	7	7
Dryer Operating Schedule, hrs/week	168	168	168	168
Minimum Dryer Feed Rate, lb(dry)/hr	2,033	2,339	2,937	3,139
Minimum Dryer Evaporation Rate, lb(water)/hr	7,908	9,095	11,422	12,207

Based on the dryer sizes presented in **Table 2-2** and the sizing methodology outlined in Section 2.2, the following dryer sizes were selected for each of the AGS BFP process options:

- AGS w/ 1 Dryer Train: DDS-60 (13,200 lb(water)/hr)
- AGS w/ 2 Dryer Trains: DDS-40 (8,800 lb(water)/hr)

Average annual and maximum two-week values are presented for the one dryer train sizing for reference, although were not used for ultimate dryer size selection. Only annual average was considered for the two dryer train sizing, but additional solids loading conditions were presented for reference and understanding of when the second dryer must be operated.

Both sludge storage requirements and dewatering sizing are based on the selected thermal dryer size. The sludge storage requirements are calculated based on the required dryer runtime as the storage volume must meet the downtime in drying operation each week. The dewatering equipment must be sized to fully load the dryer at its maximum evaporative capacity. **Table 3-2** shows the actual operating schedule based on the thermal dryer sizing for the AGS scenarios.

Table 3-2: AGS Thermal Dryer Operating Hours

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing – DDS-60				
Total Dryer Feed Rate, lb(dry)/hr	3,394	3,394	3,394	3,394
Dryer Operating Schedule, hrs/week	101	116	145	155
Dryer Operating Schedule, days/week	4.19	4.82	6.06	6.47
Dryer Operating Utilization	60%	69%	87%	92%
Required Hours of Storage, hrs/week	67	52	23	13
2 Dryer Train Sizing – DDS-40, Single Dryer in Service				
Total Dryer Feed Rate, lb(dry)/hr	2,263	2,263	2,263	2,263
Dryer Operating Schedule, hrs/week	151	174	218	233
Dryer Operating Schedule, days/week	6.29	7.23	9.09	9.71
Dryer Operating Utilization	90%	103%	130%	139%
Required Hours of Storage, hrs/week	17	N/A	N/A	N/A

For the one dryer train scenario, sludge storage will be designed to meet the average annual requirement (67 hours). For the two dryer train sizing scenario, only minimal sludge storage is required. Values where operating hours exceed the hours in a day or days in a week mean that the second dryer train must be utilized. This reflects the sizing methodology for two dryer trains. Thus, the only operational scenario for two dryer trains where only one dryer is in operation is the annual average loading scenario.

3.2 DAS Thermal Dryer Sizing

The same calculations are presented for the DAS scenarios in

Table 3-3. Though BAF was not considered in this assessment, calculations showed that thermal dryer sizing for BAF scenarios matched DAS scenarios, so if BAF is reconsidered, the DAS options will reflect the BAF alternative as well.

Table 3-3: DAS Thermal Dryer Sizing

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing				
Dryer Operating Schedule, days/week	4	5	6	7
Dryer Operating Schedule, hrs/week	96	120	144	168
Minimum Dryer Feed Rate, lb(dry)/hr	4,002	3,682	3,842	3,523
Minimum Dryer Evaporation Rate, lb(water)/hr	15,564	14,320	14,942	13,700
2 Dryer Train Sizing				
Dryer Operating Schedule, days/week	7	7	7	7
Dryer Operating Schedule, hrs/week	168	168	168	168
Minimum Dryer Feed Rate, lb(dry)/hr	2,287	2,630	3,293	3,523
Minimum Dryer Evaporation Rate, lb(water)/hr	8,894	10,228	12,807	13,700

Based on the dryer sizes presented in **Table 2-2**, the following dryer sizes were selected for each of the DAS BFP process options:

- DAS w/ 1 Dryer Train: DDS-70 (15,400 lb(water)/hr)
- DAS w/ 2 Dryer Trains: DDS-50 (11,000 lb(water)/hr)

For the DAS with two dryer trains scenario, the anticipated minimum dryer evaporation rate for the annual average loading is very close to that of the DDS-40 dryer size, 8,800 lbs water per hour. Consideration to use a DDS-40 could be investigated further if this alternative is selected. This will also provide moderate cost savings for the dryer equipment, approximately \$1,000,000, and supporting dewatering process.

Table 3-4 shows the actual dryer operating hours calculation for the DAS scenarios.

Table 3-4: DAS Thermal Dryer Operating Hours

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing – DDS-70				
Total Dryer Feed Rate, lb(dry)/hr	3,960	3,960	3,960	3,960
Dryer Operating Schedule, hrs/week	97	112	140	149
Dryer Operating Schedule, days/week	4.04	4.65	5.82	6.23
Dryer Operating Utilization	58%	66%	83%	89%
Required Hours of Storage, hrs/week	71	56	28	19
2 Dryer Train Sizing – DDS-50, Single Dryer in Service				
Total Dryer Feed Rate, lb(dry)/hr	2,829	2,829	2,829	2,829
Dryer Operating Schedule, hrs/week	136	156	196	209
Dryer Operating Schedule, days/week	5.66	6.51	8.15	8.72
Dryer Operating Utilization	81%	93%	116%	125%
Required Hours of Storage, hrs/week	32	12	N/A	N/A

For the one dryer train scenario, sludge storage will be designed to meet the average annual requirement. For the two dryer train sizing scenario, for both the average annual and maximum month loading, only one dryer is required to be in operation and only minimal sludge storage is required.

3.3 Sludge Storage Sizing

Based on the dryer operating hours, the maximum required sludge storage volume for each scenario is presented in **Table 3-5**. Based on the required hours of storage for each option, aeration is required for sludge mixing. Each footprint calculation assumes a tank depth of 20 feet, which is standard for aerated sludge storage.

Table 3-5: Sludge Storage Sizing

Parameter	AGS w/ 1 dryer	AGS w/ 2 dryers	DAS w/ 1 dryer	DAS w/ 2 dryers
Required Hours of Storage, hrs	67	17	71	32
Solids Concentration, %TS	1.0%		0.7%	
Required Storage Volume, gal	1,674,000	423,000	2,823,000	1,279,000
Required Storage Volume, cu ft	224,000	56,600	377,000	171,000
Required Footprint, sq ft	11,200	2,800	18,900	8,600

For comparison, the surface area of one of the existing gravity thickeners is 7,854 square feet. Each of the options requires substantial sludge storage volume due to the anticipated solids concentration that it will

be stored at – approximately 1.0% for blended primary and secondary AGS sludge and 0.7% for blended primary and secondary DAS sludge. For both of the two dryer train options, another option is to retrofit the existing gravity thickeners, which have a combined active volume of approximately 1.3 million gallons. This allows existing assets to be leveraged and minimize capital costs. For each option, the sludge storage footprint requirement will be considered alongside the proposed building layout to determine the best location for the sizable sludge storage tanks.

3.4 Belt Filter Press Sizing

The BFPs will be designed to fully load the thermal drying evaporative capacity for each thermal dryer scenario. **Table 3-6** shows the dry solids mass loading rate per dryer and per BFP. The data in this table also confirms that BFP loading matches the evaporative loading rate to load the dryer most efficiently. Per these calculations, the optimal design loading rate for the BFPs for each scenario is listed. Though the expected cake solids content of the BFP is 20% TS, the equipment is sized to handle a maximum cake solids concentration of 22% TS for conservatism.

Table 3-6: Belt Filter Press Sizing

Cake Solids, % TS	Dryer Evaporative Loading Rate, lb(water)/hour	Total Solids Loading per Dryer, lb(dry)/hour	Total Solids Loading to Dewatering ¹ , lb(dry)/hour	Number of Duty BFPs	Solids Loading per BFP, lb(dry)/hour
AGS w/ 1 dryer train – DDS-60					
20.0%	13,200	3,394	3,573	2	1,786
21.0%		3,616	3,806		1,903
22.0%		3,844	4,046		2,023
AGS w/ 2 dryer trains – DDS-40					
20.0%	8,800	2,263	2,382	2	1,191
21.0%		2,410	3,537		1,269
22.0%		2,562	2,697		1,349
DAS w/ 1 dryer train – DDS-70					
20.0%	15,400	3,960	4,168	3	1,389
21.0%		4,218	4,440		1,480
22.0%		4,484	4,720		1,573
DAS w/ 2 dryer trains – DDS-50					
20.0%	11,000	2,829	2,977	2	1,489
21.0%		3,013	3,172		1,586
22.0%		3,203	3,372		1,686

¹Solids loading to dewatering is 105% of solids loading to drying due to 95% assumed capture loss through dewatering.

Table 3-7 shows the required pieces of dewatering equipment based on a redundancy concept of one additional unit, which can be used as a swing unit for the two dryer trains operational scenario.

Table 3-7: Required Number of BFPs

Parameter	AGS w/ 1 dryer	AGS w/ 2 dryers	DAS w/ 1 dryer	DAS w/ 2 dryers
Number of Thermal Dryers	1	2	1	2
Number of Duty BFPs per Dryer	2	2	3	2
Number of Total Duty BFPs	2	4	3	4
Total Number of BFPs	3	5	4	5
BFP Solids Loading, lb(dry)/hr per BFP	2,050	1,400	1,600	1,700
BFP Size	2.5-m	2.0-m	2.0-m	2.0-m
BFP SLR, lb(dry)/hr-m	820	700	800	850

For each belt filter press, the following ancillary equipment is required, as noted in TM No. 2b:

- Dewatering Feed Pump, one (1) per BFP
- Washwater Booster Pump, one (1) per BFP
- Dewatered Cake Conveyor, one (1) per BFP
- Polymer Makeup Unit, one (1) per BFP

The layout concept for a combined dewatering and drying facility is a two story building, with the thermal drying space stretching into the second floor of the facility. The first floor dewatering area will contain the dewatering feed pumps and a polymer area, including bulk polymer storage. The second floor dewatering area will include the BFPs and additional space for electrical, HVAC, and control rooms. Based on this concept, footprint requirements will be presented in Section 5.

4. Process Option: Thickening, Dewatering Centrifuge and Thermal Drying

DCENs use sedimentation principles and centrifugal acceleration to dewater solids. As presented in TM No. 2b, DCENs operate by using centrifugal force to drive heavier solids towards the outside of the DCEN bowl while the lighter water remains in the center of the bowl. The advantages and disadvantages of the technology are also presented in TM No. 2b.

4.1 Sludge Blending and Mechanical Thickening

Centrifuge dewatering generally requires a feed sludge concentration of above 2% to maximize throughput and operate in solids limited mode. To achieve this solids concentration, thickening is required, and mechanical thickening is recommended. In this proposed process flow, dewatering operation is directly tied to thermal drying operation, but thickening operation can be independent of those processes. For thickening operation, sludge blending prior to thickening is recommended for a consistent feed sludge. The blend tank sizing proposed in TM No. 2b was maintained and is shown below in **Table 4-1**. The sludge blending tank was sized to provide a more reliable wide spot prior to thickening than the existing sludge blending tank, which will be repurposed for short-term primary sludge storage.

Table 4-1: Sludge Blending Tank Geometry

Parameter	Criteria
Number of Blending Tanks	1
Tank Depth, ft	20
Tank Width, ft	20
Tank Length, ft	30
Tank Volume, gallons	89,760

In this DCEN evaluation, a rotary drum thickener (RDT) was considered as the mechanical thickening technology for conservative design, as it produces a thinner sludge (~4% TS) compared to gravity belt thickeners (~5% TS). As this equipment design criteria is not connected to thermal dryer sizing, this equipment size was also maintained from TM No. 2b and is shown in **Table 4-2**.

Table 4-2: Rotary Drum Thickener Design Criteria

Parameter	Value
Solids Loading Rate, lb(dry)/hr	1,500
Hydraulic Loading Rate Capacity, gpm	400
Breakpoint Solids Concentration, % TS	0.75%
AGS Required RDTs	3
DAS Required RDTs	4

RDTs would operate in solids limited mode for the AGS and DAS scenarios and feed into thickened sludge storage tanks. This is where the process flow becomes dependent on thermal dryer sizing and differs from what was presented in the previous TM.

4.2 AGS Thermal Dryer Sizing

Based on the estimated cake solids content produced by a DCEN, 22% TS, the required dryer sizing and dryer feed rate were calculated, shown in **Table 3-1**. Based on Hazen's experience, DCENs will produce a dewatered cake greater than 20% TS. For the same feedstock, DCENs typically produce a cake that is approximately 10% higher in cake solids than that of a BFP (i.e. from 20% to 22%). The bolded values show the criteria used to select the thermal dryer size. Note that slightly less mass throughput is required than in the BFP scenario due to 95% capture efficiency in the mechanical thickening process.

Table 4-3: AGS DCEN Thermal Dryer Sizing

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing				
Dryer Operating Schedule, days/week	4	5	6	7
Dryer Operating Schedule, hrs/week	96	120	144	168
Minimum Dryer Feed Rate, lb(dry)/hr	3,381	3,110	3,255	2,982
Minimum Dryer Evaporation Rate, lb(water)/hr	11,610	10,682	11,180	10,241
2 Dryer Train Sizing				
Dryer Operating Schedule, days/week	7	7	7	7
Dryer Operating Schedule, hrs/week	168	168	168	168
Minimum Dryer Feed Rate, lb(dry)/hr	1,932	2,222	2,790	2,982
Minimum Dryer Evaporation Rate, lb(water)/hr	6,634	7,630	9,583	10,241

Based on the dryer sizes presented in **Table 2-2** and the sizing methodology outlined in Section 2.2, the following dryer sizes were selected for each of the AGS BFP process options:

- AGS w/ 1 Dryer Train: DDS-50 (11,000 lb(water)/hr)
- AGS w/ 2 Dryer Trains: DDS-40 (8,800 lb(water)/hr)

The difference between solids concentration and throughput for the AGS BFP and DCEN scenarios allowed for a decreased size on the one dryer train option. Once the thermal dryer is selected for each alternative, the actual operating hours must be considered to understand the feed requirements to the thermal dryer. This will also inform the thickened sludge storage requirement, as the storage volume must meet the downtime in drying operation each week.

Table 4-4: AGS DCEN Thermal Dryer Operating Hours

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing – DDS-50				
Total Dryer Feed Rate, lb(dry)/hr	3,203	3,203	3,203	3,203
Dryer Operating Schedule, hrs/week	101	117	146	156
Dryer Operating Schedule, days/week	4.22	4.86	6.10	6.52
Dryer Operating Utilization	60%	69%	87%	93%
Required Hours of Storage, hrs/week	67	51	22	12
2 Dryer Train Sizing – DDS-40, Single Dryer in Service				
Total Dryer Feed Rate, lb(dry)/hr	2,562	2,562	2,562	2,562
Dryer Operating Schedule, hrs/week	127	146	183	196
Dryer Operating Schedule, days/week	5.28	6.07	7.62	8.15
Dryer Operating Utilization	75%	87%	109%	116%
Required Hours of Storage, hrs/week	41	22	N/A	N/A

For the one dryer train scenario, sludge storage will be designed to meet the average annual requirement. For the two dryer train sizing scenario, for both the average annual and maximum month loading, only one dryer is operated and sludge storage is required.

4.3 DAS Thermal Dryer Sizing

The same calculations are presented for the DAS scenarios in **Table 4-5**. As with the BFP evaluation, the BAF scenario matches the DAS scenario for dryer sizing.

Table 4-5: DAS DCEN Thermal Dryer Sizing

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing				
Dryer Operating Schedule, days/week	4	5	6	7
Dryer Operating Schedule, hrs/week	96	120	144	168
Minimum Dryer Feed Rate, lb(dry)/hr	3,802	3,498	3,650	3,347
Minimum Dryer Evaporation Rate, lb(water)/hr	13,058	12,014	12,536	11,494
2 Dryer Train Sizing				
Dryer Operating Schedule, days/week	7	7	7	7
Dryer Operating Schedule, hrs/week	168	168	168	168
Minimum Dryer Feed Rate, lb(dry)/hr	2,173	2,499	3,129	3,347
Minimum Dryer Evaporation Rate, lb(water)/hr	7,461	8,581	10,745	11,494

Based on the dryer sizes presented in **Table 2-2**, the following dryer sizes were selected for each of the DAS DCEN process options:

- DAS w/ 1 Dryer Train: DDS-60 (13,200 lb(water)/hr)
- DAS w/ 2 Dryer Trains: DDS-40 (8,800 lb(water)/hr)

Table 4-6 shows the actual dryer operating hours calculation for the DAS scenarios.

Table 4-6: DAS DCEN Thermal Dryer Operating Hours

Parameter	AVG365	MAX30	MAX14	MAX07
1 Dryer Train Sizing – DDS-60				
Total Dryer Feed Rate, lb(dry)/hr	3,844	3,844	3,844	3,844
Dryer Operating Schedule, hrs/week	95	109	137	146
Dryer Operating Schedule, days/week	3.96	4.55	5.70	6.10
Dryer Operating Utilization	57%	65%	81%	87%
Required Hours of Storage, hrs/week	73	59	31	22
2 Dryer Train Sizing – DDS-40, Single Dryer in Service				
Total Dryer Feed Rate, lb(dry)/hr	2,562	2,562	2,562	2,562
Dryer Operating Schedule, hrs/week	142	164	205	219
Dryer Operating Schedule, days/week	5.94	6.83	8.55	9.14
Dryer Operating Utilization	85%	98%	122%	131%
Required Hours of Storage, hrs/week	26	4	N/A	N/A

For the one dryer train scenario, sludge storage will be designed to meet the average annual requirement. For the two dryer train sizing scenario, for both the average annual and maximum month loading, only one dryer is operated and sludge storage is required.

4.4 Thickened Sludge Storage

Based on the dryer operating hours, the maximum required thickened sludge storage volume for each scenario is presented in **Table 4-7**. Based on the required hours of storage for each option, aeration is required. Each footprint calculation assumes a tank depth of 20 feet, which is standard for aerated sludge storage.

Table 4-7: Sludge Storage Sizing

Parameter	AGS w/ 1 dryer	AGS w/ 2 dryers	DAS w/ 1 dryer	DAS w/ 2 dryers
Required Hours of Storage, hrs	67	41	73	26
Solids Concentration, %TS	4%			
Required Storage Volume, gallons	406,400	252,000	500,700	175,200
Required Storage Volume, cu ft	54,300	33,700	66,900	23,400
Required Footprint, sq ft	2,700	1,700	3,300	1,200

For comparison, the surface area of one of the existing gravity thickeners is 7,854 square feet. The sludge storage volume required for this scenario is much lower compared to the BFP scenario because the thicker sludge takes less volume. For each option, the sludge storage footprint will be considered alongside the proposed solids handling building.

4.5 Dewatering Centrifuge Sizing

The DCENs will be designed to fully load the thermal drying evaporative capacity for each thermal dryer scenario. **Table 4-8** shows the dry solids mass loading rate per dryer and per DCEN. For this evaluation, due to the ranges of DCEN sizes available, some scenarios require one duty DCEN per dryer or two duty DCENs per dryer. The data in this table also confirms that DCEN loading matches the evaporative loading rate to load the dryer most efficiently. Per these calculations, the optimal design loading rate for the DCENs for each scenario is listed. Though the expected cake solids content off the BFP is 22% TS, the equipment is sized to handle a maximum cake solids concentration of 25% TS for conservatism.

Table 4-8: Dewatering Centrifuge Sizing

Cake Solids, % TS	Dryer Evaporative Loading Rate, lb(water)/hour	Total Solids Loading per Dryer, lb(dry)/hour	Total Solids Loading to Dewatering ¹ , lb(dry)/hour	Number of Duty DCENs	Solids Loading per DCEN, lb(dry)/hour
AGS w/ 1 dryer train – DDS-50					
22.0%	11,000	3,203	3,372	1	3,372
23.0%		3,399	3,577		3,577
24.0%		3,600	3,789		3,789
25.0%		3,808	4,008		4,008
DAS w/ 1 dryer train – DDS-60					
22.0%	13,200	3,844	4,046	2	2,023
23.0%		3,078	4,293		2,146
24.0%		4,320	4,547		2,274
25.0%		4,569	4,810		2,405
AGS and DAS w/ 2 dryer trains – DDS-40					
22.0%	8,800	2,562	2,697	1	2,697
23.0%		2,719	2,862		2,862
24.0%		2,880	3,032		3,032
25.0%		3,046	3,206		3,206

¹Solids loading to dewatering is 105% of solids loading to drying due to 95% assumed capture loss through dewatering.

Table 4-9 shows the required dewatering equipment based on a redundancy concept of one additional unit, which can be used as a swing unit for the two dryer train operational scenario.

Table 4-9: Required Number of DCENs

Parameter	AGS w/ 1 dryer	DAS w/ 1 dryer	AGS and DAS w/ 2 dryers
Thermal Dryer Quantity	1	1	2
Number of Duty DCENs per Dryer	1	2	1
Number of Total Duty DCENs	1	2	2
Total Number of DCENs	2	3	3
DCEN Solids Loading Rate, lb(dry)/hr	4,000	2,400	3,200
DCEN Bowl Size, inches	28-29	20-21	24-25

Due to the available DCEN sizes, the required number of DCENs is generally less than that for BFPs, which also reduces the ancillary equipment required. For each centrifuge, the following ancillary equipment is required, as noted in TM No. 2b:

- Dewatering Feed Pump, one (1) per DCEN
- Dewatered Cake Conveyor, one (1) per DCEN
- Polymer Makeup Unit, one (1) per DCEN

Due to the space conserved by the compact DCEN footprint and reduced required equipment, the proposed solids handling facility will contain thickening, dewatering, and drying processes. The layout concept for a combined solids handling facility is a three story building, with the thermal drying space stretching into the second floor of the facility. The first floor area on the thickening and dewatering side of the facility will contain the thickening and dewatering feed pumps and a bulk polymer storage area. The second floor dewatering area will include the DCENs and additional space for electrical, HVAC, and control rooms. The third floor thickening area will include the RDTs and polymer conditioning, and any other ancillary rooms. Based on this concept, footprint requirements will be presented in Section 5.

5. Site Planning

Based on feedback provided in the thickening and dewatering technology assessment workshop with MSD, the preferred location for a new solids handling facility is in the space behind the former administration and training facility. This location is shown on the plant site, marked with a white arrow, in **Figure 5-1**.



Figure 5-1: New Solids Handling Facility Location

The space in this location is adequate for a facility with a maximum size of approximately 300 feet long and 100 feet wide. Additional sitework will be required to expand this space in the northwest direction.

Expansion in other directions is not recommended due to grade and potential conflicts with the ash lagoon. Space is also required around the facility for road access for truck hauling and service purposes.

5.1 Belt Filter Press

Based on the layout concept described in the belt filter press sizing section, the following building footprints were estimated for each BFP scenario. Additionally, the estimated sludge storage tank length was estimated based on the maximum building width of 100 feet. This method was used because there is more space lengthwise in the proposed location than widthwise.

Table 5-1: BFP Solids Handling Facility Footprint

Parameter	AGS w/ 1 dryer	AGS w/ 2 dryers	DAS w/ 1 dryer	DAS w/ 2 dryers
Thermal Dryer Quantity	1	2	1	2
Thermal Dryer Size	DDS-60	DDS-40	DDS-70	DDS-50
Belt Filter Press Quantity	3	5	3	5
Building Length, ft	180	200	185	200
Building Width, ft	75	100	75	100
Building Size, sq. ft.	13,500	20,000	13,875	20,000
Required Sludge Storage Length w/ 100 ft Tank Width, ft	112	28	190	90
Combined Solids Handling and Sludge Storage Facility Length, ft	292	228	390	290

Note that though the dryer equipment size is larger for one dryer train option, the building length for the two dryer train options was more driven by the footprint of the additional BFPs. The only scenario in which adequate space is present in this area for the required footprint of the sludge storage tankage is AGS with two thermal dryer trains. For all other scenarios, the required footprint either exceeds the footprint available in this area or does not allow adequate space around the facility for service road access.

To accommodate the large volume of sludge storage required for the BFP process flow, the gravity thickener area was determined to be an optimal location for sludge storage. The gravity thickeners are only 12 feet deep, so while this area provides more than enough space for the storage footprint, significant work would be required to retrofit the thickeners into aerated sludge storage tanks, or demolition of the thickeners would be required.

A blower pad is also required for the aeration blower enclosures. If the gravity thickeners are demolished and the space is utilized efficiently, the blower pad can also be located in this area. A dried product loadout area is proposed adjacent to the parking lot for the training facility. Dried product can be pneumatically conveyed across the short distance between the proposed solids handling facility and loadout location.

The largest of the one and two dryer train options for the BFP process option are shown based on the footprints from **Table 5-1**.

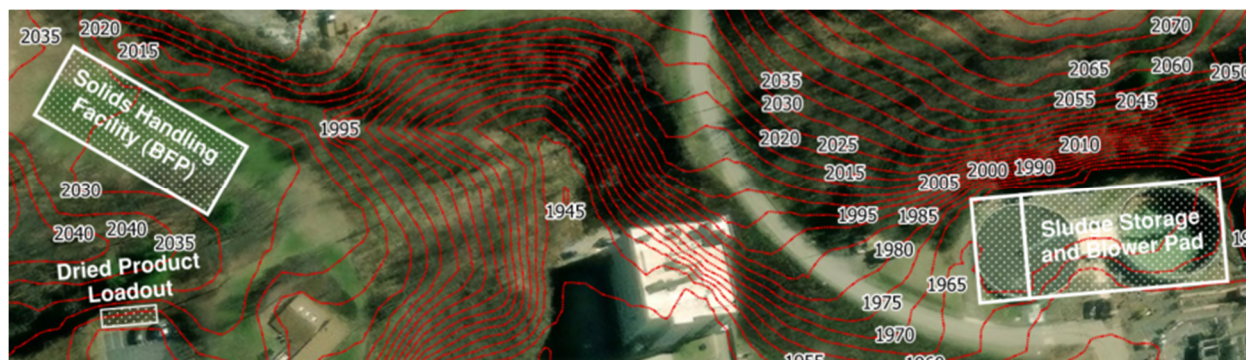


Figure 5-2: DAS 1 Dryer Train BFP Solids Handling Facility Site Plan

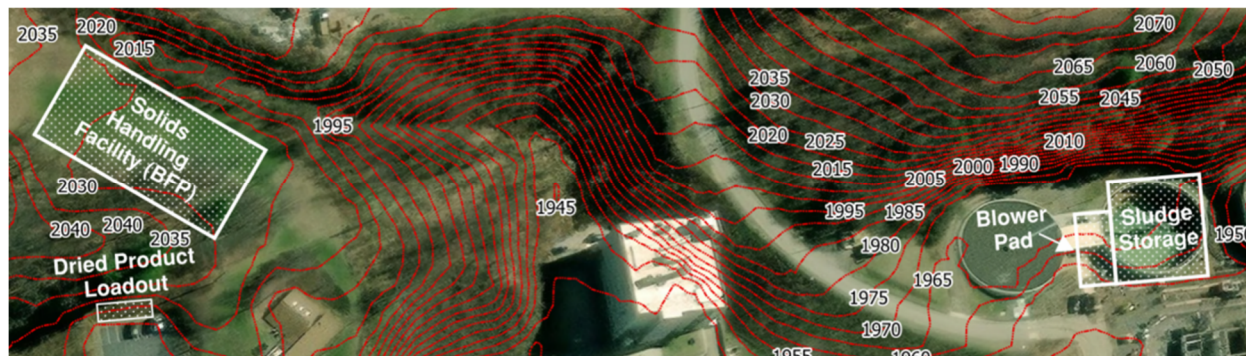


Figure 5-3: DAS 2 Dryer Train BFP Solids Handling Facility Site Plan

As previously mentioned, one option for sludge storage for the DAS two dryer train scenario is to retrofit the existing gravity thickeners for aerated sludge storage service. Both gravity thickeners would be required for this storage scenario due to the difference between the depth of the gravity thickeners and the proposed new sludge storage tanks. Cost savings are anticipated with leveraging the existing gravity thickeners. However, the location and footprint of the gravity thickeners may be desirable for liquid train improvements.

5.2 Dewatering Centrifuge

Based on the layout concept described in the centrifuge sizing section, the following building footprints were estimated for each DCEN scenario. Due to the decreased sludge storage required for thickened solids than for the BFP scenario, the sludge storage length was calculated based on the shown building width minus the width of the sludge blending tank, 30 feet. Note that though the AGS and DAS two dryer train options have the same dryer sizing and dewatering equipment requirements, the footprints are slightly different due to the additional RDT required for DAS thickening.

Table 5-2: DCEN Solids Handling Facility Footprint

Parameter	AGS w/ 1 dryer	AGS w/ 2 dryers	DAS w/ 1 dryer	DAS w/ 2 dryers
Thermal Dryer Quantity	1	2	1	2
Thermal Dryer Size	DDS-50	DDS-40	DDS-60	DDS-40
RDT Quantity	3	3	4	4
DCEN Quantity	2	3	3	3
Building Length, ft	170	165	190	175
Building Width, ft	75	100	75	100
Building Area, sq ft.	12,750	16,500	14,250	17,500
Required Sludge Storage Length, ft	60	24	74	17
Combined Solids Handling and Sludge Storage Facility Length, ft	230	189	264	197

For all four scenarios, there is adequate space for thickened sludge storage to be adjacent to the solids handling facility. Once a process option is selected, the sludge storage design can be refined to determine if aeration is required and if a swing unit can be provided for additional sludge blending. However, for conservative design, aerated storage was assumed. Thus, a blower pad is required for the aeration blower enclosures. Since smaller blowers will be required for these tanks than the pre-BFP secondary sludge storage tanks, a smaller blower pad is required. The additional space left by the shorter length of the sludge blending tank can be utilized for the blower pad.

A dried product loadout area is proposed adjacent to the parking lot for the training facility as shown on the BFP site plan. The largest of the one and two dryer train options for the DCEN process option are shown based on the footprints from **Table 5-2**.

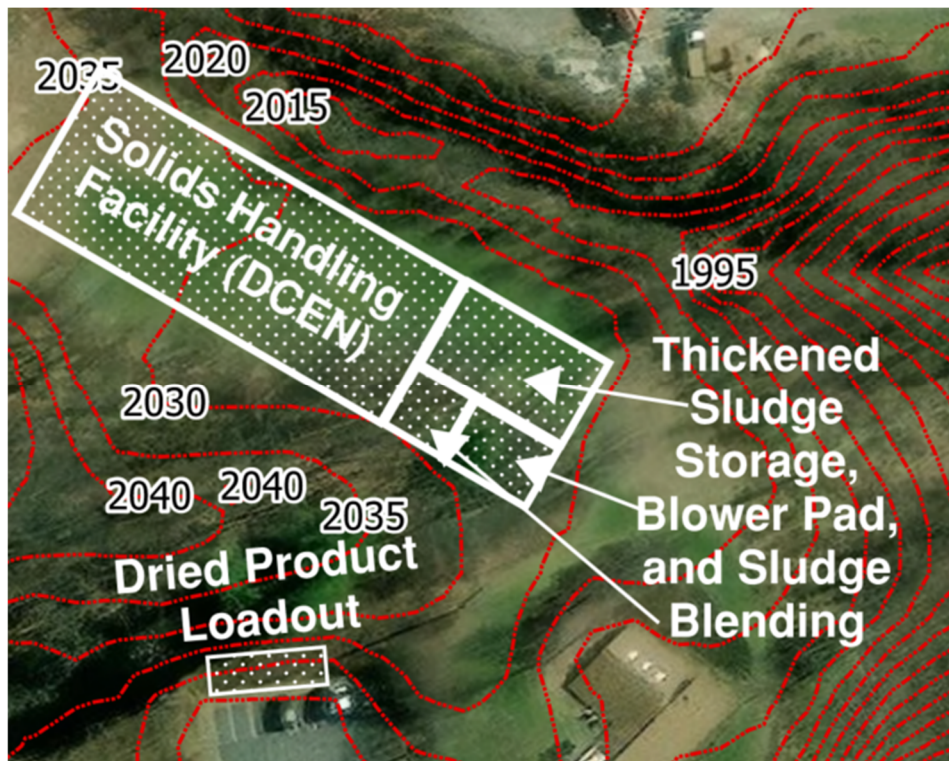


Figure 5-4: DAS 1 Dryer Train DCEN Solids Handling Facility Site Plan

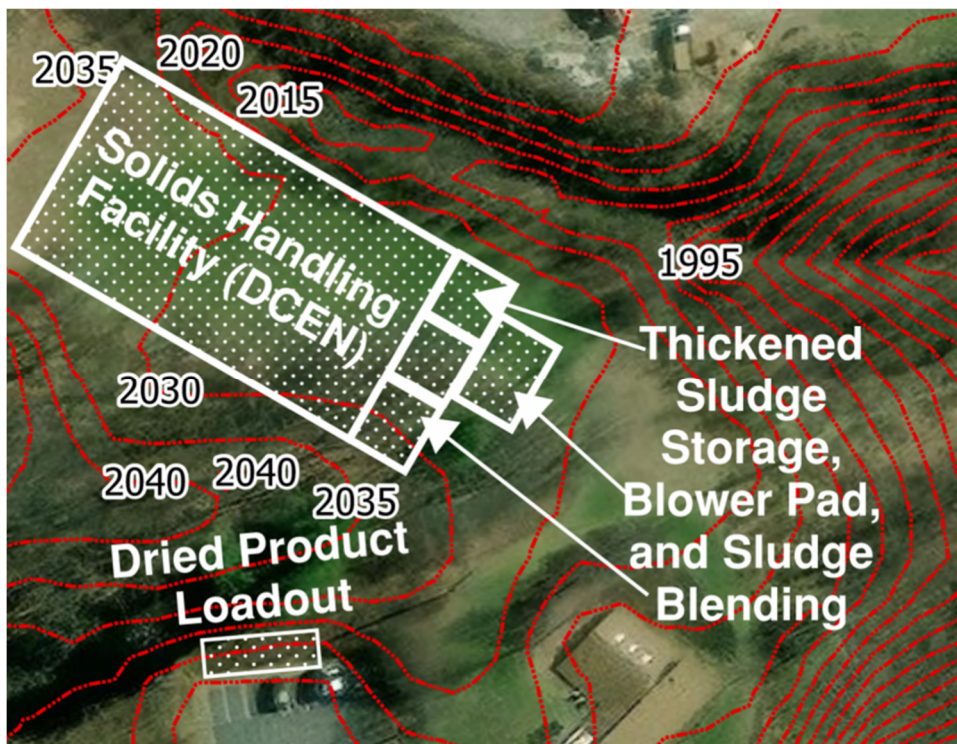


Figure 5-5: DAS 2 Dryer Train DCEN Solids Handling Facility Site Plan

6. Cost Estimate

Each facility concept was evaluated for capital and O&M costs.

6.1 Opinion of Probable Construction Cost

Capital costs are broken down by civil, mechanical, structural/architectural, and electrical/instrumentation costs. The following contingencies are then applied:

- Engineering Contingency: 30% (applied to Subtotal 1)
- Contractor Overhead, Profit, and Mobilization: 30% (applied to Subtotal 2)
- Owner's Allowance: 5% (applied to Subtotal 2)

The capital costs for each of the solids handling facility concepts previously laid out for the process options are shown in **Table 6-1**.

Table 6-1: Solids Handling Facility Capital Costs

Parameter	Belt Filter Press and Thermal Drying Scenario				Thickening, Dewatering Centrifuge and Thermal Drying Scenario			
	AGS w/ 1 dryer train	AGS w/ 2 dryer train	DAS w/ 1 dryer train	DAS w/ 2 dryer train	AGS w/ 1 dryer train	AGS w/ 2 dryer train	DAS w/ 1 dryer train	DAS w/ 2 dryer train
Civil Cost, \$	\$7,000,000	\$11,000,000	\$7,000,000	\$11,000,000	\$7,000,000	\$11,000,000	\$8,000,000	\$11,000,000
Mechanical and Equipment Cost, \$	\$35,000,000	\$56,000,000	\$36,000,000	\$60,000,000	\$33,000,000	\$58,000,000	\$36,000,000	\$58,000,000
Structural and Architectural Cost, \$	\$11,000,000	\$14,000,000	\$12,000,000	\$15,000,000	\$13,000,000	\$17,000,000	\$15,000,000	\$20,000,000
Electrical and I&C Cost, \$	\$11,000,000	\$18,000,000	\$12,000,000	\$19,000,000	\$12,000,000	\$18,000,000	\$13,000,000	\$19,000,000
Subtotal 1: Total Capital Cost, \$	\$64,000,000	\$99,000,000	\$67,000,000	\$105,000,000	\$65,000,000	\$104,000,000	\$72,000,000	\$108,000,000
Engineering Contingency (30%), \$	\$20,000,000	\$30,000,000	\$21,000,000	\$32,000,000	\$20,000,000	\$32,000,000	\$22,000,000	\$32,000,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$84,000,000	\$129,000,000	\$88,000,000	\$137,000,000	\$85,000,000	\$136,000,000	\$94,000,000	\$137,000,000
Contractor Overhead, Profit, and Mobilization (25%), \$	\$26,000,000	\$39,000,000	\$27,000,000	\$42,000,000	\$26,000,000	\$41,000,000	\$29,000,000	\$42,000,000

Parameter	Belt Filter Press and Thermal Drying Scenario				Thickening, Dewatering Centrifuge and Thermal Drying Scenario			
	AGS w/ 1 dryer train	AGS w/ 2 dryer train	DAS w/ 1 dryer train	DAS w/ 2 dryer train	AGS w/ 1 dryer train	AGS w/ 2 dryer train	DAS w/ 1 dryer train	DAS w/ 2 dryer train
Owner's Allowance (5%), \$	\$5,000,000	\$7,000,000	\$5,000,000	\$7,000,000	\$5,000,000	\$7,000,000	\$5,000,000	\$7,000,000
Total Project Cost, \$	\$115,000,000	\$175,000,000	\$120,000,000	\$186,000,000	\$116,000,000	\$184,000,000	\$128,000,000	\$186,000,000

As anticipated, the additional costs of an extra dryer and ancillary equipment significantly increase the cost of the two dryer train options compared to the one dryer train options. For each scenario, generally changing from a BFP to a DCEN allows for decreasing a dryer size, which makes the costs comparable for each liquid process alternative/dryer train scenario relative to the dewatering technology. However, this is not the case for the AGS with two dryer trains scenario for BFP and DCEN, which produces a cost discrepancy that is higher than that of other scenarios. This is particularly true because the pricing for each dryer size does not scale by processing capacity, as shown in **Table 2-2**.

Certain costs are specific to each dewatering technology or liquid process alternative, such as demolition of the GTs for the sludge storage space for BFP dewatering, construction of a sludge blending tank for DCEN dewatering, and an additional RDT for DCEN dewatering in the DAS scenario. To understand the full picture of cost differences between the two process options, the operational cost for each scenario must be considered.

In review of the alternatives with MSD, two dryer trains were deemed preferable for redundancy and future preparedness. However, installation of the second dryer train can be phased for when flows and loads require a second dryer. In the first phase of construction, a solids handling facility sized for two dryer trains will be constructed with one dryer train of equipment installed. The cost of this option is provided in Table 6-2 for the conservative DAS/DCEN scenario. Installation of the second dryer train is equal to the difference between the two options, but must be considered for the year that it will be installed.

Table 6-2: Cost of DAS with 1 dryer train installed

Parameter	DAS w/ 2 dryer train (1 installed now, 1 in future)
Civil Cost, \$	\$11,000,000
Mechanical and Equipment Cost, \$	\$33,000,000
Structural and Architectural Cost, \$	\$20,000,000
Electrical and I&C Cost, \$	\$13,000,000
Subtotal 1: Total Capital Cost, \$	\$77,000,000
Engineering Contingency (30%), \$	\$24,000,000
Subtotal 2: Total Capital and Engineering Cost, \$	\$101,000,000

Parameter	DAS w/ 2 dryer train (1 installed now, 1 in future)
Contractor Overhead, Profit, and Mobilization (25%), \$	\$31,000,000
Owner's Allowance (5%), \$	\$6,000,000
Total Project Cost, \$	\$138,000,000

6.2 Operation and Maintenance Cost

In the O&M cost evaluation, the assumptions shown in **Table 6-3** were used.

Table 6-3: O&M Cost Assumptions

Parameter	Assumed Value
Electrical Power Unit Cost ¹ , \$/kWh	\$0.058
Electrical Utilization Factor	70%
Emulsion Polymer Unit Cost ² , \$/lb active	\$2.35
RDT Polymer Dose, lb(APS)/dT	14
BFP Polymer Dose, lb(APS)/dT	25
DCEN Polymer Dose, lb(APS)/dT	40
Natural Gas Unit Cost ³ , \$/MMBtu	\$3.45
Thermal Dryer, BTU/lb water evaporated	1,400
Fully Loaded FTE Labor Cost, \$/year-FTE	\$88,000
Inflation Rate, %/year	3%
Discount Rate, %/year	5%
Real Discount Rate, %/year	1.9%
¹ Updated based on recent invoices and upgrade to large general service tier by MSD's electric utility provider.	
² Updated based on cost data from MSD on actual polymer costs.	
³ Updated from \$10/MMBtu during development of Incineration O&M based on 2024 cost data from MSD.	

In the process of developing the incineration O&M cost, the thermal drying O&M was updated. Labor requirements were developed in further detail for both options by referring to the Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants, developed by the New England Interstate Water Pollution Control Commission (NEIWPCC). This guide assumes 1,500 productive work hours per year per FTE, with 6 useful hours per shift, 5-day weeks, and 50 work weeks. **Table 6-4** provides a summary of the labor hours used in each unit process to estimate the total FTEs for each operational scenario.

Table 6-4: NEIWPCC Drying and Incineration Staffing Estimate

Parameter	Belt Filter Press and Thermal Drying Scenario		Thickening, Dewatering Centrifuge and Thermal Drying Scenario	
	1	2	1	2
Number of Dryers	1	2	1	2
Sludge Storage Annual Hours	730	730	730	730
Thickening Annual Hours	313	N/A	730	730
Dewatering Annual Hours	3,337	5,840	1,669	2,920
Final Solids (Drying or Incineration) Annual Hours	5,006	8,760	5,006	8,760
Total Annual Hours	9,386	15,330	8,134	13,140
Total FTEs Required	6.5	10.5	5.5	9.0

BFPs are more labor intensive to operate than DCENs, which results in labor savings for the DCEN scenarios, despite the additional separate thickening process. A thickening labor requirement was carried for the belt filter press scenario under 1 dryer train to account for recuperative thickening during dryer downtime to extend storage capacity. For 1 dryer train scenarios, a 24/4 operational schedule was assumed based on AVG365 sizing. For 2 dryer train scenarios, a 24/7 operational schedule was assumed per the design criteria. Thus, the labor hours scale by hours of annual operation rather than by number of dryers in operation.

Annual maintenance costs were assumed to be 3% of equipment capital costs and 1% of structural and architectural building costs. O&M costs for each of the options are shown below.

Table 6-5: Solids Handling Facility O&M Costs

Parameter	Belt Filter Press and Thermal Drying Scenario				Thickening, Dewatering Centrifuge and Thermal Drying Scenario			
	AGS w/ 1 dryer train	AGS w/ 2 dryer trains	DAS w/ 1 dryer train	DAS w/ 2 dryer trains	AGS w/ 1 dryer train	AGS w/ 2 dryer trains	DAS w/ 1 dryer train	DAS w/ 2 dryer trains
Thickening								
Power Cost, \$/dT	N/A				\$4.90			
Polymer Cost, \$/dT					\$33.90			
Total Cost, \$/dT					\$37.80			
Sludge Storage								
Power Cost, \$/dT	\$14.76	\$6.15	\$16.41	\$9.85	\$6.99	\$6.99	\$6.22	\$6.22
Dewatering								
Power Cost, \$/dT	\$3.05	\$4.33	\$3.41	\$3.56	\$5.11	\$3.83	\$5.11	\$3.83
Polymer Cost, \$/dT	\$58.75				\$94.00			
Total Cost, \$/dT	\$61.80	\$63.08	\$62.16	\$62.31	\$99.11	\$97.83	\$99.11	\$97.83
Thermal Drying								
Power Cost, \$/dT	\$8.19	\$7.16	\$14.32	\$7.16	\$12.65	\$6.33	\$12.65	\$6.33

Parameter	Belt Filter Press and Thermal Drying Scenario				Thickening, Dewatering Centrifuge and Thermal Drying Scenario			
	AGS w/ 1 dryer train	AGS w/ 2 dryer trains	DAS w/ 1 dryer train	DAS w/ 2 dryer trains	AGS w/ 1 dryer train	AGS w/ 2 dryer trains	DAS w/ 1 dryer train	DAS w/ 2 dryer trains
Fuel Demand, MMBtu/hr	18.6	12.4	21.7	15.5	15.5	12.4	18.6	12.4
Natural Gas Cost, \$/dT	\$37.73				\$33.33			
Total Cost, \$/dT	\$45.92	\$44.89	\$52.05	\$44.89	\$45.97	\$39.65	\$45.96	\$39.65
Total								
Annual Operation Cost, \$/year (2024)	\$815,000	\$759,000	\$929,000	\$833,000	\$1,222,000	\$1,175,000	\$1,302,000	\$1,251,000
Full-Time Employees	6.5	10.5	6.5	10.5	5.5	9.0	5.5	9.0
Annual Labor Cost, \$/year (2024)	\$572,000	\$924,000	\$572,000	\$924,000	\$506,000	\$792,000	\$506,000	\$792,000
Annual Maintenance Cost, \$/year (2024)	\$1,136,000	\$1,823,000	\$1,193,000	\$1,940,000	\$1,119,000	\$1,885,000	\$1,235,000	\$1,874,000
Annual OPEX Cost (2024)	\$2,524,000	\$3,506,000	\$2,694,000	\$3,697,000	\$2,847,000	\$3,852,000	\$3,043,000	\$3,918,000

6.3 Lifecycle Cost Estimate

The capital costs and O&M costs were used to determine the 20-year lifecycle cost for each of the options.

Table 6-6: Solids Handling Facility Lifecycle Costs

Parameter	Belt Filter Press and Thermal Drying Scenario				Thickening, Dewatering Centrifuge and Thermal Drying Scenario			
	AGS w/ 1 dryer train	AGS w/ 2 dryer trains	DAS w/ 1 dryer train	DAS w/ 2 dryer trains	AGS w/ 1 dryer train	AGS w/ 2 dryer trains	DAS w/ 1 dryer train	DAS w/ 2 dryer trains
CAPEX Cost (2024)	\$115,000,000	\$175,000,000	\$120,000,000	\$186,000,000	\$116,000,000	\$184,000,000	\$128,000,000	\$186,000,000
20-year Labor Cost	\$10,000,000	\$15,000,000	\$10,000,000	\$15,000,000	\$9,000,000	\$13,000,000	\$9,000,000	\$13,000,000
20-year Operation Cost	\$15,000,000	\$14,000,000	\$17,000,000	\$16,000,000	\$22,000,000	\$22,000,000	\$24,000,000	\$23,000,000
20-year Maintenance Cost	\$19,000,000	\$31,000,000	\$20,000,000	\$33,000,000	\$19,000,000	\$32,000,000	\$21,000,000	\$32,000,000
20-year Total OPEX Cost	\$44,000,000	\$60,000,000	\$47,000,000	\$64,000,000	\$50,000,000	\$67,000,000	\$54,000,000	\$68,000,000
20-year Lifecycle Cost	\$159,000,000	\$235,000,000	\$167,000,000	\$250,000,000	\$166,000,000	\$251,000,000	\$182,000,000	\$254,000,000

Fundamental cost differences are primarily present when adding a dryer train for each scenario. An additional dryer train results in added capital costs for the second dryer and ancillary equipment, added maintenance costs, and added labor costs. On average, an additional dryer train adds 40% more lifecycle costs for the same processing scenario. As mentioned previously, the increased cake content produced by centrifuge dewatering allows for decreasing dryer size, which means that costs are comparable for the same scenario with BFP or DCEN dewatering. This is not the case only for AGS with two dryer trains. This sizing can be further refined to determine if such a size reduction is possible to reduce costs.

7. Conclusions

Thermal drying presents a viable solids management technology for MSD. For each of the scenarios detailed in this report, considering the different liquid process alternatives, dewatering technologies, and number of dryer trains, a thermal drying based solids handling facility can be achieved on the FBRWRF site. There are certainly benefits to different scenarios. Proceeding with one dryer train will have a lower cost for all the alternatives, but will not maintain as much redundancy as two dryer trains. The probable construction cost range for the single dryer train options ranges from \$115-130 million, while the range for dual dryer train options is from \$175-186 million. With the phased alternative selected by MSD with one dryer train installed now and a second installed in the future, the cost is approximately \$138M, which is higher than that for a single dryer train due to the building sized for two dryers.

Due to the sludge storage requirement for 3-belt BFP combined thickening and dewatering, the footprint of the existing gravity thickeners is required for the sludge storage footprint. For the DCEN process option, all solids processes can be achieved in the desired solids handling facility location. Additionally, due to the limitations in processing capacity of BFPs, more equipment is required for the BFP dewatering process, which increases the footprint and cost of that option.

For the dewatering technology selection, there are additional cost considerations. **Table 7-1** shows a comparison of the lifecycle costs for each scenario by dewatering technology.

Table 7-1: BFP and DCEN Lifecycle Cost Comparison

Dewatering Technology Scenario	BFP		DCEN	
	DDS	Cost	DDS	Cost
AGS w/ 1 dryer train	DDS-60	\$159,000,000	DDS-50	\$166,000,000
AGS w/ 2 dryer trains	DDS-40	\$235,000,000	DDS-40	\$251,000,000
DAS w/ 1 dryer train	DDS-70	\$167,000,000	DDS-60	\$182,000,000
DAS w/ 2 dryer train	DDS-50	\$250,000,000	DDS-40	\$254,000,000

The cost differences between the process flow options become significant when dryer size reduction cannot be achieved, such as in the AGS with two dryer trains scenario, which has a DDS-40 for both dewatering technology options. If thermal drying is selected as the primary solids management technology, thermal dryer sizing can be further refined by the solids scenario to optimize capital, operational, and maintenance costs.

French Broad River Water Reclamation Facility

Asheville, NC

PRELIMINARY ENGINEERING REPORT ON LONG TERM BIOSOLIDS DISPOSAL

May 30, 2025

Presented by: Chavond-Barry Engineering Corp.

TABLE OF CONTENTS

BACKGROUND	4
1. SLUDGE DISPOSAL TECHNOLOGIES.....	4
1.A SLUDGE DISPOSAL TECHNOLOGIES – FLUIDIZED BED WITH REFRACTORY DOME	5
1.B SLUDGE DISPOSAL TECHNOLOGIES – FLUIDIZED BED WITH PIPE TUYERE	6
2 ENERGY RECOVERY	7
2.A ENERGY RECOVERY - HEAT EXCHANGERS.....	8
2.B ENERGY RECOVERY - BOILERS.....	8
3. AIR POLLUTION CONTROLS	10
3.A AIR POLLUTION CONTROLS - SCRUBBER.....	10
3.B AIR POLLUTION CONTROLS - WESP	11
4.A MERCURY CONTROL – CARBON VESSEL	11
4.A.1 MERCURY CONTROL – CARBON BED PRE-CONDITIONING SYSTEMS	13
4.B MERCURY CONTROL – SPC MODULES	13
4.C MERCURY CONTROL – CARBON INJECTION	15
5.A ADDITIONAL SYSTEM CONSIDERATIONS – DIOXIN FURAN	16
5.B ADDITIONAL SYSTEM CONSIDERATIONS – PFAS.....	17
5.C ADDITIONAL SYSTEM CONSIDERATIONS – SCRUBBER WATER MERCURY	18
5.D ADDITIONAL SYSTEM CONSIDERATIONS – REDUNDANCY	19
5.E ASH THICKENING	20
5.F AMMONIA/UREA INJECTION FOR NO _x CONTROL	21
6. EQUIPMENT SIZING AND BUDGETARY PRICING	21
7. UTILITIES CONSUMPTION	22
8. REGULATORY SUMMARY	22
9. LAND USAGE ESTIMATE	23
10. RECOMMENDATIONS AND ANALYSIS	24
11. CONCLUSIONS	28
12. APPENDIX	28
APPENDIX 1. LONG-TERM HAZEN & SAWYER SLUDGE THROUGHPUT.....	29
APPENDIX 2. PRELIMINARY INCINERATOR CROSS-SECTION (Refractory Arch Bed Dome Design).....	30

APPENDIX 3. PRELIMINARY FLUIDIZED BED PROCESS FLOW DIAGRAM (PFD)	31
APPENDIX 4. PRELIMINARY LAYOUT OF MAJOR EQUIPMENT	32

BACKGROUND

In 2023 the French Broad River Water Reclamation Facility (FBRWRF) in Asheville NC commissioned a Hazen and Sawyer and Chavond-Barry Engineering (CBE) team to perform a long-term 30-yr biosolids study to assess the optimal long-term sludge disposal options. Hazen and Sawyer performed an analysis to determine the anticipated 30-yr max weekly sludge throughput to be 89,000 dry lb/day (Ref. Appendix 1) which CBE is using to assess the sludge disposal options. In this study we will review the pros and cons of sludge disposal through sludge incineration using a fluidized bed or multiple hearth incinerator. Energy recovery options will be explored as will flue gas cleaning technologies. Preliminary utilities consumption and land coverage requirements will be analyzed. A new physical location will likely be required which would likely be the area near the ash lagoon at the top of the hill (Ref. figure 14). It is possible that during detailed engineering the existing building may be able to fit the new incinerator; however, that will be contingent upon final sizing and access requirements and elevations of the selected equipment – which is unknown at this point. We will conclude this study with recommendations about the best technology to use.

The current sludge dewatering equipment is sized to handle the needs of today; however, in 30 years the sludge processing is anticipated to increase by roughly 40% meaning the new incinerator would need new sludge dewatering equipment as well.

INCINERATOR DESIGN CRITERIA

Design sludge feed rate	89,000 dry lb/day (3,708 dry lb/day)
Sludge cake dryness	20-25%
Sludge feed turndown ratio	Primarily limited by scrubber dP requirement - typical values around 2:1 or greater but TBD during detailed design.

1. SLUDGE DISPOSAL TECHNOLOGIES

In this document we will cover two common sludge disposal options; namely, Fluidized Bed Incinerators (FBI) and Multiple Hearth Incinerators (MHI). There are many additional sludge disposal technologies available in addition to the ones discussed such as steel dome FBIs, supercritical water, Veolia's ERS (dryer and grate incinerator), and others; however, the majority of these are not commercially proven technologies yet (or may have only a couple in operation). Therefore we did not include these additional technologies to avoid the risk of being the first with a new sludge disposal technology.

Multiple hearth incinerators have largely been replaced by fluidized bed incinerators for the past 20+ years because MHI are more difficult to operate and can have emissions that can bypass the air pollution controls (resulting in fines) during upset conditions and power interruptions. Multiple hearths are typically only used for mineral roasting or activated carbon applications these days due to fluidized beds not being suited to those applications. Multiple hearth operation is complicated due to the countercurrent flows of sludge and gases through 7-10 stacked 25ft diameter incinerator hearths. Thus a change in one hearth takes up to an hour or more to fully play out and reach steady state within the

whole incinerator. The price difference between an FBI and MHI is expected to be minimal. Additionally, FBRWRF has no experience operating MHI so much of the institutional knowledge built up from operating an FBI would be lost by changing to an MHI. For these reasons, MHI are not going to be further analyzed because aforementioned reasons. Lastly, direct landfill has already been addressed by Hazen and therefore is not re-assessed in this report.

1.A SLUDGE DISPOSAL TECHNOLOGIES – FLUIDIZED BED WITH REFRACTORY DOME

The FBRWRF currently uses an FBI with refractory dome and is familiar with its intricacies and abilities. As such, the review of what this system is and does will be slightly shorter.

The fluidized bed incinerator is comprised of three sections – the windbox, the bed, and the freeboard section. The windbox acts as a combustion air distribution plenum to allow the air to access the entire bed area uniformly. The preheated combustion air passes through the refractory dome via stainless steel cast tuyeres which are anchored in the refractory dome.

The tuyeres have holes drilled around their circumference to permit the air to pass through the dome and into the bed. The bed section is filled with sand which is fluidized by the combustion air. Auxiliary fuel (natural gas or fuel oil – currently natural gas is used) and sludge are fed into the bed region and are combusted. The combustion air and products of combustion from the sludge and auxiliary fuel then enter the freeboard section of the incinerator.

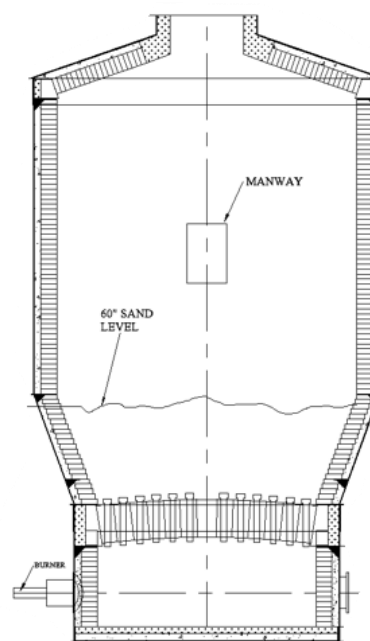


Figure 1. FBI with refractory dome

The freeboard section serves as the afterburner to ensure products of incomplete combustion leaving the bed section such as carbon monoxide, Volatile Organic Compounds (VOC), etc. are fully combusted to minimize airborne pollution emitted from the incinerator stack. The combustion gases and ash from the sludge then exit the incinerator and proceed downstream to the heat recovery and air pollution control systems.

To facilitate cold start-up there is a windbox burner which slowly heats the system up to the point where auxiliary fuel and/or sludge feed can be safely introduced. The burners typically operate using natural gas, fuel oil, or are dual fuel.

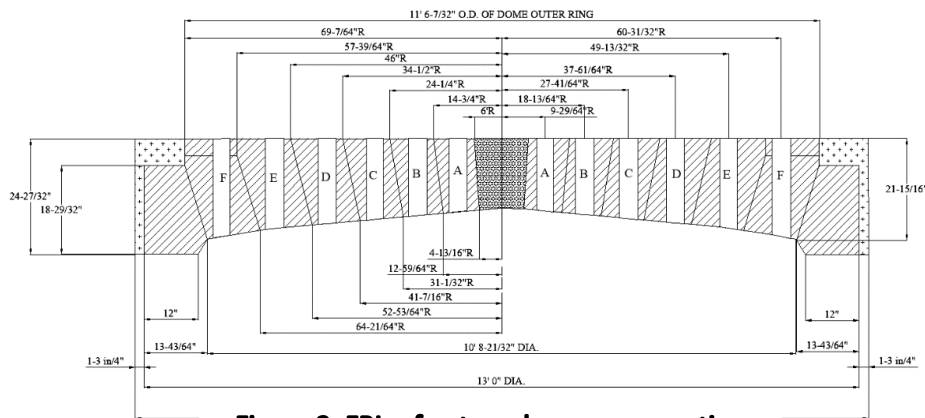


Figure 2. FBI refractory dome cross-section

The refractory dome is comprised of a series of specially cast refractory dome blocks with holes for the tuyeres in them. A sample dome block cross-section is shown to the right.

1.B SLUDGE DISPOSAL TECHNOLOGIES – FLUIDIZED BED WITH PIPE TUYERE

The other main type of air distribution system is the pipe tuyere. This system is different than a refractory dome in several ways. The windbox section is converted into part of the combustion volume of the incinerator with the windbox (air manifold) being placed outside of the incinerator, see sketch below.

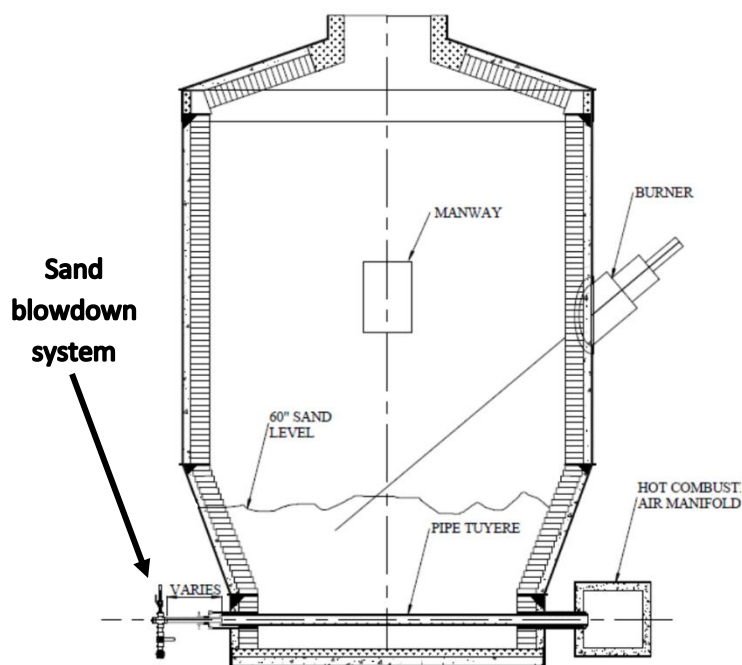


Figure 3. FBI with pipe tuyere

In a pipe tuyere system, a series of specially constructed long pipes are placed within the “windbox” section of the incinerator. Holes are placed on the underside of these pipes to uniformly distribute air into the sand. By placing the holes on the underside of the pipes the amount of sand entering into the pipes can be greatly reduced. The small amount of sand which does enter the pipes can be safely removed while operating the incinerator by use of the sand blowdown system located at the end of the pipe (left side of Figure 3). This system quenches the hot sand and air to allow the user to clean the pipe quickly and safely while online. Figure 4 below provides a more detailed view of the pipe tuyere blowdown assembly.

The pipe tuyere system undergoes thermal expansion due to the preheated combustion air and hot sand, causing the pipes to grow as much as 2-3 inches while in operation. The pipes are free to thermally expand through a packing gland placed on the blowdown end of the pipe.

To facilitate maintenance of the pipe tuyere system the area in front of the pipe tuyere would need to remain clear of other equipment so that the pipes can be easily removed or replaced in the future in the unlikely event it becomes necessary.

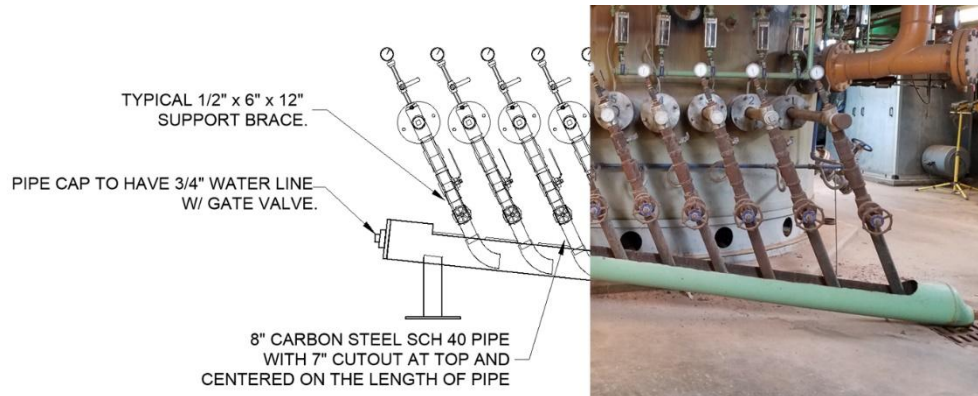


Figure 4. Pipe tuyere blowdown

2 ENERGY RECOVERY

There are two main types of energy recovery available to any fluidized bed incinerator – heat exchangers and boilers (and sometimes a combination of the two). Heat exchangers are by far the most common system primarily because they are simple to operate, provide significant fuel savings, and require minimal maintenance.

Energy recovery using a boiler is less common because the waste heat available is relatively small compared to the investment costs which causes a longer Return On Investment (ROI) period for a boiler. If a boiler is used it is typically used in addition to a heat exchanger where the heat exchanger provides fuel savings (by preheating the combustion air for the incinerator) and the boiler produces building heat, electricity, or both.

2.A ENERGY RECOVERY - HEAT EXCHANGERS

The flue gas leaving the freeboard of the incinerator typically is in the 1500-1600°F range. Typically, there is a shell and tube type Primary Heat Exchanger (PHEX) to preheat the combustion air using the waste heat contained in the flue gas. Combustion air flows up on the shell side of the heat exchanger passing around the tubes which contain the hot flue gas. This can typically achieve a combustion air temperature of around 1200°F which significantly decreases the need for auxiliary fuel.

There is often a shell and tube type Secondary Heat Exchanger (SHEX) and occasionally a tertiary heat exchanger installed downstream of the primary. These usually reheat flue gases after they are cleaned for better dispersion, plume suppression, or preheats flue gas for downstream process needs.



Figure 5. Primary heat exchanger

2.B ENERGY RECOVERY - BOILERS

Boilers are sometimes used on fluidized bed incinerators to create steam for building heat, electricity production, or both. From a return on investment perspective typically only large scale fluidized bed incinerators break even on the additional investment of a boiler. Boilers require a substantial amount of dedicated equipment beyond just the boiler itself. A typical system is comprised of a boiler with steam superheat section, steam drum, pumps, boiler water conditioning system, various safety systems, and a turbine with generator (for electricity production). Additionally, staff must be trained to maintain and operate a steam power generation / steam building heat system. These systems typically will cost several million dollars and require ongoing maintenance. There are only a handful of incinerator facilities that have boiler energy recovery (such as Metro Counsel in Minneapolis MN) and they are substantially larger facilities than FBRWRF (Metro has 3 incinerators which run simultaneously each with a 5.4 dry ton/hr sludge feed rate limit). Figure 6 below shows a simplified schematic of a boiler power generation system.

One downside to a boiler is that it causes the flue gas temperature to decrease slowly instead of quickly quenching it. This increases how long the flue gas is in a temperature range where Dioxins/Furans can recombine which might increase emissions of that pollutant class. This would need to be reviewed more carefully should a boiler be used (Ref. Section 5.B for more on PFAS).

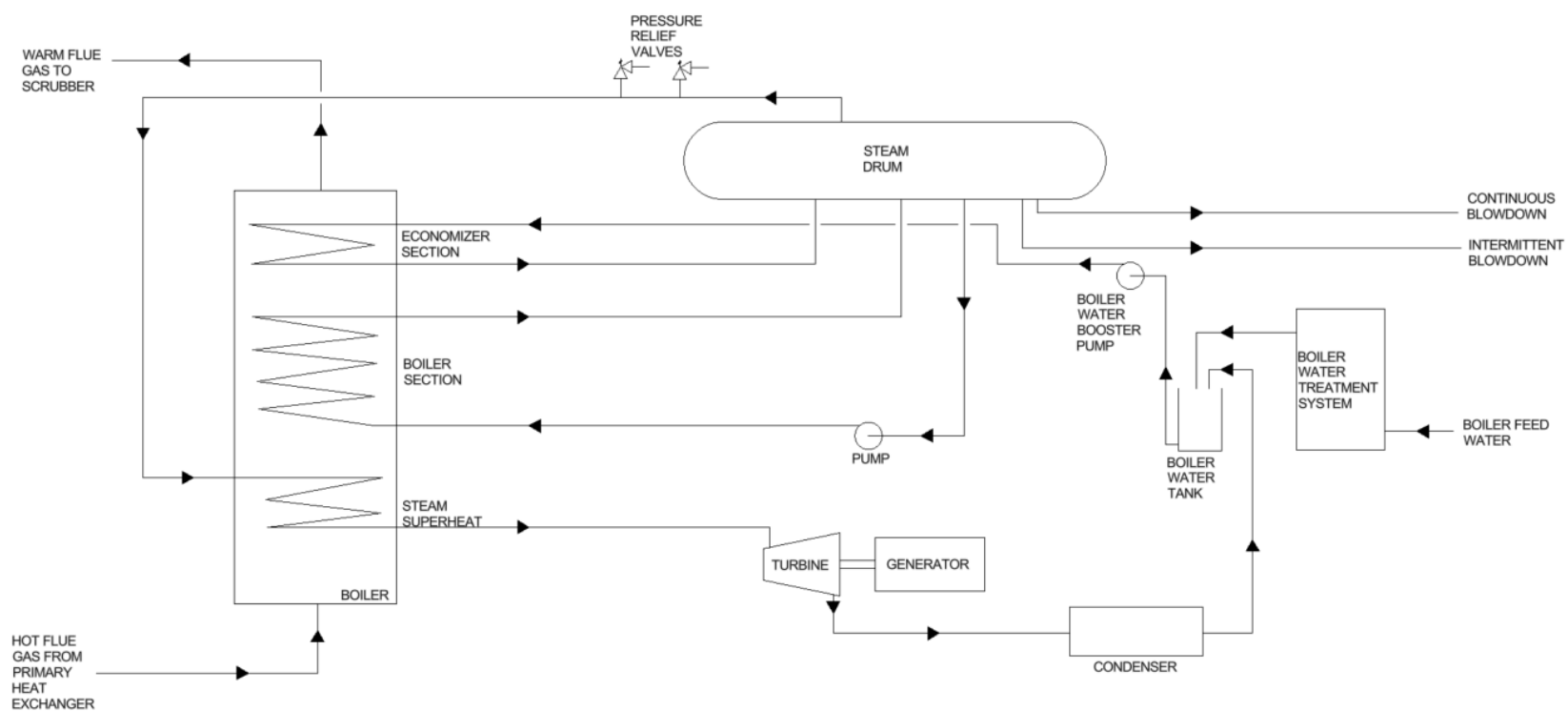


Figure 6. Boiler system power generation schematic

3. AIR POLLUTION CONTROLS

In this section we will cover the air pollution control technologies commonly found on incinerator systems. These systems have evolved to become increasingly capable of reducing emissions to protect the environment and meet regulatory requirements. There are a host of systems available which rely upon different techniques to control pollution such as cleaning with water, electric fields, filters (see section 4), and activated carbon (see Section 4).

3.A AIR POLLUTION CONTROLS - SCRUBBER

Before the flue gas can be scrubbed to control pollution the gases must be cooled by quenching them with water. The quencher uses water (typically plant effluent) to cool the gas stream to around 120°F or less from around 900°F (if heat exchangers are utilized or 1500-1600°F without heat exchangers). This equipment is then followed by the scrubber system. The scrubber is usually comprised of a venturi and tray scrubber although some manufacturers combine them into a single piece of equipment such as the EnviroCare VenturiPak scrubber system. This equipment removes acid gases (SO_2 and HCl) and most of the particulate matter. The



Figure 7. VenturiPak scrubber

water leaving the scrubber system would contain most of the ash and sand particulate (often 99+% of the ash in the sludge and entrained sand). This would then be sent to the ash lagoon to allow the particulate to precipitate. The scrubber would likely need intermittent use of caustic to help control acid gases. Acid gases that are removed by the scrubber would leave the vessel with the ash laden water and be sent to the ash lagoon. Typical sludge has around 1% Sulfur and 0.1% Chlorine. The acid loading to the scrubber (at 2 dry tons/hr) would therefore be around 80 lb/hr of SO_2 and 4.1 lb/hr of HCl . Almost all of this acid would be captured and the acidic water and salts formed by the neutralization reaction with the caustic are sent with the scrubber water to the ash lagoon.

The new scrubber would have a sizable increase in water consumption due to the increased sludge feed rate and requirements to meet stricter emission limits. The current scrubber uses approximately 680gpm of water whereas the new scrubber would require around 1100gpm.

The likely location of the new incinerator system is at a greater elevation than the current incinerator; thus, larger piping and pumps would be needed to supply water to the new scrubber. Likewise, a larger drain pipe going to the plant headworks would also be needed. We believe a likely location for the new incinerator system is on top of the hill by the ash lagoon. Assuming that an ash thickening system is used to divert most of the scrubber water away from the ash lagoon there should be ample elevation

difference to use a gravity drain instead of pumping the scrubber drain to the headworks. Similarly, the ash lagoon may need a larger drain going to the plant headworks which, given the elevation, would be a gravity drain as well.

3.B AIR POLLUTION CONTROLS - WESP



Figure 8. WESP internals

Following the scrubber would be a Wet Electrostatic Precipitator (WESP) to assist in removing metals and additional particulate matter from the flue gas stream. This equipment utilizes a strong electric field to collect many different types of metal (not mercury) and particulate onto collector plates. These collector plates are intermittently (automatically) washed through a built-in water spray to ensure the unit continues to operate efficiently. The metals and particulate which are collected on this equipment would be sent to a common drain with the scrubber water. A picture of the inside of a WESP is shown in Figure 8. A strong electric field (around 40-60kV) exists between the electrodes and the honeycomb collector plates. The electric field causes particulates to cling to the collector plates thereby cleaning the gas stream.

4.A MERCURY CONTROL – CARBON VESSEL

A carbon bed vessel is full of activated carbon pellets which are impregnated with sulfur for purposes of mercury control. The mercury in the gas stream chemically binds with the sulfur on the activated carbon to form a mercury-sulfur (HgS) compound which is stable and locked safely within the carbon. Most carbon beds are designed to handle around 8-10 years worth of worst-case (max sludge mercury concentration and 8760hr/year) mercury loading without replacing the carbon when using a HEPA prefilter. Once the carbon is spent it would need to be replaced and may be considered hazardous waste depending on the mercury content at time of disposal.



Figure 9. Activated carbon pellets in an adsorber

Carbon bed systems such as the APC Technologies Inc. brand adsorber have been installed in many locations and have a demonstrated history of meeting the new fluidized bed emission standards (40CFR 60 Subpart LLLL).

In order to start up the carbon vessel, it must first be warmed up (typically around 125-135°F). Typically, a small blower with electric resistance heater is installed that provides a stream of warm air through the vessel to get it up to operating temperature. Once at temperature the unit can be switched to normal operation to begin processing flue gas.

There are several facilities which have had thermal excursion incidents while using carbon bed systems manufactured by CPPE. Many of the early installation of carbon vessel were supplied by CPPE of Luxembourg which have caught fire over the years. To the best of our knowledge, this has only occurred on the CPPE brand systems. This has understandably caused trepidation about this technology for many clients and influenced them to utilize alternative technology. CPPE carbon vessels would not be permitted but there are other brands which have not had fires such as the firm, APC Technologies Inc. (APC). APC currently has seven SSI installations and are currently working on another six SSI installations. Their installations have worked well over the years and operated without having any fires or thermal excursion events. Over half of the CPPE units have had thermal excursions over the years, many causing damage to the equipment over the years.

Some facilities with CPPE adsorbers have installed automated carbon monoxide detectors and quench water lances to the vessels to detect if the carbon is beginning to self-heat and stop it prior to it becoming a bigger issue.

Carbon bed systems are slightly different than the Sorbent Polymer Cartridges (SPC) and carbon injection systems which will be described in sections 4.B and 4.C, respectively. Carbon bed systems require some gas pre-conditioning equipment to be installed in order to further clean and heat the flue gas stream to prolong the useful life of the carbon. The pre-conditioning systems are described next.

4.A.1 MERCURY CONTROL – CARBON BED PRE-CONDITIONING SYSTEMS

A preconditioning system is required prior to a carbon bed. This includes a prefilter that protects the carbon from fouling over years of operation with any ash that made it through the scrubber and WESP. Additionally, the cleaned flue gas must be reheated by a secondary/tertiary heat exchanger in order to avoid water condensing on the carbon. APC Technologies has used a mixture of Ultra-high Efficiency Filter (UHF) and/or High Efficiency Particulate Air (HEPA) filter to help ensure ultra clean gas is going to the mercury control system. The UHF filter (see Figure 10) uses a roll of filter fabric which automatically advances through the gas stream capturing particulate. The HEPA systems utilize disposable filter cartridges to help collect any remaining particulate matter before it reaches the mercury control system to help prolong the life of the carbon bed by reducing plugging.



Figure 10. UHF

Following the UHF/HEPA filters the gas may need to be reheated to avoid sending overly humid gas to the carbon bed system. The high humidity gas leaving the scrubber (typically saturated) could cause condensation on the carbon which would create a thin barrier of water on the carbon surface which would limit the ability of the system to adsorb mercury. The reheated gas is at a much lower humidity which helps prevent this condensation from occurring. The UHF/HEPA filter requirements are common when using a carbon bed to control mercury; however, they are not normally used if an SPC module or carbon injection system is used.

4.B MERCURY CONTROL – SPC MODULES



Figure 11. SPC modules

An alternative technology to the carbon vessel is the Sorbent Polymer Cartridge (SPC) mercury adsorbing module system which is marketed through EnviroCare. This system does not require a UHF/HEPA filter or a reheat cycle. The SPC modules work on a similar principle as the carbon bed system by utilizing sulfur impregnated activated carbon; however, with SPC modules the carbon is held within a corrugated polymer matrix to increase surface area and efficiently remove mercury from the

exhaust gases. This system would also require the flue gases to not be at saturation conditions (i.e. not at 100% humidity) for optimal control efficiency; however, the targeted reduction in humidity is much less and can typically be accomplished by the WESP purge air – which all WESPS require to operate. Thus no additional equipment is typically required to condition the flue gas for the SPC system.

To meet the new fluidized bed incinerator emission code, the SPC system would require a free-standing vessel with around 10-13 layers of modules, probably six modules wide (based upon manufacturer sizing). When a module layer reaches the end of its useful life that layer is removed and the subsequent layers rotated (layer 3 moves to layer 2, layer 4 moves to layer 3, etc.). A new layer of modules are then installed as the final layer and the unit is returned to service. The lifespan of an SPC layer varies based upon mercury concentration in the sludge, sludge feed rate, incinerator duty cycle, etc.; however, a layer will likely last 1-3 years before needing to be replaced. Disposal of the mercury modules after use will likely be considered hazardous waste due to the mercury loading (similar to how carbon bed material is typically deemed hazardous waste after use). Each SPC module costs around 10-12k thus a layer would cost around \$60-75k to replace.

It should be noted that if the mercury SPC modules are selected then the vendor, EnviroCare, will only accept the project if they also supply the (VenturiPak) scrubber and WESP to be more confident that plugging of the SPC system doesn't become an issue which would reduce system performance. EnviroCare has an exclusive deal with the SPC system so if the SPC system is desired the manufacturer will need to be EnviroCare.

While the SPC module system wouldn't require a UHF/HEPA filter the need to install one would likely rest upon the required emission limits for particulate – especially smaller particulate like PM-2.5 (2.5 micron particulate).

The advantage of SPC over activated carbon bed for mercury control is that the equipment footprint is smaller and has a lower flue gas reheat requirement. This eliminates the need of start-up heating system and complicated ducting to and from a secondary heat exchanger. However, SPC has not been installed in a location required to meet new fluidized bed dioxin and furan control levels yet so it is still unproven to meet that level. It should be able to, but it hasn't been proven yet (per manufacturer).

4.C MERCURY CONTROL – CARBON INJECTION

Option 4C would be very similar to options 4A and 4B except that the mercury control system would, yet again, be different. This option would inject a controlled amount of sulfur impregnated activated carbon powder into the flue gas stream. The carbon would be conveyed by the flue gas to adsorb mercury. The ductwork downstream of the carbon injection point would be larger than otherwise needed to increase residence time of the carbon in the flue gas, thus providing better control of mercury emissions. A bag house would then be used to collect the spent carbon and the ash.

A bag house (see Figure 12) is used to collect most of the particulate material by passing the flue gas through a grid of long fabric bags. The bag house is typically comprised of 2 or 3 chambers so that when one chamber Differential Pressure (dP) is beginning to rise due to the particulate loading (or a time limit is reached) it automatically switches to the second/next chamber. The first chamber is then automatically cleaned to be ready to accept flue gas again. The ash is collected as dry material and conveyed out of the equipment for disposal. Due to the low levels of mercury present in sludge it is unlikely that the waste carbon will count as hazardous waste. It should be noted that the amount of carbon is not expected to be a significant portion of the ash/carbon material weight.



Figure 12. Carbon injection bag house

Unlike the carbon bed or SPC system the carbon injection system would be installed between the heat recovery section and the wet scrubber. This has associated pros and cons. One of the advantages is that most of the ash is collected dry instead of as a wet slurry from the scrubber. This would fit better with the current thickener approach utilized by FBRWRF and allow a small amount of scrubber drain water to be used to convey the ash to the existing lagoon. A disadvantage would be that the ash captured by the bag house might need to be landfilled due to the spent activated carbon captured with it since the current ash lagoon may not be well suited for long-term storage of mercury laden carbon – even though the mercury is at very low levels.

The main difference between this system and the SPC/carbon bed system is that the SPC and carbon bed systems don't require moving parts or a continuous supply of material which must be delivered and stored on-site. The carbon injection design has moving parts to inject carbon, automatically clean the bags, and requires a constant supply of fresh activated carbon powder to continue operating. Additionally, the carbon injection system requires a bag house to collect the carbon which will require spare bags and periodic maintenance.

The flue gas would need to be partially cooled (to around 500°F) in order to successfully utilize a carbon injection system. The gases leaving the heat exchangers/boilers would need to be cooled several hundred degrees Fahrenheit in a controlled way. This would likely be achieved by use of a partial quench setup which sprays a carefully controlled amount of water into the gas stream to cool the gas without quenching it to saturation. Additionally, baghouses need to operate at negative pressure so an Induced Draft (ID) fan would be needed.

Acid gas control in this option could be done either in the wet scrubber after the bag house or by injecting lime into the gas stream along with the carbon. The lime would chemically react with the acid gases neutralizing them. Similar to the carbon powder the amount of lime is not expected to make up a significant portion of the ash/carbon/lime mixture thus it likely won't have much impact on disposal.

5.A ADDITIONAL SYSTEM CONSIDERATIONS – DIOXIN FURAN

Carbon beds have been demonstrated to be effective in controlling Dioxin/Furan (D/F) emissions which would be one additional benefit to their use at FBRWRF facility. The D/F emission limit for a new Fluidized Bed Incinerator (FBI) is 1/4 of the existing fluidized bed Incinerator emission limit on a Total Mass Basis (TMB). Carbon beds have demonstrated their ability by passing emissions tests at multiple facilities to meet the new fluidized bed emission limit for D/F.

Currently, EnviroCare cannot guarantee a D/F control efficiency (the percent of D/F it removes) for the SPC system; although, EnviroCare is currently evaluating if they can guarantee it. EnviroCare is seeking interested parties which would partner with them to bring an SPC pilot setup to site and perform testing to help EnviroCare determine what D/F control efficiency they could guarantee for their SPC system. EnviroCare has performed D/F studies at several WWTPs and believes that the emissions of D/F from a properly operated FBI may already be in compliance without additional control technologies; however, these studies are somewhat inconclusive at this point since they are contradicted by other emissions testing.

A carbon injection system can help control D/F; however, the duration of gas contact with the carbon and the amount of carbon present at any given time is much less than a carbon bed, thus a carbon injection system might not provide as great a control as a carbon bed system.

D/F compounds are not only controlled by adsorbing them on activated carbon. They can also be destroyed through combustion at elevated temperatures. At typical FBI exhaust temperatures of 1500-1600°F the D/F compounds can be destroyed. Using temperature to control D/F is sometimes the approach taken for FBI incinerators and is often employed by multiple hearth incinerator operators (due to their higher mercury emission limit they usually don't have any type of carbon system). D/F's optimal formation temperature is between 650°F to 850°F. Most FBIs quench the flue gas through this temperature quickly with minimal time for D/F reformation. However, if a boiler is utilized for steam/power generation the flue gas has a much longer residence time at the D/F formation

temperature range. Therefore, more consideration is needed for the D/F control scheme if a boiler is used.

5.B ADDITIONAL SYSTEM CONSIDERATIONS – PFAS

One additional design consideration would be the future pollutant category of PFAS. PFAS (per- and polyfluoroalkyl substances) is a class of thousands of compounds which contain a carbon-fluorine chemical bond(s). These compounds are very difficult to decompose which has earned them the name “forever chemicals”. They are present in a large percentage of everyday products including cosmetics, clothing, non-stick pans, fastfood wrappers, etc. They are commonly present in sewage throughout the country.

It is still unknown if/when airborne PFAS will be regulated but it is being intensely investigated by the EPA and other regulatory bodies to determine if it needs to be controlled and at what levels. There are currently no air emission limits for PFAS compounds; however, there are several emission limits and guidelines for drinking water. Activated carbon is believed to be a likely candidate to assist in removing airborne PFAS compounds and is currently used to help reduce PFAS in drinking water systems.

Carbon bed systems are believed to have PFAS control efficiencies of over 90% per the carbon bed manufacturer APC; however, this is speculative based upon the molecule types and has not been demonstrated by emissions testing so far. EnviroCare cannot provide a control efficiency for SPC modules because they haven’t tested for it. Carbon injection is likely to be in a similar vein as the SPC modules when it comes to PFAS compound control.

Temperature is also considered a likely candidate for the destruction of PFAS compounds; however, destruction may require high temperatures and may have repercussions on NOx emissions (NOx emissions increase as combustion temperature increases) and slagging problems (often a side effect of elevated temperatures with some sludge chemistries) should likewise be considered. Data is difficult to find at this point since PFAS is fairly new compound of interest but it is usually assumed that destruction of PFAS requires temperatures of 1500+°F and ideally long residence times. Studies have been conducted on the destruction of PFAS compounds by fluidized bed incinerators and they have found substantial destruction efficiencies are possible by thermal decomposition in the incinerator. Thus, depending on the quantity and type of PFAS compounds present in the sludge and the furnace operating conditions it may be possible to avoid the need for future control technologies; however, this is dependent upon what the emission limit would be set at (if or when an emission limit is set).

An important study was conducted by Winchell et al¹ and studied where PFAS compounds went and how they were destroyed in both FBIs and MHI. The combustion air, scrubber water, sludge, ash, and

¹ Winchell, L. J., Wells, M. J. M., Ross, J. J., Kakar, F., Teymouri, A., Gonzalez, D. J., Dangtran, K., Bessler, S. M., Carlson, S., Almansa, X. F., Norton, J. W. Jr, & Bell, K. Y. (2024). Fate of perfluoroalkyl and Winchell, L. J., Wells, M. J. M., Ross, J. J., Kakar, F., Teymouri, A., Gonzalez, D. J., Dangtran, K., Bessler, S. M.,

stack emissions were all monitored to determine the fate of numerous PFAS compounds. The ash and the combustion air had no measurable PFAS. The wet scrubber drain water didn't see much change in the PFAS content (the scrubber water actually measured a reduction in PFAS which seems unlikely). The PFAS in the sludge appeared to be largely destroyed through the combustion process. Stack vs sludge PFAS indicated a 95% or better destruction rate for PFAS in the sludge. It should be noted that testing of any compound in sludge is inherently an inaccurate process since the lab is analyzing a few grams of material and assuming it is representative of several tons of sludge. Additionally, if/when PFAS is regulated in air it is unknown if a 95% destruction rate would suffice or not – it will depend on the particular sludge at that time and the emission rate, neither of which are known at this point.

5.C ADDITIONAL SYSTEM CONSIDERATIONS – SCRUBBER WATER MERCURY

Chemically, there are different forms of mercury and some of them can be caught in a wet scrubber. Mercury normally comes from an incinerator as (1) elemental mercury, (2) mercury attached to a particle, or (3) as mercury ions. Elemental mercury is not soluble in water and is the type of mercury that the mercury control system is designed to control. Ionic mercury is soluble in water and can be caught in a wet scrubber. Likewise, scrubbers are very good at catching particulate matter so mercury on a particle (such as ash) would likely be caught by the wet scrubber and be discharged with the scrubber water.

Below we estimate the mercury loading to the ash lagoon over time giving us a reasonable degree of confidence the materials going to the ash lagoon will not be hazardous waste. For this estimate we assumed that 40% of the mercury was captured by the scrubber; however, if this value was taken to an extreme of 100% the conclusion would remain unchanged that the mercury loading going to the ash lagoon would likely not be hazardous waste.

Winchell, L. J., Wells, M. J. M., Ross, J. J., Kakar, F., Teymouri, A., Gonzalez, D. J., Dangtran, K., Bessler, S. M., Carlson, S., Almansa, X. F., Norton, J. W. Jr, & Bell, K. Y. (2024). Published in Water Environment Research, 96(3), e11009. <https://doi.org/10.1002/wer.11009> Fate of perfluoroalkyl and polyfluoroalkyl substances (PFAS) through two full-scale wastewater sludge incinerators

	Value	Units
Sludge mercury content	1.5	ppmw
Sludge feed rate	89000	dry lb/day
Assumed particulate born and soluble mercury %	40%	%
Total Mercury loading to ash lagoon	0.0534	lb/day
Estimated sludge ash content	20%	%
Ash sent to ash lagoon	17800	lb/day
Mercury loading as ppmw in ash	3	ppmw
Current mercury hazardous waste threshold	200	ppm
Is ash expected to be hazardous waste?	No	
Scrubber estimated water flow rate	1000	gpm
Density of water	62.4	lb/gal
Water usage	62400	lb/min
	89,856,000	lb/day
Mercury loading in scrubber water	0.0006	ppm
Is scrubber water expected to be hazardous waste?	No	

Table 1. Mercury loading in scrubber water/ash

5.D ADDITIONAL SYSTEM CONSIDERATIONS – REDUNDANCY

Due to the price and size of the equipment true redundancy is difficult to offer without 2 full capacity incinerator systems – which would likely require more funds and space than are available for this project.

Due to the lower feed rate limit of the existing incinerator a limited amount of redundancy can be achieved within an incinerator system by keeping the existing incinerator as an operable spare. Aside from that, some critical equipment such as the bag houses (if needed) may be able to have some redundancy if an extra baghouse chamber is added. Auxiliary systems such as booster pumps normally have backups to enhance reliability. Beyond this it is typically cost prohibitive to attempt additional redundancy. Large blowers for combustion and/or purge air are normally very reliable and therefore will offer minimal benefit if a backup blower is installed. Most of the downstream air pollution control equipment has proven to be very reliable. Lastly, the heat exchangers will often yield a decade of operation with little to no maintenance required.

The incinerator itself often is the most difficult portion of the system to perform maintenance on and dictates the downtime of the rest of the system. Due to the operating temperature and limits on how fast the incinerator can be cooled down/heated up, if internal work is required, a week long shutdown is

often the minimum amount of time which can be allocated for the work. By contrast, if internal work is required on a WESP for example, the work can often be performed with minimal downtime.

A limited amount of incineration redundancy can be achieved by keeping the existing incinerator in good operation condition to serve when needed; however, this may mean that the existing system would need a rehab at some point in order to maintain it in good operating condition. The existing incinerator would not have the same sludge feed rate capacity as the new incinerator and thus would only provide a limited amount of redundancy. The existing incinerator is permitted for 2,651 dry lb/hr vs the new incinerator which will have a capacity of 3,708 dry lb/hr (approx. 40% greater than the existing unit – Ref Appendix 2 for rough incinerator dimensions). Lastly, the annual/every 3 year requirements for stack emissions testing would need to be coordinated with the regulators in order to avoid onerous testing requirements on an infrequently used back-up system; however, the regulatory agencies have the ability to loosen the testing requirements on a back-up incinerator instead of maintaining the status-quo with regards to testing.

5.E ASH THICKENING

Currently, the scrubber effluent is thickened in order to reduce water content before being sent to the ash lagoon. This system works well for the existing system configuration but it is unclear how much water the current ash lagoon can accept from the scrubber. A new scrubber sized to handle the future sludge throughput will use around 1100 gpm of water to cool and scrub the flue gas. In addition to that, the sludge will send an additional 30 +/- gpm of water to the drain and an intermittent additional 90 gpm of water when the WESP washes. This equates to approximately 1.6 MGD of water coming from the scrubber system. For comparison, the current scrubber uses a total of 670 gpm of water and sends only 170 gpm of that water (0.24 MGD) to the ash thickener which is then thickened to an estimated 3-4% solids prior to going to the ash lagoon.

Sending the entire 1.6 MGD of scrubber water to the ash lagoon would likely cause problems. The ash lagoon covers approximately 9 acres of land. 1.6MGD over a 9 acre area amounts to roughly 7 inches of water per day – which is likely going to be more than can be absorbed by the ground and will cause increased overflow to the plant headworks and decreased ash settling time in the lagoon. EnviroCare has identified that their scrubber water can be divided into separate drains similar to the existing scrubber. This would reduce the water flow from approximately 1100 gpm to a more manageable 250 gpm (0.36MGD). Placing 0.36MGD of water into the 9 acre ash lagoon would equate to approximately 1.25" of water per day; the remaining 1.24 MGD of water would be returned directly to the headworks of the plant. We believe it will be necessary to install some type of ash thickening system given the flow rate that would need to be sent to the ash lagoon.

Gravity thickening is obviously the first choice due to the low power and maintenance requirements. A gravity thickener designed for a 0.36MGD flow rate likely would not increase in size much compared to the existing ash thickener which handles 0.24MGD (approximately a 50% increase in flow). A decanting centrifuge type thickener is another possibility. Centrifuges often have the smallest footprint per gallon

processed; however, they tend to compensate for that by using more electricity to handle the material. A third option would be to use a screw press. This type of unit typically uses very little power and may serve as a good compromise between the gravity thickening and the centrifuge. There are several other technologies available such as a rotary filter press, belt filter press, and alike which should also be considered to find the optimal balance of power usage and footprint. Given the uncertainty in equipment configuration which will ultimately be selected for this project it is difficult to assess which technology would best optimize the power vs footprint equation at this point.

5.F AMMONIA/UREA INJECTION FOR NO_x CONTROL

The new FBI NO_x emission limit under the 40CFR60 Subpart LLLL regulations is 30 ppmv @ 7%O₂. This limit is difficult to meet for an FBI and therefore having the ability to control NO_x becomes a key compliance requirement. NO_x is usually controlled by injecting either ammonia or urea into the freeboard of the incinerator. These compounds both work in the same way and neutralize the NO_x by chemically reacting with it to eliminate them. The reaction takes place at elevated temperatures which is why the injection point is normally situated in the incinerator freeboard. Ammonia/urea would need to be stored on-site and injected, either on an as-needed basis or at a fixed rate (depending upon the permit and regulatory requirements negotiated).

6. EQUIPMENT SIZING AND BUDGETARY PRICING

Several equipment vendors were contacted and were able to supply rough equipment sizing and budgetary pricing. A breakdown of this information is provided below.

Equipment	Notes	Rough sizing	Equipment Budgetary pricing
Primary heat exchanger		8'7"D x 42'H	\$1.25M
Secondary heat exchanger		5'6"D x 27'6"H	\$375k
EnviroCare VenturiPak 316L SS scrubber w/ quench	1	7'6"D x 48'H with WESP	\$1.265M
EnviroCare 316L SS WESP	1		\$650k
EnviroCare 316L SS SPC modules	1	82" x 82" x 20'H	\$1.34M
APC carbon bed (including HEPA filter & start-up heater system)	2	14'D x 12'H	\$1.12M

Table 2. Major equipment sizing and budgetary pricing

1. Pricing includes instrumentation, spray water lances and valves, transformers, stainless steel equipment, water booster pump skid and control panels, and necessary associated equipment.
2. Price includes startup heater with blower, 316L SS HEPA filter with filter cartridges, FRP Carbon bed vessel, NEMA 4X control panel, and the necessary activated carbon.

Note: If bulk chemical stocks are required (polymer, caustic, ammonia/urea, etc.) these could be housed as bulk storage tanks, totes, etc. which would understandably change the sizes and costs associated with the chemical storage. Therefore this line item is not included due to the variability involved.

Note: this table is only meant to identify sizes of major equipment in the system and is not intended to cover all ancillary equipment such as every blower, pump, ductwork, programming, etc. needed for a full system.

7. UTILITIES CONSUMPTION

Similar to the existing incinerator system, there will be a significant utilities consumption required for the new incinerator. Water usage is relatively easy to predict due to the scrubber vendors easily being able to calculate the usage early on in a project. The wet scrubber with WESP would need approximately 1,200 gpm of water while in operation. For planning purposes some overage would be beneficial so a total available water flow rate of roughly 1500 gpm would be desirable to ensure sufficient flow rate is available for misc. uses (dewatering polymer mixture, hoses to clean equipment, and alike).

Electricity usage is difficult to predict since elevations, pressure losses, and many other factors aren't known yet. Below are our estimates of electricity usage for the major pieces of equipment in the system. Additional power will be needed for things like HVAC, lights, powering PLCs and instrumentation, CEMS, etc.).

	Low estimate	High estimate
Fluidizing Air Blower (FAB)	250 HP (187 kW)	350 HP (261 kW)
Purge Air Blower	75 HP (56 kW)	175 HP (131 kW)
WESP	(8 kW)	(15 kW)
Scrubber water booster pumps	20 HP (15 kW)	50 HP (37 kW)
Sludge dewatering	150 HP (112 kW)	300 HP (224 kW)
ID Fan (if needed)	75 HP (56 kW)	175 HP (131 kW)
Total:	570 HP (433 kW)	1050 HP (798 kW)

Table 3. Major equipment estimated operating power requirements

Auxiliary fuel will be needed to heat up the incinerator and during operation to maintain operating temperature. The amount of auxiliary fuel required will vary depending upon the sludge dryness and energy content thus it is difficult to predict with any accuracy the amount of fuel needed.

8. REGULATORY SUMMARY

In 2016 the EPA's 40CFR60 and 40CFR62 rule took effect which set a variety of operational requirements and emission limits on sewage sludge incinerators. The rule set up a Site Specific Operating Limit (SSOL)

system whereby operating limits for scrubber flow rate, scrubber dP, WESP Power, combustion temperature, etc. are set during stack testing and must be maintained during normal operation. The thought process being that operation above these minimum values will maintain the incinerator in continuous compliance with the emission limits. Semi-annually, each facility self-reports their compliance with these limits in their deviation reports to the regulators.

The rule set numerous emission limits for sewage sludge incinerators and distinguished between existing and new incinerators in the emission limits. FBRWRF's current incinerator is classified as existing under the requirements of the federal rule but this new incinerator would be classified as new. New incinerators have stricter emission limits than existing ones. The emission limits for new fluidized bed incinerators are listed below.

TABLE 2—EMISSION LIMITS FOR **NEW** SSI UNITS

Pollutant	Units	Emission limit for MH incinerators	Emission limit for FB incinerators
Cd	mg/dscm @ 7% O ₂	0.0024	0.0011
CO	ppmvd @ 7% O ₂	52	27
HCl	ppmvd @ 7% O ₂	1.2	0.24
Hg	mg/dscm @ 7% O ₂	0.15	0.0010
NO _x	ppmvd @ 7% O ₂	210	30
Pb	mg/dscm @ 7% O ₂	0.0035	0.00062
PCDD/PCDF, TMB	ng/dscm @ 7% O ₂	0.045	0.013
PCDD/PCDF, TEQ	ng/dscm @ 7% O ₂	0.0022	0.0044
PM	mg/dscm @ 7% O ₂	60	9.6
SO ₂	ppmvd @ 7% O ₂	26	5.3

Figure 13. Federal emission limits

Annual emission testing is required under the federal rule; however, the rule provides an option to reduce emissions testing frequency to once every 3 years by satisfying the below conditions:

1. Emissions below 75% of the respective emissions limit two consecutive annual emissions tests in a row.
2. Sludge feed rate $\geq$ 85% of max rated feed rate for each run.

Additionally, the EPA's 503 regulations place additional requirements on sludge testing and high oxygen limits (also based upon stack testing).

From a state regulatory perspective they will likely rely upon the federal LLLL regulations to control emissions from the incinerators. Discussions with the ABAQA indicated that they likely don't have any additional state/local regulations that would be added to the permit for a new incinerator.

9. LAND USAGE ESTIMATE

The major equipment for a fluidized bed incinerator system is expected to fit within a 50ft x 100ft building (i.e. 1/8th of an acre plot of land). Rough layout of the major equipment attached in Appendix 4.

Below is a Google Maps © image of the FBRWRF plant with the size of the incinerator system (the blue box) overlaid.



Figure 14. Possible location of new incinerator

10. RECOMMENDATIONS AND ANALYSIS

The cost for the incinerator is estimated to be \$90-110M (Ref. Table 4) based upon similar projects that we've worked on using dollars today (i.e. not future dollar value). We should note that at this point prices are estimated to be +/-25% given the unknowns in exactly which equipment is selected, inflation, final design considerations, building construction, recent labor union pay raises, etc. The below table shows our estimated price breakdown.

Budgetary estimate		
	Material costs (in Million USD)	
	Low	High
Incinerator	10	12
Heat exchangers	2	2.5
Air pollution control equip	2.5	3
Ductwork	0.5	0.75
Dewatering	2.5	3.5
Blowers/pumps	0.75	1.25
Instrumentation	0.6	0.8
Electrical	1	1.25
Subtotal for materials	19.85	25.05
Construction costs 3x materials	59.55	75.15
Subtotal with construction	79.4	100.2
3 floor building	8	10
Engineering	1.5	2
Total estimated costs	88.9	112.2

Table 4. Budgetary price breakdown

A primary heat exchanger is employed by nearly every fluidized bed sludge incinerator (both new and existing) due to the substantial fuel savings it provides. The primary heat exchanger on this study was estimated to heat the combustion air from 160°F to 1200°F which requires approximately 9.5 million Btu/hr of energy from the flue gas to accomplish. To accomplish this same heat duty by burning natural gas (1000 Btu/scf) it would require 9500 scf/hr of natural gas. Burning this much natural gas would also require additional combustion air which would require additional natural gas to heat and a larger fluidizing air blower to provide. Even if the natural gas was \$0.50 per scf the gas consumption would be around \$5,000/hr. A \$5,000/hr fuel bill very quickly justifies the expense of a primary heat exchanger (roughly a \$1 million dollar piece of equipment).

A boiler is a more complex analysis. A boiler would require a steam drum, boiler, boiler water treatment system, pumps, safety systems, steam powered turbine to generate electricity, and specialized operator training. The primary heat exchanger flue gas outlet temperature would be approximately 1000°F.

Cooling the gas down to 600°F would constitute approximately 8.7 million Btu/hr. Assuming 4% thermal losses (radiant and steam drum blowdown losses) and a 90% efficient steam to electric conversion rate that would equate to 7.5 million Btu/hr or 2200 kW (2.2 MW) of electricity production. FBRWRF would need staff 24/7 to operate the steam power plant who are properly trained on the system. Specialized maintenance staff would be needed which likely could be one shift per day with somebody on call during other shifts. Boiler water treatment chemicals will be needed to clean the feed water, reduce minerals, inject anti-foaming agents, etc. Assuming a combined cost for all these expenses of roughly \$1 million dollars per year to operate the system and a 100% system online time (8760hrs/year) the table to the right shows the potential savings due to the boiler system per year.

Assumptions:		
2200	kW Power production	
8760	hrs/yr	
\$ 1,000,000	annual expenses *	
Electricity cost per kWh	Before expenses savings	After expenses savings
\$ 0.08	\$ 1,541,760.00	\$ 541,760
\$ 0.10	\$ 1,927,200.00	\$ 927,200
\$ 0.12	\$ 2,312,640.00	\$ 1,312,640
\$ 0.14	\$ 2,698,080.00	\$ 1,698,080
\$ 0.16	\$ 3,083,520.00	\$ 2,083,520
\$ 0.18	\$ 3,468,960.00	\$ 2,468,960
\$ 0.20	\$ 3,854,400.00	\$ 2,854,400
\$ 0.22	\$ 4,239,840.00	\$ 3,239,840
\$ 0.24	\$ 4,625,280.00	\$ 3,625,280
\$ 0.26	\$ 5,010,720.00	\$ 4,010,720
\$ 0.28	\$ 5,396,160.00	\$ 4,396,160
\$ 0.30	\$ 5,781,600.00	\$ 4,781,600
* Annual expenses for maintenance, specialty operators, specialty maintenance staff, boiler water conditioning chemicals/equipment, and alike.		

Table 5. Estimating boiler utilities savings

A boiler system is likely going to have an equipment cost of around \$3 million dollars and would likely cost about \$5 million dollars more to install and commission. Additionally, for the first decade the available sludge will not allow for max rate production. If the unit only produces 50% of rated electricity production due to the amount of sludge available it would likely take over 10 years to break even on the investment. Thus, we believe the economics of installing this power plant are going to be a stretch to justify based upon the ROI period. It will likely depend upon factors such as the anticipated increases in electricity price from the grid and other factors which are beyond the scope of this study. Lastly, depending what type of boiler system (if used) is selected additional building space may be required.

Following the boiler (if installed) a secondary heat exchanger would likely be needed for plume suppression on the stack and/or flue gas reheat to a carbon bed system (if used). If both plume suppression and flue gas reheat are required a secondary and tertiary heat exchanger may be needed. This/these heat exchanger(s) operate at much lower temperatures than a primary heat exchanger and tend to have very long life expectancies. Often they last the life of the incinerator system. These units

are by far the most economical choice if downstream systems or the stack require additional heat and a secondary (and perhaps tertiary) heat exchanger is anticipated to be needed on this project.

Following the heat recovery the flue gas then needs to be scrubbed to clean it for release into the atmosphere. This is normally accomplished through a wet scrubber system such as the EnviroCare VenturiPak scrubber system. This system uses water (typically plant effluent) to scrub the particulate (ash), acid gases, and some metals (not mercury) from the gas stream. This also cools the gas stream to around 80-100°F in the process of cleaning it. Following the wet scrubber a Wet Electrostatic Precipitator (WESP) would be needed to further control particulate and metals (not mercury) in order to meet new incinerator emission limits.

The last portion of the air pollution control system which must be weighed is the mercury control system. The federal 40CFR60 rule placed strict limits on the levels of mercury which can be emitted to the atmosphere. The three types of available control technology are carbon injection, SPC modules, and a carbon bed. We have discussed the carbon injection system with APC and they have advised that they are able to guarantee mercury emission reductions of up to 90% with a properly designed carbon injection system at this point in time. This may be insufficient to meet new incinerator emission standards on a fluidized bed incinerator unless inlet mercury concentration is quite low to begin with. Often new FBI mercury control requirements are in the high 90% range. For this reason, we are ruling out this system which leaves the SPC modules and carbon bed options. EnviroCare has identified that the SPC modules have not been proven to meet the new FBI Dioxin/Furan limits yet. They believe it is able to but cannot guarantee that limit for that reason. This may not be a deal breaker given that freeboard temperature is often used to control Dioxin/Furans. If a boiler is used this may increase the likelihood of Dioxin/Furans recombining in the flue gas ductwork; thus, if a boiler is used extra care should be exercised if SPC modules are desired. A carbon bed system has been proven in many installations to be able to meet the new FBI mercury and Dioxin/Furan limits. The APC carbon bed is also likely to be able to assist with PFAS removal depending upon the type of PFAS compound(s). The downside of the carbon bed is that the CPPE brand of carbon bed has had numerous incidences of fires. These incidences have been studied but no clear cause has been identified.

From a solely pollution control perspective a carbon bed is recommended because it can guarantee emissions reductions/emission limits for mercury and Dioxin/Furans. From a risk of fire perspective, the SPC system has a slight edge because there is much less carbon available and it operates very close to the water saturation point (APC's carbon bed has never had a fire which is why we say SPC only has a slight advantage). From a system complexity perspective the SPC modules are easier because the carbon bed requires a HEPA filter at the inlet and a modest gas preheat which requires a heat exchanger and additional ductwork and valves to accommodate. Both the SPC and carbon bed systems work well so the decision between these systems likely comes down to FBRWRF's views on carbon beds and their desire for an emissions guarantee on Dioxin/Furan. We believe a carbon bed is the best choice because it is the most efficient at removing pollutants and has likely benefits for many PFAS compounds.

Following the mercury controls the flue gas is clean enough to be released into the atmosphere. Often plume suppression is desired to help mitigate any remaining health impacts (hotter flue gas rises into the atmosphere better which dilutes pollutants and helps mitigate any health impacts) and to avoid a visible plume rising from the emissions stack. We anticipate that a secondary heat exchanger will be needed for this project to increase flue gas temperature for these purposes. Following reheating the flue gases will proceed to a Continuous Emissions Monitor (CEMS) system to monitor for Carbon Monoxide (CO), Oxygen (O₂), and potentially other pollutants if desired/required for permit compliance. Gases will then be released through the stack into the atmosphere.

11. CONCLUSIONS

In conclusion the long term biosolids study has reviewed two key sludge disposal technologies; namely, MHI vs FBI incineration. The MHI option was considered; however, due to the factors discussed it isn't the best fit for FBRWRF. The FBI was considered and is a better choice that will fit within FBRWRF's experience wheelhouse and the available space onsite. A host of energy recovery options were evaluated. We determined that a primary heat exchanger is an important cost savings option with a very short return on investment. A boiler is possibly worth the expense but it will likely depend on a host of outside factors such as projected increases in energy costs over the return on investment period, which is beyond the scope of this study. The air pollution control system was evaluated and several technologies recommended; namely, a wet scrubber with WESP. Lastly, we evaluated several types of mercury control technologies. We were able to recommend two different systems (the carbon bed and the SPC modules) based upon past performance at similar facilities. The carbon bed has an edge from an emissions perspective over the SPC system due to its ability to guarantee emissions of both mercury and Dioxin/Furans at the new FBI level; therefore, this is the technology that we recommend.

We believe these technologies will position FBRWRF to be a leader in clean and reliable sludge disposal long into the future. The ash from the sludge will continue to be safely disposed of on-site rather than rely on outside disposal options that impose financial and logistical challenges.

We would like to thank FBRWRF for the opportunity to perform this study and will readily make ourselves available to address any questions you may have.

Sincerely,
Chavond-Barry Engineering corp.

12. APPENDIX

1. Hazen & Sawyer projected sludge throughput
2. Preliminary incinerator cross-section
3. Preliminary fluidized bed Process Flow Diagram (PFD)
4. Preliminary layout of major equipment

APPENDIX 1. LONG-TERM HAZEN & SAWYER SLUDGE THROUGHPUT

Sludge Characteristics and Assumptions

- Primary = 2.0% TS
- AGS = 0.8% TS
- DAS = 0.5% TS
- Mechanical Thickening Capture Efficiency = 95%
- BFP/DCEN Capture Efficiency = 95%
- Dewatered Cake Solids = 20-25%

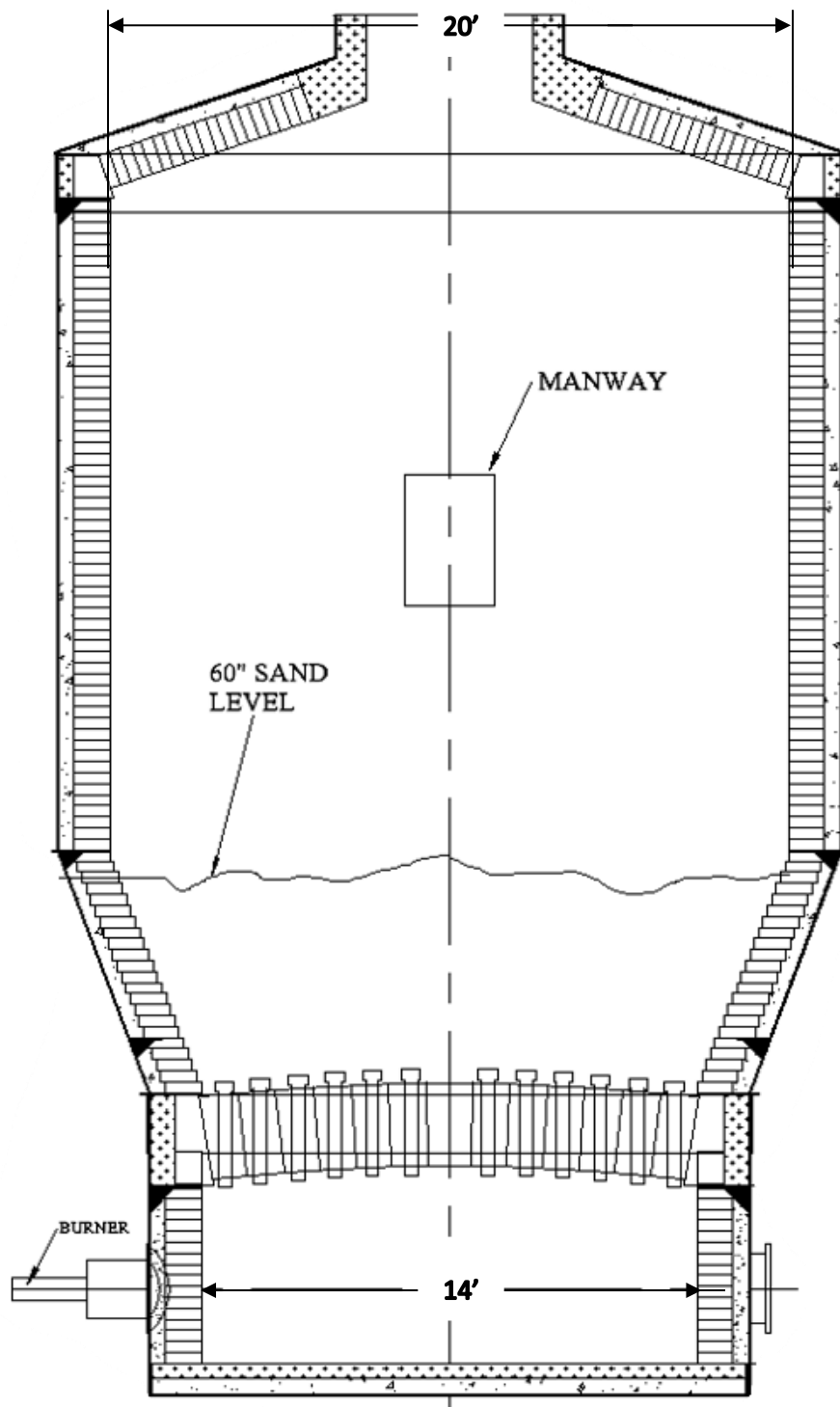
Sludge Production, lb(dry)/day	AA	MAX30	MAX14	MAX07
Primary Sludge (15 mgd to HRPT), lb/day	19,300	22,200	29,000	30,900
AGS Secondary Sludge, lb/day	32,100	36,900	45,200	48,400
DAS Secondary Sludge, lb/day	38,500	44,200	54,200	58,100

Total Sludge Production, lb(dry)/day	AA	MAX30	MAX14	MAX07	PS:WAS Ratio
Primary + AGS, lb/day	51,400	59,100	74,200	79,300	38%
Primary + DAS, lb/day	57,800	66,400	83,200	89,000	33%

Highest feed rate design case loading 89,000 dry lb/day of sludge

MM (Design) Dewatering Scenario, lb(dry)/day	AA	MAX30	MAX14	MAX07
AGS Dewatered Cake, lb/day	46,400	53,300	67,000	71,600
DAS Dewatered Cake, lb/day	52,100	60,000	75,100	80,300

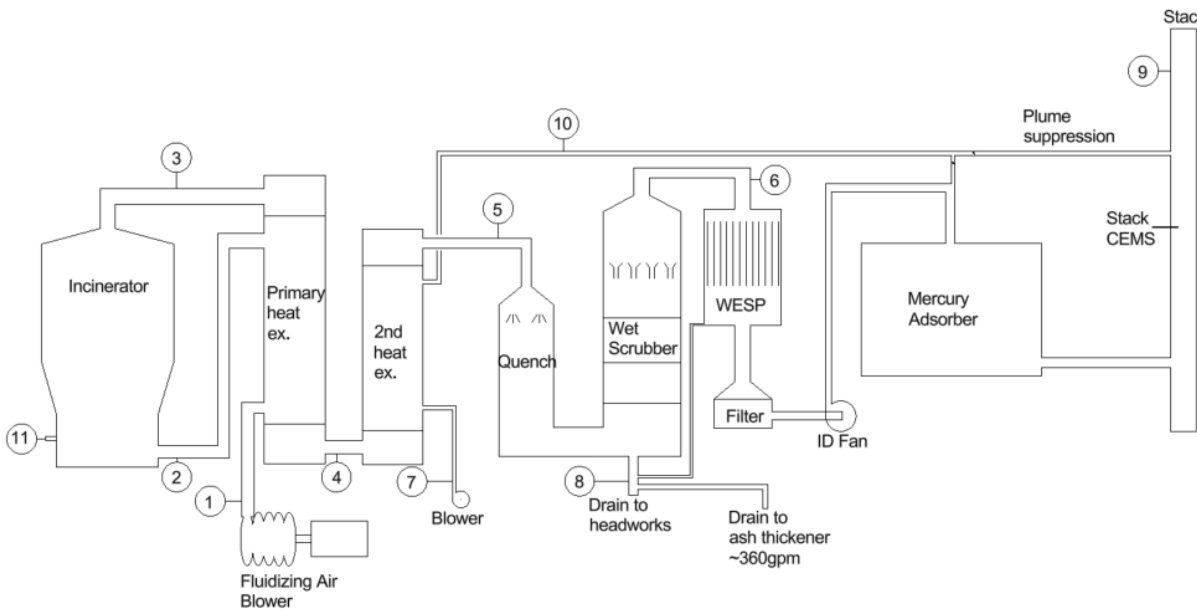
APPENDIX 2. PRELIMINARY INCINERATOR CROSS-SECTION (Refractory Arch Bed Dome Design)



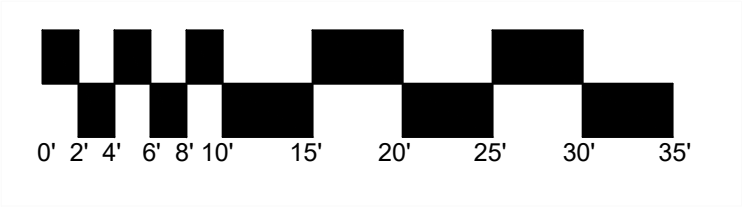
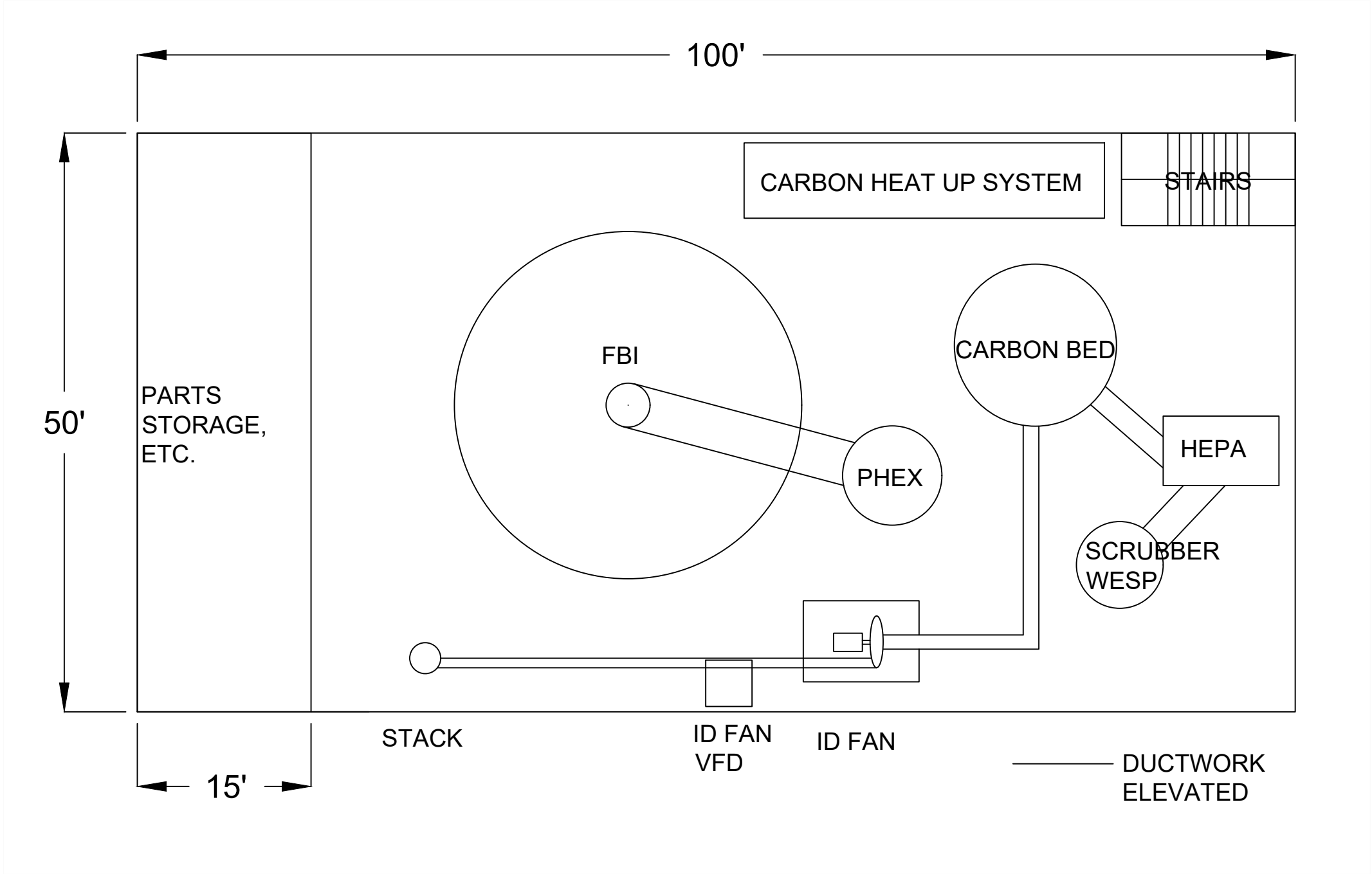
APPENDIX 3. PRELIMINARY FLUIDIZED BED PROCESS FLOW DIAGRAM (PFD)

	Fluidizing air blower	preheated fluidizing air	flue gas leaving incinerator	flue gas between primary and secondary heat exchangers	flue gas going to quench	Flue gas leaving scrubber	Plume suppression air	Scrubber drain	Stack gases	Heated plume suppression air	Sludge Feed
	1	2	3	4	5	6	7	8	9	10	11
lb/hr	35601	35601	55429	55429	55429	38681	4532	1000 gpm *	43213	4532	3708 dry
psig	5.2	5.0	1.7	1.5	1.3	-0.32	1.0	0.0	0.1 *	0.8	-
°F	160	1150	1548	1035 *	992 *	110	100	125 *	162	613	-
acfm	6856	18000	44374	33475	32944	9003	1000	0	10675	1943	-
scfm	7783	7783	12844	12844	12844	8032	992	0	8989	992	-
lb/ft ³	0.087	0.033	0.021	0.027	0.028	0.072	0.076	62 gal/ft3	0.067	0.039	-
mol. Wt.	29	29	27	27	27	30.5	29	18	30.5	29	-
lb/hr N ₂	27121	27121	27988	27988	27988	27988	3452	0	31440	3452	-
lb/hr O ₂	8188	8188	1802	1802	1802	1802	1042	0	2844	1042	-
lb/hr H ₂ O	292	292	17769	17769	17769	1782	37	62400	1820	37	14833
lb/hr CO ₂	0	0	7109	7109	7109	7109	0	0	7109	0	-
lb/hr ash	0	0	693	693	693	0	0	693	0	0	693

- Value estimated



APPENDIX 4. PRELIMINARY LAYOUT OF MAJOR EQUIPMENT



LEVEL 3 LAYOUT

DRAWN	CHECKED	APPROVED
SCALE	JOB	DRAWING NO.
AS SHOWN	MSD	P-003
		REV.
		P

PRELIMINARY

CHAVOND-BARRY
ENGINEERING CORP.

PO BOX 205
BLAWENBURG NJ 08504

MSD WWTP
Buncombe County
LONG-TERM BIOSOLIDS STUDY

Final: November 10, 2025

To: Metropolitan Sewerage District of Buncombe County (MSD)

From: Sharanya Ananth, Hazen
Aaron Babson, PE, Hazen
Ruth Borgmann, PE, Hazen
Michael Bullard, PE, Hazen
Jacqueline Yeh, PE, Hazen

Technical Memorandum No. 3 – Incineration and Thermal Drying Comparison

FINAL

Table of Contents

1. Introduction	3
2. Operation and Maintenance Cost Comparison	3
2.1 Incinerator Operation and Maintenance Cost Assumptions	3
2.2 Hauling Cost Assumptions.....	4
2.3 Labor Cost Assumptions.....	5
2.4 Incineration and Thermal Drying Comparison	6
3. Operation and Maintenance Cost Comparison for Existing and Proposed Solids Train.....	7

1. Introduction

The Metropolitan Sewerage District (MSD) of Buncombe County retained Hazen and Sawyer (Hazen) to complete a Solids Handling Preliminary Engineering Report (PER) for the French Broad River Water Reclamation Facility (FBRWRF). The PER includes a condition and capacity assessment on the existing equipment, technology assessments, permitting assistance and development of a new solids handling facility concept to be seamlessly integrated into the forthcoming liquid train project.

The purpose of this technical memorandum (TM) is to compare incineration and thermal drying for solids management at the FBRWRF. Hazen developed an operation and maintenance cost estimate for the new Fluidized Bed Incinerator (FBI) option that was developed by Chavond-Berry Engineering (CBE) as a primary solids management option for the FBRWRF for comparison purposes to the thermal dryer option.

In addition, annual thermal drying operation and maintenance costs were developed in comparison to the existing solids handling operation and maintenance costs for planning purposes.

2. Operation and Maintenance Cost Comparison

2.1 Incinerator Operation and Maintenance Cost Assumptions

For thorough comparison of the thermal drying and incineration options, an operation and maintenance cost for incineration was developed.

MSD's current operating costs and other values from Hazen incineration projects were used to develop the cost. To determine the supplemental fuel demand for the incinerator, it was assumed that the high heat value of the sludge would be an average of 8,000 Btu/lb-dry, based on Metcalf and Eddy Table 14-17 and the dewatered cake fed to the FBI would be 20% TS.

Daily operations costs for supplemental fuel usage, electrical demand and scrubber potable water demand were developed based on the following assumptions presented in **Table 2-1**. In addition, annual costs for stack testing, cold startup, incinerator sand replacement, mercury module carbon replacement and dewatered cake hauling during incinerator downtime were developed as well.

Table 2-1: Incineration O&M Assumptions

Parameter	Assumption
Incineration Supplemental Fuel Demand, MMBtu/hr	6.0
Natural Gas Unit Cost, \$/MMBtu	\$3.45 ¹
Installed Horsepower, hp	810
Utilization Factor	70%

Parameter	Assumption
Electrical Power Unit Cost, \$/kWh	\$0.058 ²
Scrubber Potable Water Demand, gpm	10
Scrubber Potable Water, \$/gal	\$0.014
Dewatered Cake Hauling Cost, \$/truck	\$1,050
Cake Hauling Truck Size, wT	10
Annual Costs	
Mercury Module Carbon Replacement, \$/yr	\$76,000 (\$228,000 every three years)
Incinerator Sand Replacement, \$/yr	\$11,000
Annual Stack Testing, \$/yr	\$100,000
Cold Startup Fuel Demand, mmBTU	125
Cold Startup Annual Fuel Cost, \$/yr	\$1,000
Total Annual Operations Costs, \$/yr	\$188,000
¹ Unit cost updated based on 2025 average natural gas cost from MSD. ² Unit cost updated based on 2025 invoices from MSD following upgrade to large general service tier by electricity provider.	

In the process of developing the incineration O&M cost, the thermal drying O&M was also updated for labor and hauling cost.

2.2 Hauling Cost Assumptions

Generally, in thermal drying analyses, the revenue from product sale is considered equal to hauling costs and not used in cost evaluation. However, MSD noted that due to their uncertainty over a market for the dried product, a hauling cost evaluation is helpful in comparing thermal drying to incineration. Therefore, the hauling cost associated with hauling thermally dried product to the Buncombe County Landfill was compared to the hauling cost associated with anticipated incinerator downtime and dewatered cake hauling. Incinerator downtime was assumed to be 2 months per year. **Table 2-2** provides a comparison of the hauling costs for each technology annually.

Table 2-2: Thermal Drying and Incineration Hauling Cost Comparison

Parameter	Thermal Drying	Incineration
Annual Hauling Cost (2024 \$)	\$725,000	\$520,000
20-year Lifecycle Hauling Cost	\$13,400,000	\$9,700,000

Hauling and management of final product represents a significant cost of operation. It should be noted that MSD has experienced incineration shutdowns up to four months long, which would double the hauling costs provided in **Table 2-2**. Shutdowns for incinerator rehab were not considered.

2.3 Labor Cost Assumptions

Labor requirements were developed in further detail for both options by referring to the Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants, developed by the New England Interstate Water Pollution Control Commission (NEIWPCC). This guide assumes 1,500 productive work hours per year per FTE, with 6 useful hours per shift, 5-day weeks, and 50 work weeks. **Table 2-3** provides a comparison of staffing requirements for thermal drying and incineration, assuming mechanical thickening, centrifuge dewatering and one dryer in operation. It should be noted that it was assumed that incineration would operate 24/7 and thermal drying would operate on the campaign schedule of 24/4 under annual average conditions.

Table 2-3: NEIWPCC Drying and Incineration Staffing Estimate

Parameter	Thermal Drying	Incineration
Sludge Storage Annual Hours	730	730
Thickening Annual Hours	730	730
Dewatering Annual Hours	1,669	2,920
Final Solids (Drying or Incineration) Annual Hours	5,006	8,760
Total Annual Hours	8,135	13,140
Total FTEs Required¹	5.5	9.0

¹Total FTEs Required was rounded to the nearest 0.5 FTE

2.4 Incineration and Thermal Drying Comparison

When developing the annual O&M cost for each alternative, the unit cost of operation, in \$/dry ton was developed to determine which aspects of the systems contributed more to the operational cost. **Table 2-4** provides the breakdown of unit costs for both technologies.

Table 2-4: Thermal Drying and Incineration Operating Unit Cost

Parameter	Thermal Drying	Incineration
Power Cost, \$/dT	\$6.50	\$13.00
Natural Gas Cost, \$/dT	\$33.50	\$11.00
Potable Water Cost ¹ , \$/dT	N/A	\$5.00
Total Final Solids Cost, \$/dT	\$40.00	\$29.00

¹The thermal dryer only requires potable water for safety systems that are used on an emergency basis only. Therefore, it was assumed that the safety systems were not activated as a part of regular operations and therefore no potable water demand was included in the annual thermal drying O&M cost.

The unit cost does not include costs only applied annually, such as the cost of cold start-up, mercury module replacement, stack testing or sand replacement for the incineration option. As anticipated, the natural gas cost of the thermal dryer is the primary cost driver that results in a higher operating cost than the incinerator.

The maintenance cost for the incinerator was developed by estimating 3% of equipment capital costs and 1% of building costs, with an added safety factor due to the tough service conditions experienced by incineration equipment.

The annual and lifecycle cost comparison of the two alternatives is shown below in **Table 2-5**. These numbers represent the O&M cost for the entire solids management train assuming mechanical thickening, centrifuge dewatering and drying or incineration.

Table 2-5: Thermal Drying and Incineration O&M Comparison

Parameter	Thermal Drying	Incineration
Full Time Employees (FTEs)	5.5	9.0
20-year Labor Cost (2024 \$)	\$9,000,000	\$13,000,000

Parameter	Thermal Drying	Incineration
20-year Operation Cost (2024 \$)	\$23,000,000	\$20,000,000
20-year Maintenance Cost (2024 \$)	\$32,000,000	\$30,000,000
20-year Hauling Cost (2024 \$)	\$13,000,000	\$10,000,000
20-year Lifecycle O&M (2024 \$)	\$77,000,000	\$73,000,000
CAPEX Cost (2024 \$)	\$138,000,000	\$132,000,000
20-year Lifecycle Cost (CAPEX + OPEX) (2024 \$)	\$215,000,000	\$205,000,000

Incineration presents a lower operating, maintenance and hauling cost compared to thermal drying, with a higher labor cost. This results in a lower lifecycle O&M cost for incineration. When combined with the capital cost for the full 20-year lifecycle cost, the thermal drying option is more expensive than the incineration option, but not by a significant amount. If OPEX is a decision driver, it must be considered which system would be easier to operate and MSD's comfort level with the technologies in each option. The incineration O&M cost does not include incinerator rehab, only maintenance of the incineration equipment and building. Rehabilitation costs may be substantial and require long shutdowns.

3. Operation and Maintenance Cost Comparison for Existing and Proposed Solids Train

Following selection of thermal drying as the preferred solids management technology, MSD requested Hazen compare the proposed solids management train (mechanical thickening, centrifuge dewatering, thermal drying) with the current solids management (gravity thickening, BFP dewatering, incineration) O&M costs. Comparisons of the two technologies to date considered a new FBI in addition to new thickening and dewatering equipment. It should be noted that the analysis in Section 2 above considered thermal drying and incineration operations cost only. This analysis in Section 3 is inclusive of thickening and dewatering. The existing solids handling system has gravity thickening and BFP dewatering. The proposed system with thermal drying will have mechanical thickening and centrifuge dewatering. Both the thickening and dewatering changes will result in an increase in operations costs. It is important to consider the increase in O&M costs as MSD is planning and budgeting for the transition from the existing solids handling system to a new thermal dryer with mechanical thickening and centrifuge dewatering.

Using 2024 operations costs provided by MSD, the following annual costs were developed for current operation. For comparison purposes to the assumptions for the thermal drying facility, this number was also converted to a dollar per dry ton cost basis.

Table 3-1: Current Solids Handling Annual Operation Cost

Current Operation	2024 Annual Cost	Unit Cost, \$/dT
2024 Mass Incinerated, dry tons/yr	7,582	
Natural Gas Annual Cost, \$/yr	\$100,000	\$13.20
Polymer Annual Cost, \$/yr	\$75,000	\$9.90
Potable Water Annual Cost, \$/yr	\$60,000	\$7.90
Electricity Annual Cost (no hydroelectric), \$/yr	\$270,000	\$35.60
Operations Unit Cost, \$/dT	\$505,000	\$66.60
Annual Operations Costs¹	\$188,000	N/A
Total Operations Cost	\$693,000	N/A
Total Hauling Cost²	\$504,000	N/A

¹Includes mercury module carbon replacement, sand replacement, NG for cold startup and annual stack testing costs.

²Based on discussions with MSD, this assumed 8 weeks of hauling, 12 trucks per day, 5 days per week at a cost of \$1,050 per truck due to incinerator annual shutdown.

Labor and maintenance costs were also estimated based on conversations with MSD staff and review of Cityworks annual work orders. For operations, MSD staff noted that 1.25 operators per shift are required to operate the existing gravity thickeners, BFPs and incinerator. Using the NEIWPC reference guide of 1,500 productive work hours per year per FTE, this would be equivalent to 7.3 FTEs for current operations.

For maintenance, work orders associated with the Incinerator Building and Gravity Thickener Pump Station from September 2023 to September 2025 were reviewed to determine the average annual maintenance cost (both parts and labor) associated with the solids train. Labor hours recorded within Cityworks can become inaccurate if a work order is not closed once the repair is complete. Therefore, labor hours in excess of 120 hours were removed from work orders to remove inaccuracies in the data. This reduced the hours recorded in Cityworks from 11,560 per year to a more reasonable 1,560 hours per year for a base assumption for maintenance labor. MSD reviewed cost records and also developed a material cost associated with each work order to sum to a total cost of \$138,000 per year. While the majority of items are captured in Cityworks, some repairs performed on an emergency basis are not recorded. Therefore, a 25% increase was applied to both the parts and labor estimated developed from Cityworks. **Table 3-2** below details the current solids handling labor and maintenance cost. MSD's current systemwide maintenance budget is \$2.5 million dollars, therefore the estimate below accounts for 11.5% of the total budget dedicated to the solids train.

Table 3-2: Current Solids Handling Labor and Maintenance Cost

Current Incinerator Operation	Value
Solids Operator Time, operators/shift	1.25
Solids Handling FTEs	7.3
Annual Operations Labor Cost, \$/yr	\$642,400
Maintenance Parts Estimate	\$172,500
Maintenance Labor Estimate, annual hours	1,950 hours/year
Annual Maintenance Labor Cost, \$/yr	\$114,000
Annual Maintenance Cost, \$/yr	\$268,500

In comparison, the annual O&M for the proposed project with mechanical thickening, centrifuge dewatering and thermal drying is dependent on a few major factors: polymer dosage for thickening and dewatering, electrical demand, natural gas requirement for drying and estimated labor and maintenance costs. A significant increase in operation and maintenance cost is anticipated for the proposed solids process. A good portion of this cost is associated with the operation, hauling and maintenance costs. The comparison is shown in **Table 3-3** below.

Table 3-3: O&M Cost Comparison between Current and Proposed Solids Handling Trains

Cost	Current Solids Handling Cost (Incineration)	Proposed Solids Handling Cost (Dryer)	% Change
Annual Operation Cost, \$/yr	\$693,000	\$1,777,000	156%
Annual Hauling Cost, \$/yr	\$504,000	\$725,000	44%
Annual Labor Cost, \$/yr	\$642,400	\$506,000	-21%
Annual Maintenance Cost, \$/yr	\$268,500	\$1,180,000	340%
Total Annual O&M Cost, \$/yr	\$2,108,000	\$4,188,000	99%

A review of each portion of the annual cost is detailed below for consideration.

- **Operation:** For the proposed system polymer usage makes up approximately 45% of the operations cost followed by 40% for natural gas and 15% for power. Polymer cost associated with mechanical thickening and centrifuge dewatering account for a significant portion of the cost increase. For reference, under the current scheme the polymer cost only accounts for 11% of the operation costs. The current polymer dosage for the BFPs is much lower than typically observed at 25 lb/dT, but on average 21% TS cake is produced. This creates uncertainty with the assumed thickening and dewatering centrifuge polymer dosages. Dewatering centrifuges typically require more polymer than BFPs; without any data a conservative dewatering centrifuge dose would be in the 40 lb/dT range. However, a tenfold increase would not be expected. For MSD, the dosage may be significantly lower to match the lower dosage required for the BFPs. However, this would also be contingent on the dewaterability of the future sludge after implementation of liquid process improvements. Considering these uncertainties, a sensitivity analysis was completed. **Table 3-4** demonstrates the impact of dewatering polymer dosage on OPEX cost.

Table 3-4: Impact of Polymer on Drying and Incineration O&M

Parameter	Current Solids Handling Cost (Incineration)	Proposed Solids Handling Cost (Dryer)			
Dewatered Polymer Dose, lb/dT	4.5	10	20	30	40
Annual Solids Operation Cost, \$/yr	\$693,000	\$1,215,000	\$1,402,000	\$1,590,000	\$1,777,000
% Change	--	75%	102%	130%	156%
Total Annual O&M Cost, \$/yr	\$2,108,000	\$3,626,000	\$3,813,000	\$4,001,000	\$4,188,000
% Change	--	72%	81%	90%	99%

- **Hauling:** As discussed previously, the hauling costs could potentially be offset by revenue associated with the final product from the thermal dryer. However, for conservatism the cost to haul dried pellets to the landfill was included. If hauling cost was excluded from the thermal dryer option, the total annual O&M cost would be reduced to \$3.46M, a 64% increase in O&M.
- **Labor:** A decrease in labor costs is anticipated with the transition to centrifuge dewatering from BFP dewatering and campaign style operations of the thermal dryer train.
- **Maintenance:** Maintenance is an assumed percentage of the overall project capital cost and is significantly higher than the current solids handling maintenance requirements accounting for almost 50% of MSD's current systemwide maintenance budget. Additional investigation into this assumption is recommended as Hazen does not think a 340% increase is accurate. **Table 3-5** below shows an estimate with a 100% increase in maintenance costs.

Table 3-5: O&M Cost Comparison between Current and Proposed Solids Handling Trains with Sensitivity Analysis

Cost	Current Solids Handling Cost (Incineration)	Proposed Solids Handling Cost (Dryer)	% Change
Annual Operation Cost, \$/yr	\$693,000	\$1,215,000 - \$1,777,000	75% - 156%
Annual Hauling Cost, \$/yr	\$504,000	\$0 - \$725,000	-100% - 44%
Annual Labor Cost, \$/yr	\$642,400	\$506,000	-21%
Annual Maintenance Cost, \$/yr	\$268,500	\$537,000 - \$1,180,000	100% - 340%
Total Annual O&M Cost, \$/yr	\$2,108,000	\$2,258,000 - \$4,188,000	7% - 99%

An increase in O&M cost is anticipated with the transition from the current solids management (gravity thickening, BFP dewatering, incineration) to the proposed solids management train (mechanical thickening, centrifuge dewatering, thermal drying). However, the actual increase will depend on many factors including:

- Actual polymer dose for mechanical thickening and dewatering and impact of changing biological treatment process on polymer dose
- Dried pellet final product management – ability to turn into revenue source
- Actual maintenance costs – would anticipate an increase as equipment ages, would be less to start