ARLINGTON RE-GEN

FACILITIES PLAN

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HDR

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Technical Memorandum No. 1

Date:	December 12, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Solids Production and Design Criteria

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Attachment A: Solids Process Flow Mass Balance

1.0 Introduction

This Technical Memorandum (TM) 1 serves to quantify the current solids production at the Arlington Water Pollution Control Plant (WPCP) and develop projections for future solids loads. Additionally, a solids process model spreadsheet was developed to generate mass balances for the future solids process configuration. This solids process model uses the solids load projections as inputs, along with assumptions for the unit process operations, which will be updated as decisions are made about various unit processes. The model will serve as a tool for evaluating the various unit process options. The WPCP data analysis and load projections are presented first, followed by the solids process model configuration and preliminary results.

2.0 Historical Flows and Loads

Historical WPCP flows and loads were evaluated to serve as a basis for projecting future solids loads. This section describes the approach for data collection and analysis, evaluation of liquid process flows and loads, and evaluation of solids process flows and loads. While the goal of this section is to quantify the solids loads, the liquid process loads were also evaluated to provide a point of reference for solids production and to allow solids production to be defined in terms of flow treated.

2.1 Data Collection

WPCP data for this analysis were exported from the WPCP's historian, Hach Water Information Management Solution (WIMS), in December 2020. Lime delivery data and annual sludge solids discharge monitoring reports were also gathered to provide an additional method of calculating and verifying overall WPCP solids production. The data analysis focused on the 3-year period from December 2017 through November 2020. In the discussion below, the average for a year (e.g., 2020) refers to the period from the previous December through November of that year.

The WPCP data set was reviewed by plotting key parameters, identifying outlier values, and developing mass balances to identify inconsistencies. An example of outlier data was unrealistically high truck scale weights on certain days, which were corrected by identifying the error in hourly data entries and then validated by comparing to sludge discharge monitoring reports. Another example is the reported solids concentration from the dissolved air flotation thickeners (DAFTs). It was found that DAFT solids values were skewed high with many outliers, and therefore would not be reliable for calculating waste activated sludge (WAS) loads. Mass balance calculations were developed to calculate loads across the solids processes using multiple methods. This approach allowed for the selection of the appropriate calculation methods and provided a means of checking overall WPCP solids production.

2.2 WPCP Flow and Influent Loads

The overall WPCP flow was evaluated along with influent biochemical oxygen demand (BOD) and total suspended solids (TSS) loads. The WPCP final effluent flow is the best measurement of WPCP flow, because it is calculated from only two measurements (post-aeration effluent minus plant effluent water used), whereas WPCP influent flow is a calculated value from multiple influent sources and WPCP recycles. WPCP effluent flows are summarized in Table 1 below. The average effluent flow of 23 million gallons per day (mgd) was used to define solids production in terms of flow treated. Flow peaking factors are shown for reference and were not used to specify the WPCP solids loads.

Table 1. WPCP Effluent Flows and Peaking Factors

Parameter	Final Effluent Flow (mgd)			
2018 average	23.9			
2019 average	23.6			
2020 average	21.7			
3-year average	**23.0**			
Parameter	**30-day PF**	**14-day PF**	**7-day PF**	**3-day PF**
2018 peaking factor	1.24	1.34	1.60	2.00
2019 peaking factor	1.20	1.26	1.51	1.94
2020 peaking factor	1.11	1.16	1.24	1.36
Average peaking factor	**1.19**	**1.26**	**1.45**	**1.77**

Primary influent loads and peaking factors (Table 2) were calculated based on influent BOD or TSS measurements and primary effluent flow, with the assumption that the measured primary effluent flow is approximately equal to the primary influent flow, which is not directly measured. Average primary effluent flow was 29 mgd, which is approximately 6 mgd higher than the WPCP effluent flow because of recycles from WPCP effluent water use, backwash, thickening, and dewatering. The primary influent BOD and TSS measurements also include WPCP recycles. A gravity thickener (GT) upset in 2018 that lasted more than a month had a dramatic effect on the load calculations. For this reason, 2018 was excluded from the analysis presented in Table 2, and 2017 data were used instead. The primary influent loads and peaking factors in Table 2 are presented for reference and were not directly used in calculating solids production. Average primary solids capture during 2017–2020 was 68 percent, calculated based on comparing primary influent and effluent TSS values.

Table 2. Primary Influent BOD, TSS Loads and Peaking Factors

Parameter	Primary Influent BOD (lb/d)			Primary Influent TSS (lb-DS/d)		
2017 average	71,100			68,400		
2019 average	65,600			58,100		
2020 average	60,300			56,800		
3-year average	**65,700**			**61,100**		
Parameter	**30-day**	**14-day PF**	**7-day PF**	**30-day PF**	**14-day PF**	**7-day PF**
2017 peaking factor	1.21	1.38	1.48	1.26	1.43	1.64
2019 peaking factor	1.16	1.31	1.45	1.13	1.29	1.56
2020 peaking factor	1.33	1.42	1.60	1.34	1.59	2.02
Average peaking factor	**1.24**	**1.37**	**1.51**	**1.24**	**1.43**	**1.74**

2.3 Solids Production

The overall goals of this analysis were to determine the following:

- The WPCP solids production in terms of dewatered cake hauled (dry tons [DT] per million gallons [MG] of flow treated)
- Primary sludge (PS) or thickened primary sludge (TPS) production
- Primary scum production
- WAS or thickened waste activated sludge (TWAS) production
- Capture rates for thickening and dewatering processes
- Load peaking factors for PS, WAS, and cake (peak 30-day, 14-day, 7-day, and 3-day)

Together these parameters define the solids loads across unit processes. Multiple calculation approaches were evaluated where possible. Data are presented for the selected calculation approach, and some of the alternative approaches are discussed to explain the reasoning for using the selected approach. Figure 1 illustrates the simplified solids process schematic with flow meter locations and total solids (TS) sample collection points identified. The approaches for calculating key solids loads are also shown.

- WAS load was calculated using the total WAS flow and average TS concentration to the DAFT.
- Cake load was calculated using two methods: centrifuge feed load minus centrate load or hauled solids minus lime and water content.
- Thickened PS and primary scum loads were calculated based on an overall mass balance using the cake load, WAS load, and capture rates for thickening and dewatering processes.

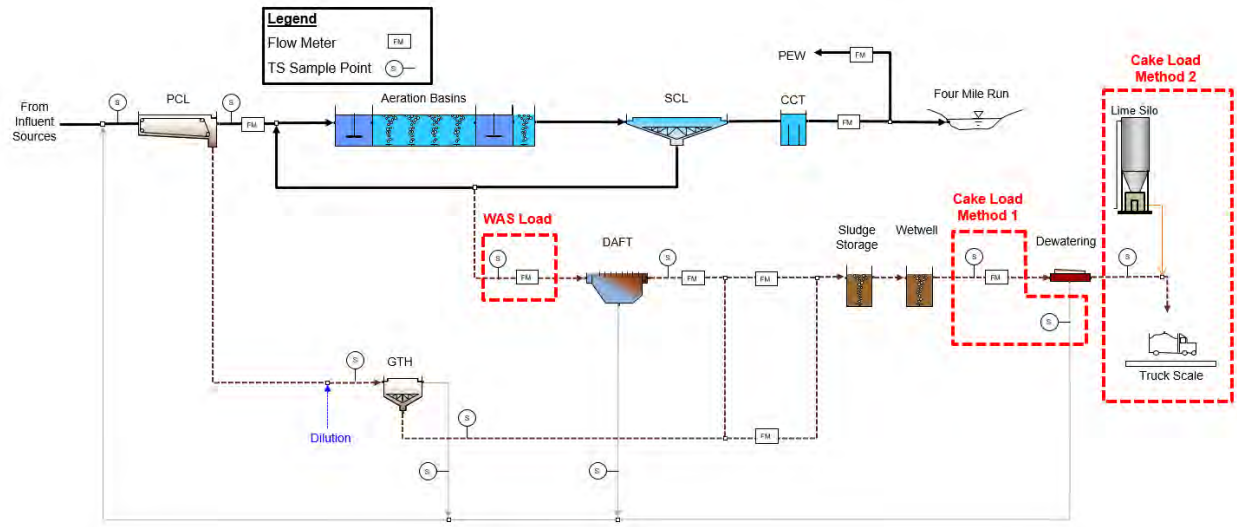

Figure 1. Simplified process schematic and solids load calculation methods

2.3.1 Primary Sludge and Scum

The concentration of the PS is not regularly measured prior to dilution water addition and gravity thickening. WPCP staff collected PS samples for TS analysis on March 9 and April 15, 2021, and PS flow was measured with a strap-on flow meter during the April 15 sampling. Based on these sampling events and analysis of PS runtimes, the typical PS concentration is estimated to be approximately 1.0 percent TS.

Average TPS plus primary scum loads and peaking factors are summarized in Table 3. PS and primary scum were quantified together based the mass balance approaches that were available, and the primary scum component is broken out later based on a separate analysis of primary scum. Loads are presented in terms of thickened sludge to dewatering, rather than un-thickened loads, because of limited flow and concentration data for PS and primary scum. Un-thickened loads can be calculated based on thickening capture rates. TPS plus primary scum loads were calculated based on the centrifuge feed solids load and subtracting the WAS load. Peaking factors were calculated based on the blended sludge solids load and subtracting the WAS load. The TPS load calculation approach using centrifuge feed was deemed to be more accurate for overall solids production because the centrifuge feed solids load was most similar to

the WPCP solids production calculated based on hauling records. The approach using the blended sludge load (north and south headers) was deemed more appropriate for peaking factors because this flow is less affected by dewatering operations, whereas the centrifuge feed experiences additional variations because of dewatering schedules. The average TPS plus scum production was approximately 41,900 pounds per day (lb/d). Solids capture at the GT was estimated at 95 percent based on the available data for GT influent TS after dilution and GT overflow TSS.

Table 3. Thickened Primary Sludge and Scum Loads and Peaking Factors

Parameter	Thickened Primary Sludge and Scum (lb-DS/d)			
2018 average	43,300			
2019 average	43,000			
2020 average	39,500			
3-year average	**41,900**			
Parameter	**30-day PF**	**14-day PF**	**7-day PF**	**3-day PF**
2018 peaking factor	1.31	1.44	1.50	1.72
2019 peaking factor	1.43	1.56	1.69	1.84
2020 peaking factor	1.31	1.37	1.41	1.60
Average peaking factor	**1.35**	**1.46**	**1.53**	**1.72**

Alternative calculation methods for TPS and primary scum loads were also evaluated. Average TPS plus scum loads for years without significant GT upsets (2017, 2019, and 2020) were calculated based on primary clarifier influent and effluent TSS along with primary effluent flow, and this method produced a slightly lower estimate of 39,500 lb/d PS (61,100 lb/d primary influent TSS from Table 2 × 68.1 percent primary clarifier capture × 95 percent thickening capture). This approach was not preferred because it cannot be applied during periods when there was a GT upset, and it has larger fluctuations that would lead to unrealistic peaking factors. TPS load was also estimated using the blended sludge flow, subtracting the TWAS flow, and applying the measured TPS solids concentration. That method produced higher results (49,400 lb/d) and was not used because inaccuracies in either the TWAS flow measurement or TPS grab sample solids concentrations could affect the results.

Historically, primary scum has been added to the DAFT. In the near future, scum will be concentrated separately and added to screenings sent to landfill. Given the calculation approach used for this analysis, primary scum and TPS load are quantified together (calculated as centrifuge feed minus WAS). Limited data were available for primary scum, so special sampling was conducted on April 29, 2021. Results for scum percentage TS and percentage VS were highly variable, but typically averaged between 0.5 and 1.0 %TS and 90 percent volatile. The current primary scum production is estimated at 4,800 lb/d based on an average primary scum pump runtime of 16 hours per day, flow of 120 gallons per minute (gpm) when running, and 0.50 percent TS.

2.3.2 Waste Activated Sludge

WAS loads and peaking factors were calculated based on the total WAS flow and WAS concentration (Table 4). Average WAS production was 21,800 lb/d. Average solids capture at the DAFT was over 99.5 percent, based on the average DAFT underflow TSS concentration of 57 milligrams per liter (mg/L) and assuming that no WPCP effluent water is added. With this high capture rate, the WAS load is nearly equal to the TWAS load. As an alternative evaluation approach, the TWAS load was calculated based on TWAS flow and solids concentration. That approach was not reliable and resulted in much higher TWAS loads (28,000 lb/d) because of the TWAS solids values being skewed high even after removing outliers.

The reported TWAS solids concentration averaged 4.1 percent after removing outliers above 9 percent solids. Based on the average TWAS flow rate (57 gpm) and the average WAS load to the DAFT (21,800 lb/d), the TWAS solids concentration is expected to be around 3.2 percent.

Table 4. WAS Loads and Peaking Factors

Parameter	WAS (lb-DS/d)			
2018 average	22,400			
2019 average	22,000			
2020 average	21,100			
3-year average	**21,800**			
Parameter	**30-day PF**	**14-day PF**	**7-day PF**	**3-day PF**
2018 peaking factor	1.21	1.26	1.32	1.47
2019 peaking factor	1.26	1.40	1.45	1.52
2020 peaking factor	1.23	1.42	1.60	1.65
Average peaking factor	**1.23**	**1.36**	**1.46**	**1.55**

2.3.3 Overall Solids Production

Centrifuge feed loads and peaking factors are summarized in Table 5. Average solids load to the centrifuges was 63,700 lb/d. The 3-day peaking factor is influenced by dewatering operation schedules, rather than purely solids generation. Instead, peaking factors for dewatering loads were selected based on a simultaneous peak in TPS and TWAS loads. This results in slightly lower and more realistic 7-day and 3-day peaking factors, while still providing a somewhat conservative estimate of peak solids production.

Table 5. Centrifuge Feed Loads and Peaking Factors

Parameter	Centrifuge Feed Load (lb-DS/d)			
2018 average	65,600			
2019 average	65,000			
2020 average	60,600			
3-year average	**63,700**			
Parameter	**30-day PF**	**14-day PF**	**7-day PF**	**3-day PF**
2018 peaking factor	1.14	1.22	1.37	1.84
2019 peaking factor	1.25	1.35	1.55	1.74
2020 peaking factor	1.41	1.54	1.67	1.96
Average peaking factor[a]	1.27	1.37	1.53	1.85
Peaking factor used[b]	**1.31**	**1.41**	**1.51**	**1.66**

a. Calculated peaking factor is influenced by dewatering operations, particularly the 3-day factor.
b. The selected peaking factor is based on simultaneous peak of TWAS and TPS production.

Dewatered cake production was calculated two ways, as shown in Table 6. The “centrifuge feed minus centrate” approach builds on the data from Table 5, subtracting the centrate solids load calculated using the Hach WIMS data. Average centrifuge solids capture was 95 percent. The “solids hauled minus lime” method is an independent calculation used to corroborate the solids production results. It is based on reported wet tons per day (wtpd) hauled from sludge solids discharge monitoring reports (~97.5 wtpd), subtracting the lime quantity used from delivery records (~4.9 tons/day), and applying the average cake solids concentration from the centrifuges (~31.3 percent). The results from these two methods were quite similar, ranging from 1.26 to 1.31 DT/MG treated. An overall sludge production value of 1.30 DT/MG was selected for developing solids process mass balances. This sludge production is reasonable given the BOD influent to the plant and the use of chemically enhanced primary treatment.

Table 6. Overall Solids Production based on Dewatering Data and Hauling Records

Parameter	Effluent Flow (mgd)	Dewatered Cake (Centrifuge Feed: Centrate)		Dewatered Cake (Solids Hauled – Lime)	
		lb-DS/d	DT/MG	lb-DS/d	DT/MG
2018 average	23.9	60,900	1.28	60,000	1.26
2019 average	23.6	62,400	1.32	60,200	1.28
2020 average	21.7	57,600	1.33	54,100	1.25
3-year average	**23.0**	**60,300**	**1.31**	**58,100**	**1.26**

The solids production factors presented above are summarized in Table 7, along with the method used for developing each factor. These parameters were used to generate a solids mass balance for current conditions, which served as the basis for scaling to future loading conditions.

Table 7. Summary of Solids Production Factors

Parameter	Value				Notes
Dewatered cake production	1.3 DT/MG treated				Based on analysis of centrifuge operating data and hauling records
Capture rates	Centrifuge: 95%, GT: 95%, DAFT: 99.5%				Based on analysis of operating data
TWAS load fraction [TWAS/(TWAS+TPS)]	34.5% of dry solids to dewatering				Based on average WAS load along with overall solids production and capture rates
Parameter	**30-day PF**	**14-day PF**	**7-day PF**	**3-day PF**	**Notes**
PS or TPS peaking factor	1.35	1.46	1.53	1.72	Based on blended sludge load minus WAS load
WAS or TWAS peaking factor	1.23	1.36	1.46	1.55	Based on WAS load to DAFT
Centrifuge feed or cake peaking factor	1.31	1.41	1.51	1.66	Based on simultaneous TWAS and TPS peak

2.3.4 Volatile Solids Fraction

The volatile solids (VS) fraction of the sludge is an important factor for evaluating future anaerobic digestion (AD) and digester gas utilization strategies. Based on the WPCP data, the TPS was 84.2 percent volatile (±5 percent standard deviation) and the TWAS was 72.4 percent volatile (±8 percent standard deviation). Variability in the VS fraction was higher for TWAS than TPS, which could be related to the primary scum added to the DAFT. Using these average values along with the quantities presented above, the mixed sludge or cake is expected to be 80.6 percent volatile by mass balance. WPCP data indicate that blended sludge was 78 percent volatile (±5 percent standard deviation) and dewatered cake was 81.4 percent volatile (±3 percent standard deviation), so this calculated value is reasonable. The primary scum is approximately 90 percent volatile, and by mass balance the TWAS without scum is estimated to be 68.5 percent volatile. Results of a two-week sampling event in December 2021 showed that the WAS was 67.5 percent volatile on average, which supports the calculated value used in this evaluation.

2.4 Solids Production Summary

Current and projected solids loads are summarized in Table 8 below. The values are based on the mass balance analysis presented above. Key calculation inputs and assumptions include the following:

- Overall solids production from the dewatering centrifuges is 1.30 DT/MG treated as currently configured.

- The solids production analysis reflects historical operating conditions including capture rates and the use of ferric chloride for enhanced primary clarification. Solids projections assume that operation of liquid treatment processes is similar in the future.
- Primary scum is included based on the available data and the current practice of sending primary scum to the DAFT and ultimately to dewatering. Peaking factors for scum are assumed to be the same as those for PS. While primary scum is included in the solids loads, it has not been decided whether scum will be included in future THP and anaerobic digestion.
- Current solids capture rates were 95 percent for gravity thickening (PS), 99.5 percent for DAFT (WAS), and 95 percent for centrifuge dewatering.
- Future load projections were evaluated for WPCP flows of 30.8 mgd and 40.0 mgd. The 30.8 mgd WPCP flow condition represents approximately 40 dry tons per day (dtpd) from the centrifuges at current operating conditions and was selected as the design condition for this project during Workshop 2 on March 17, 2021. Based on the most recent Arlington County growth projections (Arlington County Forecast Round 9.1) and assuming linear growth, this condition is expected to be met around year 2051. The 40.0 mgd WPCP flow condition represents the WPCP buildout capacity and the design capacity of the liquid side of the WPCP.

Table 8. Solids Production Summary and Future Projections

Year	Effluent Flow (mgd)	Primary Solids (lb/d)				
		Average	30-day	14-day	7-day	3-day
2020	23.0	38,400	51,800	56,000	59,100	66,000
Design	30.8	51,400	69,400	75,000	79,100	88,400
Buildout	40.0	66,700	90,100	97,400	102,800	114,800
Year	**Effluent Flow (mgd)**	**Primary Scum (lb/d)**				
		Average	**30-day**	**14-day**	**7-day**	**3-day**
2020	23.0	4,800	6,500	7,000	7,400	8,200
Design	30.8	6,400	8,600	9,400	9,900	11,000
Buildout	40.0	8,300	11,200	12,100	12,800	14,300
Year	**Effluent Flow (mgd)**	**WAS (lb/d)**				
		Average	**30-day**	**14-day**	**7-day**	**3-day**
2020	23.0	21,800	26,800	29,700	31,600	33,800
Design	30.8	29,200	36,000	39,800	42,400	45,300
Buildout	40.0	38,000	46,700	51,600	55,000	58,800
Year	**Effluent Flow (mgd)**	**Combined Thickened Solids (lb/d)**				
		Average	**30-day**	**14-day**	**7-day**	**3-day**
2020	23.0	62,900	82,400	89,800	95,000	104,600
Design	30.8	84,300	110,300	120,200	127,200	140,000
Buildout	40.0	109,500	143,300	156,100	165,200	181,900
Year	**Effluent Flow (mgd)**	**Centrifuge Cake (lb/d)**				
		Average	**30-day**	**14-day**	**7-day**	**3-day**
2020	23.0	59,800	78,300	85,200	90,200	99,300
Design	30.8	80,000	104,800	114,200	120,800	133,000
Buildout	40.0	104,000	136,100	148,300	157,000	172,800

3.0 Preliminary Solids Process Model

This section describes the preliminary solids process model, including its background and purpose, solids process model assumptions, and solids process model outputs.

3.1 Background and Purpose

A solids process model was developed using a mass balance approach to determine system operations at steady state. The model includes all major unit processes for the proposed solids handling configuration. Inputs to the model include average solids production quantities and maximum 30-day, 14-day, 7-day, and 3-day peaking factors. These solids quantities are based on the analysis of WPCP data presented in the previous section. Solids quantities are projected to future conditions based on expected increases in WPCP flow and load. The model includes inputs for each unit process, which are currently based on typical industry values and vendor information. Process parameters will be adjusted and updated as necessary as decisions are made regarding equipment selection and process configuration and as additional information is gathered from the thermal hydrolysis process (THP)/AD pilot testing.

The model output is a mass balance at each step in the solids processes. A proposed solids process configuration is illustrated in Figure 2, which is based on THP/AD as recommended by the 2018 Arlington WPCP Solids Master Plan (CDM Smith). Parameters specific to each unit process are included, such as steam demand for THP, sludge cooling requirements, nitrogen (N) released in the AD process, digester gas production, polymer use, and wash water and dilution water requirements.

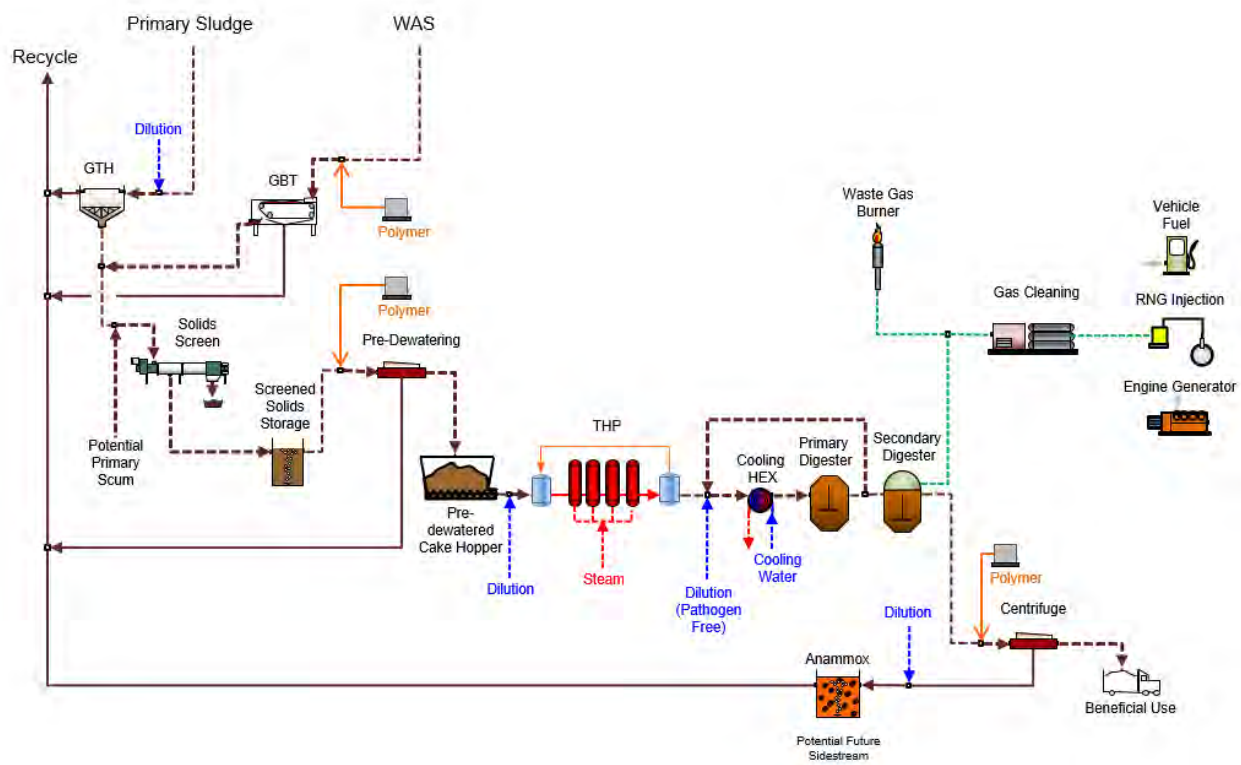

Figure 2. Proposed solids process flow diagram

3.2 Solids Process Model Assumptions

The solids process model was developed starting with the flow and load conditions presented in the previous section. This includes overall sludge production of 1.30 DT/MG treated, stated peaking factors and VS fractions, and similar liquid treatment process operation in the future.

The process model configuration was based on the process flow depicted in Figure 2, and assumptions for process operation listed in Table 9. Many of these parameters will be revised as process decisions are made (e.g., thickening approach, scum/fats, oils, and grease [FOG]) and as additional information is gathered from the WPCP and from the THP/AD pilot testing (e.g., VS destruction, sludge nitrogen content, etc.). Future changes in solids recycle loads relative to current thickening and dewatering operations are reflected in the model as additional primary solids. The process model and mass balance calculations provide a basis for further evaluations and will be updated and expanded as necessary.

Table 9. Process Model Assumptions

Primary Sludge and Thickened Primary Sludge	Value	Source
PS solids concentration	1.0%	Based on analysis of special sampling 3/9/2021 and 4/15/2021
TPS solids concentration	4.0%	Based on analysis of plant data, average was 5%
Solids capture: PS thickening	95%	Based on analysis of plant data for GT influent and overflow
Primary Scum		
Dilute primary scum concentration	0.5%	Average ranged from 0.5% to 1.0% during 2021 special sampling. Scum flow capped at 120 gpm in model and concentration increased accordingly.
WAS and TWAS		
WAS solids concentration	1.0%	Based on analysis of WPCP data, average was 1.08%
Future TWAS solids concentration	5.0%	Typical industry value
Solids capture: Future WAS thickening	98%	Based on historical DAFT capture of >99%
WAS thickening polymer dose (lb active polymer/DT)	5	Typical industry value
Pre-dewatering		
Pre-dewatered solids concentration	25%	High solids not required for pre-dewatering; feasibility to be evaluated further
Pre-dewatering solids capture	95%	Based on current centrifuge dewatering
Dewatering polymer dose (lb active polymer/DT)	10	Based on historical operation at 8 lb/DT
THP/AD		
THP steam demand (ton steam per ton dry solids)	1.0	Typical value for Cambi
Digested sludge recycle ratio to heat exchanger feed	3.5–5.0	Typically set to 3.5:1 recycle ratio at peak 3-day condition
Digester feed solids concentration	9.0%	Typical value for THP
Volatile solids reduction	60%	Typical industry value, supported by pilot results
Sludge nitrogen content (lb-N/lb-VS)	0.045	Based on replicating pilot digester effluent ammonia
Biogas yield (ft^3-biogas/lb-VSd)	15	Typical industry value, supported by pilot results
Biogas higher heating value (Btu/ft^3-biogas)	650	Typical industry value
Biogas lower heating value (Btu/ft^3-biogas)	580	Typical industry value
Post-dewatering		
Post-dewatering solids capture	95%	Typical industry value for centrifuge dewatering
Post-dewatered solids concentration	33%	Estimate; evaluations ongoing
Dewatering polymer dose (lb active polymer/DT)	30	Estimate

3.3 Solids Process Model Outputs

This section presents the modeled flows and loads for each unit process at WPCP flows and loads associated with current conditions (23 mgd annual average effluent flow), selected design year conditions (30.8 mgd), and WPCP buildout (40 mgd).

An overall mass balance process flow diagram for the selected design year annual average conditions is included as Attachment A. While only one operating condition is shown in Attachment A, the tables in this section provide flows, loads, gas production, thermal energy demands, and polymer use for each WPCP flow condition (23.0, 30.8, and 40.0 mgd) and peaking factor (annual average, peak 30-day, 14-day, 7-day, and 3-day). Table 10 through Table 12 include the major process flows and loads for each of these three WPCP flow conditions. Model input parameters included in these tables are italicized. Table 13 through Table 15 show the energy calculations, and Table 16 through Table 18 show the polymer use for each condition.

Table 10. Solids Process Model Flows: 23.0 mgd Flow (2020 Condition)

Parameter	Average	30-day	14-day	7-day	3-day
Primary Solids					
Total solids load (lb-TS/d)	39,924	53,831	58,234	61,434	68,576
Volatile solids load (lb-VS/d)	33,254	44,853	48,518	51,181	57,140
Total solids concentration	1.0%	1.0%	1.0%	1.0%	1.0%
Volatile fraction (lb-VS/lb-TS)	83.3%	83.3%	83.3%	83.3%	83.3%
Flow (gpd)	478,709	645,460	698,251	736,614	822,251
Flow (gpm)	332	448	485	512	571
Thickened Primary Solids					
Total solids load (lb-TS/d)	37,928	51,140	55,322	58,362	65,147
Volatile solids load (lb-VS/d)	31,592	42,610	46,092	48,622	54,283
Total solids concentration	4.0%	4.0%	4.0%	4.0%	4.0%
Volatile fraction (lb-VS/lb-TS)	83.3%	83.3%	83.3%	83.3%	83.3%
Flow (gpd)	113,693	153,297	165,835	174,946	195,285
Flow (gpm)	79	106	115	121	136
WAS					
Total solids load (lb-TS/d)	21,826	26,846	29,683	31,648	33,830
Volatile solids load (lb-VS/d)	14,951	18,389	20,333	21,679	23,174
Total solids concentration	1.0%	1.0%	1.0%	1.0%	1.0%
Volatile fraction (lb-VS/lb-TS)	68.5%	68.5%	68.5%	68.5%	68.5%
Flow (gpd)	261,702	321,894	355,915	379,468	405,639
Flow (gpm)	182	224	247	264	282
Primary Scum (to Solids Storage Tank with WAS)					
Total solids load (lb-TS/d)	4,784	6,458	6,985	7,367	8,228
Volatile solids load (lb-VS/d)	4,306	5,813	6,286	6,631	7,406
Total solids concentration (lb-TS/lb-sludge)	0.50%	0.50%	0.50%	0.51%	0.57%
Volatile fraction (lb-VS/lb-TS)	90%	90%	90%	90%	90%
Flow (gpd)	114,724	154,878	167,497	172,800	172,800
Flow (gpm)	80	108	116	120	120
Combined Thickened Solids/Pre-dewatering Feed					
Total solids load (lb-TS/d)	64,538	84,444	91,990	97,377	107,206
Volatile solids load (lb-VS/d)	50,848	66,812	72,711	76,932	84,863
Total solids concentration	1.6%	1.6%	1.6%	1.6%	1.7%
Volatile fraction (lb-VS/lb-TS)	78.8%	79.1%	79.0%	79.0%	79.2%

Parameter	Average	30-day	14-day	7-day	3-day
TWAS load fraction (TWAS / (TWAS + TPS + FOG))	33.8%	31.8%	32.3%	32.5%	31.6%
Flow (gpd)	490,120	630,068	689,247	727,214	773,723
Flow (gpm)	340	438	479	505	537
Pre-dewatered Solids					
Total solids load (dtpd)	30.7	40.1	43.7	46.3	50.9
Total solids load (lb-TS/d)	61,311	80,222	87,391	92,508	101,845
Volatile solids load (lb-VS/d)	48,306	63,472	69,076	73,085	80,619
Total solids concentration (lb-TS/lb-sludge)	25.0%	25.0%	25.0%	25.0%	25.0%
Flow (gpd)	29,406	38,476	41,914	44,368	48,847
Flow (gpm)	20	27	29	31	34
Cake mass (wtpd)	123	160	175	185	204
Cake volume (CY/d at 45 lb/ft^3)	202	264	288	305	335
Thermal Hydrolysis Feed Solids with Dilution Water					
Total solids load (lb-TS/d)	61,311	80,222	87,391	92,508	101,845
Volatile solids load (lb-VS/d)	48,306	63,472	69,076	73,085	80,619
Total solids concentration (lb-TS/lb-sludge)	16.5%	16.5%	16.5%	16.5%	16.5%
Flow (gpd)	44,554	58,297	63,506	67,225	74,010
Flow (gpm)	31	40	44	47	51
Thermal Hydrolysis Depressurization Tank Solids with Steam Condensate					
Total solids load (lb-TS/d)	61,311	80,222	87,391	92,508	101,845
Volatile solids load (lb-VS/d)	48,306	63,472	69,076	73,085	80,619
Total solids concentration (lb-TS/lb-sludge)	14.2%	14.2%	14.2%	14.2%	14.2%
Flow (gpd)	51,906	67,916	73,985	78,317	86,222
Flow (gpm)	36	47	51	54	60
Temperature (°F)	221	221	221	221	221
Diluted THP Solids: Depressurization Tank Output and Pathogen-Free Dilution Water					
Total solids load (lb-TS/d)	61,311	80,222	87,391	92,508	101,845
Volatile solids load (lb-VS/d)	48,306	63,472	69,076	73,085	80,619
Total solids concentration (lb-TS/lb-sludge)	9.0%	9.0%	9.0%	9.0%	9.0%
Flow (gpd)	81,683	106,877	116,428	123,246	135,685
Flow (gpm)	57	74	81	86	94
Temperature (°F)	168	168	168	168	168
Digested Solids Recycle: to Cooling Heat Exchanger					
Total solids concentration (lb-TS/lb-sludge)	4.5%	4.5%	4.5%	4.5%	4.5%
Flow (gpd)	408,414	408,395	408,399	474,909	474,899
Flow (gpm)	284	284	284	330	330
Temperature (°F)	98	98	98	98	98
Digester Feed Solids: Diluted THP Sludge with Recycled Digested Sludge					
Total solids concentration (lb-TS/lb-sludge)	5.1%	5.2%	5.2%	5.2%	5.2%
Flow (gpd)	490,097	515,272	524,827	598,155	610,584
Flow (gpm)	340	358	364	415	424
Temperature before HEX (°F)	110	113	114	112	114
Temperature after HEX (°F)	98	98	98	98	98
Digested Solids (to Final Dewatering)					
Total solids load (lb-TS/d)	30,692	39,930	43,557	46,137	50,660
Volatile solids load (lb-VS/d)	17,686	23,180	25,241	26,714	29,434
Total solids concentration (lb-TS/lb-sludge)	4.5%	4.5%	4.5%	4.5%	4.5%
Volatile fraction (lb-VS/lb-TS)	57.6%	58.1%	58.0%	57.9%	58.1%
Flow (gpd)	81,683	106,877	116,428	123,246	135,685
Flow (gpm)	57	74	81	86	94
Ammonia-N concentration (mg/L)	1,996	2,006	2,004	2,003	2,007

Parameter	Average	30-day	14-day	7-day	3-day
Final Dewatering Cake Product					
Total solids load (dtpd)	15	19	21	22	24
Total solids load (lb-TS/d)	29,157	37,934	41,379	43,831	48,127
Volatile solids load (lb-VS/d)	16,802	22,021	23,979	25,379	27,962
Total solids concentration (lb-TS/lb-sludge)	33.0%	33.0%	33.0%	33.0%	33.0%
Cake mass to end use (wtpd)	44	57	63	66	73
Cake volume (CY/d at 45 lb/ft^3)	73	95	103	109	120
Combined Recycles (Thickening, Pre-dewatering, and Final Dewatering)					
Total solids load (lb-TS/d)	6,758	8,910	9,689	10,247	11,322
Flow (mgd)	1.95	2.24	2.35	2.42	2.55
Post-dewatering recycle ammonia load (lb-N/d)	1,274	1,676	1,823	1,929	2,129

Table 11. Solids Process Model Flows: 30.8 mgd Flow (Design Condition)

Parameter	Average	30-day	14-day	7-day	3-day
Primary Solids					
Total solids load (lb-TS/d)	53,464	72,087	77,983	82,268	91,832
Volatile solids load (lb-VS/d)	44,532	60,064	64,972	68,539	76,518
Total solids concentration	1.0%	1.0%	1.0%	1.0%	1.0%
Volatile fraction (lb-VS/lb-TS)	83.3%	83.3%	83.3%	83.3%	83.3%
Flow (gpd)	641,053	864,356	935,049	986,422	1,101,101
Flow (gpm)	445	600	649	685	765
Thickened Primary Solids					
Total solids load (lb-TS/d)	50,791	68,483	74,084	78,154	87,240
Volatile solids load (lb-VS/d)	42,305	57,061	61,723	65,112	72,692
Total solids concentration	4.0%	4.0%	4.0%	4.0%	4.0%
Volatile fraction (lb-VS/lb-TS)	83.3%	83.3%	83.3%	83.3%	83.3%
Flow (gpd)	152,250	205,285	222,074	234,275	261,512
Flow (gpm)	106	143	154	163	182
WAS					
Total solids load (lb-TS/d)	29,228	35,950	39,750	42,380	45,303
Volatile solids load (lb-VS/d)	20,021	24,626	27,229	29,031	31,033
Total solids concentration	1.0%	1.0%	1.0%	1.0%	1.0%
Volatile fraction (lb-VS/lb-TS)	68.5%	68.5%	68.5%	68.5%	68.5%
Flow (gpd)	350,454	431,058	476,617	508,158	543,203
Flow (gpm)	243	299	331	353	377
Primary Scum (to Solids Storage Tank with WAS)					
Total solids load (lb-TS/d)	6,406	8,649	9,353	9,866	11,019
Volatile solids load (lb-VS/d)	5,766	7,784	8,418	8,879	9,917
Total solids concentration (lb-TS/lb-sludge)	0.50%	0.60%	0.65%	0.68%	0.76%
Volatile fraction (lb-VS/lb-TS)	90%	90%	90%	90%	90%
Flow (gpd)	153,631	172,800	172,800	172,800	172,800
Flow (gpm)	107	120	120	120	120
Combined Thickened Solids /Pre-dewatering Feed					
Total solids load (lb-TS/d)	86,425	113,082	123,187	130,400	143,562
Volatile solids load (lb-VS/d)	68,092	89,470	97,370	103,022	113,642
Total solids concentration	1.6%	1.7%	1.7%	1.7%	1.8%
Volatile fraction (lb-VS/lb-TS)	78.8%	79.1%	79.0%	79.0%	79.2%
TWAS load fraction (TWAS / (TWAS + TPS + FOG))	33.8%	31.8%	32.3%	32.5%	31.6%
Flow (gpd)	656,334	809,142	871,491	915,233	977,515
Flow (gpm)	456	562	605	636	679

Parameter	Average	30-day	14-day	7-day	3-day
Pre-dewatered Solids					
Total solids load (dtpd)	41.1	53.7	58.5	61.9	68.2
Total solids load (lb-TS/d)	82,104	107,428	117,028	123,880	136,384
Volatile solids load (lb-VS/d)	64,688	84,997	92,501	97,870	107,960
Total solids concentration (lb-TS/lb-sludge)	25.0%	25.0%	25.0%	25.0%	25.0%
Flow (gpd)	39,378	51,524	56,128	59,415	65,412
Flow (gpm)	27	36	39	41	45
Cake mass (wtpd)	164	215	234	248	273
Cake volume (CY/d at 45 lb/ft^3)	270	354	385	408	449
Thermal Hydrolysis Feed Solids with Dilution Water					
Total solids load (lb-TS/d)	82,104	107,428	117,028	123,880	136,384
Volatile solids load (lb-VS/d)	64,688	84,997	92,501	97,870	107,960
Total solids concentration (lb-TS/lb-sludge)	16.5%	16.5%	16.5%	16.5%	16.5%
Flow (gpd)	59,664	78,067	85,043	90,023	99,109
Flow (gpm)	41	54	59	63	69
Thermal Hydrolysis Depressurization Tank Solids with Steam Condensate					
Total solids load (lb-TS/d)	82,104	107,428	117,028	123,880	136,384
Volatile solids load (lb-VS/d)	64,688	84,997	92,501	97,870	107,960
Total solids concentration (lb-TS/lb-sludge)	14.2%	14.2%	14.2%	14.2%	14.2%
Flow (gpd)	69,509	90,948	99,075	104,877	115,462
Flow (gpm)	48	63	69	73	80
Temperature (°F)	221	221	221	221	221
Diluted THP Solids: Depressurization Tank Output and Pathogen-Free Dilution Water					
Total solids load (lb-TS/d)	82,104	107,428	117,028	123,880	136,384
Volatile solids load (lb-VS/d)	64,688	84,997	92,501	97,870	107,960
Total solids concentration (lb-TS/lb-sludge)	9.0%	9.0%	9.0%	9.0%	9.0%
Flow (gpd)	109,384	143,122	155,912	165,042	181,700
Flow (gpm)	76	99	108	115	126
Temperature (°F)	168	168	168	168	168
Digested Solids Recycle: to Cooling Heat Exchanger					
Total solids concentration (lb-TS/lb-sludge)	4.5%	4.5%	4.5%	4.5%	4.5%
Flow (gpd)	546,920	546,894	546,900	635,965	635,951
Flow (gpm)	380	380	380	442	442
Temperature (°F)	98	98	98	98	98
Digester Feed Solids: Diluted THP Sludge with Recycled Digested Sludge					
Total solids concentration (lb-TS/lb-sludge)	5.1%	5.2%	5.2%	5.2%	5.2%
Flow (gpd)	656,304	690,016	702,812	801,007	817,652
Flow (gpm)	456	479	488	556	568
Temperature before HEX (°F)	110	113	114	112	114
Temperature after HEX (°F)	98	98	98	98	98
Digested Solids (to Final Dewatering)					
Total solids load (lb-TS/d)	41,100	53,472	58,328	61,784	67,840
Volatile solids load (lb-VS/d)	23,684	31,041	33,802	35,774	39,416
Total solids concentration (lb-TS/lb-sludge)	4.5%	4.5%	4.5%	4.5%	4.5%
Volatile fraction (lb-VS/lb-TS)	57.6%	58.1%	58.0%	57.9%	58.1%
Flow (gpd)	109,384	143,122	155,912	165,042	181,700
Flow (gpm)	76	99	108	115	126
Ammonia-N concentration (mg/L)	1,996	2,006	2,004	2,003	2,007
Final Dewatering Cake Product					
Total solids load (dtpd)	20	25	28	29	32
Total solids load (lb-TS/d)	39,045	50,798	55,412	58,695	64,448

Parameter	Average	30-day	14-day	7-day	3-day
Volatile solids load (lb-VS/d)	22,500	29,489	32,112	33,985	37,445
Total solids concentration (lb-TS/lb-sludge)	33.0%	33.0%	33.0%	33.0%	33.0%
Cake mass to end use (wtpd)	59	77	84	89	98
Cake volume (CY/d at 45 lb/ft^3)	97	127	138	146	161
Combined Recycles (Thickening, Pre-dewatering, and Final Dewatering)					
Total solids load (lb-TS/d)	9,049	11,932	12,975	13,723	15,162
Flow (mgd)	2.27	2.62	2.75	2.84	3.01
Post-dewatering recycle ammonia Load (lb-N/d)	1,706	2,244	2,441	2,583	2,850

Table 12. Solids Process Model Flows: 40 mgd Flow (WPCP Buildout Condition)

Parameter	Average	30-day	14-day	7-day	3-day
Primary Solids					
Total solids load (lb-TS/d)	69,434	93,620	101,277	106,841	119,262
Volatile solids load (lb-VS/d)	57,834	78,005	84,379	89,011	99,374
Total solids concentration	1.0%	1.0%	1.0%	1.0%	1.0%
Volatile fraction (lb-VS/lb-TS)	83.3%	83.3%	83.3%	83.3%	83.3%
Flow (gpd)	832,537	1,122,540	1,214,350	1,281,068	1,430,002
Flow (gpm)	578	780	843	890	993
Thickened Primary Solids					
Total solids load (lb-TS/d)	65,962	88,939	94,572	94,572	94,572
Volatile solids load (lb-VS/d)	54,942	74,105	78,792	78,789	78,801
Total solids concentration	4.0%	4.0%	4.0%	4.0%	4.0%
Volatile fraction (lb-VS/lb-TS)	83.3%	83.3%	83.3%	83.3%	83.3%
Flow (gpd)	197,727	266,603	283,488	283,488	283,488
Flow (gpm)	137	185	197	197	197
Primary Solids Bypassed around GT to WAS Storage Tank					
Total solids load (lb-TS/d)	-	-	1,728	7,292	19,713
Volatile solids load (lb-VS/d)	-	-	1,439	6,075	16,426
Total solids concentration	-	-	1.00%	1.00%	1.00%
Volatile fraction (lb-VS/lb-TS)	-	-	83.3%	83.3%	83.3%
Flow (gpd)	0	0	20,714	87,432	236,366
Flow (gpm)	0	0	14	61	164
WAS					
Total solids load (lb-TS/d)	37,958	46,689	51,623	55,039	58,835
Volatile solids load (lb-VS/d)	26,001	31,982	35,362	37,702	40,302
Total solids concentration	1.0%	1.0%	1.0%	1.0%	1.0%
Volatile fraction (lb-VS/lb-TS)	68.5%	68.5%	68.5%	68.5%	68.5%
Flow (gpd)	455,134	559,815	618,983	659,945	705,458
Flow (gpm)	316	389	430	458	490
Primary Scum (to Solids Storage Tank with WAS)					
Total solids load (lb-TS/d)	8,320	11,232	12,147	12,813	14,310
Volatile solids load (lb-VS/d)	7,488	10,109	10,932	11,532	12,879
Total solids concentration (lb-TS/lb-sludge)	0.58%	0.78%	0.84%	0.89%	0.99%
Volatile fraction (lb-VS/lb-TS)	90%	90%	90%	90%	90%
Flow (gpd)	172,800	172,800	172,800	172,800	172,800
Flow (gpm)	120	120	120	120	120
Combined Thickened Solids/Pre-dewatering Feed					
Total solids load (lb-TS/d)	112,240	146,859	160,070	169,716	187,430
Volatile solids load (lb-VS/d)	88,432	116,195	126,526	134,098	148,408
Total solids concentration	1.6%	1.8%	1.8%	1.7%	1.6%

Parameter	Average	30-day	14-day	7-day	3-day
Volatile fraction (lb-VS/lb-TS)	78.8%	79.1%	79.0%	79.0%	79.2%
TWAS load fraction (TWAS / (TWAS + TPS + FOG))	33.8%	31.8%	32.6%	33.9%	35.1%
Flow (gpd)	825,662	999,219	1,095,985	1,203,666	1,398,113
Flow (gpm)	573	694	761	836	971
Pre-dewatered Solids					
Total solids load (dtpd)	53.3	69.8	76.0	80.6	89.0
Total solids load (lb-TS/d)	106,628	139,516	152,066	161,230	178,059
Volatile solids load (lb-VS/d)	84,010	110,386	120,200	127,393	140,988
Total solids concentration (lb-TS/lb-sludge)	25.0%	25.0%	25.0%	25.0%	25.0%
Flow (gpd)	51,141	66,914	72,933	77,329	85,400
Flow (gpm)	36	46	51	54	59
Cake mass (wtpd)	213	279	304	322	356
Cake volume (CY/d at 45 lb/ft^3)	351	459	501	531	586
Thermal Hydrolysis Feed Solids with Dilution Water					
Total solids load (lb-TS/d)	106,628	139,516	152,066	161,230	178,059
Volatile solids load (lb-VS/d)	84,010	110,386	120,200	127,393	140,988
Total solids concentration (lb-TS/lb-sludge)	16.5%	16.5%	16.5%	16.5%	16.5%
Flow (gpd)	77,486	101,385	110,505	117,164	129,394
Flow (gpm)	54	70	77	81	90
Thermal Hydrolysis Depressurization Tank Solids with Steam Condensate					
Total solids load (lb-TS/d)	106,628	139,516	152,066	161,230	178,059
Volatile solids load (lb-VS/d)	84,010	110,386	120,200	127,393	140,988
Total solids concentration (lb-TS/lb-sludge)	14.2%	14.2%	14.2%	14.2%	14.2%
Flow (gpd)	90,271	118,114	128,739	136,497	150,744
Flow (gpm)	63	82	89	95	105
Temperature (°F)	221	221	221	221	221
Diluted THP Solids: Depressurization Tank Output and Pathogen-Free Dilution Water					
Total solids load (lb-TS/d)	106,628	139,516	152,066	161,230	178,059
Volatile solids load (lb-VS/d)	84,010	110,386	120,200	127,393	140,988
Total solids concentration (lb-TS/lb-sludge)	9.0%	9.0%	9.0%	9.0%	9.0%
Flow (gpd)	142,057	185,873	202,593	214,802	237,222
Flow (gpm)	99	129	141	149	165
Temperature (°F)	168	168	168	168	168
Digested Solids Recycle: to Cooling Heat Exchanger					
Total solids concentration (lb-TS/lb-sludge)	4.5%	4.5%	4.5%	4.5%	4.5%
Flow (gpd)	710,286	710,252	710,643	827,707	830,277
Flow (gpm)	493	493	494	575	577
Temperature (°F)	98	98	98	98	98
Digester Feed Solids: Diluted THP Sludge with Recycled Digested Solids					
Total solids concentration (lb-TS/lb-sludge)	5.1%	5.2%	5.2%	5.2%	5.2%
Flow (gpd)	852,343	896,125	913,236	1,042,508	1,067,499
Flow (gpm)	592	622	634	724	741
Temperature before HEX (°F)	110	113	114	112	114
Temperature after HEX (°F)	98	98	98	98	98
Digested Solids (to Final Dewatering)					
Total solids load (lb-TS/d)	53,377	69,444	75,792	80,412	88,572
Volatile solids load (lb-VS/d)	30,759	40,313	43,926	46,575	51,501
Total solids concentration (lb-TS/lb-sludge)	4.5%	4.5%	4.5%	4.5%	4.5%
Volatile fraction (lb-VS/lb-TS)	57.6%	58.1%	58.0%	57.9%	58.1%
Flow (gpd)	142,057	185,873	202,593	214,802	237,222
Flow (gpm)	99	129	141	149	165

Parameter	Average	30-day	14-day	7-day	3-day
Ammonia-N concentration (mg/L)	1,996	2,006	2,004	2,003	2,008
Final Dewatering Cake Product					
Total solids load (dtpd)	25	33	36	38	42
Total solids load (lb-TS/d)	50,708	65,972	72,002	76,392	84,143
Volatile solids load (lb-VS/d)	29,221	38,297	41,729	44,246	48,926
Total solids concentration (lb-TS/lb-sludge)	33.0%	33.0%	33.0%	33.0%	33.0%
Cake mass to end use (wtpd)	77	100	109	116	127
Cake volume (CY/d at 45 lb/ft^3)	126	165	180	191	210
Combined Recycles (Thickening, Pre-dewatering, and Final Dewatering)					
Total solids load (lb-TS/d)	11,753	15,496	16,771	17,484	18,778
Flow (mgd)	2.61	3.05	3.22	3.34	3.56
Post-dewatering recycle ammonia load (lb-N/d)	2,215	2,914	3,172	3,362	3,722

Table 13. Energy Calculations: 23 mgd Flow (2020 Condition)

Parameter	Average	30-day	14-day	7-day	3-day
THP Steam Demands					
Steam to THP (ton-steam/d)	31	40	44	46	51
Steam as condensate to sludge (gpd)	7,351	9,619	10,479	11,092	12,212
Sludge Cooling Demands					
Cooling demand (million-Btu/d)	48	63	68	72	79
Cooling demand (million-Btu/hr)	2.0	2.6	2.8	3.0	3.3
Digester Gas Production					
Biogas generated (scfd)	453,158	596,095	648,553	686,112	757,234
Biogas generated (scfm)	315	414	450	476	526
Biogas generated from scum and FOG only (scfm)	38	52	56	59	66
Lower heating value (million-Btu/hr)	11.0	14.4	15.7	16.6	18.3

Table 14. Energy Calculations: 30.8 mgd Flow (Design Condition)

Parameter	Average	30-day	14-day	7-day	3-day
THP Steam Demands					
Steam to THP (ton-steam/d)	41	54	59	62	68
Steam as condensate to sludge (gpd)	9,845	12,881	14,032	14,854	16,353
Sludge Cooling Demands					
Cooling demand (million-Btu/d)	64	84	91	97	106
Cooling demand (million-Btu/hr)	2.7	3.5	3.8	4.0	4.4
Digester Gas Production					
Biogas generated (scfd)	606,837	798,248	868,498	918,793	1,014,036
Biogas generated (scfm)	421	554	603	638	704
Biogas generated from scum and FOG only (scfm)	51	69	75	79	88
Lower heating value (million-Btu/hr)	14.7	19.3	21.0	22.2	24.5

Table 15. Energy Calculations: 40 mgd Flow (WPCP Buildout Condition)

Parameter	Average	30-day	14-day	7-day	3-day
THP Steam Demands					
Steam to THP (ton-steam/d)	53	70	76	81	89
Steam as condensate to sludge (gpd)	12,785	16,729	18,233	19,332	21,350
Sludge Cooling Demands					
Cooling demand (million-Btu/d)	83	109	119	126	139
Cooling demand (million-Btu/hr)	3.5	4.5	4.9	5.2	5.8
Digester Gas Production					
Biogas generated (scfd)	788,101	1,036,686	1,128,534	1,195,835	1,323,951
Biogas generated (scfm)	547	720	784	830	919
Biogas generated from scum and FOG only (scfm)	67	90	97	103	115
Lower heating value (million-Btu/hr)	19.0	25.1	27.3	28.9	32.0

Table 16. Chemical Use: 23 mgd Flow (2020 Condition)

Parameter	Average	30-day	14-day	7-day	3-day
Pre-dewatering polymer use (lb active polymer/d)	323	422	460	487	536
Final dewatering polymer use (lb active polymer/d)	460	599	653	692	760

Table 17. Chemical Use: 30.8 mgd Flow (Design Condition)

Parameter	Average	30-day	14-day	7-day	3-day
Pre-dewatering polymer use (lb active polymer/d)	432	565	616	652	718
Final dewatering polymer use (lb active polymer/d)	617	802	875	927	1,018

Table 18. Chemical Use: 40 mgd Flow (Buildout Condition)

Parameter	Average	30-day	14-day	7-day	3-day
Pre-dewatering polymer use (lb active polymer/d)	561	734	800	849	937
Final dewatering polymer use (lb active polymer/d)	801	1,042	1,137	1,206	1,329

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A

Solids Process Flow Mass Balance

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Model Scenario	
Plant Eff Flow (mgd)	30.8
Scenario	Average <--Select scenario

Notes:
1) All flows (gpd, gpm, mgd) are based on specific gravity of 1.00. Cake volumes include a density assumption.
2) Does not show PS bypass around gravity thickener (occurs at 40 mgd peak cconditions when loading rate exceeds 30 lb/ft2/d with one GT)

Dilution Water - PS Thickening	
Flow (mgd)	1.01
Flow (gpm)	700

Polymer - WAS Thickening	
Dose (lb/lb-DS)	0
Polymer use (lb/day)	0

Primary Sludge	
TS Load (lb-TS/d)	53,464
VS Load (lb-TS/d)	44,532
Conc. (lb-TS/lb)	1.00%
Volatile Fraction	83.3%
Flow (gpd)	641,053
Flow (gpm)	445

WAS	
TS Load (lb-TS/d)	29,228
VS Load (lb-TS/d)	20,021
Conc. (lb-TS/lb)	1.00%
Volatile Fraction	68.5%
Flow (gpd)	350,454
Flow (gpm)	243

Primary Scum	
TS Load (lb-TS/d)	6,406
VS Load (lb-TS/d)	5,766
Conc. (lb-TS/lb)	0.5%
Flow (gpd)	153,631
Flow (gpm)	106.7

Thickened Primary Sludge	
TS Load (lb-TS/d)	50,791
VS Load (lb-TS/d)	42305
Conc. (lb-TS/lb)	4.00%
Flow (gpd)	152,250
Flow (gpm)	106
Solids capture	95.0%

Thickened WAS	
TS Load (lb-TS/d)	35,634
VS Load (lb-TS/d)	25787
Conc. (lb-TS/lb)	0.85%
Flow (gpd)	504,084
Flow (gpm)	350
Solids capture	100.0%

Combined Thickened Sludge	
TS Load (lb-TS/d)	86,425
VS Load (lb-TS/d)	68,092
Conc. (lb-TS/lb)	1.58%
Volatile Fraction	78.8%
Flow (gpd)	656,334
Flow (gpm)	456

Pre-dewatered Sludge	
TS Load (lb-TS/d)	82,104
VS Load (lb-TS/d)	64,688
Conc. (lb-TS/lb)	25.0%
Flow (gpd, @SG=1.0)	39,378
Flow (gpm, @SG=1.0)	27
Dry Tons/Day	41
Wet Tons/Day	164
Cubic Yards/Day @ density	270
Solids capture	95.0%

Polymer - Pre-dewatering	
Dose (lb-poly/dry ton)	10
Polymer use (lb/day)	432

Dilution Water - Pulper Feed	
Flow (gpd)	20,286
Flow (gpm)	14

Pulper Feed Sludge (after dilution)	
TS Load (lb-TS/d)	82,104
VS Load (lb-TS/d)	64,688
Conc. (lb-TS/lb)	16.5%
Flow (gpd)	59,664
Flow (gpm)	41

THP Flash Tank Sludge	
TS Load (lb-TS/day)	82,104
VS Load (lb-VS/day)	64,688
Conc. (lb-TS/lb)	14.2%
Flow (gpd)	69,509
Flow (gpm)	48
Temperature (deg-F)	221

Dilution Water - THP Sludge	
Flow (gpd)	39,875
Flow (gpm)	28

Diluted THP Sludge	
TS Load (lb-TS/day)	82,104
VS Load (lb-VS/day)	64,688
Conc. (lb-TS/lb)	9.0%
Flow (gpd)	109,384
Flow (gpm)	76
Temperature (deg-F)	168

Cooling Demand	
mmBTU/day	64
mmBTU/hr	2.7

Diluted THP Sludge + Recycle	
Flow (gpd)	656,304
Flow (gpm)	456
Temperature (deg-F)	110

Digester Gas	
Biogas Generated (scfm)	421
L. Heat Value (mmbtu/hr)	14.7

Digester Operation	
Volatile Solids Reduction	60%
Ammonia Conc. (mg-N/L)	1,996
Temperature (deg-F)	98
Operating Volume (MG)	3.60
SRT (days)	32.9
OLR (lb-VS/ft3-day)	0.13

Digested Solids	
TS Load (lb-TS/d)	41,100
VS Load (lb-TS/d)	23,684
Conc. (lb-TS/lb)	4.5%
Volatile Fraction	57.6%
Flow (gpd)	109,384
Flow (gpm)	76

Dilution Water - Digested Sludge	
Flow (gpd)	31,418
Flow (gpm)	22

Digested Solids to Dewatering (diluted)	
TS Load (lb-TS/d)	41,100
VS Load (lb-TS/d)	23,684
Conc. (lb-TS/lb)	3.5%
Flow (gpd)	140,802
Flow (gpm)	98

Polymer - Post-dewatering	
Dose (lb-poly/dry ton)	30
Polymer use (lb/day)	617

Cake	
TS Load (lb-TS/d)	39,045
VS Load (lb-TS/d)	22,500
Conc. (lb-TS/lb)	33.0%
Dry Tons/Day	20
Wet Tons/Day	59
Cubic Yards/Day @ density	97
Solids capture	95.0%

PS Thickening Recycle	
TS Load (lb-TS/d)	2,673
VS Load (lb-TS/d)	2,227
Conc. (mg-TSS/L)	214
Flow (mgd)	1.50
Flow (gpm)	1,039

WAS Thickening Recycle	
TS Load (lb-TS/d)	0
VS Load (lb-TS/d)	0
Conc. (mg-TSS/L)	#DIV/0!
Flow (gpd)	0
Flow (gpm)	0

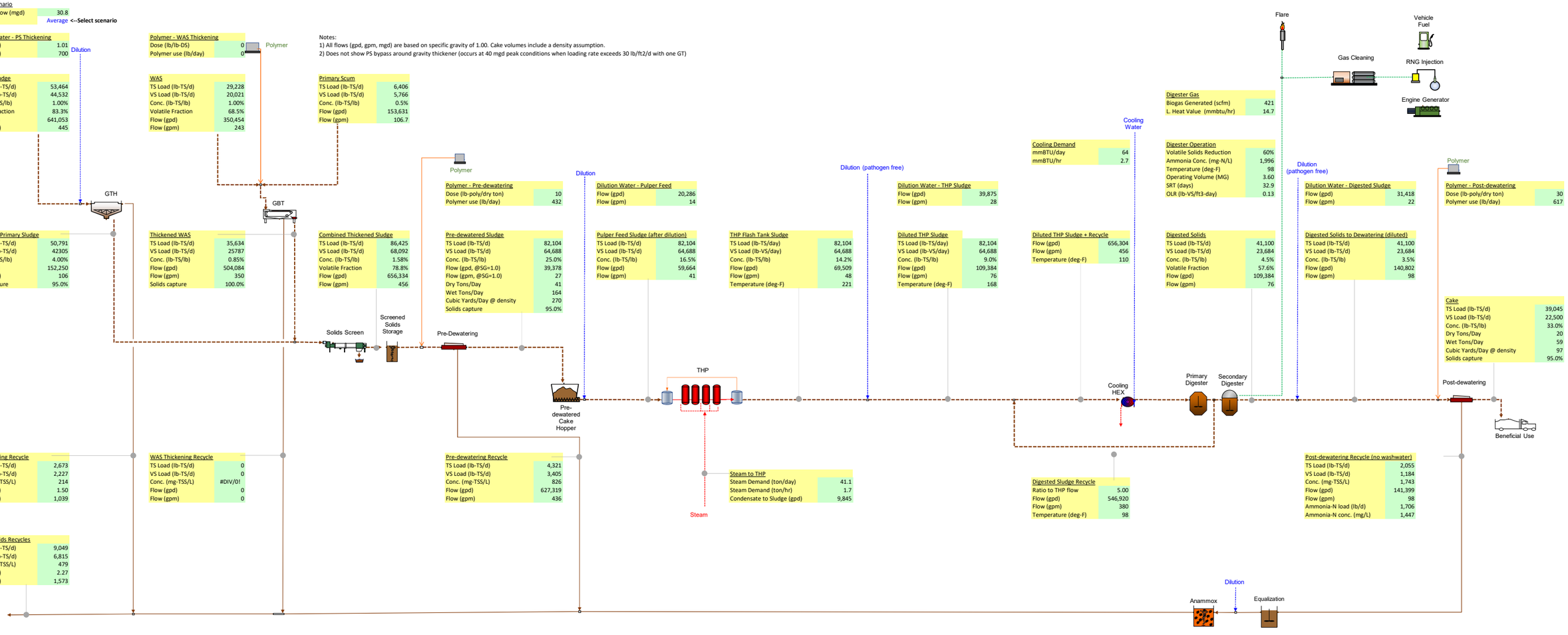
Pre-dewatering Recycle	
TS Load (lb-TS/d)	4,321
VS Load (lb-TS/d)	3,405
Conc. (mg-TSS/L)	826
Flow (gpd)	627,319
Flow (gpm)	436

Steam to THP	
Steam Demand (ton/day)	41.1
Steam Demand (ton/hr)	1.7
Condensate to Sludge (gpd)	9,845

Digested Sludge Recycle	
Ratio to THP flow	5.00
Flow (gpd)	546,920
Flow (gpm)	380
Temperature (deg-F)	98

Post-dewatering Recycle (no washwater)	
TS Load (lb-TS/d)	2,055
VS Load (lb-TS/d)	1,184
Conc. (mg-TSS/L)	1,743
Flow (gpd)	141,399
Flow (gpm)	98
Ammonia-N load (lb/d)	1,706
Ammonia-N conc. (mg/L)	1,447

Sum of Solids Recycles	
TS Load (lb-TS/d)	9,049
VS Load (lb-TS/d)	6,815
Conc. (mg-TSS/L)	479
Flow (mgd)	2.27
Flow (gpm)	1,573



Technical Memorandum No. 2

Date:	February 9, 2023
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Condition of Existing Facilities

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1.0 Introduction and Purpose

The purpose of the Arlington Water Pollution Control Plant (WPCP) site visits were to broadly assess the condition of processes being considered for replacement as a part of the new solids handling processes, and to obtain operations and maintenance (O&M) feedback on current facilities. Secondary to the condition assessment is determining whether there are any obvious reasons why the existing processes will not be able to continue to operate reliably for the next 5 years until new processes start up, or whether temporary improvements or early construction packages should be considered.

Each section of the site notes provided below includes an introduction about how the process is used now, a current assessment of operations based on WPCP O&M group comments, and considerations on the future of the process. Where noted, additional detailed evaluations are recommended to be conducted as part of the Biosolids Upgrade project to define specific facilities' repairs or renovations required to incorporate existing facilities into the new solids handling facilities. The site visits took place on January 6 and 7, 2021 and February 10, 2021. All observations represented in this technical memorandum are from those specific dates.

2.0 Overall Plant Considerations

The WPCP was first constructed in the 1930s and has had many major and minor upgrades since its original construction. The site is constrained and phasing of new treatment processes, to be constructed at the current locations of existing treatment processes, has already happened during several WPCP upgrades. A future contractor will likely uncover unknown buried process structures that will need to be investigated before demolition. One example given by WPCP staff was during a previous project the contractor found a concrete slab that could have been part of a process but was later identified as an old sidewalk. That investigation took only one day; others will take longer. This should be considered a normal issue for an 85-year-old treatment plant site. Additional general notes about the WPCP are listed below:

- The WPCP's design capacity is 40 million gallons per day (mgd), but it currently receives an average daily flow of 23 mgd. Normal dry peak hourly flow is 30 mgd, a typical severe storm will often deliver a peak hourly flow of 60 mgd, and superstorm Sandy peak flow was 120 mgd.
- Plant influent flow is the sum of the major sources: two Potomac Interceptors, Four Mile Run Gravity Flow Interceptor, and the Four Mile Run Lift Station.
- Preliminary treatment consists of ½-inch climber-type bar screens and PISTA grit removal. The WPCP has a backup headworks facility with ½-inch flex-rake type (Duperon) bar screens. The existing climber-type screens are scheduled for replacement with ½-inch flex-rake type bar screens (similar to the bypass headworks). The same project will replace scum concentration and screenings handling processes.
- Secondary treatment consists of biological nutrient removal aeration tanks.
- Tertiary treatment is performed using denitrification filters.
- Phosphorus removal is achieved through ferric chloride dose addition at the primary clarifiers and some trimming in the secondary process. Ferric chloride can also be added to the tertiary process, but such addition is used infrequently. Ferric chloride dose is also binding sulfides through the treatment processes, which is improving odor control. The WPCP is beginning early consideration to

converting to an enhanced biological phosphorus removal (EBPR) process in the future, which would change the solids handling characteristics. Any decision to convert the secondary process to EBPR is many years away.

- Total ferric chloride dose is approximately 50 mg/L, with most of the ferric chloride being added to the primary clarifiers.
- Filtered effluent is chlorinated using sodium hypochlorite and then dechlorinated with sodium bisulfite prior to being discharged into Four Mile Run.

3.0 Plant Effluent Water Pumping Station

The current plant effluent water (PEW) pump station was installed as part of the Upgrade and Expansion Phase 7A project. Pump nameplates were not legible. The PEW discharge header supplies two main PEW distribution pipes. The main header has a pressure relief valve on each side, of uncertain condition. The pressure relief valves should be investigated further for replacement. PEW discharge piping at the pump station is insulated and jacketed, so piping materials and condition were not observed during this assessment. O&M reported no specific problems with the process. With normal maintenance the PEW pumps (see Figure 1) should be able to operate long into the future. New solids handling processes will require either more water or a reallocation of the water currently being used, which will change the normal, minimum, and maximum flow and pressure of the WPCP water system. The pumps will need to be assessed for the new operating conditions. Additional notes about the process are provided below:

- There are four vertical-turbine pumps; normally two are in service, not running at maximum speed. All four pumps have a variable-frequency drive (VFD). There appeared to be slight corrosion on the pump baseplates, but repairing and recoating them with protective paint would stop current corrosion and provide adequate protection.
- PEW is chlorinated and dechlorinated before the PEW pump station via sodium bisulfite.
- Staff has observed corrosion and pitting inside PEW pipes that may be microbial in nature. Biogrowth (bisulfite slime) in the WPCP distribution system might be impacting the service life of mechanical seals, solenoid valves, and spray nozzles. The sulfite biogrowth could be creating solids in the WPCP water distribution system, which can directly damage mechanical seals or other mechanical equipment, or stop flow through solenoids that might be supplying cooling/flushing water to mechanical seals. The bacterial biogrowth can appear as a slimy bacterial growth on the inside of pipes because of residual bisulfite after reacting with chlorine.
- Sodium hypochlorite is available in the adjacent Sodium Hypochlorite Facility and can be injected into the discharge of the PEW pumps. The Milton Roy metering pumps already installed are suitable for high discharge pressure if serviceable and needed.
- PEW is normally used for WPCP hoses, process connections, elutriation water in the gravity thickener (GT), maintaining operational readiness of the wet weather filters, and seal water.

The PEW pumps, system capacities, and need for pathogen-free water will be evaluated by the Delivery Team and validated as part of the solids handling project. Assuming the pumps and piping are adequate, it is assumed that any additional rehabilitation of the PEW system will be done through regular rehabilitation projects and not part of the Biosolids Upgrade project.

Figure 1. PEW Pump

Figure 2. Side View of PEW Pump Station

4.0 Waste Activated Solids Pumps

Waste activated solids (WAS) and the east-side return activated solids (RAS) pumps are in the same room of the East Secondary Services Pump Station. This evaluation does not consider the RAS pumps or activated solids process; notes about the RAS and activated solids processes are provided for context. The West Secondary Pump Services Building, which contains the west-side RAS pumps, was not visited.

Three WAS pumps (see Figure 3 and Figure 4) currently pump to the dissolved air flotation thickening (DAFT) process. Normal WAS flow is 80 to 150 gallons per minute (gpm) depending on process needs, which vary by season. The WAS pumps were installed under the Upgrade and Expansion Phase 7B project and are Fairbanks Morse end-suction pumps with mechanical seals. The WAS pumps draw from the discharge of the RAS piping header. O&M reported no specific problems with the WAS pumping process. Note, subsequent to this site visit, issues with the WAS flow meter are being investigated by WPCP staff. No significant issues were observed during the site visit, and it is anticipated that the WAS pumps should be able to operate with normal maintenance for another 5 years. The WAS pumps are anticipated to be replaced with a future Secondary Clarifier Upgrades project. New thickening processes being considered for the Biosolids Upgrades may increase the required pumping head so the future WAS pump sizing will need to be coordinated between projects.

The following are condition assessment notes for the WAS pumps and facility:

- Three clarifiers are not in service, and associated RAS pumps are also locked out. Multiple RAS pumps are permanently out of service (components were removed and installed on other RAS pumps).
- Activated solids mixed liquor suspended solids (MLSS) concentration averages around 3,800 milligrams per liter (mg/L). RAS/WAS concentration is typically 8,000 to 11,000 mg/L, which is considered normal at 2 to 3 times the MLSS concentration.
- WPCP staff can put Clarifier 9 and Aeration Tank 6 in pilot mode to act as a mini separated wastewater treatment plant. They plan to use this mode to test various operating strategies including the Bio-P process. Bio-P allows for more phosphorus removal with less chemical dose.
- WAS pumps have newer Allen-Bradley PowerFlex drives.
- The mechanical seals on the WAS pumps are fine. O&M staff report that the impellers show no signs of wear.

The WAS pump and system capacities required will be confirmed as part of the Biosolids Upgrades. Currently the WAS is pumped to the DAFTs. Once the new site layout is finalized, the WAS pumps will be evaluated to confirm their adequacy for pumping to the new facilities. Sizing will be coordinated with the Secondary Clarifier Upgrades project.

Figure 3. Side View of WAS Pumps

Figure 4. WAS Pump

5.0 Primary Sedimentation

The WPCP has eight rectangular primary sedimentation tanks with chain-and-flight collectors. Typically, five or six trains are in service during normal conditions. During wet weather, or possibly during WPCP shutdowns, additional primary sedimentation tanks can be placed into service for additional storage capacity. Primary sedimentation tanks run with 0 to 3 feet of sludge blanket at the collection (deep) end. Figure 5 depicts the primary solids (PS) piping. The primary clarifiers were last upgraded with Upgrade and Expansion Phase IIB. A separate Primary Clarifier Upgrades project is envisioned for rehabilitation of the primary clarifiers and associated equipment. O&M reported no specific problems with the process but the description of reduced PS pumping capacity in relation to sludge blanket thickness and increase in sludge thickness is noted. Also, the fact that the PS pumps (see Figure 6) are not able operate at full speed without overload indicates a mismatch between original design and current operating conditions.

Based on preliminary observations, thickening solids in the primary sedimentation tanks may be possible with a further evaluation of the chain-and-flight collection mechanism to ensure that it has the additional strength to convey thickened sludge and replacement of the existing screw centrifugal end-suction pumps with progressive-cavity pumps better suited for lower flows of thicker sludge. There is enough room in the pump gallery to accommodate this change if desired. “In-primary” thickening would eliminate the need for GTs or other PS thickening process but increases the risk of chain-and-flight failure because of accumulated thickened PS in the basin. Considering the apparent excess primary sedimentation capacity, this could be considered. *Note subsequent discussions with the County resulted in a recommendation to rehabilitate the GTs and not thicken in the primary clarifiers.*

The following are condition assessment notes for primary sedimentation:

- PS pumps operate on a rotating cycle with one pump running at a time for 10-15 minutes.
- Pumped flow was recorded as between 0.06 and 0.16 mgd depending on PS depth of blanket and number of pumps operating. Based on operating data and pump O&M reviews, HDR questioned these flows and requested verification via measurement of a strap-on flow meter. The verification completed by the County confirmed that actual flows through this pipeline were approximately 400 gpm (0.6 mgd), which is more in line with expected flows. The PS flow meter may be reporting a low number because of grease accumulation on the liner and probes.
- The normal depth of the blanket is less than 1 foot, and ranges from 0 to 3 feet. If it is at 3 feet, then the pump is likely clogged, according to information provided by the Arlington Operations staff consulted.
- PS pumps can send sludge to the primary header drain line which discharges to the preliminary treatment influent. The primary sedimentation tanks also have dedicated end-suction centrifugal pump and piston drain pumps.
- WPCP staff normally run PS pumps at 80 percent speed. Pumps can fail (trips out on overload and VFD reset required) if they are run at 100 percent. The operating range for the pumps is a minimum of 70 percent speed, and a maximum of 85 to 90 percent speed.
- PS pump conduit/feeders are more than 30 years old and require replacement as issues arise.

It is assumed that the PS pumps will be reviewed and upgraded as part of the Primary Clarifier Upgrades and not as part of the Biosolids Upgrades.

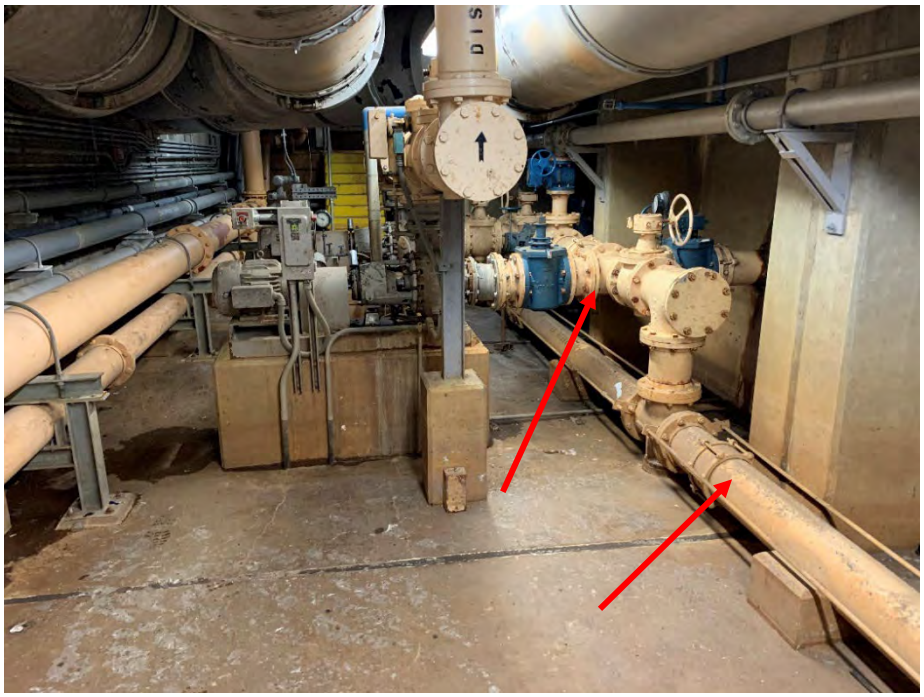

Figure 5. Primary Solids Piping

Figure 6. Primary Solids Pump

6.0 Gravity Thickeners

This section presents a condition assessment of the GTs, including a general evaluation and a structural evaluation.

6.1 General Evaluation

The WPCP has two GTs that typically operate in a duty/standby configuration (see Figure 7). The GTs have flat weirs and receive PS and approximately 700 gpm of elutriation water. The GTs were originally constructed with Contract I and last upgraded under the Upgrades and Expansion Phase IIB project. The thickened solids pumps were replaced in-house by Arlington County in the 2010's.

Some aspects of the primary sedimentation and GT process are not operating or reporting properly. The reported range of PS flow is 0.06 to 0.16 mgd (40 to 110 gpm) with an initial reported solids concentration of 0.5 to 1.5 percent total solids (TS). Based on discussions with operations, this sample includes elutriation water. The underflow of the GTs is typically 70 to 85 gpm of thickened PS with a reported average concentration of approximately 4 percent TS. With the current inlet and outlet solids concentrations, the GT underflow would typically be one-third of the feed flow. Additional information in terms of PS concentration and flows were requested to determine an accurate concentration and mass of PS. Based on this testing, it was confirmed that the average PS flow to the gravity thickeners is approximately 300-400 gpm (0.4 – 0.6 mgd) with a solids concentration of 0.5 to 2.0 percent TS.

O&M reported no specific problems with the process. However, the GT drives and collection mechanism are old and corroded, and leak gear oil. Some evidence was observed of concrete erosion, especially at the inlet channel of each GT, but the amount of exposed aggregate is minor. Electrical conduits are corroded at the entrance to the GT. The mechanical components of this process are near the end of their useful life. Refer to Section 6.2 for the structural condition assessment findings of the GTs.

If gravity thickening of PS is continued as a treatment process, then the process tanks, clarifier drives, electrical equipment, and adjoining support building should be completely rehabilitated, and electrical/ventilation should be brought up to National Fire Protection Association (NFPA) 820 standards, at a minimum. There does not appear to be an impending failure of this process so it can be kept in operation until the rehabilitation can be scheduled, one tank at a time to maintain operations. A full accounting of the feed loads needs to be conducted to assess loading for normal expected performance. WPCP staff should consider replacing the flat weirs with V-notch weirs to allow for reduced hydraulic loading. In discussions with operators, the current method to transition GT influent flow from one GT to the other requires manually pulling/inserting a stop plate. There was a request to add automatically actuated slide gates at the GT influent structure as part of any upgrades.

The following are condition assessment notes for the GTs:

- Typically, one GT is operated for 6 months (or when issues arise with sludge pumps).
- When flow to the GT gets too high, the water level overtops the inlet isolation gate and floods into the out-of-service GT. The condition assessment team was unable to see the condition of the scrapers under the septic water at the bottom of the out-of-service GT.

- GT underflow Seepex progressive-cavity pumps (see Figure 8) are approximately 5 to 6 years old and have not had any significant problems. The pump has required minimal maintenance since installation.
- Sometimes the pumps will not start if they have been out of service for months while the GT is empty. Flushing water supplied to the pump suction and adjusting VFD settings could assist the restart for those pumps that have been out of service for an extended period. WPCP staff could also try bumping the dry pump weekly to rotate the rotor impression on the stator.
- Clarifier depth is around 10 feet. GTs can hold solids for 2 days until 3-foot normal depth of blanket and the typical thickened PS concentration of 3 to 4 percent TS is reached.
- The drive mechanism works, there are no issues with over-torque, the shear pin has never needed replacement, and WPCP staff normally only change the oil.
- Inline pipe shredders (grinders) require periodic normal maintenance to maintain the cutters.
- Each GT had both foul-air fans working (normally 1+1) because of undersized foul-air pipes competing with the Headworks Building going to the odor control unit. Operators indicated that odor is a concern in this area. Overall ventilation (supply and exhaust/odorous air) should be evaluated for the GTs and thickened solids pumping station. In the next 2 years, the WPCP will exhaust foul air from the Preliminary Treatment Building (PTB) into the GTs. This is intended to be a temporary operation until a new odor control system to service the Biosolids Upgrades is constructed.
- There is no indication of copper corrosion in the GT Control Building. Pump control panels were recently replaced. Maintenance indicated that the control room had humidity problems, but new condenser units were installed and these seem to reduce humidity.

Figure 7. Gravity Thickener Center Platform

Figure 8. Gravity Thickener Pump

6.2 Structural Evaluation

GT No. 2 was empty and HDR staff accessed the tank interior via the personnel bridge (walkway). The focus of this visual inspection was not on any mechanism components but rather was limited to the structure and fiberglass roof. Direct inspection of the tank floor was not attempted because of the logistics of gaining access into the confined space. Photo A-1 in Attachment A shows the tank condition, which appears unremarkable. WPCP staff made some effort to superficially clean the wall and launder concrete near the access bridge to better assess the concrete condition (Photos A-2, A-3, and A-4 in Attachment A). This area, as anticipated, has experienced some loss of cement paste, exposing coarse aggregate, and some isolated areas where reinforcing is beginning to appear due to lack of concrete cover. The latter was also evident in other locations around the perimeter (Photos A-5 and A-6). The orange discoloration (Photos A-7, A-8, etc.) is due to staining caused by the addition of ferric chloride as part of the WPCP's wastewater treatment process; this is not harmful to concrete in the concentrations used. Some local "flaking" and discoloration of the wall surface was observed (Photo A-9), but it is anticipated that this is not a serious concern and can be addressed during the rehabilitation process.

The tank is covered by a fiberglass self-supported dome (Photos A-9, A-10, A-11, and A-14), which was a retrofit feature installed soon after the tanks went into operation. From inside, variations of the material's translucence are evident (Photos A-12 and A-13); however, there appeared to be no compromise to the roof's primary odor control function. If the GTs are to be retained and rehabilitated, the tank covers should be replaced with the same project.

The exterior of the tank is a mixture of exposed concrete with infill non-structural brick veneer (Photo A-15). The outboard launder hangs from the concrete wall and is in reasonable condition with one small wet area observed (Photo A-16). The brick has the normal signs of a structure that is more than 50 years

old (Photos A-17 and A-18) requiring mortar repointing and masonry crack repair. Some weeping of condensation onto the exterior is affecting the concrete and mortar (Photos A-19 and A-20) especially during freeze/thaw cycles.

There is no reason to expect GT No. 1 to be of significantly different structural condition (see Photos A-21 and A-22).

The interior concrete rehabilitation of the GTs should consist of the following steps:

1. Thorough hydro-cleaning of the tank wall and launder surfaces
2. Preparing exposed reinforcing and applying corrosion inhibitor
3. Protecting such reinforcing with a repair mortar to add protective cover
4. Spray-applying a mortar (fiber reinforced, with silica fume) to replace lost cement paste (approximately ⅜ to ½ inch) over full tank and launder wall surfaces.

The GT integral pump room (below grade) will require some corrosion protection of structural steel embeds (Photo A-24) and addressing the deficiencies in the pipe support systems (Photo A-24). In addition, some of the joints in this room should be investigated further (Photo A-25).

7.0 Dissolved Air Flotation Thickeners

The WPCP has two rectangular DAFTs (see Figure 9). The DAFTs were originally installed under Contract 72-6-S. Normally one is in service and the other one is empty. Operations staff favor one DAFT as the second is known to have leaks. The DAFT process at the WPCP uses a traditional high-pressure recirculation pump, saturation tank fed by reciprocating air compressors, and the pressure break valve. The DAFTs appeared to be operating well; the floated solids looked good and thick and the underflow had a reasonable number of solids.

O&M reported no specific problems with the process. However, the DAFT drives and collection mechanism are old and corroded. The bottom chain and flights do not work, and bottom sludge is not pumped from the process. The polymer makedown system is completely manual, and one batch is made approximately every 12 hours. While some DAFTs require significant attention, this unit is old and likely operating at a consistent feed rate for a long period, so less attention is required. The metal structure and mechanical components of this process are near the end of their useful life. No obvious defect was observed that would prevent operation of this process for the next 5 years.

WPCP staff should consider short-term improvements while waiting for construction of the new thickening process, such as adding an Occupational Safety and Health Administration (OSHA)-required chain guard to the drive motor and bull gear. WPCP staff should also consider operating the float chain and flight at a lower speed for a longer period to reduce stress on the equipment and potentially collect thicker thickened waste activated solids (TWAS) with less solids in the underflow.

The following are condition assessment notes for the DAFTs:

- The DAFT units were manufactured by EIMCO.
- Normal WAS feed is 80 to 150 gpm, with a solids concentration of 8,000 to 11,000 mg/L. Airflow to the saturation tanks is 1.2 standard cubic feet per minute (scfm).
- Recirculation line pressure is 75 to 80 pounds per square inch (psi).

- The float chain and flight is ON for 150 seconds, and then OFF for 750 to 1,000 seconds. The VFD speed of the chain and flight should be decreased and the ON time should be increased or run continually to improve float capture.
- TWAS pumps operate off level (DAFT sludge hopper).
- Possible vivianite mineral formation was observed in the DAFT TWAS pumped pipeline.
- Virginia's pressure limit for the pressure vessel is 100 psi, so circulation tanks for DAFT saturation tanks do not require a pressure vessel permit.
- The dry polymer mix tank (see Figure 10) is mixed by hand, and polymer amounts are eyeballed so the dose is uncertain. Each shift batches its own tank to last 12 hours. Normal polymer pot life is approximately 4 hours after a 30-minute mix time and then the polymer activity starts to degrade, so it is likely that the polymer is overdosed after initial batching to maintain consistent operations later in the batch life. Sometimes the mixing impeller falls off the shaft when the set screw loosens.
- The polymer makeup water does contain disinfection residuals; however, a normal sodium hypochlorite residual of 1 to 3 mg/L will not have a dramatic effect on polymer blending.
- Recirculation pumps start reliably.
- Some input/output (I/O) cards had to be replaced because the relays stopped working.
- Cracking was observed in the southeast corner of the brick veneer (see Figure 11). A structural condition assessment should capture this area. Crack monitors have been installed (by others) thus a procedure has been initiated. Further structural condition assessment was not completed for the DAFT Building, as it is currently unlikely to be in continued use following the Biosolids Upgrades.
- The polymer system/platform is showing significant signs of corrosion. A structural assessment should be completed to determine if modifications/repairs are needed within the next 5 years.

Figure 9. DAFT

Figure 10. DAFT Polymer Mix Tank

Figure 11. Structural Damage at the DAFT

8.0 Solids Storage Tanks

The WPCP has two solids storage tanks (SSTs) and normally only one is in service. The SSTs are some of the oldest structures on the plant, having been constructed with the first plant expansion in 1947. The SSTs were formerly operated as digesters and a part of a larger digester complex with three additional digesters, which were demolished as part of the Upgrades and Expansion Phase 7D project. The SST provides adequate capacity to hold solids for the long weekends when dewatering is not operated. Each SST has a mixer. The tanks have foul-air collection for odor control. The feed and equalization plug valves to the tank are difficult to operate. It is possible that those valves will seize in their current position. The tanks have exceeded their useful life and should be replaced with mixed tanks sized for adequate storage for the new process at a new location. Solids storage piping is depicted in Figure 12. Solids from the storage tanks are pumped in a loop to and from the Dewatering Building, with a control valve used to feed the Dewatering Building wet well.

The following are condition assessment notes for the SSTs:

- The feed and equalization valves between the tanks are not good and tend to seize up, requiring two or three people to open and close.
- Polyvinyl chloride (PVC) lines on mix pumps are not performing well and have previously broken and sprayed solids into the room.
- There is likely lead-based paint in this room (Figure 12).

Figure 12. Solids Storage Piping

9.0 Dewatering Building

The Dewatering Building (DWB) was initially constructed during the Phase IIIA Expansion in the mid-1990s and currently holds the dewatering centrifuges, solids storage hoppers, lime storage and feed system, enclosed truck loadout system, polymer mixing/aging and feed systems, and chemical storage and feed for the odorous air scrubbing system. The floor plans for the four floors of the DWB are shown on Photo A-35 in Attachment A. Dewatering is currently conducted Monday through Friday (sometimes Sunday), with truck loadout late at night during the week to help with potential traffic and odor issues. There are three centrifuges, with space for one additional centrifuge. Normally one centrifuge is needed to keep up with solids production, and during short holiday weeks two centrifuges may be used. Centrifuges, solids conveyors and hoppers, and odor control are described separately below. The DWB appears to be in sound physical condition and, with rehabilitation that will accommodate new processes, should continue to function long into the future; however, DWB support systems (i.e., odor control/heating, ventilation, and air conditioning [HVAC] and electrical) need to be evaluated and upgraded.

The following are condition assessment notes for the DWB:

- Centrifuges were manufactured by Andritz (machine type D7LHP20C-HP), circa 1997, and have approximately 29½-inch bowls.
- WPCP staff is not committed to Andritz and would be open to other centrifuge manufacturers.
- WPCP staff have issues with removing the concrete floor panels up via the hoist, which requires much effort, and odor moves throughout the DWB during this process due to short-circuiting.
- PEW supply pressure around dewatering has been pretty good. It could be an option to reduce PEW system pressure and add booster pumps.
- Hot water for cleaning has created a hazardous fog cloud in the DWB. Staff could keep hot water for polymer, but this is not necessary for the rest of the building.
- Motor control center (MCC) 31A on the first floor (below grade on the west side) was damaged when rainwater leaked in through unsealed penetrations.
- Tanks in the basement of the Bio-Building: polymer and sodium hypochlorite are the active tanks.
- The new design will be for four progressing-cavity pumps to feed the thermal hydrolysis process (THP). These could be accommodated either below the current cake hoppers or in the current lime blending room if the current dewatering space and cake bins are reused. WPCP staff could potentially use fewer hoppers in the new (or rehabilitated) DWB.
- Demolition of the current DWB will require the use of a temporary lime stabilization process. Rehabilitation could be conducted during process operation with addition of new equipment.
- It is very difficult to easily maintain or modify cake conveyors below centrifuges and cake hoppers because of the limited clearance between interconnected equipment as well as accessibility constraints.
- In addition to detailed discipline condition assessment of this structure for potential reuse, a code compliance check should be completed, with building code official consultation.

9.1 Centrifuges in Dewatering Building

Dewatering centrifuges (see Figure 13) are used to separate water from the blended thickened solids. The Andritz centrifuges, installed in the 1990s, are the first model of Andritz centrifuge installed in the United States that had a VFD back drive. The centrifuges are operating at reduced bowl speed and produce a cake solids of over 30 percent TS. Cake solids concentration produced by a dewatering process is as much a function of the feed solids characteristics as it is of machine parameters. The WPCP centrifuges are in the process of receiving upgrades from Andritz and WPCP internal staff consisting of new controls and VFDs along with mechanical rebuild of the machines, especially the gear boxes.

At the time of the site visit, there was concern about the reliability of the current dewatering process. It appears that the wear and tear of the machines plus rebuilding critical components now requires previously defined control parameters to be updated to restore reliability. HDR recommends urgent startup-style site visits from Andritz to restore previous reliability so the centrifuges can be replaced when scheduled as part of the Biosolids Upgrade project. If Andritz is unable to restore reliability, then an early construction package for the sequential replacement of centrifuges could be implemented if the decision is made to keep the current DWB with the next solids handling process. Then the new dewatering centrifuges would operate with the existing processes until the switch to new processes.

Performance of the current dewatering centrifuges in terms of polymer dose and cake solids is very good. Contributing factors to the high cake solids likely include, but are not limited to, high ferric dose, high primary to WAS ratio, polymer conditioning of WAS in the DAFT process, and chemically sequestered phosphorus. The planned pre-dewatering process upstream of THP requires only 16 to 18 percent TS, while the existing centrifuges deliver a higher cake solids concentration. When new dewatering equipment is selected for the new dewatering process, the performance of those machines may need to accommodate very different present and future operating conditions.

The following are condition assessment notes for the centrifuges in the DWB:

- During a recent period of 1 to 2 weeks in 2019, all three centrifuges were not working. WPCP operations had to store solids in process, which created significant process issues.
- Mineral deposits in the centrate split in the conveyor room have restricted centrate flow and caused process problems. Centrate lines are regularly cleaned. Buildup on the pipe walls is likely vivianite mineral, which could be mitigated with a WPCP-wide investigation of mineral cations and ferric dose.
- Centrifuge parts availability has been an issue with Andritz, as well as prompt response to service.
- There is no need to sole-source Andritz during the new centrifuge selection process.
- A fourth centrifuge might be an option for reliability, but HDR would recommend a new centrifuge selection process that begins with installation of a new centrifuge in the fourth open slot as new machines are installed.
- Any new centrifuge would likely require relocating the centrate chute, so there is no benefit to matching the configuration with the existing centrifuges. Any new centrifuge will require adjustment of the solids feed and polymer pipes along with cake and centrate discharge chutes.
- Mechanically, the gear boxes are problematic. The bearings are being eroded internally. Recent experience shows that asking Andritz for help has not been worthwhile.

- Centrifuges are running at only 2,000 revolutions per minute (rpm) instead of the 2,600 rpm on the nameplate. Some solids do not require high G-force for good dewaterability.
- Startup for the centrifuges is inconsistent because it depends on which operator is running the process that week.
- The electrical room will be upgrading centrifuge VFDs. This is probably needed for reliability though it is unfortunate when considering replacement of the entire machine.
- Some VFDs had to be replaced because of failure from power spikes during outages. New centrifuges need VFDs with better VFD protection including basics like line reactors.
- The Moyno feed pumps work well. Every centrifuge can be fed by multiple pumps. Pump VFDs are old and due for replacement.
- Solids loading reliability could be improved. Anything above 150 gpm clogs up the centrifuges; current feed concentration is 3.0 to 3.5 percent solids fed to the centrifuge, resulting in 2,200 to 2,700 pounds per hour mass feed rate.
- The polymer blend system is an automatic tank aging process that occasionally fails and requires a manual feed. The system is difficult to start up if not flushed after shutoff. The quality of polymer can be inconsistent. New dewatering should use emulsion blenders for polymer at the bulk storage tanks. Blend units may require additional controls and specified parameters to account for the height of the centrifuges above the blend units.
- Letting polymer age after blending can save 5 to 10 percent, but the savings often are negated by needing to maintain the polymer age tanks and addition of neat polymer pumps.
- The Moyno dilute polymer pumps work well. Every centrifuge can be fed by multiple pumps. The direct-current drives are about 30 years old. According to conversations with the maintenance staff, Seepex pumps are easier to repair. New polymer blend units would replace the entire existing polymer blending system.

Figure 13. Dewatering Centrifuge

9.2 Conveyors and Cake Hoppers in the Dewatering Building

Shaftless screw conveyors transport cake from the dewatering centrifuges to the cake hoppers. The cake hoppers have live-bottom floors with a pair of shafted conveyors that convey the dewatered cake to the lime blend mill. After lime blending more shaftless screw conveyors convey the cake to the trucks for loading. O&M has improved the process over the years and had no specific complaints about the conveyors. The way the conveyors are situated in the DWB makes it difficult to repair individual components. In general, there are two conveyors for every task, allowing for individual repair or complete rehabilitation of the process. Many of the cake gates are wearing and leak fluid, and occasionally fail to open or close. If the DWB is reused as part of the Biosolids Upgrade project, a complete rehabilitation of the conveyors is required, including liner replacement, and new cake gates (valves), in addition to the replacement of the centrifuges.

The following are condition assessment notes for the conveyors and cake hoppers in the DWB:

- In general, all the conveyors start reliably. The drive motors were previously replaced with greaseless bearing motors for improved maintenance.
- The cake gates sometimes do not close all the way (especially on the first floor). The gates should be replaced before wear makes them inoperable.
- The cake hoppers have a dual screw shafted live-bottom floor. One VFD runs twin screws, but sometimes the operator elects to operate only one screw depending on the needed conveyance rate. Live-bottom floor drive motors can be operated independently, so they should have independent VFDs. Cake hopper live-bottom screws have upgraded gear boxes and shafted screws, but can still overload if the hopper is overfilled.
- Throughout the cake conveyor process, pressure relief panels on the top of the conveyors, with switches that will shut down the cake conveyors, have been disabled by bolting down the lids. This eliminates a nuisance alarm but also a safety device.
- Screw conveyors on the second floor (see Figure 14) have acceptable alignment. Many of the conveyor liners are worn out. There are generally two conveyors for every required task. This is not a simple replacement; if the conveyors are kept the WPCP should accelerate the liner replacement by a specialized contractor with coordinated shutdown.
- Mineral buildup or dried sludge becomes a problem when screws are run and then stopped for a while.
- On the second floor the conveyor gates are likely bad. The conveyors' gear boxes have been rebuilt and work fairly well. When conveyors are overloaded and sludge leaks out of the conveyor lid, the room can flood with dewatered sludge.

Figure 14. Second-floor Screw Conveyors

9.3 Odor Control in and around Dewatering Building

DWB odor control exists to maintain negative pressure on the solids handling process areas. Over the years foul-airflow control has been adjusted many times. A near-future project will rebalance the foul-airflow control to original design to better assess foul-air control in the DWB process areas. Foul-air treatment is accomplished by multiple chemical scrubbers, including an acid scrubber for ammonia removal and two-stage sodium hypochlorite chemical scrubbers for sulfide removal. The acid scrubber is not currently in use. The bulk sodium hypochlorite and chemical transfer pumps are located in the basement of the Bio-Building. The chemical day tanks and chemical feed pumps are located in the DWB. O&M reported no specific problems with the process other than that it is a nest of piping and very difficult to replace components. In general, this is a difficult technology to operate, but the future possibility of odor generation will likely require reconfiguration. Additional notes about the process are provided below:

- During the visit no excessive odors were observed around the treatment site.
- Fans outside of the Dewatering Building (see Figure 15) are very difficult to access for maintenance with no lifting area.
- Chemical metering pumps, supports, and piping are corroded and in need of replacement.
- Ventilation has been improved but still has issues. Additional balancing was recently completed.
- Possible future conversion to Bio-P will reduce the overall WPCP ferric chloride dose, which could result in more sludge sulfide odors.
- No copper corrosion was observed in the DWB other than on the first floor.
- Some components are near their end of life.
- The odor control system is loud.

Figure 15. Area Where Fan outside the Dewatering Building Is Located

9.4 Dewatering Building Structural Evaluation

This four-story building built in the mid-1990s is a sound structure of reinforced moment frame concrete construction (Photo A-26). Walls are infill concrete masonry with brick veneer on the perimeter; interior partitions are also of concrete masonry, and predominantly non-load-bearing. At the southeast corner the DWB has a low-rise connector to the older Biosolids Processing Building (Bio-Building, built in the late 1970s) (Photos A-28 and A-29). The DWB elevator serves this connector down to the 18-foot elevation (below grade) (Photo A-31). At this level in the connector, the floor was wet with water (Photo A-32), presumably groundwater or rain infiltration. For future consideration, this connector should be preserved (or replaced) to allow full elevator travel.

On the at-grade first floor (level 25 feet), cracking was observed in the concrete ceiling of the MCC room (104) at the west ductwork penetrations (Photo A-35). Cracks were also visible on the floor of the sludge feed pump room (103). Neither of these cracks are considered significant or troublesome. In the truck bays (102), the only minor issue is standing water on the scales causing corrosion of the ferrous floor materials (Photo A-38) and some concrete cracks on scale decks. The conveyors and steel hoppers appeared to be in good condition (Photos A-39 and A-40). The original truck area was extended to the east circa 1999 by approximately 38 feet (Photo A-38).

On the second floor (level 43 feet) no remarkable observations were made. The north/south central corridor is extremely wide but was designed for a lower live load than some of the adjacent process rooms.

On the third floor (level 66 feet), as on the second floor, no remarkable observations were made. It is worth noting that the concrete portions of the solids hoppers are integral to the building's structural system and a cursory look inside revealed good condition for the concrete and steel hopper at the discharge end.

On the fourth floor (level 82.5 feet) the usable area at this centrifuge and control room level is reduced (compared to lower levels) because of the low roof in the southwest quadrant. The structural condition is good, again, with a very wide central corridor. The centrifuge room (Photo A-41) has ample vertical clearance and is serviced by a 7.5-ton bridge crane. The roof structure is of concrete double tees supported by concrete frames with acoustic masonry completing the envelope.

The complete exterior of the DWB is wrapped in a brick veneer (Photos A-42 and A-43). After more than 20 years of exposure, typical maintenance is required for the expansion joint sealants (Photos A-44 and A-45). Additionally, other repairs at weather-impacted areas are required where brick has been damaged by poor drainage (Photo A-46) and joints without flashing but with drainage material (Photo A-47). Wholesale review of brick tuckpointing should be undertaken, correcting mislocated weep joint material (Photo A-46, A-47), along with the other aforementioned repairs.

9.5 Dewatering Building HVAC Evaluation

This section presents an evaluation of the HVAC systems in the DWB. First an overview and general condition is described, followed by more detailed notes on each plan elevation, and concluding with a summary table (Table 1). The rooms referenced in this section refer to the floor plan and room designations in the Upgrade and Expansion – Phase IIIA drawing set.

9.5.1 Overview and General Condition

The DWB was evaluated with respect to the HVAC systems, ductwork, controls, hydronic piping, and plumbing systems. This evaluation was based only on visual inspection of visible pieces of equipment, conversations with WPCP personnel, and the 2019 Dewatering Building Requirement Detail Report (condition assessment) by Arlington County. Any non-visible ductwork, piping, or equipment was not evaluated.

The 2019 condition assessment estimated $1.8 million for HVAC-related replacement costs. Approximately $246,000 of that cost has already been spent to replace assets with the earliest likelihood of failure.

The remaining original equipment shows signs of aging and is nearing the end of its expected service life. However, the equipment is expected to operate for the next 5 years. Future WPCP processes and layout will require the complete redesign of the HVAC and boiler system. During that time all remaining original equipment should be replaced and upgraded based on current code and efficiency requirements. As part of the future solids upgrades, there is an opportunity to use the waste heat for future water or space heating needs.

Most of the ductwork and equipment was observed with only minor defects, with the exception of ductwork and equipment in the lime storage and day bin areas, which were heavily coated with lime. Domestic water piping was observed with normal signs of use and corrosion, and there are no known issues per WPCP personnel. All systems were observed during normal operating conditions.

9.5.2 Plan Elevation 25 Feet

Below are condition assessment notes about the DWB HVAC system, plan elevation 25 feet:

- **MCC room:** The MCC room is cooled via a control room air conditioner (CRAC-1) located in the room and an air-cooled condensing unit (ACC-1) located on the roof. An inline exhaust fan (EF-1) with makeup air through wall louvers provides emergency cooling. The room is mechanically ventilated via a hydronic heating and ventilating unit (HV-1).
- **Sludge feed pumps room:** The sludge feed pumps room is provided with mechanical ventilation. The room is ventilated via the DWB odor control exhaust with makeup air tempering from a hydronic heating and ventilating unit (HV-2). The room is heated with wall-mounted horizontal unit heaters.
- **VFD room:** The VFD room is cooled via a control room air conditioner (CRAC-6) located in the room and an air-cooled condensing unit (ACC-6) located on the roof. An inline exhaust fan (EF-10) with makeup air through wall louvers provides emergency cooling. The room is mechanically ventilated via a hydronic heating and ventilating unit (HV-1).
- **Polymer solution control room:** The polymer solution control room is conditioned with a control room air conditioner (CRAC-2) located in the room and an air-cooled condensing unit (ACC-2) located on the roof. The room is mechanically ventilated via a hydronic heating and ventilating unit (HV-1).
- **Polymer solution feed pumps room:** The polymer solution feed pumps room is provided with mechanical ventilation. The room is ventilated via the DWB odor control exhaust with makeup air tempering from the polymer mixing and aging tank room above via a hydronic heating and ventilating unit (HV-2). The room is heated with a wall-mounted horizontal unit heater.
- **Scrubber recirculation pump, acid storage, and caustic storage pump rooms:** These chemical rooms are provided with mechanical ventilation. The rooms are ventilated via an in-line exhaust fan (EF-2). The rooms are heated with wall-mounted horizontal unit heaters.
- **Truck bay:** The truck bay is provided with mechanical ventilation. The room is ventilated via the DWB odor control exhaust with makeup air tempering from a hydronic heating and ventilating unit (HV-4). The room is heated with wall-mounted horizontal unit heaters.
- **Tool room:** The tool room is provided with mechanical ventilation via a hydronic heating and ventilating unit (HV-4). The room is heated with wall-mounted horizontal unit heaters.
- **HVAC room:** The HVAC room is provided with mechanical ventilation via a hydronic heating and ventilating unit (HV-4). The room is heated with wall-mounted horizontal unit heaters.
- **Corridor:** The corridor is provided with mechanical ventilation via a hydronic heating and ventilating unit (HV-1).
- **Gallery:** The gallery is provided with mechanical ventilation. The room is ventilated via an inline exhaust fan (EF-11) with makeup air tempering from a hydronic heating and ventilating unit (HV-3). The room is heated with wall-mounted horizontal unit heaters.

9.5.3 Plan Elevation 43 Feet

Below are condition assessment notes about the DWB HVAC system, plan elevation 43 feet:

- **Boiler room:** The boiler room is provided with mechanical ventilation. The room is ventilated via a supply fan (SF-1) with relief through wall louvers. Combustion air for the boiler is provided via wall

louvers. The room is heated with wall-mounted horizontal unit heaters. Two domestic water heaters located in the room provide domestic hot water to the plumbing fixtures.

- **Switchgear room:** The switchgear room is intended to be cooled with a control room air conditioner (CRAC-3) located in the room and an air-cooled condensing unit (ACC-3) located on the roof. An inline exhaust fan (EF-3) with makeup air through wall louvers is intended to provide emergency cooling. Currently the switchgear room control room air conditioner unit is not operational and is being cooled with the emergency cooling ventilation system. The original air-cooled condensing unit has been removed for future replacement. The room is mechanically ventilated via a hydronic heating and ventilating unit (HV-2).
- **Sludge cake storage bin area:** The sludge cake storage bin area is provided with mechanical ventilation. The room is ventilated via the DWB odor control exhaust with makeup air tempering from a hydronic heating and ventilating unit (HV-2). The room is heated with wall-mounted horizontal unit heaters.
- **Dry polymer hopper room and hoistway:** The dry polymer hopper room and hoistway above are provided with mechanical ventilation. The room is ventilated via a hydronic heating and ventilating unit (HV-2). The room is conditioned with a control room air conditioner (CRAC-7) and an air-cooled condensing unit (ACC-7) located on the roof. The room is heated with wall-mounted horizontal unit heaters.
- **Lime day bin and storage rooms:** The lime day bin and storage area above are provided with mechanical ventilation. The room is ventilated via an inline exhaust fan (EF-19) with makeup air tempering from a hydronic heating and ventilating unit (HV-2). The room is heated with wall-mounted horizontal unit heaters.

9.5.4 Plan Elevation 66 Feet

Below are condition assessment notes about the DWB HVAC system, plan elevation 66 feet:

- **Electrical room:** The electrical room is cooled via a control room air conditioner (CRAC-4) located in the room and an air-cooled condensing unit (ACC-4) located on the roof. An inline exhaust fan (EF-5) with makeup air through wall louvers provides emergency cooling. The room is mechanically ventilated via a hydronic heating and ventilating unit (HV-2).
- **Scrubber room:** The scrubber room is mechanically ventilated. The room is ventilated via a roof-mounted exhaust fan (EF-6) with makeup air tempering from a hydronic heating and ventilating unit (HV-1).
- **Air dryer room:** The air dryer room is mechanically ventilated. The room is ventilated via a roof-mounted exhaust fan (EF-6) with makeup air tempering from a hydronic heating and ventilating unit (HV-1). The room is heated with wall-mounted horizontal unit heaters.
- **Sludge cake room:** The sludge cake room is provided with mechanical ventilation. The room is ventilated via the DWB odor control exhaust with makeup air tempering from a hydronic heating and ventilating unit (HV-2). The room is heated with wall-mounted horizontal unit heaters.
- **Compressor room:** The compressor room is intended to be cooled via an inline exhaust fan (EF-9) with makeup air through wall louvers. The exhaust fan is not operational and the room is not being cooled. The room is mechanically ventilated via a hydronic heating and ventilating unit (HV-2). The room is heated with wall-mounted horizontal unit heaters.

- **Lime transfer blower room:** The lime transfer blower room is cooled via an inline exhaust fan (EF-18) with makeup air through wall louvers. The room is heated with wall-mounted horizontal unit heaters.

9.5.5 Plan Elevation 82.5 Feet

Below are condition assessment notes about the DWB HVAC system, plan elevation 82.5 feet:

- **Centrifuge room:** The centrifuge room is provided with mechanical ventilation. The room is ventilated via roof-mounted exhaust fans (EF-7 and EF-12) with makeup air tempering from a hydronic heating and ventilating unit (HV-1). The room is heated with wall-mounted horizontal unit heaters.
- **Centrifuge control room:** The centrifuge control room is conditioned with a control room air conditioner (CRAC-5) and an air-cooled condensing unit (ACC-5) located on the roof. Operators man this control room 24 hours per day, 7 days per week.

9.5.6 Other Spaces

Below are condition assessment notes about other spaces within the DWB HVAC system:

- **Toilet rooms:** The toilet rooms throughout the DWB are exhausted via ceiling exhaust fans (EF-4 and EF-8) with makeup air from adjacent spaces. The toilet rooms are heated with convector heaters (C-4 and C-9).
- **Janitor rooms:** The janitor rooms throughout the DWB are exhausted via ceiling exhaust fans (EF-15 and EF-16) with makeup air from adjacent spaces. The janitor rooms are heated with a convector heater (C-10).
- **Stairs:** The stairs throughout the DWB are heated with convector heaters (C-1 through C-3, C-5 through C-8, and C-11).

Table 1. Dewatering Building HVAC Evaluation

Asset	Qty.	Type	Installation Year	Condition	Reliability	Comments	Recommendation [a]
Heating and ventilation units (HV-X)	4	Indoor air handler, hydronic	1996	Minor defects only/moderate deterioration	Control panel causes random breakdown.	Intake and coil bypass dampers at all units are not operational.	Replace dampers, damper actuators, and control panel.
Air conditioner (AC-1)	1	Split system	Indoor unit: 1996; outdoor unit: 2020	Indoor unit: moderate deterioration; outdoor unit: new	Unit failure not anticipated.	Air-cooled condensing unit has been replaced within the last year. Indoor unit is original.	None.
Control room air conditioners (CRAC-X) and air-cooled condensing units (ACC-X)	7	Split system	CRAC-3: 1996; CRAC/ACC-1, ACC-2, ACC-4–ACC-7: 2020	CRAC-3: moderate deterioration; CRAC/ACC-1, ACC-2, ACC-4–ACC-7: new	Unit failure not anticipated.	All are new within the last year, except for CRAC-3 (switchgear room), which is original and not operational. CRAC-7 (dry polymer hopper) cycles and locks out, which might shorten its life span.	Replace CRAC-3 and install ACC-3. Downsize CRAC-7/ACC-7.
Exhaust fans (EF-X)	19	Exhaust fans	1996	Minor defects only/moderate deterioration	EF-1–EF-8, EF-10–EF-19: failure not anticipated. EF-9 (compressor room): failed.	Motorized dampers at EF-7 and EF-12 (centrifuge room) are not operational. EF-9 is not operational.	Replace motorized dampers at EF-7 and EF-12. Replace EF-9 if compressor room is to remain in use.
Boiler (HWB-1)	1	Gas-fired boiler	1996	Moderate deterioration	Failure not anticipated.	None.	Replace flue damper and install new burner.
Unit heaters (UH-X)	39	Horizontal unit heaters	1996	Moderate deterioration	Failure not anticipated.	None.	None.
Convectors (C-X)	11	Convector unit heaters	1996	Moderate deterioration	Failure not anticipated.	None.	None.

Asset	Qty.	Type	Installation Year	Condition	Reliability	Comments	Recommendation [a]
Lime storage and day bin area HVAC equipment	N/A	N/A	1996	Moderate deterioration	Failure not anticipated.	Lime buildup on ductwork, exhaust fan, louver, unit heater, and control panel.	Clean on a regular schedule.
Ductwork	N/A	HVAC	1996	Minor defects only/moderate deterioration	Failure not anticipated.	None.	None.
Ductwork [b]	N/A	Odor control	1996	Moderate deterioration	Failure not anticipated.	The odor control exhaust duct serving the polymer solution feed pumps room is unsecure and noisily vibrates above the scrubber recirculation pump room.	Investigate and secure ductwork.
Water heaters	2	Storage tank	Unknown	Minor defects only	Failure not anticipated.	None.	None.
Plumbing piping and fixtures	1	-	1996	Moderate deterioration	Failure not anticipated.	System shows normal aging. No known leaks.	Continue annual testing and replace when needed based on testing.

Equipment tags are based on original drawings.

a. Replacement of equipment is based on replacing equipment in kind. Redesign of space, process, or systems will require evaluation and additional design to meet current NFPA 820 and building codes.

b. The odor control ductwork was not assessed. Only the obvious section of unsecure ductwork was addressed.

9.6 Dewatering Building Electrical Evaluation

The DWB is served from the WPCP 34.5-kilovolt (kV) distribution system. That system is configured as a selective radial system with A and B feeders for redundancy. The voltage is step down to 480 volts (V) at the distribution system (DS)-7 transformers and power is supplied to distribution center (DC)-7 switchgear (see Figure 16), which feeds panels, MCC-31, and MCC-32 in the DWB.

The WPCP-wide distribution system has the capacity to serve any practical expansion of the solids treatment. The capacity at 480 V is limited by the DC-7 1,500-kilovolt-ampere (kVA) transformers. Those transformers will most likely need to be replaced or augmented to serve the existing DWB and new processes.

The main DC-7 switchgear is rated for 4,000 amperes (A) (3,325 kVA) and, like the rest of the distribution equipment, it is reported to be in decent condition. However, it was constructed in 1997 and will be more than 25 years old when new facilities come online. A standard life span for electrical distribution equipment is 30 years, which means switchgear replacement would be planned a short time after the new facilities are in service. In addition, feeder circuit breakers may need to be replaced or reconfigured to match the new processes.

MCC-31 and MCC-32 (A and B) and several panelboards were installed as part of the same project as DC-7 and are about the same age. These MCCs serve process motors throughout the DWB and the need for MCCs is highly dependent on the final use of the DWB. But it is highly likely that new motor starters will be required for the repurposed space.

Given the age of the switchgear and MCC, the estimated reconfiguration that may be required, and for project flexibility, these should be replaced.

10.0WPCP Power Supply

The WPCP has two utility power feeds that form the A and B selective radials that power the seven DS substations. If a utility or WPCP power feeder is out of service, DC 480 V switchgear and MCC will automatically transfer to the other feeder. Transfer is timed to allow the DC to transfer first and then at the MCCs if needed. A standby generation facility (SGF) has three 2,500-kilowatt (kW) generators. The peak WPCP electrical demand is approximately 4,000 kW. The SGF is capable of synchronizing with the utility feeders for closed transition transfer or for peak shaving. When there is a complete utility outage the standby generators automatically start, synchronize with each other, and then energize the main 35 kV WPCP feeders. During the site visit one of the WPCP 34.5 kV switchgears was out of service because of a potential transformer (PT) failure. Without the PT it is not possible to power that switchgear from the generators and some protective functions will be lost. The result is a loss of redundancy. O&M reported no specific problems with the process. Additional notes about the process are provided below:

- The Phase 7A project completed electrical upgrades throughout the WPCP but the DWB was largely excluded.
- Switchgear and MCCs are main-tie-main for maintenance purposes.
    - Some MCCs have auto transfer, but the ones for RAS pumps do not.
    - MCCs powering critical equipment (i.e., chemical feed systems) have automatic transfer controls.

- Eliminating kirk key systems frequently happens during WPCP upgrades. Electrical staff indicated that manual/kirk key systems are still desired for non-critical equipment. This allows a staggered load switchover to avoid electrical dips.

- The WPCP has a split electrical source:
  - The power to the north side of the WPCP is supplied through either DC-1 or DC-7. A main feeder and ductbank connect DC-1 and DC-7 to DC-35 and the generators. This main feeder and ductbank are critical and should not be impacted during the Biosolids Upgrade project.
  - The WPCP has seven DCs.
  - These DCs power various MCCs.
  - The WPCP has four MCCs in the area near RAS.

- Generators switch on automatically for power outages but WPCP maintenance can turn the generators on themselves if necessary.
  - Generators are operated and maintained by contract. Parallel operation or peak shaving is done by agreement with utility.
  - On switchover, most but not all equipment usually auto-restarts. Transfer to backup utility power is 10 to 15 seconds. Transfer to the generator is 45 to 60 seconds.

- Power quality issues: Some process equipment VFDs will trip/shut off because the power is out of operation range, such as losing a phase, etc.
- Arc flash studies have been completed.
- There is no secondary fuse protection on the transformers so sometimes WPCP staff need to suit up completely, but the de-energization of the electrical equipment is mostly not a problem.

Figure 16. DC-7 Switchgear in the Dewatering Building

11.0 WPCP Process Control System

The WPCP process control system (PCS) (see Figure 17) received some upgrades during the Phase 7A project. The PCS uses Rockwell FactoryTalk version 10. The PCS has legacy graphics (no longer supported) with a red is running/open color standard. There is no formal historian. Data gets pivoted into Hach Water Information Management Solution (WIMS) and will eventually get compressed to average values. The next project, likely the Biosolids Upgrade project, should include a formal historian.

WPCP staff has a long-term project to develop PCS high-performance graphics following International Society of Automation (ISA) standards. HDR recommends that a future project include integrator-developed high-performance PCS screens for new processes to eliminate project risk of self-performance. It is also recommended that standards be developed in coordination with the WPCP PCS group.

The WPCP operators still prefer the legacy graphics and trending packages, because that is what they are used to. Operations reported no specific problems. The PCS should be able to operate with normal maintenance into the future. As is the nature with computer systems, the PCS has a shorter service life than most mechanical components of a treatment plant. Additional notes about the PCS are provided below:

- The WPCP has been standardizing on Rockwell Automation, and the PCS human-machine interface (HMI) is FactoryTalk, with Allen-Bradley PowerFlex VFDs and Allen-Bradley programmable logic controllers (PLCs).
- PLC panels around the WPCP had redundant hot-backup PLCs.
- Rockwell is no longer supporting legacy graphics in its next version.
- Red is running/open; green is not running/closed.
- Solid yellow or red is an alarm that has been acknowledged. Blinking yellow or red is an alarm and unacknowledged. Onscreen symbols include:
    - A = automatic
    - M = manual
    - NR = non-remote for either only local control, local control panel (LCP) in local, or lock-out/tag-out (LOTO) situation
- Data can go back to 5 years. Different software was used earlier than that. FactoryTalk Transaction Manager just pulls data. Pivoted data are saved by the engineer and not deleted.
- Control strategies are on SharePoint.

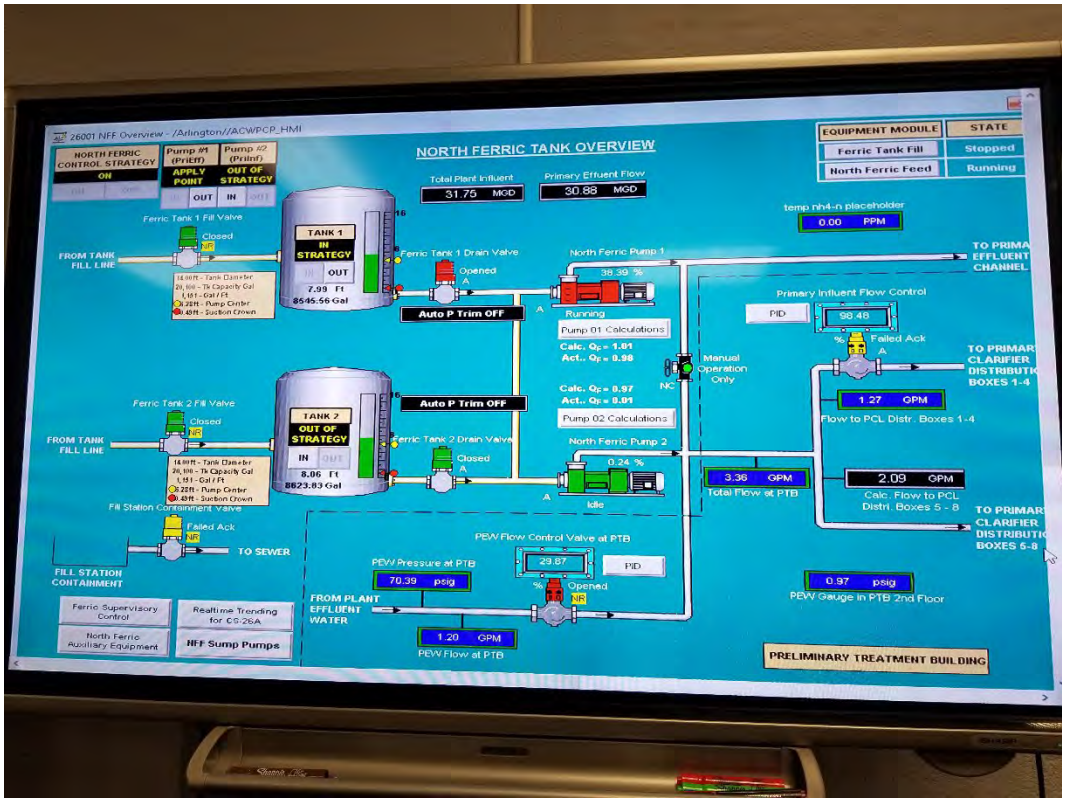

Figure 17. Sample of PCS Screen of the North Ferric Chemical Feed System

Attachment A Structural Photographs

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Gravity Thickener Photographs

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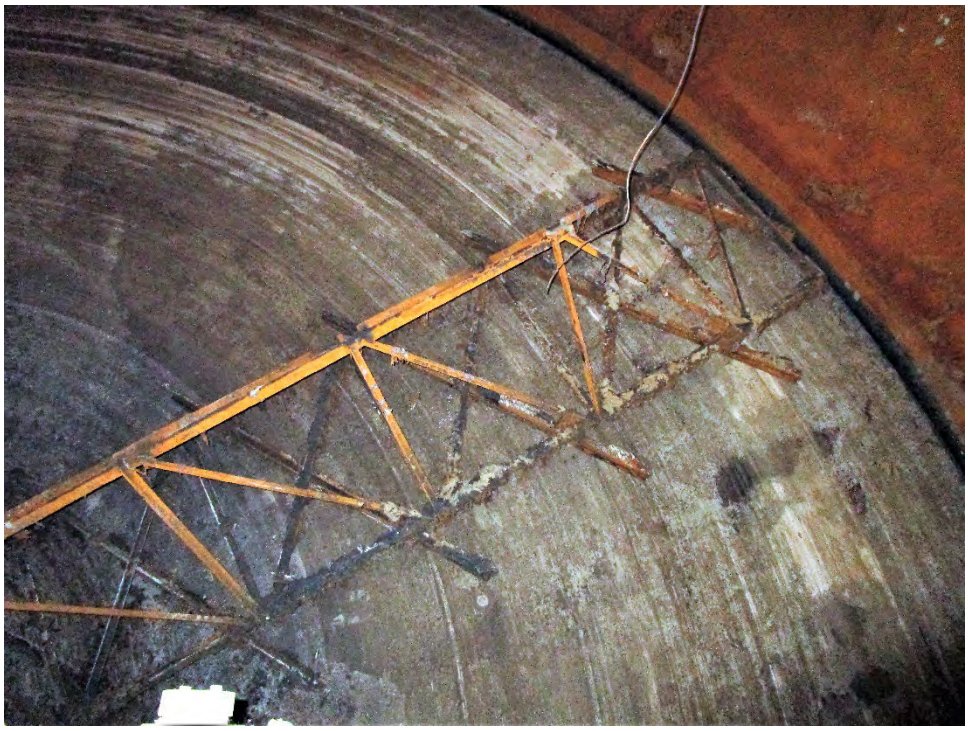

Photo A-1. Mechanical Scraper—To Be Replaced

Photo A-2. Paste Loss Rebar

Photo A-3. Ferric Discoloration

Photo A-4. Launder Joint

Photo A-5. Ferric Chloride Stain, Rebar Exposed

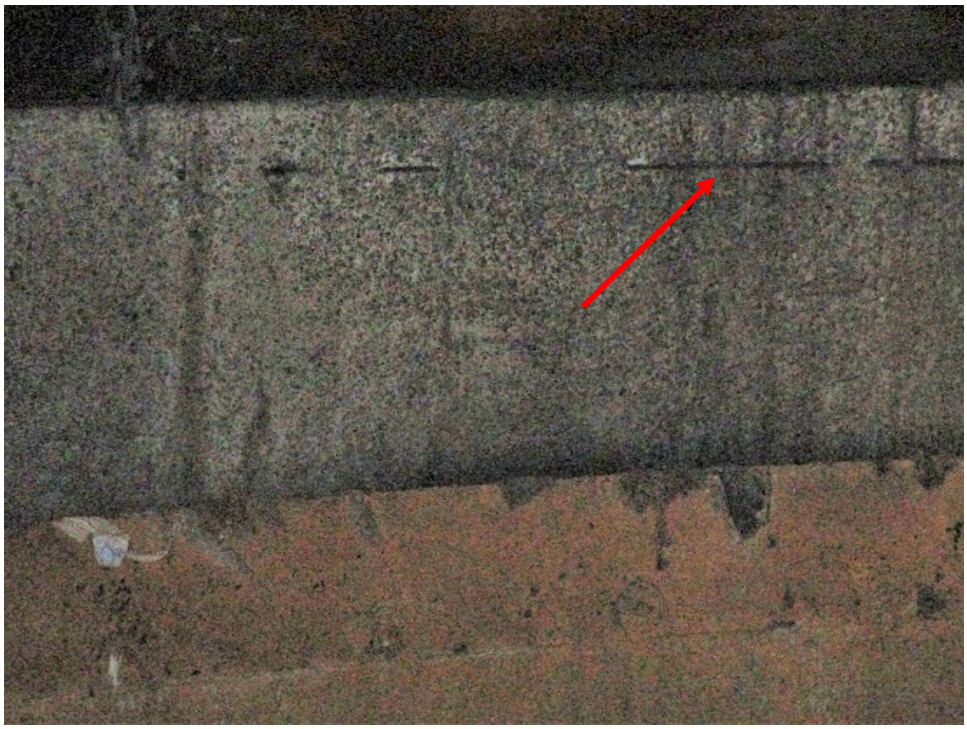

Photo A-6. Reinforcing Exposed

Photo A-7. Undetermined Peeling

Photo A-8. Substance to Be Investigated

Photo A-9. 40-year-old FRP

Photo A-10. Dome Center

Photo A-11. Dome Anchorage

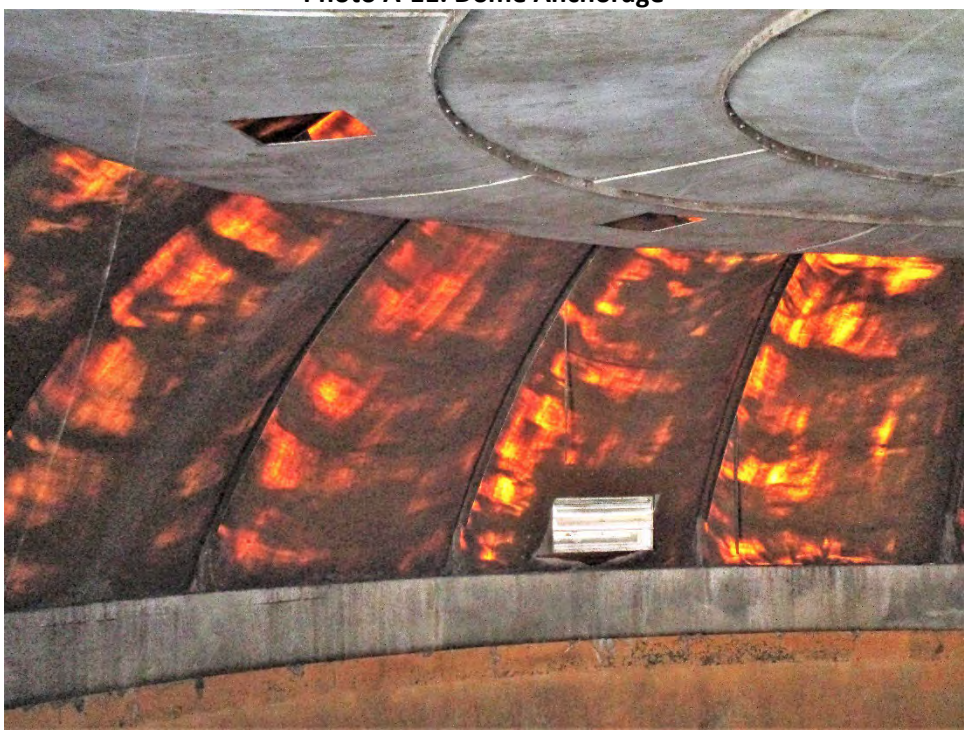

Photo A-12. Long-term UV Effect (Photo 1 of 2)

Photo A-13. Long-term UV Effect (Photo 2 of 2)

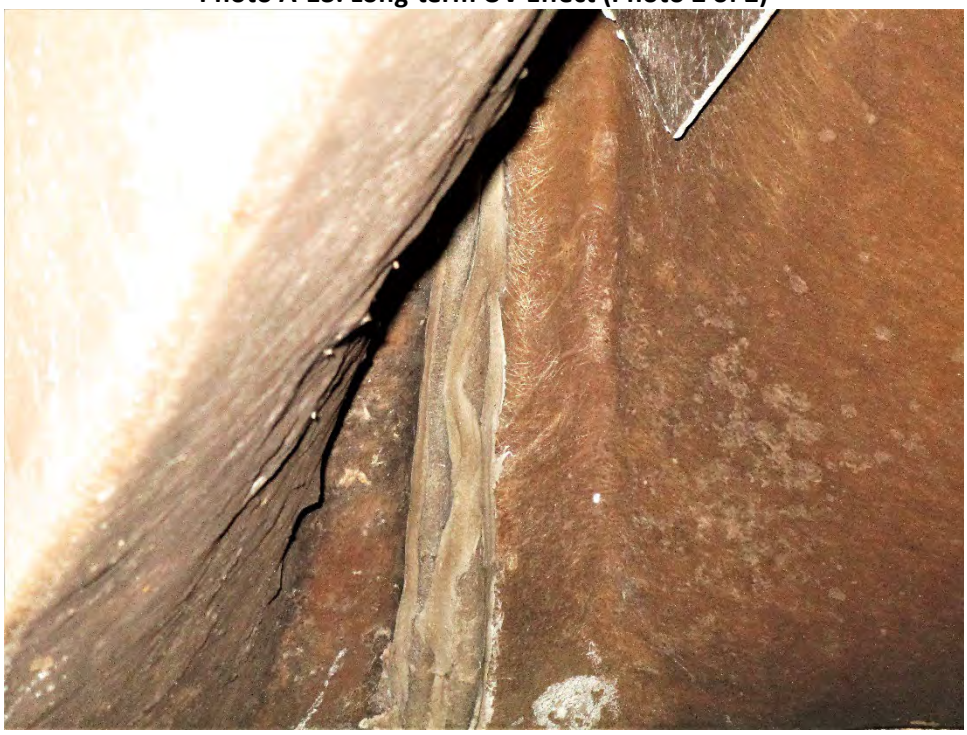

Photo A-14. FRP Joint

Photo A-15. Self Healed Dry Crack

Photo A-16. Active Weep

Photo A-17. Cement Bleeding

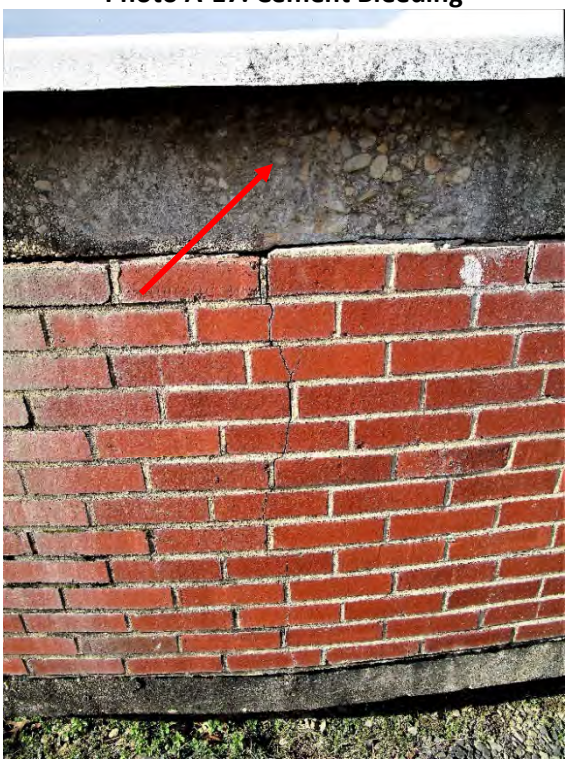

Photo A-18. Paste Loss; Brick Repairs

Photo A-19. Local Water Effect

Photo A-20. Local Moisture Effect

Photo A-21. GT No. 1 Similar (Photo 1 of 2)

Photo A-22. GT 1 Similar (Photo 2 of 2)

Photo A-23. PS Roof Beam

Photo A-24. Pipe Support Deficiency

Photo A-25. Joint Needs Investigation

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Dewatering Building Photographs

Photo A-26. Dewatering Building from Southeast

Photo A-27. Dewatering Building from East

Photo A-28. Bio-Building to Demolish (Photo 1 of 2)

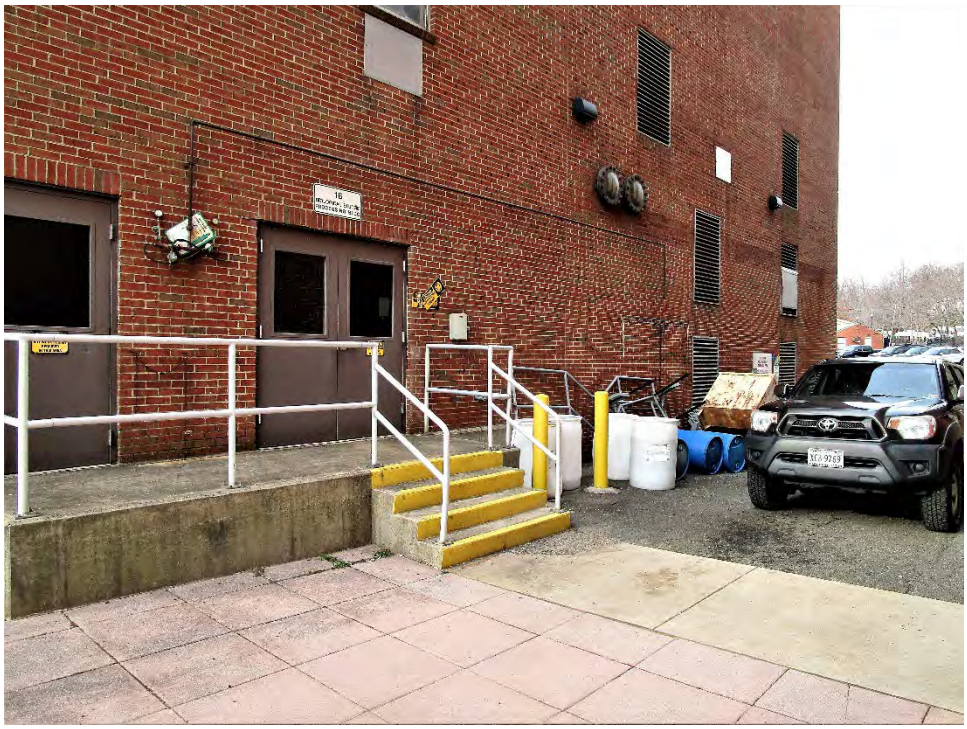

Photo A-29. Bio-Building to Demolish (Photo 2 of 2)

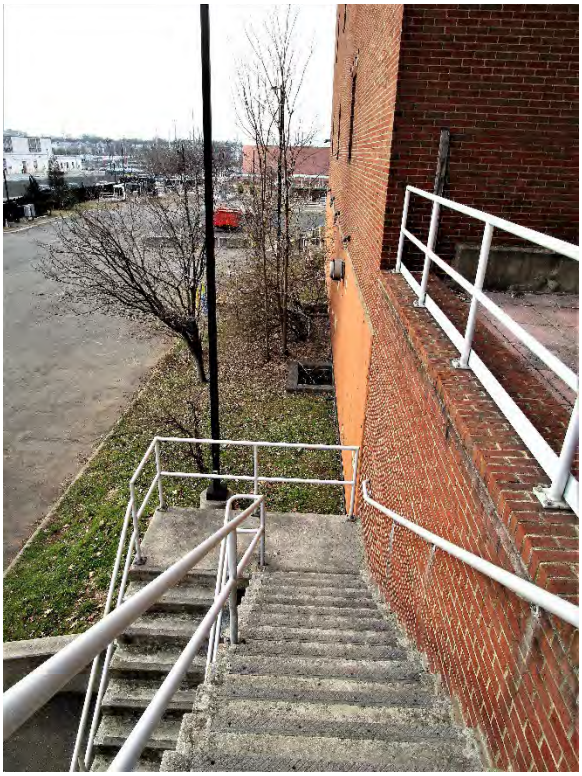

Photo A-30. East Low Link to Save

Photo A-31. Save Basement Link to South

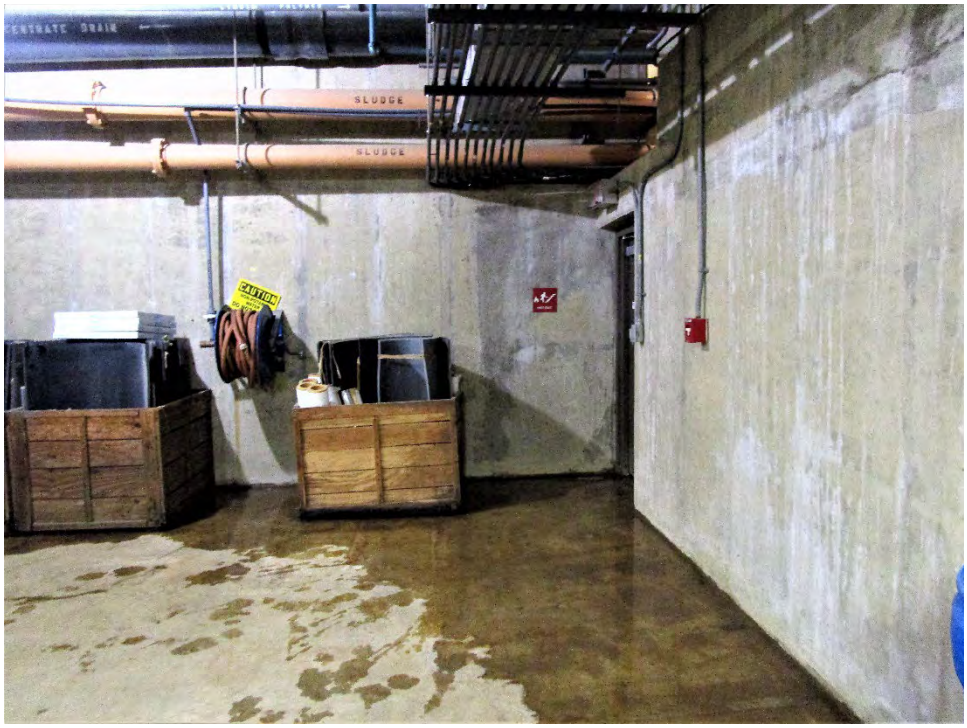

Photo A-32. Water in Link

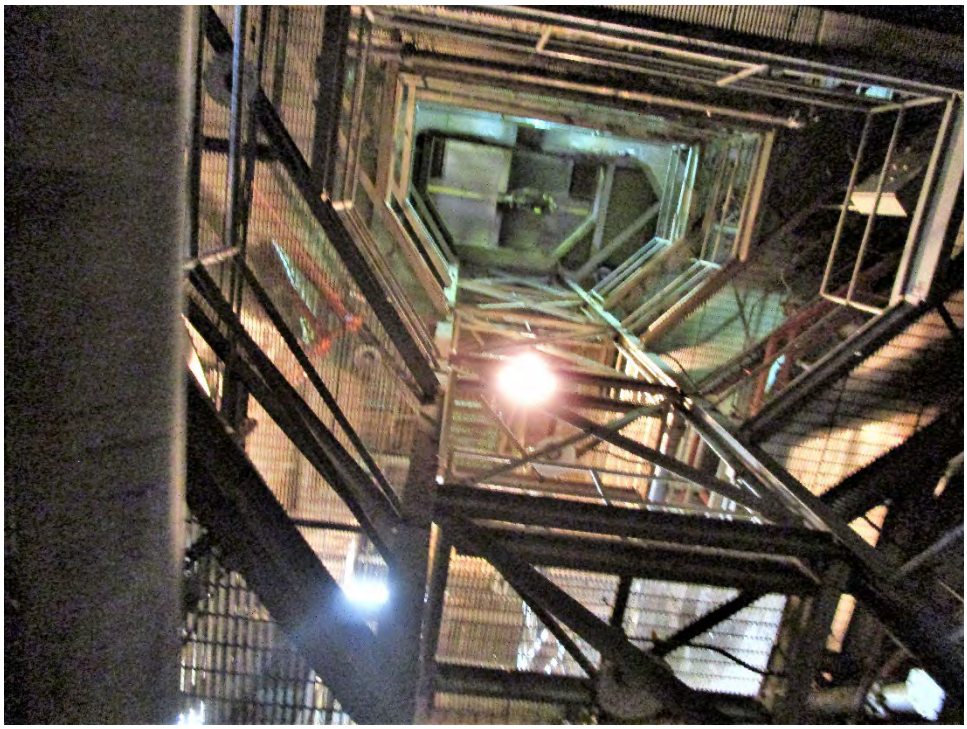

Photo A-33. Incinerator to Demolish

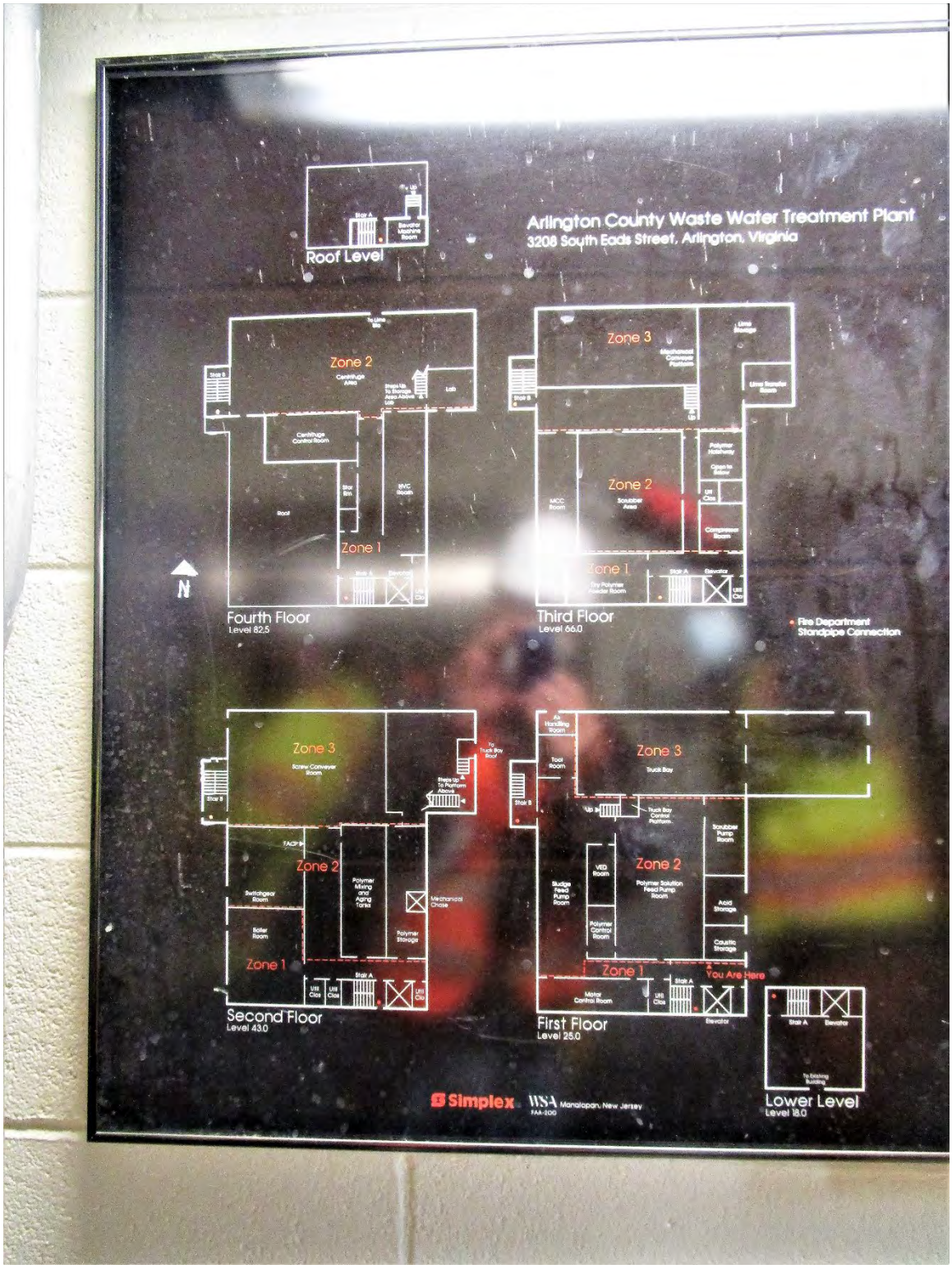

Photo A-34. Floor Map

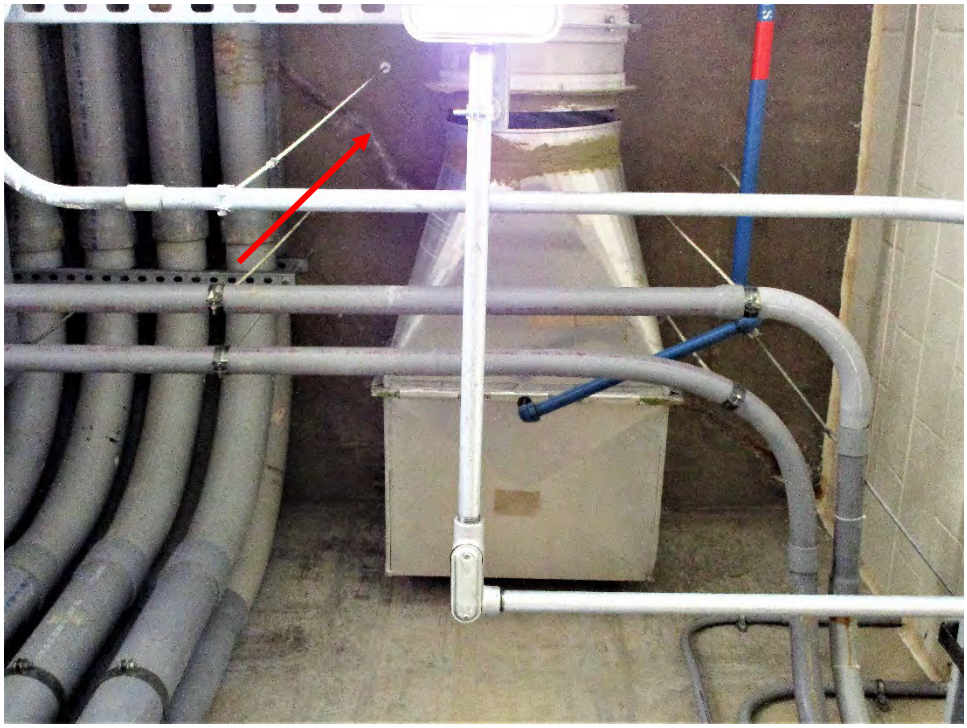

Photo A-35. MCC Ceiling Cracks

Photo A-36. Polymer Feed Pumps

Photo A-37. Extension to Loadout

Photo A-38. Truck Scale Ponding, Edge Corrosion

Photo A-39. Screws, Hopper

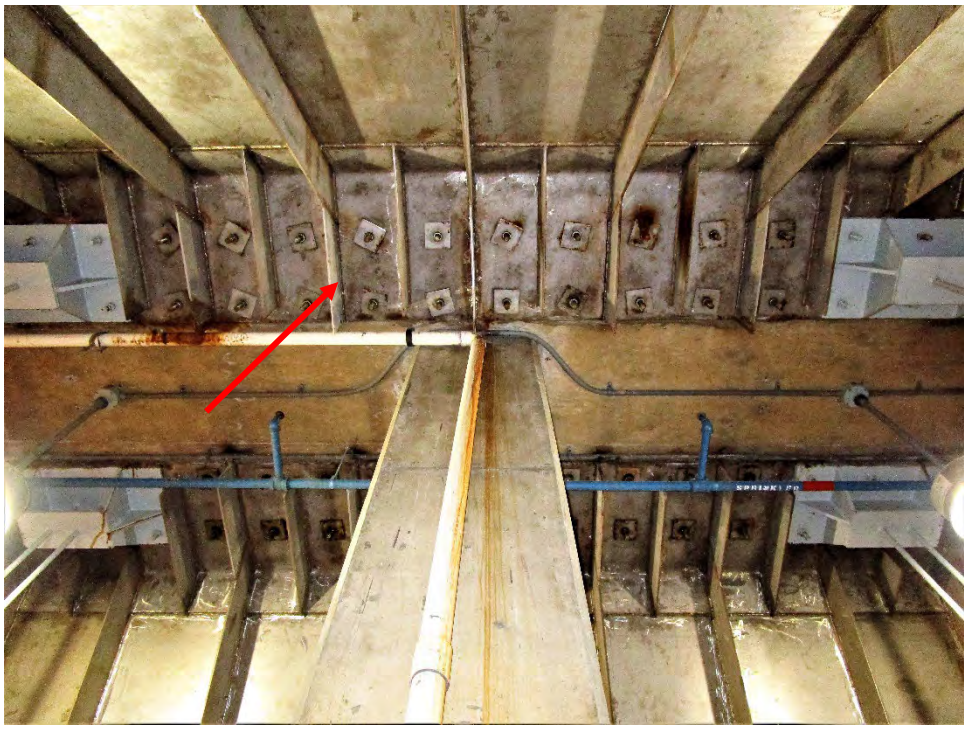

Photo A-40. Hopper Suspended

Photo A-41. Centrifuge Room and Double Tee Roof

Photo A-42. South Face

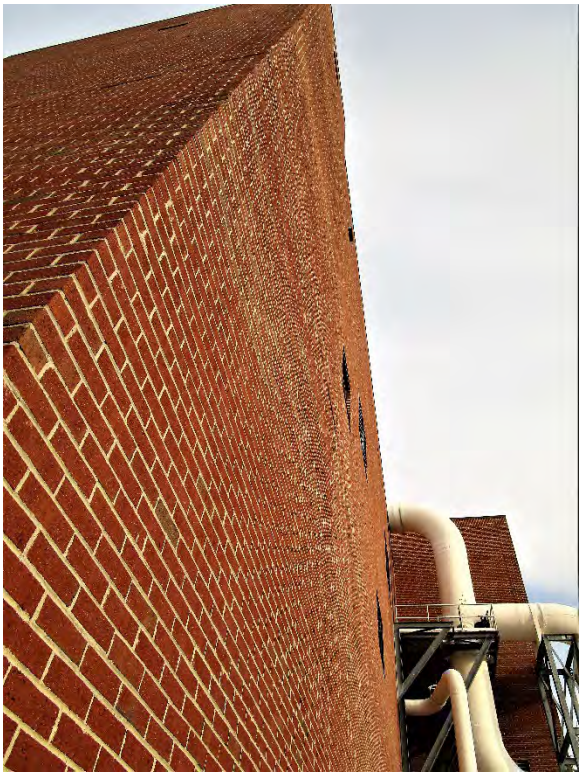

Photo A-43. Joint Damage

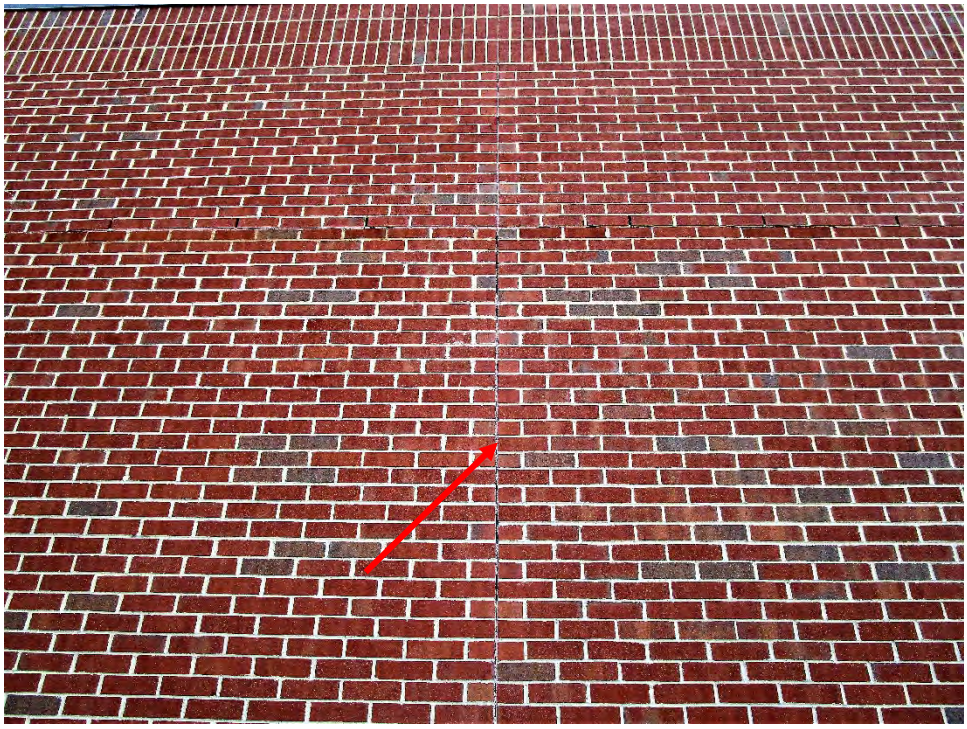

Photo A-44. Brick Expansion Joint

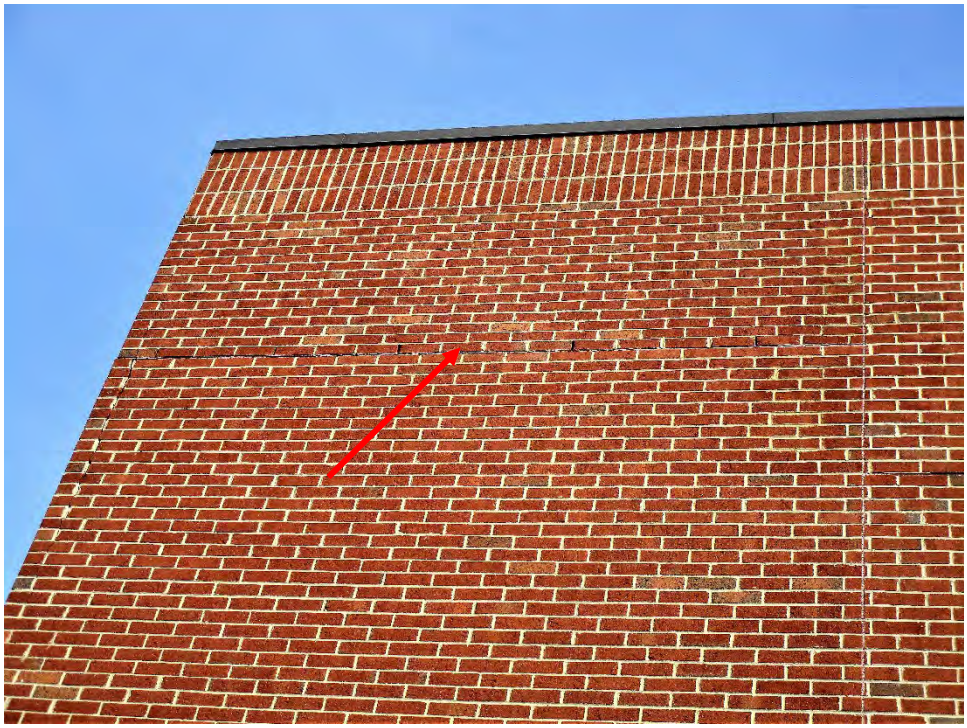

Photo A-45. Brick Joint

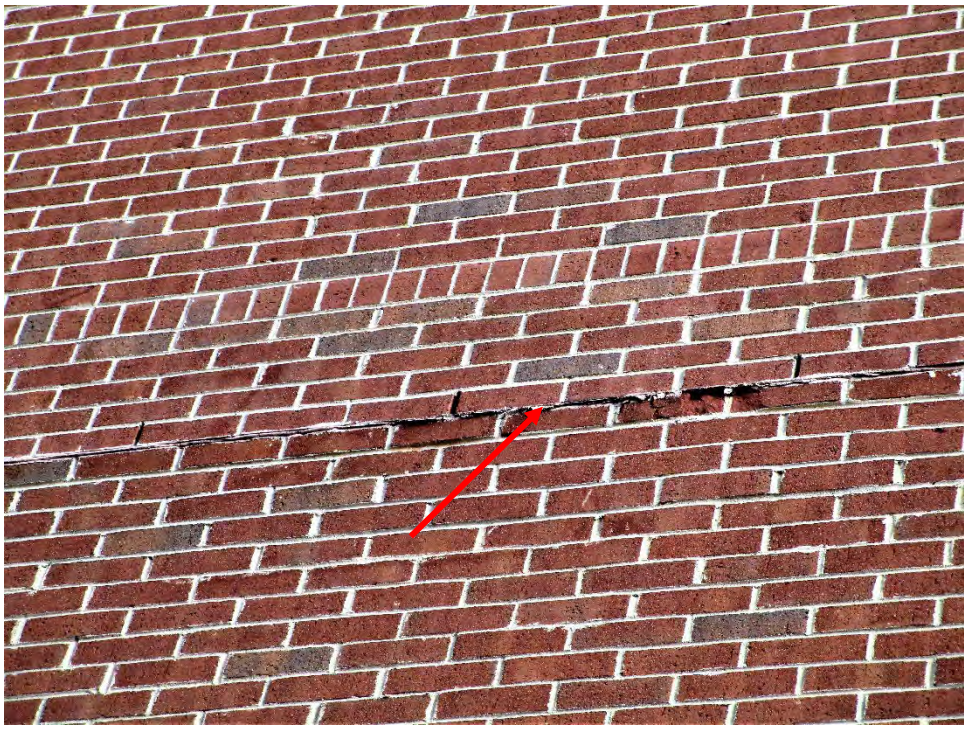

Photo A-46. Weep Water Damage, no Flashing

Photo A-47. Unusual Detailing

Photo A-48. Odor Control System To Be Demolished

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Technical Memorandum No. 3

Date:	July 21,2021
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Biosolids Technology Market Assessment

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1.0 Introduction

This introductory section presents the background and purpose of the project and describes the evaluation of selected biosolids treatment and handling technologies for the Arlington Water Pollution Control Plant (WPCP).

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington WPCP. Currently solids handling includes primary sludge (PS) and waste activated sludge (WAS) thickening, dewatering, and lime stabilization. The 2018 Solids Master Plan report (Master Plan) for the WPCP recommends replacing the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion. The Master Plan arrived at this recommendation following an evaluation of multiple biosolids treatment and handling technologies. The technologies initially screened as part of the Master Plan included:

- **Non-digestion stabilization:** composting and chemical treatment
- **Digestion stabilization:** aerobic digestion, autothermal thermophilic aerobic digestion (ATAD), mesophilic digestion, thermophilic digestion, temperature-phased anaerobic digestion (TPAD)
- **Digestion process enhancements:** thermal hydrolysis, cavitation, thermo-chemical hydrolysis
- **Drying:** solar, direct thermal, indirect thermal
- **Thermal processes:** incineration, wet air oxidation, Anuvia, gasification, pyrolysis, liquid thermal oxidation

The County has requested that certain technologies be further evaluated to identify any technology improvements that should be included for this project and considered for inclusion in the Facilities Plan.

1.2 Evaluation Approach

The following technologies evaluated in the Master Plan were identified through discussions between the County and HDR for additional evaluation because of their current and growing use at wastewater facilities in the United States and their ability to address key project drivers of Class A biosolids end product and energy recovery:

- Solids drying: rotary-drum and belt drying
- Pyrolysis
- Gasification
- THP alternate configurations

This technical memorandum (TM) revisits these solids processing technologies and viable uses for the products they produce based on current market outlets. The remaining technologies that had been screened during the Master Plan were not included in this evaluation because they either do not meet the key project drivers of Class A biosolids end product and energy recovery or the technology maturity had not substantially changed since development of the Master Plan to warrant re-evaluation. The technologies are compared based on their current level of maturity and implementation, scalability to the WPCP, and energy demands. Technology recommendations and planning considerations for the Facilities Plan are provided

2.0 Technology Alternatives

This section presents descriptions of the biosolids treatment and handling technology alternatives considered in this evaluation.

2.1 Solids Drying

Rotary-drum and belt dryers produce dried biosolids through evaporation by bringing dewatered solids into direct contact with heated air. Although it is not necessary to digest solids prior to drying, the odorous nature of dried undigested solids, particularly when the dried solids are rewetted, makes the product undesirable for most non-agricultural end uses. Additionally, digestion produces biogas that can be beneficially used, including as fuel to heat the drying air. When cake solids are dried to greater than 90% solids, both dryer technologies produce a Class A dried biosolids product that has several well-established end-use markets in the United States. In addition to bulk agricultural land application, dried biosolids are used as a solid fuel (primarily in cement kilns); as an ingredient in blended fertilizers; and for turf management, landscaping, and horticulture. Dried biosolids can also be distributed or sold to the general public in bulk or in bags for use as a fertilizer or soil amendment.

2.1.1 Rotary-Drum Drying

Rotary-drum dryers produce a dried, stabilized Class A product by drying dewatered solids through direct contact with heated air in a horizontal, enclosed triple-pass rotating drum. Dewatered solids are blended with recycled dried solids and fed into the rotating drum. Solids are conveyed through the rotating drum in the process air stream, which is heated in a gas-fired furnace. The heated air comes in contact with the solids and evaporates water. The pre-mixing of dewatered and recycled dried solids combined with the rotating action of the drum produce a hard, spherical pellet with a diameter of 3 to 4 millimeters. Dried solids exit the drum and are carried in the process air stream to a cyclone that separates the solids from the process air. Solids are sent to a screen that separates product-size pellets from oversized and undersized material, which are recycled and mixed with dewatered solids. Product-size pellets are then cooled and conveyed to storage. The process air stream passes through a venturi scrubber to removal particulates and water and then continues to an odor control system, typically consisting of a regenerative thermal oxidizer for volatile organic compound and odor (VOC) combustion.

A rotary-drum dryer process at the WPCP would be added following dewatering to dry digested, dewatered solids, as shown in Figure 1.

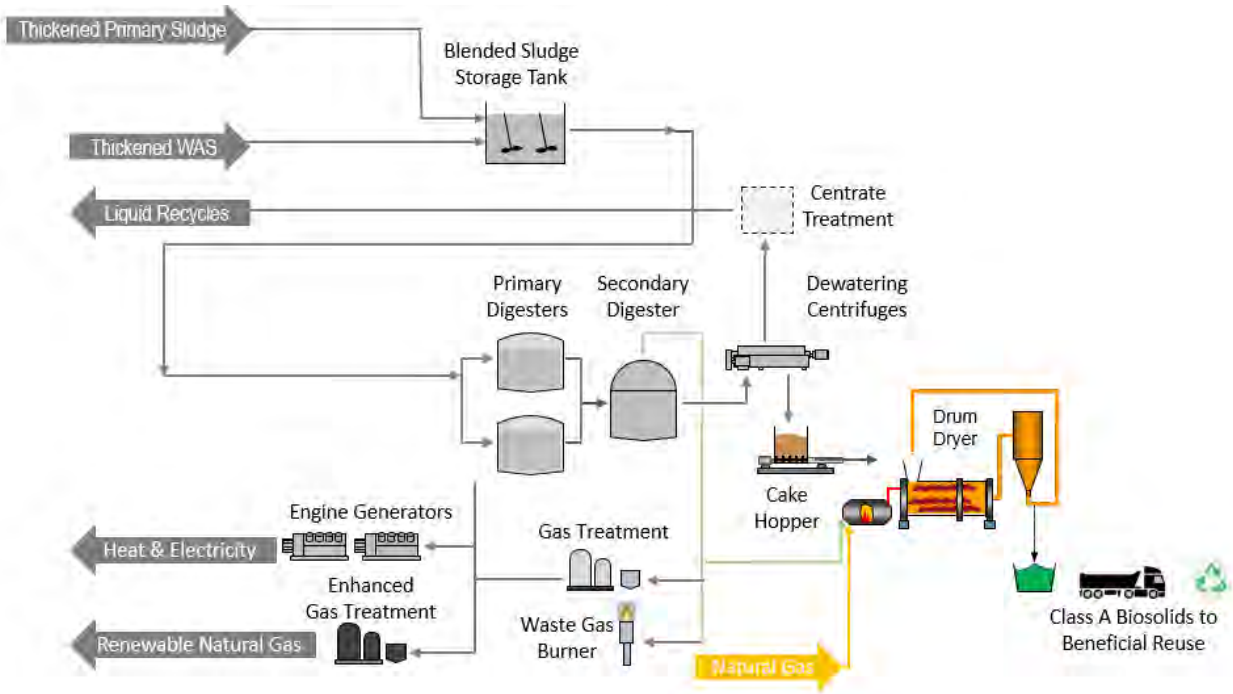


Figure 1. Rotary-Drum Dryer Process Flow Diagram

Rotary-drum drying is considered a process to further reduce pathogens (PFRP) that achieves Class A pathogen reduction by reducing the moisture content of the solids to 10 percent or less and heating the biosolids to at least 80 degrees Celsius (°C) (176 degrees Fahrenheit [°F]). Rotary-drum drying systems operate at a process air temperature of 260°C to 370°C (500°F to 700°F) and typically dry the biosolids to 90 to 95 percent total solids (TS).

Rotary-drum drying is a mature technology with more than 40 years of operating history at wastewater treatment facilities. More than 40 rotary-drum drying installations are operating at wastewater facilities in the United States and on the order of 200 worldwide. Rotary-drum dryers are commonly used at medium to large wastewater facilities of a scale similar to the County's facility.

Table 1 summarizes the benefits and challenges of rotary-drum drying.

Table 1. Rotary-Drum Dryer Benefits and Challenges

Benefits	Challenges
Mature technology in the wastewater industry	Extensive odor and emissions control systems
Class A pathogen reduction	Large energy demands (both natural gas and electricity) and greenhouse gas footprint
Significant biosolids volume reduction	Additional staff required for operations and maintenance (O&M)
Most versatile end product in the biosolids market	Not recommended for implementation with THP
	No per- and polyfluoroalkyl substances (PFAS) destruction
	Relatively high level of mechanical and operational complexity

2.1.2 Belt Drying

Belt drying systems produce a stabilized Class A biosolids product by drying dewatered cake through direct contact with hot air as the dewatered cake is conveyed through a horizontal dryer cabinet on one or more moving belts. Belt drying systems fall into one of two categories:

- **Back-mixing systems (example manufacturers: Andritz, Haarslev):** Similar to the rotary-drum dryer, these types of belt dryers mix dewatered cake and recycled dried material to pre-form a granule that is fed onto the drying belt. Crushing, screening, and recycling of the dried product are integral to the proper performance of the belt dryer.
- **Direct cake feed systems (example manufacturers: Veolia, Haarslev, Huber):** These types of belt dryers pump and extrude dewatered cake, with no back-mixing of dried product, directly onto the drying belts. This type of belt dryer produces a non-uniform product that can range from a mulch-like material to irregularly sized and shaped granules. Post-processing of the dried material (crushing, screening, optional pellet mill) can be provided to produce a more uniform final biosolids product.

Condensers are usually used to separate evaporated water from the process air and recirculate most of the process airflow back to the dryer, reducing the amount of air exhausted to the atmosphere. An odor control system consisting of a wet chemical scrubber or biofilter is typically provided to treat the air exhausted to the atmosphere.

Similar to a rotary-drum dryer, a belt dryer would be added following dewatering to dry digested, dewatered solids, as shown in Figure 2.

Belt drying is also considered a PFRP that achieves Class A pathogen reduction by reducing the moisture content of the solids to 10 percent or less and heating the biosolids to at least 80°C (176°F). Belt drying systems operate at temperatures of 90°C to 150°C (200°F to 300°F) and dry the biosolids to 90 to 95 percent TS.

Belt drying is a mature technology with more than 20 years of operating history, although it is relatively new to the United States. Approximately 15 belt drying installations are in operation at wastewater treatment facilities in the United States, several of which are at a scale similar to the WPCP, and more than 90 worldwide.

Table 2 summarizes the benefits and challenges of belt drying.

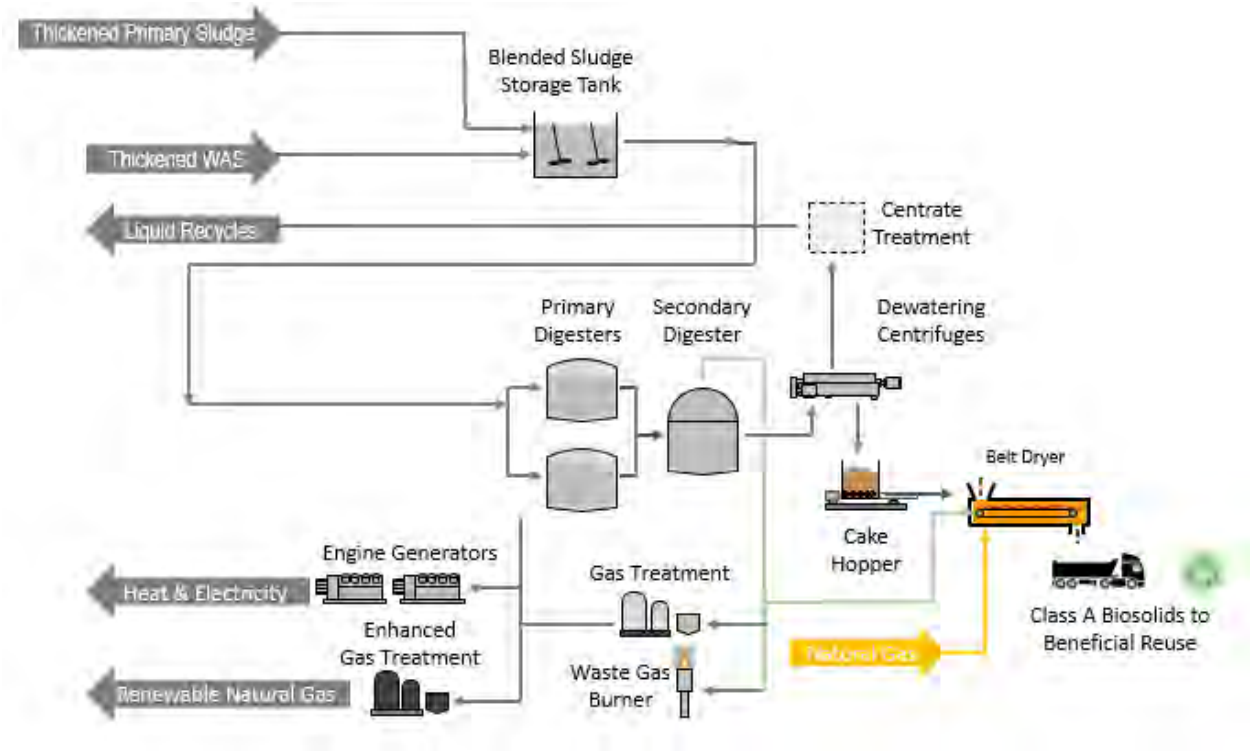


Figure 2. Belt Drying Process Flow Diagram

Table 2. Belt Dryer Benefits and Challenges

Benefits	Challenges
Relatively low operating temperature	Larger footprint compared to drum drying facility
Class A pathogen reduction	Non-uniform product possible without post-processing
Significant biosolids volume reduction	Large energy demands (smaller than drum drying) and greenhouse gas footprint
Versatile end product in the biosolids market	Additional staff required for O&M
Compatible with THP and other add-on processes, based on HDR's recent research	No PFAS destruction
Potential to use waste heat as a heat source	

2.2 Pyrolysis

Pyrolysis thermally decomposes volatile organic material in raw or undigested wastewater solids through the application of heat in the absence of oxygen. Pyrolysis can be implemented either with or without digestion. Dewatered solids are first heat-dried to 70 to 90 percent solids content. The dried solids are conveyed to a self-contained chamber (Figure 3) that breaks down volatile organic material via 350°C to 900°C (660°F to 1,650°F) operating temperatures. The by-products are synthetic gas, or syngas, and biochar. Syngas is typically combusted to provide heat for the pyrolysis reaction and dryer

equipment to achieve a near net-zero energy consumption or conditioned to remove impurities and then used to produce heat and electricity through cogeneration. Syngas can also be further processed to produce renewable natural gas (RNG); however, it is likely not cost-effective to do so.

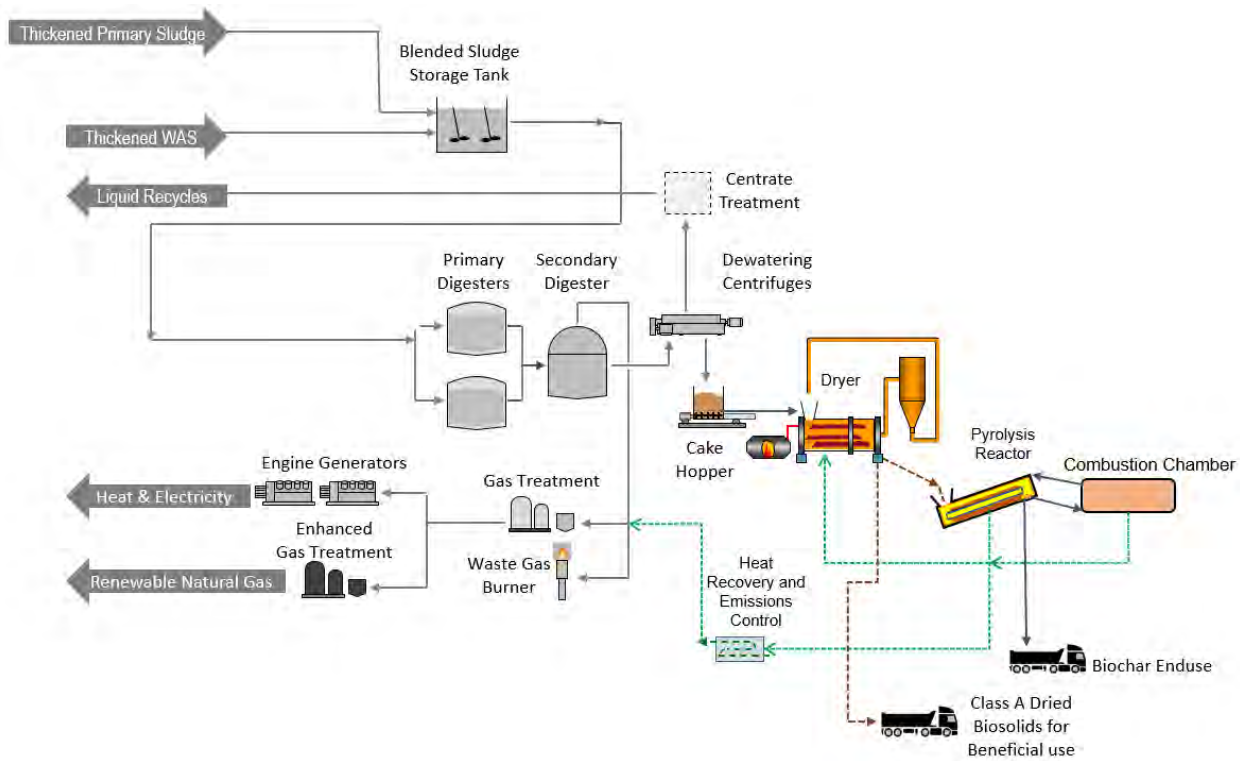


Figure 3. Pyrolysis Process Flow Diagram

Pyrolysis biochar is considered an exceptional quality (EQ) Class A product by significantly reducing the moisture content of the solids to 10 percent or less and heating the biosolids to at least 80°C (176°F) through high heat applications. Though this is considered a biosolids, biochar is a high-carbon, fine-grained product resembling a charcoal product. Biochar from pyrolysis is distinguished by the sequestered carbon emissions and is California Department of Food and Agriculture (CDFA) approved as a safe and renewable product. The pyrolysis technology has the potential to provide end-product diversity in the future as more beneficial uses are identified and accepted for the biochar. However, current management options for biochar are limited to landfilling and use of the material as a filler in manufactured products, typically concrete products. Biochar could also be land-applied to agricultural fields or for land reclamation projects or used as a soil amendment, but these are not currently considered to be viable end-use markets based on the limited history of biosolids pyrolysis in the United States (only a few operating pyrolysis facilities).

Should the pyrolysis system be offline, dried Class A solids can be produced in the dryer.

Pyrolysis is considered an emerging technology for wastewater solids with only two installations at wastewater treatment facilities in the United States. Additional installations processing feedstocks other than municipal biosolids have been in operation for approximately 5 years. Pyrolysis is typically packaged as a modular process with a set capacity and may be best suited for facilities between 0.2 and 20 million gallons per day (mgd) influent flow, smaller than the County's facility.

Table 3 summarizes the benefits and challenges of pyrolysis.

Table 3. Pyrolysis Benefits and Challenges

Benefits	Challenges
Can produce dried Class A biosolids and/or biochar products via the dryer and pyrolysis processes, respectively	Large footprint
Zero to low net energy footprint	Limited application history
Volume reduction	Process and mechanical complexity
Flexibility to adapt to changing market	Multiple new processes for O&M staff
Low odor product	Emissions and greenhouse gas controls required
Potential PFAS destruction (pending ongoing studies)	

2.3 Gasification

Gasification is a thermochemical process that converts dried biosolids into syngas (a low-grade fuel gas), biochar, and ash. Gasification can be implemented either with or without digestion. Dryers process dewatered biosolids (Figure 4) to produce Class A 70 to 90 percent dried biosolids, and the dried biosolids are introduced into a fluidized bed of the gasifier, where air is used as fluidization gas. The gasifier converts biosolids to a low-energy syngas (consisting of hydrogen, methane, and carbon monoxide) and biochar/ash through three main reactions that occur in separate zones within the gasifier reactor:

- **Pyrolysis:** thermal degradation, in the absence of oxygen, of volatile solids (VS) to gaseous products
- **Oxidation:** partial oxidation of the pyrolysis products, which produces heat to drive the pyrolysis and gasification reactions
- **Gasification:** further conversion of biochar to gaseous products

Temperatures inside the gasifier typically range from 480°C (900°F) in the pyrolysis zone to 1,100°C (2,000°F) in the oxidation zone.

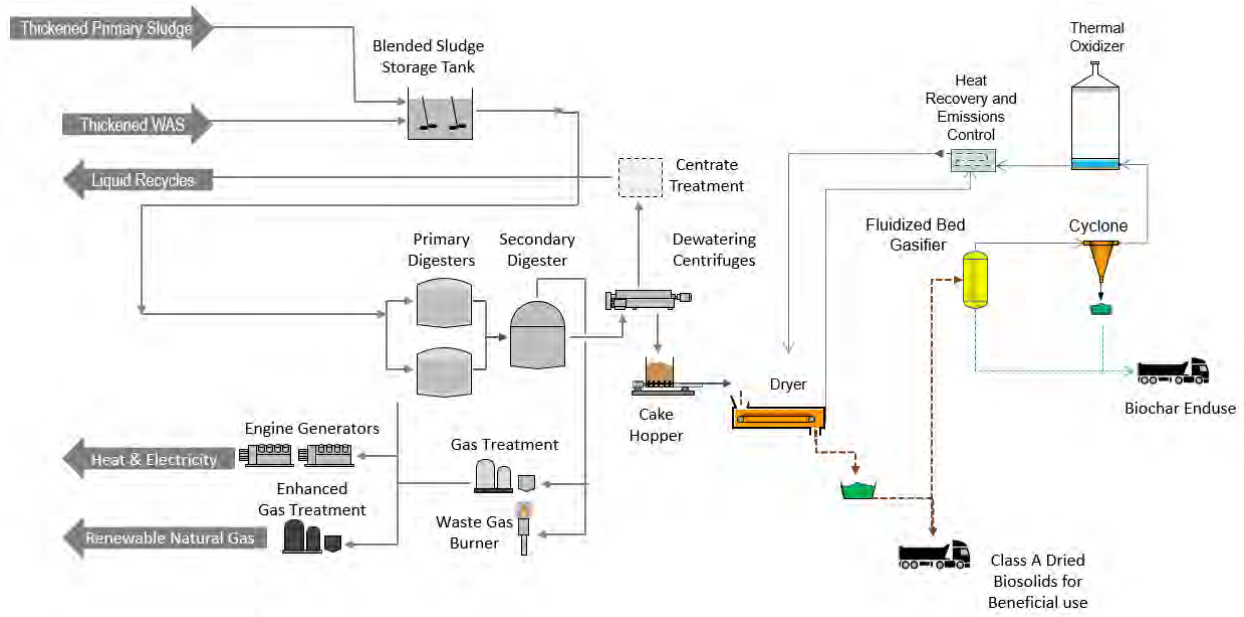


Figure 4. Gasification Process Flow Diagram

Thermal oxidizers and heat exchangers are typically provided to control odors and VOC emissions. Using the heat recovered from the flue gas produced in the thermal oxidizer in the solids drying step can make gasification an energy-neutral process. An emission control system is also provided to treat the air exhausted to the atmosphere. Biochar (unconverted carbon and residual material) is captured in the gasifier cyclone and is produced at the end of the gasification process.

Current management options for gasification biochar and ash produced in the gasification process are limited to landfilling and use of the material as a filler in manufactured products, typically concrete products. Gasification biochar could also be land applied to agricultural fields or for land reclamation projects or used as a soil amendment, but at present these are not considered to be viable end use markets based on the limited history of gasification in the US.

Gasification is considered an established technology in the solid waste field, however in the municipal wastewater market, it is considered an emerging solids technology. There are currently no installations at facilities of similar size to the County's facility. However, one new facility is currently in construction in Linden, New Jersey. This facility, scheduled for startup later in 2021, is reported to have a design capacity of 430 wet tons (92 dry tons) per day. There are also two other proposed facilities in permitting in the United States.

Table 4 provides the benefits and challenges of gasification.

Table 4. Gasification Benefits and Challenges

Benefits	Challenges
Can produce both dried Class A biosolids and biochar	Air Permitting and emissions controls
Flexibility to adapt to changing market	Largest footprint building compared to all technologies
Potential PFAS destruction (pending ongoing studies)	Limited application history
Low odor product	Process and mechanical complexity
Zero to low net energy footprint	

2.4 Thermal Hydrolysis Process Alternate Configurations

THP is a two-stage anaerobic digestion pretreatment process for PS, WAS, or combined PS and WAS comprising high-pressure steam heating of waste or sludge followed by rapid decompression. This combined action sterilizes the sludge and hydrolyzes, or breaks apart, the solids' cellular structure and makes them more biodegradable, which improves VS reduction and gas production in the downstream anaerobic digestion process. Additionally, the viscosity of the thermally hydrolyzed solids (THS) is substantially lower than non-hydrolyzed solids, so that a much higher solids concentration can be efficiently conveyed into and mixed within the digesters.

THP has multiple manufacturers. The system provided by Cambi, the predominant manufacturer for THP installations in North America, includes a pulper, multiple pressurized reactors, and a flash tank. Solids are pre-dewatered and fed to the pulper at 15 to 16 percent TS and pre-conditioned with low-pressure steam. Solids from the pulper and medium-pressure steam are fed to the batch THP reactor, where solids are held for approximately 30 minutes at a temperature of 150°C to 200°C (300°F to 390°F), which provides Class A pathogen reduction, and a pressure of 70 to 120 pounds per square inch (psi). After the holding time, the reactor is depressurized, sending the solids to the flash tank, in which rapid decompression physically lyses, or breaks apart, the cell walls of the solids. Solids leaving the flash tank are then diluted to a solids concentration of 9 to 10 percent using pathogen-free water, cooled to mesophilic anaerobic digester temperatures in cooling heat exchangers, and fed to the anaerobic digesters. The anaerobic digesters continue to operate at 35°C to 38°C (95°F to 100°F). The viscosity of the 9 to 10 percent solids from THP is comparable to thickened solids at 5 percent, allowing conventional digester pumping and mixing equipment to be used. The more readily degradable THP solids typically increase overall VS reduction in the digesters by 15 to 20 percent, with a corresponding increase in digester gas production. THP anaerobic digestion also improves the dewaterability of the digested biosolids; solids can typically be dewatered to 35 percent solids or more using centrifuges. With the increased solids destruction and dewatered cake solids content, the final solids quantity is reduced by two-thirds, substantially reducing costs for beneficial land application and other end uses.

THP is considered an established technology with more than 100 installations at municipal wastewater treatment plants worldwide, and more than 25 years of operation since their first installation. Several of the installations are at treatment facilities of similar scale to the Arlington WPCP.

The current Master Plan recommendation was for conventional THP implementation, where both PS and WAS are dewatered and treated through THP, as shown in Figure 5. Multiple THP configurations are

available, as shown in Figure 6. The key benefits and challenges to the alternate THP configurations are summarized in Table 5.

The primary end use for Class A dewatered cake from THP is traditionally bulk agricultural land application. While Class A biosolids could be distributed and marketed for other beneficial uses, the typical 30 to 35 percent dewatered solids are not widely considered a desirable product for other end uses. The Class A cake will likely require additional processing, through air drying (curing) or blending with other materials such as shredded woody waste or sand, to increase the solids content to a 50 to 60 percent range, similar to a compost material, to be suitable for land reclamation, horticultural or soil blending uses, or distribution or sale to the general public for home use.

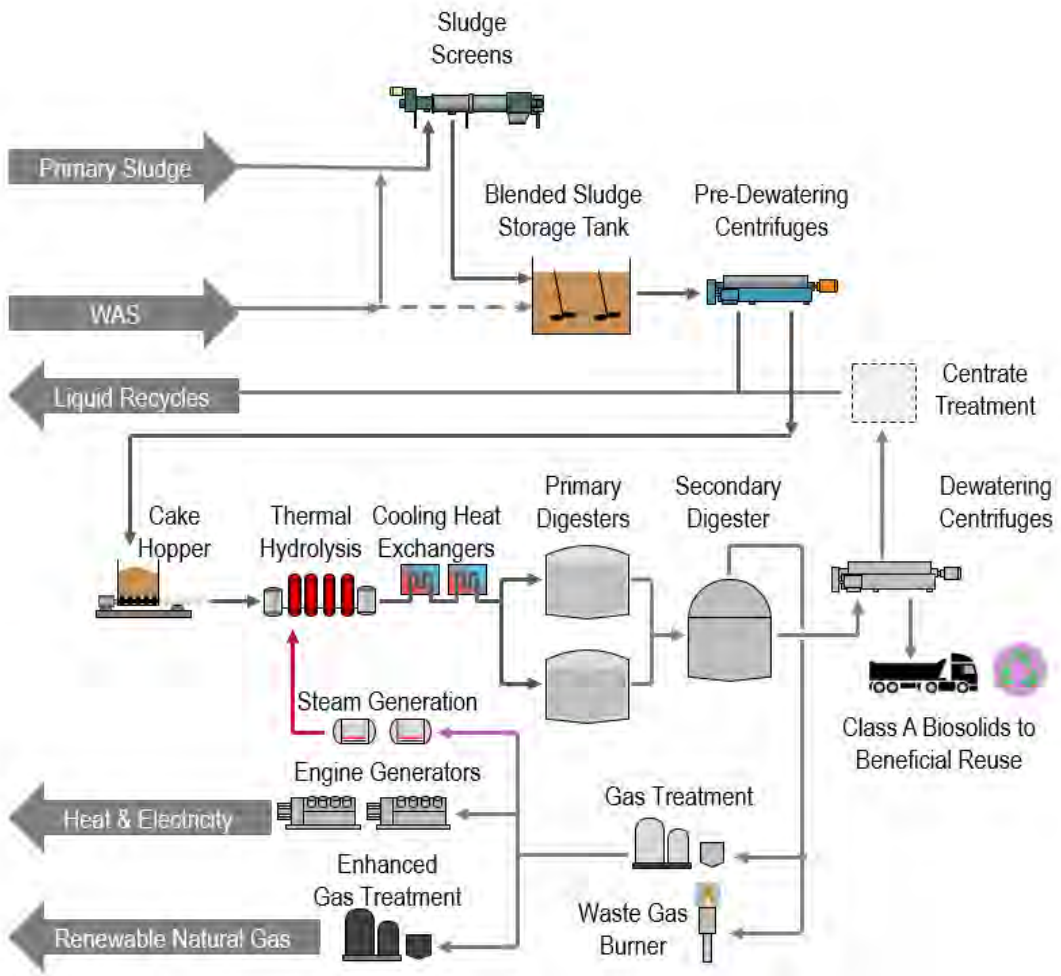


Figure 5. Conventional THP Process Flow Diagram

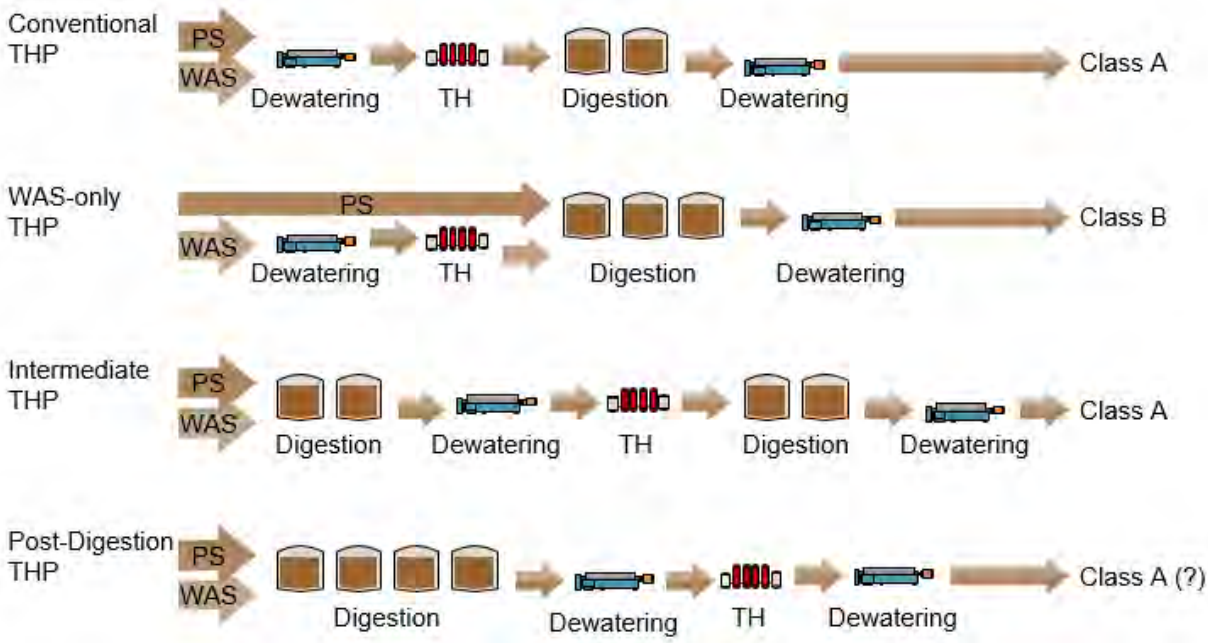


Figure 6. Alternate THP Configurations

Table 5. Alternate Thermal Hydrolysis Configurations Benefits and Challenges

Configuration	Number of Installations	Benefits	Challenges
Conventional THP[a]	63+	• Reduced digester volume (~50%) • Higher cake solids (up to 10% increase) • Class A EQ cake product • Increased VS reduction, biogas (+15%–30%)	• Screening and pre-dewatering • THS cooling • Instrumentation and controls • High-pressure steam
WAS-only THP[b]	5	• Reduced steam demand (~50%) • Smaller pre-dewatering and THP (~40%) • Cooling step may not be needed	• Not a Class A product • Reduced gas yield • Larger digester volume (~60% more than THP, but still ~20% less than anaerobic digestion)
Intermediate THP[b]	5	• Class A EQ cake product • High gas production • Smaller pre-dewatering (~60%) and cooling	• Largest digester volume • THS cooling and recycle • High steam demand
Post-digestion THP[b]	1	• Highest dewaterability • Reduced steam demand and smaller THP • Highest gas production • No cooling	• New technology (only 1 in operation) • Class A not approved • Larger digester volume

Notes:

a. Benefits and challenges for THP digestion are relative to conventional digestion.

b. Benefits and challenges for the alternate THP configurations are relative to conventional THP digestion.

3.0 Biosolids Products and End-Use Options

A key goal for the project is to have Class A biosolids for beneficial use. Class A products have varying end uses, depending on the quality, upstream processing, and market conditions. These factors will be discussed further in TM No. 5, Biosolids Product Market Analysis. For the purposes of comparing the technologies in this TM, Table 6 summarizes the biosolids product current end-use options for the evaluated technologies. THP and drying technologies have the most versatile end product, with the biochar product from pyrolysis and gasification still remaining in emerging markets for beneficial use.

Table 6. Potential Biosolids Product End Uses

Thermal Hydrolysis (Dewatered Cake)	Solids Drying (Granules/Pellets)	Pyrolysis (Biochar)	Gasification (Biochar)
Landfill/ADC	Landfill/ADC	Landfill/ADC	Landfill/ADC
Bulk agriculture	Bulk agriculture	Bulk agriculture	Bulk agriculture
Bulk horticulture	Bulk horticulture	Bulk horticulture	Bulk horticulture
Land reclamation	Land reclamation	Land reclamation	Land reclamation
Fertilizer blending	Fertilizer blending	Fertilizer blending	Fertilizer blending
Soil blending	Soil blending	Soil blending	Soil blending
Energy	Energy	Energy	Energy
Concrete filler	Concrete filler	Concrete filler	Concrete filler

Notes: Alternative daily cover (ADC) is material other than earth used to cover the surface of a landfill at the end of the day.

Legend: COMMON END USE | NEWER MARKET | NO MARKET

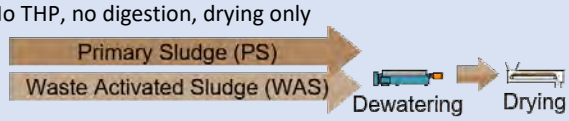
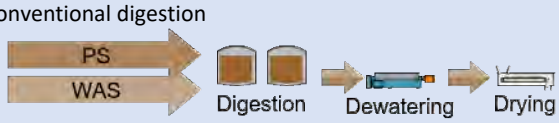
3.1 Thermal Hydrolysis and Drying

The end product from THP is a high-quality Class A cake, when implemented in the conventional arrangement. As shown above, the primary beneficial end use for the Class A dewatered cake is bulk agricultural land application. To retain additional end-use flexibility beyond bulk land application, recent research has been completed on combining THP with drying to produce an even more versatile end product.

The main benefit of implementing THP upstream of drying is a reduction in the energy required for the latter process by up to 40 to 50 percent when compared to conventional anaerobic digestion. Most of the reduction in dryer energy demand is due to the higher solids concentration of the dewatered THS, while the remainder is associated with the improved VS reduction achieved through digesting THS. As a result, implementation of THP can significantly reduce the size of a drying facility. Additionally, the lower evaporation demand of the drier THS cake can increase the efficiency of lower-temperature thermal drying technologies that recover waste heat from processes such as the THP and combined heat and power (CHP) without significantly increasing the footprint for required drying facilities.

Another benefit of implementing THP upstream of drying is the additional flexibility in the dryer design and configuration. If all the solids are processed through THP that already meet the requirements for Class A biosolids, the subsequent dryer process is not required to meet Class A requirements (minimum 80°C [176°F] and 90 percent dried solids). This allows the dryer to be sized and operated to achieve the dryness desired for product quality, based on the end user marketplace, which could be less than 90 percent solids, depending on the desired end use. This provides flexibility in equipment sizing and configuration and potential reductions in drying energy demands. In a conventional digestion-drying configuration, the heat demand for drying equals approximately 75 percent of the energy produced from anaerobic digestion, and therefore approximately 25 percent of the remaining biogas generated can be used for electricity or biomethane production. THP produces 15 to 30 percent more biogas than conventional digestion, and drying energy demand for THP cake is 40 to 50 percent lower than drying after conventional digestion. Therefore, if biogas is used as the primary fuel for the dryers, implementation of THP can result in up to three times more biogas available for other uses such as electricity or biomethane production when compared to conventional digestion followed by thermal drying. Table 7 provides energy and mass balance comparisons of various process configurations.

Table 7. Energy and Mass Balance Comparison of Thermal Hydrolysis and Drying Process Configurations

Process Configuration	Dryer Size & Energy Demand	End Product Hauled, Wet Tons	Biogas Available for electricity or biomethane production after drying and THP demands met	Dried Product Percentage Solids Requirement
No THP, no digestion, drying only 	100%	100%	0%	>90%
Conventional digestion 	70%	60%	100%	>90%
Conventional THP[a]	40%	55%	300%	N/A[b]
WAS-only THP[a]	45%	57%	240%	>90%

Notes:

a. Adapted from Barber, W., and Christy, P. (2018). *Combining thermal hydrolysis with drying and downstream thermal processes to optimize energy recovery from sewage sludge*. Residuals and Biosolids Conference (pp. 1188–1211). Phoenix: Water Environment Federation.

b. Conventional THP does not have a product dryness requirement because the cake is already Class A biosolids. However, 90% product solids was used to calculate the hauled wet tons values.

Dryer selection for THP with drying needs to consider the characteristics of the solids from THP. The high temperature and pressure of THP destroys the cell structure of the solids, leading to improved VS

destruction, and reduces extracellular polymeric substances (EPS), which can adversely impact dewaterability, resulting in a drier soil-like cake. While the qualities of this Class A cake are beneficial for land application, the different characteristics are less desirable in a dried product.

Of particular focus are energy content, friability, and bulk density of the biosolids as described below:

- **Energy content:** Energy content, or heat value, of biosolids is an important consideration for customers that use biosolids as a fuel substitute, such as cement kilns. Studies have reported that TH can reduce the energy content of biosolids by approximately 10 percent on a dry basis (British thermal units [Btu] per dry ton total suspended solids [TSS]) when compared to conventionally digested biosolids.
- **Friability:** Friability refers to the tendency of a granule to crumble or break when undergoing stress. An end product with high friability is undesirable for most end users, as it can create dust when handled, which can degrade product quality and/or create health and safety risks.
- **Bulk density:** Bulk density is an important criterion for most end users, and the preferable range varies on the end user. Farmers and fertilizer blenders generally prefer a product with high bulk density as it is easier for spreading, while other end users such as soil blenders and cement kilns prefer lower bulk densities.

To confirm the applicability of THP with drying research has been completed on other worldwide installations that have combined THP and thermal drying. The outcome of this work can be found in a 2019 paper, titled *Worthless Dust or Valuable Resource? Drying Thermally Hydrolyzed Solids the Right Way* (S. Spalding and S. Smoot, WEFTEC Conference Proceedings). In summary, it was found that most facilities that hydrolyze all the solids (PS and WAS) use belt dryers, and most drum dryer facilities have a portion of the solids bypass the THP. While there were some anecdotal reports of increased dust and fragility of the dried THS, compared to conventionally digested solids, these risks appeared to be dependent, at least in part, on the process configuration and dryer technology. The research showed that these risks can be minimized by operating THP as a WAS-only configuration, implementing drying technologies that deliver low amounts of mechanical energy (e.g., belt dryers as opposed to drum dryers), or both. There is a greater possibility of degradation because of the shearing of the materials with rotary-drum dryers, when compared to belt dryers.

It has historically been uncommon to couple drying and THP. However, this combination of technologies can open up new end markets that are less affected by seasonal demand (such as soil blenders and cement kilns), thereby increasing end-use reliability. Addition of THP and the resulting improvement in VS reduction, higher biogas production, and enhanced solids dewaterability all can reduce both the capital and operating costs of a dryer. Additionally, if all solids are treated through THP, it is no longer required to achieve 90 percent solids dryness to meet the requirements for Class A biosolids, further reducing dryer size and energy use by 20 to 40 percent, depending on the target end product dryness. Dried products also cost less to transport as compared to dewatered products, further increasing the geographic reach of the County's biosolids program. Further evaluation of the biosolids marketplace would be required to define the design criteria for a dryer to confirm the design dryness and therefore the required equipment.

Overall, the bulk density of dried TH solids is lower than that of conventionally digested solids. The bulk density of dried TH solids varies based on the wastewater characteristics, treatment processes, TH

configuration, digester performance, and dryer technology. Results from laboratory testing of the dried TH solids samples are not yet available as this work remains underway. As such, quantifiable differences in bulk density between drying technologies and TH configurations have not been identified at this time. The desired bulk density of the end product and any concerns with the lower bulk density of dried THS would need to be assessed via the evaluation of the biosolids marketplace, including conducting a market survey to determine what characteristics are preferred by potential end users, and then designing and operating the biosolids treatment processes to meet the market's preferences.

It has also been found that TH, and the resulting reduction in VS due to the increased digestibility, does impact the energy content of the final product. The potential reduced energy content for TH-processed biosolids could make dried THS less attracted for use as a supplemental fuel, such as in cement kilns. However, it is likely that chemical addition, such as ferric, is more detrimental to the energy content of the solids than the enhanced VS reduction of TH digestion due to the increased inert solids fraction generated. Pilot or lab testing would quantify the impact of TH on the digested biosolids heating value, and would determine if the dried THS would still be acceptable for this end use.

4.0 Summary and Conclusions

This section presents a summary and conclusions from the thickening evaluation.

4.1 Technology Alternatives

Table 8 summarizes the results of the technology evaluation, including the technologies' maturity in the industry's market.

Table 8. Biosolids Technology Comparison

Parameter	THP	Rotary-Drum Solids Drying	Belt Solids Drying	Pyrolysis	Gasification
Number of installations	100+	200	75	40	3
Years in operation	25	50	20	5	--
Similar plant size installations?	Yes	Yes	Yes	No	No
Energy consumption	$$$	$$$$$	$$$$	$	$
Technological maturity?	Yes	Yes	Yes	No	No

THP and drying are mature and well-established technologies with several dozen online systems, and overall operation history of more than 20 years. Pyrolysis and gasification are considered emerging technologies for municipal biosolids applications. Energy consumption is highest with drying technologies, whereas pyrolysis and gasification are near net-zero energy consumption processes. Similar-sized installations to the WPCP exist for THP and drying technologies, but not for pyrolysis and gasification.

4.2 Conclusions and Recommendations

Based on the analysis presented in this TM, it is recommended that the solids handling improvements replace the existing lime stabilization process with THP and anaerobic digestion, as recommended in the Master Plan for the WPCP.

Anaerobic digestion is an appropriate process for the WPCP's size. Digestion reduces solids output from the WPCP, generates biogas that can be reused, and provides a Class B product should further treatment processes be offline. THP increases digestibility and reduces the size of new digesters required, while creating a versatile, high-quality Class A product.

It is also recommended that the WPCP plan for future upgrades to increase the versatility of beneficial uses of the final end product, to provide greater flexibility and responsiveness to potential future changes in land application regulations and limitations. As a dried product currently has the widest versatility and lower hauling costs than cake, it is recommended that the site plan developed for the Facilities Plan incorporate footprint for future post-processing of the Class A cake product through a belt dryer, if feasible.

It has been shown that belt drying is preferred downstream of THP because of the characteristics of THS. Additionally, the energy required for belt drying can be reduced by using recovered heat from other thermal processes. The footprint for the belt dryer facility will be sized for drying the THS Class A cake,

reduced in size to account for the improved VS destruction from THP and the higher solids concentration in the THS cake. However, the footprint will be allocated for a dryer facility to dry the THS to 90 percent TS, as the marketplace demands are not yet known that would have preference for a less-dry product. Additionally, should the pyrolysis or gasification technologies mature to the point where they are considered by the County as potential future add-on processes or as a response to future regulatory drivers, drying is the first step for both. Allocating space on the site now for a future dryer facility can provide many future benefits and the flexibility for the County to continue to evolve and meet changing regulations and market for the beneficial use of high-quality Class A biosolids end products.

Future changes in regulations could result in the need for additional evaluations of appropriate technologies for additional biosolids processing and additional beneficial end uses of the final product. Implementation of the THP and anaerobic digestion and site plan allocation for future post-processing should position the WPCP to be able to respond effectively to future uncertainties.

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Technical Memorandum No. 4

Date:	December 2, 2021
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Thermal Hydrolysis Process Evaluation

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1.0 Introduction

The purpose of the Arlington County Water Pollution Control Plant (WPCP) Re-Gen project (Project) is well captured in the internal team Project Mission Statement:

> *Upgrade resource recovery facilities to produce Class A biosolids and renewable energy, maximizing sustainability and community acceptance. Collaborate with team members to select and implement processes that are safe, reliable, and financially responsible throughout planning, design, construction, operations and maintenance.*

The following goals and objectives have been established to guide the Project team to fulfill the mission:

- Recover biogas for beneficial use
- Produce a Class A exceptional quality (EQ) end product
- Provide ease of maintenance and repairs
- Keep safety in mind
- Apply proper process selection and configuration
- Use an open, transparent, and collaborative process between all team members
- Promote community acceptance
- Provide a cost-effective program
- Provide an operator-friendly facility
- Promote long-term reliability
- Implement active staff engagement throughout the process
- Ensure that staff are well prepared to operate and maintain the new processes

Thermal hydrolysis (TH) has been selected as the process best able to achieve the above goals and objectives. It produces a Class A EQ biosolids product while minimizing the total quantity of final product produced and maximizing energy recovery from the solids in the form of biogas generated in the anaerobic digesters.

2.0 Background and Purpose

The purpose of this technical memorandum (TM) is to provide an introduction to the thermal hydrolysis process (THP) and compare the process configurations that have been developed by vendors that have frequently competed for municipal biosolids projects in the United States as well as one new to the market.

All TH technologies use steam and pressure to hydrolyze solids. However, these systems vary widely in their process configurations, equipment arrangement, and operational strategies. Additionally, the solids handling facility interfaces upstream and downstream of the THP are different with each technology. Therefore, it is recommended to select the specific THP configuration before proceeding into detailed design.

THP systems manufactured by one manufacturer are currently in use in biosolids projects in the United States. This manufacturer also has the largest number of THP installations worldwide. The second most prominent manufacturer does not have any installations in the U.S but is actively seeking to gain entry to the U.S market. One emerging system has been developed that shows future promise for the U.S.

market. These systems will be evaluated to determine the configuration that is most aligned with the goals, objectives, and requirements of the Project. This TM compares the following THP technologies:

- Cambi™
- Bio Thelys™ by Veolia
- Haarslev Continuous Hydrolysis System (CHS)

Other THP vendor configurations exist overseas, but they have not been proposed for biosolids projects in the United States and have few installations compared to Cambi, Veolia, and Haarslev.

The scope of this evaluation is limited to TH technologies, where steam is used to achieve the temperature and pressure process requirements for cellular hydrolysis. Other methods of cell hydrolysis such as thermo-chemical hydrolysis (example: PONDUS™) and biological hydrolysis (example: Monsal Enzymic Hydrolysis) were analyzed as part of the Solids Master Plan Report in 2018 and determined not to meet the Project goals. Veolia also has a continuous-flow THP process, Exelys™; however, this technology is not being marketed in the United States and is not under consideration for this evaluation.

3.0 Overview of Thermal Hydrolysis

At the Arlington County WPCP, TH will treat primary sludge (PS) and waste activated sludge (WAS) with high pressure and temperature to hydrolyze, or break apart, the solids' cellular structure. TH occurs in two steps: screened and pre-dewatered solids are heated to 150 to 170 degrees Celsius via steam pressure, which is followed by a depressurization step, which assists in cell wall breakage. THP, when in a batch configuration, meets the time and temperature requirements as a process to further reduce pathogens (PFRP), as defined by the U.S. Environmental Protection Agency (EPA). The resulting thermally hydrolyzed solids (THS) are sterile (pathogen-free) and highly digestible by microbes in anaerobic digesters. Additionally, the viscosity of THS is substantially lower than that of non-hydrolyzed solids, so that a higher solids concentration can be efficiently conveyed into and mixed within the digesters.

The ability to load the digesters at a higher rate with more readily digestible solids achieves the goals of solids stabilization in less time with significantly reduced digester volume. The greater digestion and volatile solids destruction increases biogas production and reduces the total digested solids produced by the system. Solids processed through TH dewater more readily, typically resulting in a final dewatered cake being drier by 5 to 10 percentage points compared to conventional anaerobic digestions. The final product is a drier, high-quality, Class A biosolids, with minimal to no offensive odors. By maximizing solids destruction and dewatering, the final wet solids quantity is reduced by two-thirds, substantially reducing costs for beneficial land application and other end uses. The technology is well established abroad, with more than 60 installations internationally since 1995.

3.1 North American Thermal Hydrolysis Installations

The first THP installation in the United States was DC Water's Blue Plains Advanced Wastewater Treatment Plant (WWTP), which was started up and commissioned in 2014 and 2015. Currently, there are four operating THP installations in the United States, with five more in construction. Current and planned THP installations in North America are listed in Table 1.

Table 1. North American THP Project Status

Agency		Project Status	THP System
DC Water, Washington, D.C.	Blue Plains Advanced WWTP	Startup in 2014	4 × Cambi B12 Mark I
Pontiac, Michigan	Clinton River WRRF	Started up in 2018	Cambi B2 Mark II
Medina, Ohio	Holtz WWTP	Started up in 2018	Cambi B2 Mark II
HRSD, Virginia	Atlantic WWTP	Started up in 2020	Cambi B6 Mark II
Trinity River Authority (Dallas, Texas)	Central Regional Wastewater System	In construction; startup in 2021	3 × Cambi B6 Mark II
City of Raleigh, North Carolina	Neuse River RRF Bioenergy Recovery Project	In construction; startup in 2022	Cambi B6 Mark II
WSSC, Maryland	Piscataway WRRF Bioenergy Facility	In construction; startup in 2023	Cambi B6 Mark II 2P/2F
City of Franklin, Tennessee	Franklin WRF	In construction; startup in 2022	Cambi B2 Mark II
San Francisco PUC, California	Southeast WWTP Biosolids Digester Facility	Construction just starting	3 × Cambi B6 Mark II
Kansas City, Missouri	Blue River Biosolids Facility	In design	Cambi B6 Mark II 2P/2F
Charlotte Water, North Carolina	McAlpine Creek Wastewater Management Facility	Preliminary design	2 × Cambi B6 Mark II
City of Calgary, Alberta, Canada	Bonnybrook WWTP	Project currently on hold	2 × Cambi B6 Mark II
Winnipeg, Manitoba, Canada	North End STP	Project currently on hold	3 × Cambi B6 Mark II

To date, all installed and planned THP installations in North America have been supplied by Cambi.

4.0 Thermal Hydrolysis Configurations

This section summarizes TH configurations, including Cambi, Veolia Bio Thelys, and Haarslev CHS.

4.1 Cambi™

The Cambi THP system is a continuous batch process consisting of a pulper tank, reactor vessels, and a flash tank. Screened and pre-dewatered solids are fed to the pulper, which preheats the solids while serving as a buffer tank for the reactor batch cycles. Solids are pumped from the pulper to the reactor, which is then filled with steam to reach the temperature and pressure set point. At the end of the retention time, the pressure is released, rapidly conveying the treated solids to the flash tank where the depressurization completes the cell lysing. Steam is recycled from the flash tank to the pulper to serve as the preheating heat source for the next batch. The solids are pumped from the flash tank and blended with digested solids prior to cooling to mesophilic temperatures in heat exchangers (HEXs) before being fed to the digesters.

A conceptual process flow diagram for Cambi THP is presented in Figure 1.

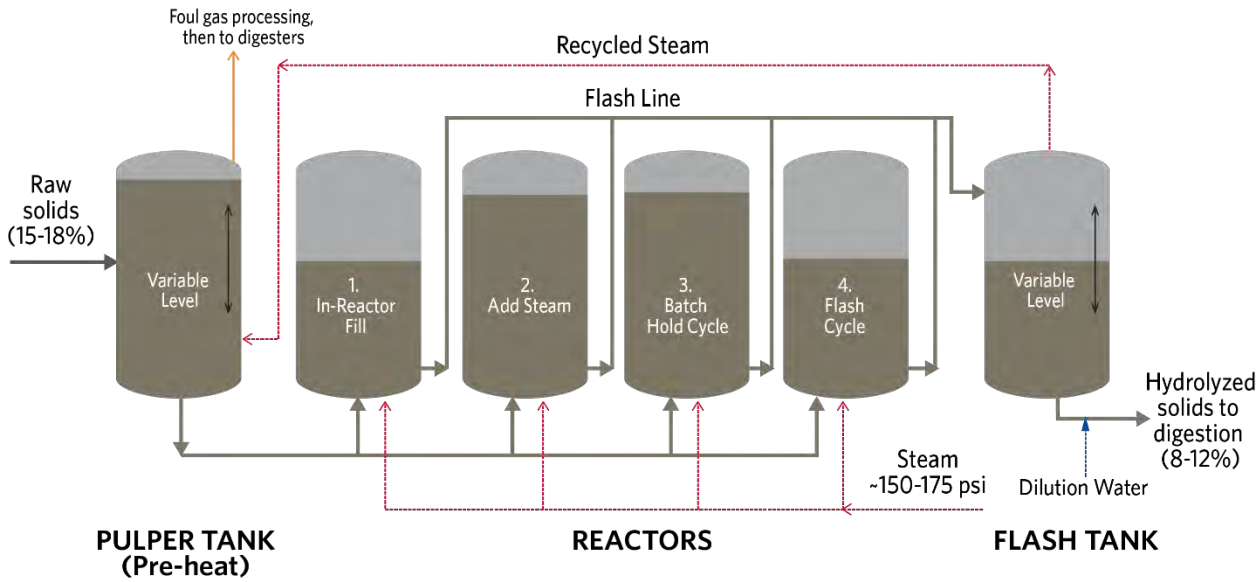

Figure 1. Cambi THP Process Flow Diagram

The Cambi THP has undergone several refinements and evolutions since its first installation in 1995. The most recent was the transition from the Mark I operating system to the new Mark II operating system. This modification was coupled with the transition from 12-cubic-meter reactors (B12) to smaller 6-cubic-meter reactors (B6), and included additional mechanical modifications in the flash tank, removal of the radiation level sensors in the reactor, and simplification of the steam recycle to the pulper, as well as improvements to the foul gas system, as discussed further below. These changes supported process modifications to reduce the duration of the depressurization step by completely and immediately releasing the reactor contents to the flash tank, and immediately sending the steam to the pulper, resulting in a higher throughput of the Cambi THP with reduced steam demand. The complete recycling of steam to the pulper has resulted in a more energy-efficient system. The improvements have also maximized the usage of the reactor volume. The new Mark II generation of Cambi is a standard skid-based system shop fabricated in multiple modules to be assembled on site and has half the footprint of the site-built Mark I systems yet has 80 percent of the solids throughput.

Cambi uses a patented system for the management of the foul gases generated in the THP. Foul gases are sent from the reactors to the flash tank along with the steam, from which they are conveyed to the pulper along with the steam recycle. The foul gases are then cooled using a gas cooler (HEX) before being condensed into the foul-gas tank using an eductor and pathogen-free water. The foul-gas condensate is then sent to the digester feed lines or directly to the digesters, where it is treated within the digestion biological process. The foul-gas system has also evolved in recent years to simplify the system and reduce the risk of odor release and is more effective than the odor control of other THP systems.

Cambi has 63 installations worldwide, with a total installed capacity of 5,600 dry tons per day (dtpd). Of these, 33 are the older Mark I operating system and 30 are the Mark II system, which has a throughput capacity of 92 dtpd. The first Mark II version was placed into service in 2014. There are currently 45 installations with a capacity of 50 dtpd or greater, which are similar in size or larger than the THP proposed for installation at the WPCP.

4.2 Veolia Bio Thelys™

The Bio Thelys process has recently undergone significant modifications from the original version to the new updated process. These process updates are typical of technologies with additional experience. This new Bio Thelys process is being considered in this evaluation. As there is only one Bio Thelys online and operating with the new configuration, an overview of the original version, including operational experience, is provided in this section.

The original Bio Thelys system is a batch system consisting of paired reactors and a buffer tank. Pre-dewatered solids are pumped to a reactor, which retains some hot THS to reduce the "thermal shock" by injecting steam directly into cold solids. Flash steam from the depressurization of the reactor's paired tank increases the temperature in the reactors and further preheats the solids. The reactor is then brought up to pressure using steam injected directly into the reactor through lances and held at the target temperature and pressure. The reactor is then partially depressurized, with flash steam going back to the reactor's paired tank, and the solids sent to the horizontally configured buffer tank using the remaining steam pressure in the reactor. The solids are pumped from the buffer tank and diluted with pathogen-free water prior to cooling to mesophilic temperatures in HEXs before being fed to the digesters. Because of the steam that is carried through to the buffer tank, there is a loss of energy and a higher steam demand. Additionally, the hotter solids result in a larger cooling demand (large HEX and more cooling water) for the original Bio Thelys THS relative to the Cambi Mark II system.

As a result of performance issues experienced at older installations, such as clogging steam lances, reduced throughput with higher steam demand, and foul gas excursions, Veolia has worked to improve and optimize the Bio Thelys process. The company has implemented several modifications in current and future Bio Thelys installations to improve capacity, steam delivery and economy, and operational reliability. The largest change is the transition to a process flow very similar to Cambi, as shown on Figure 2. Screened and pre-dewatered solids are fed to the preheat tank through a dynamic mixer, which preheats the solids while serving as an equalization tank for the reactor batch cycles. Solids are pumped from the preheat tank through another dynamic mixer that combines live steam with the preheated solids and to the reactor to reach a pressure set point. At the end of the retention time, the pressure is released, rapidly conveying the treated solids to the buffer tank where the depressurization completes the cell lysing. Steam is recycled from the buffer tank to the preheating dynamic mixer to serve as the preheating heat source. The solids are pumped from the buffer tank, diluted using pathogen-free water, and cooled to mesophilic temperatures in HEXs before being fed to the digesters. The new version of the Bio Thelys has eliminated the use of steam lances for a dynamic mixer, which has improved the contact between the steam and pre-dewatered solids, allowing a higher pre-dewatered cake concentration (as high as 22 percent), relative to other installed batch processes. This also has eliminated previous issues with clogged steam lances. The steam demand for the updated Bio Thelys is therefore lower than that required for Cambi, attributed primarily to the higher pre-dewatered cake concentration to the system through the dynamic mixer, as well as improved recovery of the flash steam from the buffer tank.

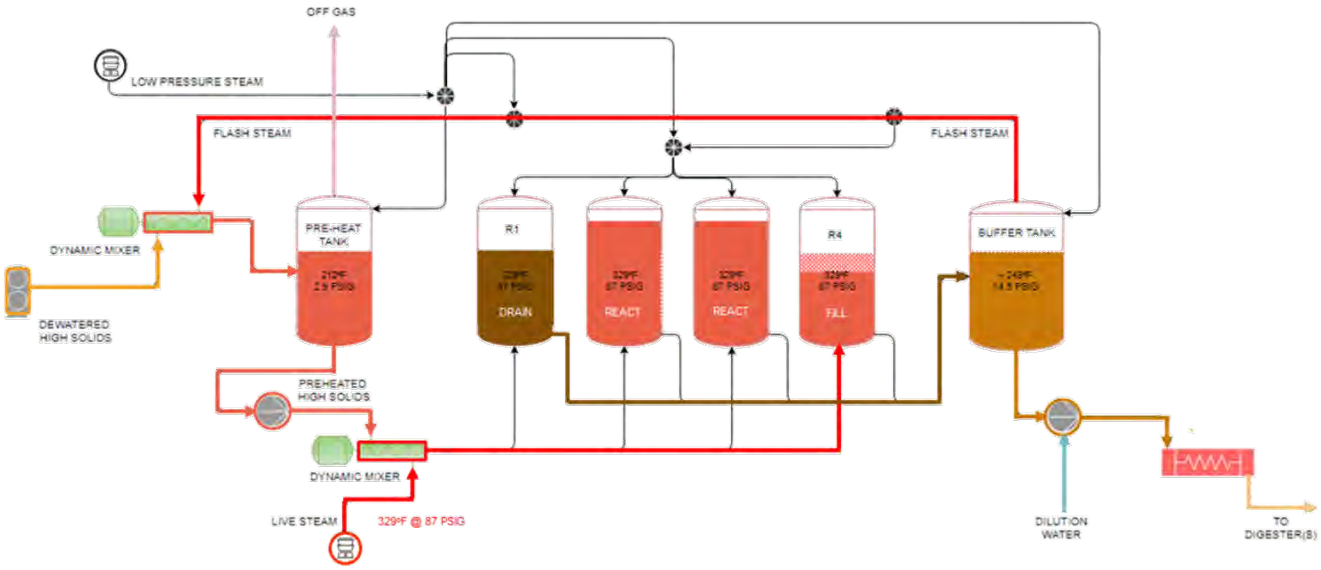

Figure 2. Updated Bio Thelys THP Process Flow Diagram

The foul gases generated in the Bio Thelys THP are cooled to remove condensables from the gas. The remaining gas has been treated in a variety of different methods over time, but is often sent to the digesters. Based on the review of site visit reports and discussions with the plant owners of installations of the older version of Bio Thelys, there were multiple instances of odorous excursions with this system. The new version of Bio Thelys has a similar odor control approach, but it is expected that the incidences of odorous excursions are reduced with the new process flow and larger buffer tanks downstream of the reactors, as well as the steam/gas recycle to the preheat tank.

Veolia has seven operating original Bio Thelys installations worldwide, with a total installed capacity of 89,000 dry tons per year. The two largest installations, in Oxford and Esholt, United Kingdom (UK), with a combined installed capacity of 64,000 dry tons per year, had multiple operational challenges during startup and were not accepted by the client for several years following installation. These systems had multiple issues, including clogged steam lances in the reactors, which were ultimately replaced and multiple foul-gas excursions. These two installations have now been accepted by the owner and are in operation, are the two longest-operating Bio Thelys installations similar in size to the THP proposed for installation at the WPCP.

The first installation of the new version of Bio Thelys is a 56 dtpd facility in Toulouse, France. Because of travel restrictions, the project team has not been able to visit the facility. However, according to Veolia, the facility which started up in 2019 has been operating reliably. Additionally, three other projects with the new Bio Thelys configuration are currently in design and construction in Europe.

4.3 Haarslev CHS

Haarslev CHS is a continuous-flow process, in contrast to the Cambi and Bio Thelys batch processes. Haarslev is newer to the municipal biosolids processing market, but has been well-known in the industrial solids market for more than 30 years, hydrolyzing by-products of factory meat processing operations (feathers and hair). The first installation of CHS on municipal biosolids was started up in 2014 in Grevesmühlen, Germany.

Similar to the newer version of Veolia's Bio Thelys, Haarslev CHS uses a dynamic mixer in the preheater to mix pre-dewatered solids (as high as 22 percent) with steam. The preheated solids are pumped to a small pressurization tank that heats and pressurizes the solids in 90-second batches before being sent to the reactor. The reactor's temperature and pressure are maintained with steam injection while the solids flow in a plug flow to the economizer (similar to the Cambi flash tank) in a continuous process with a minimum 30-minute duration in the reactor. As the solids leave the reactor and go to the economizer, the differential pressure between these two vessels effectively lyses the cells. The cooler is the final step, which operates at a vacuum to cool the temperature of the solids to mesophilic temperatures without requiring a HEX. A conceptual process flow diagram for the Haarslev CHS is shown on Figure 3.

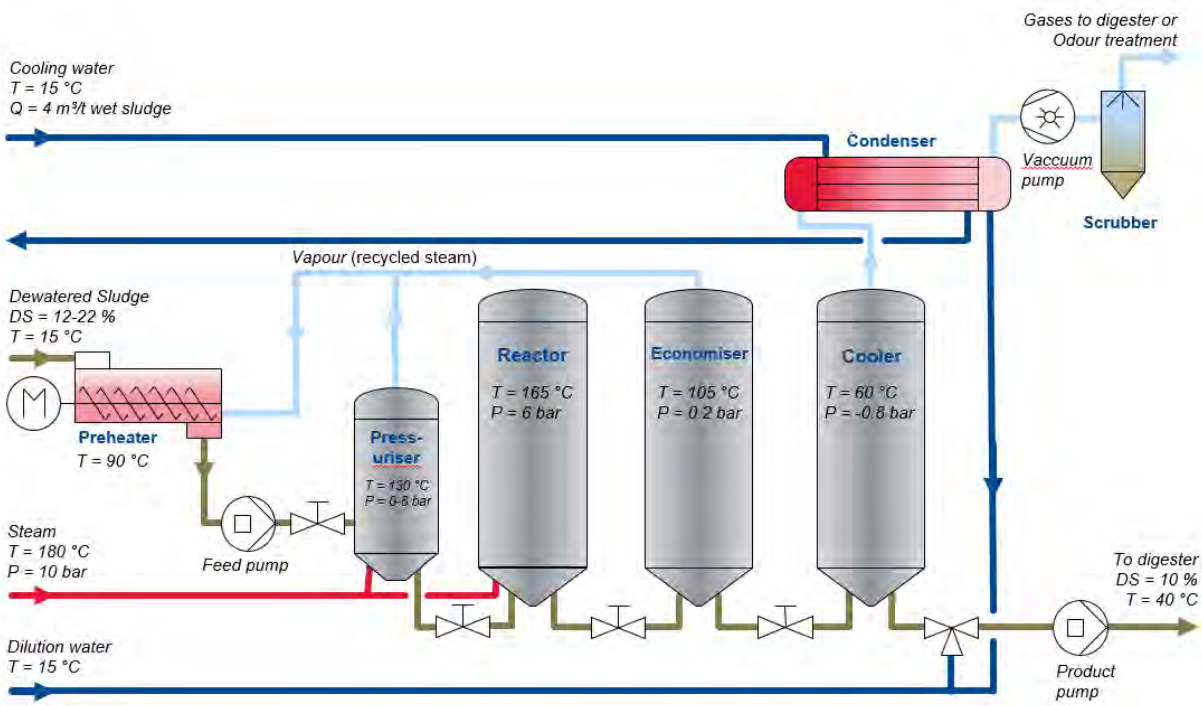

Figure 3. Haarslev CHS Process Flow Diagram

The steam demand for the CHS is lower than that required for Cambi, attributed primarily to the higher pre-dewatered cake concentration to the system through the dynamic mixer.

The continuous-flow configuration of this process does not explicitly meet the Class A time and temperature requirements because short-circuiting of the flow through such systems can occur. To achieve Class A, time and effort would be required to demonstrate and prove a plug flow performance, and pathogen reduction prior to submitting to the Virginia Department of Environmental Quality (VDEQ) for equivalency approval.

Haarslev has four CHS installations worldwide, all in Europe, operating on municipal biosolids with a total installed capacity of 52 dtpd, with the largest single installation at a 24 dtpd capacity in Braunschweig, Germany, or approximately half of the capacity of the THP proposed for installation at the WPCP. Another 24 dtpd installation, currently in construction in Dijon, France, is scheduled to be online by the end of 2021.

5.0 Basis of Evaluation

A list of criteria and requirements has been established as evaluation parameters for comparing the THP vendors and configurations. The criteria include:

- **Proven experience at facilities of comparable size:** The selected THP vendor/ configuration must be able to show significant successful experience with THP systems of comparable size to the Project.
- **Proven reliability:** Arlington is not in a position to help develop or demonstrate an untried or unproven THP configuration. Arlington will select a well-established and highly reliable THP system that has proved these qualities at multiple sites with similar or larger scale.
- **Maximize overall energy efficiency:** A key Project goal is to maximize the biogas for beneficial use and maximize overall energy efficiency. Therefore, the THP system should be able to prove this concept and approach.
- **Process details:** Arlington needs to be assured that the myriad process and technical details are sound and have worked well on previous facilities. Odor control is of particular concern because of close proximity to neighbors at the WPCP.
- **Proven ability to produce Class A biosolids:** The ability to provide Class A biosolids is mandatory. Arlington is not in the position to conduct further research and development to validate Class A compliance or to test out new process features.

6.0 Evaluation

A comparison of the THP technologies per the evaluation criteria identified above is provided in Table 2, and discussed further below.

6.1 Proven Experience at Facilities of Comparable Size

The installation progression of total worldwide TH installed capacities for the evaluated technologies is shown on Figure 4. Based on the installation information provided by the manufacturers included in Table 2, Cambi currently has 63 installations in operation, compared to 7 Bio Thelys and 5 Haarslev installations.

The Mark I and Mark II Cambi generations are shown separately to highlight the shorter operating history of the Mark II system. Since 2014, 30 Mark II systems have been brought online and several more have been ordered by owners. There are currently 18 Mark II installations with capacity greater than 50 million gallons per day (mgd).

The original Veolia Bio Thelys THP has a 17-year operational history; however, the newer version of Veolia Bio Thelys has been in operation for nearly 2 years at one installation, and it is markedly different from the original Bio Thelys. The newer Bio Thelys installation is comparable in size to Arlington County.

The first full-scale installation on municipal wastewater biosolids of the Haarslev CHS continuous-flow THP configuration went into operation in July 2014. The Haarslev CHS does not have any have installations of comparable size to Arlington County.

Table 2. Hydrolysis Technology Installation and Experience Summary

Evaluation Criterion	Unit	Cambi		Veolia		Haarslev
		Mark I	Mark II	Bio Thelys® (old version)	Bio Thelys® (new version)	CHS
Installation and operation experience						
Number of installations	No.	33	30	6	1	5
First installation	Year	1995	2014	2004	1999	2014
Longest operating installation	No. of years	26	7	12	2	7
Total installed capacity	dtpd	4,000	1,600	244	56	53
Largest installation	dtpd	405	242	99	56	26
Number of installations with capacity greater than 50 dtpd	No.	24	18	2	1	0

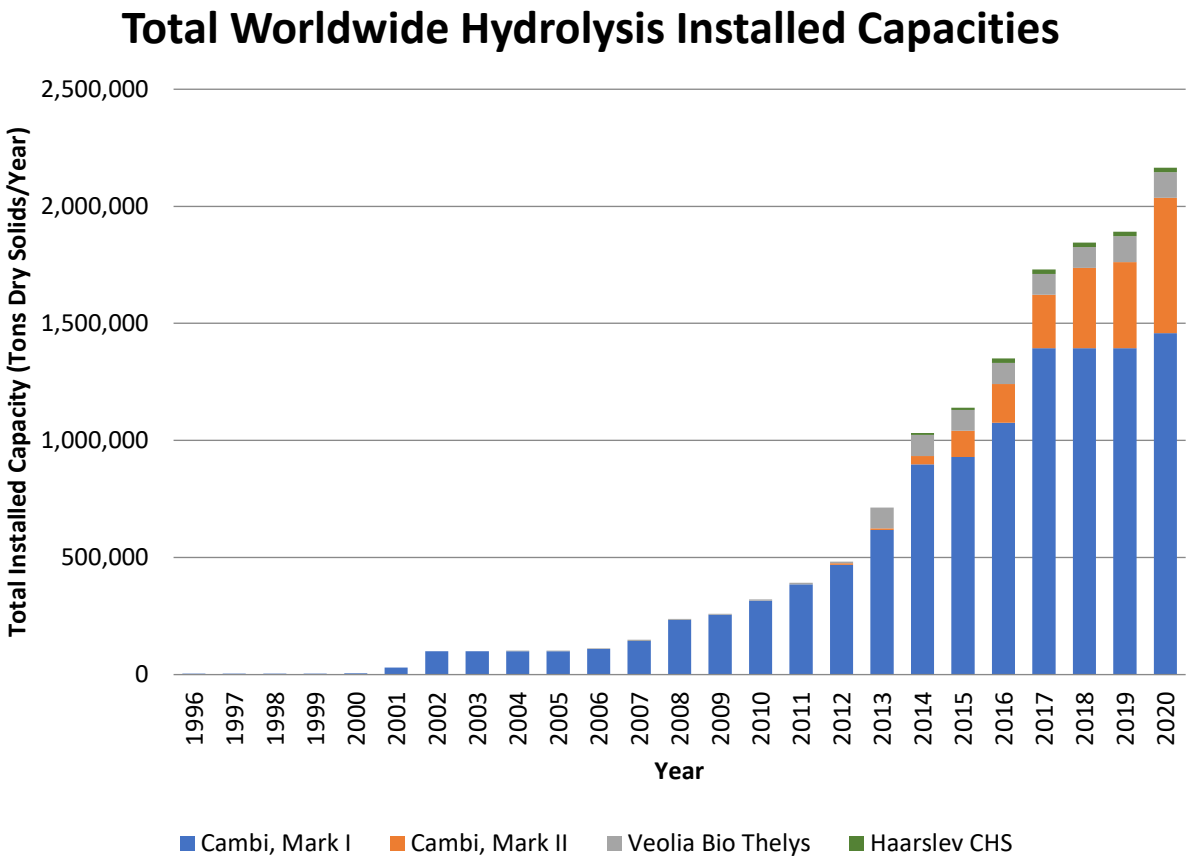

Figure 4. Total Worldwide Thermal Hydrolysis Installed Capacities

6.2 Proven Reliability

Over Cambi's more than 25 years of operational experience, multiple mechanical modifications have been made to the THP to optimize operations and improve reliability and throughput capacity. The Mark II configuration is considered the third generation of the Cambi THP, following multiple installations with lessons learned.

Bio Thelys has a shorter operational experience and had substantial challenges during the startup of its two largest facilities in the United Kingdom. Issues at these facilities included clogging of the steam lances, odor excursions of the foul gas, and high steam demand. Veolia is troubleshooting these systems and has implemented modifications that, in the newer version of Bio Thelys, should mitigate many areas of concern. However, this new configuration has been in service only since 2019 and there are process and equipment risks inherent to being one of the first installations with this new configuration.

From a process, equipment, and operations standpoint, the Haarslev CHS continuous-flow THP is substantially different from the batch-configured processes and there is an anticipated period that will be necessary for Haarslev to refine and optimize this new approach to THP on municipal wastewater biosolids. Haarslev has been operating primarily in the industrial market for the last 30 years.

6.3 Process Details

This section reviews the process details of the THP technologies. Table 3 provides a comparison of some key details of the THP technologies.

Table 3. Hydrolysis Technology Process Comparison

Evaluation Criterion	Unit	Cambi	Veolia	Haarslev
		Mark II	**Bio Thelys®**	**CHS**
Process type: batch or continuous	--	Batch	Batch	Continuous
Pre-dewatered cake feed	Percentage dry solids	16%–18%	Up to 22%	Up to 22%
Steam consumption (average)	kg steam/DT DS	1,000	800	705
Steam/biosolids mixing	--	Lances in reactors	Dynamic mixing	Dynamic mixing
Cooling	--	HEXs	Dilution water and HEXs	Depressurization and dilution water (no HEXs)
Class A final product when fed PS and WAS	--	Yes	Yes	Undetermined

The overall cooling demand of the Cambi Mark II is less than what is required for the Cambi Mark I. The Mark II flashing and improved steam recycle to the pulper and resultant heat recovery results in a lower temperature for the THS leaving the THP with the Mark II system relative to the Mark I system. Steam is injected directly into the reactors using lances for the Cambi Mark II. We are unaware of any recent instances of the Cambi steam lances plugging. The steam lances limit Cambi's pre-dewatered cake to between 16 and 18 percent solids.

The current version of the Bio Thelys and Haarslev CHS use a dynamic mixer to combine the steam, eliminating the need for lances. This allows for a higher pre-dewatered cake (up to 22 percent solids), while the lances limit Cambi's pre-dewatered cake to between 16 and 18 percent solids.

In both the current version of the Bio Thelys and Haarslev CHS, more pathogen-free water is added to the higher-concentration pre-dewatered cake following hydrolysis to achieve the desired digester concentration of 9 to 10 percent. This additional dilution water reduces the temperature of the THS, and thereby the cooling demands. Additionally, this dilution eliminates the need to combine the THS with digested solids prior to the cooling HEXs, as is required with the Cambi THP. Therefore, the cooling HEX equipment size for Veolia's Bio Thelys is significantly smaller than that required by Cambi. The cooler employed by Haarslev uses a vacuum condition in the cooler to reduce the temperature of the THS to mesophilic temperatures, and no downstream cooling HEX is required.

Effective and reliable foul-gas management is critical because of the high intensity and persistence of the odors in the foul-gas stream. Based on the review of the information provided by the manufacturers, as well as firsthand reports from site visits and owner discussions at both Cambi and Bio Thelys installations, Cambi's patented foul-gas handling arrangement has distinct advantages. The Cambi system is a simpler configuration and it has been consistently reliable in preventing the incidence of fugitive odors. The Cambi Mark II version regularly operates without odor release, providing no odor impact even at close range with the THP facilities. Additional operational experience is required to determine the effectiveness of the foul-gas management approach for both the newer Bio Thelys and Haarslev CHS THP systems.

6.4 Maximize Overall Energy Efficiency: Steam Demand

The relative efficiency of the three THP systems was evaluated based on the steam demand of the systems. Cambi has optimized steam demand in the Mark II configuration. Both the current version of the Bio Thelys and Haarslev CHS employ the use of a dynamic mixer to combine the pre-dewatered solids and steam, which results in a better steam economy than Cambi.

6.5 Proven Ability to Produce Class A Biosolids

The Cambi and Bio Thelys batch systems both meet time and temperature requirements for producing Class A biosolids. However, only the Cambi system has been approved by U.S. and state regulators to date.

The Haarslev CHS has a continuous-flow process, rather than batch configuration, and it is anticipated that the efforts to gain approval from VDEQ for Class A equivalency would require time and effort to demonstrate and prove a plug flow performance, and pathogen reduction prior to submitting to the Virginia Department of Environmental Quality (VDEQ) for equivalency approval, as discussed in Section 4.3.

7.0 Summary, Conclusion, and Recommendations

TH is a rapidly evolving technology with many paths being taken by different manufacturers. While all TH technologies use steam and pressure to hydrolyze solids, these systems vary widely in their process configurations, equipment arrangement, and operational strategies. Additionally, the solids handling facility interfaces upstream and downstream of the THP are different with each technology. Therefore, it is recommended to select the specific THP configuration before proceeding into detailed design.

The Haarslev CHS continuous-flow THP configuration has had a very small share of the market, with the first installation on municipal wastewater biosolids in operation since 2014. This process is substantially different from the batch-configured THP systems and there is an anticipated period that will be necessary to develop and prove the process for Class A performance and to confirm operational reliability. In addition, if employed at the Arlington WPCP, it would be the first Haarslev CHS system in the United States.

The Cambi and Bio Thelys batch systems both meet time and temperature requirements for producing Class A biosolids. However, only the Cambi system has obtained regulatory approval in the United States.

The Cambi THP has an advantage in proven and reliable capacity performance with multiple installations similar to the throughput and configuration required for the Arlington WPCP Re-Gen project. The current operating configuration of Cambi also has a proven approach and details for steam efficiency, heat recovery, and odor control. The current version of Bio Thelys has very limited experience, and the older version previously faced challenges with the startup of its largest installations.

The results of vendor selections and evaluations in North America are summarized in Table 4.

Table 4. North American THP Vendor Selections

Agency		Year	THP Selection Process Used	Vendor System Selected
DC Water, Washington, D.C.	Blue Plains Advanced WWTP	2009	Sole source	4 × Cambi B12 Mark I
HRSD, Virginia	Atlantic WWTP	2013	Sole source	Cambi B6 Mark II
City of Franklin, Tennessee	Franklin WRF	2015	Pre-selection competition	Cambi B2 Mark II
Trinity River Authority (Dallas, Texas)	Central Regional Wastewater System	2015	Pre-selection competition	3 × Cambi B6 Mark II
City of Calgary, Alberta, Canada	Bonnybrook WWTP	2016	Pre-selection competition	2 × Cambi B6 Mark II
San Francisco PUC, California	Southeast WWTP Biosolids Digester Facility	2016	Sole source	3 × Cambi B6 Mark II
City of Raleigh, North Carolina	Neuse River RRF Bioenergy Recovery Project	2016	Sole source	Cambi B6 Mark II
WSSC, Maryland	Piscataway WRRF Bioenergy Facility	2018	Sole source	Cambi B6 Mark II 2P/2F
Medina, Ohio	Holtz WWTP	2018	Sole source	Cambi B2 Mark II
Pontiac, Michigan	Clinton River WRRF	2017	Sole source	Cambi B2 Mark II
Winnipeg, Manitoba, Canada	North End STP	2017	Pre-selection competition	3 × Cambi B6 Mark II
Kansas City, Missouri	Blue River Biosolids Facility	2020	Sole source	Cambi B6 Mark II 2P/2F
Charlotte Water, North Carolina	McAlpine Creek Wastewater Management Facility	2021	Pre-selection competition	2 × Cambi B6 Mark II

Because of the differences in technologies and the desire to select the THP configuration before proceeding into detailed design, Arlington County Purchasing has recommended to proceed with a competitive negotiation process to pre-select the THP equipment manufacturer. The evaluation factors will include those provided in Section 6.0 of this memo. The exact mechanism for the competitive negotiation, including evaluation factor scoring and proposal requirements will be developed in conjunction with the WPCB and Arlington County Purchasing.

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Technical Memorandum No. 5

Date:	October 20, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Biosolids Product Market Analysis

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1.0 Background and Purpose

Regulatory and beneficial-use market assessments for various biosolids products, including Class B dewatered cake and Class A exceptional quality (EQ) dewatered cake, dried biosolids, compost, and blended soils, were performed for the 2018 Master Plan report (Master Plan). The purpose of Technical Memorandum (TM) No. 5 is to present updated regulatory and beneficial-use market assessments based on current and emerging regulatory trends and the recent introduction of additional Class A EQ biosolids products from the thermal hydrolysis anaerobic digestion (AD) process in the Mid-Atlantic region. TM No. 5 also presents a recommended outline for a distribution and marketing plan and specific activities to be performed over the next several years to inform that plan. The full distribution and marketing plan will be developed nearer to the time when Class A EQ biosolids will be generated at the Arlington County (County) Water Pollution Control Plant (WPCP).

1.1 Definitions and Description of Biosolids

Biosolids are a resource that is created when wastewater solids are treated to reduce pathogens in accordance with evidence-based regulations established by the U.S. Environmental Protection Agency (EPA). Biosolids generated from the treatment of municipal sewage sludge tend to be rich in nutrients, minerals, micronutrients, and organic matter, which increases crop yields. Additionally, biosolids provide numerous environmental benefits, including enhancing soil microbiology, improving soil structure, and enabling carbon sequestration.

The use of biosolids as a soil amendment also reduces the global environmental impacts of synthetic fertilizers, which include: the consumption of non-renewable resources such as phosphate rock, carbon emissions related to the manufacture of fertilizer using the energy-intensive Haber process, and watershed pollution (the nutrients in synthetic fertilizer are more mobile and water soluble than those in biosolids, increasing the risk of runoff).

Biosolids are considered safe for beneficial use when they have been treated using a process that reduces pathogens. EPA has established Code of Federal Regulations (CFR) Title 40 Part 503, which defines “Class A” and “Class B” standards, which are explained in more detail below.

Solids that have not been treated in accordance with either Class A or B criteria are referred to as “unstabilized solids” and cannot be beneficially reused for any purpose: unstabilized solids must be landfilled, incinerated, or treated on or off site using a Class A or Class B process.

Individual state and local governments can establish additional restrictions above those set by EPA regarding the transport, storage, and distribution of biosolids. State and local regulations can have a significant impact on the availability of biosolids end uses, for example, by capping the allowable amount of biosolids that can be land-applied on farms or prohibiting all land application of biosolids during winter months.

Class B refers to solids that have been treated using a process that significantly reduces pathogens. To protect the public from the risk that some pathogens may escape treatment in a Class B process, federal and state laws set limits on when, where, and how Class B biosolids may be used. These science-based regulations are intended to reduce or minimize exposure to the public and are based on criteria such as application methods, setbacks, access restrictions, and minimum duration between biosolids application and harvesting of crops. Because of these restrictions, Class B biosolids are typically limited to

agricultural purposes on farms that grow food not intended for human consumption. In the Mid-Atlantic, the most common Class B products include:

- Lime-stabilized cake
- Anaerobically digested biosolids

Class A refers to solids that have undergone a higher level of treatment to further reduce pathogens, including viruses. The treatment requirements to achieve Class A designation are established by EPA's 40 CFR Part 503 regulations. Class A biosolids face fewer restrictions than Class B biosolids, and can even be sold directly to the public. Hence, there are many potential end-use markets for Class A biosolids. In the Mid-Atlantic, the most common Class A products include:

- Lime-stabilized cake
- Dewatered thermal hydrolysis process (THP) cake
- Cured THP biosolids
- Dried biosolids
- Compost

In addition to the classification, biosolids are often categorized based on the treatment method, post-processing method, and amendments. Some of the more common products in the Mid-Atlantic are defined below:

- **Dewatered cake** refers to biosolids that have been dewatered to 15 to 30 percent solids content (70 to 85 percent water content). Dewatered cake can be either Class A or Class B, depending on the level of treatment prior to dewatering:
    - **Lime-stabilized cake** refers to dewatered solids treated with lime to raise the pH to a level that reduces pathogens. Lime stabilization systems are typically designed to meet Class B requirements, but can also be designed to achieve Class A, with the addition of heat for pasteurization (70 degrees Celsius [°C]/158 degrees Fahrenheit [°F] for 30 minutes). Lime addition increases the weight and volume of end product by 20 to 40 percent, depending on the dose required to meet EPA requirements, satisfy end user preferences, and reduce odors.
    - **Anaerobically digested biosolids** are solids that have been digested in anaerobic conditions. In addition to reducing pathogens, AD reduces the quantity of end product by 35 to 55 percent via the conversion of organic matter into biogas. AD processes are typically designed to meet only Class B requirements, but can also be designed to achieve Class A.
    - **Dewatered THP cake,** for the purposes of this TM, refers to anaerobically digested biosolids that are pretreated in THP. Class A requirements are met by a time-temperature regime (50°C/122°F for 20 minutes) in the THP reactor and volatile solids reduction in the digester. THP enhances the dewaterability of the cake, typically resulting in 25 to 35 percent solids.
- **Dried biosolids** (or "heat dried") refer to solids that have been heated in a dryer after dewatering. Biosolids products with a solids content of 90 percent or greater meet EPA's requirements for Class A. Dewatered THP cake is typically not dried because it already meets Class A requirements, but several facilities in Europe combine the two technologies to reduce hauling costs and/or enhance end product value.

  - **Partially dried biosolids** refer to solids that have been dried to a concentration less than 90 percent. Partial drying is uncommon because it requires a lot of energy but does not meet Class A requirements. However, the District of Columbia Water and Sewer Authority (DC Water) and other utilities have experimented with partial heat drying (50 to 70 percent solids) of dewatered THP cake to generate new end products that may be more attractive for certain markets.

- **Cured biosolids** are dewatered biosolids that have been air-dried in unaerated static piles for several days. The curing process reduces odors and increases solids content (generally to 50 to 70 percent). Curing is typically performed only with Class A biosolids.
- **Compost** refers to solids that have been mixed with a bulking agent such as wood chips. Unstabilized solids can be treated to Class A or B with aerobic composting (EPA has specific time and temperature requirements for meeting Class A or B designations), and Class B biosolids can be treated to Class A via composting (e.g., digested Class B solids from Baltimore's Back River Wastewater Treatment Plant [WWTP] are hauled to an off-site composting facility to meet Class A requirements). Composted biosolids can be marketed and sold to landscapers, nurseries, wholesalers, and hardware stores.

  - Note: Class A biosolids can also be blended with a bulking amendment to create a compost-like product. Because the solids are already Class A, it is not necessary to meet any time or temperature requirements; this is the approach DC Water uses to create "Woody Bloom." This *compost-like* material has similar properties and end uses to compost. In this TM, the term "compost" is used to refer to dewatered THP cake that is blended with a bulking agent, not necessarily solids that have been aerobically composted according to a specific time and temperature regime.

- **Soil blends** are biosolids with an amendment such as water treatment residuals or sandy soils to create a product that is more soil-like in appearance. These blends can be marketed as a topsoil or fill material for construction companies and landscapers, or as a daily cover material for landfills (see Section 5.2).

Arlington County is planning to replace the existing lime stabilization process with a Class A THP and AD, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP. This TM evaluates the marketability of the following potential end products:

- Dewatered THP cake
- Dried biosolids
- Cured biosolids
- Compost (dewatered THP cake blended with a bulking agent to create compost-like product)
- Soil blends

2.0 Regional Biosolids Product Market Update

This section presents a review of the current biosolids product market in the Mid-Atlantic region, including a 2018 market assessment review summary, THP biosolids market updates, and a summary of current biosolids markets and products.

2.1 2018 Market Assessment Review

Findings from the Master Plan market assessment for biosolids products in the Mid-Atlantic region are summarized in Table 1.

Table 1. 2018 Market Assessment Summary

Biosolids Product	End-Use Market	Market Maturity
Class B dewatered cake	Bulk agricultural land application, land reclamation	Well-established
Class A dewatered cake	Bulk agricultural land application, wholesale to agricultural market, land reclamation, feedstock for blended products	Well-established and growing
Class A dried	Bulk agricultural land application, wholesale to agricultural market, non-agricultural land application[a], retail sales, fuel, feedstock for blended products	Established bulk, wholesale and retail markets, some effort to enter non-agricultural markets
Class A compost	Bulk agricultural land application, wholesale to agricultural market, land reclamation, non-agricultural land application[a], retail sales, feedstock for blended products	Established wholesale markets, some effort to enter non-agricultural markets
Soil blends	Bulk agricultural land application, wholesale to agricultural market, land reclamation, retail sales, urban land reclamation	Established wholesale market, growing retail market

a. Non-agricultural land application includes use of biosolids as a fertilizer or soil conditioner in horticulture, landscaping, and turf management applications, both commercial and residential.

In general, the 2018 market assessment aligns with current biosolids market conditions in the Mid-Atlantic region. One exception is the fuel market, in which biosolids are used as a substitute for low-grade coal in cement manufacturing. The 2018 market assessment notes that the Lehigh Cement Company plant in Union Bridge, Maryland, receives 14,000 metric tons per year of dried biosolids, and there are plans to increase capacity. However, based on recent discussions with the City of Baltimore, Lehigh Cement apparently has not been accepting biosolids since February 2019 because of reductions in the price of coal and the aging condition of its solids receiving and handling equipment.

As noted in the 2018 market assessment, bulk agricultural land application is still the major beneficial-use outlet for Class A dewatered cake. Class A cake, including THP biosolids, typically must be post-processed to increase the solids content to 50 percent or more or blended with other materials to produce a drier, compost-like product to meet product requirements and preferences of retail, blended soils, and urban land/site reclamation or restoration markets.

2.2 THP Biosolids Product Market Updates

The beneficial use of Class A EQ THP biosolids has evolved and expanded in the Mid-Atlantic region since the 2018 market assessment was completed. Updates to the 2018 market assessment for THP biosolids are summarized as follows.

2.2.1 DC Water

DC Water has been producing Class A EQ THP biosolids at the Blue Plains Advanced WWTP since 2014. At the time the 2018 market assessment was performed, almost all of DC Water's Class A EQ cake was land-applied to farms in Virginia. Since then, DC Water has diversified its beneficial-use program and currently produces a variety of biosolids and blended products serving the bulk agricultural land application, soil blending, and horticultural and landscaping markets.

DC Water produces and markets several types of biosolids products under the brand name Bloom, described as follows (source: https://bloomsoil.com):

- Fresh Bloom is dewatered THP cake, with a solids content of 30 to 35 percent. Fresh Bloom is distributed primarily in bulk for agricultural land application. DC Water also markets Fresh Bloom for soil blending; for example, a local general contractor has used Fresh Bloom as a topsoil amendment on several of its building projects.
- Cured Bloom consists of dewatered biosolids that have been air-dried to approximately 70 percent solids. Cured Bloom is marketed for horticultural and landscaping uses and is available in bulk and bagged form at several retail gardening centers in the metropolitan Washington area.
- Woody Bloom consists of dewatered biosolids blended with shredded or ground hardwood to produce a compost-like material with a solids content of approximately 50 percent. Woody Bloom is marketed in bulk as a general-purpose soil amendment for horticultural and landscaping applications.
- Sandy Bloom consists of dewatered biosolids blended with sand and sawdust. Sandy Bloom can have a solids content of 80 percent or more and is marketed as a top dressing for turf and lawns.

Product analyses of DC Water's products are provided in Appendix B.

DC Water currently produces approximately 150,000 wet tons of Bloom products annually. Bloom is distributed for bulk agricultural land application by third-party contractors and through Blue Drop, a nonprofit entity formed by DC Water to market Bloom and DC Water's technology innovations. In 2020 DC Water reported selling more than 40,000 wet tons of Bloom, compared to slightly less than 10,000 tons in 2017. Approximately 80 percent of Bloom sales in 2017 was direct sale to farms in Maryland with 20 percent to landscapers, soil blenders, and construction companies. From 2018 to 2021, non-agricultural customers accounted for nearly one-third of sales (soil blenders: 17 percent; construction firms: 8 percent; landscapers: 3 percent; nurseries: 2 percent). The remaining 110,000 tons were hauled and land-applied by third-party contractors to farms in Virginia and Pennsylvania. A summary of DC Water's pricing strategy is presented in Table 2.

Table 2. DC Water Pricing Strategy

Product	Approximate Price	Comments
Fresh Bloom, subsidized rate for agricultural customers	$2–$6 per wet ton, including delivery	Price varies based on distance. For some large customers, DC Water also spreads the product for free.
Fresh Bloom, all other customers (e.g., soil blenders, construction)	$5 per wet ton, not including delivery	$3.50 per cubic yard. Most customers have the product delivered. Some customers pick up the product with their own trucks, which is more profitable for DC Water because delivery fees do not fully cover the cost.
Bloom Blends (Sandy and Woody Bloom)	$14–$36 per wet ton	Price varies on order size, product type, and delivery ($5/mile/truck)
Cured Bloom (50 lb bags)	$200+ per wet ton	Suggested retail price: $9.50 per bag ($380 per ton); typically sold to distributors and wholesalers for $5–$6 per bag.

a. Costs compiled from Bloom's website (bloomsoil.com/get-a-quote/) and "Bloom: Lessons in Biosolids Marketing & Sales," an August 2021 webinar presented by James Fotouhi and April Thompson of DC Water and hosted by the Metropolitan Water Reclamation District of Greater Chicago (mwrd.org/sites/default/files/documents/M&R_Seminar_8.27.21.pdf).

2.2.2 Hampton Roads Sanitation District

The Hampton Roads Sanitation District (HRSD) has implemented THP AD at its 54-million-gallon per day (mgd) Atlantic Treatment Plant (ATP) and is projected to produce approximately 39,000 wet tons of Class A biosolids per year (27 dry tons per day [dtpd]) following the closure of another treatment plant and the completion of the flow diversion to ATP. It is currently in the process to work with the Virginia Department of Environmental Quality (VDEQ) to secure a Class A EQ designation for the dewatered cake. HRSD's beneficial-use program will rely almost entirely on bulk agricultural land application by a third-party land application contractor for the near-term future. Based on findings of its 2020 biosolids market study, HRSD may also explore preparing a cured dewatered cake product to market as a soil amendment.

2.2.3 WSSC Water

WSSC Water is currently implementing its Piscataway Bioenergy project, which includes THP AD at the Piscataway WWTP to stabilize approximately 50 dtpd of solids (at startup) from Piscataway and four other WSSC Water resource recovery facilities. The Piscataway THP facility is expected to generate 50,000 to 62,000 wet tons of Class A biosolids per year once it is fully operational in 2024. At startup, WSSC Water will rely almost entirely on bulk agricultural land application by a third-party land application contractor. However, the utility is investigating options for developing cured or upgraded products for additional markets as part of continued biosolids master planning efforts.

2.3 Summary of Current Biosolids Markets and Products

In general, the market for dewatered cake products is limited to bulk agricultural land application.

Non-agricultural markets typically prefer biosolids products that are similar in appearance and consistency to traditional materials, such as compost, fertilizer, potting mix, and soils. Therefore, Class A THP cake may need to be cured, dried, and/or blended with other materials to meet customer expectations in non-agricultural markets.

provides a summary of viable biosolids end-use markets and the types of potential biosolids products (listed at the end of Section 1.1) that may be used or preferred in each market.

Table 3. Biosolids Beneficial-Use Markets and Suitable Products

Market	Market Maturity					Comments
	Cake	Dried	Cured	Compost	Blends	
Bulk agricultural land application	●	●				Established market.
Horticulture, landscaping, and turf management (including retail sales to the general public)		●	◐	●	◐	Emerging market: Markets for dried products and compost are fairly well established (e.g., Milorganite and Orgro). Market for cured cake and soil blends is small but growing (e.g., DC Water).
Commercial soil blending	○	◐	◐		◐	Emerging market: Future investigations are necessary to confirm if soil blenders would consider curing product themselves. Market for cured cake is small but growing (e.g., DC Water). For dried solids, soil blenders may prefer more granular belt-dried than spherical drum-dried biosolids
Site development	○		◐	◐	◐	Emerging market: Cured, compost, or blends are anticipated to be most attractive for this market; however, construction contractors may be willing to use cake at 30%–35% solids for site restoration.
Commercial fertilizer blenders		◐				Emerging market: May be limited to spherical, drum-dried products matching size, shape, or other fertilizer materials.
Biofuel (substitute for low-grade coal at cement kilns)		○				Limited outlet: Local cement kilns have stopped accepting biosolids recently because of current low cost of coal.
Land reclamation (mining, brownfield sites)	○		○	○	○	Limited outlet: Opportunities on a project-by-project basis rather than routine recurring use.

Legend: ● = Established market with strong demand
◐ = Emerging market with potential for strong demand
○ = Potential market

Refer to Section 1.1 for descriptions of products.

- Cake = dewatered THP cake
- Dried = THP cake that has been heat-dried to 90% solids content
- Cured = dewatered THP cake that has been air-dried to 50%–70% solids
- Compost = dewatered THP cake blended with a bulking agent to create a compost-like product
- Blends = dewatered THP cake blended with sandy soils or water treatment residuals to create a soil-like product

3.0 Regulatory and Permitting Update

Regulatory and permitting requirements for beneficial use of biosolids were presented in the Master Plan. Key regulatory and permitting requirements reported in the Master Plan are summarized below for reference:

- Biosolids regulations in most states closely align with the 40 CFR Part 503 biosolids regulations promulgated by the EPA.
- Beneficial use of Class B and Class A EQ biosolids requires a state-issued permit. The permit is typically issued to the generator of the biosolids. For Class B materials, a permit is typically required for each land application field. Utilities that generate Class A biosolids can obtain a "general use" permit that extends to all end users, including any land application fields.
- Bulk agricultural land application of biosolids in Virginia, Maryland, and Pennsylvania typically must be done in accordance with a nutrient management plan (NMP). For sites associated with animal feeding operations or high soil concentrations of phosphorus, Virginia law additionally requires that NMPs be approved by the Virginia Department of Conservation and Recreation (DCR).
- VDEQ has historically viewed "cake-like" Class A EQ biosolids, considered to be anything other than compost or with a solids content of less than 90 percent, as Class B biosolids in its permitting decisions. Many of the site management requirements for Class B cake, including signage and setbacks from the property line, are also required for Class A EQ cake. For example, VDEQ does not require individual permitting and associated public notice for land application sites receiving Class A biosolids from DC Water, but does require the following:
  - 200-foot setback from the property line of a publicly accessible site
  - 400-foot setback from "odor sensitive receptors" (hospitals, schools, churches, etc.)
  - Setbacks must comply with those established in the NMP
  - Setbacks may be extended at VDEQ's discretion, if requested by adjacent property owners
  - Daily notification to VDEQ, including locations and quantities of solids deliveries
  - Notification signage at each site
- Class A EQ biosolids that are distributed and marketed as fertilizers or soil amendments typically must be registered with and have product labeling that has been approved by the relevant state agency. For example, Class A EQ biosolids distributed and marketed in Virginia must be registered with the Virginia Department of Agriculture and Consumer Services (VDACS).
  - DC Water's "Fresh Bloom" product is registered with VDACS as a specialty fertilizer; the Bloom blended products are registered as soil amendments.
- Requirements for storing biosolids vary among the Mid-Atlantic states. Field storage is time limited (on the order of weeks to a month or so) and typically limited to the amount of biosolids to be applied in a single application cycle. A permitted storage facility is typically required for routine storage of larger quantities of bulk biosolids or for extended periods.
  - The requirements for biosolids storage in Virginia are established in Virginia Administrative Code (VAC) Title 9 Section 25-32-550. Virginia storage regulations are the same for Class A and Class B biosolids.

- Localities generally cannot establish stricter requirements than states. However, they can establish stricter requirements for biosolids storage and require additional inspections and monitoring.

This section of TM No. 5 provides updates on recent regulatory activities at the federal level; in the Mid-Atlantic states of Virginia, Maryland, and Pennsylvania; and in North Carolina since the Master Plan regulatory evaluation was completed.

3.1 U.S. Environmental Protection Agency

The 40 CFR Part 503 regulations include pollutant limits for 10 heavy metal pollutants, as well as pathogen reduction and vector attraction reduction requirements. EPA is required to review and identify needed updates to the 503 regulations every 2 years, but to date the reviews have been limited to literature reviews and a targeted data collection survey. EPA has indicated its intent to perform risk assessments for additional pollutants following its 2003 biennial review (targeting barium, beryllium, manganese, silver, fluoranthene, pyrene, 4-chloroaniline, nitrate, and nitrite) and in response to several biosolids program assessments including one in 2002 by the National Research Council and in 2018 by the EPA Office of Inspector General. To date, EPA has made only minor updates and has not added to the list of regulated pollutants in the 503 regulations since they were originally promulgated in the early 1990s.

EPA's most recent major activity on the biosolids front is the assessment of perfluoroalkyl and polyfluoroalkyl substances (PFAS) in biosolids. EPA established a health advisory level of 70 nanograms per liter (ng/L) (parts per trillion [ppt]) for two PFAS compounds in drinking water, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). Measuring the vast number of PFAS compounds created is difficult, so the industry has used the sub-categories of PFOS and PFOA for which toxicology data were available as an industry indicator for PFAS concentrations. An increased focus on the presence of PFAS in biosolids management has been driven by environmental advocacy groups, regulators, and the public. EPA is in the early stages of a risk assessment for PFAS compounds in biosolids, just recently preparing the "problem statement" as the first step in the assessment. EPA expects to complete and issue the risk assessment for public comment by the end of 2022. Once the risk assessment process is completed, EPA will determine if regulatory action at the federal level to address PFAS in biosolids is needed. Regulatory action would likely consist of adding concentration limits for specific PFAS compounds to the 503 regulations.

Note that while EPA is in the early stages of its PFAS risk assessment, several states are beginning to assess the risk associated with PFAS compounds in biosolids. State efforts include sampling and data collection and studies for potential impacts of PFAS compounds on soil and groundwater at biosolids land application sites. The state of Maine also requires sampling for biosolids that are applied to the land, including Class B biosolids, Class A dried biosolids, and Class A composted biosolids, and has established screening-level concentrations for three PFAS compounds (perfluorobutane sulfonate [PFBS], PFOA, and PFOS).

3.2 Virginia

The major regulatory development in Virginia since the Master Plan evaluation has been the first permit for distribution and marketing of Class A EQ dewatered cake and products derived from cake, issued to DC Water for its Bloom biosolids products. The DC Water permit was issued for a 2-year period from

February 2018 through January 2020 and has since been administratively continued. A copy of the permit is provided in 0. Notable provisions of that permit include the following:

- Class A EQ biosolids and products derived from Class A EQ biosolids (Bloom) may be distributed and applied in bulk for application to agricultural and non-agricultural sites, distributed in bulk for blending with other materials, and distributed in bulk or bags for sale and use by the general public.
- DC Water must report monthly to VDEQ the amounts of Class A EQ biosolids and Bloom products distributed in bulk and bagged form. Reporting must include the name and location of the recipient and end user for each transaction in which 1 metric ton or more of Class EQ biosolids or blended Bloom product is distributed.
- Bulk land application of Class A EQ biosolids and Bloom products must be in accordance with an approved NMP.
- DC Water is responsible for ensuring that land application and site management requirements in the Virginia Pollution Abatement regulations are followed for bulk land application of Class A EQ biosolids and Bloom products.

The consensus opinion within the regulated wastewater treatment and biosolids management industry of the initial DC Water distribution and marketing permit, especially the extensive reporting requirements, is that VDEQ is approaching and permitting "cake-like" Class A EQ biosolids and blended products much the same as Class B cake. VDEQ is expected to issue in 2021 notice for public comment on the draft of its first 5-year permit for distribution and marketing of Class A EQ dewatered cake, for the THP biosolids from HRSD's ATP. A draft permit is not yet available for review but is expected to present the template for future distribution and marketing permits for similar Class A EQ cake-like products. It remains to be seen if VDEQ, with 2 years of experience with DC Water's distribution and marketing program, will lessen reporting and other requirements for Class A EQ biosolids in HRSD's and potentially other future distribution and marketing permits.

VDEQ has not announced any planned regulatory action on PFAS compounds in biosolids in lieu of activity at the federal level.

3.3 Maryland

The Maryland Department of Environment (MDE) regulates biosolids management under Sewage Sludge Utilization (SSU) permits. Permits are required for facilities in the state that treat and distribute biosolids and for the land application of Class B biosolids. Class A EQ biosolids from out of state can be distributed and marketed in Maryland under an SSU marketing permit. Mixing and using Class A EQ biosolids blended with other materials such as sand, soil, wood chips, or compost requires written authorization from MDE but not a formal SSU permit. SSU permits are not specifically required for agricultural land application of Class A EQ biosolids, which may be land-applied in accordance with an approved NMP. Maryland does not allow land application of any organic materials, including biosolids, during the winter months (November 2 if east of the Susquehanna River and November 16 if west of the Susquehanna River and continuing through February 28). In addition to NMPs, Maryland has implemented a Phosphorus Management Tool that can limit or prohibit the application of phosphorus-containing fertilizers on farm fields with high levels of phosphorus in the soil and/or high risk of phosphorus entering surface waters in runoff.

In 2016, MDE issued an SSU marketing permit with a 10-year term to DC Water to market Class A EQ biosolids, referred to in the permit as Bloom. The Maryland SSU permit provision requires annual reporting on the amount and disposition of biosolids marketed in the state but does not contain any special requirements for agricultural land application of other beneficial uses of Bloom.

MDE has not announced any planned regulatory action on PFAS compounds in biosolids in lieu of activity at the federal level.

3.4 Pennsylvania

Pennsylvania is in the process of reissuing its general permits for use of Class A EQ biosolids (PAG-07) and Class B biosolids (PAG-08). Notable revisions being proposed include:

- PFOS and PFOA monitoring requirements for biosolids.
- Requiring use of a P-Index to determine allowable land application rates. Similar to Maryland's Phosphorus Management Tool, the P-Index could limit or disallow biosolids application on farm fields with high levels of phosphorus in the soil and/or a high risk of phosphorus entering surface waters in runoff from the field.

3.5 North Carolina

North Carolina regulatory and permitting requirements were not included in the Master Plan evaluation. North Carolina's biosolids regulations align with the Part 503 regulations. North Carolina regulations also include certain management requirements for bulk application of Class A biosolids that are typically reserved for Class B biosolids, including setbacks from surface waters and wells; field storage limits; and prohibitions on applying biosolids on fields that are wet or frozen, are steeply sloped, or where the groundwater level is close to the surface.

There does not appear to be any pending or planned future regulatory activity for biosolids, including for PFAS compounds, in North Carolina.

4.0 Outlook for Beneficial Use of Biosolids in the Mid-Atlantic Region

Bulk agricultural land application has been the dominant market for beneficial use of Class B and Class A EQ biosolids, both dewatered and dried, in the Mid-Atlantic region. However, there has been a declining trend in land application in Virginia, from an average of 220,000 dry tons per year of biosolids applied to 65,000 acres of farmland during the 2008 through 2013 period to approximately 130,000 dry tons per year land-applied to roughly 45,000 acres over the past several years.[1] Part of this decline is likely due to the growth in the horticultural, soil blending, and retail markets as more Class A EQ products have been generated. Part is likely due to a reported shift from Virginia to out-of-state land application of a portion of DC Water's uncured Bloom biosolids during the initial 2-year "trial" distribution and marketing permit. Structural changes in the agricultural market, including the loss of farmland to development, may also account for the reported decline in biosolids land application. While biosolids are land-applied to only a small percentage of agricultural land, less than 1 percent in Virginia, it is assumed that there will be little if any growth, and perhaps a continued decline over time, in the agricultural land

[1] Source: VDEQ 2015. "Biosolids Frequently Asked Questions". Available online at https://www.deq.virginia.gov/home/showpublisheddocument/5564/637552183171470000. Biosolids agricultural land application data and trends for other Mid-Atlantic states are still being compiled and evaluated.

application market for biosolids in the Mid-Atlantic states. The outlook for non-agricultural markets appears good as evidenced by the growth in Class A EQ products generated and used in the non-agricultural markets. However, the following factors and trends that can affect market demands for biosolids should be considered.

4.1 Regulatory Trends

Current and recent regulatory activities and trends can have both positive and negative effects on the beneficial use of biosolids in agricultural and non-agricultural markets. Key activities and trends include the following:

- Winter restrictions on land application of organic materials and biosolids, recently imposed in Maryland, have not appeared on the regulatory agenda in other Mid-Atlantic states. To date, other states in the region appear to have absorbed biosolids diverted out of Maryland during the winter season.
- Phosphorus management tools that may constrain biosolids land application on some farm fields are being implemented in Maryland and Pennsylvania. Virginia has not yet indicated that a P-Index or phosphorus management tool will be developed and implemented in the state. Implementation of a phosphorus management tool may prohibit land application of biosolids on fields that have received repeated applications of manure and poultry litter, especially in the Delmarva Peninsula, with less impact on cropland in the Piedmont.
- PFAS regulatory action will continue to move forward at the federal level and potentially the state level. There is some evidence that regulatory uncertainty over PFAS is negatively affecting the biosolids land application market, and even landfill disposal, with reports of some operators no longer taking biosolids because of concern over potential future liability for PFAS contamination. Regulation of PFAS in biosolids at the federal level, when it occurs, is likely to be based on concentration limits to mirror the regulation of metals and will likely serve as a template for state regulation. This would have a positive impact on biosolids land application by eliminating the current regulatory uncertainty and alleviating fear of potential liability in most cases.

4.2 Farming Trends

Trends in the agricultural sector that may affect land application include the reduction in the number of farms. Business trends that may include larger corporately owned and managed farms, which would tend to be less receptive to using biosolids, appear to be less prevalent in the Mid-Atlantic states than in other parts of the United States, with the possible exception of the poultry and livestock industry.

There has been a documented increase in the number of organic farms in the Mid-Atlantic states. This trend can impact wastewater utilities because United States Department of Agriculture (USDA) regulation 7 CFR 205.105(g) specifically prohibits the application of biosolids on organic fields[2]. The number of organic farms in Virginia has increased from approximately 260 in 2012 to nearly 320 in 2017, as reported in the U.S. Department of Agriculture's most recent comprehensive farm census survey[3].

[2] While USDA regulations categorically prohibit the use of biosolids on organic farms, regardless of level of treatment, raw animal manure can be applied to organic crops, including those intended for human consumption, subject to a minimum 90-day interval between application and harvesting (7 CFR 205.203(c)(1)).

[3] USDA National Agricultural Statistics Service. Results from the 2019 Organic Survey (2017 Census of Agriculture). https://www.nass.usda.gov/Publications/AgCensus/2017/index.php

While conversion from conventional to organic farming would preclude the use of biosolids, the number of organic farms is a small percentage (approximately 1 percent) of the roughly 42,000 farming operations in Virginia. Growth in organic farming is expected to have little if any impact on the land application market.

4.3 Weather and Climate Change

Biosolids land application was severely impacted in Virginia and other Mid-Atlantic states during 2018 by the unusually wet spring and summer. Wet field conditions shut down operations of most land application contractors, which coupled with a lack of storage facilities led to claims of *force majeure* by some contractors. Wetter springs and summers may be a future trend as a result of climate change. This will drive the need for additional biosolids storage, including on-site storage at wastewater treatment plants, and may also be a driver toward the production of drier biosolids to reduce volume and Class A EQ biosolids that can be marketed for non-agricultural uses.

4.4 Public Perception

Negative public perception and opposition to beneficial use of biosolids has typically been tied to odors, dust, truck traffic, and spills related to bulk agricultural land application. A low-odor Class A EQ product and a well-managed land application program can go a long way toward defusing public opposition.

Emerging concerns and growing attention to PFAS have resulted in negative perceptions of biosolids in certain areas of the United States among traditional users such as farmers and landfill operators. The recent report issued by the Sierra Club, *Sludge in the Garden: Toxic PFAS in home fertilizers made from sewage sludge,* has also raised concerns over public acceptance and perceptions in both the agricultural and retail horticultural and landscaping markets. The full impact of PFAS on public perception and acceptance remains to be seen but it does create a risk of diminishing demands for biosolids across multiple market sectors.

4.5 Contract Terms and Pricing

Most producers of Class A EQ biosolids continue to use a third-party contractor to manage some or all of their biosolids distribution. Contract terms and pricing, which can fluctuate significantly over a period of a few years, have not been evaluated in detail for this market assessment TM but should be tracked and evaluated in detail as the County nears completion of the biosolids upgrades at the WPCP. In general, contract pricing for a wet ton of biosolids tends to be lower for Class A EQ biosolids than for Class B biosolids because of the less restrictive permitting requirements. Additionally, the total annual contract cost can be lowered by achieving a higher solids content, resulting in fewer wet tons hauled. Typical contract terms should include provisions that require the third-party contractor to manage up to the facility's entire biosolids distribution but specify an amount that the producer may reserve for direct marketing.

5.0 Potential Opportunities for Arlington County

Bulk agricultural land application will be the major market outlet for the County's Class A EQ biosolids. Other non-agricultural markets can be developed over time. Several local market opportunities are discussed here.

5.1 Enhanced THP Biosolids

Arlington County's Department of Environmental Services Solid Waste Bureau operates a leaf, wood, and yard waste mulch production and marketing program out of the County's Earth Products Yard. These types of mulch materials can be readily blended with Class A EQ dewatered biosolids to produce a compost-like material that can be marketed as a soil amendment similar to DC Water's blended Bloom products. Details on how much blended biosolids-mulch product could be produced, operational capabilities for blending at the Earth Products Yard, distribution options (bulk and/or bagged product), and the overall feasibility of a biosolids blending operation should be discussed with staff at the Earth Products Yard.

5.2 Landfill Daily Cover

VDEQ's landfill operation regulations require covering the active landfill face with 6 inches of compacted soil or other approved cover material at the end of each working day. Intermediate cover of 6 additional inches of soil or approved material is also required when additional waste will not be applied within a 30-day period.

VDEQ has approved using biosolids blended with soil material at a ratio of 1:1 as a daily and intermediate cover material but would not be receptive to using unblended dewatered or dried biosolids as cover material. Using unblended biosolids for cover material would also be an operational issue for landfill operators and equipment, as biosolids tend to become slick when wet.

Landfill operators may be receptive to using blended biosolids and soils for daily cover if the material were available at little to no cost to them. For intermediate cover, landfill operators often have difficulty finding suitable materials that are resistant to erosion and capable of supporting grass or vegetative growth. Biosolids blended with sandy soils would be well-suited for intermediate cover and could potentially be marketed for sale to landfills for this purpose.

5.3 Licensing as a Bloom Product

DC Water continues to expand its direct marketing of Bloom products, recently increasing its annual direct sales and distribution from 40,000 to 100,000 wet tons. To date, most of DC Water's direct sales of Bloom have been in Maryland. Demand for Bloom products may increase in Virginia as both DC Water and VDEQ gain experience in distribution and marketing of the products in the region. Having a local source of Class A EQ biosolids for Bloom products may be an attractive option for DC Water to reduce hauling and distribution costs. Outreach to DC Water to discuss a potential licensing arrangement is recommended at a later date.

6.0 Summary/Conclusions

Bulk agricultural land application is likely to continue to be a major market outlet for biosolids, including Class A EQ dewatered and dried biosolids. Non-agricultural beneficial-use markets require enhanced Class A EQ biosolids, which may include dried biosolids, composted biosolids, or dewatered Class A biosolids that has been "cured" to reduce the moisture content or blended with other materials to produce a compost-like product. It is recommended that the County plan for a diversified biosolids portfolio that includes both dewatered THP biosolids to serve the bulk agricultural land application market and cured and blended THP biosolids products suitable for non-agricultural markets.

6.1 Design Considerations for Future Biosolids Operations

Site constraints and odor considerations at the WPCP make on-site biosolids curing using air drying or blending operations infeasible. Performing these types of post-processing operations at the Earth Products Yard or using a third-party partner such as a soil blender or landscape supply company should be explored further. Curing dewatered THP solids on site using a low-temperature belt dryer is a potential alternative to off-site curing using air drying, with an added benefit of reduced biosolids hauling traffic to and from the WPCP. It should also be noted that while unlikely, there is still some small risk that federal or state regulatory action or heightened public opposition could significantly and negatively impact the feasibility or desirability of applying biosolids to the land for any beneficial use

Should future trends indicate that this worst-case scenario could become a reality, pyrolysis or gasification may become the most viable alternative for biosolids management. A belt drying facility intended for curing THP biosolids could also serve a future pyrolysis or gasification facility should this worst-case scenario occur.

Reserving space on site for a belt drying facility is recommended, and preliminary sizing and space requirements for a belt drying facility should be included in the ongoing site utilization and configuration evaluation. Similarly, it would be informative to evaluate space requirements for a future pyrolysis or gasification process as part of the site utilization analysis.

6.2 Biosolids Distribution and Marketing Plan

The County should develop a detailed distribution and marketing plan as construction of the biosolids facility improvements progresses, prior to startup and commissioning, and closer to the time when actual biosolids product is available to share with potential users. This timing also supports a plan that is based on current market conditions.

The distribution and marketing plan should include the following elements:

- **Biosolids management approach:** evaluate and select the preferred approach from among the following models:
    - **Full-service provider:** A third-party contractor loads, hauls, and applies biosolids, in most cases entirely for bulk agricultural land application. The full-service provider is responsible for identifying and permitting if required at the land application sites. The full-service provider typically does not generate revenue from the sale of biosolids but is paid by the generator to manage its biosolids.

- **Broker:** A third-party entity markets to and secures, sells, and arranges distribution of biosolids to end users, which may include both agricultural and non-agricultural users. The broker may pay the biosolids generator or be paid a fee by the generator, typically at a lower cost than the full-service provided model because the broker is generating revenue from the sale of the biosolids.
- **Direct marketing:** The biosolids generator also manages all marketing and distribution, including marketing to and securing end users and handling sales and distribution of the product. This model typically can provide the most revenue to the biosolids generator but usually requires full-time staff to run the program.
- **Hybrid model:** This model is a combination of direct marketing for some market outlets, typically as product sales, and either a full-service provider or broker for other markets such as bulk agricultural land application. DC Water uses a hybrid model distribution and marketing its Bloom products.

- **Permitting and product registration requirements** for Virginia and potentially Maryland, Pennsylvania, and North Carolina:
  - Distribution and marketing permits
  - Product registration as a fertilizer and soil amendment
- **Targeted non-agricultural end-use market analysis, outreach, and market development:**
  - Surveys and outreach to specific end users to identify targeted quantities, delivery schedules, seasonal/year-round use, and storage capabilities
  - Specific field trials or demonstration projects for targeted markets
- **Product branding:** name, logo, etc.
- **Product type evaluation:** adding post-processing steps to generate products other than dewatered THP cake, such as curing, drying, composting, or blending.
- **End use evaluation:** evaluating potential markets beyond bulk land application.
- **Regional collaboration opportunities,** such as a regional facility for curing, drying, blending, etc.

6.3 Recommended Next Steps

While preparation of a detailed distribution and marketing plan for the County's Class A EQ biosolids is several years away, the County can be taking certain steps and actions now to help inform the plan. These include the following:

- Initiate outreach to Arlington County government agencies (Department of Parks and Recreation, Department of Environmental Services, Department of Transportation, etc.) that may be potential users of blended biosolids products, as an alternative to commercial compost, soil amendments, or fill material.
- Initiate outreach to staff at the Solid Waste Bureau, which manages the Earth Products Yard, to discuss and evaluate the potential for producing blended biosolids products. Conducting a blending trial using a truckload or more of both fresh and cured Bloom procured from DC Water is recommended to help inform the evaluation.
- Identify and make initial contact with landfill operators to learn more about their needs and requirements for daily and intermediate cover and potential interest in alternative cover materials.

- Identify and perform preliminary outreach to specific potential non-agricultural users of biosolids to determine if they use or might be interested in using biosolids, and to identify product requirements and potential demand.
- Initiate outreach to DC Water to discuss the potential for licensing the County's Class A EQ biosolids as a Bloom product.
- Develop a communications strategy for soliciting public perceptions on biosolids and beneficial use of Class A EQ biosolids.
- Develop and implement a PFAS sampling program for WPCP influent, effluent, and biosolids to position the County for a proactive rather than reactive stance on the PFAS in biosolids issue.
- Continue to monitor metals in biosolids.

Appendix A Virginia DEQ Permit for DC Water Bloom

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
Street address: 1111 East Main Street, Suite 1400, Richmond, VA 23219
Mailing address: P.O. Box 1105, Richmond, Virginia 23218
www.deq.virginia.gov

Russell W. Baxter
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4000
1-800-592-5482

February 2, 2018

Mr. Chris Peot
Director, Resource Recovery
5000 Overlook Ave., SW
Washington, DC 20032

RE: Issuance of VPA Permit No. VPA04002
DC Water - Bloom

Dear Mr. Peot:

The Virginia Pollution Abatement (VPA) permit for the distribution and marketing of biosolids associated with the above referenced project is enclosed. In accordance with the permit, you are required to submit Monitoring Reports by the fifteenth of each month to:

If submitting hardcopies:
Virginia Department of Environmental Quality
Office of Land Application
PO Box 1105
Richmond, VA 23218

If submitting electronically:
Christina.Wood@deq.virginia.gov
cc: Bryan.Cauthorn@deq.virginia.gov

Electronic submittal is preferred in lieu of hardcopy. The first report for the month ending February 28, 2018 is due by March 15, 2018. DEQ has not developed specific forms for the distribution and marketing reports, so please use your own reporting forms. Please continue to report the biosolids monitoring data in the format that you have been using.

As provided by Rule 2A:2 of the Supreme Court of Virginia, you have thirty days from the date of service (the date you actually received this decision or the date it was mailed to you, whichever occurred first) within which to appeal this decision by filing a notice of appeal in accordance with the Rules of the Supreme Court of Virginia with the Director, Department of Environmental Quality. In the event that this decision is served on you by mail, three days are added to that period. Refer to Part 2A of the Rules of the Supreme Court of Virginia for additional requirement governing appeals from administrative agencies.

Alternatively, any owner under §§ 62.1 - 44.16, 62.1 - 44.17, and 62.1 - 44.19 of the State Water Control Law aggrieved by any action of the State Water Control Board taken without a formal hearing, or by inaction of the Board, may petition in writing a formal hearing of such owner's grievance, provided a petition requesting such hearing is filed with the Board. Said petition must meet the requirements set forth in 9VAC25-230-130(B) of the Board's Procedural Rule No. 1. In cases involving actions of the Board, such petition must be filed within thirty days after notice of such action is mailed to such owner by certified mail.

If you have any questions regarding the permit, please contact me at (804) 840-0681 or anita.tuttle@deq.virginia.gov.

Respectfully,

Christina M. Wood
Biosolids Regulation and Guidance Coordinator

Enclosure: Permit No. VPA04002
Fact Sheet

cc: Permit file
Neil Zahradka (via email)

Part I
DISTRIBUTION AND MARKETING OF EXCEPTIONAL QUALITY BIOSOLIDS

During the period beginning with the permit's effective date and lasting until the permit's expiration date, and in accordance with 9VAC25-32-10 *et seq*. and the limitations, conditions and requirements set forth in this permit, the Permittee, District of Columbia Water and Sewer Authority (DC Water), is authorized to market and distribute Exceptional Quality (EQ) biosolids produced at the District of Columbia Advanced Wastewater Treatment Plant at Blue Plains (Blue Plains).

EQ biosolids shall meet an approved Class A pathogen reduction standard, including treatment alternative and indicator organism monitoring, one Vector Attraction Reduction Option, 1 – 8, have monthly average metals concentration below the Pollutant Concentration (PC) and all maximum metals concentrations below the ceiling limits. Exceptional Quality biosolids shall also be monitored annually for organic chemicals.

The DC Water - Blue Plains EQ biosolids, known as "Bloom Products"[(1)], may be marketed and distributed throughout Virginia in the following ways:

1. The sale or giveaway of bulk EQ cake[(2)] biosolids for the purpose of land application on agricultural[(3)] land in accordance with a Nutrient Management Plan (NMP) prepared by a certified nutrient management planner as stipulated in regulations promulgated pursuant to § 10.1-104.2 of the Code of Virginia;

2. The sale or giveaway of bulk EQ cake[(2)] biosolids for the purpose of land application on sites in accordance with a Nutrient Management Plan (NMP) prepared by a certified nutrient management planner as stipulated in regulations promulgated pursuant to § 10.1-104.2 of the Code of Virginia. The use of an application rate greater than the prescribed agronomic rate will be considered the reclamation of disturbed land and shall be managed in accordance with Part I.D.4 of this permit;

3. The sale or giveaway of EQ cake biosolids in a bag or other container[(4)];

4. The sale or giveaway of bulk EQ cake[(2)] biosolids to a facility for the purpose of blending;

5. The sale or giveaway of bulk blended EQ biosolids products for the purpose of land application on turf farms or other agricultural[(3)] land in accordance with a NMP prepared by a certified nutrient management planner as stipulated in regulations promulgated pursuant to § 10.1-104.2 of the Code of Virginia;

6. The sale or giveaway of bulk blended EQ biosolids products for non-agricultural use;

7. The sale or giveaway of blended EQ biosolids products in a bag or other container. [(4)]

[(1)] **Bloom Products –** The term "Bloom Products" refers to (i) EQ cake biosolids treated and produced at DC Water - Blue Plains; (ii) Blended EQ biosolids derived from EQ cake biosolids treated and produced at DC Water - Blue Plains that are blended with mulch and other wood products, including ground, shredded or chipped woody waste and other materials that are routinely distributed for the purposes of landscaping such as vegetative compost, mineral products (including sand) and topsoil. Bloom Products may be marketed under various names as registered with the Virginia Department of Agriculture and Consumer Services (VDACS)

(2) **Cake biosolids** – refers to dewatered biosolids with a solids content greater than 15% solids and less than 90% solids and may include digested, lime stabilized, or pasteurized biosolids, etc. Cake biosolids does not include composted biosolids, blended biosolids, or other biosolids products that include bulking agents or other feed stocks.

(3) **Agricultural land -** For the purposes of this permit, refers to land dedicated to **agricultural use** which includes the bona fide production of crops, or animals, or fowl including the production of fruits and vegetables of all kinds; meat, dairy, and poultry products; nuts, tobacco, nursery, and floral products; and the production and harvest of products from silviculture activity.

(4) **Other container** - For the purposes of this permit, "other container" means either an open or a closed receptacle, including, but not limited to, a bucket, box, carton, vehicle or trailer with a load capacity of one metric ton or less.

A. LIMITATIONS AND MONITORING REQUIREMENTS

All biosolids samples shall be collected and analyzed in accordance with Title 40 of the Code of Federal Regulations, Parts 503 and 136. Analyses shall be conducted by a VELAP accredited environmental laboratory.

1. EQ BIOSOLIDS

a. Metals Limitations – EQ cake biosolids, for distribution and marketing and for use in the production of a blended product, and blended EQ biosolids products shall be monitored and limited as specified below. Biosolids shall not be marketed and distributed as a cake or blended product, or used to produce a blended product if:
   1) The monthly average concentration of any pollutant in the biosolids exceeds the Pollutant Concentration (PC) limitation of that pollutant; or
   2) The maximum concentration of any pollutant in a single sample exceeds the ceiling limitation of that pollutant.

	PC LIMITATIONS	CEILING LIMITATION	MONITORING REQUIREMENTS	
PARAMETERS(1)	Monthly Average (mg/kg) (2)	Maximum (mg/kg) (2)	Frequency	Sample Type
Arsenic	41	75	1/Month	Composite
Cadmium	39	85	1/Month	Composite
Copper	1,500	4,300	1/Month	Composite
Lead	300	840	1/Month	Composite
Mercury	17	57	1/Month	Composite
Molybdenum	NL(3)	75	1/Month	Composite
Nickel	420	420	1/Month	Composite
Selenium	100	100	1/Month	Composite
Zinc	2,800	7,500	1/Month	Composite

NL = No Limitation, monitor and report

(1) All parameters are subject to pollutant concentrations (PC) and ceiling limitations. "PC biosolids" contain the parameters identified above at concentrations below the monthly average specified in Part I.A.1.b.

(2) All limits and criteria are expressed on a dry weight basis.

(3) The monthly average concentration is currently under study by USEPA. Research suggests that a monthly average Molybdenum concentration below 40 mg/kg may be appropriate to reduce the risk of copper deficiency in grazing animals.

b. Class A Pathogen Reduction and VAR Requirements – EQ cake biosolids shall be treated and monitored to meet Class A Pathogen Reduction and VAR standards prior to sale or giveaway in bulk, bag or other container for the purpose of land application or blending, and prior to use in a blended product. Biosolids shall be monitored and limited in accordance with the treatment option identified below:

TREATMENT OPTION: CLASS A PATHOGEN REDUCTION ALTERNATIVE 1	MONITORING REQUIREMENT
a) Either the density of fecal coliform in the biosolids shall be less than 1,000 Most Probable Number per gram of total solids (dry weight basis), or the density of Salmonella sp. bacteria in the sewage sludge shall be less than three Most Probable Number per four grams of total solids (dry weight basis) at the time the biosolids is used or disposed; at the time the biosolids is prepared for sale or give away in a bag or other container for application to the land; or at the time the sewage sludge or material derived from sewage sludge is prepared to meet the requirements in 9VAC25-32-356 B, C, E or F.	1/Month [(1)(2)]
b) The temperature of the sewage sludge that is used or disposed shall me maintained at a specific value for a period of time in accordance with 9VAC25-32-710.A.3.b. (1) When the percent solids of the sewage sludge is 7.0% or higher, the temperature of the sewage sludge shall be 50°C or higher; the time period shall be 20 minutes or longer; and the temperature and time period shall be determined using equation (1), except when small particles of sewage sludge are heated by either warmed gases or an immiscible liquid. EQUATION (1) $D = 131{,}700{,}000/10^{0.1400t}$ D = time in days t = temperature in degrees Celsius (2 When the percent solids of the sewage sludge is 7.0% or higher and small particles of sewage sludge are heated by either warmed gases or an immiscible liquid, the temperature of the sewage sludge shall be 50°C or higher; the time period shall be 15 seconds or longer; and the temperature and time period shall be determined using equation (1). (3) When the percent solids of the sewage sludge is less than 7.0% and the time period is at least 15 seconds, but less than 30 minutes, the temperature and time period shall be determined using equation (1). (4) When the percent solids of the sewage sludge is less than 7.0%; the temperature of the sewage sludge is 50°C or higher; and the time period is 30 minutes or longer, the temperature and time period shall be determined using equation (2). EQUATION (2) $D = 50{,}070{,}000/10^{0.1400t}$ D = time in days t = temperature in degrees Celsius	[(1)(2)]
VECTOR ATTRACTION REDUCTION TREATMENT STANDARD OPTION 1	MONITORING REQUIREMENT
38% Reduction of volatile solids by digestion (9VAC25-32-720.B.1).	1/Month [(1)(2)]

(1) Between sampling events, operating records shall demonstrate that the wastewater treatment plant (WWTP) is operating at a performance level known to meet pathogen reduction and VAR standards.

(2) Process monitoring shall be sufficient to demonstrate compliance with Pathogen Reduction Alternative 1 and VAR Option1 requirements.

c. Nutrient Characteristics – All EQ cake biosolids and blended EQ biosolids products shall be monitored and limited as specified below prior to distribution and marketing:

PARAMETERS	LIMITATIONS		MONITORING	
	Monthly Average	Minimum and Maximum	Frequency	Sample Type
Percent Solids (%)	NL	NA	1/Month	Composite
Volatile Solids (%)	NL	NA	1/Month	Composite
Total Kjeldahl Nitrogen (mg/kg)[1]	NL	NA	1/Month	Composite
Ammonium Nitrogen (mg/kg) [1]	NL	NA	1/Month	Composite
Nitrate Nitrogen (mg/kg) [1]	NL	NA	1/Month	Composite
Total Phosphorus (mg/kg) [1]	NL	NA	1/Month	Composite
Total Potassium (mg/kg) [1]	NL	NA	1/Month	Composite
pH (s.u.)	NA	NL	1/Month	Composite
Alkalinity as $CaCO_3$ (mg/kg) [1]	NL	NA	1/Month	Composite

NL = No Limitation, monitor and report
NA = Not Applicable

[1] Expressed on a dry weight basis

d. EQ Biosolids Characteristics – All EQ cake biosolids and blended EQ biosolids products shall be monitored and limited as specified below prior to distribution and marketing:

PARAMETERS	LIMITATIONS		MONITORING REQUIREMENTS	
	Monthly Average [1] (mg.kg)	Minimum and Maximum [1] (mg/kg)	Frequency	Sample Type
Polychlorinated biphenols (PCBs)	NL	NL	Annually	Composite
Aldrin/dieldrin (total)	NL	NL	Annually	Composite
Benzo (a) pyrene	NL	NL	Annually	Composite
Chlordane	NL	NL	Annually	Composite
4 4' DDT/DDE/DDD (total) [2]	NL	NL	Annually	Composite
Dimethyl nitrosamine	NL	NL	Annually	Composite
Heptachlor	NL	NL	Annually	Composite
Hexachlorobenzene	NL	NL	Annually	Composite
Hexachlorobutadiene	NL	NL	Annually	Composite
Lindane	NL	NL	Annually	Composite
Toxaphene	NL	NL	Annually	Composite
Trichloroethylene	NL	NL	Annually	Composite
Aluminum	NL	NL	Annually	Composite
Boron, water soluble	NL	NL	Annually	Composite
Calcium	NL	NL	Annually	Composite
Chorides	NL	NL	Annually	Composite
Manganese	NL	NL	Annually	Composite
Total Sulfur	NL	NL	Annually	Composite

NL = No Limit, monitor and report

[1] All parameters are expressed on a dry weight basis.
[2] 4 4' DDT = 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane
4 4' DDE = 1,1-Bis (p-chlorophenyl)-2,2—dichloroethylene;
4 4' DDD = 1,1-Bis (p-chlorophenyl)--2,2--dichloroethane

B. REPORTING REQUIREMENTS

1. Monthly Reporting – The permittee shall submit biosolids monitoring data and a monthly distribution report to the Department of Environmental Quality (DEQ) - Office of Land Application (OLAP) by the 15th day of each month (as evidenced by the transmission date or postmark), for monitoring and land application activities that occurred in the previous calendar month. When the report is submitted electronically, the sender must include the attestation statement in Part I.B.1.d. which states that the transmitted documents are being submitted under his/her signature.

   If no EQ cake biosolids or blended EQ biosolids products are produced or distributed under this permit during a calendar month, a report shall be submitted stating that no EQ cake biosolids or blended EQ biosolids products were produced and/or distributed. All reports shall include the name of the permittee and the DEQ permit number.

   a. Biosolids Monitoring Data – The following data shall be submitted with the monthly report for all biosolids land applied during the previous month:
      1) The results of the monitoring specified in:
         (a) Part I.A.1.b. Metals Limitations for:
            i. EQ cake biosolids – for sale or giveaway and used in blending:
            ii. Blended EQ biosolids products;
         (b) Part I.A.1.c. Class A Pathogen Reduction and Vector Attraction Reduction – for cake biosolids for sale or giveaway and used in blending:
            i. Indicator organism monitoring;
            ii. CambiTHP ™ process control time and temperature data for pathogen reduction;
            iii. Digester volatile solids reduction for VAR;
         (c) Part I.A.1.d. Nutrient Characteristics for:
            i. EQ cake biosolids for sale or giveaway;
            ii. Blended EQ biosolids;
         (d) Part I.A.1.e. EQ Biosolids Characteristics for:
            i. EQ cake biosolids for sale or giveaway and used in blending;
            ii. Blended EQ biosolids;
      2) Monitoring required by Part I.B.1.a.1) shall be submitted in the format provided in the Biosolids Monitoring Report. Supporting documentation, including laboratory chain of custody forms and certificates of analyses, shall be included in the report;
      3) Monthly average shall be reported as the average of the results of all samples collected within a calendar month and analyzed using an approved method, in accordance with Part II.C. of this permit. For monitoring periods which include multiple months, if one sample is collected during the monitoring period, that result shall be reported as the monthly average. If samples are collected in different months during the monitoring period, each monthly average shall be calculated for each month samples were collected in the monitoring period and the highest monthly average reported. Individual results and calculations shall be submitted with the report; and
      4) The maximum concentration shall be reported as the highest single result from all samples collected and analyzed during a monitoring period.
      5) The following certification statement:
         "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

b. Monthly Distribution Report – The monthly distribution report shall include the following information for the month:
   1) Monthly Production:
      (a) Total amount of EQ cake biosolids produced, in dry tons and wet tons;
      (b) Total amount of EQ cake biosolids distributed, in wet tons;
      (c) The total amount of EQ cake biosolids used in the blended product, in wet tons;
      (d) The total amount of blended EQ biosolids product produced, in wet tons;
      (e) The total amount of blended EQ biosolids product distributed, in wet tons.
   2) For EQ cake biosolids and blended EQ biosolids product distributed in a bag or other container in Virginia include:
      (a) The total amount of EQ cake biosolids or blended EQ biosolids products bagged, in wet tons;
      (b) The amount of EQ cake biosolids or blended EQ biosolids products distributed in bags, in wet tons;
      (c) When bagged EQ cake biosolids or blended EQ biosolids products are distributed in amounts greater than 1 metric ton in a single transaction, for each such transaction include:
         i. The amount of bagged EQ cake biosolids or blended EQ biosolids products distributed, in wet tons;
         ii. The name of the recipient;
         iii. The name of the business that will use the biosolids products, if applicable; and
         iv. The date of each transaction.
      (d) The amount of EQ cake biosolids or blended EQ biosolids products distributed in other containers, in wet tons;
   3) For EQ cake biosolids distributed in bulk to permitted blending facilities in Virginia, include:
      (a) Total amount of EQ cake biosolids distributed in bulk to permitted blending facilities, in wet tons;
      (b) The amount of EQ cake biosolids distributed in bulk for blending, by transaction, in wet tons;
      (c) The name of the permitted blending facility receiving the EQ cake biosolids;
      (d) The blending facility's Virginia Pollution Abatement permit number authorizing blending, marketing and distribution of EQ biosolids products; and
      (e) The date of each transaction;
   4) For blended EQ biosolids product distributed in bulk for use in Virginia include:
      (a) The amount of blended EQ biosolids product distributed in bulk, by transaction;
      (b) The name of the recipient of bulk blended EQ biosolids product;
      (c) The name of the business that will use the biosolids products, if applicable; and
      (d) The date of each transaction;
   5) For EQ cake biosolids and blended EQ biosolids products distributed in bulk for the purpose of land application in Virginia, include:
      (a) Total amount of EQ cake biosolids distributed in bulk for land application at agricultural operations, including turf farms, in dry tons and wet tons;
      (b) The amount of EQ cake biosolids distributed in bulk for land application at non-agricultural sites, by transaction, in dry tons and wet tons;
      (c) The amount of blended EQ biosolids products distributed in bulk for land application at agricultural sites, by transaction, in wet tons;
      (d) The name of the recipient of bulk EQ cake biosolids or blended EQ biosolids products;
      (e) The name of the agricultural operations where the bulk EQ cake biosolids or blended EQ biosolids products were applied;
      (f) The address of the agricultural operation where the bulk EQ cake biosolids or blended EQ biosolids products were applied, as identified on the Nutrient Management Plan;
      (g) The latitude and longitude of the delivery location, in decimal degrees; and
      (h) The date of each transaction.

(i) For EQ cake biosolids, provide a presentation of the calculation of the total fee; and
(j) A summary list of the total amount of biosolids applied and the calculated fee broken down by County, presented in alphabetical order by county.

6) The name of a responsible official or authorized representative of the permittee and a statement signed and dated by that responsible official or authorized representative, indicating that the information submitted has been verified by that responsible official or authorized representative as correctly reported, in accordance with the Part II.K.

7) Electronic Submittal Attestation Statement – When submitting a report via email, the following statement shall be included in the email.
"I, representative official's or authorized representative's name, hereby declare that I am submitting the attached documents under my signature for the purposes of compliance with the reporting requirements of VPA Permit number VPA04002. With the transmission of this email, I attest that the above statement is true and valid to the best of my knowledge."

2. Biosolids Land Application Fee – The permittee shall remit to the DEQ a fee of $3.75 per dry ton of Exceptional Quality cake biosolids distributed in bulk for land application in the Commonwealth of Virginia.

Billing and payment procedures are as follows:

1) Upon reviewing the Monthly Distribution Report in Part I.B.1.b.5., DEQ will bill the permittee for the fee that is due. Payment is due 30 days after receipt of the bill from DEQ;

2) The permittee shall collect this fee from the facilities that generated the biosolids that were applied; and

3) A check or money order shall be made payable to the "Treasurer of Virginia", and mailed with the invoice to:

Department of Environmental Quality
Receipts Control
P.O. Box 1104
Richmond, VA 23218

Failure to submit payment by the due date may result in the permit being revoked or approved sources being reclassified as unapproved. This permit shall not be reissued, administratively continued or modified without full payment of any past due fee.

3. Annual Report – The permittee shall submit an Annual Report not later than February 19th of each year to the DEQ - OLAP. The report shall be for the previous calendar year's activity. If no EQ cake biosolids were generated or distributed under this permit during a calendar year, a report shall be submitted stating that no EQ cake biosolids were generated or distributed. The report shall include at minimum:

   a. The annual total amount of EQ cake biosolids produced, in dry tons and wet tons;

   b. The annual total amount of EQ cake biosolids and blended EQ biosolids products distributed in Virginia, in dry tons and wet tons;

   c. The annual total amount of EQ cake biosolids distributed in bulk for land application in Virginia, in dry tons and wet tons;

   d. The annual total amount of blended EQ biosolids products distributed in bulk for land application in Virginia, in wet tons;

   e. The annual total amount of EQ cake biosolids distributed in bulk to permitted blending facilities in Virginia, in wet tons;

   f. The annual total amount of EQ cake biosolids and blended EQ biosolids products bagged, in wet tons;

   g. The annual total amount of EQ cake biosolids and blended EQ biosolids products distributed in bags in Virginia, in wet tons;

   h. The annual total amount of EQ cake biosolids and blended EQ biosolids products distributed in other containers in Virginia, in wet tons;

   i. The results of the EQ Biosolids Characteristics monitoring data required by Part I.A.1.e.;

   j. Any biosolids monitoring data required by Part I.A. that were not submitted during the reporting calendar year; and

   k. The annual report shall be certified and signed in accordance with Part II.K.

C. RECORD KEEPING REQUIREMENTS

1. Records Retention – The permittee shall retain records of EQ cake biosolids and blended EQ biosolids products production, marketing and distribution activities for a period of at least five years from the date of the sample, measurement, report or application, unless otherwise specified in this permit. This period of retention may be extended by request of the Board at any time. Records to be retained include:

    a. Monitoring information required in Part I.A.;

    b. Reports required in Part I.B.;

    c. Records required below in Part I.C.2.;

    d. Records required below in Part I.E.; and

    e. Site Operator Notification and Information as required in Part I.E.6.;

2. Exceptional Quality Biosolids Record Keeping – Records shall include:

    a. The following certification statement:
    "I certify, under penalty of law, that the information that will be used to determine compliance with the Class A pathogen requirements in 9VAC25-32-675 A and the vector attraction reduction requirement in (insert one of the vector attraction reduction requirements in 9VAC25-32-685 B 1 through B 8) was prepared under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate this information. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment.";

    b. A description of how the Class A pathogen requirements in 9VAC25-32-675 A are met; and

    c. A description of how one of the vector attraction reduction requirements in 9VAC25-32-685 B 1 through B 8 is met.

D. BIOSOLIDS MANAGEMENT PLAN (BSMP)

1. BSMP – The BSMP and all of its components are an enforceable part of the permit. The permittee shall implement and maintain a BSMP which shall consist of the following components:

    a. The materials developed and submitted at the time of permit application or permit modification in accordance with 9VAC25-32-60.F.;

    b. The Operations and Maintenance (O&M) Manual;

    c. The Odor Control Plan; and

    d. Reclamation plan for mined and disturbed land.

    Any proposed changes in biosolids production, marketing or distribution practices or procedures followed by the permittee, as represented in the documents required by Part I.D.1.a. – c., shall be documented and submitted to DEQ-OLAP within 90 days of the effective date of the changes.

2. O&M Manual Requirement – An O&M Manual shall be submitted to DEQ-OLAP within 90 days of the effective date of this permit. The permittee shall conduct all biosolids production, marketing or distribution practices activities in accordance with the O&M Manual. The O&M Manual shall include at a minimum:

   a. A copy of this permit;

   b. Procedures for making the blended EQ biosolids products as registered or licensed by VDACS;

   c. Procedures for a Virginia Certified Land Applicator to provide oversight, as described in Part I.E.5, of the farm sites where EQ cake biosolids or blended EQ biosolids are delivered and land applied, including procedures for:

      1) Confirming presence of the NMP upon delivery of EQ cake biosolids or blended EQ biosolids at the agricultural site where the biosolids will be applied;
      2) Reviewing site management requirements with the farm operator;
      3) Sign posting or evaluation of adequate sign placement at the farm site; and
      4) Evaluation of appropriate staging location and on-site storage facility at the farm site.

   d. Schedules and record keeping instructions for a Virginia Certified Land Applicator assigned to oversight on the farm sites where EQ cake biosolids or blended EQ biosolids are delivered and land applied;

   e. Sampling schedules for:
      1) Required monitoring, including a list of required minimum tests; and
      2) Operational control testing;

   f. Sample collection, preservation, and analysis procedures, including selection of sample locations, and laboratories and methods used;

   g. Instructions for recording and reporting of all monitoring activities; and

   h. Spill response, remediation, and reporting procedures for offsite spills, including telephone numbers for immediate reporting to the DEQ - OLAP; and

3. Odor Control Plan (OCP) Requirement – The generating facility's OCP shall include at a minimum:
   a. Methods used to minimize odor in producing biosolids;

   b. Methods used to identify malodorous biosolids before delivery to the land applier (at the generating facility);

   c. Methods used to identify and abate malodorous biosolids if delivered to the field, prior to land application; and

   d. Methods used to abate malodor from biosolids if land applied.

4. Reclamation of Mined and Disturbed Land – EQ biosolids may be land applied at greater than agronomic rates on sites that have been mined or disturbed, as identified in an approved Reclamation Plan for the purpose of mineral sands mine soil reconstruction; construction site top soil replenishment, or other such soil restoration at disturbed sites in accordance with 9VAC25-32-300 et seq., this permit and the Reclamation Plan.

   a. Prior to delivery of EQ biosolids to a reclamation site, the permittee shall submit the following:
      1) Reclamation Plan for the reclamation activity:
         A Reclamation Plan developed with the assistance of the Department of Crop and Soil Environmental Sciences of the Virginia Polytechnic Institute and State University for all sites and VDMME for mined sites, that includes at minimum:
         (a) A site map showing area included in the field, including any setbacks that are required;
         (b) The Soil Reconstruction Protocol(s) to be used at the site;
         (c) EQ biosolids rate(s) of application;
         (d) Soil analysis results;
         (e) Crop to be planted following application, including information on the seeding mixture and a seeding schedule; and
         (f) Other practices as required by the Reclamation Plan; and
      2) Approved NMP for agricultural activity or turf maintenance following reclamation or release from VDMME for mined sites.

   b. The following conditions also apply to reclamation activities on mined and disturbed land:
      1) The EQ biosolids application rate shall be limited by the most restrictive cumulative trace element loading in accordance with the table below:

PARAMETER	LIMITATIONS		MONITORING REQUIREMENTS	
	Maximum CPLR[1]		Frequency	Sample Type
	(kg/ha)[2][3]	(lb/A)[2][3]		
Arsenic	41	36	Each Application	Calculated
Cadmium	39	35	Each Application	Calculated
Copper	1,500	1,340	Each Application	Calculated
Lead	300	270	Each Application	Calculated
Mercury	17	16	Each Application	Calculated
Molybdenum	NL[4]	NL[4]	Each Application	Calculated
Nickel	420	375	Each Application	Calculated
Selenium	100	89	Each Application	Calculated
Zinc	2,800	2,500	Each Application	Calculated
Aluminum[5]	4,570	4,113	Each Application	Calculated

(1) The CPLR is the maximum cumulative application of trace elements that can be applied to soils used for crop production. The maximum cumulative application rate is limited for all ranges of cation exchange capacity due to soil background pH in Virginia of less than 6.5 s.u. and lack of regulatory controls of soil pH adjustment after biosolids application ceases.

(2) All limits and criteria are expressed on a dry weight basis in kg/ha and lb/A.

(3) No person shall apply bulk biosolids subject to the CPLRs identified above to agricultural land, forest, a public contact site, or a reclamation site if any of the CPLRs identified above has been reached.

(4) The maximum cumulative application is currently under study by USEPA. Research suggests that for Molybdenum a cumulative pollutant loading rate below 40 kg/ha may be appropriate to reduce the risk of copper deficiency in grazing animals.

(5) All sites that receive WTP residuals containing aluminum are subject to the tracking of aluminum loading, regardless of concentration of aluminum in the residuals.

2) If the cadmium concentration of the EQ biosolids is greater than 21 mg/kg, post application soil pH shall maintained at 6.0 or greater during the first year after the initial application.
3) The site shall be revegetated with grass and legumes in accordance with the Reclamation Plan.

c. After a reclaimed site has been released from its permit conditions with the Virginia Department of Mines, Mineral and Energy, or any local government bond obligation, EQ biosolids may not be applied at reclamation rates. The site must be managed in accordance with the approved nutrient management plan.

E. DISTRIBUTION AND MARKETING

1. DISTRIBUTION AND MARKETING OF EQ CAKE BIOSOLIDS AND BLENDED EQ BIOSOLIDS

a. Under the authority of this permit:
   1) EQ cake biosolids produced at DC Water - Blue Plains may be marketed and distributed in Virginia in bulk, bag or other container;
   2) EQ cake biosolids produced at DC Water - Blue Plains may be distributed in bulk to facilities for blending,; and
   3) Blended EQ biosolids products derived from EQ cake biosolids produced at DC Water - Blue Plains may be marketed and distributed in Virginia in bulk, bag or other container.

b. Prior to the distribution and marketing of any EQ cake biosolids or blended EQ biosolids products, the biosolids product must be registered with the Virginia Department of Agriculture and Consumer Services in accordance with the provisions of § 3.2-3607 of the Code of Virginia. A copy of the registration shall be submitted to the DEQ OLAP.

   The permittee shall maintain the VDACS registration for the duration of this permit.

c. Product Labeling – A label shall be affixed to a bag or other container in which biosolids is sold or given away, or an information sheet shall be provided to the person who receives the biosolids. The label or information sheet provided to users of marketed or distributed biosolids shall include the following:
   1) The name and address of the preparer of the biosolids;
   2) The nutrient content;
   3) A statement that application of the exceptional quality biosolids to the land is prohibited except in accordance with the instructions on the label or information sheet; and
   4) Other information in accordance with regulations promulgated under § 3.2-3601 of the Code of Virginia and with the labeling provisions of § 3.2-3611 of the Code of Virginia.

2. DISTRIBUTION OF EQ CAKE OR BLENDED EQ BIOSOLIDS IN BAGS OR OTHER CONTAINERS

   a. EQ cake biosolids and blended EQ biosolids products may be sold or given away in bag or other containers for resale or direct use.

   b. The permittee shall document the following information for the sale or giveaway of bagged EQ biosolids – cake or blended:
      1) The amount of EQ cake biosolids and blended EQ biosolids bagged;
      2) The amount of EQ cake biosolids and blended EQ biosolids sold or given away in bags; and
      3) The amount of EQ cake biosolids and blended EQ biosolids sold or given away in other containers.

   c. The permittee shall document the following information for the sale or giveaway of bagged EQ biosolids – cake or blended – in amounts greater than 1 metric ton:
      1) Name of recipient;
      2) Name of business that will land apply or resell the biosolids, if applicable;
      3) Amount distributed, in wet tons; and
      4) The date of the transaction.

3. DISTRIBUTION OF EQ CAKE BIOSOLIDS FOR THE PURPOSE OF BLENDING

   a. EQ cake biosolids produced at DC Water – Blue Plains may be sold or given away in bulk to a facility that will blend the EQ biosolids in accordance with a valid VDACS license and registration.

   b. The permittee shall document the following information for the sale or giveaway of EQ cake biosolids in bulk to a blending facility:
      1) Total amount of EQ cake biosolids distributed in bulk to permitted blending facilities, in wet tons;
      2) The name of the blending facility receiving the EQ cake biosolids;
      3) The amount of EQ cake biosolids distributed in bulk for blending, by transaction, in wet tons; and
      4) The date of each transaction.

   c. Notice and Necessary Information - The permittee shall provide to the operator of the blending facility that receives EQ cake biosolids notification and information. The notification shall include at minimum:

      1) A statement that biosolids land applied meet
         (a) Class A pathogen reduction; and
         (b) VAR requirements 1 through 8; and
      2) A statement that metals concentrations in the biosolids were below the pollution concentration and the ceiling limit;
      3) The concentration of Nitrogen and Phosphorus in lbs/wet ton.

4. BULK DISTRIBUTION OF BLENDED EQ BIOSOLIDS PRODUCTS FOR USE AT NON-AGRICULTURAL SITES

   a. Blended EQ biosolids products may be sold or given away in bulk for non-agricultural use in Virginia.

   b. The permittee shall document the following information for the sale or giveaway of bulk blended EQ biosolids products in amounts greater than 1 metric ton:
      1) Name of recipient;
      2) Name of business that will use the blended EQ biosolids, if applicable;
      3) Amount of blended EQ biosolids products distributed, in wet tons; and
      4) The date of the transaction.

   c. Notice and Necessary Information - The permittee shall provide to the recipient of the biosolids notification and information. The notification shall include at minimum:

      1) A statement that biosolids land applied meet
         (a) Class A pathogen reduction;
         (b) VAR requirements 1 through 8; and
      2) A statement that metals concentrations in the biosolids were below the pollution concentration and the ceiling limit;
      3) The concentration of Nitrogen and Phosphorus in lbs/wet ton.

5. BULK DISTRIBUTION OF EQ CAKE BIOSOLIDS FOR LAND APPLICATION AT AGRICULTURAL AND NON-AGRICULTURAL SITES AND BLENDED EQ BIOSOLIDS FOR LAND APPLICATION AT AGRICULTURAL SITES

   The following conditions apply to EQ cake biosolids and blended EQ biosolids products that are marketed or distributed in bulk for the purpose of land application at agricultural operations, including turf farms, in Virginia, and EQ cake biosolids marketed or distributed in bulk for the purpose of land application:

   a. If EQ cake biosolids are land applied at a site that is authorized to receive biosolids under a VPA or VPDES permit, the biosolids shall be land applied under the authority and conditions of the VPA or VPDES permit; and the site will be managed as such.

   b. The permittee shall have on site prior to the start of land application, a certified land applier. While on-site the land applier shall:
      1) Ensure proper staging of the biosolids;
      2) Inspect the on-site storage pad, as applicable;
      3) Post the signs at appropriate locations, or ensure that the signs have been posted at appropriate locations;
      4) Verify the presence of the NMP on site; and
      5) Discuss site specific staging requirements, on-site storage requirements and setbacks with the recipient or operations manager.

   c. Nutrient Management Plan
      1) Bulk quantities of EQ cake biosolids or blended EQ biosolids products shall be land applied in accordance with a NMP prepared by a certified nutrient management planner as stipulated in regulations promulgated pursuant to § 10.1-104.2 of the Code of Virginia.
      2) The NMP shall be developed prior to delivery of bulk EQ cake biosolids or blended EQ Biosolids to the farm site.
         (a) If the NMP is prepared by the permit holder:

i. When EQ cake biosolids or blended EQ biosolids products are bulk applied by the permit holder, the permit holder shall provide a copy of the NMP to the farm operator of the site and the Department of Conservation and Recreation (DCR) within 30 days after bulk land application at the site has commenced; or
ii. When EQ cake biosolids or blended EQ biosolids products are bulk applied by the recipient, the permit holder shall provide a copy of the NMP to the farm operator of the site at the time of delivery of EQ cake biosolids or blended EQ biosolids products to the recipient. The permit holder shall provide a copy of the NMP to DCR within 30 days after bulk land application at the site has commenced.

(b) If the NMP is prepared by the recipient of EQ cake biosolids or blended EQ biosolids products:
i. When EQ cake biosolids or blended EQ biosolids products are bulk applied by the permit holder, the permit holder shall obtain a copy of the NMP from the recipient prior to bulk land application at the site. The permit holder shall provide a copy of the NMP to DCR within 30 days after bulk land application at the site has commenced; or
ii. When EQ cake biosolids or blended EQ biosolids products are bulk applied by the recipient, the permit holder shall obtain a copy of the NMP from the recipient at the time of delivery of EQ cake biosolids or blended EQ biosolids products to the recipient. The permit holder shall provide a copy of the NMP to DCR within 30 days after bulk land application at the site has commenced.

3) After submittal of the NMP to DCR, the permittee is not required to maintain a copy of the NMP.
4) The amount of bulk EQ cake biosolids or blended EQ Biosolids distributed shall not exceed the amount required to meet the application rate established in the NMP.
5) The permittee shall instruct the recipient that the NMP must be onsite during the application of biosolids.
6) Site specific application rates shall not exceed the rates established in the NMP.

d. The permittee shall maintain records of the transaction, including:
1) The amount of EQ cake biosolids distributed, in dry tons and wet tons;
2) The amount of blended EQ biosolids products distributed, in wet tons;
3) The name of the recipient;
4) The name of the farm where the biosolids will be applied;
5) The latitude and longitude, in decimal degrees, of the delivery location;
6) The address of the farm as identified on the NMP; and
7) The date of the transaction.

e. Site Management
1) EQ cake biosolids or blended EQ biosolids shall not be land applied in the setbacks established in the NMP;
2) EQ cake biosolids or blended EQ biosolids shall not be applied in the setbacks from property lines and occupied dwellings that have been extended due to health concerns;
3) EQ cake biosolids or blended EQ biosolids shall not be applied within 200 feet from the property line of a publicly accessible site, or 400 feet from an odor sensitive receptor, such as a hospital, school or church, etc;
4) Upon delivery to an agricultural site, biosolids that will be land applied within 7 days must be staged in accordance with the staging requirements in Part I.G. below.
5) Biosolids may be stored up to 45 days from the day of delivery on an agricultural site in accordance with the on-site storage requirements in Part I.H. below.

f. Daily Notification – The permittee shall provide to DEQ-OLAP written notification each day bulk EQ cake biosolids or bulk blended EQ biosolids are distributed for land application at an agricultural site. This notification shall include:

1) Deliveries pre-scheduled for the day, including
   (a) Name of the recipient;
   (b) Name of the farm where biosolids will be delivered, as identified on the NMP;
   (c) The amount of EQ cake biosolids, or blended EQ biosolids ordered for delivery, in wet tons; and
   (d) Latitude and longitude, in decimal degrees, of the delivery location.
2) Unscheduled deliveries that occurred on the previous day, including
   (a) Name of the recipient;
   (b) Name of the farm where biosolids will be delivered, as identified on the NMP;
   (c) The amount of EQ cake biosolids, or blended EQ biosolids delivered, in wet tons; and
   (d) Latitude and longitude, in decimal degrees, of the delivery location.

g. Sign Posting
1) Upon delivery of bulk EQ cake biosolids, the permittee shall provide to the recipient a minimum of 2 signs for each field indicated in the nutrient management plan to receive EQ cake biosolids. The permittee shall instruct the recipient to post signs at the site so that they are visible and legible from the public right-of-way in both directions of travel, and conform to the specifications herein.

   Alternatively, the permittee may have a Certified Land Applicator who oversees delivery of biosolids to the site post the signs at the site in accordance with the specifications herein.

   (a) Signs shall be posted at or near the intersection of the public right-of-way and the main site access road or driveway to the site used by the biosolids transport vehicles.
   (b) If the field is located adjacent to a public right-of-way, at least one sign shall be posted along each public road frontage beside the field to which biosolids are to be land applied.
   (c) Signs shall remain in place until application has been completed at the site. From the time of posting until the land application has been completed, the farm operator shall make a good faith effort to repair any sign that has been damaged so as to render any of its required information illegible or replace any sign that has been removed from a land application site.
2) Signs shall be made of weather-resistant materials and shall be sturdily mounted so as to be capable of remaining in place and legible throughout the period that the sign is required at the site. Signs required by this section shall be temporary, nonilluminated, and four square feet or more in area, and contain at least the following information:
   (a) A statement that Exceptional Quality biosolids are being land-applied at the site;
   (b) The name of the permitted product;
   (c) The telephone number of an individual designated by the permittee to respond to inquiries; and
   (d) Contact information for DEQ, including a telephone number for inquiries.

h. Notice and Necessary Information - The permittee shall provide to the operator of the site that receives biosolids notification and information. The notification shall include at minimum:

1) A statement that biosolids land applied meet
   (a) Class A pathogen reduction; and
   (b) VAR requirements 1 through 8;
2) A statement that metals concentrations in the biosolids applied to the site were below the pollution concentration and the ceiling limit; and
3) The concentration of Nitrogen and Phosphorus in lbs/wet ton.

F. TRANSPORT

1. Transport routes should follow primary highways, shall avoid residential areas when possible, and shall comply with all Virginia Department of Transportation requirements and standards.

2. Transport vehicles shall be sufficiently sealed to prevent leakage and spillage of biosolids. For biosolids with a solids content of less than 15%, totally closed watertight transport vehicles with rigid tops shall be used to prevent spillage unless adequate justification is provided to DEQ-OLAP demonstrating that such controls are unnecessary prior to transport. DEQ-OLAP may also require certain dewatered biosolids exceeding 15% solids content to be handled as liquid Biosolids.

3. The permittee shall take appropriate steps to prevent drag-out and track-out of dirt and debris or biosolids from land application sites onto public roads. Where material is transported onto a paved or public road surface, the road surface shall be cleaned thoroughly as soon as practicable, but no later than the end of each day.

4. The permittee shall be responsible for the prompt cleanup and removal of biosolids spilled during transport. The operations manual shall include a plan for the prevention of spills during transport and for the cleanup and removal of spills. The permit holder shall ensure that its personnel, subcontractors or the drivers of vehicles transporting biosolids for land application shall be properly trained in procedures for spill removal and cleanup.

5. The permittee shall promptly report offsite spills to DEQ-OLAP, the chief executive officer or designee for the local government jurisdiction in which the spill occurred, and the owner of the facility generating the biosolids. The report shall be made verbally as soon as possible, but no later than 24 hours after the discovery of the spill. After business hours, notification may be provided by voicemail, facsimile or email.

6. A written report, which shall include a description of measures taken in response to the spill, shall be submitted by the permittee to DEQ, the chief executive officer or designee for the local government and the owner of the facility generating the biosolids within five working days of the spill. The report may be sent by first class mail, facsimile or email, or it may be hand delivered.

G. STAGING

Biosolids may be staged in preparation for commencing land application or during an ongoing application at agricultural sites. Biosolids shall be staged within the land application area of the field identified in the NMP or an adjacent field. Staging is not considered storage and shall not take the place of storage.

a. Staging of biosolids shall not commence unless the field meets the requirements for land application in accordance with Part IX of 9VAC25-32-303 and field conditions are favorable for land application.

b. Biosolids may be staged for up to seven days, including the first day biosolids are offloaded onto the staging area, with the following exceptions:

   1) In areas of Karst topography;
   2) In areas identified in the U.S. Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS) soil survey as frequently flooded; or
   3) At sites that have on-site storage.

c. If staged biosolids cannot be spread by the end of the seventh day of staging, the permittee shall ensure the following actions are taken:

   1) Biosolids shall be covered to prevent contact with precipitation;
   2) DEQ-OLAP shall be notified in writing within 24-hours of determining that the biosolids will not be spread by the end of day seven, and no later than the close of business on day seven. Notification shall include the biosolids source(s) and amounts, location of the site, and reason for staging biosolids longer than seven days; and
   3) Biosolids which have been staged for greater than seven days shall be spread or removed from the field as soon as field conditions that prohibit access to the field by loaders and spreaders no longer exist.

d. Staging shall be limited to the amount of biosolids specified in the NMP to be applied at the intended field.

e. Biosolids will be staged within the land application area of the field in which the biosolids will be applied or in a field adjacent to the subject field, in a location selected to prevent runoff to waterways and drainage ditches.

f. Biosolids shall not be staged in the setback areas identified in the NMP.

g. Biosolids shall not be staged overnight within 400 feet of an occupied dwelling unless the setback is reduced or waived with the written consent of the dwelling occupant and landowner.

h. Biosolids shall not be staged overnight within 200 feet of a property line unless the setback is reduced or waived with the written consent of the landowner.

i. Management practices, as described in the BSMP, shall be utilized as appropriate to prevent pollution of state waters by staged biosolids.

j. The certified land applier will instruct the farm operator to inspect the staged biosolids daily and after precipitation events of 0.1 inches or greater to ensure that runoff controls are in good working order. Observed excessive slumping, erosion, or movement of biosolids is to be corrected within 24 hours of observation. Any ponding at the site is to be eliminated and any malodor shall be addressed in accordance with the OCP.

k. Staged biosolids shall be managed so as to prevent adverse impacts to water quality or public health.

H. ON-SITE STORAGE

a. Biosolids may be stored for up to 45 days on a constructed surface at a location preapproved by DEQ-OLAP. These stored biosolids shall be applied only to sites under the operational control of the same owner or operator of the agricultural site where the on-site storage is located.

b. Operational requirements for on-site storage include the following:

1) The permittee shall notify DEQ-OLAP on the day of delivery whenever it is necessary to implement on-site storage. Notification shall include the amount of biosolids and the location of biosolids to be stored;
2) Storage shall be limited to the amount of biosolids specified in the NMP to be applied at sites under the operational control of the same owner or operator of the site where the on-site storage is located;
3) If malodors related to the stored biosolids are verified by DEQ-OLAP at any occupied dwelling on surrounding property(ies), the malodor shall be corrected, in accordance with the OCP, within 48 hours following DEQ's notification to the permittee, or the biosolids must be removed from the storage site;
4) All biosolids stored on the on-site storage pad shall be land applied by the 45th day, including the first day of on-site storage;
5) Best management practices shall be utilized as appropriate to prevent contact of the biosolids with storm water run on or runoff;
6) The certified land applier shall instruct the farm operator to inspect the stored biosolids at least every seven days and after precipitation events of 0.1 inch or greater to ensure that runoff controls are in good working order;
7) Observed excessive slumping, erosion, or movement of biosolids is to be corrected within 24 hours of observation. Any ponding or malodor at the storage site is to be corrected in accordance with the OCP; and
8) Storage of biosolids shall be managed so as to prevent adverse impacts to water quality or public health.

c. Construction requirements for on-site storage include the following:
1) Existing on-site storage shall comply with the requirements of this section as of September 1, 2014;
2) An on-site storage "pad" shall be constructed within a site approved for land application;
3) On-site storage shall be located to provide minimum visibility of the biosolids from adjacent properties;
4) The surface shall be constructed with sufficient strength to support operational equipment and with a maximum permeability of 10^{-7} cm/sec; and
5) In areas of Karst topography and environmentally sensitive sites, on-site storage may be prohibited or require additional restrictions.

I. OTHER SPECIAL CONDITIONS

1. Threatened and Endangered Species Protection – No person shall apply biosolids to the land if it is likely to adversely affect a threatened or endangered species listed in 4VAC15-20-130 and § 4 of the Endangered Species Act (16 USC § 1533) or if the land application is likely to adversely affect its designated critical habitat.

2. The Board will modify or, alternatively, revoke and reissue this permit as appropriate and necessary to incorporate changes to any applicable standard or requirement for the use or disposal of biosolids promulgated under Section 405(d) of the Clean Water Act, the State Water Control Law, or 9VAC 25-32-10, *et seq.*, of the Virginia Pollutant Abatement Permit Regulation.

3. All pollutant management activities covered under this permit shall maintain no point source discharge of pollutants to surface waters except in the case of a storm event greater than the 25-year, 24-hour storm. The operation of the facilities of the owner permitted herein shall not contravene the Water Quality Standards, as adopted and amended by the Board, or any provision of the Water Control Law.

4. Any and all product, materials, industrial wastes, and/or other wastes resulting from the purchase, sale, mining, extraction, transport, preparation, and/or storage of raw or intermediate materials, final product, by-product or wastes, shall be handled, disposed of, and/or stored in such a manner so as not to permit a discharge of such product, materials, industrial wastes, and/or other wastes to State waters, except as expressly authorized.

CONDITIONS APPLICABLE TO ALL VPA PERMITS

A. MONITORING.

1. Samples and measurements taken as required by this permit shall be representative of the monitored activity.
2. Monitoring shall be conducted according to procedures listed under Title 40 Code of Federal Regulations Part 136, unless other procedures have been specified in this permit.
3. The permittee shall periodically calibrate and perform maintenance procedures on all monitoring and analytical instrumentation at intervals that will insure accuracy of measurements.
4. Samples taken as required by this permit shall be analyzed in accordance with 1VAC30-45, Certification for Noncommercial Environmental Laboratories, or 1VAC30-46, Accreditation for Commercial Environmental Laboratories except for the following:
   a. Field sample testing and measurements performed at the site where the sample is taken, are not subject to the requirements of 1VAC30-45 or 1VAC30-46; and
   b. Tests, analyses, measurements or monitoring, using protocols established pursuant to §10.1-104.2 to determine soil fertility, animal manure nutrient content, or plant tissue nutrient uptake for the purposes of nutrient management.

B. RECORDS.

1. Records of monitoring information shall include:
   a. The date, exact place, and time of sampling or measurements;
   b. The name of the individual(s) who performed the sampling or measurements;
   c. The date(s) and time(s) analyses were performed;
   d. The name of the individual(s) who performed the analyses;
   e. The analytical techniques or methods used, with supporting information such as observations, readings, calculations and bench data; and
   f. The results of such analyses.
2. The permittee shall retain records:
   a. Of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for this permit, for a period of at least 3 years or in the case of activities regulated under Part IX of the Virginia Pollution Abatement Permit Regulation (9VAC25-32-10 et seq.), at least five years from the date of the sample, measurement, report or application. This period of retention may be extended by request of the Board at any time.
   b. Records related to biosolids data and information specified in agreements between generator, owner, agents, landowners and farmers shall be described and maintained for a minimum period of five years or the duration of the permit or subsequent revisions if longer than five years.

C. REPORTING MONITORING RESULTS.

1. The permittee shall submit the results of the monitoring required by this permit as specified in Part I.B. of this permit.
2. Monitoring results shall be reported on forms provided or specified by the Department.
3. If the permittee monitors any pollutant specifically addressed by this permit, at a sampling location specified in this permit, more frequently than required by this permit using test procedures approved under Title 40 of the Code of Federal Regulations Part 136 or using other test procedures approved by the U.S. Environmental Protection Agency or using procedures specified in this permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted on the reporting form specified by the Department
4. If the permittee monitors any pollutant that is not required to be monitored by this permit, at a sampling location specified in this permit, and uses test procedures approved under Title 40 of the Code of Federal Regulations Part 136 or using other test procedures approved by the U.S. Environmental Protection

Agency, or using procedures specified in this permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted on the reporting form specified by the Department.

5. Calculations for all limitations which require averaging of measurements shall utilize an arithmetic mean unless otherwise specified in this permit.

D. DUTY TO PROVIDE INFORMATION.

1. The permittee shall furnish to the Department, within a reasonable time, any information which the Board may request to determine whether cause exists for modifying, revoking and reissuing, terminating this permit, or to determine compliance with this permit. The permittee shall also furnish to the Department, upon request, copies of records required to be kept by the permittee.
2. Plans, specifications, maps, conceptual reports and other relevant information shall be submitted as requested by the Board prior to commencing construction.

E. COMPLIANCE SCHEDULE REPORTS.

Reports of compliance or noncompliance with, or any progress reports on, interim and final requirements contained in any compliance schedule of this permit shall be submitted no later than 14 days following each schedule date.

F. UNAUTHORIZED DISCHARGES.

Except in compliance with this permit, or another permit issued by the Board, it shall be unlawful for any person to:

1. Discharge into state waters sewage, industrial wastes, other wastes, or any noxious or deleterious substances; or
2. Otherwise alter the physical, chemical or biological properties of such state waters and make them detrimental to the public health, or to animal or aquatic life, or to the use of such waters for domestic or industrial consumption, or for recreation, or for other uses.

G. REPORTS OF UNAUTHORIZED DISCHARGES.

Any permittee who discharges or causes or allows a discharge of sewage, industrial waste, other wastes or any noxious or deleterious substance into or upon state waters in violation of Part II F; or who discharges or causes or allows a discharge that may reasonably be expected to enter state waters in violation of Part II F, shall notify the Department of the discharge immediately upon discovery of the discharge, but in no case later than 24 hours after said discovery. A written report of the unauthorized discharge shall be submitted to the Department, within five days of discovery of the discharge. The written report shall contain:

1. A description of the nature and location of the discharge;
2. The cause of the discharge;
3. The date on which the discharge occurred;
4. The length of time that the discharge continued;
5. The volume of the discharge;
6. If the discharge is continuing, how long it is expected to continue;
7. If the discharge is continuing, what the expected total volume of the discharge will be; and
8. Any steps planned or taken to reduce, eliminate and prevent a recurrence of the present discharge or any future discharges not authorized by this permit.

Discharges reportable to the Department under the immediate reporting requirements of other regulations are exempted from this requirement.

H. REPORTS OF UNUSUAL OR EXTRAORDINARY DISCHARGES.

If any unusual or extraordinary discharge including a bypass or upset should occur from a treatment works and the discharge enters or could be expected to enter state waters, the permittee shall promptly notify, in no case later than 24 hours, the Department by telephone after the discovery of the discharge. This notification shall provide all available details of the incident, including any adverse effects on aquatic life and the known number of fish killed. The permittee shall reduce the report to writing and shall submit it to the Department within five days of discovery of the discharge in accordance with Part II I 2. Unusual and extraordinary discharges include but are not limited to any discharge resulting from:

1. Unusual spillage of materials resulting directly or indirectly from processing operations;
2. Breakdown of processing or accessory equipment;
3. Failure or taking out of service some or all of the treatment works; and
4. Flooding or other acts of nature.

I. REPORTS OF NONCOMPLIANCE.

The permittee shall report any noncompliance which may adversely affect state waters or may endanger public health.

1. An oral report shall be provided within 24 hours from the time the permittee becomes aware of the circumstances. The following shall be included as information which shall be reported within 24 hours under this paragraph:
   a. Any unanticipated bypass; and
   b. Any upset which causes a discharge to surface waters.
2. A written report shall be submitted within 5 days and shall contain:
   a. A description of the noncompliance and its cause;
   b. The period of noncompliance, including exact dates and times, and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and
   c. Steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance.
3. The Board may waive the written report on a case-by-case basis for reports of noncompliance under Part II I if the oral report has been received within 24 hours and no adverse impact on state waters has been reported.
4. The permittee shall report all instances of noncompliance not reported under Parts II I 1 or 2, in writing, at the time the next monitoring reports are submitted. The reports shall contain the information listed in Part II I 2.

NOTE: The immediate (within 24 hours) reports required in Parts II G , H and I may be made to the Department's Central Office at (804) 698-4000 (voice) or (804) 698-4032 (fax), or online at http://www.deq.virginia.gov/programs/pollutionresponsepreparedness/makingareport.aspx. For reports outside normal working hours, leave a message and this shall fulfill the immediate reporting requirement. For emergencies, the Virginia Department of Emergency Services Management maintains a 24 hour telephone service at 1-800-468-8892.

J. NOTICE OF PLANNED CHANGES.

1. The permittee shall give notice to the Department as soon as possible of any planned physical alterations or additions to the design or operation of the pollutant management activity.
2. The permittee shall give at least 10 days advance notice to the Department of any planned changes in the permitted facility or activity which may result in noncompliance with permit requirements.

K. SIGNATORY REQUIREMENTS.

1. Applications. All permit applications shall be signed as follows:
   a. For a corporation: by a responsible corporate officer. For the purpose of this section, a responsible corporate officer means: (i) A president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy- or decision-making functions for the corporation, or (ii) the manager of one or more manufacturing, production, or operating facilities employing more than 250 persons or having gross annual sales or expenditures exceeding $25 million (in second-quarter 1980 dollars), if authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures;
   b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively; or
   c. For a municipality, state, federal, or other public agency: By either a principal executive officer or ranking elected official. For purposes of this section, a principal executive officer of a public agency includes: (i) The chief executive officer of the agency, or (ii) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency.
2. Reports, etc. All reports required by permits, and other information requested by the Board shall be signed by a person described in Part II K 1, or by a duly authorized representative of that person. A person is a duly authorized representative only if:
   a. The authorization is made in writing by a person described in Part II K 1;
   b. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity such as the position of plant manager, operator of a well or a well field, superintendent, position of equivalent responsibility. (A duly authorized representative may thus be either a named individual or any individual occupying a named position.); and
   c. The written authorization is submitted to the Department.
3. Changes to authorization. If an authorization under Part II K 2 is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of Part II K 2 shall be submitted to the Department prior to or together with any reports, or information to be signed by an authorized representative.
4. Certification. Any person signing a document under Parts II K 1 or 2 shall make the following certification:

   "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

L. DUTY TO COMPLY.

The permittee shall comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the State Water Control Law. Permit noncompliance is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or denial of a permit renewal application. Compliance with a permit during its term constitutes compliance, for purposes of enforcement, with the State Water Control Law.

M. DUTY TO REAPPLY.

If the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee shall apply for and obtain a new permit. All permittees with a currently effective permit shall submit a new application at least 180 days before the expiration date of the existing permit, unless permission for a later date has been granted by the Board. The Board shall not grant permission for applications to be submitted later than the expiration date of the existing permit.

N. EFFECT OF A PERMIT.
This permit does not convey any property rights in either real or personal property or any exclusive privileges, nor does it authorize any injury to private property or invasion of personal rights, or any infringement of federal, state or local law or regulations.

O. STATE LAW.
Nothing in this permit shall be construed to preclude the institution of any legal action under, or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any other state law or regulation or under authority preserved by Section 510 of the Clean Water Act. Except as provided in permit conditions on "bypassing" (Part II U), and "upset" (Part II V) nothing in this permit shall be construed to relieve the permittee from civil and criminal penalties for noncompliance.

P. OIL AND HAZARDOUS SUBSTANCE LIABILITY.
Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under Sections 62.1-44.34:14 through 62.1-44.34:23 of the State Water Control Law.

Q. PROPER OPERATION AND MAINTENANCE.
The permittee shall be responsible for the proper operation and maintenance of all treatment works, systems and controls which are installed or used to achieve compliance with the conditions of this permit. Proper operation and maintenance includes effective plant performance, adequate funding, adequate staffing, and adequate laboratory and process controls, including appropriate quality assurance procedures.

R. DISPOSAL OF SOLIDS OR SLUDGES.
Solids, sludges or other pollutants removed in the course of treatment or management of pollutants shall be disposed of in a manner so as to prevent any pollutant from such materials from entering state waters.

S. DUTY TO MITIGATE.
The permittee shall take all reasonable steps to minimize or prevent any pollutant management activity in violation of this permit which has a reasonable likelihood of adversely affecting human health or the environment.

T. NEED TO HALT OR REDUCE ACTIVITY NOT A DEFENSE.
It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

U. BYPASS.
1. Prohibition - Bypass means intentional diversion of waste streams from any portion of a treatment works. A bypass of the treatment works is prohibited except as provided herein.
2. Anticipated Bypass - If the permittee knows in advance of the need for a bypass, he shall notify the Department promptly at least 10 days prior to the bypass. After considering its adverse effects the Board may approve an anticipated bypass if:
   a. The bypass will be unavoidable to prevent loss of human life, personal injury, or severe property damage ("Severe Property Damage" means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production); and
   b. There are no feasible alternatives to bypass such as the use of auxiliary treatment facilities, retention of untreated waste, or maintenance during normal periods of equipment downtime. However, if bypass occurs during normal periods of equipment downtime or preventive maintenance and in the exercise of reasonable engineering judgment the permittee could have installed adequate backup equipment to prevent such bypass, this exclusion shall not apply as a defense.

3. Unplanned Bypass - If an unplanned bypass occurs, the permittee shall notify the Department as soon as possible, but in no case later than 24 hours, and shall take steps to halt the bypass as early as possible. This notification will be a condition for defense to an enforcement action that an unplanned bypass met the conditions in paragraphs U 2 a and b and in light of the information reasonably available to the permittee at the time of the bypass.

V. UPSET.

A permittee may claim an upset as an affirmative defense to an action brought for noncompliance. In any enforcement proceedings a permittee shall have the burden of proof to establish the occurrence of any upset. In order to establish an affirmative defense of upset, the permittee shall present properly signed, contemporaneous operating logs or other relevant evidence that shows:

1. That an upset occurred and that the cause can be identified;
2. That the permitted facility was at the time being operated efficiently and in compliance with proper operation and maintenance procedures;
3. That the 24-hour reporting requirements to the Department were met; and
4. That the permittee took all reasonable steps to minimize or correct any adverse impact on state waters resulting from noncompliance with the permit.

W. INSPECTION AND ENTRY.

Upon presentation of credentials, any duly authorized agent of the Board may, at reasonable times and under reasonable circumstances:

1. Enter upon any permittee's property, public or private and have access to records required by this permit;
2. Have access to, inspect and copy any records that must be kept as part of permit conditions;
3. Inspect any facility's equipment (including monitoring and control equipment) practices or operations regulated or required under the permit; and
4. Sample or monitor any substances or parameters at any locations for the purpose of assuring permit compliance or as otherwise authorized by the State Water Control Law.

For purposes of this section, the time for inspection shall be deemed reasonable during regular business hours, and whenever the facility is involved in managing pollutants. Nothing contained herein shall make an inspection unreasonable during an emergency.

X. PERMIT ACTIONS.

Permits may be modified, revoked and reissued, or terminated for cause upon the request of the permittee or interested persons, or upon the Board's initiative, to reflect the requirements of any changes in the statutes or regulations. If a permittee files a request for a permit modification, revocation, or termination, or files a notification of planned changes, or anticipated noncompliance, the permit terms and conditions shall remain effective until the request is acted upon by the Board. This provision shall not be used to extend the expiration date of the effective VPA permit.

Y. TRANSFER OF PERMITS.

1. Permits are not transferable to any person except after notice to the Department. The Board may require modification or revocation and reissuance of the permit to change the name of the permittee and to incorporate such other requirements as may be necessary. Except as provided in Part II Y 2, a permit may be transferred by the permittee to a new owner or operator only if the permit has been modified to reflect the transfer or has been revoked and reissued to the new owner or operator.
2. As an alternative to transfers under Part II Y 1, this permit shall be automatically transferred to a new permittee if:
   a. The current permittee notifies the Department at least 30 days in advance of the proposed transfer of the title to the facility or property;
   b. The notice includes a written agreement between the existing and new permittees containing a specific date for transfer of permit responsibility, coverage, and liability between them; and

c. The Board does not, within the 30-day time period, notify the existing permittee and the proposed new permittee of its intent to modify or revoke and reissue the permit. If this notice is not received, the transfer is effective on the date specified in the agreement mentioned in Part II.Y.2.b.

Z. SEVERABILITY.

The provisions of this permit are severable, and if any provision of this permit or the application of any provision of this permit to any circumstance is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

Appendix B Product Analyses for DC Water Biosolids

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

TEL: 831-724-5422
FAX: 831-724-3188
www.compostlab.com

"Fresh Bloom" Soil Analysis

Account #: 9060695-1/3-8679
Group: Jun19C #46
Reporting Date: July 8, 2019

DC Water & Sewer Authority
5000 Overlook Avenue, SW
Washington, DC 20032
Attn: James Fotouhi

Date Received: 19 Jun. 19
Sample Identification: BLM-Fresh
Sample ID #: 9060695 - 1/3

Nutrients	Dry wt.	As Rcvd.	units
Total Nitrogen:	4.8	1.4	%
Ammonia (NH_4-N):	4100	1200	mg/kg
Nitrate (NO_3-N):	< 1.0	< 0.3	mg/kg
Org. Nitrogen (Org.-N):	4.4	1.3	%
Phosphorus (as P_2O_5):	6.8	2.0	%
Phosphorus (P):	30000	8600	mg/kg
Potassium (as K_2O):	0.11	0.033	%
Potassium (K):	950	270	mg/kg
Calcium (Ca):	2.4	0.68	%
Magnesium (Mg):	0.32	0.092	%
Sulfate (SO_4-S):	460	130	mg/kg
Boron (Total B):	5.0	1.4	mg/kg
Moisture:	0	71.3	%
Sodium (Na):	0.042	0.012	%
Chloride (Cl):	0.048	0.014	%
pH Value:	NA	8.43	unit
Bulk Density :	14	50	lb/cu ft
Carbonates ($CaCO_3$):	28	8.0	lb/ton
Conductivity (EC5):	4.7	NA	mmhos/cm
Organic Matter:	63.6	18.3	%
Organic Carbon:	33.0	9.6	%
Ash:	36.4	10.4	%
C/N Ratio	7.0	7.0	ratio
AgIndex	> 10	> 10	ratio

Stability Indicator:

CO2 Evolution	Respirometery
mg CO_2-C/g OM/day	6.5
mg CO_2-C/g TS/day	4.1
Stability Rating	*moderately unstable*

Maturity Indicator: Cucumber Bioassay

Compost:Vermiculite (v:v)	1:2
Emergence (%)	93
Seedling Vigor (%)	68
Description of Plants	*stunted*

Pathogens	Results	Units	Rating
Fecal Coliform	< 7.5	MPN/g	*pass*
Salmonella	< 3	MPN/4g	*pass*

Date Tested: 19 Jun. 19

Physical Contaminants**	% by weight
Total Plastic	< 0.1
Film Plastic	< 0.1
Glass	< 0.1
Metal	< 0.1
Sharps	ND
Total	< 0.5

Metals	Dry wt.	EPA Limit	units
Aluminum (Al):	4000	-	mg/kg
Arsenic (As):	4.4	41	mg/kg
Cadmium (Cd):	1.2	39	mg/kg
Chromium (Cr):	64	-	mg/kg
Cobalt (Co)	7.6	-	mg/kg
Copper (Cu):	440	1500	mg/kg
Iron (Fe):	87000	-	mg/kg
Lead (Pb):	33	300	mg/kg
Manganese (Mn):	530	-	mg/kg
Mercury (Hg):	< 1.0	17	mg/kg
Molybdenum (Mo):	13	75	mg/kg
Nickel (Ni):	26	420	mg/kg
Selenium (Se):	4.1	100	mg/kg
Zinc (Zn):	780	2800	mg/kg

Size Distribution

MM	% by weight
> 50	0.0
25 to 50	0.0
16 to 25	8.4
9.5 to 16	35.3
6.3 to 9.5	17.5
4.0 to 6.3	12.8
2.0 to 4.0	14.0
< 2.0	12.0

**Greater than 4mm in size (Sharps greater than 2mm)

Analyst: Assaf Sadeh

*Sample was received and handled in accordance with TMECC procedures.

Account No.:		Date Received	19 Jun. 19
9060695 - 1/3 - 8679		Sample i.d.	BLM-Fresh
Group:	Jun19C No. 46	Sample I.d. No.	1/3 9060695

INTERPRETATION: "Fresh Bloom" Soil Analysis

Is Your Compost Stable?

Respiration Rate Biodegradation Rate of Your Pile

6.5 mg CO2-C/ g OM/day

++++++++++++++++++++++++++
< Stable >|<Moderately Unstable>|< Unstable >|< High For Mulch

Is Your Compost Mature?

AmmoniaN/NitrateN ratio

37000 Ratio

++
VeryMature>|< Mature >|< Immature

Ammonia N ppm

4100 mg/kg dry wt.

++
VeryMature>|< Mature >|< Immature

Nitrate N ppm

< 1.0 mg/kg dry wt.

+
< Immature >|< Mature

pH value

8.43 units

++
< Immature >|< Mature >|< Immature

Cucumber Emergence

93.3 percent

++
< Immature >|< Mature

Is Your Compost Safe Regarding Health?

Fecal Coliform

< 1000 MPN/g dry wt.

+++++++
< Safe >|< High Fecal Coliform

Salmonella

Less than 3 /4g dry wt.

+++++++
<Safe (none detected) >|< High Salmonella Count(> 3 per 4 grams)

Metals US EPA 503

Pass dry wt.

+++++++++
<All Metals Pass >|< One or more Metals Fail

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)

11.7 Percent dry wt.

++
<Low >|< Average >|< High Nutrient Content

AgIndex (Nutrients / Sodium and Chloride Salts) ((N+P2O5+K2O) / (Na + Cl))

15 Ratio

++
Na & Cl >|< Nutrient and Sodium and Chloride Provider >|< Nutrient Provider

Plant Available Nitrogen (PAN) Estimated release for first season

5 lbs/ton wet wt.

++++++++++++++++++++
Low Nitrogen Provider>|< Average Nitrogen Provider >|<High Nitrogen Provider

C/N Ratio

7.0 Ratio

++++++++++++++
< Nitrogen Release >|< N-Neutral >|< N-Demand>|< High Nitrogen Demand

Soluble Available Nutrients & Salts (EC5 w/w dw)

4.7 mmhos/cm dry wt.

++++++++++++++++++++++++++
SloRelease>|< Average Nutrient Release Rate >|<High Available Nutrients

Lime Content (CaCO3)

28 Lbs/ton dry wt.

++
< Low >|< Average >|< High Lime Content (as CaCO3)

What are the physical properties of your compost?

Percent Ash

36.4 Percent dry wt.

++++++++++++++++++++++++++++++
< High Organic Matter >|< Average >|< High Ash Content

Sieve Size % > 6.3 MM (0.25")

61.1 Percent dry wt.

++
All Uses >|< Size May Restrict Uses for Potting mix and Golf Courses

Account No.:		Date Received	19 Jun. 19
9060695 - 1/3 - 8679		Sample i.d.	BLM-Fresh
Group:	Jun19C No. 46	Sample I.d. No.	1/3 9060695

INTERPRETATION: "Fresh Bloom" Soil Analysis

Is Your Compost Stable?

Respiration Rate

6.5 Moderate-selected use mg CO2-C/g OM/day

The respiration rate is a measurement of the biodegradation rate of the organic matter in the sample (as received). The respiration rate is determined by measuring the rate at which CO2 is released under optimized moisture and temperature conditions.

Is Your Compost Mature?

AmmoniaN:NitrateN ratio

37000 immature

Ammonia N ppm

4100 immature

Nitrate N ppm

< 1.0 immature

pH value

8.43 immature

Composting to stabilize carbon can occur at such a rapid rate that sometimes phytotoxins remain in the compost and must be neutralized before using in high concentrations or in high-end uses. This step is called curing. Typically ammonia is in excess with the break-down of organic materials resulting in an increase in pH. This combination results in a loss of volatile ammonia (it smells). Once this toxic ammonia has been reduced and the pH drops, the microbes convert the ammonia to nitrates. A low ammonia + high nitrate score is indicative of a mature compost, however there are many exceptions. For example, a compost with a low pH (<7) will retain ammonia, while a compost with high lime content can lose ammonia before the organic fraction becomes stable. Composts must first be stable before curing indicators apply.

Cucumber Bioassay

93.3 Percent

Cucumbers are chosen for this test because they are salt tolerant and very sensitive to ammonia and organic acid toxicity. Therefore, we can germinate seeds in high concentrations of compost to measure phytotoxic effects without soluble salts being the limiting factor. Values above 80% for both percent emergence and vigor are indicative of a well-cured compost. Exceptions include very high salts that affect the cucumbers, excessive concentrations of nitrates and other nutrients that will be in range when formulated to make a growing media.

Is Your Compost Safe Regarding Health?

Fecal Coliform

< 1000 / g dry wt.

Fecal coliforms can survive in both aerobic and anaerobic conditions and is common in all initial compost piles. Most human pathogens occur from fecal matter and all fecal matter is loaded in fecal coliforms. Therefore fecal coliforms are used as an indicator to determine if the chosen method for pathogen reduction (heat for compost) has met the requirements of sufficient temperature, time and mixing. If the fecal coliforms are reduced to below 1000 per gram dry wt. it is assumed all others pathogens are eliminated. Potential problems are that fecal coliform can regrow during the curing phase or during shipping. This is because the conditions are now more favorable for growth than during the composting process.

Salmonella Bacteria

Less than 3 3 / 4g dry wt.

Salmonella is not only another indicator organism but also a toxic microbe. It has been used in the case of biosolids industry to determine adequate pathogen reduction.

Metals

Pass

The ten heavy metals listed in the EPA 503 regulations are chosen to determine if compost can be applied to ag land and handled without toxic effects. Most high concentrations of heavy metals are derived from woodwaste feedstock such as chrome-arsenic treated or lead painted demolition wood. Biosolids are rarely a problem.

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)

11.7 High nutrient content

This value is the sum of the primary nutrients Nitrogen, Phosphorus and Potassium. Reported units are consistent with those found on fertilizer formulations. A sum greater than 5 is indicative of a compost with high nutrient content, and best used to supply nutrients to a receiving soil. A sum below 2 indicates low nutrient content, and is best-used to improve soil structure via the addition of organic matter. Most compost falls between 2 and 5.

Account No.:		Date Received	19 Jun. 19
9060695 - 1/3 - 8679		Sample i.d.	BLM-Fresh
Group:	Jun19C No. 46	Sample I.d. No.	1/3 9060695

INTERPRETATION: "Fresh Bloom" Soil Analysis

AgIndex (Nutrients/Na+Cl)

15 High nutrient ratio Composts with low AgIndex values have high concentrations of sodium and/or chloride compared to nutrients. Repeated use of a compost with a low AgIndex (< 2) may result in sodium and/or chloride acting as the limiting factor compared to nutrients, governing application rates. These composts may be used on well-draining soils and/or with salt-tolerant plants. Additional nutrients form another source may be needed if the application rate is limited by sodium or chloride. If the AgIndex is above 10, nutrients optimal for plant growth will be available without concern of sodium and/or chloride toxicity. Composts with an AgIndex of above 10 are good for increasing nutrient levels for all soils. Most composts score between 2 and 10. Concentrations of nutrients, sodium, and chloride in the receiving soil should be considered when determining compost application rates. The AgIndex is a product of feedstock quality. Feedstock from dairy manure, marine waste, industrial wastes, and halophytic plants are likely to produce a finished compost with a low AgIndex.

Plant Available Nitrogen (lbs/ton)

5 Low N Provider Plant Available Nitrogen (PAN) is calculated by estimating the release rate of Nitrogen from the organic fraction of the compost. This estimate is based on the respiration rate, ammonia, and nitrate values. Despite the PAN value of the compost, additional sources of Nitrogen may be needed during he growing season to offset the Nitrogen demand of the microbes present in the compost. With ample nutrients these microbes can further breakdown organic matter in the compost and release bound Nitrogen. Nitrogen demand based on a high C/N ratio is not considered in the PAN calculation because additional Nitrogen should always be supplemented to the receiving soil when composts with a high C/N ratio are applied.

C/N Ratio

7.0 Indicates maturity As a guiding principal, a C/N ratio below 14 indicates maturity and above 14 indicates immaturity, however, there are many exceptions. Large woodchips (>6.3mm), bark, and redwood are slow to breakdown and therefore can result in a relatively stable product while the C/N ratio value is high. Additionally, some composts with chicken manure and/or green grass feedstocks can start with a C/N ratio below 15 and are very unstable. A C/N ratio below 10 supplies Nitrogen, while a ratio above 20 can deplete Nitrogen from the soil. The rate at which Nitrogen will be released or used by the microbes is indicated by the respiration rate. If the respiration rate is too high the transfer of Nitrogen will not be controlable.

Soluble Nutrients & Salts (EC5 w/w dw - mmhos/cm)

4.7 Average salts This value refers to all soluble ions including nutrients, sodium, chloride and some soluble organic compounds. The concentration of salts will change due to the release of salts from the organic matter as it degrades, volatilization of ammonia, decomposition of soluble organics, and conversion of molecular structure. High salts + high AgIndex is indicative of a compost high in readily available nutrients. The application rate of these composts should be limited by the optimum nutrient value based on soil analysis of the receiving soil. High Salts + low AgIndex is indicative of a compost low in nutrients with high concentrations of sodium and/or chloride. Limit the application rate according to the toxicity level of thesodium and/or chloride. Low salts indicates that the compost can be applied without risking salt toxicity, is likely a good source of organic matter, and that nutrients will release slowly over time.

Lime Content (lbs. per ton)

28 High lime content Compost high in lime or carbonates are often those produced from chicken manure (layers) ash materials, and lime products. These are excellent products to use on a receiving soil where lime has been recommended by soil analysis to raise the pH. Composts with a high lime content should be closely considered for pH requirements when formulating potting mixes.

Physical Properties

Percent Ash

36.4 Average ash content Ash is the non-organic fraction of a compost. Most composts contain approximately 50% ash (dry weight basis). Compost can be high in ash content for many reasons including: excess minerilzation(old compost), contamination with soil base material during turning, poor quality feedstock, and soil or mineral products added. Finding the source and reducing high ash content is often the fastest means to increasing nutrient quality of a compost.

Particle Size % > 6.3 MM (0.25")

61.1 May restrict use Large particles may restrict use for potting soils, golf course topdressings, seed-starter mixes, and where a fine size distribution is required. Composts with large particles can still be used as excellent additions to field soils, shrub mixes and mulches.

Appendix:

Plant Available Nitrogen (PAN) calculations:

PAN = (X * (organic N)) + ((NH4-N) + (NO3-N))

X value = If RR < 2 then X = 0.1
If RR =2.1 to 5 then X = 0.2
If RR =5.1 to 10 then X = 0.3
If RR > 10 then X = 0.4

Note: If C/N ratio > 15 additional N should be applied.
RR = Respiration rate

Estimated available nutrients for use when calculating application rates

	lbs/ton (As Rcvd.)
Plant Available Nitrogen (PAN)	5.0
Ammonia (NH4-N)	2.40
Nitrate (NO3-N)	0.00
Available Phosphorus (P2O5*0.64)	25.0
Available Potassium (K2O)	0.7

ANALYTICAL CHEMISTS
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"Cured Bloom" Soil Analysis

Account #: 9050879-1/2-8679
Group: May19E #8
Reporting Date: June 8, 2019

DC Water & Sewer Authority
5000 Overlook Avenue, SW
Washington, DC 20032
Attn: James Fotouhi

Date Received: 30 May. 19
Sample Identification: BLM-Wnd1-BF-89d-flip+8
Sample ID #: 9050879 - 1/2

Nutrients	Dry wt.	As Rcvd.	units
Total Nitrogen:	3.9	2.8	%
Ammonia (NH_4-N):	350	250	mg/kg
Nitrate (NO_3-N):	360	260	mg/kg
Org. Nitrogen (Org.-N):	3.8	2.7	%
Phosphorus (as P_2O_5):	8.2	5.9	%
Phosphorus (P):	36000	26000	mg/kg
Potassium (as K_2O):	0.11	0.080	%
Potassium (K):	930	670	mg/kg
Calcium (Ca):	3.1	2.2	%
Magnesium (Mg):	0.39	0.28	%
Sulfate (SO_4-S):	1300	910	mg/kg
Boron (Total B):	12	8.3	mg/kg
Moisture:	0	28.1	%
Sodium (Na):	0.042	0.030	%
Chloride (Cl):	0.018	0.013	%
pH Value:	NA	6.11	unit
Bulk Density :	35	49	lb/cu ft
Carbonates ($CaCO_3$):	9.0	6.4	lb/ton
Conductivity (EC5):	3.3	NA	mmhos/cm
Organic Matter:	52.5	37.8	%
Organic Carbon:	28.0	20.0	%
Ash:	47.5	34.1	%
C/N Ratio	7.3	7.3	ratio
AgIndex	> 10	> 10	ratio

Stability Indicator:	
CO2 Evolution	Respirometery
mg CO_2-C/g OM/day	2.8
mg CO_2-C/g TS/day	1.4
Stability Rating	*stable*

Maturity Indicator: Cucumber Bioassay	
Compost:Vermiculite (v:v)	1:2
Emergence (%)	93
Seedling Vigor (%)	88
Description of Plants	*healthy*

Pathogens	Results	Units	Rating
Fecal Coliform	25	MPN/g	*pass*
Salmonella	< 3	MPN/4g	*pass*

Date Tested: 30 May. 19

Physical Contaminants**	% by weight
Total Plastic	< 0.1
Film Plastic	< 0.1
Glass	< 0.1
Metal	< 0.1
Sharps	ND
Total	< 0.5

Metals	Dry wt.	EPA Limit	units
Aluminum (Al):	5100	-	mg/kg
Arsenic (As):	6.5	41	mg/kg
Cadmium (Cd):	1.6	39	mg/kg
Chromium (Cr):	78	-	mg/kg
Cobalt (Co)	6.8	-	mg/kg
Copper (Cu):	450	1500	mg/kg
Iron (Fe):	100000	-	mg/kg
Lead (Pb):	33	300	mg/kg
Manganese (Mn):	600	-	mg/kg
Mercury (Hg):	< 1.0	17	mg/kg
Molybdenum (Mo):	15	75	mg/kg
Nickel (Ni):	28	420	mg/kg
Selenium (Se):	4.6	100	mg/kg
Zinc (Zn):	790	2800	mg/kg

Size Distribution	
MM	% by weight
> 50	0.0
25 to 50	0.0
16 to 25	2.9
9.5 to 16	6.9
6.3 to 9.5	10.3
4.0 to 6.3	25.0
2.0 to 4.0	27.3
< 2.0	27.6

**Greater than 4mm in size (Sharps greater than 2mm)

Analyst: Assaf Sadeh

*Sample was received and handled in accordance with TMECC procedures.

Account No.: Date Received 30 May. 19
9050879 - 1/2 - 8679 Sample i.d. BLM-Wnd1-BF-89d-flip+8
Group: May19E No. 8 Sample I.d. No. 1/2 9050879

INTERPRETATION: "Cured Bloom" Soil Analysis Page one of three

Is Your Compost Stable?

Respiration Rate Biodegradation Rate of Your Pile
2.8 mg CO2-C/ g OM/day
+++++++++++
< Stable >|<Moderately Unstable>|< Unstable >|< High For Mulch

Is Your Compost Mature?

AmmoniaN/NitrateN ratio
0.97 Ratio
+++++++++++++++++++
VeryMature>|< Mature >|< Immature

Ammonia N ppm
350 mg/kg dry wt.
++
VeryMature>|< Mature >|< Immature

Nitrate N ppm
360 mg/kg dry wt.
+++
< Immature >|< Mature

pH value
6.11 units
+++
< Immature >|< Mature >|< Immature

Cucumber Emergence
93.3 percent
++
< Immature >|< Mature

Is Your Compost Safe Regarding Health?

Fecal Coliform
< 1000 MPN/g dry wt.
+++++++
< Safe >|< High Fecal Coliform

Salmonella
Less than 3 /4g dry wt.
+++++++
<Safe (none detected) >|< High Salmonella Count(> 3 per 4 grams)

Metals US EPA 503
Pass dry wt.
+++++++++
<All Metals Pass >|< One or more Metals Fail

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)
12.2 Percent dry wt.
+++
<Low >|< Average >|< High Nutrient Content

AgIndex (Nutrients / Sodium and Chloride Salts) ((N+P2O5+K2O) / (Na + Cl))
15 Ratio
++
Na & Cl >|< Nutrient and Sodium and Chloride Provider >|< Nutrient Provider

Plant Available Nitrogen (PAN) Estimated release for first season
7 lbs/ton wet wt.
+++++++++++++++++++++++++
Low Nitrogen Provider>|< Average Nitrogen Provider >|<High Nitrogen Provider

C/N Ratio
7.3 Ratio
++++++++++++++
< Nitrogen Release >|< N-Neutral >|< N-Demand>|< High Nitrogen Demand

Soluble Available Nutrients & Salts (EC5 w/w dw)
3.3 mmhos/cm dry wt.
+++++++++++++++++
SloRelease>|< Average Nutrient Release Rate >|<High Available Nutrients

Lime Content (CaCO3)
9.0 Lbs/ton dry wt.
++++++++++++++
< Low >|< Average >|< High Lime Content (as CaCO3)

What are the physical properties of your compost?

Percent Ash
47.5 Percent dry wt.
++++++++++++++++++++++++++++++++++++++
< High Organic Matter >|< Average >|< High Ash Content

Sieve Size % > 6.3 MM (0.25")
20.2 Percent dry wt.
+++
All Uses >|< Size May Restrict Uses for Potting mix and Golf Courses

Account No.:		Date Received	30 May. 19
9050879 - 1/2 - 8679		Sample i.d.	BLM-Wnd1-BF-89d-flip+8
Group:	May19E No. 8	Sample I.d. No.	1/2 9050879

INTERPRETATION: "Cured Bloom" Soil Analysis

Is Your Compost Stable?

Respiration Rate

2.8 Low: Good for all uses mg CO2-C/g OM/day

The respiration rate is a measurement of the biodegradation rate of the organic matter in the sample (as received). The respiration rate is determined by measuring the rate at which CO2 is released under optimized moisture and temperature conditions.

Is Your Compost Mature?

AmmoniaN:NitrateN ratio

0.97 mature

Ammonia N ppm

350 mature

Nitrate N ppm

360 mature

pH value

6.11 immature

Composting to stabilize carbon can occur at such a rapid rate that sometimes phytotoxins remain in the compost and must be neutralized before using in high concentrations or in high-end uses. This step is called curing. Typically ammonia is in excess with the break-down of organic materials resulting in an increase in pH. This combination results in a loss of volatile ammonia (it smells). Once this toxic ammonia has been reduced and the pH drops, the microbes convert the ammonia to nitrates. A low ammonia + high nitrate score is indicative of a mature compost, however there are many exceptions. For example, a compost with a low pH (<7) will retain ammonia, while a compost with high lime content can lose ammonia before the organic fraction becomes stable. Composts must first be stable before curing indicators apply.

Cucumber Bioassay

93.3 Percent

Cucumbers are chosen for this test because they are salt tolerant and very sensitive to ammonia and organic acid toxicity. Therefore, we can germinate seeds in high concentrations of compost to measure phytotoxic effects without soluble salts being the limiting factor. Values above 80% for both percent emergence and vigor are indicative of a well-cured compost. Exceptions include very high salts that affect the cucumbers, excessive concentrations of nitrates and other nutrients that will be in range when formulated to make a growing media.

Is Your Compost Safe Regarding Health?

Fecal Coliform

< 1000 / g dry wt.

Fecal coliforms can survive in both aerobic and anaerobic conditions and is common in all initial compost piles. Most human pathogens occur from fecal matter and all fecal matter is loaded in fecal coliforms. Therefore fecal coliforms are used as an indicator to determine if the chosen method for pathogen reduction (heat for compost) has met the requirements of sufficient temperature, time and mixing. If the fecal coliforms are reduced to below 1000 per gram dry wt. it is assumed all others pathogens are eliminated. Potential problems are that fecal coliform can regrow during the curing phase or during shipping. This is because the conditions are now more favorable for growth than during the composting process.

Salmonella Bacteria

Less than 3 3 / 4g dry wt.

Salmonella is not only another indicator organism but also a toxic microbe. It has been used in the case of biosolids industry to determine adequate pathogen reduction.

Metals

Pass

The ten heavy metals listed in the EPA 503 regulations are chosen to determine if compost can be applied to ag land and handled without toxic effects. Most high concentrations of heavy metals are derived from woodwaste feedstock such as chrome-arsenic treated or lead painted demolition wood. Biosolids are rarely a problem.

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)

12.2 High nutrient content

This value is the sum of the primary nutrients Nitrogen, Phosphorus and Potassium. Reported units are consistent with those found on fertilizer formulations. A sum greater than 5 is indicative of a compost with high nutrient content, and best used to supply nutrients to a receiving soil. A sum below 2 indicates low nutrient content, and is best-used to improve soil structure via the addition of organic matter. Most compost falls between 2 and 5.

Account No.:		Date Received	30 May. 19
9050879 - 1/2 - 8679		Sample i.d.	BLM-Wnd1-BF-89d-flip+8
Group:	May19E No. 8	Sample I.d. No.	1/2 9050879

INTERPRETATION: "Cured Bloom" Soil Analysis

AgIndex (Nutrients/Na+Cl)

15 High nutrient ratio Composts with low AgIndex values have high concentrations of sodium and/or chloride compared to nutrients. Repeated use of a compost with a low AgIndex (< 2) may result in sodium and/or chloride acting as the limiting factor compared to nutrients, governing application rates. These composts may be used on well-draining soils and/or with salt-tolerant plants. Additional nutrients form another source may be needed if the application rate is limited by sodium or chloride. If the AgIndex is above 10, nutrients optimal for plant growth will be available without concern of sodium and/or chloride toxicity. Composts with an AgIndex of above 10 are good for increasing nutrient levels for all soils. Most composts score between 2 and 10. Concentrations of nutrients, sodium, and chloride in the receiving soil should be considered when determining compost application rates. The AgIndex is a product of feedstock quality. Feedstock from dairy manure, marine waste, industrial wastes, and halophytic plants are likely to produce a finished compost with a low AgIndex.

Plant Available Nitrogen (lbs/ton)

7 Average N Provider Plant Available Nitrogen (PAN) is calculated by estimating the release rate of Nitrogen from the organic fraction of the compost. This estimate is based on the respiration rate, ammonia, and nitrate values. Despite the PAN value of the compost, additional sources of Nitrogen may be needed during he growing season to offset the Nitrogen demand of the microbes present in the compost. With ample nutrients these microbes can further breakdown organic matter in the compost and release bound Nitrogen. Nitrogen demand based on a high C/N ratio is not considered in the PAN calculation because additional Nitrogen should always be supplemented to the receiving soil when composts with a high C/N ratio are applied.

C/N Ratio

7.3 Indicates maturity As a guiding principal, a C/N ratio below 14 indicates maturity and above 14 indicates immaturity, however, there are many exceptions. Large woodchips (>6.3mm), bark, and redwood are slow to breakdown and therefore can result in a relatively stable product while the C/N ratio value is high. Additionally, some composts with chicken manure and/or green grass feedstocks can start with a C/N ratio below 15 and are very unstable. A C/N ratio below 10 supplies Nitrogen, while a ratio above 20 can deplete Nitrogen from the soil. The rate at which Nitrogen will be released or used by the microbes is indicated by the respiration rate. If the respiration rate is too high the transfer of Nitrogen will not be controlable.

Soluble Nutrients & Salts (EC5 w/w dw - mmhos/cm)

3.3 Average salts This value refers to all soluble ions including nutrients, sodium, chloride and some soluble organic compounds. The concentration of salts will change due to the release of salts from the organic matter as it degrades, volatilization of ammonia, decomposition of soluble organics, and conversion of molecular structure. High salts + high AgIndex is indicative of a compost high in readily available nutrients. The application rate of these composts should be limited by the optimum nutrient value based on soil analysis of the receiving soil. High Salts + low AgIndex is indicative of a compost low in nutrients with high concentrations of sodium and/or chloride. Limit the application rate according to the toxicity level of thesodium and/or chloride. Low salts indicates that the compost can be applied without risking salt toxicity, is likely a good source of organic matter, and that nutrients will release slowly over time.

Lime Content (lbs. per ton)

9.0 Average lime content Compost high in lime or carbonates are often those produced from chicken manure (layers) ash materials, and lime products. These are excellent products to use on a receiving soil where lime has been recommended by soil analysis to raise the pH. Composts with a high lime content should be closely considered for pH requirements when formulating potting mixes.

Physical Properties

Percent Ash

47.5 Average ash content Ash is the non-organic fraction of a compost. Most composts contain approximately 50% ash (dry weight basis). Compost can be high in ash content for many reasons including: excess minerilzation(old compost), contamination with soil base material during turning, poor quality feedstock, and soil or mineral products added. Finding the source and reducing high ash content is often the fastest means to increasing nutrient quality of a compost.

Particle Size % > 6.3 MM (0.25")

20.2 May restrict use Large particles may restrict use for potting soils, golf course topdressings, seed-starter mixes, and where a fine size distribution is required. Composts with large particles can still be used as excellent additions to field soils, shrub mixes and mulches.

Appendix:

Plant Available Nitrogen (PAN) calculations:

PAN = (X * (organic N)) + ((NH4-N) + (NO3-N))

X value = If RR < 2 then X = 0.1
If RR =2.1 to 5 then X = 0.2
If RR =5.1 to 10 then X = 0.3
If RR > 10 then X = 0.4

Note: If C/N ratio > 15 additional N should be applied.
RR = Respiration rate

Estimated available nutrients for use when calculating application rates

	lbs/ton (As Rcvd.)
Plant Available Nitrogen (PAN)	6.5
Ammonia (NH4-N)	0.50
Nitrate (NO3-N)	0.52
Available Phosphorus (P2O5*0.64)	75.6
Available Potassium (K2O)	1.6

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"Woody Blend" Soil Analysis

Account #: 9010135-1/2-8679
Group: Jan19B #16
Reporting Date: January 24, 2019

DC Water & Sewer Authority
5000 Overlook Avenue, SW
Washington, DC 20032
Attn: Bill Brower

Date Received: 08 Jan. 19
Sample Identification: FBLM: Fines (GCM) 3:7 V-1
Sample ID #: 9010135 - 1/2

Nutrients	Dry wt.	As Rcvd.	units
Total Nitrogen:	2.1	1.0	%
Ammonia (NH_4-N):	2300	1100	mg/kg
Nitrate (NO_3-N):	53	26	mg/kg
Org. Nitrogen (Org.-N):	1.9	0.92	%
Phosphorus (as P_2O_5):	2.3	1.1	%
Phosphorus (P):	10000	4900	mg/kg
Potassium (as K_2O):	0.30	0.15	%
Potassium (K):	2500	1200	mg/kg
Calcium (Ca):	1.9	0.91	%
Magnesium (Mg):	0.34	0.16	%
Sulfate (SO_4-S):	1900	910	mg/kg
Boron (Total B):	9.3	4.5	mg/kg
Moisture:	0	51.8	%
Sodium (Na):	0.028	0.013	%
Chloride (Cl):	0.026	0.013	%
pH Value:	NA	7.94	unit
Bulk Density :	17	36	lb/cu ft
Carbonates ($CaCO_3$):	15	7.3	lb/ton
Conductivity (EC5):	5.3	NA	mmhos/cm
Organic Matter:	60.9	29.3	%
Organic Carbon:	29.0	14.0	%
Ash:	39.1	18.8	%
C/N Ratio	14	14	ratio
AgIndex	> 10	> 10	ratio

Stability Indicator:

CO2 Evolution	Respirometery
mg CO_2-C/g OM/day	3.0
mg CO_2-C/g TS/day	1.8
Stability Rating	*stable*

Maturity Indicator: Cucumber Bioassay

Compost:Vermiculite (v:v)	1:2
Emergence (%)	100
Seedling Vigor (%)	51
Description of Plants	*stunted*

Pathogens	Results	Units	Rating
Fecal Coliform	9.3	MPN/g	*pass*
Salmonella	< 3	MPN/4g	*pass*

Date Tested: 08 Jan. 19

Physical Contaminants**	% by weight
Total Plastic	< 0.1
Film Plastic	< 0.1
Glass	< 0.1
Metal	< 0.1
Sharps	ND
Total	< 0.5

Metals	Dry wt.	EPA Limit	units
Aluminum (Al):	5800	-	mg/kg
Arsenic (As):	3.9	41	mg/kg
Cadmium (Cd):	< 1.0	39	mg/kg
Chromium (Cr):	45	-	mg/kg
Cobalt (Co)	6.4	-	mg/kg
Copper (Cu):	180	1500	mg/kg
Iron (Fe):	36000	-	mg/kg
Lead (Pb):	20	300	mg/kg
Manganese (Mn):	380	-	mg/kg
Mercury (Hg):	< 1.0	17	mg/kg
Molybdenum (Mo):	6.8	75	mg/kg
Nickel (Ni):	23	420	mg/kg
Selenium (Se):	1.9	100	mg/kg
Zinc (Zn):	320	2800	mg/kg

Size Distribution

MM	% by weight
> 50	0.0
25 to 50	0.0
16 to 25	0.0
9.5 to 16	0.0
6.3 to 9.5	3.0
4.0 to 6.3	6.9
2.0 to 4.0	18.8
< 2.0	71.4

**Greater than 4mm in size (Sharps greater than 2mm)

Analyst: Assaf Sadeh

*Sample was received and handled in accordance with TMECC procedures.

Account No.:		Date Received	08 Jan. 19
9010135 - 1/2 - 8679		Sample i.d.	FBLM: Fines (GCM) 3:7 V-1
Group:	Jan19B No. 16	Sample I.d. No.	1/2 9010135

INTERPRETATION: "Woody Blend" Soil Analysis

Is Your Compost Stable?

Respiration Rate — Biodegradation Rate of Your Pile

3.0 mg CO2-C/ g OM/day

```
++++++++++++
< Stable          >|<Moderately Unstable>|<          Unstable          >|< High For Mulch
```

Is Your Compost Mature?

AmmoniaN/NitrateN ratio

43 Ratio

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
VeryMature>|<          Mature                          >|<   Immature
```

Ammonia N ppm

2300 mg/kg dry wt.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
VeryMature>|<          Mature                          >|<   Immature
```

Nitrate N ppm

53 mg/kg dry wt.

```
++++++++++++++++++++++++++++++++++++++++++++
<   Immature                          >|<  Mature
```

pH value

7.94 units

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
<   Immature                                          >|< Mature        >|< Immature
```

Cucumber Emergence

100.0 percent

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
<   Immature                                                                  >|< Mature
```

Is Your Compost Safe Regarding Health?

Fecal Coliform

< 1000 MPN/g dry wt.

```
+++++++
<  Safe                                                  >|< High Fecal Coliform
```

Salmonella

Less than 3 /4g dry wt.

```
+++++++
<Safe   (none detected)                    >|< High Salmonella Count(> 3 per 4 grams)
```

Metals US EPA 503

Pass dry wt.

```
+++++++++
<All Metals Pass                           >|< One or more Metals Fail
```

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)

4.7 Percent dry wt.

```
++++++++++++++++++++++++++++++++++++
<Low            >|< Average                    >|< High Nutrient Content
```

AgIndex (Nutrients / Sodium and Chloride Salts) ((N+P2O5+K2O) / (Na + Cl))

15 Ratio

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Na & Cl    >|<  Nutrient and Sodium and Chloride Provider          >|<  Nutrient Provider
```

Plant Available Nitrogen (PAN) Estimated release for first season

4 lbs/ton wet wt.

```
++++++++++++++++
Low Nitrogen Provider>|<        Average Nitrogen Provider                  >|<High Nitrogen Provider
```

C/N Ratio

14 Ratio

```
+++++++++++++++++++++++++++
< Nitrogen Release    >|< N-Neutral >|< N-Demand>|<  High Nitrogen Demand
```

Soluble Available Nutrients & Salts (EC5 w/w dw)

5.3 mmhos/cm dry wt.

```
++++++++++++++++++++++++++
SloRelease>|<  Average Nutrient Release Rate      >|<High Available Nutrients
```

Lime Content (CaCO3)

15 Lbs/ton dry wt.

```
++++++++++++++++++++++++
<  Low  >|<              Average            >|<  High  Lime Content (as CaCO3)
```

What are the physical properties of your compost?

Percent Ash

39.1 Percent dry wt.

```
++++++++++++++++++++++++++++++
<   High Organic Matter            >|<    Average                    >|<  High Ash Content
```

Sieve Size % > 6.3 MM (0.25")

3.0 Percent dry wt.

```
++++++++++++++++++++++++
All Uses            >|< Size May Restrict Uses for Potting mix and Golf Courses
```

Account No.:		Date Received	08 Jan. 19
9010135 - 1/2 - 8679		Sample i.d.	FBLM: Fines (GCM) 3:7 V-1
Group:	Jan19B No. 16	Sample I.d. No.	1/2 9010135

INTERPRETATION: "Woody Blend" Soil Analysis

Is Your Compost Stable?

Respiration Rate

3.0 Low: Good for all uses mg CO2-C/g OM/day

The respiration rate is a measurement of the biodegradation rate of the organic matter in the sample (as received). The respiration rate is determined by measuring the rate at which CO2 is released under optimized moisture and temperature conditions.

Is Your Compost Mature?

AmmoniaN:NitrateN ratio

43 immature

Ammonia N ppm

2300 immature

Nitrate N ppm

53 mature

pH value

7.94 mature

Composting to stabilize carbon can occur at such a rapid rate that sometimes phytotoxins remain in the compost and must be neutralized before using in high concentrations or in high-end uses. This step is called curing. Typically ammonia is in excess with the break-down of organic materials resulting in an increase in pH. This combination results in a loss of volatile ammonia (it smells). Once this toxic ammonia has been reduced and the pH drops, the microbes convert the ammonia to nitrates. A low ammonia + high nitrate score is indicative of a mature compost, however there are many exceptions. For example, a compost with a low pH (<7) will retain ammonia, while a compost with high lime content can lose ammonia before the organic fraction becomes stable. Composts must first be stable before curing indicators apply.

Cucumber Bioassay

100.0 Percent

Cucumbers are chosen for this test because they are salt tolerant and very sensitive to ammonia and organic acid toxicity. Therefore, we can germinate seeds in high concentrations of compost to measure phytotoxic effects without soluble salts being the limiting factor. Values above 80% for both percent emergence and vigor are indicative of a well-cured compost. Exceptions include very high salts that affect the cucumbers, excessive concentrations of nitrates and other nutrients that will be in range when formulated to make a growing media.

Is Your Compost Safe Regarding Health?

Fecal Coliform

< 1000 / g dry wt.

Fecal coliforms can survive in both aerobic and anaerobic conditions and is common in all initial compost piles. Most human pathogens occur from fecal matter and all fecal matter is loaded in fecal coliforms. Therefore fecal coliforms are used as an indicator to determine if the chosen method for pathogen reduction (heat for compost) has met the requirements of sufficient temperature, time and mixing. If the fecal coliforms are reduced to below 1000 per gram dry wt. it is assumed all others pathogens are eliminated. Potential problems are that fecal coliform can regrow during the curing phase or during shipping. This is because the conditions are now more favorable for growth than during the composting process.

Salmonella Bacteria

Less than 3 3 / 4g dry wt.

Salmonella is not only another indicator organism but also a toxic microbe. It has been used in the case of biosolids industry to determine adequate pathogen reduction.

Metals

Pass

The ten heavy metals listed in the EPA 503 regulations are chosen to determine if compost can be applied to ag land and handled without toxic effects. Most high concentrations of heavy metals are derived from woodwaste feedstock such as chrome-arsenic treated or lead painted demolition wood. Biosolids are rarely a problem.

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)

4.7 Average nutrient content

This value is the sum of the primary nutrients Nitrogen, Phosphorus and Potassium. Reported units are consistent with those found on fertilizer formulations. A sum greater than 5 is indicative of a compost with high nutrient content, and best used to supply nutrients to a receiving soil. A sum below 2 indicates low nutrient content, and is best-used to improve soil structure via the addition of organic matter. Most compost falls between 2 and 5.

Account No.:		Date Received	08 Jan. 19
9010135 - 1/2 - 8679		Sample i.d.	FBLM: Fines (GCM) 3:7 V-1
Group:	Jan19B No. 16	Sample I.d. No.	1/2 9010135

INTERPRETATION: "Woody Blend" Soil Analysis

AgIndex (Nutrients/Na+Cl)

15 High nutrient ratio Composts with low AgIndex values have high concentrations of sodium and/or chloride compared to nutrients. Repeated use of a compost with a low AgIndex (< 2) may result in sodium and/or chloride acting as the limiting factor compared to nutrients, governing application rates. These composts may be used on well-draining soils and/or with salt-tolerant plants. Additional nutrients form another source may be needed if the application rate is limited by sodium or chloride. If the AgIndex is above 10, nutrients optimal for plant growth will be available without concern of sodium and/or chloride toxicity. Composts with an AgIndex of above 10 are good for increasing nutrient levels for all soils. Most composts score between 2 and 10. Concentrations of nutrients, sodium, and chloride in the receiving soil should be considered when determining compost application rates. The AgIndex is a product of feedstock quality. Feedstock from dairy manure, marine waste, industrial wastes, and halophytic plants are likely to produce a finished compost with a low AgIndex.

Plant Available Nitrogen (lbs/ton)

4 Low N Provider Plant Available Nitrogen (PAN) is calculated by estimating the release rate of Nitrogen from the organic fraction of the compost. This estimate is based on the respiration rate, ammonia, and nitrate values. Despite the PAN value of the compost, additional sources of Nitrogen may be needed during he growing season to offset the Nitrogen demand of the microbes present in the compost. With ample nutrients these microbes can further breakdown organic matter in the compost and release bound Nitrogen. Nitrogen demand based on a high C/N ratio is not considered in the PAN calculation because additional Nitrogen should always be supplemented to the receiving soil when composts with a high C/N ratio are applied.

C/N Ratio

14 Indicates maturity As a guiding principal, a C/N ratio below 14 indicates maturity and above 14 indicates immaturity, however, there are many exceptions. Large woodchips (>6.3mm), bark, and redwood are slow to breakdown and therefore can result in a relatively stable product while the C/N ratio value is high. Additionally, some composts with chicken manure and/or green grass feedstocks can start with a C/N ratio below 15 and are very unstable. A C/N ratio below 10 supplies Nitrogen, while a ratio above 20 can deplete Nitrogen from the soil. The rate at which Nitrogen will be released or used by the microbes is indicated by the respiration rate. If the respiration rate is too high the transfer of Nitrogen will not be controlable.

Soluble Nutrients & Salts (EC5 w/w dw - mmhos/cm)

5.3 Average salts This value refers to all soluble ions including nutrients, sodium, chloride and some soluble organic compounds. The concentration of salts will change due to the release of salts from the organic matter as it degrades, volatilization of ammonia, decomposition of soluble organics, and conversion of molecular structure. High salts + high AgIndex is indicative of a compost high in readily available nutrients. The application rate of these composts should be limited by the optimum nutrient value based on soil analysis of the receiving soil. High Salts + low AgIndex is indicative of a compost low in nutrients with high concentrations of sodium and/or chloride. Limit the application rate according to the toxicity level of thesodium and/or chloride. Low salts indicates that the compost can be applied without risking salt toxicity, is likely a good source of organic matter, and that nutrients will release slowly over time.

Lime Content (lbs. per ton)

15 Average lime content Compost high in lime or carbonates are often those produced from chicken manure (layers) ash materials, and lime products. These are excellent products to use on a receiving soil where lime has been recommended by soil analysis to raise the pH. Composts with a high lime content should be closely considered for pH requirements when formulating potting mixes.

Physical Properties

Percent Ash

39.1 Average ash content Ash is the non-organic fraction of a compost. Most composts contain approximately 50% ash (dry weight basis). Compost can be high in ash content for many reasons including: excess minerilzation(old compost), contamination with soil base material during turning, poor quality feedstock, and soil or mineral products added. Finding the source and reducing high ash content is often the fastest means to increasing nutrient quality of a compost.

Particle Size % > 6.3 MM (0.25")

3.0 May restrict use Large particles may restrict use for potting soils, golf course topdressings, seed-starter mixes, and where a fine size distribution is required. Composts with large particles can still be used as excellent additions to field soils, shrub mixes and mulches.

Appendix:

Plant Available Nitrogen (PAN) calculations:

PAN = (X * (organic N)) + ((NH4-N) + (NO3-N))

X value = If RR < 2 then X = 0.1

If RR =2.1 to 5 then X = 0.2

If RR =5.1 to 10 then X = 0.3

If RR > 10 then X = 0.4

Note: If C/N ratio > 15 additional N should be applied.

RR = Respiration rate

Estimated available nutrients for use when calculating application rates

	lbs/ton (As Rcvd.)
Plant Available Nitrogen (PAN)	4.0
Ammonia (NH4-N)	2.20
Nitrate (NO3-N)	0.05
Available Phosphorus (P2O5*0.64)	14.3
Available Potassium (K2O)	2.9

BLOOM GOOD SOIL,® BETTER EARTH.

"Sandy Blend"

Sand-Sawdust Bloom Blend - Nutrient Analysis

Date Received: 02 Jun. 16
Sample Identification: Blend
bs:s:sd -70d flip+6
Sample ID #: 6060088 - 2/3

Nutrients	Dry wt.	As Rcvd.	units
Total Nitrogen:	1.6	1.4As	%
Ammonia (NH4-N):	1700	1400	mg/kg
Nitrate (NO3-N):	54	46	mg/kg
Org. Nitrogen (Org.-N):	1.4	1.2	%
Phosphorus (as P2O5):	3.3	2.7	%
Phosphorus (P):	14000	12000	mg/kg
Potassium (as K2O):	0.18	0.15	%
Potassium (K):	1500	1200	mg/kg
Calcium (Ca):	1.2	1.0	%
Magnesium (Mg):	0.20	0.16	%
Sulfate (SO4-S):	1900	1600	mg/kg
Boron (Total B):	9.7	8.2	mg/kg
Moisture:	0	16.1	%
Sodium (Na):	0.040	0.033	%
Chloride (Cl):	0.05	0.042	%
pH Value:	NA	6.67	unit
Bulk Density :	30	35	lb/cu ft
Carbonates (CaCO3):	5.4	4.5	lb/ton
Conductivity (EC5):	4.0	NA	mmhos/cm
Organic Matter:	34.02	28.52795	%
Organic Carbon:	14	12	%
Ash:	65.98	55.32846	%
C/N Ratio	8.7	8.7	ratio
AgIndex	>10	>10	ratio

Metals	Dry wt.	EPA Limit	units
Aluminum (Al):	2600	-	mg/kg
Arsenic (As):	4.0	41	mg/kg
Cadmium (Cd):	<1.0	39	mg/kg
Chromium (Cr):	25	1200	mg/kg
Cobalt (Co)	4.3	-	mg/kg
Copper (Cu):	160	1500	mg/kg
Iron (Fe):	42000	-	mg/kg
Lead (Pb):	18	300	mg/kg
Manganese (Mn):	170	-	mg/kg
Mercury (Hg):	<1.0	17	mg/kg
Molybdenum (Mo):	5.0	75	mg/kg
Nickel (Ni):	13	420	mg/kg
Selenium (Se):	1.9	36	mg/kg
Zinc (Zn):	310	2800	mg/kg

Stability Indicator:

CO2 Evolution	Respirometery	Biologically Available C
mg CO2-C/g OM/day	3.4	3.4
mg CO2-C/g TS/day	1.1	1.0
Stability Rating	stable	stable

Maturity Indicator: Cucumber Bioassay

Compost:Vermiculite(v:v)	1.2
Emergence (%)	100
Seedling Vigor (%)	119.2308
Description of Plants	healthy

Pathogens	Results	Units	Rating
Fecal Coliform	<7.5	MPN/g	pass
Salmonella	<3	MPN/g	pass

Date Tested: 02 Jun. 16

Inerts	% by weight
Plastic	<0.5
Glass	<0.5
Metal	<0.5
Sharps	ND

Maturity Indicator: Cucumber Bioassay

MM	% by weight
>50	0
25 to 50	0
16 to 25	0
9.5 to 16	0
6.3 to 9.5	0.076407
4.0 to 6.3	2.026028
2.0 to 4.0	16.309 28
<2.0	81.58829

Technical Memorandum No. 6

Date:	October 20, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Thickening Evaluation

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Executive Summary

The Arlington County (County) Water Pollution Control Plant (WPCP) Solids Master Plan report's (March 2018) (Master Plan) preferred alternative eliminated thickening of primary solids (PS) and waste activated solids (WAS). The purpose of this thickening evaluation is to validate the Master Plan's preferred alternative of no thickening, and to compare potential thickening configurations and technologies. The following thickening technologies were included in this evaluation:

- Gravity thickeners (GTs): currently used for PS thickening
- Dissolved air flotation thickeners (DAFTs): currently used for WAS thickening
- Gravity-belt thickeners (GBTs)
- Rotary-drum thickeners (RDTs)
- Thickening centrifuges

The following eight alternatives were originally identified for inclusion in this thickening evaluation:

- **Alternative 1:** no thickening
- **Alternative 2:** GTs for PS and DAFTs for WAS
- **Alternative 3:** GTs for PS and GBTs for WAS
- **Alternative 4:** GTs for PS and RDTs for WAS
- **Alternative 5:** GTs for PS and thickening centrifuges for WAS
- **Alternative 6:** co-thickening (PS and WAS) with GTs
- **Alternative 7:** un-thickened (UT) PS and GBT or RDT thickening for WAS
- **Alternative 8:** co-thickening (PS and WAS) with GBTs or RDTs

Solids loading projections used for the evaluation are based on the 30.8-million-gallon per day (mgd) (approximately year 2052, refer to Technical Memorandum (TM) No. 1, *Solids Production and Design Criteria* for design criteria) design condition. Thickening, solids screening, solids storage, and pre-dewatering facilities were preliminarily sized based on the 30.8 mgd, peak 3-day solids loading projections. It is assumed for Alternatives 2 through 6 that the existing GTs would be used, following concrete rehabilitation and replacement of the internal mechanical equipment. A condition assessment was performed on the existing GTs and it was determined that the mechanical components are at the end of their useful life and should all be replaced. However, the GT tanks are structurally sound but require some concrete rehabilitation, including concrete repairs and a new domed cover.

Preliminary thickening and pre-dewatering facility layouts were prepared and used as a basis for preparing conceptual capital costs. A workshop was held on March 17, 2021, to review the initial thickening evaluation during which Alternatives 2, 5, 6, and 8 were eliminated from further evaluation. The County requested that new Alternatives 7A and 8A be added to the evaluation, as variations on Alternatives 7 and 8, respectively. Alternative 7A includes gravity thickening of PS and no thickening of WAS (plan for future thickening). Alternative 8A includes separate mechanical thickening of PS and WAS located in the same facility. Alternatives 1, 3, 4, 7, 7A, and 8A were retained for further evaluation.

Following the initial alternatives screening and elimination, operation and maintenance (O&M) costs were prepared for the remaining alternatives. A summary of the shortlisted alternatives is provided in Table 1 below.

Based on the analyses, Alternative 7A (GT/no WAS thickening) appears to provide the best overall value to Arlington County, balancing operational flexibility, proven performance, lower energy profile, and ability to fit within the site constraints. Space will be allocated for future GBTs or RDTs. Alternative 7A is recommended over Alternative 1 because of the reduced storage and odor control requirements and greater flexibility in site utilization. Figure 1 provides the process flow diagram (PFD) for the recommended thickening alternative.

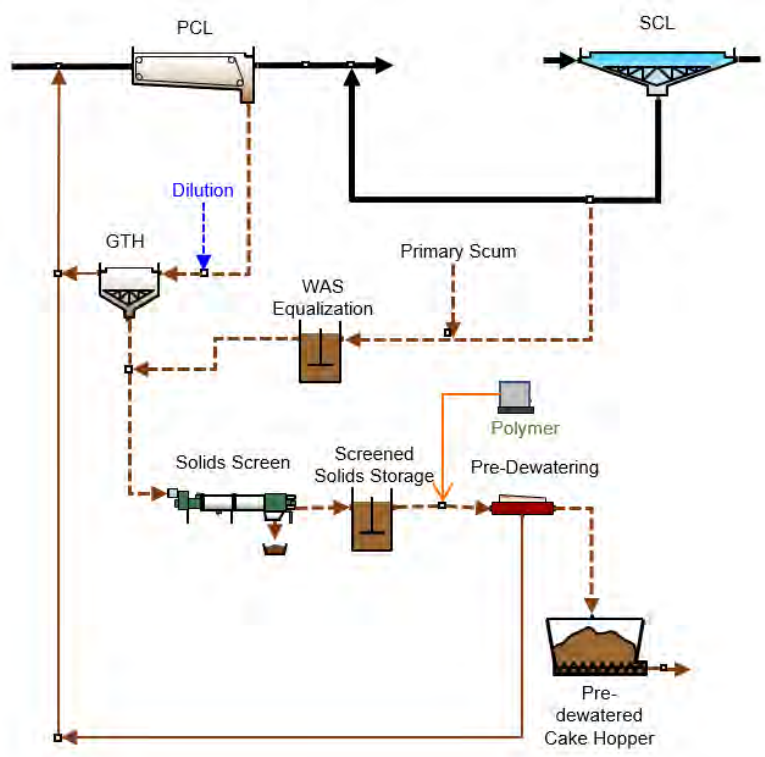

Figure 1. Alternative 7A Process Flow Diagram

Table 1. Summary of Shortlisted Alternatives

Parameter	Alt. 1: No Thickening	Alt. 3: GT/GBT	Alt. 4: GT/RDT	Alt. 7: Un-thickened PS/TWAS	Alt. 7A: GT/ Un-thickened WAS	Alt. 8A: Separate GBT/RDT
Site impacts	• Requires most solids storage volume (can consider reusing GTs) • Largest pre-dewatering facility footprint	• Provides one of the most compact layouts • Smallest pre-dewatering facility footprint	• Provides the most compact layout • Smallest pre-dewatering facility footprint	• Large volume of storage required for un-thickened PS • Larger pre-dewatering facility footprint	• Additional WAS storage required upstream of screening • More storage than Alternative 3 or 4	• Additional PS storage required upstream of thickening • Smallest pre-dewatering facility footprint
Operability	• Fewer unit processes to operate • Limited flexibility (with 1 day of solids storage) • 24/7 solids screening and pre-dewatering is required	• GTs are a familiar process to WPCP staff and have performed well • GBTs require periodic operator attention, but do not require constant care	• GTs are a familiar process to WPCP staff and have performed well • RDTs require even less operator attention than GBTs	• Limited flexibility because of un-thickened PS • GBT/RDT requires periodic operator attention	• GTs are a familiar process to WPCP staff and have performed well • Un-thickened WAS eliminates a unit process	• GBT/RDT for PS thickening would require more operator attention because of PS solids concentration variability • Potentially two types of polymer required for PS and WAS
Maintenance	• No thickening maintenance • Largest number of solids screens, mixing, and pre-dewatering units requiring additional attention	• GT maintenance is relatively low • GBT maintenance can be done in-house	• RDT maintenance is relatively low • RDT maintenance can be done in-house	• GBT/RDT maintenance similar to Alts. 3 and 4 • Larger number of solids screens, mixing, and pre-dewatering units requiring additional attention	• GT maintenance is relatively low • No maintenance for WAS as it will remain un-thickened	• GBT or RDT maintenance can be performed in-house, but will be greater than Alts. 3 and 4 because of more thickening units needed for PS and WAS
Energy	• No thickening energy required • High energy demands for multiple storage tanks	• Low energy demand for thickening • Lowest energy demand for pre-dewatering	• Low energy demand for thickening • Lowest energy demand for pre-dewatering	• Lowest energy demand for thickening WAS only • Higher energy demand for pre-dewatering	• Lowest energy demand for thickening • Slightly higher energy demand for pre-dewatering	• Higher energy demand for mechanical thickening of PS and WAS

Parameter	Alt. 1: No Thickening	Alt. 3: GT/GBT	Alt. 4: GT/RDT	Alt. 7: Un-thickened PS/TWAS	Alt. 7A: GT/ Un-thickened WAS	Alt. 8A: Separate GBT/RDT
	• Highest energy demand for pre-dewatering					• Lowest energy demand for pre-dewatering
Downstream process impacts	• Requires the most screening and pre-dewatering capacity	• Minimizes screening and pre-dewatering	• Minimizes screening and pre-dewatering	• Greater screening and pre-dewatering capacity	• Slightly larger screening but pre-dewatering capacity same as other thickening options	• Minimizes screening and pre-dewatering
Odors	• Significant odor control needed for storage volume	• GTs are covered, and GBTs can be enclosed to reduce odors	• GTs are covered and RDTs are enclosed	• Significant odor control needed for large PS storage volume	• GTs and SSTs are covered	• Local odor issues associated with GBTs especially for thickening PS; RDTs are enclosed
Conceptual capital cost	$31.1M	$32.1M	$32.6M	$31.7M	$28.8M	$37.7M
O&M present value	$12.0M	$15.1M	$15.9M	$14.1M	$13.3M	$18.4M
Net present value	$43.3M	$47.1M	$48.5M	$45.8M	$42.1M	$56.1M

1.0 Introduction

This introductory section presents the background and purpose of the project and describes the evaluation approach applied to the thickening system at the Arlington Water Pollution Control Plant (WPCP).

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington WPCP. Currently solids handling includes primary solids (PS) and waste activated solids (WAS) thickening, dewatering, and lime stabilization. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The Master Plan included a recommendation to eliminate solids thickening to send un-thickened (UT) solids directly to new solids screening and pre-dewatering facilities upstream of the THP system. Eliminating the thickening process may reduce operations and maintenance (O&M) demands but will also impact sizing and operations of the downstream solids storage, screening, and pre-dewatering processes. The purpose of this thickening evaluation is to further assess and compare thickening alternatives with the no-thickening approach, including impacts to downstream solids handling processes. The results of this evaluation will inform and validate a final decision on eliminating or providing PS and WAS thickening that will be included in the Facilities Plan.

1.2 Evaluation Approach

A suite of alternatives using various thickening technologies, including the existing gravity thickeners (GTs) and dissolved air flotation thickeners (DAFTs), as well as other mechanical thickening processes, was developed for separate and co-thickening of PS and WAS. Conceptual process sizing, configurations, site layouts, and conceptual costs for thickening facilities as well as downstream solids storage, screening, and pre-dewatering were prepared for each alternative. Alternatives were presented and reviewed at a March 17, 2021, project workshop with the County. Workshop participants screened and selected a short list of preferred alternatives. Shortlisted alternatives were further evaluated and compared based on conceptual O&M cost estimates and non-cost considerations including impacts to downstream solids handling processes, site layout and space requirements, and odors. Selected shortlisted alternatives will be considered further in forthcoming evaluations of site utilization and other facility improvements.

2.0 Summary of Existing Facilities and Processing

This section presents a summary of the major process mechanical equipment/systems of the existing thickening facilities at Arlington WPCP, including an overview of existing solids handling and a description of solids thickening and storage.

2.1 Overview of Existing Solids Handling

A process flow diagram (PFD) for existing solids handling at the WPCP is shown in Figure 2. Solids are thickened using GTs for PS and DAFTs for WAS. Thickened solids are blended in solids storage tanks (SSTs) and dewatered using centrifuges. Lime is added to the dewatered solids to achieve Class B pathogen and vector attraction reduction. Stabilized biosolids are hauled off site for beneficial use through bulk land application.

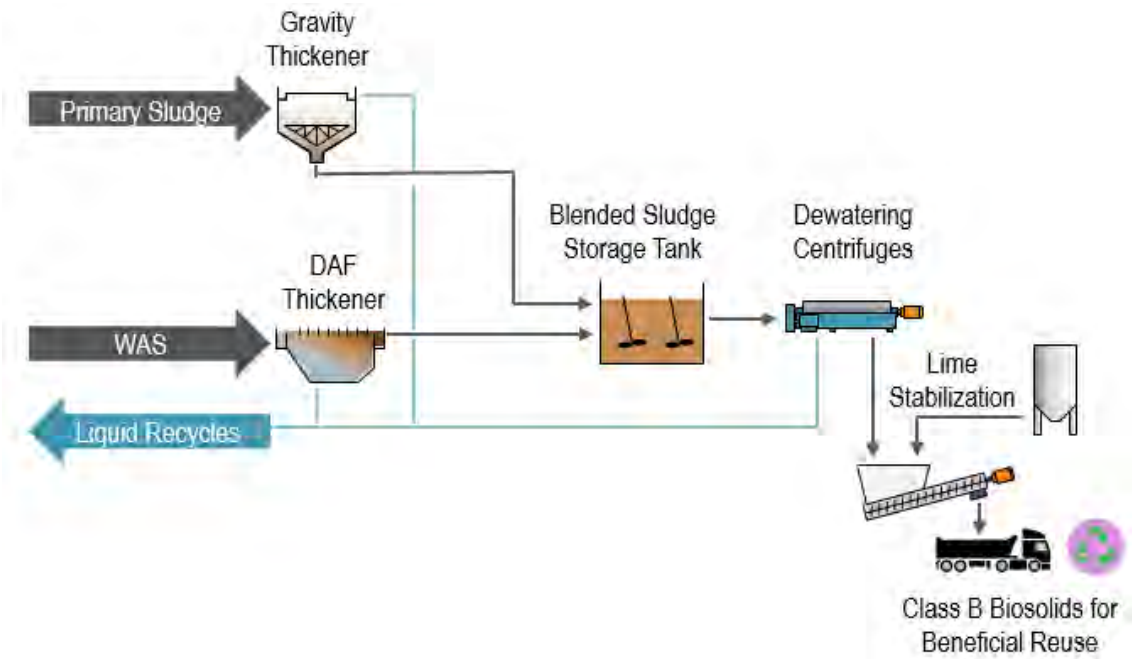

Figure 2. Existing PS and WAS Process Flow Diagram

2.2 Solids Thickening and Storage

PS are pumped from the primary clarifiers to GTs 1 and 2 at an average of 1.0 percent solids, prior to the addition of elutriation water. As documented in TM No. 1, the percent solids data are based on recent special samples as the daily measurements of PS are taken at a location that includes elutriation water. Typically, one of two GTs is in operation. PS are thickened to an average of 4 percent solids. Thickened PS are pumped to the solids storage tanks for storage and blending with thickened waste activated solids (TWAS) prior to dewatering. Refer to Table 2 for the existing GT characteristics.

Table 2. Existing Gravity Thickener Characteristics

Characteristic	Value	Unit
Number of units	2 (1 operating, 1 standby)	
GT diameter	65	ft
Surface area, ea.	3,300	ft^2
Side water depth (SWD)	10	ft
Volume, ea.	0.25	MG
Tank material	Concrete	

WAS is collected from the secondary clarifiers and pumped to DAFTs 1 and 2 at an average of 1.1 percent solids. Typically, one DAFT unit is in operation for WAS thickening. WAS is thickened to an average of 4 percent solids. TWAS is pumped to the solids storage tanks for storage and blending with thickened PS prior to dewatering. See Table 3 for the existing DAFT characteristics.

Table 3. Existing DAFT Characteristics

Characteristic	Value	Unit
Number of units	2 (1 operating, 1 standby)	
Length	50	ft
Width	12	ft
Height	10.75	ft
Surface area, ea.	600	ft^2

The WPCP has two existing solids storage tanks. Gravity thickened PS and DAFT TWAS are pumped to one of two storage tanks, prior to dewatering. Characteristics for the existing solids storage tanks are summarized in Table 4.

Table 4. Existing Solids Storage Tanks Characteristics

Characteristic	Value	Unit
Number of tanks	2 (1 operating, 1 standby)	
Diameter	53	ft
Side water depth	25.5	ft
Volume, each	0.42	MG
Total volume	0.84	MG
Storage duration at current (2020) peak 3-day solids loading	2.5	Days

3.0 Design Criteria

This section presents the major process mechanical design criteria for the thickening system at the Arlington WPCP, including solids loading; thickening technologies; and solids screening, storage, and pre-dewatering requirements. Design criteria for ancillary equipment/systems (i.e., solids pumping, polymer, etc.) and other disciplines will be developed and documented in the Facilities Plan.

3.1 Solids Loading

Thickening alternatives were evaluated based on projected PS and WAS loadings documented in TM No. 1. The following design loading conditions were considered in the thickening evaluation:

- **30.8 million gallons per day (mgd):** design condition
- **40.0 mgd:** projected buildout loading

Peak 3-day solids loadings at the 30.8 mgd and 40.0 mgd design conditions were used to develop preliminary process equipment selections and facility concepts. A summary of the solids loading projections used for the design conditions is provided in Table 5. Startup/minimum conditions were not considered for this evaluation but will be considered in the Facilities Plan.

PS and WAS have an average solids concentration of 1.4 percent and 1.1 percent, respectively. The average PS:WAS ratio is 70:30.

Table 5. Summary of Solids Loading Design Criteria

Design Condition: 30.8 mgd	Flow (gpm)	Solids Concentration	Solids Loading (lb-DS/hr)
PS (3-day)	770	1.0%	3,900
WAS (3-day)	340	1.1%	1,900
Total	1,110	1.0%	5,800
Design Condition: 40.0 mgd	**Flow (gpm)**	**Solids Concentration**	**Solids Loading (lb-DS/hr)**
PS (3-day)	1,000	1.0%	5,000
WAS (3-day)	450	1.1%	2,500
Total	1,450	1.0%	7,500

3.2 Thickening Technologies

The thickening evaluation considered multiple thickening technologies for separate and co-thickening of PS and WAS. Thickening technologies considered include the existing GTs and DAFTs, as well as gravity-belt thickeners (GBTs), rotary-drum thickeners (RDT), and thickening centrifuges. Preliminary process sizing and alternative evaluations were based on the technology-specific design criteria presented in the following sections.

3.2.1 Gravity Thickeners

Continued use of the existing GTs was evaluated both for separate thickening of PS as well as co-thickening of PS and WAS. Design criteria used for the GTs are summarized in Table 6. Rehabilitation and improvements to the GT complex are required to extend the service life of the existing facilities. Refer to TM No. 2, *Condition of Existing Facilities*, for a condition assessment of the existing facility and recommended improvements including concrete repairs and complete replacement of the tank covers and mechanical equipment internal to the tanks. Conceptual costs for structural and major process

mechanical rehabilitation have been developed and included in the capital cost estimate for those alternatives that include gravity thickening.

Table 6. Gravity Thickener Design Criteria

Parameter	Value	Unit
PS (maximum loading)	30 (4,150)	lb/ft^2-d (lb/hr)
WAS (maximum loading)	8	lb/ft^2-d
PS and WAS (maximum loading)	14	lb/ft^2-d
Thickened PS concentration	4.0	Percent
Co-thickened PS and WAS concentration	3.0	Percent

3.2.2 Dissolved Air Flotation Thickeners

The two existing DAFT units were included in this evaluation for WAS thickening. DAFT design criteria are summarized in Table 7. For the purposes of this evaluation, the maximum solids loading for the DAFTs assumes polymer addition as they currently operate. Although DAFT units require high levels of energy and maintenance, they were included in the evaluation as the WPCP currently uses this technology.

Table 7. DAFT Design Criteria

Parameter	Value	Unit
Hydraulic loading	1,200	gpm
Maximum solids loading (no polymer addition)	600	lb-DS/hr
Maximum solids loading (with polymer addition)	1,200	lb-DS/hr
Typical polymer dosages	0–5	lb/DT
TWAS concentration	4.0	Percent

Based on the solids design criteria included in TM No. 1, the existing DAFT units are likely exceeding recommended loading rates during peak 3-day loadings. Operations has been able to accommodate these flows previously, but it is expected to become more difficult as flows increase.

3.2.3 Gravity-Belt Thickeners

GBTs are a proven technology for mechanical thickening and provide a competitive balance of thickening performance per footprint, operational cost, and power usage. Typically, polymer is injected into the solids stream and mixed upstream of the GBTs. The solids/polymer slurry is fed into a feedbox for a consistent distribution across the belt. The belt conveys the solids through stationary plows that furrow the slurry to promote water/solids separation. The belt discharges the thickened solids into a hopper, which is connected to a pump. Filtrate is collected in drain pans and flows by gravity to the process drain system. A spraywater system, including a booster pump and spray header, is used to clean the belt on the bottom side of the GBT as it returns to the feedbox. A schematic of the GBT process is shown on Figure 3.

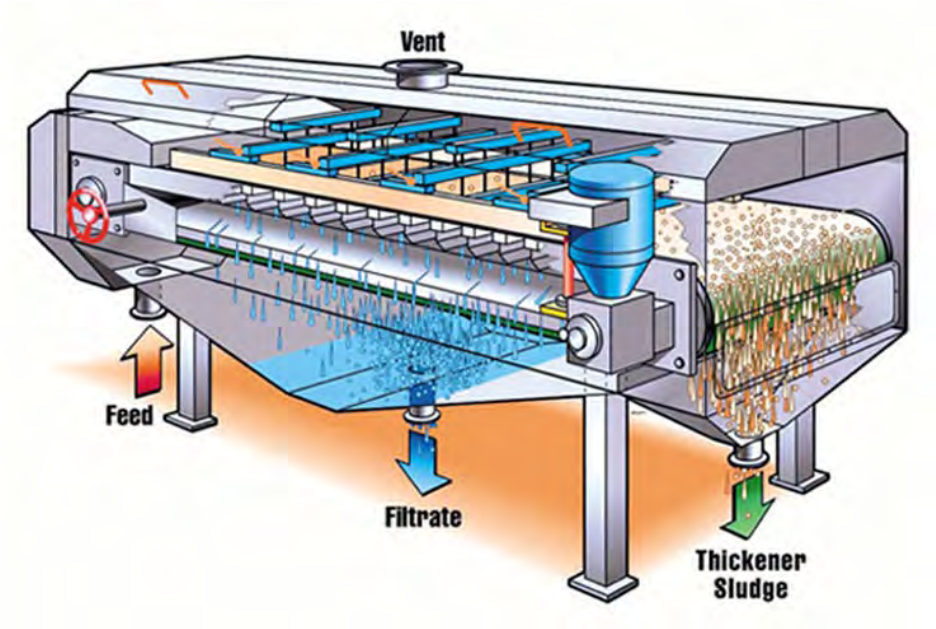

Image credit: BDP Industries.

Figure 3. GBT Schematic

GBTs can be open to allow for easy observation of the thickening process; however, this can lead to local odor issues as the solids are exposed to the atmosphere, especially for co-thickened solids. GBTs can be covered to contain odors but covers can hinder the ability to easily observe the thickening process. GBTs are typically located indoors and off-site odors can be managed through ventilation and odor treatment. An image of an enclosed GBT is shown on Figure 4, and an open GBT is shown on Figure 5. Typical GBT design criteria used for this evaluation are summarized in Table 8.

Figure 4. Enclosed GBT

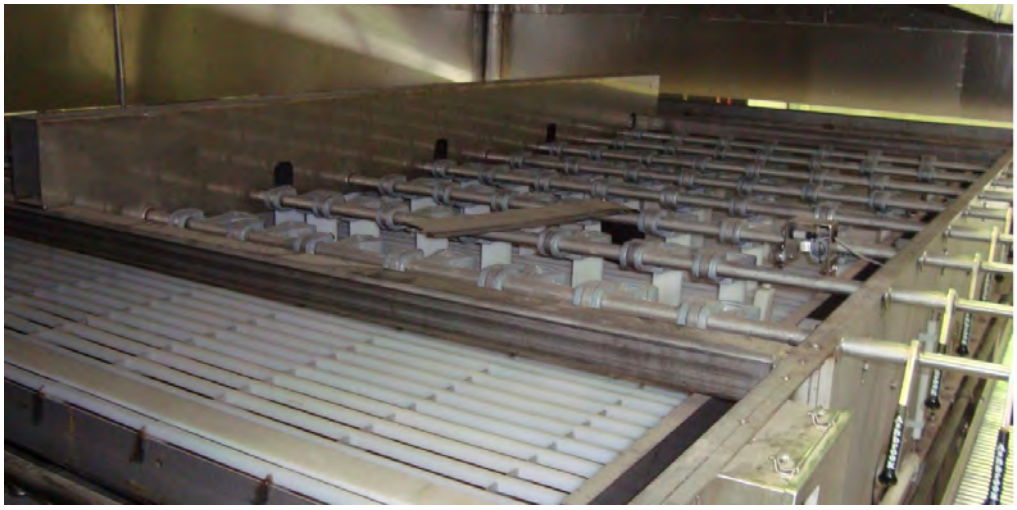

Figure 5. Open GBT

Table 8. GBT Design Criteria

Parameter	Value	Unit
Belt width	2.0	Meters
Hydraulic loading	400	gpm
Solids loading	2,000	lb-DS/hr
Typical polymer dosages	6–10	lb/DT
GBT thickened solids concentration	5.0	Percent

3.2.4 Rotary-Drum Thickeners

RDTs are another proven mechanical thickening technology and offer similar performance to GBTs. Polymer is added and mixed with the solids feed in a flocculation tank upstream of the RDT. A schematic of an RDT is shown on Figure 6.

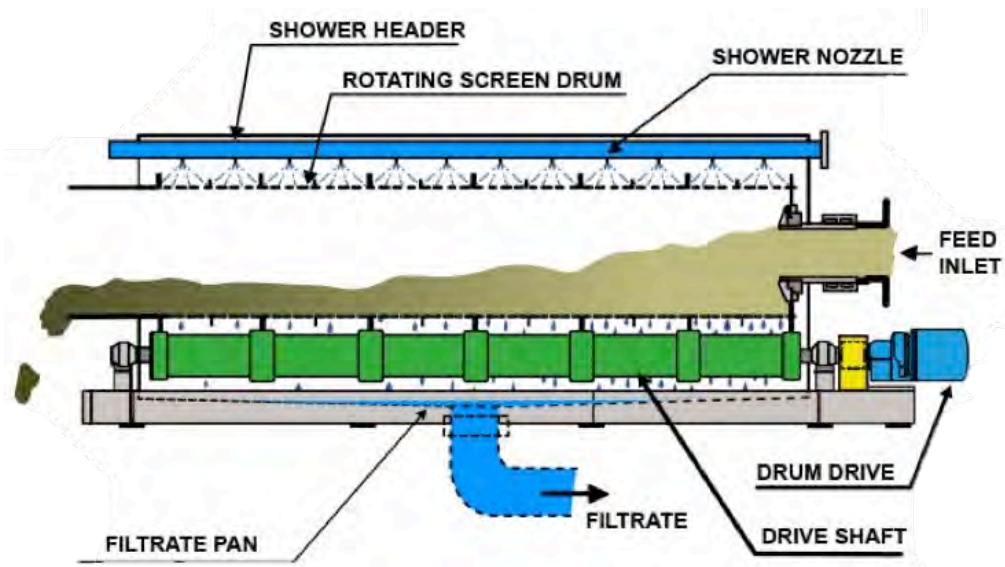

Figure 6. RDT Schematic

An image of an RDT, with floc tank, is shown on Figure 7. Solids are fed into a rotating cylindrical screen fitted with a screw and flights to furrow and convey solids forward. Water is drained through the screen into a filtrate drain. Solids are discharged into a hopper at the downstream end of the RDT. A spraywater system is used to constantly clean the screen. Typical RDT design criteria used for this evaluation are summarized in

Table 9.

Figure 7. RDT and Floc Tank

Table 9. RDT Design Criteria

Parameter	Value	Unit
Hydraulic loading	350	gpm
Solids loading	1,800	lb-DS/hr
Typical polymer dosages	5-15	lb/DT
RDT thickened solids concentration	5.0	Percent

3.2.5 Thickening Centrifuges

Thickening centrifuges were included in this evaluation for mechanical thickening. WPCP staff are familiar with centrifuge operation and maintenance because centrifuges are currently used for dewatering. Thickening centrifuges have the same operation principle as a dewatering centrifuge. The main difference between thickening centrifuges and dewatering centrifuges is how they are controlled, and the instrumentation used to monitor and produce a consistent thickened solids or dewatered cake concentration. Dewatering centrifuges typically monitor torque to control the bowl/scroll speed(s). However, in a thickening centrifuge, torque is not significant as the scroll is conveying a much more liquid slurry through the bowl. Instrumentation is needed to monitor feed solids and/or thickened solids concentrations, which is used to adjust the differential speed. Some manufacturers offer an automatically adjustable pond (depth of liquid within the centrifuge) varying system that adjust while the centrifuge is operating to allow the pond depth to increase or decrease, depending on feed solids concentration and/or thickened solids concentration. Typical design criteria used in the evaluation of centrifuge thickening for WAS are listed in Table 10.

Table 10. Thickening Centrifuge Design Criteria

Parameter	Value	Unit
Bowl diameter	29	Inch (nominal)
Hydraulic loading	400	gpm
Solids loading	4,000	lb-DS/hr
TWAS concentration	Up to 10	Percent
Typical polymer dosages	10–15	lb/DT

3.3 Solids Screening, Storage, and Pre-Dewatering

Solids thickening directly and significantly impacts the size and configuration of the solids screening, storage, and pre-dewatering facilities located downstream. These technologies, facilities, and site impacts will be evaluated in detail, separately from this thickening evaluation. However, conceptual sizing and layouts are included in the thickening evaluation to assess and compare how each thickening alternative impacts these downstream process facilities. Table 11 provides the criteria used in this thickening evaluation. It is assumed these facilities will operate 24 hours per day, 7 days per week.

Table 11. Solids Screening, Storage, and Pre-Dewatering Criteria

Parameter	Solids Screening	Solids Storage	Pre-Dewatering
Configuration/type	Inline	Circular	Centrifuge
Size	5 mm (perforations)	60 ft diameter/20 ft SWD 0.42 MG volume	29 in. bowl (nominal)
Manufacturer/model	Huber/SP290	N/A	GEA/CF8000
Hydraulic loading	370 gpm at 1.3%	1 day of storage at 30.8 mgd, peak 3-day	500 gpm
Solids loading	6.0% maximum	N/A	4,000 lb-DS/hr

Following the selection of approach for thickening, these other systems, including screening, thickened solids storage, and pre-dewatering will be refined and optimized. The solids storage tanks used for the thickening evaluation assumes a common size and construction for each alternative. For some alternatives, the required volume in order to store 24 hours of solids at the peak 3-day design condition results in only one storage tank at this common size. Ultimately, the conceptual design for liquid (un-thickened and thickened) solids storage will be refined, including tank volume, construction, mixing and odor control, as required, and a minimum of two solids storage tanks will be provided in the Facilities Plan, providing both the required liquid solids storage as well as the redundancy needed for operational flexibility of this unit process.

4.0 Thickening Alternatives

Eight thickening alternatives were developed and presented at the March 17, 2021, workshop. Two additional alternatives (7A and 8A) were added to the evaluation through discussions with the County at workshops. Table 12 summarizes each alternative and provides a brief description of the process flow. In each alternative discussion, the total number of thickening units, solids screens, pre-dewatering units, and liquid solids storage tanks needed for both the 30.8 mgd and 40.0 mgd design conditions are listed.

Table 12. Thickening Alternatives Evaluated

Alternative	Thickening Technologies	General Process Flow
1	No thickening	PS/WAS → storage → solids screens → storage → pre-dewatering
2	GT/DAFT	PS → GTs WAS → DAFTs → solids screens → storage → pre-dewatering
3	GT/GBT	PS → GTs WAS → GBTs → solids screens → storage → pre-dewatering
4	GT/RDT	PS → GTs WAS → RDTs → solids screens → storage → pre-dewatering
5	GT/centrifuge	PS → GTs WAS → centrifuges → solids screens → storage → pre-dewatering
6	Co-thickening (GT)	PS + WAS → GTs → solids screens → storage → pre-dewatering
7	Un-thickened PS/GBT or RDT	PS → storage WAS → GBTs or RDTs → solids screens → storage → pre-dewatering
7A	GT/Un-thickened WAS	PS → GTs WAS → storage → solids screens → storage → pre-dewatering
8	Co-thickening (GBT or RDT)	PS → storage WAS → → GBTs or RDTs → solids screens → storage → pre-dewatering
8A	Separate thickening (GBT or RDT)	PS → storage → GBTs or RDTs WAS → GBTs or RDTs → solids screens → storage → pre-dewatering

4.1 Conceptual Design and Capital Cost Development

Conceptual process configurations, equipment sizing, and building and site layouts were developed for each thickening alternative. Preliminary design criteria were distributed to various manufacturers for thickening, solids screening, and pre-dewatering equipment to obtain preliminary equipment quotes and equipment dimensions and layout drawings. Based on the preliminary design criteria, equipment layout drawings and building footprint/dimensions were established as a basis for estimating facility costs. The building footprint included the process equipment needed to meet the 30.8 mgd, peak 3-day solids loading; space for adding additional equipment in the future to meet the 40.0 mgd, peak 3-day solids loading; and space for various support facilities including polymer storage and feed, electrical and control room spaces, and bridge cranes to allow for equipment removal.

4.1.1 Conceptual Pre-Dewatering Building Layouts

A conceptual pre-dewatering building layout was prepared for each alternative to determine the approximate footprint of the facility as a basis for conceptual cost preparation and site layout considerations. The pre-dewatering building layout assumes that the solids screens and pre-dewatering equipment will be located in the same building. For the purposes of this evaluation, the pre-dewatering building layout includes solids screens and pre-dewatering centrifuges for the 30.8 mgd, peak 3-day solids projections, and includes space for future expansion of solids screens and pre-dewatering centrifuges as needed to meet the 40.0 mgd, peak 3-day solids projections. Electrical and control room spaces, polymer area, and space needed for equipment maintenance/removal have been considered in the conceptual pre-dewatering building layouts.

4.1.2 General Site Layouts

General site layout figures are provided for each alternative. The intent of these site figures is to show approximate site space required by the alternative and assumes that new buildings/structures are provided for the new thickening, solids screening, storage, and pre-dewatering facilities, except for the GTs and DAFTs (where applicable). Site layout(s) will be further developed in the site utilization evaluation.

4.1.3 Conceptual Capital Costs

Conceptual capital and construction costs were prepared for each alternative based on preliminary equipment quotes from vendors; cost per square foot (ft^2) for buildings; and general percentages for ancillary facilities, site work, contingencies, and general contractor costs shown in Table 13. Demolition costs were included for the alternatives where the existing thickening facilities were not used (GT, DAFT, or both). GT rehabilitation costs were included for the alternatives that included gravity thickening. The rehabilitation costs include concrete repair, replacement of major process mechanical equipment, and replacement of the covers.

Table 13. General Percentage Adders to Base Cost for Conceptual Cost Development

Parameter	Percentage
Sitework	15%
Electrical	20%
Instrumentation and controls	8%
Large and specialty pipe	5%
Geotechnical (piles)	7%
Project contingency	20%
Contractor mobilization/staging	5%
Contractor bonds/insurance	3%
Contractor overhead and profit	15%

The conceptual cost is only a rough order of magnitude to use for relative comparisons between the various alternatives. The conceptual costs presented herein are not for budgeting purposes. Opinions of probable construction costs (OPCCs) will be prepared as part of the Facilities Plan, separate from this thickening evaluation.

4.2 Thickening Alternative Descriptions

This section presents descriptions of the thickening alternatives under consideration.

4.2.1 Alternative 1: No Thickening

Alternative 1 would eliminate thickening in its entirety, as recommended in the Master Plan. A PFD of Alternative 1 is shown on Figure 8. As PS is pumped intermittently from the primary clarifiers, a small approximately 8-hour PS buffer tank is recommended upstream of the solids screens. Although existing operations could be altered to pump continuously, this would require modifications to the existing pumping systems, which are beyond the scope of this analysis. The buffer tank provides additional benefit of decoupling operation of the existing primary clarifiers from the screens and pre-dewatering units, reducing the chance for process upset. For purposes of this evaluation, it is assumed that one 60-foot-diameter storage tank (420,000 gallons) would be provided for storing un-thickened solids. This equates to just over 6 hours of storage at the 3-day peak design condition (just over 12 hours at average design conditions). The existing GT tanks could be retrofit to store primary solids upstream of screening, requiring new covers and mixing systems for PS storage. The two existing GTs would provide approximately as much storage as one new solids storage tank. For purposes of this evaluation, only the new solids storage tank was priced.

WAS would be pumped to the solids storage tanks to be combined with the PS. Additional combined storage of PS and WAS is required before pre-dewatering, for a total storage of 24 hours for peak 3-day load at 30.8 mgd. Screening and dewatering un-thickened PS and WAS has a significant impact on the hydraulic loading and sizing for these facilities and for the required screened solids storage prior to pre-dewatering. Table 14 summarizes the solids flows and the number of solids screens, pre-dewatering centrifuges, and storage tanks needed for 30.8 mgd and 40.0 mgd solids loading projections. Figure 9 shows a general layout of the pre-dewatering facility and the solids storage tanks required for this alternative. Figure 10 shows a conceptual layout of the pre-dewatering building for this alternative.

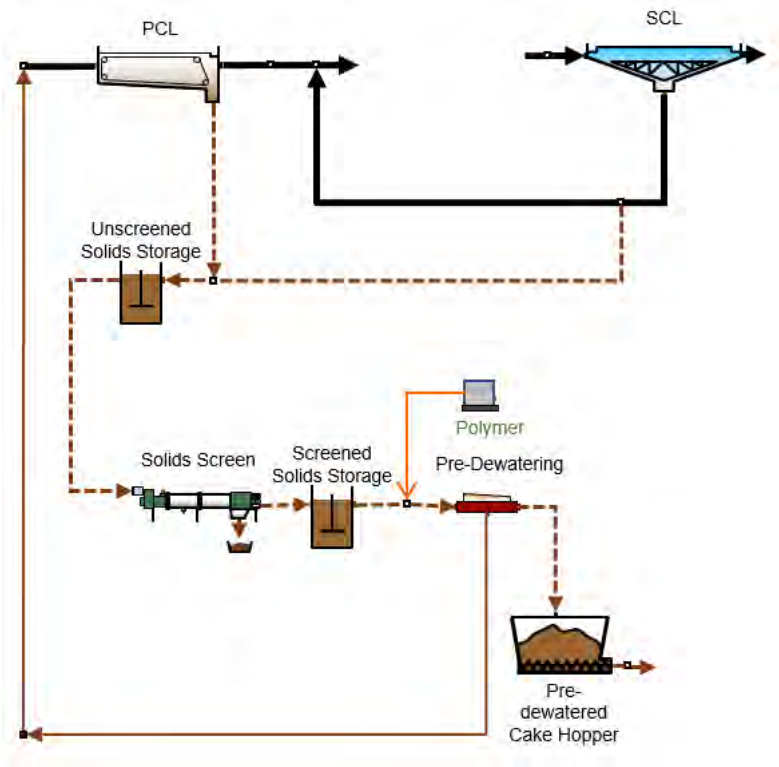

Figure 8. Alternative 1 Process Flow Diagram

Table 14. Alternative 1 Design Criteria

Parameter	30.8 mgd	40.0 mgd
PS/WAS concentration	1.03%	1.03%
PS/WAS flow to screens (gpm)	1,120	1,450
Number of solids screens (duty/standby)	3/1	4/1
Number of pre-dewatering centrifuges (duty/standby)	3/1	3/1
Liquid solids storage tanks (duty/standby)	4/0[a]	
Conceptual capital cost	$31M	

Notes:
a. Includes 1 tank for un-thickened PS (8 hr storage).

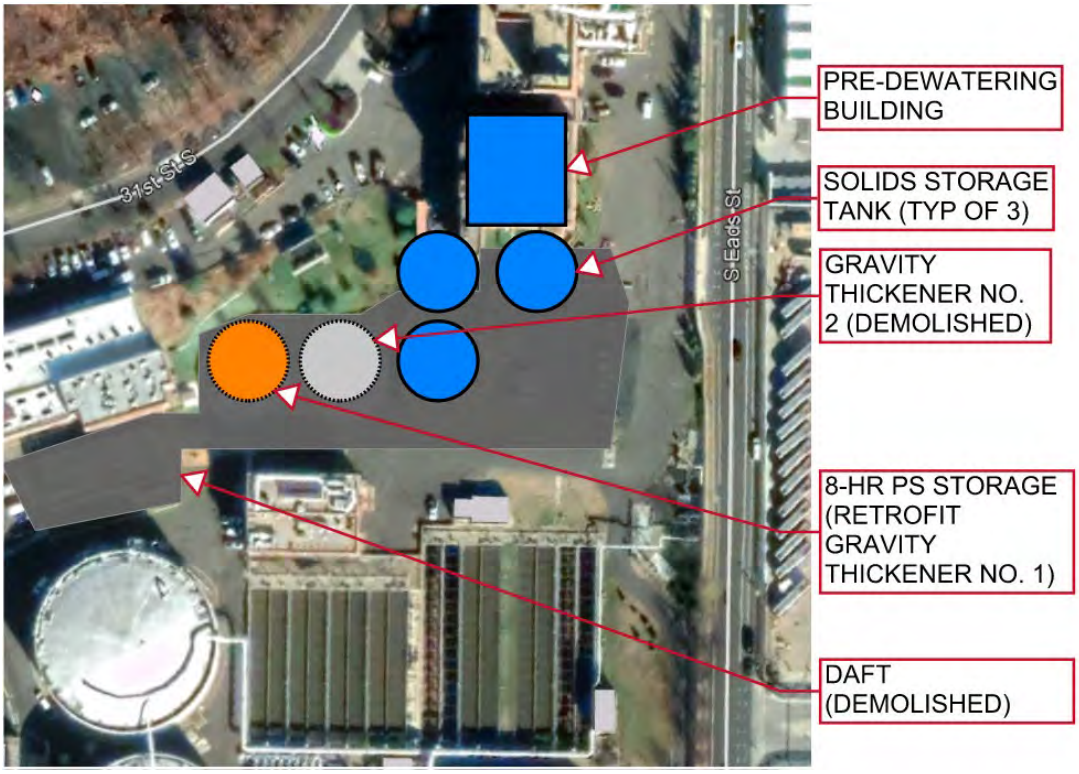

Figure 9. Alternative 1 General Site Layout

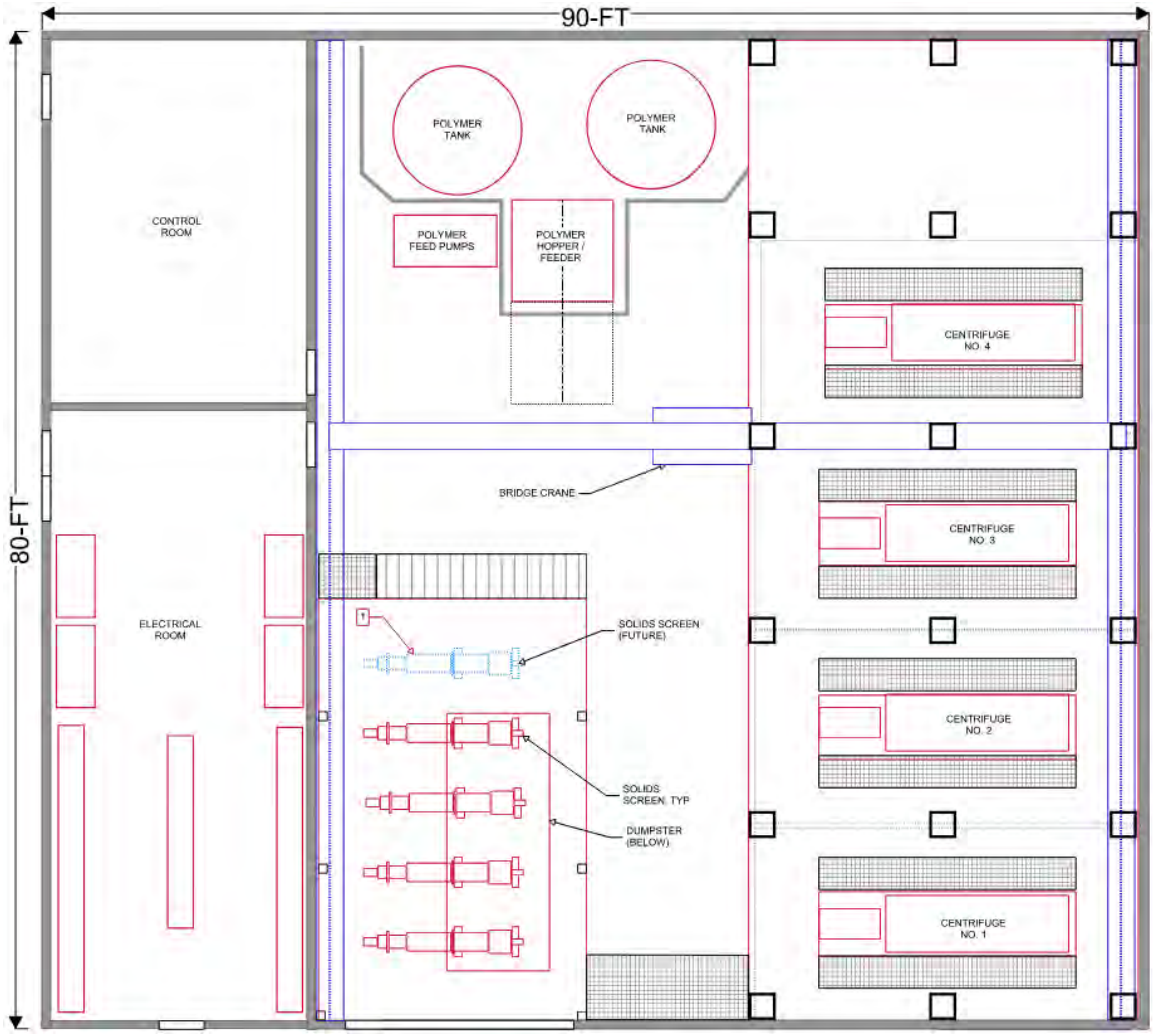

Figure 10. Conceptual Pre-dewatering Building Layout

The County requested that the existing GT tanks be considered for storage in lieu of constructing new storage. The volume of one existing GT tank is approximately half that of the new storage tank used for this evaluation. Therefore, using two GT tanks would reduce the number of new storage tanks by one. The conceptual cost difference between installing three new storage tanks versus installing two new storage tanks and using the two existing GT tanks is not expected to be significant. While cost savings would be realized from eliminating one new storage tank, the existing GTs would require concrete rehabilitation and would need to be converted to storage tanks, which would include replacement covers as well as mixing equipment. Additionally, this alternative requires a buffer tank for PS storage prior to the solids screens. One GT would provide approximately 8 hours of PS storage, or a new tank would need to be constructed.

The advantages and disadvantages of this alternative are listed in Table 15.

Table 15. Alternative 1 Advantages and Disadvantages

Advantages	Disadvantages
Eliminates thickening process and associated O&M costs, including polymer and plant effluent water	Site constrictions during construction and maintenance of plant operations considerations are more significant because of the volume of storage required for un-thickened solids and an 8-hour PS storage/buffer tank upstream of solids screening.
Lower conceptual capital and O&M costs	Higher volume of storage for un-thickened solids results in increased volume of odorous air to treat from storage tank headspace, although similar to GTs.
	Additional solids screening and pre-dewatering equipment units are required to process un-thickened solids.
	Screening and pre-dewatering facility footprint increased to accommodate additional solids screening and pre-dewatering equipment units.

4.2.2 Alternative 2: Gravity Thickeners (PS)/Dissolved Air Flotation Thickeners (WAS)

Alternative 2 would be similar to the current solids thickening processes at the WPCP as shown on the PFD on Figure 11. The GT would require structural repairs, major process mechanical equipment improvements, and replacement of the covers, as well as connection to a new or upgraded odor control station. Table 16 presents design criteria for Alternative 2, Figure 12 provides a general site layout for Alternative 2, and Figure 13 shows a conceptual layout of the pre-dewatering building for this alternative and all subsequent alternatives that include thickening.

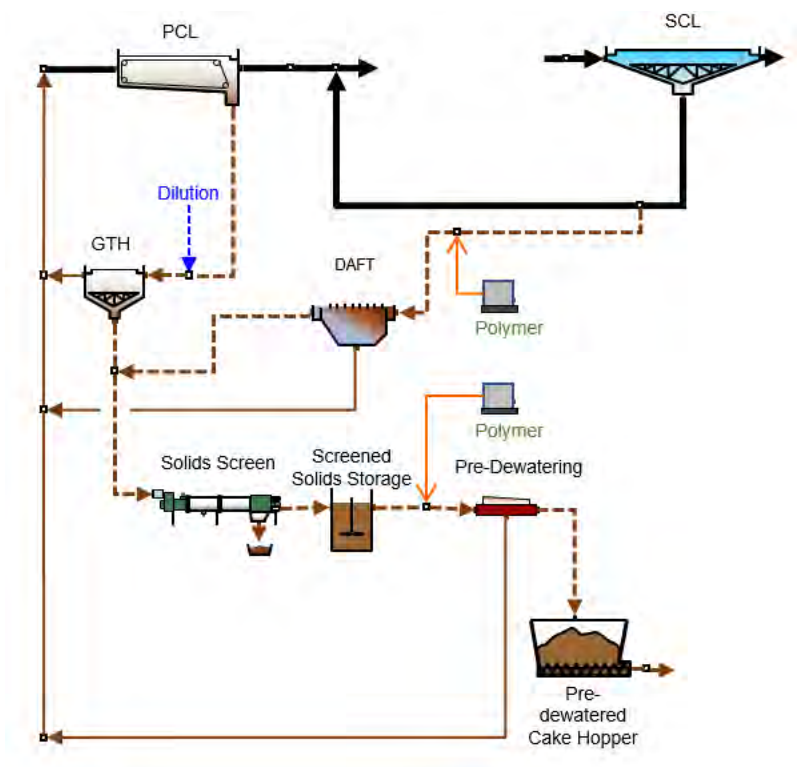

Figure 11. Alternative 2 Process Flow Diagram

Table 16. Alternative 2 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	4.0%	4.0%
Number of GTs (duty/standby)	1/1	1/1 [a]
Number of DAFT (duty/standby)	2/1	3/1
PS/WAS flow to screens (gpm)	290	370
Number of solids screens (duty/standby)	2/1	2/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	1	
Conceptual cost	$44M	

Notes:

a. At 40 mgd, peak 3-day solids projections, GT maximum loading is exceeded. There is sufficient time to evaluate GT performance at higher loading rates. Options for future consideration (post-2050) include: proofing performance with higher loading rates, operating both GTs during peak loading events, building a third GT in the future, or bypassing a portion of un-thickened PS (estimated at less than 20%) if only one GT is available and it is unable to perform at higher loading rates.

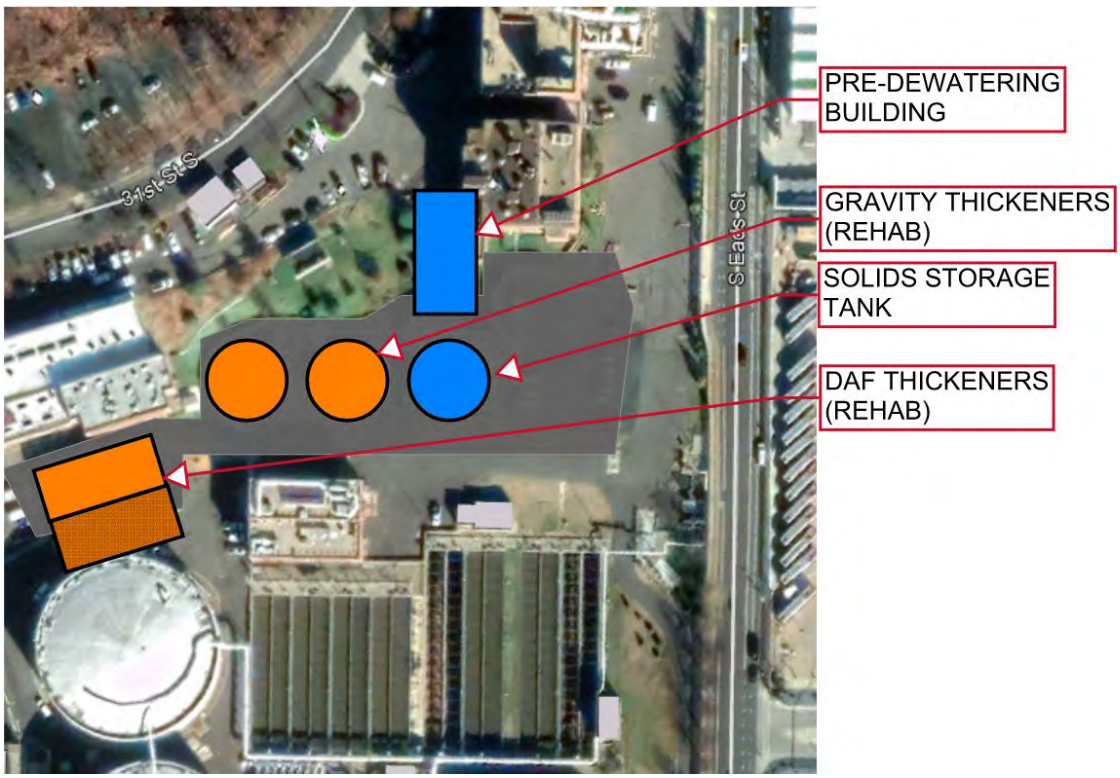

Figure 12. Alternative 2 General Site Layout

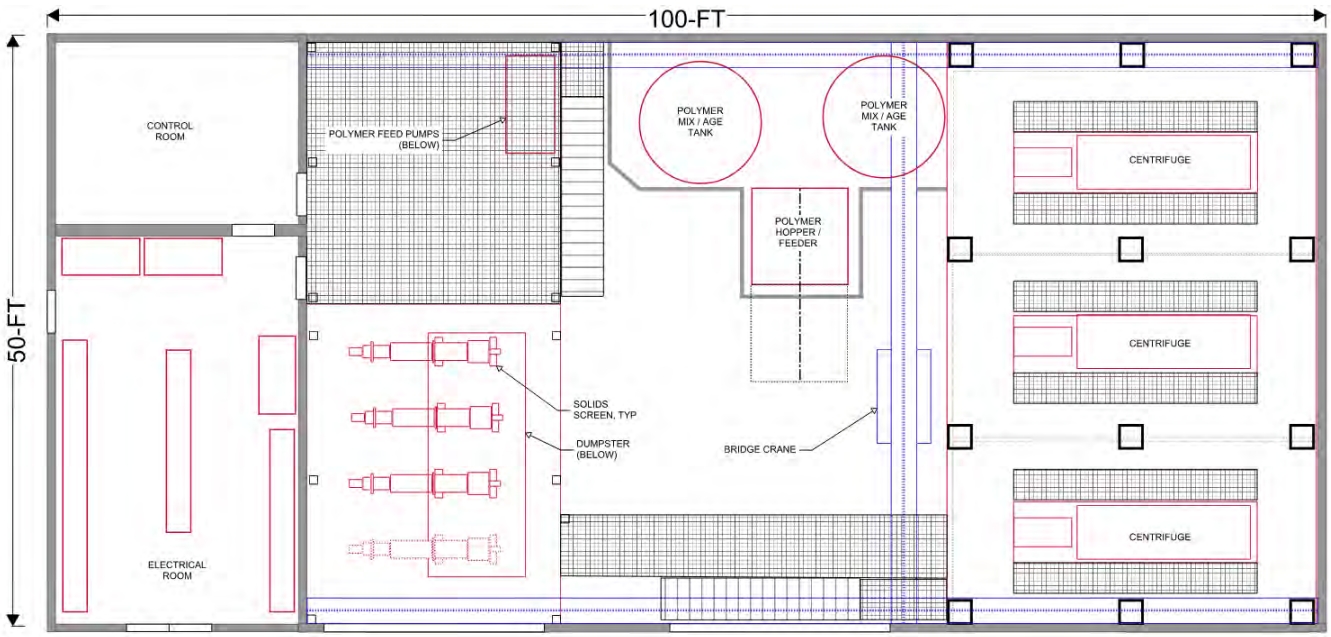

Figure 13. Conceptual Pre-dewatering Building Layout

During the March 17, 2021, workshop, Alternative 2 was eliminated from consideration as there is not sufficient site space for the DAFT facility to be expanded as required to meet future flows. Additionally, the conceptual cost is much higher than that of other alternatives and the DAFTs are high-energy, mechanically intensive units.

4.2.3 Alternative 3: Gravity Thickeners (PS)/Gravity-Belt Thickeners (WAS)

Alternative 3 would include gravity thickening of PS and mechanical thickening of WAS using a GBT and is shown in the PFD on Figure 14. GT rehabilitation would be required, as described for Alternative 2. For the purposes of this evaluation, a new facility to house the GBTs ancillary equipment, including polymer, was considered. The GBTs offer a small footprint per thickening performance compared to the existing DAFT process and are responsive to operator adjustment to control thickening operations.

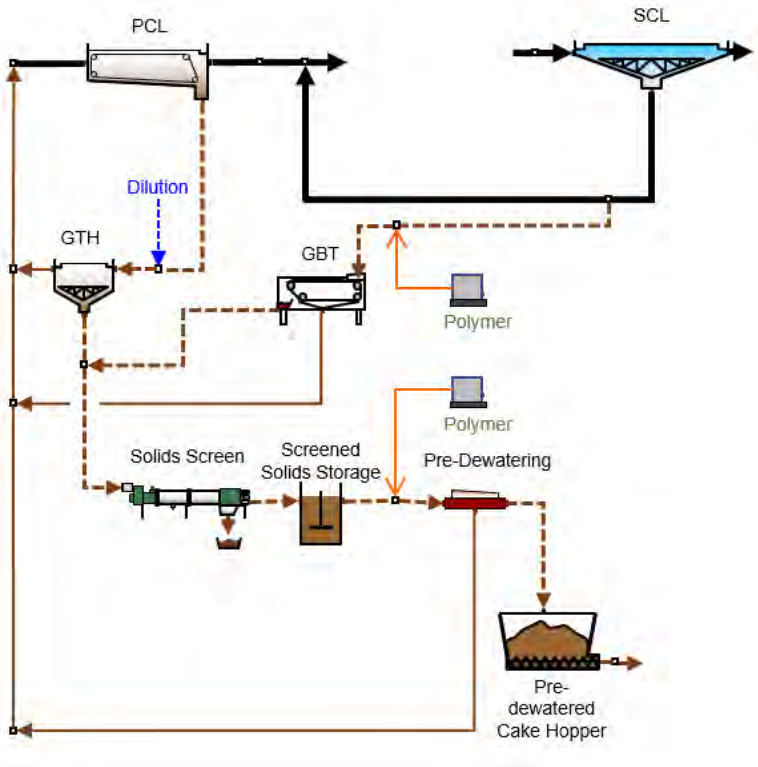

Figure 14. Alternative 3 Process Flow Diagram

This alternative would provide benefits to the overall site impacts. Solids storage and the pre-dewatering equipment/facility quantities and layouts would be minimized. Additionally, the DAFT building can be demolished, providing additional space on site for other uses. The conceptual cost for this alternative is on the lower end of the alternative costs. Table 17 presents design criteria for Alternative 3. The site layout provided in Figure 15 shows a separate GBT building for WAS thickening and a new pre-dewatering building. A conceptual layout of a GBT facility is shown in Figure 16. The pre-dewatering equipment and building layout for this option would be similar to the one shown for Alternative 2.

Table 17. Alternative 3 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	4.28%	4.28%
Number of GTs (duty/standby)	1/1	1/1 [a]
Number of GBTs (duty/standby)	1/1	2/1
PS/WAS flow to screens (gpm)	270	350
Number of solids screens (duty/standby)	2/1	2/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	1	
Conceptual cost	$32M	

Notes:

a. At 40 mgd, peak 3-day solids projections, GT maximum loading is exceeded. There is sufficient time to evaluate GT performance at higher loading rates. Options for future consideration (post-2050) include: proofing performance with higher loading rates, operating both GTs during peak loading events, building a third GT in the future, or bypassing a portion of un-thickened PS (estimated at less than 20%) if only one GT is available and it is unable to perform at higher loading rates.

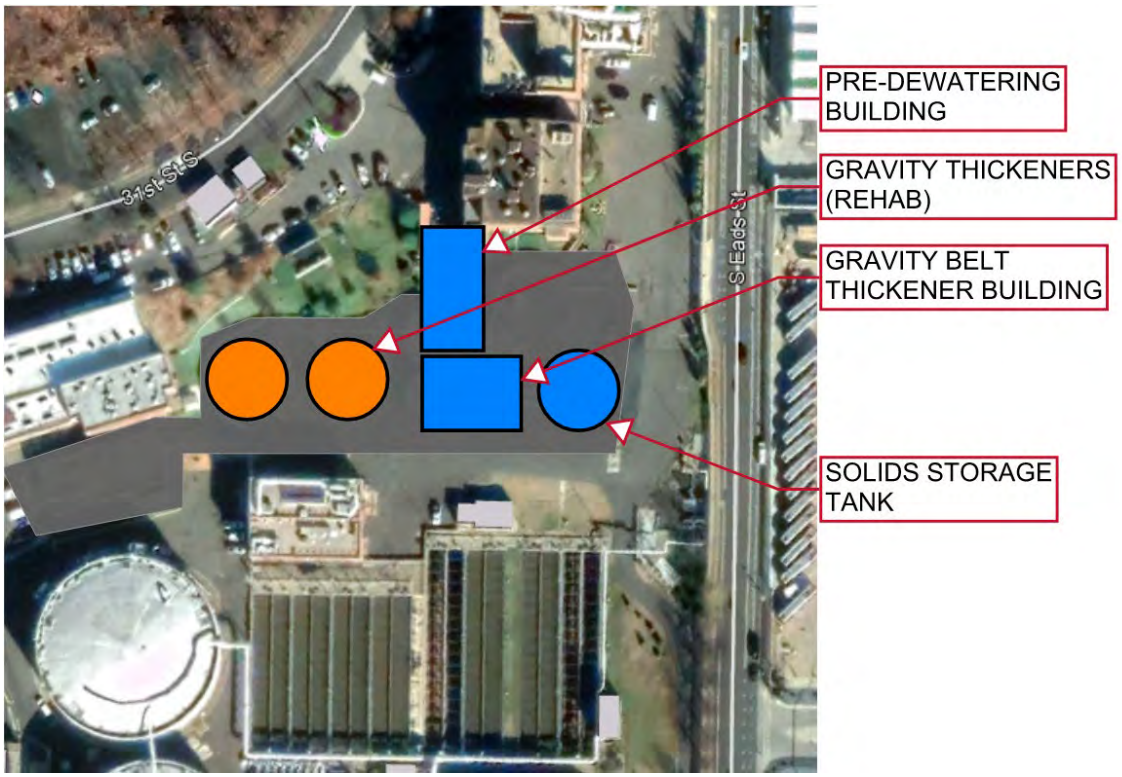

Figure 15. Alternative 3 General Site Layout

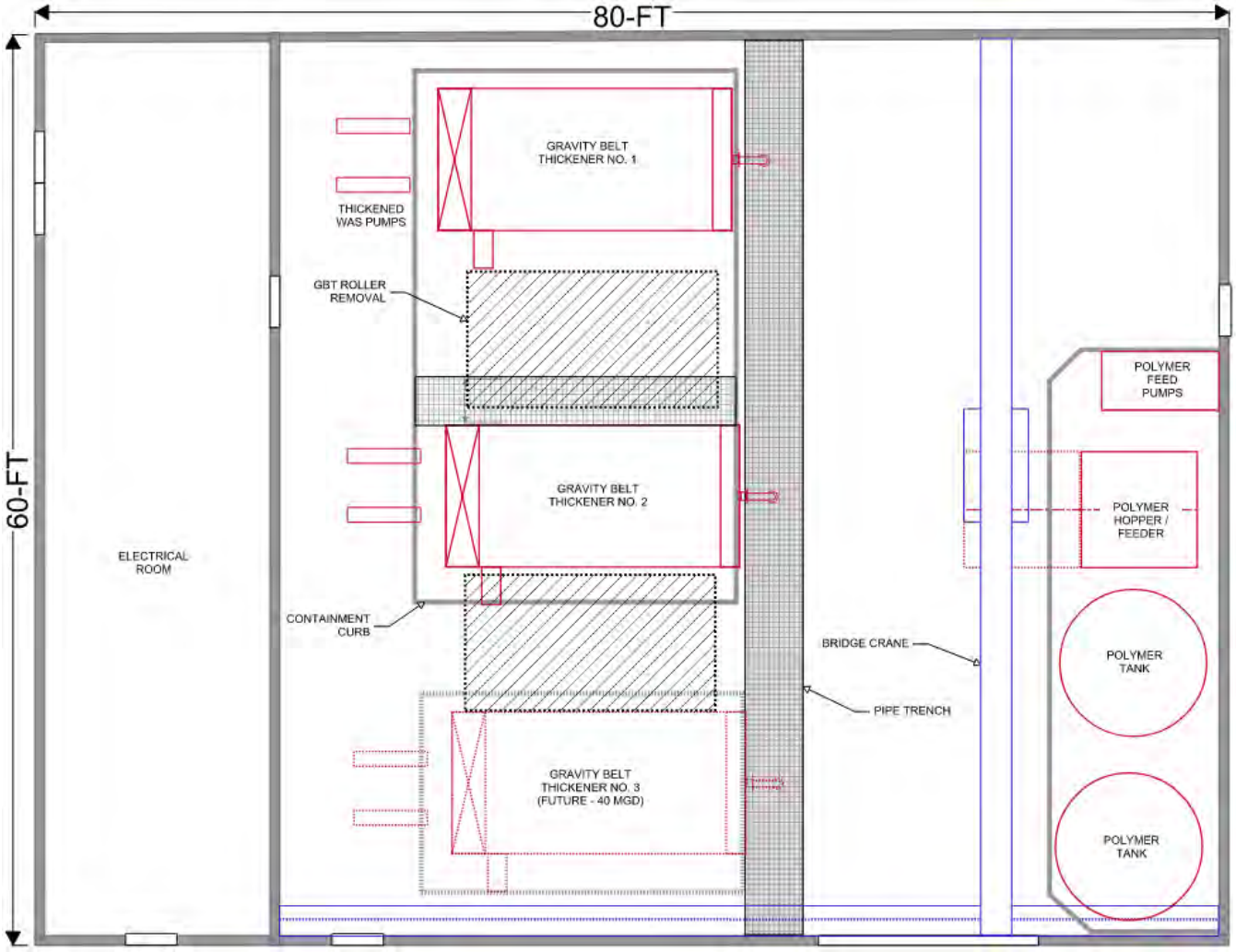

Figure 16. Alternative 3 GBT Building Layout

The advantages and disadvantages of this alternative are listed in Table 18.

Table 18. Alternative 3 Advantages and Disadvantages

Advantages	Disadvantages
GBTs offer high thickening performance per square foot, minimizing WAS thickening footprint.	GBT technology is new to the WPCP staff.
GTs provide a "buffer" for PS upstreaming of solids screens, no separate PS storage/buffer tank is necessary.	GBTs can have local odor issues if not enclosed, especially for co-thickened solids. Some enclosures reduce operation observation and access for maintenance.
Lower conceptual capital and O&M costs.	GT loading is exceeded at 40.0 mgd, peak 3-day solids projections. Mitigation measures may be required beyond 2050.
GTs and GBTs both have relatively low energy requirements.	Flushing of PS lines to GTs needs to be considered.
GBTs for WAS thickening is a common and effective practice.	Belt changes after 2 years of operation.
GBT operations and maintenance is less significant/intensive than other thickening technologies (thickening centrifuges and DAFTs).	Potential roller replacements required.
Open GBTs as well as many enclosures permit operator observation of thickening process, allowing for fine-tuning processes.	
Thickening PS/WAS upstream of solids screens, solids storage, and pre-dewatering reduces equipment quantities and facility footprint on constrained site.	

4.2.4 Alternative 4: Gravity Thickeners/Rotary-Drum Thickeners

Alternative 4 would include gravity thickening for PS and RDTs for WAS. A PFD for Alternative 4 is shown on Figure 17. A new facility was assumed for the RDTs. RDTs have a slightly lower solids throughput (approximately 10 percent lower) than GBTs. Table 19 presents design criteria for Alternative 4. Figure 18 provides the site plan with a new RDT facility and a new pre-dewatering building similar to that shown for Alternative 2. Figure 19 shows an RDT building layout for Alternative 4. Conceptual cost for this alternative is comparative to Alternative 3 (GT/GBTs).

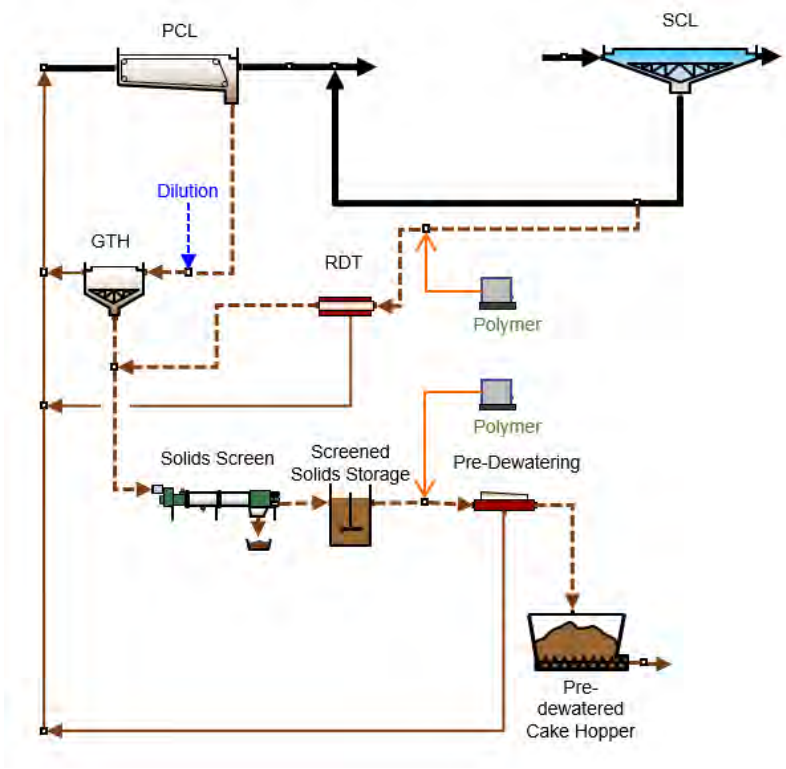

Figure 17. Alternative 4 Process Flow Diagram

Table 19. Alternative 4 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	4.23%	4.23%
Number of GTs (duty/standby)	1/1	1/1 [a]
Number of RDTs (duty/standby)	2/1	2/1
PS/WAS flow to screens (gpm)	270	350
Number of solids screens (duty/standby)	2/1	2/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	1	
Conceptual cost	$33M	

Notes:

a. At 40 mgd, peak 3-day solids projections, GT maximum loading is exceeded. There is sufficient time to evaluate GT performance at higher loading rates. Options for future consideration (post-2050) include: proofing performance with higher loading rates, operating both GTs during peak loading events, building a third GT in the future, or bypassing a portion of un-thickened PS (estimated at less than 20%) if only one GT is available and it is unable to perform at higher loading rates.

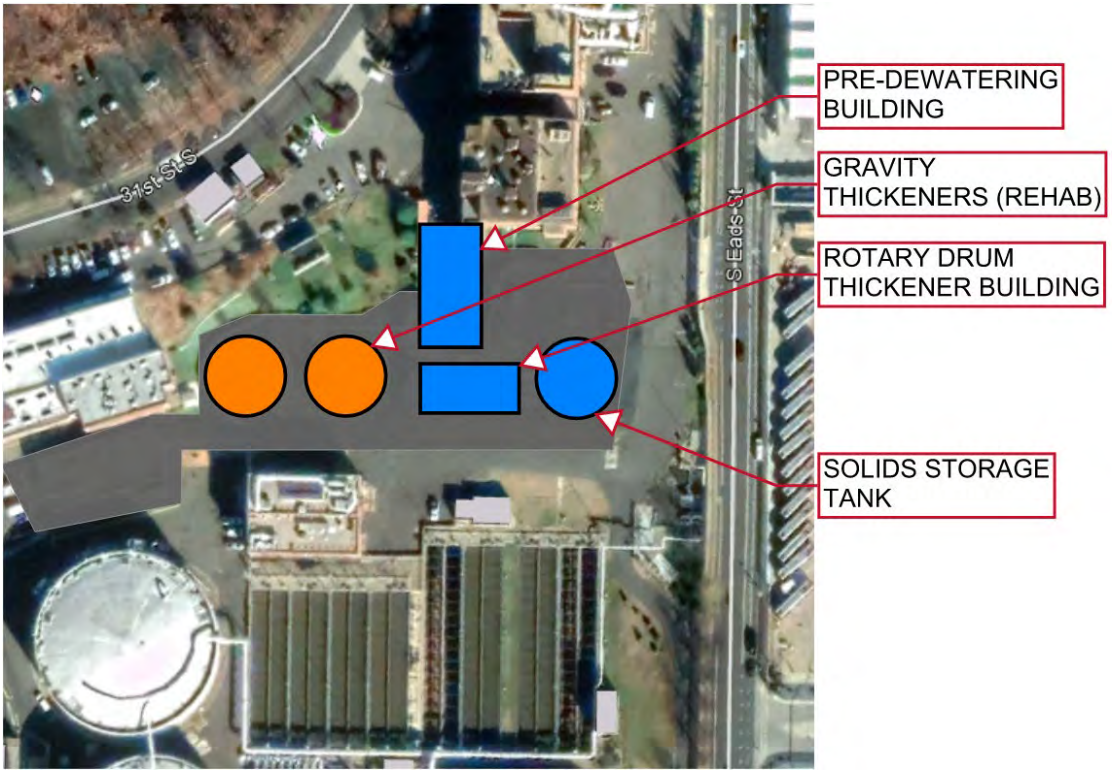

Figure 18. Alternative 4 General Site Layout

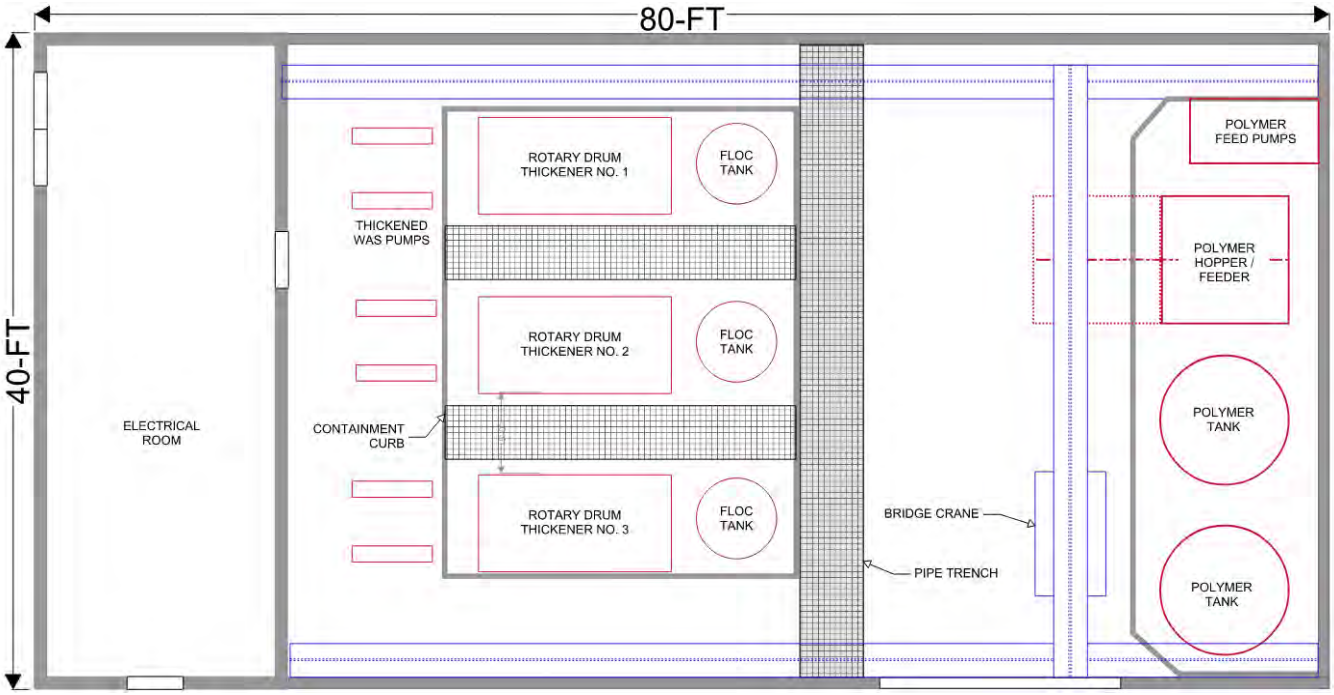

Figure 19. Alternative 4 RDT Building Layout

The advantages and disadvantages of this alternative are listed in Table 20.

Table 20. Alternative 4 Advantages and Disadvantages

Advantages	Disadvantages
RDTs offer high thickening performance per square foot, minimizing WAS thickening footprint.	RDT technology is new to the WPCP staff.
GTs provide a "buffer" for PS upstreaming of solids screens, no separate PS storage/buffer tank is necessary.	RDT solids thickening capacity is typically lower, requiring more units, and can require more polymer than GBTs.
Lower conceptual capital and O&M costs.	RDTs are enclosed, observation of thickening process is not available.
GTs and RDTs both have relatively low energy requirements.	RDTs offer less operator control for adjustments in thickening process and preventing "over-thickening" can be difficult.
RDTs for WAS thickening is a common and effective practice.	GT loading is exceeded at 40.0 mgd, peak 3-day solids projections. Mitigation measures may be required beyond 2050.
RDTs are enclosed, minimizing local odor issues.	
RDT operations and maintenance is less significant/intensive than other thickening technologies (thickening centrifuges and DAFTs).	
Thickening PS/WAS upstream of solids screens, solids storage and pre-dewatering reduces equipment quantities and facility footprint on constrained site.	
Minimal wear components and maintenance.	

4.2.5 Alternative 5: Gravity Thickeners/Centrifuges

Alternative 5 would include gravity thickening for PS and WAS thickening using thickening centrifuges. A PFD of Alternative 5 is shown on Figure 20. Blending centrifuge TWAS with gravity-thickened PS would result in a thickened PS/TWAS concentration of approximately 4.7 percent as indicated in Table 21. Figure 21 below shows a site layout and Figure 22 shows a preliminary centrifuge thickening building layout for Alternative 5.

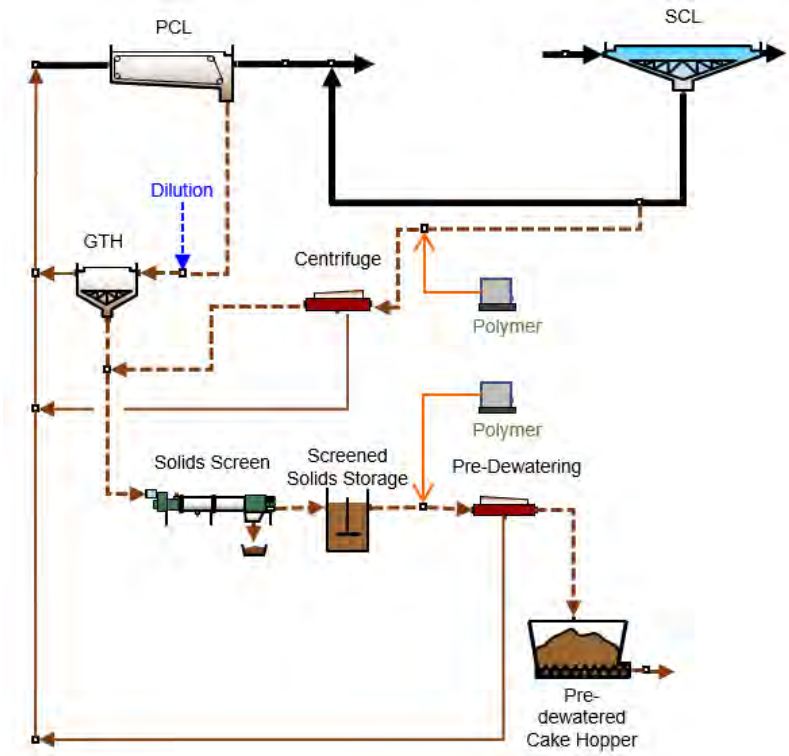

Figure 20. Alternative 5 Process Flow Diagram

This alternative provides similar benefits as Alternatives 3 (GT/GBT) and 4 (GT/RDT). However, there are some drawbacks for this alternative, especially that thickening centrifuges require much higher power demands and potential need for off-site maintenance. Based on these drawbacks, this alternative was eliminated from consideration during the March 17, 2021, workshop.

Table 21. Alternative 5 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	4.28%	4.28%
Number of GTs (duty/standby)	1/1 [a]	1/1 [a]
Number of thickening centrifuges (duty/standby)	1/1	2/1 [b]
PS/WAS flow to screens (gpm)	270	350
Number of solids screens (duty/standby)	2/1	2/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	1	
Conceptual cost	$38M	

Notes:

a. At 30.8 mgd, peak 3-day solids projections, and at 40.0 mgd, peak 30-day solids projections and above, GT loading is exceeded. A portion of un-thickened PS would need to bypass the GTs if two GTs are not online.

b. Two centrifuges are required at peak load conditions because of hydraulic capacity limitations.

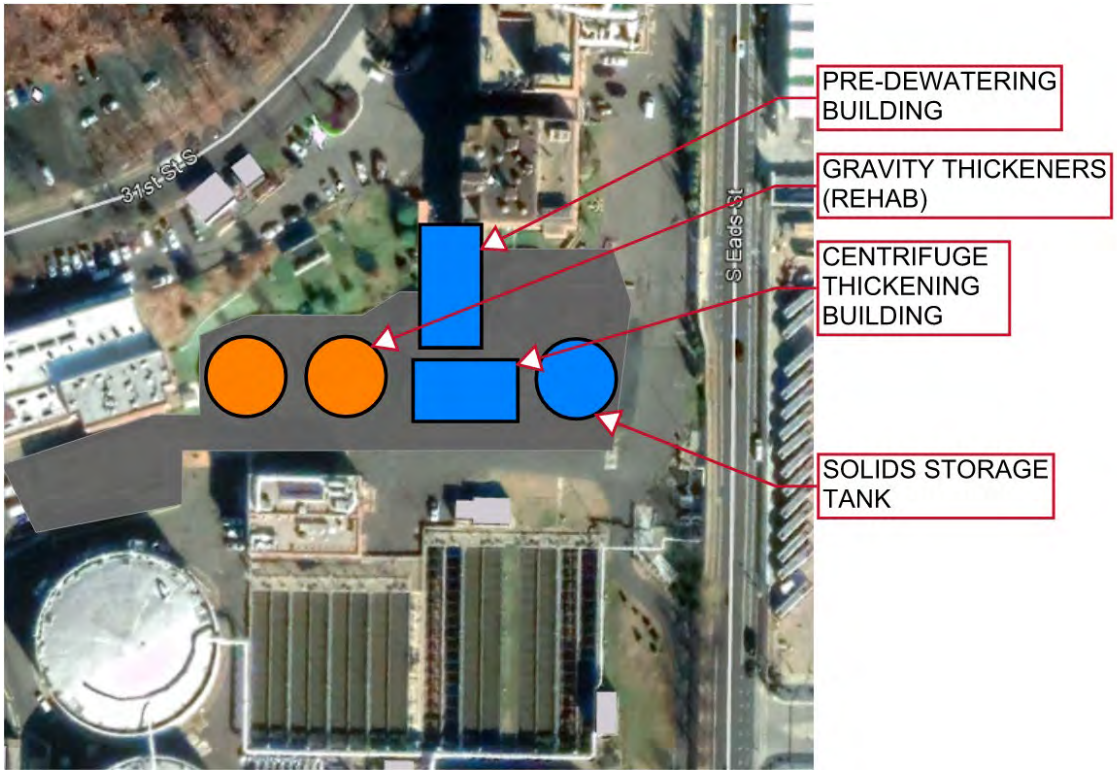

Figure 21. Alternative 5 General Site Layout

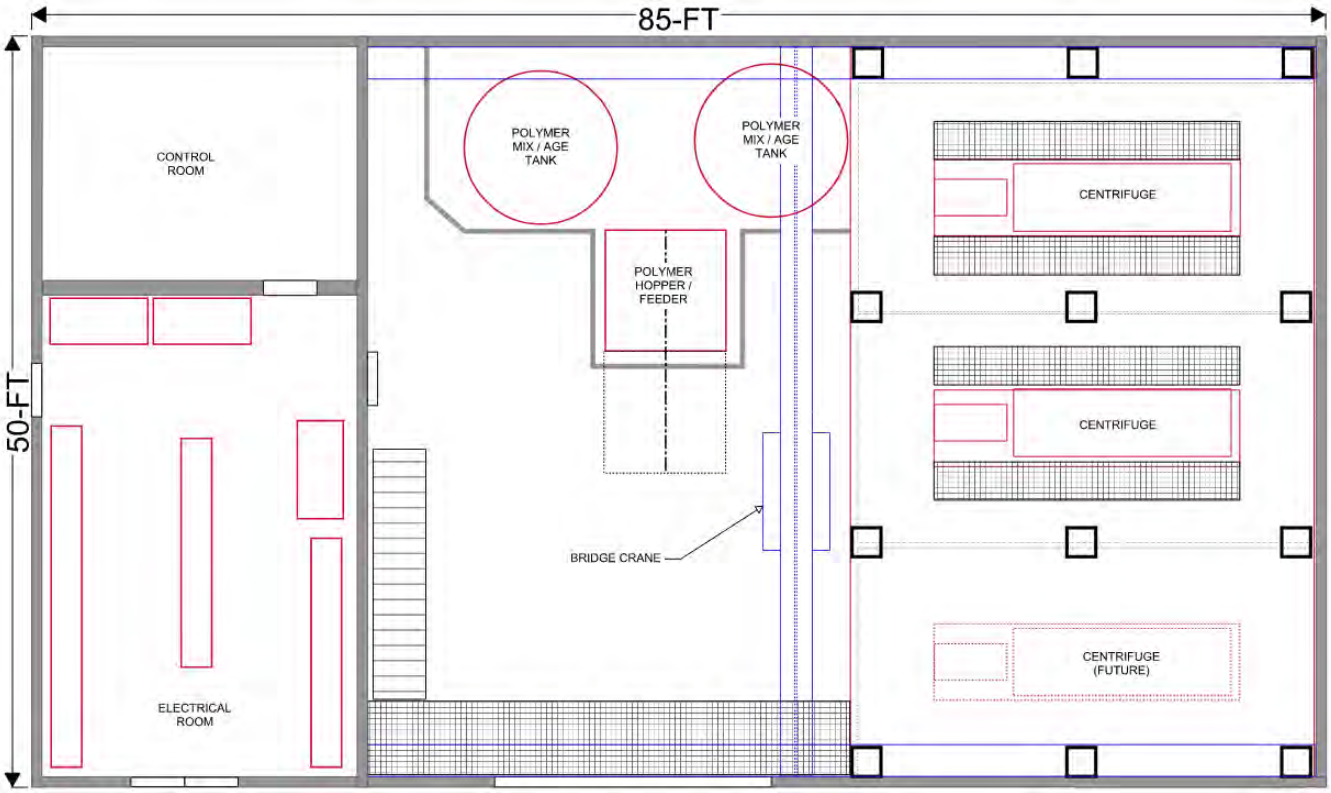

Figure 22. Alternative 5 Centrifuge Thickening Building Layout

4.2.6 Alternative 6: Co-Thickening (Gravity Thickeners)

Alternative 6 would include co-thickening of PS and WAS with GTs. The existing GTs would require rehabilitation, similar to previous alternatives. Additional GTs would be needed to meet 30.8 mgd and 40.0 mgd solids loading projections. The pre-dewatering equipment and building layout for this option would be similar to the one shown for Alternative 2.

A PFD for Alternative 6 is shown on Figure 23. Table 22 presents design criteria for Alternative 6. Figure 24 below shows a site layout for Alternative 6.

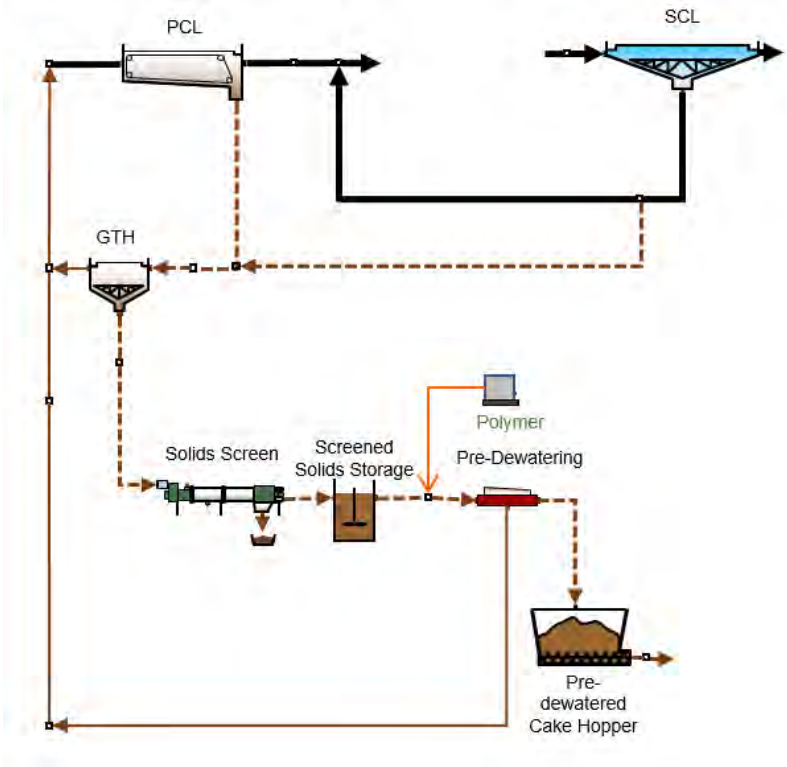

Figure 23. Alternative 6 Process Flow Diagram

Table 22. Alternative 6 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	3%	3%
Number of GTs (duty/standby)	3/1	4/1
PS/WAS flow to screens (gpm)	380	500
Number of solids screens (duty/standby)	2/1	3/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	1	
Conceptual cost	$42M	

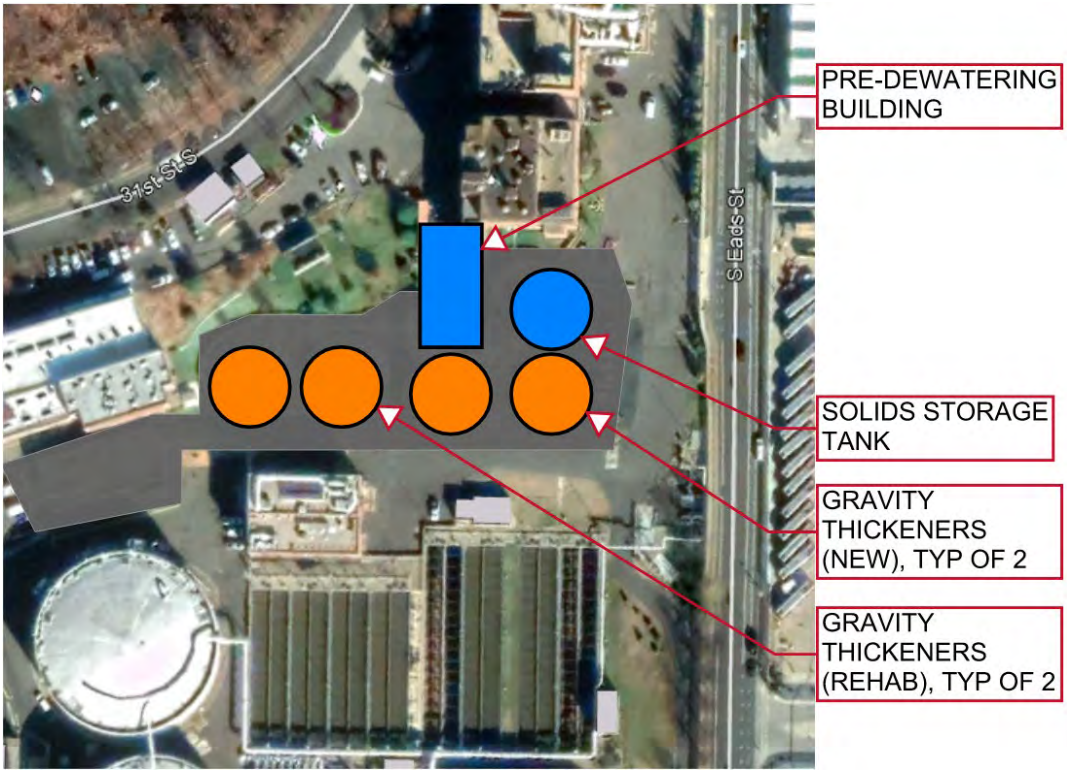

Figure 24. Alternative 6 General Site Layout

The site space required for additional GTs for co-thickening is a major drawback. In addition, co-thickening has the potential to cause process upsets and additional odors, and phosphorus release should the WPCP implement biological phosphorus removal in the future. For these reasons, this alternative was eliminated from further consideration during the March 17, 2021, workshop.

4.2.7 Alternative 7: Un-thickened PS/TWAS

Alternative 7 would include mechanical thickening for WAS, similar to Alternatives 3, 4, and 5 (GBTs, RDTs, or thickening centrifuges) but would not include PS thickening. Un-thickened PS and TWAS would be screened and stored prior to pre-dewatering, as shown in the PFD provided on Figure 25. Additional screened solids storage is needed for this option because of the large quantity of un-thickened PS. The existing GTs and DAFT building could be demolished to help make more space available around the site. The pre-dewatering facility would be minimized, similar in size to the pre-dewatering facility shown in Alternative 5. However, additional O&M attention would be necessary to process the larger hydraulic quantity associated with un-thickened PS. Table 23 presents design criteria for Alternative 7. Figure 26 shows a site layout for Alternative 7. The pre-dewatering building layout would be similar to that shown in Alternative 1.

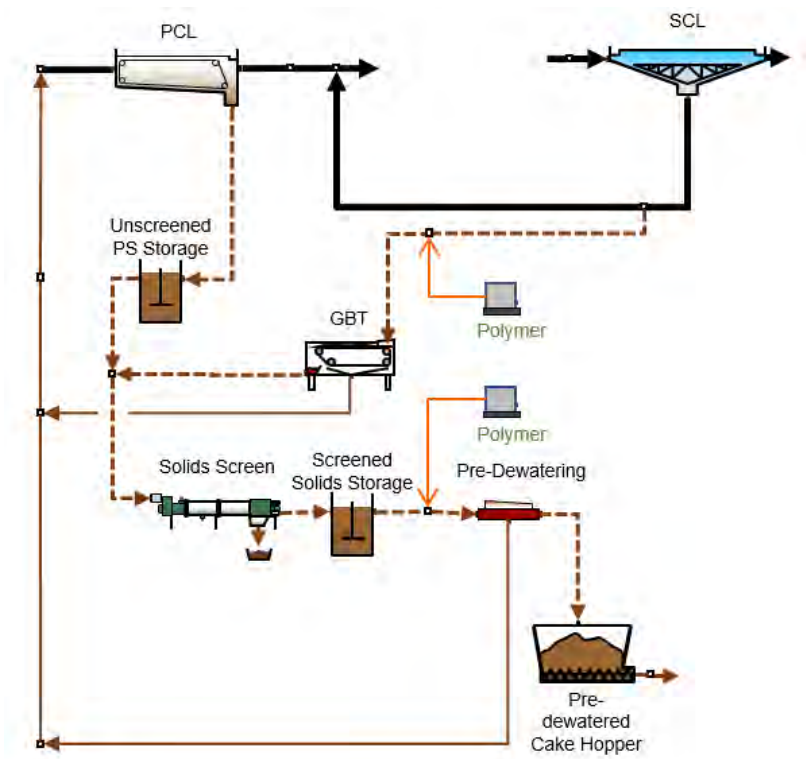

Figure 25. Alternative 7 Process Flow Diagram

Table 23. Alternative 7 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Un-thickened PS/TWAS concentration	1.36%	1.36%
GBT (WAS thickening) (duty/standby)	1/1	2/1
RDT (WAS thickening) (duty/standby)	2/1	2/1
PS/WAS flow to screens (gpm)	850	1,100
Number of solids screens (duty/standby)	3/1	4/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	3/1
Liquid solids storage tanks	3[a]	
Conceptual cost	$31M	

Notes:

a. Includes 1 tank for un-thickened PS (8 hr storage).

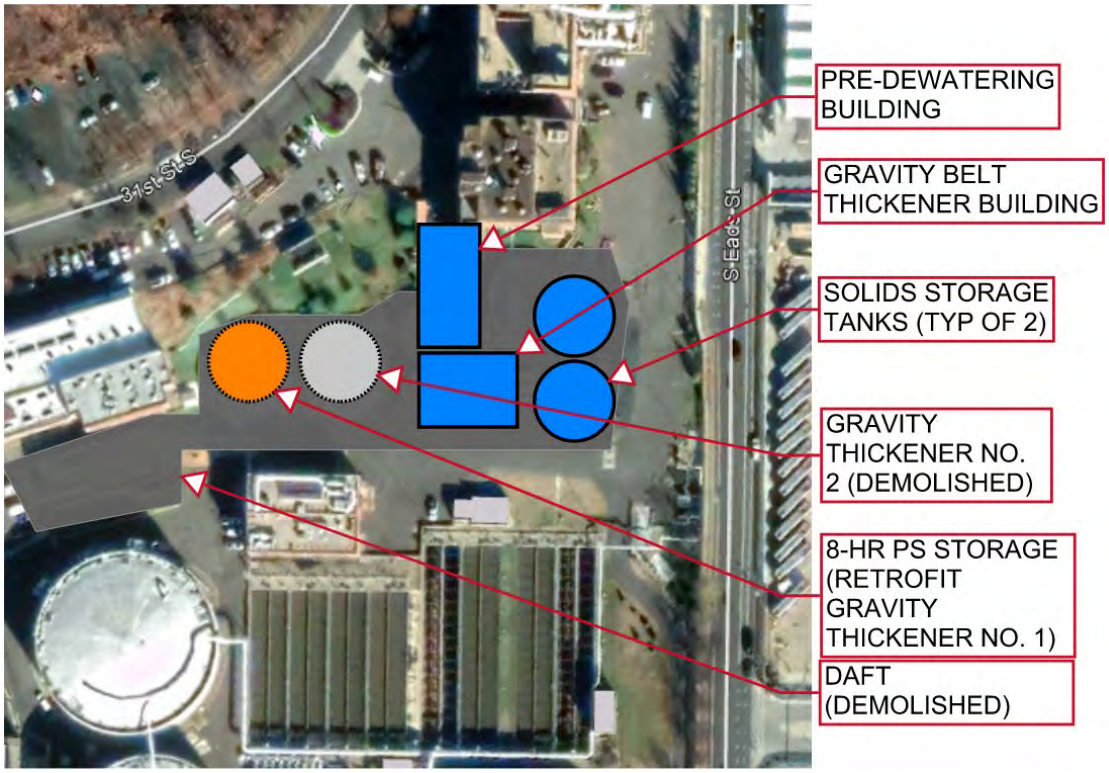

Figure 26. Alternative 7 General Site Layout

The advantages and disadvantages of this alternative are listed in Table 24.

Table 24. Alternative 7 Advantages and Disadvantages

Advantages	Disadvantages
GBTs/RDTs offer high thickening performance per square foot, minimizing WAS thickening footprint.	Site constrictions are more significant because of the volume of storage required for un-thickened PS as well as an 8-hour PS storage/buffer tank upstream of solids screening.
Lower conceptual capital and O&M costs.	Higher volume of storage for un-thickened PS results in increased volume of odorous air to treat from storage tank headspace although similar to GTs.
GBTs and RDTs both have relatively low energy requirements.	Additional solids screening and pre-dewatering equipment units required to process un-thickened PS, relative to other alternatives, other than Alternative 1.
GBTs/RDTs for WAS thickening is a common and effective practice.	Screening and pre-dewatering facility footprint increased in order to accommodate additional solids screening and pre-dewatering equipment units, relative to other alternatives, other than Alternative 1.
GBTs/RDTs operations and maintenance is less significant/intensive than other thickening technologies (thickening centrifuges and DAFTs).	GBTs/RDTs are new technology to the WPCP staff.
Open GBTs as well as many enclosures permit operator observation of thickening process, allowing for fine-tuning processes.	GBTs can have local odor issues if not enclosed. Some enclosures reduce operation observation and access for maintenance.
Thickening WAS upstream of solids screens, solids storage and pre-dewatering reduces equipment quantities some, relative to un-thickened PS/WAS and facility footprint on constrained site.	RDT solids thickening capacity is typically lower, requiring more units, and can require more polymer than GBTs.
	RDTs are enclosed, observation of thickening process is not available.
	RDTs offer less operator control for adjustments in thickening process and preventing “over-thickening” can be difficult.

4.2.8 Alternative 7A: Gravity Thickeners/Un-thickened WAS

Alternative 7A would include gravity thickening for PS and no thickening for WAS. A PFD for Alternative 7A is shown on Figure 27. Table 25 presents design criteria for Alternative 7A. Figure 28 provides the site plan with a new a new pre-dewatering building similar to that shown for Alternative 2.

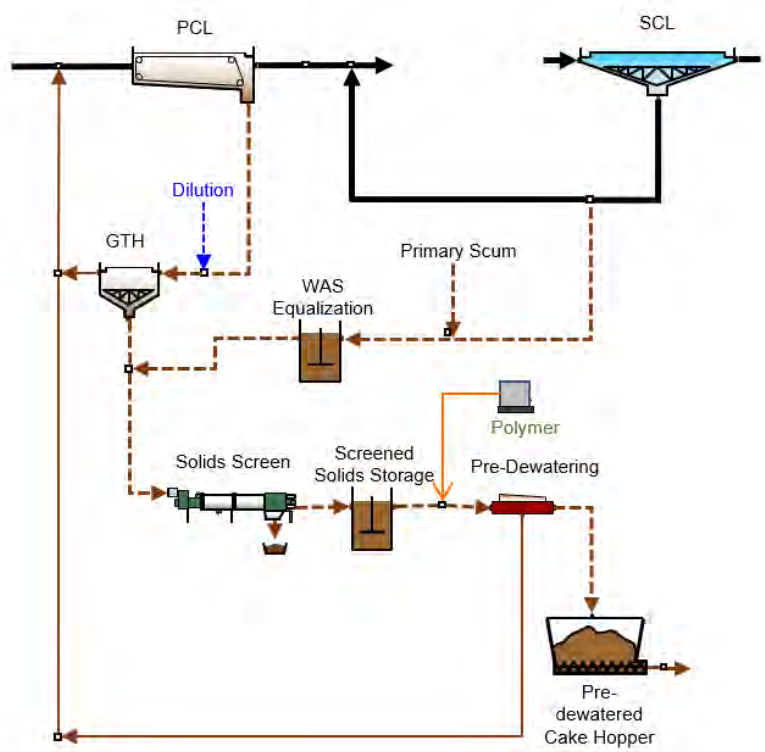

Figure 27. Alternative 7A Process Flow Diagram

Table 25. Alternative 7A Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	2.1%	2.1%
Number of GTs (duty/standby)	1/1	1/1 [a]
PS/WAS flow to screens (gpm)	540	700
Number of solids screens (duty/standby)	2/1	3/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	2 + 1 un-thickened	
Conceptual cost	$29M	

Notes:

a. At 40 mgd, peak 3-day solids projections, GT maximum loading is exceeded. There is sufficient time to evaluate GT performance at higher loading rates. Options for future consideration (post-2050) include: proofing performance with higher loading rates, operating both GTs during peak loading events, building a third GT in the future, or bypassing a portion of un-thickened PS (estimated at less than 20%) if only one GT is available and it is unable to perform at higher loading rates.

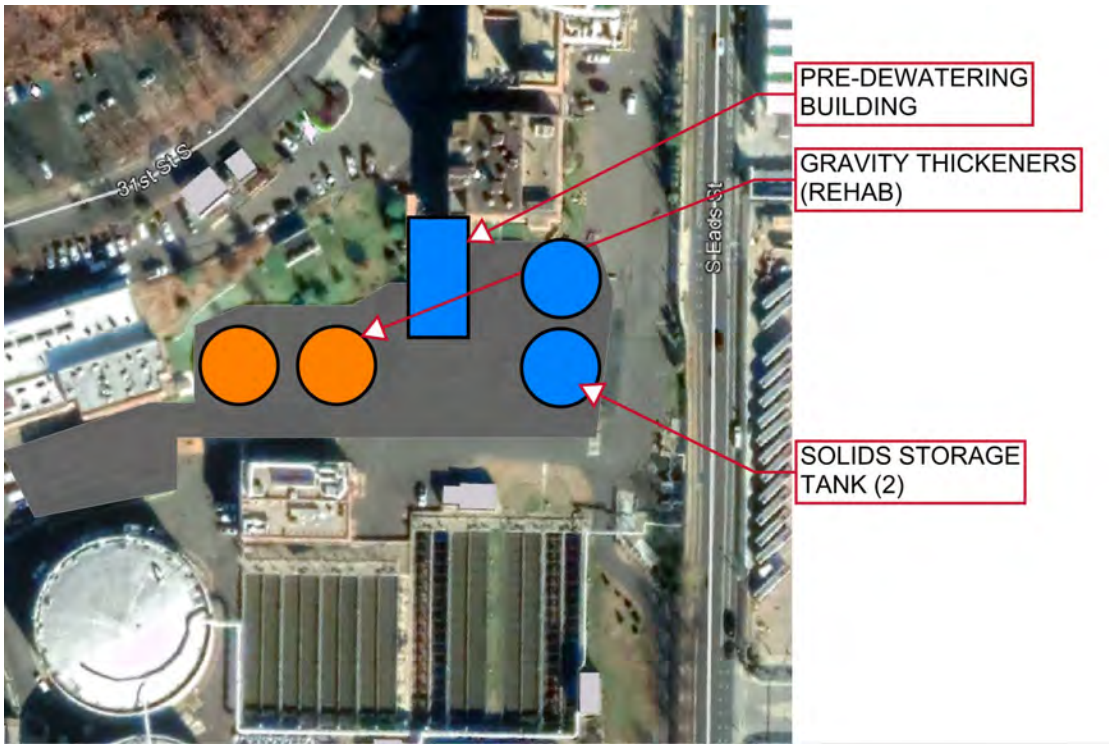

Figure 28. Alternative 7A General Site Layout

The advantages and disadvantages of this alternative are listed in Table 26.

Table 26. Alternative 7A Advantages and Disadvantages

Advantages	Disadvantages
Eliminating WAS thickening eliminates one unit process without impacting dewatering sizing.	Site constrictions are more significant because of volume of storage required for un-thickened WAS as well as an 8-hour WAS storage/buffer tank upstream of solids screening.
GTs provide a "buffer" for PS upstreaming of solids screens; no separate PS storage/buffer tank is necessary.	Higher volume of storage results in increased volume of odorous air to treat from storage tank headspace.
Lower conceptual capital and O&M costs.	GT loading is exceeded at 40.0 mgd, peak 3-day solids projections. Mitigation measures may be required beyond 2050.
GTs have relatively low energy requirements.	
Thickening PS upstream of solids screens, solids storage, and pre-dewatering reduces equipment quantities and facility footprint on a constrained site.	
Minimal wear components and maintenance.	

4.2.9 Alternative 8: Co-Thickening (GBT or RDT)

Alternative 8 would include co-thickening of PS and WAS using either GBTs or RDTs. The pre-dewatering equipment and building layout for this option would be similar to the one shown for Alternative 2. A

new facility was assumed for the co-thickening process equipment. This facility would be larger compared to the WAS-only GBT or RDT facilities in previous alternatives as additional thickening units would be needed. Additionally, it is recommended that a separate storage tank be provided for un-thickened PS to provide a buffer upstream of thickening, as shown in the PFD on Figure 29. The site layout in Figure 30 below shows the two required solids storage tanks (one for un-thickened PS and one for thickened/screened solids) in new locations. Note that one existing GT has the volume to provide 8 hours of storage of PS at the 30.8 mgd, peak 3-day solids loading projections, and could be converted as an alternative to building a second solids storage tank. Table 27 presents design criteria for Alternative 8. Figure 31 shows the preliminary thickening building layout for Alternative 8.

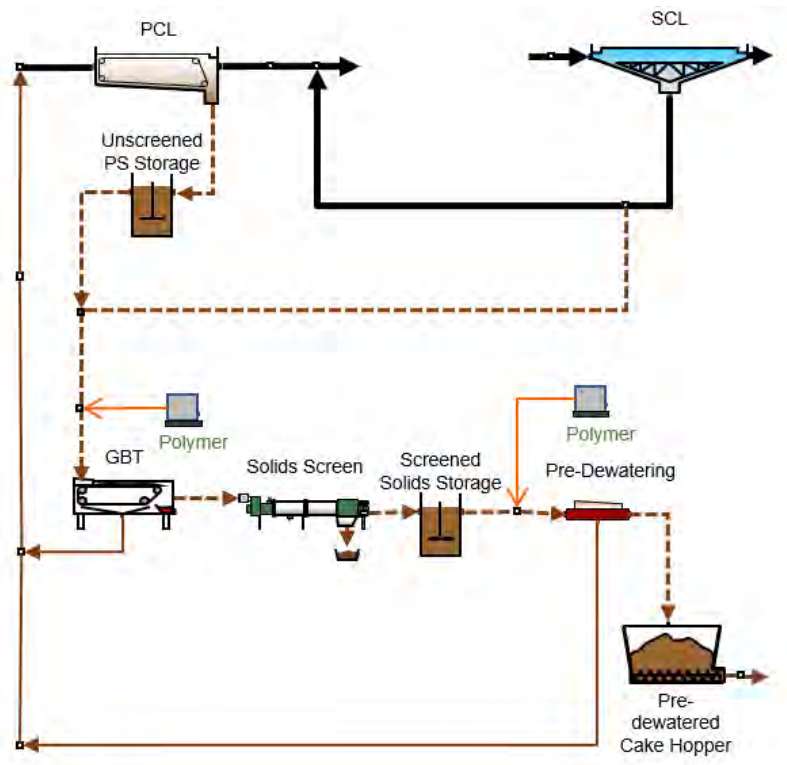

Figure 29. Alternative 8 Process Flow Diagram

The major drawback for this alternative is that co-thickening can lead to process issues such as additional odors and phosphorus release should the WPCP implement biological phosphorus removal in the future. The County agreed that this alternative should be eliminated from further consideration during the March 17, 2021, workshop. However, the County inquired about separate thickening of PS and WAS with GBTs or RDTs in the same facility. This has been added as Alternative 8A.

Table 27. Alternative 8 Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	5%	5%
Number of GBTs/RDTs (duty/standby)	4/1	5/1
PS/WAS flow to screens (gpm)	230	300
Number of solids screens (duty/standby)	2/1	2/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	2 [a]	
Conceptual cost	$36M	

Notes:

a. 1 tank for un-thickened PS (8 hr storage) and 1 tank for co-thickened PS and WAS.

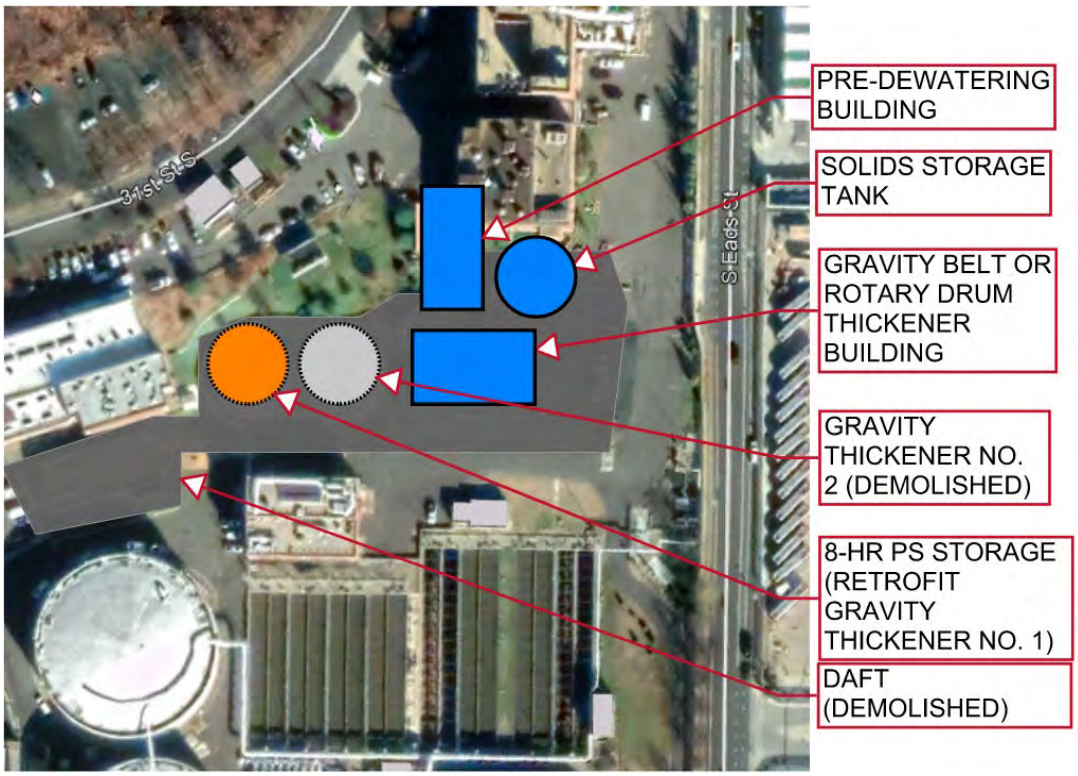

Figure 30. Alternative 8 General Site Layout

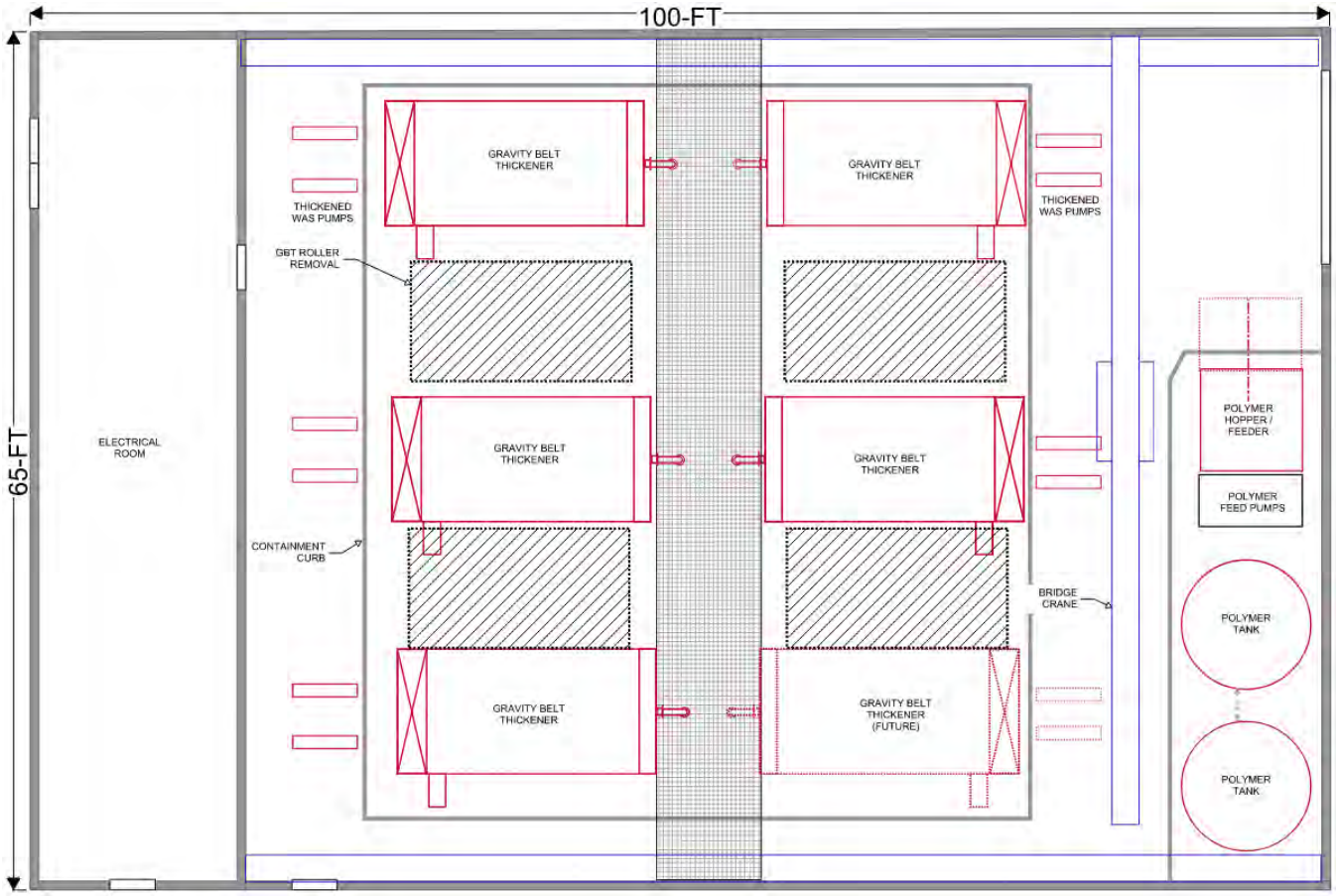

Figure 31. Alternative 8 Thickening Building Layout

4.2.10 Alternative 8A: Separate PS and WAS Thickening (GBT or RDT)

Alternative 8A includes separate thickening of PS and WAS using the same mechanical thickening technology (either GBTs or RDTs) in the same building. For the purposes of this evaluation, thickened PS concentration is 5.0 percent and 5.0 percent WAS. There are limited installations that use GBTs or RDTs for PS thickening only. A key challenge with thickening PS with GBTs or RDTs is the variability in solids concentration of the solids feed. Polymer could be overdosed or underdosed as the PS feed solids concentration varies, unless proper monitoring and controls are in place to monitor feed solids concentrations and adjusting polymer feed rate accordingly. Additionally, there is potential that different polymer types are required for PS and WAS. It is recommended that a separate storage tank be provided for un-thickened PS to provide a buffer upstream of thickening, as shown in the PFD on Figure 32. The number of GBT/RDT units listed in Table 28 below suggests that seven thickening units are required. However, this accounts for a redundant unit for both PS and WAS. One unit can be eliminated, and a single “swing” unit could be installed to back up the PS and WAS units. This would make the thickening building layout similar to the layout shown in Alternative 8. The pre-dewatering equipment and building layout for this option would be similar to the one shown for Alternative 2. The site layout would also be similar to Alternative 8.

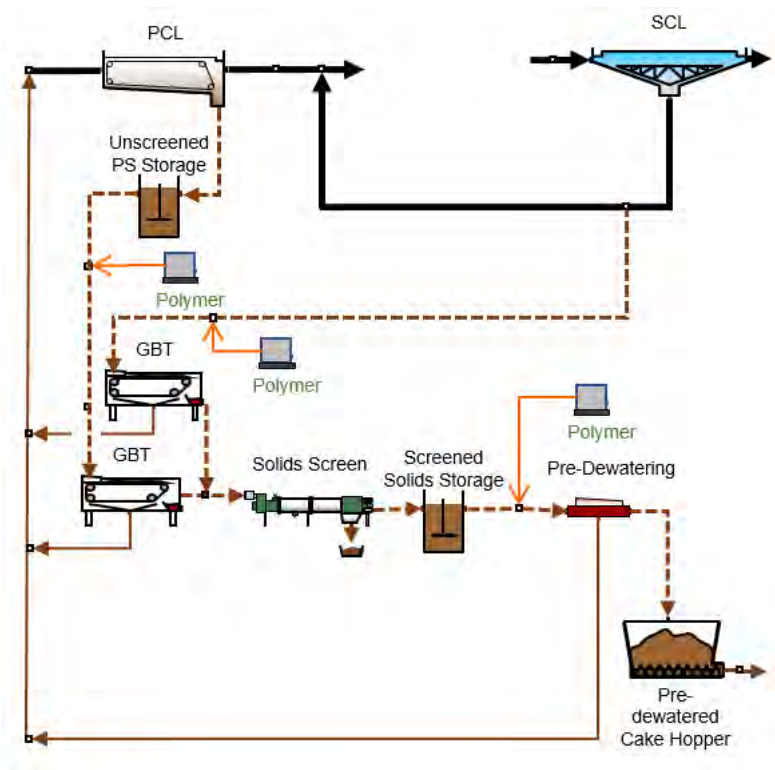

Figure 32. Alternative 8a Process Flow Diagram

Table 28. Alternative 8A Design Criteria

Parameter	30.8 mgd	40.0 mgd
Thickened PS/TWAS concentration	5.0%	5.0%
Number of GBTs/RDTs for PS (duty/standby)	3/1	3/1
Number of GBTs/RDTs for WAS (duty/standby)	2/1	2/1
PS/WAS flow to screens (gpm)	230	300
Number of solids screens (duty/standby)	2/1	2/1
Number of pre-dewatering centrifuges (duty/standby)	2/1	2/1
Liquid solids storage tanks	2 [a]	
Conceptual cost	$38M	

Notes:

a. One storage tank required for screen solids storage. One storage tank is required to provide 8-hours of un-thickened primary solids storage prior to thickening. One existing GT tank has the capacity to provide 8-hours of un-thickened primary solids storage at 30.8 mgd, peak 3-day solids loading.

The advantages and disadvantages of this alternative are listed in Table 29.

Table 29. Alternative 8A Advantages and Disadvantages

Advantages	Disadvantages
GBTs/RDTs offer high thickening performance per square foot, minimizing WAS thickening footprint.	Higher conceptual capital and O&M costs. Highest net present value of all alternatives.
GBTs and RDTs both have relatively low energy requirements.	Additional tank required for 8-hour PS storage/buffer tank upstream of mechanical thickening.
GBTs/RDTs for WAS thickening is a common and effective practice.	
GBTs/RDTs operations and maintenance is less significant/intensive than other thickening technologies (thickening centrifuges and DAFTs).	
Open GBTs as well as many enclosures permit operator observation of thickening process, allowing for fine-tuning processes.	Challenges with uncommon operation of thickening PS on GBTs RDTs.
Thickening PS/WAS upstream of solids screens, solids storage and pre-dewatering reduces equipment quantities and facility footprint on constrained site.	GBTs/RDTs are new technology to the WPCP staff.
	GBTs can have local odor issues if not enclosed, likely exacerbated with thickening PS. Some enclosures reduce operation observation and access for maintenance.
	RDT solids thickening capacity is typically lower, requiring more units, and can require more polymer than GBTs.
	RDTs are enclosed, observation of thickening process is not available.
	RDTs offer less operator control for adjustments in thickening process.

5.0 O&M Cost Comparison for Shortlisted Alternatives

Alternatives 1, 3, 4, 7, and 8A were selected during the March 17, 2021, workshop for further consideration. O&M cost estimates were prepared at a conceptual level for each of these shortlisted alternatives for comparison purposes. O&M costs were developed based on the following:

- **GTs:** power costs, elutriation water
- **GBTs and RDTs:** power, polymer, washwater, and maintenance costs
- **Solids screening, storage (mixing), and pre-dewatering centrifuge costs:**
    - **Solids screening:** power cost
    - **Solids storage:** power cost for storage mixing
    - **Pre-dewatering centrifuges**: power, polymer, and annual maintenance cost

Table 30 shows the annual O&M costs (based on a WPCP influent flow of 28 mgd) and associated present value. Annual O&M costs were estimated at 28 mgd, the approximate midpoint flow condition and assumed average annual O&M costs over the 20-year analysis period.

Table 30. O&M Cost Comparison

Category	1: No Thickening	3: GT/GBT	4: GT/RDT	7: UT PS/RDT WAS	7A: GT/UT WAS	8A: Separate Mechanical
Electricity	$110,000	$70,000	$70,000	$90,000	$70,000	$80,000
Polymer	$590,000	$690,000	$730,000	$730,000	$590,000	$990,000
Water	--	$140,000	$140,000	$5,000	$130,000	$20,000
Maintenance	$30,000	$20,000	$30,000	$40,000	$20,000	$30,000
Total	**$730,000**	**$920,000**	**$970,000**	**$860,000**	**$810,000**	**$1,120,000**
Annual present worth	**$12.0M**	**$15.1M**	**$15.9M**	**$14.1M**	**$13.3M**	**$18.4M**

Notes:
a. Inflation rate: 2%
b. Interest rate (nominal): 4.0%
c. Interest rate (real): 1.96%
d. Term: 20 years
e. Power cost: $0.06/kWh
f. Polymer cost: $2.45/lb

6.0 Summary and Conclusions

This section presents a summary and conclusions from the thickening evaluation.

6.1 Shortlisted Alternatives

The following alternatives were selected from through workshops for further consideration:

- **Alternative 1:** no thickening
- **Alternative 3:** GTs (PS)/GBTs (WAS)
- **Alternative 4:** GTs (PS)/RDTs (WAS)
- **Alternative 7:** un-thickened PS/GBT or RDT-thickened WAS
- **Alternative 7A:** GTs (PS)/un-thickened WAS
- **Alternative 8A:** separate thickening (either GBT or RDT) in same facility

A summary of the major considerations for these shortlisted alternatives is presented in Table 31 including key advantages and/or disadvantages and a summary of conceptual capital and O&M costs.

Table 31. Summary of Shortlisted Alternatives

Parameter	Alt. 1: No Thickening	Alt. 3: GT/GBT	Alt. 4: GT/RDT	Alt. 7: Un-thickened PS/TWAS	Alt. 7A: GT/ Un-thickened WAS	Alt. 8A: Separate GBT/RDT
Site impacts	• Requires most solids storage volume (can consider reusing GTs) • Largest pre-dewatering facility footprint	• Provides one of the most compact layouts • Smallest pre-dewatering facility footprint	• Provides the most compact layout • Smallest pre-dewatering facility footprint	• Large volume of storage required for un-thickened PS • Larger pre-dewatering facility footprint	• Additional WAS storage required upstream of screening • More storage than Alt. 3 or 4	• Additional PS storage required upstream of thickening • Smallest pre-dewatering facility footprint
Operability	• Fewer unit processes to operate • Limited flexibility (with 1 day of solids storage) • 24/7 solids screening and pre-dewatering is required	• GTs are a familiar process to WPCP staff and have performed well • GBTs require periodic operator attention, but do not require constant care	• GTs are a familiar process to WPCP staff and have performed well • RDTs require even less operator attention than GBTs	• Limited flexibility because of un-thickened PS • GBT/RDT requires periodic operator attention	• GTs are a familiar process to WPCP staff and have performed well • Un-thickened WAS eliminates a unit process	• GBT/RDT for PS thickening would require more operator attention because of PS solids concentration variability • Potentially two types of polymer required for PS and WAS
Maintenance	• No thickening maintenance • Largest number of solids screens, mixing, and pre-dewatering units requiring additional attention	• GT maintenance is relatively low • GBT maintenance can be done in-house	• RDT maintenance is relatively low • RDT maintenance can be done in-house	• GBT/RDT maintenance similar to Alts. 3 and 4 • Larger number of solids screens, mixing, and pre-dewatering units requiring additional attention	• GT maintenance is relatively low • No maintenance for WAS as it will remain un-thickened	• GBT or RDT maintenance can be performed in-house, but will be greater than Alts. 3 and 4 because of more thickening units needed for PS and WAS
Energy	• No thickening energy required • High energy demands for multiple storage tanks	• Low energy demand for thickening • Lowest energy demand for pre-dewatering	• Low energy demand for thickening • Lowest energy demand for pre-dewatering	• Lowest energy demand for thickening WAS only • Higher energy demand for pre-dewatering	• Lowest energy demand for thickening • Slightly higher energy demand for pre-dewatering	• Higher energy demand for mechanical thickening of PS and WAS

Parameter	Alt. 1: No Thickening	Alt. 3: GT/GBT	Alt. 4: GT/RDT	Alt. 7: Un-thickened PS/TWAS	Alt. 7A: GT/ Un-thickened WAS	Alt. 8A: Separate GBT/RDT
	• Highest energy demand for pre-dewatering					• Lowest energy demand for pre-dewatering
Downstream process impacts	• Requires the most screening and pre-dewatering capacity	• Minimizes screening and pre-dewatering	• Minimizes screening and pre-dewatering	• Greater screening and pre-dewatering capacity	• Slightly larger screening but pre-dewatering capacity same as other thickening options.	• Minimizes screening and pre-dewatering
Odors	• Significant odor control needed for storage volume	• GTs are covered, and GBTs can be enclosed to reduce odors	• GTs are covered and RDTs are enclosed	• Significant odor control needed for large PS storage volume	• GTs and solids storage tanks are covered	• Local odor issues associated with GBTs especially for thickening PS; RDTs are enclosed
Conceptual capital cost	$31.1M	$32.1M	$32.6M	$31.7M	$28.8M	$37.7M
O&M present value	$12.0M	$15.1M	$15.9M	$14.1M	$13.3M	$18.4M
Net present value	$43.3M	$47.1M	$48.5M	$45.8M	$42.1M	$56.1M

6.2 Conclusions and Recommendation

Alternative 1 offers the lowest O&M cost because of the avoided costs of thickening (power, polymer, and equipment maintenance). However, the drawback associated with this alternative is the significant storage volume needed for un-thickened solids, including an 8-hour buffer tank for PS, the additional process capacity for solids screening and pre-dewatering, and significantly more odor control equipment and volume (sizing of which was beyond the scope of this evaluation). If this alternative is retained for further evaluation, implications for storing and dewatering un-thickened solids will need to be further evaluated in the solids screening and pre-dewatering and site impact evaluations.

Alternatives 3 and 4 are similar, except Alternative 3 uses GBTs for WAS thickening and Alternative 4 uses RDTs for WAS thickening. The major differences are that GBTs can typically process more solids and require less polymer than RDTs. These major differences contribute to the O&M cost differences between GBTs and RDTs. Alternatives 3 and 4 offer advantages from a site layout perspective; have moderately low O&M cost; and minimize solids screening, storage, and pre-dewatering facility capacities.

Alternative 7 occupies significant site space for storage, which is due to the added storage volume needed for un-thickened PS. O&M costs are similar to Alternatives 3 and 4. This alternative does not seem to provide any advantages to set it apart from others and is recommended to be eliminated from further consideration.

Alternative 7A reduces the site space needed for storage from Alternative 7 and has lower O&M costs than Alternatives 3 and 4 with the avoidance of polymer. The sizing for screening and pre-dewatering is similar to Alternatives 3 and 4, and it has the advantage of eliminating one unit process.

Alternative 8A is less advantageous from a cost perspective. The higher O&M cost for this alternative is largely due to polymer cost for mechanical thickening PS. Additionally, limited installations thicken PS only with either GBTs or RDTs. While PS thickening can be achieved with either GBTs or RDTs, polymer dosage is a challenge as PS concentration can vary. This would result in inconsistent thickened PS concentration and/or potential overdosing/underdosing of polymer. These factors can significantly impact the O&M cost. This alternative does not provide advantages that set it apart from others and is recommended to be eliminated from further consideration.

Two preferred alternatives were identified in workshops and discussed with the County: Alternative 3 or 4 (GT/mechanically thickened WAS) and Alternative 7A (GT/un-thickened WAS). Alternatives 3 and 4 are considered together as they are very similar and a decision on the type of mechanical thickening could come at a later date. A comparison of the various design criteria for these preferred alternatives is provided in Table 32.

Table 32. Preferred Alternative Comparison

Component	3/4: GT/Mechanical WAS		7A: GT/Un-thickened WAS	
	30.8 mgd	40.0 mgd	30.8 mgd	40.0 mgd
Un-thickened WAS storage volume (gallons)	0	0	180,000	180,000
Peak 3-day un-thickened WAS storage time (hours)	0	0	8.7	6.7
Number of installed WAS thickeners	3	3	0	0
Flow to screens and pre-dewatering (gpm)	270	350	540	700
Thickened solids concentration	4.3%	4.3%	2.1%	2.1%
Number of installed screens	3	3	3	4
Thickened solids storage volume (gallons)	400,000	400,000	800,000	800,000
Peak 3-day thickened storage time (days)	1.0	0.8	1.0	0.8
Number of installed pre-dewatering centrifuges	3	3	3	3
Conceptual capital cost		**$32.6 M**		**$28.8M**
Total annual costs ($/yr)		**$920,000**		**$810,000**
Annual present worth		**$15.9M**		**$13.3M**
Total present worth		**$48.5M**		**$42.1M**

In conclusion, Alternative 7A (GT/un-thickened WAS) is the recommended thickening alternative based on its operational flexibility, proven performance, lower energy profile, and ability to fit within the site constraints. Alternative 7A is preferred over Alternatives 3 and 4 because of the lower cost and one less unit process. Space should be allocated for future mechanical WAS thickening should process considerations change (e.g., biological phosphorus removal). This alternative will be carried forward and used as the basis for the pre-dewatering evaluation that will include pre-dewatering technology selection, thickening and pre-dewatering building configurations, including potential reuse of the existing dewatering building, and site plan development.

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Technical Memorandum No. 7

Date:	January 5, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Dewatering Equipment Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the dewatering evaluation, followed by a description of the dewatering evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary sludge (PS) and waste activated sludge (WAS) thickening, dewatering, and lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

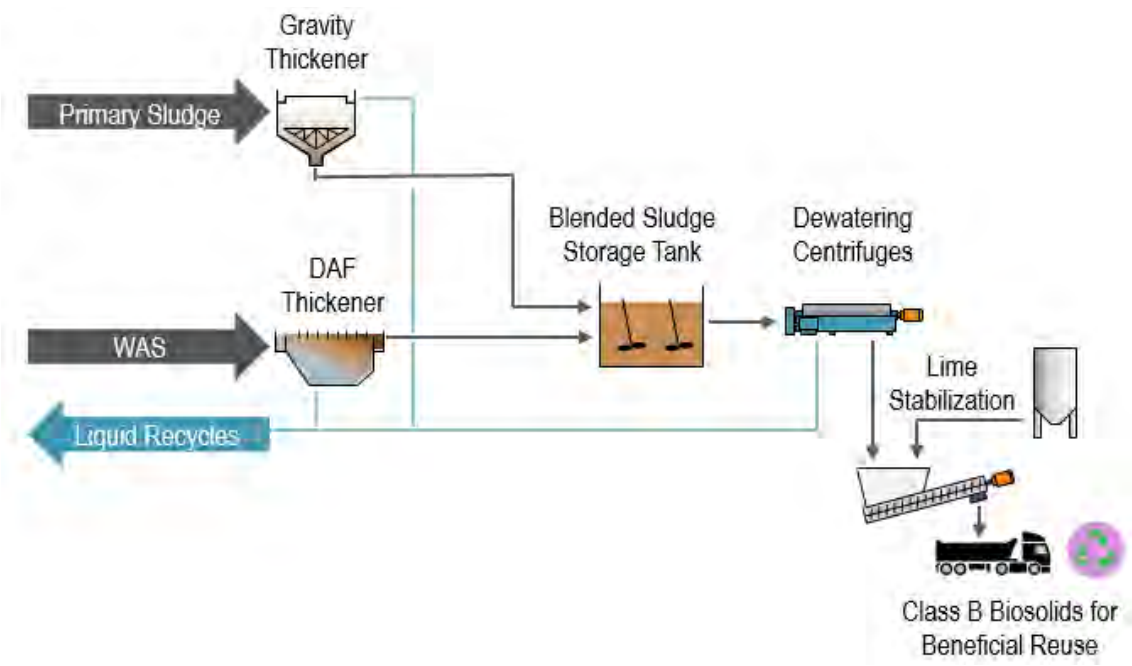
The purpose of this dewatering evaluation is to further assess and compare dewatering alternatives. The results of this evaluation will inform and validate a final decision on which technology will be chosen for pre-dewatering and final dewatering for inclusion in the Facilities Plan.

1.2 Evaluation Approach

A suite of alternatives using various dewatering technologies was developed for pre-dewatering and final dewatering. Conceptual process sizing, configurations, site layouts, and conceptual costs for dewatering facilities were prepared. Technology options were presented and reviewed at the April 26 and May 10, 2021, project workshops with the County. Workshop participants screened and selected a short list of preferred technologies. In this evaluation, the shortlisted technologies are further evaluated and compared based on conceptual operations and maintenance (O&M) cost estimates and non-cost considerations, site layout and space requirements, and odors.

2.0 Summary of Existing Facilities and Processing

A process flow diagram for existing solids handling at the WPCP is shown in Figure 1. Solids are thickened using gravity thickeners (GTs) for PS and dissolved air flotation thickeners (DAFTs) for WAS. Thickened solids are blended in solids storage tanks and dewatered using centrifuges. Liquid centrate from the centrifuges is returned to the head of the WPCP. Lime is added to the dewatered solids to achieve Class B pathogen and vector attraction reduction. Lime-stabilized biosolids are hauled off site for beneficial use through bulk land application.



The new solids handling process will include two dewatering steps, as shown in Figure 2: a pre-dewatering process to provide the appropriate solids concentration to feed the THP and subsequent digestion process, and a final dewatering process for creation of the dewatered cake for beneficial use. The equipment evaluations for both dewatering processes, indicated in the blue dashed area in the figure, are included in this technical memorandum (TM).

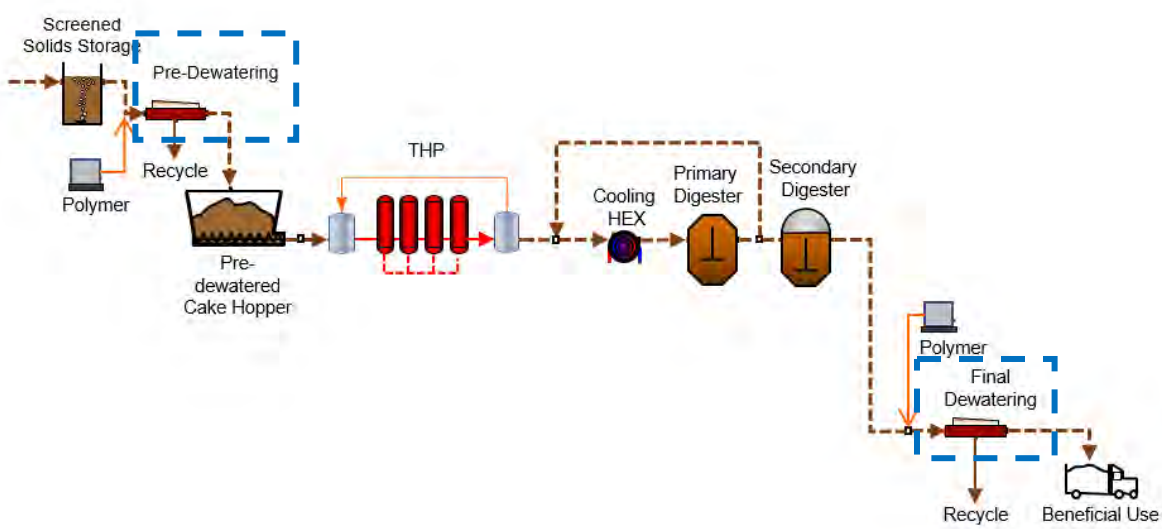


Figure 2. Future Solids Handling Process Dewatering Locations

3.0 Design Criteria

Three design loading conditions were considered for dewatering equipment evaluation:

- **23.0 million gallons per day (mgd):** 2020 current conditions
  - Annual average (AA) loading was considered for "minimum" operating conditions and as a baseline for annual O&M costs
- **30.8 mgd:** 2052 projected conditions
  - Used as the basis for equipment sizing and number of units required for the Facilities Plan
- **40.0 mgd:** final/buildout conditions
  - Used to establish total footprint requirements and dewatering facility sizing with space reserved for potential future equipment

Equipment sizing and number of units required is based on peak 3-day loadings for pre-dewatering and peak 14-day loadings for final dewatering. Annual average and peak 30-day (maximum month) loadings are used for a sensitivity analysis.

Summaries of the design loading criteria for pre-dewatering and final dewatering are provided in Table 1 and Table 2, respectively. For pre-dewatering, the feed solids concentration is assumed to be 4.3 percent with a PS:WAS ratio of 70:30. THP is required to be fed at 15 to 18 percent solids. However, it is understood that any of the pre-dewatering systems being evaluated will have a higher solids concentration and additional dilution will be required prior to feeding THP. The operation schedule for pre-dewatering will be 24 hours per day, 7 days per week. For final dewatering, the feed solids concentration is assumed to be 4.6 percent. The targeted dewatered cake concentration is expected to be greater than 30 percent. The operation schedule for final dewatering will be 24 hours per day, 5.5 days per week.

Table 1. Summary of Pre-Dewatering Loading Design Criteria

Design Condition	Avg (gpm)	Avg (lb/hr)	3-day (gpm)	3-day (lb/hr)
23.0 mgd	120	2,700	210	4,400
30.8 mgd	170	3,600	280	**5,900**
40.0 mgd	215	4,600	358	7,700

Table 2. Summary of Final Dewatering Loading Design Criteria

Design Condition	Avg (gpm)	Avg (lb/hr)	14-day (gpm)	14-day (lb/hr)
23.0 mgd	70	1,600	100	2,300
30.8 mgd	100	2,200	140	**3,100**
40.0 mgd	125	2,900	180	4,000

4.0 Solids Dewatering Technologies

This section describes the following dewatering technologies applicable to the Arlington WPCP:

- Belt filter press (BFP)
- Screw press
- Centrifuge
- Rotary fan press
- Bucher press

For each technology, the following information is presented:

- Design criteria including equipment sizing and number of units required
- Space requirements and layouts for both pre-dewatering and final dewatering facilities
- Equipment and annual O&M cost estimates (for shortlisted alternatives)

4.1 Belt Filter Presses

BFPs are widely used in the United States for municipal solids dewatering. The BFP, an example of which is shown in Figure 3, uses two or more serpentine belts and a series of rollers to mechanically filter and separate solids from free liquid. The BFP is typically not enclosed to allow the operator to visually inspect the operation and performance as the basis for making adjustments to the belt speed, incoming sludge feed rate, and polymer dosing. This results in increased fugitive odors around the equipment, a less comfortable working environment, a more corrosive environment, and larger odor control systems. Odor is a particular concern with dewatering undigested solids. BFPs also have a continuous and relatively high belt wash water demand. BFPs require a large footprint and high ceiling because of their size. While capital costs for equipment are typically moderate, building infrastructure and ancillary systems add to the overall cost. Maintenance costs are moderately high because of the periodic replacement of belts. However, this work can generally be completed in-house.

Figure 3. Belt Filter Press

HDR Engineering, Inc. (HDR) contacted two BFP manufacturers, Komline-Sanderson and Alfa Laval, for information and cost proposals for both pre-dewatering and final dewatering. Additional equipment manufacturers offer similar equipment, but these two contacts are sufficient for the purposes of this technology review. Preliminary design criteria, shown below in Table 3 for pre-dewatering and Table 4 for final dewatering, are based on the vendor proposals, assuming that the equipment is a 2-meter BFP unit. The maximum solids loading for the final dewatering units is anticipated to be lower than a pre-dewatering application for the following reasons:

- The goal total solids (TS) content for pre-dewatered cake solids is between 15 and 18 percent TS, whereas for final dewatering it is above 30 percent TS. Because pre-dewatering requires a lower cake solids, the belt is able to run faster.
- Pre-dewatered solids are undigested and easier to dewater than digested solids. In final dewatering applications, the belt is expected to run slower to allow for more squeeze time in order to remove as much free water from the solids as possible.

Polymer consumption for final dewatered solids is expected to be twice the consumption of pre-dewatering applications because of the sludge properties of digested solids. This is also reflected in the O&M cost comparison.

Table 3. Belt Filter Press Preliminary Design Criteria: Pre-Dewatering

Parameter	Belt Filter Press	Unit
Solids loading	2,400	lb/hr (per unit)
Number of units at 30.8 mgd	3/1	Duty/standby
Number of units at 40.0 mgd	4/1	Duty/standby
Estimated solids capture	97	Percent
Equipment space required	34 × 100 3,400	ft (total) SF (total)
Dry equipment weight	25,000 100,000	lb/unit lb total weight
Water consumption (AA)	345,600	gpd (total)
Power requirement (AA)	8	hp/unit
Polymer consumption	10	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$350k $1.4M	$/unit $ total equipment cost

Table 4. Belt Filter Press Preliminary Design Criteria: Final Dewatering

Parameter	Belt Filter Press	Unit
Solids loading	2,000	lb/hr (per unit)
Number of units at 30.8 mgd	2/1	Duty/standby
Number of units at 40.0 mgd	2/1	Duty/standby
Estimated solids capture	97	Percent
Anticipated cake dryness	30–35	Percent
Equipment space required	34 × 60 2,040	ft (total) SF (total)
Dry equipment weight	25,000 75,000	lb/unit lb total weight
Water consumption (AA)	230,400	gpd (total)
Power requirement (AA)	7	hp/unit
Polymer consumption	20	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$440k $1.32M	$/unit $ total equipment cost

The relative advantages and disadvantages of BFPs are listed in Table 5. BFPs generally have a higher solids capture rate with a lower polymer and electrical demand than the other technologies. However, BFPs have a high continuous water demand, and generally are open to the air, creating a more corrosive and odorous work environment.

Table 5. Belt Filter Press Advantages and Disadvantages

Advantages	Disadvantages
Low polymer demand	Medium footprint
Simple to operate	Not enclosed, requires additional odor control
High solids capture (97% +/-)	Expect lower dewatered cake solids content than centrifuges
Low electrical demand	High and continuous water demand
Maintenance can be performed on site by WPCP staff	Unfamiliar to current operating staff
Visual observation of feed solids and cake	Higher level of corrosion resistance required in building because of humidity and ammonia potential
	Frequent belt replacement and potential belt alignment issues
	Require platforms for O&M access
	Many moving parts and pieces of equipment

Space requirements for BFPs are based on providing 5 feet of space on all sides of the units (exclusive of platforms) for personnel access and the removal of rollers. Platforms are provided to move and take out rollers and to provide access for observing the process, raising the plow handles, and washing the machine after shutdown. Space requirements for BFPs are summarized as follows:

- **Pre-dewatering:** 34 feet by 100 feet, or 3,400 square feet (SF)
- **Final dewatering:** 34 feet by 60 feet, or 2,040 SF

Figure 4 and Figure 5 show the pre-dewatering and final dewatering space footprints, respectively. These footprints are for equipment only and do not include polymer, odor control, or operational areas.

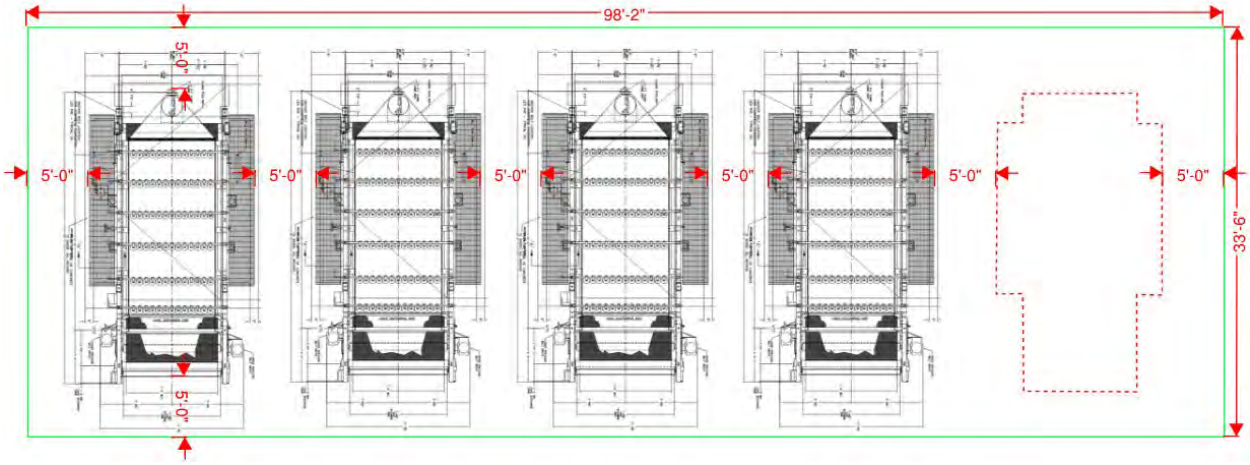


Figure 4. Belt Filter Press Pre-Dewatering Space Requirement

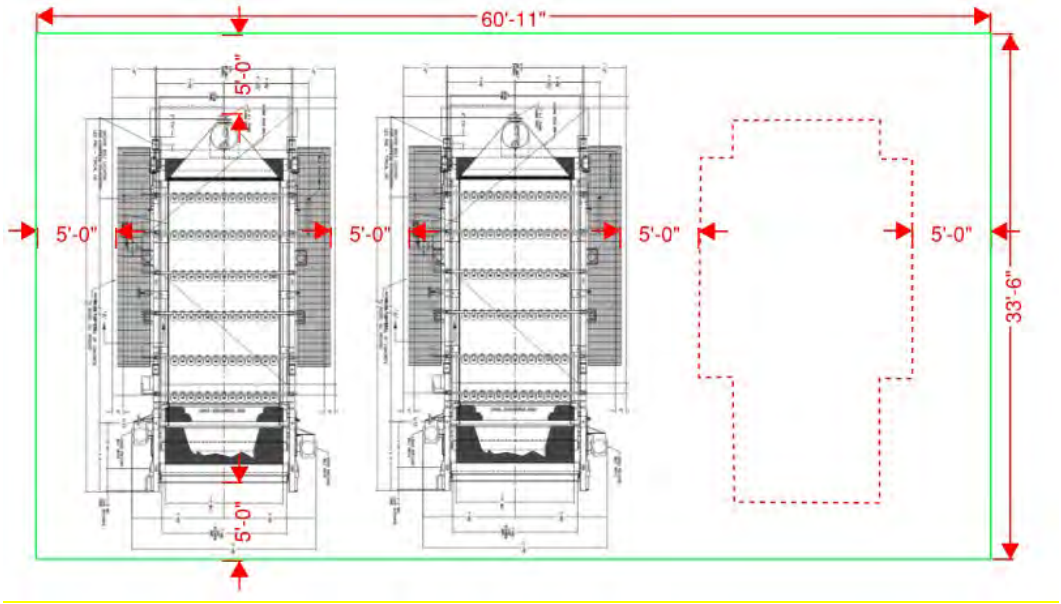


Figure 5. Belt Filter Press Final Dewatering Space Requirement

As a comparison, Figure 6 displays the BFP space required within the existing dewatering space on the fourth floor of the Dewatering Building. The existing dewatering space can fit only four units, so BFPs could fit in the space for final dewatering but not for pre-dewatering because there would be no place to expand for the final buildout condition. The use of the existing space for dewatering would also be contingent on the structural evaluation of the space and layouts of discharge screw conveyors, feed piping, and other ancillary equipment. The ultimate locations of pre-dewatering and final dewatering will be documented in a separate evaluation.

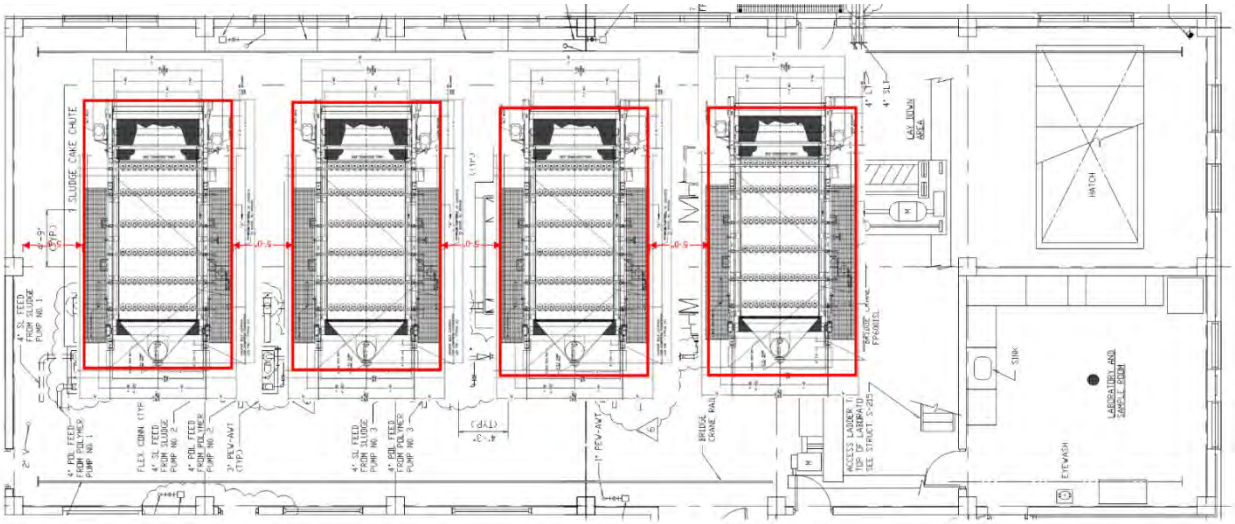


Figure 6. Belt Filter Press Existing Dewatering Space Comparison

4.2 Screw Presses

The screw press is a low-speed, low-shear dewatering process that uses a slow rotating auger inside a porous wire cage to compress solids and filter water. Free water is released through the wire cage and the dewatered solids cake is pushed out through the end of the wire cage. Screw presses operate at a low rotating speed and have low energy requirements. Because the pressure inside the screw press can occasionally result in blinding of the wire cage, a wash cycle is programmed for 5 minutes every 30 to 60 minutes to remove any solids that have squeezed through the basket screen or cage. Figure 7 shows an example screw press.

Figure 7. Screw Press

HDR contacted two screw press manufacturers, Huber and Andritz, for information and cost proposals for screw presses for pre-dewatering and final dewatering. Additional equipment manufacturers are available, but these two contacts are sufficient for the purposes of this technology review. Preliminary design criteria, shown in Table 6 for pre-dewatering and Table 7 for final dewatering, are based on these vendor proposals.

For both pre-dewatering and final dewatering, the screw press has low design loading rates resulting in additional units required compared to other technologies. The screw press has relatively low water consumption and energy demands, with a tradeoff of high polymer demands and the lowest capture rate of any technology, as the separation forces are not as high as those of other technologies. Note that there are currently no installations using screw presses for final dewatering with THP. h

Table 6. Screw Press Preliminary Design Criteria: Pre-Dewatering

Parameter	Screw Press	Unit
Solids loading	1,280	lb/hr (per unit)
Number of units at 30.8 mgd	5/1	Duty/standby
Number of units at 40.0 mgd	6/1	Duty/standby
Estimated solids capture	90	Percent
Equipment space required	30 × 90 2,700	ft (total) SF (total)
Dry equipment weight	8,200 49,200	lb/unit lb total weight
Water consumption (AA)	6,120	gpd (total)
Power requirement (AA)	5	hp/unit
Polymer consumption	15	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$310k $1.86M	$/unit $ total equipment cost

Table 7. Screw Press Preliminary Design Criteria: Final Dewatering

Parameter	Screw Press	Unit
Solids loading	1,280	lb/hr (per unit)
Number of units at 30.8 mgd	3/1	Duty/standby
Number of units at 40.0 mgd	4/1	Duty/standby
Estimated solids capture	90	Percent
Anticipated cake dryness	30–35	Percent
Equipment space required	30 × 70 2,100	ft (total) SF (total)
Dry equipment weight	8,200 32,800	lb/unit lb total weight
Water consumption (AA)	4,080	gpd (total)
Power requirement (AA)	5	hp/unit
Polymer consumption	30	Active lb/dry ton
Used with THP	No	
Equipment cost	$310k $1.24M	$/unit $ total equipment cost

The relative advantages and disadvantages of screw presses are listed in Table 8.

Table 8. Screw Press Advantages and Disadvantages

Advantages	Disadvantages
Low energy use	Several units are required
Simple to operate	High polymer usage
Few moving parts	Medium-sized footprint
Require minimal operator attention	Lower solids capture (90%)
Enclosed process, which results in low odors	Unfamiliar to current operating staff
Light pieces of equipment	No THP installations for final dewatering

Screw press space requirements are based on providing 5 feet of space on all sides of the units for O&M access. Screw presses require 15 additional feet of open space for laydown for maintenance of the basket and scroll. Space requirements for screw presses are summarized as follows:

- **Pre-dewatering:** 30 feet by 90 feet, or 2,700 SF (includes laydown)
- **Final dewatering:** 30 feet by 70 feet, or 2,100 SF (includes laydown)

Note that compared to BFPs, screw presses would require less total space even though more units and laydown space are required, which is due to the smaller footprint of each individual screw press.

Figure 8 and Figure 9 display the pre-dewatering and final dewatering space requirement, respectively, including the laydown space required.

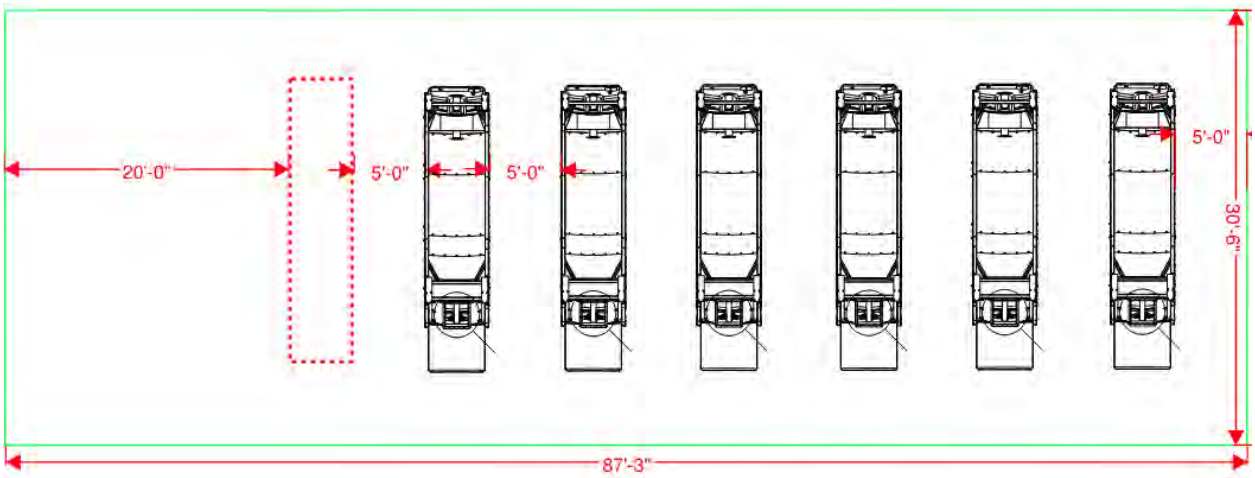


Figure 8. Screw Press Pre-Dewatering Space Requirement

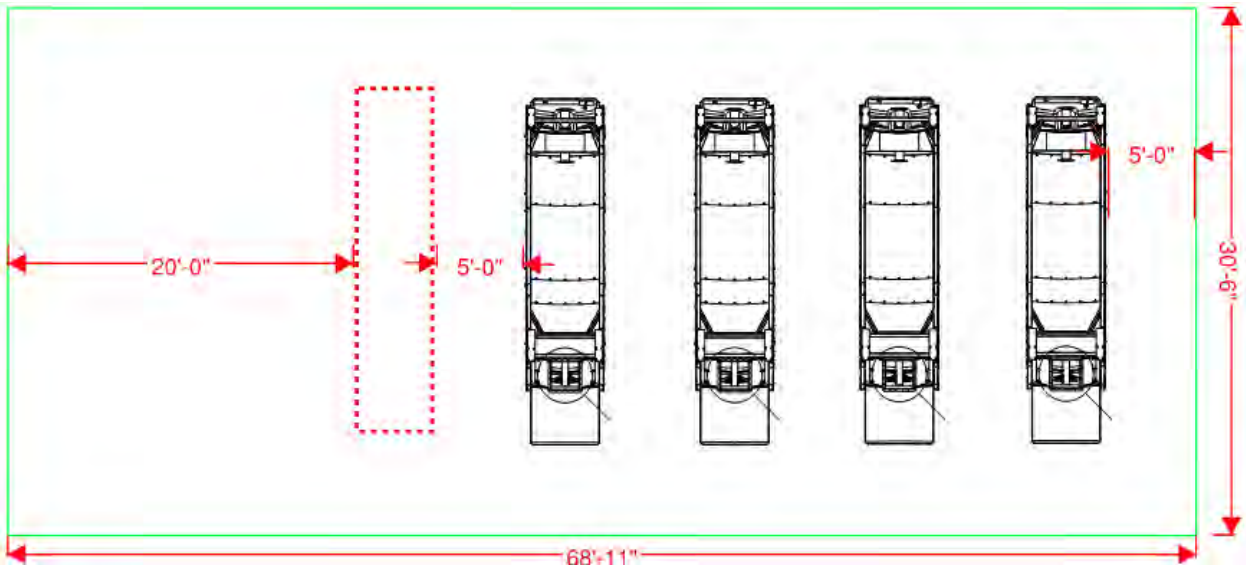


Figure 9. Screw Press Final Dewatering Space Requirement

As a comparison, Figure 10 displays the screw press space required within the existing dewatering space on the fourth floor of the Dewatering Building. The existing dewatering space allows room for laydown and room for expansion for final dewatering, but no room for laydown other than the space near the hatch, and no room for expansion for pre-dewatering. The use of the existing space for dewatering would also be contingent on the structural evaluation of the space and layouts of discharge screw conveyors, feed piping, and other ancillary equipment. The ultimate locations of pre-dewatering and final dewatering will be documented in a separate evaluation.

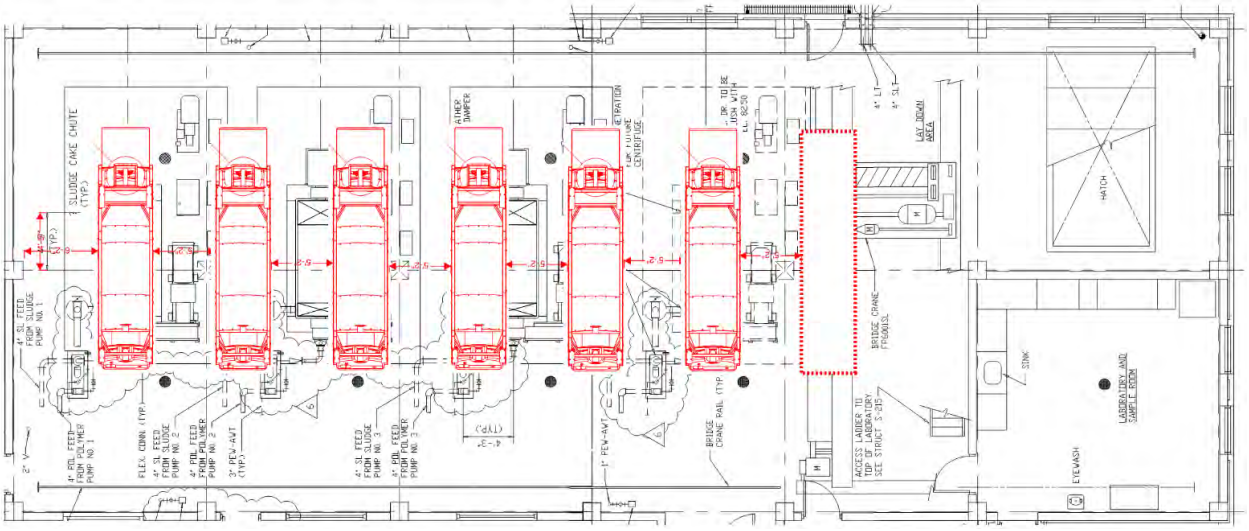


Figure 10. Screw Press Existing Dewatering Space Comparison

4.3 Centrifuges

An overview of centrifuge operation principles was described previously for WAS thickening in TM No. 6: *Thickening Evaluation*. Centrifuges work in a similar manner for solids dewatering.

Centrifuges are an enclosed process with high solids loading, low water consumption, and a small footprint. They are high-speed machines that are complex with many wear components. Figure 11 shows a dewatering centrifuge.

Figure 11. Dewatering Centrifuge

HDR contacted three centrifuge manufacturers—GEA, Alfa Laval, and Centrisys—for information and cost proposals for dewatering centrifuges for pre-dewatering and final dewatering. Additional manufacturers are available, but the contacted manufacturers are sufficient for purposes of this technology review. Preliminary design criteria, shown in Table 9 for pre-dewatering and Table 10 for final dewatering, are based on these vendor proposals.

Table 9. Centrifuge Preliminary Design Criteria: Pre-Dewatering

Parameter	Centrifuge	Unit
Solids loading	4,240	lb/hr (per unit)
Number of units at 30.8 mgd	2/1	Duty/standby
Number of units at 40.0 mgd	3/1	Duty/standby
Estimated solids capture	95	Percent
Equipment space required	32 × 72 2,304	ft (total) SF (total)
Dry equipment weight	20,000 60,000	lb/unit lb total weight
Water consumption (AA)	9,000 (1,290)	gal/wk (total) gpd (total)
Power requirement (AA)	165	hp/unit
Polymer consumption	8	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$600k–$800k $2.1M	$/unit $ total equipment cost

Table 10. Centrifuge Design Criteria: Final Dewatering

Parameter	Centrifuge	Unit
Solids loading	4,240	lb/hr (per unit)
Number of units	1/1	Duty/standby
Estimated solids capture	95	Percent
Anticipated cake dryness	32–38	Percent
Equipment space required	30 × 60 1,800	ft (total) SF (total)
Dry equipment weight	20,000 40,000	lb/unit lb total weight
Water consumption (AA)	9,000 (1,640)	gal/wk (total) gpd (total)
Power requirement (AA)	165	hp/unit
Polymer consumption	16	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$600k–$800k $1.4M	$/unit $ total equipment cost

The relative advantages and disadvantages of centrifuges are listed in Table 11.

Table 11. Centrifuge Advantages and Disadvantages

Advantages	Disadvantages
High solids loading throughput	High energy demand
Enclosed, which minimizes odors	Additional operator attention to changing solids
Smaller footprint	Long startup and shutdown times with potential solids discharge (slop)
Operators are familiar with equipment	Require lengthy off-site rebuilds
	Higher maintenance

Space requirements are based on providing 6.5 feet of space between centrifuges and 9.75 feet of space from the ends of the centrifuge to the walls for O&M access plus additional 20 ft for laydown space for bowl and scroll maintenance. Figure 12 and Figure 13 show the pre-dewatering and final dewatering space requirements, respectively, including laydown. Centrifuge space requirements are summarized as follows:

- **Pre-dewatering:** 32 feet by 72 feet, or 2,304 SF (includes laydown)
- **Final dewatering:** 32 feet by 60 feet, or 1,920 SF (includes laydown)

Centrifuges require the least amount of space of the technologies evaluated because of their compact footprint and the fewest number of units required for both pre-dewatering and final dewatering.

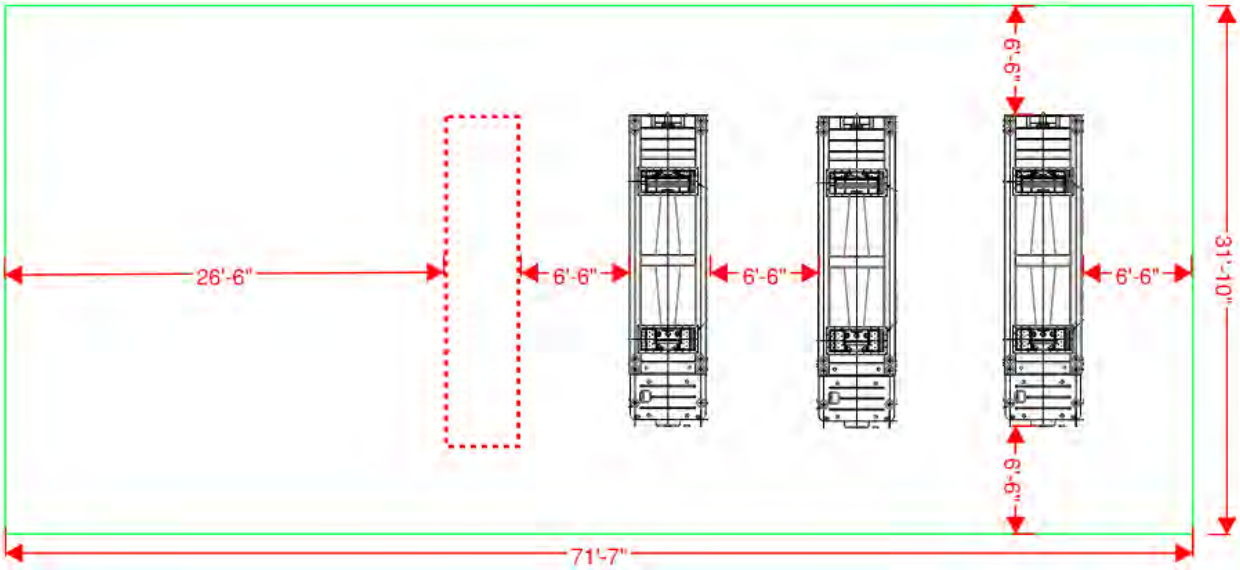


Figure 12. Centrifuge Pre-Dewatering Space Requirement

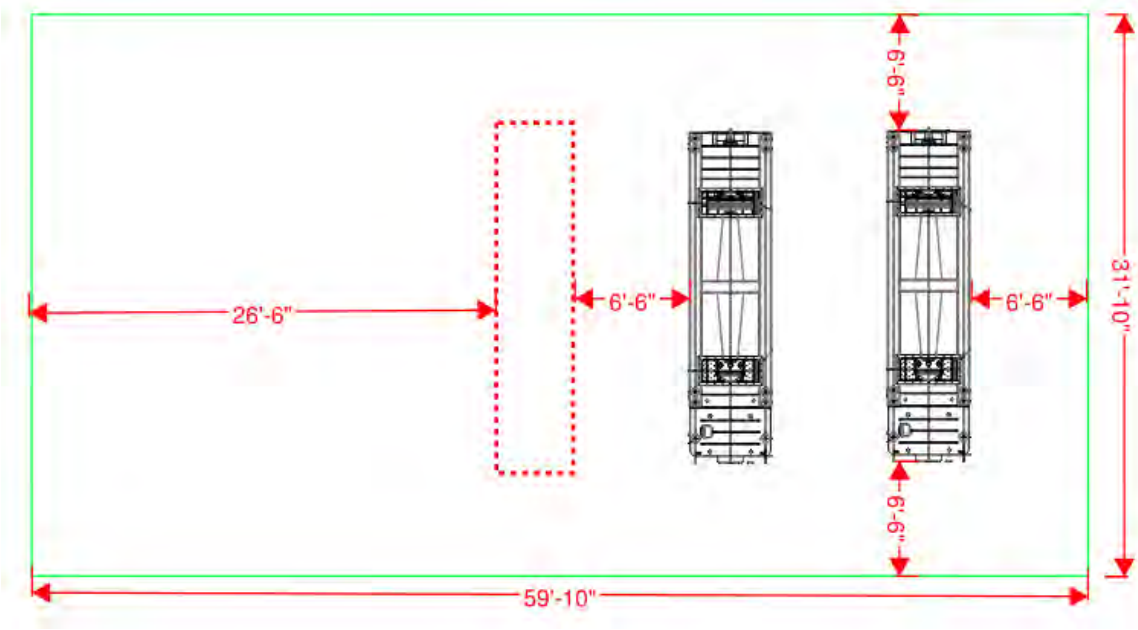


Figure 13. Centrifuge Final Dewatering Space Requirement

As a comparison, Figure 14 displays the centrifuge space required within the existing dewatering space on the fourth floor of the Dewatering Building. The existing dewatering space allows room for laydown and room for expansion for final dewatering or pre-dewatering. A structural analysis using the weight and rotational dynamics of proposed units would be required to confirm if the existing dewatering space can be used for new centrifuges. The use of the existing space for dewatering would also be contingent on the structural evaluation of the space and layouts of discharge screw conveyors, feed piping, and other ancillary equipment. The ultimate locations of pre-dewatering and final dewatering will be documented in a separate evaluation.

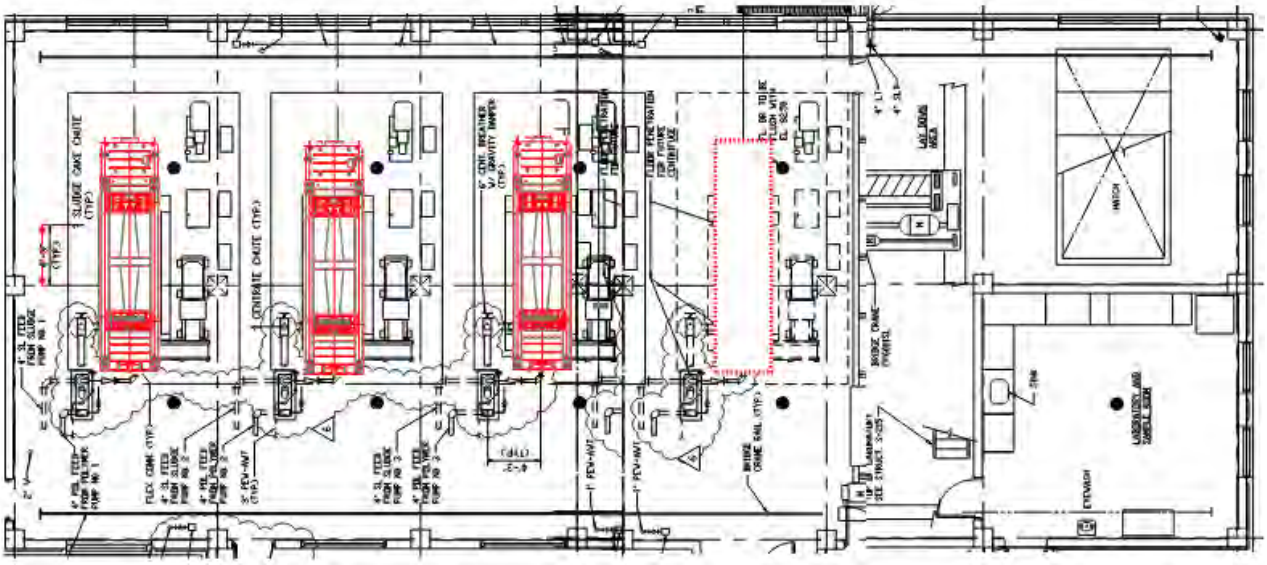


Figure 14. Centrifuge Existing Dewatering Space Comparison

4.4 Rotary Fan Presses

The rotary fan press consists of two round, porous, metal discs that slowly rotate on a horizontal shaft. Solids are pumped between the discs and water is released through the pores in the discs as the discs rotate and compress the sludge against a pressure bar. Rotary fan presses have a low power requirement because of the slow rotational speed. The machine operates with few moving parts. Rotary fan presses have a smaller hydraulic capacity than a centrifuge for the footprint of the machine. Additionally, this equipment typically requires a higher polymer dose. Figure 15 shows a rotary fan press.

Figure 15. Rotary Fan Press

HDR contacted Fournier for information and cost proposals for rotary fan presses for pre-dewatering and final dewatering. Fournier is the most reputable manufacturer of rotary fan presses with limited competition that has significant experience. Preliminary design criteria, shown in Table 12 for pre-dewatering and Table 13 for final dewatering, are based on the vendor proposal. For both pre-dewatering and final dewatering, the rotary fan press has the lowest solids loading rate, resulting in additional units. There is one existing installation using rotary fan presses for final dewatering with THP.

Table 12. Rotary Fan Press Preliminary Design Criteria: Pre-Dewatering

Parameter	Rotary Fan Press	Unit
Solids loading	1,090	lb/hr (per unit)
Number of units at 30.8 mgd	6/1	Duty/standby
Number of units at 40.0 mgd	7/1	Duty/standby
Estimated solids capture	92	Percent
Equipment space required	35 × 110 3,850	ft (total) SF (total)
Dry equipment weight	19,000 133,000	lb/unit lb total weight
Water consumption (AA)	5,800	gpd (total)
Power requirement (AA)	30 180	hp/unit hp total
Polymer consumption	15	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$440k $3.08M	$/unit $ total equipment cost

Table 13. Rotary Fan Press Preliminary Design Criteria: Final Dewatering

Parameter	Rotary Fan Press	Unit
Solids loading	1,090	lb/hr (per unit)
Number of units at 30.8 mgd	3/1	Duty/standby
Number of units at 40.0 mgd	4/1	Duty/standby
Estimated solids capture	92	Percent
Anticipated cake dryness	30–35	Percent
Equipment space required	35 × 82 2,870	ft (total) SF (total)
Dry equipment weight	19,000 76,000	lb/unit lb total weight
Water consumption (AA)	4,420	gpd (total)
Power requirement (AA)	30	hp/unit
Polymer consumption	30	Active lb/dry ton
Used with THP	Yes (1 Installation)	
Equipment cost	$440k $1.76M	$/unit $ total equipment cost

The advantages and disadvantages of rotary fan presses are listed in Table 14.

Table 14. Rotary Fan Press Advantages and Disadvantages

Advantages	Disadvantages
Low energy use	Higher polymer usage
Enclosed, which minimizes odors	Not a highly used technology for medium to large facilities
Require minimal operator attention	Limited competition
Simple to operate	Unfamiliar technology to operators
	Require high levels of maintenance
	Several units required
	Lower solids capture (92%)
	Only one installation with THP for final dewatering (in Norway)

Space requirements for rotary fan presses are based on input by the manufacturer for removal of the channels and other maintenance items. Figure 16 and Figure 17 display the pre-dewatering and final dewatering space requirement, respectively, including laydown. However, this will be needed on a limited basis because channels are small and easier to maintain. Space requirements for rotary fan presses are summarized as follows:

- **Pre-dewatering:** 35 feet by 110 feet, or 3,850 SF
- **Final dewatering:** 35 feet by 82 feet, or 2,870 SF

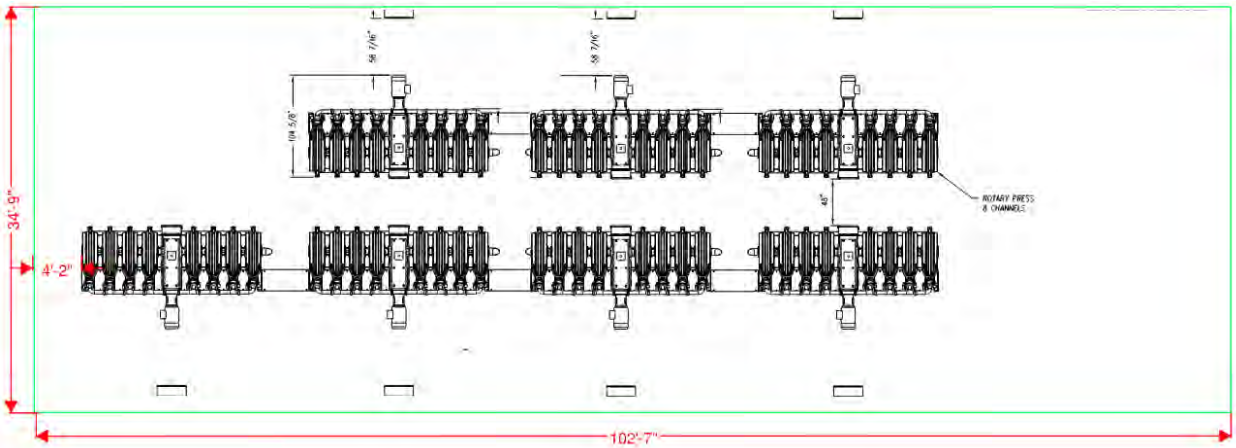


Figure 16. Rotary Fan Press Pre-Dewatering Space Requirement

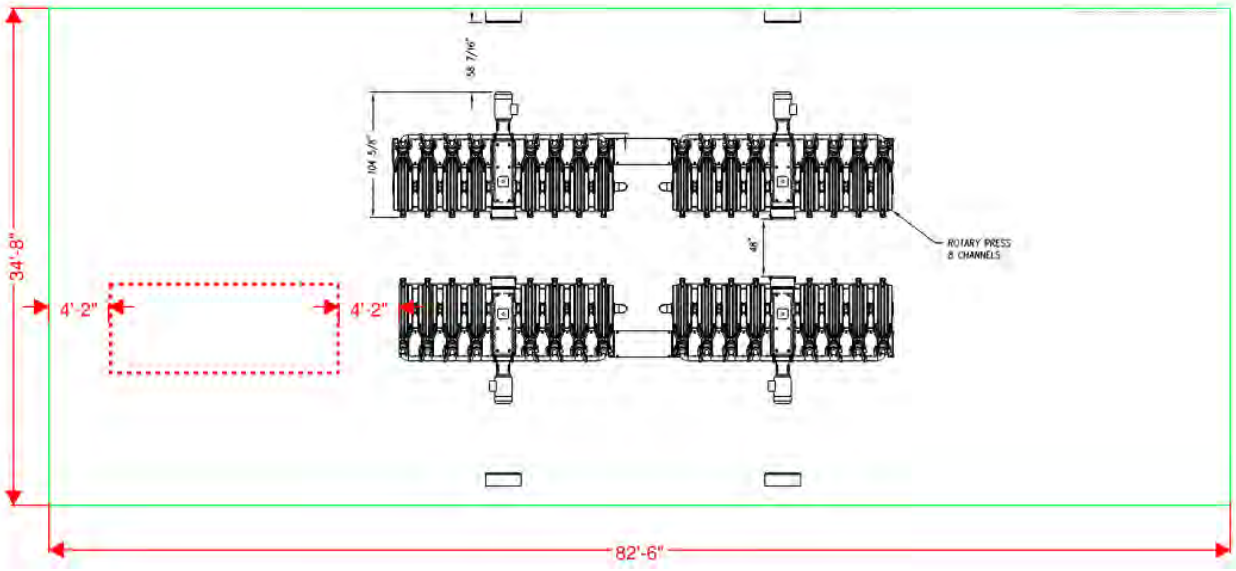


Figure 17. Rotary Fan Press Final Dewatering Space Requirement

As a comparison, Figure 18 displays the rotary fan press space required within the existing dewatering space on the fourth floor of the Dewatering Building. The existing dewatering space does not allow room for a redundant unit for pre-dewatering. The space does have adequate space for final dewatering. The use of the existing space for dewatering would also be contingent on the structural evaluation of the space and layouts of discharge screw conveyors, feed piping, and other ancillary equipment. The ultimate locations of pre-dewatering and final dewatering will be documented in a separate evaluation.

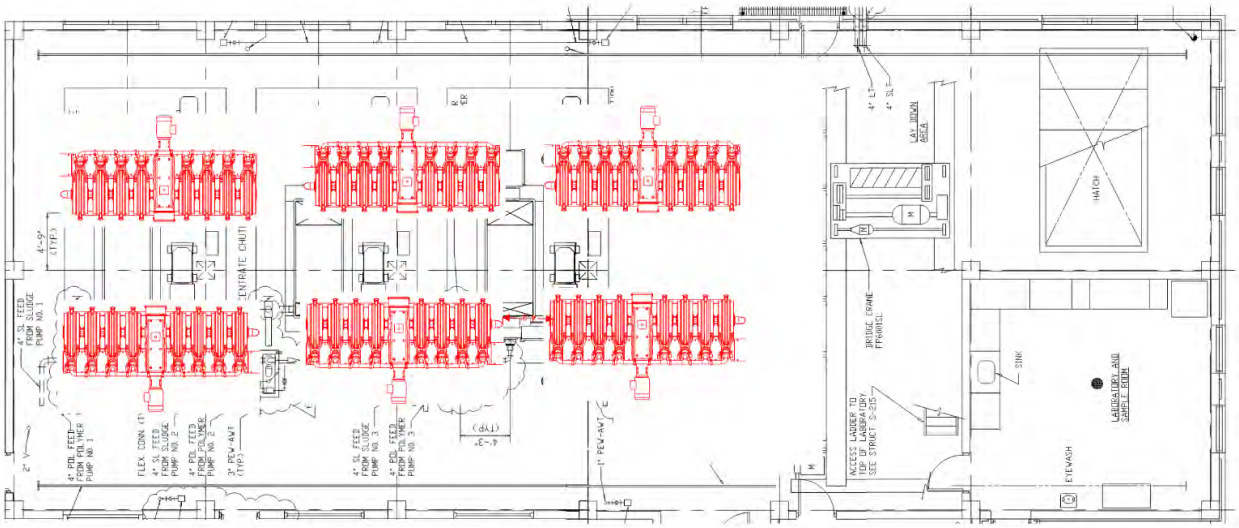


Figure 18. Rotary Fan Press Existing Dewatering Space Comparison

4.5 Bucher Press

The Bucher press, often referred to as a “hydraulic filter press” or piston press, was originally used in the fruit juice industry. The Bucher press consists of a slowly rotating body with a series of cloths through which the filtrate passes. The cake drops from the bottom when the press fully opens, and more sludge

moves into the unit. The Bucher press runs on a batch cycle with 2-hour duration. The cycle consists of filling, pressing, loosening, and emptying. It is recommended to use a dynamic inline mixer with the Bucher press to incorporate polymer into the solids. Figure 19 shows a Bucher press.

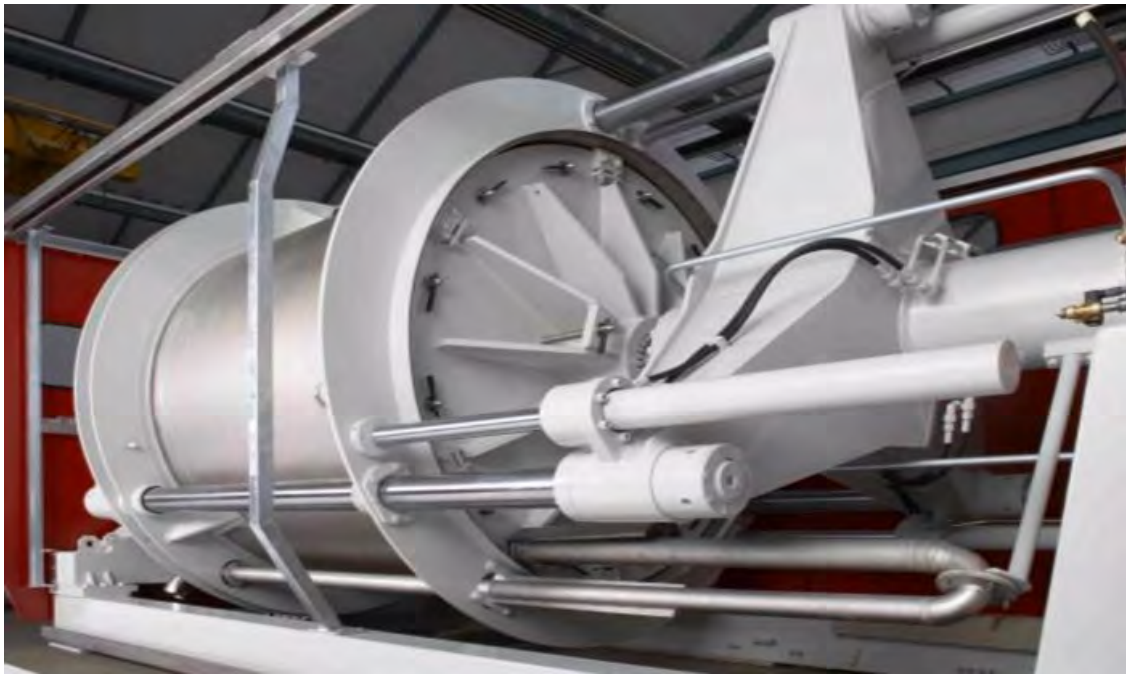


Figure 19. Bucher Press

HDR contacted Bucher for information and cost proposals for the Bucher press for final dewatering only. The main advantage of the Bucher press is higher cake solids, which is not required for pre-dewatering because required dewatered cake is between 15 and 18 percent TS. Therefore, the technology is considered for final dewatering only where a greater cake dryness is an advantage. Preliminary design criteria, shown in Table 15, are based on that proposal.

The units are relatively large and require the most space for dewatering of any technology. In addition, there is currently no U.S. representation for Bucher.

Table 15. Bucher Press Preliminary Design Criteria: Final Dewatering

Parameter	Bucher Press	Unit
Solids loading	1,500	lb/hr (per unit)
Number of units at 30.8 mgd	3/1	Duty/standby
Number of units at 40.0 mgd	3/1	Duty/standby
Estimated solids capture	98	Percent
Anticipated cake dryness	38+	Percent
Equipment space required	38 × 85 3,230	ft (total) SF (total)
Dry equipment weight	62,600 250,400	lb/unit lb total weight
Water consumption (AA)	265+ 800	gpd (total) gal/wk (total)
Power requirement (AA)	65	hp/unit
Polymer consumption	22	Active lb/dry ton
Used with THP	Yes	
Equipment cost	$865k $3.46M	$/unit $ total equipment cost

The relative advantages and disadvantages of Bucher presses are listed in Table 16.

Table 16. Bucher Press Advantages and Disadvantages

Advantages	Disadvantages
High solids capture	High energy costs
High cake dryness	Uncommon technology
Used with THP	Unfamiliar to WPCP staff
Maintenance can be performed in place	Require a large footprint
Require low operator attention	There is currently no U.S. representation (but soon Thermax will represent Bucher)
Relatively quick startup	High capital cost
Low odors because of being mostly enclosed	High maintenance in replacement of socks
	Sludge pumping and polymer dosing complexity because of batch process operation

Space requirements for the Bucher press are based on manufacturer input for O&M space requirements. No laydown space is required because the Bucher press can be serviced in place. Figure 20 shows the final dewatering space requirement, measuring 38 feet by 85 feet for a total of 3,230 SF.

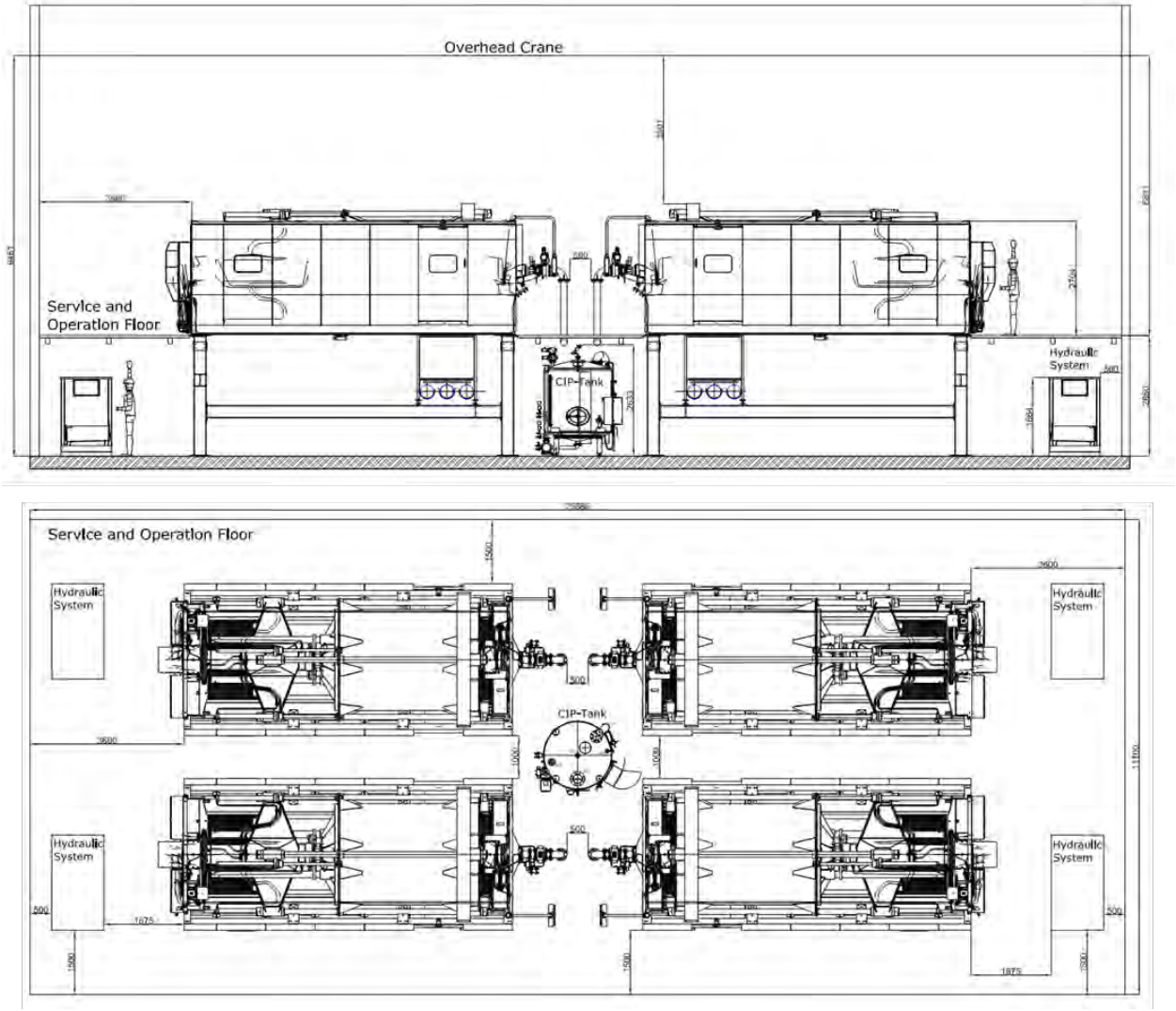


Figure 20. Bucher Press Final Dewatering Space Requirement

As a comparison, Figure 21 displays the Bucher press space required within the existing dewatering space on the fourth floor of the Dewatering Building. The Bucher press fits in the existing dewatering space if the hydraulic units are located in a separate part of the building. There would not be any room for future expansion, but additional units would not be needed for the buildout condition. The use of the existing space for dewatering would also be contingent on the structural evaluation of the space and layouts of discharge screw conveyors, feed piping, and other ancillary equipment. The ultimate locations of pre-dewatering and final dewatering will be documented in a separate evaluation.

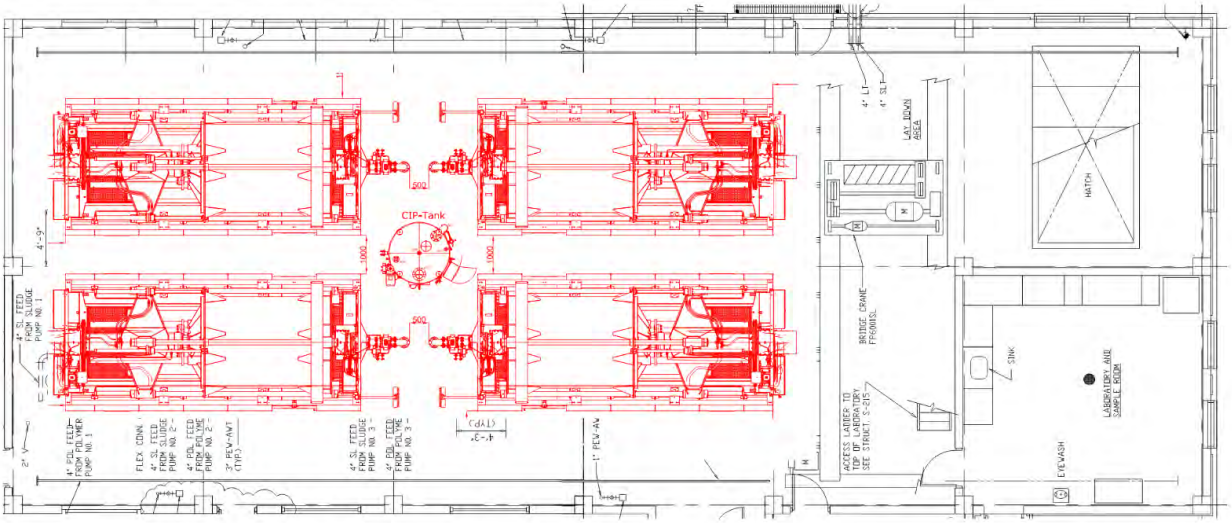


Figure 21. Bucher Press Existing Dewatering Space Comparison

5.0 Equipment Comparison

This section presents a side-by-side comparison of the relative advantages and disadvantages, design criteria, and equipment costs for the dewatering technologies evaluated. It also identifies and compares O&M costs for the shortlisted technologies selected at the May 10, 2021, workshop.

5.1 Technology Comparison

Table 17 provides a side-by-side comparison of the relative advantages and disadvantages of each technology. Design criteria are compared in Table 18 for pre-dewatering and Table 19 for final dewatering.

Table 17. Advantages and Disadvantages Technology Comparison

Advantages/ Disadvantages	Belt Filter Press	Screw Press	Centrifuge	Rotary Press	Bucher Press
Advantages	+ Low polymer demand + Simple to operate + High solids capture (97% +/-) + Low electrical demand + On-site maintenance + Visual operation of feed solids and cake + Commonly used with THP	+ Low energy use + Simple to operate + Few moving parts + Requires minimal operator attention + Enclosed; low odors + Low shear	+ Large solids loading throughput + Enclosed; low odors + Small footprint + Operator familiarity + Commonly used with THP	+ Low energy use + Enclosed; low odors + Minimal operator attention + Simple to operate	+ High solids capture (98%) + High cake dryness (35+%) + Used with THP + Maintenance in place + Low operator attention + Start up immediately + Low odors (mostly enclosed)
Disadvantages	- Medium footprint - Not enclosed, requires additional odor control - Lower cake solids content than centrifuge - High water demand (continuous) - Unfamiliar to current operating staff - High building wear - Frequent belt-related O&M - Access platforms required - Many moving parts	- Several units required - High polymer usage - Medium-sized footprint - Lower solids capture (90%) - Unfamiliar to current operating staff - No THP installations (final dewatering)	- High energy costs - Operator-intensive - Long startup and shutdown times - Lengthy off-site rebuilds - Higher maintenance	- Higher polymer usage - Not widely used technology - Low competition - Not a visible process - Unfamiliar technology to operators - High maintenance - Several units required - Lower solids capture (92%) - One installation with THP (Norway)	- High energy costs - Uncommon technology - Unfamiliar to WPCP staff - Large footprint - No U.S. representation (soon Thermax) - High capital cost - High maintenance (sock replacement) - Sludge pumping and polymer dosing complexity because of batch process operation

Table 18. Pre-dewatering Design Criteria Technology Comparison

Parameter	Belt Filter Press	Screw Press	Centrifuge	Rotary Press	Unit
Solids loading	2,400	1,280	4,240	1,090	lb/hr (per unit)
Number of units at 30.8 mgd	3/1	5/1	2/1	6/1	Duty/standby
Estimated solids capture	97	90	95	92	Percent
Equipment space required	34 × 100 3,400	30 × 90 2,700	32 × 72 2,304	35 × 110 3,850	ft (total) SF (total)
Dry equipment weight	25,000 100,000	8,200 49,200	20,000 60,000	19,000 133,000	lb/unit lb total weight
Water consumption (AA)	230,400	6,120	1,290	5,800	gpd
Power requirement (AA)	7 21	5 25	165[a] 330	30 180	hp/unit hp total
Polymer consumption	10	15	8	15	Active lb/dry ton
Used with THP	Yes	Yes	Yes	Yes	
Equipment cost	$353k $1.4M	$325k $1.95M	$625k–$725k $1.9M	$440k $3.08M	$/unit $ total equipment cost

a. 125 hp for the main drive and 40 hp for the scroll drive per centrifuge.

Table 19. Final Dewatering Design Criteria Technology Comparison

Parameter	Belt Filter Press	Screw Press	Centrifuge	Rotary Press	Bucher Press	Unit
Solids loading	2,000	1,280	4,240	1,080	1,500	lb/hr (per unit)
Number of units	2/1	3/1	1/1	3/1	3/1	Duty/standby
Estimated solids capture	97	90	95	92	98	Percent
Anticipated cake dryness	33	33	35	33	40	Percent
Equipment space required (buildout)	34 × 60 2,040	30 × 70 2,100	30 × 60 1,800	35 × 82 2,870	38 × 85 3,230	ft (total) SF (total)
Dry equipment weight	25,000 75,000	8,200 32,800	20,000 40,000	19,000 76,000	62,600 250,400	lb/unit lb total weight
Water consumption (AA)	230,400	4,080	1,290	4,420	400	gpd
Power requirement (AA)	7 14	5 15	165 165	30 90	65 195	hp/unit hp total
Polymer consumption	20	30	16	30	22	Active lb/dry ton
Used with THP	Yes	No	Yes	Yes (1 Installation)	Yes	
Equipment cost	$440k $1.32M	$310k $1.24M	$625k–$725k $1.25M	$440k $1.76M	$865k $3.46M	$/unit $ total equipment cost

5.2 Shortlisted Technologies

Technology options were presented and reviewed at a May 10, 2021, project workshop with the County. Workshop participants screened and selected a short list of preferred technologies.

5.2.1 Pre-dewatering

For pre-dewatering, screw presses, BFPs, and centrifuges were shortlisted. Rotary presses were removed from consideration because of the high equipment cost, high number of units required, and large amount of required space.

5.2.2 Final Dewatering

For final dewatering, BFPs and centrifuges were shortlisted. Screw presses were removed from consideration because of the low capture and lack of any installations used with THP for final dewatering. Rotary presses were removed from consideration because of the high equipment cost, high number of units required, large amount of required space, and limited operating history with only one existing installation used for dewatering THP solids. Bucher presses were removed from consideration because of the high equipment cost, high equipment weight, and large amount of required space.

5.3 O&M Cost Comparison for Shortlisted Technologies

Annual and 20-year present-value O&M costs were estimated for the shortlisted pre-dewatering and final dewatering technologies. O&M estimates include annual costs for power (at $0.06 per kilowatt-hour [kWh]), polymer (at $2.45 per pound [lb]), wash water at $0.50/1,000 gallons, and staff maintenance hours for both pre-dewatering and final dewatering technologies. Off-site maintenance for centrifuges is also included at a cost of $250,000 per unit once every 10 years. The labor hourly rate is the raw pay rate plus overhead and benefits for the employee. For final dewatering technologies, contract hauling and beneficial use costs were also included. Annual O&M costs were estimated at 28 mgd, the approximate midpoint flow condition, and used as the average annual O&M costs over the 20-year analysis period. Present-value costs were calculated for the 20-year analysis period using an inflation rate of 2 percent, a nominal interest rate of 4.0 percent, and a real interest rate of 1.96 percent.

5.3.1 Pre-dewatering

Pre-dewatering O&M costs are compared in Table 20. Centrifuges and BFPs have similar O&M costs. The lower power usage for BFPs is offset by higher polymer and water use. Screw presses have the highest O&M cost, largely due to the higher polymer cost compared to BFPs and centrifuges. At current condition of 28.0 mgd, the same number of units would be operational as the 30.8 mgd condition.

Table 20. Pre-Dewatering O&M Cost Summary

Criteria	BFP	Screw Press	Centrifuge
Number of units at 28 mgd (duty/standby)	3/1	5/1	2/1
Electricity	$6,000	$6,000	$69,000
Polymer	$353,000	$530,000	$283,000
Water	$42,000	$1,000	$0
Maintenance	$39,000	$59,000	$118,000
Total ($/year)	**$440,000**	**$596,000**	**$470,000**
Total (annual PW)	**$7,200,000**	**$9,800,000**	**$7,700,000**

5.3.2 Final Dewatering

Final dewatering O&M costs are compared in Table 21. Centrifuges have slightly lower O&M costs as higher power costs are offset by lower polymer and disposal costs.

Table 21. Final Dewatering O&M Cost Summary

Criteria	BFP	Centrifuge
Electricity	$4,000	$69,000
Polymer	$444,000	$355,000
Water	$33,000	$0
Maintenance	$29,000	$84,000
Beneficial use (hauling)	$1,032,000	$973,000
Total ($/year)	**$1,542,000**	**$1,481,000**
Total (annual PW)	**$25,300,000**	**$24,400,000**

6.0 Summary and Conclusions

The following technologies were selected from the May 10, 2021, workshop for further consideration:

- **Pre-dewatering:** Screw press, BFP, and centrifuge
- **Final dewatering:** BFP and centrifuge

Summaries of the major considerations for these shortlisted pre-dewatering and final dewatering technologies are presented in Table 22 and Table 23, respectively, including key design criteria and a summary of conceptual capital and O&M costs.

Table 22. Summary of Pre-Dewatering Technologies

Parameter	Belt Filter Press	Screw Press	Centrifuge	Unit
Solids loading	2,400	1,280	4,240	lb/hr (per unit)
Number of equipment	3/1	5/1	2/1	Duty/standby
Estimated capture	97	90	95	Percent
Equipment space required	34 × 100 3,400	30 × 90 2,700	32 × 72 2,304	ft (total) SF (total)
Dry equipment weight	25,000 125,000	8,200 49,200	20,000 80,000	lb/unit lb total weight
Water consumption (AA)	230,400 gpd	6,120 gpd	9,000 gal/wk	As labeled (total)
Power requirement (AA)	7 14	5 15	165 165	hp/unit hp total
Polymer consumption	10	15	8	Active lb/dry ton
Used with THP	Yes	Yes	Yes	
Equipment cost	$353k $1.4M	$310k $1.86M	$600k–$800k $2.1M	$/unit $ total equipment cost
O&M present value	$7,200,000	$9,800,000	$7,700,000	$

Table 23. Summary of Final Dewatering Technologies

Parameter	Belt Filter Press	Centrifuge	Unit
Solids loading	2,000	4,240	lb/hr (per unit)
Number of equipment	2/1	1/1	Duty/standby
Estimated capture	97	95	Percent
Anticipated cake dryness	33	35	Percent
Equipment space required	34 × 80 2,720	30 × 60 1,800	ft (total) SF (total)
Dry equipment weight	25,000 100,000	20,000 60,000	lb/unit lb total weight
Water consumption (AA)	230,400 gpd	9,000 gal/wk (1,290 gpd)	As labeled (total)
Power requirement (AA)	7 14	165 165	hp/unit hp total
Polymer consumption	20	16	Active lb/dry ton
Used with THP	Yes	Yes	
Equipment cost	$440k $1.32M	$600–$800k $1.4M	$/unit $ total equipment cost
O&M present value	$25,300,000	$24,400,000	$

The O&M present value for pre-dewatering technologies shows that screw presses are the highest cost, with centrifuges as the second highest cost, and BFPs as the lowest cost. However, the difference in O&M present-value cost is negligible. For final dewatering, BFPs are the highest O&M present-value cost, with centrifuges at the lowest total O&M cost.

Centrifuges are a proven technology that is familiar to Arlington WPCP staff. Although there have been maintenance challenges with the existing centrifuges over the last several years, it is thought that this is

primarily due to the age of the existing equipment exceeding its useful life. With newer technology and training, centrifuges should serve the County well for years to come. In addition, a common technology across all dewatering processes will benefit the County and allow for a common set of spare parts across both sets of equipment. WPCP staff are already familiar with this technology, which eases the transition of the completed project to O&M personnel. The learning curves and lessons learned for staff using similar dewatering equipment are paramount relative to other criteria.

Based on this, and the technology comparison, equipment costs, and O&M costs, it is recommended to use centrifuges for both pre-dewatering and final dewatering. Though BFPs have the lowest cost for pre-dewatering, using the same size centrifuges for pre-dewatering and final dewatering has O&M benefits that are not represented through a cost analysis. Additionally, centrifuges use less polymer and water, produce less odor, and create a less corrosive and humid work environment. For building layouts and facilities, centrifuges will be carried forward for these evaluations.

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Technical Memorandum No. 8

Date:	October 4, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Recycle Management and Sidestream Treatment

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1.0 Introduction

Biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP) will include a new thermal hydrolysis process (THP) and anaerobic digestion (AD) process. These processes will generate a concentrated nitrogen recycle stream from final dewatering, which will increase the nitrogen load to the WPCP. The purpose of this Technical Memorandum (TM) No. 8 is to evaluate treatment approaches for the nitrogen recycle load. A sidestream deammonification nitrogen removal process was evaluated and compared with the baseline alternative of treating the full nitrogen recycle load in the mainstream activated sludge process.

This evaluation uses the nitrogen recycle load projections developed in TM No. 1: *Solids Production and Design Criteria*. Mainstream treatment operating costs were calculated based on conventional nitrification and denitrification, with costs included for methanol, supplemental alkalinity, additional electricity for aeration, and processing solids generated from methanol. Sidestream treatment costs were based on a dedicated deammonification process for the final dewatering recycle stream. A budgetary proposal was solicited from a deammonification process vendor. Using the vendor-supplied information, a conceptual process configuration and layout were developed for estimating construction costs. Sidestream treatment operating costs were calculated based on costs for operating a new deammonification process along with costs for removing the remaining nitrogen recycle in the mainstream process. The net present value (NPV) of each alternative was compared based on conceptual construction costs and projected 20-year operating cost. A sensitivity analysis was also conducted to illustrate the potential change in NPVs because of changes in key assumptions and commodity costs.

2.0 Evaluation Basis

This section describes the conceptual basis for the evaluation. This includes the flows and loads used for the evaluation as well as the treatment concepts and assumptions for both nitrogen removal alternatives.

2.1 Flows and Loads

Nitrogen recycle load projections from TM No. 1 (revised draft submittal, May 25, 2021) are summarized in Table 1 below. These loads are based on assumptions for volatile solids reduction and nitrogen content of the THP feedstock and may be updated based on future pilot testing results if the findings differ significantly. The ammonia-nitrogen concentration in the anaerobic digester is expected to be approximately 2,100 milligrams per liter (mg/L) with a 9 percent total solids feed to the digester. Without sidestream treatment, the final dewatering recycle would increase the total Kjeldahl nitrogen (TKN) load to the aeration basins by approximately 15 to 20 percent.

Table 1. Projected Sidestream Flows and Loads

Condition	WPCP Effluent Flow (mgd)	Recycle Ammonia Load (lb/d)	Recycle Flow before Dilution (gpd)
Using 2020 annual average	23.0	1,410	79,000
Design midpoint annual average	28.0	1,720	98,000
Design year annual average	30.8	1,890	108,000
Design year maximum month	36.7	2,490	141,000
Buildout annual average	40.0	2,460	140,000

a. Midpoint condition was applied where annual operating costs are listed.

The THP/AD process also produces refractory dissolved organic nitrogen (rDON), which is not removed by biological treatment and will contribute to WPCP effluent organic nitrogen. The rDON generated from THP was estimated based on conversion of 2.2 percent of the total nitrogen (TN) fed to THP, resulting in an additional 0.35 mg/L of effluent organic nitrogen. Table 2 illustrates the expected change in effluent TN due to rDON, assuming a similar level of treatment in the future. Current discharge permit limits are also listed. While rDON is not the focus of this TM, it should be noted that effluent organic nitrogen will increase with THP, and maintaining the current effluent TN would require using more methanol to achieve additional denitrification.

Table 2. Example Effluent Nitrogen Concentrations with THP-generated rDON

Effluent Nitrogen Species	Average Effluent, 2018–2020 (mg/L)	Effluent with THP-generated rDON (mg/L)	Effluent Limits (mg/L)
rDON from THP	-	0.35	-
Organic nitrogen (without THP)	0.7	0.7	-
Ammonia N	0.0	0.0	1.0/2.7 Apr.–Oct.[a] 3.5/4.2 Nov.–Mar.[a]
NOx	1.8	1.8	-
TN	2.5	2.85	3.0[b]

a. Weekly/monthly limits.
b. Annual limit.

2.2 Mainstream Treatment

The baseline alternative for treating the final dewatering nitrogen recycle load is to use the existing mainstream treatment process. This process uses conventional nitrification and denitrification. In this scenario, the final dewatering recycle load would be treated with the WPCP influent. This section describes the assumptions used to evaluate mainstream treatment.

2.2.1 Process Configuration

The existing activated sludge process is not reviewed in detail in this TM because extensive modifications are not anticipated as part of the biosolids upgrades. The only improvement identified was to provide additional capacity for storing and feeding supplemental alkalinity. The mainstream treatment alternative includes costs for new sodium hydroxide storage and feed facilities. The costs for this system are based on two new 12,500-gallon storage tanks for 25 percent caustic, providing an estimated 30 days of storage at 30.8 million gallons per day (mgd) WPCP flow, as well as feed pumps and accessories. Supplemental alkalinity demand and storage capacity should be evaluated further if mainstream treatment is selected.

2.2.2 Operating Cost Assumptions

The major operating costs for mainstream treatment of the recycle load are methanol for denitrification, handling solids generated from denitrification, supplemental alkalinity, and additional air for nitrification. Details for each of these cost factors are provided below.

Methanol is currently used as a carbon source for denitrification. Final dewatering recycle stream has a low biochemical oxygen demand (BOD)-to-TKN ratio and does not provide the carbon required for denitrification. For this analysis it was assumed that 100 percent of the final dewatering ammonia-nitrogen load recycled to the mainstream process will be denitrified with methanol. For sidestream treatment, this same assumption was applied to the ammonia load not removed by deammonification and thus recycled to the mainstream process. The methanol dosing ratio applied was 3.5 pounds (lb) of methanol per 1.0 pound of nitrogen. This ratio was based on an analysis of recent WPCP data and is in line with literature values.

The use of methanol for denitrification generates biological solids that must be processed and removed from the WPCP. Additional solids handling costs were estimated based on the increased methanol use for mainstream treatment. The additional solids production was estimated based on an estimated overall biomass yield of 0.3 pound total suspended solids per pound chemical oxygen demand (lb-TSS/lb-COD), and incremental solids handling cost of $175 per dry ton (DT) of biological solids generated and sent to THP/AD[1]. This solid handling cost captures the product hauling cost and polymer use associated with the additional biological solids from methanol.

Currently the WPCP does not normally add supplemental alkalinity to the activated sludge process. Supplemental alkalinity can be added as needed in the form of 25 percent caustic (sodium hydroxide). The activated sludge effluent (ASE) alkalinity averages 48 mg/L with an average pH of 7.05, and the outfall alkalinity averages 62 mg/L. The ASE pH is strongly correlated to alkalinity. Based on this correlation, the ASE pH would likely drop below 7.0 when the alkalinity is below 44 mg/L. The outfall alkalinity is higher than the ASE because of additional denitrification, which recovers alkalinity. At average flows and loads, the future final dewatering recycle load would consume about 30 mg/L of the mainstream alkalinity after full nitrification and before denitrification, accounting for the alkalinity provided by the recycle stream itself which is about 50% of the alkalinity required for full nitrification. Although denitrification can recover much of this alkalinity, it is expected that some amount of supplemental alkalinity will be required to treat the recycle load and maintain an acceptable pH throughout the activated sludge process. The amount of supplemental alkalinity required will depend on the target activated sludge pH, internal recycle and return activated sludge (RAS) rates, and amount of denitrification within the activated sludge process. For this analysis it was assumed that 35 percent of the alkalinity deficiency for full nitrification and denitrification would be supplemented by caustic. For reference, an assumption of 100 percent replacement would maintain the current ASE alkalinity without denitrification of the new recycle load in the activated sludge process, and an assumption of 0 percent

[1] Estimated biomass yield from methanol was based on literature. Cost for handling additional WAS generated from methanol was calculated based on the following assumptions: 72% volatile solids; 50% volatile solids reduction for WAS only; thickening, pre-dewatering, and final dewatering polymer doses of 5, 10, and 20 lb/DT, respectively; $2.50 per pound active polymer; and final dewatered cake at 33% total solids and $55/WT hauling cost. Additional energy costs were not included.

replacement would require full denitrification of this load in the activated sludge to maintain the current ASE alkalinity.

Mainstream aeration energy costs were estimated based on a typical aeration energy use of 1.2 kilowatt-hours per pound of nitrogen (kWh/lb-N)[2]. This typical energy demand for nitrification was not modified for WPCP conditions because available data were limited on the actual energy use for nitrification. This mainstream aeration energy use factor was also applied for ammonia not removed in the sidestream treatment alternative. For mainstream treatment, the existing aeration system should be evaluated to determine the excess capacity available to treat the recycle loads. The evaluation should consider that the centrate will be returned 5.5 days per week (during dewatering operation) because centrate equalization is not anticipated without sidestream treatment.

2.3 Sidestream Treatment

An alternative approach for treating the final dewatering nitrogen recycle load is to use a sidestream deammonification process. This would require a new treatment process that takes advantage of the warm, concentrated recycle stream to remove nitrogen in a relatively compact footprint and with less air and chemicals compared to mainstream treatment. The deammonification process converts a portion of the ammonia to nitrite aerobically by ammonia-oxidizing bacteria (AOB), and anaerobic ammonia-oxidizing biomass (anammox) consumes the combination of ammonia and nitrite. These reactions occur simultaneously in one reactor at low dissolved oxygen (DO) conditions. The process is successful on sidestreams because the warm temperature increases activity of the slow-growing anammox biomass, and the dewatering stream provides a consistent ammonia load to the process. Benefits of sidestream deammonification include:

- **Less aeration:** Deammonification has 60 percent less oxygen demand than full nitrification/denitrification and operates at a low DO concentration.
- **Less supplemental alkalinity:** Deammonification typically operates without supplemental alkalinity.
- **Less methanol:** Supplemental carbon is not used in the process.
- **Less sludge production:** Deammonification has a low biomass yield and avoids biomass growth from supplemental carbon.

Sidestream deammonification systems typically achieve about 85 percent ammonia removal and 75 percent TN removal without supplemental alkalinity. The nitrogen that is not removed in the sidestream process would be treated in the mainstream activated sludge process. While sidestream deammonification requires construction of a new facility, the operating costs are significantly less than those for full mainstream treatment because of less overall methanol use, supplemental alkalinity, energy for aeration, and solids production.

This section describes the process configuration and operating cost assumptions for sidestream treatment. Background information regarding deammonification downstream of THP is provided as part of the process description.

[2] Aeration energy based on "Economic analysis of electrodialysis, denitrification, and anammox for nitrogen removal in municipal wastewater treatment," Vineyard et al., *Journal of Cleaner Production*, Vol. 262, July 20, 2020.

2.3.1 Process Configuration

Multiple vendors have provided systems for deammonification downstream of THP, as shown in Table 3. A single system, ANITA™ Mox, was used as the basis for this evaluation. Costs between vendors are expected to be similar for this level of evaluation, and therefore a single process configuration was used as the basis of evaluation. If sidestream deammonification is implemented, a separate process selection evaluation should be conducted.

Table 3. Deammonification Systems with THP

Facility	THP and Deammonification Systems
Växjö (Sweden)	Cambi THP + ANITA™ Mox
Five Fords (UK)	Cambi THP + ANITA™ Mox
Piscataway (USA): in construction	Cambi THP + ANITA™ Mox
Raleigh, NC (USA): in construction	Cambi THP + ANITA™ Mox
Washington, D.C. (USA)	Cambi THP + Demon™
Santiago (Chile)	Cambi WAS-only THP + Demon™
Vigo (Spain)	Cambi THP + Demon™
Basingstoke (UK)	Cambi THP + Demon™
Ourense (Spain)	Cambi THP + Clear green™
Burgos (Spain)	Cambi THP + Clear green™
Leigh (UK)	Cambi THP + Am treat
Tilburg (Netherlands)	Cambi THP + Anammox™
Minworth (UK)	Cambi THP + Anammox™
Hengelo (NL)	WAS-only THP + Colsen NAS
Beijing plants	Reno car Anammox process
Whittingham (UK)	Cambi THP + Sharon™

There are several design considerations particular to deammonification systems downstream of THP. Compared to conventional anaerobic digestion, the recycle stream from THP has higher concentrations of soluble chemical oxygen demand (sCOD) and ammonia-nitrogen. As a result, dilution water is required to help mitigate biological inhibition, which has been attributed to COD in the THP recycle stream, and to control temperature rise in the reactor because of the exothermic biological process. Dilution ratios are typically in the range of 1:1 to 2:1. While the dilution water helps to overcome the biological inhibition from THP recycles, deammonification systems downstream of THP are still designed for lower nitrogen loading rates compared to systems paired with conventional AD. This is a result of biological inhibition associated with THP.

An important design consideration for all deammonification systems is the TSS content of the recycle stream. Poor solids capture in the final dewatering process (e.g., centrate TSS greater than 1,000 mg/L) can result in high solids loads to sidestream deammonification and negatively impact the performance because of inhibition, increased oxygen demand, and displacement of active biomass. Deammonification systems should be designed based on the expected solids content of the recycle stream and with consideration to removing settled solids from equalization. Excess polymer dosed to final dewatering may lead to foaming in the deammonification reactor, and management of foam must also be considered in the design.

All sidestream deammonification systems benefit from upstream equalization to decouple the operation from dewatering, resulting in a steadier loading to the deammonification system. Deammonification systems achieve better nitrogen removal performance when the nitrogen load is consistent. For this analysis the equalization tank was sized based on 24 hours of equalization volume at design average conditions. The size of the equalization tank should be refined during detailed design, with consideration to dewatering schedule and the selected deammonification process. THP recycle streams have a high ammonia concentration which results in a strong ammonia odor near the equalization tank. The ammonia is expected to dissipate quickly and not result in offsite odors. Because the deammonification process is aerobic it has low odor potential. No odor control measures were included in this evaluation.

The ANITA™ Mox system configuration that was evaluated is shown schematically in Figure 1. It is a continuous-flow process, where anammox biomass is retained on plastic media. Suspended biomass is wasted periodically from the RAS with a motorized valve.

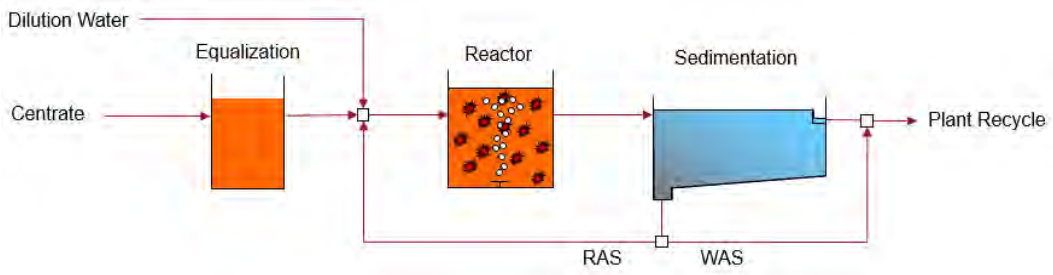

Figure 1. ANITA™ Mox IFAS General Process Flow Diagram

ANITA™ Mox is typically configured as a flow-through moving-bed biofilm reactor (MBBR) with conventional anaerobic digestion. However, with THP, an integrated fixed-film activated sludge (IFAS) process with a clarifier is recommended. The IFAS configuration is more robust for treating THP recycles with high sCOD and can operate at a higher loading rate compared to the MBBR configuration. The IFAS configuration is less sensitive to incoming COD because the mixed liquor suspended solids (MLSS) contain heterotrophic organisms and the MLSS concentration can be adjusted. This also helps to reduce the amount of dilution water required because dilution water is added to help mitigate inhibition from sCOD. The IFAS system operates at lower DO (0.2 to 0.5 mg/L) compared to MBBR (0.5 to 1.5 mg/L), which helps AOB to outcompete nitrite-oxidizing bacteria (NOB). This further improves process stability. Aeration is typically operated continuously in the ANITA™ Mox system.

The structures, equipment, and instrumentation for the ANITA™ Mox system are listed in Table 4. The process was configured with one reactor and one clarifier. The use of one large reactor rather than parallel reactors results in lower construction cost and simpler operation and monitoring. Reactor volume is based on the nitrogen loading rate at design maximum month conditions. The ANITA™ Mox vendor recommended a design loading rate of 1.0 kilogram nitrogen per cubic meter per day (kg-N/m^3/d), which results in a reactor volume of 0.34 million gallons (MG).

A conceptual layout for the sidestream treatment system is shown in Figure 2. Common wall construction was used where possible, and tank dimensions in the figure account for typical wall thicknesses. The building is configured between the tanks with pumps on the lower level for RAS/waste activated sludge (WAS) and feeding from the equalization tank to the reactor. The upper level would be

used for blowers, variable-frequency drives (VFDs), and controls. The reactor and clarifier would not be covered since it is an aerobic process with relatively low odor, similar to aerobic activated sludge. The equalization tank may be covered if there is a need to limit ammonia odors in the selected location.

A general site layout is shown in Figure 3. The sidestream deammonification system is shown in the location of the current dissolved air flotation thickeners (DAFTs) which are slated to be demolished. Costs for demolition of the DAFTs is not included in the analysis as this was included in the thickening evaluation. To install sidestream treatment in this location, consideration must be given to conveying the recycle flow to the facility. It is likely that an existing drain from the DAFTs could be configured for the sidestream treatment effluent, and existing plant effluent water (PEW) piping to the DAFTs could be repurposed for dilution water.

Table 4. Sidestream Treatment Equipment and Instrumentation

Structure	Size and Details
Equalization tank	0.11 MG, 35 ft × 21 ft × 20 ft SWD
Reactor	0.34 MG, 50 ft × 45 ft × 20 ft SWD
Clarifier	35 ft × 13 ft × 13 ft SWD
Building	Two levels, 35 ft × 16 ft
Equipment	**Quantity and Details**
Plastic carrier media	20,900 ft^3
Media retention screens	2
Medium-bubble diffusers	5 grids
Airlift pumps for foam control	5
Hybrid screw blowers with VFD	1 duty/1 standby, ~100 hp ea.
Top-entry mixer with VFD	1
Reactor feed pumps with VFD	1 duty/1 standby
RAS/WAS pumps with VFD	1 duty/1 standby
Chain and flight clarifier mechanism	1
Equipment	**Quantity and Details**
PLC control panel	1
RAS/WAS control valves	2
RAS/WAS flow meters	2
Reactor feed flow meter	1
Dilution water flow control valve	1
Dilution water flow meter	1
Air supply flow meter	1
Level indication transmitter: equalization	1
Level float: reactor and equalization	2
DO probe: reactor	1
pH probe: reactor	1
Nitrate probe: reactor	1
Ammonia analyzer: reactor and equalization	1

ft = feet.
ft^3 = cubic feet.
hp = horsepower.

PLC = programmable logic controller.
SWD = side water depth.

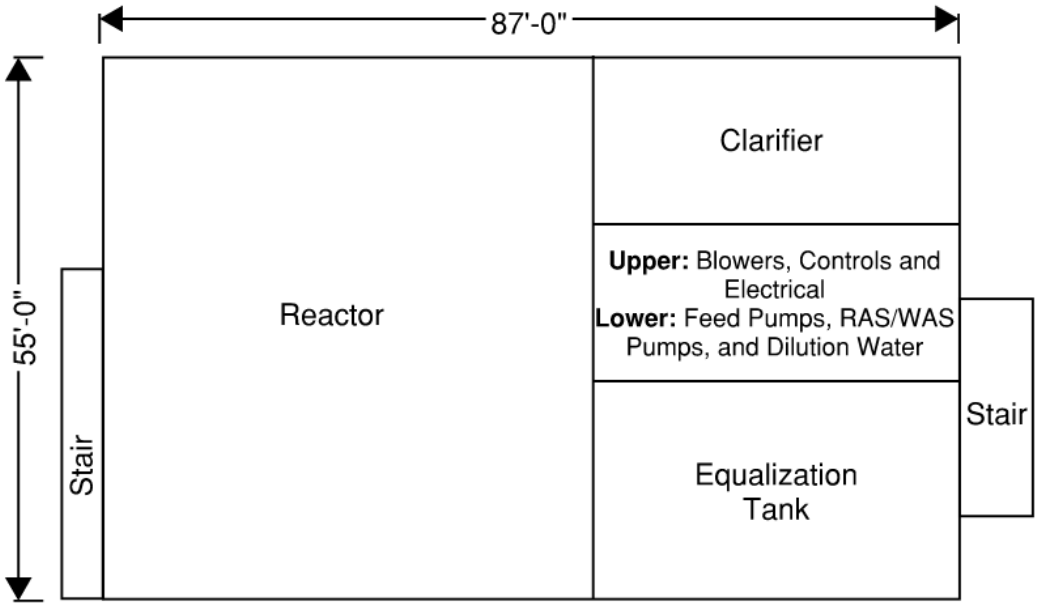

Figure 2. Sidestream Deammonification Conceptual Facility Layout

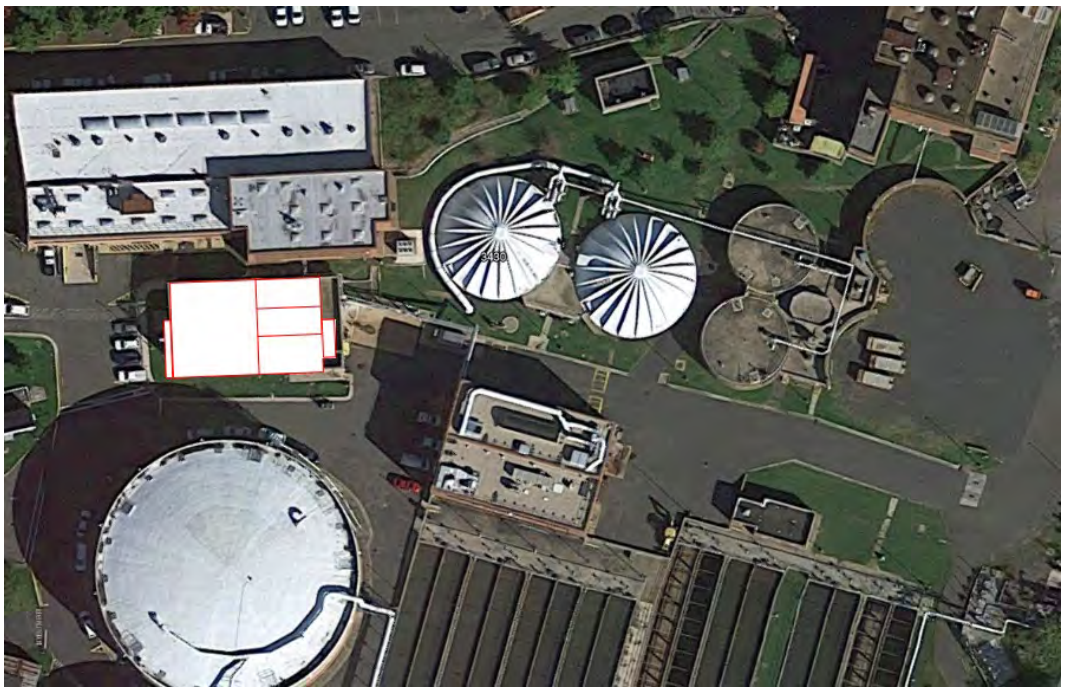

Figure 3. Sidestream Deammonification General Site Layout

2.3.2 Operating Cost Assumptions

Operating costs for the sidestream treatment alternative were evaluated assuming 85 percent ammonia removal in the sidestream process, with the remaining removal occurring in the mainstream process.

Approximately 10 percent of the ammonia removed in the sidestream treatment process is converted to nitrate, which is recycled to the head of the WPCP along with the residual ammonia. The costs for treating this nitrate recycle are assumed to be negligible because it will be mixed with the raw influent and may be consumed through denitrification before reaching the aeration basins.

Costs to operate sidestream treatment include electricity, dilution water, operations labor, and equipment maintenance. Methanol cost is included for treating the residual ammonia load that is recycled to the mainstream process. Costs were also included for handling additional solids generated by methanol, similar to the mainstream alternative. It was assumed that with sidestream treatment, supplemental alkalinity will not be required to treat the remaining portion of the nitrogen load in the mainstream process.

3.0 Alternatives Evaluation and Comparison

This section summarizes the costs assumptions applied for the evaluation and overall NPV of each alternative.

3.1 Cost Factors

The cost factors listed in Table 5 were used to develop the conceptual costs for deammonification. Base costs were first established using the vendor proposal along with concrete, structural, and additional equipment and piping costs based on the conceptual layout. Sitework, electrical, instrumentation and controls (I&C), and geotechnical factors were applied to the base cost. The remaining three cost factors were applied in series (contingency, mobilization/staging plus bonds/insurance, and overhead/profit).

Table 5. General Percentages for Cost Preparation

Parameter	Percentage
Sitework	15%
Electrical	20%
Instrumentation and controls	8%
Geotechnical	7%
Project contingency	20%
Contractor mobilization/staging, bonds/insurance	8%
Contractor overhead and profit	15%

Operations and maintenance (O&M) and present-value costs applied to the evaluation are summarized in Table 6. Commodity costs were based on current delivery contracts. Caustic price is based on 25 weight percent solution, which is used in the current system. The price for 50 weight percent caustic is currently 10 percent less ($648/DT). To avoid crystallization, 50 percent caustic should be used only with heat tracing, and therefore 25 percent caustic has been used historically at Arlington WPCP. Solids handling costs for additional solids generated from methanol were estimated based on final product hauling costs and polymer use, as described in Section 2.2.2.

Table 6. Cost Assumptions for Commodities, Labor, Maintenance, and Present Value

Parameter	Percentage
Methanol	$0.215/lb
Caustic, 25wt%	$721/DT
Electricity	$0.06/kWh
Solids handling (growth on methanol)	$175/DT
Dilution water	$0.50/1,000 gallons
Operations labor	$70/hr
Annual maintenance	2.5% of moving equipment cost
Present value factors	4% interest, 2% inflation

3.2 Comparison of Alternatives

Quantities for chemicals, electricity, and sludge production for each alternative are summarized in Table 7. The values shown are at design midpoint conditions (28 mgd WPCP flow).

Table 7. Chemicals, Energy, Sludge Production and Operations Labor

Item	Unit	Mainstream	Sidestream	Notes
Additional methanol	gpd	1,050	160	100% of ammonia recycled to mainstream is denitrified with methanol at 3.5 lb methanol/lb-N
Additional caustic	gpd at 25wt%	740	0	Supplementing 35% of alkalinity deficiency for complete nitrification prior to denitrification
Additional electricity	kWh/d	2,400	1,600	
Additional solids to THP (from methanol)	DT/d	1.23	0.18	
Dilution Water	gpd	0	98,000	Assuming 1:1 dilution ratio for sidestream
Additional operations labor	Full-time equivalent	0	0.25	

Costs for both alternatives are compared in Table 8. The annual costs shown are at design midpoint conditions, while present-value calculations consider operating conditions for each year as flows increase. Sidestream treatment has a much lower annual operating cost, primarily because of lower chemical requirements, but requires construction of a new facility at a significant capital expenditure. The sidestream treatment alternative has a lower overall 20-year NPV based on the assumptions used in this evaluation.

Table 8. Alternatives Cost Comparison

Parameter	Mainstream	Sidestream
Annual O&M	$932,000	$216,000
Methanol	$544,000	$82,000
Caustic	$258,000	$0
Electricity	$52,000	$33,000
Mainstream solids (from methanol)	$78,000	$12,000
Dilution water	$0	$18,000
Operations	$0	$36,000
Maintenance	$0	$35,000
Conceptual capital costs	$900,000	$9,500,000
O&M present value (20 year)	$15,150,000	$3,530,000
Net present value (20 year)	$16,050,000	$13,030,000

A year-by-year comparison of NPV is shown in Figure 4. Costs are based on projected operating conditions each year after startup. Based on the calculated NPVs over time, the payback period for sidestream treatment is approximately 14.3 years.

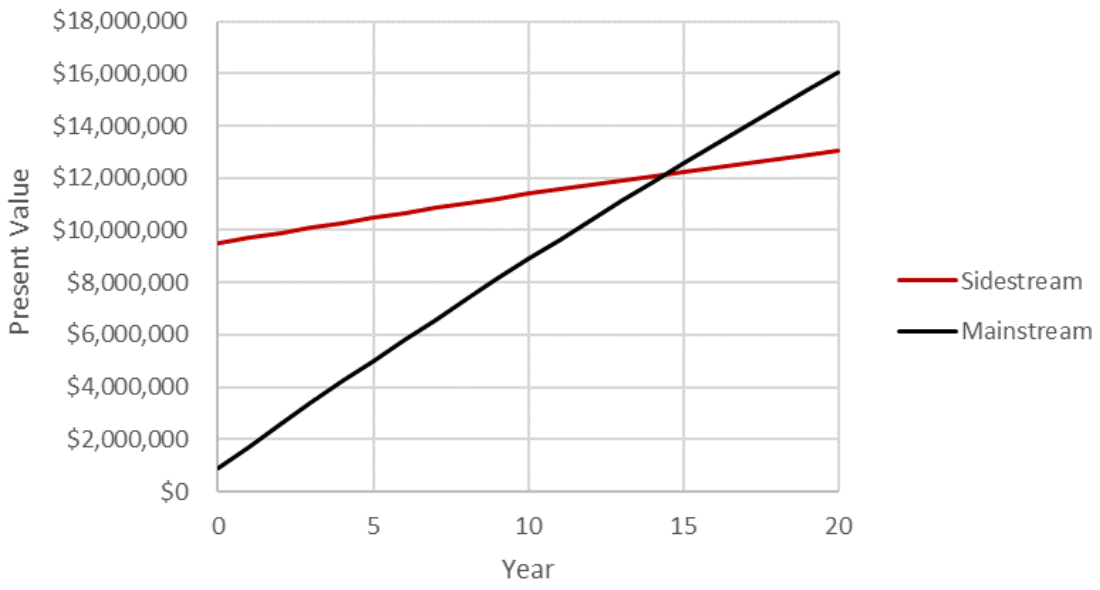

Figure 4. Net Present Value of Alternatives

A sensitivity analysis was conducted to evaluate the effect of assumptions for commodity costs and other factors that could be different in the future. Table 9 lists the 20-year NPV and years to equal NPV (i.e., payback) when cost factors are adjusted. Higher chemical costs would result in a shorter payback period for sidestream treatment. The sidestream treatment alternative is less sensitive to fluctuations in commodity costs because of lower chemical and energy use.

Table 9. Cost Sensitivity Analysis

Change	Mainstream NPV	Sidestream NPV	Years to Equal NPV
Baseline assumptions	$16,050,000	$13,030,000	14.3
Methanol cost increases by 40%, from $0.215/lb to $0.301/lb	$19,590,000	$13,560,000	11.3
Caustic cost increases 20%, from $721/DT to $865/DT	$16,900,000	$13,030,000	13.3
Electricity cost increases 50%, from $0.06/kWh to $0.09/kWh	$16,470,000	$13,300,000	14.2
Methanol, caustic, and electricity costs all increase as listed above	$20,850,000	$13,820,000	10.5
Mainstream alkalinity replacement is 20% (rather than 35%) of the alkalinity deficiency for complete nitrification	$14,260,000	$13,030,000	17.3
Mainstream alkalinity replacement is 50% (rather than 35%) of the alkalinity deficiency for complete nitrification	$17,850,000	$13,030,000	12.4

Mainstream treatment costs may be lower than predicted if actual chemical requirements for mainstream treatment are lower than the estimates in this evaluation. Additional confidence in the cost projections could be gained by a more detailed evaluation of the existing biological process and particularly the need for supplemental alkalinity. Currently 25 percent caustic can be fed to the activated sludge process. For mainstream treatment at design midpoint conditions (28 mgd WPCP flow) and with the baseline assumptions used for this analysis, caustic feed would be about 740 gallons per day (gpd) for 25 percent caustic or 310 gpd for 50 percent caustic. Lower-cost options for supplemental alkalinity could also be evaluated.

4.0 Summary and Conclusions

Sidestream deammonification has a lower annual operating cost than treating the final dewatering nitrogen recycle load in the existing mainstream activated sludge process. The lower operating cost for sidestream treatment is primarily due to lower chemical requirements, as well as lower energy use and sludge production. On the other hand, a new sidestream treatment process comes with a significant capital cost and would require operating and maintaining an additional facility.

A sensitivity analysis was conducted to evaluate the impact of chemical requirements and commodity costs on the NPV of each alternative. The payback period for sidestream treatment was estimated at 14.3 years with a range of 10.5 to 17.3 years. A key area of uncertainty is the chemical demands for mainstream treatment, particularly the amount of supplemental alkalinity.

Further evaluation of the mainstream activated sludge process is recommended to quantify the supplemental alkalinity requirements and help optimize the process for treating additional nitrogen load. This evaluation should include process modeling and evaluations of equipment and processes to confirm sufficient nitrogen removal capacity and to develop measures for improving nitrogen removal performance. Chemical storage and feed facilities should be evaluated based on the projected chemical demands and commodity costs.

It is recommended that space be reserved for a future sidestream deammonification process, which would be selected and constructed in a later project. The future sidestream deammonification process should ideally be located close to final dewatering to minimize the distance for conveying centrate to the equalization tank. Initially the recycle load can be treated in the activated sludge process. The activated sludge process currently has excess aeration capacity because the blowers are sized for WPCP buildout flow. Methanol use will increase significantly, and it is likely that supplemental alkalinity will be required. Chemical storage and feed facilities for the existing process should be reviewed to confirm capacity and expanded as required. Postponing the design and construction of a new deammonification process to a future project would allow for additional local experience treating thermal hydrolysis recycles in similar processes. The economic justification for a new sidestream deammonification process could also be confirmed based on full-scale operating data for mainstream treatment at Arlington WPCP.

Technical Memorandum No. 9

Date:	October 20, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Dewatering Facility Evaluation

Contents

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1.0 Introduction

This introductory section presents the background and purpose of this project and the dewatering facilities evaluation, followed by a description of the evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary solids (PS) and waste activated solids (WAS) thickening, dewatering, and lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this dewatering facilities evaluation is to further assess and compare dewatering equipment locations and the reuse or repurposing of existing facilities. The results of this evaluation will inform a decision on whether existing facilities will be retained or decommissioned and the overall site planning for inclusion in the Facilities Plan.

1.2 Evaluation Approach

Various existing and new building layouts were developed for pre-dewatering and final dewatering. Conceptual building configurations, site layouts, and costs for dewatering facilities were prepared. Facility alternatives are evaluated and compared based on conceptual cost estimates, non-cost considerations, site layout, and space requirements.

2.0 Summary of Existing Facilities and Future Solids Processing

A process flow diagram for existing solids handling at the WPCP is shown in Figure 1. Solids are thickened using gravity thickeners (GTs) for PS and dissolved air flotation thickeners (DAFTs) for WAS. Thickened solids are blended in solids storage tanks and dewatered using centrifuges. Liquid centrate from the centrifuges is returned to the head of the WPCP. Lime is added to the raw dewatered solids to achieve Class B pathogen and vector attraction reduction. Lime-stabilized biosolids are hauled off site for beneficial use through bulk agricultural land application.

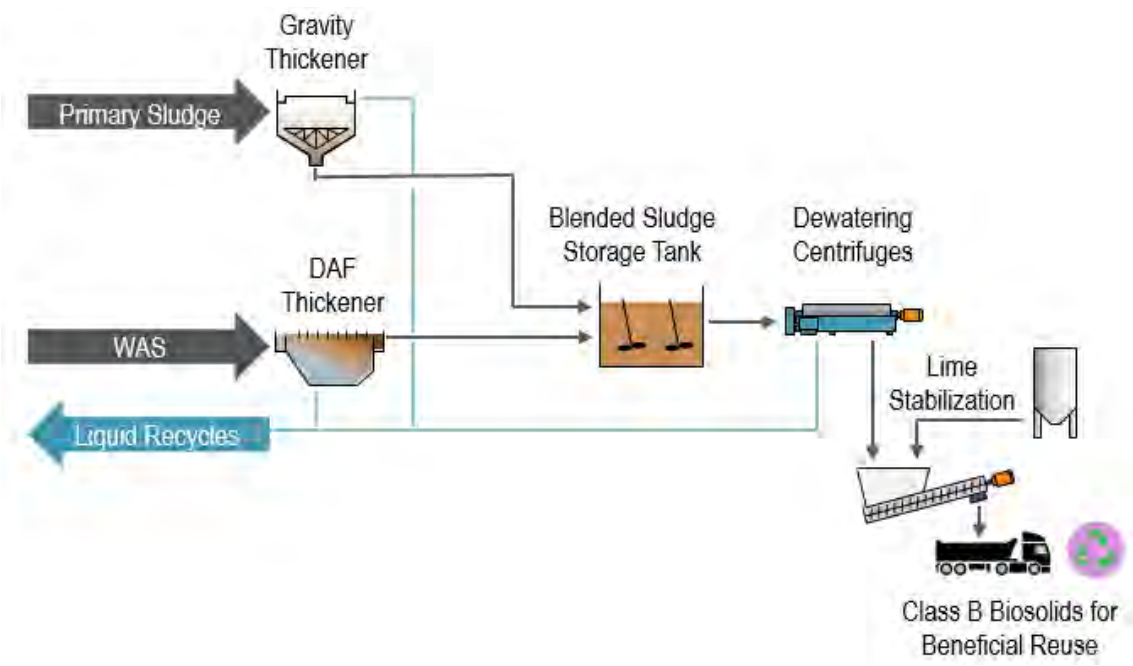

Figure 1. Existing PS and WAS Process Flow Diagram

All existing dewatering and lime stabilization processes are housed in the existing dewatering building (DWB). The DWB, constructed in the 1990s, includes the following equipment:

- Dry and liquid polymer storage and feed (only liquid polymer is used, the dry polymer system is abandoned)
- Centrifuge feed well and centrifuge feed pumps
- Dewatering centrifuges
- Dewatered cake bins and conveyors
- Lime storage and feed, including storage silo, day bins, and lime metering system
- Sludge/lime mixers
- Truck loading bays
- Ancillary facilities, including air compressors; boilers; heating, ventilation, and air conditioning (HVAC); and fire suppression
- Bathrooms
- Egress (stairways/elevator)

As noted in Technical Memorandum (TM) No. 2, *Condition of Existing Facilities*, the DWB structure is sound and could continue to be used for future facilities. The existing process mechanical equipment is approaching the end of its useful life, and it is recommended that all new equipment be provided and the building be reconfigured as necessary to serve the new treatment processes. Although some recent HVAC modifications have been made, it is likely that any building reconfiguration will require a complete HVAC overhaul, as well as retrofits to the electrical and controls systems.

The new solids handling process will include two dewatering steps, as highlighted in Figure 2: a pre-dewatering process to provide the appropriate solids concentration to feed the THP and subsequent digestion process and a final dewatering process for creation of the dewatered cake for beneficial use.

This TM includes evaluations of facility configurations for both dewatering processes. Thickening and screening processes noted in previous evaluations (TM No. 6, *Thickening Evaluations*) are also accounted for in these facility configurations.

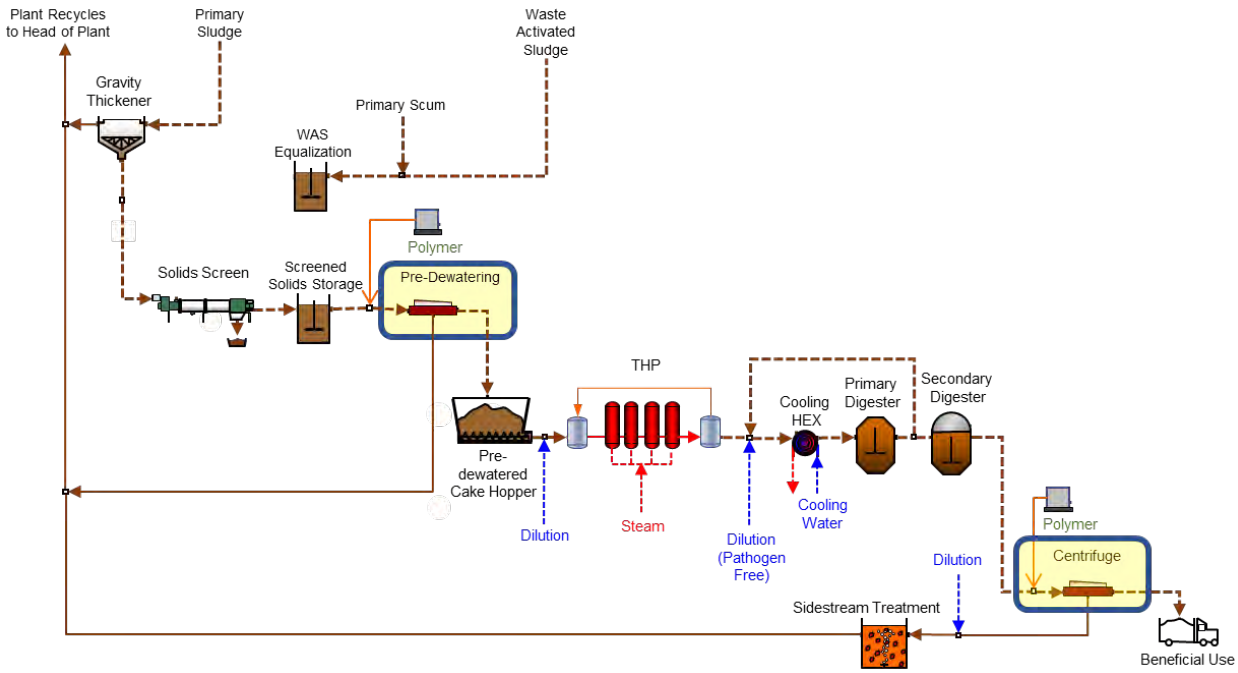

Figure 2. Future Solids Handling Process Flow Diagram

Preliminary evaluations presented in Workshop 4.1 on June 16, 2021, considered reuse of the existing DWB and new facilities for both pre-dewatering and final dewatering. At that workshop, it was concluded that the existing DWB should be considered only for pre-dewatering for the following reasons:

- The existing DWB space is very large and exceeds what is needed for final dewatering. The space can be used more effectively to add unit processes such as mechanical WAS thickening and solids screening.
- The existing truck loadout requires trucks to back into the facility from Eads Street, which presents safety concerns.
- The existing dewatered cake bins and conveyors are not well suited for rapid truck loadout and could provide greater benefit as pre-dewatered cake storage ahead of thermal hydrolysis.

At Workshop 5.2 on August 6, 2021, it was decided to evaluate an alternative where final dewatering and pre-dewatering are in a common building. Based on Workshop 4.1 and Workshop 5.2 conclusions, this TM compares the following alternatives:

1. **Alternative 1: Renovate the Dewatering Building.** The existing DWB would be rehabilitated and renovated for pre-dewatering, and a new final DWB would be constructed.
2. **Alternative 2: Demolish the Dewatering Building.** New pre-dewatering and final dewatering buildings would be constructed, and the existing DWB would be demolished.
3. **Alternative 3: Decommission the Dewatering Building.** A new combined pre-dewatering and final dewatering building would be constructed without impacting the existing DWB.

This TM presents building concepts for the facilities included in the alternatives listed above.

Note that while the focus of this TM is on the dewatering facilities, space within the new or renovated building(s) is also allocated for the following:

- Future mechanical WAS thickening
- Solids screening and associated pumping
- Solids storage mixing systems and associated pumping

In addition, given the available space of the existing DWB, Alternative 1 would include allocated space for the steam boilers and associated equipment. As the evaluation progressed, space was also identified in Alternative 3 for steam boilers (to provide a direct comparison to Alternative 1 as described later in this TM).

3.0 Design Criteria

Two design loading conditions were considered for the dewatering facilities evaluation. These conditions were defined based on WPCP flow treated, as follows:

- **30.8 million gallons per day (mgd):** design conditions:
  - Used as the basis for equipment sizing and number of units required for the Facilities Plan
  - Based on projected 2052 WPCP flow
- **40.0 mgd:** buildout conditions:
  - Used to establish total footprint requirements and dewatering facility sizing with space reserved for potential future equipment

Equipment sizing and number of units required were based on peak 3-day loadings for pre-dewatering and peak 14-day loadings for final dewatering as established in TM No. 1, *Solids Production and Design Criteria*. A lower peaking factor is appropriate for final dewatering as the solids loads are buffered through the digestion process.

Summaries of the design loading criteria for pre-dewatering and final dewatering are provided in Table 1 and Table 2, respectively. For pre-dewatering, it is assumed that the PS will be thickened with GTs and mixed with un-thickened WAS to achieve a total feed solids concentration of 2.1 percent with a PS:WAS ratio of 70:30. THP is required to be fed at 15 to 18 percent solids. Any of the pre-dewatering systems being evaluated will produce a higher solids concentration and dilution of the pre-dewatered solids will be required prior to feeding THP. The operation schedule for pre-dewatering will be 24 hours per day, 7 days per week to maintain a consistent feed to the THP and digestion processes. For final dewatering, the feed solids concentration is assumed to be 4.4 percent. The final dewatered cake concentration is expected to be greater than 30 percent. The operation schedule for final dewatering will be 24 hours per day, 5.5 days per week, consistent with current dewatering operations.

Table 1. Summary of Pre-dewatering Loading Design Criteria

Design Condition	Avg (gpm)	Avg (lb/hr)	3-day (gpm)	3-day (lb/hr)
23.0 mgd (current)	250	2,700	395	4,500
30.8 mgd (year 2052)	330	3,600	530	6,000
40.0 mgd (buildout)	430	4,700	685	7,800

Flows and loads in this table are based on a 24-hour per day, 7-day per week operating schedule assumption.

Table 2. Summary of Final Dewatering Loading Design Criteria

Design Condition	Avg (gpm)	Avg (lb/hr)	14-day (gpm)	14-day (lb/hr)
23.0 mgd (current)	70	1,600	100	2,300
30.8 mgd (year 2052)	100	2,200	140	3,100
40.0 mgd (buildout)	125	2,900	180	4,000

Flows and loads in this table are based on a 24-hour per day, 5.5-day per week operating schedule assumption.

4.0 Facility Evaluation Assumptions

This section discusses the assumptions made for the thickening/pre-dewatering facility and final dewatering facility. The purpose of this evaluation is to provide reasonable building footprints and conceptual facility sizing. Internal building layouts are not yet optimized for site layout, and may require rotation, mirroring, or other reconfiguration. Details for equipment orientation will be provided during design of the facilities.

The sections below describe the assumptions for equipment selection and sizing of the major unit processes to be located within these facilities

4.1 Future Thickening Units

As discussed at Workshop 5.1 on July 22, 2021, mechanical WAS thickening will not initially be included, and un-thickened WAS will be combined with thickened PS prior to pre-dewatering. However, space will be allocated for future WAS thickening implementation , as it is anticipated that increased flows and loads over time will make WAS thickening a necessity in the future.

For Alternative 1, rotary-drum thickeners (RDTs) are assumed for future WAS thickening because they have a relatively compact footprint. Layouts allocate space for three RDTs, which meets both design and buildout conditions with one unit out of service. GBTs could also be considered in the future. For Alternatives 2 and 3, GBTs are assumed for future WAS thickening because of the increased available space in a new facility. Space for three GBTs would be provided to meet buildout conditions. RDTs would also fit in the space allocated.

4.2 Dewatering Units

For both pre-dewatering and final dewatering, centrifuges are assumed as documented in TM No. 7, *Dewatering Evaluation*. Three pre-dewatering centrifuges are required (two duty, one standby) with space for a fourth to meet buildout conditions. Final dewatering requires two centrifuges (one duty, one standby) with space for a third to meet buildout conditions. All alternatives include bridge cranes and floor hatches to facilitate maintenance of the centrifuges.

4.3 Polymer System

One polymer system is assumed to be dedicated to pre-dewatering and future WAS thickening. A second, separate polymer system is assumed to be dedicated to final dewatering. Each system includes two polymer storage tanks, providing more than 30 days of storage at 40 mgd WPCP flow conditions. All facility layouts include a rapid-mix polymer activation unit for each dewatering unit with space for similar future thickening polymer systems.

4.4 Pre-dewatering Cake Storage

A minimum 24 hours of storage at 40 mgd average conditions is recommended between the pre-dewatering centrifuges and THP pulper tank. Pre-dewatered cake will be pumped to THP using pulper feed pumps below the storage bins.

For Alternative 1, the existing cake storage bins would be used for cake storage. The existing bins have a total capacity of 430 cubic yards (CY) and would provide 29 hours of storage at 40 mgd average conditions.

Alternatives 2 and 3 would include two 175 CY cake storage bins, providing a total capacity of 350 CY, which is equivalent to 24 hours of cake storage at 40 mgd average conditions.

4.5 Final Dewatering Cake Storage

Final dewatering cake storage bin sizing was based on providing 1.5 days of cake storage at 30.8 mgd 14-day peak conditions, resulting in 200 CY of storage capacity. Screw conveyors are assumed for all cake conveyance for final dewatering.

4.6 Truck Loadout

Emergency truck loadout is assumed for pre-dewatering. During emergency loadout, the THP feed pumps would convey cake to a chute outside of the dewatering building as opposed to the THP.

A pull-through truck loadout with a truck scale is assumed for final dewatering.

4.7 Auxiliary Facilities

HVAC is assumed to be housed in the facility for the new final dewatering facility and repurposed pre-dewatering facility. For the new pre-dewatering facility, the HVAC equipment can be configured on a roof adjacent to the control room. Odor control is assumed to be housed outside of the facilities in a separate location. One elevator is planned for each of the new facility alternatives. Control rooms and lab space are included, as well as bathrooms and space for storage. Two stairways are shown to provide egress per Occupational Safety and Health Administration (OSHA) requirements.

4.8 Construction Costs

Conceptual construction costs were prepared for each alternative based on preliminary equipment quotes from vendors; cost per square foot for buildings; and general percentages for ancillary facilities, site work, contingencies, and general contractor costs shown in Table 3 (for new facilities). A built-up estimate for demolition, structural/architectural, and mechanical is provided. Percentage cost adders are applied to these built-up estimates to determine the final conceptual costs, as shown in Table 3. Percentage cost adders and estimates for Alternative 1 are described further in Section 5.1.6.

Table 3. General Percentages for Cost Preparation

Parameter	Percentage
Demolition	Built-up estimate
Structural/architectural	Built-up estimate
Mechanical	Built-up estimate
Base subtotal	*Base subtotal*
Sitework (percentage of base subtotal)	15%
Electrical (percentage of base subtotal)	20%
Instrumentation and controls (percentage of base subtotal)	8%
Large and specialty pipe (percentage of base subtotal)	5%
Geotechnical (percentage of base subtotal)	7%
Subtotal	*Subtotal*
Project contingency (percentage of subtotal)	20%
Contractor mobilization/staging (percentage of subtotal and project contingency)	5%
Contractor bonds/insurance (percentage of subtotal and project contingency)	3%
Contractor overhead and profit (percentage of subtotal and project contingency)	15%
Total construction cost	**Total**

The conceptual cost is only a rough order of magnitude to use for relative comparisons between the various alternatives. The conceptual costs presented herein are not for budgeting purposes. Opinions of probable construction costs (OPCCs) will be prepared as part of the Facilities Plan, separate from this dewatering evaluation.

5.0 Facility Alternatives

A description of each facility alternative, including layout, conceptual costs, and advantages and disadvantages, is provided in this section.

5.1 Alternative 1: Renovate the Existing Dewatering Building

In Alternative 1, the existing DWB would be renovated for screening and pre-dewatering processes, with space allocated for a future thickening process. This alternative must be paired with the new final dewatering facility (Section 5.3).

5.1.1 Process Equipment and Building Components

New process equipment and electrical equipment would include the following:

- Screen feed pumps
- Solids storage mixing compressors
- Steam boilers and boiler chemical feed
- Polymer storage and feed, shared for pre-dewatering and future WAS thickening
- Future RDTs for WAS thickening
- Sludge screens and screenings loadout
- Pre-dewatering centrifuge feed pumps
- Pre-dewatering centrifuges with emergency cake loadout
- New HVAC and electrical

- New process piping throughout
- New elevator, controls, and mechanical equipment

The following components would be reused:

- Existing cake bins with live bottoms: four bins at 107 CY each, providing 29 hours of storage at 40 mgd average conditions
- Overall building structure, with significant modifications for new equipment and processes
- Bathrooms
- Egress (stairways, elevator shaft)

The existing odor control system would be demolished and provided in a separate facility. One of the existing truck bays can be used for emergency dewatered solids unloading.

5.1.2 Building Layout

The first floor of the building would include the following equipment:

- Pre-dewatering feed pumps
- Space for future RDTs and thickened waste activated sludge (TWAS) pumps
- Polymer storage tanks and blend units for pre-dewatering, with space for additional blend units for future thickening
- Truck bay for emergency loadout (existing truck bay)
- Screen feed pumps
- Solids storage mixing compressors

The pre-dewatering feed pumps would replace the existing centrifuge feed pumps. The polymer system would be configured in the location of an existing truck bay and would include bulk storage tanks, a recirculation pump, and polymer blend units for pre-dewatering. One truck bay would be retained for emergency cake loadout. The location for the future RDTs would require demolishing the existing odor control chemical room, polymer tanks, and polymer feed pumps. The first-floor layout is shown in Figure 3, and a section is shown in Figure 4.

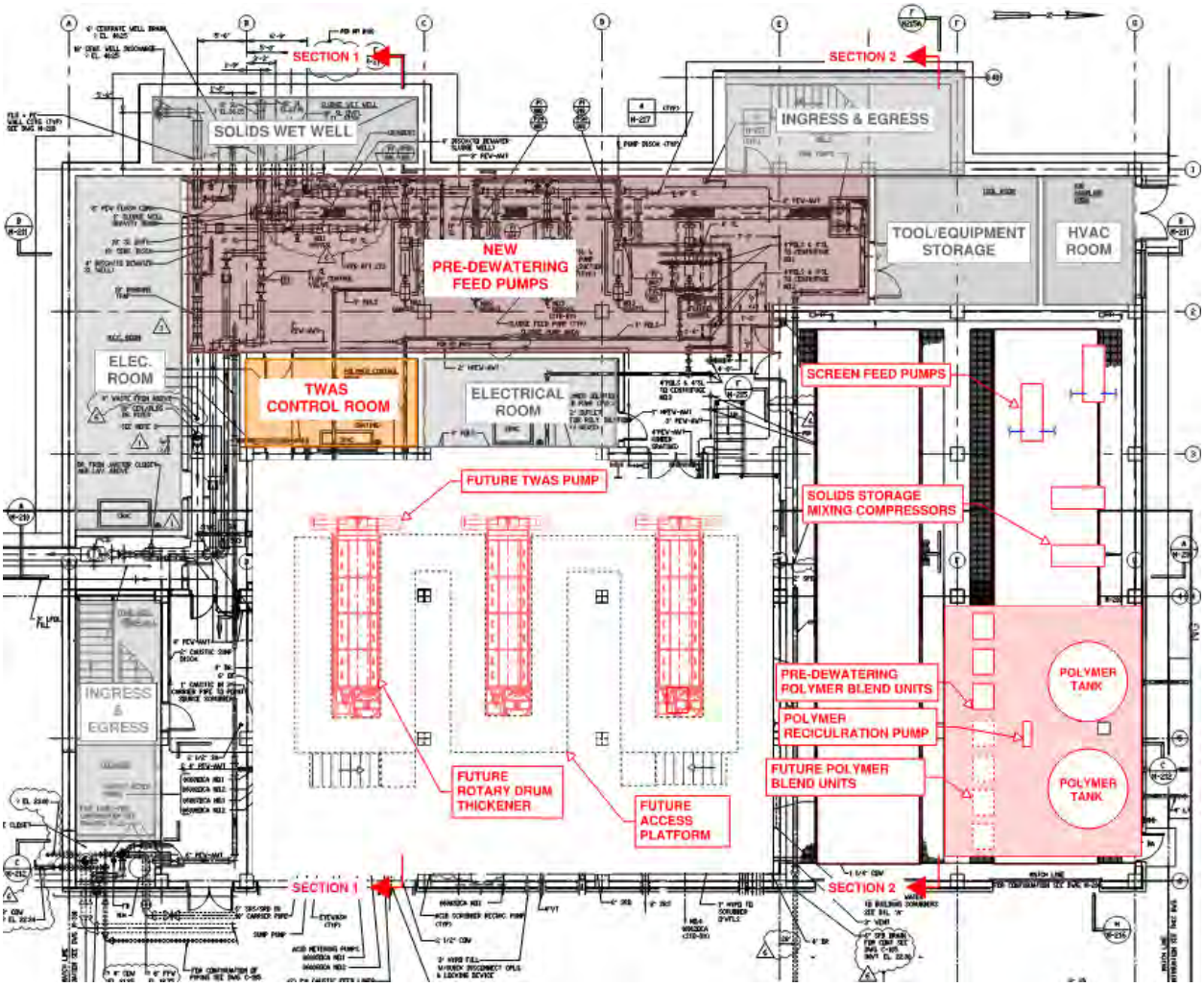

Figure 3. Existing Building First-Floor Plan

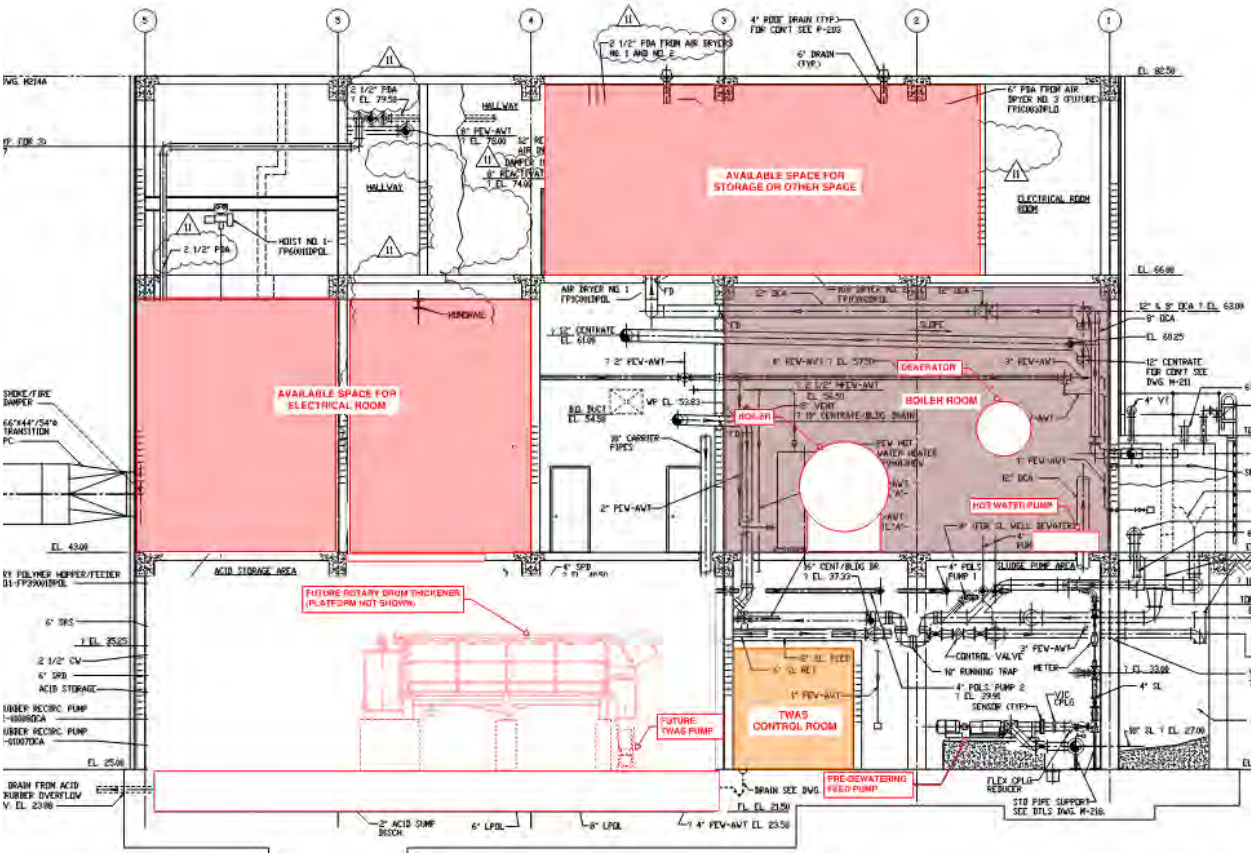

Figure 4. Existing Building Section 1

The second floor of the building would include the following equipment:

- Two cross conveyors
- Two THP pulper feed pumps
- Steam boilers and boiler chemical feed

Each cross conveyor would move pre-dewatered cake from the bins to a pulper feed pump. The layout on this floor would include an area for pre-dewatering cake piping, a floor hatch for centrifuge maintenance, and a boiler room. Additional electrical rooms or mechanical rooms could be created in the existing polymer rooms. The existing boiler room could be repurposed for the full THP boiler requirements. The layout is shown in Figure 5, and a section is shown in Figure 6.

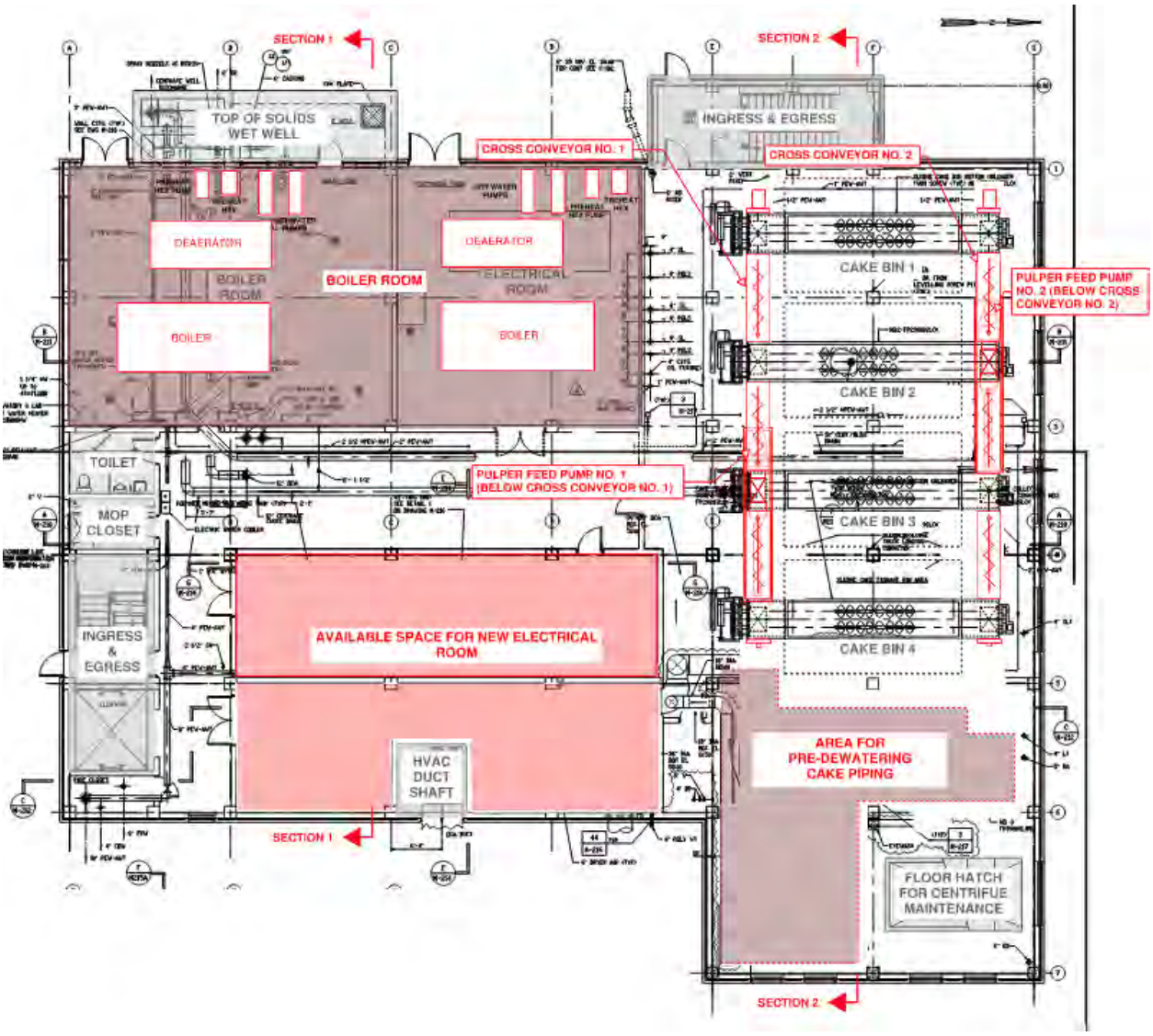

Figure 5. Existing Building Second-Floor Plan

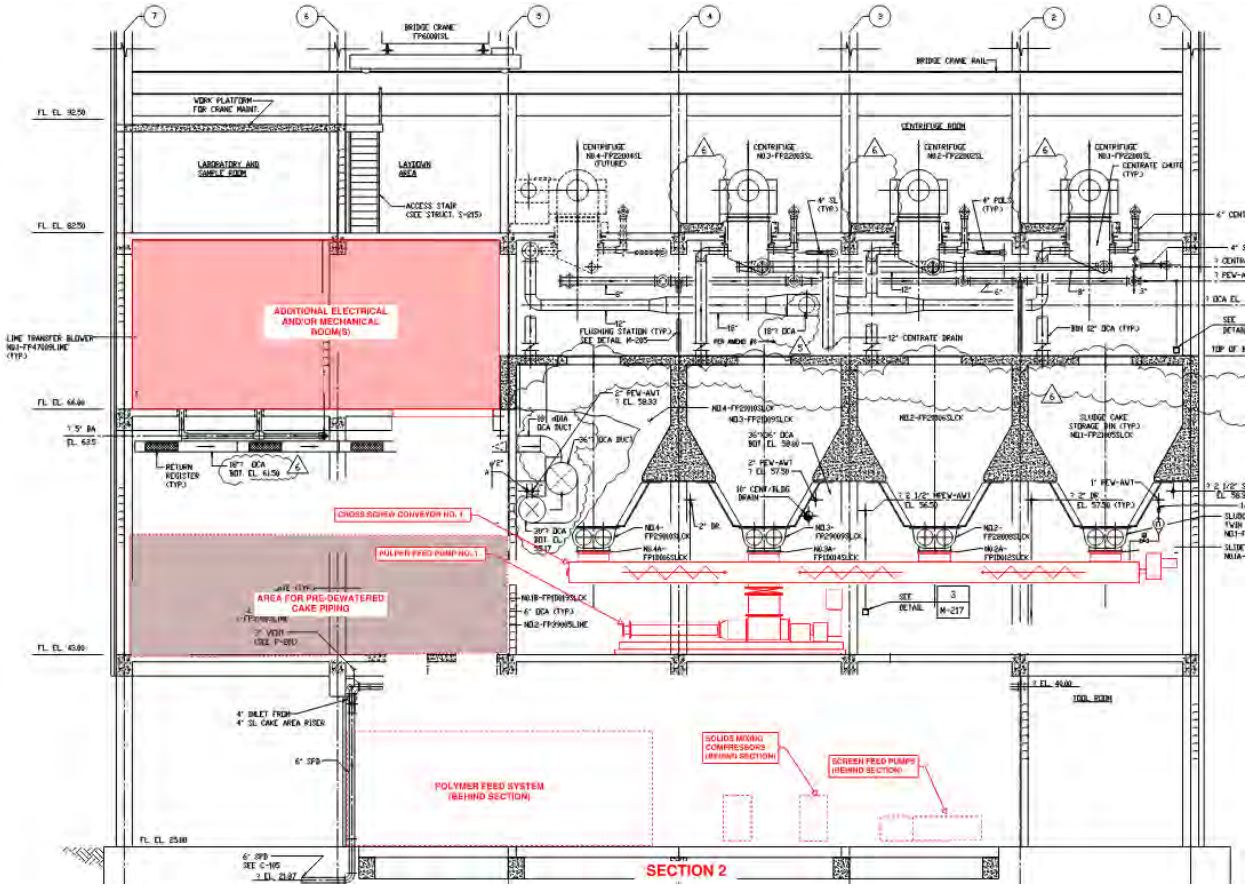

Figure 6. Existing Building Section 2

The third floor of the building would include the following equipment:

- Solids screens, with screenings conveyors to dumpster below
- Pre-dewatered cake pant-leg diverter gates and one screw conveyor

The pant-leg diverters below each centrifuge can divert cake directly to the bin below, or to a screw conveyor to deliver cake to any of the other adjacent bins. This configuration would allow for operation without using the conveyor. This floor as configured would retain the existing storage room. Demolition of the existing lime feed equipment would make additional space available for a mechanical or storage room. The third-floor layout is shown in Figure 7.

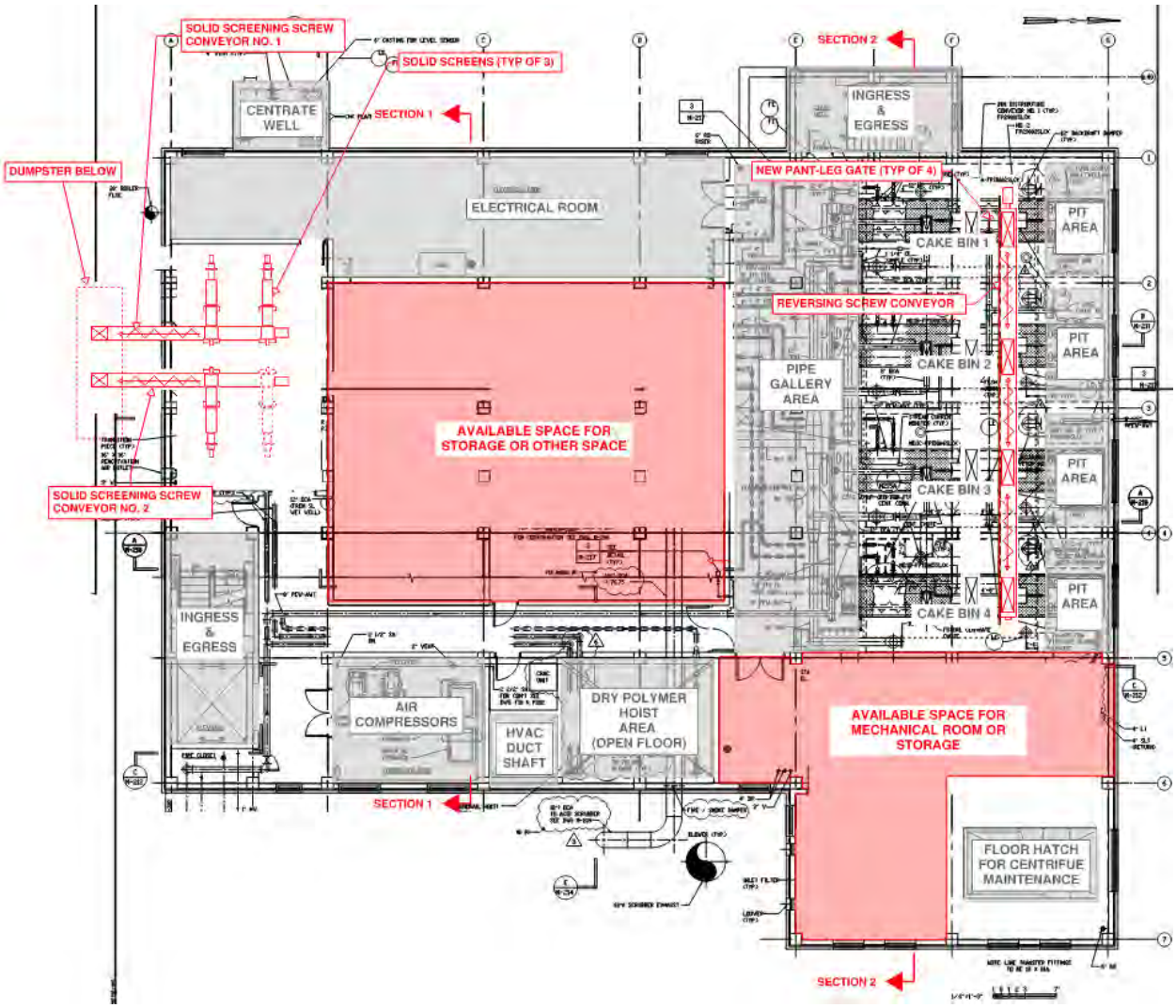

Figure 7. Existing Building Third-Floor Plan

The fourth floor of the building would include the following equipment:

- Pre-dewatering centrifuges
- Centrifuge control room

New pre-dewatering centrifuges would be provided. This floor also would retain space for centrifuge laydown, a lab/sample room, bathroom, and an HVAC room. The fourth-floor layout is shown in Figure 8. The existing floor hatch would need to be further analyzed for specific centrifuges to confirm that it can continue to be used.

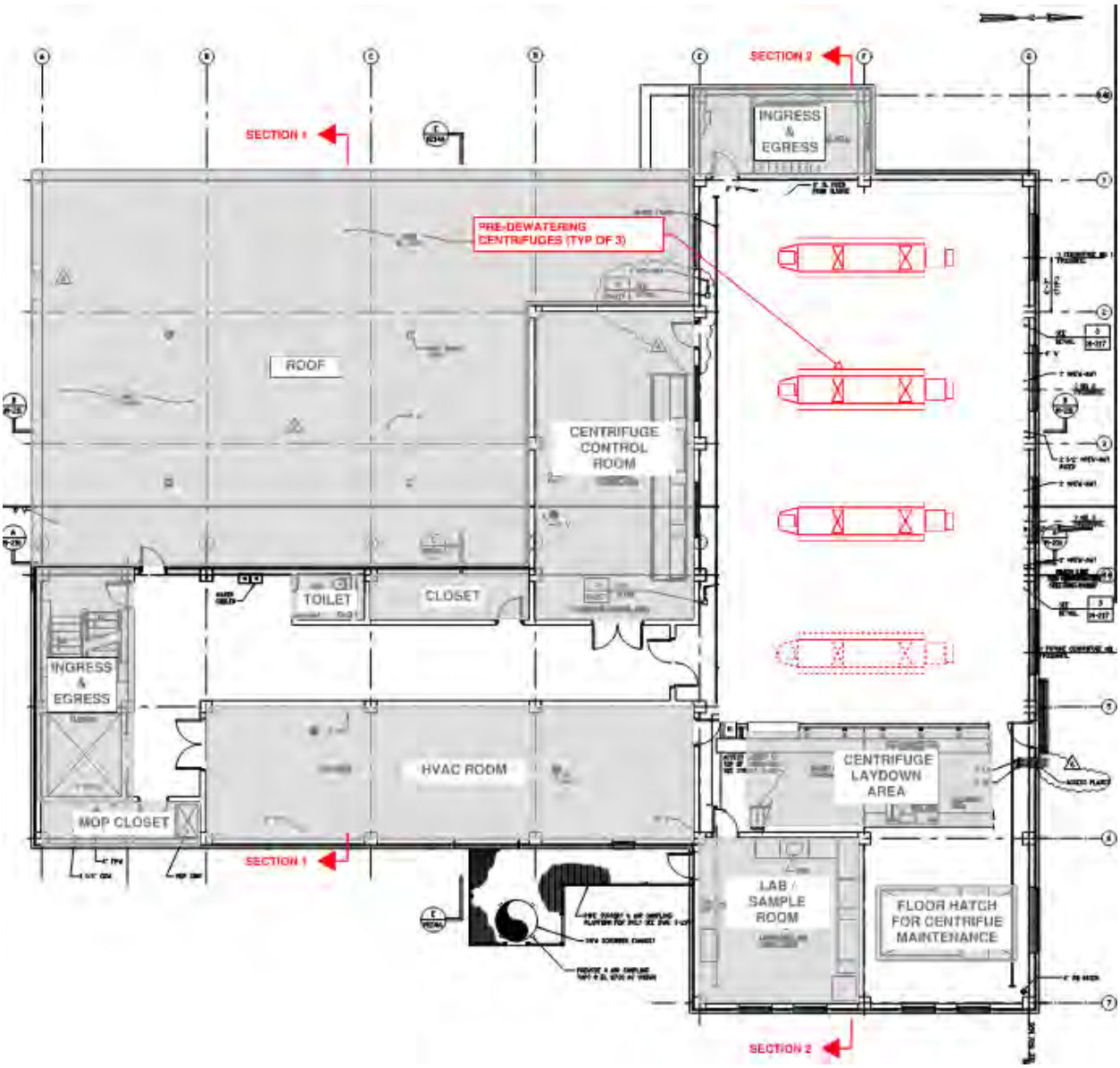

Figure 8. Existing Building Fourth-Floor Plan

5.1.4 Site Layout and Maintenance of Plant Operation Considerations

A potential site layout is shown in Figure 9 below.

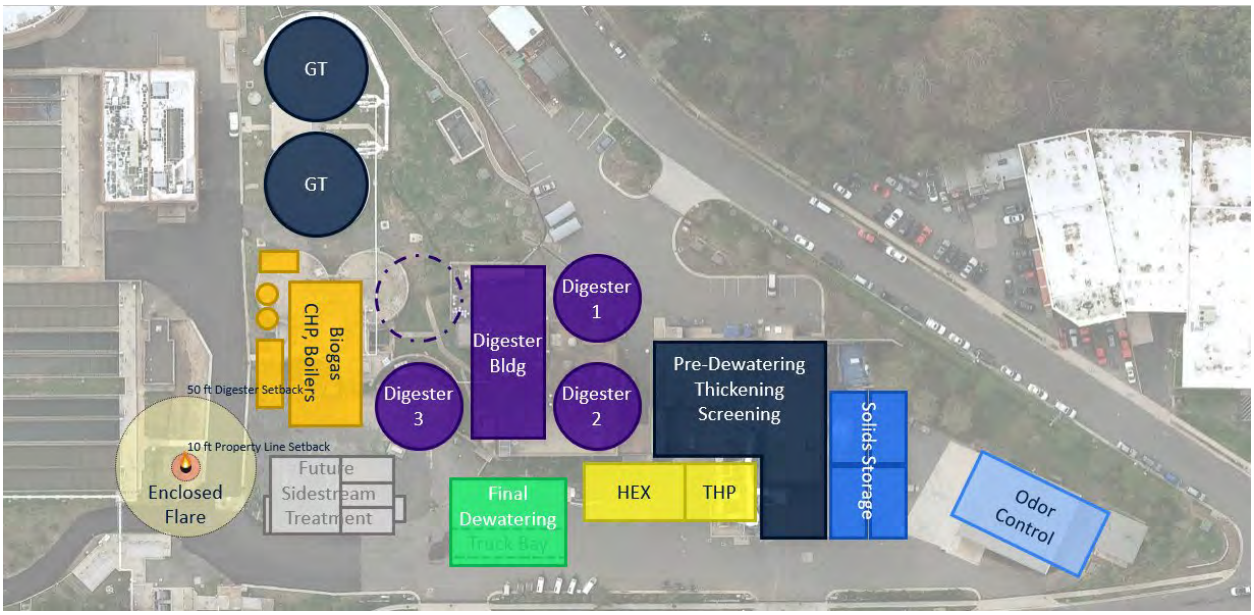

Figure 9. Preliminary Site Layout, Alternative 1: Renovate Existing DWB

This site layout is preliminary and will continue to be refined as unit processes are evaluated.

Key construction and maintenance of plant operation (MOPO) considerations for this alternative include:

- The new final dewatering facility coupled with a temporary lime stabilization facility would be constructed first and used for Class B bulk land application while the existing DWB is rehabilitated. To provide appropriate dewatering redundancy during temporary operations, additional trailer-mounted mobile dewatering equipment may be required as only two centrifuges would be installed for final dewatering. If the final dewatering facility is used during construction on raw solids, it would need to be cleaned and disinfected prior to use with Class A solids.
- Significant construction of the digester complex can occur prior to taking the existing DWB offline, reducing the time needed for temporary lime stabilization. It is assumed that temporary lime stabilization would be required for 18 months.
- A detailed code analysis of the existing building would be required to confirm that all applicable building and National Fire Protection Association (NFPA) codes could be met.
- THP would be screened from the neighbors located north and west of the WPCP by the height of the existing DWB.
- Odor control dispersion is likely to be negatively impacted by the height of the existing DWB. Tall stacks may be required to allow for proper dispersion.

5.1.5 Building Advantages and Disadvantages

The advantages and disadvantages for Alternative 1 are listed in Table 4.

Table 4. Alternative 1 Advantages/Disadvantages

Advantages	Disadvantages
• Reuse of existing infrastructure, which has significant useful design life remaining • Shorter period for temporary lime system during construction as more construction elements can proceed before or during DWB rehabilitation • Existing DWB would screen THP facilities from neighbors • Additional space in existing DWB could potentially be used for THP boilers, reducing footprint of biogas handling systems • Space for thickening units on first floor facilitates future installation	• Cost and design uncertainty due to modifying existing facility • Building is compartmentalized, which would require many modifications to the structure for both final use and constructibility • Potential code compliance issues • Significant unused space in building with the space not being optimized for current needs • Additional HVAC because of the larger footprint • Dewatering capacity limitations during temporary operations when final dewatering facilities are used on undigested solids • Cleaning and disinfection of final dewatering facilities prior to transitioning to Class A dewatering

5.1.6 Conceptual Construction Costs

Conceptual construction costs are presented in Table 5. Because the existing DWB is renovated, minimal costs were applied to concrete, sitework, and building materials categories. Demolition costs apply for demolition of interior rooms for repurposing for new spaces, as well as disposal costs for construction debris. Rehabilitation and HVAC costs were estimated based on total building square footage. Equipment costs for a new bridge crane and elevator were applied in the building/structural category, and new screening, pre-dewatering, and polymer systems were applied in the mechanical category. Costs for screen feed pumps, solids storage mixing systems, and boilers are not included to keep the comparison to subsequent alternatives with like equipment.

For Alternative 1, percentages of the base total cost were not used to develop the following discipline costs. Instead, the costs were developed as follows:

- **Sitework:** minimal with new structure, assumed to be 50 percent of the sitework cost for the new building alternative
- **Instrumentation and controls (I&C)/supervisory control and data acquisition (SCADA):** assumed to be equal to the I&C/SCADA cost for the new facility alternative
- **Electrical:** assumed to be 25 percent higher than the electrical cost for Alternative 2, as the new electrical facilities would need to fit in existing spaces with longer conduit runs
- **Large and specialty piping:** assumed to be equal to the large and specialty piping for the new facility alternative
- **Geotechnical:** not required as the existing DWB is already supported on piles

Temporary lime stabilization costs were applied for 18 months, the anticipated duration that the existing dewatering system is offline while the new space is being constructed. The construction contingency is higher for Alternative 1 in comparison to Alternatives 2 and 3, mainly to capture unknowns with a rehabilitation of this scale.

Table 5. Renovate Existing Dewatering Building Conceptual Cost Estimate

Demolition		$850,000
Building/structural		$1,970,000
Mechanical		$7,530,000
Subtotal		**$10,350,000**
Sitework		$1,180,000
I&C/SCADA		$1,260,000
Electrical		$3,930,000
Large and specialty piping		$790,000
Geotechnical		--
Temporary lime feed		$1,060,000
Subtotal		**$18,570,000**
Contingency	30%	$5,580,000
Subtotal		**$24,150,000**
Contractor mobilization, staging, and security	5%	$1,210,000
Contractor bonds and insurance	3%	$730,000
Subtotal		**$26,090,000**
Contractor overhead and profit	15%	$3,920,000
Total		**$30,010,000**

5.2 Alternative 2: Demolish Existing DWB, New Thickening, Screening, Dewatering Facility

In Alternative 2, a new facility would be constructed for screening, pre-dewatering, and future thickening. This alternative must be paired with the new final dewatering facility (Section 5.3).

5.2.1 Facility Features

New process equipment and electrical equipment would include the following:

- Polymer storage and feed, shared for pre-dewatering and future WAS thickening
- Future GBTs or RDTs for WAS
- Sludge screens and screenings loadout
- Pre-dewatering centrifuge feed pumps
- Pre-dewatering centrifuges with emergency cake loadout
- Cake bins and pulper feed pumps:
  - Two bins at 175 CY each, providing 24 hours storage at 40 mgd average conditions
- Auxiliary facilities:
  - Control room
  - Electrical room
  - Unisex bathroom
  - HVAC
- Egress:
  - Two stairways
  - Elevator

5.2.2 Facility Layout

The first floor of the facility would include the following equipment:

- Polymer storage tanks and blend units for pre-dewatering, with space for additional blend units for future WAS thickening (this assumes the same polymer would be used for pre-dewatering and thickening)
- Pre-dewatering centrifuge feed pumps
- Two pre-dewatered cake bins
- Two THP pulper feed pumps
- Emergency cake loadout/centrifuge loadout area
- Screenings dumpster

One pulper feed pump would be located below each cake bin. Access would be provided around the cake bins for removal of the live-bottom screws. The first-floor layout is shown in Figure 10. Section views are included at the end of this section.

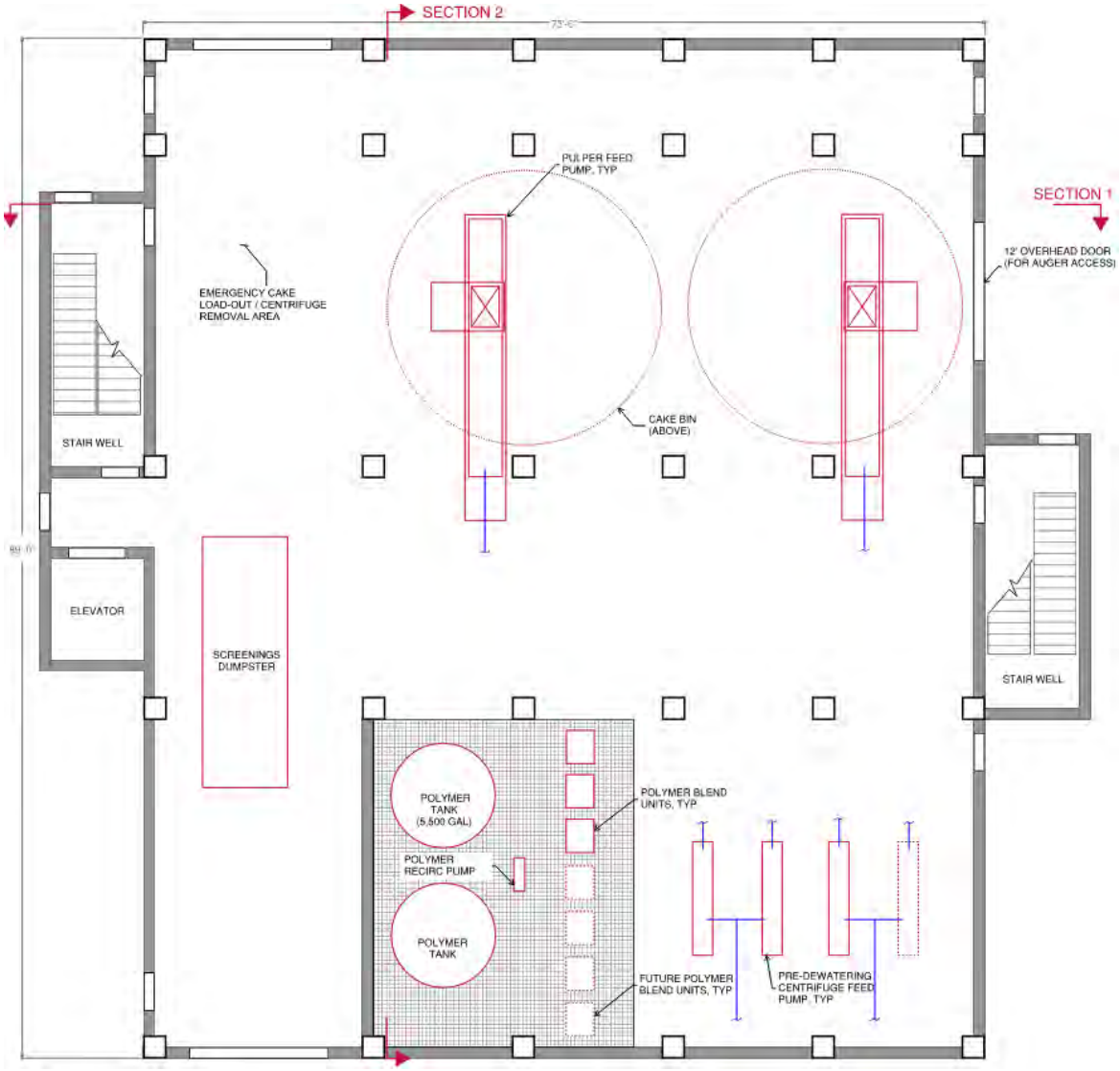

Figure 10. New Thickening/Screening/Dewatering Facility First-Floor Plan

The second floor of the facility would include the following equipment:

- Sludge screens
- Future mechanical WAS thickening (GBTs or RDTs)
- Future TWAS pumps

This floor also would include air compressors for the screens. The pre-dewatered cake bin area would be open to the first floor at this level. The layout is shown in Figure 11.

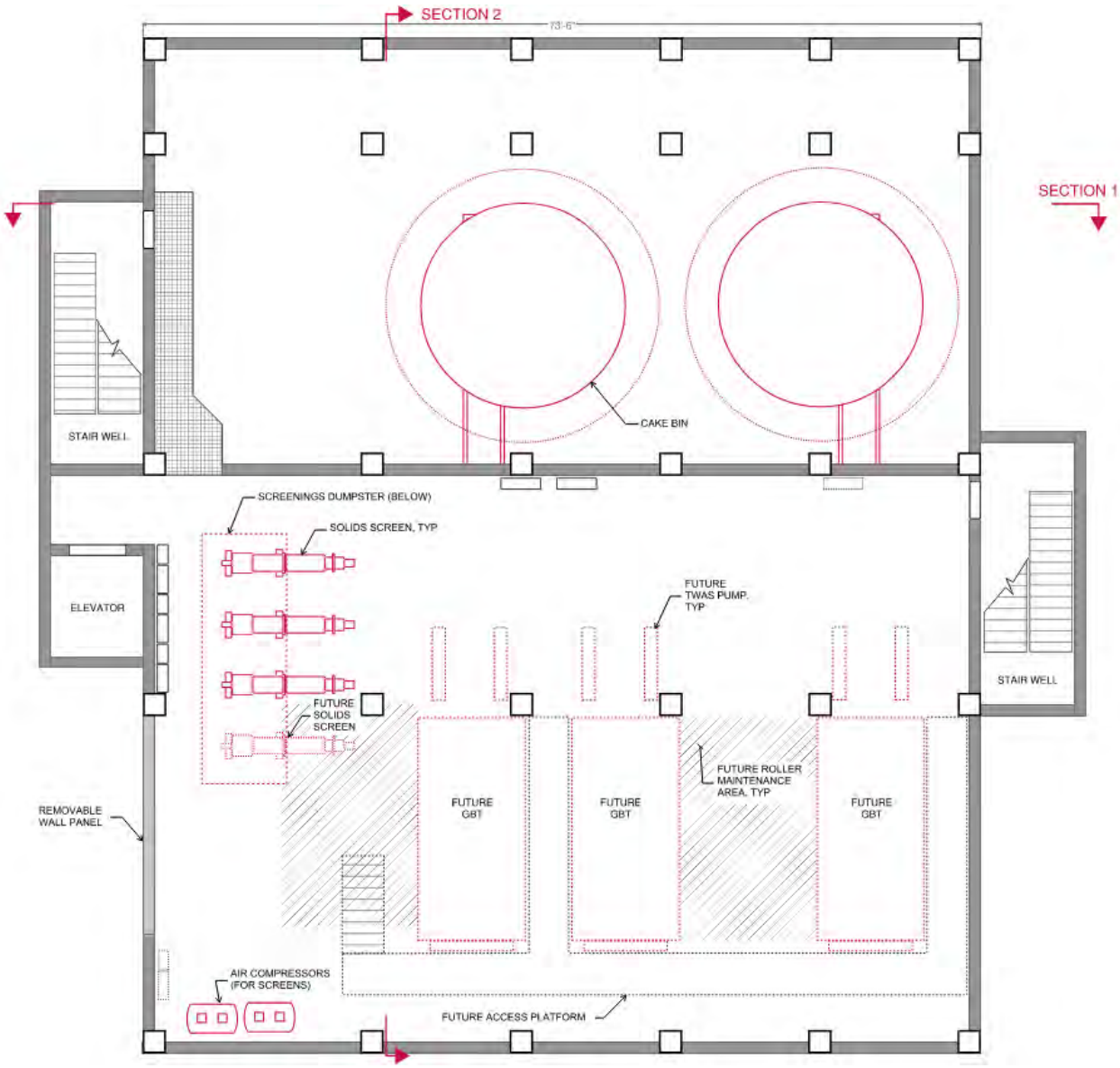

Figure 11. New Thickening/Screening/Dewatering Facility Second-Floor Plan

The mezzanine floor of the facility above the cake bins would include the following equipment:

- Pre-dewatered cake pant-leg diverter gates
- Reversing screw conveyor

The pant-leg diverter gates would direct the cake either to the bin below the centrifuge or to the screw conveyor for transfer to the adjacent bin. This level would also include piping for centrate, slop drain, and centrifuge feed. The layout is shown in Figure 12.

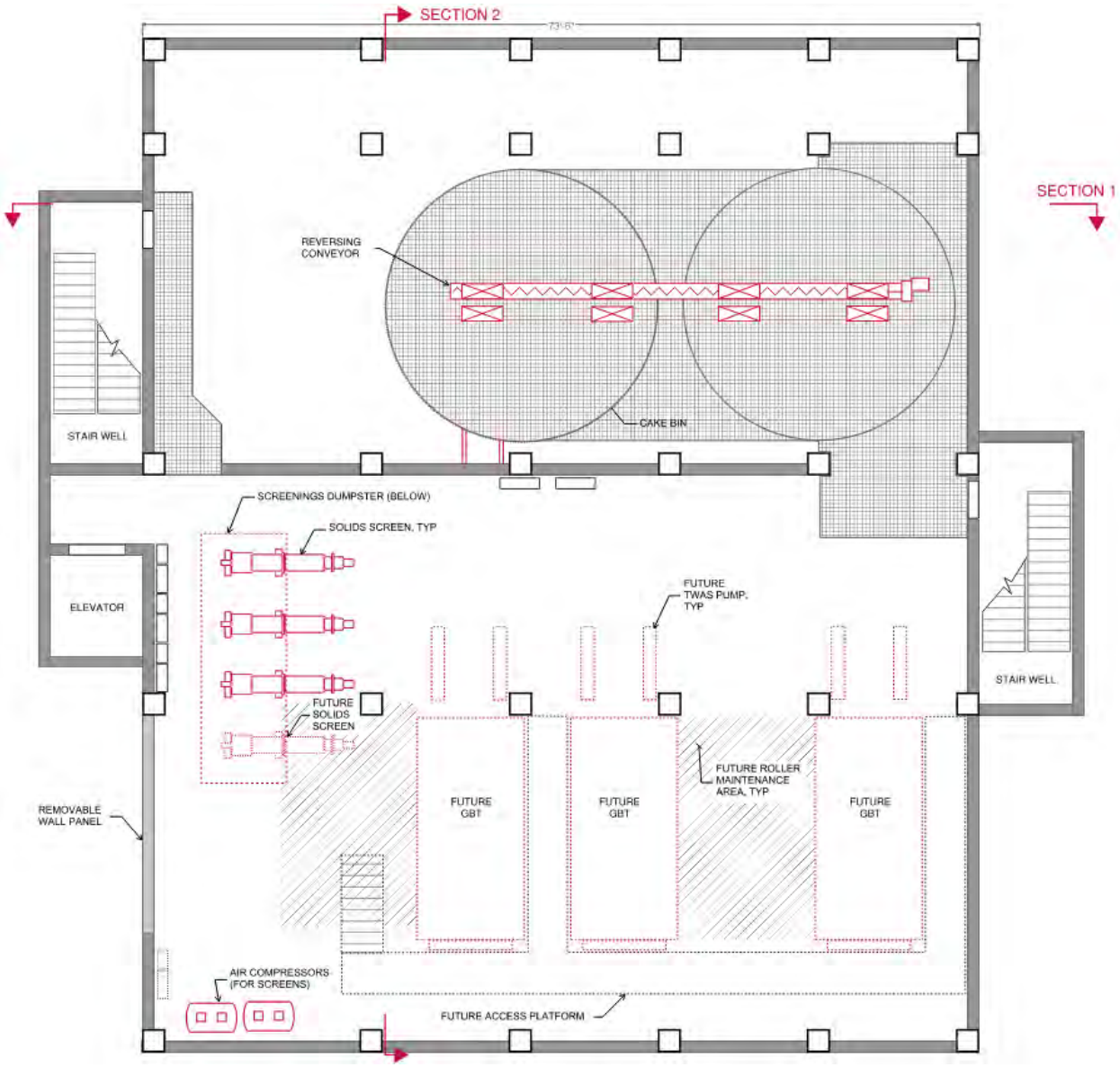

Figure 12. New Thickening/Screening/Dewatering Facility Mezzanine Floor Plan

The upper floor of the facility would include the following equipment:

- Pre-dewatering centrifuges
- Centrifuge control room
- Electrical room

This floor would include a bridge crane and an access hatch for centrifuge maintenance. A bathroom would be included as well as a small mechanical room. The HVAC equipment would be installed on the adjacent roof. This level of the facility could also be extended to enclose all HVAC equipment. The layout is shown in Figure 13. Section views for all levels are shown in Figure 14 and Figure 15.

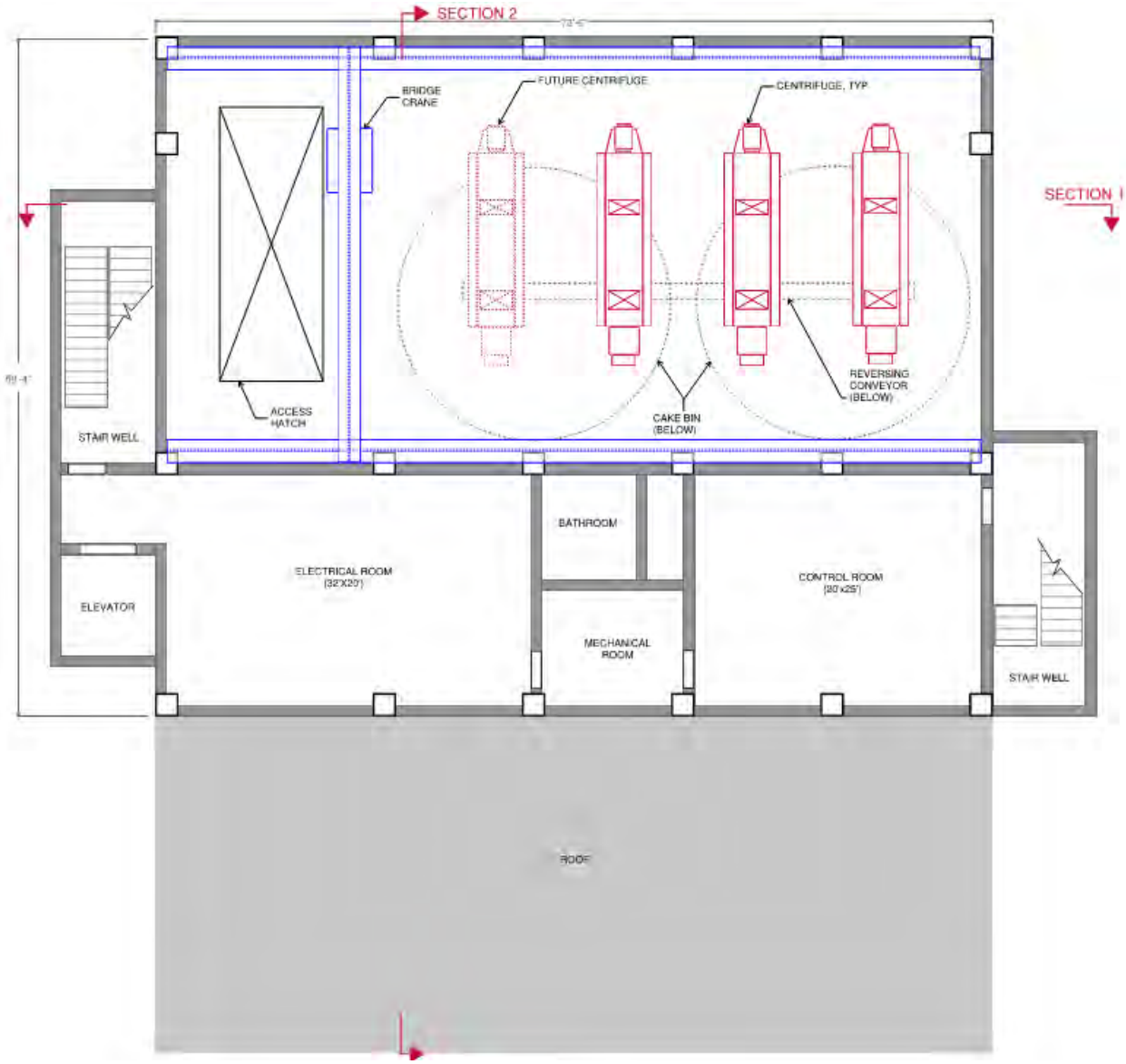

Figure 13. New Thickening/Screening/Dewatering Facility Upper Floor Plan

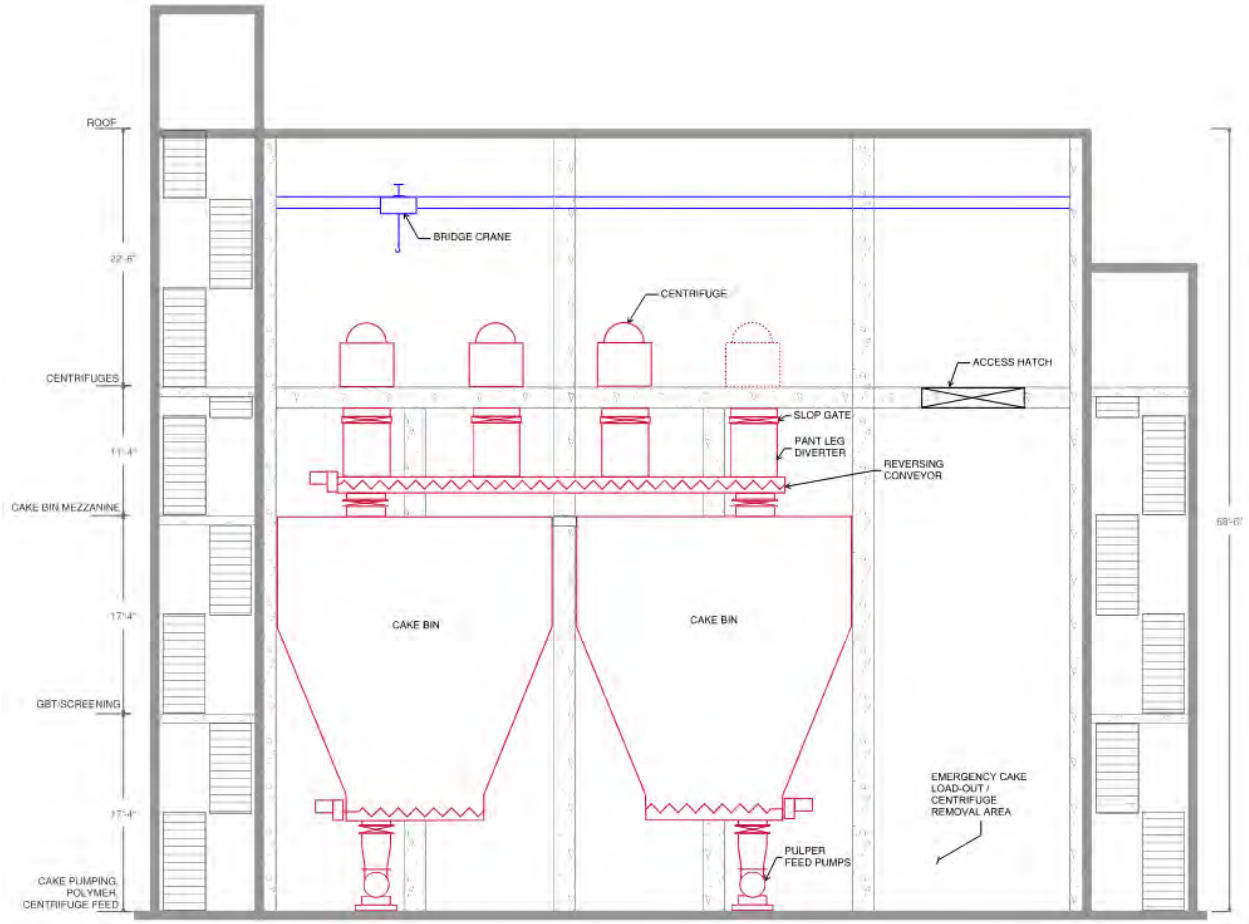

Figure 14. New Thickening/Screening/Dewatering Facility Section 1

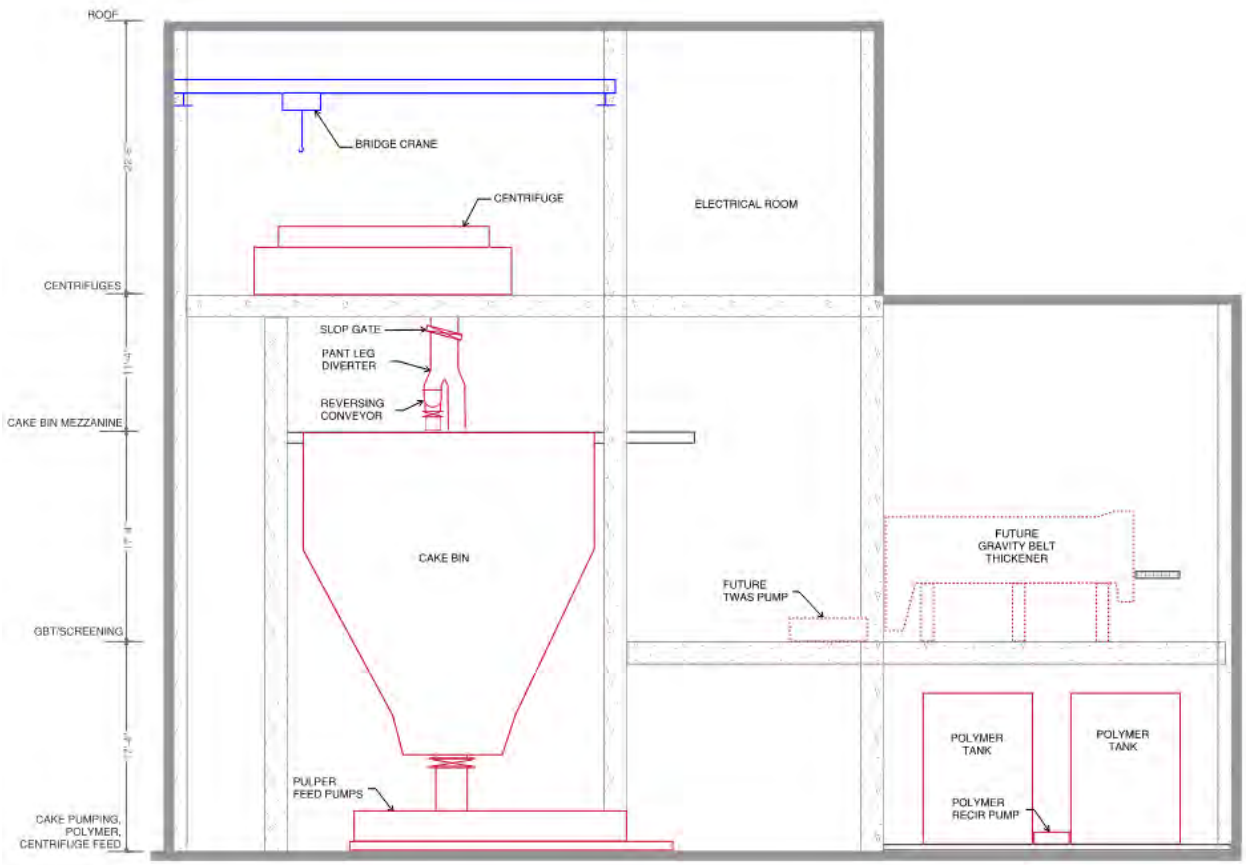

Figure 15. New Thickening/Screening/Dewatering Facility Section 2

5.2.4 Site Layout and MOPO Considerations

A potential site layout is shown in Figure 16.

Figure 16. Preliminary Site Layout, Alternative 2: New Dewatering Facility

This site layout is preliminary and will continue to be refined as unit processes are evaluated.

Key construction MOPO considerations for demolition of the existing DWB include the following:

- The new pre-dewatering facility coupled with a temporary lime stabilization facility would be constructed first and used for Class B bulk land application while the existing DWB is demolished and digesters are constructed in that area. As the new pre-dewatering facility would be sized for undigested solids, there would be no issues with dewatering redundancy during this temporary operation and no need to disinfect these facilities in the future.
- The digester complex would be constructed after the existing DWB is demolished. Digester construction is likely to have the longest schedule path and would result in potentially longer temporary lime stabilization operations compared to the option for reusing the existing DWB. It is assumed that temporary lime stabilization would be required for 35 months with Alternative 2.
- THP would be more visible to surrounding neighborhoods than with Alternative 1.
- Odor control would be centrally located away from the fence line and away from large buildings, improving dispersion.

5.2.5 Facility Advantages and Disadvantages

The advantages and disadvantages for Alternative 2 are listed in Table 6.

Table 6. Alternative 2 Advantages/Disadvantages

Advantages	Disadvantages
• All new facility • Can accommodate any type of thickening and dewatering equipment • Footprint can avoid unused space and be designed for intended uses • No dewatering capacity limitations during temporary lime stabilization • Final dewatering facilities would not be used for dewatering undigested solids, so no disinfection would be required prior to dewatering Class A biosolids	• Higher cost due to not reusing the existing DWB • Existing DWB infrastructure not reused • Likely longer period for temporary lime system during construction, as construction of digester facilities would need to await the demolition of the DWB • Would need to accommodate future installation of thickening units—may require roll-up doors or removable facility panels

5.2.6 Conceptual Construction Costs

Conceptual construction costs are presented in Table 7. Because Alternative 2 would involve construction of a new facility, sitework, concrete, and all building costs would apply. Discipline multipliers are provided as explained in Section 4.8. Demolition for this alternative would include removal of the existing DWB and all equipment. Temporary lime stabilization costs were applied for the anticipated duration from the time existing dewatering facilities are taken offline to the time the full new processes could be started (35 months).

Table 7. New Thickening, Screening, and Pre-dewatering Facility Conceptual Cost Estimate

Demolition		$2,550,000
Building/structural		$4,340,000
Mechanical		$8,780,000
Subtotal		**$15,670,000**
Sitework	15%	$2,360,000
I&C/SCADA	8%	$1,260,000
Electrical	20%	$3,140,000
Large and specialty piping	5%	$790,000
Geotechnical	7%	$1,100,000
Temporary lime		$1,400,000
Subtotal		**$25,7200,000**
Contingency	20%	$5,010,000
Subtotal		**$30,870,000**
Contractor mobilization, staging, and security	5%	$1,550,000
Contractor bonds and insurance	3%	$930,000
Subtotal		**$33,350,000**
Contractor overhead and profit	15%	$5,010,000
Total		**$38,360,000**

5.3 New Final Dewatering Facility

A new facility for final dewatering would be constructed and paired with either Alternative 1 or 2.

5.3.1 Facility Features

New process equipment and electrical equipment would include the following:

- Polymer storage and feed for final dewatering
- Final dewatering centrifuge feed pumps
- Final dewatering centrifuges
- Cake bin for final product:
  - One 200 CY bin, providing 1.5 days of storage at 30.8 mgd peak 14-day conditions
- Drive-through truck loading with viewing platform
- Auxiliary facilities:
  - Control room
  - Electrical room
  - Unisex bathroom
  - HVAC
- Egress:
  - Two stairways
  - Elevator

5.3.2 Facility Layout

The first floor of the facility would include the following equipment:

- Polymer storage tanks and blend units for final dewatering
- Drive-through truck bay with truck scale

The polymer system configuration would be similar to the pre-dewatering facility alternatives, with bulk liquid storage, recirculation pump, and a blend unit for each dewatering device. The truck bay would include a loading viewing platform and walking space around the truck. The layout is shown in Figure 17.

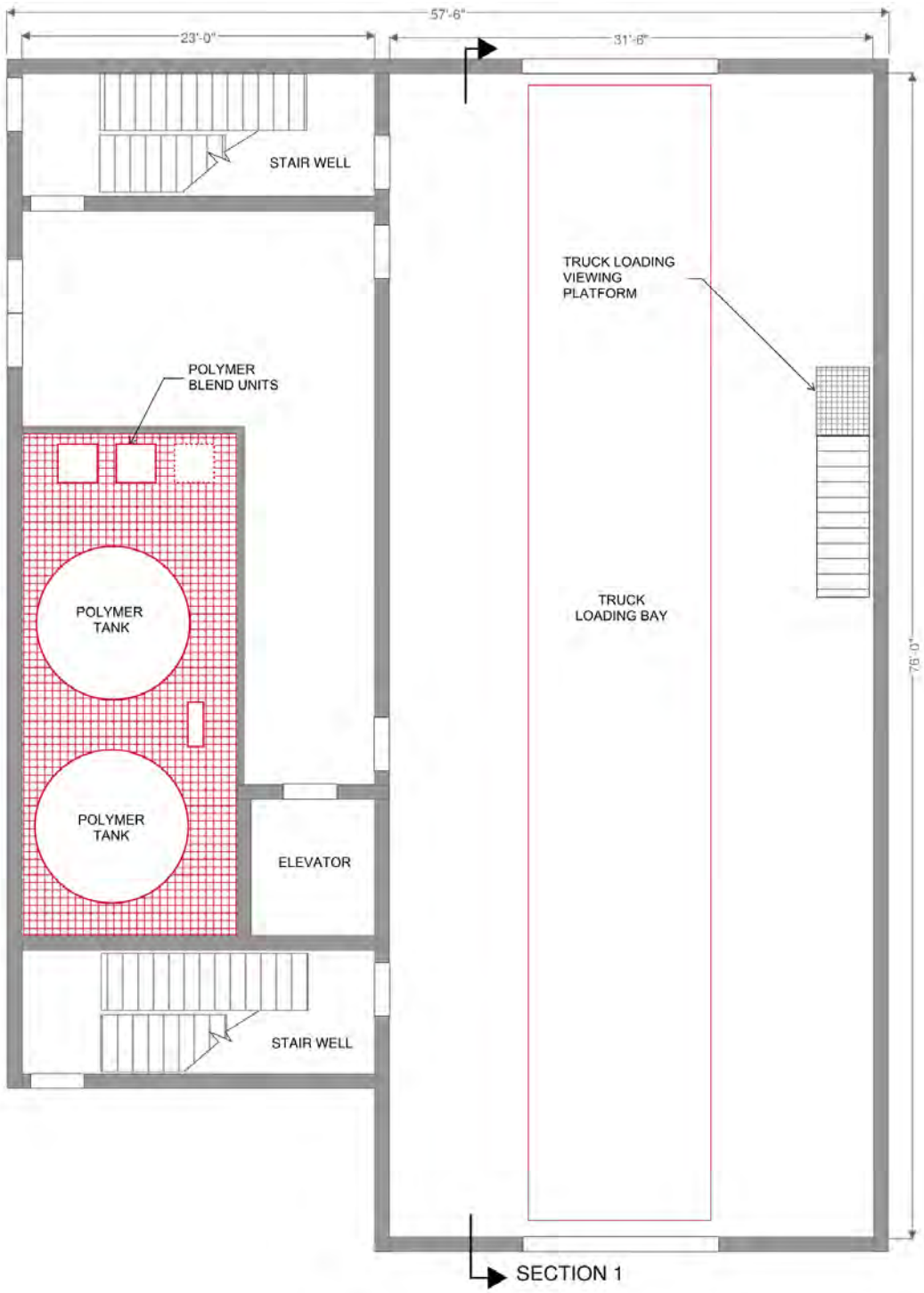

Figure 17. New Final Dewatering Facility First-Floor Plan

The mezzanine level of the facility, shown in Figure 18, would include the following equipment:

- Screw conveyor above cake bin
- Mechanical room

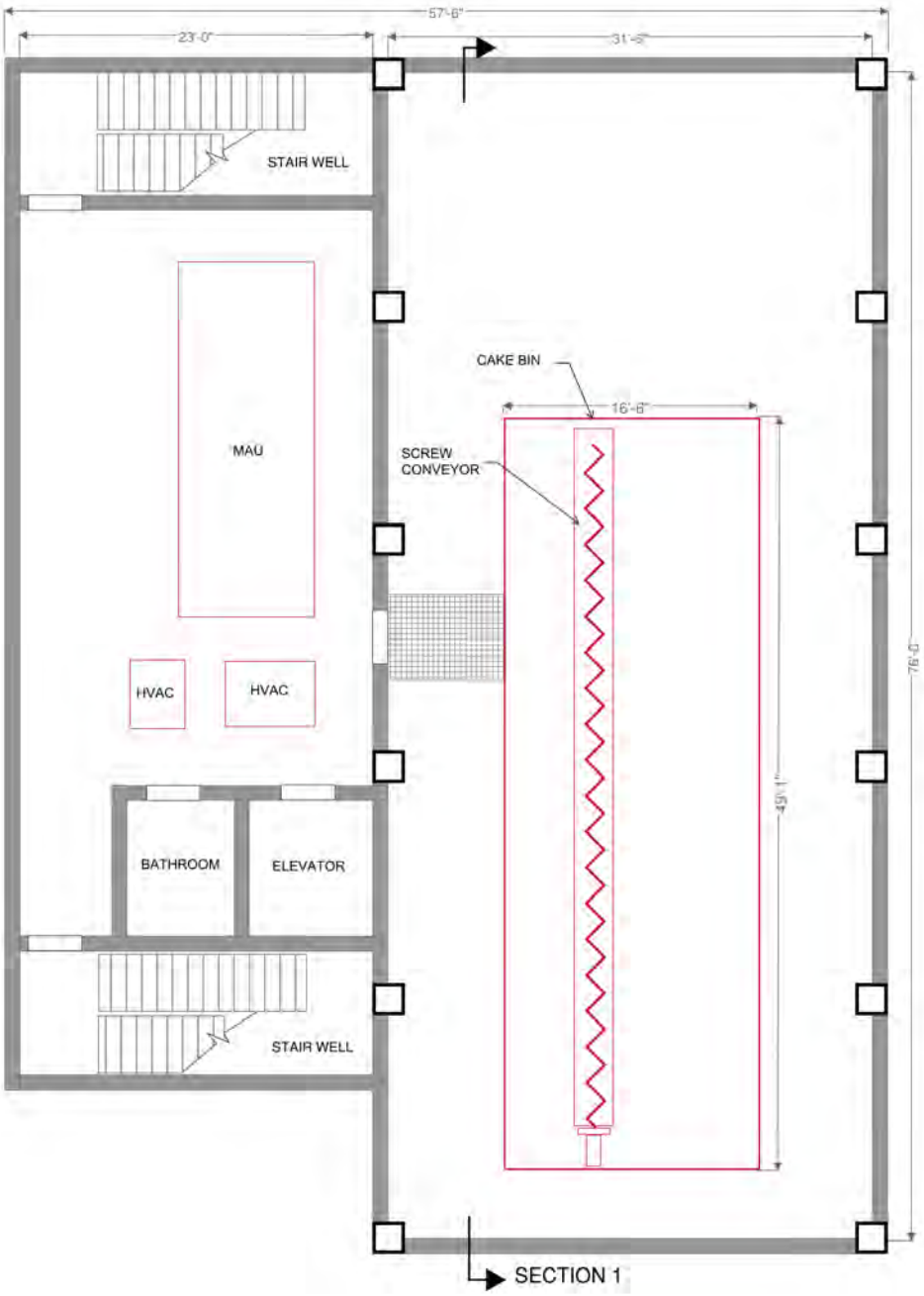

Figure 18. New Final Dewatering Facility Mezzanine Floor Plan

The upper floor of the facility would include the following equipment:

- Final dewatering centrifuges
- Control room
- Electrical room

The centrifuge room would include a laydown area, a floor access hatch, and a bridge crane for centrifuge maintenance. The layout is shown in Figure 19. A facility section is shown in Figure 20.

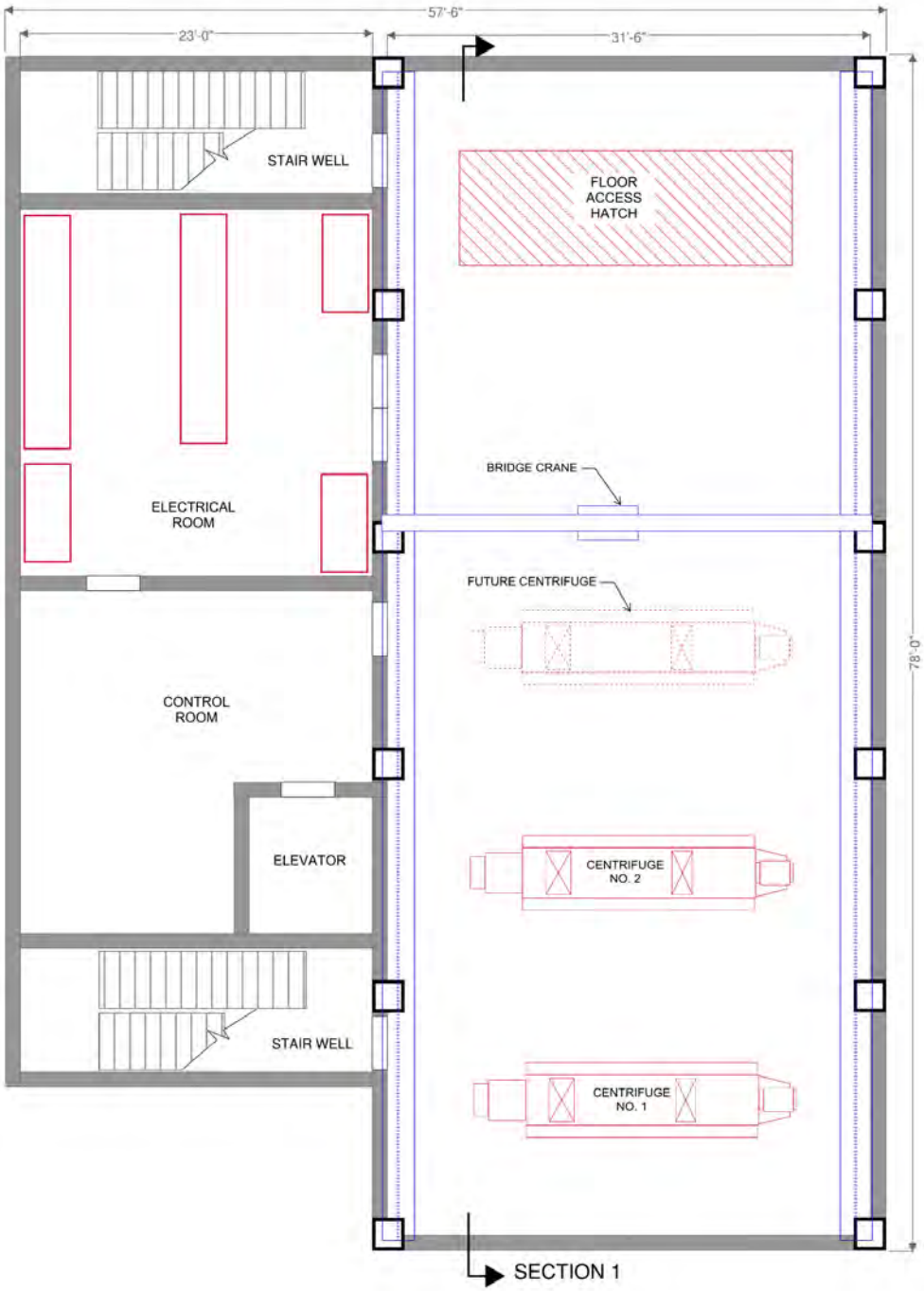

Figure 19. New Final Dewatering Facility Upper Floor Plan

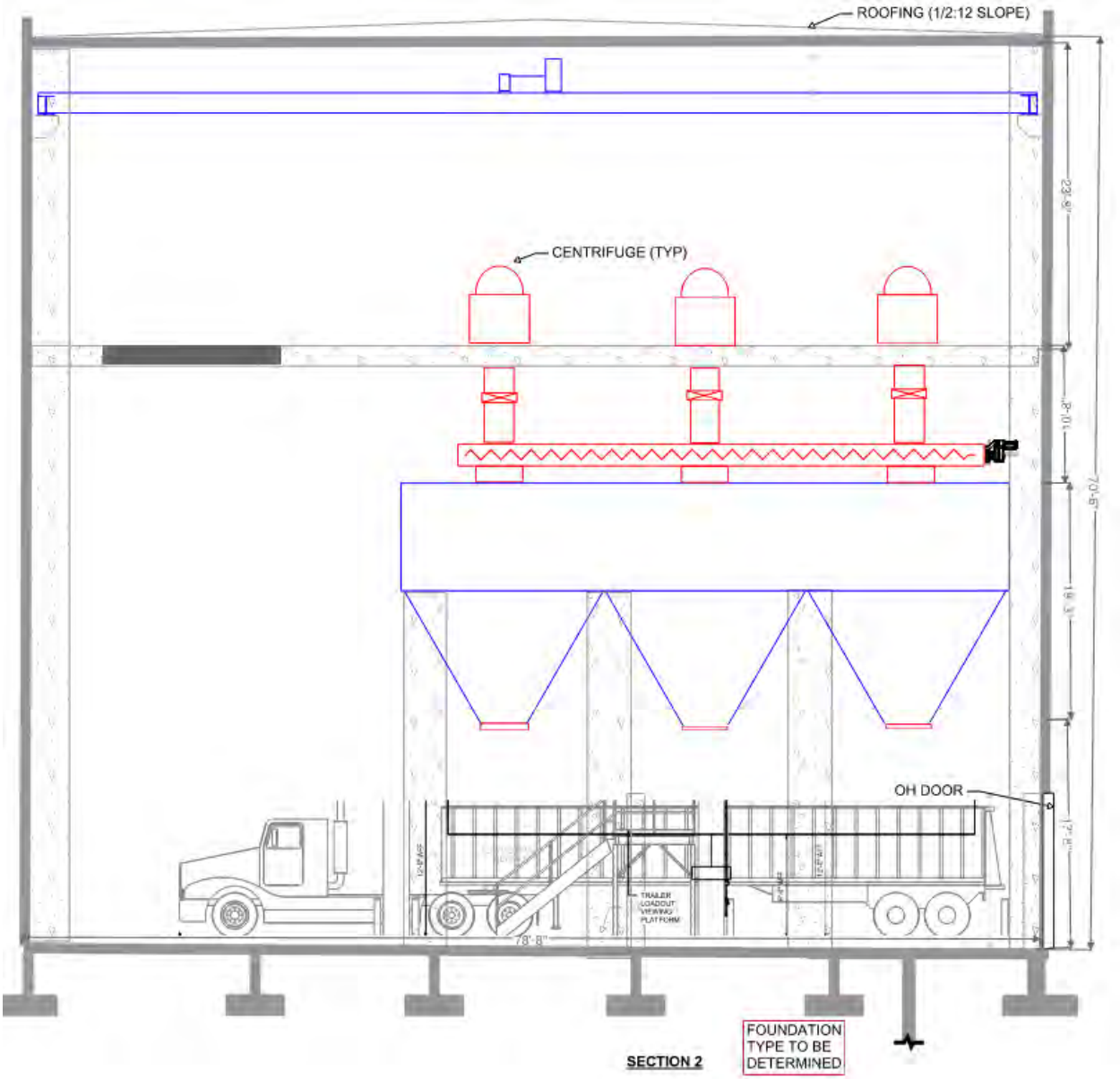

Figure 20. New Final Dewatering Facility Section

5.3.3 Site Layout

Potential site layouts including the final dewatering facility are shown on Figure 9 and Figure 16 above. In both layouts, the final dewatering facility is proposed to be located on the east side of the property, near Eads Street, to promote drive-through truck unloading.

5.3.4 Conceptual Construction Costs

Conceptual construction costs are presented in Table 8. Because this alternative would involve construction of a new facility, sitework, concrete, and all building costs would apply. Discipline multipliers are provided as explained in Section 4.8.

Table 8. New Final Dewatering Facility Conceptual Cost Estimate

Building/structural		$2,960,000
Mechanical		$4,610,000
Subtotal		**$7,570,000**
Sitework	15%	$1,140,000
I&C/SCADA	8%	$610,000
Electrical	20%	$1,520,000
Large and specialty piping	5%	$380,000
Geotechnical	7%	$530,000
Subtotal		**$11,750,000**
Contingency	20%	$2,350,000
Subtotal		**$14,100,000**
Contractor mobilization, staging, and security	5%	$710,000
Contractor bonds and insurance	3%	$430,000
Subtotal		**$15,240,000**
Contractor overhead and profit	15%	$2,290,000
Total		**$17,530,000**

5.4 Alternative 3: Decommission Existing DWB, New Combined Pre-dewatering and Final Dewatering Facility

For Alternative 3, a new building would be constructed to contain pre-dewatering, final dewatering, future thickening, as well as anaerobic digestion equipment and boilers. The existing DWB would be decommissioned but remain in place.

5.4.1 Facility Features

New process equipment and electrical equipment would include the following:

- Digester pumps in lower level (recirculation, mixing, transfer pumps, and final dewatering centrifuge feed)
- Polymer storage and feed for final dewatering and for pre-dewatering and future WAS thickening
- Future GBTs or RDTs for WAS thickening
- Sludge screen feed pumps
- Solids storage mixing compressors
- Sludge screens and screenings loadout
- Pre-dewatering centrifuge feed pumps
- Pre-dewatering centrifuges with emergency cake loadout
- Pre-dewatered cake bins and pulper feed pumps:
  - Two bins at 175 CY each, providing 24 hours storage at 40 mgd average conditions
- Final dewatering centrifuges
- Cake bin for final product:
  - One 200 CY bin, providing 1.5 days of storage at 30.8 mgd peak 14-day conditions
- Drive-through truck loading with viewing platform
- Auxiliary facilities:
  - Control room
  - Electrical room
  - Unisex bathroom
  - HVAC

- Egress:
  - Two stairways
  - Elevator

5.4.2 Facility Layout

The first floor of the facility would include the following equipment:

- Polymer storage tanks and blend units for pre-dewatering, with space for additional blend units for future thickening
- Polymer storage tanks and blend units for final dewatering
- Pre-dewatering centrifuge feed pumps
- Screen feed pumps
- Solids storage mixing compressors
- Digester mixing, recirculation, and transfer pumps
- Final dewatering centrifuge feed pumps
- Four THP pulper feed pumps, located below two pre-dewatered cake bins
- Emergency cake loadout/centrifuge loadout area
- Final dewatered cake loadout drive-through truck bay with truck scale
- Screenings dumpster
- Bathroom

This level would be at elevation 24 feet, which would be at grade and have a walkout and truck loading area on the east side. Digester pumps would be on the west side of the building, which is below grade in that area. The first-floor layout is shown in Figure 21. A section view is included at the end of this section.

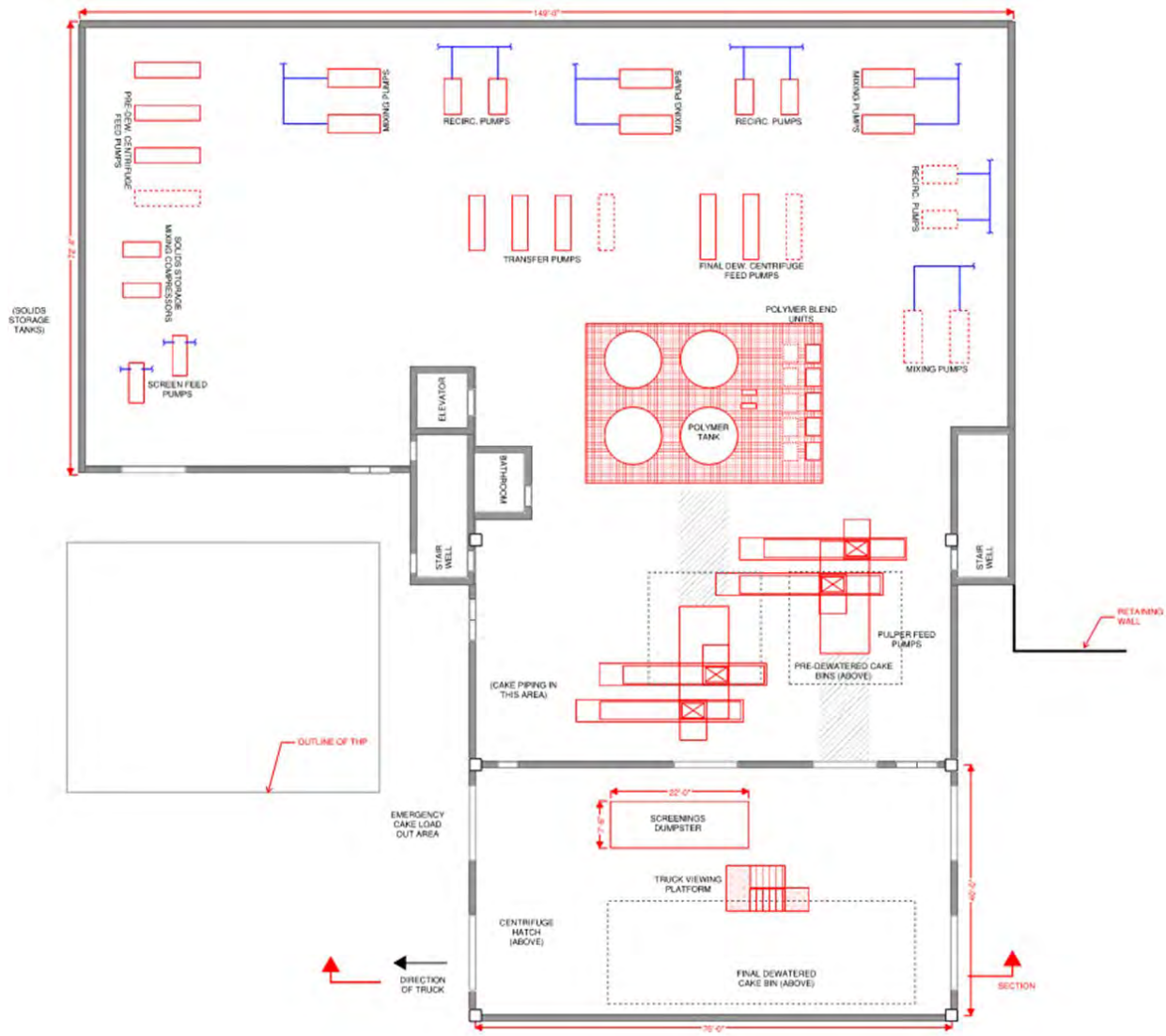

Figure 21. New Thickening/Screening/Pre-dewatering and Final Dewatering Facility First-Floor Plan

The second floor of the facility would include the following equipment:

- Sludge screens and air compressors
- Future mechanical WAS thickening (GBTs or RDTs)
- Future TWAS pumps
- Boiler room and boiler chemical feed
- Heat exchangers outside on roof of level below

This level would be at elevation 42 feet, which is at grade on the west side of the building. The layout is shown in Figure 22.

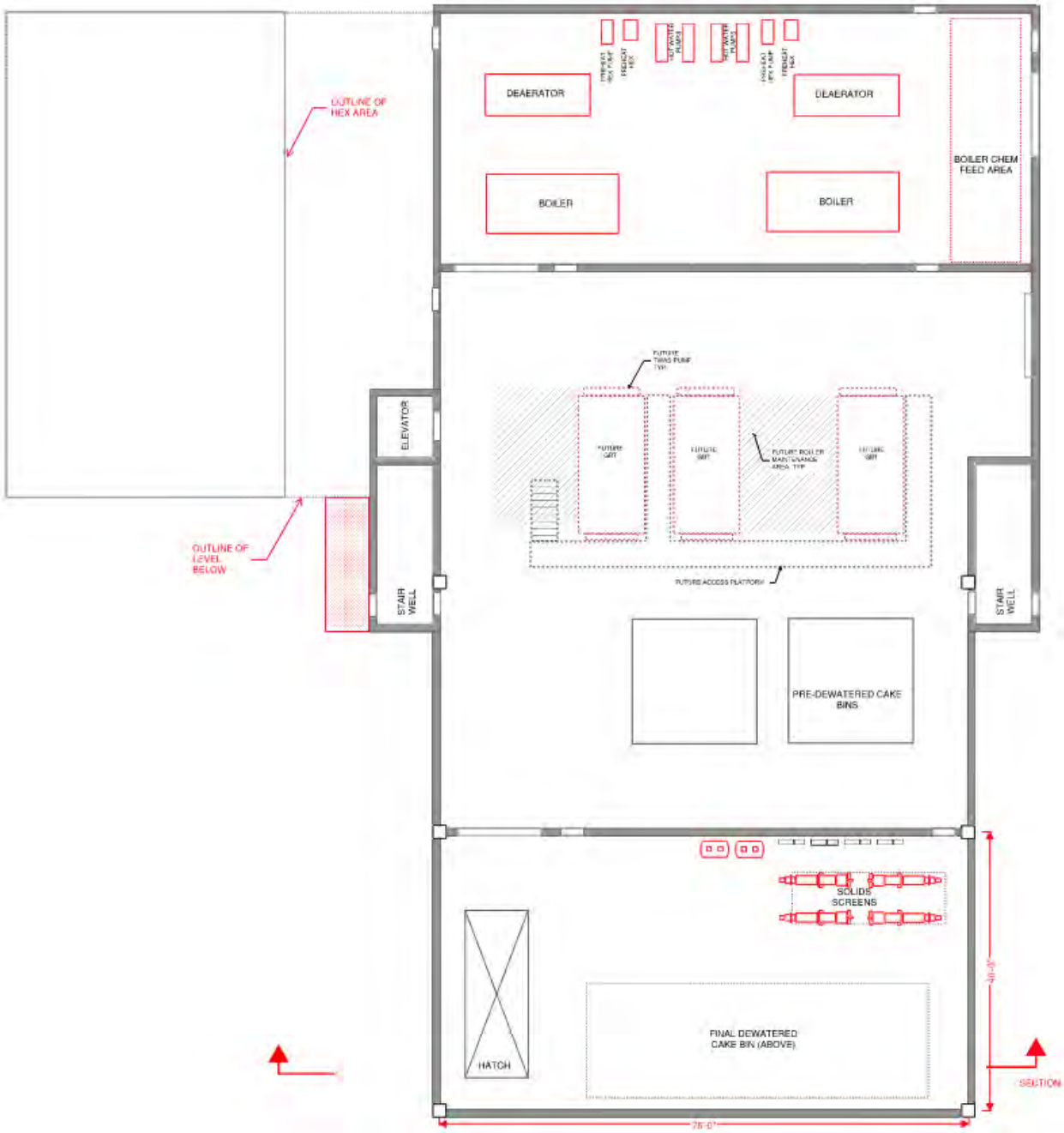

Figure 22. New Thickening/Screening/Pre-dewatering and Final Dewatering Facility Second-Floor Plan

The third floor of the facility would include the area above the cake bins and would include the following equipment:

- Cake pant-leg diverter gates and reversing screw conveyor above each cake bin
- Electrical room
- Mechanical room

The pant-leg diverter gates would direct the cake either to the bin below the centrifuge or to the screw conveyor for transfer to the adjacent bin. This level would also include piping for centrate, slop drain, and centrifuge feed. The layout is shown in Figure 23.

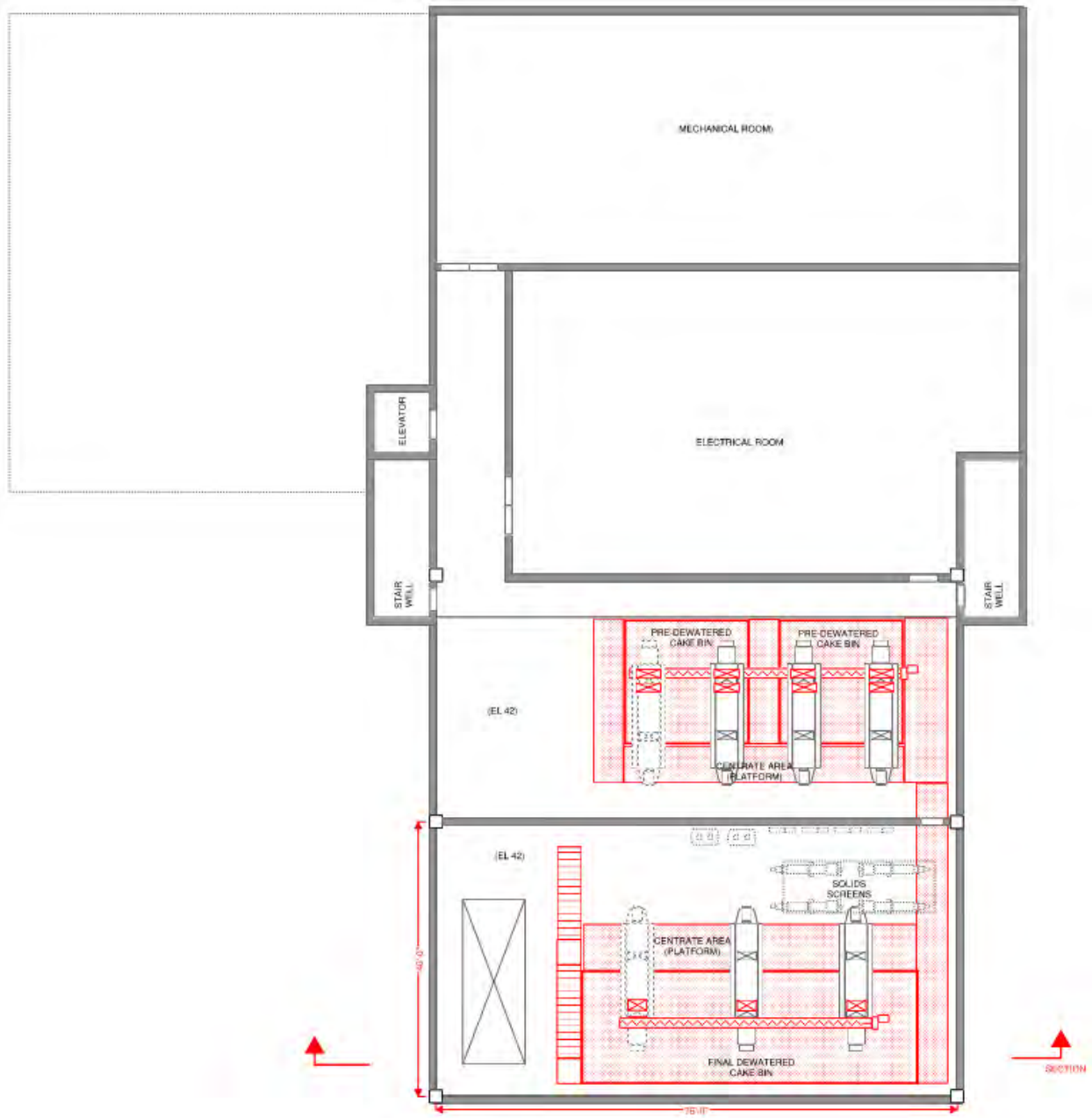

Figure 23. New Thickening/Screening/Pre-dewatering and Final Dewatering Facility Third-Floor Plan

The upper floor of the facility would include the following equipment:

- Pre-dewatering and final dewatering centrifuges
- Centrifuge control room
- Lab space
- Break room

- Bathroom

This floor would include two bridge cranes (one per set of centrifuges) and a shared access hatch for centrifuge maintenance. The layout is shown in Figure 24. A section view is shown in Figure 25.

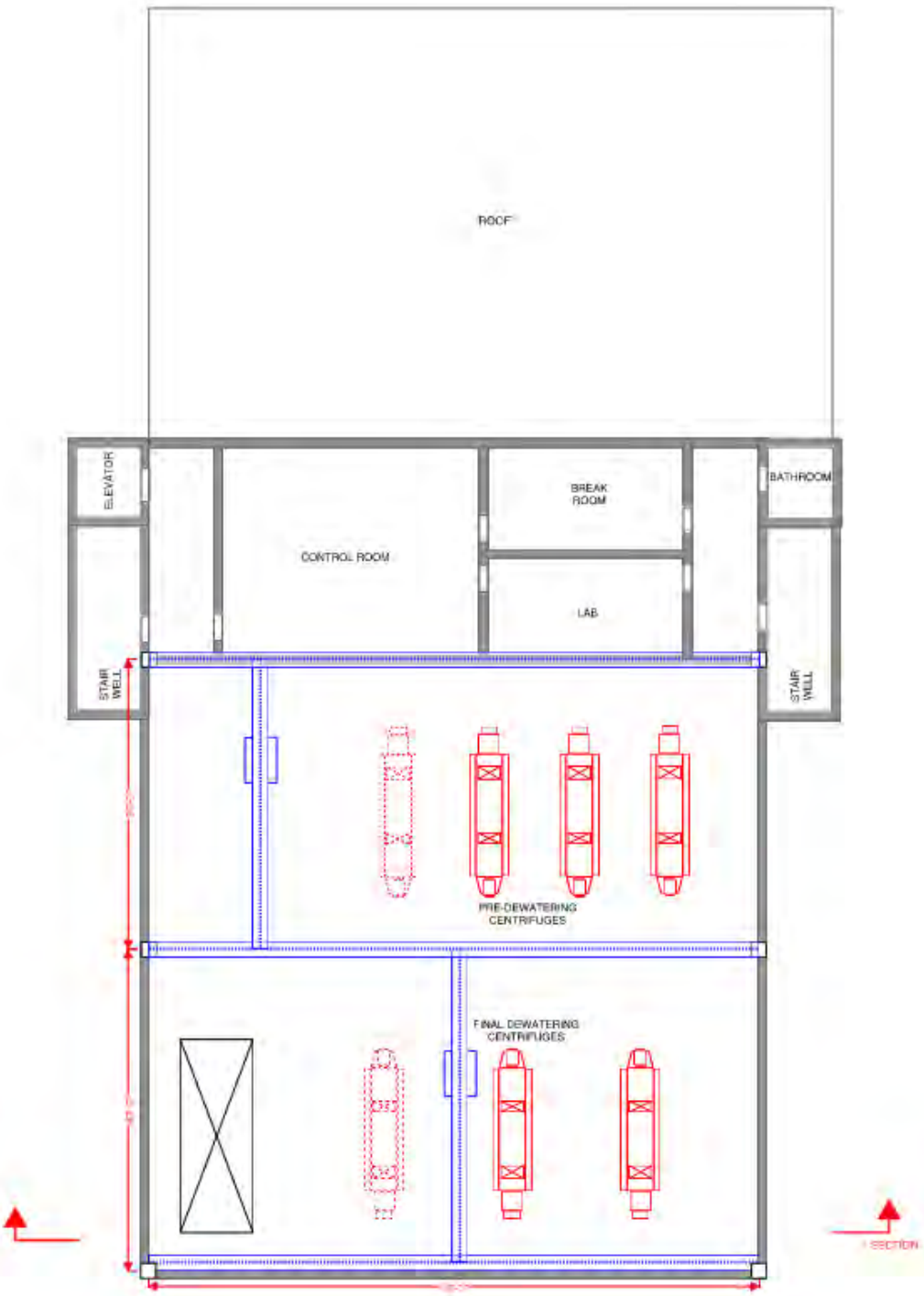

Figure 24. New Thickening/Screening/Pre-dewatering and Final Dewatering Facility Upper Floor Plan

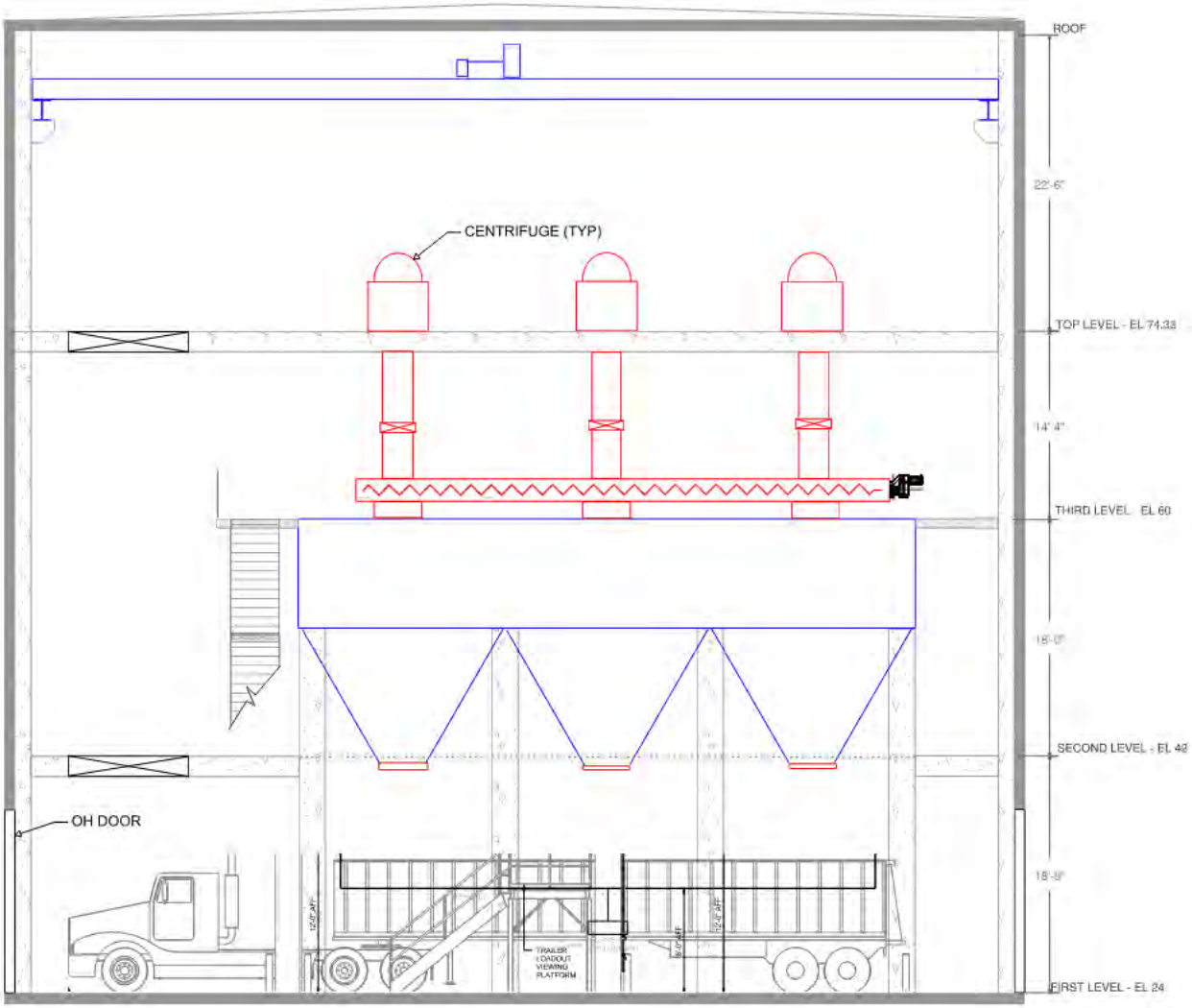

Figure 25. New Thickening/Screening/Pre-dewatering and Final Dewatering Facility Section 1

5.4.4 Site Layout and MOPO Considerations

A potential site layout is shown in Figure 26.

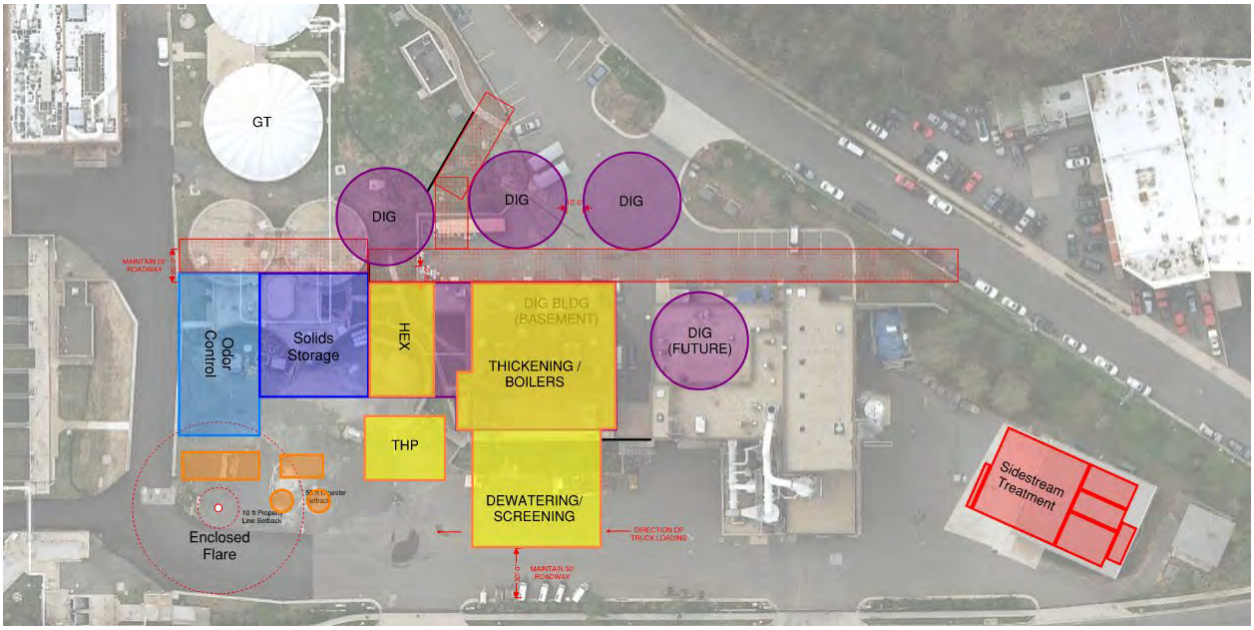

Figure 26. Preliminary Site Layout, Alternative 3: New Pre-dewatering and Final Dewatering Facility

This site layout is preliminary and will continue to be refined as unit processes are evaluated. As the existing DWB is not being reused and construction activities avoid the area of the existing DWB, no temporary lime stabilization is required, thereby minimizing MOPO risks. Coordination will be key, however, in maintaining operations with all of the construction activities occurring between the main treatment processes and the existing DWB.

5.4.5 Facility Advantages and Disadvantages

The advantages and disadvantages for Alternative 3 are listed in Table 9.

Table 9. Alternative 3 Advantages/Disadvantages

Advantages	Disadvantages
• All new facility • Can accommodate any type of thickening and dewatering equipment • Footprint can avoid unused space and be designed for intended uses • Flexibility in quantity of pre-dewatered cake storage volume and conveyance configuration • No temporary dewatering or lime stabilization facilities required	• Higher cost due to not reusing existing DWB • Existing DWB infrastructure not reused • Need to accommodate future installation of thickening units—may require roll-up doors or removable facility panels

5.4.6 Conceptual Construction Costs

Conceptual construction costs are presented in Table 10. Because Alternative 3 would involve construction of a new facility, sitework, concrete, and all building costs would apply. Discipline multipliers are provided as explained in Section 4.8. Building costs were included only for the future thickening, pre-dewatering, and final dewatering areas of the building to make it comparable to other

alternatives evaluated in this TM. Building and equipment costs for the digester facilities are not included. No DWB demolition or temporary lime stabilization is required for this alternative.

Table 10. New Thickening, Screening, Pre-dewatering, and Final Dewatering Facility Conceptual Cost Estimate

Demolition		--
Building/structural		$8,780,000
Mechanical		$13,380,000
Subtotal		**$22,160,000**
Sitework	15%	$3,330,000
I&C/SCADA	8%	$1,780,000
Electrical	20%	$4,440,000
Large and specialty piping	5%	$1,110,000
Geotechnical	7%	$1,560,000
Temporary lime		--
Subtotal		**$34,380,000**
Contingency	20%	$6,880,000
Subtotal		**$41,260,000**
Contractor mobilization, staging, and security	5%	$2,070,000
Contractor bonds and insurance	3%	$1,240,000
Subtotal		**$44,570,000**
Contractor overhead and profit	15%	$6,690,000
Total		**$51,260,000**

6.0 Schedule and Overall Cost Comparison

Given the constraints on sequencing of work, each of the alternatives identified above will have a different overall construction schedule. This in turn impacts overall project costs through extended general conditions. A preliminary schedule analysis was completed for each alternative.

6.1 Alternative 1: Renovate the Existing Dewatering Building

A preliminary critical-path schedule for Alternative 1 is provided in Figure 27 below. The total duration (for comparison purposes) is 64 months. The critical path would be through construction of the final dewatering and temporary lime stabilization facilities, followed by the interior DWB demolition and reconstruction. Digesters, gas upgrading, and odor control would not be on the critical path. It is assumed that the new final dewatering facilities would be paired with a temporary lime stabilization facility for 18 months (16 months for DWB demolition and reconstruction plus 2 months for startup and shutdown).

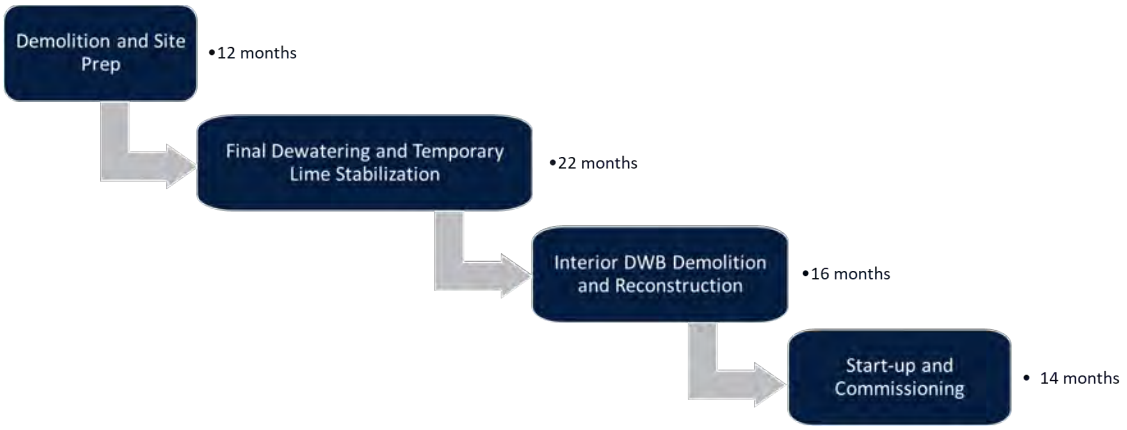

Figure 27. Critical-Path Schedule for Alternative 1: Renovate the Existing DWB

6.2 Alternative 2: Demolish the Existing Dewatering Building

A preliminary critical-path schedule for Alternative 2 is provided in Figure 28 below. The total duration (for comparison purposes) is 83 months. The critical path would be through construction of the pre-dewatering and temporary lime stabilization facilities, followed by the DWB demolition and construction of the new digester complex. Final dewatering, gas upgrading, and odor control would not be on the critical path. It is assumed that the new pre-dewatering facilities would be paired with a temporary lime stabilization facility for 35 months (33 months for DWB demolition and reconstruction plus 2 months for startup and shutdown). The overall schedule would be significantly longer because of the time required for the existing DWB demolition and digester construction.

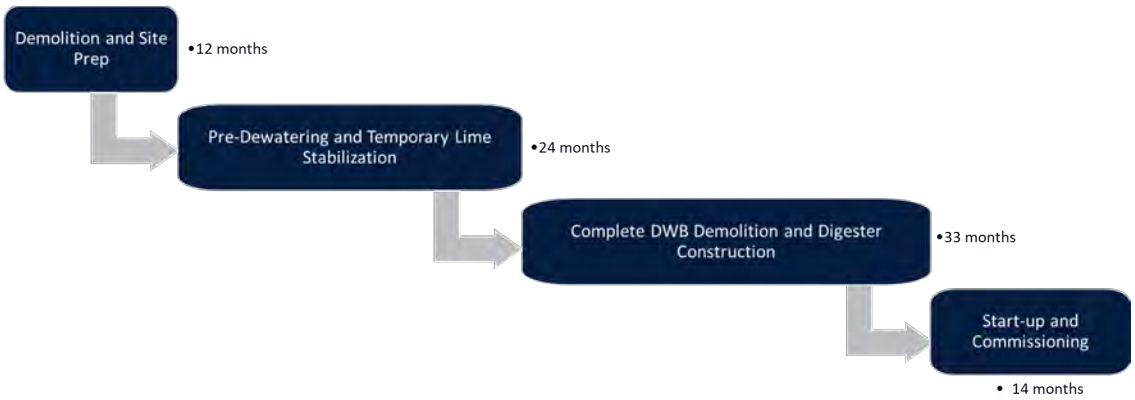

Figure 28. Critical-Path Schedule for Alternative 2: Demolish the Existing DWB

6.3 Alternative 3: Decommission the Existing Dewatering Building

A preliminary critical-path schedule for Alternative 3 is provided in Figure 29 below. The total duration (for comparison purposes) would be 58 months. The critical path would be through construction of the new digester complex. Dewatering, gas upgrading, and odor control would not be on the critical path. No temporary lime stabilization would be required if the existing DWB can remain in service throughout construction.

Figure 29. Critical-Path Schedule for Alternative 3: Decommission the Existing DWB

6.4 Cost Impacts for Different Schedules

The different schedules will impact overall project costs through additional general conditions. For comparison purposes, it is assumed that general conditions are approximately $300,000 per month. This value is based on knowledge of a similar project in the region. An overall cost and schedule comparison is provided in Table 11 below. The base cost provided includes the separate final dewatering facility for Alternatives 1 and 2.

Table 11. Overall Schedule and Cost Comparison

Parameter	Alternative 1: Renovate DWB	Alternative 2: Demolish DWB	Alternative 3: Decommission DWB
Schedule (months)	64	83	58
Length of temporary operations (months)	18	35	0
Base cost for pre-dewatering and final dewatering ($ millions)	$47.5	$55.9	$51.3
Adder for general contractors at $0.3M/month over base)	$1.8	$7.5	$0.0
Total costs	$49.3	$63.4	$51.3
Percentage of minimum	100%	128%	104%

7.0 Comparison of Alternatives

Table 12 provides a side-by-side comparison of the relative advantages and disadvantages of the alternatives.

Table 12. Alternatives Comparison

Consideration	Alternative 1	Alternative 2	Alternative 3
OPCC	✓ $49.3 million	✗ $63.4 million	✓ $51.3 million
Overall schedule	✓ 5.3 years	✗ 6.9 years	✓ 4.8 years
Duration of temporary lime stabilization	! 18 months	✗ 35 months	✓ Not required
Uses existing infrastructure	✓ Reuse existing DWB, which has significant useful life remaining	✗ Existing DWB is demolished	✗ Existing DWB is decommissioned
Requires modifications to existing DWB	✗ Building requires significant modifications for both final use and constructability	✓ Existing DWB is demolished	✓ Existing DWB is decommissioned
Site footprint utilization	✗ Least site footprint available for future use (approx. 0.20 acre)	! More site footprint available for future use (approx. 0.45 acre)	✓ Most site footprint available for future use (approx. 0.75 acre)
Building utilization	✗ Significant unused space in building; not optimized for current needs	✓ Building will be designed for intended uses	✓ Building will be designed for intended uses
Undesirable viewshed impacts	✓ Ex. DWB would screen THP from neighbors	✗ THP would be visible from 31st St.	✓ New DWB would screen THP from neighbors
Code compliance	✗ Existing DWB may require significant upgrades to meet current codes	✓ New building will be designed for compliance with latest codes	✓ New building will be designed for compliance with latest codes
Limitations in dewatering capacity during construction may require temp. dewatering	✗ Final dewatering facility will be used during temporary operations, and it is not sized for undigested solids production	✓ Pre-dewatering facility will be used during temporary operations	✓ No temporary operations required
Requires cleaning and disinfection of final dewatering	✗ Final dewatering will have to be disinfected after it has processed unstabilized solids	✓ No, because final dewatering will not be used for temporary operations	✓ No, because final dewatering will not be used for temporary operations
Future WAS thickening can be installed on the ground floor	✓ Yes	✗ No: located on second floor	✗ No: located on second floor

8.0 Summary and Conclusions

This TM summarizes and compares the pre-dewatering and final dewatering facility alternatives for the Arlington County Biosolids program. Given the extended schedule and added costs of Alternative 2, it is recommended to remove that alternative from consideration.

It is recommended to continue to develop and evaluate Alternative 1, Renovate the Existing Dewatering Building, and Alternative 3, Decommission the Existing Dewatering Building. Site layout and risks will be further evaluated with both alternatives and will be described further in the Facilities Plan. It is anticipated that delivery team input will be sought prior to a final decision being made.

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Technical Memorandum No. 10

Date:	February 15, 2023
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Air Emissions Analysis

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1.0 Introduction

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary sludge (PS) and waste activated sludge (WAS) thickening, dewatering, and lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this air emissions evaluation is to assess the anticipated WPCP emission changes and resulting ambient air impacts associated with the planned improvements. This information will be used to develop the applicable air quality permit application, and to inform public stakeholders regarding the anticipated impacts on the air quality in the area surrounding the WPCP.

2.0 Air Emissions and Permitting Evaluation

This section presents a summary of the permitted air emissions of the existing WPCP, as well as a summary of the air emissions of the WPCP after implementation of the planned improvements. Also included is a discussion of the anticipated air permitting requirements that will be triggered by the planned improvements.

2.1 Existing Facility

The existing WPCP operates under air quality Registration 70026, issued by the Virginia Department of Environmental Quality (VDEQ) Northern Regional Office (NRO). The permit, which was issued on October 30, 2009, and amended on July 2, 2012, includes several emission units that are currently in operation at the WPCP as well as four boilers that have been replaced since the permit was issued (the two New Maintenance Building [NMB] boilers and the two Operations Control Building [OCB] boilers). Per guidance provided by the permitting manager of the VDEQ NRO, the permit did not need to be updated because the WPCP replaced minor sources with minor sources. The emission units currently at the WPCP are listed in Table 1, along with an indication of how they will be impacted by the planned improvements project.

Table 1. Existing Air Emission Units

Reference Number	Equipment Description	Affected by Planned Improvements Project?
A	Caterpillar 3516-C diesel engine-generator set	No
B	Caterpillar 3516-C diesel engine-generator set	No
C	Caterpillar 3516-C diesel engine-generator set	No
Tank 1	12,000 gal fixed-roof methanol storage tank	No
Tank 2	12,000 gal fixed-roof methanol storage tank	No
Tank 3	12,000 gal fixed-roof methanol storage tank	No
DWB-Boil	5.021 MMBtu/hr Kewanee water heater	Yes—will be removed
NMB-Boil 1	2 MMBtu/hr Cleaver-Brooks water heater	No
NMB-Boil 2	2 MMBtu/hr Cleaver-Brooks water heater	No
OCB-Boil 1	5 MMBtu/hr steam generator	No
OCB-Boil 2	5 MMBtu/hr steam generator	No

The current permitted "potential to emit" (PTE) of the WPCP is summarized in Table 2. By definition, the WPCP's PTE represents the maximum emissions from all WPCP emission units operating full time at full capacity or as limited by enforceable permit terms. Actual emissions are expected to be significantly

lower because only three of the five boilers will typically be used at less than capacity at a time and the engine-generator sets will be operated infrequently.

Table 2. Existing WPCP Potential to Emit (tons per year)

Pollutant	Engines A, B, and C [a]	Boilers[b]	Existing Total	Major NSR Threshold	Title V Major Source Threshold
PM/PM10/PM2.5	7.7	0.3	8.0	250	100
NO_x	23.1	2.2	25.3	100 [c]	100
SO_2	6.1	0.02	6.1	250	100
CO	31.2	2.9	34.1	250	100
VOC	3.9	0.4	4.3	50 [c]	50 [e]
CO_2e	59,748	4,168	63,916	-[d]	100,000

a. Obtained from Registration Permit 70026.
b. Calculated using the permitted boiler fuel use limit, 20 parts per million (ppm) oxides of nitrogen (NO_x) for the replacement NMB and OCB boilers and methanol tank volatile organic compound (VOC) emissions obtained from CDM Smith's Technical Memorandum (TM) 4.4 dated March 29, 2018.
c. Per the 9 VAC5-80-2010.C definition of major stationary source for facilities located in the Ozone Transport Region. The applicability of these thresholds will be verified with VDEQ as part of the permit application process.
d. CO_2e is a regulated pollutant for the Prevention of Significant Deterioration (PSD) major source pre-construction permitting program only if another PSD-regulated pollutant exceeds its major source threshold.
e. Per the 9 VAC5-80-60.C definition of major stationary source for facilities located in the Ozone Transport Region. The applicability of this threshold will be verified with VDEQ as part of the permit application process.

Based on the current VDEQ rule language and permitted PTE, the WPCP is an existing minor facility for both new source review (NSR) construction permit and Title V (operating permit) purposes.

2.2 Planned Improvements

The planned improvements include installation and operation of the following new sources at the WPCP:

- Two 350-horsepower (hp) boilers each with a rated heat input of 14.7 million British thermal units per hour (MMBtu/hr) and capable of combusting digester gas and natural gas. Emissions were calculated using Hurst, Series 300 boilers.
- One waste gas flare capable of combusting all of the gas produced by the new digesters being installed as part of the planned improvements. Emissions were calculated and modeled using a Varec 244E waste gas flare.
- One regenerative thermal oxidizer (RTO) that will treat (combust) the tailgas produced by the gas upgrading process. At this time no design information is available regarding the size of this RTO. That tailgas is a subset of the digester gas that would otherwise be combusted by the waste gas flare. Therefore, the emissions calculated for the waste gas flare conservatively reflect emissions that would be generated by the RTO.

2.2.1 Potential to Emit

Potential emissions for this new equipment were calculated based on anticipated vendor guarantees and U.S. Environmental Protection Agency (EPA) default emission factors obtained from the AP-42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources, accessed at AP-42: Compilation of Air Emissions Factors | US EPA. The resulting estimated PTE values are summarized in Table 3. The PTE calculation is based on the maximum amount of emissions with all boiler units and the flare in operation (i.e., the ability to emit simultaneously). Actual emissions are

expected to be significantly lower as only one boiler will be used at a time and the flare will be operated infrequently. Based on the current VDEQ rule language and estimated PTE, the planned improvements project is a minor modification of an existing minor facility for NSR permitting purposes. However, the project will trigger VDEQ's minor NSR permitting requirements for modification of an existing source.

Table 3. Planned Improvements Project Potential to Emit (tons per year)

Pollutant	Boilers	Waste Gas Flare	Project Total	Major NSR Threshold	Minor NSR Threshold
$PM/PM_{10}/PM_{2.5}$	1.0	1.2	2.2	250	25/10/6
NO_x	12.6	5.2	17.8	100 [a]	10
SO_2	0.1	3.3	3.4	250	10
CO	10.6	22.9	33.5	250	100
VOC	0.7	1.6	2.3	50 [a]	10
CO_2e	15,098	9,171	24,269	- [b]	Not applicable

a. Per the 9 VAC5-80-2010.C definition of major stationary source for facilities located in the Ozone Transport Region. The applicability of these thresholds will be verified with VDEQ as part of the permit application process.
b. CO_2e is a regulated pollutant for NSR purposes only if another PSD-regulated pollutant exceeds its major source threshold.

2.2.2 Applicable Regulatory Requirements

This section presents applicable regulatory requirements of the planned improvements, including minor NSR permitting and other regulatory requirements.

2.2.2.1 Minor NSR Permitting

The planned improvements project will require a minor NSR construction permit, which will need to be issued prior to beginning construction of any of the applicable equipment.

Minor NSR permits do not go through public participation unless VDEQ determines that public interest concerning air quality issues warrants it. The air permitting process should be started well in advance of when construction is scheduled to commence in order to avoid undue delays associated with the permitting process. VDEQ indicates the following time frames associated with processing and issuing a minor NSR permit:

- **Completeness review:** 30 days from receipt of application
- **Processing of application:** 90 days from receiving a complete application, or 180 days if public participation is required

One key term in the application processing timeline is "complete." If VDEQ determines that additional information is required in order for VDEQ to process the submitted application, it will request that information and the time clock will stop until VDEQ receives the information. Within 30 days after receipt of any additional information VDEQ will either request additional information (starting another 30-day review cycle) or deem the application complete. Once VDEQ deems the application complete the processing timeline clock then begins.

2.2.2.2 Other Requirements

Based on their rated input capacity (greater than 10 MMBtu/hr), each of the new boilers will be subject to the requirements of Code of Federal Regulations (CFR) Title 40 Part 60, Subpart Dc: Standards of Performance for Small Industrial-Commercial-Institutional Steam Generating Units. This rule will require submittal of a notification of the date that construction commenced, as well as daily or monthly monitoring of each fuel type used (biogas or pipeline natural gas) in each boiler.

2.3 Post-Project Facility

The estimated PTE values for the WPCP after completion of the planned improvements project are summarized in Table 4. Based on the current VDEQ rule language and estimated PTE the post-project WPCP will not trigger the Title V permitting requirements.

Table 4. Post-Project Potential to Emit (tons per year)

Pollutant	Existing Facility [a]	Project Emissions	Post Project Total	Title V Major Source Threshold
$PM/PM_{10}/PM_{2.5}$	7.8	2.2	10.0	100
NO_x	24.3	17.8	42.1	100
SO_2	6.1	3.4	9.5	100
CO	31.7	33.5	65.2	100
VOC	4.0	2.3	6.3	50 [b]
CO_2e	61,268	24,269	85,537	100,000

a. Values reflect removal of the dewatering building (DWB) and associated boilers.
b. Per the 9 VAC5-80-2010.C definition of major stationary source for facilities located in the Ozone Transport Region. The applicability of these thresholds will be verified with VDEQ as part of the permit application process.

3.0 Dispersion Modeling Analysis

Air quality dispersion modeling was performed for this project to assess local environmental impacts from the proposed equipment. This information will be used to inform public stakeholders regarding the anticipated impacts on the air quality in the area surrounding the WPCP.

3.1 Methodology

While there is currently no regulatory requirement for air dispersion modeling analysis at the WPCP, standard regulatory modeling methodology was used as outlined in the sections below. Dispersion analysis is limited to the project impacts only and does not represent a WPCP-wide analysis.

3.1.1 Dispersion Model Selection

EPA's American Meteorological Society (AMS)/EPA Regulatory Model (AERMOD) version 21112 was used in the analysis of direct pollutant emissions from this project. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. AERMOD is listed as a preferred model in EPA's Guideline on Air Quality Models. Third-party software from Lakes Environmental (AERMOD View version 10.0.1) was used to facilitate model setup and produce graphical results.

The suite of AERMOD software includes the following associated programs:

- AERMAP (terrain data preprocessor)
- AERMET (meteorological data preprocessor)
- BPIP (building profile input preprocessor)

3.1.1.1 Selected Model Setup Options

For this analysis, the processing options for AERMOD were designed as follows:

- **Urban dispersion (236,842):** population of Arlington County, 2019
- **Tier 2 oxides of nitrogen (NO_x) to nitrogen dioxide (NO_2) conversion:** Ambient Ratio Method (ARM2) with In-Stack Ratio default range of 0.5 to 0.9

3.1.2 Facility Layout

The WPCP spans two separate processing areas on the north and south sides of South Glebe Road. New equipment for this biosolids project will be located on the northern side of the property, with no changes to the equipment or facilities on the south side of S Glebe Road.

Spatial layout information is a key component of dispersion analysis. For this project, two alternate construction scenarios were modeled, as shown in Figure 1 through Figure 4 below. Figure 1 and Figure 2 show the proposed layout for decommissioning the existing dewatering building (DWB) (without demolition) and building a new DWB south of the existing structure. The boilers would be located within the new DWB and have exhaust stacks on the western side of the rooftop. This configuration is referenced as Iteration 1 in the analysis.

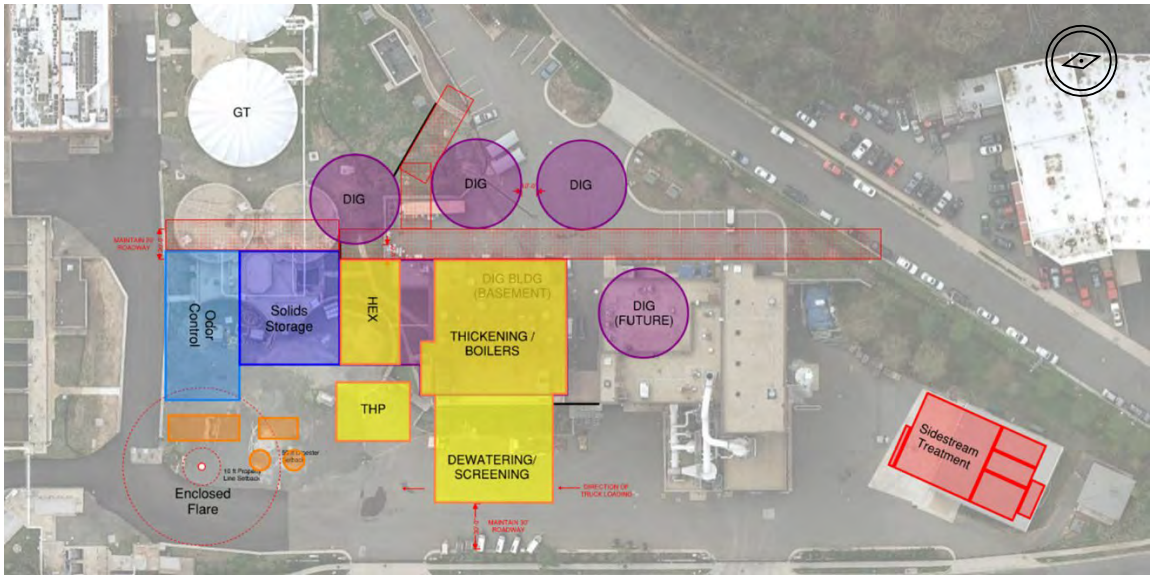

Figure 1. Decommission Existing Dewatering Building, Build New Dewatering Building

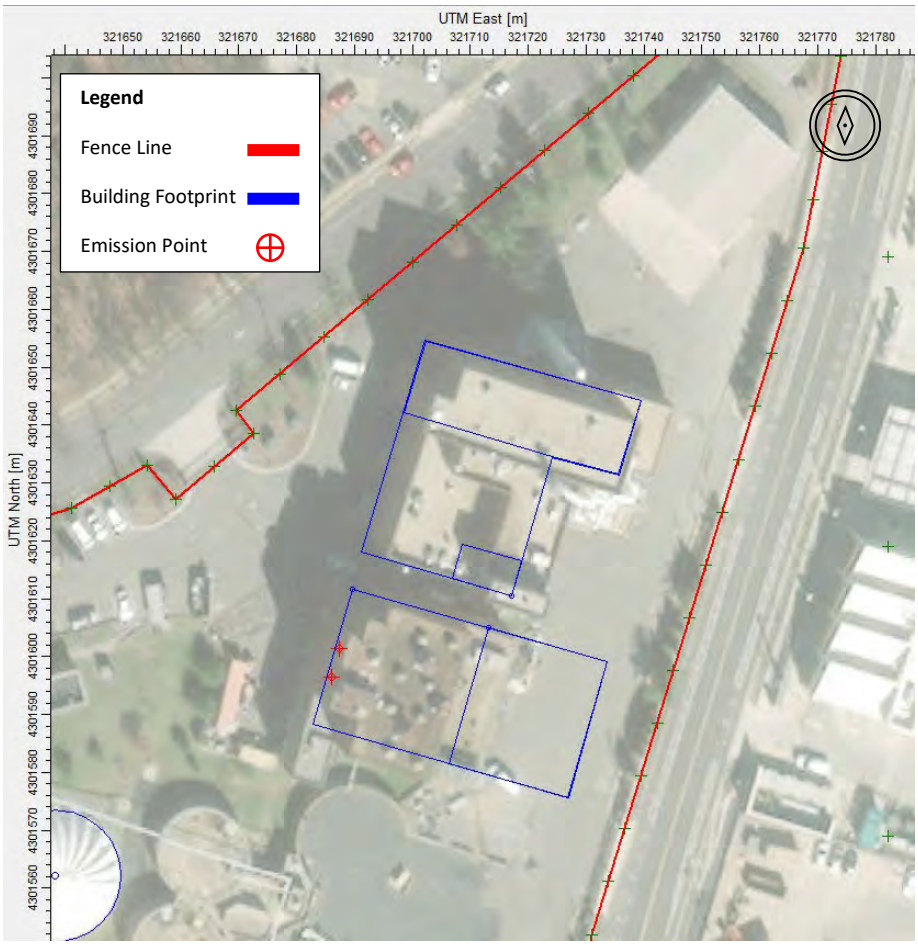

Figure 2. Modeled Boiler Stack Locations: Rooftop of New Dewatering Building

Figure 3 and Figure 4 show the proposed layout for renovating the existing DWB and adding new structures to the southeast of the structure for biosolids treatment. The boilers would be located within the existing DWB after renovation and have exhaust stacks on the western side of the rooftop. This configuration is referenced as Iteration 2 in the analysis.

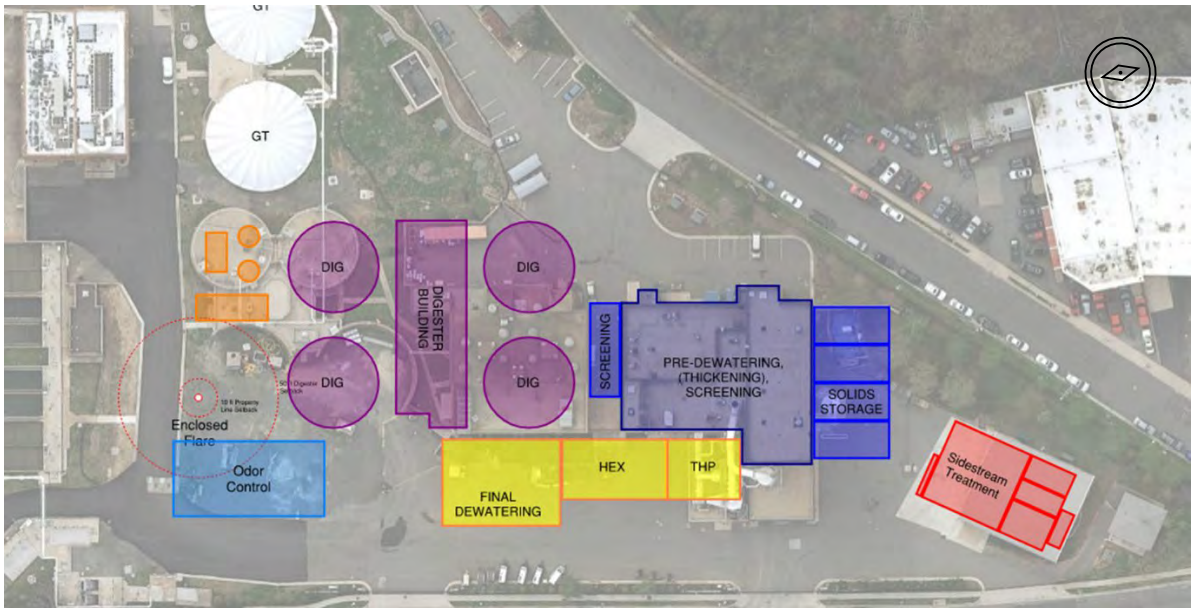

Figure 3. Renovate Existing Dewatering Building

Figure 4. Modeled Boiler Stack Locations: Rooftop of Existing Dewatering Building

Results are presented for both site configurations for comparison, with detailed plot images included in Appendix B .

Building design information was used to produce three-dimensional structures within the dispersion model to assess the impacts of building downwash on the dispersion of pollutants at the site.

3.1.3 Elevation Data

Terrain values were sourced from the United States Geological Survey (USGS) National Elevation Database (NED) at a resolution of 1/3 arc second. All coordinate data for this analysis are referenced to the North American Datum of 1983 (NAD83) and listed in Universal Transversal Mercator (UTM) Zone 18 in meters (m).

3.1.4 Receptor Grid

A nested grid of receptors was placed surrounding the WPCP outward to a radius of 2,500 meters. Receptors were placed at the following densities:

- 25-meter spacing along the fence lines of the northern and southern portions of WPCP
- 50-meter spacing from the fence lines to 500 meters
- 100-meter spacing from 500 meters to 2,500 meters

The receptor grid is not shown on the Appendix B isopleths as the focus of the Appendix B plots is on the contours of the impacts, therefore the receptors are muted to not clutter the image and impact legibility.

3.1.5 Meteorological Data

AERMOD relies on real-world weather observations to produce calculated dispersion impacts. Data are combined in the AERMET preprocessing program from the following two sources:

- Hourly surface observation data
- Upper-level rawinsonde (weather balloon) observations collected twice per day

Consistent with regulatory methodology, the most recent 5 years of observation data were compiled from the most appropriate observation sites. For surface data, the Integrated Surface Hourly Database (ISHD) data files were obtained from Ronald Reagan Washington National Airport (Station 13473), including 1-minute data from the Automated Surface Observing System (ASOS) wind sensors. For upper air observations, data files were obtained from the National Oceanic and Atmospheric Administration (NOAA) rawinsonde observation (RAOB) database from Sterling, Virginia (Station 93734).

Data were processed within AERMET version 21112 for the period of 2016–2020. The following selections were made in AERMET for data processing:

- Default seasonal parameters for the Northern Hemisphere
- Non-arid region
- No continuous snow cover
- Average surface moisture
- Adjusted surface friction velocity (ADJ_U*)
- Inclusion of 1-minute surface observation data through AERMINUTE
- Calm threshold of 0.5 meter per second (m/s)

Wind speed and direction for each hourly time step in the 5-year data set are represented in the wind rose diagram shown in Figure 5 below. The prevailing wind direction is from the south, with a second distribution from the northwest.

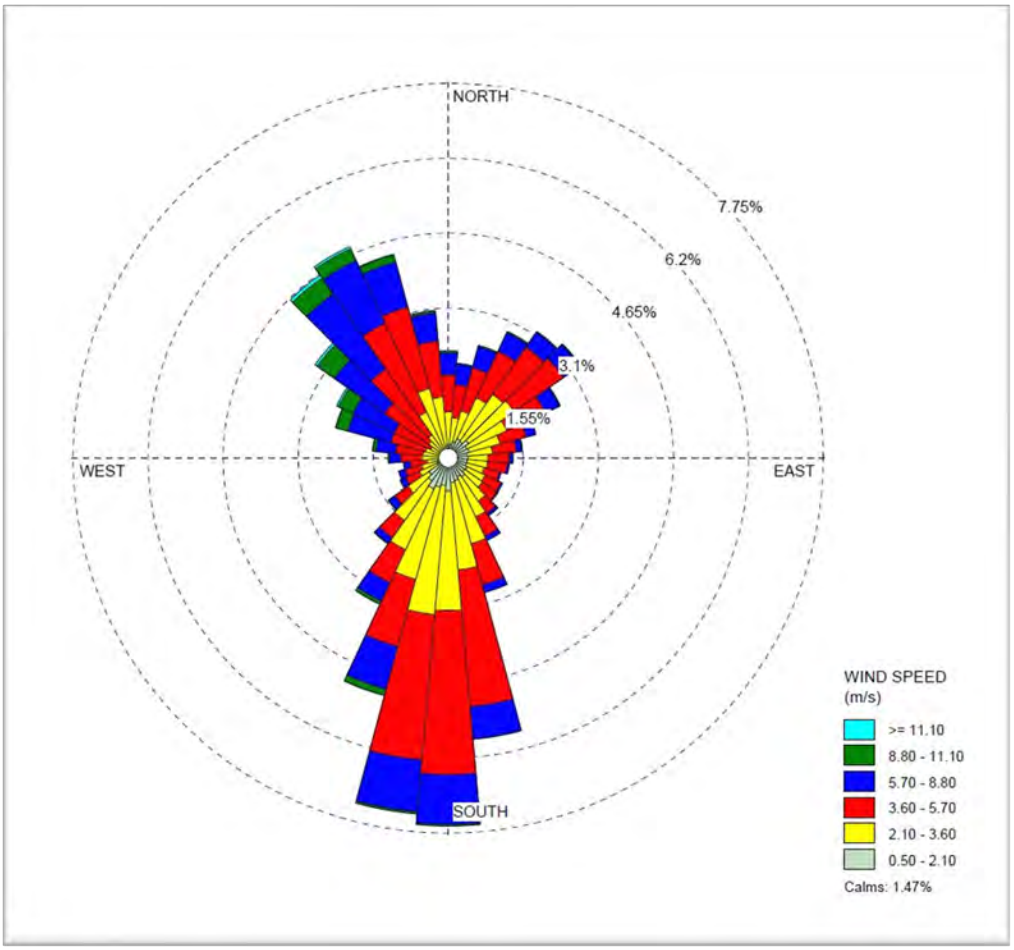

Figure 5. Observed Wind Speed and Direction, Ronald Reagan Washington National Airport, 2016–2020

3.1.6 Background Concentrations

Ambient air quality monitoring data were used to provide background levels for each analyzed pollutant to add to project impacts for a more comprehensive assessment of conditions surrounding the WPCP. Background concentrations from the most recent 3 years (2018–2020) were selected from the nearest monitoring stations.

Table 5 outlines the data and each monitor source.

Table 5. Ambient Monitor (Background) Data

Pollutant	Averaging Period	Statistical Ranking (averaged over 2018–2020)	Background Concentration (µg/m3)	Monitor Station
CO	1 hr	Max high–2nd high	1.53	S 18th and Hayes St. Arlington, Virginia
	8 hr	Max high–2nd high	0.40	
NO_2	1 hr	98th percentile	41.67	
	Annual	Max annual arithmetic mean	8.86	
$PM_{2.5}$	24 hr	98th percentile	17.67	
	Annual	Avg annual arithmetic mean	7.33	
PM_{10}	24 hr	Max high–2nd high 2017–2019 (null 2020 data)	14.67	435 Ferdinand Day Dr. Alexandria, Virginia
SO_2	1 hr	99th percentile	3.67	Station 46-B9, Lee Park, Telegraph Rd. Alexandria, Virginia
	24 hr	Max high–2nd high	1.70	
	Annual	Max annual arithmetic mean	0.38	

3.1.7 Emission Sources

Project emission sources were identified as the two proposed new boilers and the proposed ground flare, each of which was modeled as a POINT source within AERMOD. The FLARE modeling options were not selected for the proposed flare as the flame is enclosed by a surround that results in a similar dispersion profile to a traditional exhaust stack. Stack parameters reflect preliminary design values and engineering estimates and may or may not represent final design and construction.

Boiler stacks are assumed to be routed to the top of the building in which they are housed, which varies between the two potential construction layouts. Assumptions for stack heights are listed in Table 6 and Table 7 below. There are two potential locations for the proposed flare: one places the flare more than 100 feet from the fence line; the second location is 50 feet from the fence line. To ensure that the highest possible impacts are captured in the modeling demonstration, the flare is modeled at a worst-case placement in both models, 50 feet west of the eastern fence line.

Existing combustion emission sources were included in the modeling to calculate site-wide emission impacts to the surrounding area. Three diesel generators and two additional boiler sets (one active and one standby) are currently located at the portion of the WPCP that is on the south side of S Glebe Road.

Table 6. Modeled Parameters for Emission Sources: Iteration 1

Equipment	Easting X (m)	Northing Y (m)	Stack Height (ft)	Stack Diameter (ft)	Stack Temperature (°F)	Exit Velocity (m/s)
Proposed boiler 1	321,686	4,301,596	80	2.0	400	20.0
Proposed boiler 2	321,687	4,301,601	80	2.0	400	20.0
Proposed flare	321,701	4,301,539	25	6.6	1,832	20.0
Existing NMB boiler	321,534	4,301,573	30	1.3	200	1.6
Existing OCB boiler	321,491	4,301,430	30	1.0	200	7.1
Existing diesel generator A	321,528	4,301,408	30	1.5	572	56.0
Existing diesel generator B	321,534	4,301,404	30	1.5	572	56.0
Existing diesel generator C	321,540	4,301,401	30	1.5	572	56.0

Table 7. Modeled Parameters for Emission Sources: Iteration 2

Equipment	Easting X (m)	Northing Y (m)	Stack Height (ft)	Stack Diameter (ft)	Stack Temperature (°F)	Exit Velocity (m/s)
Proposed boiler 1	321,696	4,301,626	65	2.0	400	20.0
Proposed boiler 2	321,697	4,301,630	65	2.0	400	20.0
Proposed flare	321,701	4,301,539	25	6.6	1,832	20.0
Existing NMB boiler	321,534	4,301,573	30	1.3	200	1.6
Existing OCB boiler	321,491	4,301,430	30	1.0	200	7.1
Existing diesel generator A	321,528	4,301,408	30	1.5	572	56.0
Existing diesel generator B	321,534	4,301,404	30	1.5	572	56.0
Existing diesel generator C	321,540	4,301,401	30	1.5	572	56.0

This analysis presents two project scenarios based on differences in boiler stack locations (Iterations 1 and 2), and also two scenarios for WPCP operations. The first is a worst-case analysis for short-term emissions based on the maximum operation of WPCP combustion units all running simultaneously to illustrate the localized impacts and compare to the National Ambient Air Quality Standards (NAAQS). This is not an operationally feasible scenario. Short-term emissions are modeled as each unit operating at maximum allowable capacity (either permitted limit or maximum design capacity) simultaneously for all hours of the year:

1. The proposed boilers (one main unit and one standby unit) were modeled as operating together at maximum capacity; this is not a feasible scenario as that level of operation would exceed the steam demand for the WPCP and represents a worst-case, highly conservative estimate.

2. The proposed flare was modeled as operating at maximum hourly capacity; this is not a feasible scenario because it exceeds the availability of biogas during biosolids treatment for flaring and represents a worst-case, highly conservative estimate. The flare is expected to operate less than 5 percent of the year.
3. The existing NMB boiler was modeled as operating at maximum hourly capacity; this is not a feasible scenario as it would over-produce steam load for the WPCP and represents a worst-case, highly conservative estimate. The standby NMB boiler was not modeled as it is not permitted to run simultaneously with the main unit.
4. The existing OCB boiler was modeled as operating at maximum hourly capacity; this is not a feasible scenario as it would over-produce steam load for the WPCP and represents a worst-case, highly conservative estimate. The standby OCB boiler was not modeled as it is not permitted to run simultaneously with the main unit.
5. The diesel generators were modeled with their maximum permitted hourly operational limit and on a testing schedule of 1 hour per week. As a worst case, all three diesel generators are modeled as running during the same hour each week for testing.

The second is a long-term analysis for emissions based on actual operations, to show the low impacts due to intermittent operation of most of the sources. For existing units, reportable emissions data were used to develop annualized emission rates for comparison to annual NAAQS. As an example, the diesel generators have historically operated infrequently; therefore, their annualized emissions are low. For proposed equipment, the maximum hourly rate was applied to all hours of the year, resulting in a very conservative overestimation of the impacts from those units.

The short-term emission rates were developed for the WPCP based on hourly equipment capacity, including permitted values for existing equipment and design information for proposed equipment, and are attached to this technical memorandum (TM) as Appendix A . Annualized emissions are calculated based on historical operational data for existing emissions and expected operational conditions for proposed equipment.

3.2 Model Results

As outlined above, calculations were performed for all selected pollutants and averaging periods. The maximum impacted receptors were identified and, combined with background concentrations, were compared against the NAAQS with the corresponding form of each pollutant standard. The Clean Air Act (CAA) requires EPA to set the NAAQS for pollutants that are common in outdoor air. The NAAQS are established through a rigorous review process and are designed to be protective of human health for ambient air exposure, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly.[1] The NAAQS have been established for carbon monoxide (CO), particulate matter less than 10 microns in diameter (PM_{10}), particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), NO_2, sulfur dioxide (SO_2), lead (Pb), and ozone (O_3). The pollutants for which NAAQS have been established are referred to as the criteria pollutants.

Ozone is a secondary pollutant, which forms in the atmosphere as a result of chemical reactions between other pollutants (precursor compounds) that can vary based on ambient regional concentrations. Ozone formation is seasonal and can be impacted by weather conditions and localized

[1] https://www.epa.gov/criteria-air-pollutants/naaqs-table

sources such as transportation emissions or other industrial facilities. Precursor compounds include NO_x and volatile organic compounds (VOC), which are included in this modeling study. Ozone has not been discretely modeled in this analysis.

Similarly, $PM_{2.5}$ is considered to be both a primary and secondary pollutant. There are direct $PM_{2.5}$ emissions from units at the WPCP, and $PM_{2.5}$ can also form through atmospheric reactions of precursor compounds. This analysis does not attempt to quantify the secondary formation of $PM_{2.5}$ based on WPCP emissions. In addition, lead is not emitted from this WPCP and therefore lead is not included in this modeling analysis.

Compliance with each NAAQS is determined based on meeting specified design values that differ by averaging period and pollutant. These design values incorporate allowable exceedances of the NAAQS. More information on the NAAQS is available at https://www.epa.gov/criteria-air-pollutants/naaqs-table. The NAAQS values, averaging periods, and design values are listed below in Table 8.

Table 8. National Ambient Air Quality Standards

Pollutant	Averaging Period	NAAQS (µg/m^3)	Design Value
CO	1 hr	40,000	H2H
	8 hr	10,000	H2H
NO_2	1 hr	188	H8H
	Annual	100	5-year maximum
PM_{10}	24 hr	150	H6H
$PM_{2.5}$	24 hr	35	H8H
	Annual	12	5-year maximum
SO_2	1 hr	196	H4H
	24 hr	365	H2H
	Annual	78	5-year maximum

Contour plots were produced for each pollutant that was analyzed and can be found in Appendix B to this TM. Tabular results are presented for each iteration in Table 9 and Table 10 below. This project is not expected to cause any exceedances of the NAAQS. As stated previously, the modeling results are presented for all units operating simultaneously as a worst case; however, because of the operational design of the WPCP this scenario would not be operationally feasible.

An initial screening analysis was performed to determine the impact of various layout options as combined heat and power (CHP) gas utilization scenarios were being considered. Appendix C details preliminary modeling results for co-locating the proposed boilers with proposed engines that would combust the biogas from the digesters to produce electricity. The boilers and engines would have been housed in a smaller, separate structure (referred to as the “power block structure”) with a much lower roof height than the surrounding biosolids handling facilities, so building downwash was a significant focus in the preliminary design modeling. The power block designs had boilers and engines exhausting much closer to ground level and, with wake cavities produced by the larger buildings, resulted in potential impacts above the NAAQS, as shown in Table C-2 of the Appendix.

In this current analysis, both Iterations 1 and 2 relocate the boiler exhaust stacks to the rooftop of the DWB (either new or renovated existing), which is significantly higher above ground level than the proposed power block structure and promotes good dispersion of pollutants before reaching ground-level receptors. This improvement of dispersion results in lowered air quality impacts for the boilers than what was previously identified in the preliminary screening analysis in Appendix C without changing operational design capacities. In summary, the results presented below for Iterations 1 and 2 show that despite overestimating emissions for all units and operational scenarios, WPCP-wide air quality impacts are significantly below any established NAAQS and do not pose a significant risk to human health.

Table 9. Iteration 1: Decommission Existing Dewatering Building

	Boiler stack heights are above new DWB rooftop; flare is at ground level south of thickening/dewatering									
	CO	CO	NO_2	NO_2	SO_2	SO_2	SO_2	PM_{10}	$PM_{2.5}$	$PM_{2.5}$
	1 hr	8 hr	1 hr	Annual	1 hr	24 hr	Annual	24 hr	24 hr	Annual
	H1H	H1H	H8H	Max	H4H	H1H	Max	H6H	H8H	Max
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
New DWB boilers	33.4	20.5	28.6	3.5	0.0	0.0	0.0	1.4	1.2	0.3
Flare	93.9	49.3	14.9	0.3	12.7	4.4	0.2	0.9	0.5	0.1
Diesel generators	250.9	31.4	26.9	10.9	39.9	2.1	1.5	1.9	0.3	0.0
OCB boiler	16.6	7.7	14.5	0.4	0.4	0.1	0.0	1.3	0.9	0.2
NMB boiler	29.5	15.9	6.2	0.4	0.2	0.1	0.0	0.8	0.7	0.2
All units together running simultaneously	253.2	57.2	35.1	11.6	39.9	4.4	1.5	2.3	1.2	0.3
Background	1.5	0.4	41.7	8.9	3.7	1.7	0.4	14.7	17.7	7.3
Total	255	58	77	20	44	6.1	1.9	16.9	19	7.7
NAAQS	40,000	10,000	188	100	196	365	78	150	35	12
Percentage of standard	0.6%	0.6%	41%	20%	22%	2%	2.4%	11%	54%	64%

H1H: high–1st-high
H4H: high–4th-high
H6H: high–6th-high
H8H: high–8th-high
µg/m³: micrograms per cubic meter

Table 10. Iteration 2: Renovate Existing Dewatering Building

	Boiler stack heights are above existing DWB rooftop; flare is at ground level south of thickening/dewatering									
	CO	CO	NO_2	NO_2	SO_2	SO_2	SO_2	PM_{10}	$PM_{2.5}$	$PM_{2.5}$
	1 hr	8 hr	1 hr	Annual	1 hr	24 hr	Annual	24 hr	24-hr	Annual
	H1H	H1H	H8H	Max	H4H	H1H	Max	H6H	H8H	Max
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Flare	47.2	40.9	47.0	7.7	0.0	0.0	0.0	2.9	2.4	0.6
Boilers	63.7	34.7	8.4	0.2	8.2	1.8	0.2	0.6	0.4	0.0
Diesel generators	250.9	31.4	26.9	10.9	39.9	2.1	1.5	1.9	0.3	0.0
OCB boiler	16.6	7.7	14.5	0.4	0.4	0.1	0.0	1.3	0.9	0.2
NMB boiler	29.5	15.9	6.2	0.4	0.2	0.1	0.0	0.8	0.7	0.2
All units together running simultaneously	253.2	57.9	47.7	11.5	39.9	3.1	1.5	3.1	2.7	0.7
Background	1.5	0.4	41.7	8.9	3.7	1.7	0.4	14.7	17.7	7.3
Total all	255	58	89	20	44	4.8	1.9	17.8	20	8.0
NAAQS	40,000	10,000	188	100	196	365	78	150	35	12
Percentage of standard	0.6%	0.6%	48%	20%	22%	1%	2.4%	12%	58%	67%

H1H: high–1st-high
H4H: high–4th-high
H6H: high–6th-high
H8H: high–8th-high
µg/m3: micrograms per cubic meter

Appendix A Emission Calculations

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Arllington County
Biosolids Gas Utilization - SA2
Current Facility PTE Calculation

All values in tons per year

Pollutant	Existing Faclity		Post-Project Total	NSR Major Source Threshold	NSR Major?	Title V Major Source Threshold	Title V Major?
	Engines [1]	Other [2]					
PM	7.7	0.3	8.0	250	NO	100	NO
PM_{10}	7.7	0.3	8.0	250	NO	100	NO
$PM_{2.5}$	7.7	0.3	8.0	250	NO	100	NO
NO_x	23.1	3.2	26.3	100	NO	100	NO
SO_2	6.1	0.02	6.1	250	NO	100	NO
CO	31.2	1.37	32.6	250	NO	100	NO
VOC	3.9	0.2	4.1	50	NO	50	NO
CO_2e [3]	59,748	4,086	63,834			100,000	NO

[1] With the exception of CO_2e, values obtained from facility registration number 70026 dated October 30, 2009 (amended July 2, 2012). CO2e emissions were estimated based on permitted engine limites and GHG emission factors obtained from 40 CFR Part 98.

Arllington County
Biosolids Gas Utilization - SA2
Post-Project PTE Calculation

All values in tons per year

Pollutant	Project			Existing Faclity		Post-Project Total	Title V Threshold	Title V Major?
	Boiler 1	Boiler 2	Flare	Engines [1]	Other [2]			
PM	0.12	0.12	1.23	7.7	0.10	9.3	100	NO
PM_{10}	0.48	0.48	1.23	7.7	0.10	10.0	100	NO
$PM_{2.5}$	0.48	0.48	1.23	7.7	0.10	10.0	100	NO
NO_x	6.31	6.31	5.18	23.1	1.19	42.1	100	NO
SO_2	0.04	0.04	3.3	6.1	0.008	9.5	100	NO
CO	5.30	5.30	22.9	31.2	0.51	65.2	100	NO
VOC	0.35	0.35	1.59	3.9	0.07	6.25	50	NO
CO_2e [3]	7,549	7,549	9,171	59,741	1,527	85,537	100,000	NO

[1] With the exception of CO_2e, values obtained from facility registration number 70026 dated October 30, 2009 (amended July 2, 2012). CO2e emissions were estimated based on permitted engine limites and GHG emission factors obtained from 40 CFR Part 98.
[2] Reflects decommissioning of the Kewanee L3W-150G-LE boiler located in the Dewatering Building.

Arllington County
Biosolids Gas Utilization - SA2
Project PTE Calculation

All values in tons per year

Pollutant	Boiler 1	Boiler 2	Flare	Project Total	NSR/PSD Threshold	PSD/NSR Major?	VDEQ Minor NSR Threshold	Minor NSR Triggered?
PM	0.12	0.12	1.23	1.47	250	NO	15	NO
PM_{10}	0.48	0.48	1.23	2.19	250	NO	10	NO
$PM_{2.5}$	0.48	0.48	1.23	2.19	250	NO	6	NO
NO_x	6.31	6.31	5.18	17.8	100	NO	10	YES
SO_2	0.04	0.04	3.3	3.4	250	NO	10	NO
CO	5.30	5.30	22.9	33.5	250	NO	100	NO
VOC	0.35	0.35	1.59	2.28	50	NO	10	NO
CO_2e	7,549	7,549	9,171	24,269				

Arllington County
Biosolids Gas Utilization - SA2
Boilers
PTE Calculation

Manufacturer:	Hurst 350 BHP, Series 300	
Fuel:	Natural Gas/Digester Gas	
Digester Gas Heat Content:	580	Btu/cf (Design basis)
Heat Input Rating:	14.70	MMBtu/hr
Design Digester Gas Usage:	422	scfm (Calculated)
Annual Operating Hours:	8,760	

		Natural Gas				
		Emission Factor			PTE	
Pollutant	CAS	Value	Units	Source	lb/hr	ton/yr
PM [1]		0.002	lb/MMBtu	A	0.03	0.12
PM_{10} [2]		0.007	lb/MMBtu	A	0.11	0.48
$PM_{2.5}$ [2]		0.007	lb/MMBtu	A	0.11	0.48
NO_x	10102-44-0	0.10	lb/MMBtu	A	1.44	6.31
SO_2	7446-09-5	0.0006	lb/MMBtu	A	0.009	0.04
CO	630-08-0	0.08	lb/MMBtu	A	1.21	5.30
VOC		0.005	lb/MMBtu	A	0.08	0.35
CO_2e					1,721	7,539
CO_2					1,720	7,532
Combustion		53.06	kg/MMBtu	B	1,720	7,532
Pass Through						
N_2O	10024-97-2	0.0001	kg/MMBtu	B	0.003	0.01
CH_4	74-82-8	0.001	kg/MMBtu	B	0.03	0.14
Hydrogen Sulfide	7783-06-4					
Lead	7439-92-1	4.90E-07	lb/MMBtu	A	7.21E-06	3.16E-05
Arsenic	7440-38-2	2.0E-07	lb/MMBtu	A	2.88E-06	1.26E-05
Benzene	71-43-2	2.1E-06	lb/MMBtu	A	3.03E-05	1.33E-04
Beryllium	7440-41-7	<1.2E-08	lb/MMBtu	A	1.73E-07	7.57E-07
Cadmium	7440-43-9	1.1E-06	lb/MMBtu	A	1.59E-05	6.94E-05
Chromium	7440-47-3	1.4E-06	lb/MMBtu	A	2.02E-05	8.84E-05
Cobalt	7440-48-4	8.2E-08	lb/MMBtu	A	1.21E-06	5.30E-06
Formaldehyde	50-00-0	7.4E-05	lb/MMBtu	A	1.08E-03	4.73E-03
Hexane	110-54-3	1.8E-03	lb/MMBtu	A	2.59E-02	1.14E-01
Manganese	7439-96-5	3.7E-07	lb/MMBtu	A	5.48E-06	2.40E-05
Mercury	7439-97-6	2.5E-07	lb/MMBtu	A	3.75E-06	1.64E-05
Naphthalene	91-20-3	6.0E-07	lb/MMBtu	A	8.79E-06	3.85E-05
Nickel	7440-02-0	2.1E-06	lb/MMBtu	A	3.03E-05	1.33E-04
POM	Sum of individual POM				1.01E-05	4.41E-05
2-Methylnaphthalene	91-57-6	2.4E-08	lb/MMBtu	A	3.46E-07	1.51E-06
3-Methylchloranthrene	56-49-5	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
7,12-Dimethylbenz(a)anthracene	57-97-6	<1.6E-08	lb/MMBtu	A	2.31E-07	1.01E-06
Acenaphthene	83-32-9	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Acenaphthylene	208-96-8	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Anthracene	120-12-7	<2.4E-09	lb/MMBtu	A	3.46E-08	1.51E-07
Benz(a)anthracene	56-55-3	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Benzo(a)pyrene	50-32-8	<1.2E-09	lb/MMBtu	A	1.73E-08	7.57E-08
Benzo(b)fluoranthene	205-99-2	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Benzo(g,h,i)perylene	191-24-2	<1.2E-09	lb/MMBtu	A	1.73E-08	7.57E-08
Benzo(k)fluoranthene	207-08-9	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Chrysene	218-01-9	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Dibenzo(a,h)anthracene	53-70-3	<1.2E-09	lb/MMBtu	A	1.73E-08	7.57E-08
Fluoranthene	206-44-0	2.9E-09	lb/MMBtu	A	4.32E-08	1.89E-07
Fluorene	86-73-7	2.7E-09	lb/MMBtu	A	4.04E-08	1.77E-07
Indeno(1,2,3-cd)pyrene	193-39-5	<1.8E-09	lb/MMBtu	A	2.59E-08	1.14E-07
Phenanathrene	85-01-8	1.7E-08	lb/MMBtu	A	2.45E-07	1.07E-06
Pyrene	129-00-0	4.9E-09	lb/MMBtu	A	7.21E-08	3.16E-07
Selenium	7782-49-2	<2.4E-08	lb/MMBtu	A	3.46E-07	1.51E-06
Toluene	108-88-3	3.3E-06	lb/MMBtu	A	4.90E-05	2.15E-04
Total HAP	Sum of Individual HAP				0.0272	0.1191

[1] Includes filterable particulate matter only.
[2] Includes both filterable and condensable particulate matter.

NOTES:
A - Fifth Edition AP-42, Section 1.4 (7/98).
B - See H_2S, SO_2 and CO_2 Emission Factors tab.
C - 40 CFR pt. 98 - Mandatory Greenhouse Gas Reporting, Table C -1 and C -2, reflecting the update effective January 1, 2014.

Greenhouse Gas	GWP
CO_2	1
N_2O	298
CH_4	25

Arllington County
Biosolids Gas Utilization - SA2
Flare
PTE Calculation

Description:	Flare Varec 244E	
	500	cfm (Anaerobic digester system design)
Maximum Design Digester Gas Flow:	30,000	ft^3/hr (Calculated)
	16,500	ft^3 methane/hr (assume 55% methane)
Digester Gas Heat Content:	580	Btu/cf (Design basis)
Digester Gas Heat Input:	17.4	MMBtu/hr (Calculated)
Annual Hours of Operation:	8,760	hr/yr

		Emission Factor			Potential Emissions	
Pollutant	**CAS**	Number	Units	Source	lb/hr	ton/yr
PM		17	lb/MMft^3 methane	A	0.28	1.23
PM_{10}		17	lb/MMft^3 methane	A	0.28	1.23
$PM_{2.5}$		17	lb/MMft^3 methane	A	0.28	1.23
NO_x	10102-44-0	0.068	lb/MMBtu	B	1.18	5.18
SO_2	7446-09-5	2.53E-05	lb/ft^3 gas	C	0.76	3.3
CO	630-08-0	0.30	lb/MMBtu	B	5.22	22.9
VOC		12.10	lb/MMft^3 gas	D	0.36	1.59
CO_2e					2,094	9,171
CO_2					2,084	9,126
Combustion		52.07	kg/MMBtu	E	1,997	8,749
Pass Through		5.22E-03	lb/dcf	C	86	377
N_2O	10024-97-2	6.3E-04	kg/MMBtu	E	0.02	0.11
CH_4	74-82-8	3.2E-03	kg/MMBtu	E	0.12	0.54
Hydrogen Sulfide	7783-06-4	2.69E-07	lb/dcf	C	0.008	0.04
Lead	7439-92-1	0.0005	lb/MMft^3 gas	F	0.0000	0.0001
Arsenic	7440-38-2	2.0E-04	lb/MMft^3 gas	F	0.0000	0.0000
Benzene	71-43-2	2.1E-03	lb/MMft^3 gas	F	0.0001	0.0003
Beryllium	7440-41-7	<1.2E-05	lb/MMft^3 gas	F	0.0000	0.0000
Cadmium	7440-43-9	1.1E-03	lb/MMft^3 gas	F	0.0000	0.0001
Chromium	7440-47-3	1.4E-03	lb/MMft^3 gas	F	0.0000	0.0002
Cobalt	7440-48-4	8.4E-05	lb/MMft^3 gas	F	0.0000	0.0000
Formaldehyde	50-00-0	7.5E-02	lb/MMft^3 gas	F	0.0023	0.0099
Hexane	110-54-3	1.8E+00	lb/MMft^3 gas	F	0.0540	0.2365
Manganese	7439-96-5	3.8E-04	lb/MMft^3 gas	F	0.0000	0.0000
Mercury	7439-97-6	2.6E-04	lb/MMft^3 gas	F	0.0000	0.0000
Naphthalene	91-20-3	6.1E-04	lb/MMft^3 gas	F	0.0000	0.0001
Nickel	7440-02-0	2.1E-03	lb/MMft^3 gas	F	0.0001	0.0003
POM		Sum of individual POM			0.0000	0.0001
2-Methylnaphthalene	91-57-6	2.4E-05	lb/MMft^3 gas	F	0.0000	0.0000
3-Methylchloranthrene	56-49-5	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
7,12-Dimethylbenz(a)anthracene	57-97-6	<1.6E-05	lb/MMft^3 gas	F	0.0000	0.0000
Acenaphthene	83-32-9	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Acenaphthylene	208-96-8	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Anthracene	120-12-7	<2.4E-06	lb/MMft^3 gas	F	0.0000	0.0000
Benz(a)anthracene	56-55-3	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Benzo(a)pyrene	50-32-8	<1.2E-06	lb/MMft^3 gas	F	0.0000	0.0000
Benzo(b)fluoranthene	205-99-2	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Benzo(g,h,i)perylene	191-24-2	<1.2E-06	lb/MMft^3 gas	F	0.0000	0.0000
Benzo(k)fluoranthene	207-08-9	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Chrysene	218-01-9	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Dibenzo(a,h)anthracene	53-70-3	<1.2E-06	lb/MMft^3 gas	F	0.0000	0.0000
Fluoranthene	206-44-0	3.0E-06	lb/MMft^3 gas	F	0.0000	0.0000
Fluorene	86-73-7	2.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Indeno(1,2,3-cd)pyrene	193-39-5	<1.8E-06	lb/MMft^3 gas	F	0.0000	0.0000
Phenanathrene	85-01-8	1.7E-05	lb/MMft^3 gas	F	0.0000	0.0000
Pyrene	129-00-0	5.0E-06	lb/MMft^3 gas	F	0.0000	0.0000
Selenium	7782-49-2	<2.4E-05	lb/MMft^3 gas	F	0.0000	0.0000
Toluene	108-88-3	3.4E-03	lb/MMft^3 gas	F	0.0001	0.0004
Total HAP		Sum of Individual HAP			0.0566	0.2480

A - Obtained from Fifth Edition AP-42, Table 2.4-5.

B - Vendor guarantee.

C - See H_2S, SO_2 and CO_2 Emission Factors tab.

D - SDAPCD emission factors for biogas flares, accessed at
http://www.sdapcd.org/content/dam/sdc/apcd/PDF/Misc/EFT/Gas_Combustion/APCD_Flares_Digester_Gas_Fired_Enclosed.pdf in November 2017.

E - 40 CFR pt. 98 - Mandatory Greenhouse Gas Reporting, Table C -1 and C -2, reflecting the update effective January 1, 2014, corresponding to Biomass Fuels - Gaseous.

Greenhouse Gas	GWP
CO_2	1
N_2O	298
CH_4	25

F - Fifth Edition AP-42, Section 1.4 (7/98).

Arllington County
Biosolids Gas Utilization - SA2
Digester Gas H_2S, SO_2 and CO_2 Emission Factors

Gas Law Inputs & Conversions

Pressure	1	atmosphere
Temperature	60	F =
Gas Constant	0.08206	lit-atm/mol deg K
Mol. Wt. H_2S	34.0819	grams/mol
Mol. Wt. SO_2	64.0628	grams/mol
Mol. Wt. CO_2	44.01	grams/mol
1 ft^3 =	28.316	liters
1 lb=	453.6	grams

$$m = \frac{p * V * MW}{R * T}$$

	H_2S Concentration (ppm)	H_2S Emission Factor (lb/dcf) ***	SO_2 Emission Factor (lb/dcf)
Raw Digester Gas	150 *	2.69E-07	2.53E-05
Treated Digester Gas	15 **	2.69E-08	2.53E-06

	CO_2 Concentration (ppm)	CO_2 Emission Factor (lb/dcf)
Digester Gas	45,000 ****	5.22E-03

* Design basis.

** Design basis achieved using an iron sponge.

*** Assumes a minimum of 98% of the H_2S is converted to SO_2 during combustion.

**** Assumes 55% of the biogas is methane and the remainder is CO_2.

Arllington County
Biosolids Gas Utilization - SA2
Air Toxics Ambient Impact Evaluation [a]

lb/hr

TAP	CAS	Boiler 1		Boiler 2		Flare		Facility Total		Exemption Emission Rate *		Further Review?	
		lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr	lb/hr	ton/yr
Arsenic	7440-38-2	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.000	0.0132	0.029	NO	NO
Benzene	71-43-2	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.00	2.112	4.64	NO	NO
Beryllium	7440-41-7	0.00	0.00	0.00	0.00	0.00	0.00	0.000001	0.00000	0.000132	0.00029	NO	NO
Cadmium	7440-43-9	0.00	0.00	0.00	0.00	0.00	0.00	0.0001	0.00028	0.0033	0.00725	NO	NO
Chromium	7440-47-3	0.00	0.00	0.00	0.00	0.00	0.00	0.0001	0.00036	0.0033	0.00725	NO	NO
Cobalt	7440-48-4	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.00002	0.0033	0.00725	NO	NO
Formaldehyde	50-00-0	0.00	0.00	0.00	0.00	0.00	0.01	0.0044	0.019	0.0825	0.174	NO	NO
Hexane	110-54-3	0.03	0.11	0.03	0.11	0.05	0.24	0.106	0.46	11.616	25.52	NO	NO
Lead	7439-92-1	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.00013	0.0099	0.02175	NO	NO
Manganese	7439-96-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.33	0.725	NO	NO
Mercury	7439-97-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00002	0.00007	0.00066	0.00145	NO	NO
Methanol	67-56-1							0.000	0.00	10.824	37.99	NO	NO
Naphthalene	91-20-3	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.00	2.607	7.54	NO	NO
Nickel	7440-02-0	0.00	0.00	0.00	0.00	0.00	0.00	0.0001	0.0005	0.0066	0.0145	NO	NO
POM		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Selenium	7782-49-2	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0132	0.0290	NO	NO
Toluene	108-88-3	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.001	18.645	54.665	NO	NO

* Obtained from VDEQ document titled "VDEQ Toxics_Spreadsheet.xlsx", accessed at https://www.deq.virginia.gov/home/showpublisheddocument/5546/637516769161600000 in July 2021.

Arllington County
Biosolids Gas Utilization - SA2
Existing Equipment Emission Rates

	Short-term Emission Rates (g/s)						
Emission Source	NOx	CO	SO_2	PM_{10}	$PM_{2.5}$	VOC	Emission Rate Basis
Diesel Generator A	0.75	0.81	0.16	0.2	0.2	0.1	Permit Limits
Diesel Generator B	0.75	0.81	0.16	0.2	0.2	0.1	Permit Limits
Diesel Generator C	0.75	0.81	0.16	0.2	0.2	0.1	Permit Limits
Operations Control Building (OCB) Boiler[1]	0.0189	0.0151	0.000371	0.00469	0.00469	0.0034	CO, SOx, PM and VOC from AP-42 emission factors;(1) based on maximum rated heat input capacity; 20 ppm low NOx burner, emission rate calculated for NOx
New Maintenance Building (NMB) Boiler[1]	0.00612	0.0208	0.000148	0.00188	0.00188	0.00136	CO, SOx, PM and VOC from AP-42 emission factors;(1) based on maximum rated heat input capacity; 20 ppm low NOx burner, emission rate calculated for NOx

	Long-term Emission Rates (g/s)						
Emission Source	NOx	CO	SO_2	PM_{10}	$PM_{2.5}$	VOC	Emission Rate Basis
Diesel Generator A	0.75	0.36	0.08	0.1	0.1	0.05	2016 Emissions Inventory worst-case for each generator
Diesel Generator B	0.75	0.36	0.08	0.1	0.1	0.05	2016 Emissions Inventory
Diesel Generator C	0.75	0.36	0.08	0.1	0.1	0.05	2016 Emissions Inventory
Operations Control Building (OCB) Boiler[1]	0.0189	0.0151	0.000371	0.00469	0.00469	0.0034	2016 Emissions Inventory, AP-42 emission factors; 20ppm low NOx burner
New Maintenance Building (NMB) Boiler[1]	0.00612	0.0208	0.000148	0.00188	0.00188	0.00136	2016 Emissions Inventory, AP-42 emission factors; 20ppm low NOx burner

[1] Emission factors from U.S. EPA Compilation of Air Pollutant Emission Factors (AP-42). https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

Source: CDM Smith, 2017

Appendix B Isopleth Figures

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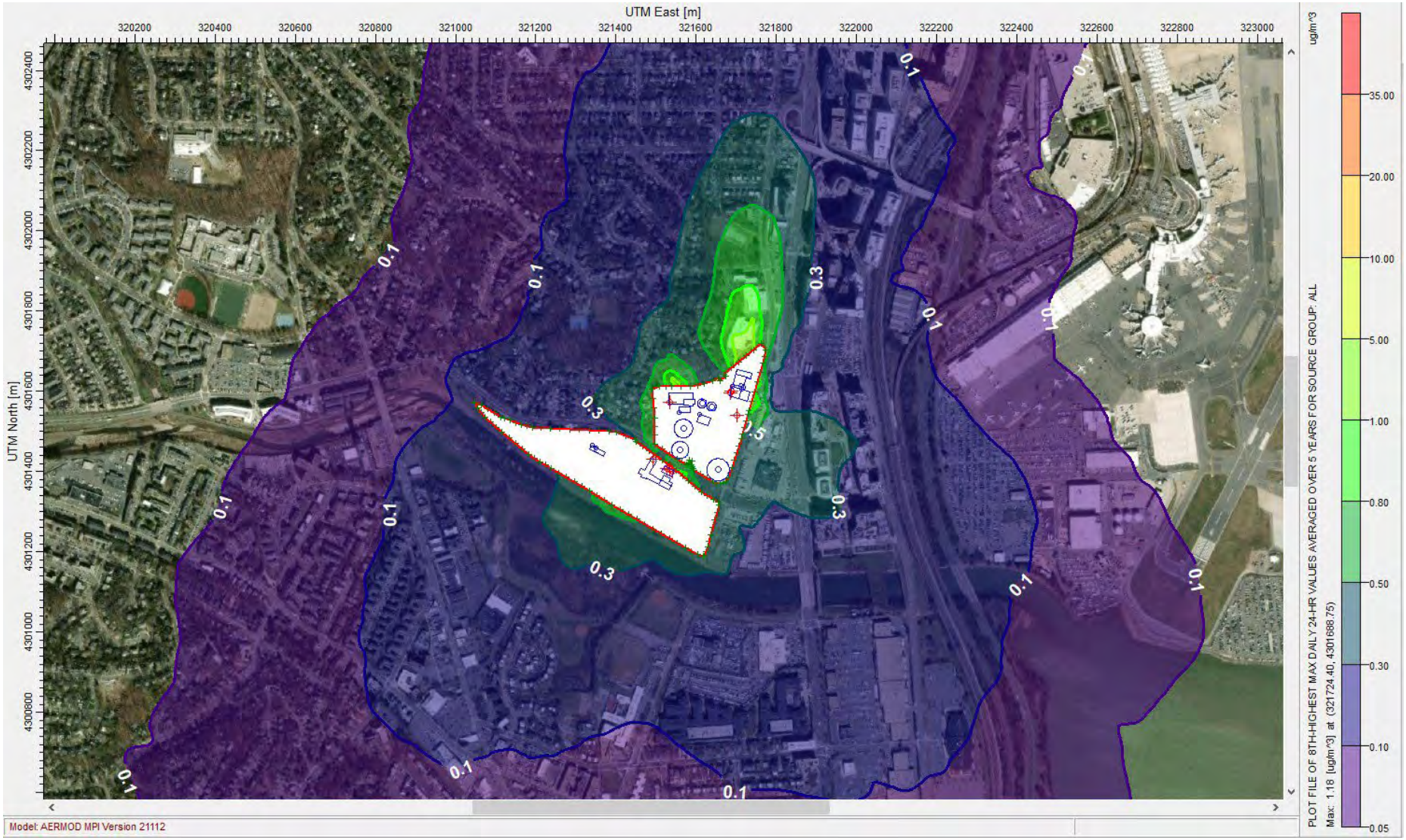
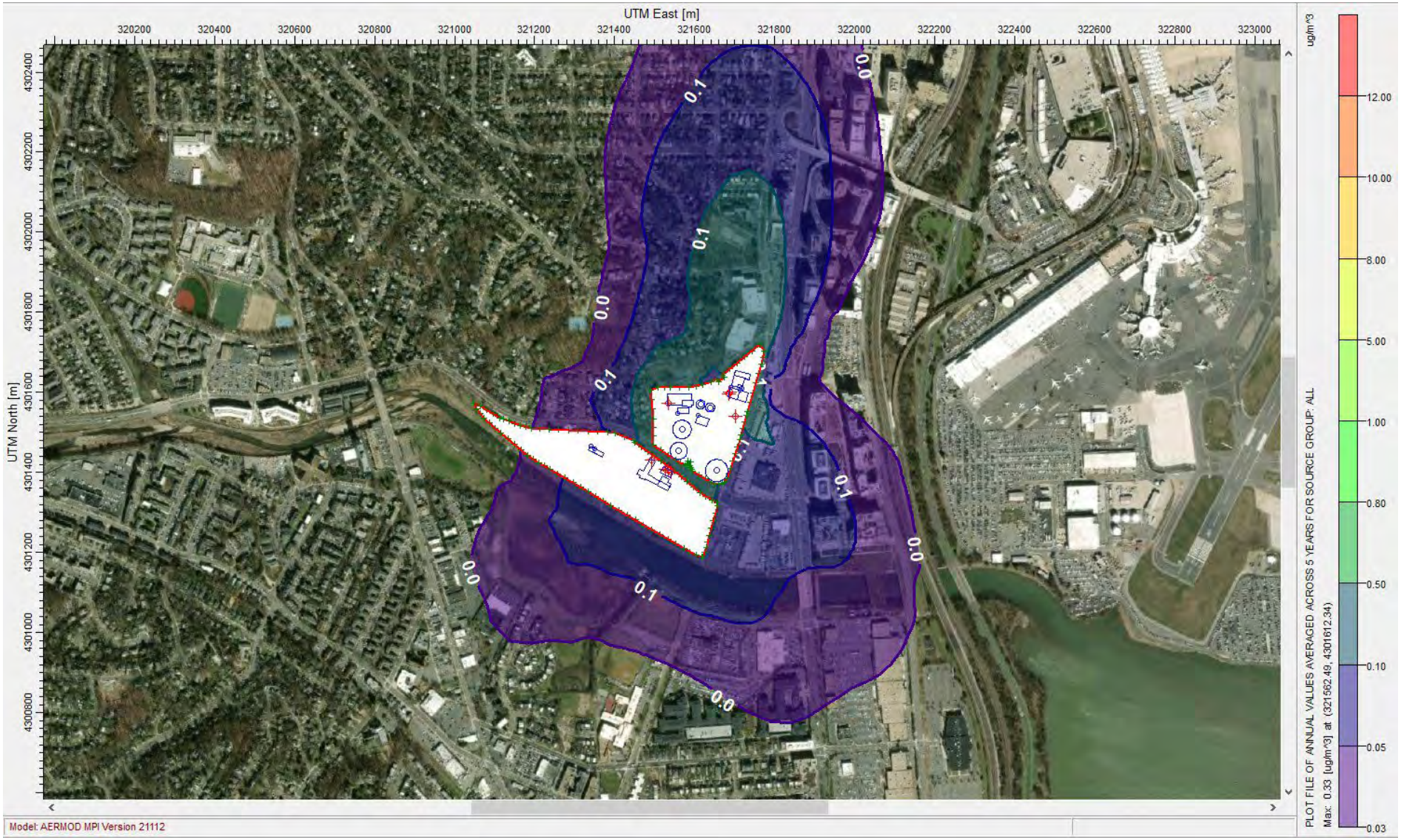
Iteration 1 – Decommission Existing Dewatering Building

$PM_{2.5}$ 24HR – All Sources



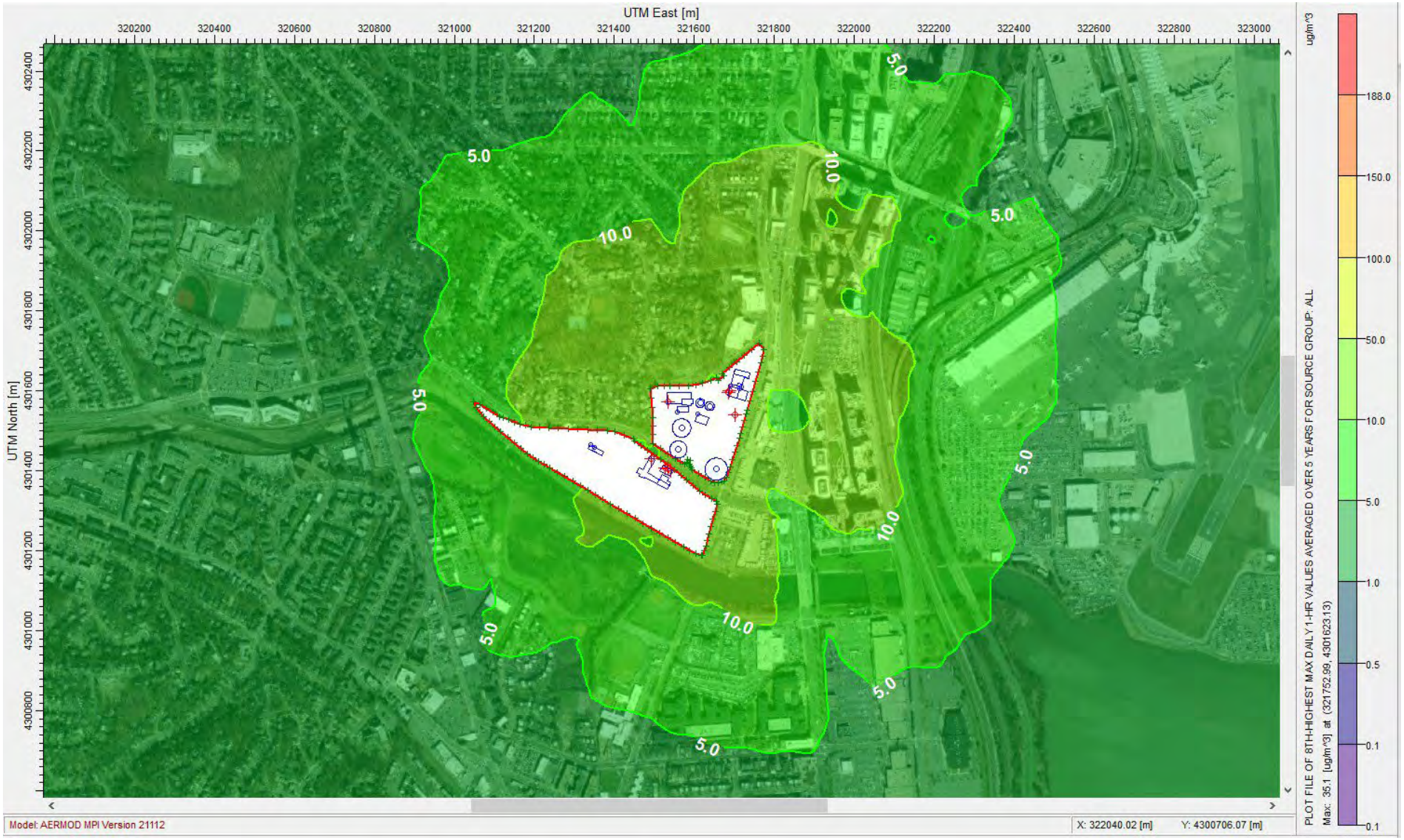
Iteration 1 – Decommission Existing Dewatering Building

$PM_{2.5}$ Annual – All Sources



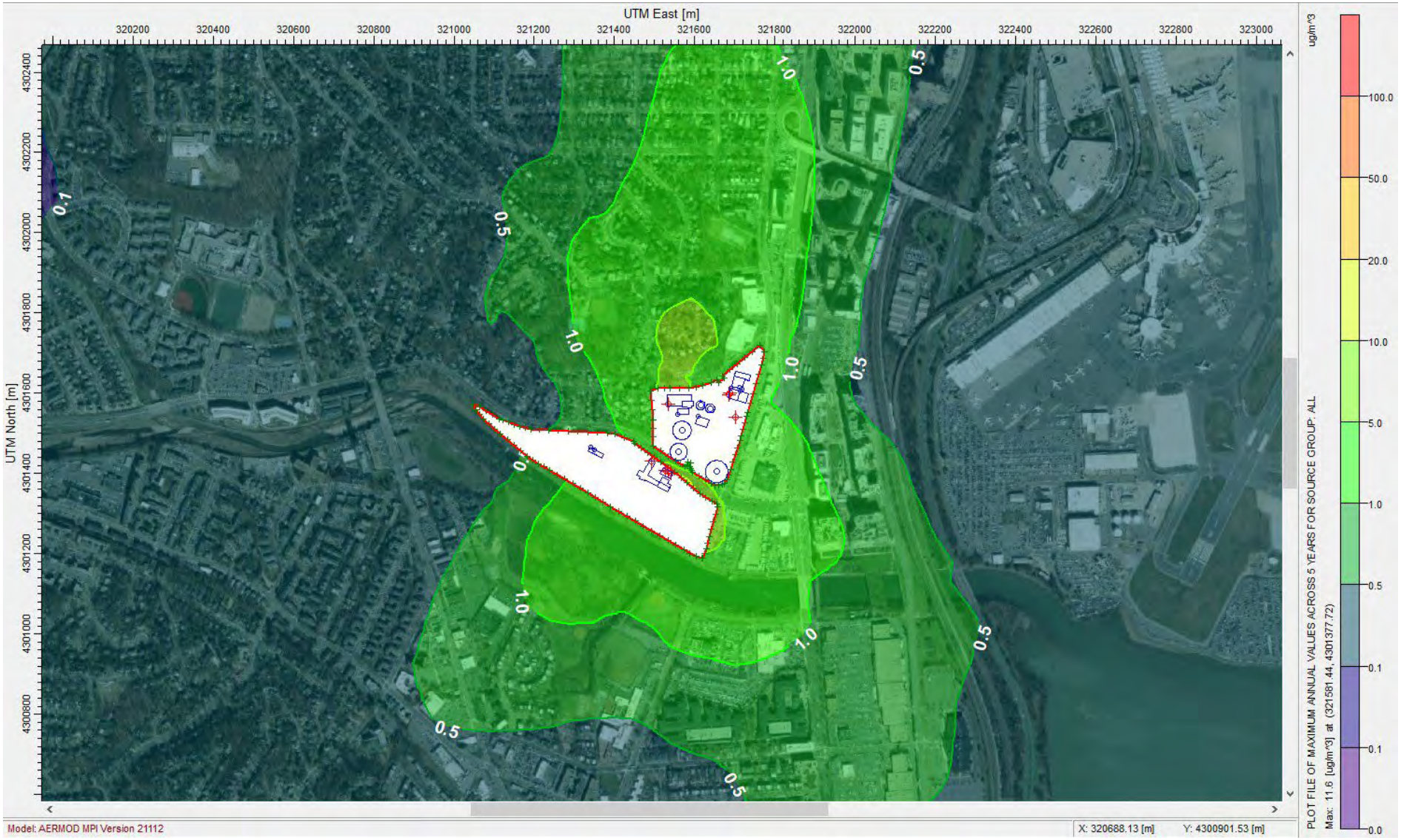
Iteration 1 – Decommission Existing Dewatering Building

NO_2 1HR – All Sources



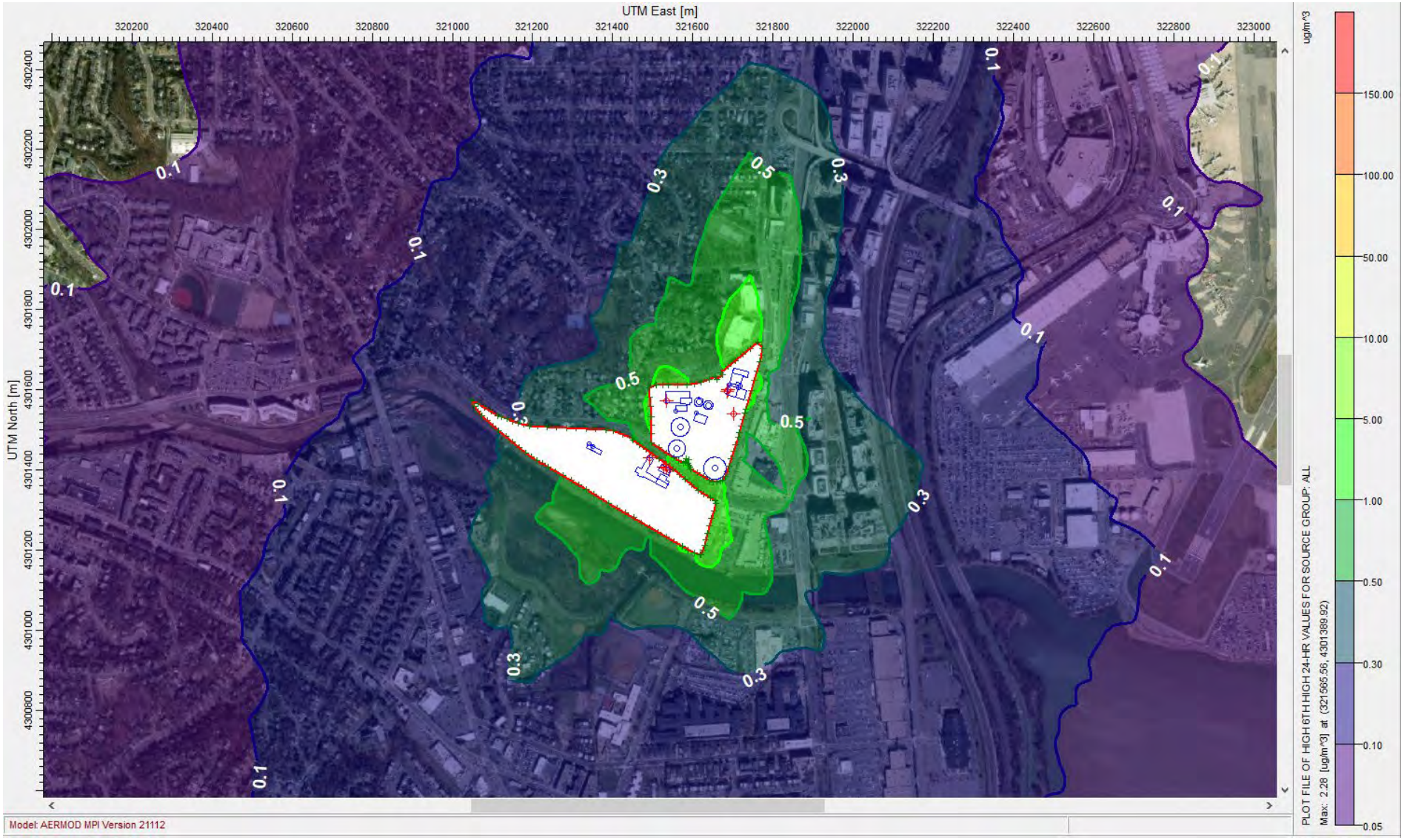
Iteration 1 – Decommission Existing Dewatering Building

NO_2 Annual – All Sources



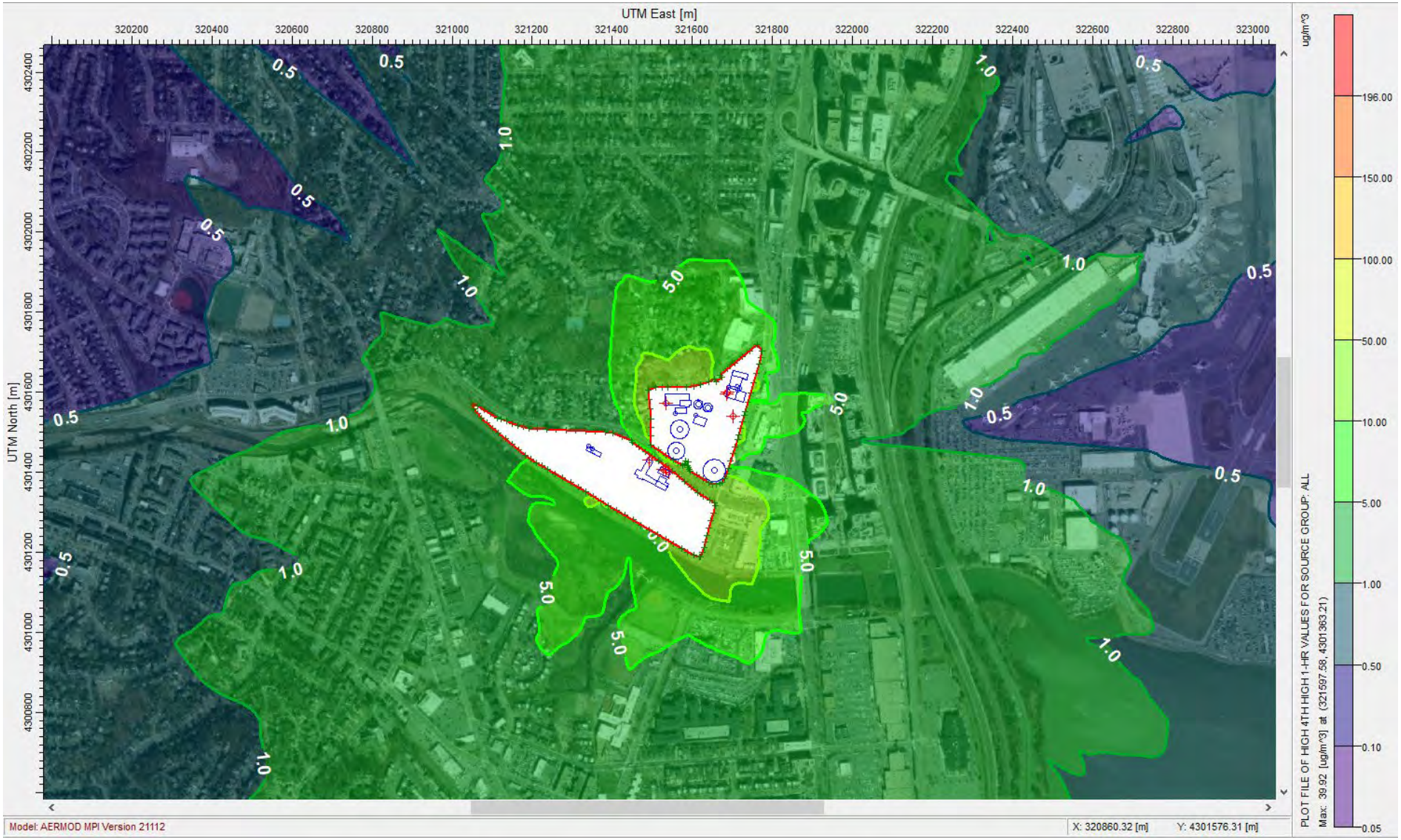
Iteration 1 – Decommission Existing Dewatering Building

PM_{10} 24HR – All Sources



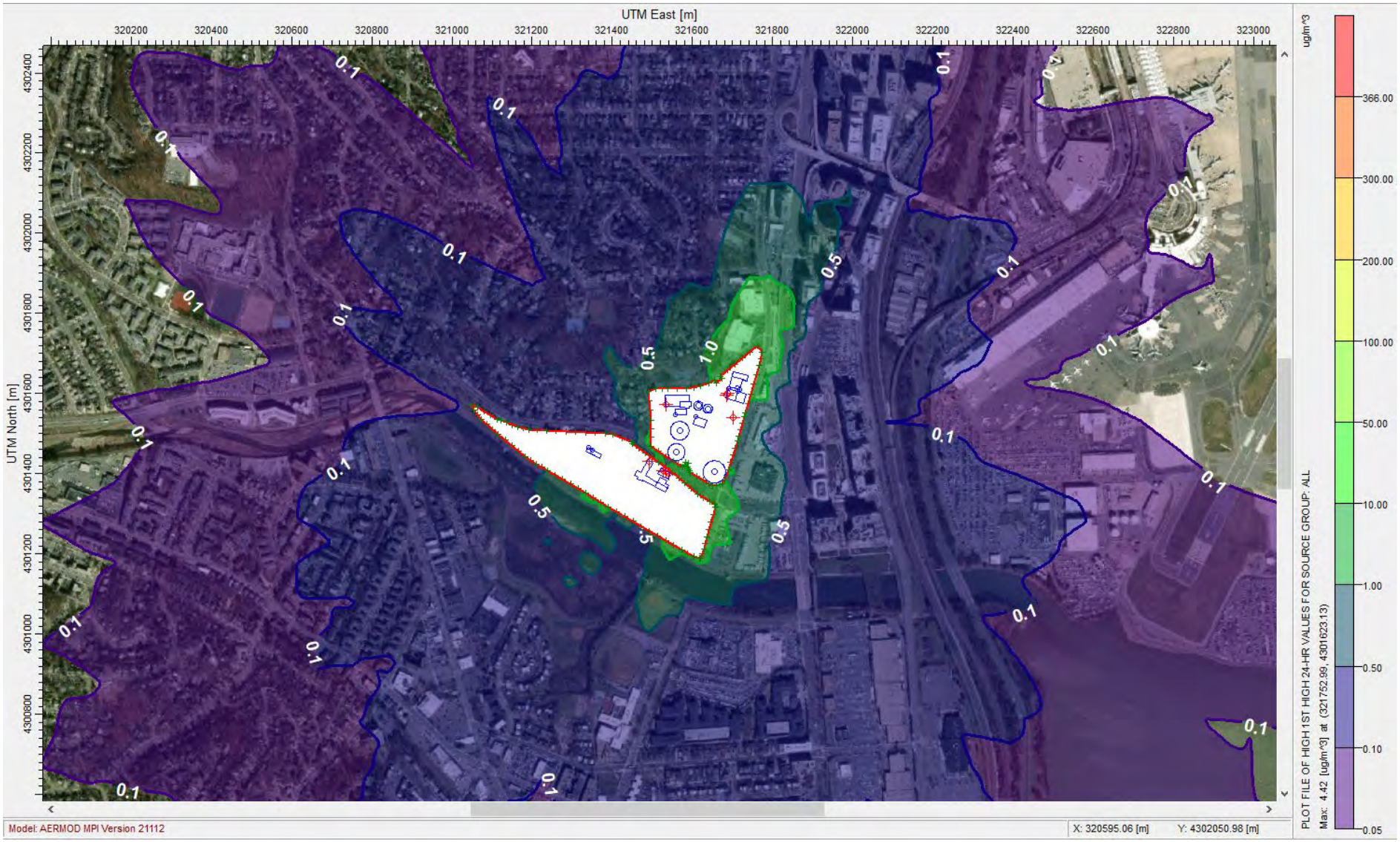
Iteration 1 – Decommission Existing Dewatering Building

SO_2 1HR – All Sources



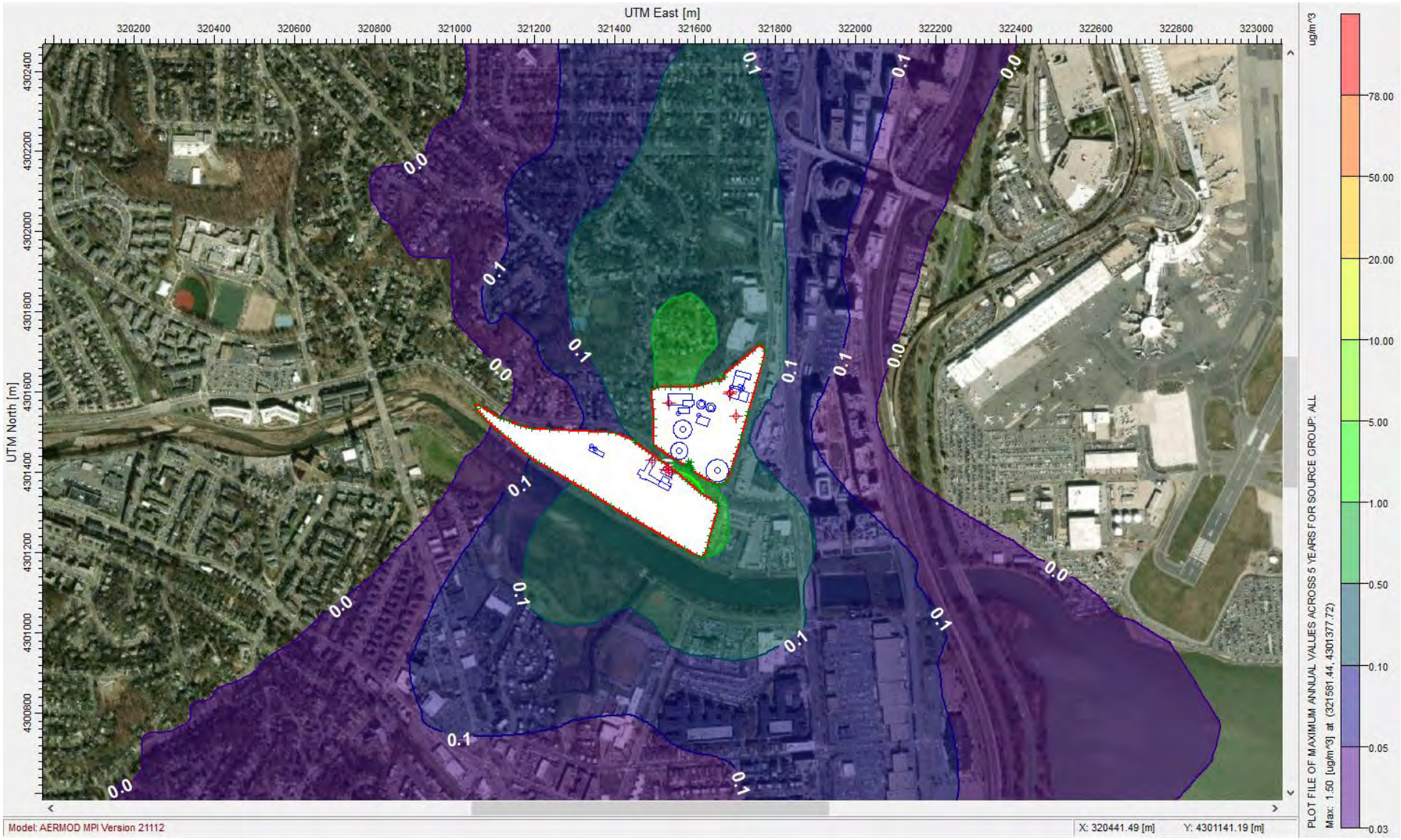
Iteration 1 – Decommission Existing Dewatering Building

SO_2 24HR – All Sources



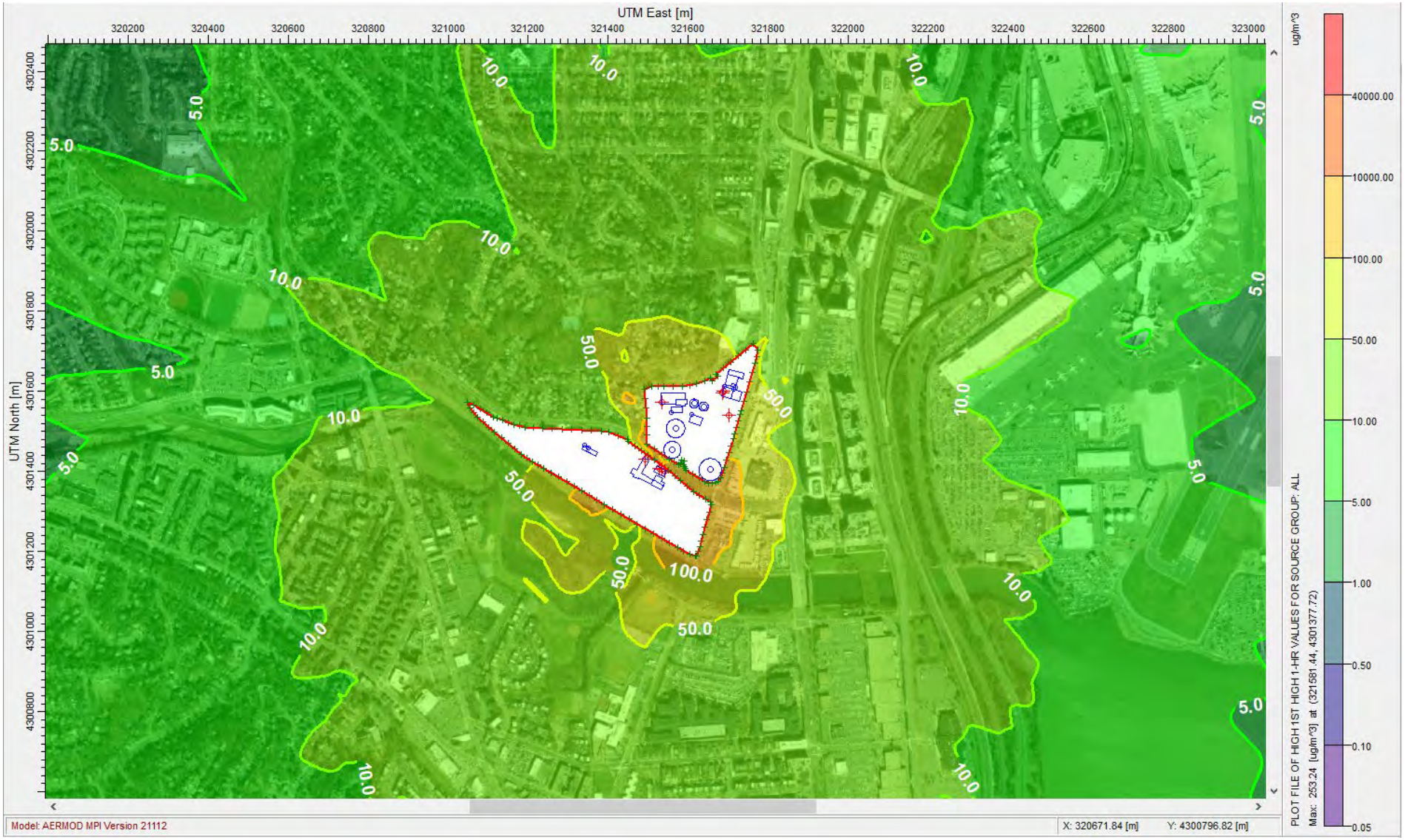
Iteration 1 – Decommission Existing Dewatering Building

SO_2 Annual – All Sources



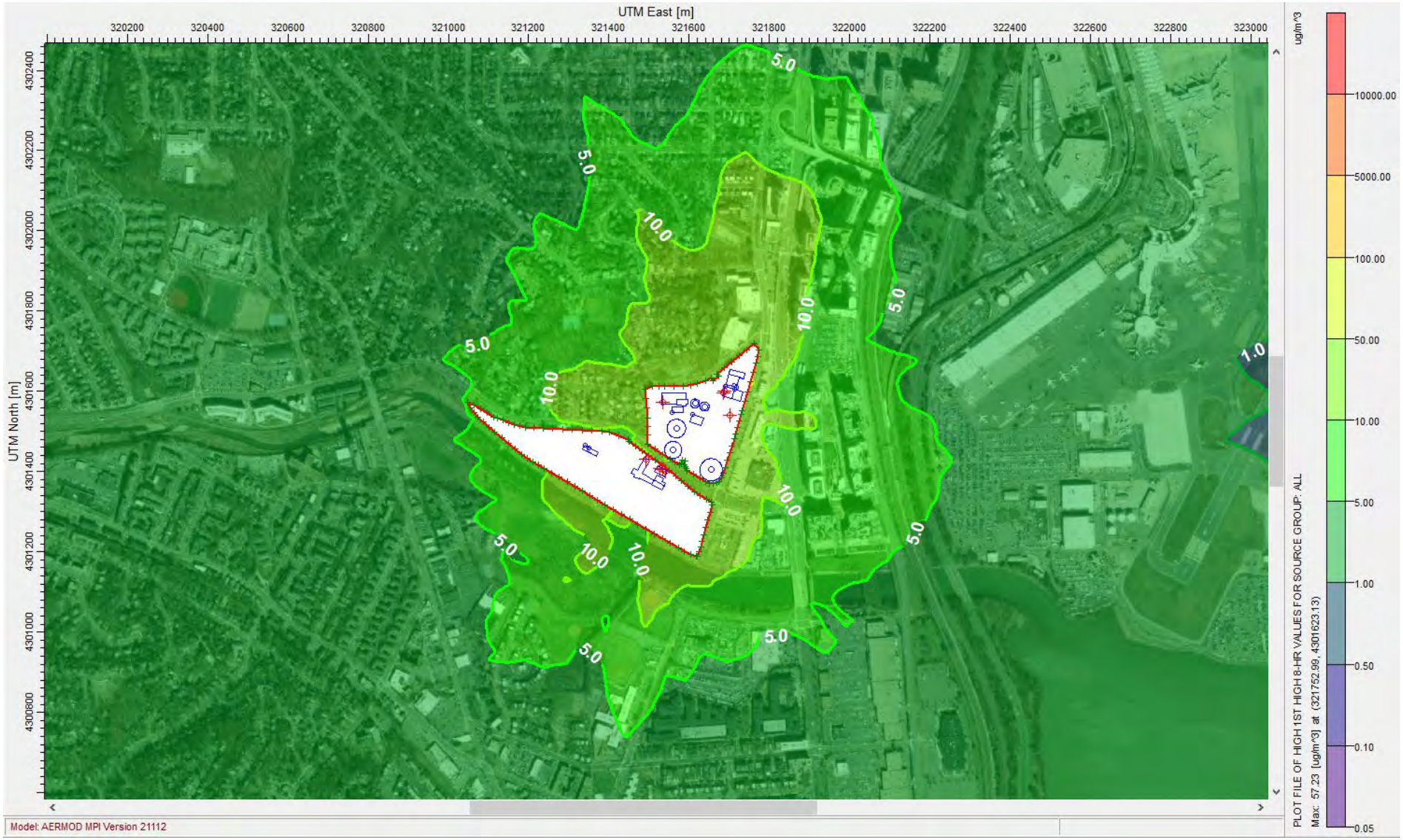
Iteration 1 – Decommission Existing Dewatering Building

CO 1HR – All Sources



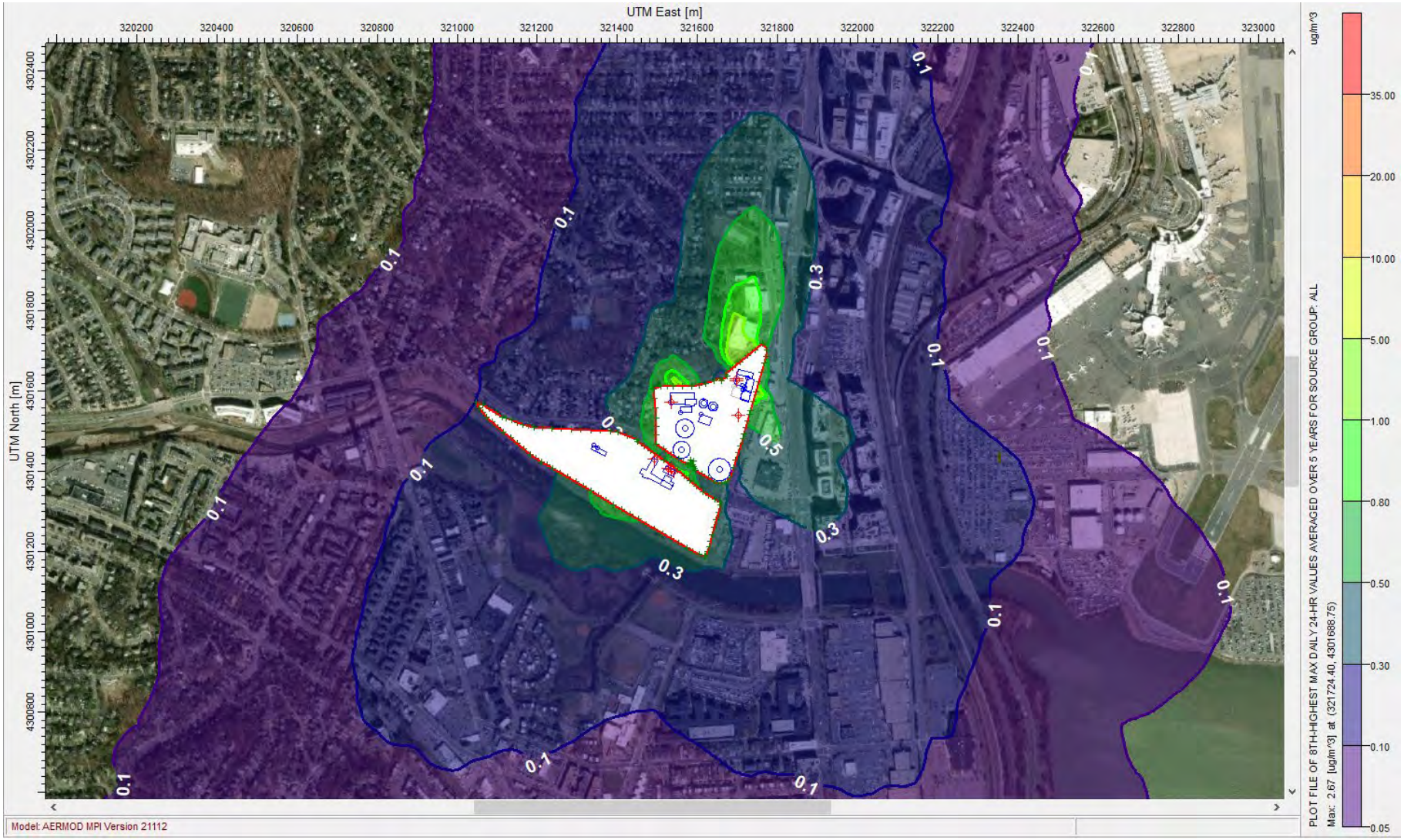
Iteration 1 – Decommission Existing Dewatering Building

CO 8HR – All Sources



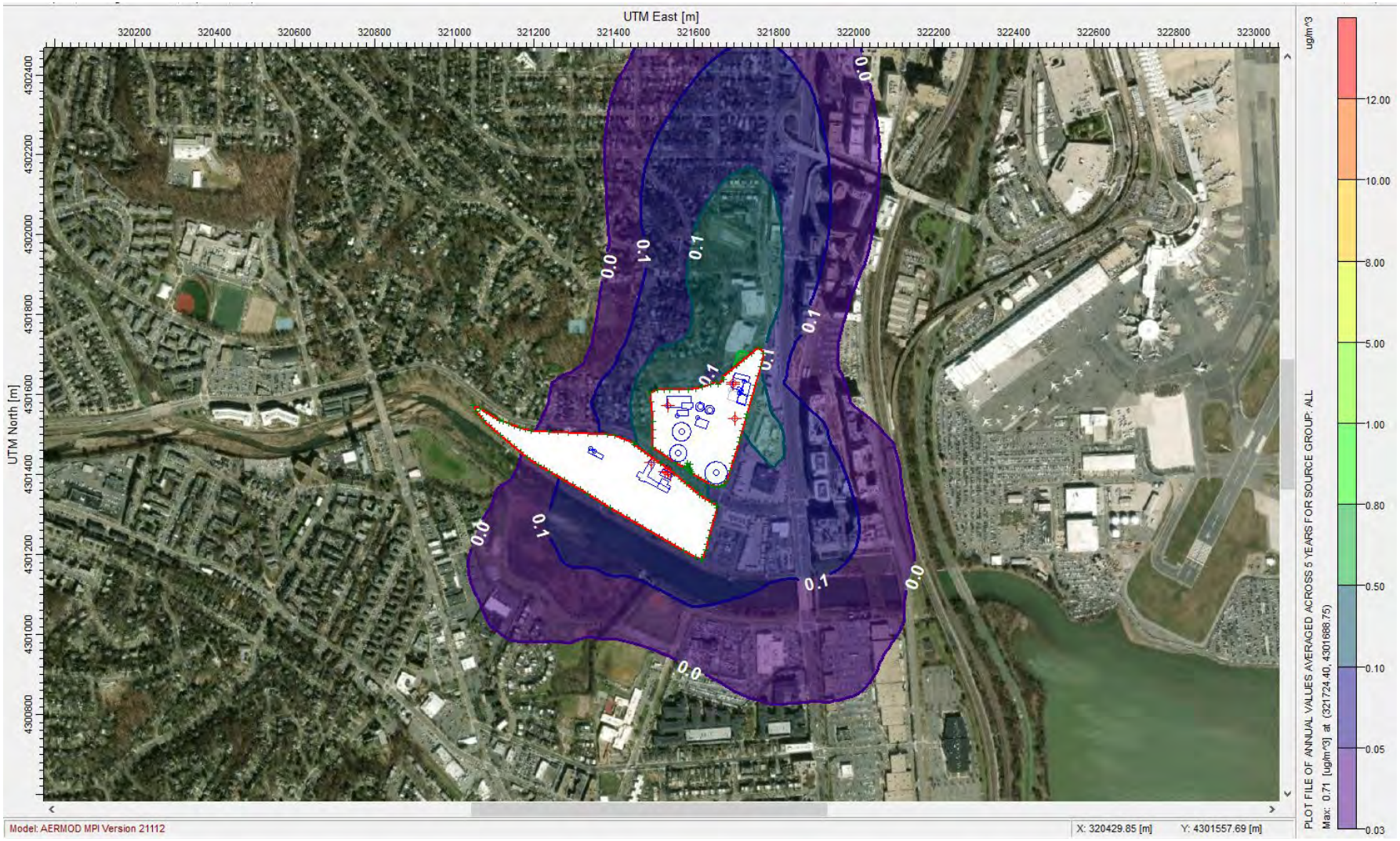
Iteration 2 – Renovate Existing Dewatering Building

$PM_{2.5}$ 24HR – All Sources



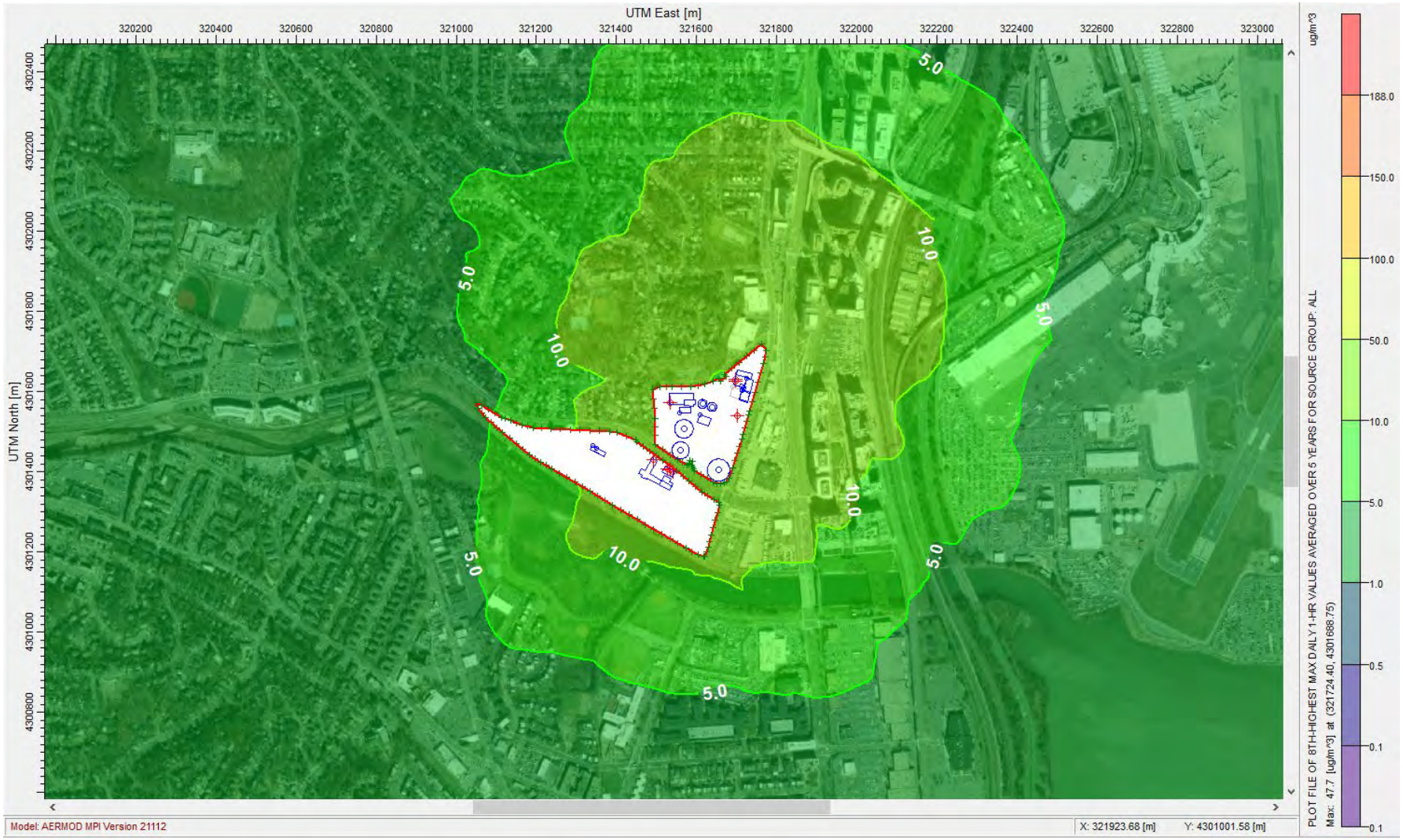
Iteration 2 – Renovate Existing Dewatering Building

$PM_{2.5}$ Annual – All Sources



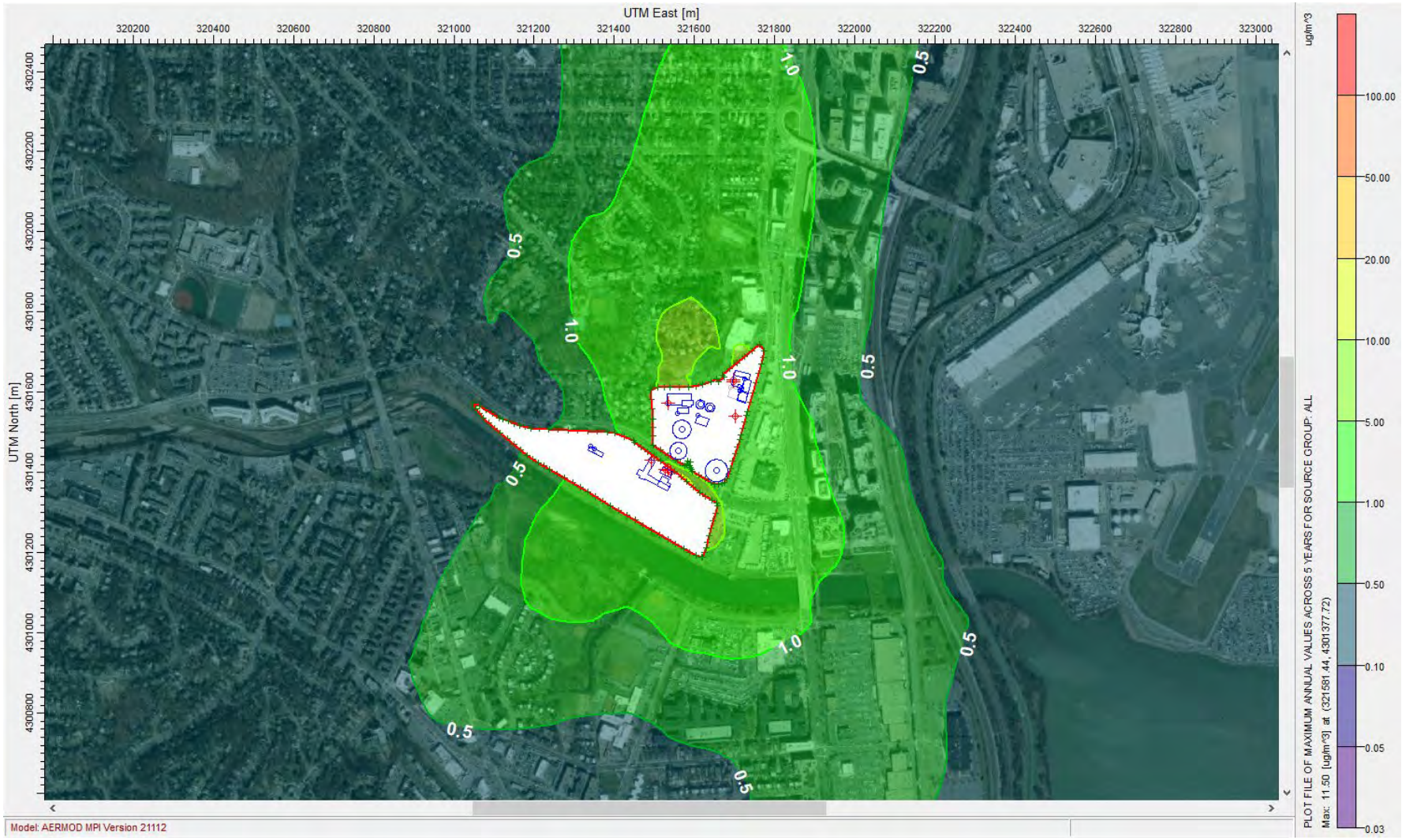
Iteration 2 – Renovate Existing Dewatering Building

NO_2 1HR – All Sources



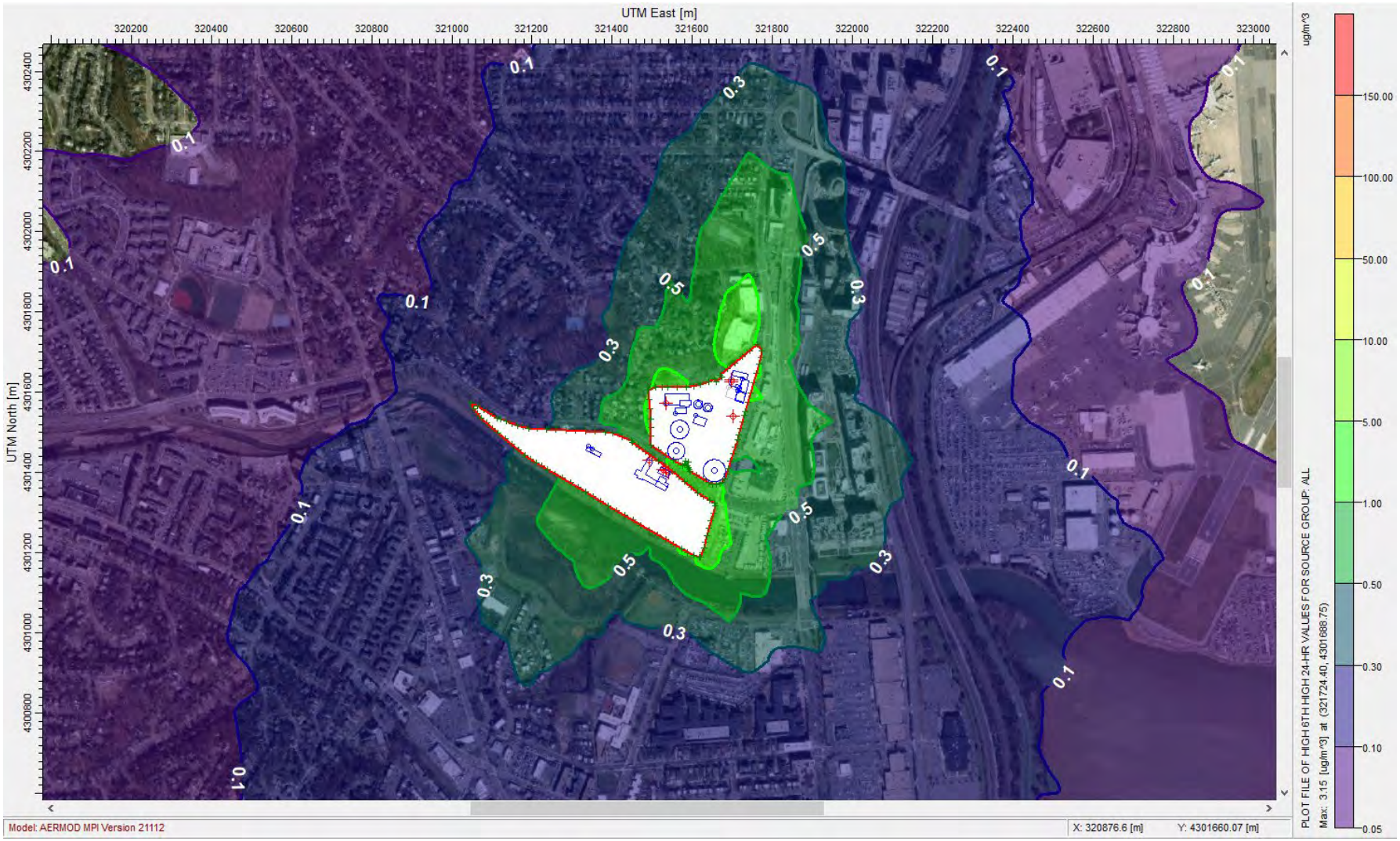
Iteration 2 – Renovate Existing Dewatering Building

NO_2 Annual – All Sources



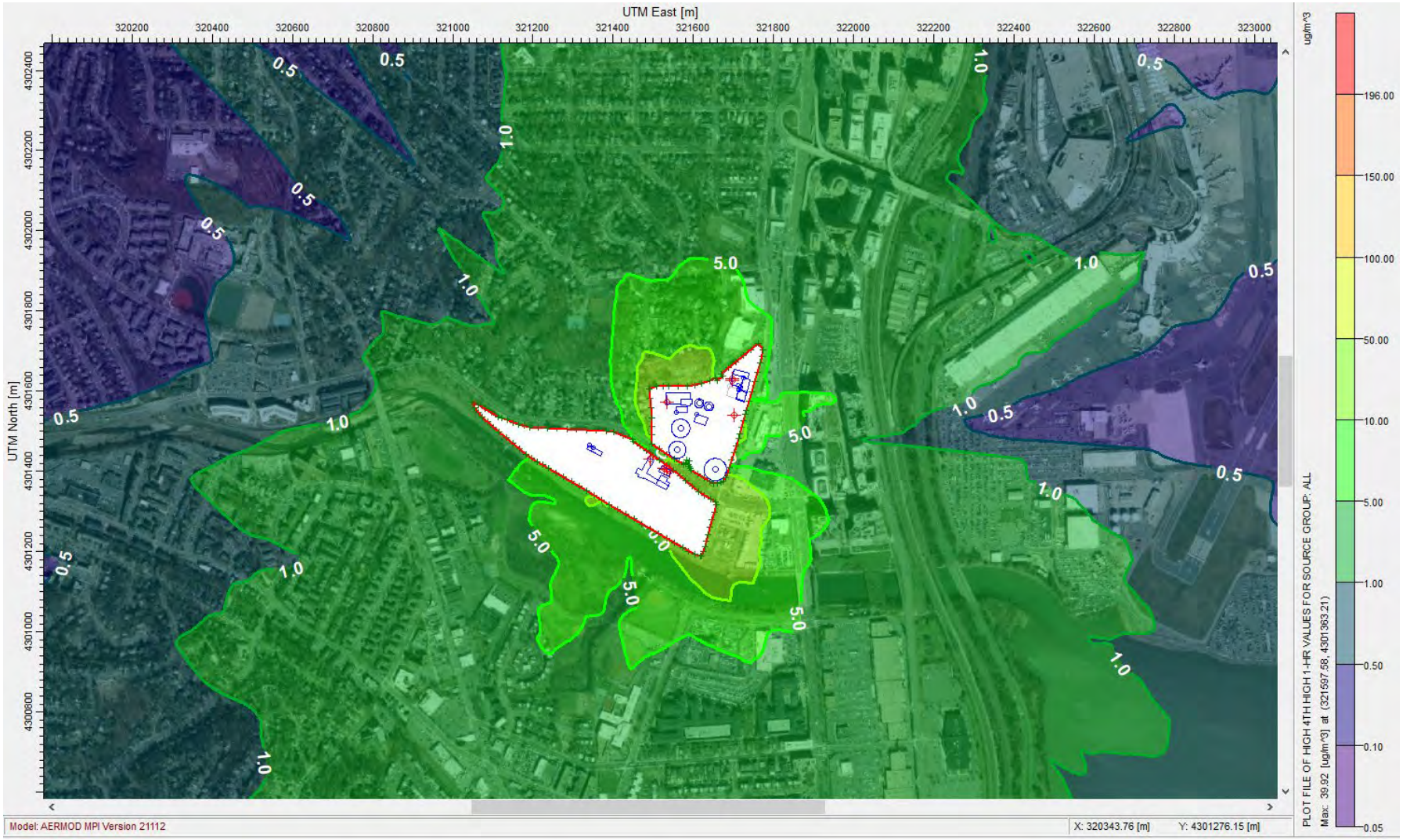
Iteration 2 – Renovate Existing Dewatering Building

PM_{10} 24HR – All Sources



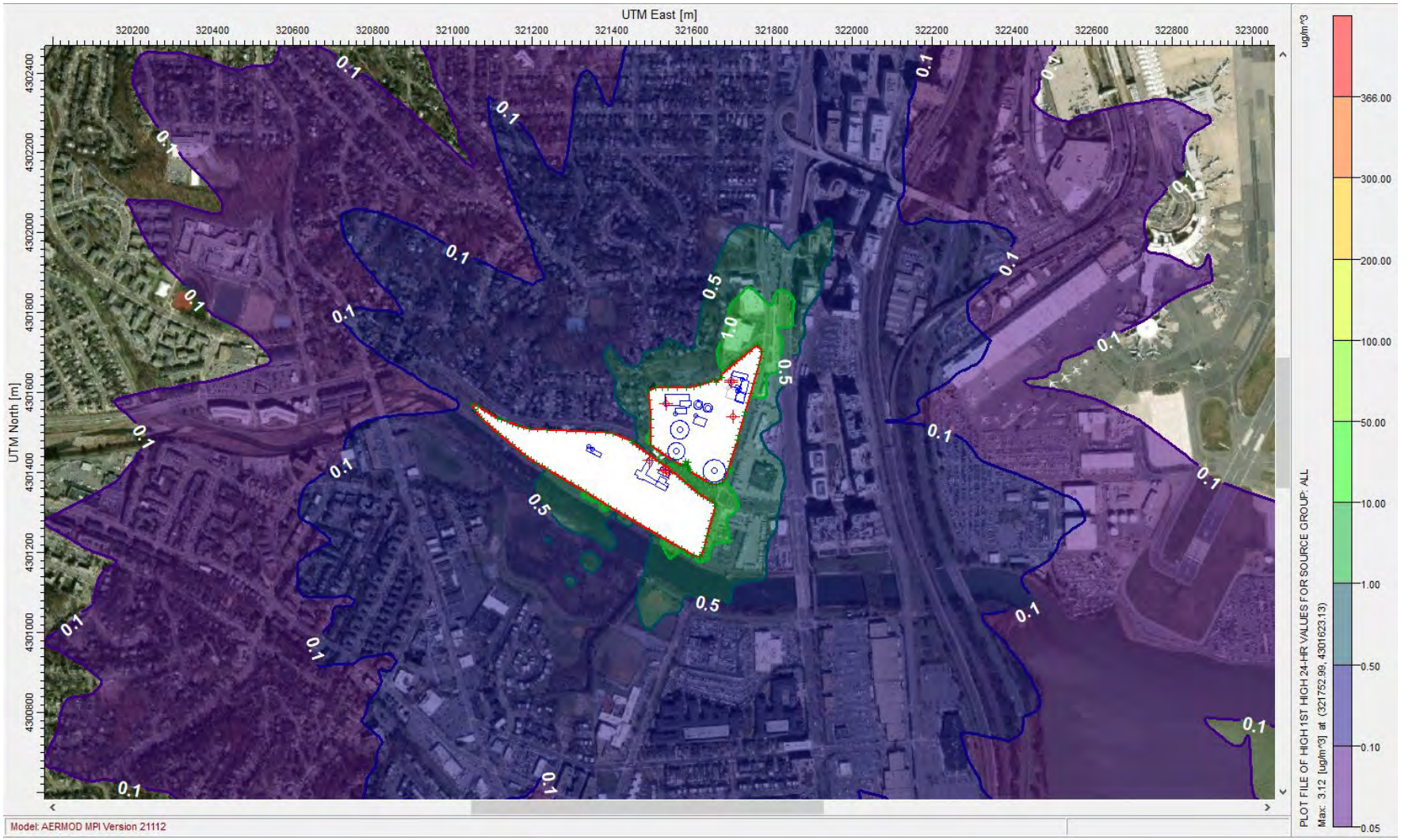
Iteration 2 – Renovate Existing Dewatering Building

SO_2 1HR – All Sources



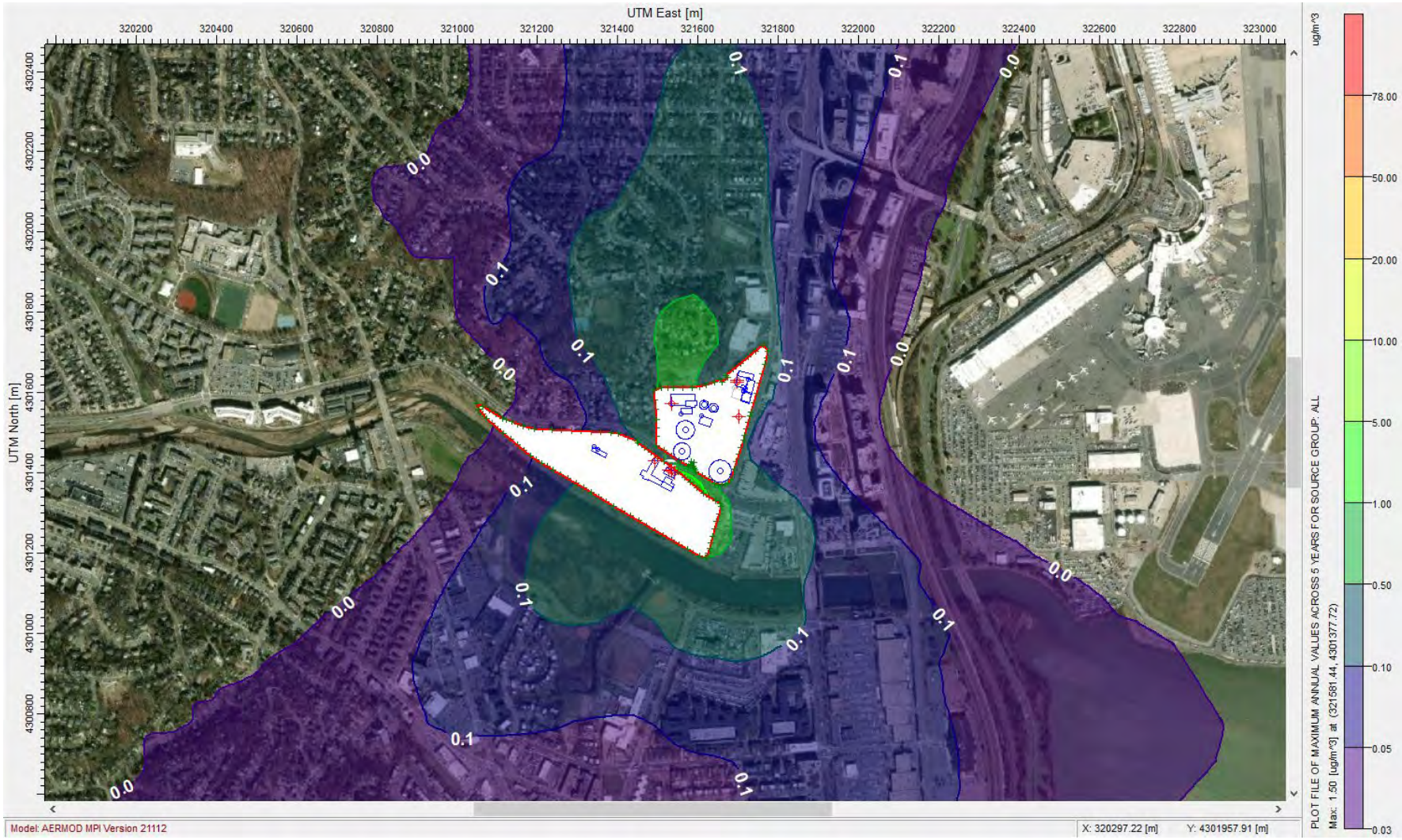
Iteration 2 – Renovate Existing Dewatering Building

SO_2 24HR – All Sources



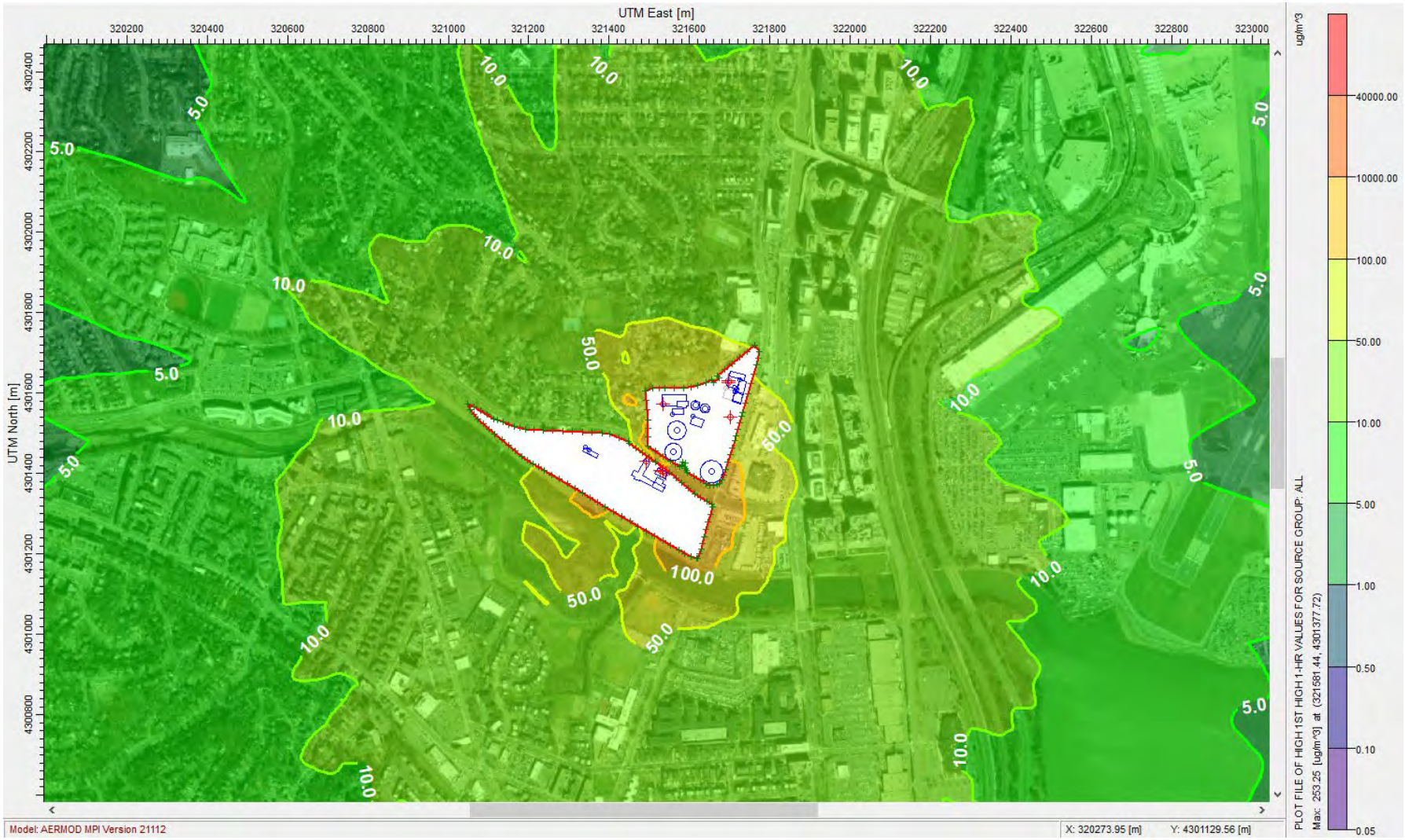
Iteration 2 – Renovate Existing Dewatering Building

SO_2 Annual – All Sources



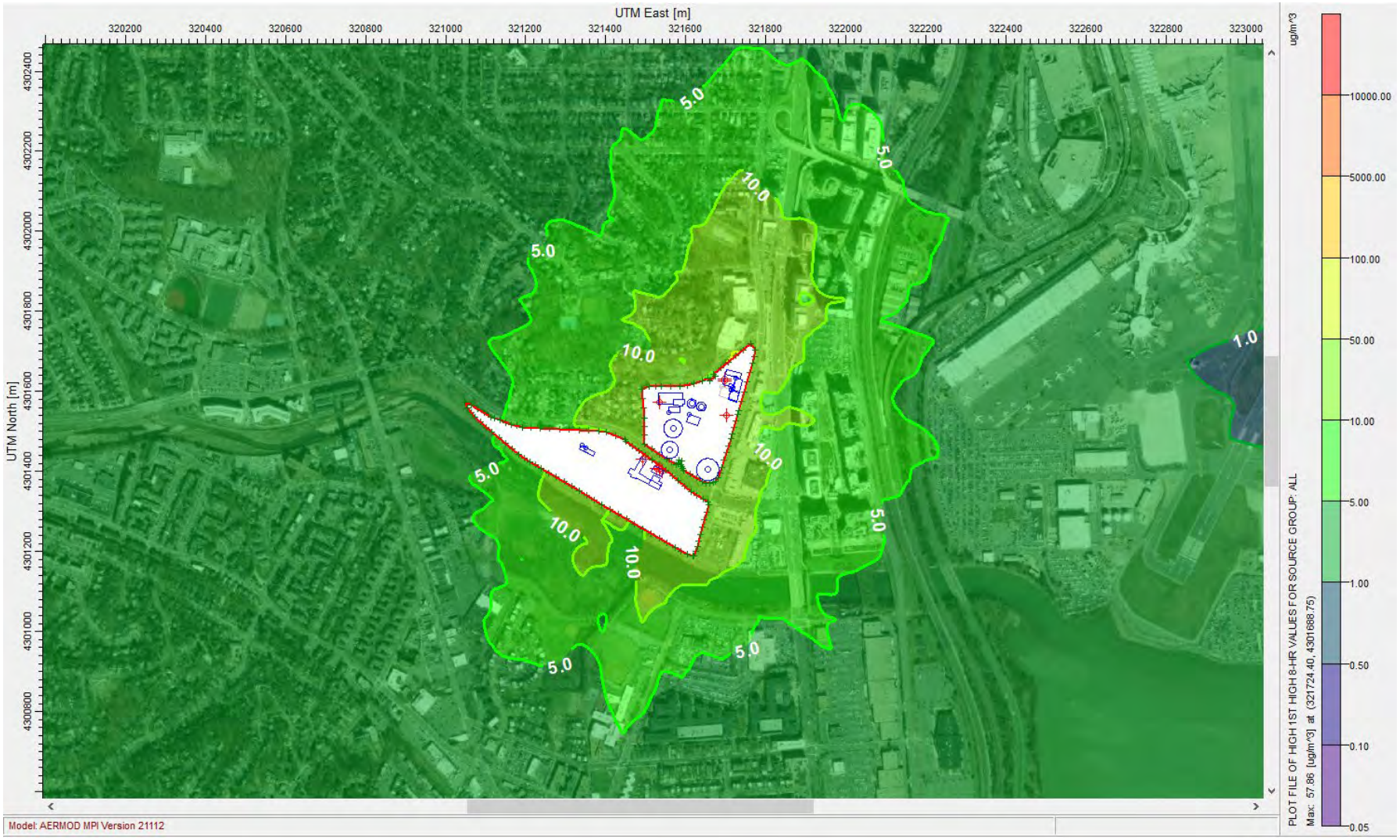
Iteration 2 – Renovate Existing Dewatering Building

CO 1HR – All Sources



Iteration 2 – Renovate Existing Dewatering Building

CO 8HR – All Sources



Appendix C Preliminary Screening of Alternative Gas Utilization Scenarios

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1.0 Introduction

HDR Engineering, Inc.'s (HDR's) analysis began with a preliminary screening of emissions and impacts from various potential biogas utilization alternatives. To develop the alternatives for evaluation, the following potential uses were considered feasible, either alone or in combination:

- On-site use for process and building heating
- Producing electrical power and recovering wasted heat (combined heat and power [CHP])
- Production of renewable natural gas (RNG) for use as vehicle fuel

Use of either internal-combustion engines or gas turbines was identified as viable for the alternatives including CHP.

Based on these potential biogas uses the following seven major alternatives were developed (note that all alternatives include a flare):

- **Alternative 1:** process and building heating
- **Alternative 2A:** CHP with engines, boilers
- **Alternative 2B:** CHP with gas turbine, boilers
- **Alternative 3:** RNG, boilers
- **Alternative 4A:** RNG, CHP with engines, boilers
- **Alternative 4B:** RNG, CHP with gas turbine, boilers

Between the five major alternatives, four main equipment types were identified as sources of emissions: CHP turbines, boilers, CHP engines, and waste gas flaring. Alternative 1 was the baseline and was not considered as a viable option for implementation. Alternatives 4A/B were eliminated from consideration because of cost and complexity. Of the remaining alternatives, CHP (2A/B) had the most emissions. For the CHP alternative, engines were determined to be a worst-case selection for equipment based on levels of emissions and dispersion modeling characteristics. Typically, engines generate equal or higher rates of pollutants, on a pounds (lb) per megawatt (MW) basis, than turbines and have a lower exhaust temperature, which results in worse dispersion characteristics. Therefore, turbines were not specifically evaluated in this initial screening because impacts are anticipated to be lower than those of engines.

2.0 Proposed Project Equipment

Potential emissions were evaluated from different categories of proposed equipment based on anticipated vendor guarantees and U.S. Environmental Protection Agency (EPA) default emission factors obtained from AP-42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources.

2.1 Potential to Emit

The emissions listed in Table C-1 below represent the annual total in tons per year of each major criterion pollutant that is regulated by the Clean Air Act (CAA). Each unit is represented as operating at maximum load capacity for all hours of the year with no limitations (commonly referred to as the "potential to emit" [PTE]). This is not intended to be reflective of actual levels of operations and emissions, but accounts for a worst-case scenario based on equipment design. In reality, these units

would be limited in hours of operation based on available biogas and/or Arlington Water Pollution Control Plant (WPCP) needs.

Table C-1. Project Potential to Emit (tons per year)

Pollutant	Proposed Equipment				
	CHP Engine 1	CHP Engine 2	Boiler 1	Boiler 2	Flare
PM	1.70	1.70	0.12	0.12	1.23
PM_{10}	1.70	1.70	0.48	0.48	1.23
$PM_{2.5}$	1.70	1.70	0.48	0.48	1.23
NO_x	2.27	2.27	6.31	6.31	5.18
SO_2	0.14	0.14	0.04	0.04	3.3
CO	28.4	28.4	5.30	5.30	22.9
VOC	6.5	6.5	0.35	0.35	1.59
CO_2e	4,143	4,143	7,549	7,549	9,171
Total hazardous air pollutants (HAP)	1.1848	1.1848	0.1191	0.1191	0.2480
Total reduced sulfur (TRS) (including H_2S)	0.002	0.002	0.00005	0.00005	0.04

Post-project WPCP-wide emissions were calculated for both of the identified alternatives discussed above. Alternatives 2A and 2B would provide CHP via either engines or turbines operating on site, and of those two equipment types, engines are the larger source of emissions and impacts. Alternatives 2A, 2B, and 3 would all use natural gas-fired boilers as part of the solids treatment process, with a flare to handle any excess waste gas for safety and control of the biogas system.

From an air permitting standpoint, the CHP engines would push the carbon monoxide (CO) emissions for the WPCP above the CAA Title V major source threshold, which would trigger additional regulatory review and potentially a more restrictive air permit for WPCP operations. Alternately, operational limits could be developed to keep the WPCP's CO potential to emit below the major source threshold.

Table C-2. Post-Project WPCP Potential to Emit (tons per year)

Pollutant	Existing Facility Minus Existing DWB [a]	Project Emissions: CHP Engines (Alternative 2A)	Project Emissions: RNG Production (Alternative 3)	Post Project Total (Alternative 2A)	Post Project Total (Alternative 3)	Title V Major Source Threshold
$PM/PM_{10}/PM_{2.5}$	7.8	5.6	2.2	13.4	10.0	100
NO_x	24.3	22.3	17.8	46.6	42.1	100
SO_2	6.1	3.7	3.4	9.8	9.5	100
CO	31.7	90.2	33.5	**121.9**[c]	65.2	100
VOC	4.0	1.6	2.3	19.4	6.3	50 [b]
CO_2e	61,268	32,556	24,269	93,824	85,537	100,000

a. Values reflect removal of the dewatering building (DWB) and associated boilers.
b. Per the 9 VAC5-80-2010.C definition of major stationary source for facilities located in the Ozone Transport Region. The applicability of these thresholds will be verified with VDEQ as part of the permit application process.
c. This value exceeds the Title V major source permitting threshold of 100 tons per year.

3.0 Initial Dispersion Modeling

This section describes initial dispersion modeling analyses that were performed to help characterize the impact of WPCP layout on ambient air quality impacts.

3.1 Proposed Layouts

Differences in the potential gas utilization alternatives also led to development of multiple WPCP layout concepts. Two preliminary options included reuse of the existing dewatering building (DWB), or demolition of dewatering and replacing the building with new digesters and a new central digester building. Those two layouts are shown in Figure C-1 and Figure C-2.

Figure C-1. Preliminary Design Option 1

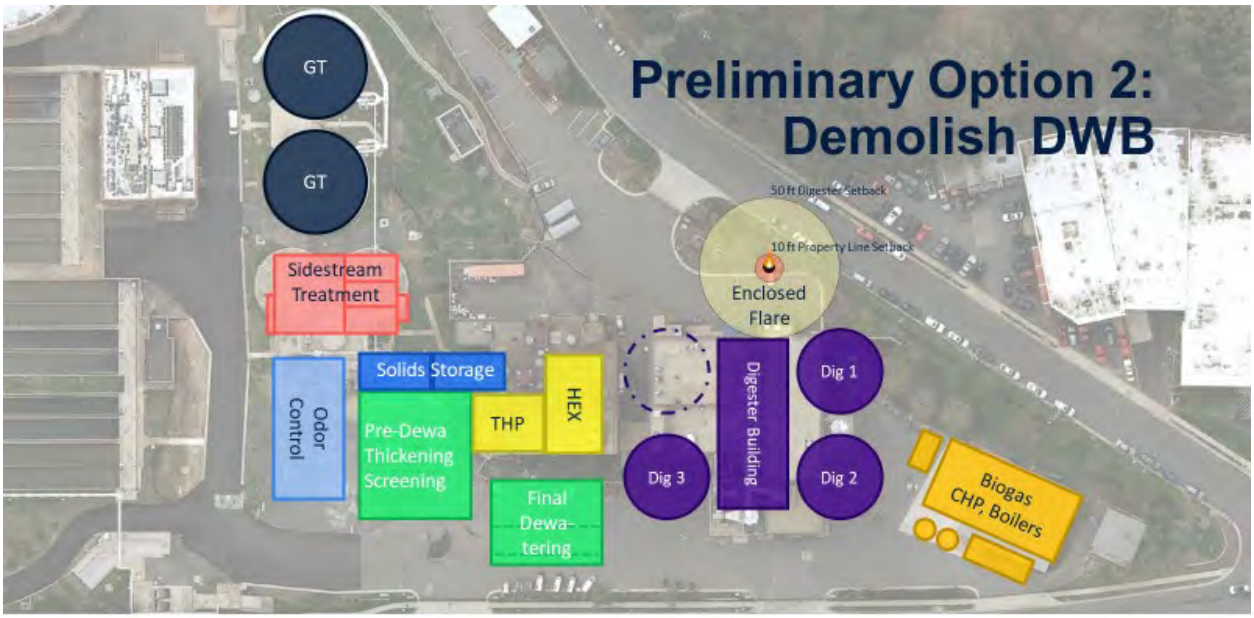

Figure C-2. Preliminary Design Option 2

For either option, all emission units (aside from the flare) would be located at the far northern side of the WPCP in a power block structure that would be roughly 20 feet tall.

3.2 Worst-Case Pollutant Analysis

To help narrow down the scope of the modeling analysis, a "first cut" dispersion analysis was performed with worst-case assumptions. All proposed units were modeled as operating simultaneously, at maximum capacity (PTE), and were located in the northern corner of the WPCP with the lowest expected stack heights.

For all modeled pollutants except nitrite (NO_2), the proposed engines would be a larger source of emissions than the proposed boilers. For NO_2, the boilers would be higher based on the lack of specific nitrogen oxide (NO_x) controls such as low NO_x burners, ultra-low NO_x burners, or selective catalytic reduction (SCR). Emissions from the proposed engines were assumed to have SCR systems installed to provide a 90 percent control efficiency, as described in New Source Performance Standards (NSPS) Subpart JJJJ emissions limits. Even with the overly conservative assumptions outlined above, only one pollutant had modeled impacts that were significant when compared with the relevant ambient air quality standards: particulate matter with a diameter of 2.5 microns or less ($PM_{2.5}$). For the remainder of this analysis, $PM_{2.5}$ is the pollutant of interest, with the assumption that any design changes made to improve dispersion of $PM_{2.5}$ would also improve dispersion of all other pollutants.

3.3 Building Downwash Investigation

Prevailing winds at the WPCP are from the south, creating a large downwash cavity on the north side of the WPCP as the wind comes across the tall existing dewatering structures (or proposed digester structures). Building downwash can increase ground-level concentrations of pollutants that become entrained in the resultant eddy as shown in Figure C-3 below.

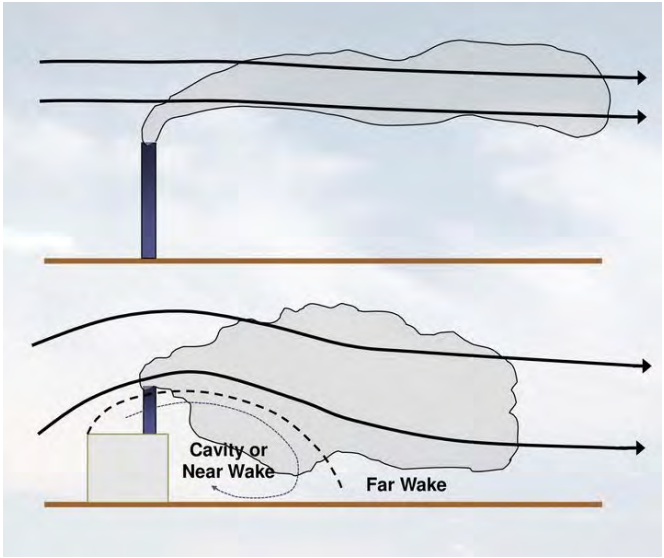

Figure C-3. Building Downwash Cavity

In each of the proposed layouts, the power block building is sited on the northern side of the WPCP, which would be affected by this downwash cavity. To illustrate the differences in impacts caused by building downwash, an alternate location for the power block structure was modeled farther to the south of the digester structures, which represent a worst-case scenario as they are larger than the existing DWB. Comparisons were done for emissions of $PM_{2.5}$ as the pollutant of interest. Figure C-4 and Figure C-5 show these two proposed configurations of equipment and the comparative ambient air impacts from each, with all other modeled parameters remaining equal. Because of differences in $PM_{2.5}$ emission rates, and exhaust stack characteristics, results from each major equipment type (engines or boilers) are presented separately. Because of the prevailing wind from the south (left sides of Figure C-4 and Figure C-5), pollutant concentrations increase when emission sources are placed at the north side of the WPCP (right sides of Figure C-4 and Figure C-5) and are better dispersed (i.e., result in lower impacts) when the power block structure is moved upwind of the main dewatering facilities. This spatial change improves dispersion and lessens air quality impacts to the surrounding area without relying on operational constraints or added control technologies.

These figures also demonstrate the difference in magnitude between emissions generated by the proposed engines and emissions generated by the proposed boilers. For all modeled pollutants except NO_2, the proposed engines are a larger source of emissions than the proposed boilers.

Figure C-4. Building Downwash Comparison: Engines Only

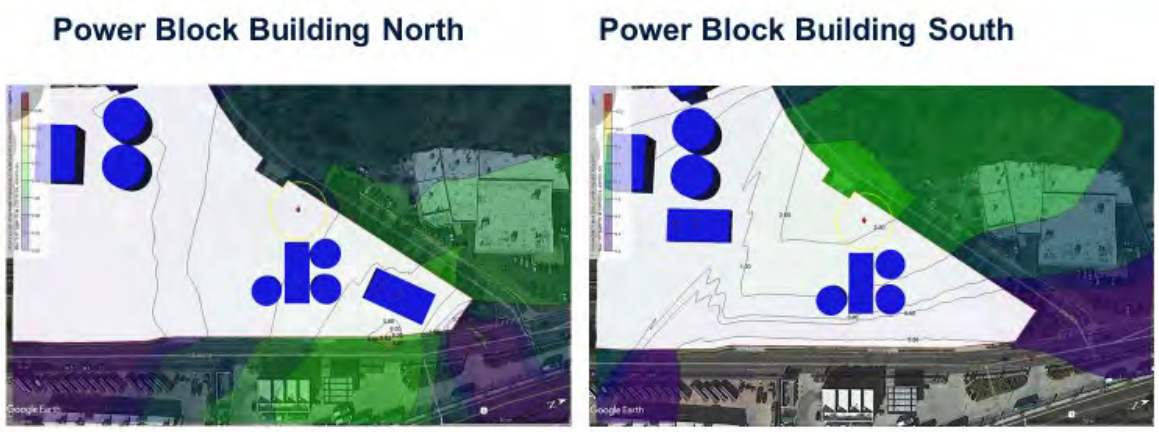

Figure C-5. Building Downwash Comparison: Boilers Only

Overall, the preferred location for the power block structure is central to the WPCP, rather than the northern corner of the WPCP. It should also be noted that for $PM_{2.5}$, the CHP engines are more significant sources of modeled impacts than the boilers.

3.4 Iterative Modeling Analysis

Focusing on $PM_{2.5}$ as the pollutant of interest, four modeling iterations were performed to illustrate the differences in impacts to ambient air quality as driven by changes to buildings, location of emission units, and changes to stack heights.

3.4.1 Spatial Layouts and Stack Parameters

Iterations 1 through 4 had the model layout selections shown in Table C-3.

Table C-3. Modeling Iteration Descriptions

Iteration	WPCP Design Option	Location of Power Block Building	Stack Heights of Boilers/Engines
1	Existing DWB	North	30 feet (10 feet above building rooftop)
2	Existing DWB	North	50 feet (30 feet above building rooftop)
3	Demolish DWB/build digesters	North	30 feet (10 feet above building rooftop)
4	Existing DWB	South	30 feet (10 feet above building rooftop)

For all iterations, the proposed waste gas flare was located near the northern WPCP fence line (west of the DWB) with a stack height of 25 feet above ground level. In all iterations, the power block building that houses both the engines and boilers was assumed to be 20 feet tall.

3.4.2 Operating Scenarios

Based on design for gas utilization scenarios, the boilers and engines would not typically be fired with fuel simultaneously, as heat from the engines would be recovered to create the steam necessary for THP. Similarly, the waste gas flare would only be operational with the boilers as there would be excess biogas generated that would need to be flared. The flare would not be necessary for the scenario including engines as all of the biogas would be utilized in the engines. In the iterative modeling analysis, these emission units were split by those operational scenarios:

- Only engines, each operating 8,760 hours per year
- Only boilers and flaring, each operating 8,760 hours per year

3.4.3 Background Concentrations

To help understand the existing air quality in the region, ambient air monitoring data were identified for $PM_{2.5}$ from nearby monitors in the EPA Air Quality Monitor Network. Concentrations were included from the most recent 3 years of data available from the monitor located at the intersection of S 18th and Hayes Streets in Arlington. For the 24-hour averaging period, a background concentration of 17.7 $\mu g/m^3$ of $PM_{2.5}$ was derived. For the annual averaging period, a background concentration of 7.3 $\mu g/m^3$ of $PM_{2.5}$ was derived.

3.4.4 Comparison with National Ambient Air Quality Standards

Modeled impacts from the project equipment were added to background concentrations for comparison with the National Ambient Air Quality Standards (NAAQS) to provide context for the impact of the evaluated gas utilization alternatives. Emissions were modeled at maximum PTE, operating for all hours of the year, with a period of 5 years of meteorological data. Results are presented in Table C-3 below. The maximum values reported below may or may not occur at the same receptor location or during the same 24-hour or annual period, so the individual source maximums should not be summed to estimate total impacts. Total modeled impacts from all units operating simultaneously are provided as a separate maximum in Table C-4 below.

Table C-4. Iterative Modeling Results: $PM_{2.5}$

	Iteration 1 - North of Existing DWB		Iteration 2 - North of Existing DWB		Iteration 3 - North of Proposed DWB/Digesters		Iteration 4 - South of Existing DWB	
	Stack heights at 30 feet; power building at 20 feet; flare at 25 feet (WORST-CASE LAYOUT)		Stack heights at 50 feet; power building at 20 feet; flare at 25 feet		Stack heights at 30 feet; power building at 20 feet; flare at 25 feet		Stack heights at 30 feet; power building at 20 feet; flare at 25 feet	
	24HR ug/m3	Annual ug/m3	24HR ug/m3	Annual ug/m3	24HR ug/m3	Annual ug/m3	24HR ug/m3	Annual ug/m3
FLARE	2.3	0.34	2.3	0.34	9.7	1.6	2.2	0.27
BOILERS	5.5	0.96	2.1	0.30	6.4	0.99	3.1	0.78
ENGINES	38	12	30	8.5	38	6.6	20	5.7
BOILERS + FLARE	5.5	0.98	2.6	0.44	9.8	1.8	3.1	0.8
ALL UNITS TOGETHER	41.9	12.7	30.6	8.8	41.9	7.6	23	6.4
BACKGROUND	17.7	7.3	17.7	7.3	17.7	7.3	17.7	7.3
TOTAL ENGINES	55.7	19.6	47.3	15.8	55.6	13.9	38	13
NAAQS	35	12	35	12	35	12	35	12
PERCENT OF STANDARD	159%	163%	135%	132%	159%	116%	108%	108%
TOTAL BOILERS + FLARE	23.1	8.3	20.3	7.8	27.5	9.1	20.7	8.1
NAAQS	35	12	35	12	35	12	35	12
PERCENT OF STANDARD	66%	69%	58%	65%	79%	76%	59%	68%

4.0 Conclusions

Based on iterative modeling analysis, the recommended location for the power block structure would be south of the DWB. The waste gas flare is not expected to have a significant impact on ambient air quality, especially considering that flaring would be far less than 8,760 hours per year. Design for CHP engines would need to be developed further to minimize impacts through enhanced dispersion techniques or limitation of operation if it remains a viable alternative. As discussed previously, impacts from turbines would likely be less than those from engines; however, the effect of moving the location of the power block structure may not be enough to reduce the emission impacts below the NAAQS for those units and would require further design and analysis.

Technical Memorandum No. 11

Date:	December 14, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Digestion Facilities Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the digestion facilities evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary solids (PS) and waste activated solids (WAS) thickening, dewatering, and Class B lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a Class A thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this digester evaluation is to assess and compare digester alternatives. The results of this evaluation will inform and validate a final decision on the digester type, configuration, and covers for the Facilities Plan.

1.2 Evaluation Approach

A suite of alternatives was developed for digester tank types, sizing, configuration, mixing systems, and digester covers. Conceptual footprints and costs were prepared for each alternative. Alternatives were presented and reviewed at several project workshops with the County. Workshop participants screened and selected a short list of preferred alternatives, as described in later sections of this technical memorandum (TM).

In this evaluation, the shortlisted alternatives are further evaluated and compared based on the following criteria:

- Site layout and space requirements
- Constructability
- Energy efficiency and electrical requirements
- Operations and maintenance (O&M) demands
- Operational flexibility
- Capital costs
- Net present value (capital plus O&M costs)
- History of installations at THP facilities

2.0 Summary of Facilities and Processing

The existing biosolids processes consist of thickening, dewatering, and lime stabilization. Gravity-thickened PS and dissolved air flotation-thickened secondary solids are blended in solids storage tanks and dewatered using centrifuges. Lime is added to the dewatered solids to achieve Class B pathogen and vector attraction reduction. Lime-stabilized biosolids are hauled off site for beneficial use through bulk land application.

The proposed biosolids processes will consist of thickening, pre-dewatering, THP, anaerobic digestion, and dewatering. In this process, thickened PS and unthickened secondary solids would be sent to pre-dewatering and be fed to the THP. Hydrolyzed solids would be pumped through cooling heat exchangers

and fed to the primary digesters. A secondary digester would provide storage of solids and biogas from the primary digesters. The gas would be cleaned and used as vehicle fuel or renewable natural gas injection with excess gas sent to either the boiler or the boiler and waste gas burner. Class A stabilized biosolids will be hauled off site for beneficial use. A process flow diagram is provided in Figure 1.

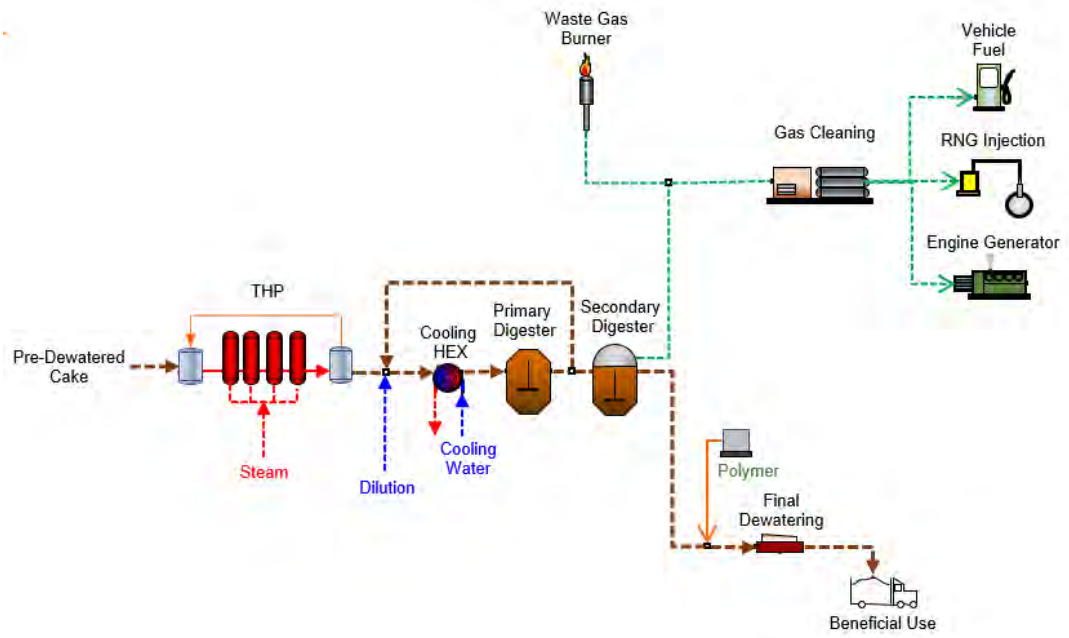


Figure 1. Future Process Flow Diagram

3.0 Design Criteria

The following three design loading conditions were considered for digester equipment evaluation:

- **23 million gallons per day (mgd)—current conditions:** annual average loading was considered for "minimum" operating conditions and as a baseline for annual O&M costs
- **30.8 mgd—2052 projected conditions:** used as the basis for equipment sizing and number of units required for the Facilities Plan
- **40 mgd—buildout conditions:** used to establish total footprint requirements and facility sizing, with space reserved for future tanks and equipment

The proposed process consists of mesophilic digesters in a primary/secondary configuration. Hydrolyzed solids from the THP will be fed to two or three primary digesters (in parallel), and the digested solids from the primary digesters will be fed to the secondary digester. The system will be designed to provide a minimum solids residence time (SRT) in the primary digesters; the volume of the secondary digester is not included in the SRT calculations.

Typically, anaerobic digesters are sized for 15-day SRT to meet U.S. Environmental Protection Agency (EPA) requirements for Class B pathogen reduction. However, because THP meets the requirements for Class A pathogen reduction, the proposed digesters for this project can be sized for a lower SRT. THP pilot testing recently performed by Virginia Tech using solids generated at Arlington WPCP evaluated digester performance at 10.0-, 12.5-, and 15.0-day SRTs; digester performance was determined to be

acceptable at the lower SRTs. A **12-day SRT** target at peak 14-day loading will be used to size the primary digesters. The possibility of operating the digesters at a 10-day SRT can be evaluated in the future, but the project team selected 12 days as a more conservative basis of design. In addition, all configurations were checked to make sure peak volatile solids (VS) loading rates were lower than 0.4 pound volatile solids per cubic foot (lb-VS/ft^3) per day and that predicted ammonia concentrations in the digesters were below 3,000 mg/L. These parameters are important to maintain digester health.

The project team selected a minimum **4 days of storage** downstream of the primary digesters. This value was based on the County's preference to have the flexibility to not operate the dewatering system for 4 consecutive days, for operational or maintenance reasons or for intermittent interruptions in the hauling of final dewatered cake. The digested sludge storage can also help mitigate disruptions that prevent biosolids from being hauled from the WPCP, such as inclement weather or scheduling issues with the biosolids hauling contractor.

The option to provide digested sludge storage tanks (DSSTs) was considered and eliminated in preliminary evaluations. Instead, the project team opted for a secondary digester downstream of the primary digesters, as the volume, equipment, and energy requirements were similar to DSSTs. In addition to providing digested sludge storage, a secondary digester provides operational flexibility of being able to function as a primary if one of the other digesters is out of service. Furthermore, using a similar shape and dimensions for the secondary digester as the other tanks is anticipated to reduce the complexity and cost of construction. The secondary digester will capture any residual biogas that was not released in the primary digesters, although this volume is not heated so it is not counted toward the SRT and volatile solids reduction (VSR) calculations.

4.0 Digester Alternatives

Digester alternatives are described in this section, including digester shape and construction, configuration and sizing, covers, and mixing.

4.1 Digester Shape and Construction

Three digester shapes were considered: conventional cylindrical, silo, and egg-shaped. A comparison of the different types of configurations is shown in Table 1.

Table 1. Comparison of Digester Shape and Construction Options

Evaluation Consideration	Conventional	Silo	Egg-Shaped
Compatible mixing options	Draft tube mixers Gas and pump mixing Top-mounted mixers	Draft tube mixers Gas and pump mixing	Draft tube mixers
Mixing efficiency	Medium	High	Highest
Tank material options	Concrete or steel	Concrete	Steel
Cover options	All options	Fixed concrete	Steel
Relative cleanout frequency	Frequent or routine 5–10 years	Moderate 10–15 years	Minimum 10–20 years
Relative capital cost	Low	Medium	High
Relative operating cost	High	Medium	Low
Ability to store biogas in tank	Yes	No	No

Conventional cylindrical digesters have a digester height-to-diameter ratio between 1:1 and 1:2. Of the three options considered, a conventional shape is least costly to construct and offers the greatest flexibility for mixing systems, covers, and materials of construction. It also provides the largest headspace surface area, which makes them better suited to provide biogas storage and mitigate a potential rapid volume expansion caused by a process upset. The main disadvantage of the conventional shape is the reduced mixing efficiency, which results in higher energy and maintenance requirements to prevent accumulation of grit and scum because of the shallow floor slope, as compared to the other two configurations.

Silo digesters have a height-to-diameter ratio greater than 1:1, reducing the footprint required compared to conventional digesters. Mixing efficiency is also better because silo digesters are taller than they are wide, reducing the surface area available for grit and scum accumulation. They typically have a steeply sloped floor to further discourage grit accumulation on the floor, which in turn reduces the frequency required to take the tank out of service for cleaning. Silo digesters are more expensive to construct than conventional digesters and have fewer options for mixing and cover systems. The reduced surface area also reduces the ability to contain a volume expansion event. Additionally, the taller height of a silo digester might be objectionable to adjacent neighborhoods.

Egg-shaped digesters are known to have the highest mixing efficiency but are also the most expensive to build. They have the fewest mixing and cover options. They require the least cleaning of the three configurations because of the mixing efficiency combined with a steep floor slope. Because of the limited headspace, overflows are more likely; therefore, downstream storage tanks are necessary. The project team determined that egg-shaped digesters would negatively affect the viewshed.

Given the preference to reduce construction costs and minimize impacts to the viewshed, a conventional cylindrical configuration with a 1:1 height-to-diameter ratio was selected. This ratio balances footprint and height and aligns with the recommendations of the THP supplier. To reduce the cost and complexity of construction, a gradual floor slope of 1:6 (2 inches per foot [ft]) was selected.

Cylindrical digesters can be constructed of concrete or steel. Steel is not recommended for a project of this size. The following two methods of American Water Works Association (AWWA) D110 concrete construction were considered:

- **Type III** tanks use precast concrete walls with an embedded steel diaphragm. The tank wall is placed in permanent compression with horizontal prestressing.
- **Type I** tanks use a cast-in-place concrete wall, horizontal strand prestressing, and vertical post-tensioning. The tank wall is placed in permanent compression with horizontal prestressing, like the Type III tanks.

No recommendation is being made at this time for the construction method. There is value in an early pre-selection because of the need to keep manufacturers closely involved in the design process. The type of construction can be further evaluated at a later stage of design.

4.2 Digester Configuration and Sizing

Digester sizing is determined by the design SRT and maximum allowable organic loading rate. Selected values for this project are presented in Table 2.

Table 2. Digester Sizing Design Criteria

Process Metric	Unit	Basis of Design at 14-day Peak Loads
Maximum organic loading rate	lb-VS/ft^3-digester-day	0.4
Minimum solids residence time (days)	Days	12
Maximum total ammonia-N concentration	mg-N/L	3,000

lb-VS/ft^3 = pounds volatile solids per cubic foot.
mg-N/L = milligrams nitrogen per liter.

To provide redundancy and comply with Virginia Sewage Collection and Treatment (SCAT) regulations, the digesters will be sized for a target SRT of 12 days at peak 14-day flows and loads with one digester out of service. As noted in Section 3.0, one of these digesters will be a secondary digester that can provide sludge storage or serve as a primary digester if another digester is out of service. Therefore, the dimensions are based on achieving a 12-day SRT with 2 primary digesters in service.

Four digester sizing configurations were considered, as listed below and presented in Figure 2. The metrics for each configuration are listed in Table 3.

- **Configuration 1:** three (2 primary + 1 secondary) 62-foot-diameter digesters sized for the 40 mgd buildout condition
- **Configuration 2:** four (3+1) 54-foot-diameter digesters sized for the 40 mgd buildout condition
- **Configuration 3:** three (2+1) 56-foot-diameter digesters sized for the 30.8 mgd (year 2052) condition
- **Configuration 4:** four (3+1) 49-foot-diameter digesters sized for the 30.8 mgd (year 2052) condition

As noted previously, a 1:1 height-to-diameter ratio was selected. The normal liquid operating level, also referred to as the side water depth (SWD), was assumed to be approximately 90 percent of the tank height, to provide 10 percent freeboard to accommodate fluctuations in liquid level. It should be noted that the design digester SRT does not need to be based off the permitted average daily flow of the plant.

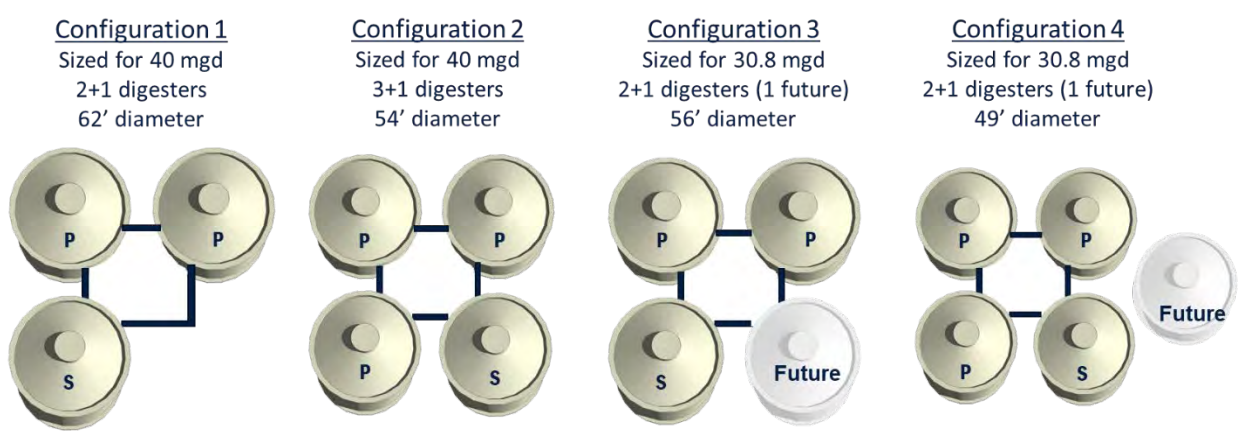


Figure 2. Digester Configurations

Table 3. Digester Configurations: Sizing Metrics

Process Metric	Configuration 1	Configuration 2	Configuration 3	Configuration 4
1. Basis of design	40 mgd—buildout conditions		30.8 mgd—2052 projected conditions	
2. Number of primary digesters	2	3	2	3
3. Number of secondary digesters	1	1	1	1
4. Diameter and height, ft	62	54	56	49
5. Side wall depth, ft	55	48	50	44
6. Volume including freeboard, MG	1.36	0.91	1.05	0.70
7. Liquid volume per digester, MG	1.22	0.81	0.94	0.62
8. SRT provided by one tank, days [a]				
30.8 mgd condition	7.8	5.2	6.0	4.0
40.0 mgd condition	6.0	4.0	4.6	3.1
9. Storage provided by one tank, days [b]				
30.8 mgd condition	7.0	4.7	5.4	3.6
40.0 mgd condition	5.4	3.6	4.1	2.8
10. Total primary digester volume, MG	2.43	2.43	1.87	1.87
11. SRT, all primary digesters, days				
Average loading at 30.8 mgd condition	22.2 (exceeds target)		17.1 (exceeds target)	
Peak 14-day load at 30.8 mgd condition	15.6 (exceeds target)		12.0 (meets target)	
12. SRT, all primary digesters, days				
Average loading at 40.0 mgd condition	17.1 (exceeds target)		13.2 (exceeds target)	
Peak 14-day load at 40.0 mgd condition	12.0 (meets target)		9.2 (below target)	
13. Total primary + secondary volume, MG	3.65	3.24	2.81	2.50
14. SRT, primary + secondary, days				
Peak 14-day load at 30.8 mgd condition	23	21	18	16
Peak 14-day load at 40.0 mgd condition	18	16	14	12
15. SWD in primary digesters for 12-day SRT at peak 14-day 30.8 mgd condition, ft (percentage of tank height)	42 (70%)	37 (70%)	50 (90%)	44 (90%)
16. Freeboard available when operating at SWD required for peak 14-day loads at 30.8 mgd, ft (percentage of tank height)	19 ft (30%)	17 ft (30%)	6 ft (10%)	5 ft (10%)
MG of freeboard	0.85	0.85	0.22	0.22
Volume expansion (ft freeboard ÷ SWD)	45%	45%	12%	12%
Equiv. days of storage at 14-day peak	5.5	5.5	1.4	1.4
17. SWD required to provide 4-day storage in one tank, ft (percentage of tank height) [b]				
Peak 14-day load at 30.8 mgd condition	28 (45%)	37 (70%)	34 (60%)	44 (90%) [b]
Peak 14-day load at 40.0 mgd condition	37 (60%)	48 (90%) [b]	44 (80%)	Inadequate

a. The SRTs shown in row 8 were calculated based on the liquid volume per digester, which is 90% of the total tank volume, to account for 10% freeboard.

b. The days of storage shown in row 9 were calculated based on 80% of the total tank volume because approximately 20% of the tank height must remain full to ensure proper mixing (height of a floor-mounted pump mix nozzle) and to maintain a liquid seal on piping to prevent biogas from entering sludge piping. For this reason, the SWD shown in row 17 must be no more than 80% of the tank height to ensure that 4 days' worth of storage volume is available above the minimum operating level.

Configurations 1 and 2 are sized for 40 mgd buildout conditions; therefore, the primary digesters could be operated at a lower liquid level in the near term. The larger freeboard would mitigate the risk of overflows caused by rapid volume expansions of the digester contents. Operating the primary digesters at a level that provides the target 12-day SRT for the 14-day peak 30.8 mgd condition (Table 3, row 15) provides enough freeboard to accommodate either a 45 percent volume expansion or 5.5 days of storage at peak 14-day flows (row 16).

Configurations 3 and 4 are sized for the 30.8 mgd (year 2052) design conditions. If one of the digesters is out of service, then the remaining digesters must operate as primary digesters at 90 percent of tank height to meet the 12-day SRT target at 14-day peak flows and loads (row 15). The only remaining space available to accommodate volume expansion or solids storage would be the 10 percent freeboard. Therefore, if a digester outage occurred in Configuration 3 or 4, the digester contents would have to be pumped out and dewatered continuously (7 days per week) to reduce the risk of over-filling the digesters.

Configurations 3 and 4 do not provide adequate primary digester volume to meet the 12-day SRT target at peak 14-day loads for the 40 mgd buildout conditions (row 11); however, they do provide adequate volume for the average loads at buildout (row 12). If operating at a lower SRT during peak loading is considered acceptable, addition of the future digester can be deferred.

The County would like to consider accepting fats, oils, and grease (FOG) in the future. Configurations 3 and 4 do not provide adequate primary digester volume to accept FOG at peak 14-day loads at 30.8 mgd conditions, but they are able to accept FOG at current peak conditions and future average conditions. Configurations 1 and 2 are able to accept FOG at peak 14-day loads at 30.8 mgd. Before implementing FOG receiving and processing, the County will need to consider all potential impacts of FOG, including impacts on THP, digestion, and value of renewable natural gas.

A minimum 4 days of digested sludge storage in the secondary digester is recommended for operational reliability, to accommodate the preferred dewatering schedule. The volume of each digester tank in Configurations 2 and 4 provides approximately 4 days of storage at 14-day peak loads in the 30.8 and 40.0 mgd conditions(Table 3, row 9). The volumes of each digester tank in Configurations 1 and 3 are 50 percent larger and provide approximately 6 days of storage at 30.8 and 40.0 mgd conditions. The liquid level required to provide 4 days of storage (row 17 of Table 3) must be no more than 80 percent of the tank height to ensure that 4 days' worth of storage volume is available above the minimum operating level that ensures mixing and maintaining a liquid seal to prevent biogas from entering sludge piping. The minimum level is currently assumed to be approximately 20 percent of the tank height, but this level constraint will become clearer during final design.

As noted in the paragraph above, the secondary digesters in Configurations 2 and 4 provide only the minimum 4 days of storage; therefore, additional volume should be considered to accommodate a rapid volume expansion. For Configuration 2, this volume can be provided by operating the digester at a lower level than the design SWD. For Configuration 4, an external containment tank may be recommended to accommodate overflow from a rapid volume expansion. Also note that the digester tanks are currently sized to have 12 percent freeboard to accommodate volume expansion.

The layout and location of the digesters depends on the selected option for the existing dewatering building. Three options are under consideration for the dewatering building: (1) renovation, (2)

demolition, or (3) decommissioning. Figure 3 presents the preliminary footprints for all four digester configurations under the "renovate" option.

Figure 4 shows preliminary footprints under the "decommission" option for Configurations 1 and 3. Configurations 2 and 4 would not fit on the site unless the dewatering building is renovated and reused or demolished.

Figure 5 shows the preliminary footprint under the "demolition" option. For brevity, only Configuration 4 is shown (the other configurations are similar in appearance).

A high-level screening at the September 23, 2021, project workshop with the County eliminated Configurations 1 and 4. Configuration 1 was eliminated because the total digester volume was considered excessive: nearly double that required to provide 14-day SRT (3.65 million gallons [MG] of primary plus secondary volume provided versus 1.87 MG primary volume required). Configuration 4 was eliminated to avoid the need for a fifth digester in the future. Configurations 2 and 3 were carried forward for further evaluation.

A comparison of each digester configuration option is presented in Section 5.1.

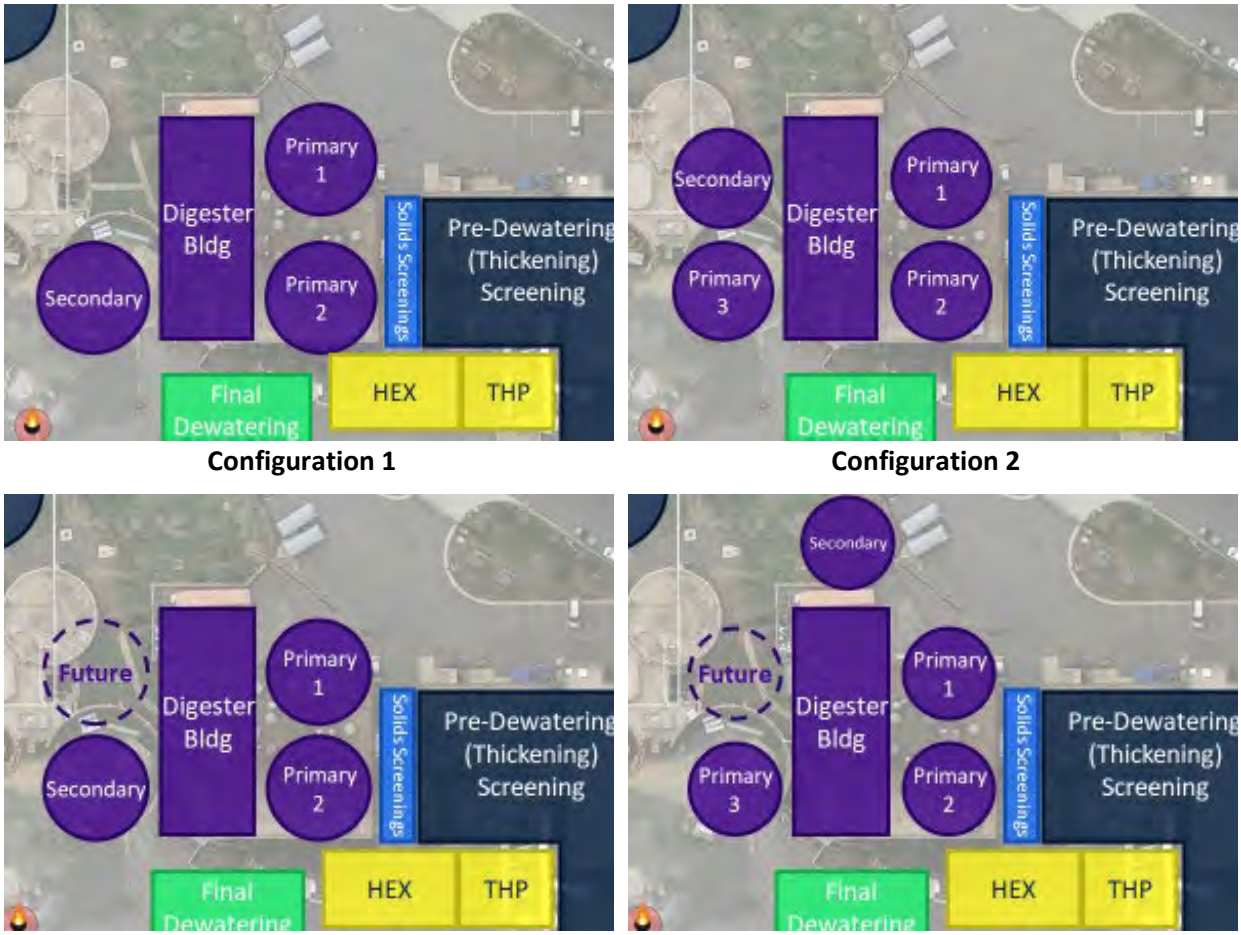
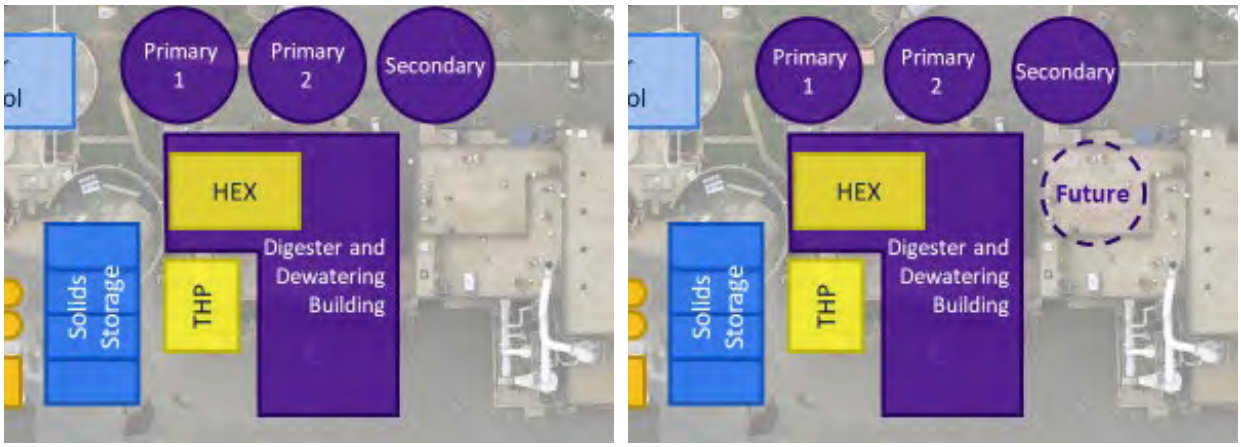


Figure 3. Preliminary Digester Facility Footprints: Renovate Dewatering Building Option



Configuration 1 **Configuration 3**

Figure 4. Preliminary Digester Facility Footprints: Decommission Dewatering Building Option

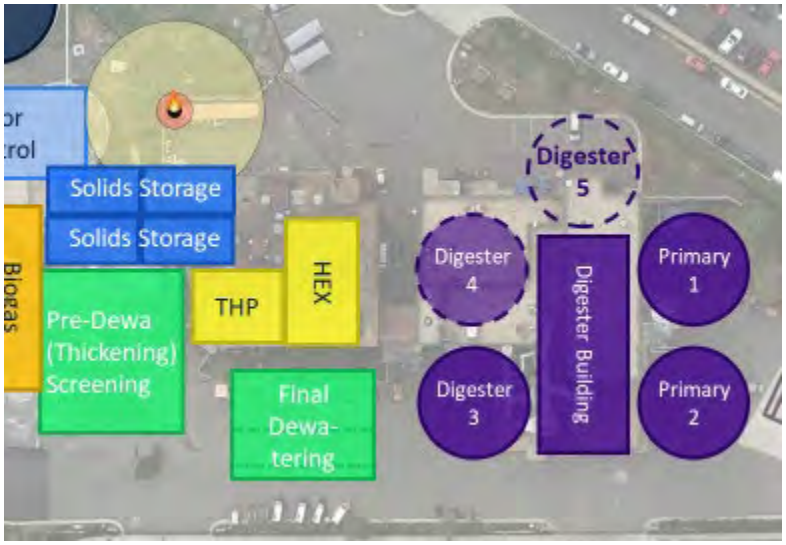


Figure 5. Preliminary Digester Facility Footprint: Demolish Dewatering Building Option

4.3 Digester Covers

Four types of digester covers were considered: floating, fixed, fixed submerged, and membrane. A high-level screening at the August 30, 2021, project workshop with the County eliminated floating covers and fixed submerged covers from further consideration and shortlisted fixed and membrane covers, as detailed later in this section.

The evaluation criteria for digester covers include the following:

- Ability to collect and convey digester gas
- Ability to contain digester foam, which can lead to nuisance, odor, and safety issues
- Ability to reduce fugitive odors
- Ability to accommodate a variety of mixing systems, including top-mounted equipment
- Ability to mitigate risks associated with tank overfilling and volume expansion

4.3.1 Floating Covers

Floating covers are the type of covers that were on the original Arlington WPCP digesters. These covers ride up and down on rails with the liquid surface. Floating gas holder covers ride up and down on both the liquid surface and the gas storage volume. The weight of a floating gas holder cover dictates the gas pressure. Floating covers were eliminated from further consideration for the following reasons:

- The gap between the cover and digester wall, which can allow fugitive odors
- The requirement of a flexible gas connection
- The fixed primary digester level
- The possibility of getting stuck in their tracks

4.3.2 Fixed Covers

Fixed covers are the most common type of covers used in THP applications. They are typically constructed of steel, but concrete fixed covers have become more common in the past few years. Fixed covers provide a large headspace, large surface area for gas release, the possibility of top-mounted mixers, and the ability to withdraw solids from the liquid surface via digester overflow piping. However, the underside is exposed to the corrosive atmosphere in the digester. Steel fixed covers are easier and less costly to install, but they require a side skirt and gas seal, which can be exposed to the corrosive tank atmosphere if the digester is operated at a low liquid level. Steel fixed covers require repainting approximately every 10 years. Concrete fixed covers are sealed regardless of liquid level and do not require periodic painting, but they are more costly and difficult to install.

4.3.3 Fixed Submerged Covers

Fixed submerged covers mimic the top of an egg-shaped digester, but for a cylindrical tank. These covers have limited headspace and only have a concrete construction option. Fixed submerged covers have limited surface exposed to the corrosive atmosphere and can have a top-mounted mixer. However, because of the limited headspace, the risk of overflows is higher. For these reasons, fixed submerged covers were eliminated from further consideration.

4.3.4 Membrane Gas Holder Covers

Membrane covers are inflatable hemispherical domes made of polyvinyl chloride (PVC)-impregnated fabric with the ability to store biogas. They typically consist of two membranes: the inner membrane contains the digester gas headspace, and the outer membrane provides structural support for the cover and is designed to resist wind and snow loads (Figure 6). Air at a fixed pressure is introduced and vented between the two membranes to regulate digester gas pressure. When more gas is being consumed than generated, the chamber is filled with air and the inner membrane deflates. When more gas is being generated than consumed, the chamber is vented and the inner membrane inflates.

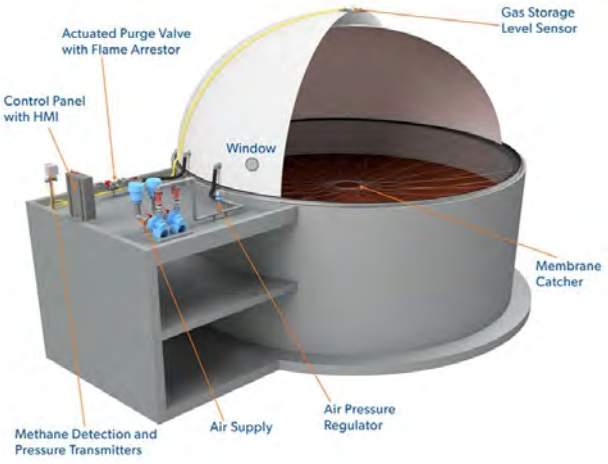


Figure 6. Membrane Gas Holder Cover

The main benefit of membrane covers is the variable headspace volume, which provides flexibility for biogas management and utilization. The most common mixing systems used with membrane covers are pumping or outboard draft tube systems. Membrane covers typically cannot be used with most types of roof-mounted mixers. Membrane covers typically have a life span of 10 to 20 years.

4.4 Digester Mixing

Digester mixing is intended to homogenize the contents of the digester, prevent settling of solids, prevent stratification, reduce short-circuiting, promote gas release, and prevent foaming. Mixing should minimize dead volume and distribute feed throughout the tank. Inadequate mixing can negatively impact digester performance (reduced volatile solids reduction and gas production), increase the risk of rapid volume expansions, and increase the frequency of tank cleaning.

The following five types of digester mixing systems were considered:

- Gas mixing
- Pump mixing
- Linear-motion mixing
- Mechanical draft tube mixing
- Slow-speed mechanical turbine mixing

A high-level screening at the August 30, 2021, project workshop with the County eliminated gas mixing, linear-motion mixing, and slow-speed mechanical turbine mixing from further consideration. The shortlisted alternatives were pump mixing and mechanical draft tube mixing.

4.4.1 Gas Mixing

Gas mixing operates by using compressors to withdraw biogas from the headspace and inject it back into the sludge using gas lances. This option was eliminated from further consideration because of the maintenance requirements associated with the gas compressors, the risk of foaming and scum accumulation, and lack of implementation with THP.

4.4.2 Pump Mixing

Pump mixing systems withdraw solids from the digester and discharge the sludge through nozzles located throughout the tank at a high velocity to maintain circulation and mixing in each digester. An example of a typical mixing pump and mixing nozzles is pictured in Figure 7.

Figure 7. Typical Pump Mixing System
Left: mixing pump Right: mixing nozzle

The main advantages of pump mixing systems are that there is no mechanical equipment within the digesters, it is compatible with all types of tank covers, and it does not require a minimum liquid level to operate. Redundancy can be provided by installing spare mixing pumps. Multiple manufacturers exist, so the system can be competitively bid to vendors.

The main disadvantage of pump mixing systems is the higher energy requirements compared to other options because of the head loss associated with pumping sludge through the mixing nozzles at high velocity. Additionally, gas entrainment or plugging of the pumps, nozzles, and piping can reduce system efficiency, further raising energy requirements to ensure adequate mixing. Because the pump suction and most of the discharge nozzles are in the lower portion of the tank, pump mixing has limited ability to fight stratification.

4.4.3 Linear-Motion Mixing

Linear-motion mixing consists of a paddle that moves up and down in the center of the tank. These mixers have low energy requirements and are relatively simple mechanically. This type of mixing minimizes retrofit costs, and mechanical maintenance can take place outside of the tank. This type of mixing works on fixed and floating covers. However, the mechanical equipment must be placed in the liquid, and no redundancy is provided. Linear-motion mixing is relatively new so there is not much information on mixer longevity and linear-motion mixing has not been implemented with THP. This mixing system can be challenging to operate with variable-level tanks because of the minimum level required for mixing. There is only one supplier of linear-motion mixers. For these reasons, linear-motion mixing was eliminated from further consideration.

4.4.4 Draft Tube Mixing

Mechanical draft tube mixers continuously transfer high volumes of sludge from the upper layer of the digester to the bottom using a propeller pump.

The main advantages of draft tube mixing systems are the lower energy requirements and better mixing performance compared to pump mixing. The propeller rotation can be reversed to change the direction

of mixing and to free up rags that may have accumulated. Redundancy can be provided by installing additional draft tubes.

Draft tube mixers can be located either inside or outside the digester (Figure 8, top). External draft tube mixers are easier to maintain but typically cost 10 percent more than internal draft tube mixers because of the additional piping and maintenance platform. The motor for internal draft tube mixers can be mounted directly on a fixed digester cover. For digesters with membrane covers, the motor can be mounted on a platform on the inside edge of the tank; in this application, the sides of the mixer platform can be provided with walls that follow the slope of the membrane cover (Figure 9).

Figure 8. Typical Draft Tube Mixers
Left: internal roof-mounted draft tube Right: external draft tube

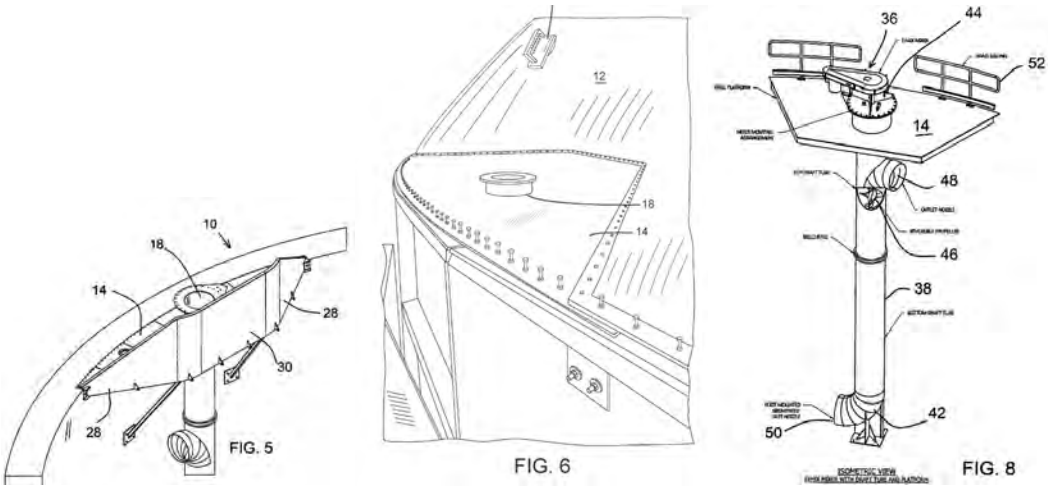


Figure 9. Draft Tube Mixer Design for Digesters with Membrane Covers

Draft tube mixing systems typically require a crane for removal and maintenance of the mixing propeller; however, maintenance of other components, such as the motor and gearbox, can generally be performed without a crane. Unlike pump mixing systems, draft tubes are sensitive to the liquid level

and require a minimum level to operate effectively. Internal draft tubes are typically recommended for tanks with varying liquid levels.

4.4.5 Slow-Speed Mechanical Turbine Mixing

Slow-speed mechanical turbine mixing consists of a single roof-mounted turbine mixer in the center of the tank. This system has lower energy and maintenance requirements than other options. The mixer can be operated in forward or reverse. Mechanical equipment must be placed in the liquid, and no redundancy is provided. This mixing system is not compatible with membrane covers and has not been implemented with THP. Turbine mixers require a minimum liquid level and are not suitable for variable-level tanks. For these reasons, slow-speed mechanical turbine mixing was eliminated from further consideration.

5.0 Alternatives Comparison

This section presents a comparison of the relative advantages, disadvantages, and costs for the various digester alternatives evaluated.

5.1 Digester Configuration

A comparison of each digester configuration option is presented in Table 4. As noted in Section 4.2, Configurations 1 and 4 were eliminated at a previous workshop but are included in Table 4 for comparison.

Table 4. Comparison of Digester Configurations

Evaluation Consideration	Configuration 1	Configuration 2	Configuration 3	Configuration 4
Number of digesters (primary + secondary)	2 + 1	3 + 1	2 + 1	3 + 1
Compatible with site plan options?				
Renovate dewatering building	✓	✓	✓	✓
Demolish dewatering building	✓	✓	✓	✓
Decommission dewatering building	✓	No	✓	No
Able to meet target SRT at peak 14-day flows and loads at 30.8 mgd condition?	✓	✓	✓	✓
Excess digester volume to avoid 24/7 dewatering when one digester offline?	✓	✓	No	No
Total (primary + secondary) volume provided ÷ primary volume required for 30.8 mgd condition, MG	3.65 ÷ 1.87 195%	3.24 ÷ 1.87 173%	2.81 ÷ 1.87 150%	2.50 ÷ 1.87 133%
Sufficient capacity to accept FOG?				
Current (24.2 mgd) peak loads	✓	✓	✓	✓
Average loading at 30.8 mgd condition	✓	✓	✓	✓
Peak 14-day load at 30.8 mgd condition	✓	✓	No	No
Storage provided in secondary digester at 14-day peak load loads at 30.8 mgd, days (percentage of target 4 days)	7.0 (175%)	4.7 (116%)	5.4 (134%)	3.6 (90%)
Membrane volume, ft^3 per tank	62,000	41,000	46,000	31,000
Hours of gas storage at current average loading, assuming 10,000 gpd of FOG	2.6	1.8	2.0	1.4
Mitigation options to accommodate rapid volume expansion, between now and 30.8 mgd condition (estimated year 2052)	Operate primary digesters at lower level and/or use excess secondary digester volume	Operate primary digesters at lower level (~37 ft SWD).	Use excess secondary digester volume or divert overflow to external containment	Divert overflow to external containment
Able to meet target SRT at 40 mgd?	✓	✓	Only for average loads; a third primary digester is required for 14-day peak loads	Only for average loads; a fourth primary digester is required for 14-day peak loads

Of the shortlisted alternatives, Configuration 2 provides more volume, and thus offers more operational flexibility, especially at the design flow of 30.8 mgd. In order to construct Configuration 2 with the Decommission Dewatering Building option, it will be necessary to demolish the existing dewatering building as part of the Re-Gen program in order to construct the future 4th digester. Configuration 3 has lower initial construction costs and is easier to locate on site because of the fewer number of tanks and does not require the demolition of the existing Dewatering Building as part of the Re-Gen program for either the Renovate or Decommission Dewatering Building options. Configuration 3 would require that a fourth digester be built beyond the 30.8 mgd design condition. With the Renovate Dewatering Building option, all site work, prep, demolition, etc. will be completed for the 4th digester as part of the Re-Gen program. For the Decommission Dewatering Building option, the demolition of the existing dewatering building can be deferred to the later project at which time the 4th digester is to be constructed. Key differences between Configurations 2 and 3 are presented in the conclusion of this TM.

5.2 Digester Covers

Table 5 provides a side-by-side comparison of the relative advantages and disadvantages of each digester cover type. As noted in Section 4.3, floating and fixed submerged cover options were eliminated at a previous workshop but are included for comparison.

Table 5. Comparison of Digester Covers

Evaluation Consideration	Floating	Fixed Steel	Fixed Concrete	Fixed Submerged	Membrane
Odor containment	Poor	✓	✓	✓	✓
Maintenance requirements and mechanical reliability	Cover can get stuck on side tracks	Repaint ceiling every 10 years	✓ (Minimal)	✓ (Minimal)	Replace membrane every 10–20 years
Tanks can be designed to mitigate risk of overfilling	✓	✓	✓	No	✓
Compatible with top-mounted mixers	No	✓	✓	✓	Only draft tube
Allows sludge withdrawal from liquid surface	✓	✓	✓	No	✓
Ability to store digester gas	✓	No	No	No	✓

Fixed concrete covers are recommended for the primary digesters, as they provide more advantages over all other options, except for the ability to store gas. A membrane gas holder cover is recommended for the secondary digester to provide gas storage. The headspace of all digesters would be connected to allow gas to flow from the primary digesters to the gas storage.

5.3 Digester Mixing

Table 6 provides a side-by-side comparison of the relative advantages and disadvantages of each digester mixing system. As noted in Section 4.4, gas mixing, linear motion, and slow-speed mechanical turbine mixing systems were eliminated at a previous workshop but are included for comparison.

Table 6. Comparison of Digester Mixing Technologies

Evaluation Consideration	Gas Mixing	Pump Mixing	Draft Tube	Linear Motion	Turbine
Mechanical equipment located outside liquid	✓	✓	No	No	No
Low energy requirements	No	No	✓	✓	✓
Ability to prevent stratification	Poor	Limited	✓	✓	✓
Can be designed for redundancy	✓	✓	✓	No	No
Implemented with THP	No	✓	✓	No	No
Compatible with membrane covers	✓	✓	✓	No	No
Applicable for tanks with varying liquid levels	✓	✓	Medium	Poor	Poor
Common O&M challenges and other considerations	Gas compressors Scum layer Foaming	Air entrainment Nozzle plugging	Requires crane for mixer replacement	Single manufacturer (sole source)	

The energy requirements for pump mixing and draft tube mixing are compared for each shortlisted digester configuration in Table 7. Annual costs assume an electricity cost of $0.06 per kilowatt-hour (kWh).

Table 7. Shortlisted Alternatives Yearly Mixing Costs

Mixing Option	Digester Configuration 2: 3+1 54' digesters		Digester Configuration 3: 2+1 56' digesters	
	Total hp	Annual Electricity Cost	Total hp	Annual Electricity Cost
Pump Mixing	337	$132,000	283	$111,000
Draft Tube Mixing	91	$36,000	77	$30,000

Pump and draft tube mixing have the most advantages compared to the other three options. Pump mixing systems are generally easier to operate and maintain than draft tube mixing, especially for tanks with varying liquid levels, but they are not as effective at preventing stratification and require nearly four times as much energy as draft tube mixing systems. The type of mixing system will be further evaluated at a later stage of design.

5.4 Cost Comparison

Planning-level opinions of capital costs were prepared for each alternative based on preliminary quotes from vendors, with added multipliers for installation, contingencies, and other construction costs as shown in Table 8. Quoted costs of tanks and equipment provided by equipment suppliers are presented in Table 9.

Table 8. General Percentages for Cost Preparation

Parameter	Percentage
Sitework	15%
Electrical	20%
Instrumentation and controls	8%
Large and specialty pipe	5%
Geotechnical (piles)	7%
Project contingency	20%
Contractor mobilization/staging	5%
Contractor bonds/insurance	3%
Contractor overhead and profit	15%

Table 9. Tank and Equipment Costs

Item	Cost	Notes
54' diameter concrete tanks, each	$ 1,900,000	Precast construction (AWWA D110 Type III) Includes foundation, walls, and concrete cover Assumes deep foundations are required Cost is similar for concrete tank with open top
56' diameter concrete tanks, each	$ 2,100,000	
Membrane cover, each	$ 371,000	Similar cost is assumed for 56' and 54' diameter
Pump mixing system, per digester	$ 189,000	Similar cost is assumed for 56' and 54' diameter
External draft tube mixer, per digester	$ 481,000	For primary digesters with fixed covers
Internal draft tube mixer, per digester	$ 435,000	For primary digesters with fixed covers (provided for reference only, not used in capital costs)
Internal draft tube mixer, per digester	$ 535,000	For secondary digester with membrane cover

Preliminary 20-year costs (capital + 20-year O&M costs) were developed for both shortlisted digester configurations with both shortlisted pumping options and are presented in Table 10 and Table 11. Membrane replacement and pump mixing system maintenance are not included in the O&M costs, as they were assumed to apply equally to all alternatives.

Table 10. 20-Year Costs for Shortlisted Digester Configurations with Pump Mixing

Cost Item	Configuration 2 with Pump Mixing	Configuration 3 with Pump Mixing
Equipment Costs		
Tanks	$ 7,600,000	$ 6,300,000
Membrane cover	$ 371,000	$ 371,000
Mixing system	$ 759,000	$ 569,000
Equipment costs subtotal	$ 8,730,000	$ 7,240,000
Construction Costs		
Sitework	$ 1,310,000	$ 1,086,000
Electrical	$ 1,746,000	$ 1,448,000
Instrumentation and controls	$ 698,000	$ 579,000
Large and specialty pipe	$ 437,000	$ 362,000
Geotechnical (piles)	$ 611,000	$ 507,000
Project contingency	$ 1,746,000	$ 1,448,000
Contractor mobilization/staging	$ 437,000	$ 362,000
Contractor bonds/insurance	$ 262,000	$ 217,000
Contractor overhead and profit	$ 1,310,000	$ 1,086,000
Construction costs subtotal	$ 8,557,000	$ 7,095,000
O&M Costs		
20 years of mixing energy costs	$ 2,640,000	$ 2,220,000
O&M costs subtotal	$ 2,640,000	$ 2,220,000
Total 20-year cost (sum of subtotals above)	**$ 19,927,000**	**$ 16,555,000**

Table 11. 20-Year Costs for Shortlisted Digester Configurations with Draft Tube Mixing

Cost Item	Configuration 2 with draft tube mixing	Configuration 3 with draft tube mixing
Equipment Costs		
Tanks	$ 7,600,000	$ 6,300,000
Membrane cover	$ 371,000	$ 371,000
Mixing system	$ 1,978,000	$ 1,497,000
Equipment costs subtotal	$ 9,949,000	$ 8,168,000
Construction Costs		
Sitework	$ 1,492,000	$ 1,225,000
Electrical	$ 1,990,000	$ 1,634,000
Instrumentation and controls	$ 796,000	$ 653,000
Large and specialty pipe	$ 497,000	$ 408,000
Geotechnical (piles)	$ 696,000	$ 572,000
Project contingency	$ 1,990,000	$ 1,634,000
Contractor mobilization/staging	$ 497,000	$ 408,000
Contractor bonds/insurance	$ 298,000	$ 245,000
Contractor overhead and profit	$ 1,492,000	$ 1,225,000
Construction costs subtotal	$ 9,748,000	$ 8,004,000
O&M Costs		
20 years of mixing energy costs	$ 720,000	$ 600,000
O&M costs subtotal	$ 720,000	$ 600,000
Total 20-year cost (sum of subtotals above)	**$ 20,417,000**	**$ 16,772,000**

6.0 Summary and Conclusions

The following digester alternatives were shortlisted for further consideration:

- **Digester shape and construction:** Conventional concrete with a 1:1 height-to-diameter ratio.
  - The type of construction (precast AWWA D110 Type III or cast-in-place AWWA D110 Type I) will be evaluated as the design progresses.
- **Digester configuration and sizing:**
  - Primary digesters sized for 12-day target SRT at peak 14-day flows and loads.
  - One secondary digester of identical size, with ability to operate as a primary digester if one digester is out of service.
  - Shortlisted configurations:
    - **Configuration 2:** four (3+1) 54-foot-diameter digesters sized for the 40 mgd buildout condition
    - **Configuration 3:** three (2+1) 56-foot-diameter digesters sized for the 30.8 mgd (year 2052) condition
- **Digester covers:** Fixed concrete for primary digesters, membrane gas holder for secondary digester.
- **Digester mixing:** Pump and draft tube mixing systems.

- For the draft tube option, external mixers are recommended for the primary digesters, for ease of maintenance; internal mixers are recommended for the secondary digester, to accommodate variations in liquid level.

Key differences between the shortlisted digester configurations are presented in Table 12
Digester Configuration 3 is recommended, as capital costs are anticipated to be 20 percent lower than Configuration 2 (approximately $1.5 million lower cost). Configuration 3 is also compatible with all site plan alternatives, while Configuration 2 is possible only if the existing dewatering building is renovated or demolished. Additionally, the slightly larger tanks of Configuration 3 provide more volume for storage of digested sludge or gas in the secondary digester.

Two digester mixing systems are recommended for further consideration. Pump mixing has lower equipment costs and is more adaptable to varying tank levels. On the other hand, draft tube mixing provides better mixing and requires less energy. When taking into account operating costs, draft tube mixing is anticipated to have lower life-cycle costs than a pumped mixing system. Further investigations are recommended to determine which option is better suited for this project. Both mixing options are compatible with the shortlisted digester and cover options.

As design progresses, the project team will also consider measures to mitigate the disadvantages of Configuration 3. Because it provides less total volume, an emergency overflow tank or detailed operating procedures may be required to manage digester levels in the event of a tank outage or rapid volume expansion. Additionally, Configuration 3 is limited in the ability to accept FOG at peak 14-day loads under 30.8 mgd design conditions; however, it will likely be able to accept FOG at peak loads under current (24.2 mgd) conditions as well as average loads at 30.8 mgd conditions.

Finally, it should be noted that Configuration 3 would likely require an additional digester to provide a 12-day SRT at 14-day peak loads for 40 mgd buildout conditions; however, based on current projections, those conditions are unlikely to occur within the next few decades.

Table 12. Comparison of Shortlisted Digester Alternatives

Parameter	Configuration 2	Configuration 3
Design condition	40 mgd (buildout)	30.8 (year 2052)
Number of digesters (primary + secondary)	3 + 1	2 + 1
Capital cost with pump mixing system	$ 8.6 million	$ 7.1 million
Capital cost with draft tube mixing	$ 9.8 million	$ 8.0 million
20-year cost with pump mixing system	$ 19.9 million	$ 16.6 million
20-year cost with draft tube mixing	$ 20.4 million	$ 16.8 million
Compatible with all site plan options?	Not compatible with "decommission dewatering building"	✓
Digester volume adequate to avoid 24/7 dewatering when one digester offline?	✓	24/7 dewatering may be necessary at 30.8 mgd conditions when one digester is out of service
Sufficient capacity to accept FOG at 30.8 mgd?	✓	Only at average loads
Storage provided in secondary digester at 14-day peak load at 30.8 mgd, days	4.7	5.4
Membrane volume, ft^3 per tank	41,000	46,000
Mitigation options to accommodate rapid volume expansion, between now and 30.8 mgd condition (estimated year 2052)	Operate primary digesters at lower level (~37 ft SWD)	Use excess secondary digester volume or divert overflow to external containment
Able to meet target 12-day SRT at 40 mgd?	✓	Only for average loads; additional digester required for 14-day peak loads

Technical Memorandum No. 12

Date:	November 29, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Cooling Technologies Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the thermal hydrolysis process (THP) pre-digester cooling evaluation, followed by a description of the evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary solids (PS) and waste activated solids (WAS) thickening, dewatering, and Class B lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a Class A THP and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this THP pre-digester cooling evaluation is to further assess and compare pre-digester sludge cooling alternatives following the workshop at which the options were presented. The results of this evaluation will inform and validate a final decision on which technology will be chosen for THP pre-digester cooling for inclusion in the Facilities Plan.

1.2 Evaluation Approach

A range of alternatives using various cooling technologies was developed for the THP pre-digester cooling. Conceptual process conditions, configurations, cooling technology sizing, and conceptual operating costs were prepared and then presented and reviewed at the September 23, 2021, project workshop with the County. Workshop participants screened and selected a short list of preferred technologies. In this evaluation, the shortlisted technologies are further evaluated and compared based on budgetary capital equipment costs, conceptual operating cost estimates, and non-cost considerations including space requirements and noise. A 20-year life-cycle cost analysis was completed to compare the shortlisted technologies.

2.0 Summary of THP and Cooling

A process flow diagram for the proposed THP process and pre-digester cooling is shown in Figure 1. After the hydrolyzed solids leave the THP flash tank at approximately 221 degrees Fahrenheit (°F), pathogen-free dilution water is added allowing the solids concentration to be reduced to approximately 0.09 pound total solids per pound sludge (lb-TS/lb-sludge) (9 percent). Digested sludge recycle is subsequently added to the stream to promote fluid flow, which also lowers the sludge temperature before entering the cooling heat exchangers (HEXs). The HEXs cool the sludge further to the mesophilic digestion design temperature of 98°F. There will be two primary digesters and one secondary digester that could act as a primary during maintenance. Each primary digester will have a HEX available and both HEXs will be piped to the secondary digester to provide the required redundancy when the secondary digester is acting as a primary. The THP process and downstream cooling is expected to operate continuously. The equipment evaluations for the HEX and cooling water, indicated in the blue dashed area in Figure 1, are included in this technical memorandum (TM).

All the cooling technology options presented in this TM include a similar style and configuration of HEX but differ in size, how cooling water is provided, and what happens to the cooling water after it has been used.

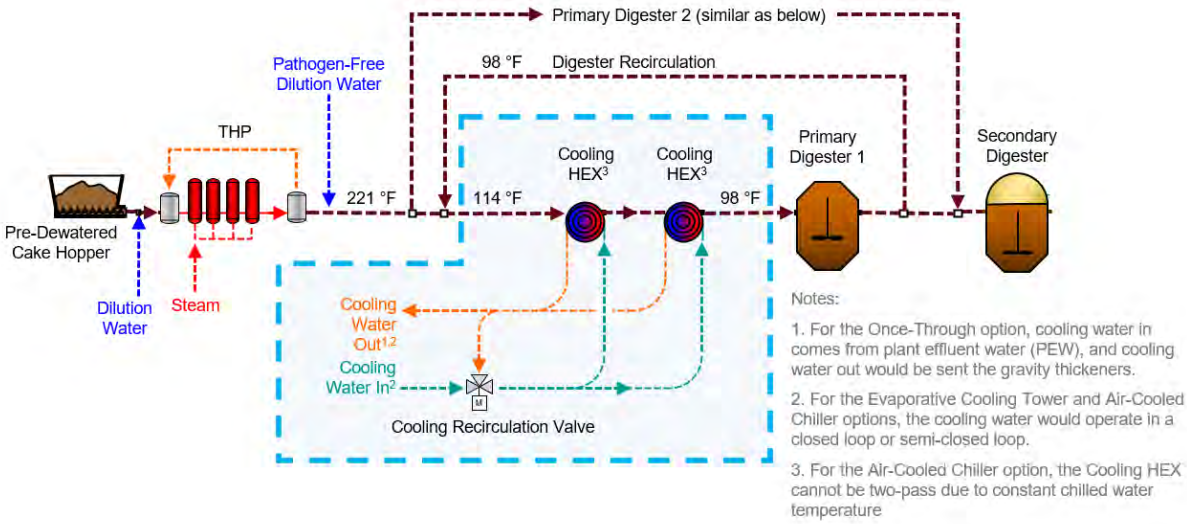

Figure 1. THP and Pre-Digester Cooling Process Flow Diagram

3.0 Design Criteria

This section presents the design criteria for the cooling technologies considered, including cooling demand and controls.

3.1 Cooling Demand

Concept engineering for cooling options is dependent on the required thermal load reduction of the mixed sludge through the HEX. The design conditions for the cooling HEX sizing and cooling water technologies were based on the WPCP peak 3-day loadings using 30.8-million-gallon per day (mgd) flow as detailed in *TM No. 1 Solids Production and Design Criteria.* The amount of heat transfer required to lower the mixed sludge temperature from 114°F to 98°F is given by the following equation and detailed in Table 1 below. The following assumes a specific heat (Cp) of 1.0 for the sludge:

$$\frac{MMBtu}{hr} = \frac{\Delta T\left(GPM * 60\ \frac{min}{hr}\right)\left(8.34\frac{lb}{gal}\right)\left(1.0\ \frac{BTU}{lb - °F}\right)}{1{,}000{,}000}$$

Table 1. Digester Feed Sludge Process Design Conditions

Parameter	Design
Total mixed sludge flow from THP (gpm)	568
Mixed sludge flow per digester (gpm)	284
Mixed sludge temperature post-dilution/recycle (°F)	114
Mixed sludge viscosity (cP)	25.0
Mixed sludge density (lbm/ft^3)	61.3
Target digester feed temperature (°F)	98
Total cooling demand (MMBtu/hr)	4.4
Cooling demand per digester (MMBtu/hr)	2.2

3.2 Heat Exchanger Sizing and Design Conditions

One HEX is required for each primary digester under all cooling options described in this TM. The type and size of HEX will vary based on the cooling technology selected. Sizing of the HEX depends on the cooling flow temperature, mass flow rate, and specific temperatures of the HEX material and fluids. As the temperature difference increases across the HEX, the surface area required to maintain the same heat transfer rate decreases.

The material choice for the HEX tubes depends on the cooling liquid properties for each respective cooling option. Historically, THP installations have installed 316L stainless steel HEX for cooling the thermally hydrolyzed solids (THS). However, at the first THP installation in the United States, at the DC Water Blue Plains Advanced Wastewater Treatment Plant (WWTP), the installed 316 cooling HEXs exhibited pinhole leaks on the water side, which has been attributed to a high manganese content of the plant effluent cooling water. It was determined that the leaks were most likely from microbial-induced corrosion (MIC) from manganese consuming bacteria among other factors. Based on this experience, similar occurrences at Arlington when PEW has been used in HEXs, and the uncertainty associated with long-term corrosion resistance of 316 stainless steel with sludge cooling operations using plant effluent water (PEW) as the cooling liquid, Super Duplex 2507 alloy is recommended for the HEX tubes. This higher alloy material provides exceptional resistance to MIC. For the evaporative cooling tower and air-cooled chiller options, the cooling water will be a municipal-supplied treated closed loop, significantly less corrosive than PEW. The municipal water would be treated with a custom chemical treatment plan typically consisting of biocides such as bromine and sodium hypochlorite as well as anti-scalant and corrosion inhibitors. Therefore, 316 stainless steel is recommended for the cooling HEX material for these cooling options, as the treated cooling water has a substantially reduced risk of MIC.

The HEXs will be concentric steel tube, counterflow design (Figure 2), and will have two sludge and two water passes in series. The two-pass design allows flow to bypass one or both sections, allowing each pass to operate independently of the other during low-flow operating conditions or during maintenance operations where one pass can be taken offline (typically during winter months when the HEX cooling load can be met with less HEX area). The two-pass design will also allow a lower pressure drop for the sludge and water sides, lowering pumping costs.

Figure 2. Concentric-Tube Heat Exchanger

Figure 3 shows a simplified process flow diagram for a two-pass design with both HEXs operating to provide the full design cooling duty.

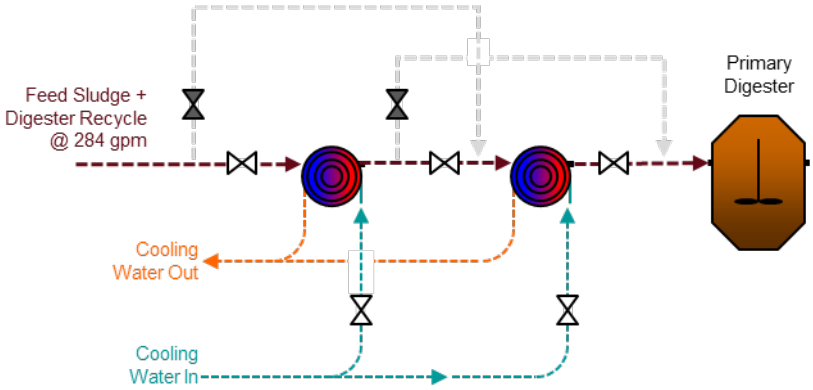

Figure 3. Two-Pass HEX Process Flow Diagram: Normal Conditions

Figure 4 shows a simplified process flow diagram for one of the two passes being isolated to handle the entire cooling duty.

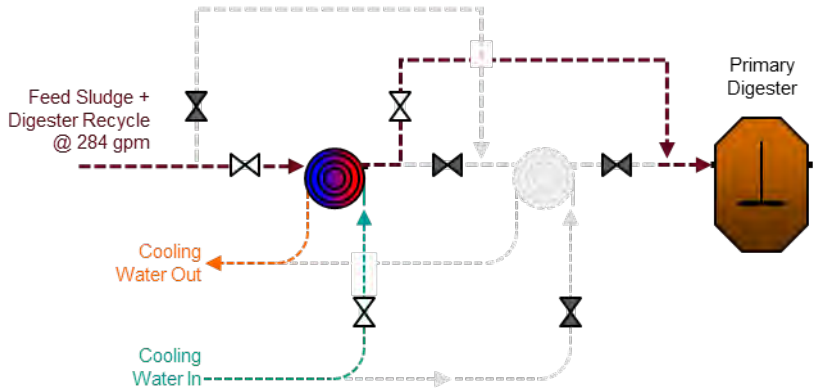

Figure 4. Two-Pass HEX Process Flow Diagram: Maintenance/Low Flow Conditions

3.3 Controls

The cooling water system controls the temperature of the cooled solids feed to the digester. This is accomplished primarily by modulating the cooling water flow rate. Cooling water temperature can also be controlled to a limited degree by recirculating a controlled water flow from HEX water effluent back to the HEX water influent. Cooling water temperature control has the added benefit of preheating cooling water during cold weather, minimizing the chances of fats, oils, and grease (FOG) from condensing on the HEX piping.

To have precise control over digester temperature and to prevent cycles of undershooting and overshooting the digester temperature set point, it is recommended that several tuning features be incorporated in the temperature control programming. These include, but are not limited to:

- Signal conditioning: adjustable time averages
- Adjustable set point dead bands
- Adjustable temperature correction rates
- Closed-loop control

The cooling water flow control should be programmed to use the flows and inlet and outlet temperatures to calculate heat exchange rate and efficiency and warn of fouling. Additionally, inlet and outlet pressures can be compared against expected head loss to warn of potential clogging.

In addition to control programming features, physical design elements can increase the stability and precision of the digester temperature control. These include selecting feedback signals that respond quickly to control changes. One example would be to control the cooling water flow based on feedback from HEX sludge outlet temperature rather than temperature in the digester (the latter of which would take many hours to reflect a temperature change resulting from a change in cooling water flow and could result in a choppy on/off control of water). Another physical recommendation is to place temperature-sensing devices in a flow stream; for example, placing digester temperature sensing on mixing pump suction, not on the digester itself.

4.0 Cooling Technology Evaluation

Five cooling water alternatives were reviewed at the September 16, 2021, project workshop with the County:

- Once-through cooling with PEW
- Mechanical draft evaporative cooling tower
- Air-cooled chiller
- Water-cooled chiller
- Air-cooled HEX (radiator)

The water-cooled chiller is an indoor unit that uses a refrigeration cycle to produce chilled water with heat rejected by the water loop to a cooling tower. This option was ruled out because of the high equipment costs and system complexity.

The air-cooled HEX, otherwise known as an air cooler or radiator, uses fans to force ambient air over tubes containing the water being used for the HEX cooling. This option was ruled out because of its inability to provide the amount of cooling required on the warmest days.

The once-through cooling, evaporative cooling tower, and air-cooled chiller cooling options were shortlisted following the workshop and are presented below with additional context on design criteria, space requirements, equipment costs, and annual operating cost estimates.

4.1 Once-Through Cooling

Using the existing site PEW in a once-through cooling design would provide the least complex option because no additional mechanical equipment would be required to cool the water. PEW would provide the necessary cooling through the concentric-tube HEX and then be sent to the gravity thickeners (GTs) to provide elutriation water to be confirmed during detailed design. Additionally, a new pump would be required in the PEW recirculation line to provide warm HEX water effluent back to water influent to control the HEX inlet temperature.

The PEW temperature varies throughout the year depending on outdoor ambient temperature conditions. Three years of temperature data were given and the monthly average, maximum, and minimum temperatures were extracted and are presented in Figure 5 and Table 2 below. The hottest effluent temperature recorded (84.3°F) was used as the design condition for sizing the HEX.

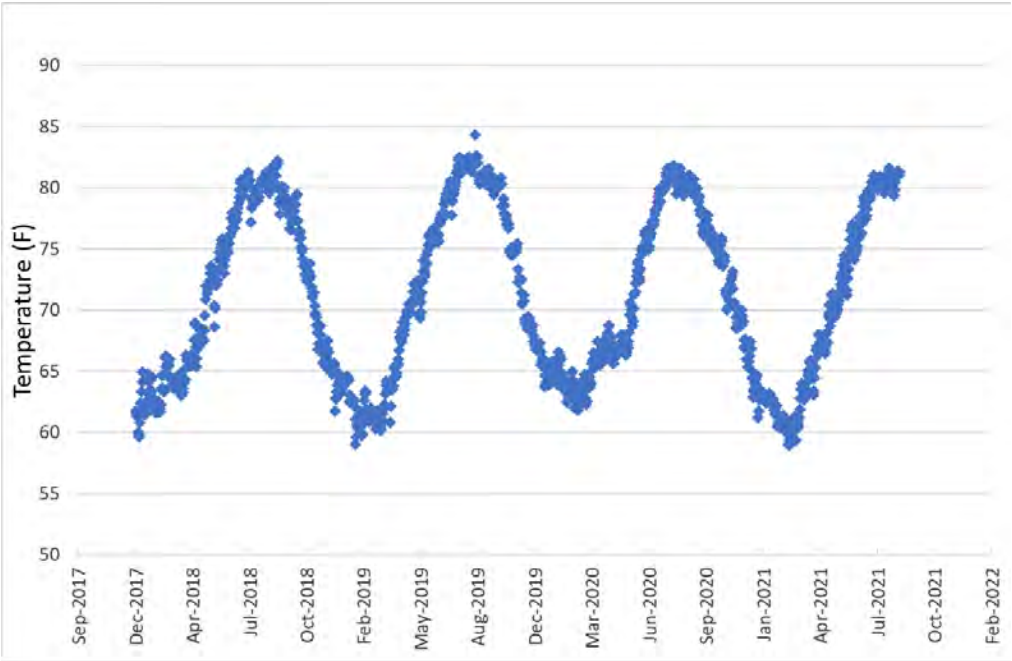

Figure 5. Plant Effluent Water Historical Temperatures, 2018–2021

Table 2. Plant Effluent Water Monthly Temperature Data, 2018–2021

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Effluent average (°F)	62.9	62.1	63.8	67.2	71.4	76.3	80.2	80.8	79.4	75.8	69.7	65
Effluent maximum (°F)	66.6	66.2	67.4	70.6	76.2	79.5	82.5	84.3	82.2	80.8	73.8	67.6
Effluent minimum (°F)	59.1	58.9	59.4	63.1	66.3	73.4	77.2	78.9	76.1	71.2	65.4	61.2

The lower effluent temperatures in the winter reduce the required flow through a flow control valve to the HEXs, allowing one pass of the HEX to be taken offline for maintenance. The average effluent winter temperature of 64.3°F was used to size the HEX so that the winter-temperature effluent could handle the entire cooling duty with one pass. This eliminates the need to provide a redundant third HEX that would serve both primary digesters, and maintenance can be performed on the out-of-service portion of the HEX during winter months.

Water chemistry of the WPCP effluent may cause MIC in HEXs, even those made of stainless steel, thus requiring Super Duplex 2507 alloy to reduce that risk. The PEW also presents a higher risk of HEX fouling than using treated municipal water. The higher amount of fouling may require more periodic cleanings to take place than the other options. In addition, the relatively warm temperatures of the WPCP effluent would require larger HEX surface areas than the other options, leading to the most expensive HEXs of all the options.

This type of HEX typically requires low maintenance because it has no moving parts. Tube cleaning will be required when the pressure drop is abnormally high based on typical operating conditions or if HEX efficiency has decreased. Cleaning can typically be done with a pressure washer, stainless-steel tube

brush, or pigging system; however, a maintenance schedule is not known at this time and will be based off specific site sludge and cooling water conditions. Feedback from a HEX supplier indicated that coupling gaskets may require maintenance attention if return bends are not properly removed and reinstalled during maintenance operation. The HEX supplier provided no indication that other THP installations have seen major HEX reliability issues.

The existing PEW pumps were assumed to be able to handle the additional system pressure head of pumping to and from the new HEXs. A hydraulic model will need to be completed to confirm this assumption. Table 3 below shows once-through cooling preliminary design criteria.

Table 3. Once-Through Cooling Preliminary Design Criteria

Parameter	Once-Through HEX	Unit
Total heat transfer capacity	4.4	MMBtu/hr
Heat transfer per digester	2.2	MMBtu/hr
Heat transfer per HEX pass	1.1	MMBtu/hr
PEW maximum inlet temperature	84.3	°F
PEW maximum outlet temperature	102.5	°F
PEW minimum inlet temperature	64.3	°F
PEW minimum outlet temperature	99.0	°F
HEX space required (L × W) per HEX	24 × 7 (qty. 2)	ft
Maximum PEW demand per HEX	250	gpm
Minimum PEW demand per HEX	105	gpm
Recirculation pump size per HEX	5	hp

Approximate sizes of the two HEXs are shown in Figure 6 and Figure 7 below with the dashed line indicating the pull space required for HEX maintenance.

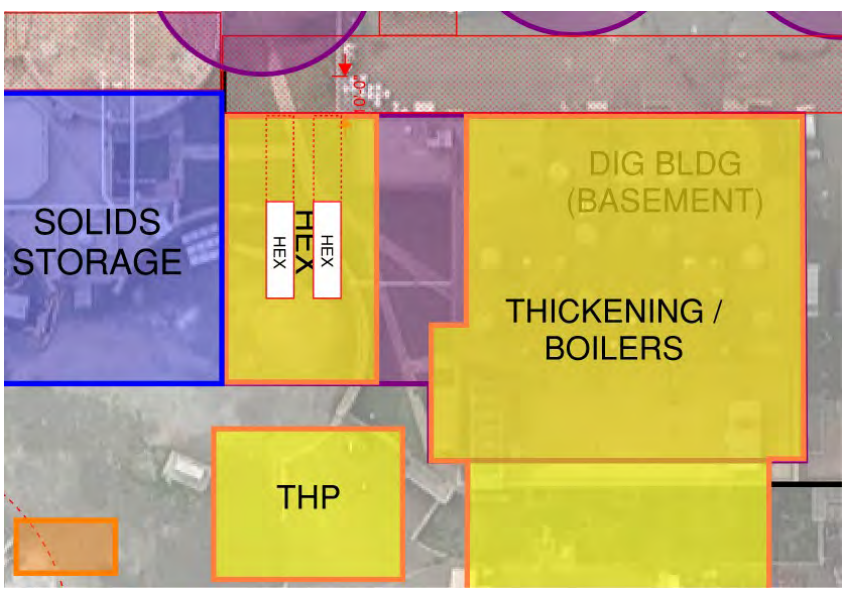

Figure 6. Once-Through Cooling: Equipment Plan View—Decommission Dewatering Building Option

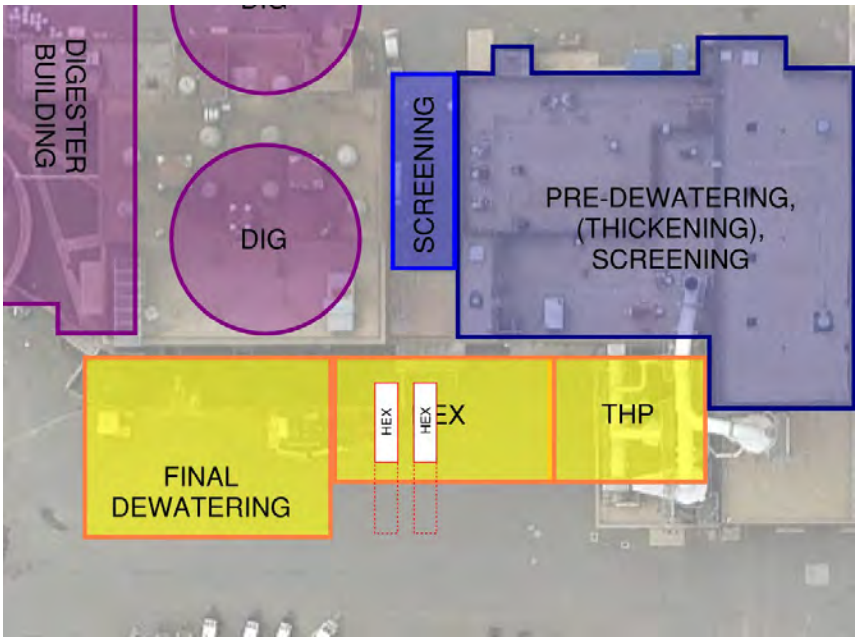

Figure 7. Once-Through Cooling: Equipment Plan View—Renovate Dewatering Building Option

The relative advantages and disadvantages of the once-through cooling option are listed in Table 4.

Table 4. Once-Through Cooling Advantages and Disadvantages

Advantages	Disadvantages
No additional cooling equipment required (beyond HEX)	Largest HEX required compared to other options
Smallest electrical load and simplest equipment complexity	More HEX maintenance because of PEW fouling
Fewer moving parts, low noise	Potential for corrosion: suggest high alloy steel HEX material
Small footprint	PEW would need to be recycled and retreated (optional if not sent to GTs)

4.2 Evaporative Cooling Tower

The concept for evaporative cooling towers is to cool the HEX discharge water through an evaporation process. Cooling water would be pumped through the HEX to the top of the cooling tower and sprayed onto a packed fill media, falling to the bottom basin. To maximize evaporative cooling capacity, fans would be used to pull a countercurrent stream of dry, cooler air through the packed fill media, evaporating some of the cooling water and providing the cooling effect. In winter, the cooling tower outlet water temperature would decrease and a portion of the flow would need to bypass the HEX to maintain the correct sludge temperatures. A continuous amount of treated municipal-supplied makeup water would be required to replenish the water lost through evaporation and the periodic blowdowns required to maintain the proper water chemistry in the cooling loop. A typical evaporative cooling tower is shown in Figure 8.

Figure 8. Evaporative Cooling Tower: Typical Unit

In the colder months of the year, the moisture from the sprayed water within the packed fill media would be absorbed in the air and condense in the cold, humid air. This condensate would be visible and create a "plume," which the project team considers to be an unacceptable visual impact to the neighboring community. This problem can be mitigated by a plume abatement feature that typically works by equipping the tower with an additional section of coils near the exhaust air discharge. The hot process water piped through this section would heat the air before it contacts the cold ambient air outside of the tower. By discharging the air/water vapor mixture at a warmer temperature, the amount of water condensed after contacting the cold ambient air would be limited, and the visible plume would be reduced or eliminated. Additional pumping power would be required compared to a tower without plume abatement because of the additional pressure loss of sending the hot water through the heating coils. Figure 9 shows a cooling tower with and without plume abatement.

Figure 9. Evaporative Cooling Tower Example: Left Side Operating with Plume Abatement Off, Right Side Operating with Plume Abatement On

The climatic design temperatures for ambient air-cooled options were taken from the 2017 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) design standards for Ronald Reagan Washington National Airport (see Table 5). The 0.4 percent design conditions are commonly used in cooling tower design, signifying that the given temperatures are exceeded only 0.4 percent of hours in a year.

Table 5. ASHRAE 2017 Reagan National Airport Design Conditions

Monthly Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry bulb average	37.2	39.4	47.1	57.4	66.3	75.4	80	78.4	71.3	59.9	49.4	40.9

Table 6 shows the evaporative cooling design conditions taken from ASHRAE. The 0.4 percent ambient wet bulb temperature was used as the design condition for the evaporative cooling tower.

Table 6. ASHRAE 2017 Reagan National Airport Cooling Tower Design Conditions

Cooling Design Data	0.4% Design Condition
Ambient air dry bulb, °F	94.7
Ambient air wet bulb, °F	78.4

To provide redundancy for the system, the cooling tower would consist of two cells, each independently capable of handling 100 percent of the design conditions. A single cooling tower would provide the cooling requirements for both HEXs. The fans would be outfitted with a variable-frequency drive (VFD) to control motor speed. During maximum cooling load operation, the towers would each operate at half capacity, and during maintenance or unplanned outages, a single unit would operate at full capacity. A second cooling water pump would also be required as a redundant unit that could run in parallel at part load or be used in a standby capacity.

In the colder months, the cooling tower can produce outlet water temperatures much below those that the tower was sized for. To lower energy usage, the cooling tower equipment can include fan VFDs to control "free cooling" benefits where the fan speed is lowered to reduce the amount of cooling. To maintain a set cooling water temperature into the HEX, a controlled cooling tower bypass line could be incorporated, but considerations would need to be made for minimum flow requirements through the cooling tower. For plume abatement, a minimum flow would be required through the heating coils, which would limit the controllability of the HEX inlet water temperature.

HDR contacted two cooling tower manufacturers as representative suppliers for this type of equipment, Baltimore Aircoil (BAC) and SPX Cooling Technologies, for information and cost proposals. For both manufacturers, plume abatement is not available at the required size; therefore, the unit would be oversized for the application to include plume abatement. A preliminary estimate showed the cooling capacity of a plume-abated tower meeting the design criteria to be 50 percent oversized compared to a standard tower with plume (increasing the cost by approximately $250,000). A minimum hot water flow would be required through the cooling tower that would require additional bypass around the HEX.

Preliminary design criteria, shown in Table 7, are based on these vendor proposals.

Table 7. Evaporative Cooling Tower Preliminary Design Criteria

Parameter (per Tower)	Evaporative Cooling Tower (Plume Abatement)	Evaporative Cooling Tower (No Plume Abatement)	Unit
Number of fans	2	2	Qty.
Fan power	20	15	hp
Hot water inlet temperature	96	96	°F
Cooling water outlet temperature	86	86	°F
Cooling water flow	1,180	940	gpm
Total cooling tower space required (includes maintenance clearances) (L × W × H)	23 × 24 × 26	17 × 18 × 12	ft
HEX space required (L × W) per HEX	24 × 7 (qty. 2)	24 × 7 (qty. 2)	ft
Equipment operating weight (2-cell tower)	96,000	31,000	lb
Minimum cooling demand to tower	1,180	N/A	gpm
Water demand (makeup)	14	10	gpm
Power requirement	15	11	kW
Noise	86	86	dB(A) at 5 ft

Approximate sizes of the HEXs and cooling tower are shown in Figure 10 and Figure 11 below with the dashed line indicating the pull space required for HEX maintenance.

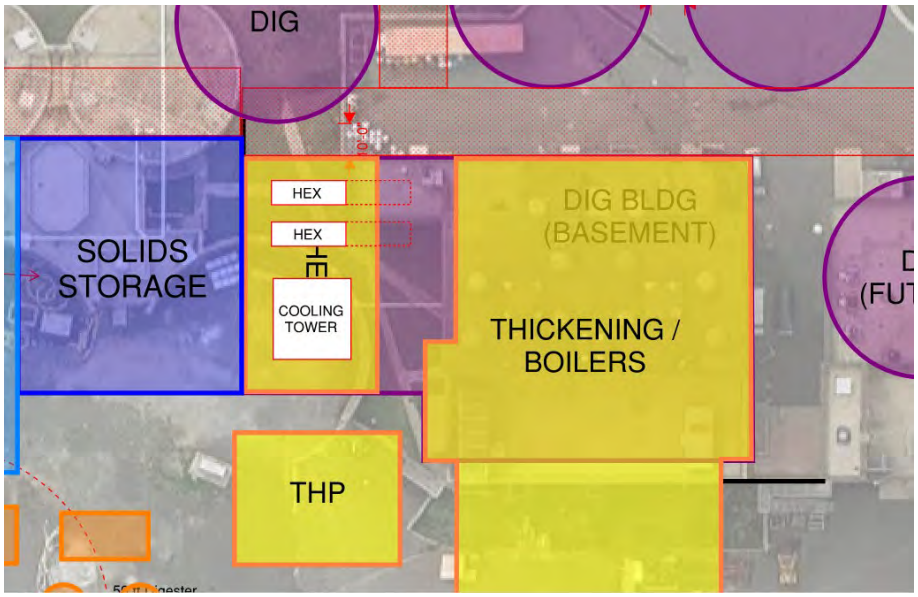

Figure 10. Evaporative Cooling Tower (Plume Abatement): Equipment Plan View—Decommission Dewatering Building Option

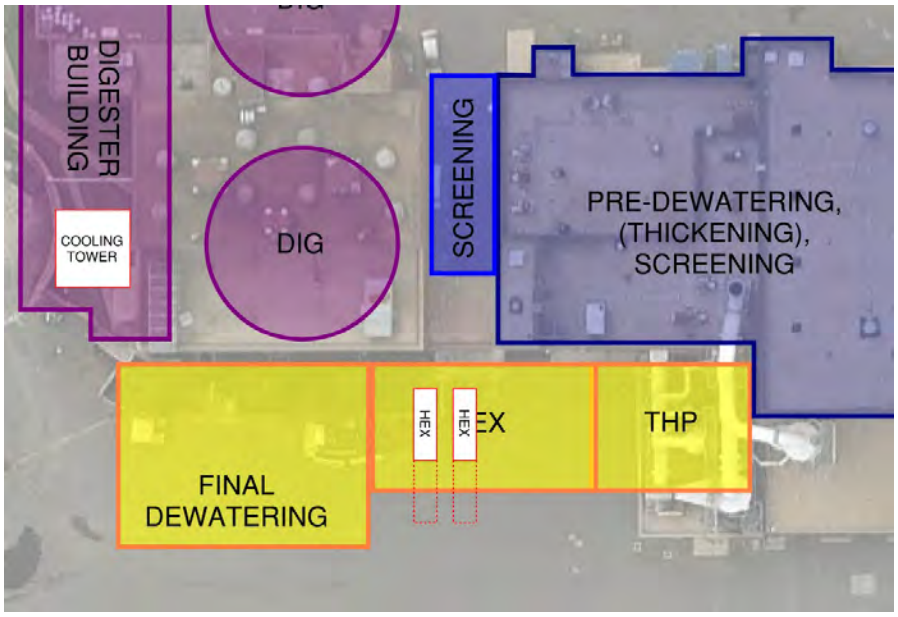

Figure 11. Evaporative Cooling Tower (Plume Abatement): Equipment Plan View—Renovate Dewatering Building Option

The relative advantages and disadvantages of the evaporative cooling tower option are listed in Table 8.

Table 8. Evaporative Cooling Tower Advantages and Disadvantages

Advantages	Disadvantages
Closed-loop system with treated municipal-supplied water: HEX less likely to have fouling, corrosion, and scaling	Cooling tower located outdoors: plume abatement may be required (higher cost)
316L stainless-steel material acceptable	Unit physical height may cause aesthetic concern
Reduced size of HEX compared with once-through HEX	Requires treated water makeup source
	Additional noise for fan operation
	Minimum allowable cooling water temperature to the HEX and minimum cooling water flow required for plume abatement option may complicate operation and control of the system

4.3 Air-Cooled Chiller

Mechanical air chillers make use of the vapor-compression refrigeration cycle to remove heat from a propylene glycol liquid stream and reject it to a warmer heat sink. Operation of a mechanical chilling cycle requires the use of an electrically driven compressor. The major advantage of this technology is that it can achieve lower cooling temperatures than both the once-through and cooling tower options, which are limited by the PEW temperatures and ambient air temperature, respectively. The lower temperatures would reduce the required size of the HEX. However, air-cooled chillers typically operate at a constant chilled water temperature, which does not make a design case for a single-pass isolation redundancy method feasible. A third redundant two-pass HEX is used as the basis for design for the air-cooled chiller cooling option.

In the colder months when the ambient air temperature is less than the target cooling temperature, an air-cooled chiller can be outfitted with a water-side economizer that can use “free cooling.” In this configuration, ambient air is used to directly remove heat from the cooling water, reducing the load on the refrigeration cycle, thereby reducing the compressor electrical load. The fan’s speed can also be modulated with a VFD to save on power when the required cooling load is reduced.

A single chiller would provide the cooling requirements for both HEXs. To provide redundancy, a second chiller would be required that can provide the full design cooling load. A second cooling water pump would also be required as a redundant unit that could run in parallel at part load or be used in a standby capacity. A typical air-cooled chiller is shown in Figure 12. Table 9 shows air-cooled chiller preliminary design criteria.

Figure 12. Air-Cooled Chiller: Typical Unit

Table 9. Air-Cooled Chiller Preliminary Design Criteria

Parameter (Per Chiller)	Air-Cooled Chiller	Unit
Cooling load	396	Tons cooling
Number of fans	20	Qty.
Water inlet temperature	85	°F
Chilled water outlet temperature	65	°F
Cooling water flow	500	gpm
Chiller space required (L × W × H): per chiller	38 × 8 x 8	ft
HEX space required (L × W) per HEX	24 × 7 (qty. 3)	ft
Equipment operating weight: per chiller	22,000	lb
Water demand	Closed cycle	-
Max power	410	kW
Noise	101	dB(A) at 30 ft

Approximate sizes of the HEXs and air-cooled chillers are shown in Figure 13 and Figure 14 below with the dashed line indicating the pull space required for HEX maintenance.

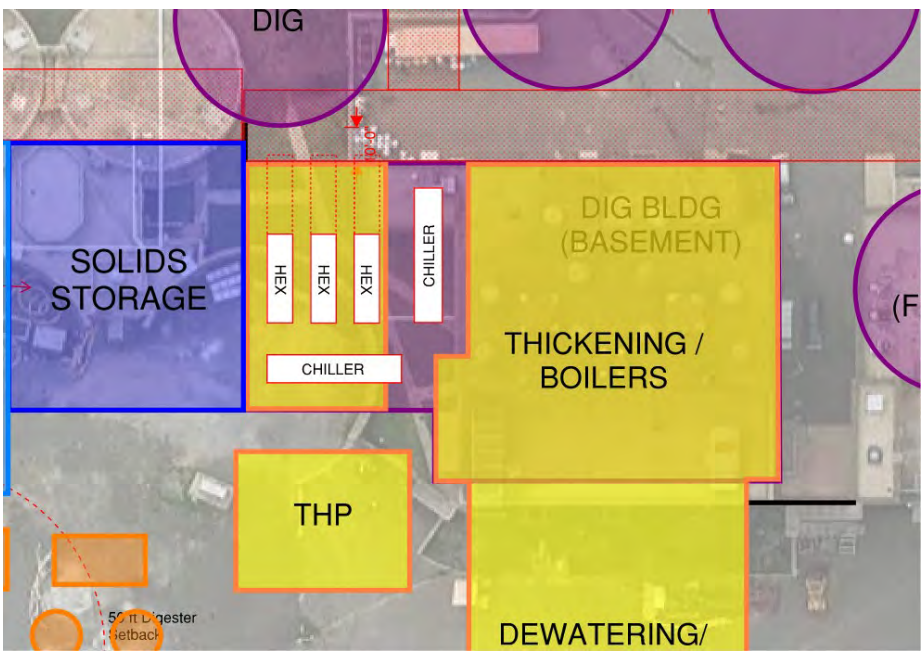

Figure 13. Air-Cooled Chiller: Equipment Plan View—Decommission Dewatering Building Option

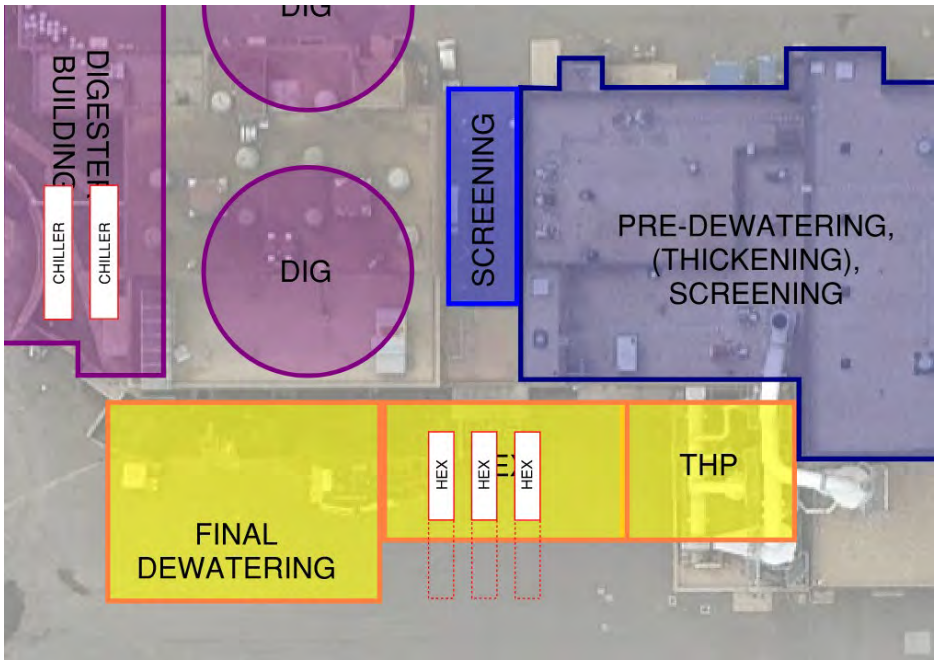

Figure 14. Air-Cooled Chiller: Equipment Plan View—Renovate Dewatering Building Option

The relative advantages and disadvantages of the air-cooled chiller are listed in Table 10.

Table 10. Air-Cooled Chiller Advantages and Disadvantages

Advantages	Disadvantages
Closed-loop system with treated municipal-supplied water: HEX less likely to have fouling, corrosion, and scaling	Redundancy requires additional chiller and chilled water pump
316L stainless-steel material acceptable	Located outside: aesthetics and impact of weather on performance and equipment degradation
Reduced surface area per HEX	High operating costs for electricity consumption
	Additional noise for fan/compressor operation

5.0 Technology Comparison

This section presents a side-by-side comparison of the relative advantages and disadvantages, design criteria, and equipment costs for the cooling technologies evaluated. It also identifies and compares operating costs for the shortlisted technologies.

5.1 Market Comparison

A market analysis was completed looking at current facilities with THP installed or in construction in the United States. All the facilities shown in Table 11 below use once-through technologies with plant effluent or evaporative cooling towers. No THP facility in the United States uses an air-cooled chiller technology.

Table 11. Cooling Technologies Implemented at North American THP Facilities

Agency	Site	Project Status	Cooling Technology
DC Water, Washington, DC	Blue Plains Advanced WWTP	Started up in 2014	Once-through with plant effluent
Medina, Ohio	Holtz WWTP	Started up in 2018	Once-through with plant effluent
HRSD, Virginia	Atlantic WWTP	Started up in 2020	Once-through with plant effluent
Trinity River Authority (Dallas, Texas)	Central Regional Wastewater System	In construction; startup in 2021	Evaporative cooling tower
City of Raleigh, North Carolina	Neuse River RRF Bioenergy Recovery Project	In construction; startup in 2022	Evaporative cooling tower
WSSC, Maryland	Piscataway WRRF Bioenergy Facility	In construction; startup in 2023	Once-through with plant effluent
Kansas City, Missouri	Blue River Biosolids Facility	In design	Evaporative cooling tower (tentative)

5.2 Advantages/Disadvantages Comparison of Technologies

Table 12 provides a side-by-side comparison of the relative advantages and disadvantages of each technology. Design criteria are compared in Table 13 for the different cooling technologies.

Table 12. Cooling Technology Advantages and Disadvantages Comparison

Advantages/ Disadvantages	Once-Through	Evaporative Cooling Tower	Air-Cooled Chiller
Advantages	+ No additional cooling equipment required + Smallest electrical load and simplest equipment complexity + Fewer moving parts, low noise + Small footprint + Commonly used with THP	+ Closed-loop system with treated municipal-supplied water: HEX less likely to have fouling, corrosion, and scaling + Stainless-steel material acceptable + Reduced size of HEX + Has been implemented with THP	+ Closed-loop system with treated municipal-supplied water: HEX less likely to have fouling, corrosion, and scaling + Stainless-steel material acceptable + Reduced size of HEX
Disadvantages	- Largest HEX required compared to other options - More HEX maintenance because of PEW fouling - Potential for corrosion: suggest high alloy steel HEX material - PEW would need to be recycled and retreated (optional if not sent to GTs)	- Cooling tower located outdoors: plume abatement has higher capital costs - Unit physical height may cause aesthetic concern - Requires treated water makeup source - Additional noise for fan operation - Minimum allowable cooling water temperature to the HEX and minimum cooling water flow required for plume abatement may complicate operation and control of the system	- Redundancy requires additional chiller and chilled water pump - Located outside: aesthetics and impact of weather on performance and equipment degradation - High operating costs for electricity consumption - Additional noise for fan/compressor operation - No known THP installations

Table 13. Cooling Technology Design Criteria Comparison

Parameter	Once-Through	Evaporative Cooling Tower (Plume Abatement)	Evaporative Cooling Tower (No Plume Abatement)	Air-Cooled Chiller	Unit
Cooling equipment quantity	N/A	2 (cells)	2 (cells)	2	Qty.
HEX inlet water temperature	84.3	86.0	86.0	65.0	°F
Max cooling water flow	250 (per HEX)	1,180 (total)	940 (total)	500 (total)	gpm
Min cooling water flow	105 (per HEX)	1,180 (total)	470 (total)	500 (total)	gpm
HEX outlet water temperature	98.5	90.3	90.3	80.7	°F
HEX heat transfer area (per HEX)	2,100	1,500	1,500	700	ft^2
HEX sludge velocity	6.4	6.4	6.4	6.4	ft/s
HEX water velocity	3.1	4.5	4.5	3.1	ft/s
Mixed sludge pressure drop	79	48	48	21	psi
Cooling water pressure drop	16	25	25	4	psi
Total cooling equipment space required (L x W x H)	N/A	23 × 24 × 26 552	17 × 18 × 12 306	38 × 20 × 8 760	ft ft^2 (total)
Cooling equipment operating weight	N/A	96,000	31,000	22,500 45,000	lb per unit lb total weight
Maximum water demand	500 (PEW)	14 (makeup)	10 (makeup)	N/A	gpm
Cooling water pump configuration	4 × 5 hp (recirculation)	2 × 30 hp	2 x 25 hp	2 × 15 hp	
Max cooling equipment power requirement (excluding pumps)	N/A	15	11	410	kW total
Used with existing THP sites	Yes	Yes	Yes	No	

5.3 Operating Cost Assumptions

Annual and 20-year operating costs were estimated at the design average WPCP flow of 30.8 mgd, and the 3-day peaking factor as detailed in *TM No. 1 Solids Production and Design Criteria*. The annual and 20-year operating costs were calculated based on a constant THP sludge flow of 568 gallons per minute (gpm). Operating costs included cooling water pump electricity, cooling tower fans, makeup water pump electricity, and municipal water supply costs.

5.3.1 Once-Through Cooling Operating Costs

For the once-through cooling method, the maximum PEW temperatures shown in Table 2 above were used to calculate the mass flow rate of PEW required to meet the cooling demand. The total PEW cooling demand for both digesters was calculated to range between approximately 200 gpm in the colder months and 500 gpm in the hotter months. The existing PEW pumps were assumed to be capable of handling the additional system pressure head of pumping to and from the new HEX. A hydraulic model is required to confirm this assumption. A recirculation pump preliminarily sized at 5 horsepower (hp) per HEX is operating throughout the year to provide temperature control of the PEW into each HEX.

The recirculation pump will be variable speed and will modulate the PEW recirculation to maintain a constant temperature into the HEXs.

It is assumed that the PEW can be used as elutriation water for the GTs, thus not requiring any additional operating costs for retreatment. In the operating scenario where the PEW would need to bypass the GTs, a retreatment cost of $0.50/1,000 gallons should be applied to the PEW flow that accounts for pumping costs to and from the PEW source.

5.3.2 Cooling Tower Operating Costs

The cooling tower operating costs were based on a two-cell tower, each sized for 100 percent of the design cooling load. Only one fan is required to operate at full load, and the fan is equipped with a VFD to reduce the fan speed and electrical load in the colder months. For the plume abatement option, the fan was assumed to operate between its rated power of 20 hp in the summer months and 5 hp in the colder months. For the non-plume abatement option, the rated fan power is 15 hp in the summer months and 5 hp in the colder months.

The selected model of cooling tower with plume abatement required a minimum flow through the tower of 1,180 gpm. Using an assumed design system head of 75 feet (includes static lift of cooling tower, pressure drop through HEX, and piping friction losses), the circulating water pump size is estimated to be 30 hp. This pump was assumed to operate at a constant speed throughout the year. For the non-plume abatement option, the circulating water pump size was estimated at 25 hp because of the lower flow rate requirements.

It was assumed that the makeup water was supplied by the municipal source at a pressure capable of meeting the cooling tower requirements. Further analysis needs to be completed to verify that a makeup water pump is not required.

Municipal water chemical treatment costs were assumed to be negligible for this analysis. The municipal water will need to be periodically tested and may need a biocide and chemical treatment for scaling and corrosion prevention in the tower. The costs for this testing and chemical addition were assumed to be negligible for this analysis.

5.3.3 Air-Cooled Chiller Operating Costs

Based on the outside ambient temperature, an air-cooled chiller equipped with variable-speed fans, variable-speed compressor, and free cooling can be modulated, saving electricity costs. As the ambient temperature decreases, a chiller can use the free cooling capabilities and reduce the compressor power, decreasing the power from around 410 kilowatts (kW) to around 30 kW during the coldest days. The total compressor and fan power was modeled as an average monthly usage based on the average ambient dry-bulb temperature shown in Table 5 above.

The required flow through both HEXs using 65°F chilled water was approximately 500 gpm to meet the full cooling load. Using an assumed design system head of 75 feet (includes pressure drop through chiller, pressure drop through HEX, and piping), a 15 hp pump was chosen that would operate at a constant speed throughout the year.

5.4 Cost Comparison for Shortlisted Technologies

Conceptual equipment and construction costs were prepared for each alternative based on preliminary equipment quotes from vendors and general percentages for site work, contingencies, and general contractor costs as shown in Table 14.

Table 14. General Percentages for Cost Preparation

Parameter	Percentage
Contractor mechanical and installation	50%
Contractor mobilization/staging	5%
Contractor bonds/insurance	3%
Contractor overhead and profit	15%
Project contingency	20%

Annual and 20-year present-value operating costs were estimated for the shortlisted cooling technologies. Operating cost estimates considered the following annual costs:

- Power at $0.06 per kilowatt-hour [kWh]
- Retreatment of WPCP effluent at $0.50/1,000 gallons (for retreatment operating condition—not included in base option)
- Municipal supply makeup water at $4.91/1,000 gallons

Present-value costs were calculated for the 20-year analysis period using a nominal interest rate of 4.0 percent. Cooling option costs are compared in Table 15. A 20-year present value of costs for each option is presented for comparison.

Table 15. Capital and Operating Costs: Annual and 20-Year Present Value

Parameter	Once-Through Cooling	Evaporative Cooling Tower (Plume Abatement)	Evaporative Cooling Tower (No Plume Abatement)	Air-Cooled Chiller
Capital Costs				
Cooling equipment	$0	$420,000	$155,000	$650,000
Pumps	$10,000	$40,000	$36,000	$30,000
HEX	$1,540,000	$1,150,000	$1,150,000	$666,000
Subtotal equipment cost	*$1,550,000*	*$1,610,000*	*$1,341,000*	*$1,346,000*
Contractor cost	$775,000	$805,000	$671,000	$673,000
Mobilization and bonds	$124,000	$129,000	$108,000	$108,000
Contractor overhead and profit	$233,000	$242,000	$202,000	$202,000
Contingency	$310,000	$322,000	$269,000	$270,000
Total capital cost	*$2,992,000*	*$3,108,000*	*$2,591,000*	*$2,599,000*
Annual Operating Costs				
Cooling equipment electricity	$0	$6,000	$4,000	$95,000
Pump electricity	$4,000	$12,000	$10,000	$6,000
Makeup water costs	$0	$37,000	$26,000	$0
Water treatment costs	$0	$0	$0	$0
Total annual operating cost	$4,000	*$55,000*	*$40,000*	*$101,000*
20-year Present-Worth Operating Costs				
Cooling equipment electricity	$0	$70,000	$53,000	$1,290,000
Pump electricity	$60,0000	$160,000	$140,000	$80,000
Makeup water costs	$0	$500,000	$360,000	$0
Water treatment costs	$0	$0	$0	$0
Total 20-year present-worth operating costs	*$60,000*	*$730,000*	*$553,000*	*$1,370,000*
Total 20-year Present Value of Costs	**$3,052,000**	**$3,838,000**	**$3,144,000**	**$3,969,000**

As part of the once-through cooling option, the annual and 20-year present-value operating costs were analyzed in the scenario where the WPCP effluent from the HEX could not be sent as elutriation for the GTs and instead, to drain. Using the approximate cost of $0.50/1,000 gallons, the estimated annual cost based on the maximum PEW demand at design conditions would be approximately $90,000 and approximately $1.2 million for a 20-year present value basis, resulting in a total 20-year cost of $4.2 million.

6.0 Summary and Conclusions

The cooling tower option with plume abatement presented the highest capital costs primarily because of the increased cooling tower size and the additional piping needed for plume abatement. The once-through design option had the next-highest costs because it required the largest HEX surface area and because of the high cost of the upgraded HEX alloy to prevent corrosion. The air-cooled chiller option had the next-highest capital costs primarily because of the low chilled water temperature, reducing the required HEX size and cost. The evaporative cooling tower option without plume abatement had the lowest capital costs because of the much cheaper tower compared to the plume abatement option as well as the smaller stainless-steel HEX compared to the once-through option.

The air-cooled chiller option had the highest operating costs because of the high compressor electricity loads. The savings from the smaller HEX did not pay for the high operating costs compared to the other three options. The options with the next-highest operating costs were the cooling tower options because of the fan power, pumping costs for the cooling water, and the cost of the municipal-supplied makeup water needed for evaporation losses and periodic blowdown. The operating costs were very low for the WPCP effluent option because the water can be used as elutriation for the GTs and would not need to be retreated, leaving only a small electrical pumping load because of recirculation of the effluent for temperature control.

The cooling tower could be placed on a roof or on the ground; however, pumping costs would increase as the height of the cooling tower water inlet is increased. The overall footprint would be lower for the cooling tower than for the chiller; however, the approximate 26-foot height of the cooling tower with plume abatement could pose an aesthetic issue for the site.

Although not included at this stage of the quantitative analysis, replacement and maintenance costs for the cooling tower and chiller equipment should be considered because of the added mechanical complexity and moving parts. This equipment can be assumed to have a life expectancy of 20 years.

HDR recommends including the once-through cooling with PEW as the basis for costs and design in the Facilities plan. The evaporative cooling tower options could be considered for the final design should any design parameters or equipment costs significantly change.

Next steps required to confirm the design of the cooling system should include analysis of the following items:

1. PEW/cooling tower pumping total dynamic head (TDH) analysis including preliminary piping model
2. Minimum cooling water temperature for the cooling HEX to prevent FOG buildup
3. Water quality analysis on PEW to confirm suitability of materials and fouling potential.
4. Effect of warm effluent for GT elutriation
5. Impact of a cooling tower plume on community aesthetics

Technical Memorandum No. 13

Date:	December 14, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Odor Control Facility Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the odor control facilities evaluation, followed by a description of the evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary solids (PS) and waste activated solids (WAS) thickening, dewatering, and lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this odor control facilities evaluation is to assess and compare alternatives for establishing permanent odor control facilities for the new solids processes. The results of this evaluation will inform decisions on overall site planning and utility requirements for inclusion in the Facilities Plan.

1.2 Evaluation Approach

Four odor control alternatives were developed for comparison based on preliminary design criteria established through:

- Estimated foul-air exhaust rates for the potential odor sources
- Estimated peak and average concentrations of odorants in combined foul-air exhaust flows
- Identified odor treatment system design parameters
- Identified odor collection and treatment system arrangement and redundancy requirements

For each odor control alternative, conceptual odor control facility layouts and life-cycle costs were developed.

2.0 Summary of Existing Facilities

There are three existing odor control systems at the WPCP: the south, north, and dewatering building (DWB) odor control systems.

The south odor control system currently serves the following areas:

- Four Mile Run Pump Station
- Preliminary treatment building (PTB)
- Dissolved air flotation thickener (DAFT)
- Gravity thickeners (GTs)
- Sludge storage tanks (SSTs)

The north odor control system primarily serves the equalization (EQ) tanks, the primary clarifier effluent channel, the backup screens and various flow structures. The DWB odor control system serves the entire DWB including multiple process points within the building and the truck bays.

The locations of the three scrubber systems and facilities served are shown in Figure 1.

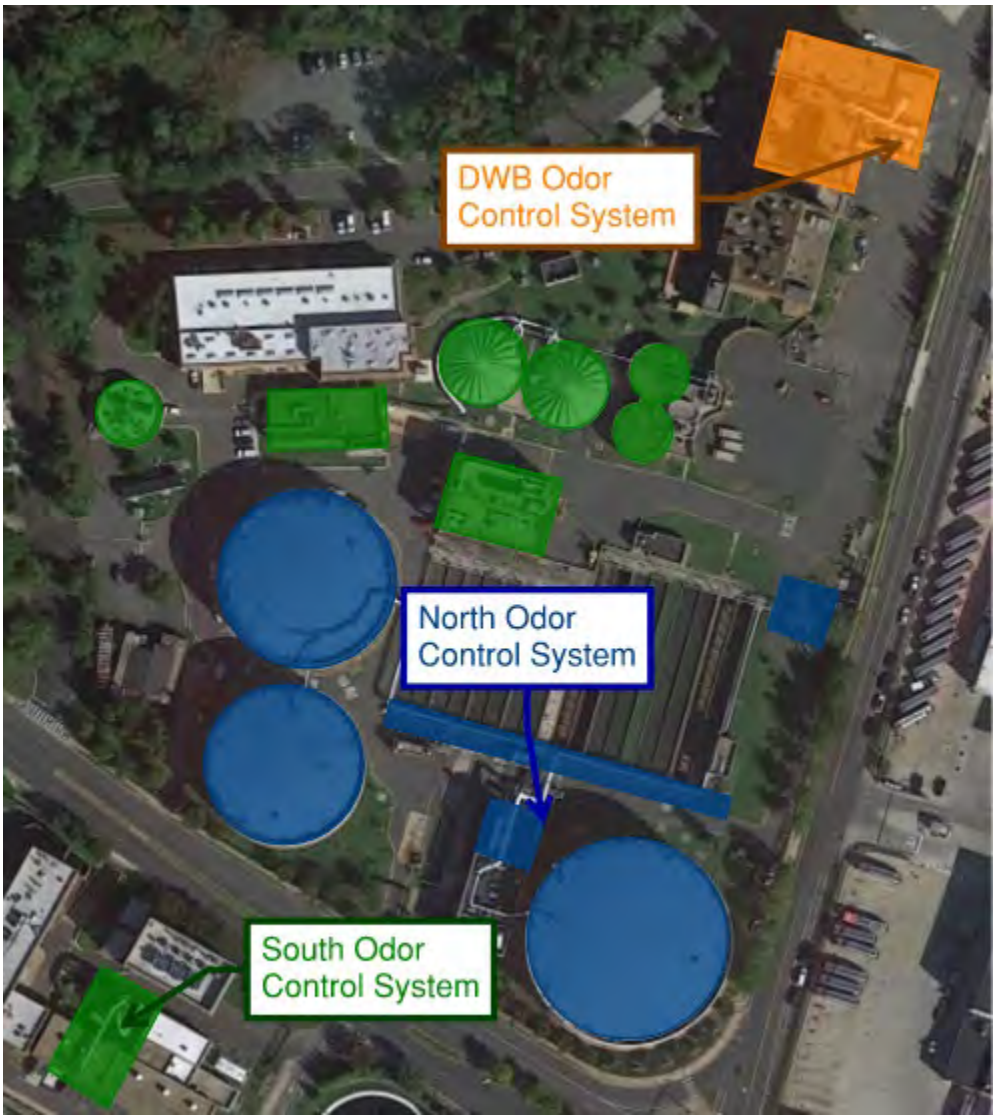

Figure 1. Locations of Existing Odor Control Facilities

The south odor control system includes a two-stage packed-tower scrubber for removal of hydrogen sulfide (H_2S) and low molecular weight organic sulfur compounds, also referred to as organic reduced sulfur compounds (orgS). This system has a capacity of approximately 31,000 cubic feet per minute (cfm). Many recent studies have been completed to review the design and capacity of the south and DWB odor control systems, including the *Foul Air Study for Preliminary Treatment Building and Dewatering Building* (CDM Smith 2017) and the *Preliminary Treatment Upgrades (WPB2) Phase 9B Odor Control Alternatives Ventilation System Evaluation and Recommendations* (CDM Smith 2019).

The design for the Preliminary Treatment Upgrades (WPB2) Phase 9B (PTB Upgrades) includes new ventilation for the PTB. Odor control for this new ventilation will be provided by directing the PTB airflow through the GTs, and then on to the south odor control system. The expected odor control ventilation rates to the south odor control system subsequent to the PTB Upgrades is provided in Table 1. All areas served by South Odor Control have dedicated four air fans exhausting from the source.

Table 1. Expected Exhaust to the South Odor Control System Following WPB2 PTB Upgrades

Source	Flow (cfm)	Notes
PTB	23,000	Directed through GTs
GTs	20,000	Captures PTB airflow
DAFTs	5,300	
Four Mile Run Pump Station	4,800	
SSTs	700	
Minor sources	450	
Total to south odor control	**34,250**	Airflow from PTB not additive as it goes through GTs

The north odor control system treats odors from flow equalization tanks and primary effluent channel in a two-stage packed-tower scrubber for removal of H_2S and orgS. The system is designed to treat up to 39,000 cubic feet per minute. No modifications to the north odor control system are expected as part of the Arlington Re-Gen Program.

The DWB odor control system treats odors collected from the existing DWB in a multistage process: packed-tower scrubbers with acid to remove ammonia (NH_3) followed by two-stage packed-tower scrubbers with sodium hypochlorite (NaOCl) to remove H_2S and a wide range of organic sulfur compounds. The two ammonia scrubbers are designed to operate in parallel and provide treatment capacity up to 17,660 cubic feet per minute (4,350 and 13,310 cubic feet per minute respectively). The sulfide scrubbers are designed to operate in series and provide treatment capacity up to 41,830 cubic feet per minute.

Rehabilitation of the existing DWB or construction of the new solids processing building will result in replacement of all existing processes, requiring new takeoffs and ductwork. The existing DWB chemical scrubber process mechanical equipment is approaching the end of its useful life and it is recommended that a new odor control system be designed and new equipment be provided.

3.0 Summary of Future Facilities

The following new facilities will generate odors that should be collected and treated as part of the Arlington Re-Gen Program:

- WAS EQ storage tanks
- Solids screens
- Thickened solids storage tanks
- Screw conveyors
- Pre-dewatering centrifuges
- Pre-dewatered cake bins
- Final dewatering centrifuges
- Final dewatered cake bins
- Truck bay
- Future facilities

It is assumed that screenings from the solids screens will be bagged using a continuous bagging system prior to discharge into the screenings dumpsters and the screenings dumpsters will not generate odors.

Future odor control needs may include future WAS thickening; future fats, oils, and grease (FOG) receiving; etc.

While definitive information on the character of odors from the new potential sources will not be available until construction is complete and operation is underway, experience can provide an idea of what is likely.

Wastewater treatment processes are capable of producing a range of odors, including the following:

- H_2S
- OrgS:
    - Mercaptans
    - Dimethyl sulfide
    - Dimethyl disulfide
- Amines:
    - NH_3
- Volatile organic compounds (VOCs):
    - Ketones
    - Aldehydes
    - Organic acids
    - Alcohols

Most wastewater treatment processes will typically produce some H_2S and, to a lesser degree, methyl mercaptan. Generally, H_2S dominates in preliminary and primary treatment; for aeration tanks and solids processing, orgS (e.g., methyl mercaptan, dimethyl sulfide, dimethyl disulfide) tend to become more pronounced. Following heating (i.e., THP) and/or pH elevation, sludge cake can also emit amines, whereNH_3 typically dominates. Long-chain amines are uncommon.

Odors produced by future facilities will likely consist mostly of H_2S, orgS, and NH_3. Exhaust flow from solids processing as far downstream as the pre-dewatered cake storage hoppers would be expected to have H_2S and orgS but no NH_3. The most significant sulfur odors will likely be produced by the pre-dewatered raw cake prior to THP. Exhaust flow from the final dewatering centrifuges, final dewatered cake storage hoppers, and truck bay will likely have a strong NH_3 odor but diminished sulfur odor. Odor from the truck bay is expected to be strong but intermittent, primarily driven by NH_3 and some orgS (i.e., only when the truck bay is in use).

4.0 Odor Control Technology Review

This section provides a review of the following three odor control technologies considered for use at the WPCP:

- Packed-tower chemical scrubbers
- Biological systems
- Activated carbon adsorption

All three of these are gas-phase treatment technologies, requiring effective capture and ventilation of odors to contain them and convey the odorous air for treatment.

4.1 Packed-Tower Chemical Scrubbers

Packed-tower chemical scrubbers are included in the odor control technology evaluation because they can be very effective for the types of odors observed with the solids handling process and Arlington County is familiar with the equipment. Figure 2 provides a schematic and photo of packed-tower chemical scrubbers.

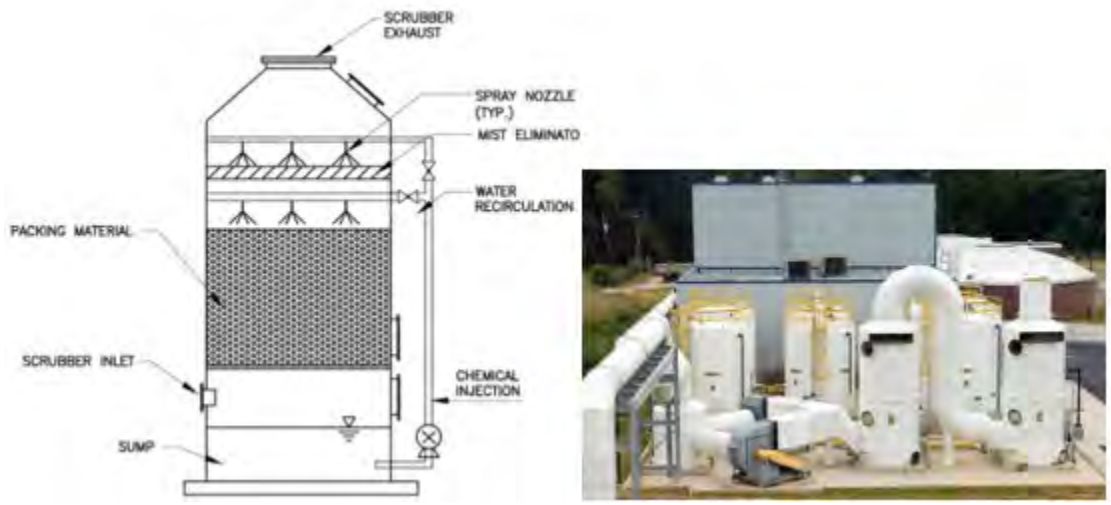

Figure 2. Packed-tower Chemical Scrubbers Schematic and Photo

Packed-tower chemical scrubbers have been used extensively to control odors at wastewater treatment plants and are classified as wet scrubbers because they use a scrubbing solution to remove odor-causing compounds from odorous air streams.

System configurations for packed-tower scrubbers range from single-stage systems that may or may not use oxidants to two-stage systems that typically use both absorption and oxidation to remove odorous air contaminants. The packed-tower chemical scrubber system chemistries are selected and designed specifically for the types of odorous compounds being treated. These systems can be effective at removing a wide range of odorants, including H_2S, orgS, and NH_3-based compounds. As noted previously, Arlington County currently has three packed-tower chemical scrubber systems at the WPCP.

Advantages of packed-tower chemical scrubbers include the following:

- Can achieve high levels of H_2S and other odorous compound removal over a wide range of airflow rates
- Low required contact time allows for smaller scrubber vessel volumes
- Proven technology with a long track record
- Scrubber systems can be turned on and off at will, or throttle down or up if the odor load changes
- WPCP staff have experience with chemical scrubbers

Disadvantages of packed-tower chemical scrubbers include the following:

- Cost and risk of handling potentially challenging chemicals such as caustic (NaOH), sodium hypoclorite (NaOCl), and sulfuric acid (H_2SO_4).
- Produce a continual flow of contaminant scrubbing solution known as blowdown. Scrubber system blowdown flows are a waste product that needs to be managed. Depending on the chemicals used in the scrubber, the blowdown can often be discharged to the WPCP drain.
- High capital costs associated with chemical pumping, piping, and containment.
- Require periodic cleaning of the media by acid washing.

4.2 Biological Systems

Like chemical treatment, biological treatment relies on absorption of odorants into solution and subsequent liquid-phase processes. Unlike chemical treatment, it relies on biomass, rather than chemical dosing, for ultimate removal of the odorants.

In the same way that chemical treatment of foul air containing H_2S, orgS, and NH_3 requires the use of multiple chemicals, biological treatment requires the growth of different types of bacteria depending on the odorants. The bacteria most suited to consuming H_2S are autotrophic and thrive in low-pH conditions; the bacteria most effective at treating orgS are heterotrophic and can survive only in neutral pH conditions. Biological treatment does not directly treat NH_3 and amine odors. However, biological treatment can treat NH_3 and amines indirectly through the same acid-base chemistry of a packed-tower chemical scrubber.

Two types of systems are used for biological treatment: biofilters and biotowers.

4.2.1 Biofilters

Biofilters consist of solid media where bacteria and other organisms form and biologically consume the odor-causing compounds. Figure 3 provides a schematic and photo of a biofilter system.

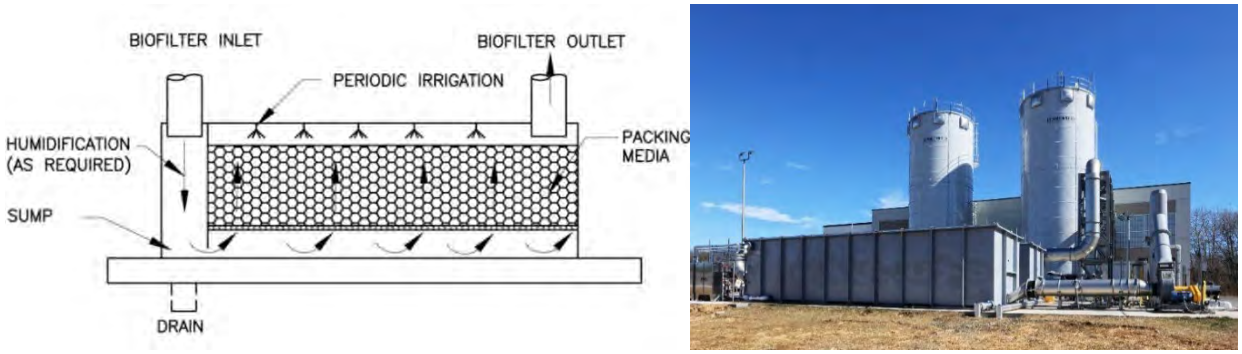

Figure 3. Biofilter Schematic and Photo

Biofilter systems—particularly the media used—have evolved over time. The older biofilter systems were made with bark mulch style media that would gradually decay and compact, which required regular media replacements. The older biofilter systems also required larger footprints because of longer empty-bed contact time (EBCT) requirements of at least 60 seconds. More recently, long-life media biofilter systems have been developed that do not decay and compact and come with 10-year warranties. Some of these long-life biofilter systems have been in proven service for more than 10 years.

These long-life biofilter systems also require less EBCT because the manufactured media achieves a better performance. Although the EBCT is lower on the newer systems, further decreasing the overall sizing requirements of the biofilter footprint, it still has a large footprint compared to other treatment options. Biofilters generally operate at a near-neutral pH.

Advantages of biofilter systems include the following:

- They are proven technologies for treating a wide range of compounds including H_2S, methyl mercaptan, and other orgS (dimethyl sulfide, dimethyl disulfide, etc.).
- They have relatively low maintenance requirements.
- Biofilters do not require any chemical storage or handling other than small nutrient addition systems.

Disadvantages of biofilter systems include the following:

- They have larger footprints because of long EBCT requirements.
- Biofilters are living systems that require initial acclimation of the biology and they must stay in service to keep the biology alive.
- Biofilters have an upper reasonable limit for inlet H_2S. Sustained long-term levels above 50 parts per million (ppm) are not desirable as they can overload the media with sulfur deposits and acid by-product attack. This is likely not anticipated as an issue for the WPCP.
- Because the systems are biological, consideration must be given to cooler winter conditions, and the inlet air temperature from the odor sources. Sustained odorous air temperatures below 40 degrees Fahrenheit are not desirable. This is not considered a serious limitation for Arlington, given the lowest typical winter weather and the lowest historical wastewater temperatures.

4.2.2 Biotowers

Biotowers are odor control treatment technologies that also consist of solid media for bacteria to grow. Figure provides a schematic and photo of a biotower system.

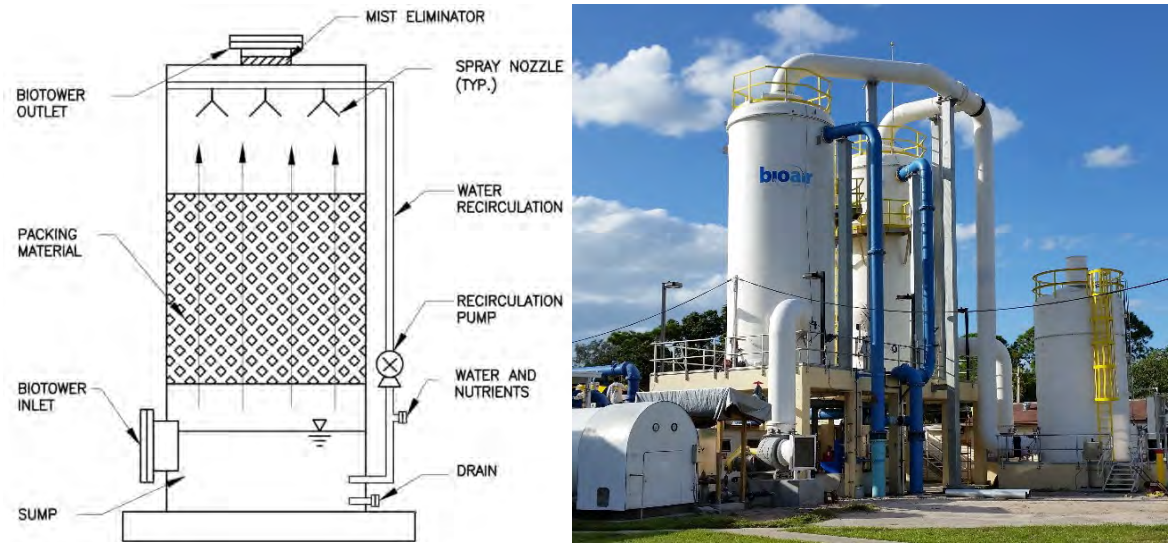

Figure 4. Biotower Schematic and Photo

The key differences between biofilters and biotowers are the EBCT and the biology being grown. Biofilters typically rely on heterotrophic organisms that remove multiple odorous compounds, whereas biotowers typically rely on autotrophic organisms targeting H_2S removal. Biotower media is completely inert and resistant to decay and compaction. For that reason, nutrient addition (such as trace organics, nitrogen, phosphorus, and potassium) is required for the biology and is added to biotower systems with spray water. Typically, the spray water consists of plant effluent water; however, it may be supplemented with dilute fertilizer injected into the spray water.

Advantages of biotower systems include the following:

- Biotowers have much shorter EBCTs (typically 10 to 15 seconds) compared to biofilters, and the media can be stacked much higher. These result in much smaller footprint requirements.
- Because the media in biotowers is inert, it has a very long bed life and likely requires little, if any, media replacement.
- The system likely does not require any significant chemical addition (potential for some nutrient addition) or safety concerns.

Disadvantages of biotower systems include the following:

- Biotowers are better suited to removing H_2S than other odorous compounds and can be less effective at removing orgS (dimethyl sulfide, dimethyl disulfide, etc.).
- Biotowers produce a continual flow of contaminant solution known as blowdown or leachate that is very acidic (H_2SO_4). Biotower blowdown flows are a waste product that needs to be managed.

- Biotowers work best at high H_2S loading rates (averaging more than 20 ppm).

4.3 Activated Carbon Adsorption

Activated carbon adsorption treats odor by adsorbing select odorants to its surface as foul air passes across it. Figure 5 provides a photo of a carbon adsorption system.

Figure 5. Carbon Adsorption System

Odorous air is passed through a bed of media composed of carbon-based adsorbents that adhere to or chemically react with odorous gases. As the gas-phase odor contaminants pass through the media, they contact and collide with the internal surfaces and are removed via adsorption from the air stream exiting the system. As the gas-phase odor contaminants accumulate on the internal surface area of the carbon (adsorbent), the carbon becomes exhausted, and the media must be regenerated or replaced. This can be a downside to this technology because replacing the carbon can be expensive and labor-intensive.

When H_2S concentrations are low (below 5 ppm), and NH_3 is not present at high concentrations, carbon-adsorption systems typically have lower capital costs compared to other gas-phase treatment systems (such as chemical scrubbers and biological systems) because odors can be removed with a much shorter contact time. The height of activated carbon systems is limited, so airflows above 10,000 cfm typically require multiple vessels. When concentrations of H_2S or NH_3 are higher, or when other odor species are present besides H_2S, carbon systems become uncompetitive because of the costs of replacing the media (high H_2S) and/or need for additional media types. There have also been case studies where odor sources with varying odor species (orgS, etc.) have been treated with carbon systems and resulted in desorption or chemical reactions, leaving more of these compounds in the effluent air.

Advantages of activated carbon adsorption systems include the following:

- Typically, carbon adsorption systems have lower initial capital costs compared to other treatment technologies.
- The systems do not require any chemical handling or storage.
- The systems can have a smaller footprint because of the short contact time requirements.
- The systems can be used as a polishing step for treated odorous air.

Disadvantages of activated carbon adsorption systems include the following:

- Exhausted carbon media replacements are costly and labor-intensive. If not replaced timely, spent carbon can result in off-site odor excursions.
- Influent loads with odor sources with varying odor species (organic sulfides, etc.) can result in effluent air with higher organic sulfur compound formation.
- The systems are not recommended for systems with very high odor concentrations.

4.4 Comparison of Treatment Technologies

The advantages and disadvantages of the four odor treatment systems are discussed above. An expanded summary comparison of the four treatment systems is presented in Table 2.

Table 2. Comparison of Odor Technologies

Technology	Packed Tower	Biotower	Biofilter	Carbon Adsorption
Removal of H_2S	✓ 99%+	✓ 99%+, works best at higher loadings (>20 ppm)	✓ 95%+, works best at lower loadings (<50 ppm)	! 99%+, 0% after carbon is spent
Removal of orgS	✓ With the right chemistry	✗ Research is ongoing but original design concept for biotowers was for H_2S removal only	✓ Effective at low inlet concentrations	! Can be designed for organic sulfur removal, but some research has shown desorption, leading to odor issues
Adjustment period	✓ None required	✗ Can take 2–3 weeks to acclimate during initial start, typically a polishing unit is provided	! Faster acclimation than biotower but can still take several days to acclimate	✓ None required
Footprint	✓ Lowest contact time required	! Vertical vessels for contact time, but still requires ~10-second EBCT	✗ Shallower depth than others with ~30-second EBCT	✓ Low contact time required, vessels limited in height
Capital cost	! Moderate: has multiple ancillary systems (pumping, chemicals, containment)	! Moderate: larger footprint and vessels than packed towers	✗ Typically highest because of large space requirements	✓ Typically lowest because of small space requirements and simplicity of system
Operating cost	! Moderate because of chemical costs, generally low water use	✓ Little to no chemical costs, can have high water use	✓ Little to no chemical costs, moderate water use	! Limited O&M costs but frequent carbon replacement can be expensive
O&M burden	! Generally low day to day, but have added burden of chemical handling	✓ Very low: monitor pH and nutrient addition chemicals	✓ Very low: make sure irrigation is functioning as intended	! Very low day to day but high when carbon replacement is required
Health and safety concern	! Chemical handling concerns	✓ No major concerns	✓ No major concerns	! Low risk of fires in carbon bed

The information presented in Table 2 is included to provide a sense of how each technology performs, relative to the other technologies; differences between technologies on one factor (e.g., operating cost) should not be viewed as being as significant as differences listed on other factors (e.g., capital cost or footprint). For example, with the types and concentrations of odors expected at the WPCP, differences in annual operating cost between a packed-tower scrubber system and a biofilter are unlikely to outweigh the differences in footprint or capital costs.

5.0 Design Criteria

To guide development of the new odor control alternatives, preliminary design criteria were established. The design criteria consist of the following:

- Estimated foul-air exhaust rates for potential odor sources
- Estimated peak and average concentrations of odorants in combined foul-air exhaust flows
- Identified odor collection and treatment system arrangement and redundancy requirements

The preliminary design criteria are discussed in the following sections.

5.1 Odor Collection

Establishing design criteria for odor source ventilation requires delineating odor source spaces (e.g., tank headspaces, gravity belt thickener [GBT] enclosures, etc.) in terms of fixed volumes and then defining one or more of the following factors to be maintained within those volumes (i.e., ventilation bases):

- Minimum air changes per hour (ACH)
- Minimum vacuum (i.e., negative pressure)
- Maximum concentration of specific odor species

The latter two factors are directly related to physical processes. Maintaining a relative vacuum within an odor source establishes a pressure gradient from the outside in and prevents the uncontrolled flow of foul air into otherwise non-odorous spaces. Maintaining a maximum concentration of, for example, H_2S, can prevent corrosion. Determining the ventilation (i.e., exhaust) rate necessary to maintain some negative pressure and/or some maximum concentration of a specific odorant in source volumes, however, typically requires more detail (e.g., leakage area and odorant flux rate, respectively) than is available ahead of detailed design or even odor sampling. The other ventilation basis, maintenance of some number of ACH, can be used to estimate required ventilation in lieu of having some of these data. Estimating the ventilation rate on an ACH basis only requires defining the minimum allowable ACH and estimating the volume of the odor source to be ventilated.

Table 3 presents the estimated exhaust rates for the processes and facilities to potentially be treated by the new odor control. Ventilation of buildings will be in accordance with other standards, including National Fire Protection Association (NFPA) 820 requirements. Odor collection will be based on point-source collection within the buildings and room air will be ventilated separately. Odorous gases from the THP will be cooled and condensed at the THP equipment skid before being conveyed directly to the digesters for treatment, and is not considered in this evaluation. Staff will need to follow proper procedures for preventing odor release during maintenance of the thermal hydrolysis system (such as flushing vessels and piping before exposing to the atmosphere). These procedures will be documented separately.

Foul-air takeoff rates for the potential odor sources were estimated based on the following:

- 12 ACH applied to the headspace of the existing GTs in accordance with industry standards for enclosed areas directly exposed to wastewater with entry requirements.

- 12 ACH applied to the total estimated hopper volume of the new cake storage hoppers based on experience at other similar facilities.
- 6 ACH applied to the total room volume (first floor only) of the new truck bay, consistent with industry standards for similar areas. Takeoffs should be located directly above the maximum filled truck trailer elevation expected, in order to focus ventilation on the actual source of odor.
- 2 ACH applied to the total tank volume (empty) of the SSTs.
- According to manufacturer-recommended rates based on maintaining negative pressure for similar equipment (i.e., GBTs, sludge screens, screw conveyors, pre-dewatering centrifuges, and final dewatering centrifuges) installed elsewhere.

Table 3. Estimated Foul-Air Takeoff Rates

Source	Criterion	Basis	Number of Units	Rate, Unit (cfm)	Rate, Total (cfm)
GTs	12	ACH	2	10,000	20,000
Storage tank (WAS EQ)	2	ACH	1	1,050	1,050
Future GBTs (WAS thickening)	-	Mfr.	2	600	1,200
Storage tanks (thickened and screened sludge)	2	ACH	3	1,050	3,150
Sludge screens	-	Mfr.	3	200	600
Screw conveyors	-	Mfr.	2	100	200
Pre-dewatering centrifuge cake	-	Mfr.	4	100	400
Pre-dewatering centrifuge centrate	-	Mfr.	4	100	400
Pre-dewatered cake storage	12	ACH	2	950	1,900
Final dewatering centrifuge cake	-	Mfr.	3	100	300
Final dewatering centrifuge centrate	-	Mfr.	3	100	300
Final dewatering cake storage	12	ACH	1	1,100	1,100
Truck bay	6	ACH	1	5,500	5,500
Total					**36,100**

The values listed in Table 3 are preliminary for initial sizing purposes and will change based on the final configuration designed by the delivery teams. For design, it is recommended that the estimates be revisited and the design rates be coordinated with manufacturers, to ensure that exhaust rates will both maintain vacuum (i.e., a maximum of -0.1 inch water column [w.c.] pressure) in odor spaces and avoid wasting treatment capacity with over-generous ventilation. The design will also need to evaluate if a

single induced draft fan at the odor control system is sufficient or if multiple booster fans will be required.

The 20,000 cfm listed for the GTs represents ventilating both GTs simultaneously. At present, the WPCP operates only a single GT. Consideration could be given to not continuously ventilating the GT that is not in service.

5.2 Design Criteria for Odor Treatment

At this preliminary stage, instead of establishing design peak and average odorant loading to treatment, several combinations of foul-air gas flows from different potential odor sources were developed and design peak and average concentrations of H_2S, orgS, and NH_3 were assigned to each.

The three combined exhaust flows are listed in
Table 4.

Table 4. Properties of Combined Exhaust Flows

Combined Exhaust	Source	Source Description
GTs	GTs	Potential for low levels of H_2S and methyl mercaptan Potential for lower levels of other orgS High ventilation rates lead to lower concentrations
Sludge storage and pre-dewatering	Storage tank (WAS EQ)	Potential for moderate levels of H_2S Potential for moderate levels of orgS
	GBTs	
	SSTs	
	Sludge screens	
	Screw conveyors	
	Pre-dewatering centrifuge cake	
	Pre-dewatering centrifuge centrate	
	Pre-dewatered cake storage	
Final dewatering	Final dewatering centrifuge cake	Potential for lower levels of H_2S Potential for lower levels of orgS Potential for moderate levels of NH_3
	Final dewatering centrifuge centrate	
	Final dewatering cake storage	
	Truck bay	

The flow rate and peak and average design odorant concentrations associated with each combined exhaust flow are indicated in Table 5. The design concentrations reflect HDR Engineering, Inc. (HDR) experience at other sites; however, the concentrations are subject to significant uncertainty. Actual concentrations will be a function of site-specific factors including liquid-phase wastewater chemistry and operating conditions and design criteria should be validated with the delivery teams.

Table 5. Basis of Design for Foul-Air Loading

Exhaust	Airflow (cfm)	H_2S (ppm)		orgS (ppm)		NH_3 (ppm)	
		Average	Peak	Average	Peak	Average	Peak
GTs	20,000[a]	1.0	10.0	0.5	2.0	0.0	0.0
Sludge storage and pre-dewatering	8,900	5.0	25.0	2.0	10.0	0.0	0.0
Final dewatering	7,200	1.0	10.0	1.0	5.0	10.0	50.0

a. 10,000 cfm if only one GT is in operation at any given time.

6.0 Odor Control Alternatives

Odor control alternatives were developed by evaluating the full range of potential treatment sequencing options in the context of each combined exhaust flow.

For each pairing, the following were determined:

- Minimum required stages and packing/media depth of each stage to achieve the following:
  - 99 percent removal of H_2S
  - 90 percent removal of orgS
  - 99 percent removal of NH_3
- Minimum number of trains in parallel to satisfy industry-standard, treatment-specific constraints on vessel area, airflow velocity, and gas loading rate

Conceptual construction costs were prepared for each alternative based on preliminary equipment quotes from vendors and cost-capacity curves for blowers, packed-tower scrubbers, biotowers, biofilters, and carbon scrubbers; cost per cubic yard for concrete treatment facility slabs; and general percentages for ancillary facilities, site work, contingencies, and general contractor costs shown in Table 6. A built-up estimate for mechanical and treatment-facility-slab structural work is provided. Percentage cost adders are applied to these built-up estimates to determine the final conceptual costs, as shown in Table 6. Percentage cost adders and estimates for the four alternatives are developed further in the following section.

Table 6. General Assumptions for Opinions of Probable Construction Costs

Parameter	Percentage
Base subtotal: Mechanical and structural/architectural	Built-up estimate
Sitework	15% of base subtotal
Electrical	20% of base subtotal
Instrumentation and controls	8% of base subtotal
Large and specialty pipe	5% of base subtotal
Geotechnical	7% of base subtotal
Subtotal	*Subtotal*
Project contingency	20% of subtotal
Contractor mobilization/staging (percentage of subtotal and project contingency)	5% of subtotal plus
Contractor bonds/insurance (percentage of subtotal and project contingency)	3%
Contractor overhead and profit (percentage of subtotal and project contingency)	15%
Total construction cost	**Total**

The conceptual costs are only rough order-of-magnitude costs to use for relative comparisons between the various alternatives. The conceptual costs presented herein are not for budgeting purposes.

Operating costs were estimated based on irrigation/makeup water, H_2SO_4, sodium hydroxide (NaOH), and NaOCl required to treat average loading, assumed activated carbon replacement frequency, and power required by blowers and recirculation pumps for continuous duty. To estimate the annual operating cost of each developed alternative, the unit costs in Table 7 were assumed.

Table 7. Assumed Unit Costs of Site Water, Chemical, Carbon, and Power

Demand	Cost ($/gal)
PEW	$0.0005
H_2SO_4 (97.0%)	$0.66
NaOH (25.0%)	$2.66
NaOCl (12.5%)	$0.50
Activated carbon	$4.00[a]
Power	$0.06[b]

a. $ per pound
b. $ per kilowatt-hour.

Finally, as a single point of comparison, a net present value (NPV) for each odor control alternative was estimated based on the capital and operating costs. It was assumed that all capital costs are paid during year 0; operating costs were assumed to continue over a 20-year period. A discount rate of 3 percent was assumed.

Each alternative includes rerouting exhaust from the existing GTs to new odor control. In concert with the decommissioning of the DAFTs, migrating the odor load of the existing GTs and SSTs to new odor control would reduce existing design flow to the south odor control system by 23,000 cfm. That freed-up capacity could theoretically be allocated for ventilation and treatment of the PTB.

The effect of decommissioning the DAFTs and migrating load from the existing GTs and SSTs from the south odor control system to new odor control is illustrated in Table 8.

Table 8. Impact of Contemplated Changes on Design Flow to the South Odor Control System

Source	Current Design Flow (cfm)	Potential Future Design Flow (cfm)
GTs	20,000	-
PTB	-	23,000
DAFTs	5,300	-
Four Mile Pump Station	4,800	4,800
SSTs	700	-
Minor sources	450	450
Total	31,250	28,250

Four alternatives were developed using these treatment options:

- Alternative 1: Combined Treatment of Gravity Thickener Exhaust
- Alternative 2: Dedicated Treatment of GT Exhaust Flow via Biotower and Activated Carbon Adsorption Polishing
- Alternative 3: Dedicated Treatment of GT Exhaust via Biofilter and Activated Carbon Adsorption Polishing
- Alternative 4: Dedicated Treatment of GT Exhaust via Activated Carbon Adsorption

All four alternatives include two-stage packed-tower scrubbers (both for sulfur removal) for the combined sludge storage and pre-dewatering odor load and separate treatment of the combined final dewatering odor load via two-stage packed-tower scrubbers (one for NH_3 and one for sulfur) activated carbon adsorption for polishing. Packed-tower scrubbers are considered the best available technology for dealing with moderate levels of ammonic and organic sulfur compounds, and thus the reason they are included in all alternatives. The alternatives differ only in how the GT exhaust is treated.

The four alternatives are described further below.

6.1 Alternative 1: Combined Treatment of Gravity Thickener Exhaust

Under Alternative 1, there would be two treatment schemes: one to treat exhaust flow from final dewatering sources and one to treat combined exhaust flow the GTs and sludge storage and pre-dewatering sources. The latter scheme is not expected to contain any NH_3 while the former is.

The combined exhaust flow from final dewatering sources would be treated for NH_3 odor via a first-stage packed-tower scrubber using H_2SO_4 then treated for sulfur odor via a second-stage packed-tower scrubber with NaOH and NaOCl. The scrubbers would be followed by activated carbon adsorption polishing. The combined exhaust flow from the GTs, sludge storage, and pre-dewatering sources would be expected to need treatment only for sulfur odor and would be treated via two-stage packed-tower scrubber using NaOH and NaOCl.

6.1.1 Summary of Odor Control Facility Sizing and Estimated Performance

The design parameters for the treatment stages are listed in and Table 9 and Table 10.

Table 9. Treatment Parameters under Alternative 1 for Treating Final Dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2	Stage 3
Target odor		NH_3	Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower	Activated carbon adsorption
Chemical		H_2SO_4	NaOH + NaOCl	
Size	ft	5'-0"	5'-0"	12'-0"
Gas loading	cfm	7,200	7,200	7,200
Liquid loading	gpm	250	250	-
Packing/media depth	ft	12	12	6
Makeup water	gpd	360	9,000	-
H_2SO_4 dose	gpd	1.4	0.0	-
NaOH dose	gpd	0.0	14.3	-
NaOCl dose	gpd	0.0	31.0	-

Table 10. Treatment Parameters under Alternative 1 for Treating Combined GT and Sludge Storage and Pre-dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2
Target odor		Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower
Chemical		NaOH + NaOCl	NaOH + NaOCl
Size	ft	10'-0"	10'-0"
Gas loading	cfm	28,900	28,900
Liquid loading	gpm	700	700
Packing/media depth	ft	12	12
Makeup water	gpd	1,008	1,008
NaOH dose	gpd	4.7	1.8
NaOCl dose	gpd	144	21.9

6.1.2 Odor Control Facility Layout

Both odor treatment systems can be located on the same pad. It is estimated that the pad would need to be a minimum of 50 feet wide by 75 feet long to fit the requisite vessels, equipment, and ductwork. A plan view showing one potential arrangement is provided as Figure 6. Chemical storage and feed would be located in a separate building.

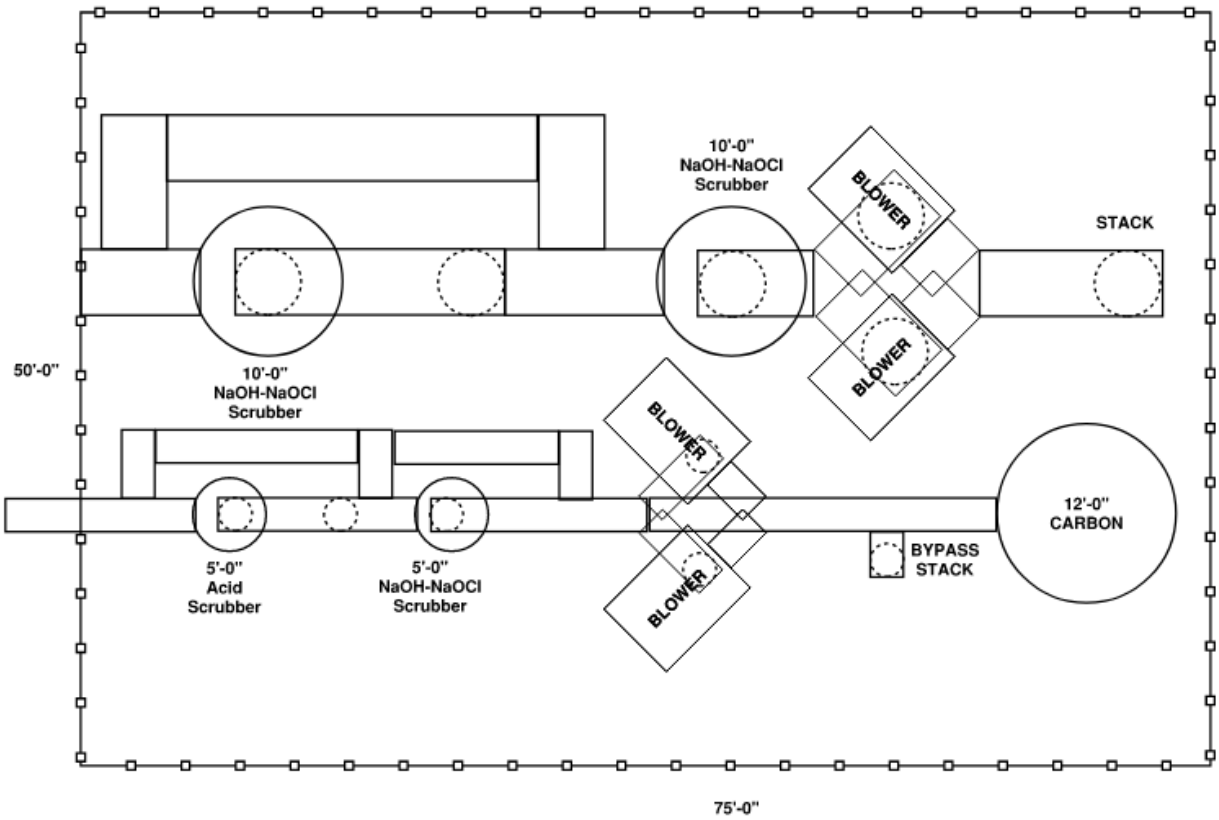

Figure 6. Layout of Pad for Odor Treatment Systems under Alternative 1

6.1.3 Summary of Conceptual Costs

A summary of the conceptual cost estimate and estimated annual operating costs is provided in Table 11 and Table 12, respectively.

Of note, the lone carbon scrubber will be used for polishing. As a result, the media will likely only need to be replaced every 3 to 5 years, in accordance with the carbon manufacturer's standard recommended minimum changeout frequency. Each carbon replacement would cost roughly $120,000. At a changeout frequency of 3 years, the annualized operating cost of carbon replacement is estimated as $40,000.

Table 11. Conceptual Cost Estimate for Alternative 1

Parameter	Percentage	Cost
Structural		$90,000
Mechanical		$1,360,000
Base Subtotal		**$1,450,000**
Sitework	15%	$220,000
I&C/SCADA	8%	$120,000
Electrical	20%	$290,000
Large and specialty piping	5%	$80,000
Geotechnical	7%	$110,000
Subtotal		**$2,270,000**
Contingency	20%	$460,000
Subtotal		**$2,730,000**
Contractor mobilization, staging, and security	5%	$140,000
Contractor bonds and insurance	3%	$90,000
Subtotal		**$2,960,000**
Contractor overhead and profit	15%	$450,000
Total		**$3,410,000**

Table 12. Summary of Estimated Annual Operating Costs for Alternative 1

Parameter	Cost ($/year)
Water	$2,080
Chemical	$37,200
H_2SO_4	$350
NaOH	$20,100
NaOCl	$16,750
Carbon	$40,000
Power	$32,260
Blowers	$23,630
Recirculation pumps	$8,630
Total	**$111,540**

Over a 20-year period and assuming a discount rate of 3 percent, the NPV of Alternative 1 would be $5,070,000.

6.2 Alternative 2: Dedicated Treatment of GT Exhaust Flow via Biotower and Activated Carbon Adsorption Polishing

Under Alternative 2, there would be three treatment schemes: one to treat exhaust flow from final dewatering sources, one to treat exhaust flow the sludge storage and pre-dewatering sources, and one to treat exhaust flow from the GTs.

Exhaust flow from final dewatering sources would be treated as in Alternative 1. The combined exhaust flow from sludge storage and pre-dewatering sources would be treated for sulfur odor via two-stage packed-tower scrubber using NaOH and NaOCl. The third exhaust flow from the GTs is expected to contain relatively little organic sulfur, and would be treated via a biotower followed by activated carbon

adsorption polishing. Because the system would treat only GT exhaust flow and would be located in close proximity to the GTs, and given that, at present, the WPCP operates only a single GT, the system would be sized to ventilate and treat only 10,000 cfm, the estimated exhaust rate for a single GT.

6.2.1 Summary of Odor Control Facility Sizing and Estimated Performance

The design parameters for the treatment stages are listed in Table 13, Table 14, and Table 15.

Table 13. Treatment Parameters under Alternative 2 for Treating Final Dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2	Stage 3
Target odor		NH_3	Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower	Activated carbon adsorption
Chemical		H_2SO_4	NaOH + NaOCl	
Size	ft	5'-0"	5'-0"	12'-0"
Gas loading	cfm	7,200	7,200	7,200
Liquid loading	gpm	250	250	-
Packing/media depth	ft	12	12	6
Makeup water	gpd			
H_2SO_4 dose	gpd	1.4	0.0	-
NaOH dose	gpd	0.0	14.3	-
NaOCl dose	gpd	0.0	31.0	-

Table 14. Treatment Parameters under Alternative 2 for Treating Sludge Storage and Pre-dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2
Target odor		Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower
Chemical		NaOH + NaOCl	NaOH + NaOCl
Size	ft	6'-0"	6'-0"
Gas loading	cfm	8,900	8,900
Liquid loading	gpm	170	170
Packing/media depth	ft	12	12
Makeup water	gpd	245	245
NaOH dose	gpd	0.8	0.4
NaOCl dose	gpd	74.9	5.6

Table 15. Treatment Parameters under Alternative 2 for Treating Gravity Thickener Exhaust

Parameter	Unit	Stage 1	Stage 2
Target odor		Sulfur	Sulfur
Treatment unit		Biotower	Activated carbon adsorption
Chemical		[Nutrient]	
Size	ft	8'-0"	14'-0"
Gas loading	cfm	10,000	10,000
Liquid loading	gpm	50	-
Packing/media depth	ft	8	6
Makeup water	gpd	72,000	-

6.2.2 Odor Control Facility Layout

The two odor treatment systems treating exhaust from sludge storage and pre-dewatering sources and exhaust from final dewatering sources can be located on the same pad. It is estimated that the pad would need to be a minimum of 45 feet wide by 65 feet long, slightly smaller than the single pad associated with Alternative 1, to fit the requisite vessels, equipment, and ductwork. A plan view showing one potential arrangement is provided as Figure 7. Chemical storage and feed facilities would be located in a separate building.

A second pad for the system treating the GT exhaust would also be needed. It is estimated that the pad would need to be a minimum of 45-feet-wide by 65-feet-long. A plan view showing one potential arrangement is provided as Figure 8.

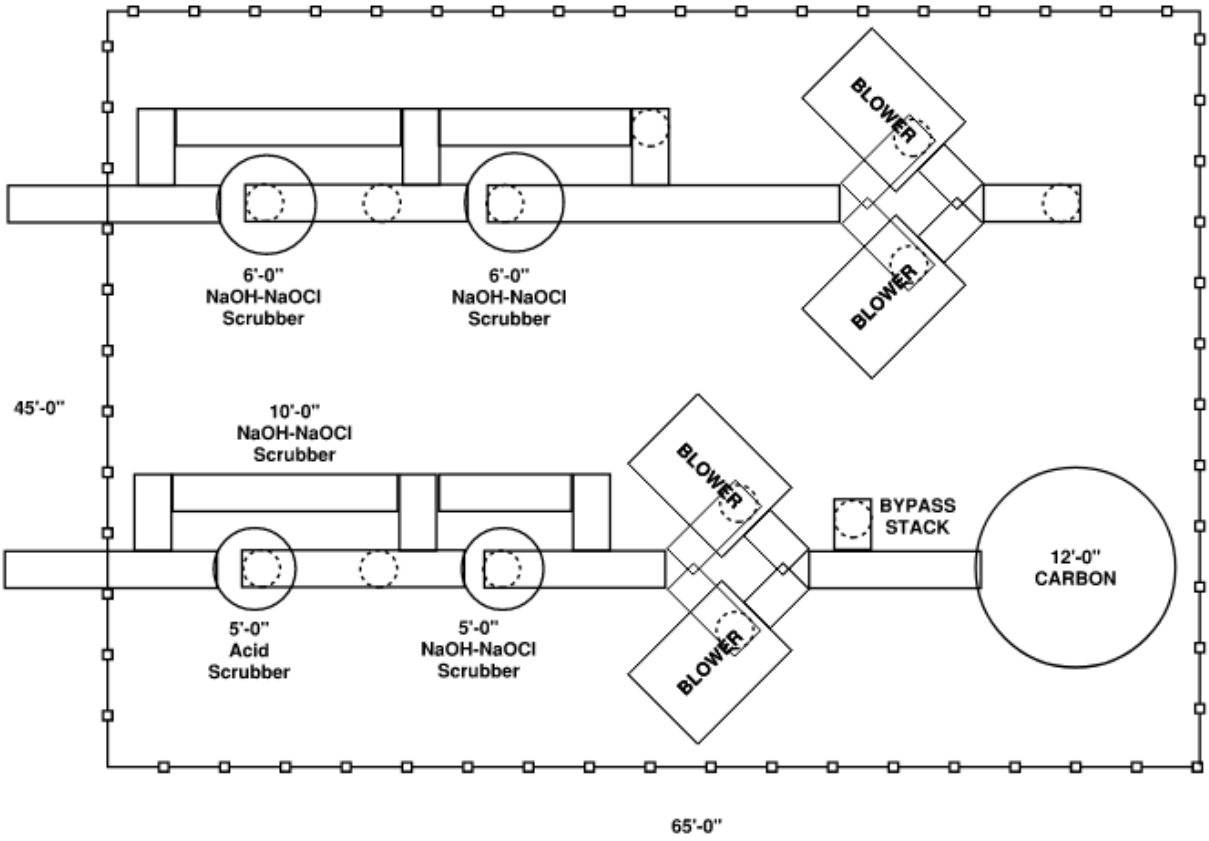

Figure 7. Layout of Pad for Odor Treatment Systems Treating Exhaust from Sludge Storage and Pre-dewatering Sources and Exhaust from Final Dewatering Sources under Alternative 2

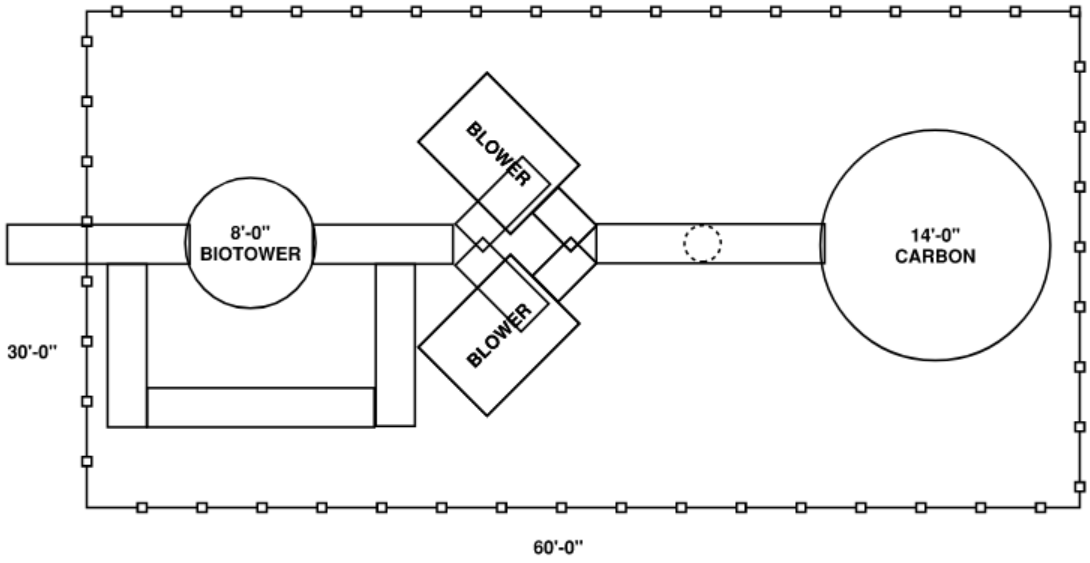

Figure 8. Layout of Pad for Odor Treatment Systems Treating Exhaust from Gravity Thickeners under Alternative 2

6.2.3 Summary of Costs

A summary of the conceptual cost estimate and estimated annual operating costs is provided in Table 16 and Table 17, respectively.

Of note, both carbon scrubbers will be used for polishing. As a result, the media in each vessel will likely only need to be replaced every 3 to 5 years, in accordance with the carbon manufacturer's standard recommended minimum changeout frequency. Each carbon replacement in the 12-ft-diameter vessel would cost roughly $120,000; each in the 14-ft-diameter vessel would cost roughly $150,000. At a changeout frequency of 3 years for both vessels, the annualized operating cost of carbon replacement is estimated as $90,000.

Table 16. Alternative 2 Conceptual Cost Estimate

Parameter	Percentage	Cost
Structural		$110,000
Mechanical		$2,030,000
Base Subtotal		**$2,140,000**
Sitework	15%	$330,000
I&C/SCADA	8%	$180,000
Electrical	20%	$430,000
Large and specialty piping	5%	$110,000
Geotechnical	7%	$150,000
Subtotal		**$3,340,000**
Contingency	20%	$670,000
Subtotal		**$4,010,000**
Contractor mobilization, staging, and security	5%	$210,000
Contractor bonds and insurance	3%	$130,000
Subtotal		**$4,350,000**
Contractor overhead and profit	15%	$660,000
Total		**$5,010,000**

Table 17. Summary of Estimated Annual Operating Costs for Alternative 2

Parameter	Cost ($/year)
Water	$14,940
Chemical	$29,050
H_2SO_4	$350
NaOH	$16,660
NaOCl	$12,040
Carbon	$90,000
Power	$30,060
Blowers	$26,210
Recirculation pumps	$3,850
Total	**$164,050**

Over a 20-year period and assuming a discount rate of 3 percent, the NPV of Alternative 2 would be $7,460,000.

6.3 Alternative 3: Dedicated Treatment of GT Exhaust via Biofilter and Activated Carbon Adsorption Polishing

Under Alternative 3, like under Alternative 2, there would be three treatment schemes: one to treat exhaust flow from final dewatering sources, one to treat exhaust flow from the sludge storage and pre-dewatering sources, and one to treat exhaust flow from the GTs. The only difference from Alternative 2 is that the GT exhaust would be treated through a biofilter followed by carbon adsorption instead of a biotower followed by carbon adsorption.

6.3.1 Summary of Odor Control Facility Sizing and Estimated Performance

The design parameters for the treatment stages are listed in Table 18, Table 19, and Table 20.

Table 18. Treatment Parameters under Alternative 3 for Treating Final Dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2	Stage 3
Target odor		NH_3	Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower	Activated carbon adsorption
Chemical		H_2SO_4	NaOH + NaOCl	
Size	ft	5'-0"	5'-0"	12'-0"
Gas loading	cfm	7,200	7,200	7,200
Liquid loading	gpm	250	250	-
Packing/media depth	ft	12	12	6
Makeup water	gpd			
H_2SO_4 dose	gpd	1.4	0.0	-
NaOH dose	gpd	0.0	14.3	-
NaOCl dose	gpd	0.0	31.0	-

Table 19. Treatment Parameters under Alternative 3 for Treating Sludge Storage and Pre-dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2
Target odor		Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower
Chemical		NaOH + NaOCl	NaOH + NaOCl
Size	ft	6'-0"	6'-0"
Gas loading	cfm	8,900	8,900
Liquid loading	gpm	170	170
Packing/media depth	ft	12	12
Makeup water	gpd	245	245
NaOH dose	gpd	0.8	0.4
NaOCl dose	gpd	74.9	5.6

Table 20. Treatment Parameters under Alternative 3 for Treating Gravity Thickener Exhaust

Parameter	Unit	Stage 1	Stage 2
Target odor		Sulfur	Sulfur
Treatment unit		Biofilter	Activated carbon adsorption
Chemical			
Size	ft	30'-0" × 30'-0"	14'-0"
Gas loading	cfm	10,000	10,000
Liquid loading	gpm	5	-
Packing/media depth	ft	6	6
Makeup water	gpd	7,200	-

6.3.2 Odor Control Facility Layout

The two odor treatment systems treating exhaust from sludge storage and pre-dewatering sources and exhaust from final dewatering sources can be located on the same pad. As with Alternative 2, it is estimated that the pad would need to be a minimum of 45 feet wide by 65 feet long.

A second pad for the system treating the GT exhaust would also be needed. It is estimated that the pad would need to be a minimum of 40 feet wide by 85 feet long, significantly larger than that associated with Alternative 2 because of the relative large size of the biofilter. A plan view showing one potential arrangement is provided as Figure 9.

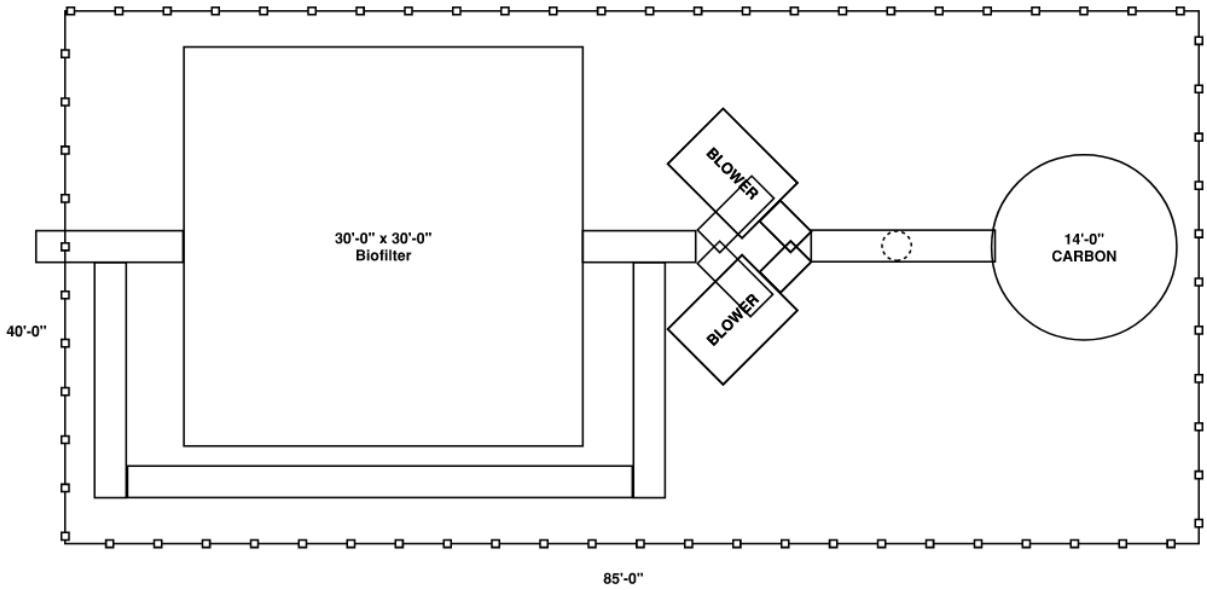

Figure 9. Layout of Pad for Odor Treatment Systems Treating Exhaust from Gravity Thickeners under Alternative 3

6.3.3 Summary of Costs

A summary of the conceptual cost estimate and estimated annual operating costs is provided in Table 21 and Table 22, respectively.

Of note, both carbon scrubbers will be used for polishing. As a result, the media in each vessel will likely only need to be replaced every 3 to 5 years, in accordance with the carbon manufacturer's standard recommended minimum changeout frequency. Each carbon replacement in the 12-ft-diameter vessel would cost roughly $120,000; each in the 14-ft-diameter vessel would cost roughly $150,000. At a changeout frequency of 3 years for both vessels, the annualized operating cost of carbon replacement is estimated as $90,000.

Table 21. Alternative 3 Conceptual Cost Estimate

Parameter	Percentage	Cost
Structural		$150,000
Mechanical		$2,530,000
Base Subtotal		**$2,680,000**
Sitework	15%	$410,000
I&C/SCADA	8%	$220,000
Electrical	20%	$540,000
Large and specialty piping	5%	$140,000
Geotechnical	7%	$190,000
Subtotal		**$4,180,000**
Contingency	20%	$840,000
Subtotal		**$5,020,000**
Contractor mobilization, staging, and security	5%	$260,000
Contractor bonds and insurance	3%	$160,000
Subtotal		**$5,440,000**
Contractor overhead and profit	15%	$820,000
Total		**$6,260,000**

Table 22. Summary of Estimated Annual Operating Costs for Alternative 3

Parameter	Cost ($/year)
Water	$3,120
Chemical	$29,050
H_2SO_4	$350
NaOH	$16,660
NaOCl	$12,040
Carbon	$90,000
Power	$30,060
Blowers	$26,210
Recirculation pumps	$3,850
Total	**$152,230**

Over a 20-year period and assuming a discount rate of 3 percent, the NPV of Alternative 3 would be $8,530,000.

6.4 Alternative 4: Dedicated Treatment of GT Exhaust via Activated Carbon Adsorption

Under Alternative 4, as under the previous two alternatives, there would be three treatment schemes: one to treat exhaust flow from final dewatering sources, one to treat exhaust flow the sludge storage and pre-dewatering sources, and one to treat exhaust flow from the GTs. The difference is that standalone carbon adsorption would be used for the GT exhaust in lieu of biological systems followed by carbon adsorption for polishing.

For this alternative to be considered, a rigorous field sampling program would be recommended to validate H_2S concentrations in the existing GT exhaust, followed by carbon selection and a full life-cycle assessment including cost of carbon replacement based on the measured H_2S concentrations.

6.4.1 Summary of Odor Control Facility Sizing and Estimated Performance

The design parameters for the treatment stages are listed in Table 23, Table 24, and Table 25.

Table 23. Treatment Parameters under Alternative 4 for Treating Final Dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2	Stage 3
Target odor		NH_3	Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower	Activated carbon adsorption
Chemical		H_2SO_4	NaOH + NaOCl	
Size	ft	5'-0"	5'-0"	12'-0"
Gas loading	cfm	7,200	7,200	7,200
Liquid loading	gpm	250	250	-
Packing/media depth	ft	12	12	6
Makeup water	gpd			
H_2SO_4 dose	gpd	1.4	0.0	-
NaOH dose	gpd	0.0	14.3	-
NaOCl dose	gpd	0.0	31.0	-

Table 24. Treatment Parameters under Alternative 4 for Treating Sludge Storage and Pre-dewatering Exhaust

Parameter	Unit	Stage 1	Stage 2
Target odor		Sulfur	Sulfur
Treatment unit		Packed tower	Packed tower
Chemical		NaOH + NaOCl	NaOH + NaOCl
Size	ft	6'-0"	6'-0"
Gas loading	cfm	8,900	8,900
Liquid loading	gpm	170	170
Packing/media depth	ft	12	12
Makeup water	gpd	245	245
NaOH dose	gpd	0.8	0.4
NaOCl dose	gpd	74.9	5.6

Table 25. Treatment Parameters under Alternative 4 for Treating Gravity Thickener Exhaust

Parameter	Unit	Stage 1
Target odor		Sulfur
Treatment unit		Activated carbon adsorption
Chemical		
Size	ft	14'-0"
Gas loading	cfm	10,000

6.4.2 Odor Control Facility Layout

The packed-tower odor control system layout would be the same as for Alternatives 2 and 3. A separate pad for the system treating the GT exhaust would also be needed. It is estimated that the pad would need to be a minimum of 30 feet wide by 45 feet long, slightly smaller than that associated with Alternative 2. A plan view showing one potential arrangement is provided as Figure 10.

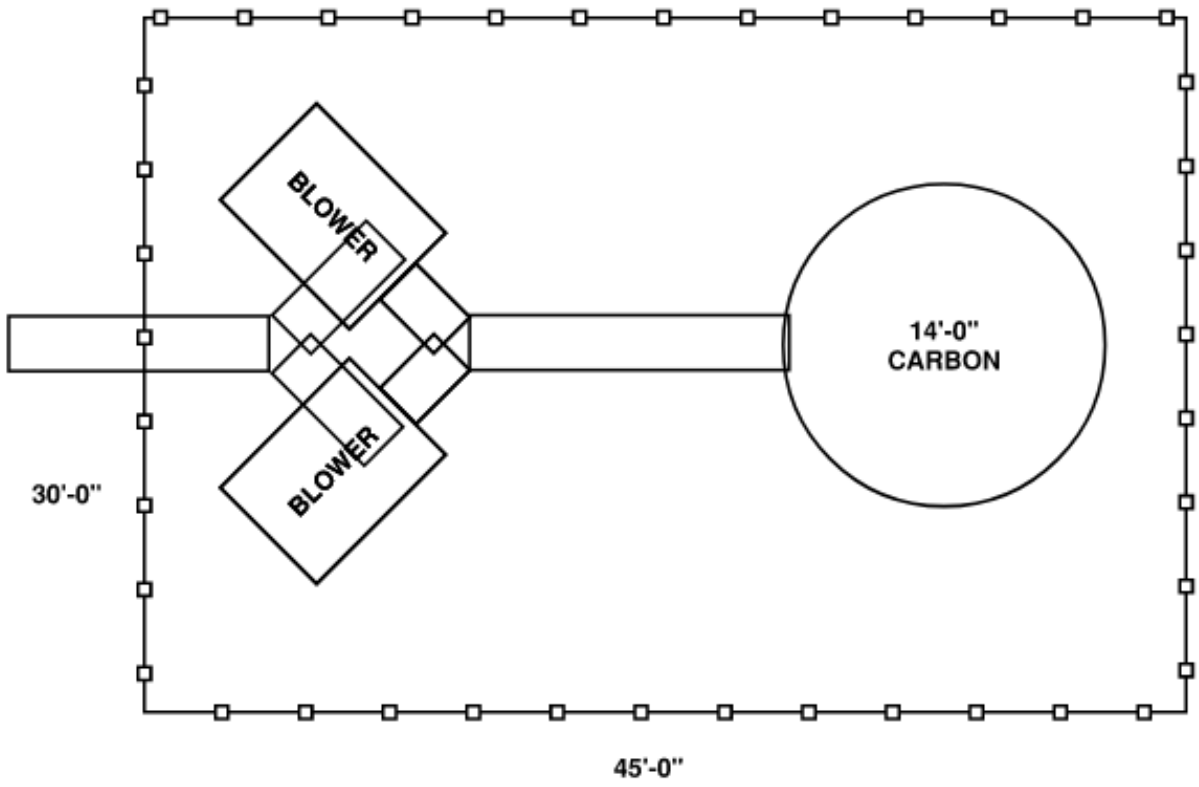

Figure 10. Layout of Pad for Odor Treatment Systems Treating Exhaust from Gravity Thickeners under Alternative 4

6.4.3 Summary of Costs

A summary of the conceptual cost estimate and estimated annual operating costs is provided in Table 26 and Table 27, respectively.

Of note, while the 12-ft-diameter scrubber will be used for polishing, the larger 14-ft-diameter scrubber will be used for primary treatment. The media in the latter will likely need to be replaced more frequently. At a changeout frequency of 1 year for the carbon scrubber treating gravity thickener exhaust and a changeout frequency of 3 years for the other scrubber, the annualized operating cost of carbon replacement is estimated as $190,000.

Table 26. Alternative 4 Conceptual Cost Estimate

Parameter	Percentage	Cost
Structural		$150,000
Mechanical		$1,440,000
Base Subtotal		**$1,590,000**
Sitework	15%	$240,000
I&C/SCADA	8%	$130,000
Electrical	20%	$320,000
Large and specialty piping	5%	$80,000
Geotechnical	7%	$120,000
Subtotal		**$2,480,000**
Contingency	20%	$500,000
Subtotal		**$2,980,000**
Contractor mobilization, staging, and security	5%	$150,000
Contractor bonds and insurance	3%	$90,000
Subtotal		**$3,220,000**
Contractor overhead and profit	15%	$490,000
Total		**$3,710,000**

Table 27. Summary of Estimated Annual Operating Costs for Alternative 4

Parameter	Cost ($/year)
Water	$1,800
Chemical	$29,050
H_2SO_4	$350
NaOH	$16,660
NaOCl	$12,040
Carbon	$190,000
Power	$25,500
Blowers	$21,650
Recirculation pumps	$3,850
Total	**$246,350**

Over a 20-year period and assuming a discount rate of 3 percent, the NPV of Alternative 4 would be $7,380,000.

7.0 Comparison of Alternatives and Recommendation

The alternatives can be evaluated and compared based on the following:

- Estimated treatment effectiveness
- Estimated conceptual costs
- Estimated space required
- Operations and maintenance (O&M) familiarity with the requisite odor control technologies
- O&M responsibilities
- Health and safety concerns (unrelated to exposure to odorous emissions)

All four alternatives have similar levels of treatment effectiveness. All also have some level of chemical treatment including multiple chemicals. Therefore, the evaluation is driven primarily by NPV costs and site constraints.

A summary of conceptual costs is provided in Table 28.

Table 28. Comparison of Estimated Conceptual Costs

	Alternative Description	Combined Treatment of GT Exhaust	Dedicated Treatment of GT Exhaust via Biotower and Activated Carbon Polishing	Dedicated Treatment of GT Exhaust via Biofilter and Activated Carbon Polishing	Dedicated Treatment of GT Exhaust via Activated Carbon Adsorption
Cost	**Alternative No.**	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Capital cost	$	$3,410,000	$5,010,000	$6,260,000	$3,710,000
Operating cost	$/year	$111,540	$164,050	$152,230	$246,350
NPV	$	$5,070,000	$7,460,000	$8,530,000	$7,380,000

Alternatives 2, 3 and, 4 would all have a significantly higher cost than Alternative 1 and would require additional space requirements on a tight site. Although these alternatives would reduce chemical consumption, some chemical treatment would still be required. Therefore, Alternatives 2, 3, and 4 are not recommended for implementation.

Based on discussions with the County, Alternative 1 has the following advantages over other alternatives and is thus recommended for implementation as part of the Re-Gen Program:

- Lowest capital cost and NPV
- Consolidated footprint on a tight site
- No concern about carbon media life
- Proven technology for hard-to-remove odorants
- Familiar technology for WPCP staff

Technical Memorandum No. 14

Date:	November 12, 2021
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Tom Broderick Lisa Racey
From:	HDR
Subject:	Program Delivery Recommendation

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Figure 2. Proposed Solids Handling Processes at the Arlington WPCP 2

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1.0 Purpose and Project Background

The Arlington County (County) Water Pollution Control Bureau (WPCB) is implementing new solids handling processes at the Arlington Water Pollution Control Plant (WPCP), an advanced wastewater treatment plant located on S Glebe Road with capacity to treat up to 40 million gallons per day (mgd). The WPCP provides wastewater treatment for a service area that includes most of Arlington County plus areas of Falls Church, Alexandria, and Fairfax County.

Due to the age and condition of the existing facilities as well as opportunities to increase sustainability and reliability, it is necessary to replace the solids handling processes at the WPCP. Nearly all the solids handling processes at the WPCP will require upgrades or replacement.

This Technical Memorandum contains project background information and a detailed discussion of the recommendation to use the Design-Build delivery method for project implementation.

1.1 Current Solids Handling Process

The WPCP uses a combination of physical, chemical, and biological processes to treat wastewater. Solids removed from the treatment processes receive additional treatment before being hauled off site by trucks. Solids are thickened and dewatered prior to lime stabilization. Approximately 36,000 wet tons of lime-stabilized biosolids are hauled annually by truck from the site for beneficial use as Class B biosolids in bulk land application, which equates to about 30 dry tons per day. The current solids handling processes are shown schematically on Figure 1.

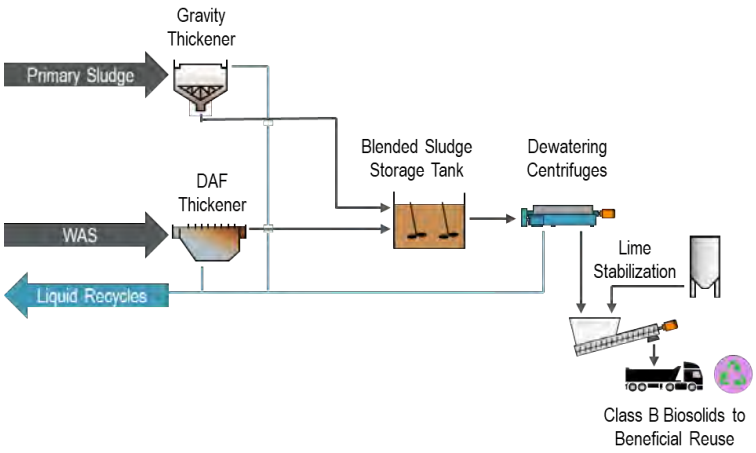

Figure 1. Existing Solids Handling Processes at the Arlington WPCP

The existing solids handling processes, which were constructed between the 1950s and 1990s, are well beyond their 20-year equipment life. Many need replacement because of high operation and maintenance costs, sub-optimal performance, or non-operational status.

1.2 Solids Master Plan

In 2015, the WPCB initiated a comprehensive Solids Master Plan (Master Plan) to address the long-term needs of the WPCB. The goals of the Master Plan included the following:

- Replacing failing and end-of-life equipment

- Mitigating the risk of potential future regulatory changes to the current practice of recycling Class B biosolids through application to agricultural land
- Providing a solution that reduces the energy and greenhouse-gas footprint of the WPCP
- Furthering County-wide sustainability goals
- Developing a solids management strategy that offers long-term reliability
- Establishing an implementation plan compatible with County capital improvement program (CIP) funding

The Master Plan recommended processes include the thermal hydrolysis process (THP) followed by anaerobic digestion (AD), which will recover energy and nutrient resources. The Class A biosolids product generated can be both land-applied, used in the community, and will provide resilience against potential future regulatory changes. The methane generated through the process will be beneficially used as renewable natural gas or to generate electricity and heat on the WPCP site. The proposed processes are shown schematically on Figure 2.

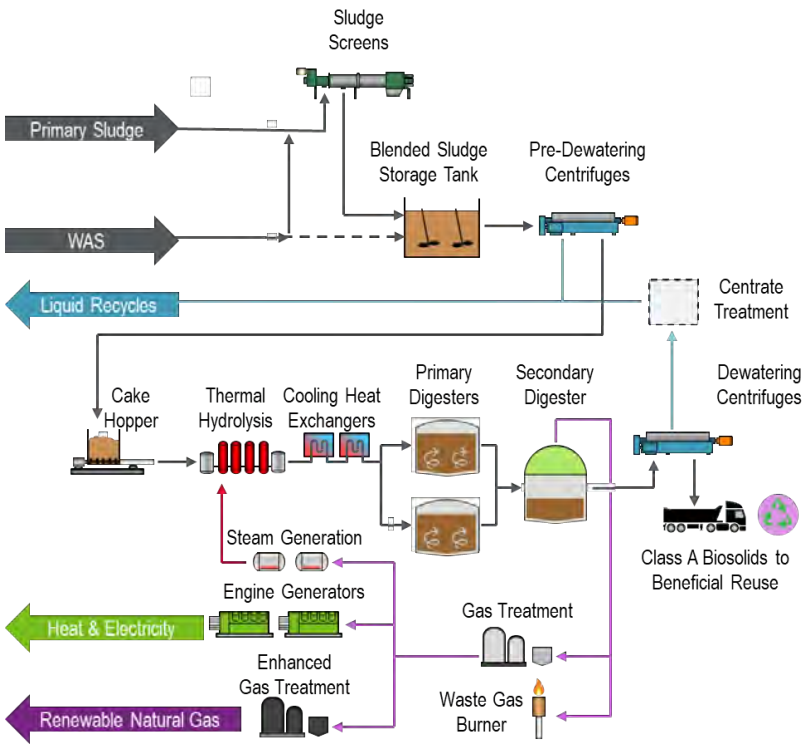

Figure 2. Proposed Solids Handling Processes at the Arlington WPCP

The Master Plan was adopted by the County Board concurrent with the fiscal year (FY) 2019–2028 CIP, with a total value of $155 million.

1.3 Current Program Status

In 2020, the County hired HDR Engineering, Inc. (HDR) as Program Manager to assist with the development and execution of the improvements identified in the Master Plan (collectively, the Program). Initial efforts under the Program include development of a Facilities Plan to further define the

scope of the improvements, and an evaluation of project packaging, and delivery methods for implementation.

2.0 Delivery Method Risks

To facilitate the evaluation of project packaging and delivery methods for implementation, HDR and the WPCB completed a thorough risk review of the Program elements in a series of interactive workshops. The top Program delivery risks identified by the WPCB team are shown in in Table 1 below.

Table 1. Project Delivery Risks

Risk	Risk Description
Startup	The new facilities include multiple integrated facilities that need to work together seamlessly, requiring collaboration between the County, Engineer, and Contractor.
Constructability	The site available for construction is tight and construction will impact the ability to maintain operations. Constructability and temporary operations decisions that impact costs and schedule will need to be made during design.
Process performance	There is responsibility of both the Engineer and the Contractor on ensuring performance meets the requirements of the County to make a successful project.
Budget	There is significant uncertainty in pricing in the current market, and decisions made during design can have a large impact on the overall budget.
Scope Uncertainty	Engineering errors or omissions and scope gaps could impact cost and schedules.
Quality	The new facilities will need to be designed and constructed to maintain the expected quality of the final product.
Collaboration and County Input	Collaboration is desired between all parties to minimize other project risks.
Schedule	Schedule delays could impact overall cost and result in failures of existing equipment.

Through the risk analysis and discussion of potential delivery approaches, the WPCB determined that the traditional competitive sealed bidding approach (Design-Bid-Build) does not adequately address key project risks, as identified in Table 2 below. Additionally, risk ownership of these key risks remains solely with the County.

Table 2. Risks Associated with Competitive Sealed Bidding

Risk	Risk Ownership	Potential Issue	Cost Impacts	Schedule Impacts
Startup	County	Lack of coordination between the contractor and engineer on critical sequencing and startup procedures for the complex facilities leads to schedule delays and conflict during execution.	✓	✓
Site utilization	County	Lack of contractor input during design leads to uninformed decisions on site utilization, site layout, and temporary operations, leading to added costs and schedule delays during construction.	✓	✓
Process performance	County	Lack of coordination and execution of performance guarantees to prove process performance leads to added costs, schedule delays, and conflict during execution.	✓	✓
Budget	County	Lack of price certainty until the project bids leads to budget overruns and schedule delays if additional funding is required.	✓	✓
Scope uncertainty	County	Conflicts, errors, and omissions identified during construction lead to budget overruns and schedule delays.	✓	✓

Due to the inability of the competitive sealed bidding to adequately address the risks and the potential impacts on cost and schedule, the WPCB believes that the use of competitive sealed bidding is not practicable for implementation of the Program.

3.0 Recommendation for Use of Design-Build

The WPCB recommends use of the design-build (DB) delivery method through competitive negotiations for delivery of the major portions of the Program, as authorized by the Arlington County Purchasing Resolution (July 2021), Section 4-102(3)D. The primary advantages to the WPCB of the DB delivery method for this Program are as follows:

- Single point of responsibility for design and construction, including startup and performance requirements
- Contractor input during design, both to inform the design and to allow the contractor to be more informed to accurately price the work
- Decision making informed through real-time pricing discussions
- Deliberate teaming of design and construction partners in a collaborative manner

The WPCB has determined that the DB delivery method mitigates many of the risks identified in Table 1 that are associated with competitive sealed bidding. These mitigation strategies are described in Table 3. Using the DB delivery method, the risk is assigned to the most appropriate entity and is not the sole responsibility of the County.

Table 3. Risk Mitigation through Design Build Delivery

Risk	Risk Ownership	Risk Mitigation
Startup	Design-builder	Design-builder is fully responsible for coordination and startup of complex, integrated facilities as a single point of accountability.
Site utilization	Design-builder and County	Design-builder offers input during design phase, including risk analysis, constructability, and site utilization planning, prior to final pricing being set. County maintains risk for uncontrollable conditions.
Process performance	Design-builder	Design-builder is fully responsible for process performance as a single point of accountability.
Budget	County	While County maintains risk ownership, detailed cost estimates during design process can inform County decisions on scope and scope changes.
Scope uncertainty	Design-builder	Design-builder is fully responsible for foreseeable conflicts, errors, and omissions identified during construction. In addition, design-builder maintains responsibility during design for identifying potential conflicts.

The project team understands that there are risks associated with the DB delivery method. Working in partnership with HDR and the County's Purchasing Agent, the project team will actively monitor and manage the risks before they become problematic and work with the delivery team to address them. Three key areas of focus will be:

- Owner involvement: HDR will facilitate County design reviews to identify areas for the County review team to focus on and confirm critical aspects of the review. In addition, HDR will perform independent design reviews focused on constructability, operability, and maintainability of the new facilities.

- Quality during construction: HDR will provide independent onsite quality assurance during construction to confirm quality procedures are being properly followed.
- Performance: Prior to issuance of the DB RFP, the program team will agree on performance guarantees needed for ultimate project success. The selected DB Team will be responsible for proven performance against the performance guarantees.

The County will continue to use HDR as the Program Manager to assist the County with preparation of procurement documents and to facilitate the County review of proposals received. A tentative schedule of the DB procurement is provided below:

- Issue Request for Qualifications: March 2022
- Statement of Qualifications due: April 2022
- Issue Request for Proposals: May 2022
- Technical proposals due: August 2022
- Interviews: September 2022
- Recommendation for negotiations: October 2022
- Recommendation for award: January 2023
- Board recommendation: February 2023

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Technical Memorandum No. 15

Date:	December 2, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Envision Rating System Recommendations

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1.0 Background

Arlington County (County) has initiated the implementation of the Arlington Re-Gen Biosolids Upgrade Program (Program) for the next generation of biosolids management facilities at the Arlington County Water Pollution Control Plant (WPCP). A comprehensive Program will be developed and managed by the Program Team for the engineering, design, construction, maintenance, startup, and operation necessary to add sustainable equipment and systems to effectively recover the County's renewable resources, produce a Class A biosolids product, and most efficiently utilize the biogas. The new solids handling processes (Facilities) will entail upgrades to or replacement of nearly all existing solids handling facilities at the WPCP. A thermal hydrolysis process (THP) followed by anaerobic digestion (AD) form the backbone of the new treatment train. A marketable Class A biosolids product and biogas utilization system to clean and make use of recovered biogas gas either on or off site are also envisioned. The completed Program will enhance operating conditions and reliability of the Facilities while continuing to meet all permit requirements and ensure an unrelenting commitment to environmental stewardship.

Mission Statement: *Upgrade resource recovery facilities to produce Class A biosolids and renewable energy, maximizing sustainability and community acceptance. Collaborate with team members to select and implement processes that are safe, reliable, and financially responsible throughout planning, design, construction, operations and maintenance.*

The Arlington County Facility Sustainability Policy for New Construction and Major Renovation (Green Building Policy, April 30, 2019) requires that "all County buildings and public facilities shall strive to incorporate the highest environmental performance standards using the LEED, International Living Futures Institute (ILFI), or Viridiant's EarthCraft Virginia green building rating system." Further, the policy notes that all eligible new construction must achieve at least Leadership in Energy and Environmental Design (LEED) Silver certification "to demonstrate and communicate comprehensive sustainability to the public, including management of energy, water, materials, indoor environment, and sustainable sites."

Because of the industrial, process-oriented nature of the Program, it would be difficult for the facility to meet several of the LEED prerequisites. The Envision® V3 Sustainable Infrastructure Framework (Envision) was created by a strategic alliance of the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure (ISI) to foster "the dramatic and necessary improvement in the sustainable performance and resiliency of physical infrastructure."[1] Whereas LEED is intended to evaluate interior spaces with the primary purpose of human occupancy, Envision covers projects in broad civil infrastructure. Refer to Appendix A for more background on Envision and representative water and wastewater infrastructure projects that are Envision Verified. The WPCP can use the Envision framework to improve sustainable performance, as a project guide, and to pursue Envision verification.

The purpose of this technical memorandum (TM) is to provide context to the Envision framework and provide comparisons between the Envision and LEED rating systems to assist with the approval process to use the Envision program for the Program.

[1] https://sustainableinfrastructure.org/wp-content/uploads/EnvisionV3.9.7.2018.pdf

2.0 Comparison of Envision to Arlington County's Green Building Policy and LEED

This section presents a comparison between Envision and Arlington County's Green Building Policy and LEED.

2.1 Envision Sustainability Infrastructure Framework Comparison to Existing Policies

The Program team reviewed the County's Green Building Policy and found that it aligns well with the Envision framework, as shown in Appendix B. Table B1 provides a direct comparison between the Green Building Policy and Envision. Table B2 provides a list of Envision topics not explicitly covered by the Green Building Policy.

2.2 Envision Sustainability Infrastructure Framework Comparison to LEED

Given the County's LEED requirement, the Program team compared and contrasted Envision and LEED, specifically related to the Program.

Envision is similar in structure to the LEED rating system. While LEED is intended to be used for buildings, Envision provides industry-wide sustainability metrics for all infrastructure types, including industrial facilities such as the WPCP. Envision provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects, giving recognition to those projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of a project's life cycle. Similar to LEED, Envision has multiple levels of verification, depending on the number of points achieved: Verified, Silver, Gold, or Platinum.

Appendix C provides additional information on the Envision/LEED comparison. Table C1 provides a high-level comparison of the LEED and Envision rating systems. Table C2 shows how LEED credits correlate to Envision credits. Table C3 shows how Envision credits correlate to LEED credits, noting how closely they correlate using green, yellow, and red dots. Table C4 provides detail on LEED v4.1 Prerequisite Credits and their criteria, showing which Envision credits correlate with the prerequisites, if the project would anticipate pursing those credits, the anticipated level of achievement (LOA), and the credit criteria or requirements for the anticipated LOA.

Together, these comparisons provide support for use of Envision in place of LEED Program.

3.0 LEED/Envision Energy

LEED and Envision both have credits that focus on energy use and emissions.

The LEED v4.1 Energy and Atmosphere category includes four prerequisites and six credits as follows:

- Energy and Atmosphere prerequisites:
    - Fundamental Commissioning and Verification
    - Minimum Energy Performance
    - Building-Level Energy Metering
    - Fundamental Refrigerant Management
- Energy and Atmosphere credits:

- Enhanced Commissioning
- Optimize Energy Performance
- Advanced Energy Metering
- Grid Harmonization
- Renewable Energy
- Enhanced Refrigerant Management

The Envision Resource Allocation category includes four credits focused on energy, and the Climate and Resilience category includes three credits related to emissions. There are no prerequisites.

- Resource Allocation credits:
    - RA2.1 Reduce Operational Energy Consumption
    - RA2.2 Reduce Construction Energy Consumption
    - RA2.3 Use Renewable Energy
    - RA2.4 Commission & Monitor Energy Systems
- Climate and Resilience credits:
    - CR1.1 Reduce Net Embodied Carbon
    - CR1.2 Reduce Greenhouse Gas Emissions
    - CR1.3 Reduce Air Pollutant Emissions

Details about Envision's energy- and emissions-related credits are outlined in Appendix D. Table D1 lists Envision credits, the LOA at which they are anticipated to be pursued, and rationale as to why credits cannot be pursued at the highest LOA, if applicable. Appendix D also includes excerpts of the Envision Guidance Manuals showing the energy and emissions-related credits.

Another approach for tracking energy efficiency is the EnergyStar program, which provides energy efficiency metrics and ratings for a range of applications. Most commonly found on commercial appliances, the EnergyStar program has also been applied to commercial buildings with the same principles: buildings that are designed to require fewer resources and less energy are rated accordingly.

Some wastewater treatment facilities have also been evaluated with the EnergyStar program and given a score based on their relative use of purchased power and other operational metrics compared against a database compiled from survey information of other wastewater treatment facilities across the country. From there, a facility can be assigned a rank within the database, which then corresponds to an assigned EnergyStar score.

Comparing the energy use of the Program to other wastewater treatment facilities is not recommended, as the EnergyStar rating system is intended to be used for entire wastewater treatment facility operations, rather than specific portions, such as biosolids processing. The rating system also does not account for vast differences in treatment requirements at various wastewater treatment facilities. This difference in treatment requirements can mean that significantly more energy is needed to achieve treatment, and some facility designs are inherently more energy intensive. Therefore, it is not recommended to use an EnergyStar rating as another tracking tool for energy efficiency.

4.0 Envision Assessment

An Envision assessment was completed for the Program to:

- Evaluate the Program's alignment with Envision criteria (sustainable performance), in the context of planning and design decisions made up to this point
- Identify areas for future/further consideration as opportunities to improve the Program's sustainable performance

To evaluate the Program, the team worked with HDR's Envision specialist to conduct an initial review of the Program's preliminary conceptual facilities related to each of the 64 Envision credits and associated criteria. Preliminary research was also conducted to review County plans and their relationship to the Program and Envision. This review was done to:

- Evaluate each credit for relevance
- Conduct initial analysis into the potential level of achievement (LOA)
- Discuss potential documentation sources
- Identify potential opportunities for incremental improvements in sustainable performance
- Note areas for improvement or efforts that may push the program to achieve higher LOAs

On September 30, 2021, an Envision workshop was held with the Program's Sustainability Workgroup. The purpose of the workshop was to:

- Continue to build understanding of Envision and what is needed to document the Program for verification
- Discuss 13 credits identified as needing additional input from the Sustainability Workgroup to try to determine if they will be pursued and, if so, at which LOA

A high-level overview of the assessment results, including potential LOA targets or ranges, is included in Appendix E. Some credits are shown with an LOA range. The low LOA indicates the level the Program might attain with the current preliminary concepts. Ranges indicate a potential for increased LOA depending on decisions made in the future throughout detailed design and construction that might improve the Program's sustainable performance. Refer to TM No. 17: *Envision Assessment Summary* for a detailed analysis of the preliminary assessment of the Program's sustainable performance, estimated credit LOA, and recognition level likely to be achieved by the Program.

This assessment represents an early review of Envision for the Program, including a review of the Program's sustainable attributes and County's sustainable practices. At this stage, some credits are difficult to gauge because related design decisions have not yet been made. This is a limitation for the Envision review but offers opportunities for the team to improve sustainable performance in some areas. In addition, Envision includes five construction-specific credits. These credits would require guidance to and monitoring of the contractor during the construction phase. The team has made some assumptions about the LOA for these five credits.

5.0 Recommendation

Based on the initial evaluation, the Arlington Re-Gen Biosolids Upgrade Program is well-suited to pursue credits that could result in an Envision verification, provided that the required supporting

documentation is compiled. The Program currently demonstrates that it can achieve a Silver verification goal, which aligns with the Green Building Policy's requirement for LEED Silver certification. There may be sufficient points to target a Gold verification when submitted.

As the nature of the Arlington Re-Gen Biosolids Upgrade Program is a broad and complex civil infrastructure project, it is recommended that the Program proceed with the Envision verification system as a means to achieve a more sustainable Program while fulfilling the intent of the Arlington County Green Building Policy.

To assist with the concerns with omitted credits between LEED and Envision, is it recommended that all Envision credits that correlate to LEED prerequisites be included, with the exception of those discussed above, as shown in the preliminary Envision scorecard.

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Appendix A. Envision Overview

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ENVISION™

Envision® **v3** Sustainable Infrastructure Framework

The framework provides a **flexible system of criteria and performance objectives** to aid decision makers and help project teams identify sustainable approaches during planning, design, and construction that will carry forward throughout the project's operations and maintenance and end-of-life phases.

Envision Benefits

Economic

- Consideration of future expansion
- Extend useful life of project
- Lower heating bills
- Lower O&M costs
- Reduce energy and water costs
- Reduce wastewater fees
- Return on investment

Societal

- Create more livable communities
- Demonstrating good governance to voters, taxpayers, or ratepayers
- Develop durable infrastructure, with less maintenance
- Improve/increase local job market
- Improve business environment
- Improve community safety, mobility, recreational opportunities
- Increase community/stakeholder involvement in process
- Integrate into the local environment
- Preserve community culture/ history
- Reduce construction impacts
- Reduce environmental impacts
- Reduce noise

Environmental

- Conserve energy and water
- Optimize resource efficiency
- Preserve greenfields/redevelop brownfields
- Reduced air pollution
- Reduce greenhouse gas emissions
- Reduce light pollution
- Reduce stormwater runoff
- Reduce waste sent to landfills
- Source local materials
- Use materials more efficiently
- Use recycled materials

Other

- Calibrate internal assessment against a common set of sustainability criteria
- Demonstrate commitment to environmental stewardship and social responsibility
- Improve public perception
- Strengthen inter-agency and project team collaboration

PURPOSE OF ENVISION

The purpose of Envision is to foster the dramatic and necessary improvement in the sustainable performance and resiliency of physical infrastructure by helping owners, planners, engineers, communities, contractors, and other infrastructure stakeholders to implement more cost-effective, resource-efficient and adaptable long-term infrastructure investments.

ENVISION BACKGROUND

Institute for Sustainable Infrastructure

Envision was created by a strategic alliance of the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure (ISI). ISI is a not-for-profit education and research organization, dedicated to developing and maintaining a civil infrastructure rating system, and was formed by the American Council of Engineering Companies, the American Public Works Association and the American Society of Civil Engineers.

WHERE DOES ENVISION APPLY?

- Designed as a holistic framework for all types and sizes of both public and private infrastructure
- Covers project in energy, water, waste, transportation, landscape, information and other civil infrastructure
- Not intended to evaluate interior, conditioned, buildings with the primary purpose of human occupation
- Has been applied extensively throughout the U.S. and Canada but is applicable, and has been used, all over the world
- Used by infrastructure owners, design teams, community groups, environmental organizations, constructors, regulators and policy makers

STRUCTURE

Credit Categories & Subcategories

1 | Quality of Life – Wellbeing, Mobility, Community

2 | Leadership – Collaboration, Planning, Economy

3 | Resource Allocation – Materials, Energy, Water

4 | Natural World – Siting, Conservation, Ecology

5 | Climate and Resilience – Emissions, Resilience

Levels of Achievement

1 | Improved – Performance that is above conventional.

2 | Enhanced – Sustainable performance that is on the right track.

3 | Superior – Sustainable performance at a very high level.

4 | Conserving – Performance that has achieved essentially zero negative impact.

5 | Restorative – Performance that restores natural or social systems.

Innovation Points

Potential points awarded in each category for methods that advance sustainable infrastructure practices or show exceptional performance beyond expectations.

VERIFICATION

Registration and Verification Fees

Registration: $2,000

Verification: Fees based on project size, membership and verification pathway. HDR is a member of ISI and can register client project's to receive member pricing.

Verification Pathways

Projects may pursue verification either after:

- The design phase (at or after 95% design completion)
- The construction phase (at or after 95% construction completion).

Projects pursuing verification after the design phase will be required to complete an additional post-construction review follow-up.

The post-construction review is required to maintain the Envision award earned after the design phase. The purpose of the post-construction review is to validate that commitments made in the planning and design stages of the project were carried through during construction

Project Award Levels

To receive recognition, projects must achieve a minimum percentage of the total applicable Envision points. Projects can be recognized at four levels.

- Verified: 20%
- Silver: 30%
- Gold: 40%
- Platinum: 50%

ENVISION v3 POINTS TABLE

			Improved	Enhanced	Superior	Conserving	Restorative
QUALITY OF LIFE	PURPOSE	QL1.1 Improve Community Quality of Life	2	5	10	20	26
		QL1.2 Enhance Public Health and Safety	2	7	12	16	20
		QL1.3 Improve Construction Safety	2	5	10	14	-
		QL1.4 Minimize Noise and Vibration	1	3	6	10	12
		QL1.5 Minimize Light Pollution	1	3	6	10	12
		QL1.6 Minimize Construction Impacts	1	2	4	8	-
	WELLBEING	QL2.1 Improve Community Mobility and Access	1	3	7	11	14
		QL2.2 Encourage Sustainable Transportation	-	5	8	12	16
		QL2.3 Improve Access and Wayfinding	1	5	9	14	-
	COMMUNITY	QL3.1 Advance Equity and Social Justice	3	6	10	14	18
		QL3.2 Preserve Historic and Cultural Resources	-	2	7	12	18
		QL3.3 Enhance Views and Local Character	1	3	7	11	14
		QL3.4 Enhance Public Space and Amenities	1	3	7	11	14
					Maximum QL Points	200*	
LEADERSHIP	COLLABORATION	LD1.1 Provide Effective Leadership and Collaboration	2	5	12	18	-
		LD1.2 Foster Collaboration and Teamwork	2	5	12	18	-
		LD1.3 Provide for Stakeholder Involvement	3	6	9	14	18
		LD1.4 Pursue Byproduct Synergies	3	6	12	14	18
	PLANNING	LD2.1 Establish a Sustainability Management Plan	4	7	12	18	-
		LD2.2 Plan for Sustainable Communities	4	6	9	12	16
		LD2.3 Plan for Long-Term Monitoring and Maintenance	2	5	8	12	-
		LD2.4 Plan for End-of-Life	2	5	8	14	-
	ECONOMY	LD3.1 Stimulate Economic Prosperity and Development	3	6	12	20	-
		LD3.2 Develop Local Skills and Capabilities	2	4	8	12	16
		LD3.3 Conduct a Life-Cycle Economic Evaluation	5	7	10	12	14
					Maximum LD Points	182*	
RESOURCE ALLOCATION	MATERIALS	RA1.1 Support Sustainable Procurement	3	6	9	12	-
		RA1.2 Use Recycled Materials	4	6	9	16	-
		RA1.3 Reduce Operational Waste	4	7	10	14	-
		RA1.4 Reduce Construction Waste	4	7	10	16	-
		RA1.5 Balance Earthwork On Site	2	4	6	8	-
	ENERGY	RA2.1 Reduce Operational Energy Consumption	6	12	18	26	-
		RA2.2 Reduce Construction Energy Consumption	1	4	8	12	-
		RA2.3 Use Renewable Energy	5	10	15	20	24
		RA2.4 Commission and Monitor Energy Systems	3	6	12	14	-
	WATER	RA3.1 Preserve Water Resources	3	5	7	9	12
		RA3.2 Reduce Operational Water Consumption	4	9	13	17	22
		RA3.3 Reduce Construction Water Consumption	1	3	5	8	-
		RA3.4 Monitor Water Systems	1	3	6	12	-
					Maximum RA Points	196*	
NATURAL WORLD	SITING	NW1.1 Preserve Sites of High Ecological Value	2	6	12	16	22
		NW1.2 Provide Wetland and Surface Water Buffers	2	5	10	16	20
		NW1.3 Preserve Prime Farmland	-	2	8	12	16
		NW1.4 Preserve Undeveloped Land	3	8	12	18	24
	CONSERVATION	NW2.1 Reclaim Brownfields	11	13	16	19	22
		NW2.2 Manage Stormwater	2	4	9	17	24
		NW2.3 Reduce Pesticide and Fertilizer Impacts	1	2	5	9	12
		NW2.4 Protect Surface and Groundwater Quality	2	5	9	14	20
	ECOLOGY	NW3.1 Enhance Functional Habitats	2	5	9	15	18
		NW3.2 Enhance Wetland and Surface Water Functions	3	7	12	18	20
		NW3.3 Maintain Floodplain Functions	1	3	7	11	14
		NW3.4 Control Invasive Species	1	2	6	9	12
		NW3.5 Protect Soil Health	-	3	4	6	8
					Maximum NW Points	232*	
CLIMATE & RESILIENCE	EMISSIONS	CR1.1 Reduce Net Embodied Carbon	5	10	15	20	-
		CR1.2 Reduce Greenhouse Gas Emissions	8	13	18	22	26
		CR1.3 Reduce Air Pollutant Emissions	2	4	9	14	18
	RESILIENCE	CR2.1 Avoid Unsuitable Development	3	6	8	12	16
		CR2.2 Assess Climate Change Vulnerability	8	14	18	20	-
		CR2.3 Evaluate Risk and Resilience	11	18	24	26	-
		CR2.4 Establish Resilience Goals and Strategies	-	8	14	20	-
		CR2.5 Maximize Resilience	11	15	20	26	-
		CR2.6 Improve Infrastructure Integration	2	5	9	13	18
					Maximum CR Points	190*	

Maximum TOTAL Points **1,000***

*Not every credit has a restorative level. Therefore totals include the maximum possible points for each credit whether conserving or restorative.

May 2018

Envision Context – Water and Wastewater Treatment

110 **Verified**, publicly announced, projects

49 **Water** projects

- 19 Wastewater
- 7 Drinking Water
- 23 Water Resources

4 Projects in Virginia

Figure 1: Verified Water Sector Projects; ISI website 1/14/2022

Figure 2: Verified Wastewater Treatment Projects; ISI website 1/14/202

Figure 3: Verified Regional Wastewater Treatment Projects; ISI website 1/14/2022

Water and Wastewater Envision Project Examples

Envision benefits can often best be illustrated through project examples. The following are a few of the Envision verified wastewater projects, which illustrate the benefits of sustainable infrastructure and use of the Envision framework. HDR projects are marked with an *. Information for other examples was referenced on ISI's website (sustainableinfrastructure.org).

*Little Patuxent Water Reclamation Plant Biosolids Processing Facilities Improvement Project, Howard County, MD**

Envision Silver, September 2021

Key factors contributing to the project earning Envision Silver include:

- Stimulating sustainable growth and development. This project implements new process methods into the overall wastewater solids treatment process.
- Finding beneficial uses for waste products. A detailed biosolids market study was conducted to research potential end uses for the new Class A dried biosolids waste product.
- Use of recycled and regionally sourced materials – over 50% recycled materials by weight, over 90% locally or regionally sources.
- More than 80 percent of excavated materials were kept onsite in stockpiles with the intent to reuse for topsoil and fill.

"Participating in this project has truly been a pleasure thanks to the collaboration of HDR Engineering as designer and Clark Construction as Construction Manager at Risk. The Little Patuxent Water Reclamation Plant has been a leader in our industry and region with the highest levels of treatment performance, especially as it pertains to nutrients in discharged effluent water. The improved biosolids product we are now producing is another example of our ability to produce a high-quality product that can be beneficially reused in various markets and minimize impacts to the Chesapeake Bay watershed and the environment in general. We are very pleased that ISI has awarded this project a silver award and appreciate all of the efforts put forth by the entire design and construction teams." Robert Hindt, Plant Manager

*Big Dry Creek Wastewater Treatment Facility, Solids Dewatering and Campus Wide Improvements Project, Westminster, CO**

Envision Bronze, June 2021

Key factors contributing to the project earning Envision Bronze include:

- Improving efficiencies and saving costs – By reducing the water content of biosolids and allowing more material to be applied to the same acreage
- Extending the life of the project
- Reducing the number of hauling trips by two-thirds
- Holistic facility design, in conjunction with efficient coordination of on-site design elements with off-site elements
- Providing flexibility to meet current needs and projected future needs
- Enhancing nitrogen removal to improve biosolids quality

"Using the Envision certification process has helped the City become a better fiscal, social and environmental steward. Sustainability and safe, reliable service are top priorities for our residents and will be a continued focus of our strategic infrastructure investments." Max Kirschbaum, City of Westminster's Public Works and Utilities Director

Water and Wastewater Envision Project Examples

AlexRenew, Nutrient Management Facility (NMF), Alexandria, VA

Image from ISI website 1/14/2022: sustainableinfrastructure.org/project-awards/nutrient-management-facility

Envision Platinum, November 2016

The Nutrient Management Facility includes 18 million gallons in tank capacity with associated pumps, chemical analysis equipment, and an extensive odor control system. It also includes a lit, regulation athletic field located on top of the process tanks, created as a community amenity. The NMF stores wastewater to balance the amount of nitrogen that goes into AlexRenew's biological treatment process.

Key factors contributing to the project earning Envision Platinum include:

- Removed 85,000 cubic yards of contaminated soil from the site and selected only native plant species with high habitat value that require no pesticides, herbicides, and fertilizers for the site's landscaping
- Many considerations to improve community quality of life were incorporated, including a multi-purpose lit athletic field, built on top of the NMF.
- Acres of impervious surface were replaced with vegetated areas to restore infiltration and water quality functions. A fish and sediment barrier was removed, which improved aquatic habitat connectivity, and a crucial wooded riparian buffer was expanded, enhancing the natural habitat.

Grand Bend Area Wastewater Treatment Facility, Ontario, Canada

Image from Stantec website 1/14/2022: www.stantec.com/en/projects/canada-projects/g/grand-bend-area-wwt-facility

Envision Platinum, February 2015

Converted one of four existing lagoons into an extended aeration mechanical treatment facility and wetland nature reserve. The facility prevents effluent discharges from adversely impacting surface and groundwater quality and allows for responsible community development.

Key factors contributing to the project earning Envision Platinum include:

- Key design features enhance its durability, flexibility, and resiliency. The facility can be reconfigured and/or expanded to meet new demands, and respond to changing sewage inflows through the use of flow equalization to prevent sewage bypass events.
- Construction of wetland provided an opportunity to reuse excavated soils on-site and significantly reduced the need for imported fill and associated costs.
- Habitat was created through the design of the constructed wetland and restoration of a tallgrass prairie on-site. The project team worked with local conservation groups, volunteers, and municipal staff to develop a plan that supports the elimination of invasive species.
- The project design addresses projected changes in population and service area growth and increases in frequency and severity of extreme rainfall events in southern Ontario.

Water and Wastewater Envision Project Examples

Noman M. Cole, Jr. Pollution Control Plant (NMCPCP), Fairfax Disinfection Improvements, Fairfax County, VA

Image from ISI website 1/14/2022: sustainableinfrastructure.org/project-awards/fairfax-disinfection-improvements

Envision Gold, October 2019

The project includes a UV facility, an auxiliary chemical storage and feed facility, separate disinfection for water reuse/plant water purposes, reuse water pump station, plant water pump station, filter backwash storage and pumping, a new outfall pipe and associated electrical improvements.

Key factors contributing to the project earning Envision Gold include:

- Conducted a thorough analysis of water requirements for the project and found many ways to reduce potable water use for plant operations, thereby protecting the availability of freshwater resources in the area.
- UV disinfection process eliminates two major chemical uses at the NMCPCP: sodium hypochlorite for disinfection and sodium bisulfite for dechlorination.
- Eliminating chemical uses reduces the number of truck deliveries required to transport liquid chemicals and subsequently related greenhouse gas emissions.
- Modifying the hydraulic grade line of the facility allowed for the complete elimination of a pump station resulting in operational energy savings and reduced greenhouse gas emissions.

"We are honored that this is the second Envision award achieved by Fairfax County DPWES. Wastewater utilities projects, although might not be visible to the communities they serve, actively create more livable and resilient communities. We have always been driven by the principles of sustainability throughout our project planning and implementation and we are fortunate to provide environmental, social, and economic benefits to the community. Working alongside community partners who value sustainability and support efforts like this have increased the positive impact on our local waterways." Guiying Xiao, Project Manager, Fairfax County Department of Public Works and Environmental Services (DPWES)

Northeast Ohio Regional Sewer District (NEORSD) Southerly Wastewater Treatment Plant, Cleveland, OH

Image from ISI website 1/14/2022: sustainableinfrastructure.org/project-awards/neorsd-southerly-plant

Envision Silver, January 2018

Key factors contributing to the project earning Envision Silver include:

- Facilitating economic growth and development, including college assistance program and training opportunities
- The facility expands educational opportunities by offering introductory level workshops about the history and future of sewer systems, water quality, and sustainability in the region.
- The recently completed Renewable Energy Facility (REF) at the plant uses sludge, septage, and grease from both the Southerly and Easterly plants to generate energy. Construction of the REF, along with the decommissioning of the Southerly Plant's Biosolids Thermal Conditioning System, contributes to a reduction in natural gas usage by approximately 137,000 mcf per year.

Water and Wastewater Envision Project Examples

San Antonio River Authority, Martinez IV Wastewater Treatment Plant, Saint Hedwig, TX

Image from ISI website 1/14/2022: sustainableinfrastructure.org/project-awards/martinez-iv-wastewater-treatment-plant

Envision Silver, September 2019

This is a new facility built to accommodate the significant projected population growth of the surrounding communities. Without this facility, the increased raw sewage would need to be pumped and hauled by truck on a daily basis to other facilities for treatment, causing significant impacts to soil, watershed quality, air pollution, and carbon dioxide emissions.

Key factors contributing to the project earning Envision x include:

- Onsite renewable solar energy provides 41.5% of energy for process equipment.
- Invasive species were removed from the site and it was re-vegetated with several native species.
- Plant positioned beyond the 500-year floodplain to reduce risks from flooding.

"The San Antonio River Authority is committed to safe, clean, and enjoyable creeks and rivers, so the decision to provide the community with sustainable infrastructure and pursue an Envision rating for the Martinez IV Project is in line with our vision and mission." Amy Middleton, San Antonio River Authority Utilities Manager and Martinez IV Project Manager

Water Treatment Plant Residuals Management Facility, Red Deer, Alberta, CA

Image from ae.ca website 1/14/2022: www.ae.ca/ae-today/latest-updates/details/blog/2021/10/07/red-deers-water-treatment-plant-residuals-management-facility-will-reduce-environmental-impacts-associated-with-treating-water

Envision Bronze, July 2021

Key factors contributing to the project earning Envision x include:

- Minimizing noise and vibration from plant operations
- Reducing operational energy consumption by 23.6% compared to industry norms.
- Developing a comprehensive plan for long-term monitoring and maintenance.
- Supporting sustainable procurement practices by aligning procurement with the City's Environmental Sustainability Policy which encourages staff to minimize the environmental impact of the city's infrastructure and employ environmentally sound operational practices.
- Preventing surface and groundwater contamination by including several features and monitoring systems into the project's design.

"It is an honour for ISI to recognize the City of Red Deer Water Treatment Plant Residuals Management Facility project as a leader in sustainable infrastructure. Our drinking water and our environment are high priorities for the City. The project is not only a proactive step in our ongoing upgrades to our water treatment plant but also demonstrates the City's environmental leadership and commitment to achieving environmental sustainability. The City worked closely with its Engineering Consultant, General Contractor and regulators: Alberta Environment and Parks, Fisheries and Oceans Canada, Transport Canada, Alberta Public Lands, and Alberta Culture and Tourism to make the project a reality."
Kingsford Amoah, City of Red Deer's Environmental Planning Engineer and ENV SP Lead

Appendix B. Comparison Tables: Envision and the Arlington County Green Building Policy

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Table B1. Comparison of Arlington County Facility Sustainability Policy: for New Construction and Major Renovation (Green Building Policy) to the Envision Sustainable Infrastructure Framework

Green Building Policy	Envision Framework
This policy was developed to support Arlington County's mission of sustainability and to support the County's overall greenhouse gas reduction goals.	
Purpose: • To reduce operating costs through energy and water efficiency • To achieve high-performing, durable, and efficient buildings that are easy to operate and maintain • To invest in healthy indoor environments for staff and visitors • To demonstrate Arlington's commitment to environmental, economic, and social stewardship • To set a community standard of sustainable building practices	**Purpose:** To foster the dramatic and necessary improvement in the sustainable performance and resilience of physical infrastructure by helping owners, planners, engineers, communities, contractors, and other infrastructure stakeholders to implement more cost-effective, resource-efficient, and adaptable long-term infrastructure investments
Guiding Principles	**Envision Alignment/Related Credits**
1. **Function:** Achieve **high-performing and efficient building operations** with systems and components that are easy to use and **maintain**. Ensure that the building operates as intended and **reduce long-term operating costs**: • Prioritize simple, passive solutions over mechanical solutions for **energy use reduction** and **stormwater management** • Minimize use of complicated sensor and control systems • Design and locate building systems for **ease of access and maintenance** • Ensure that building systems are compatible with the building programming, are fully functional, and operate as intended before the building is accepted • As new facilities are acquired or built, facilities maintenance budgets should be reassessed and planned	LD2.3 Plan for Long-Term Monitoring & Maintenance LD2.4 Plan for End-of-Life RA1.3 Reduce Operational Waste RA2.1 Reduce Operational Energy Consumption RA2.4 Commission & Monitor Energy Systems RA3.2 Reduce Operational Water Consumption RA3.4 Monitor Water Systems NW2.2 Manage Stormwater CR2.3 Evaluate Risk & Resilience CR2.4 Establish Resilience Goals and Strategies CR2.5 Maximize Resilience
2. **Energy:** Use integrated design and passive strategies to **minimize heating, cooling, and lighting loads and reduce long-term operating costs**: • Prioritize the building thermal envelope and right-size mechanical equipment • Use building orientation and daylight devices to evenly distribute daylight • Avoid elements that are solely aesthetic that increase energy use • Optimize solar photovoltaic exposure and vegetated roof space • Incorporate efficient space utilization	RA2.1 Reduce Operational Energy Consumption RA2.3 Use Renewable Energy RA2.4 Commission & Monitor Energy Systems
3. Human Experience: Support occupant health and well-being with: • Fresh air and ventilation • Humidity control • Selection of low-toxicity materials • Evenly distributed daylight and minimal glare	QL1.1 Improve Community Quality of Life QL1.2 Enhance Public Health & Safety QL1.3 Improve Construction Safety QL1.4 Minimize Noise and Vibration QL1.5 Minimize Light Pollution QL1.6 Minimize Construction Impacts QL2.1 Improve Community Mobility and Access QL2.2 Encourage Sustainable Transportation QL2.3 Improve Access and Wayfinding QL3.1 Advance Equity and Social Justice QL3.2 Preserve Historic & Cultural Resources QL3.3 Enhance Views and Local Character QL3.4 Enhance Public Space and Amenities CR1.2 Reduce Greenhouse Gas Emissions

	CR1.3 Reduce Air Pollutant Emissions
4. **Durability:** Select quality materials, systems, and equipment to **reduce maintenance, operations, and replacement costs**: • County buildings and facilities should be built to last and be flexible in their design to support occupant and community needs as they change over time • Select materials that are easy to maintain and durable for the intended use and expected life of the building • Commission all building systems starting at the design phase and test the building enclosure for air and water infiltration	LD2.3 Plan for Long-Term Monitoring & Maintenance LD2.4 Plan for End-of-Life RA1.2 Use Recycled Materials RA2.4 Commission & Monitor Energy Systems RA3.4 Monitor Water Systems CR2.2 Assess Climate Change Vulnerability CR2.3 Evaluate Risk & Resilience CR2.4 Establish Resilience Goals and Strategies CR2.5 Maximize Resilience
Minimum Sustainability Targets	**Envision Alignment/Related Credits**
1. New County buildings, additions, and major renovations shall be designed and constructed to **reduce energy use intensity (EUI)** below 28 kBtu/ft²/yr and optimize solar exposure to be "Net Zero Energy Ready." A power purchase agreement may be used to install on-site solar equipment necessary to achieve Net Zero Energy certification through the International Living Futures Institute. Renewable Energy Credits (RECs) should remain on site, if possible.	RA2.1 Reduce Operational Energy Consumption RA2.2 Reduce Construction Energy Consumption RA2.3 Use Renewable Energy RA2.4 Commission & Monitor Energy Systems *RA2.3 Use Renewable Energy: Projects may only count RECs purchased or under contract at the time of assessment. Nonbinding commitments for future REC purchases cannot be counted toward achievement in this credit. Purchased RECs must be annualized over the life of the project. For example, if a project with a 20-year life purchases RECs for 100% of its energy consumption for one year, this would translate to 5% of its overall energy consumption.*
2. Net Zero Energy Ready goals may be waived, as described in item 6 below, if analysis shows sufficient technical constraints such as high density or inherently high energy intensity uses such as aquatic centers or other constraint. If determined that the project will not pursue Net Zero Energy Ready goals, then new County buildings, additions, and major renovations will be designed and constructed to operate at or below a site EUI based on building type in kBtu/ft²/yr.	
3. New County buildings, additions, and major renovations eligible for LEED for New Construction certification must achieve **at least LEED Silver certification** to demonstrate and communicate comprehensive sustainability to the public, including **management of energy, water, materials, indoor environment, and sustainable sites**. Projects may achieve Viridiant's EarthCraft Commercial or Residential certification as applicable in lieu of LEED Silver certification.	The Arlington Re-Gen Biosolids Upgrade Program is contractually obligated to reach at least a Silver level of Envision verification, but will likely target a Gold level of Envision verification. Like LEED, Envision's verification levels are based on points earned: • LEED-certified buildings can earn a total of 110 points. A project must earn 50–59 points for Silver and 60–79 points for Gold. • The Envision framework has a total of 1,000 potential points. To earn an Envision verification, the threshold for Silver is 30% of applicable points and Gold is 40% of applicable points.
4. Buildings to be constructed or renovated with less than 5,000 ft² gross floor area (GFA), buildings leased by the County with less than 8,000 ft² GFA or an initial lease term 8 years or less, and buildings without climate-control systems may be exempt from these Policy Standards but will follow the Guiding Principles.	See Envision alignment with Guiding Principles on pages 9–10.
5. If analysis shows that a major renovation does not include the scope of work necessary to pursue the **Net Zero Energy Ready goal**, the target EUI, and/or is ineligible for LEED or EarthCraft certification, then it shall be determined that this policy has been met if applicable Guiding Principles have been incorporated.	See Envision alignment with Guiding Principles on pages 9–10.

6. Each County project will be evaluated on a case-by-case basis. Waiver of **Net Zero Energy Ready goals** will be determined by the Director of Environmental Services or designee. Unless the County Manager determines that the application of this policy to a particular building or facility is not in the County's best interest (for example, because of time urgency or lack of funding), all County buildings and facilities will be constructed or renovated in accordance with this policy.	
Procedures and Responsibilities	**Envision Alignment/Related Credits**
1. The directors of all County departments whose responsibilities include planning, designing, developing, constructing, renovating, managing, and decommissioning County-owned and -leased buildings and facilities shall be responsible for **ensuring that facilities and buildings comply with this policy**.	LD1.1 Provide Effective Leadership & Commitment LD1.2 Foster Collaboration & Teamwork
2. Budget planning should include **life-cycle cost analysis** (LCCA) to support implementation of this policy.	LD3.3 Conduct a Life-Cycle Economic Evaluation The life-cycle economic evaluation prompts a comprehensive assessment to better understand the tradeoffs of upfront capital costs and the longer-term anticipated operational savings that may accrue from sustainable design. It can also measure and value community, environmental, and societal benefits, which are typically assessed qualitatively. In the Arlington WPCP Solids Master Plan, annual costs and 20-year life-cycle costs were developed using annual projections of solids for years 2021–2040. The Program has also used an LCCA to compare components for gas utilization.
3. Include stakeholders in the scoping, design, and construction process to effectively implement this policy, including a post-occupancy survey to identify lessons learned.	13 Envision credits include a stakeholder engagement component: QL1.1 Improve Community Quality of Life QL1.4 Minimize Noise and Vibration QL1.6 Minimize Construction Impacts QL2.1 Improve Community Mobility and Access QL3.1 Advance Equity & Social Justice QL3.2 Preserve Historic & Cultural Resources QL3.3 Enhance Views & Local Character QL3.4 Enhance Public Space & Amenities **LD1.3 Provide for Stakeholder Involvement** LD2.4 Plan for End of Life LD3.2 Develop Local Skills & Capabilities CR2.3 Evaluate Risk & Resilience CR2.4 Establish Resilience Goals & Strategies
4. When selecting design teams, include a competitive preference for design and construction professionals experienced in ultra-low energy buildings.	
5. Agencies shall include in their calculations for maintenance costs for new or renovated buildings an adjustment in cost per square foot to support new buildings.	
6. County staff must have LEED and building science training appropriate for their level of involvement in the project(s).	

Table B2. Envision Credits That Cover Topics Not Included in the Arlington Green Building Policy

Credit	Intent
LD1.4 Pursue Byproduct Synergies	Critically reconsider whether traditional waste streams can be beneficially reused
LD2.1 Establish a Sustainability Management Plan	Create a project sustainability management plan that can manage the scope, scale, and complexity of a project seeking to improve sustainable performance
LD2.2 Plan for Sustainable Communities	Incorporate sustainability principles into project selection/identification to develop the most sustainable project for the community
LD3.1 Stimulate Economic Prosperity & Development	Support economic prosperity and sustainable development, including job growth, capacity building, productivity, business attractiveness, and livability
RA1.1 Support Sustainable Procurement Practices	Develop sustainable procurement policies and programs to source materials and equipment from manufacturers and suppliers that implement sustainable practices
RA1.4 Reduce Construction Waste	Divert construction and demolition waste streams from disposal to recycling and reuse
RA1.5 Balance Earthwork On Site	Minimize the movement of soils and other excavated materials off site to reduce transportation and environmental impacts
RA3.1 Preserve Water Resources	Assess and reduce the negative net impact on freshwater availability, quantity, and quality at a watershed scale to positively impact the region's water resources
RA3.3 Reduce Construction Water Consumption	Reduce potable water consumption during construction
NW1.1 Preserve Sites of High Ecological Value	Avoid placing the project and temporary works on a site that has been identified as being of high ecological value
NW1.2 Provide Wetland & Surface Water Buffers	Protect, buffer, enhance, and restore wetlands, shorelines, and water bodies by providing natural buffer zones, vegetation, and soil-protection zones
NW1.3 Preserve Prime Farmland	Identify and protect soils designated as prime farmland, unique farmland, or farmland of importance
NW1.4 Preserve Undeveloped Land	Conserve undeveloped land by locating projects on previously developed land
NW2.1 Reclaim Brownfields	Locate projects on sites classified as brownfields
NW2.3 Reduce Pesticide & Fertilizer Impacts	Reduce nonpoint-source pollution by reducing the quantity, toxicity, bioavailability, and persistence of pesticides and fertilizers
NW2.4 Protect Surface & Groundwater Quality	Preserve water resources by preventing pollutants from contaminating surface water and groundwater and monitoring impacts during construction and operations
NW3.1 Enhance Functional Habitats	Preserve and improve the functionality of terrestrial (land) habitats
NW3.2 Enhance Wetland & Surface Water Functions	Maintain and restore the ecosystem functions of streams, wetlands, water bodies, and their riparian areas
NW3.3 Maintain Floodplain Functions	Preserve floodplain functions by limiting development and impacts of development in the floodplain
NW3.4 Control Invasive Species	Use appropriate non-invasive species, and control or eliminate existing invasive species
NW3.5 Protect Soil Health	Preserve the composition, structure, and function of site soils
CR1.1 Reduce Net Embodied Carbon	Reduce the impacts of material extraction, refinement/manufacture, and transport over the project life
CR2.1 Avoid Unsuitable Development	Minimize or avoid development on sites prone to hazards

Appendix C. Comparison Tables: Envision and LEED

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Table C1. Envision/LEED Alignment and Comparison

	LEED® BD+C (V4)	Envision (v3)
Basics	• Most recognizable sustainable certification available for **building projects** • Rigorous set of clearly defined standards that encourage improve building performance and occupant well-being • Prerequisite requirements must be met if a project is to be considered for certification • Building rating systems (BD+C, ID+C, O&M) for occupied buildings • LEED Zero available for all LEED projects certified under the BD+C or O+M rating systems that have net zero goals in carbon and/or resources	• Holistic view of **infrastructure development** • Recognized and rapidly growing program • Dual pathways allow projects to be submitted for verification either after design reaches 95% with a follow-up at construction completion, or at 95% construction completion • No prerequisites—not required to pursue all credits, but a certain number of credit points must be approved for a project to achieve verification • If used in conjunction with LEED, complements building rating system to inform project elements outside building and direct site; LEED documentation can be used to support some Envision credits
Description	Green building certification program and the globally recognized standard for the design, construction, and operation of high-performance green buildings and neighborhoods	Sustainable best practices and rating system for planning, designing, building, and maintaining civil infrastructure. Provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects.
Managing body	Green Business Certification, Inc. (GBCI) gbci.org U.S. Green Building Council (USGBC) usgbc.org LEED website	Institute for Sustainable Infrastructure (ISI) sustainableinfrastructure.org
Geography	International	International
Intended for	New buildings, existing buildings, renovations, interior fit-outs (also modules for Neighborhood Development [ND] and Cities)	New and existing infrastructure; new and existing buildings that are primarily process focused
Applicable project phase(s)	Design and construction: LEED Building Design and Construction (BD+C) and LEED Interior Design and Construction (ID+C) Operations and maintenance: LEED Building Operations and Maintenance (O&M)	Planning and design, construction, and operations and maintenance in one framework
Categories	• Location & Transportation • Sustainable Sites • Water Efficiency • Energy & Atmosphere • Materials & Resources • Indoor Environmental Quality • Innovation • Regional Priority	• Quality of Life • Leadership • Resource Allocation • Natural World • Climate and Resilience
# Credits/ prerequisites	57 credits/12 prerequisites	64 credits/no prerequisites
Registration cost	$1,500 ($1,200 if Silver, Gold, and Platinum Level Member)	$2,000
Certification cost	Based on building square footage Precertification: $5,000 ($4,000 if Silver, Gold, and Platinum Level Member)	Based on project cost ($M), membership status of the project team pursuing verification; verification pathway
Rating scale	Certified, Silver, Gold, Platinum	Verified, Silver, Gold, Platinum

Table C2. Envision/LEED Alignment and Comparison

Envision	Related LEED V4 BD+C Credits
Quality of Life	
QL1.1 Improve Community Quality of Life	LT: High-Priority Site (Option 2) ~SS: Site Assessment
QL1.2 Enhance Public Health and Safety	~EQ: Construction Indoor Air Quality Management Plan SS Prerequisite: Construction Activity Pollution Prevention
QL1.3 Improve Construction Safety	
QL1.4 Minimize Noise and Vibration	EQ: Acoustic Performance EQ Prerequisite: Minimum Acoustic Performance?
QL1.5 Minimize Light Pollution	SS: Light Pollution Reduction
QL1.6 Minimize Construction Impacts	
QL2.1 Improve Community Mobility and Access	LT: Surrounding Density and Diverse Uses LT: Access to Quality Transit LT: Bicycle Facilities ~LT: Reduced Parking Footprint?
QL2.2 Encourage Sustainable Transportation	LT: Surrounding Density and Diverse Uses LT: Access to Quality Transit LT: Bicycle Facilities ~LT: Reduced Parking Footprint?
QL2.3 Improve Access & Wayfinding	
QL3.1 Advance Equity & Social Justice	Pilot credits related to this
QL3.2 Preserve Historic & Cultural Resources	LT: High-Priority Site (Option 1)? MR: Building Life-Cycle Impact Reduction (Option 1)
QL3.3 Enhance Views & Local Character	EQ: Quality Views
QL3.4 Enhance Public Space & Amenities	SS: Open Space LT: Surrounding Density and Diverse Uses (public park, plaza) LT: Access to Quality Transit LT: Bicycle Facilities (access to bike network)
Leadership	
LD1.1 Provide Effective Leadership and Commitment	SS: Site Master Plan Prerequisite: Integrative Project Planning and Design IP: Integrative Process
LD1.2 Foster Collaboration and Teamwork	Credit: Integrative Process
LD1.3 Provide for Stakeholder Involvement	IP: Integrative Process?
LD1.4 Pursue Byproduct Synergies	MR: Prerequisite: Construction and Demolition Waste Management Planning MR: Construction and Demolition Waste Management
LD2.1 Establish a Sustainability Management Plan	~EA: Enhanced Commissioning
LD2.2 Plan for Sustainable Communities	
LD2.3 Plan for Long-Term Monitoring & Maintenance	~WE: Water Metering ~EA: Enhanced Commissioning ~EA: Advanced Energy Monitoring
LD2.4 Plan for End-of-Life	MR: Building Life Cycle Impact Reduction MR: Design for Flexibility
LD3.1 Stimulate Economic Prosperity & Development	LT: Surrounding Density and Diverse Uses ~MR: Building Life-Cycle Impact Reduction (Options 1 and 2)
LD3.2 Develop Local Skills & Capabilities	
LD3.3 Conduct a Life-Cycle Economic Evaluation	MR: Building Life-Cycle Impact Reduction
Resource Allocation	
RA1.1 Support Sustainable Procurement Practices	MR: Building Product Disclosure and Optimization-EPD MR: Building Product Disclosure and Optimization—Sourcing of Raw Materials MR: Building Product Disclosure Optimization—Material Ingredients MR: Construction and Demolition Waste Management (take back

	programs, Option 2 reduction of total waste material) EQ: Low-Emitting Materials
RA1.2 Use Recycled Materials	MR: Building Life-Cycle Impact Reduction MR: Building Product Disclosure and Optimization—Sourcing of Raw Materials MR: Construction and Demolition Waste Management
RA1.3 Reduce Operational Waste	MR Prerequisite: Storage and Collection of Recyclables MR: Building Life-Cycle Impact Reduction (Option 3) ~MR: Building Product Disclosure and Optimization-Sourcing of Raw Materials?
RA1.4 Reduce Construction Waste	MR Prerequisite: Construction and Demolition Waste Management Planning MR: Construction and Demolition Waste Management
RA1.5 Balance Earthwork On Site	SS: Site Development—Protect or Restore Habitat?
RA2.1 Reduce Operational Energy Consumption	EA Prerequisite: Minimum Energy Performance ~LT: Green Vehicles (Scope 3 of Envision Credit) EA: Optimize Energy Performance EA: Renewable Energy Production EA: Green Power and Carbon Offsets? EQ: Interior Lighting EQ: Daylight
RA2.2 Reduce Construction Energy Consumption	
Use renewable energy	EA: Renewable Energy Production EA: Green Power and Carbon Offsets
Commission and monitor energy systems	EA Prerequisite: Fundamental Commissioning and Verification EA Prerequisite: Building-Level Energy Metering EA: Enhanced Commissioning EA: Advanced Energy Monitoring
RA3.1 Preserve Water Resources	SS: Rainwater Management
RA3.2 Reduce Operational Water Consumption	WE: Prerequisite: Outdoor Water Use Reduction WE: Prerequisite: Indoor Water Use Reduction WE: Outdoor Water Use Reduction WE: Indoor Water Use Reduction WE: Cooling Tower Water Use
RA3.3 Reduce Construction Water Consumption	
RA3.4 Monitor Water Systems	WE: Prerequisite: Building-Level Water Metering WE: Water Metering
Natural World	
NW1.1 Preserve Sites of High Ecological Value	LT: Sensitive Land Protection SS: Site Assessment SS: Site Development- Protect or Restore Habitat
NW1.2 Protect Wetland and Surface Water Buffers	LT: Sensitive Land Protection SS: Rainwater Management
NW1.3 Preserve Prime Farmland	LT: Sensitive Land Protection ~LT: Reduced Parking Footprint
NW1.4 Preserve Undeveloped Land	LT: Sensitive Land Protection LT: High-Priority Site (Option 3)
NW2.1 Reclaim Brownfields	
NW2.2 Manage Stormwater	~LT: Reduce Parking Footprint? SS: Rainwater Management
NW2.3 Reduce Pesticide & Fertilizer Impacts	WE: Prerequisite: Outdoor Water Use Reduction WE: Outdoor Water Use Reduction (native and adaptive plants)
NW2.4 Protect Surface & Groundwater Quality	SS Prerequisite Construction Activity Pollution Prevention
NW3.1 Enhance Functional Habitats	LT: Sensitive Land Protection

NW3.2 Enhance Wetland & Surface Water Functions	~SS: Site Assessment
Maintain floodplain functions	LT: Sensitive Land Protection SS: Rainwater Management
NW3.4 Control Invasive Species	(Maybe Regional Priority Credits?)
NW3.5 Protect Soil Health	SS: Site Development—Protect or Restore Habitat
Climate and Resilience	
CR1.1 Reduce Net Embodied Carbon	MR: Life-Cycle Impact Reduction
CR1.2 Reduce Greenhouse Gas Emissions	LT: Green Vehicles EA Prerequisite: Minimum Energy Performance ~EA: Renewable Energy Production? EA: Green Power and Carbon Offsets MR: Building Life-Cycle Impact Reductions (Option 4)
CR1.3 Reduce Air Pollutant Emissions	LT: Green Vehicles LT: Access to Quality Transit MR: Building Life-Cycle Impact Reduction (Option 4) EA Prerequisite: Fundamental Refrigerant Management? EA Prerequisite: Minimum Energy Performance EA: Minimum Energy Performance EQ Prerequisite: Minimum Indoor Air Quality Performance? EQ: Indoor Air Quality Assessment
CR2.1 Avoid Unsuitable Development	SS: Site Assessment
CR2.2 Assess Climate Change Vulnerability	SS: Site Assessment EA Credit: Enhanced Refrigerant Management
CR2.3 Evaluate Risk and Resilience	
CR2.4 Establish Resilience Goals and Strategies	
CR2.5 Maximize Resilience	MR: Design for Flexibility
Improve infrastructure integration	LT: Access to Quality Transit LT: Bicycle Facilities ~LT: Reduced Parking Footprint EA: Renewable Energy Production

Table C3: LEED / Envision Credit Correlation

- ● Substantial correlation
- ● Minor correlation
- ● No correlation

LEED V4 FOR NEW CONSTRUCTION AND MAJOR RENOVATION

		Points		Correlating Envision Credits	
LOCATION AND TRANSPORTATION	LEED for Neighborhood Development Location	16	●	N/A	
	Sensitive Land Protection	1	●	- NW1.1 Preserve Sites of High Ecological Value - NW1.2 Protect Wetland and Surface Water Buffers - NW1.3 Preserve Prime Farmland	- NW1.4 Preserve Undeveloped Land - NW3.1 Enhance Functional Habitats - NW3.3 Maintain Floodplain Functions
	High-Priority Site and Equitable Development	2	●	- LD3.1 Stimulate Economic Prosperity & Development - QL3.1 Advance Equity & Social Justice	- NW2.1 Reclaim Brownfields
	Surrounding Density and Diverse Uses	5	●	- QL2.1 Improve Community Mobility and Access - QL2.2 Encourage Sustainable Transportation	- QL3.4 Enhance Public Space & Amenities - LD3.1 Stimulate Economic Prosperity & Development
	Access to Quality Transit	5	●	- QL2.1 Improve Community Mobility and Access - QL2.2 Encourage Sustainable Transportation - QL3.4 Enhance Public Space & Amenities	- CR1.3 Reduce Air Pollutant Emissions - CR2.6 Improve infrastructure integration
	Bicycle Facilities	1	●	- QL2.1 Improve Community Mobility and Access - QL2.2 Encourage Sustainable Transportation	- QL3.4 Enhance Public Space & Amenities - CR2.6 Improve infrastructure integration
	Reduced Parking Footprint	1	●	- QL2.1 Improve Community Mobility and Access - QL2.2 Encourage Sustainable Transportation	- CR2.6 Improve infrastructure integration - CR0.0 Manage heat island effects
	Electric Vehicles	1	●	- QL2.2 Encourage Sustainable Transportation - CR1.2 Reduce Greenhouse Gas Emissions	- CR1.3 Reduce Air Pollutant Emissions - RA2.1 Reduce Operational Energy Consumption
		16			
SUSTAINABLE SITES	Construction Activity Pollution Prevention	Req	●	- QL1.6 Minimize Construction Impacts	- NW2.4 Protect Surface & Groundwater Quality
	Site Assessment	1	●	- QL1.2 Enhance Public Health & Safety - QL2.3 Improve Access & Wayfinding - QL3.2 Preserve Historic & Cultural Resources - QL3.3 Enhance Views & Local Character - NW1.1 Preserve Sites of High Ecological Value - NW1.2 Provide Wetland & Surface Water Buffers - NW1.3 Preserve Prime Farmland - NW1.4 Preserve Undeveloped Land	- NW2.1 Reclaim Brownfields - NW3.1 Enhance Functional Habitats - NW3.2 Enhance Wetland & Surface Water Functions - NW3.3 Maintain Floodplain Functions - NW3.4 Control Invasive Species - CR2.1 Avoid Unsuitable Development - CR2.2 Assess Climate Change Vulnerability
	Protect or Restore Habitat	2	●	- NW1.1 Preserve Sites of High Ecological Value - NW3.4 Control Invasive Species	- NW3.5 Protect Soil Health
	Open Space	1	●	- QL3.4 Enhance Public Space & Amenities	
	Rainwater Management	3	●	- NW1.2 Protect Wetland and Surface Water Buffers - NW2.2 Manage Stormwater	- NW3.3 Maintain Floodplain Functions
	Heat Island Reduction	2	●	- CR0.0 Manage heat island effects	
	Light Pollution Reduction	1	●	- QL1.5 Minimize light pollution	
		10			
WATER EFFICIENCY	Outdoor Water Use Reduction	Req	●	- RA3.2 Reduce Operational Water Consumption	- NW2.3 Reduce Pesticide & Fertilizer Impacts
	Indoor Water Use Reduction	Req	●	- RA3.2 Reduce Operational Water Consumption	
	Building-Level Water Metering	Req	●	- RA3.4 Monitor water systems	
	Outdoor Water Use Reduction	2	●	- RA3.2 Reduce Operational Water Consumption	- NW2.3 Reduce Pesticide & Fertilizer Impacts
	Indoor Water Use Reduction	6	●	- RA3.2 Reduce Operational Water Consumption	
	Cooling Tower Water Use	2	●	- RA3.2 Reduce Operational Water Consumption	
	Water Metering	1	●	- RA3.4 Monitor water systems	
		11			
ENERGY & ATMOSPHERE	Fundamental Commissioning and Verification	Req	●	- RA2.4 Commission and monitor energy systems	
	Minimum Energy Performance	Req	●	- RA2.1 Reduce Operational Energy Consumption	- CR1.2 Reduce Greenhouse Gas Emissions
	Building-Level Energy Metering	Req	●	- RA2.4 Commission and monitor energy systems	
	Fundamental Refrigerant Management	Req	●	- CR2.2 Assess Climate Change Vulnerability	- CR1.3 Reduce Air Pollutant Emissions
	Enhanced Commissioning	6	●	- LD2.3 Plan for Long-Term Monitoring & Maintenance	- RA2.4 Commission and monitor energy systems
	Optimize Energy Performance	18	●	- RA2.1 Reduce Operational Energy Consumption	- CR1.2 Reduce Greenhouse Gas Emissions
	Advanced Energy Metering	1	●	- RA2.4 Commission and monitor energy systems	- LD2.3 Plan for Long-Term Monitoring & Maintenance
	Grid Harmonization	2	●	- RA2.1 Reduce Operational Energy Consumption - RA2.3 Use renewable energy	- CR1.2 Reduce Greenhouse Gas Emissions - CR2.6 Improve infrastructure integration
	Renewable Energy	5	●	- RA2.3 Use renewable energy	
	Enhanced Refrigerant Management	1	●	- CR2.2 Assess Climate Change Vulnerability	- CR1.3 Reduce Air Pollutant Emissions
		33			
MATERIALS & RESOURCES	Storage and Collection of Recyclables	Req	●	- RA1.3 Reduce Operational Waste	
	Construction and Demolition Waste Management Planning	Req	●	- LD1.4 Pursue Byproduct Synergies - RA1.1 Support sustainable procurement practices	- RA1.2 Use recycled materials - RA1.4 Reduce Construction Waste
	Building Life-Cycle Impact Reduction	5	●	- LD2.4 Plan for End-of-Life - LD3.3 Conduct a Life-Cycle Economic Evaluation - CR1.1 Reduce Net Embodied Carbon - RA1.2 Use recycled materials	- RA1.3 Reduce Operational Waste - CR1.3 Reduce Air Pollutant Emissions - CR1.2 Reduce Greenhouse Gas Emissions
	BPDO - Environmental Product Declarations	2	●	- RA1.1 Support sustainable procurement practices	- RA1.2 Use recycled materials
	BPDO - Sourcing of Raw Materials	2	●	- RA1.1 Support sustainable procurement practices	- RA1.2 Use recycled materials
	BPDO - Material Ingredients	2	●	- RA1.1 Support sustainable procurement practices	- RA1.2 Use recycled materials
	Construction and Demolition Waste Management	2	●	- LD1.4 Pursue Byproduct Synergies - RA1.1 Support sustainable procurement practices	- RA1.2 Use recycled materials - RA1.4 Reduce Construction Waste
		13			
INDOOR ENVIRONMENTAL QUALITY	Minimum Indoor Air Quality Performance	Req	●	- CR1.3 Reduce Air Pollutant Emissions	
	Environmental Tobacco Smoke Control	Req	●	N/A	
	Enhanced Indoor Air Quality Strategies	2	●	N/A	
	Low-Emitting Materials	3	●	- RA1.1 Support sustainable procurement practices	
	Construction Indoor Air Quality Management Plan	1	●	- QL1.6 Minimize Construction Impacts	
	Indoor Air Quality Assessment	2	●	- CR1.3 Reduce Air Pollutant Emissions	
	Thermal Comfort	1	●	N/A	
	Interior Lighting	2	●	- RA2.1 Reduce Operational Energy Consumption	
	Daylight	3	●	- RA2.1 Reduce Operational Energy Consumption	
	Quality Views	1	●	- QL3.3 Enhance Views & Local Character	
	Acoustic Performance	1	●	- QL1.4 Minimize noise and vibration	
		16			
INNOVATION	Innovation	5	●	Innovation credits	
	LEED Accredited Professional	1	●	Project requirement: ENV SP on team	
		6			
	PROJECT TOTAL	110			

BPDO= Building Product Disclosure and Optimization

ENVISION CREDITS NOT CORRELATED TO LEED CREDITS:

- QL1.3 Improve Construction Safety
- LD2.2 Plan for Sustainable Communities
- LD3.2 Develop Local Skills & Capabilities
- RA1.5 Balance Earthwork On Site
- RA2.2 Reduce Construction Energy Consumption
- RA3.1 Preserve Water Resources
- RA3.3 Reduce Construction Water Consumption
- CR2.3 Evaluate Risk and Resilience
- CR2.4 Establish Resilience Goals and Strategies
- CR2.5 Maximize Resilience

Table C4: LEED v4.1 Prerequisite Credits/ Envision Credit Correlation

	LEED v4.1 Prerequisite Credits	LEED Criteria	Envision Correlation	Correlating Envision Credit(s)	Anticipate Pursuing for Re-Gen	Anticipated LOA or LOA Range (*indicates highest LOA)	Notes/ Explanation	Envision Credit Criteria or Requirements for the Anticipated LOA
SUSTAINABLE SITES	Construction Activity Pollution Prevention	Intent: To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation, and airborne dust. Requirements: NC, CS, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Create and implement an erosion and sedimentation control plan for all construction activities associated with the project. The plan must conform to the erosion and sedimentation requirements of the 2017 U.S. Environmental Protection Agency (EPA) Construction General Permit (CGP) or local equivalent, whichever is more stringent. Projects must apply the CGP regardless of size. The plan must describe the measures implemented.	●	QL1.6 Minimize Construction Impacts	Yes	Conserving*		A) The project team implements a construction management plan or policies to address the temporary inconveniences associated with construction. The plan or policies are informed by stakeholder engagement. (B, C, D, or E) The management plan addresses 1-**4** type(s) of construction impact: (B) noise, (C) safety/wayfinding, (D) access/mobility, or (E) lighting. (F) The construction management plan or policies include robust feedback mechanisms and performance monitoring and reporting for construction impacts.
				NW2.2 Manage Stormwater	No	-		Improved level of achievement: (A) Detain and treat 100% of the 85th percentile local 24-hour event. Ensure compliance with local requirements if stricter. (B) Do not exceed rate or quantity of runoff for the 2-year 24-hour rainfall event relative to the existing condition (greenfield, greyfield, or brownfield). (C) The project includes an erosion, sedimentation, and pollutant control plan for construction activities.
				NW2.4 Protect Surface & Groundwater Quality	Yes	Improved		(A) The project team determines potential impacts to surface water or groundwater quality, including temperature, during construction and operations. (B) The project includes spill and leak diversion systems, spill prevention plans, and cleanup. The project does not create new direct pathways for surface water and/or groundwater contamination
WATER EFFICIENCY	Outdoor Water Use Reduction	Intent: To reduce outdoor water consumption. Requirements: NC, CS, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Reduce outdoor water use through one of the following options. Nonvegetated surfaces, such as permeable or impermeable pavement, should be excluded from the landscape area calculations. Athletic fields and playgrounds (if vegetated) and food gardens may be included or excluded at the project team's discretion. Option 1. No Irrigation Required Show that the landscape does not require a permanent irrigation system beyond a maximum two-year establishment period. OR Option 2. Reduced Irrigation Reduce the project's landscape water requirement by at least 30% from the calculated baseline for the site's peak watering month. Reductions must be achieved through plant species selection and irrigation system efficiency, as calculated by the Environmental Protection Agency (EPA) WaterSense Water Budget Tool.	●	RA3.2 Reduce Operational Water Consumption	No	-	Upgraded facility will use more water than existing facility	(A) The project team conducts planning or design reviews to identify potable water reduction strategies during operation of the project. The team has considered using alternatives such as nonpotable water, reused water, recycled water, and stormwater. (B) The project reduces potable water use by at least __%. Improved: 25% - Enhanced: 50% - Superior: 75% - Conserving: 95% - Restorative: 100% (C) Overall water use (potable and nonpotable) is reduced by at least __%. Enhanced: 20%- Superior: 30% - Conserving: 40% - Restorative: 50% (D) The project not only reduces potable water consumption to zero, but also provides water that can be used by the community.
				NW2.3 Reduce Pesticide & Fertilizer Impacts	Yes	Conserving		(C) Landscaping is designed with plant species that do not require pesticides or fertilizers.
	Indoor Water Use Reduction	Intent: To reduce indoor water consumption. Requirements: NC, CS, SCHOOLS, NC-RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, NC-HOSPITALITY, HEALTHCARE Building Water Use For the fixtures and fittings listed in Table 1, as applicable to the project scope, reduce aggregate water consumption by 20% from the baseline. Base calculations on the volumes and flow rates shown in Table 1. All newly installed toilets, urinals, private lavatory faucets, and showerheads that are eligible for labeling must be WaterSense labeled. Appliance and Process Water Use Install appliances, equipment, and processes within the project scope that meet the requirements listed in the guidance document.	●	RA3.2 Reduce Operational Water Consumption	No	-	Upgraded facility will use more water than existing facility	See criteria noted for RA3.2 above.
	Building-Level Water Metering	Intent: To support water management and identify opportunities for additional water savings by tracking water consumption. Requirements: NC, CS, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Install permanent water meters that measure the total potable water use for the building and associated grounds. Meter data must be compiled into monthly and annual summaries; meter readings can be manual or automated. Commit to sharing with USGBC the resulting whole-project water usage data for a five-year period beginning on the date the project accepts LEED certification or typical occupancy, whichever comes first. This commitment must carry forward for five years or until the building changes ownership or lessee.	●	RA3.4 Monitor water systems	Yes	Enhanced		(A) The project includes monitoring capabilities. Equipment and/or software are incorporated in the design to allow detailed monitoring of performance (quantity or quality). The equipment is capable of monitoring all primary project functions, accounting for at least 75% of water use. (Superior: 95%)

LEED v4.1 Prerequisite Credits/ Envision Credit Correlation (cont.)

	LEED v4.1 Prerequisite Credits	LEED Criteria	Envision Correlation	Correlating Envision Credit(s)	Anticipate Pursuing for Re-Gen	Anticipated LOA or LOA Range (*indicates highest LOA)	Notes/ Explanation	Envision Credit Criteria or Requirements for the Anticipated LOA
ENERGY & ATMOSPHERE	Fundamental Commissioning and Verification	Intent: To support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water, indoor environmental quality, and durability. Requirements: NC, CS, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Commissioning Process Scope Complete the following commissioning (Cx) process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies, in accordance with ASHRAE Guideline 0-2013 and ASHRAE Guideline 1.1-2007 for HVAC&R Systems, as they relate to energy, water, indoor environmental quality, and durability. Commissioning Authority Qualifications By the end of the design development phase, engage a commissioning authority with the following qualifications... Current Facilities Requirements and Operations and Maintenance Plan Prepare and maintain a current facilities requirements and operations and maintenance plan that contains the information necessary to operate the building efficiently.	●	RA2.4 Commission and monitor energy systems	Yes	Enhanced		(A) The project includes energy monitoring capability. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for at least 75% of energy use/consumption. (B) The project conducts an initial commissioning of energy systems accounting for at least 75% of the total energy consumption/generation. Commissioning includes a detailed log of issues.
	Minimum Energy Performance	Intent: To reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the building and its systems. Requirements: NC, CS, SCHOOLS, RETAIL,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Comply with ANSI/ASHRAE/IESNA Standard 90.1-2016, with errata or a USGBC-approved equivalent standard. For projects using Normative Appendix G Performance Rating Method: Greenhouse gas emissions: The total greenhouse gas emissions, in terms of carbon dioxide equivalents, shall be calculated for the baseline building performance rating and for the proposed building performance rating, and the percentage improvement shall be determined using carbon dioxide equivalent emissions.	●	RA2.1 Reduce Operational Energy Consumption	Yes	Improved		(A) The project team determines the estimated annual energy consumption of the project. If annual energy consumption varies, the project team submits the range of estimated performance over the project life. (B) Operational energy is reduced **at least 10%**. Enhanced: 30% - Superior: 50% - Conserving: 70%
				CR1.2 Reduce Greenhouse Gas Emissions	Yes	at least Improved		(A) The project team demonstrates at least a __% reduction in total CO2e over the operational life of the project compared to the baseline. Calculations should be in tons CO2e. **Improved: 10%** - Enhanced: 25% - Superior: 50% - Conserving: 100% - Restorative: carbon negative (B) The project team maps and calculates the total annual greenhouse gas emissions of the final project design for reporting purposes. This includes direct and indirect greenhouse gas emissions and sequestration associated with project operations.
	Building-Level Energy Metering	Intent: To support energy management and identify opportunities for additional energy savings by tracking building-level energy use. Requirements: NC, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Install new or use existing building-level energy meters, or submeters that can be aggregated to provide building-level data representing total building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc). Utility-owned meters capable of aggregating building-level resource use are acceptable. Commit to sharing with USGBC the resulting energy consumption data and electrical demand data (if metered) for a five-year period beginning on the date the project accepts LEED certification. At a minimum, energy consumption must be tracked at one-month intervals. This commitment must carry forward for five years or until the building changes ownership or lessee.	●	RA2.4 Commission and monitor energy systems	Yes	Enhanced		(A) The project includes energy monitoring capability. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for at least 75% of energy use/consumption. (B) The project conducts an initial commissioning of energy systems accounting for at least 75% of the total energy consumption/generation. Commissioning includes a detailed log of issues.
	Fundamental Refrigerant Management	Intent: To reduce stratospheric ozone depletion. Requirements: NC, CS, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE Do not use chlorofluorocarbon (CFC)-based refrigerants in new heating, ventilating, air-conditioning, and refrigeration (HVAC&R) systems. When reusing existing HVAC&R equipment, complete a comprehensive CFC phase-out conversion before project completion. Phase-out plans extending beyond the project completion date will be considered on their merits. Existing small HVAC&R units (defined as containing less than 0.5 pound [225 grams] of refrigerant) and other equipment, such as standard refrigerators, small water coolers, and any other equipment that contains less than 0.5 pound (225 grams) of refrigerant, are exempt.	●	CR2.2 Assess Climate Change Vulnerability	Yes	Improved-Superior		(A) The project team conducts, or relies on, an existing, comprehensive threat/hazard identification study, or assessment, due to climate change. The assessment should account for climate change's impact on the frequency, duration, and severity of threats/hazards. (B) The project team determines vulnerabilities and increased risk to the project, or performance, over its operational life due to climate change-related threats. This should include whether current design variables will continue to meet performance goals over the life of the project under changing operating conditions (i.e., climate, weather patterns, natural hazard frequency and intensity). (C) The project team determines vulnerabilities and increased risk to the connected/related infrastructure system or network due to climate change-related threats. This should include how project vulnerabilities may impact system performance and how system vulnerabilities may impact the project. This should include direct and indirect impacts such as resource and service availability. (D) The project team determines vulnerabilities and increased risk to the broader community due to climate change threats. This should include how project vulnerabilities may impact the broader community and how
				CR1.3 Reduce Air Pollutant Emissions	Yes	Improved		(A) The project meets all applicable air quality standards and regulations for air pollutants. (B) The project implements strategies to reduce air pollutant emissions during operations.

LEED v4.1 Prerequisite Credits/ Envision Credit Correlation (cont.)

	LEED v4.1 Prerequisite Credits	LEED Criteria	Envision Correlation	Correlating Envision Credit(s)	Anticipate Pursuing for Re-Gen	Anticipated LOA or LOA Range (*indicates highest LOA)	Notes/ Explanation	Envision Credit Criteria or Requirements for the Anticipated LOA
MATERIALS & RESOURCES	Storage and Collection of Recyclables	Intent: To reduce the waste that is generated by building occupants and hauled to and disposed of in landfills. Requirements: NC, CS, SCHOOLS, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY NC, HEALTHCARE Provide dedicated areas accessible to waste haulers and building occupants for the collection and storage of recyclable materials for the entire building. Collection and storage areas may be separate locations. Recyclable materials must include mixed paper, corrugated cardboard, glass, plastics, and metals. Take appropriate measures for the safe collection, storage, and disposal of two of the following: batteries, mercury-containing lamps, and electronic waste.	●	RA1.3 Reduce Operational Waste	Yes	Conserving*		(A) Develop an operational waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on site or commingled. (B) The project team identifies waste streams or byproducts that will occur as a result of the operation of the project. The project is planned or designed to divert at least __% of operational waste. Improved: 25% - Enhanced: 50% - Superior: 75% - **Conserving: 95%**
	Construction and Demolition Waste Management Planning	Intent: To reduce construction and demolition waste disposed of in landfills and incineration facilities by recovering, reusing, and recycling materials. Requirements: NC, CS, SCHOOLS, RETAIL NC, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY NC, HEALTHCARE Develop and implement a construction and demolition waste management plan: • Establish waste diversion goals for the project by identifying at least five materials (both structural and nonstructural) targeted for diversion. • Specify whether materials will be separated or comingled and describe the diversion strategies planned for the project. Describe where the material will be taken and how the recycling facility will process the material including expected diversion rates for each material stream. Provide a final report detailing all major waste streams generated, including disposal and diversion rates. Alternative daily cover (ADC) does not qualify as material diverted from disposal. Include materials destined for ADC in the calculations as waste. Land-clearing debris is not considered construction, demolition, or renovation waste that can contribute to waste diversion.	●	RA1.4 Reduce Construction Waste	Yes	Superior-Conserving*		(A) Implement a construction waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on site or commingled. (B) The project team sets a target goal for construction waste diversion. During construction at least __% of waste materials are recycled, reused, and/or salvaged. Improved: 25% - Enhanced: 50% - **Superior: 75% - Conserving: 95%**
				LD1.4 Pursue Byproduct Synergies	Yes	Restorative*		(A) The project team conducts an assessment of the availability and viability of excess resources (i.e., waste) or capacity, including but not limited to waste materials, heating or cooling, financial capacity, land area/space, or management/personnel capacity. (B) Candidates for byproduct synergies or reuse are identified. This can include finding a beneficial reuse for the project's waste or excess resources, or the project's beneficial reuse of external waste or excess resources. Project teams should also consider ecosystem services where project waste or excess resources can support natural systems, or where natural systems can process and remove project waste. (E) The project is fully engaged in a circular economy system whereby the majority of its operational waste is beneficially reused OR the majority of its operational resources are sourced from external waste streams.
				RA1.1 Support sustainable procurement practices	No	-		(A) A written sustainable procurement policy/program is in place that includes a well-defined process for selecting suppliers and/or manufacturers of materials, supplies, and equipment, including selection criteria focused on environmental practices and social responsibility. (B) At least __% of all project materials, supplies, and equipment meet the sustainable procurement policy/program requirements. Improved: 5% - Enhanced: 15% - Superior: 25% - Conserving: 50%
				RA1.2 Use recycled materials	Yes	Improved		(A) At least __% (by weight, volume, or cost) of recycled materials including materials with recycled content and/or reused existing structures or materials. **Improved: 5%** - Enhanced: 15% - Superior: 25% - Conserving: 50%
INDOOR ENVIRONMENTAL QUALITY	Minimum Indoor Air Quality Performance	Intent: To contribute to the comfort and well-being of building occupants by establishing minimum standards for indoor air quality (IAQ). Requirements: NC, CS, SCHOOLS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY Mechanically Ventilated Spaces For mechanically ventilated spaces (and for mixed-mode systems when the mechanical ventilation is activated), meet the requirements for both ventilation (option 1 or option 2) and monitoring. Naturally Ventilated Spaces For naturally ventilated spaces (and for mixed-mode systems when the mechanical ventilation is inactivated), confirm that natural ventilation is an effective strategy for the project by following the flow diagram in the Chartered Institution of Building Services Engineers (CIBSE) Applications Manual AM10, March 2005, Natural Ventilation in Nondomestic Buildings, Figure 2.8 and meet the requirements for both ventilation (option 1, option 2, or option 3) and monitoring. All Spaces The indoor air quality procedure defined in ASHRAE Standard 62.1–2016, Section 6.3 may not be used to comply with this prerequisite.	●	CR1.3 Reduce Air Pollutant Emissions	Yes	Improved	Because Envision is not intended for conditioned indoor spaces, the framework does not include credits focused on indoor air quality improvements	(A) The project meets all applicable air quality standards and regulations for air pollutants. (B) The project implements strategies to reduce air pollutant emissions during operations.
	Environmental Tobacco Smoke Control	Intent: To prevent or minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke. Requirements: NC, CS, RETAIL, DATA CENTERS,WAREHOUSES & DISTRIBUTION CENTERS, HOSPITALITY, HEALTHCARE For this prerequisite smoking includes tobacco smoke, as well as smoke produced from the combustion of cannabis and controlled substances and the emissions produced by electronic smoking devices. Prohibit smoking inside the building. Prohibit smoking outside the building except in designated smoking areas located at least 25 feet (7.5 meters) (or the maximum extent allowable by local codes) from all entries, outdoor air intakes, and operable windows. This smoking requirement also applies to any spaces outside the property line that are used for business purposes. Communicate the no-smoking policy to occupants. Have in place provisions for enforcement or no-smoking signage.	●	No equivalent	-	-		

Appendix D. Envision Energy- and Emissions-Related Credits

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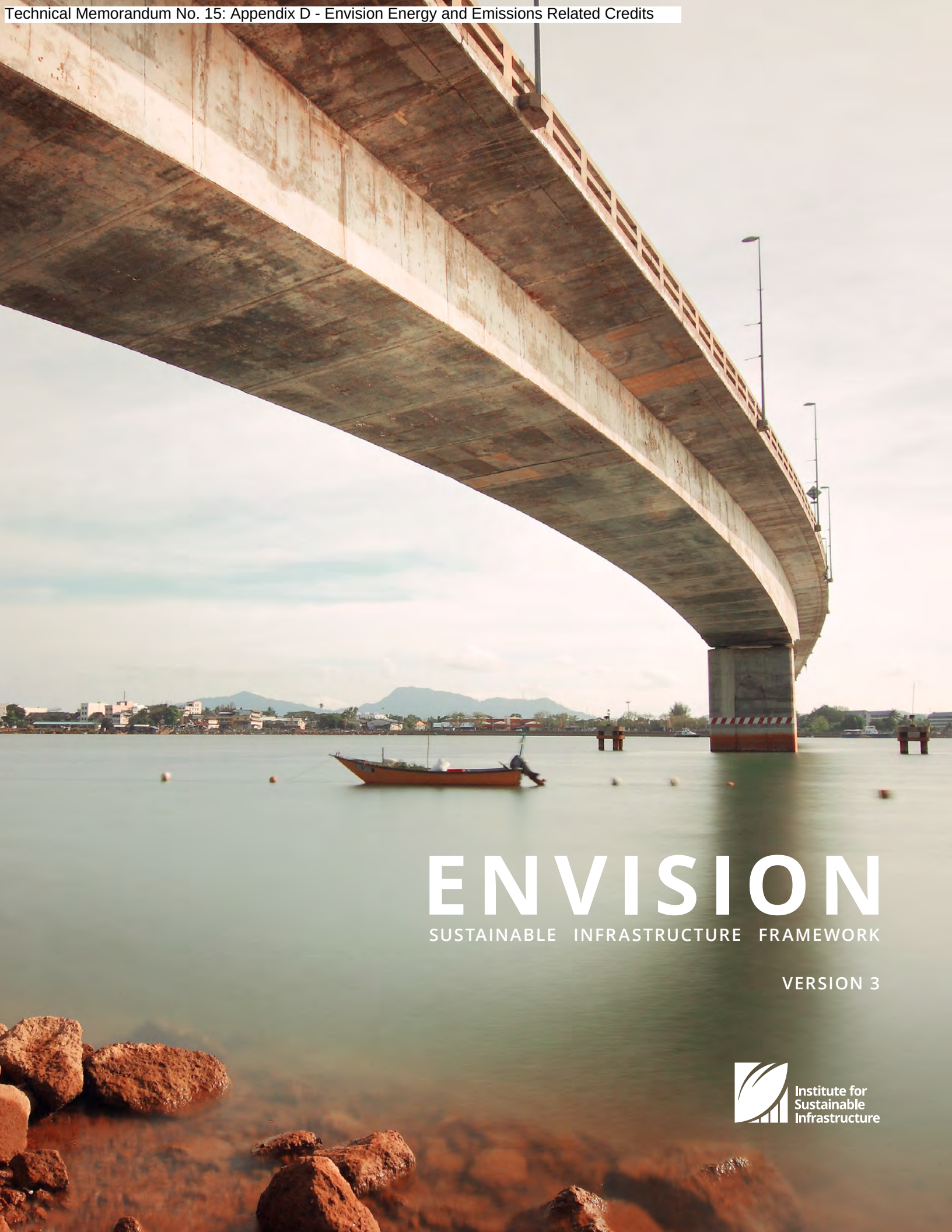
Table D1. Energy and Emissions Envision Credits

Credit	Anticipated LOA	Notes
RA2.1 Reduce Operational Energy Consumption *Accepted methodologies for establishing baseline performance data include existing conditions, a seriously considered alternative, standard practice, or a comparable existing project/facility.*	**Improved** Operational energy is reduced **at least 10%** over the established baseline. The baseline for this credit would likely be existing conditions or seriously considered alternative.	Conserving is the highest level of achievement for this credit. The criterion for Conserving is for operational energy to be reduced by **at least 70%.** Given the energy intensity of the processes involved in the operating project, significant energy reduction would be difficult. Energy optimization through the use and production of renewable energy will help to offset the energy use.
RA2.2 Reduce Construction Energy Consumption	**Enhanced** The project implements, or has written requirements to implement, at least **two energy reduction strategies** during construction.	Conserving is the highest level of achievement for this credit. The criterion for Conserving is for the project to implement at least **six energy reduction strategies** during construction. The project team discussed that challenging the contractor to implement two strategies advanced beyond current practices. Requesting more to get to higher LOAs would likely be cost prohibitive. LEED does not have a comparable credit.
RA2.3 Use Renewable Energy	**Restorative** The project generates a net positive amount of renewable energy.	
RA2.4 Commission & Monitor Energy Systems	**Enhanced** The project includes **energy monitoring capability**. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for at least 75% of energy use/consumption. The project conducts an **initial commissioning** of energy systems accounting for at least 75% of the total energy consumption/ generation. Commissioning includes a detailed log of issues.	Conserving is the highest level of achievement for this credit. The criterion for Conserving includes energy monitoring accounting for at least 90% of energy use/consumption, engaging an **independent third-party commissioning agent**, and developing a comprehensive plan for **ongoing periodic re-commissioning**/review of energy systems throughout the expected life of the project.

Credit	Anticipated LOA	Notes
CR1.1 Reduce Net Embodied Carbon	Likely not pursued	This credit addresses the embodied carbon of materials used over the life of the project. This combines concepts of sourcing local materials, using materials more efficiently, and using lower-impact materials to reduce the combined environmental impacts of material use. Criteria include: • Identifying primary materials to be used on the project during construction and operation; and team determining which materials are the primary contributors to net embodied carbon (collectively >80%) • Calculating embodied carbon for the primary materials • Demonstrating a reduction (5%–15%–30%–50%) in total embodied carbon of materials over the life of the project compared to the baseline
CR1.2 Reduce Greenhouse Gas Emissions	Improved The project team demonstrates at least a 10% reduction in total CO_2e over the operational life of the project compared to the baseline. The baseline for this credit would likely be existing conditions.	The criterion for a Restorative LOA is for the completed project to be **carbon negative** (i.e., sequesters/removes more CO_2e than it produces over the operational life).
CR1.3 Reduce Air Pollutant Emissions	Improved The project implements strategies to **reduce air pollutant emissions** during operations.	The criterion for a Restorative LOA includes: • Eliminating air pollutant sources in the design, choosing a non-polluting alternative, or achieving at **least a 98% net reduction in air pollution emissions compared to the baseline** • Putting systems in place for the ongoing monitoring of any direct sources of air pollution, with processes in place to identify and address changes in emissions to maintain performance targets • Assessing whether volatile organic compounds harmful to human health are material to the project and, if so, implementing strategies to reduce their use during construction and/or within occupied spaces of the completed project • Including the direct removal of previously existing air pollutant sources, or capturing and safely storing/disposing of air pollutants for a net positive impact



ENVISION

SUSTAINABLE INFRASTRUCTURE FRAMEWORK

VERSION 3

Institute for Sustainable Infrastructure

ENVISION POINTS TABLE

			Improved	Enhanced	Superior	Conserving	Restorative	Maximum Points
Quality of Life	Purpose	QL1.1 Improve Community Quality of Life	2	5	10	20	26	200
		QL1.2 Enhance Public Health & Safety	2	7	12	16	20	
		QL1.3 Improve Construction Safety	2	5	10	14	—	
		QL1.4 Minimize Noise & Vibration	1	3	6	10	12	
		QL1.5 Minimize Light Pollution	1	3	6	10	12	
		QL1.6 Minimize Construction Impacts	1	2	4	8	—	
	Wellbeing	QL2.1 Improve Community Mobility	1	3	7	11	14	
		QL2.2 Encourage Sustainable Transportation	—	5	8	12	16	
		QL2.3 Improve Access & Wayfinding	1	5	9	14	—	
	Community	QL3.1 Advance Equity & Social Justice	3	6	10	14	18	
		QL3.2 Preserve Historic & Cultural Resources	—	2	7	12	18	
		QL3.3 Enhance Views & Local Character	1	3	7	11	14	
		QL3.4 Enhance Public Space & Amenities	1	3	7	11	14	
Leadership	Collaboration	LD1.1 Provide Effective Leadership & Commitment	2	5	12	18	—	182
		LD1.2 Foster Collaboration & Teamwork	2	5	12	18	—	
		LD1.3 Provide for Stakeholder Involvement	3	6	9	14	18	
		LD1.4 Pursue Byproduct Synergies	3	6	12	14	18	
	Planning	LD2.1 Establish a Sustainability Management Plan	4	7	12	18	—	
		LD2.2 Plan for Sustainable Communities	4	6	9	12	16	
		LD2.3 Plan for Long-Term Monitoring & Maintenance	2	5	8	12	—	
		LD2.4 Plan for End-of-Life	2	5	8	14	—	
	Economy	LD3.1 Stimulate Economic Prosperity & Development	3	6	12	20	—	
		LD3.2 Develop Local Skills & Capabilities	2	4	8	12	16	
		LD3.3 Conduct a Life-Cycle Economic Evaluation	5	7	10	12	14	
Resource Allocation	Materials	RA1.1 Support Sustainable Procurement Practices	3	6	9	12	—	196
		RA1.2 Use Recycled Materials	4	6	9	16	—	
		RA1.3 Reduce Operational Waste	4	7	10	14	—	
		RA1.4 Reduce Construction Waste	4	7	10	16	—	
		RA1.5 Balance Earthwork On Site	2	4	6	8	—	
	Energy	RA2.1 Reduce Operational Energy Consumption	6	12	18	26	—	
		RA2.2 Reduce Construction Energy Consumption	1	4	8	12	—	
		RA2.3 Use Renewable Energy	5	10	15	20	24	
		RA2.4 Commission & Monitor Energy Systems	3	6	12	14	—	
	Water	RA3.1 Preserve Water Resources	3	5	7	9	12	
		RA3.2 Reduce Operational Water Consumption	4	9	13	17	22	
		RA3.3 Reduce Construction Water Consumption	1	3	5	8	—	
		RA3.4 Monitor Water Systems	1	3	6	12	—	
Natural World	Siting	NW1.1 Preserve Sites of High Ecological Value	2	6	12	16	22	232
		NW1.2 Provide Wetland & Surface Water Buffers	2	5	10	16	20	
		NW1.3 Preserve Prime Farmland	—	2	8	12	16	
		NW1.4 Preserve Undeveloped Land	3	8	12	18	24	
	Conservation	NW2.1 Reclaim Brownfields	11	13	16	19	22	
		NW2.2 Manage Stormwater	2	4	9	17	24	
		NW2.3 Reduce Pesticide & Fertilizer Impacts	1	2	5	9	12	
		NW2.4 Protect Surface & Groundwater Quality	2	5	9	14	20	
	Ecology	NW3.1 Enhance Functional Habitats	2	5	9	15	18	
		NW3.2 Enhance Wetland & Surface Water Functions	3	7	12	18	20	
		NW3.3 Maintain Floodplain Functions	1	3	7	11	14	
		NW3.4 Control Invasive Species	1	2	6	9	12	
		NW3.5 Protect Soil Health	—	3	4	6	8	
Climate and Resilience	Emissions	CR1.1 Reduce Net Embodied Carbon	5	10	15	20	—	190
		CR1.2 Reduce Greenhouse Gas Emissions	8	13	18	22	26	
		CR1.3 Reduce Air Pollutant Emissions	2	4	9	14	18	
	Resilience	CR2.1 Avoid Unsuitable Development	3	6	8	12	16	
		CR2.2 Assess Climate Change Vulnerability	8	14	18	20	—	
		CR2.3 Evaluate Risk and Resilience	11	18	24	26	—	
		CR2.4 Establish Resilience Goals and Strategies	—	8	14	20	—	
		CR2.5 Maximize Resilience	11	15	20	26	—	
		CR2.6 Improve Infrastructure Integration	2	5	9	13	18	
							Maximum TOTAL Points	1,000

RESOURCE ALLOCATION: ENERGY

RA2.1 Reduce Operational Energy Consumption

26
POINTS

INTENT
Conserve energy by reducing overall operational energy consumption throughout the project life.

METRIC
Percentage of operational energy reductions achieved.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A + B	A + B	A + B	A + B	Not Available
(6) 10% Energy Reduction	(12) 30% Energy Reduction	(18) 50% Energy Reduction	(26) 70% Energy Reduction	
(A) The project team determines the estimated annual energy consumption of the project. If annual energy consumption varies, the project team submits the range of estimated performance over the project life.				
(B) Operational energy is reduced at least 10%.	**(B)** Operational energy is reduced at least 30%.	**(B)** Operational energy is reduced at least 50%.	**(B)** Operational energy is reduced at least 70%.	

DESCRIPTION

This credit addresses the important need to reduce overall energy consumption. Energy generation is the primary source of greenhouse gas emissions and numerous other pollutants harmful to the environment and human health. While use of renewable energy reduces impacts, the primary goal of all projects should be to minimize the overall energy consumed as much as possible.

There are significant and compounding cost savings to reducing operational energy use. Project teams should take a whole-systems design approach when considering options in order to maximize achievement. While single actions like replacing fluorescent lights with light emitting diodes (LEDs) are a positive first step, large energy savings can be achieved when considering project alternatives and the design of major energy consuming systems.

PERFORMANCE IMPROVEMENT

Improving – Conserving: Levels in this credit are distinguished by the percentage of operational energy reductions. As industry standards on operational energy use do not exist for most infrastructure projects, project teams are required to provide calculations for an appropriate base case. Accepted methodologies for establishing baseline performance data are explained in detail in the front of this manual and include existing conditions, a seriously considered alternative, standard practice, or a comparable existing project/facility. It is the intent of Envision to support data collection in order to eventually provide this baseline data for project teams and the industry as a whole. This is why it is required to submit calculations in acceptable standard units.

Calculations should include the anticipated annual energy consumption during the operational life of the project. If industry standards such as ASHRAE (formerly American Society of Heating Refrigerating and Air-Conditioning Engineers) are available for the project type, they can be used in calculating the project's anticipated energy consumption as well as the industry base case. Calculations should include energy purchased from the grid, energy generated and used on site, and fuels used on site by the project.

Energy generation projects should use energy conversion efficiency as the measure of energy efficiency, with the goal of increasing the capture of electrical, mechanical, or thermal energy output of the system. Similarly, energy distribution projects should calculate reductions in energy loss, with the goal of achieving better efficiency in energy delivery.

Applicability: This credit is applicable to all projects that consume energy during their operation. Projects that do not include operational energy may apply to have this credit deemed not applicable with supporting documentation. In rare cases, where the amount of operational energy use is insignificant in comparison to the scale of the project, teams may apply to have this credit deemed not applicable with supporting documentation. However, the reviewer may exercise his/her discretion in determining what constitutes an insignificant quantity of operational energy use in the context of the project.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

A. Has the project team determined the estimated annual energy consumption of the project during operations?

1. *Estimates of the annual energy consumption of the project during operations. Energy data should be presented in standard units. If annual energy consumption varies, the project team submits the range of estimated performance over the project life. Energy consumption of the project includes:*

- *Energy purchased from the grid*
- *Energy generated on site*
- *Fuels used on site by the project*

Note that energy generation projects should use energy conversion efficiency as the measure of energy efficiency, with the goal of increasing the capture of electrical, mechanical, or thermal energy output of the system. Similarly, energy distribution projects should calculate reductions in energy loss, with the goal of achieving better efficiency in energy delivery.

B. To what extent has the project reduced operational energy consumption?

1. *Calculation of the baseline energy consumption. All energy sources should be converted into standard units.*
2. *Submit calculations for the project's estimated annual energy consumption over the life of the project. Document the percentage reduction over the baseline. All energy sources should be converted into standard units.*

RELATED ENVISION CREDITS

QL1.5 Minimize Light Pollution

QL2.2Encourage Sustainable Transportation

LD2.1 Establish a Sustainability Management Plan

RA2.4 Commission and Monitor Energy Systems

CR1.2Reduce Greenhouse Gas Emissions

CR1.3Reduce Air Pollutant Emissions

PROJECT EXAMPLE: SOUTH LOS ANGELES WETLAND PARK

The South Los Angeles Wetland Park (Envision Platinum, 2014) in California reduced operational energy use by 77% by disconnecting all lighting associated with the project from the electrical grid and using solar powered lighting instead. The project team also designed the pump systems to further reduce operational energy requirements; two smaller sump pumps requiring less energy operate throughout the majority of the year when stormwater discharge rates are low. Only during rain events will three large process pumps that consume more energy operate.

RESOURCE ALLOCATION: ENERGY

RA2.2 Reduce Construction Energy Consumption

12
POINTS

INTENT

Conserve resources and reduce greenhouse gases and air pollutant emissions by reducing energy consumption during construction.

METRIC

The number of strategies implemented on the project during construction that reduce energy consumption and emissions.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A	A + B	A + B	A + B	Not Available
(1) Identify Reduction Opportunities	**(4) At Least Two Reduction Strategies**	**(8) At Least Four Reduction Strategies**	**(12) At Least Six Reduction Strategies**	
(A) The project team conducts one or more planning reviews to identify and analyze options for reducing energy consumption during construction.				
	(B) The project implements, or has written requirements to implement, at least two (2) energy reduction strategies.	**(B)** The project implements, or has written requirements to implement, at least four (4) energy reduction strategies.	**(B)** The project implements, or has written requirements to implement, at least six (6) energy reduction strategies.	

DESCRIPTION

This credit addresses the important need to reduce construction energy consumption. As construction energy use is closely linked to emissions, many actions in this credit address energy efficiency, energy reduction, renewable energy use, and reduced emissions. Therefore, in addition to other Resource Allocation credits, RA2.2 Reduce Construction Energy Consumption is also connected to CR1.1 Reduce Net Embodied Carbon, and CR1.2 Reduce Greenhouse Gas Emissions.

Significant cost savings can be achieved by reducing fuel consumption during construction. Project teams should consider the secondary and tertiary benefits of reduced truck trips, improved air quality, and support for renewable energy systems. While single actions like replacing fluorescent lights with light emitting diodes (LEDs) is a positive first step, large energy savings can be achieved when considering broader construction logistics and coordination.

PERFORMANCE IMPROVEMENT

Improved: Project teams begin with a thorough review of the means and methods of constructing the project, including a review of how energy is to be consumed during construction and opportunities for energy reduction. The list of energy reduction strategies should be used as a guide to identify and analyze options.

Enhanced – Conserving: Conducting detailed calculations of construction energy consumption can be burdensome if not impossible. Additionally, like other Resource Allocation credits, industry standards on construction energy use do not exist. Therefore, this credit assesses the number of energy-conserving and emission-reducing strategies deployed on the project as the metric for achievement. Strategies that meet the credit requirements are listed under criterion B. These activities may be more or less difficult to achieve depending on the project type and context, which is why a wide range of options are available.

Applicability: This credit is applicable to all projects that consume energy during construction. It would therefore be difficult to demonstrate that the credit is not relevant or applicable to a project seeking an Envision award. In rare cases, where the amount of energy used during construction is insignificant in comparison to the scale of the project, teams may apply to have this credit deemed not applicable with supporting documentation. However, the reviewer may exercise his/her discretion in determining what constitutes an insignificant quantity of construction energy use in the context of the project.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

A. Has the project team conducted planning reviews to reduce energy consumption during construction?

1. *Documentation that one or more planning reviews were conducted to identify and analyze the potential for reducing energy consumption during construction.*

B. To what extent have energy conservation strategies been implemented during construction?

1. *Documentation that the project has implemented, or has policies to implement, energy conservation strategies during construction. Strategies that meet the credit requirements include:*

a. Tier IV construction equipment or Tier III with Best Available Technology (BAT) for at least 75% of non-road equipment fleet greater than 50 horsepower;

b. Alternative fuels in heavy equipment such as biodiesel for at least 5% of total fuel consumption;

c. Hybrid or fully electric project vehicles for at least 50% of fleet;

d. Electrified equipment for at least 20% of equipment (vs. gas or diesel engines);

e. Employee commuting programs with incentives (shuttles to transit, ride-share programs, biking facilities, etc.);

f. Reduce purchased energy for workstations (construction trailer/ office energy) by 30% for two of the following: (1) lighting; (2) HVAC; (3) plug loads;

g. Purchase green power (RECs) for 30% of workstation energy consumption;

h. Offset electrical consumption by generating 5% renewable energy on site (e.g., solar panels on trailer complex, solar-powered temporary light plant, solar-powered cameras and variable message sign boards); and

i. Reduce overall fuel consumption by 10% through improved planning and logistics. Specific strategies may include:

i. Reduce number of deliveries;

ii. Reduce idle times;

iii. On-site reuse of soils or other materials to decrease truck traffic to and from site (ties into Reduced Excavated Material taken off site);

iv. Reduce on-site trucking – proper logistics planning such as staging material in close proximity to installation location;

v. Schedule acceleration without additional resource consumption;

vi. Waterborne/rail transportation of materials versus trucking (third-party distribution or logistics);

vii. On-site plants (concrete plant/asphalt plant) in lieu of trucking material to the site; and

viii. Prefabrication of design elements.

RELATED ENVISION CREDITS

LD2.1 Establish a Sustainability Management Plan

RA1.5 Balance Earthwork On Site

CR1.2Reduce Greenhouse Gas Emissions

CR1.3Reduce Air Pollutant Emissions

PROJECT EXAMPLE: HIGHWAY I-4 ULTIMATE

On the Highway I-4 Ultimate project (Envision Platinum, 2017), a 21 mile stretch of highway between Orange County and downtown Orlando in Florida, the contractor deployed state-of-the-art equipment monitoring technologies and software to reduce environmental impacts during construction. Fuel management technologies to monitor fuel dispensing into each piece of equipment and to track consumption were deployed. Also, auxiliary air conditioning units on crawler cranes were implemented. These measures led to a 20% reduction of machine hours and associated fuel consumption.

RESOURCE ALLOCATION: ENERGY

RA2.3 Use Renewable Energy

24 POINTS

INTENT

Meet operational energy needs through renewable energy sources.

METRIC

Extent to which renewable energy sources are incorporated.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A	A	A	A	A
(5) At Least 5%	**(10) At Least 15%**	**(15) At Least 30%**	**(20) At Least 50%**	**(24) Net Positive**
(A) The project meets: 5% of energy needs (electricity and fuel) from renewable sources.	**(A)** The project meets: 15% of energy needs (electricity and fuel) from renewable sources.	**(A)** The project meets: 30% of energy needs (electricity and fuel) from renewable sources.	**(A)** The project meets: 50% of energy needs (electricity and fuel) from renewable sources.	**(A)** The project generates a net positive amount of renewable energy.

DESCRIPTION

While reducing energy use is the primary goal, a net-zero energy society will require significant investment in renewable energy sources. When appropriate, renewable energy can be generated on site to help reduce the need for fossil fuel sources. However, it is important to note that large-scale off-site renewable energy sources, such as wind farms, large hydroelectric facilities, or solar arrays, are often more efficient. It can be challenging to demonstrate a direct connection to these sources and ensure that their energy generation is not double-counted by other projects. Project teams should evaluate the feasibility of renewable energy, including nontraditional energy sources, to effectively increase the portion of operational energy that comes from renewable sources.

PERFORMANCE IMPROVEMENT

Improved – Conserving: Levels in this credit are distinguished by the percentage of total energy use from renewable sources. Unlike energy consumption in buildings, which are almost always dominated by electricity, infrastructure operational energy use can include both electricity and fuel consumption. For this credit, project teams should consider both electricity and fuel consumption in their calculations.

Renewable energy can be sourced from on-site generation, purchased in fuels, or purchased from the grid through a direct purchase agreement (e.g., renewable energy power purchase agreement). For purchased renewable energy from the grid, the electricity service provider sources power from a renewable energy source and sells that power directly to the project. Renewable energy sources must be in the same power grid as the project in this type of transaction. Project teams cannot attribute latent renewable energy within the grid to the project without a purchase agreement.

Projects may only count Renewable Energy Credits (RECs) purchased or under contract at the time of assessment. Nonbinding commitments for future REC purchases cannot be counted toward achievement in this credit. Purchased RECs must be annualized over the life of the project. For example, if a project with a 20-year life purchases RECs for 100% of its energy consumption for one year, this would translate to 5% of its overall energy consumption.

On-site generation put back onto the grid is accounted for in determining percentage of electricity used. For example, in a case with 100 kWh of electricity used on site, 20 kWh of renewables purchased from the grid, 10 kWh of renewables generated and used on site, and 5 kWh of renewables returned to the grid, the result is a level of 35% renewables attained.

Applicability: This credit is applicable to all projects that consume energy (fuel or electricity) during their operation. Projects that do not include operational energy may apply to have this credit deemed not applicable with supporting documentation. In rare cases, where the amount of operational energy use is insignificant in comparison to the scale of the project, teams may apply to have this credit deemed not applicable with supporting documentation. However, the reviewer may exercise his/her discretion in determining what constitutes an insignificant quantity of operational energy use in the context of the project.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

A. To what extent does the project meet electricity or fuel needs from renewable sources?

1. *Documentation of the anticipated annual output of all renewable sources, direct renewable electricity purchases, or exports to the grid, and the resulting overall percentage of renewable energy*

to total energy consumption. The latent renewable energy mix within the grid does not contribute to achievement in this credit. Calculations should be in standard units of energy (Btu or kJ).

2. *Breakdown of renewable energy sources by type. Renewable energy may include:*
   - *solar energy (thermal heating, both active and passive, and photovoltaic);*
   - *wind (electricity generation);*
   - *water (hydro or tidal for electricity generation);*
   - *biomass (electricity generation or as fuels);*
   - *geothermal (electricity generation or heating and cooling); and*
   - *hydrogen/fuel cells (used as a fuel).*
   - *renewable transportation fuel or electric vehicle use.*

RELATED ENVISION CREDITS

CR1.2 Reduce Greenhouse Gas Emissions

CR1.3 Reduce Air Pollutant Emissions

Common Fuel Conversions

Fuel	Imperial Unit	Btu	Metric Unit	kJ
Electricity	1 Kilowatt-hour	3,412	1 Kilowatt-hour	3,600
Gasoline	1 Gallon	120,476	1 Litre	33,579
Diesel	1 Gallon	137,452	1 Litre	38,310
Natural Gas	1 Cubic foot	1,037	1 Cubic Meter	38,638
Propane LPG	1 Gallon	91,333	1 Litre	25,456
Propane Gas	1 Cubic Foot	2,550	1 Cubic Meter	95,011
Ethanol	1 Gallon	76,330	1 Litre	21,275

Source: US Energy Information Administration

PROJECT EXAMPLE: WATER SOURCE GEOTHERMAL

A lake formed in an abandoned quarry near the Nashville International Airport in Tennessee, long considered a liability for the Airport Authority, was turned into a beneficial resource with the implementation of a Water Source Geothermal project (Envision Silver, 2017). By harnessing the chilled water of the quarry lake, the Airport Authority was able to save more than $430,000 in electricity costs per year, a 50% improvement over the baseline that was established for the project.

RESOURCE ALLOCATION: ENERGY

RA2.4 Commission and Monitor Energy Systems

14 POINTS

INTENT

Ensure efficient functioning and extend useful life by specifying commissioning and monitoring of energy systems.

METRIC

The inclusion of monitoring equipment and software, the extent of commissioning, and the commissioning agent's independence from the project.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A + B	A + B	A + B + C	A + B + C	Not Available
(3) Basic Initial Commissioning	**(6) Extensive Initial Commissioning**	**(12) Long-Term Commissioning**	**(14) Advanced Initial And Long-Term Commissioning**	
(A) The project includes energy monitoring capabilities. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for at least 50% of energy use/consumption.	**(A)** The project includes energy monitoring capability. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for at least 75% of energy use/consumption.	**(A)** The project includes integrated energy management systems. Energy management software is incorporated to allow for detailed and centralized monitoring and reporting of performance. The equipment is capable of independently monitoring all primary project functions, accounting for at least 90% of energy use/consumption.		
(B) The project conducts an initial commissioning of energy systems accounting for at least 50% of the total energy consumption/generation. Commissioning includes a detailed log of issues.	**(B)** The project conducts an initial commissioning of energy systems accounting for at least 75% of the total energy consumption/generation. Commissioning includes a detailed log of issues.	**(B)** The project conducts an initial commissioning of energy systems accounting for at least 90% of the total energy consumption/generation. Commissioning includes a detailed log of issues. The owner engages a third party or in-house commissioning agent not involved in the planning/design of the project.	**(B)** The project conducts an initial commissioning of energy systems accounting for at least 90% of the total energy consumption/generation. Commissioning includes a detailed log of issues. The owner engages an independent third-party commissioning agent.	
		(C) A comprehensive plan is developed for ongoing periodic re-commissioning/review of energy systems throughout the expected life of the project.		

DESCRIPTION

Planning, designing, and constructing projects to reduce energy use is the first step toward achieving energy efficiency goals. However, commissioning and ongoing monitoring are necessary to ensure the proper operation of the energy system in order to realize those goals. Systems designed to be energy efficient can fail because of installation errors or degradation over time during operations. Commissioning ensures systems are functioning as intended from the start of operations. Installing advanced monitoring equipment and software better allows operators to identify efficiency loss. In addition, monitoring equipment allows operators to identify high-energy processes and target them in their own sustainability efforts. Higher-resolution monitoring increases the likelihood that projects will achieve and maintain high levels of energy efficiency throughout their useful life.

PERFORMANCE IMPROVEMENT

Improved: The assessment is based on the scope of the energy monitoring capabilities and initial commissioning. The intent is to focus on important or primary sources of energy consumption.

Enhanced: The project team expands the scope of monitoring capabilities and commissioning.

Superior: The project team can demonstrate that the commissioning agent was independent from the project, though the commissioning may still be conducted within the same organization. Energy management systems include detailed performance monitoring and management capabilities. An operations plan is developed for ongoing performance reviews.

Conserving: The commissioning was conducted by an independent third-party agent.

Applicability: This credit is applicable to all projects that consume energy during their operation. Projects that do not include operational energy may apply to have this credit deemed not applicable with supporting documentation. In rare cases, where the amount of operational energy use is insignificant in comparison to the scale of the project, teams may apply to have this credit deemed not applicable with supporting documentation. However, the reviewer may exercise his/her discretion in determining what constitutes an insignificant quantity of operational energy use in the context of the project.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

A. Does the design incorporate advanced integrated monitoring systems in order to enable more efficient operations?

1. *Documentation that equipment and/or software are incorporated in the design to allow detailed monitoring of performance. Design documents and specifications showing the location, purpose, and type of monitoring equipment installed. Documentation that the equipment installed is capable of monitoring all primary project functions, accounting for the required percentage of energy consumption (e.g., 50%, 75%, 90%).*
2. *Rationale as to how the monitoring equipment may enable more efficient operations over the industry norm.*
3. *Documentation that energy management systems and associated software are incorporated into the project accounting for the required percentage of energy consumption (e.g., 50%, 75%, 90%).*

B. To what extent has a commissioning been conducted?

1. *Documentation that the project has undergone or will undergo a commissioning (e.g., specification, tender document, contract document).*
2. *Documentation that the commissioning was executed and covered systems responsible for using or generating the required percentage of energy (e.g., 50%, 75%, 90%).*
3. *Documentation of the relationship between the owner and the commissioning agent depending on the level of achievement being pursued.*

   Note that for Superior, the owner may engage an in-house commissioning agent so long as they are independent of the planning/design of the project. For Conserving, an independent third-party agent must be used.
4. *Documentation of the commissioning log of issues.*

C. Is there a plan for ongoing commissioning of the energy systems throughout the project's life?

1. *Documentation of a plan for ongoing recommissioning/review of these systems throughout the expected life of the project.*

RELATED ENVISION CREDITS

LD2.3 Plan for Long-Term Monitoring and Maintenance

RA2.1 Reduce Operational Energy Consumption

CLIMATE AND RESILIENCE: EMISSIONS

CR1.1 Reduce Net Embodied Carbon

20 POINTS

INTENT

Reduce the impacts of material extraction, refinement/manufacture, and transport over the project life.

METRIC

Percentage of reduction in net embodied carbon of materials.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A + B + C	A + B + C	A + B + C	A + B + C	Not Available
(5) At Least 5% Reduction	**(10) At Least 15% Reduction**	**(15) At Least 30% Reduction**	**(20) At Least 50% Reduction**	
(A) The project team identifies primary materials to be used on the project during construction and operation. The team determines which materials are the primary contributors to net embodied carbon (collectively >80%).				
(B) Embodied carbon is calculated, or acquired by a validated source, for the primary materials identified in criterion A. Calculations include: • Embodied carbon of production, including raw material extraction, refinement, and manufacture. • Embodied carbon of transporting materials to the project site. • The replacement, repair, or refurbishment of materials over the life of the project.				
(C) The project team demonstrates at least a 5% reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	**(C)** The project team demonstrates at least a 15% reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	**(C)** The project team demonstrates at least a 30% reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	**(C)** The project team demonstrates at least a 50% reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	

DESCRIPTION

This credit addresses the embodied carbon of materials used over the life of the project. This combines concepts of sourcing local materials, using materials more efficiently, and using lower-impact materials in order to reduce the combined environmental impacts of material use. In the calculations, carbon is used as a proxy unit of measure to compare various impacts across the entire supply chain of material consumption. One stage of this supply chain involves raw material extraction/harvesting, refinement, and manufacturing into products. The second involves transportation of the materials from the manufacturer to their final destination on site. By designing projects to use less material, use material efficiently, or specifying materials with lower embodied carbon, as well as reducing transportation distances, project teams can reduce the overall impact of the project.

Material use is specifically addressed over the life of the project, including the necessary replacement or renewal of materials. Often, materials with slightly higher initial embodied carbon will have a lower net embodied carbon over the life of the project if they are more durable and less likely to require repair or replacement.

PERFORMANCE IMPROVEMENT

Improved – Conserving: Levels are distinguished by the percentage reduction in embodied carbon of materials over a baseline. As industry standards on carbon intensity of materials do not exist for most infrastructure projects, project teams are required to provide calculations for an appropriate base case. Accepted methodologies for establishing baseline performance data are explained in detail in the front of this manual and include (1) existing conditions, (2) a seriously considered alternative, (3) standard practice, or (4) a comparable existing project/facility. Envision intends to support data collection in order to eventually provide this baseline data for project teams and the industry as a whole. This is why it is required to submit calculations in acceptable standard units.

Availability of data on the carbon intensity of materials is often limited, and some projects may involve hundreds or thousands of products. Therefore, ISI accepts a streamlined method for conducting calculations on this credit. Project teams may identify a select list of primary materials/products that collectively make up greater than 80% of the total embodied carbon. If data on embodied carbon or material intensity is not available from the manufacturer, project teams may use averages or generalized data from studies or material databases. Project teams should track, document, and clearly explain their methodology for calculating material intensity in this credit.

Transportation of materials to project sites can be a significant contributor to the embodied carbon of materials. Local or regional materials—even materials sourced or processed on site—reduce the impact of long transport and support local economies. It is important to note that while it is generally desirable to use locally sourced materials for the aforementioned reasons, use of local materials could have negative impacts on performance if those materials result in reduced durability, safety, or service life. Carbon emissions associated with the transportation of materials to the project site are specifically broken out as they are often simpler to calculate based on distance; quantity; and standard truck, air, rail, or shipping fuel consumption. They are also calculated separately in order to show the possible conflicts that exist of sourcing a lower-intensity material from farther away. Project teams should consider choices that reduce the overall net embodied carbon of materials.

Applicability: This credit is applicable to all projects that include the use or consumption of physical materials in construction or operation.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

A. Has the project team determined materials that are the primary contributors to embodied carbon for the project during construction and operation?

1. *Documentation of the primary materials to be used in the construction and ongoing operation of the project over its life. Documentation should include:*
   a. *The materials used.*
   b. *General estimates of the quantities of materials used. Note that operations materials may need to be multiplied by the frequency of use over the project life. Material estimates should include anticipated repairs/upkeep (e.g., road resurfacing).*
   c. *Estimates of the embodied carbon of materials. Estimates may use readily available public information such as regional, national, or global averages.*
2. *Identification of the select materials that collectively will make up over 80% of the total estimated embodied carbon of the project.*

B. Has the project team calculated the primary contributors to overall embodied carbon?

1. *Index of the embodied carbon calculations of the primary contributors to carbon intensity over the life of the project (construction and operations) identified in criterion A. This should include:*
   a. *Carbon emissions to produce the material, including raw material extraction, refinement, and manufacture including secondary or tertiary processing.*
   b. *Carbon emissions from transporting the material from the manufacturer to the project site, including intermediary points.*

Embodied carbon data may come from the manufacturer, reputable databases, reputable embodied energy software, or from project team calculations. If the source or specific type of materials is not known at the time of assessment, calculations may present a range of values or rely on likely material choices. Calculations should be in tons CO_2.

C. To what extent does the project reduce the net embodied carbon of materials used in construction and operation?

1. *Documentation that the project has set targets for reducing net embodied carbon.*
2. *Documentation of strategies/plans to reduce net embodied carbon. These may include but are not limited to:*
   a. *Sizing the project to require less material;*
   b. *Designing the project to use less material;*
   c. *Choosing materials that have lower embodied carbon;*
   d. *Reducing material needed for repair and maintenance;*
   e. *Reducing material waste during construction;*
   f. *Reducing material waste during operation;*
   g. *Sourcing local materials to reduce transportation emissions;*
   h. *Utilizing lower-carbon transportation modes.*
3. *Calculations of reductions in embodied carbon achieved. Calculations should compare total carbon intensity of materials for the project against the total carbon intensity of the baseline. Calculations should be in tons CO_2.*

RELATED ENVISION CREDITS

LD2.3 Plan for Long-Term Monitoring and Maintenance

LD2.4 Plan for End-of-Life

CR1.2 Reduce Greenhouse Gas Emissions

CR1.3 Reduce Air Pollutant Emissions

CLIMATE AND RESILIENCE: EMISSIONS

CR1.2 Reduce Greenhouse Gas Emissions

26 POINTS

INTENT

Reduce greenhouse gas emissions during the operation of the project, reducing project contribution to climate change.

METRIC

Percentage of reduction in operational greenhouse gas emissions.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A + B	A + B	A + B	A + B	A + B
(8) At Least 10% Reduction	**(13) At Least 25% Reduction**	**(18) At least 50% Reduction**	**(22) 100% Reduction**	**(26) Carbon Negative**
(A) The project team demonstrates at least a 10% reduction in total CO_2e over the operational life of the project compared to the baseline. Calculations should be in tons CO_2e.	**(A)** The project team demonstrates at least a 25% reduction in total CO_2e over the operational life of the project compared to the baseline. Calculations should be in tons CO_2e.	**(A)** The project team demonstrates at least a 50% reduction in total CO_2e over the operational life of the project compared to the baseline. Calculations should be in tons CO_2e.	**(A)** The project team demonstrates a 100% reduction in total CO_2e over the operational life of the project compared to the baseline. Calculations should be in tons CO_2e.	**(A)** The completed project is carbon negative (i.e., sequesters/removes more CO_2e than it produces over the operational life).
(B) The project team maps and calculates the total annual greenhouse gas emissions of the final project design for reporting purposes. This includes direct and indirect greenhouse gas emissions and sequestration associated with project operations. Calculations must be in CO_2e.				

DESCRIPTION

This credit addresses greenhouse gas emissions during operations and the project's contribution in reducing the impacts of climate change. The embodied carbon of materials is specifically addressed in CR1.1 Reduce Net Embodied Carbon. Emission of greenhouse gases during construction is addressed in RA2.2 Reduce Construction Energy Consumption.

The increased release of carbon dioxide (CO_2) and other greenhouse gases (GHGs) has caused a significant increase in the concentration of CO_2 in the atmosphere, enhancing the greenhouse effect. The subsequent increase in the average temperature of the earth's surface causes various cascading effects, including melting glaciers, arctic sea ice loss, sea level rise, increased ocean temperatures, increased ocean acidity, changing vegetation patterns, increased range of disease vectors, decreased snowmelt, changing precipitation patterns, increased flooding, increased storm intensity, and increased storm frequency, to name a few. This can have many unintended consequences such as flooding when historic periods of snowfall change to rain, drought from increased evaporation and lack of snowmelt, loss of coral reefs and aquatic biodiversity from ocean acidification, and food scarcity as increased temperatures reduce crop production. Reducing the emission of GHGs now will help mitigate the effects of climate change in the future.

PERFORMANCE IMPROVEMENT

Improved – Restorative: Levels in this credit are distinguished by the percentage of reduction in greenhouse gas emissions over a base case. As industry standards on greenhouse gas emissions do not exist for many infrastructure projects, project teams are required to provide calculations for an appropriate base case. Accepted methodologies for establishing baseline performance data are explained in detail in the front of this manual and include existing conditions (or no-build alternative), a seriously considered alternative, standard practice, or a comparable existing project/facility. Envision intends to support data collection in order to eventually provide this baseline data for project teams and the industry as a whole. This is why it is required to submit calculations in acceptable standard units.

Greenhouse gases are factored according to their global warming potential (GWP), resulting in a CO_2 equivalency (CO_2e). All greenhouse gas emissions calculations should be quantified in tons of CO_2e. Unavoidable CO_2e emissions can be offset by carbon sequestration, in which CO_2 is removed from the atmosphere (e.g., planting trees that absorb and use CO_2 for their growth).

Project teams should take care not to double count greenhouse gas reductions as offsets. For example, if a project will produce 50 percent less greenhouse gas emissions than the baseline over its 25-year life, then it has achieved a 50 percent reduction. This project would not be able to claim that because produced emissions (50%) equal displaced emissions (50%), so it has achieved 'net-zero' carbon emissions (i.e., 100% reduction).

Applicability: This credit is applicable to all projects that consume energy, fuel, or otherwise produce greenhouse gas emissions during their operation. Projects that do not include greenhouse gas emissions during operations may apply to have this credit deemed not applicable with supporting documentation. However, projects that do not produce greenhouse gas

emissions because of intentional planning decisions may apply for the Conserving level with supporting documentation.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

A. To what extent does the project reduce greenhouse gas emissions during its operational life?

1. *Calculations of the baseline greenhouse gas emissions over a period equivalent to the operational life of the project (e.g., 25 years).*
2. *Submit calculations for:*
   a. *the project's estimated annual greenhouse gas emissions over the life of the project;*
   b. *the operational life of the project over which the calculations are made (e.g., 2025-2050); and*
   c. *Calculations of the percentage reduction compared to the baseline used over the same period.*

   Calculations should include any natural or mechanical methods of carbon sequestration. Purchased carbon offsets may be included in the calculations.

   In certain cases where a demand or volume increase is anticipated over the life of the project, project teams may choose to calculate emissions reductions on a per unit basis (passenger miles traveled, millions of gallons of water treated, etc.).

B. Has the project team calculated and reported the annual greenhouse gas emissions of the project?

1. *Calculation of annual greenhouse gas emissions over the life of the project. All greenhouse gas emissions should be in tons of CO_2e (tCO_2e). Calculations include all sources of emissions from facilities, processes, or vehicles owned or controlled within the project boundary, as well as indirect emissions from the off-site generation of energy used by the project. Emissions should be classified by the following categories if applicable:*
   a. *Off-Site Energy Generation*
   b. *Stationary Fuel Combustion Emissions (non-vehicular combustion occurring at the facility intended for energy production)*
   c. *Operations Transportation Emissions*
   d. *Waste Emissions*
   e. *Wastewater Emissions*
   f. *Biomass Emissions*
   g. *Industrial Process Emissions*
   h. *Fugitive Emissions*

RELATED ENVISION CREDITS

QL2.2 Encourage Sustainable Transportation

LD2.1 Establish a Sustainability Management Plan

CR1.1 Reduce Net Embodied Carbon

RA1.5 Balance Earthwork On Site

RA3.2 Reduce Operational Water Consumption

RA3.3 Reduce Construction Water Consumption

PROJECT EXAMPLE: HOLLAND ENERGY PARK

The Holland Board of Public Works in Michigan considered a number of ways to meet the community's need for more local power and in 2012, they conducted a comprehensive Sustainable Return on Investment (SROI) study to determine whether less expensive and less carbon-intensive alternatives could be pursued rather than the original plan to build a coal-fired power plant. In part through this SROI, the decision was made to build a natural gas combined cycle (NGCC) power plant, known as the Holland Energy Park (Envision Platinum, 2016). The project team undertook a life-cycle assessment (LCA) of greenhouse gas emissions to compare the emissions from the NGCC and the emissions from a coal-fired plant. The LCA revealed the NGCC would result in a more than 50% reduction of greenhouse gas emissions over the life of the project.

CLIMATE AND RESILIENCE: EMISSIONS

CR1.3 Reduce Air Pollutant Emissions

18 POINTS

INTENT

Reduce emissions of air pollutants: particulate matter (including dust), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, lead, and volatile organic compounds.

METRIC

Reduction of air pollutants compared to baseline.

LEVELS OF ACHIEVEMENT

IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
A + B	A + B + C	A + B + C + D	A + B + C + D	A + B + C + D + E
(2) Exceeding Requirements	**(4) Ongoing Monitoring**	**(9) VOC Minimization**	**(14) Air Pollutant Elimination**	**(18) Air Quality Improvement**
(A) The project meets all applicable air quality standards and regulations for air pollutants.				
(B) The project implements strategies to reduce air pollutant emissions during operations.	**(B)** The project reduces emissions through the use of best available control systems or best management practices.	**(B)** Air pollution controls are within the 95th percentile, or represent the lowest levels possible compared to projects of similar type.	**(B)** The project eliminates air pollutant sources in the design, chooses a non-polluting alternative, or achieves at least a 98% net reduction in air pollution emissions compared to the baseline.	
	(C) Systems are in place for the ongoing monitoring of any direct sources of air pollution. Processes are in place to identify and address changes in emissions in order to maintain performance targets.			
		(D) The project team assesses whether volatile organic compounds harmful to human health are material to the project and, if so, implement strategies to reduce their use during construction and/or within occupied spaces of the completed project.		
				(E) The project includes the direct removal of previously existing air pollutant sources, or captures and safely stores/disposes of air pollutants for a net positive impact.

DESCRIPTION

The criteria pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, suspended particulate matter smaller than PM-10, ozone, lead, and volatile organic compounds. These pollutants damage human health, property, and the environment. Those most at risk are children, the elderly, and people with lung diseases such as asthma, chronic bronchitis, and emphysema. Dust and odors also can cause a nuisance for nearby residents, reduce property values, and aggravate the aforementioned lung conditions.

PERFORMANCE IMPROVEMENT

The credit assessment begins with demonstrating attainment of applicable air quality standards and/or regulations. Note that use of the terms, or variations of the terms "best available control technology" and "lowest achievable emissions rates" within this credit have no relationship to US EPA guidelines with similar names. These terms should be interpreted at face value.

Project teams are only required to provide supporting documentation for air pollutants relevant to the project. If a project does not emit certain air pollutants listed in the credit intent they can clarify this in their documentation.

Improved: Projects can demonstrate strategies were implemented to reduce air pollutants emissions during operations.

Enhanced: Modeling life-cycle air pollutant emissions can be challenging for some types of infrastructure. This level recognizes project teams that have utilized the best available control systems, technologies, or methods to reduce emissions with the assumption that, if properly monitored and maintained, these will significantly reduce air pollutants emissions over the project life. Project teams are required to provide documentation as to how controls represent industry best practices.

Superior: Completely eliminating air pollutant emissions may not be possible for certain projects. However, this level

recognizes projects that have achieved 'best-in-class' status by reducing air pollutant emissions to the lowest possible levels or within the 95th percentile compared to similar projects. This may include, for example, replacing old or outdated systems with state-of-the-art systems. Project teams are required to determine and provide supporting documentation for what constitutes best-in-class status for their project type.

Conserving: The project completely eliminates air pollutant emissions. Often this is because a non-polluting alternative was chosen. Projects that can demonstrate at least a 98% reduction compared to the baseline are included in this level.

Volatile organic compounds have negative health impacts on building/facility occupants and, in certain conditions, construction workers.

Restorative: Reserved for rare cases where the project eliminates existing sources of air pollutants or captures and safely stores/repurposes air pollutants. Note that replacing existing sources of air pollutants with less polluting sources would count toward a reduction and not an 'elimination' of air pollutants.

Applicability: This credit is applicable to all projects that directly produce any of the criteria pollutants. Projects that do not include air pollutant emissions may apply to have this credit deemed not applicable with supporting documentation. However, projects that do not produce air pollutant emissions because of intentional planning decisions to choose non-polluting alternatives may apply for the Conserving level with supporting documentation.

EVALUATION CRITERIA AND DOCUMENTATION GUIDANCE

Note that use of the terms, or variations of the terms, "best available control technology" and "lowest achievable emissions rates" within this credit have no relationship to US EPA guidelines with similar names. For Envision use of these terms should be interpreted at face value.

A. Does the project meet all relevant minimum air quality standards and regulations?

1. *Documentation indicating the local, regional, or national standards and regulations relevant to the project.*
2. *Documentation demonstrating that the project has met or will meet all relevant standards and regulations.*

B. To what extent does the project reduce air pollutant emissions during operations?

1. *Estimates of total annual air pollutant emissions over the life of the project.*
2. *Documentation of all strategies deployed to reduce air pollutant emissions.*
   a. *Documentation demonstrating that the project uses best available control systems or best management practices (Enhanced).*

   OR

   b. *Documentation demonstrating that air pollution controls are within the 95th percentile, or represent the lowest levels possible compared to projects of similar type (Superior)*

   OR

   c. *Documentation that the project eliminates all air pollutant sources, chooses a non-polluting alternative, or achieves at least a 98% net reduction in air pollution emissions compared to the baseline (Conserving and Restorative).*

C. Does the project include the ongoing monitoring and management of direct air pollutant emissions?

1. *Documentation that the project includes systems for monitoring any air pollutants directly emitted during operations.*
2. *Documentation of processes, procedures, or systems designed to identify and address changes in emissions in order to maintain performance.*

   Note that monitoring is not necessary if the project does not produce air pollutants. Documentation that the project does not produce air pollutants emissions is sufficient to satisfy criterion C for certain projects pursuing Conserving or Restorative. If the project produces air pollutants but achieves zero emissions through control systems, the project is still required to meet the monitoring requirements.

D. Has the project team assessed the materiality of volatile organic compounds to the health of construction workers and the project operators?

1. *Documentation that the use of products and materials containing volatile organic compounds (VOCs) and their potential impact on human health over the project life was assessed. If VOCs will be present during construction or operations documentation must include:*
   a. *Specifications limiting the use of, or controlling the exposure to, volatile organic compounds during construction.*
   b. *For projects/facilities with interior occupied spaces, documentation of steps taken to reduce VOCs in material choices.*

E. Does the project remove existing air pollutant sources?

1. *Documentation of how the project includes the direct removal of existing air pollutant sources or the capture and sequestration of air pollutants in order to achieve a net positive impact.*

RELATED ENVISION CREDITS

QL1.2 Enhance Public Health and Safety

QL2.2 Encourage Sustainable Transportation

LD2.1 Establish a Sustainability Management Plan

RA2.1 Reduce Operational Energy Consumption

RA2.3 Use Renewable Energy

Appendix E. Envision Assessment Scorecard

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Arlington Re-Gen

ISI ENVISION 3.0 CREDITS

Must provide a clear justification if a credit is identified as not applicable to a project for exclusion.

CATEGORY	SUB-CATEGORY	CREDIT NAME/NUMBER	Excluded	None	Improved	Enhanced	Superior	Conserving	Restorative
				LEVEL OF ACHIEVEMENT					
QUALITY OF LIFE	PURPOSE	QL1.1 Improve Community Quality of Life	0	0	2	5	10	20	26
		QL1.2 Enhance Public Health and Safety	0	0	2	7	12	16	20
		QL1.3 Improve Construction Safety	0	0	2	5	10	14	-
		QL1.4 Minimize Noise and Vibration	0	0	1	3	6	10	12
		QL1.5 Minimize Light Pollution	0	0	1	3	6	10	12
		QL1.6 Minimize Construction Impacts	0	0	1	2	4	8	-
	WELLBEING	QL2.1 Improve Community Mobility and Access	0	0	1	3	7	11	14
		QL2.2 Encourage Sustainable Transportation	0	0	-	5	8	12	16
		QL2.3 Improve Access and Wayfinding	0	0	1	5	9	14	-
	COMMUNITY	QL3.1 Advance Equity and Social Justice	0	0	3	6	10	14	18
		QL3.2 Preserve Historic and Cultural Resources	-18	0	-	2	7	12	18
		QL3.3 Enhance Views and Local Character	0	0	1	3	7	11	14
		QL3.4 Enhance Public Space and Amenities	0	0	1	3	7	11	14
		QL0.0 Innovation *(earn up to 8 points)*		2					
						Maximum QL Points	200		
						Excluded (n/a)	-18		
						High	98		*53.8%*
						Low	88		*48.4%*
LEADERSHIP	COLLABORATION	LD1.1 Provide Effective Leadership and Collaboration	0	0	2	5	12	18	-
		LD1.2 Foster Collaboration and Teamwork	0	0	2	5	12	18	-
		LD1.3 Provide for Stakeholder Involvement	0	0	3	6	9	14	18
		LD1.4 Pursue Byproduct Synergies	0	0	3	6	12	14	18
	PLANNING	LD2.1 Establish a Sustainability Management Plan	0	0	4	7	12	18	-
		LD2.2 Plan for Sustainable Communities	0	0	4	6	9	12	16
		LD2.3 Plan for Long-Term Monitoring and Maintenanc	0	0	2	5	8	12	-
		LD2.4 Plan for End-of-Life	0	0	2	5	8	14	-
	ECONOMY	LD3.1 Stimulate Economic Prosperity and Developme	0	0	3	6	12	20	-
		LD3.2 Develop Local Skills and Capabilities	0	0	2	4	8	12	16
		LD3.3 Conduct a Life-Cycle Economic Evaluation	0	0	5	7	10	12	14
		LD0.0 Innovation *(earn up to 6 points)*		2					
						Maximum LD Points	182		
						Excluded (n/a)	0		
						High	148		*81.3%*
						Low	131		*72.0%*
RESOURCE ALLOCATION	MATERIALS	RA1.1 Support Sustainable Procurement	0	0	3	6	9	12	-
		RA1.2 Use Recycled Materials	0	0	4	6	9	16	-
		RA1.3 Reduce Operational Waste	0	0	4	7	10	14	-
		RA1.4 Reduce Construction Waste	0	0	4	7	10	16	-
		RA1.5 Balance Earthwork On Site	0	0	2	4	6	8	-
	ENERGY	RA2.1 Reduce Operational Energy Consumption	0	0	6	12	18	26	-
		RA2.2 Reduce Construction Energy Consumption	0	0	1	4	8	12	-
		RA2.3 Use Renewable Energy	0	0	5	10	15	20	24
		RA2.4 Commission and Monitor Energy Systems	0	0	3	6	12	14	-
	WATER	RA3.1 Preserve Water Resources	0	0	3	5	7	9	12
		RA3.2 Reduce Operational Water Consumption	0	0	4	9	13	17	22
		RA3.3 Reduce Construction Water Consumption	0	0	1	3	5	8	-
		RA3.4 Monitor Water Systems	0	0	1	3	6	12	-
		RA0.0 Innovation *(earn up to 9 points)*		4					
						Maximum RA Points	196		
						Excluded (n/a)	0		
						High	79		*40.3%*
						Low	70		*35.7%*

Arlington Re-Gen

ISI ENVISION 3.0 CREDITS

Must provide a clear justification if a credit is identified as not applicable to a project for exclusion.

CATEGORY	SUB-CATEGORY	CREDIT NAME/NUMBER	Excluded	None	Improved	Enhanced	Superior	Conserving	Restorative
				LEVEL OF ACHIEVEMENT					
NATURAL WORLD	SITING	NW1.1 Preserve Sites of High Ecological Value	-22	0	2	6	12	16	22
		NW1.2 Provide Wetland and Surface Water Buffers	-20	0	2	5	10	16	20
		NW1.3 Preserve Prime Farmland	-16	0	-	2	8	12	16
		NW1.4 Preserve Undeveloped Land	0	0	3	8	12	18	24
	CONSERVATION	NW2.1 Reclaim Brownfields	-22	0	11	13	16	19	22
		NW2.2 Manage Stormwater	0	0	2	4	9	17	24
		NW2.3 Reduce Pesticide and Fertilizer Impacts	0	0	1	2	5	9	12
		NW2.4 Protect Surface and Groundwater Quality	0	0	2	5	9	14	20
	ECOLOGY	NW3.1 Enhance Functional Habitats	-18	0	2	5	9	15	18
		NW3.2 Enhance Wetland and Surface Water Function	-20	0	3	7	12	18	20
		NW3.3 Maintain Floodplain Functions	-14	0	1	3	7	11	14
		NW3.4 Control Invasive Species	0	0	1	2	6	9	12
		NW3.5 Protect Soil Health	0	0	-	3	4	6	8
		NW0.0 Innovation *(earn up to 8 points)*		0					
				Maximum NW Points		232			
				Excluded (n/a)		-132			
				High		35		35.0%	
				Low		31		31.0%	
CLIMATE & RESILIENCE	EMISSIONS	CR1.1 Reduce Net Embodied Carbon	0	0	5	10	15	20	-
		CR1.2 Reduce Greenhouse Gas Emissions	0	0	8	13	18	22	26
		CR1.3 Reduce Air Pollutant Emissions	0	0	2	4	9	14	18
	RESILIENCE	CR2.1 Avoid Unsuitable Development	-16	0	3	6	8	12	16
		CR2.2 Assess Climate Change Vulnerability	0	0	8	14	18	20	-
		CR2.3 Evaluate Risk and Resilience	0	0	11	18	24	26	-
		CR2.4 Establish Resilience Goals and Strategies	0	0	-	8	14	20	-
		CR2.5 Maximize Resilience	0	0	11	15	20	26	-
		CR2.6 Improve Infrastructure Integration	0	0	1	4	8	14	18
		CR0.0 Innovation *(earn up to 5 points)*		0					
				Maximum CR Points (w/o Innovation)		190			
				Excluded (n/a)		-16			
				High		99		56.9%	
				Low		74		42.5%	

**Maximum points adjusted for category if criteria are determined not applicable (for high estimate only).

*** Not every credit has a restorative level. Therefore totals include the maximum possible points for each credit whether conserving or restorative.

1,000 total points (w/o 50 possible innovation points)	1000		
Total Excluded (n/a)	-166		
High	459	55.0%	Platinum
Low	394	39.4%	Silver

DEFINITIONS

Innovation Credits: The Envision framework strongly encourages innovative methods that advance sustainable infrastructure practices or show exceptional performance beyond the expectations of the credit requirements. Each category includes an "Innovate or Exceed Credit Requirements" credit, indicated by a "0.0." Projects may achieve all or part of the points in these credits. Maximum points allotted for innovation in any one category is 10 points and the submitter determines the number of points (zero to the maximum) for which the credit will be submitted. The 0.0 credits are not required, and these points act as bonus points that are added to the category or total score.

Not Applicable Credits: ISI has provided guidance indicating that a project should not be awarded Envision points for avoiding certain situations or locations if there is no reasonable chance that those locations or situations were being considered during the project decision-making process. Providing documentation to support the exclusion of these credits would ultimately help the project increase the percentage of points earned by reducing the total points available.

Technical Memorandum No. 16

Date:	November 30, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Biogas Conditioning Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the biogas conditioning evaluation, followed by a description of the evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary sludge (PS) and waste activated sludge (WAS) thickening, dewatering, and Class B lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a Class A THP and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this biogas conditioning evaluation is to further assess requirements and technologies for biogas conditioning. The results of this evaluation will inform a final decision on which technology will be chosen for biogas conditioning.

1.2 Evaluation Approach

A suite of alternatives using various biogas conditioning technologies was developed. Conceptual process conditions, configurations, cooling technology sizing, and conceptual operation costs were prepared and then presented and reviewed at the July 22, 2021 and August 30, 2021 project workshops with the County. In this evaluation, the technologies are evaluated and compared based on budgetary capital equipment costs, conceptual operating cost estimates, and non-cost considerations including space requirements and noise. A 20-year life-cycle cost analysis was also completed.

2.0 Biogas Conditioning

The level of biogas conditioning required is directly related to the end use of the biogas. With the recommended alternative of upgrading the biogas to renewable natural gas, the required biogas conditioning will include H_2S, moisture, siloxane, carbon dioxide, and volatile organic compound (VOC) removal with compression and tail gas disposal. Emergency biogas disposal will be through a waste gas flare.

2.1 Hydrogen Sulfide Removal

Hydrogen sulfide removal would be required for any of the gas utilization alternatives considered. When hydrogen sulfide (H_2S) is combusted (either onsite in boilers or engines or offsite as RNG), sulfur dioxide forms. This can condense into sulfuric acid with the presence of water vapor and cause significant corrosion issues. Removing H_2S prior to combustion reduces the likelihood of corrosion. Hydrogen sulfide is typically removed by precipitating the dissolved sulfide in the anaerobic digesters (thus preventing its formation in the biogas) or by directly removing the hydrogen sulfide from the biogas in a biogas scrubber. Removal with biogas scrubbers requires the gas to be fully saturated with moisture to reduce safety concerns (fires) associated with the exothermic nature of the treatment process. Therefore, hydrogen sulfide is normally the first constituent removed from raw biogas in traditional biogas uses as the raw biogas is fully saturated,

The Arlington WPCP currently uses iron salt addition, in the form of ferric chloride ($FeCl_3$), to provide chemical phosphorus removal in the liquid stream process. $FeCl_3$ is added at multiple locations in the process including the primary clarifiers and secondary clarifiers to precipitate dissolved orthophosphate, which ends up in the solids treatment train. At the current high dosage levels, it is anticipated that a significant amount of dissolved hydrogen sulfide in the digesters will also be precipitated along with the phosphate, which will

significantly lower the H_2S concentrations in the biogas. If this practice continues, the H_2S concentrations in the biogas may be below 200 ppm, in which case no further removal would be required for any of the alternatives. However, if the facility were to move away from chemical phosphorus removal to an enhanced biological phosphorus removal (EBPR) approach, hydrogen sulfide concentrations would increase and additional treatment would be required. For the purposes of this alternative, H_2S removal is retained in all alternatives. Pilot testing currently being conducted by Virginia Tech will provide data on potential H_2S concentrations in the biogas and ultimately inform the final design.

2.1.1 Precipitation with Iron Salt Addition

Iron salts combine chemically with dissolved sulfide to form relatively insoluble metal sulfides that precipitate from the wastewater, thus preventing the release of H_2S gas. Iron sulfide precipitates exist as soft, black, or reddish-brown flocs that usually do not settle well in the collection system but are easily removed at treatment plants. Sulfur precipitation with iron salts has the following advantages and disadvantages:

- Advantages:
    - Long residuals can be maintained to precipitate sulfides as they are generated.
    - Iron salts Iron salts can be used to treat sludge or full wastewater flows.
    - Reaction by-products are harmless.
    - The precipitates are beneficial to downstream treatment processes because they help increase settling and remove phosphorus.
- Disadvantages:
    - Precipitates can dissociate at lower pH levels (less than 6.5), allowing sulfides to release back into the wastewater.
    - Dissolved sulfide cannot be decreased to much lower than 0.2 to 0.5 milligram per liter (mg/L) using iron salts.
    - Iron salts can form a film on pipe walls, instrument sensors, and ultraviolet treatment equipment.
    - Precipitates increase sludge production.

As stated previously, the Arlington WPCP currently uses iron salt addition, in the form of FeCl3, to provide chemical phosphorus removal in the liquid stream process. A stoichiometric dose of 3.3 to 4.9 pounds of FeCl3 is required per pound of sulfide. However, field and laboratory experiments indicate that the typical required dose to remove sulfide in domestic wastewater is between 3 and 7 pounds of FeCl3 per pound of sulfide removed. In the near term, it is anticipated that the WPCP will continue to utilize FeCl3 optimized for phosphorus (not sulfide removal). Impacts of this $FeCl_3$ dosing strategy on biogas H_2S removal will be evaluated in on-going pilot tests with Virginia Tech.

2.1.2 Adsorptive Media

Adsorptive media is commonly used to remove hydrogen sulfide from biogas ahead of downstream unit processes. Hydrogen sulfide is removed by chemical adsorption in the fixed-media vessel using metal oxides. Common media types include iron sponge, Sulfatreat™, and other proprietary products.

Iron sponge media is typically wood chips impregnated with iron oxide. The iron oxide reacts with the hydrogen sulfide and binds to the media as iron sulfide and water. The metal sulfides are contained within the media. Once the media is spent, it must be replaced. Engineered iron oxide media, such as Sulfatreat™, is also available for H_2S removal. This media is typically more expensive than iron sponge but is easier to

remove once the media is exhausted. The primary advantages of the solid media technology are the passive operation, simple use, and reliability. If the $FeCl_3$ addition continues, the County's low H_2S concentrations will likely require infrequent media replacement.

Several companies manufacture the adsorptive media treatment systems for installation in the United States. Common iron sponge providers for installation at wastewater treatment plants include Unison Solutions, Marcab, Varec Biogas, and DMT Clear Gas Solutions. Figure 1 shows a photo of an adsorptive media system installation.

Figure 1. Adsorptive Media Installation Example

Table 1 below presents the advantages and disadvantages of the H_2S removal technologies.

Table 1. Advantages and Disadvantages of H_2S Removal Technologies

Alternative	Advantages	Disadvantages
Iron salt addition	• Already used at WPCP • Improves phosphorus removals and odor control • Can achieve good H_2S removal with high doses	• Safety considerations with storage and feed facilities • May not be used in the future if WPCP switches to biological phosphorus removal • High costs of chemicals
Adsorptive media (iron sponge)	• Proven technology with many installations • Simple configuration with no moving parts • Removes sulfur from the system • Lower media replacement costs at concentrations anticipated with iron salt addition	• Higher media replacement costs at anticipated H_2S levels without iron salt addition • Media can combust

2.2 Moisture Removal

Biogas is saturated with moisture as it leaves the digester and nearly all end uses require at least some level of moisture removal. For RNG, moisture must be nearly completely removed to meet injection specifications. It is recommended that a two-step process be used for moisture removal, where the first step is mechanical

refrigeration for the bulk of the moisture, followed by an adsorption technology for final biogas drying. Figure 2 presents an example of a moisture removal installation.

Figure 2. Moisture Removal Installation Example

2.3 Siloxane and VOC Removal

Siloxanes and VOCs are typically removed following moisture removal and initial compression, as the vessels have higher head loss and require a dry gas environment to work properly. Siloxanes and VOCs at normal levels within biogas (between 1 and 5 parts per million by volume [ppmv]) are removed using similar solid sorptive media as with hydrogen sulfide, described above. The most common media choice is activated carbon. In addition to siloxane removal, the media also serves as polishing to remove residual hydrogen sulfide and VOCs that may be in the biogas. Because of this polishing, the media is exhausted as much by residual hydrogen sulfide and VOCs as it is by siloxanes. Figure 3 presents an example of siloxane removal equipment and media.

Figure 3. Siloxane Removal Equipment and Media

Caution should be used with media selection because gas flow is very important for effective removal. If the media size is too large, at lower gas flow rates the flow will channelize, resulting in breakthrough occurring because media is exhausted in a concentrated area, while the overall bed is in good condition. Small media size will distribute flow better. However, if flows are higher, small media size will result in high pressure drops and potentially fluidizing the bed, leading to carry-over of media out of the treatment vessel. Careful coordination between the engineers and vendors on the range of gas flows is important for selection of media size.

2.4 Carbon Dioxide Removal

Biogas treatment to natural gas quality requires the removal of carbon dioxide from the biogas stream. Several technologies are available to condition the biogas to RNG quality, including water wash, pressure swing adsorption (PSA), and membranes. These technologies are described in more detail later in this Chapter, but Table 2 provides a summary of the advantages and disadvantages of each.

Table 2. Biogas Storage Scenarios

Alternative	Advantages	Disadvantages
Water wash	• Proven technology with many installations • No media to be replaced • High CH_4 recovery (98%) at design efficiency point	• More appropriate for larger installations (>750 scfm) • Requires high-pressure water (~150 psig) and water cooling • Requires post-scrubbing drying • Reduction in CH_4 recovery efficiency at turndown • Moderate energy use
PSA	• Proven technology with many installations • Regenerative adsorbent has long media life	• Lowest CH_4 recovery (95%) • Continuous actuation of vessel valves during operation is loud and causes mechanical wear of equipment • Moderate energy use
Membrane	• Proven technology with many installations • Highest CH_4 recovery (99%) with three-pass system • Fewer moving parts • Modular design • Good for smaller installations (<600 scfm)	• Requires separate upstream treatment of H_2S, VOCs, and siloxanes • Requires multiple passes to get higher CH_4 recovery • Higher energy use

2.5 Waste Gas Management

In addition to biogas treatment options, there are alternatives for how to properly dispose of waste gas generated at the WPCP. Below are the viable options for waste gas management at Arlington County WPCP.

2.5.1 Enclosed Waste Gas Flares

The most common method of waste gas disposal is with a waste gas flare. Waste gas flares are mostly used to combust raw biogas or off-spec RNG that is higher in heating value, or Btu content, and can provide self-sustaining direct combustion. Waste gas flares are always provided at anaerobic digestion facilities as a safety provision to be able to dispose of the flammable biogas during system downtime regardless of the biogas utilization method. Because of the visibility of the WPCP and footprint constraints an enclosed waste gas flare is recommended for the Arlington WPCP. An example of an enclosed flare is shown in Figure 4.

Figure 4. Enclosed Waste Gas Flare

2.5.2 Regenerative Thermal Oxidizers

For lower-Btu waste gases, or tail gas, produced as a by-product from the processing of RNG, RTOs are often used. RTOs provide higher efficiencies than regular thermal oxidizers when the waste gas does not have the Btu content to provide self-sustaining combustion. They provide this efficiency with a common combustion chamber and two sets of ceramic media with switching valves to capture and reuse the heat provided by the combustion to preheat the incoming waste gas. Once the heat is recovered from one combustion cycle the waste gas flow is reversed with the valves to recover heat from the recently combusted gas. An RTO is shown in Figure 5 and Figure 6.

Like any other form of thermal oxidation, a startup burner (fueled by natural gas) is employed to raise the temperature of the unit to proper destruction conditions. Once at the proper temperature, the process gas can be introduced and blended with the correct amount of dilution/combustion air, and the RTO cycles through the combustion sequence. The burner provides supplemental fuel to maintain the combustion chamber temperature should the heat content fall below that required for self-sustaining operation. Using a hot-gas bypass can expand the range of possible operating conditions by diverting some of the combusted air directly to atmosphere, rather than sending it through the heat-recovery media.

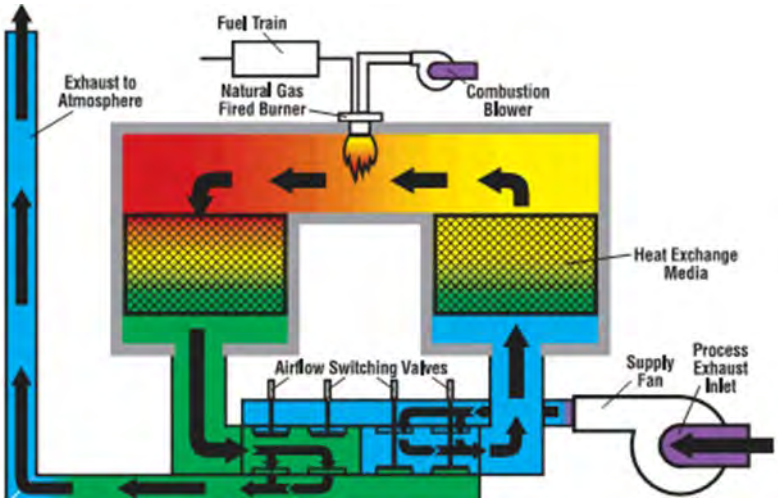

Figure 5. Regenerative Thermal Oxidizer

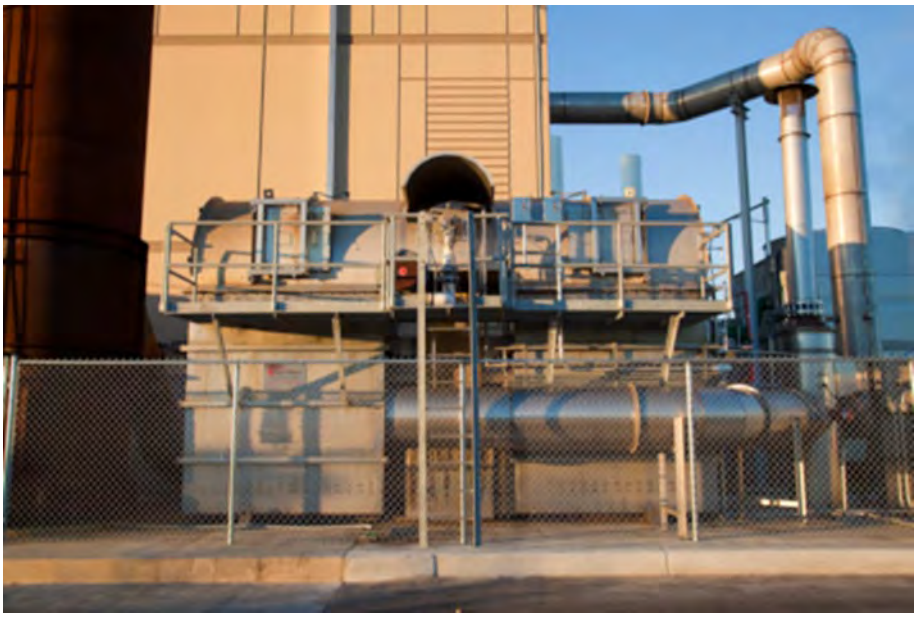

Figure 6. Regenerative Thermal Oxidizer

2.6 Pressure Boosting

Digester pressure is typically around 6 to as much as 20 inches of water column (in WC) or 0.2 to 0.7 psig. There are a wide range of pressure requirements for end use and for the associated treatment requirements described above that must be considered as part of a project. Depending on the technology used for biogas upgrading, a large range of pressure requirements are necessary to account for pressure losses through pipelines and the treatment system and achieve the required delivery pressure of the biogas equipment. Different RNG upgrading equipment technologies require a range between 100 and 250 psig for CO_2 removal. Typically, the upgrading equipment includes a compressor that can increase pressure necessary to the full requirement of that system. If there is pipeline injection, then it is also possible that an additional compressor would be needed to meet the requirement of the natural gas pipeline pressure for injection. Figure 7 shows an example of a biogas compression skid.

Figure 7. Biogas Compression Equipment Example

3.0 Biogas Upgrading Alternatives

With the recommended alternative of conditioning the biogas to be used as RNG off site, an additional analysis is needed to select the most appropriate carbon dioxide removal conditioning technology. There are three main types of biogas conditioning to produce RNG: membrane separation, pressure swing adsorption, and water wash scrubbing. The following sections provide additional descriptions of each technology followed by a life-cycle cost analysis to compare the three types and make a recommended selection for the Arlington WPCP.

3.1 Membrane Treatment

Membrane treatment systems consist of bundles of hollow membrane fibers fashioned together in canisters to remove carbon dioxide and other contaminants from the methane. The pores in the membrane fibers are sized to allow CO_2 molecules to pass through, while retaining the CH_4 molecules, as shown in Figure 8. Biogas is pressurized to 150 to 200 psig and conveyed through a series of canisters in a multi-pass configuration to improve CH_4 recovery and maintain a high CH_4 content in the product gas.

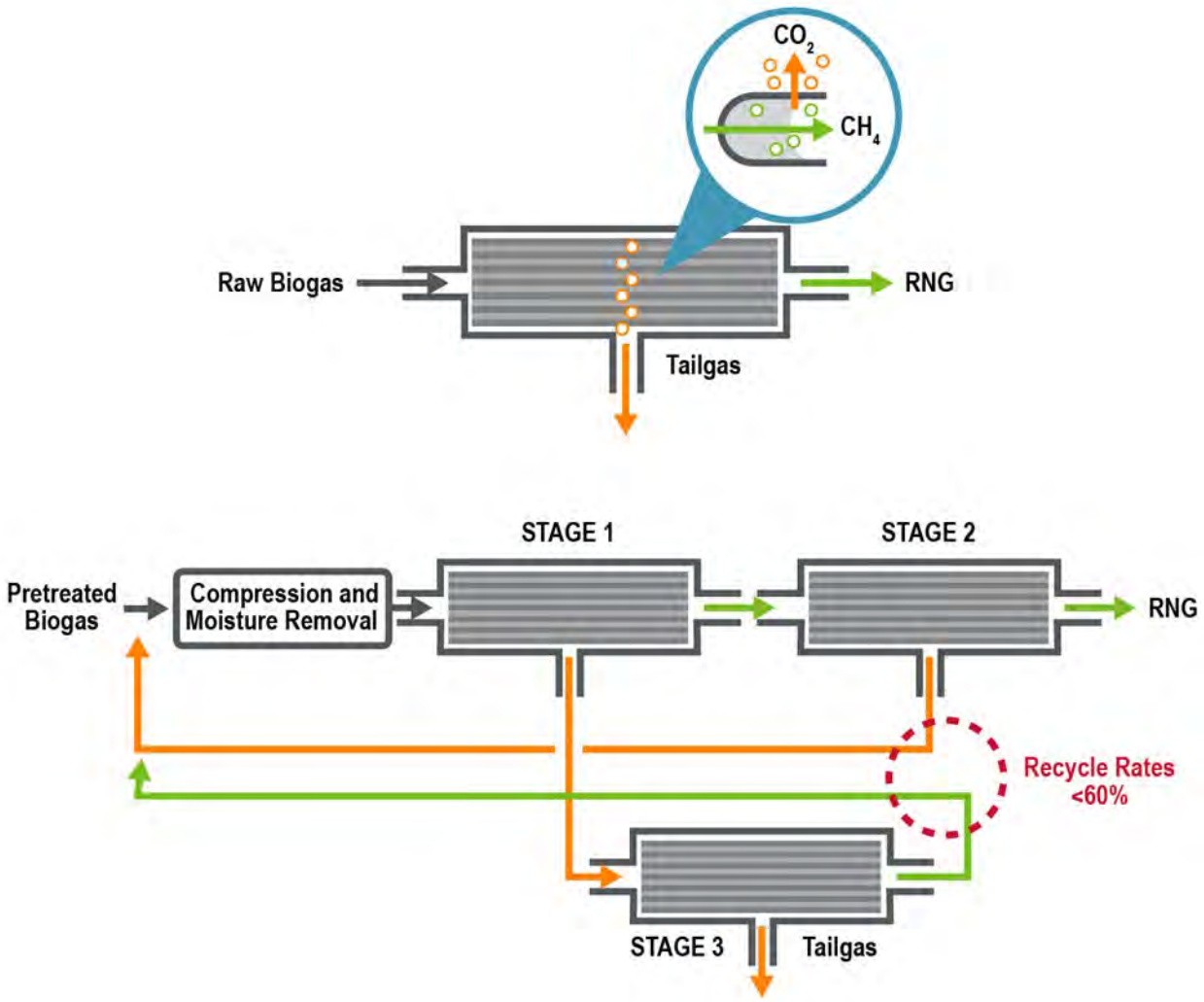

Figure 8. Membrane Treatment Schematic

Membrane systems must be used in combination with other technologies to remove hydrogen sulfide, siloxanes, moisture, and VOCs ahead of the membranes to protect the integrity of the fibers. The number of membrane filtration steps, or passes, determines the quality of the RNG and the methane recovery of the system. With additional membrane steps, higher finished gas quality is produced and/or more methane is captured from the waste tail gas stream. Gas typically passes through the membranes two to three times.

Currently, several companies manufacture membrane systems for installation in the United States: Unison Solutions, DMT Clear Gas Solutions, Greenlane Biogas, Air Liquide, and Pentair. A simplified schematic of a typical membrane system with mass balance is shown Figure 9. Figure 10 shows a photo of a typical membrane system installation.

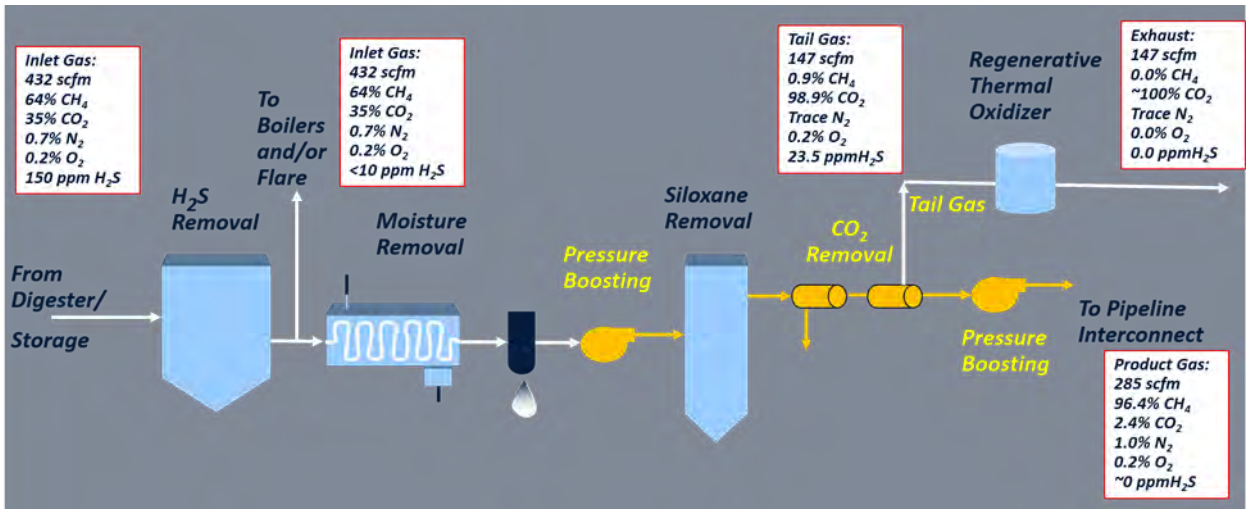

Figure 9. Membrane Treatment Process Flow Diagram

Figure 10. Typical Membrane Treatment Installation

3.2 Pressure Swing Adsorption

PSA systems remove hydrogen sulfide, carbon dioxide, and siloxanes in a single vessel by the adsorption of contaminants onto media under pressure (approximately 100 psig) and then regenerating the media under a vacuum. The systems operate with multiple pressure vessels so that the batch process of pressurizing the vessel, treating, and vacuum regeneration can be done while allowing for continuous operation. Figure 11 shows a schematic of the PSA treatment process. The systems are cost-effective; however, they typically have lower methane recovery rates (95 percent) compared to other gas upgrading systems being considered.

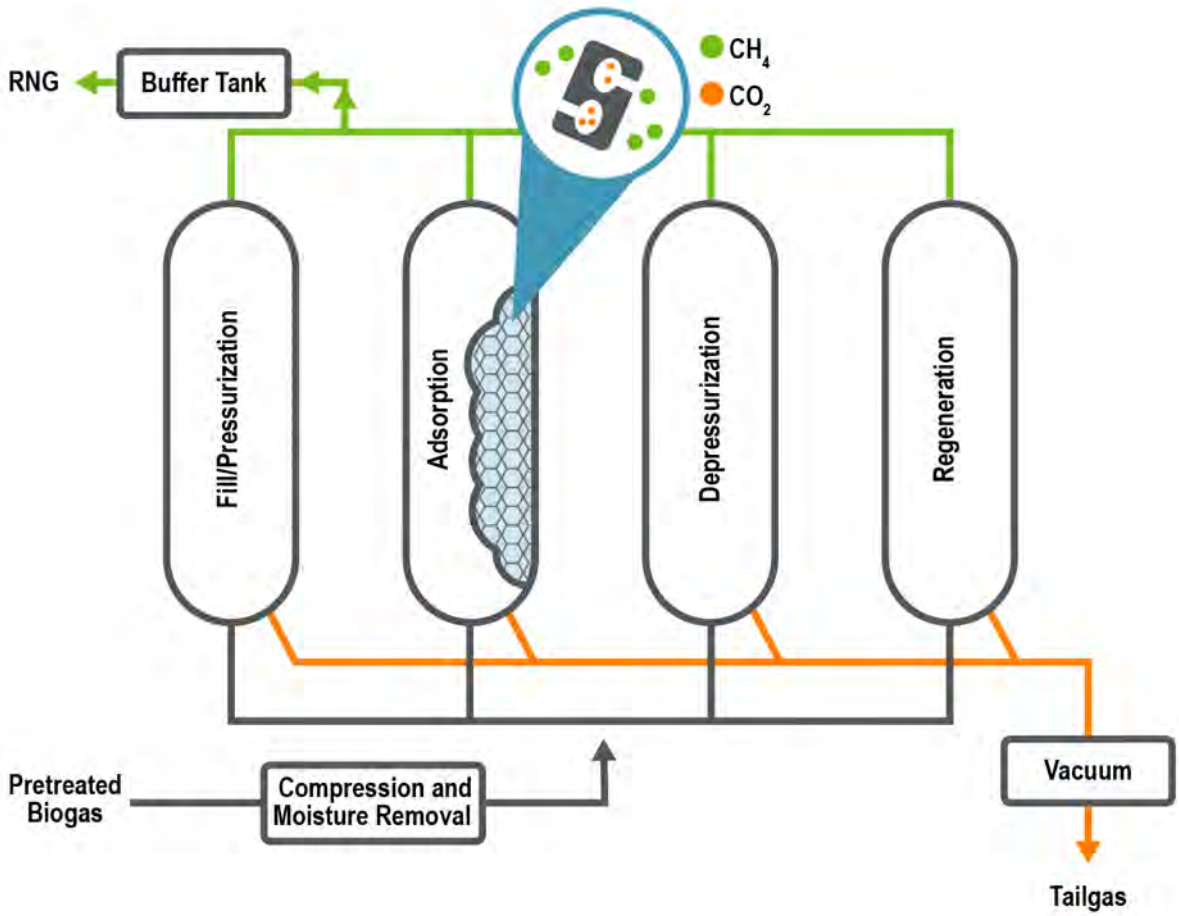

Figure 11. PSA Treatment Schematic

H_2S removal could occur upstream of the PSA or on the waste tail gas stream. The level of treatment provided will determine if an RTO or flare on the tail gas stream is needed to convert remaining hydrogen sulfide to sulfur oxides or if the stream can be vented to the atmosphere.

Currently, four companies manufacture PSAs for installation in the United States: Greenlane Biogas, Guild Associates, Xebec, and BioFERM. A simplified process flow diagram of a typical PSA system with mass balance is shown in Figure 12. Figure 13 shows a photo of a PSA system installation.

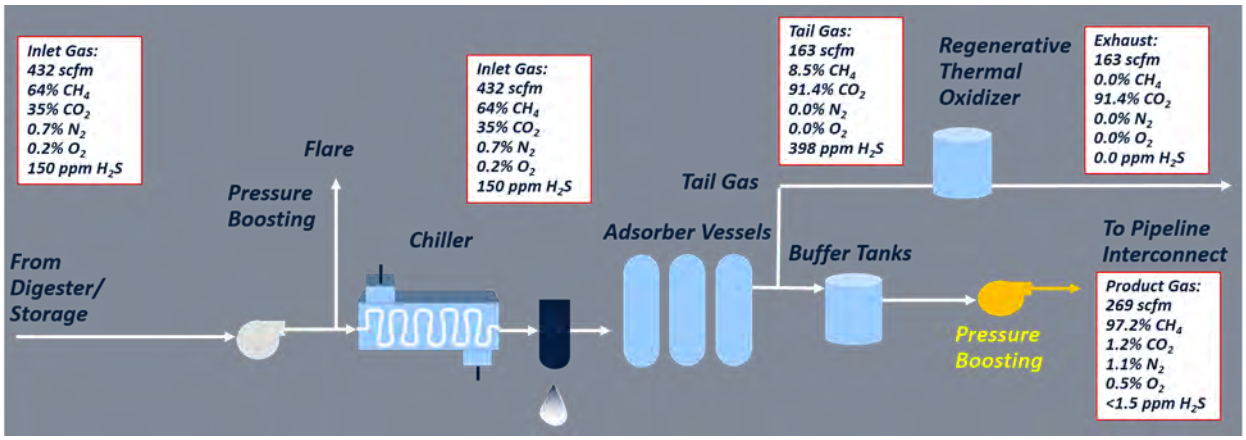

Figure 12. PSA Treatment Schematic

Figure 13. Typical PSA Installation

3.3 Water Wash Scrubber

The water wash, or water scrubber, treatment system dissolves carbon dioxide and other impurities in water to separate the CH_4 gas stream. Biogas compressed to approximately 150 psig enters the bottom of the scrubber vessel and flows upward through packing media as chilled water sprays downward. The carbon dioxide and other gas impurities (hydrogen sulfide, siloxanes, and VOCs) are dissolved in the water, the methane exits through the top of the scrubbing tower, and moisture is removed with a drier. The water, now saturated with carbon dioxide, is then depressurized in the flash tank, which operates as an intermediate step to release and recycle any methane that may have been absorbed in the water. The flash tank water is sent to the stripper vessel where pressure is lowest within the system. Lowering the pressure releases the carbon dioxide and contaminants into the tail gas waste stream. A schematic of the water wash treatment

process is shown in Figure 14. A defoaming, antimicrobial, and pH adjustment solution may be fed to the water wash system to improve performance.

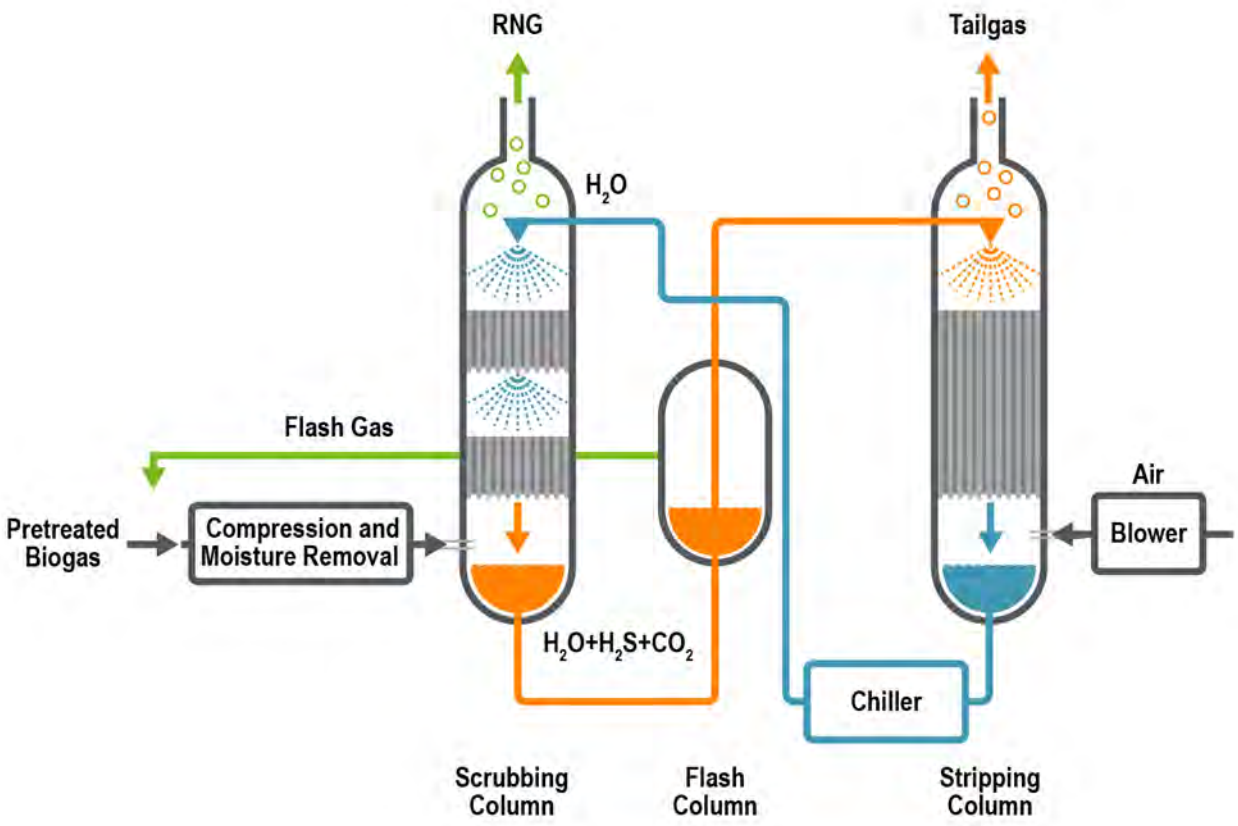

Figure 14. Water Wash Treatment

It should be noted that while the water wash systems remove hydrogen sulfide from the methane stream, the process does not actually treat it to a final product. The H_2S removal could occur upstream of the water wash process or on the waste tail gas stream. The level of treatment provided will determine if an RTO on the tail gas stream is needed to convert remaining hydrogen sulfide to sulfur oxides or if the stream can be vented to the atmosphere.

Water wash systems can achieve CH_4 recovery rates of up to 98 percent. However, this recovery rate drops when the system is operating below the designed best efficiency point.

Currently, two companies manufacture water wash systems for installation in the United States: Greenlane Biogas and Dürr Megtec. A simplified schematic of a typical water wash system with mass balance is shown in Figure 15. Figure 16 shows a photo of a water wash system installation.

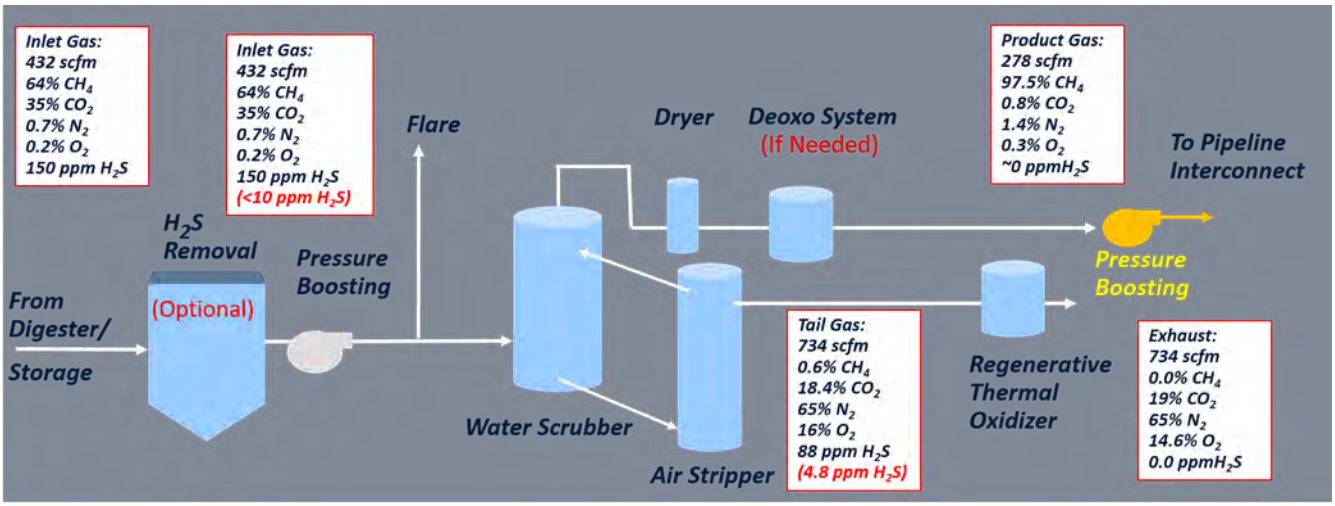

Figure 15. Water Wash System Process Flow Diagram

Figure 16. Typical Water Wash systems Installation
Source: HDR, Portland, Oregon.

4.0 Life-Cycle Cost Comparison

Similar to the gas utilization alternatives analysis, a life-cycle cost comparison was developed to evaluate and compare the three technologies from a capital and O&M cost basis.

4.1.1 Conceptual Capital Costs

Conceptual capital costs have been developed for each biogas conditioning alternative. Manufacturers for each equipment type were contacted for budgetary equipment pricing. The following multiplier percentages were used in the capital cost development:

- Electrical and instrumentation/controls: 28 percent
- Sitework/general civil: 15 percent
- Specialty piping: 5 percent
- Contractor general requirements (O&P, mobilization, etc.): 23 percent
- Contingency: 20 percent

No salvage or deep foundation costs or engineering, legal, and administrative costs are included in the cost estimates.

Capital costs are associated with the interconnection to the natural gas utility pipeline injection. These costs typically include the custody transfer station and the pipeline to the tie-in location. An estimated cost of $5 million is applied to all RNG injection alternatives and is based on preliminary feedback from the gas utility. This cost will be confirmed as additional discussions with the natural gas utility are conducted.

It is assumed that the natural gas pipeline will require post-treatment compression to 600 psig to inject RNG into the pipeline. Each pipeline injection alternative includes capital cost for this pressure increase. Each CO_2 removal technology discharges RNG at a different pressure, between 80 and 190 psig, so the compression needs vary for each alternative.

Capital costs for the conditioning alternatives are summarized in Table 3. The vendor quotes for each alternative are included in Appendix D.

Table 3. Biogas Conditioning Conceptual Capital Costs

Item		Membrane	PSA	Water Wash
Boilers		$0.60M	$0.60M	$0.60M
Building requirements		$2.45M	$2.45M	$2.45M
Pretreatment H_2S and siloxane removal		$0.50M	$0.00M	$0.00M
Inlet conditioning		$0.27M	$0.27M	$0.27M
CO_2 removal		$3.53M	$3.39M	$3.86M
Tail gas handling		$0.15M	$0.15M	$0.25M
Compression to delivery		$0.49M	$0.49M	$0.49M
Custody transfer station and pipeline		$5.00M	$5.00M	$5.00M
Total direct costs		$7.98M	$7.34M	$7.92M
Markups				
Electrical, instrumentation/controls	28%	$2.24M	$2.06M	$2.22M
Sitework	15%	$1.20M	$1.10M	$1.19M
Specialty piping	5%	$0.40M	$0.37M	$0.40M
Contingency	20%	$2.36M	$2.17M	$2.34M
Contractor general requirements	23%	$3.26M	$3.00M	$3.23M
Conceptual Capital costs		**$22.44M**	**$21.04M**	**$22.30M**
Compared to minimum		107%	100%	106%

4.2 O&M Costs

Similar to the capital costs, O&M costs have been estimated from vendor proposals, reference project experience, and the County's historical cost information. Anticipated O&M costs were developed and are presented in Table 4. Assumptions include costs related to operations labor, maintenance labor, labor parts, power requirements, water use, media replacement, and chemical costs. The common values used across all alternatives include the following:

- Power cost: $0.06/kWh
- Natural gas cost: $0.85/therm
- Operations labor: $80/hr
- Maintenance labor: $60/hr

Annual O&M cost summaries for the conditioning alternatives are provided in Table 4.

Table 4. Annual Biogas Conditioning O&M Costs at Start-up

Item	Membrane	PSA	Water Wash
Pretreatment H_2S and siloxane removal	$29,700	$0	$0
Inlet conditioning	$25,900	$25,900	$25,900
CO_2 removal	$237,500	$197,000	$252,600
Tail gas H_2S treatment	$0	$0	$0
Tail gas handling	$12,000	$12,000	$12,900
Compression to delivery	$17,900	$17,900	$17,900
Total O&M	**$323,000**	**$252,800**	**$309,300**
Total O&M $/MMBtu	**$2.45**	**$1.91**	**$2.34**

The membrane system has the highest annual O&M cost of the three options because of the higher power requirements and also media costs associated with H_2S and siloxane removal systems.

4.3 Present Values

The net present financial values for each technology option were calculated using the same heating requirements, biogas production quantities, annual costs, and financial assumptions as Alternatives 3A and 3B presented in Chapters 04 and 05 of the Arlington Re-Gen Biogas Utilization Report. These included the same WPCP energy costs for electricity and natural gas, O&M inflation, discount rate, and planning period.

Table 5 presents the present financial values for Alternatives 1, 3A, and 3B for each of the biogas conditioning technologies. The present financial values are presented for a range of RIN market values from $5/RIN to $35/RIN. The main differences between the options are the specific capital and O&M costs presented above as well as the methane capture for each of the technologies.

This analysis shows that the PSA technology has the lowest net present financial value as compared to the membrane and water wash system. This is mostly due to the difference in capital costs and slightly lower O&M costs for the PSA system. Even with the higher percentage methane capture for membranes and water wash, the difference in capital and O&M cannot be overcome through RNG revenue.

Table 5. Net Financial Values, $M

Item	Membrane	PSA	Water Wash
Conceptual Capital Cost	$22.4M	$21.0M	$22,3M
Annual Operating and Maintenance Costs	($0.32M)	($0.25M)	($0.31M)
Annual RIN Revenue at $15/MMBtu	$1.85M	$1.78M	$1.84M
Total Net Present Value	$3.46M	$1.92M	$3.32M

4.4 Summary

Overall, the three biogas conditioning technologies are very comparable in present value and performance; however, some differences should be discussed before the final decision is made.

Table 6 presents these differences graphically. The membrane system has the highest capital and O&M costs, but also the highest methane capture while the PSA has the lowest capital and O&M costs and the lowest methane capture. From an uptime perspective, all the technologies are similar. The PSA equipment will likely by louder and will not have the flexibility to simply add CHP in the future (additional pre-treatment would be required). The noise production of the PSA will be evaluated as part of the future site visits. Water wash has similar challenges and also will be less aesthetically pleasing because of its height, and tail gas management would be more costly because of higher gas flows. Membranes will be similar to or better than PSA and water wash in all of these categories.

Table 6. Technology Comparison

Criterion	Membranes	PSA	Water Wash
Capital cost	↑	↓	↑
O&M cost	↑	↓	↓
Methane capture	↑	↓	↑
Uptime	↔	↔	↔
Noise	↓	↑	↓
Aesthetics	↑	↑	↓
Flexibility for future CHP	↑	↓	↓
Tail gas management	↑	↑	↓

5.0 Recommended Alternative

Based on the analysis presented, it was recommended that the Program continue to pursue all three biogas treatment technologies until more understanding of the day-to-day operations and maintenance can be obtained. This was accomplished with additional discussions with the equipment vendors and site visits to existing installations to see the equipment in person and talk to O&M staff who have experience with the equipment options. Recommended next steps for the biogas utilization equipment selection included:

- Schedule technical brown bag sessions with equipment suppliers for the membrane, water wash, and PSA conditioning systems. This next step is currently in progress and potential dates and times are being discussed. *These technical brown bag sessions were conducted over three lunch and learn sessions in October 2021.*
- Identify potential facilities to perform in-person site visits. The equipment suppliers have provided lists of relevant installations, but additional facilities are currently being identified. A preliminary list of facilities that are being considered is shown in Table 7. The site visits should have relevance to the Arlington WPCP

where biogas from domestic wastewater digestion is conditioned to natural gas quality. Facilities of similar size and biogas conditioning capacity will be preferred.

- Schedule and perform site visits. It is anticipated that this will occur sometime in late 2021 or early 2022 depending on COVID-19 protocols. *Site visits to representative installations were conducted in October 2022.*
- Select a technology for implementation based on the results of the vendor discussions, site visits, and further refinement of the WPCP requirements as part of the Program.

Based on the results of this analysis, lessons learned from vendor presentations and discussions with operations and maintenance staff during site visits at representative installations, the preferred biogas treatment technology for implementation at the WPCP is membrane separation. The final technology and manufacturer selection will be determined during the detailed design phase of the Program.

Table 7. Technology Installation Lists

Water Wash (Greenlane)	PSA (Guild)	Membrane (Unison/Air Liquide)
Fair Oaks, Indiana (manure)	San Antonio, Texas (muni)	Atlanta, Georgia (LFG)
Perris, California	Dayton, Ohio (muni)	Pittsburgh, Pennsylvania (LFG)
Canton, Michigan	Newark, Ohio (muni)	Waste Management (LFG: multiple locations)
Weld County, Colorado (manure, food waste)	Des Moines, Iowa (muni)	Avondale, Louisiana (LFG)
Portland, Oregon (muni) startup end of 2021		Lincoln, Nebraska (muni)

Technical Memorandum No. 17

Date:	February 14, 2023
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Arlington Re-Gen Envision Assessment Summary

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1.0 Program Overview and Workshop Purpose

Arlington County (County) has initiated the implementation of the Arlington County Water Pollution Control Plant (WPCP) Re-Gen Program (Program) for the next generation of biosolids management facilities at the Arlington WPCP. A comprehensive Program will be developed and managed by the Program Team for the engineering, design, construction, maintenance, startup, and operation necessary to add sustainable equipment and systems to effectively recover the County's renewable resources, produce a Class A biosolids product, and most efficiently utilize the biogas. The new solids handling processes (Facilities) will entail upgrades or replacement of nearly all Facilities. A thermal hydrolysis process (THP) followed by anaerobic digestion (AD) form the backbone of the new treatment train. A marketable Class A biosolids product and biogas utilization system to clean and make use of methane gas either on or off site are also envisioned. The completed Program will enhance operating conditions and reliability of the Facilities while continuing to meet all permit requirements and ensure an unrelenting commitment to environmental stewardship.

Mission Statement: *Upgrade resource recovery facilities to produce Class A biosolids and renewable energy, maximizing sustainability and community acceptance. Collaborate with team members to select and implement processes that are safe, reliable, and financially responsible throughout planning, design, construction, operations, and maintenance.*

The Envision sustainability rating system will be used to track and verify the Program's sustainable elements. For a description and background of the Envision framework and a discussion on how its use will support the Program's alignment with the Arlington County Facility Sustainability Policy for New Construction and Major Renovation (Green Building Policy, April 30, 2019), refer to *Technical Memorandum No. 15: Envision Recommendations*. An Envision workshop was held with the Program's Sustainability Workgroup on September 30, 2021. This memorandum and appendices record the results of the initial Envision credit assessment discussed during this workshop and provides a snapshot in time for the credits the Program could achieve. As the Program progresses, the level of achievement for each Envision credit will be reassessed and revised as design decisions are made.

Prior to the workshop, HDR Engineering, Inc. (HDR) conducted an internal credit review to:

- Evaluate each credit for relevance
- Conduct initial analysis into the potential Level of Achievement (LOA)
- Discuss potential documentation sources
- Identify potential opportunities for incremental improvements in sustainable performance
- Note areas for improvement or efforts that may push the Program to achieve higher LOAs

The outcome of the internal credit review provided a status for the 59 credits in the Envision framework:

- **21 credits:** confident with LOA/range
- **10 credits:** need additional discussion once an alternative is selected
- **9 credits:** not applicable (N/A)
- **6 credits:** not likely to pursue
- **13 credits:** for discussion

The purpose of the Envision workshop was to:

- Continue to build understanding of Envision and what is needed to document the Program for verification
- Discuss the 13 credits identified as needing additional input from the Sustainability Workgroup to try to determine if they will be pursued and, if so, at which LOA

Participants included the following entities and individuals:

- Arlington County:
  - Mary Strawn, Chief Engineer
  - Lisa Racey, Principal Engineer
  - Wilbur Brown, Management Specialist
  - Christian Zepeda, Operator
  - Beau Dodge, Pretreatment Program Coordinator
  - Charles Njoku, Environmental Management Specialist, Office of Sustainability and Environmental Management
- HDR:
  - Brian Balchunas, Program Manager
  - Laurissa Hoyle, Service Area (SA) 1, Program Management
  - Stephanie Spalding, SA2, Scope Development
  - Jen Ninete, Senior Sustainability Consultant
  - Michaella Wittman, Sustainability and Resilience Director

The internal assessment in conjunction with the Envision workshop represents a preliminary review of Envision for Arlington Re-Gen, including a review of the Program's sustainable attributes, as well as the potential effort required to earn recognition through the Envision verification process. The Program team will continue discussions to refine credit LOAs and determine documentation needs and responsibilities required to submit the Program for verification.

The Program is currently in the facilities planning phase. Envision is often launched during planning or at the design kickoff, allowing Envision conversations throughout the planning and design processes and offering the most opportunities to integrate scope considerations during the entire Program process.

2.0 Envision Overview

Envision is a sustainable infrastructure framework developed through a joint collaboration between the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure (ISI). ISI is a not-for-profit education and research organization, dedicated to developing and maintaining a civil infrastructure rating system, and was formed by the American Council of Engineering Companies (ACEC), American Public Works Association (APWA), and American Society of Civil Engineers (ASCE).

Envision provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects, giving recognition to those projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle. The system has 64 sustainability credits divided into five sections: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience. Envision is similar in structure to the Leadership in Energy and Environmental Design (LEED) rating system. While LEED evaluates buildings, Envision provides industry-wide sustainability metrics for **infrastructure projects of all types**.

An overview of the Envision framework and a one-page summary of the credits is included as Appendix A.

Any infrastructure project may use Envision as a framework for evaluating sustainability performance. Recognition is sometimes a driver when using the system, but most agencies use Envision because of benefits like:

- Raising the bar for sustainability decisions by starting project team dialogue about issues that might not otherwise have been raised
- Illustrating that the project addresses community concerns
- Ensuring that public funds are being spent in the public's best interest
- Looking at long-term costs and risks
- Drawing public attention to good work being done throughout the community
- Providing a quality control system for project decisions
- Tracking performance and establishing design, construction, and operations metrics
- Demonstrating agency commitment to implementing more sustainable infrastructure

To earn formal recognition from ISI, a project must be officially registered and submitted for verification. To do so, supporting documentation must be submitted electronically to ISI through its online system. ISI then provides the documentation to a trained third-party verifier who evaluates the information and returns an assessment to ISI for review and authentication.

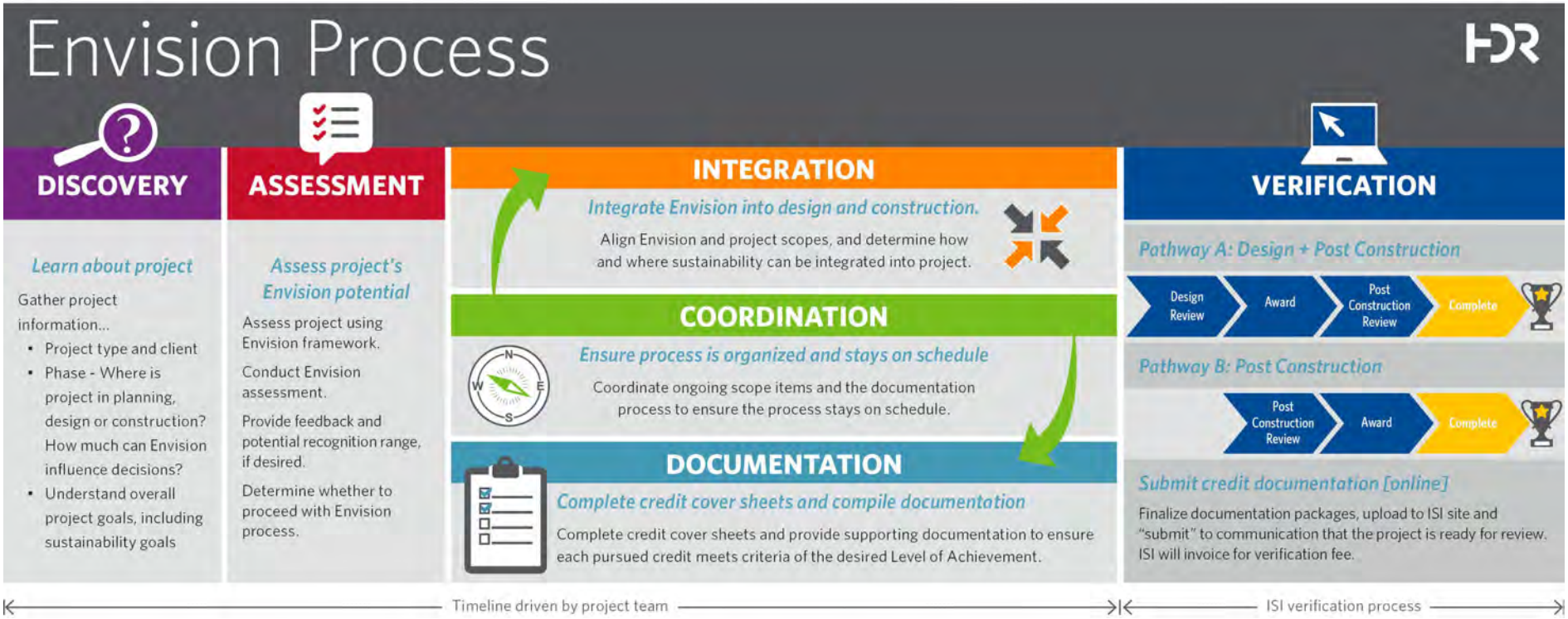


Figure 1. Envision Process

2.1 Pathways

Infrastructure projects may seek third-party verification at or after 95 percent design completion. This means that all major design decisions must be made prior to seeking third-party verification and award. There are two verification pathways—Pathway A: Design + Post-Construction and Pathway B: Post-Construction—the steps of which are outlined in Figure 2. The Arlington Re-Gen Program will use Pathway A.

Figure 2. Verification Pathways

2.2 Recognition Levels

Envision recognition levels are awarded based on the percentage of total applicable points achieved. This recognition provides third-party confirmation of the team's commitment to the environment and its community. Higher levels of recognition illustrate greater levels of contribution to environmental, economic, and social aspects of sustainability (see Figure 3):

- **Verified:** 20 percent or more, but less than 30 percent
- **Silver:** 30 percent or more, but less than 40 percent
- **Gold:** 40 percent or more, but less than 50 percent
- **Platinum:** 50 percent or more

Envision establishes standard practices as the benchmark; therefore, project teams should consider their percentage score as the degree to which sustainability was incorporated above and beyond standard practice rather than as a fraction of 100.

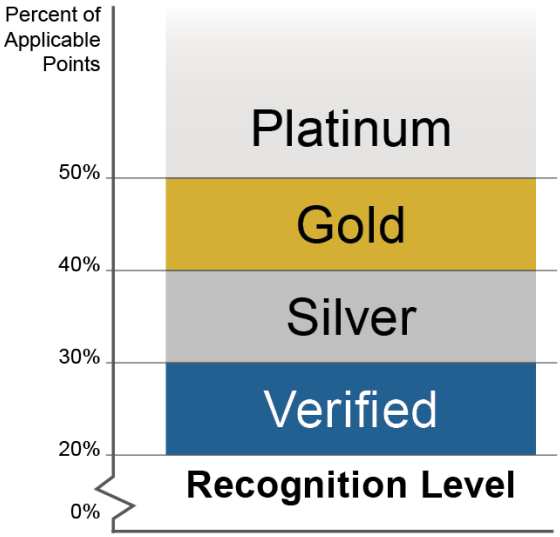


Figure 3. Envision Recognition Levels

3.0 Envision Credit Review

To complete the preliminary Envision assessment for the Re-Gen Program, the workshop participants reviewed the Program against the 64 Envision credits, which are discussed further in subsequent sections and grouped by category. It is important to note that the evaluation considered not only project design, but the full scope of the project from planning through operations, and how it fits within the community. This process takes into consideration the project's life cycle, is consistent with how Envision is applied from the start of a project and takes into account all of the decision points from ideation through completion of construction. These subsequent sections detail the results of the initial Envision credit assessment discussed during this workshop and provides a snapshot in time for the credits the Program could achieve. As the Program progresses, the level of achievement for each Envision credit will be reassessed and revised as design decisions are made.

3.1 Envision Rating Exercise

A detailed review of each credit, including the estimated range of points attainable for each, is included as Appendix B. Based on the level of current development for the Program, the Envision review exercise concluded that the Program could reasonably pursue credits that could result in a Silver or Gold recognition level, provided that supporting documentation is available. Figure 4 illustrates the Program's score range after the preliminary Envision assessment, showing the recognition level(s) that the Program may be able to attain.

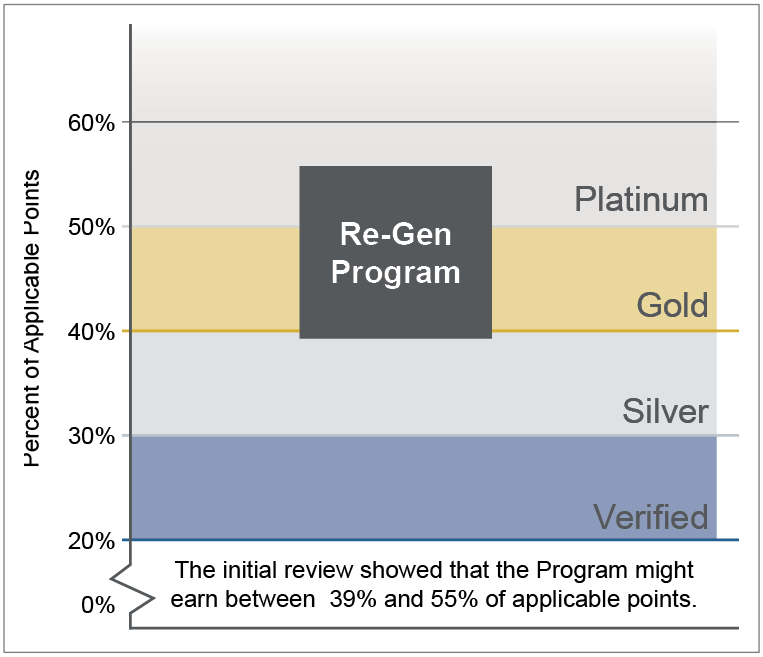


Figure 4. Projected Envision Recognition Level

Though the review shows that a Gold recognition level is possible, it may require the Program team to apply additional effort or add to the Program's scope. Additional costs that could be incurred may be related to supplemental research and reports for credits like LD3.3 Conduct a Life-cycle Economic Evaluation, or for specifying additional contractor responsibilities for activities like reducing construction water consumption. There are no requirements for these additional efforts. For each instance where the

Program may consider striving to attain a higher LOA by expending additional effort, the Program team would conduct a simple and informal cost/benefit analysis to determine if the value to the Program corresponds with the required level of effort and/or cost. The ultimately desired LOA, including the decision to expend additional effort or add to Program scope, will be determined by the County during the detailed design phase. The final decision on recognition level achieved will be determined by the third-party verifier and ISI authenticator—who will confirm if each credit achieves the pursued LOA. Based on experience with other Envision projects, it is unlikely that all submitted credits will achieve the pursued LOA as determined by the verifier.

Each Envision credit applicable to a project is scored at one of the following LOAs, with an associated number of points achieved for each credit level achieved (or zero points if not even the improved level is achieved):

- ***Improved:*** performance that is above conventional
- ***Enhanced:*** sustainable performance that is on the right track; indications that superior performance is in reach
- ***Superior:*** sustainable performance that is noteworthy
- ***Conserving:*** performance that has achieved essentially zero impact
- ***Restorative:*** performance that restores natural or social systems

Envision is designed to help the Program strive for incremental sustainability improvement by setting challenging goals of net-zero impacts or restorative actions. However, ISI states that achieving a conserving or restorative level of achievement for every credit, and therefore achieving a 100 percent score, is not possible. Envision points are designed to encourage the team to focus efforts where the Program can achieve the greatest impact. The benefit of using the rating system is the ability to document deliberate decisions using a standardized system.

Figure 5 shows the total points per category and the projected achievement by the Program. Each bar illustrates the estimated achievable points and potential additional points, as well as points that are not applicable to the project and points that are not achievable by the Program in each category.

The range of estimated achievable points for the Program reflects the potential LOA by category using the current level of Program development, showing what level is potentially possible with additional effort or information. The low end of the range is a projection based on what has been done to date and where documentation is already reasonably available or is anticipated to be available. The high end of the range is an estimate based on what could still be implemented or determined based on additional Program development and documentation efforts.

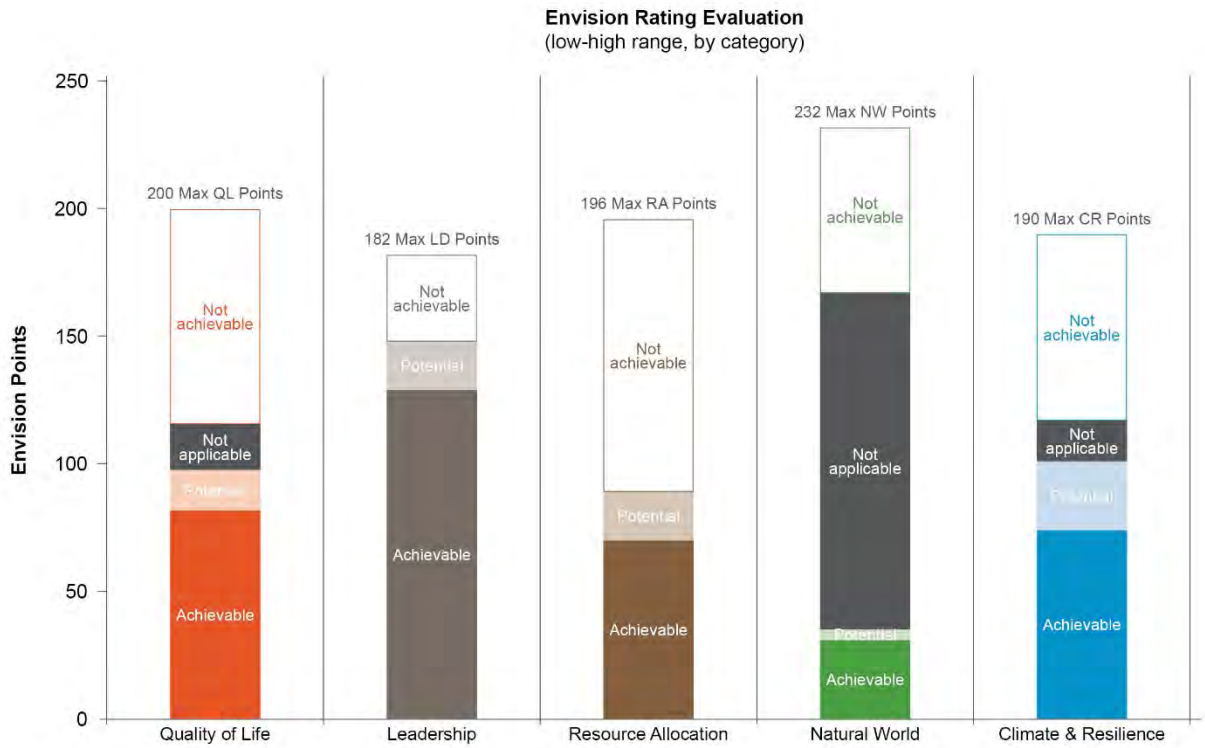


Figure 5. Envision Rating Evaluation (low–high range, by category)

Points are considered not achievable for two primary reasons:

- Some credits will not be pursued but are still applicable to the Program, meaning that all the points for that credit are not achievable. For example, QL3.4 Enhance Public Space and Amenities, a credit worth 14 points, will not be pursued. The intent of the credit is to improve amenities and publicly accessible spaces to enhance community livability. Because of the nature and scope of the Program, there are not practical ways to meet the intent of the credit within the current scope. It was determined during the assessment that it would be unlikely for the Program to add scope to enhance public space, so the Sustainability Working Group decided that the credit would not be pursued.
- Many credits will not be pursued at the highest LOA, thus not achieving all possible points on those credits. For example, the highest LOA for RA3.3 Reduce Construction Water Consumption (Conserving) is 8 points. The Program could likely achieve an Improved LOA for 1 point. To increase the LOA, additional potable-water conservation strategies would need to be implemented during construction. The Sustainability Working Group determined that implementing three strategies would be unlikely or would cause undue burden for the contractor, which may result in additional cost.

3.2 Credit Designation

This section describes the credit designation process, including innovation credits and not applicable credits.

3.2.1 Pursued Credits

Pursued credits have a target level LOA and will be tracked as the Program progresses. Pursued credits include both those related to planning-level decisions that have already been made and credits related to design and/or construction. For design/construction-related credits, the team will need to integrate sustainable considerations into the Program to fulfill Envision criteria requirements. Because the Program intends to submit the project to ISI for verification, the team will prepare ISI-provided credit cover sheets and supporting documentation for each of these credits.

3.2.2 Not Applicable Credits

ISI has provided guidance indicating that a project should not be awarded Envision points for avoiding certain situations or locations if there is no reasonable chance that those locations or situations were being considered during the project decision-making process. For the credits to be deemed not applicable during the verification process, the project team must provide documentation to support the exclusion of these credits. This is beneficial to the project because it reduces the number of applicable points used in the project award level calculation.

For example, the intent of credit NW1.3 Preserve Prime Farmland is to "identify and protect soils designated as prime farmland, unique farmland, or farmland of importance." The entirety of the Program is located on the existing WPCP site, which has already been completely developed and does not include any prime farmland. The Program team would submit this credit as not applicable based on the applicability criteria in the Envision Guidance manual, "projects that do not contain prime farmland, and for which no siting options containing prime farmland were possible or seriously considered, may apply to have this credit deemed not applicable with supporting documentation."

3.2.3 Innovation Credits

The Envision framework strongly encourages innovative methods that advance sustainable infrastructure practices or show exceptional performance beyond the expectations of the credit requirements. Each category includes an "Innovate or Exceed Credit Requirements" credit, indicated by a "0.0." Projects may achieve all or part of the points in these credits. Maximum points allotted for innovation in any one category is 10 points and the submitter determines the number of points (zero to the maximum) for which the credit will be submitted. The 0.0 credits are not required, and these points act as bonus points that are added to the category or total score.

3.3 Envision Credit Assessment Scorecard Snapshot

The Envision credit assessment scorecard snapshot illustrated by Table 1 is a record of the Envision assessment discussion and shows the outcomes at the time of the assessment with the Sustainability Workgroup. The highlighted or shaded points for each credit reflect the anticipated LOA based on the preliminary assessment. This scorecard is part of an Envision Workbook, which is a living document that continues to evolve over the life of the Program. Refer to Appendix B.

Note that credit and Program LOAs are anticipated based on assessment discussions, but actual LOAs may vary depending on available documentation, as well as the verifiers' review process.

Table 1. Envision Credit Assessment Scorecard Snapshot (September 30, 2021)

Category	Credit	N/A	None	Improved	Enhanced	Superior	Conserving	Restorative
Quality of Life	QL1.1 Improve Community Quality of Life	0	0	2	5	10	20	26
	QL1.2 Enhance Public Health and Safety	0	0	2	7	12	16	20
	QL1.3 Improve Construction Safety	0	0	2	5	10	14	-
	QL1.4 Minimize Noise and Vibration	0	0	1	3	6	10	12
	QL1.5 Minimize Light Pollution	0	0	1	3	6	10	12
	QL1.6 Minimize Construction Impacts	0	0	1	2	4	8	-
	QL2.1 Improve Community Mobility and Access	0	0	1	3	7	11	14
	QL2.2 Encourage Sustainable Transportation	0	0	-	5	8	12	16
	QL2.3 Improve Access and Wayfinding	0	0	1	5	9	14	-
	QL3.1 Advance Equity and Social Justice	0	0	3	6	10	14	18
	QL3.2 Preserve Historic and Cultural Resources	-18	0	-	2	7	12	18
	QL3.3 Enhance Views and Local Character	0	0	1	3	7	11	14
	QL3.4 Enhance Public Space and Amenities	0	0	1	3	7	11	14
	QL0.0 Innovation		2					
	Maximum QL points	200		Low	88		48.4%	
	Applicable QL points	182		High	98		53.8%	
Leadership	LD1.1 Provide Effective Leadership and Collaboration	0	0	2	5	12	18	-
	LD1.2 Foster Collaboration and Teamwork	0	0	2	5	12	18	-
	LD1.3 Provide for Stakeholder Involvement	0	0	3	6	9	14	18
	LD1.4 Pursue Byproduct Synergies	0	0	3	6	12	14	18
	LD2.1 Establish a Sustainability Management Plan	0	0	4	7	12	18	-
	LD2.2 Plan for Sustainable Communities	0	0	4	6	9	12	16
	LD2.3 Plan for Long-Term Monitoring and Maintenance	0	0	2	5	8	12	-
	LD2.4 Plan for End-of-Life	0	0	2	5	8	14	-
	LD3.1 Stimulate Economic Prosperity and Development	0	0	3	6	12	20	-
	LD3.2 Develop Local Skills and Capabilities	0	0	2	4	8	12	16
	LD3.3 Conduct a Life-Cycle Economic Evaluation	0	0	5	7	10	12	14
	LD0.0 Innovation		2					
	Maximum LD points	182		Low	129		70.9%	
	Applicable LD points	182		High	148		81.30%	
Resource Allocation	RA1.1 Support Sustainable Procurement	0	0	3	6	9	12	-
	RA1.2 Use Recycled Materials	0	0	4	6	9	16	-
	RA1.3 Reduce Operational Waste	0	0	4	7	10	14	-
	RA1.4 Reduce Construction Waste	0	0	4	7	10	16	-
	RA1.5 Balance Earthwork On Site	0	0	2	4	6	8	-
	RA2.1 Reduce Operational Energy Consumption	0	0	6	12	18	26	-
	RA2.2 Reduce Construction Energy Consumption	0	0	1	4	8	12	-
	RA2.3 Use Renewable Energy	0	0	5	10	15	20	24
	RA2.4 Commission and Monitor Energy Systems	0	0	3	6	12	14	-
	RA3.1 Preserve Water Resources	0	0	3	5	7	9	12
	RA3.2 Reduce Operational Water Consumption	0	0	4	9	13	17	22
	RA3.3 Reduce Construction Water Consumption	0	0	1	3	5	8	-
	RA3.4 Monitor Water Systems	0	0	1	3	6	12	-
	RA0.0 Innovation		4					
	Maximum RA points	196		Low	70		35.7%	
	Applicable RA points	196		High	83		42.30%	

Category	Credit	N/A	None	Improved	Enhanced	Superior	Conserving	Restorative
Natural World	NW1.1 Preserve Sites of High Ecological Value	-22	0	2	6	12	16	22
	NW1.2 Provide Wetland and Surface Water Buffers	-20	0	2	5	10	16	20
	NW1.3 Preserve Prime Farmland	-16	0	-	2	8	12	16
	NW1.4 Preserve Undeveloped Land	0	0	3	8	12	18	24
	NW2.1 Reclaim Brownfields	-22	0	11	13	16	19	22
	NW2.2 Manage Stormwater	0	0	2	4	9	17	24
	NW2.3 Reduce Pesticide and Fertilizer Impacts	0	0	1	2	5	9	12
	NW2.4 Protect Surface and Groundwater Quality	0	0	2	5	9	14	20
	NW3.1 Enhance Functional Habitats	-18	0	2	5	9	15	18
	NW3.2 Enhance Wetland and Surface Water Functions	-20	0	3	7	12	18	20
	NW3.3 Maintain Floodplain Functions	-14	0	1	3	7	11	14
	NW3.4 Control Invasive Species	0	0	1	2	6	9	12
	NW3.5 Protect Soil Health	0	0	-	3	4	6	8
	NW0.0 Innovation		0					
	Maximum NW points	232		Low	31		31.00%	
	Applicable NW points	100		High	35		35.0%	
Climate Resilience	CR1.1 Reduce Net Embodied Carbon	0	0	5	10	15	20	-
	CR1.2 Reduce Greenhouse Gas Emissions	0	0	8	13	18	22	26
	CR1.3 Reduce Air Pollutant Emissions	0	0	2	4	9	14	18
	CR2.1 Avoid Unsuitable Development	-16	0	3	6	8	12	16
	CR2.2 Assess Climate Change Vulnerability	0	0	8	14	18	20	-
	CR2.3 Evaluate Risk and Resilience	0	0	11	18	24	26	-
	CR2.4 Establish Resilience Goals and Strategies	0	0	-	8	14	20	-
	CR2.5 Maximize Resilience	0	0	11	15	20	26	-
	CR2.6 Improve Infrastructure Integration	0	0	1	4	9	14	18
	CR0.0 Innovation (earn up to 5 points)		2					
	Maximum CR points	190		Low	74		42.50%	
	Applicable CR points	174		High	101		58.0%	

Maximum of 1,000 total points (without 50 possible innovation points)	1,000	Low	392	39.2%
Applicable points	834	High	465	55.8%

High percentage calculated with applicable points; low percentage calculated with maximum points to consider the potential for N/A credits not being approved as submitted.

3.4 Credit Review by Envision Category

The sections below provide the preliminary LOA by the Re-Gen Program for each Envision credit, by Envision category, based on the workshop assessment.

3.4.1 Quality of Life

The Quality of Life category addresses a project's impact on affected communities, from the health and wellbeing of individuals to the wellbeing of the larger social fabric as a whole. These impacts may be physical, economic, or social. Quality of Life focuses on assessing whether infrastructure projects align with community goals, are incorporated into existing community networks, and will benefit the community in the long term. The section also assesses to what degree community members affected by the project were considered important stakeholders in the decision-making process.

The Quality of Life section includes 13 credits and 200 points, representing 20 percent of the total points available. Based on the review, the Program could potentially earn between 88 and 96 points by pursuing 10 credits. Those credits are outlined in Table 2 below, which also provides topics, notes, and/or documentation that would likely be included in the credit package and action items, next steps, or future considerations to work toward submitting the credit for verification.

Table 2. Quality of Life Credits

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
QL1.1: Improve Community Quality of Life	Conserving	• Reference to goals in County plans, Comprehensive Plan, Solids Master Plan • Replacing failing and end-of-life equipment • Mitigating the risk of potential future regulatory changes to the current practice of recycling Class B biosolids through application to agricultural land • Providing a solution that reduces the energy and GHG footprint of the WPCP • Achieving additional County-wide sustainability goals • Developing a solids management strategy that offers long-term reliability • Establishing an implementation plan compatible with County Capital Improvement Program (CIP) funding • Plan supports the Chesapeake Bay Preservation Ordinance, a statewide program to help restore the Bay to health	• Incorporate poll/survey to ask about stakeholder engagement/satisfaction • Consider potential for website where community can submit comments
QL1.2: Enhance Public Health and Safety	Superior–Conserving	• Reference Safety, Health, and Environmental (SH&E) Plan • Moving from a Class B product to a pathogen-free, Class A Exceptional Quality product • Reducing truck traffic from solids and lime hauling • Demographics of customers/area: statics/map	• Develop statistics/map showing demographics of customers/area • Research/explain where land application of biosolids has been going and will go to after project is complete; different counties and farms

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
		• CIP: implement more effective technology that will reduce the need for maintenance and reduce safety risks to staff	
QL1.3: Improve Construction Safety	Conserving	• Specifications: contractor hired to do the work will be required to develop its own safety plan • County's internal programs for health screenings, and new policy has been put into place requiring contractors to have either COVID-19 vaccines or regular COVID-19 testing	• Develop specifications outlining contractor requirements for developing a safety plan to fulfill Envision criteria, including feedback mechanism • Collect/provide information about County programs and new contractor policy
QL1.4: Minimize Noise and Vibration	Superior–Conserving	• Baseline: existing facility • Note change in noise during operation of updated facility over existing facility • Less truck traffic, but potentially more noise from equipment • Standby generators located on site, used as needed, tested biweekly; located in a building with sound attenuation • Noise and vibration outlined as an issue at stakeholder meeting	• Document how the stakeholder engagement process demonstrates community awareness of noise and vibration targets
QL1.5: Minimize Light Pollution	Improved (or better)	• Exterior lighting needs and solutions • If applicable, specifications: lighting requirements, i.e., backlight, uplight, and glare (BUG) requirements, cutoff fixtures • Explanation for additional lighting: more equipment outside, safety/security issues • Updates to Green Building Incentive Policy: "minimum light pollution reduction criteria for exterior light fixtures must be met to safely reduce light pollution"	• Assess exterior lighting needs • Review mitigation hierarchy form • Review lighting plan • Consider light fixture selection to meet BUG rating uplight requirements • Consider higher LOA
QL1.6: Minimize Construction Impacts	Conserving	• Specifications: construction management plan requirement, including all items listed in manual—noise, safety/wayfinding, access/mobility, lighting • Construction Management Plan • Documentation of signage on the construction fencing to share information with the public	• Develop specifications outlining contractor requirements for developing a Construction Management Plan to fulfill Envision criteria • Add contractor "Envision Action Plan" to the Sustainability Management Plan (SMP)/Envision management plan
QL2.1: Improve Community Mobility and Access	Enhanced	• Changes in truck logistics • Trucks currently cross Eads Street and back into WPCP; new solids loading facilities will be drive-	• Include mobility issues, like truck traffic in stakeholder discussions

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
		through instead of back-in, which will eliminate the need to back in across Eads Street into the WPCP • Solids reduced by 50%, resulting in less truck traffic and hauling costs	• Share any input from the community regarding changes in mobility/access during operation of finished project
QL2.2: Encourage Sustainable Transportation	Restorative	• Bike paths and bike-friendly roads adjacent that connect to trail along river • Electric transportation stations worth including, if already planned for the project • Think about this project from the perspective of project processes vs. land use—because of renewable natural gas (RNG) being supplied for potential use by adjacent facilities to support mass transit	• Follow up to see if WPCP is getting an electric vehicle (EV) on site; provide update. If so, consider how EV contributes to power requirements for the project
QL2.3: Improve Access and Wayfinding	Enhanced	• May be modifying access from WPCP for trucks • Addition of street-facing signage • Changing gates onto WPCP site; will need to have good wayfinding because of changes	• Consider impact of wayfinding signage
QL3.3: Enhance Views and Local Character	Enhanced	• Very visible from surrounding neighborhoods • Viewshed discussion part of site planning • Screening; much of the piping hidden; do not want project to look like equipment • Many discussions with stakeholders • A lot of current aesthetic was driven by stakeholders' input; have taken this into account in the past. Will assess aesthetic standard for this project. Use this as basis for "Guidelines are adopted or developed to preserve or enhance views and local character." • The Public Art Master Plan, adopted in November 2021, notes County-owned utility infrastructure, such as the WPCP and associated pump stations, as possible locations for public art.	• Continue discussion as part of site planning • Determine if anything needs to, and/or will, be done regarding public artwork • Collect documentation supporting previous stakeholder discussions • Collect documentation supporting previous decisions about WPCP aesthetic based on stakeholder input

One credit would likely be submitted as "not applicable" and excluded from scoring:

- QL2.2: Preserve Historic and Cultural Resources

The project would likely not earn any points in the following credits:

- QL3.1: Advance Equity and Social Justice
  - Likely not to pursue because of specific criteria requirements
- QL3.4: Enhance Public Space and Amenities
  - This credit would be deemed applicable but would be difficult or costly to pursue. Per the Envision guidance manual, "Not addressing the potential for public space or amenities is not sufficient alone to designate this credit not applicable. Infrastructure projects, especially those traditionally viewed as inaccessible, are encouraged to consider how they can benefit their surrounding community through the enhancement or provision of public space and amenities."

Innovation credit: The assessment brought up one topic that may be considered for submission in an Innovation credit for Quality of Life: QL0.0. Content for this credit could include:

- Project branding: mission, vision, etc. for 2 points

3.4.2 Leadership

The Leadership category encourages and rewards projects that embrace a new way of thinking about project development and delivery. Specifically, projects achieve a higher LOA when teams communicate and collaborate early, involve a wide variety of people, and understand the long-term, holistic view of the project and its life cycle. The Leadership section rewards these actions under the view that, together with traditional sustainability actions such as reducing energy and water use, effective and collaborative leadership produces a truly sustainable project that contributes positively to the world around it.

The Leadership section includes 11 credits and 182 points, representing 18 percent of the total points available. Based on the review, the Program could potentially earn between 129 and 148 points by pursuing 10 credits. Those credits are outlined in Table 3 below, which also provides topics, notes, and/or documentation that would likely be included in the credit package and action items, next steps, or future considerations to work toward submitting the credit for verification.

Table 3. Leadership Credits

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations

LD1.1: Provide Effective Leadership and Commitment	Conserving	• Arlington County
		  • Facility Sustainability Policy
		  • Community Energy Plan (CEP); goal for Arlington to be a carbon-neutral community by 2050
		  • Green Building Incentive Policy for Site Plan Projects
			• All key members of the project team provide evidence showing they have made organizational commitments to sustainability: in their businesses, not project-specific

LD1.2: Foster Collaboration and Teamwork	Conserving	• Sustainability Workgroup; meetings, etc. • Inclusion of diverse group, operations and maintenance (O&M) staff	• Keep criteria in mind going forward

LD1.3: Provide for Stakeholder Involvement	Restorative	• Public involvement (PI) leadership
		• The County has a well-documented engagement process
		• Criterion E: Feedback is sought from stakeholders as to their satisfaction with the engagement process, and the resulting decisions were made "based on their input."
		  • Reduction of noise for lime delivery
		  • Stakeholder involvement has informed four feedback categories: noise, odor, emissions, visual
			• Continue to gather feedback and consider/document how public input influences or validates solutions
			• Determine how to show that our decisions were based upon stakeholder issues; stakeholder satisfaction

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
		• Criterion F: Partner—Arlington Transit, potential beneficial use of biogas	
LD1.4: Pursue Byproduct Synergies	Restorative	• Class A fertilizer product that can be marketed to the community • High-quality soil amendment available to agriculture and community • RNG generated by the process can be reused on site for power generation or off site for vehicle fuel • Potential for future phosphorus harvesting can be considered • Potential for future receiving of fats, oils, and greases (FOG) to generate additional RNG	• Review once final decisions are made for byproduct use
LD2.1: Establish a Sustainability Management Plan	Superior–Conserving	• Program sustainability goals • Project-specific SMP • Include Envision work plan	• Draft Sustainability Management Plan, including Envision work plan and contractor action plan
LD2.2: Plan for Sustainable Communities	Conserving–Restorative	• Reference to goals in County plans and Solids Master Plan	• No action items
LD2.3: Plan for Long-Term Monitoring and Maintenance	Conserving	• Comparison of new facilities vs. using existing facilities; evaluation criteria • CIP: implement more effective technology that will reduce the need for maintenance • Show how Monitoring Plan drives decisions regarding operations	• Consider/document how monitoring and maintenance plan supports sustainability performance targets • Discuss O&M staffing plan for upgrades
LD2.4: Plan for End-of-Life	Improved (or better)	• TBD	• Consider pursuing • Discuss what an “end-of-life” plan might include, such as a table with anticipated end-of-life for components/equipment • Document discussions around adaptability and plans for expansion in the future
LD3.1: Stimulate Economic Prosperity and Development	Superior	• Biosolids: fertilizer product • Increased capacity; meeting regulations • Criterion C: reducing carbon footprint—less negative impact; reducing truck traffic; biogas—expanding offerings • Criterion D: helping Arlington meet its sustainability goals	• No action items

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
LD3.3: Conduct a Life-Cycle Economic Evaluation	Enhanced–Restorative	• Solids master plan • Gas utilization life-cycle cost analysis (LCCA) (component) sustainable return on investment (SROI)	• Review credit criteria and connect to Solids Master Plan, gas utilization LCCA (component) SROI, and other previous assessments/evaluations

No Leadership credits would be submitted as "not applicable" and excluded from scoring.

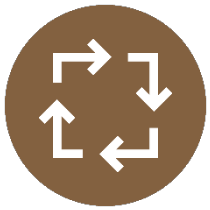
The project would likely not earn any points for the following credit:

- LD3.2: Develop Local Skills and Capabilities
    - Likely not to pursue because of specific criteria requirements
    - This credit focuses on training programs, particularly those that target local skill gaps

Innovation credit: The assessment concluded that an Innovation credit could be submitted for Leadership: LD0.0. Content for this credit could include:

- Additional information related to byproduct synergies, noting that only a handful of organizations are doing biogas utilization for 2 points

3.4.3 Resource Allocation



The Resource Allocation category recognizes natural resources as assets that are needed to build and operate infrastructure. This category is broadly concerned with the quantity, source, and characteristics of these resources and their impacts on the overall sustainability of the project. Resources addressed include physical materials (both those that are consumed and those that leave the project), energy, and water use. Projects earn points for treating these finite resources as assets and showing that they are used respectfully.

The Resource Allocation section includes 13 credits and 196 points, representing 20 percent of the total points available. Based on the review, the Program could potentially earn at least 70 points by pursuing 11 credits. Those credits are outlined in Table 4 below, which also provides topics, notes, and/or documentation that would likely be included in the credit package and action items, next steps, or future considerations to work toward submitting the credit for verification.

Table 4. Resource Allocation Credits

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
RA1.2: Use Recycled Materials	Improved (or better)	• Include building reuse if applicable • Include reuse of gravity thickeners • Reference Department of Solid Waste zero waste policy; how does it apply to this project?	• After alternative is selected, assess what structures will be reused and which types of materials will be used in the project that could contain recycled content • Record if any materials were selected because of including recycled content • Calculate (estimated) percentage of recycled/reused materials vs. overall materials • Investigate/evaluate the Department of Solid Waste's zero waste policy and determine if anything has to be done for this project • Consider higher LOA
RA1.3: Reduce Operational Waste	Conserving	• Operational waste: biosolids product (higher-quality biosolids than produced by existing processes), energy, wastewater (back to creek or used for process) • Only landfilled waste would be screenings; estimate vs. total waste produce • Reference County operational waste policy, update to Solid Waste Management Plan • County Zero Waste Resolution (11/19/2015)	• Calculate percentage of screenings that will go to landfill, to use in calculation of the percentage of waste that is diverted from landfill

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
RA1.4: Reduce Construction Waste	Enhanced: superior	• Specifications: construction waste diversion goal and require a Construction Waste Management Plan • Construction Waste Management Plan document	• Determine what previous projects have done regarding construction waste • Assess what types of waste will be generated during construction • Determine potential for Department of Solid Waste processing of asphalt and concrete recycling on site • If available, determine quantities • Confirm construction waste diversion goal (75%?) • Develop specifications outlining construction waste diversion goal and contractor requirements for developing a Construction Waste Management Plan to fulfill Envision criteria
RA1.5: Balance Earthwork On Site	Improved (or better)	• Earthwork required because of hill • Goal would be to reuse soil on site, but likely have to haul off soil	• After alternative is selected, determine amount of earthwork needed • Determine if any related requirements will be outlined for the delivery team; determine if these would create any cost implications • Determine if the County has any nearby location that could use any extra soil • Consider higher LOA

RA2.1: Reduce Operational Energy Consumption	Improved (or better)	• Determine baseline: existing facility or equipment alternatives
		• There is an ISI calculator for this calculation
		• Calculation may be based on equipment selection, showing that the selected alternative uses less energy than other seriously considered alternatives
		• Reference CIP: "Implement more effective technology that will be more energy efficient; recover energy from the wastewater process—energy recovered in the form of methane may be utilized to power the ART fleet, reduce the Plant's energy footprint, and/or sold back into the power grid or to Washington Gas as renewable natural gas."
			• Determine operational energy uses:
			  • Equipment
			  • Lighting
			  • What type of lighting is used in existing facility, i.e., fluorescent vs. light-emitting diode (LED)?
			  • How will lighting type change because of project? (Previously said more lighting will be added)
			  • Cooling options
			  • Heating, ventilation, and air conditioning (HVAC)
			• Look at RA2.1 calculator to determine inputs and do a preliminary calculation
			• Consider higher LOA

RA2.2: Reduce Construction Energy Consumption	Enhanced	• There is an ISI calculator for this calculation • County truck idling policy • Specifications: re: contractor to implementation of energy reduction strategies	• Conduct a review to identify/analyze potential options for reducing energy consumption during construction

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
		• Information about contractor energy reduction strategies	• Develop specifications outlining contractor requirements to implement at least 2 energy reduction strategies to fulfill Envision criteria
RA2.3: Use Renewable Energy	Restorative	• There is an ISI calculator for this calculation • Note that this credit is referenced in the manual for offsetting the project's energy needs through renewal energy • Making energy on site via biogas; used to offset fossil fuels in transportation vehicles	• Contact ISI to discuss; ask ISI about this credit re: Study/LCC done to determine the biggest value and best GHG reduction. • Look at RA2.3 calculator to determine inputs and do a preliminary calculation
RA2.4: Commission and Monitor Energy Systems	Enhanced	• There is an ISI calculator for this calculation • Systems in place for energy monitoring at current WPCP for 100% of energy usage; Business Intelligence (BI) dashboard with all energy/electricity usage • Commissioning is required	• Look at RA2.4 calculator to determine inputs and do a preliminary calculation
RA3.1: Preserve Water Resources	Enhanced	• Reference site planning • Use of plant effluent water (PEW) vs. potable water when possible • Reduced amount of lime trucked on site • County Comprehensive Plan: Stormwater Management Plan, Chesapeake Bay preservation plan, Water Distribution Management Plan • May reference Watershed Retrofit Study • MS4 permit compliance on site	• Estimate water use and wastewater generation over the life of the project)
RA3.3: Reduce Construction Water Consumption	Improved	• Project team planning review • Specifications: re: construction water monitoring or other water reduction strategy(s)	• Conduct a review to identify/analyze potential options for reducing water consumption during construction • Develop specifications outlining contractor requirements for implementing one potable water conservation strategy, likely water monitoring
RA3.4: Monitor Water Systems	Enhanced	• Systems in place to monitor water at current plan	• No action items

No credits would be submitted as “not applicable” and excluded from scoring.

The project would likely not earn any points for the following credits:

- RA1.1: Support Sustainable Procurement Practices

- Likely not to pursue because of specific criteria requirements and additional level of effort needed

- RA3.2: Reduce Operational Water Consumption
  - Likely not to pursue because project upgrades will use more water during operation than the existing facility

Innovation credit: The assessment concluded that an Innovation credit could be submitted for Resource Allocation: EA0.0. Content for this credit could include:

- Biofuel analysis/study for 2 points
- Energy analysis for process cooling needs for 2 points

3.4.4 Natural World

The Natural World section addresses the impacts that infrastructure projects have on the natural world around them, including habitats, species, and non-living natural systems. The way a project is located within these systems and the new elements they may introduce to a system can create unwanted impacts. This Natural World section rewards projects that understand and minimize negative impacts while incorporating ways in which the project interacts with natural systems in a synergistic, positive way.

The Natural World section includes 13 credits and 232 points, representing 23 percent of the total points available. Based on the review, the project could potentially earn at least 30 points by pursuing four to five credits. Those credits are outlined in Table 5 below, which also provides topics, notes, and/or documentation that would likely be included in the credit package and action items, next steps, or future considerations to work toward submitting the credit for verification.

Table 5. Natural World Credits

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
NW1.4: Preserve Undeveloped Land	Conserving	• Proposed facilities fit within existing WPCP site	• No action items
NW2.2: Manage Stormwater	TBD	• Project may pursue credit after additional review • Reference County stormwater goals; Comprehensive Plan • Compare criteria to what is required for permitting	• Compare criteria to what is required for permitting to determine which, if any LOA could be pursued
NW2.3: Reduce Pesticide and Fertilizer Impacts	Conserving	• Specify plants shall not require pesticides or fertilizers • Reference County Comprehensive Plan and specification; website resources for verification of native plants • Reference landscaping contracts, if applicable	• Look at Arlington's landscaping contracts to determine if there is any language related to reduced fertilizer and/or native plants • Develop specifications outlining planting of native plants that do not require pesticides or fertilizers to fulfill Envision criteria
NW2.4: Protect Surface and Groundwater Quality	Improved	• Reference Solids Master Plan • Spill and leak diversion systems, spill prevention plans, and cleanup protocols	• No action items
NW3.4: Control Invasive Species	Enhanced–Superior	• Reference best practices should be used to prevent unintentional introduction of invasive species • Invasive-species site investigation map/report • Reference urban forest master plan	• HDR environmental specialist to identify, map, and/or document invasive-species infestations on site • Determine if the County has any policies or practices that would apply to this credit/site • Consider conserving LOA if documentation already exists

Seven credits would likely be submitted as “not applicable” and excluded from scoring:

- NW1.1: Preserve Sites of High Ecological Value
- NW1.2: Provide Wetland and Surface Water Buffers
- NW1.3: Preserve Prime Farmland
- NW2.1: Reclaim Brownfields
- NW3.1: Enhance Functional Habitats
- NW3.2: Enhance Wetland and Surface Water Functions
- NW3.3: Maintain Floodplain Functions

The project would likely not earn any points for the following credit:

- NW3.5: Protect Soil Health
    - Likely not to pursue because of specific criteria requirements and additional level of effort needed

Innovation credit: The assessment did not bring up any opportunities for the Innovation credit during the workshop. There may be opportunities for innovation points for Natural World: NW0.0. This topic will be revisited as the project progresses.

3.4.5 Climate and Resilience

The Climate and Resilience category focuses on minimizing emissions that may contribute to increased short- and long-term risks and ensuring resilience to short-term hazards or adaptability to long-term future conditions.

The Climate and Resilience section includes nine credits and 190 points, representing 19 percent of the total points available. Based on the review, the project could potentially earn between 74 and 99 points by pursuing seven credits. Those credits are outlined in Table 6 below, which also provides topics, notes, and/or documentation that would likely be included in the credit package and action items, next steps, or future considerations to work toward submitting the credit for verification.

Table 6. Climate and Resilience Credits

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
CR1.2: Reduce Greenhouse Gas Emissions	Improved (or better)	• Baseline: existing condition (over a period equivalent to the operational life of the project) • Solids reduced by 50% resulting in less truck traffic and hauling costs • Reference project-related GHG analysis • Reference CEP • Reference CEP Analysis for the Solids Master Plan	• Ongoing work re: GHG emissions
CR1.3: Reduce Air Pollutant Emissions	Improved (or better)	• Baseline: TBD • Reduced product odors • Solids Master Plan: Appendix K Air Emissions Modeling Report • Reference project-related air pollutant emissions analysis	• Ongoing work re: air pollutant emissions
CR2.2: Assess Climate Change Vulnerability	Improved–Superior	• Reference Comprehensive Plan: CEP; Climate Action Resolution; Climate Change, Energy, and Environment Commission (C2E2); Arlington Emergency Operations Plan; Northern Virginia Hazard Mitigation Plan Update; and Virginia Coastal Resilience Master Planning Framework	• Compile related information from available reports • Use HDR resilience review format to include information needed for related Envision criteria
CR2.3: Evaluate Risk and Resilience	Improved–Enhanced	• Additional discussions needed after project alternative selected • There are two ongoing projects on evaluating flood risk and mitigating strategies: one by the Arlington County Department of Environmental Services and one by the U.S. Army Corps of Engineers	• TBD

Credit	Targeted LOA	Credit Topics, Notes, and Documentation	Action Items, Next Steps, and Future Considerations
CR2.4: Establish Resilience Goals and Strategies	Conserving	• Additional discussions needed after project alternative selected	• TBD
CR2.5: Maximize Resilience	Improved–Enhanced	• Additional discussions needed after project alternative selected	• TBD
CR2.6: Improve Infrastructure Integration	Conserving–Restorative	• Additional discussions needed after project alternative selected	• TBD

One credit would likely be submitted as "not applicable" and excluded from scoring:

- CR2.1: Avoid Unsuitable Development

The project would likely not earn any points for the following credit:

- CR1.1: Reduce Net Embodied Carbon
    - Likely not to pursue because of specific criteria requirements and additional level of effort needed

Innovation credit: The assessment did not bring up any opportunities for the Innovation credit during the workshop. There may be opportunities for innovation points for Climate and Resilience: CR0.0. This topic will be revisited as the project progresses.

4.0 Envision Application

Because this Program is still in the facilities planning phase, the Envision process can be used to inform design decisions and construction guidelines. The following provides an overview of how Envision could be approached for the Program at the current stage.

The Envision process is managed by the Envision Lead (or Lead Envision Sustainability Professional [ENV SP]). This person is a Program team member and a professional credentialed through ISI and familiar with the Envision framework. The Envision Lead ensures that Envision discussions continue throughout the Program and related design decisions are documented, develops a plan for obtaining and organizing needed documentation, coordinates development of submittal materials, submits information for verification, and interfaces with ISI and the verifier as needed.

4.1 Potential Improvement Areas

"Potential improvement areas" are considered changes to processes, scope, design, and specifications that will improve Program sustainability and offer opportunities for the Program to rate more favorably when verified with Envision. These are items that likely would not have been included if the Program had not completed an Envision assessment. The items mentioned are not required by Envision, but are meant to start a conversation into the larger perspective of Program and community sustainability. During the assessment, specific discussions occurred for each credit regarding additional level of effort and potential for scope and/or Program changes. For example, at the Envision workshop, there was discussion about setting a construction waste diversion goal, challenging the contractor to implement two energy reduction strategies, and specifying plants that do not require pesticides or fertilizers. See credit-specific action items, next steps, and future considerations for each category in Section 3.4.

4.2 Documentation Requirements

Achieving Envision recognition is dependent upon providing a third-party verifier with a clear narrative description of how the Program meets the evaluation criteria of each credit, and providing documentation to support these assertions. For some credits, existing documents are available that can be used as supporting evidence to fulfill the credit requirements. For example, excerpts from the Solids Master Plan can be used as part of the documentation for multiple credits. Stakeholder engagement documentation also supports multiple credits. See .

For other credits, required documentation will be available as the Program progresses, as a result of either design or construction. An example of this might be RA1.2: Use Recycled Materials. Stating that structures will be reused or that materials contain recycled content is not adequate to earn points for this credit. Documentation requirements include inventories for both materials containing recycled and existing materials or structures being reused. This includes weight, volume, or cost so that the percentage of reused and/or recycled materials relative to total materials used on the Program can be calculated. In this case, because the Program plans to submit the design for verification review prior to construction, credit documentation would need to show Program specifications requiring reuse or procurement of materials and estimates of identified structures/materials.

Finally, there are some credits for which the Program may meet the credit intent but gathering the supporting documentation would not be feasible or would require too great an effort for the benefit of the additional points. For example, for RA 1.1: Support Sustainable Procurement Practices, the County

mentioned that it has been talking about which vendors have green practices, but there is not a formal program in place. While the Program may be able to show that a modest amount of materials are purchased from manufacturers or suppliers that demonstrate sustainable practices, the criteria call for evidence of written procurement policies, an inventory of materials, and documentation from manufacturers and suppliers. As such, this credit was deemed "likely not to pursue" during the assessment because the costs and level of effort outweigh the benefit. Based on policy acceptance and the County's recent membership to Sustainable Purchasing Leadership Council, the project team could revisit if the credit requirements could be met. This would include assessing manufacturer and supplier practices, inventorying materials and calculating the percent of materials that meet the sustainable policy requirements.

4.3 Steps for Envision Documentation and Verification

This section outlines steps for Envision documentation and verification.

4.3.1 Project Registration

The following are tasks for project registration:

- Projects may be registered at any time in the process, although documentation typically cannot be submitted for the design review in Pathway A until design is at least at 95 percent completion. A new project needs to be created in the ISI system. The ISI project record includes a score sheet that will be updated to include the targeted LOA for each credit. The LOA can be changed at any time.
- Using the online project record, the project is registered and the registration fee ($2,000 for all projects) is invoiced. The Envision Lead will input project details into the record, including project cost, project team, and description, as well as estimated design and construction completion timing, so that ISI can understand when a verifier might need to be assigned.

4.3.2 Design Submittal Credit Writing and Compiling Documentation

The following are tasks for design submittal credit writing and compiling documentation:

- To support each credit at the targeted LOA, a narrative will be developed to describe how the project meets the evaluation criteria. This is done using ISI-provided credit cover sheets.
- In addition to the narrative, supporting documentation for each evaluation criterion must be included to enable the verifier (selected by ISI) to validate the LOA.
- For Pathway A (pre-construction verification), this process takes place at the end of the design phase and is submitted after 95 percent design completion. Credits that will need to be confirmed after construction will be marked as "pending" in the scorecard. For credits marked "pending," narratives and additional supporting documentation will need to be submitted after 95 percent construction completion.

4.3.3 Submittal of Documentation for Verification

The following are tasks for submittal of documentation for verification:

- The online score sheet is completed and all credit documentation is uploaded.
- The project team submits the Verification Quality Assurance Checklist to ISI, along with a project description and project boundary map.
- Once the project is submitted, a verification invoice will be generated.

- The verification fee is based on project size. For projects ranging from $25 million to $100 million, the verification fee is $26,000 (Pathway A, member pricing). For projects ranging from $100 million to $250 million, the verification fee is $33,000 (Pathway A, member pricing).

4.3.4 Verification

The following are tasks for verification:

- The verifier reviews the credit documentation and communicates with ISI for any clarification or additional information that may be needed.
- The verifier and ISI develop a round 1 review score and recognition level, along with providing comments for any credits that may not have achieved the desired LOA.
- The project team has the opportunity to submit additional documentation for credits needing additional explanation or documentation for a second review.

4.3.5 Authentication

The following are tasks for authentication:

- ISI reviews and authenticates the verifier's score.
- The project team completes the verification closeout. If using Pathway A, the project would begin to prepare for the post-construction submittal.

4.3.6 Recognition

The project team works with ISI to prepare a press release and determines plans for an award ceremony or celebration to be recognized for its Envision verification.

4.3.7 Preparation for Post-construction Submittal/Monitoring Documentation through Construction

The following are tasks for preparation for post-construction submittal/monitoring documentation through construction:

- The project team compiles a document to guide documentation collection and credit content for pending credits, to be submitted at substantial construction completion
- The project team continues documentation collection throughout construction.

4.3.8 Post-construction Submittal Credit Writing and Compiling Documentation

The following are tasks for post-construction submittal credit writing and compiling documentation:

- To support each pending credit at the targeted LOA, the project team develops a narrative to describe how the project has met the construction-related evaluation criteria. This is done using ISI-provided credit cover sheets.
- The project team must include supporting documentation outlined in the design-review credits/post-construction guidance document for each pending credit to confirm achievement of LOA.

4.3.9 Complete Project Verification Process

The project concludes once the final score is returned to the project team.

5.0 Discussion and Next Steps

This section presents a discussion of additional information and next steps.

5.1 Leverage the Envision Framework

The project team should use the Envision framework to ensure that the project is meeting sustainability goals and striving not only to reduce impacts, but also to provide environmental, social, and economic benefits to the community. Design discussions should continue to reference Envision credits that can influence and improve design decisions and project solutions, including and beyond those listed under credit-specific action items, next steps, and future considerations described for each category in Section 3.4.

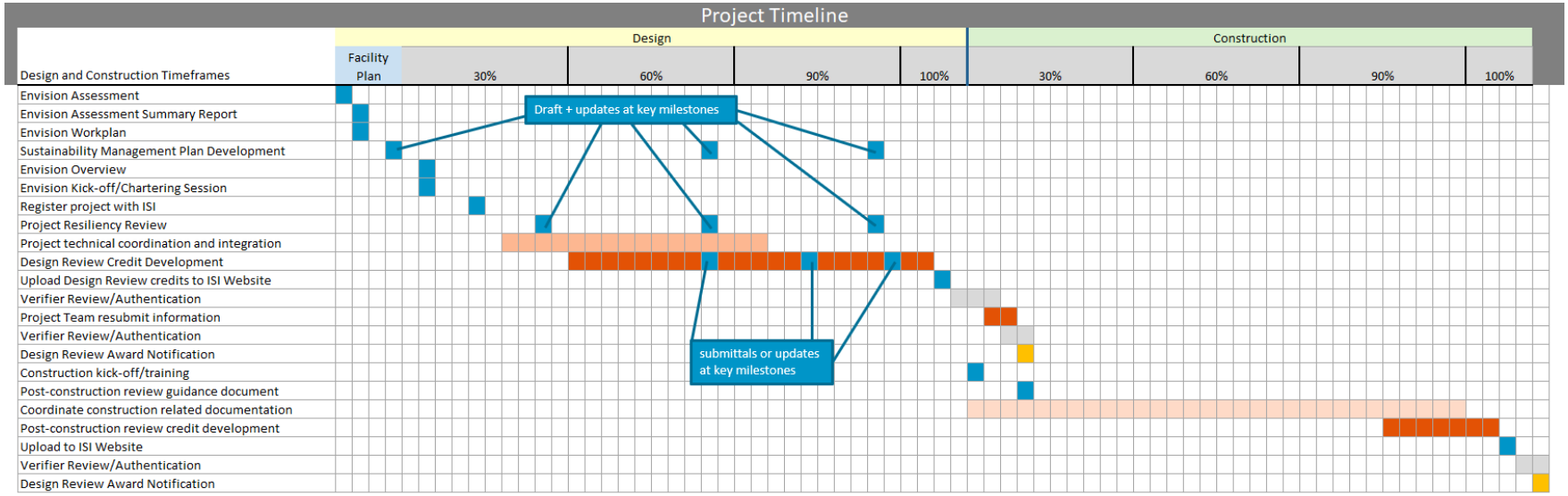
The project team should consider how to best leverage submitting for Innovation credits in the five Envision categories. Innovation credits award additional points for projects that exceed credit requirements or pilot innovative methods, applications, or technologies.

5.2 Project Documentation and Verification

Based on assessment and Envision workshop discussion, alternative selection, and costs associated with potential additional effort, the Envision team will continue to narrow the LOA range for each credit. The project team should periodically reassess the assessment to consider if any credits currently identified as pursuable become unachievable or result in too great an additional level of effort.

5.2.1 Credit Development Schedule

The Envision Lead will create a preliminary Envision Work Plan and Schedule (Figure 7) for inclusion in the project's Sustainability Management Plan that outlines the recommended sequence of credit development based on types of documentation available throughout the project process. This will allow credit development to be spread out over a period of time, depending on when the information is available to complete the documentation.



* Estimated - Driven by third-party verifier and ISI

Figure 6. Preliminary Credit Development Schedule

5.2.2 Collecting Documentation

During the Envision workshop, the Sustainability Workgroup discussed a process for gathering and storing documentation that may be needed to support credit narratives. It was determined that a folder structure will be developed on the project Teams site to serve as a document repository. This folder structure will include a general documentation folder for documents that may apply to credits in multiple categories and folders for each category. A documentation log will be developed to list the documents and note to which credits each will likely apply.

Types of documentation include the following:

- Solids Master Plan
- Project-related studies and reports
- Public involvement information
- Design documents/specifications
- Meeting minutes
- Presentations
- County policies/procedures

Once credit writing begins, the project team will designate someone as the Envision team's designated point of contact (POC) for project documentation. This will allow the Envision Lead to direct documentation requests to one person knowledgeable about the project who can locate and/or provide documentation needed to successfully complete the Envision credit packages.

5.2.3 Envision Administration

The Envision Lead should organize credit documentation, facilitate quality reviews, and communicate with the project team to ensure that the process stays on schedule. It is helpful to schedule regular status update calls or progress reports to convey credit package progress and stay informed on project progress and changes that may affect the Envision documentation.

It is beneficial to maintain a status document for all credits being pursued so that information is easily accessible or transmittable to the project team as needed.

5.2.4 Envision Support

HDR's staff has successfully worked with clients on numerous Envision projects—through both the assessment and documentation phases. This has prompted development of numerous tools and resources that are used to streamline facilitation of the Envision process. These tools will be leveraged throughout the documentation and verification process.

Appendix A. Overview of Envision Framework

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ENVISION™

Envision® **v3** Sustainable Infrastructure Framework

The framework provides a **flexible system of criteria and performance objectives** to aid decision makers and help project teams identify sustainable approaches during planning, design, and construction that will carry forward throughout the project's operations and maintenance and end-of-life phases.

Envision Benefits

Economic

- Consideration of future expansion
- Extend useful life of project
- Lower heating bills
- Lower O&M costs
- Reduce energy and water costs
- Reduce wastewater fees
- Return on investment

Societal

- Create more livable communities
- Demonstrating good governance to voters, taxpayers, or ratepayers
- Develop durable infrastructure, with less maintenance
- Improve/increase local job market
- Improve business environment
- Improve community safety, mobility, recreational opportunities
- Increase community/stakeholder involvement in process
- Integrate into the local environment
- Preserve community culture/ history
- Reduce construction impacts
- Reduce environmental impacts
- Reduce noise

Environmental

- Conserve energy and water
- Optimize resource efficiency
- Preserve greenfields/redevelop brownfields
- Reduced air pollution
- Reduce greenhouse gas emissions
- Reduce light pollution
- Reduce stormwater runoff
- Reduce waste sent to landfills
- Source local materials
- Use materials more efficiently
- Use recycled materials

Other

- Calibrate internal assessment against a common set of sustainability criteria
- Demonstrate commitment to environmental stewardship and social responsibility
- Improve public perception
- Strengthen inter-agency and project team collaboration

PURPOSE OF ENVISION

The purpose of Envision is to foster the dramatic and necessary improvement in the sustainable performance and resiliency of physical infrastructure by helping owners, planners, engineers, communities, contractors, and other infrastructure stakeholders to implement more cost-effective, resource-efficient and adaptable long-term infrastructure investments.

ENVISION BACKGROUND

Institute for Sustainable Infrastructure

Envision was created by a strategic alliance of the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure (ISI). ISI is a not-for-profit education and research organization, dedicated to developing and maintaining a civil infrastructure rating system, and was formed by the American Council of Engineering Companies, the American Public Works Association and the American Society of Civil Engineers.

WHERE DOES ENVISION APPLY?

- Designed as a holistic framework for all types and sizes of both public and private infrastructure
- Covers project in energy, water, waste, transportation, landscape, information and other civil infrastructure
- Not intended to evaluate interior, conditioned, buildings with the primary purpose of human occupation
- Has been applied extensively throughout the U.S. and Canada but is applicable, and has been used, all over the world
- Used by infrastructure owners, design teams, community groups, environmental organizations, constructors, regulators and policy makers

STRUCTURE

Credit Categories & Subcategories

1 | Quality of Life – Wellbeing, Mobility, Community

2 | Leadership – Collaboration, Planning, Economy

3 | Resource Allocation – Materials, Energy, Water

4 | Natural World – Siting, Conservation, Ecology

5 | Climate and Resilience – Emissions, Resilience

Levels of Achievement

1 | Improved – Performance that is above conventional.

2 | Enhanced – Sustainable performance that is on the right track.

3 | Superior – Sustainable performance at a very high level.

4 | Conserving – Performance that has achieved essentially zero negative impact.

5 | Restorative – Performance that restores natural or social systems.

Innovation Points

Potential points awarded in each category for methods that advance sustainable infrastructure practices or show exceptional performance beyond expectations.

VERIFICATION

Registration and Verification Fees

Registration: $2,000

Verification: Fees based on project size, membership and verification pathway. HDR is a member of ISI and can register client project's to receive member pricing.

Verification Pathways

Projects may pursue verification either after:

- The design phase (at or after 95% design completion)
- The construction phase (at or after 95% construction completion).

Projects pursuing verification after the design phase will be required to complete an additional post-construction review follow-up.

The post-construction review is required to maintain the Envision award earned after the design phase. The purpose of the post-construction review is to validate that commitments made in the planning and design stages of the project were carried through during construction

Project Award Levels

To receive recognition, projects must achieve a minimum percentage of the total applicable Envision points. Projects can be recognized at four levels.

- Verified: 20%
- Silver: 30%
- Gold: 40%
- Platinum: 50%

ENVISION v3 POINTS TABLE

			Improved	Enhanced	Superior	Conserving	Restorative
QUALITY OF LIFE	PURPOSE	QL1.1 Improve Community Quality of Life	2	5	10	20	26
		QL1.2 Enhance Public Health and Safety	2	7	12	16	20
		QL1.3 Improve Construction Safety	2	5	10	14	-
		QL1.4 Minimize Noise and Vibration	1	3	6	10	12
		QL1.5 Minimize Light Pollution	1	3	6	10	12
		QL1.6 Minimize Construction Impacts	1	2	4	8	-
	WELLBEING	QL2.1 Improve Community Mobility and Access	1	3	7	11	14
		QL2.2 Encourage Sustainable Transportation	-	5	8	12	16
		QL2.3 Improve Access and Wayfinding	1	5	9	14	-
	COMMUNITY	QL3.1 Advance Equity and Social Justice	3	6	10	14	18
		QL3.2 Preserve Historic and Cultural Resources	-	2	7	12	18
		QL3.3 Enhance Views and Local Character	1	3	7	11	14
		QL3.4 Enhance Public Space and Amenities	1	3	7	11	14
					Maximum QL Points	200*	
LEADERSHIP	COLLABORATION	LD1.1 Provide Effective Leadership and Collaboration	2	5	12	18	-
		LD1.2 Foster Collaboration and Teamwork	2	5	12	18	-
		LD1.3 Provide for Stakeholder Involvement	3	6	9	14	18
		LD1.4 Pursue Byproduct Synergies	3	6	12	14	18
	PLANNING	LD2.1 Establish a Sustainability Management Plan	4	7	12	18	-
		LD2.2 Plan for Sustainable Communities	4	6	9	12	16
		LD2.3 Plan for Long-Term Monitoring and Maintenance	2	5	8	12	-
		LD2.4 Plan for End-of-Life	2	5	8	14	-
	ECONOMY	LD3.1 Stimulate Economic Prosperity and Development	3	6	12	20	-
		LD3.2 Develop Local Skills and Capabilities	2	4	8	12	16
		LD3.3 Conduct a Life-Cycle Economic Evaluation	5	7	10	12	14
					Maximum LD Points	182*	
RESOURCE ALLOCATION	MATERIALS	RA1.1 Support Sustainable Procurement	3	6	9	12	-
		RA1.2 Use Recycled Materials	4	6	9	16	-
		RA1.3 Reduce Operational Waste	4	7	10	14	-
		RA1.4 Reduce Construction Waste	4	7	10	16	-
		RA1.5 Balance Earthwork On Site	2	4	6	8	-
	ENERGY	RA2.1 Reduce Operational Energy Consumption	6	12	18	26	-
		RA2.2 Reduce Construction Energy Consumption	1	4	8	12	-
		RA2.3 Use Renewable Energy	5	10	15	20	24
		RA2.4 Commission and Monitor Energy Systems	3	6	12	14	-
	WATER	RA3.1 Preserve Water Resources	3	5	7	9	12
		RA3.2 Reduce Operational Water Consumption	4	9	13	17	22
		RA3.3 Reduce Construction Water Consumption	1	3	5	8	-
		RA3.4 Monitor Water Systems	1	3	6	12	-
					Maximum RA Points	196*	
NATURAL WORLD	SITING	NW1.1 Preserve Sites of High Ecological Value	2	6	12	16	22
		NW1.2 Provide Wetland and Surface Water Buffers	2	5	10	16	20
		NW1.3 Preserve Prime Farmland	-	2	8	12	16
		NW1.4 Preserve Undeveloped Land	3	8	12	18	24
	CONSERVATION	NW2.1 Reclaim Brownfields	11	13	16	19	22
		NW2.2 Manage Stormwater	2	4	9	17	24
		NW2.3 Reduce Pesticide and Fertilizer Impacts	1	2	5	9	12
		NW2.4 Protect Surface and Groundwater Quality	2	5	9	14	20
	ECOLOGY	NW3.1 Enhance Functional Habitats	2	5	9	15	18
		NW3.2 Enhance Wetland and Surface Water Functions	3	7	12	18	20
		NW3.3 Maintain Floodplain Functions	1	3	7	11	14
		NW3.4 Control Invasive Species	1	2	6	9	12
		NW3.5 Protect Soil Health	-	3	4	6	8
					Maximum NW Points	232*	
CLIMATE & RESILIENCE	EMISSIONS	CR1.1 Reduce Net Embodied Carbon	5	10	15	20	-
		CR1.2 Reduce Greenhouse Gas Emissions	8	13	18	22	26
		CR1.3 Reduce Air Pollutant Emissions	2	4	9	14	18
	RESILIENCE	CR2.1 Avoid Unsuitable Development	3	6	8	12	16
		CR2.2 Assess Climate Change Vulnerability	8	14	18	20	-
		CR2.3 Evaluate Risk and Resilience	11	18	24	26	-
		CR2.4 Establish Resilience Goals and Strategies	-	8	14	20	-
		CR2.5 Maximize Resilience	11	15	20	26	-
		CR2.6 Improve Infrastructure Integration	2	5	9	13	18
					Maximum CR Points	190*	

Maximum TOTAL Points: 1,000*

*Not every credit has a restorative level. Therefore totals include the maximum possible points for each credit whether conserving or restorative.

May 2018

Appendix B. Envision Credit Review Workbook

Note that credit and project LOAs are anticipated based on the initial assessment and Envision workshop discussions on September 30, 2021, but actual LOAs may vary depending on future decisions and available documentation, as well as the verifier review process.

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ISI ENVISION 3.0 CREDITS

**If the "Not Applicable" selection has an asterisk, it would be difficult to demonstrate that the credit is not applicable to a project - per the Envision v3 Guidance Manual.*

Stakeholder | Need additional review

ALL CREDITS *- The team will decide whether or not to exclude a credit and must provide a clear justification if a credit is deemed not applicable to a project.*

CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
QUALITY OF LIFE	PURPOSE	**QL1.1 Improve Community Quality of Life**	A + B	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F	A + B + C + D + E + F + G
		Projected Level of Achievement (Low) **(20) Holistic assessment and collaboration**	(2) Community Considerations	(5) Community Linkages	(10) Broad Community Alignment	(20) Holistic Assessment and Collaboration	(26) Protecting The Future
		Projected Level of Achievement (High) **(20) Holistic assessment and collaboration**	**(A) The project team identifies and takes into account community needs, goals, and issues. For example, the project team has located and reviewed the most recent community planning information and assessed relevant community needs, goals, and/or issues.** **(B) The project meets or supports community needs and/or goals.** **(C) The project assesses the social impacts it will have on the host and affected communities' quality of life.** **(D) The affected communities are meaningfully engaged in identifying how the project supports community needs and/or goals.** **(E) Based on the social assessment, potential negative impacts on the host or nearby affected communities are mitigated following a hierarchy that prioritizes avoidance, minimization, restoration, and offsetting.** **(F) Community satisfaction is demonstrated by feedback from the stakeholder engagement process verifying actions taken in criteria A, B, C, and D.** (G) The project proactively addresses trends in changing social, economic, and/or environmental conditions within the community in order to ensure a high quality of life over the long term.				
		Notes: Goals from the Solids Master Plan - Replacing failing and end of life equipment - Mitigating the risk of potential future regulatory changes to the current practice of recycling Class B biosolids through application to agricultural land - Providing a solution that reduces the energy and greenhouse gas footprint of the WPCP - **Achieving additional County-wide sustainability goals** - Developing a solids management strategy that offers long-term reliability - Establishing an implementation plan compatible with County CIP funding Plan supports the Chesapeake Bay Preservation Ordinance, a statewide program to help restore the bay to health Incorporate poll/survey to ask about stakeholder engagement/satisfaction. Potential for website where community can submit comments.					
		QL1.2 Enhance Public Health and Safety	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low) **(12) Improving Health & Safety**	(2) Understanding Impacts	(7) Prioritizing Risk Reduction	(12) Improving Health & Safety	(16) Shared Benefits	(20) Protecting Communities
		Projected Level of Achievement (High) **(16) Shared Benefits**	**(A) The project meets all health and/or safety regulations and laws for operation.** **(B) The project includes health and/or safety improvements beyond minimum requirements established by regulations and laws.** **(C) The project improves health and/or safety for its immediate surroundings.** **(D) The project demonstrates a net positive impact on health and/ or safety for the host or affected communities.** **(E) The health and safety benefits and/or negative impacts are equitably distributed within affected communities, and the project team can demonstrate that the project does not disproportionately burden one community over another (i.e., social/environmental justice).** (F) The project provides critical infrastructure services to communities experiencing, or at risk of experiencing, imminent, negative health and/or personal safety impacts				
		Notes: Move from a Class B product to a Pathogen free, Class A product Reducing truck traffic SH&E Plan Demographics of customers/area - statistics/map Land application of biosolids - different counties and farms; know where it has been going CIP - Implement more effective technology that will reduce the need for maintenance and reduce safety risks to staff					
		QL1.3 Improve Construction Safety	A + B	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low) **(14) Health Beyond the Site**	(2) Commitment to Safety	(5) Risk Analysis, Training and Security	(10) Safe Work Practices and a Secure Site	(14) Health Beyond the Site	
		Projected Level of Achievement (High) **(14) Health Beyond the Site**	**(A) The owner and general contractor/construction manager have made strong commitments to monitor and improve health and safety for onsite construction operations.** **(B) The project execution plan requires internal documentation that tracks health and safety performance and corrects deficiencies or promotes best practices during construction.** **(C) Contractor implements safety and/or security competency training for all field personnel. Contractor or owner provides minimum training requirements for health and safety programs.** **(D) The owner and contractor have a specific site and project security plan. The plan includes physical security as well as information security when appropriate. The contractor provides minimum training requirements.** (E) The owner or contractor provides programs that promote health and wellbeing, such as free health screenings or workshops.				
		Notes: SITE-SPECIFIC SH&E PLAN - confirm this would be communicated to contractor via specs specs to contractor hired to do the work will be required to develop their own safety plan [Discuss inclination of County toward including Envision requirements in contractor specs] Envision workshop: Mary – County has a lot of internal programs for health screenings, and a new policy has been put into place requiring contractors to either have COVID vaccines or regular COVID testing.					

ISI ENVISION 3.0 CREDITS

**If the "Not Applicable" selection has an asterisk, it would be difficult to demonstrate that the credit is not applicable to a project - per the Envision v3 Guidance Manual.*

Stakeholder | Need additional review

ALL CREDITS *- The team will decide whether or not to exclude a credit and must provide a clear justification if a credit is deemed not applicable to a project.*

CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
QUALITY OF LIFE	WELLBEING	**QL1.4 Minimize Noise and Vibration**	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E
		Projected Level of Achievement (Low)	(1) Noise Assessment	(3) Target Noise Levels	(6) Stakeholder Support	(10) No Noise Increase	(12) Noise Reductions
		(6) Stakeholder Support	**(A) The project team assesses the potential for operational noise impacts on the surrounding community and/or environment. This assessment occurs when applicable vibrations are considered as a potential source of noise and/or disruption.**				
		Projected Level of Achievement (High)	**(B) Strategies are implemented to mitigate noise and/or vibrations during operations. Noise reduction follows a mitigation hierarchy of avoidance/source elimination, minimization, abatement/receiver reduction, and offsetting/compensation.**				
		(10) No Noise Increase	**(C) The project adopts existing, or works with the community to set, target project noise levels for the impacted community**				
		Baseline: Existing facility	**(D) The stakeholder engagement process demonstrates community awareness of targets (i.e. criterion C), mitigation strategies (i.e. criterion B), and noise impacts (i.e. criterion A).**				
		Notes: Any change in noise during operation over existing facility? Less truck traffic, but potentially more noise from equipment; were going to put generators on site, but not using now Noise outlined as an issue at stakeholder meeting	**(E - Conserving) Noise reduction strategies and controls are sufficient to not increase noise within the surrounding community beyond existing conditions.** (E - Restorative) Noise reduction strategies and controls are sufficient to reduce noise within the surrounding community beyond existing conditions.				
		QL1.5 Minimize Light Pollution	A + B	A + B + C	A + B + C + D	A + E	A + E + F
		Projected Level of Achievement (Low)	(1) Light Pollution Reduction	(3) Master Lighting Plan	(6) Eliminating Uplight	(10) Backlight, Uplight, and Glare Reduction	(12) Night Sky Restoration
		(1) Light Pollution Reduction	(A) The project identifies lighting needs and sensitive community and environmental areas potentially impacted by light pollution during operations.				
		Projected Level of Achievement (High)	(B) The project reduces light pollution following a mitigation hierarchy of avoidance, minimization, protection, and offsetting.				
		(1) Light Pollution Reduction	(C) The project implements a master lighting plan establishing lighting zones. For each zone, the plan outlines lighting goals, safety and security needs, specifies environmental conservation, and reduces lighting when no longer needed.				
		Notes: Exterior lighting needs? Inclination to spec lighting requirements, i.e. BUG requirements? More equipment outside, with lighting. Potential for higher LOA; review. Updates to Green Building Incentive Policy: In order to address how buildings interact with nature, the Policy includes three new provisions focused on the relationship between urban development and nature. Finally, minimum light pollution reduction criteria for exterior light fixtures must be met to safely reduce light pollution.	(D) Light emission beyond 90 degrees is prevented. All project lighting meets BUG rating uplight requirements with no light emitted above 90 degrees. (E) All project lighting meets backlight, uplight, and glare requirements according to IES BUG rating standards. (F) The project involves the removal or retrofitting of existing lighting so as to significantly reduce (>10%) overall existing lighting.				
		QL1.6 Minimize Construction Impacts	A + (B, C, D or E)	A + (B, C, D or E)	A + (B, C, D or E) + F	A + B + C + D + E + F	Not Available
		Projected Level of Achievement (Low)	(1) Initial Management Plan	(2) Expanded Plan	(4) Stakeholder Feedback	(8) Complete Plan	
		(8) Complete Plan	(A) The project team implements a **construction management plan** or policies to address the temporary inconveniences associated with construction. The plan or policies are informed by stakeholder engagement.				
		Projected Level of Achievement (High)	(B, C, D, or E) The management plan addresses one (1, 2, 3, or 4) type(s) of construction impact: noise, safety/wayfinding, access/mobility, or lighting.				
		(8) Complete Plan	(F) The construction management plan or policies include robust feedback mechanisms and performance monitoring and reporting for construction impacts.				
		Notes: Discuss inclination of County toward including Envision requirements in contractor specs **Construction management plan Include contractor "Envision Action Plan" SMP/Envision management plan Envision workshop: - Brian – A construction management plan will be required for this project. - Mary – County requires all of these items. - Agree with pursuing conserving level. - We have used signage on the construction fencing to share information with the public.					
		QL2.1 Improve Community Mobility and Access	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(1) Satisfactory Coordination	(3) Controlled Access	(7) Increased Access and Flow	(11) Connected Networks	(14) Restoring Community Connections
		(3) Controlled Access	**(A) The project team demonstrates consistency with local and regional transportation plans.**				
		Projected Level of Achievement (High)	**(B) The project team obtains input from the community and key stakeholders (e.g., public officials and operators of adjacent facilities, amenities, or transportation hubs) regarding improved access.**				
		(3) Controlled Access	**(C) The project includes strategies to increase capacity, manage congestion, reduce vehicle distance traveled, or lower accident rates**				
		Notes: Trucks currently cross eads street and back into plant; new solids loading facilities will be drive through instead of back-in, which will eliminate the needs to back in across Eads street into the plant. Solids reduced by 50% resulting in less truck traffic and hauling costs	(D) The project team works with the community to expand mobility and access options and/or incorporate complete streets policies. (E) The project addresses long-term mobility and access needs of the community. (F) The project creates new or restores previous connections between communities.				

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Stakeholder | Need additional review

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CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
QUALITY OF LIFE	WELLBEING	**QL2.2 Encourage Sustainable Transportation**	Not Available	A	A + B	A + B + C	A + B + C + D
		Projected Level of Achievement (Low)		(5) Access to Transit or Active Transportation	(8) Encourages Transit or Active Transportation	(12) Transit or Active Transportation Programs	(16) New Connections
		(16) New Connections		**(A) The project creates or offers convenient access to shared/mass transportation OR active transportation (e.g., extended contiguous trails and/or bicycle networks).**			
		Projected Level of Achievement (High)		(B) Beyond proximity, the project is configured and designed to encourage the use of active, shared, or mass transportation.			
		(16) New Connections		(C) The project provides programs and/or facilities that support the use of active, shared, or mass transportation.			
		Notes: Bike paths and bike-friendly roads adjacent that connect to trail along river. Consider higher LOA when thinking about "configured" as project processes vs. land use EV charging - plans for EV charging on south side of plant; potential for adding EV charging on north side New prerequisites include renewable energy, **electric vehicle charging,** social equity, and other energy and community sustainability criteria. Trail adjacent to WWTP along river Renewable fuel produced by project		(D) The active and/or shared transportation improvements contribute to a larger integrated transportation strategy for the community or region. The project creates new connections or rehabilitates/repurposes unused, underused, or previously disconnected pathways, bikeways, rail, and/or other modes of transportation to enhance the efficiency, quality, or level of service of the overall network.			
		QL2.3 Improve Access and Wayfinding	A	A + B	A + B + C	A + B + C + D	Not Available
		Projected Level of Achievement (Low)	(1) Emergency Management	(5) Protecting Surroundings	(9) Safety Audits	(14) Public Access	
		(5) Protecting Surroundings	**(A) The project clearly accommodates incident management for users and emergency personnel.**				
		Projected Level of Achievement (High)	**(B) The project identifies and utilizes access routes, safety features, and clear signage to reduce negative impact on its surroundings caused by vehicle or pedestrian traffic. The project integrates well with its surroundings through clear signage and wayfinding.**				
		(5) Protecting Surroundings	(C) The project provides points for safe public access. Universal design standards are used to ensure broad accessibility and safety.				
		Notes: May be modifying access from plant for trucks; addition of street-facing signage. Changing gates onto plant site; will need to have good wayfinding due to changes.	(D) The project has a positive and transformative impact on community or neighborhood access and/or wayfinding.				
	COMMUNITY	**QL3.1 Advance Equity and Social Justice**	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F	A + B + C + D + E + F + G
		Projected Level of Achievement (Low)	(3) Understanding Equity	(6) Mitigation	(10) Empowerment	(14) Equitable Access to Benefits	(18) Equitable Futures
		None	(A) Stakeholder engagement is conducted early and informed by the historic context of equity, social justice, and environmental justice. When projects impact, or potentially impact, indigenous communities, specific attention is given to developing a relationship of respect and mutual understanding that supports the autonomy, authority, and rights of these communities.				
		Projected Level of Achievement (High)	(B) The project team assesses the social impacts the project will have on the host and affected communities. This includes mapping impacts and benefits across local communities.				
		None	(C) Key members of the project team make institutional commitments to equity and social justice, including non-discrimination; diversity and inclusion; and pay equity. Large-scale projects make targeted and project-specific commitments.				
		Notes: Desktop analysis of populations, but hasn't looked specifically Updates to Green Building Incentive Policy: Equity: In keeping with the County Board's Equity Resolution (September 21, 2019), staff included a provision to support racial equity, diversity, and inclusion policies and programs within the firms on the development team. This was provision was modeled	(D) Based on the assessment of social impacts, the project addresses or mitigates social impacts. Mitigation strategies are informed by stakeholder consultation and participation. (E) The social, economic, and environmental benefits and impacts of the project are shown to not disproportionately favor or disfavor any community. (F) The project empowers communities to engage in the development process. Qualified professionals identify unconscious biases and barriers to inclusion. Programs target higher rates of engagement, and include transparent grievance mechanisms to facilitate resolutions. (G) The project positively addresses or corrects an existing or historic injustice or imbalance.				
		QL3.2 Preserve Historic and Cultural Resources	Not Available	A + B	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)		(2) Stakeholder Consultation	(7) Expanded Search	(12) Conservation	(18) Restoration
		Not applicable		(A) The project team works with the community and required regulatory and resource agencies to identify historic and cultural resources in and around the project site.			
		Projected Level of Achievement (High)		(B) The project implements strategies to document, protect, or enhance historic and cultural resources.			
		Not applicable		(C) The assessment of cultural resources intentionally extends beyond national or subnational registries to identify important parts of the community culture such as places, events, natural features, oral traditions, or local skills.			
		Notes: Documentation to support N/A.		(D) Stakeholders of the historic/cultural resources are consulted early in the project's development and contribute to developing a sensitive design approach. (E) For historic and/or cultural resources identified in criteria A and C the project is designed to fully preserve/protect the character-defining features of those resources. (F) The project enhances or restores a threatened or degraded historic/cultural resource or results in a historical resource being added to a protected registry.			

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CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
QUALITY OF LIFE	COMMUNITY	**QL3.3 Enhance Views and Local Character**	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(1) Value Identification	(3) Alignment With Community Values	(7) Preservation and Enhancement	(11) Connections and Collaboration	(14) Restoring Community Character
		(3) Alignment With Community Values	(A) The project team identifies community values and concerns regarding protection and enhancement of views and local character.				
		Projected Level of Achievement (High)	(B) Specific design features preserve or enhance views and local character, and are informed by the stakeholder consultation process.				
		(3) Alignment With Community Values	(C) Guidelines are adopted or developed to preserve or enhance views and local character. The aesthetic quality of the project is important.				
		Notes: Very visible from surrounding neighborhoods. Viewshed discussion part of site planning. All piping hidden; don't want it to look like equipment Screening? Envision workshop: - Mary – So many discussions with stakeholder engagement – we should definitely get to A and B. - Mary – on C – a lot of current aesthetic was driven by input from stakeholders. Have taken this into account in the past. Will assess aesthetic standard for this project. - Decision: Confident on A and B – C and D may happen, based on county policies for public art or engagement with stakeholders. - The County would have to get public input for any public art. There is an existing Public Art Commission.	(D) A construction management plan protects character features, high-value landscapes, or landscape features during construction. (E) Community feedback from the stakeholder engagement process verifies actions taken in criteria A, B, and C. (F) The project restores previously lost or degraded views or community features OR enhances the community by creating new features of local character. Actions are supported through the stakeholder engagement process.				
		QL3.4 Enhance Public Space and Amenities	A + B	A + B + C	A + B + C + D	A + B + C + D	A + B + C + D
		Projected Level of Achievement (Low)	(1) No Net Loss	(3) Community Involvement	(7) Improvement and Enhancement	(11) Overall Net Benefit	(14) Substantial Restoration
		None	(A) The project assesses impacts to existing public amenities and implements mitigation strategies. The project will not result in the net loss of public amenities.				
		Projected Level of Achievement (High)	(B) The stakeholder engagement process specifically includes issues of public space and amenities.				
		None	(C) The project team can demonstrate stakeholder support for aspects of the project related to public space/amenities.				
		Notes: Likely not pursued.	(D - Superior) The project involves significant enhancements to existing public space or amenities (e.g., not minor resurfacing or component replacements). (D - Conserving) The project creates a new public resource or amenity to the community that did not previously exist. The scope of the new public space/amenity is commensurate with the scope and scale of the project. (D - Restorative) The project restores lost, degraded/unusable, or at-risk public space or amenities. The public space/amenity is an asset of significance to the local community commensurate with the scope and scale of the project.				
		Innovation	**(+10) Innovate or exceed credit requirements.** (A) Implement innovative methods, technologies, or processes that are novel either in their use, application, or within the local regulatory or cultural context. OR (B) Implement measures that exceed the highest existing requirements within one or more Quality of Life credits. OR (C) Address additional aspects of sustainability not currently recognized in Envision				
		Projected Level of Achievement (Low)					
		None					
		Projected Level of Achievement (High)					
		+2 points					
		Notes: - Project branding; mission, vision Potential "stretch" considerations from Green Building Incentive Policy: Human Interaction with Nature (Biophilia), Bird Friendly and Light pollution reduction: In order to address how buildings interact with nature, the Policy includes three new provisions focused on the relationship between urban development and nature. First, applicants must submit a narrative describing how the project optimizes energy efficiency and environmental conservation in the community. Second, the project must minimize bird strikes by meeting specific criteria outlined by the American Bird Conservancy. Finally, minimum light pollution reduction criteria for exterior light fixtures must be met to safely reduce light pollution.					

Maximum QL Points (w/o Innovation) 200

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			LEVEL OF ACHIEVEMENT				
LEADERSHIP	COLLABORATION	**LD1.1 Provide Effective Leadership & Commitment/Collaboration**	A	A + B	A + B + C	A + B + C + D	Not Available
		Projected Level of Achievement (Low)	(2) Limited commitment.	(5) Strong Commitment	(12) Strong Commitment	(18) Sustainability as a Core Value	
		(18) Sustainability as a Core Value	**(A) A written commitment by the owner and project team to address the social, environmental, and economic aspects of the project. Commitments to sustainability are clearly articulated at the project level in a project chartering session and/or contract documents.**				
		Projected Level of Achievement (High)	**(B) Commitments are supported by a sustainability management policy that is commensurate with the scope, scale, and complexity of the project.**				
		(18) Sustainability as a Core Value	**(C) Sustainability commitments, and progress toward their achievement, are revisited periodically through meetings or written reports.**				
		Notes: Arlington County - Facility Sustainability Policy - Community Energy Plan; goal for Arlington to be a Carbon Neutral Community by 2050 - Green Building Incentive Policy for Site Plan Projects	**(D) Key members of the project team have made clear commitments to sustainability, as evidenced by:** • Organizational sustainability policies and/or reports. • Examples of projects, or initiatives, to improve sustainable performance. • Sustainability strategies embedded into their business strategy. • Third-party organizational recognition or commitments.				
		LD1.2 Foster Collaboration & Teamwork	A	A + B	A + B + C	A + B + C + D	Not Available
		Projected Level of Achievement (Low)	(2) Early Collaboration	(5) Achieving Goals	(12) Ongoing Collaboration	(18) Life-Cycle Collaboration	
		(18) Life-Cycle Collaboration	**(A) Sustainability goals are defined early during interdisciplinary collaborative project kickoff meetings among project staff at all levels.**				
		Projected Level of Achievement (High)	**(B) The project team can demonstrate sustainability performance enhancements that resulted from the interdisciplinary collaborative process. Performance enhancements should result from a whole-systems design approach, rather than sustainability add-ons.**				
		(18) Life-Cycle Collaboration	**(C) Ongoing collaboration meetings are conducted throughout design with the owner and the interdisciplinary project team to clarify expectations, discuss potential opportunities, and identify potential barriers to integrated design. Meetings involve a broad set of project participants.**				
		Notes:	**(D) The interdisciplinary collaboration or integrated design process specifically includes stakeholders from later construction, operations, and/or maintenance phases. Important considerations over the project life are understood and incorporated into the project.**				
		LD1.3 Provide for Stakeholder Involvement	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(3) Active Engagement	(6) Direct Engagement	(9) Community Involvement	(14) Community Satisfaction	(18) Stakeholder Partnerships
		(18) Stakeholder Partnerships	**(A) Primary and secondary stakeholders are identified through a stakeholder mapping process. Stakeholder concerns and specific objectives for stakeholder engagement are defined.**				
		Projected Level of Achievement (High)	**(B) A proactive stakeholder engagement process is established with clear objectives. This occurs at the earliest stages of planning and is sustained through project construction. Engagement moves beyond education into active dialogue. Stakeholder views are monitored, and a two-way line of communication is established to reply to inquiries. Sufficient opportunities are provided for stakeholders to be involved in decision making. The participation process is transparent with opportunities to provide meaningful input.**				
		(18) Stakeholder Partnerships	**(C) A lead person from the project team, in addition to any public involvement lead or manager, works with stakeholder groups to understand communication needs and the desire for and scope of involvement.**				
		Notes: The update to the Green Building Incentive Policy followed the "Involve" level of public engagement. - Outreach Method, Community Feedback Project specific Criteria F: Arlington Regional Transit - beneficial use of biogas Envision workshop: - Charles – we have a well-documented engagement process for this - Beau – Can you please explain item E on this slide: "Feedback is sought from stakeholders as to their satisfaction with the engagement process, and the resulting decisions were made based on their input." How can we show that our decisions were based upon stakeholder issues? - Mary – I wasn't aware of the lime noise delivery issue - Mary – four feedback categories: noise, odor, emissions, visual are those where stakeholder involvement have informed this project.	**(D) There are specific cases in which public input influenced or validated project outcomes. Potentially conflicting stakeholder views were evaluated and addressed equitably during decision making.** **(E) Feedback is sought from stakeholders as to their satisfaction with the engagement process, and the resulting decisions were made based on their input.** (F) One or more stakeholders, having mutual interests or interdependencies, are identified and engaged as partners.				
		LD1.4 Pursue Byproduct Synergies	A + B	A + B + C	A + B + D	A + B + D	A + B + E
		Projected Level of Achievement (Low)	(3) Initial Investigation	(6) Synergy Pursued	(12) Short-Term Byproduct Reuse	(14) Long-Term Byproduct Reuse	(18) Circular Economy
		(18) Circular Economy	**(A) The project team conducts an assessment of the availability and viability of excess resources (i.e., waste) or capacity, including but not limited to waste materials, heating or cooling, financial capacity, land area/space, or management/personnel capacity.**				
		Projected Level of Achievement (High)	**(B) Candidates for byproduct synergies or reuse are identified. This can include finding a beneficial reuse for the project's waste or excess resources, or the project's beneficial reuse of external waste or excess resources. Project teams should also consider ecosystem services where project waste or excess resources can support natural systems, or where natural systems can process and remove project waste.**				
		(18) Circular Economy	**(C) The project team demonstrates an active attempt to incorporate at least one byproduct synergy or reuse into the project.**				
		Notes: Class A fertilizer product that can be marketed to the community. High-quality soil amendment available to agriculture and community Natural gas generated by the process can be reused onsite for power generation or offsite for vehicle fuel Potential for future phosphorus harvesting can be considered 2 byproducts -	(D - Superior) The project successfully includes a byproduct synergy or reuse. Execution is a short-term or one-time byproduct synergy/reuse (e.g., during construction). **(D - Conserving) The project successfully includes a byproduct synergy or reuse. Execution is a long-term regularly recurring byproduct synergy/reuse throughout project operations.** (E) The project is fully engaged in a "circular economy" system whereby the majority of its operational waste is beneficially reused OR the majority of its operational resources are sourced from external waste streams.				

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			LEVEL OF ACHIEVEMENT				
LEADERSHIP	PLANNING	**LD2.1 Establish a Sustainability Management Plan**	A + B	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low)	(4) Plan	(7) "Plan-Do-Check-Act"	(12) Full Implementation	(18) Managing Change	Not Available
		(12) Full Implementation	**(A) Roles and responsibilities for addressing sustainability are assigned to key members of the project team. Their authority on the project to affect change is sufficient and clear.**				
		Projected Level of Achievement (High)	**(B) The project team develops a sustainability management plan, or adopts existing sustainability management plans or policies sufficient in scope and scale to address the sustainable performance of the project. The plan includes an index of all project features related to sustainability, and an assessment of the environmental, social, and economic aspects of the project. Sustainability goals and performance objectives are established and prioritized to reduce the project's impact. They are aligned with community needs and issues.**				
		(18) Managing Change	**(C) The project management plan contains sufficient processes, action plans, and management controls to achieve its sustainability goals and performance targets.**				
		Notes: Develop program sustainability goals ✓	**(D) Implementation of the sustainability management plan, and progress toward established goals, is revisited periodically through meetings or written reports.** (E) The plan is adaptable, flexible, and resilient enough to manage changes in environmental, social, or economic conditions of the project over time.				
		LD2.2 Plan for Sustainable Communities	A	A + B	A + B + C	A + B + C + D	A + B + C + D + E
		Projected Level of Achievement (Low)	(4) Sustainability Indicators	(6) Alternative Analysis	(9) Sustainability Assessment	(12) Sustainable Planning	(16) More Sustainable Communities
		(12) Sustainable Planning	**(A) Sustainability indicators or outcomes are considered in project selection/identification and planning.**				
		Projected Level of Achievement (High)	**(B) Sustainable performance is included in alternative analyses during project identification. Alternatives include the sustainability of a "no-build" option.**				
		(16) More Sustainable Communities	**(C) During project identification, the project's potential impact to broader external systems is assessed, such as growth patterns, congestion, energy and water demand/production, and how these impact the overall long-term sustainability of the community or region.**				
		Notes:	**(D) The project is part of a comprehensive sustainable development plan at the level of the infrastructure system, municipality/community, or region. The project demonstrates a direct connection and contribution to achieving specific sustainable development goals identified in the plan.** **(E) The project addresses an inherently unsustainable condition within the community.**				
		LD2.3 Plan for Long-Term Monitoring & Maintenance	A	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low)	(2) Reduced Maintenance	(5) Maintenance Plan	(8) Securing Resources	(12) Ongoing Improvement	
		(12) Ongoing Improvement	**(A) The project includes strategies to reduce maintenance impacts. This may include better design, durable longer-lasting materials, or ease of access for maintenance and repair with minimal disruption to users and affected communities.**				
		Projected Level of Achievement (High)	**(B) A monitoring and maintenance plan is developed with specific sustainability performance targets and an implementation schedule with clear goals and milestones. It addresses any unique challenges of monitoring or maintaining the project's sustainability features.**				
		(12) Ongoing Improvement	**(C) The project team meets with operations, monitoring, and maintenance staff to explain and discuss the operations plan.**				
		Notes: New facilities vs. using existing facilities. Evaluation criteria. CIP - implement more effective technology that will reduce the need for maintenance Envision workshop: - Team discussion whether the Monitoring Plan drives decisions regarding operations and the conclusion was yes, which is directly related to this credit.	**(D) Owner identifies the key personnel to carry out the plan, funding sources, and other resources to cover associated costs. This includes training for the operation, monitoring, and maintenance staff, and provisions for necessary future training.** (E) A schedule is developed for future re-evaluation and modification of the maintenance plan based on monitored data.				
		LD2.4 Plan for End-of-Life	A + B	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low)	(2) End-of-Life Plan	(5) Enhancements	(8) Pushing Boundaries	(14) Extending Boundaries	
		(2) End-of-Life Plan	**(A) The project team develops an end-of-life plan, including the necessary replacement/refurbishment of major components over the project life and its ultimate decommissioning, deconstruction, or replacement. Consideration is given to recyclability of materials and components and/or the ease of deconstruction or replacement (e.g., components or materials that can be easily separated for recycling or reuse). The plan is included in operations and maintenance documents.**				
		Projected Level of Achievement (High)	**(B) Relevant future demands, loads, or other requirements on the infrastructure system are estimated over the anticipated project life. The project extends useful life by providing opportunities for reconfiguration, future expansion, flexibility, or to beneficially repurpose the project after end-of-life.**				
		(2) End-of-Life Plan	**(C) End-of-life impacts are assessed, including the environmental, social, and economic conditions of the site and surrounding community.**				
		Notes: Inclination to create an 'end-of-life' plan? Envision workshop: - Mary – may be tough to do an end of life at this point. - Brian – additional evaluations are being done? - Lisa – concerns with getting there. But could we put together a table with anticipated end of life. - Let's say "improved" for now. - Mary – concur. Could be very beneficial to document new assets for asset management system – for end of life. - Brian - we are looking at adaptability and plans for expansion in the future.	(D) The project includes an analysis of end-of-life costs and salvage value associated with deconstruction, decommissioning, or replacement. (E) The project team demonstrates proactive stakeholder engagement in end-of-life planning and can demonstrate that the community understands the full life-cycle costs and benefits of the project.				
	ECONOMY	**LD3.1 Stimulate Economic Prosperity & Development**	A + B	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low)	(3) New Capacity	(6) Improved Choices	(12) Business Attraction	(20) Development Rebirth	
		(12) Business Attraction	**(A) Jobs are created during design, construction, and/or operation. The project team determines the number, type, and duration of jobs created as a result of the project.**				
		Projected Level of Achievement (High)	**(B) The project adds new operating capacity. Capacity additions can apply to business, industry, or the public.**				
		(12) Business Attraction	**(C) The project provides additional access, increases the number of choices, and/or increases the quality of services. The project team can demonstrate that the addition of choices will drive competitiveness, efficiency, or improved productivity for business, industry, or cultural and recreational facilities.**				
		Notes: Biosolids - fertilizer Capacity; regulations C-reducing carbon footprint - less negative impact; reducing truck traffic; biogas - expanding offerings D- helping Arlington meet their sustainability goals	**(D) The project contributes to the host community's attractiveness for businesses, industries, or their workforce by improving the overall business or community environment (i.e., people want to live and/or work in the community).** (E) The project will stimulate local, regional, or national economic development. The economic projections take into account changing social, economic, and/or environmental conditions.				

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CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
LEADERSHIP	ECONOMY	**LD3.2 Develop Local Skills & Capabilities**	A	A + B	A + B	A + B + C	A + B + C + D
		Projected Level of Achievement (Low)	(2) Gaining Skills	(4) Growing Capacity	(8) Building Communities	(12) Long-Term Opportunities	(16) Community Revitalization
		None	(A) The project includes training programs for local skill development. This may include designers, contractors, subcontractors, or operators.				
		Projected Level of Achievement (High)	(B - Enhanced) Beyond general skill development, the project team identifies specific skill or capability gaps in the local workforce. Training programs target these gaps to improve local capacity. Skills are transferable beyond the end of the project.				
		None	(B - Superior, Conserving, Restorative) The project team works with, or is informed by, community and local/state workforce development agencies to assess local employment and educational needs. Training programs target these gaps to improve local capacity. Skills are transferable beyond the end of the project. Skills developed are likely to provide the local workforce, agencies, and/or companies with a competitive advantage in the future.				
		Notes:	(C) Education, skill development programs and/or opportunities will continue after project delivery. This may include community education and awareness training. Programs may be at the organizational level but must be relevant to the project.				
			(D) Training and skill development programs specifically target economically depressed, underemployed, or disadvantaged communities.				
		LD3.3 Conduct a Life-Cycle Economic Evaluation	A	A + B	A + B + C	A + B + C + D	A + B + C + D + E
		Projected Level of Achievement (Low)	(5) Life-Cycle Cost Analysis	(7) Life-Cycle Cost Alternatives Analysis	(10) Benefit Mapping	(12) Sustainability Cost Benefit Analysis	(14) Sustainability CBA Alternatives Analysis
		(7) Life-Cycle Cost Alternatives Analysis	**(A) A life-cycle cost analysis (LCCA) is conducted on the whole project to identify the total economic impacts of the project and provide additional insight into decision making.**				
		Projected Level of Achievement (High)	**(B) LCCA is used to compare and assess alternatives for at least one major design component.**				
		(14) Sustainability CBA Alternatives Analysis	**(C) The project team maps the social, environmental, and financial costs and benefits of the project. Costs and benefits must be quantified but not necessarily monetized.**				
		Notes: Solids master plan; gas utilization lcca (component) SROI	(D) The LCCA in criterion A is expanded into a comprehensive sustainability cost benefit analysis based on monetizing the social, environmental, and financial costs and benefits identified in criterion C.				
			(E) The sustainability cost benefit analysis is used to compare and assess alternatives for at least one major design component. The selected alternative produces a net positive present value including social and environmental benefits.				
		Innovation	**(+10) Innovate or exceed credit requirements.**				
		Projected Level of Achievement (Low)	(A) Implement innovative methods, technologies, or processes that are novel either in their use, application, or within the local regulatory or cultural context.				
		+2 points	OR				
		Projected Level of Achievement (High)	(B) Implement measures that exceed the highest existing requirements within one or more Leadership credits.				
		+2 points	OR				
		Notes: Possibly something here related to Byproduct Synergies - only a handful of places that are doing the biogas utilization	(C) Address additional aspects of sustainability not currently recognized in Envision				
						Maximum LD Points (w/o Innovation)	**182**

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CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
RESOURCE ALLOCATION	MATERIALS	**RA1.1 Support Sustainable Procurement Practices**	A + B	A + B	A + B	A + B	Not Available
		Projected Level of Achievement (Low)	(3) 5% Sustainable Procurement	(6) 15% Sustainable Procurement	(9) 25% Sustainable Procurement	(12) 50% Sustainable Procurement	
		None	(A) A written sustainable procurement policy/program is in place. The program includes a well-defined process for selecting suppliers and/or manufacturers of materials, supplies, and equipment, including selection criteria focused on environmental practices and social responsibility.				
		Projected Level of Achievement (High)					
		None					
		Notes: Any written sustainable procurement policy/program is in place? Envision workshop: Will likely not pursue this one.	(B) **At least 5%** of all project materials, supplies, and equipment meet the sustainable procurement policy/program requirements.	(B) **At least 15%** of all project materials, supplies, and equipment meet the sustainable procurement policy/program requirements.	(B) **At least 25%** of all project materials, supplies, and equipment meet the sustainable procurement policy/program requirements.	(B) **At least 50%** of all project materials, supplies, and equipment meet the sustainable procurement policy/program requirements.	
		RA1.2 Use Recycled Materials	A	A	A	A	Not Available
		Projected Level of Achievement (Low)	(4) At Least 5% from Recycled	(6) At Least 15% from Recycled	(9) At Least 25% from Recycled	(16) At Least 50% from Recycled	
		None	(A) **At least 5%** (by weight, volume, or cost) of recycled materials including materials with recycled content and/or reused existing structures or materials. ***Mechanical, electrical, water equipment, and their components may be excluded from the calculations. In these instances, the most efficient equipment should be specified.*	(A) **At least 15%** (by weight, volume, or cost) of recycled materials including materials with recycled content and/or reused existing structures or materials.	(A) **At least 25%** (by weight, volume, or cost) of recycled materials including materials with recycled content and/or reused existing structures or materials.	(A) **At least 50%** (by weight, volume, or cost) of recycled materials including materials with recycled content and/or reused existing structures or materials.	
		Projected Level of Achievement (High)					
		(4) At Least 5% from Recycled					
		Notes: Review after alternative is selected Reuse of building? Ensuring quality and cost implications of specifying recycled materials. Reuse of existing structures? What materials would be used in the project? Envision workshop: - Mary – Make sure we're including the gravity thickeners in the "building reuse" calculation. - Charlies – Dept of solid waste has policies for zero waste - Mary – need to investigate/evaluate what the zero waste policy is with the solid waste division and determine what (if anything) has to be done for this project.					
		RA1.3 Reduce Operational Waste	A + B	A + B	A + B	A + B	Not Available
		Projected Level of Achievement (Low)	(4) Recycle/Reuse At Least 25%	(7) Recycle/Reuse At Least 50%	(10) Recycle/Reuse At Least 75%	(14) Recycle/Reuse 95%	
		(14) Recycle/Reuse 95%	(A) Develop an operational waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on site or commingled.				
		Projected Level of Achievement (High)					
		(14) Recycle/Reuse 95%					
		Baseline: Existing facility? **Notes:** List operational waste: biosolids product (better land application), energy, wastewater (back to creek or used for process) What % of total waste would go to landfill? County operational waste policy? Update to Solid Waste Management Plan? Zero Waste Resolution 11/19/15	(B) The project team identifies waste streams or byproducts that will occur as a result of the operation of the project. The project is planned or designed to **divert at least 25%** of operational waste. Diversion may be a combination of waste reduction measures and/or sourcing waste to other facilities for recycling or reuse.	(B) The project team identifies waste streams or byproducts that will occur as a result of the operation of the project. The project is planned or designed to **divert at least 50%** of operational waste. Diversion may be a combination of waste reduction measures and/or sourcing waste to other facilities for recycling or reuse.	(B) The project team identifies waste streams or byproducts that will occur as a result of the operation of the project. The project is planned or designed to **divert at least 75%** of operational waste. Diversion may be a combination of waste reduction measures and/or sourcing waste to other facilities for recycling or reuse.	(B) The project team identifies waste streams or byproducts that will occur as a result of the operation of the project. The project is planned or designed to **divert at least 95%** of operational waste. Diversion may be a combination of waste reduction measures and/or sourcing waste to other facilities for recycling or reuse.	
		RA1.4 Reduce Construction Waste	A + B	A + B	A + B	A + B	Not Available
		Projected Level of Achievement (Low)	(4) Recycle/Reuse 25%	(7) Recycle/Reuse 50%	(10) Recycle/Reuse 75%	(16) Recycle/Reuse 95%	
		(7) Recycle/Reuse 50%	(A) Implement a construction waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on site or commingled.				
		Projected Level of Achievement (High)					
		(10) Recycle/Reuse 75%					
		Notes: Discuss inclination of County toward specifying a construction waste diversion goal and requiring a construction waste management plan. Envision workshop: - Brian – we will look and see what previous project have done, and provide guidance. Would like to include guidance from the contractors regarding - Mary – Suggest reaching out to solids waste – they do asphalt and concrete recycling on site. Need to determine what they could handle. - Lisa – In a previous project, contractor greatly exceeded goal (50-75%), as self-reported recycling/reuse as waste, just as a matter of course. - Reasonable to target 75%?	(B) The project team sets a target goal for construction waste diversion. During construction **at least 25%** of waste materials are recycled, reused, and/or salvaged. Diversion may be a combination of waste-reduction measures and sourcing waste to other facilities for recycling or reuse.	(B) The project team sets a target goal for construction waste diversion. During construction **at least 50%** of waste materials are recycled, reused, and/or salvaged. Diversion may be a combination of waste-reduction measures and sourcing waste to other facilities for recycling or reuse.	(B) The project team sets a target goal for construction waste diversion. During construction **at least 75%** of waste materials are recycled, reused, and/or salvaged. Diversion may be a combination of waste-reduction measures and sourcing waste to other facilities for recycling or reuse.	(B) The project team sets a target goal for construction waste diversion. During construction **at least 95%** of waste materials are recycled, reused, and/or salvaged. Diversion may be a combination of waste-reduction measures and sourcing waste to other facilities for recycling or reuse.	

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CATEGORY	SUB-CATEGORY	CREDIT NAME	IMPROVED	ENHANCED	SUPERIOR	CONSERVING	RESTORATIVE
			LEVEL OF ACHIEVEMENT				
RESOURCE ALLOCATION	MATERIALS	**RA1.5 Balance Earthwork On Site**	A	A	A	A	Not Available
		Projected Level of Achievement (Low) **None** *Projected Level of Achievement (High)* **(2) Reuse At Least 30% On Site**	(2) Reuse At Least 30% On Site	(4) Reuse At Least 50% On Site	(6) Reuse At Least 80% On Site	(8) Fully Balanced Site	
		Notes: Amount of earthwork needed? Plan to balance cut/fill? Distance of county source and/or disposal sites? Will be earthwork required due to hill. Likely have to haul off soil. Goal would be to reuse soil on site. Requirement for delivery team - cost implication? Does the county have a location nearby that could use extra soil?	(A) Excavated material moved off site and/or fill brought onto the site does not exceed 70% of total site soil handling. OR 100% of fill and excavated materials are sourced or reused within 25 mi/40 km of the site.	(A) Excavated material moved off site and/or fill brought onto the site does not exceed 50% of total site soil handling. OR 100% of fill and excavated materials are sourced or reused within 10 mi/16 km of the site.	(A) Excavated material moved off site and/or fill brought onto the site does not exceed 20% of total site soil handling. OR 100% of fill and excavated materials are sourced or reused within 5 mi/8 km of the site.	(A) The site is fully balanced. No earthwork is removed from the site and no earthwork is imported.	
	ENERGY	**RA2.1 Reduce Operational Energy Consumption**	A + B	A + B	A + B	A + B	Not Available
		Projected Level of Achievement (Low) **(6) 10% Energy Reduction** *Projected Level of Achievement (High)* **(6) 10% Energy Reduction**	(6) 10% Energy Reduction	(12) 30% Energy Reduction	(18) 50% Energy Reduction	(26) 70% Energy Reduction	
			(A) The project team determines the estimated annual energy consumption of the project. If annual energy consumption varies, the project team submits the range of estimated performance over the project life.				
		Baseline: Existing facility? or Equipment Alternatives? ***There is a calculator for this calculation*** **Notes:** This calculation may be based on equipment selection, showing that the selected alterative uses less energy than another seriously considered alternative. What are other operational energy uses? Lighting? What type of lighting is used in existing facility, i.e. fluorescent vs. LED? Will lighting type change due to project? Previously said more lighting will be added. - lighting - cooling options - HVAC Solids reduced by 50% resulting in less truck traffic and hauling costs (truck fuel would not be included in this credit.) CIP - Implement more effective technology that will be more energy efficient; Recover energy from the wastewater process - energy recovered in the form of methane may be utilized to power the ART fleet, reduce the Plant's energy footprint, and/or sold back into the power grid or to Washington Gas as renewable natural gas. Updates to Green Building Incentive Policy: Include baseline items that address specific **energy measures including energy** and water efficient appliances, electric vehicle charging, renewable energy, **ventilation performance**, refrigerant leakage, and energy benchmarking. Meet specified energy optimization criteria to ensure energy efficiency above the LEED baseline *incentivize exceptional energy efficient design and construction New prerequisites include renewable energy, electric vehicle charging, social equity, and other **energy** and community sustainability criteria.	(B) Operational energy is **reduced at least 10%.** Energy consumption of the project includes: • Energy purchased from the grid • Energy generated on site • Fuels used on site by the project Natural gas; ability to use natural gas being created. Makes more sense to sell the gas produced by the project (net exporting). Offsets fossil fuel 100% with the export.	(B) Operational energy is **reduced at least 30%**.	(B) Operational energy is **reduced at least 50%**.	(B) Operational energy is **reduced at least 70%.**	
		RA2.2 Reduce Construction Energy Consumption	A	A + B	A + B	A + B	Not Available
		Projected Level of Achievement (Low) **(4) At Least Two Reduction Strategies** *Projected Level of Achievement (High)* **(4) At Least Two Reduction Strategies**	(1) Identify Reduction Opportunities	(4) At Least Two Reduction Strategies	(8) At Least Four Reduction Strategies	(12) At Least Six Reduction Strategies	
			(A) The project team conducts one or more planning reviews to identify and analyze options for reducing energy consumption during construction.				
		There is a calculator for this calculation **Notes:** Discuss with client - planning session + discussion of strategies Envision workshop: - Mary – likes the idea of putting the goal in the specifications "at least 2" and then leaving it up to the contractor to choose how to implement them. - There is a truck idling policy.		(B) The project implements, or has written requirements to implement, **at least two (2)** energy reduction strategies.	(B) The project implements, or has written requirements to implement, **at least four (4)** energy reduction strategies.	(B) The project implements, or has written requirements to implement, **at least six (6)** energy reduction strategies.	

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			LEVEL OF ACHIEVEMENT				
RESOURCE ALLOCATION	ENERGY	**RA2.3 Use Renewable Energy**	A	A	A	A	A
		Projected Level of Achievement (Low)	(5) At Least 5%	(10) At Least 15%	(15) At Least 30%	(20) At Least 50%	(24) Net Positive
		(24) Net Positive	(A) The project meets: **5%** of energy needs (electricity and fuel) from renewable sources.	(A) The project meets: **15%** of energy needs (electricity and fuel) from renewable sources.	(A) The project meets: **30%** of energy needs (electricity and fuel) from renewable sources.	(A) The project meets: **50%** of energy needs (electricity and fuel) from renewable sources.	(A) The project generates a net positive amount of renewable energy.
		Projected Level of Achievement (High)					
		(24) Net Positive					
		There is a calculator for this calculation **Notes: **This credit is related to offsetting the PROJECT's energy needs through renewal energy** Engine generators - making energy on site via biogas - evaluating option May depend on where fuel goes - offset fossil fuels in transportation vehicles. Ask ISI about this question. Study - LCC - biggest value and best GHG reduction. Updates to Green Building Incentive Policy: Renewable Energy/Solar: The Policy update requires applicants to install on-site solar generation (or other acceptable forms of renewable energy) equal to at least 2.0 watts per square foot of roof area. For most buildings this would result in about 15-20% of the roof area being covered by solar panels. An off-site renewable purchase option is available. For buildings without sufficient solar exposure due to unavoidable shading, a contribution to the Green Building Fund ($4/ square foot or roof area) is permitted. This update supports Arlington's Community Energy Plan goal to increase Arlington's renewable energy resources with the installation and use of 160 megawatts (MW) of onsite solar electricity.					
		RA2.4 Commission & Monitor Energy Systems	A + B	A + B	A + B + C	A + B + C	Not Available
		Projected Level of Achievement (Low)	(3) Basic Initial Commissioning	(6) Extensive Initial Commissioning	(12) Long-Term Commissioning	(14) Advanced Initial and Long-Term Commissioning	
		(6) Extensive Initial Commissioning	(A) The project includes energy monitoring capabilities. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for **at least 50%** of energy use/consumption. (B) The project conducts an initial commissioning of energy systems accounting for at least 50% of the total energy consumption/generation. Commissioning includes a detailed log of issues.	(A) The project includes energy monitoring capability. Equipment and/or software are incorporated to allow detailed monitoring of performance during operation. The equipment is capable of independently monitoring all primary project functions, accounting for **at least 75%** of energy use/consumption. (B) The project conducts an initial commissioning of energy systems accounting for at least 75% of the total energy consumption/generation. Commissioning includes a detailed log of issues.	(A) The project includes integrated energy management systems. Energy management software is incorporated to allow for detailed and centralized monitoring and reporting of performance. The equipment is capable of independently monitoring all primary project functions, accounting for **at least 90%** of energy use/consumption. (B) The project conducts an initial commissioning of energy systems accounting for at least 90% of the total energy consumption/generation. Commissioning includes a detailed log of issues. (B - Superior) The owner engages a third party or in-house commissioning agent not involved in the planning/design of the project. (B - Conserving) The owner engages an independent third-party commissioning agent. (C) A comprehensive plan is developed for ongoing periodic re-commissioning/review of energy systems throughout the expected life of the project.		
		Projected Level of Achievement (High)					
		(6) Extensive Initial Commissioning					
		Notes: Monitoring at current plant - for energy? 100% Is commissioning required? Yes BI dashboard with all energy/electricity usage. Updates to Green Building Incentive Policy: Post-Occupancy Building Performance and Certification: Energy models are predictive and guide the design and construction of the building. However, they do not ensure that the building will operate to the specified level of energy efficiency. All building types must comply with post occupancy energy performance standards either through Energy Star certification or by demonstrating with utility data that the project meets the LEED approved energy model's predicted energy use.					
	WATER	**RA3.1 Preserve Water Resources**	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(3) Increased Awareness of Watershed Issues	(5) Good Water Resource Management	(7) Wise Water Resource Management	(9) Total Water Management	(12) Positive Impact
		(5) Good Water Resource Management	(A) Assess the project's watershed context and the watershed-scale fresh water issues, including location, type, quantity, rate of recharge, and quality of water resources, as well as source and impacts of water used and the destination and impacts of wastewater. (B) Estimates of water usage and wastewater generation over the life of the project. (C) The project has features intended to reduce the identified negative impacts of water usage, and/or improve watershed-scale issues. (D) The project has a net-zero impact on the quantity and availability of fresh surface water and groundwater supplies without compromising water quality. (E) The project is part of, or contributes to, a watershed or regional water plan. (F) The project makes a direct and significant net-positive improvement to the watershed.				
		Projected Level of Achievement (High)					
		(5) Good Water Resource Management					
		Notes: Site planning Use plant water vs. potable water when possible Reduce amount of lime trucked on site Comprehensive Plan - Stormwater MP, Chesapeake Bay preservation plan, Water Distribution MP; Watershed Retrofit Study MS4 permit compliance on site					

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			LEVEL OF ACHIEVEMENT				
RESOURCE ALLOCATION	WATER	**RA3.2 Reduce Operational Water Consumption**	A + B	A + B + C	A + B + C	A + B + C	A + B + C + D
		Projected Level of Achievement (Low)	(4) At Least 25% Reduction	(9) At Least 50% Reduction	(13) At Least 75% Reduction	(17) 95% Reduction	(22) Water Purification
		None	(A) The project team conducts planning or design reviews to identify potable water reduction strategies during operation of the project. The team has considered using alternatives such as nonpotable water, reused water, recycled water, and stormwater.				
		Projected Level of Achievement (High)					
		None	(B) The project reduces potable water use by **at least 25%**.	(B) The project reduces potable water use by **at least 50%**. (C) Overall water use (potable and nonpotable) is reduced by **at least 20%**.	(B) The project reduces potable water use by **at least 75%**. (C) Overall water use (potable and nonpotable) is reduced by **at least 30%.**	(B) The project reduces potable water use by **at least 95%**. (C) Overall water use (potable and nonpotable) is reduced by **at least 40%**.	(B) The project reduces potable water use **by 100%**. (C) Overall water use (potable and nonpotable) is reduced by **at least 50%.** (D) The project not only reduces potable water consumption to zero, but also provides water that can be used by the community.
		Baseline: Existing facility? **Notes:** Using more water - likely wouldn't pursue.					
		RA3.3 Reduce Construction Water Consumption	A + B	A + B	A + B	A + B	Not Available
		Projected Level of Achievement (Low)	(1) Identify Consumption and Reduction Options	(3) At Least Two Strategies	(5) At Least Four Strategies	(8) No Potable Water Consumption	
		(1) Identify Consumption and Reduction Options	(A) The project team conducts one or more planning reviews to identify and analyze options for reducing water consumption during construction.				
		Projected Level of Achievement (High)					
		(1) Identify Consumption and Reduction Options					
		Notes: Any opportunities to reduce construction water consumption? Would the project team conduct a planning review? Monitoring may be reasonable	(B) At least one (1) potable water conservation strategy is implemented.	(B) At least three (3) potable water conservation strategies are implemented.	(B) At least five (5) potable water conservation strategies are implemented.	(B) No potable water consumption, except for human consumption and hygiene, by means of implementing as many strategies as necessary.	
		RA3.4 Monitor Water Systems	A	A	A	A + B	Not Available
		Projected Level of Achievement (Low)	(1) One-Time Monitoring	(3) Operations Monitoring	(6) Long-Term Monitoring	(12) Responsive Monitoring	
		(3) Operations Monitoring	(A) The project includes monitoring capabilities. Equipment and/or software are incorporated in the design to allow detailed monitoring of performance (quantity or quality). The equipment is capable of monitoring all primary project functions, accounting for **at least 50%** of water use.	(A) The project includes monitoring capabilities. Equipment and/or software are incorporated in the design to allow detailed monitoring of performance (quantity or quality). The equipment is capable of monitoring all primary project functions, accounting for **at least 75%** of water use.	(A) The project includes monitoring capabilities. Equipment and/or software are incorporated in the design to allow detailed monitoring of performance (quantity or quality). The equipment is capable of monitoring all primary project functions, accounting for **at least 95%** of water use.		
		Projected Level of Achievement (High)					
		(3) Operations Monitoring				(B) The project demonstrates that real-time water monitoring equipment and/or software has been incorporated along with a plan for using this data to improve water equality and efficiency, reduce leakage, and/or conserve water.	
		Notes: Are systems in place in the current system(s) that monitor water quality and/or quantity? Will those be used by systems included in this project? Any upgrades or additions to monitoring?					
		RA0.0 Innovate or Exceed Credit Requirements	**(up to +10) Innovate or exceed credit requirements.** (A) Implement innovative methods, technologies, or processes that are novel either in their use, application, or within the local regulatory or cultural context. OR (B) Implement measures that exceed the highest existing requirements within one or more Resource Allocation credits. OR (C) Address additional aspects of sustainability not currently recognized in Envision				
		Projected Level of Achievement (Low)					
		+2 points					
		Projected Level of Achievement (High)					
		+4 points					
		Notes: Updates to Green Building Incentive Policy: Electric Vehicle Charging: All projects will include electric vehicle charging stations and electric vehicle "ready" infrastructure to support anticipated future demand for electric vehicle charging. Biofuel analysis/study Energy analysis for process cooling needs					
						Maximum RA Points (w/o Innovation)	**196**

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			LEVEL OF ACHIEVEMENT				
NATURAL WORLD	SITING	**NW1.1 Preserve Sites of High Ecological Value**	A + B	A + B	A + C	(A + C + D) or E	A + C + D + F
		Projected Level of Achievement (Low)	(2) Improved Siting	(6) Full Mitigation	(12) Total Avoidance	(16) Habitat Protection	(22) Habitat Expansion
		Not applicable	(A) The project team identifies areas of high ecological value.				
		Projected Level of Achievement (High)	(B) Mitigation measures, including avoidance, minimization, restoration, and offsets, fully compensate for project impacts to sites of high ecological value. Mitigation may occur off site.	(B) Mitigation measures including avoidance, minimization, restoration, and offsets, fully compensate for project impacts to sites of high ecological value. Mitigation is on site or an adjacent	(C) The project avoids developing or disturbing 100% of areas of high ecological value located on site.		
		Not applicable				(D) The project establishes effective protective buffer zones around areas of high ecological value.	
		Notes:				(E) The project team can demonstrate that the site was intentionally chosen to avoid development on or near sites of high ecological value.	
		NW1.2 Provide Wetland and Surface Water Buffers	A + B + C	A + B + C	A + B + C	(A + B + C) or D	A + B + C + E
		Projected Level of Achievement (Low)	(2) Buffers	(5) Managed Buffers	(10) Mixed Buffers	(16) Natural Buffers	(20) Buffer Restoration
		Not applicable	(A) The project team identifies wetlands and surface water on or near the site, or with the potential to be impacted by the project.				
		Projected Level of Achievement (High)	(B) The project team identifies the appropriate type and width of buffer zones for wetlands and surface waters.				
		Not applicable	(C) The project provides vegetated or natural buffer zones around at least 90% of wetlands and surface waters on site. The remaining areas (<10%) are	(C) The project provides a buffer of managed vegetated zones around all wetlands and surface waters. Managed zones may include grass. The buffer	(C) The project provides a mixed buffer of managed vegetation and natural zones around all wetlands and surface waters. Natural areas are not managed and	(C) The project provides a buffer of natural zones around all wetlands and surface waters. The buffer is of sufficient width to slow surface runoff, and trap sediments, pesticides, and other pollutants. Minimum width is 200 ft/60 m unless otherwise justified under criterion B.	
		Notes:					
		NW1.3 Preserve Prime Farmland	Not Available	A + B + C	A + B + C	(A + B) or D	A + B + E
		Projected Level of Achievement (Low)		(2) Less than 10% Disturbance	(8) Less than 5% Disturbance	(12) 100% Avoidance	(16) Restore Productive Farmland
		Not applicable		(A) The project team identifies soils designated as prime farmland, unique farmland, or farmland of importance.			
		Projected Level of Achievement (High)		(B) **Less than 10%** of the project site is developed or disturbed prime farmland.	(B) **Less than 5%** of the project site is developed or disturbed prime farmland.	(B) The project avoids developing or disturbing any prime farmland located on site.	
		Not applicable					
		Notes: Proposed facilities fit within existing plant site		(C) Farmland permanently damaged or disturbed as a result of the project is mitigated through offsets. Any farmland temporarily disturbed as a result of construction impacts is restored to a level that does not decrease the capacity of the preserved land.		OR (D) The project team can demonstrate the site was intentionally chosen to avoid areas of prime farmland.	(E) In addition to 100% avoidance, the project includes protecting farmlands for posterity against future disturbance, or restoring previously developed areas to a contiguous.
		NW1.4 Preserve Undeveloped Land	A	A	A	A	A + B
		Projected Level of Achievement (Low)	(3) At Least 25% Previously Developed	(8) At Least 50% Previously Developed	(12) At Least 75% Previously Developed	(18) 100% Previously Developed	(24) Restore Natural Areas
		(18) 100% Previously Developed	(A) **At least 25%** of the developed area of the project is located on previously developed land.	(A) **At least 50%** of the developed area of the project is located on previously developed land.	(A) **At least 75%** of the developed area of the project is located on previously developed land.	(A) **100%** of the developed area of the project is located on previously developed land.	
		Projected Level of Achievement (High)					
		(18) 100% Previously Developed					
		Notes: Proposed facilities fit within existing plant site					(B) Return developed areas to a condition that supports, or could support, open space, habitat, or natural hydrology.
	CONSERVATION	**NW2.1 Reclaim Brownfields**	A	B + C	B + C	B + C	B + C + D
		Projected Level of Achievement (Low)	(11) Reuse Former Brownfield	(13) Mitigate Exposure	(16) Passive Remediation	(19) Active Remediation	(22) Complete Remediation
		Not applicable	(A) The project is located on a site classified as a brownfield that has been remediated by others.	(B) The project is located on a site classified as a brownfield, or is known to contain contamination.			
		Projected Level of Achievement (High)		(C) Minimum required capping and remediation is performed to reduce human exposure to safe levels. Contaminants remain generally on site at levels that can be addressed by engineering and/or institutional controls.	(C) Passive remediation is performed to reduce human exposure and to gradually remove or break down contamination on the site.	(C) Active remediation, or a combination of active and passive remediation, is performed to reduce human exposure and to remove or break down contamination on the site.	(C) Active remediation, or a combination of active and passive remediation, is performed to restore the entirety of site soils and/or groundwater back to regional background or unrestricted use levels. (D) The site is closed/deregulated by regulators,
		Not applicable					
		Notes:					
		NW2.2 Manage Stormwater	A + B + C	A + B + C	A + B + C	A + B + C	A + B + C + D
		Projected Level of Achievement (Low)	(2) Expanded Options	(4) 85th percentile/2-year event	(9) 90th percentile/10-year event	(17) 95th percentile/50-year event	(24) 95th percentile/100-year event
		None	(A) Detain and treat 100% of the 85th percentile local 24-hour event. Ensure compliance with local requirements if stricter.				
		Projected Level of Achievement (High)	(B) Do not exceed rate or quantity of runoff for the 24-hour rainfall event relative to the existing condition (greenfield, greyfield, or brownfield).				
		None	Improved: 2-year | Enhanced: 2- and 5-year | Superior: 2-, 5-, and 10-year | Conserving: 2-, 5-, 10-, 25-, and 50-year | Restorative: 2-, 5-, 10-, 25-, 50-, and 100-year				
		Notes: County goal Compare criteria to what is required for permitting	(C) The project includes an erosion, sedimentation, and pollutant control plan for construction activities.				(C) The project includes an erosion, sedimentation, and pollutant control plan for construction activities. (D) The project manages or treats stormwater from other sites according to criterion A, OR returns the site to a predevelopment hydrological condition.

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			LEVEL OF ACHIEVEMENT				
NATURAL WORLD	CONSERVATION	**NW2.3 Reduce Pesticide & Fertilizer Impacts**	A + B	A + B + C	A + B + C + D	C	C
		Projected Level of Achievement (Low)	(1) Application Management	(2) Less Pesticide or Fertilizer	(5) Better Selection, Lower Use	(9) No Pesticide or Fertilizer Use	(12) Pesticide or Fertilizer Elimination
		(9) No Pesticide or Fertilizer Use	(A) Operational policies and programs are designed to control the application of pesticides and fertilizers so they are not over-applied.				
		Projected Level of Achievement (High)	(B) Runoff controls are put in place to minimize contamination of groundwater and surface water.				
		(9) No Pesticide or Fertilizer Use		(C) Landscaping is designed to incorporate plant species that require **fewer** fertilizers/pesticides.		(C) Landscaping is designed with plant species that **do not** require pesticides or fertilizers.	(C) Landscaping is designed with plant species that **do not** require pesticides or fertilizers. This includes eliminating the need for pesticides and/or fertilizers on sites with prior use of pesticides or fertilizers.
		Notes: County policy or program for county properties?? Any landscaping? Around edge of facility Stakeholder discussions - do they want to use the end product for other landscaping? Envision workshop: - Mary - Can be included in the specs now – plants shall not require pesticides or fertilizers - Charles – Some of this should be included in the "public master plan" - Lisa – Is there anything in Arlington's Landscaping contracts about reduced fertilizer? - Mary – We should look through the contracts. We do require native plants, I believe, so it may be in there.			(D) When needed, pesticides and fertilizers with low toxicity, persistence, and/or bioavailability are specified.		
		NW2.4 Protect Surface & Groundwater Quality	A + B	A + B + C	A + B + C + D	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(2) New Pathway Avoidance	(5) Community Support	(9) Risk Reduction	(14) Public Reporting	(20) Quality Improvement
		(2) New Pathway Avoidance	(A) The project team determines potential impacts to surface water or groundwater quality, including temperature, during construction and operations.				
		Projected Level of Achievement (High)	(B) The project includes spill and leak diversion systems, spill prevention plans, and cleanup. The project does not create new direct pathways for surface water and/or groundwater contamination such as: • Direct runoff into karst terrain; • Untreated industrial or chemical discharge to unlined industrial ponds or lakes; • Reinjection water wells unless water is treated to secondary levels, or local regulations, whichever is more stringent; or • Chemical, byproduct, or fracking water, injection.				
		(2) New Pathway Avoidance	(C) Based on the types of impacts identified in criterion A, the project reduces the risk of quality degradation to surface water and/or groundwater. This should include water temperature.				
		Baseline: _____ (needed for criterion F)	(D) Adequate measures enable responsive surface water and/or groundwater quality monitoring and reporting mechanisms to provide the public with water quality data.				
		Notes:	(E) The project has actively eliminated at least one source of hazardous and/or potentially polluting substances, or replaced them with nonhazardous or nonpolluting substances or materials.				
			(F) The project improves surface water and/or groundwater quality beyond existing conditions.				
	ECOLOGY	**NW3.1 Enhance Functional Habitats**	A + B	A + B + (C, D, or E)	A + B + (C, D, or E)	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(2) Mitigate Impacts	(5) One Ecosystem Function	(9) Two Ecosystem Functions	(15) Three Ecosystem Functions	(18) Restore and Create Habitats
		Not applicable	(A) The project team identifies existing habitat types on or near the project site. Efforts are made to avoid and minimize impacts to existing terrestrial habitats.				
		Projected Level of Achievement (High)	(B) Mitigation measures ensure that existing habitat functions as defined in criteria C, D, and E are maintained (i.e., not degraded or lost). Mitigation must occur on or adjacent to the site and follow a hierarchy that prioritizes avoidance, minimization, restoration, and compensation.			(B) The project ensures that no existing habitats are disturbed or damaged.	
		Not applicable					
		Notes:		(C, D, or E) Enhance **one or more** ecosystem functions compared to existing conditions;	(C, D, or E) Enhance **two or more** ecosystem functions compared to existing conditions;	(C, D, and E) Enhance **all three** ecosystem functions compared to existing conditions;	(C, D, and E) Enhance all three ecosystem functions compared to existing conditions;
		NW3.2 Enhance Wetland & Surface Water Functions	A + B + (C, D, E or F)	A + B + (C, D, E or F)	A + B + (C, D, E or F)	A + B + C + D + E + F	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(3) Enhance One Ecosystem Function	(7) Enhance Two Ecosystem Functions	(12) Enhance Three Ecosystem Functions	(18) Enhance Four Ecosystem Functions	(20) Restore Ecosystem Function
		Not applicable	(A) Project team identifies project impacts to hydrologic connection, water quality, aquatic habitat, and sediment transport.				
		Projected Level of Achievement (High)	(B) Efforts are made to avoid and minimize negative impacts to wetland and surface water functions and to compensate for remaining unavoidable losses. Mitigation measures must maintain net aquatic habitat quality and quantity and follow a hierarchy that prioritizes avoidance, minimization, restoration, and compensation.			(B) The project ensures that no existing wetlands or surface water functions are disturbed or damaged as a result of the project.	
		Not applicable					
		Notes:	(C, D, E or F) Actively protect **one** ecosystem function. • Hydrologic Connection (C)	(C, D, E or F) Actively protect **two** ecosystem functions.	(C, D, E or F) Actively protect **three** ecosystem functions.	(C, D, E and F) Actively protect **four** ecosystem functions.	(C, D, E and F) Actively protect **four** ecosystem functions.
		NW3.3 Maintain Floodplain Functions	A + B	A + B + C	A + B + C	(A + B + C) OR D	A + B + C + E
		Projected Level of Achievement (Low)	(1) 75% Avoidance	(3) 85% Avoidance	(7) 95% Avoidance	(11) Floodplain Preservation	(14) Floodplain Restoration
		Not applicable	(A) The project team identifies the 100-year or design frequency floodplain. Consideration is given to future floodplain scenarios.				
		Projected Level of Achievement (High)	(B) The project site maintains a net quantity of at least XX% (see above) of natural/vegetated area within the floodplain.				
		Not applicable		(C) Project mitigates impacts to floodplain functions including conveyance and storage. Overall floodplain functions are not diminished as a result of the project. Functions should be maintained both above and below the 10-year flood.			
		Notes: It appears that most of the treatment plant is in the floodplain, but that none of the land that this project is on is shown in the floodplain.	**Applicability**: Projects that are not within the floodplain ***and do not impact floodplain functions*** , may apply to have this credit deemed not applicable			OR (D) The project team can demonstrate the site was intentionally chosen to avoid development on or near the 100-year or design frequency floodplain.	(E) Structures are removed from the floodplain, or previously developed areas are restored to natural/ vegetated zones in order to improve floodplain functions.

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			LEVEL OF ACHIEVEMENT				
NATURAL WORLD	ECOLOGY	**NW3.4 Control Invasive Species**	A	A + B	A + B + C	A + B + C + D + E	A + B + C + D + E + F
		Projected Level of Achievement (Low)	(1) Prevention	(2) Assessment and Prevention	(6) Program Controls	(9) Minor Infestation Control	(12) Major Infestation Control
		(2) Assessment and Prevention	(A) **Best practices should be used to prevent unintentional introduction** of known invasive species to the site. Landscaping utilizes only species known to be noninvasive. A construction management plan, or policies, includes provisions for preventing the introduction of invasive species (plant or animal).				
		Projected Level of Achievement (High)	(B) **Identify, map and/or document invasive species infestations on site**, or collaborate with local, state/provincial, and/or federal agencies.				
		(6) Program Controls	(C) **Establish and implement a program that controls minor infestations** of invasive species on site **before and throughout construction**.				
		Notes: Likely no invasive species on site - confirm. Envision workshop: - A and B are pretty easy to get. - Charles – Urban forest master plan may cover all of this. - Baseline – say "Enhanced" for now. - Consider conserving if documentation already exists.	(D) The project guards against future infestations by supporting the **establishment of native and/or noninvasive species.** (E) **Long-term controls** are in place through a minimum three-year management plan to prevent the introduction or reintroduction of invasive species and perform follow-up control actions if populations persist. (F) Additionally, the project implements similar programs for controlling major infestations on site, or aquatic invasive species.				
		NW3.5 Protect Soil Health	Not Available	A + B	A + B + C	A + B + C	A + B + C + D
		Projected Level of Achievement (Low)		(3) Restore Soils	(4) Special Feature Plan	(6) Best Management Practices	(8) Soil Restoration
		None		(A) The project limits the area that is disturbed by development activities.			
		Projected Level of Achievement (High)		(B) **100% of post-construction vegetated areas disturbed during construction are restored** for appropriate soil type, structure, and function to support healthy plant and tree growth.			
		None			(C) A soil protection plan, or policies, are prepared and implemented. The plan/policies specifically include any special landscape features.	(C) A soil protection plan, or policies, are prepared and implemented. The plan/policies specifically include any special landscape features. The plan is expanded to comply with best management practices from a local soil conservation agency, or is reviewed or prepared under the guidance of a certified soil scientist.	
		Notes: Likely not to pursue					
		Innovation	**(+10) Innovate or exceed credit requirements.** (A) Implement innovative methods, technologies, or processes that are novel either in their use, application, or within the local regulatory or cultural context. OR (B) Implement measures that exceed the highest existing requirements within one or more Natural World credits. OR (C) Address additional aspects of sustainability not currently recognized in Envision				
		Projected Level of Achievement (Low)					
		None					
		Projected Level of Achievement (High)					
		None					
		Notes:					
						Maximum NW Points (w/o Innovation)	232

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			LEVEL OF ACHIEVEMENT				
CLIMATE AND RESILIENCE	EMISSIONS	**CR1.1 Reduce Net Embodied Carbon**	A + B + C	A + B + C	A + B + C	A + B + C	Not Available
		Projected Level of Achievement (Low)	(5) At Least 5% Reduction	(10) At Least 15% Reduction	(15) At Least 30% R	(20) At Least 50% Reduction	
		None	(A) The project team identifies primary materials to be used on the project during construction and operation. The team determines which materials are the primary contributors to net embodied carbon (collectively >80%).				
		Projected Level of Achievement (High)	(B) Embodied carbon is calculated, or acquired by a validated source, for the primary materials identified in criterion A. Calculations include: Embodied carbon of production, including raw material extraction, refinement,				
		None					
		Baseline: _____ **Notes:** Likely would not pursue	(C) The project team demonstrates **at least a 5%** reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	(C) The project team demonstrates **at least a 15%** reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	(C) The project team demonstrates **at least a 30%** reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	(C) The project team demonstrates **at least a 50%** reduction in total embodied carbon of materials over the life of the project compared to the baseline. Calculations should be in tons CO_2.	
		CR1.2 Reduce Greenhouse Gas Emissions	A + B	A + B	A + B	A + B	A + B
		Projected Level of Achievement (Low)	(8) At Least 10% Reduction	(13) At Least 25% Reduction	(18) At least 50% Reduction	(22) 100% Reduction	(26) Carbon Negative
		(8) At Least 10% Reduction	(A) The project team demonstrates **at least a 10% reduction** in total CO2e over the operational life of the project compared to the baseline.	(A) The project team demonstrates **at least a 25% reduction** in total CO2e over the operational life of the project compared to the baseline.	(A) The project team demonstrates **at least a 50% reduction** in total CO2e over the operational life of the project compared to the baseline.	(A) The project team demonstrates a **100% reduction** in total CO2e over the operational life of the project compared to the baseline.	(A) The completed project is carbon negative (i.e., sequesters/removes more CO2e than it produces over the operational life).
		Projected Level of Achievement (High)					
		(8) At Least 10% Reduction					
		Baseline: Existing condition (over a period equivalent to the operational life of the project) **Notes:** Solids reduced by 50% resulting in less truck traffic and hauling costs Credit requirements sent to Miranda.	(B) The project team maps and calculates the total annual greenhouse gas emissions of the final project design for reporting purposes. This includes direct and indirect greenhouse gas emissions and sequestration associated with project operations. Calculations must be in CO2e.				
		CR1.3 Reduce Air Pollutant Emissions	A + B	A + B + C	A + B + C + D	A + B + C + D	A + B + C + D + E
		Projected Level of Achievement (Low)	(2) Exceeding Requirements	(4) Ongoing Monitoring	(9) VOC Minimization	(14) Air Pollutant Elimination	(18) Air Quality Improvement
		(2) Exceeding Requirements	(A) The project meets all applicable air quality standards and regulations for air pollutants.				
		Projected Level of Achievement (High)	(B) The project implements strategies to reduce air pollutant emissions during operations.	(B) The project reduces emissions through the use of best available control systems or best management practices.	(B) Air pollution controls are within the 95th percentile, or represent the lowest levels possible compared to projects of similar type.	(B) The project eliminates air pollutant sources in the design, chooses a non-polluting alternative, or achieves at least a 98% net reduction in air pollution emissions compared to the baseline.	
		(2) Exceeding Requirements					
		Baseline: _____ **Notes:** Lower product odors Solids MP - Appendix K Air Emissions Modeling Report Credit requirements sent to Miranda.		(C) Systems are in place for the ongoing monitoring of any direct sources of air pollution. Processes are in place to identify and address changes in emissions in order to maintain performance targets. (D) The project team assesses whether volatile organic compounds harmful to human health are material to the project and, if so, implement strategies to reduce their use during construction and/or within occupied spaces of the completed project. (E) The project includes the direct removal of previously existing air pollutant sources, or captures and safely stores/ disposes of air pollutants for a net positive impact.			
	RESILIENCE	**CR2.1 Avoid Unsuitable Development**	A + B	A + B + C	A + B + C + D	A + B + C + E	A + B + C + F
		Projected Level of Achievement (Low)	(3) Alternative Assessment	(6) Risk Mitigation	(8) Lowest Risk Alternative	(12) Unsuitable Development Avoided	(16) Strategic Retreat
		Not applicable	(A) During planning and project siting, the project team identifies potential siting hazards and determines both the vulnerability of the project to the hazard and the potential for the project to exacerbate the hazard (e.g., creating impervious surfaces in a floodplain, building on potentially unstable hillsides). Potentially adverse sites include but are not limited to: • Steep slopes (> 20 degrees) • Permafrost • Adverse geology (e.g., risk of liquefaction, subsidence, or sinkholes) • Flood-prone areas • At-risk coastline (coastal surges, coastal erosion) (B) The project team assesses siting alternatives that avoid or minimize hazard exposure and/or project alternatives less vulnerable to, or likely to exacerbate, site hazards. (C) The project includes specific strategies to mitigate the impact of site hazards on the project (e.g., elevating structures and equipment above flood levels), as well as the project development impacts on the site hazard (e.g., erosion controls on steep slopes). This may include monitoring and response plans. (D) Based on alternatives identified in criterion C, the project team can demonstrate the selected project and site resulting in the lowest exposure to site risk while still meeting project objectives and requirements. (E) The project is intentionally sited to completely avoid site hazards. (F) The project intentionally modifies or removes existing structures from areas prone to frequent damage and/or at high risk of future damage in order to prevent losses.				
		Projected Level of Achievement (High)					
		Not applicable					
		Notes:					
		CR2.2 Assess Climate Change Vulnerability	A + B	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low)	(8) Project Vulnerability	(14) System Vulnerability	(18) Community Vulnerability	(20) Knowledge Sharing	
		(8) Project Vulnerability	(A) The project team conducts, or relies on, an existing, comprehensive threat/hazard identification study, or assessment, due to climate change. Threats/hazards are classified by: • Duration: acute shocks over hours and days, or chronic stressors over years and decades. • Extent of effects: project site (e.g., localized stormwater overflow), infrastructure system wide, or community wide (e.g., changes in climate). The assessment should account for climate change's impact on the frequency, duration, and severity of threats/hazards. (B) The project team determines vulnerabilities and increased risk to the project, or performance, over its **operational life** due to climate change-related threats. This should include whether current design variables will continue to meet performance goals over the life of the project under changing operating conditions (i.e., climate, weather patterns, natural hazard frequency and intensity). (C) The project team determines vulnerabilities and increased risk to the connected/related infrastructure system or network due to climate change-related threats. This should include how project vulnerabilities may impact system performance and how system vulnerabilities may impact the project. This should include direct and indirect impacts such as resource and service availability. (D) The project team determines vulnerabilities and increased risk to the broader community due to climate change threats. This should include how project vulnerabilities may impact the broader community and how community vulnerabilities may impact the project. (E) The project team or owner shares climate threat findings in order to support and facilitate community awareness and their inclusion in future projects.				
		Projected Level of Achievement (High)					
		(18) Community Vulnerability					
		Notes: Comprehensive Plan - CEP, Climate Action Resolution, Climate Change, Energy and Environment Commission (C2E2)					

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			LEVEL OF ACHIEVEMENT				
CLIMATE AND RESILIENCE	RESILIENCE	**CR2.3 Evaluate Risk and Resilience**	A + B + C + D + E	A + B + C + D + E	A + B + C + D + E	A + B + C + D + E + F	Not Available
		Projected Level of Achievement (Low)	(11) Project Evaluation	(18) System Evaluation	(24) Community Evaluation	(26) Integrated and Inclusive Approach	
		(11) Project Evaluation	(A) The project team draws the assessment boundary for subsequent criteria (B, C, D, and E) around the project and its site.	(A) The project team draws the assessment boundary for subsequent criteria (B, C, D, and E) around the interdependencies of the project and its	(A) The project team draws the assessment boundary for subsequent criteria (B, C, D, and E) around the interdependencies of the project, its associated/connected infrastructure system/network, and the broader community.		
		Projected Level of Achievement (High)					
		(18) System Evaluation					
		Notes:	(B) Understand the Asset: The project team identifies the objectives and performance goals of the project and related systems. It also identifies the critical assets, systems, and networks that are essential to meeting objectives and performance goals. This should include the associated dependencies and interdependencies within the system. (C) Identify Threats/Hazards: The project team identifies threats/hazards (natural hazards and human-induced threats). Project teams may reference existing studies or assessments if relevant to the project and its context. Threats should include both acute shocks and chronic stressors. (D) Identify Vulnerability: The project team identifies the vulnerabilities of the critical functions and dependencies of the infrastructure asset and its primary components identified in criterion B to the threats/hazards identified in criterion C. (E) Evaluate Risk: The project team evaluates the project risk by determining the likelihood/probability of a threat/hazard occurring and the associated consequences/impacts. Consequences and impacts should be classified as social, environmental, and/or economic/financial. (F) The project team conducts the risk evaluation with the owner and a diverse and integrated team of key stakeholders.				
		CR2.4 Establish Resilience Goals and Strategies	Not Available	A + B	A + B + C	A + B + C + D	Not Available
		Projected Level of Achievement (Low)		(8) Strategy Development	(14) Stakeholder Input	(20) Shared Community Goals	
		(20) Shared Community Goals		(A) The project team determines the performance goals of the project and the owner's acceptable level of risk. (B) The project team uses the results of a risk evaluation to develop risk management strategies that meet project performance goals and budget, and increase project resilience. The project team prioritizes strategies that result in the greatest reduction of risk within project cost constraints.			
		Projected Level of Achievement (High)					
		(20) Shared Community Goals			(C) The project team engages the owner and key stakeholders in developing or reviewing resilience goals and strategies.		
		Notes: Biogas -				(D) The project team aligns project resilience goals with broader community- or regionwide resilience goals and plans. OR If community resilience goals are lacking, the project team publicly shares its resilience goals in support of developing broader community goals.	
CLIMATE AND RESILIENCE	RESILIENCE	**CR2.5 Maximize Resilience**	A + B	A + B + C	A + B + C + D	A + B + C + D + E	Not Available
		Projected Level of Achievement (Low)	(11) Improved Resilience Performance	(15) Thorough Implementation	(20) Ongoing Resilience Monitoring	(26) Quantifying Improvement	
		(11) Improved Resilience Performance	(A) The project team develops resilience goals and strategies (e.g., CR2.4) based on a detailed risk evaluation of the project (e.g., CR2.3). (B) The project team takes a comprehensive approach to implementing resilience strategies. (C) The project team periodically monitors the implementation of resilience strategies and revisits their effectiveness in addressing project risk throughout project development. (D) Resilience strategies are incorporated into the operations and maintenance of the project. Organization(s) responsible for the ongoing operation of the project have systems in place to maintain, grow, learn, and continually improve resilience capabilities (i.e., "plan, do, check, act"). (E) The project team establishes methods for measuring/quantifying the benefits of resilience strategies implemented (e.g., monetary savings from avoided damage or service loss, accelerated recovery time).				
		Projected Level of Achievement (High)					
		(15) Thorough Implementation					
		Notes:					
		CR2.6 Improve Infrastructure Integration	A	A + B	A + B + C	A + B + C + D	A + B + C + D + E
		Projected Level of Achievement (Low)	(1) Internal Integration	(4) Risk Reduction	(8) Systems Integration	(14) Community/Network Integration	(18) Information Integration
		(14) Community/Network Integration	(A) The project increases internal systems integration in order to achieve efficiency or system diversity. (B) Integration strategies increase resilience and reduce the risk of systemic or cascading failures. (C) The project leverages its relationship within a larger infrastructure system in order to achieve efficiency or system diversity. (D) The project integrates networks of infrastructure systems (e.g., water and transportation) in order to achieve efficiency or system diversity. In certain cases, projects may substitute the community integration of non-physical social or economic systems. (E) The project integrates data or monitoring systems with reporting or preparedness systems in order to learn and improve performance over time.				
	Projected Level of Achievement (High)						
	(18) Information Integration						
	Notes:						
		Innovation	**(+1-10) Innovate or exceed credit requirements.** (A) Implement innovative methods, technologies, or processes that are novel either in their use, application, or within the local regulatory or cultural context. OR (B) Implement measures that exceed the highest existing requirements within one or more Climate and Resilience credits. OR (C) Address additional aspects of sustainability not currently recognized in Envision				
		Projected Level of Achievement (Low)					
		None					
		Projected Level of Achievement (High)					
		None					
		Notes: GHG Emission work - fit within CEP					
					Maximum CR Points (w/o Innovation)	190	

**** Not every credit has a restorative level. Therefore totals include the maximum possible points for each credit whether conserving or restorative.*

1,000 total pts + 50 extra **= 1,050 TOTAL**

Appendix C. Envision Credit Documentation Sources

Documentation to support the verification submission can come from all Program development phases (planning, design, construction, etc.), as well as external to the project, such as Arlington County policies and initiatives that can support Envision. The matrix in Appendix C provides a snapshot of potential Program phase or source of documents that may support each credit, depending on the pursued LOA.

The documentation sources identified in the matrix are identified as follows:

- **Owner:** The owner can be the organization/agency leading the project or any connected agencies that may have policies, standards, procedures, design guidelines, standard specifications, or regulations that impact project design, construction, or operation.
- **Planning/environmental:** This documentation may result from planning efforts, including an environmental assessment or environmental impact statement. Planning documents may extend beyond project planning to related master plans, capital plans, etc., developed by the owner or related organizations.
- **Designer:** These documents are produced by a designer, engineer, etc. and would be primarily project-specific, with the exception of organizational commitments. This could include documents like alternatives analyses and basis-of-design reports, but would explicitly include Program specifications, drawings, and related materials.
- **Contractor:** This documentation is provided by the construction contractor and would include items like a construction management plan, construction waste management plan, and site security plan, as well as information on organizational commitments.
- **External:** Because many Envision credits reference the Program's connections to community needs and goals, there may be documents external to the Program that can be used to support some credits. This could include community plans, climate action plans, strategic plans, databases, and ordinances or regulations. Research may also be conducted to support credits, such as using the U.S. Department of Agriculture Web Soil Survey to locate or disprove prime farmland within the project area.

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Envision Credit Documentation Sources

	Credit	Likely Documentation Source(s)				
		Owner (Policy/Standards)	Planning/Environmental	Designer	Contractor	External
QUALITY OF LIFE	QL1.1 Improve Community Quality of Life		■	■		■
	QL1.2 Enhance Public Health and Safety	■	■	■		■
	QL1.3 Improve Construction Safety	■		■	■	
	QL1.4 Minimize Noise and Vibration	■	■	■		
	QL1.5 Minimize Light Pollution	■	■	■		
	QL1.6 Minimize Construction Impacts	■		■	■	
	QL2.1 Improve Community Mobility and Access	■	■	■		■
	QL2.2 Encourage Sustainable Transportation		■	■		
	QL2.3 Improve Access and Wayfinding	■	■	■		
	QL3.1 Advance Equity and Social Justice	■	■	■	■	
	QL3.2 Preserve Historic and Cultural Resources		■	■		
	QL3.3 Enhance Views and Local Character	■	■	■		■
	QL3.4 Enhance Public Space and Amenities		■	■		
LEADERSHIP	LD1.1 Provide Effective Leadership and Commitment	■	■	■	■	
	LD1.2 Foster Collaboration and Teamwork	■	■	■	■	
	LD1.3 Provide For Stakeholder Involvement		■	■		
	LD1.4 Pursue Byproduct Synergies		■	■		■
	LD2.1 Establish A Sustainability Management Plan	■	■	■	■	
	LD2.2 Plan For Sustainable Communities	■	■			■
	LD2.3 Plan For Long-Term Monitoring and Maintenance	■	■	■		
	LD2.4 Plan For End-of-Life	■		■		
	LD3.1 Stimulate Economic Prosperity and Development	■	■	■		
	LD3.2 Develop Local Skills and Capabilities	■	■	■	■	
	LD3.3 Conduct a Life-Cycle Economic Evaluation		■	■		■
RESOURCE ALLOATION	RA1.1 Support Sustainable Procurement Practices	■		■	■	
	RA1.2 Use Recycled Materials	■		■	■	
	RA1.3 Reduce Operational Waste	■				
	RA1.4 Reduce Construction Waste	■		■	■	
	RA1.5 Balance Earthwork On Site	■		■	■	
	RA2.1 Reduce Operational Energy Consumption	■		■	■	
	RA2.2 Reduce Construction Energy Consumption	■		■	■	
	RA2.3 Use Renewable Energy	■				■
	RA2.4 Commission and Monitor Energy Systems	■		■		
	RA3.1 Preserve Water Resources	■	■	■		
	RA3.2 Reduce Operational Water Consumption	■	■	■		
	RA3.3 Reduce Construction Water Consumption	■		■	■	
	RA3.4 Monitor Water Systems	■				
NATURAL WORLD	NW1.1 Preserve Sites of High Ecological Value		■	■	■	
	NW1.2 Provide Wetlands and Surface Water Buffers		■	■	■	
	NW1.3 Preserve Prime Farmland		■			
	NW1.4 Preserve Undeveloped Land	■	■			
	NW2.1 Reclaim Brownfields	■	■			
	NW2.2 Manage Stormwater	■		■	■	
	NW2.3 Reduce Pesticide and Fertilizer Impacts	■		■	■	
	NW2.4 Protect Surface and Groundwater Quality	■	■	■	■	
	NW3.1 Enhance Functional Habitats		■	■	■	
	NW3.2 Enhance Wetland and Surface Water Functions		■	■	■	
	NW3.3 Maintain Floodplain Functions		■	■	■	
	NW3.4 Control Invasive Species	■	■	■	■	■
	NW3.5 Protect Soil Health	■		■	■	
CLIMATE AND RESILENCE	CR1.1 Reduce Net Embodied Carbon		■	■	■	■
	CR1.2 Reduce Greenhouse Gas Emissions	■	■	■		
	CR1.3 Reduce Air Pollutant Emissions		■	■		■
	CR2.1 Avoid Unsuitable Development		■	■		
	CR2.2 Assess Climate Change Vulnerability	■	■	■		■
	CR2.3 Evaluate Risk and Resilience	■	■	■		
	CR2.4 Establish Resilience Goals and Strategies	■		■		
	CR2.5 Maximize Resilience	■		■	■	
	CR2.6 Improve Infrastructure Integration	■	■	■		

Appendix D. Envision Credit Documentation Examples

The Appendix D matrix builds on Appendix C to provide discrete examples of documentation that could be used to support project narratives, originating from the program owner, external or programmatic documentation, and project-specific documentation.

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Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
QL1.1 Improve Community Quality of Life	• Agency/org master plans • Agency/org Strategic plans • Agency process for reviewing community needs, goals, and issues • Feedback and endorsement as part of larger planning efforts • Meeting minutes with stakeholders as part of planning efforts • Social impact assessment as part of larger planning efforts	• Community planning documents • Comprehensive plans • Strategic plans • Meeting minutes with key stakeholders, community leaders, decision makers • Presentations • Letters/emails • Design Guidelines • Potentially EIS/EIR/EA, Environmental documents completed for larger program	• Alternatives Analysis • Comments and reactions from social media platforms • Committee reports • Communication plan • Communications with representatives of affected communities, i.e, letters, emails, comment forms • Community satisfaction surveys • EIS/EIR/EA, Environmental documents • EIS/EIR/EA, Environmental documents comments and letters • Examples of how the project meets the needs could be a matrix • Interviews with representatives of affected communities • Letters • Meeting minutes (including with key stakeholders, community leaders, decision makers) • Memos • Mitigation hierarchy form (HDR)" • Notes from design charrettes • Social impact assessment as part of environmental assessment or stand-alone" • Workshop/charrette presentations
QL1.2 Enhance Public Health and Safety	• Agency/org master plans • Agency/org Strategic Plans • Agency/org policies related to health and safety • Agency/facility permits, standards, etc.	• Community plans (less likely, but could have ties to overall • Community health and safety)	• Alternatives analysis • EIS/EIR/EA, Environmental documents • Project permits
QL1.3 Improve Construction Safety	• Agency/org health & wellbeing programs • Agency/org site safety and/or security policies • Agency/org standard feedback mechanisms to identify safety risk • An agency could consider noting in an agency-level policy or plan where monitoring is committed to and encourage improvement. • An agency could develop a foundational plan and modify it to fit specific project needs; determine if any requirements need to be added to general specifications. • An agency could document standard procedures followed by all projects • Consider implementing elements of the criteria and requesting information from contractors and/or consultants • Contractor training requirements (standard spec or other) • Requirement that the contractor develop a project safety plan/program • Standard specifications re: contractor health & safety • Typical or facility site security plan		• Contractor "lesson learned" reports • Contractor communication (e.g., agendas from daily briefings, etc.) • Contractor H&S training programs (e.g., agendas or presentations for toolbox trainings, firm policies for CPR, first aid, OSHA training, etc.) • Contractor injury management documentation/process • Contractor organization health & wellbeing programs • Contractor Safety/Security Trainings • Contractor site security plan • Health and/or well-being programs • Job Hazard Analysis • Project Execution Plan • Project safety plan/program • Safety rewards program" • Security Plan (Site and Project)
QL1.4 Minimize Noise and Vibration	• Agency/org master plan(s) • Agency/org policies related to noise and/or vibration during operation • Agency/org master plan(s) -stakeholder engagement/feedback	• Potentially - EIS/EIR/EA, Environmental documents completed for larger program • Community noise ordinance or regulation	• Alternatives analysis • EIS/EIR, Environmental documents • Letters/emails • Meeting minutes • Mitigation hierarchy form • Noise monitoring plan • Plans and specifications (indicating quieter or modified equipment, noise barriers, etc.) • Project-specific noise and/or vibration assessment • Public feedback • Public surveys
QL1.5 Minimize Light Pollution	• Agency could consider adding standard lighting specification to meet backlight, uplight, and glare requirements according to IES BUG rating standards. • Agency could specify a standard cutoff lens (or options) in lighting specification for exterior use. • Agency/org fixture standards • Facility master plan • If on an existing facility, facility lighting information / facility lighting plan	• City policy/ordinance • if multiple projects, program lighting assessment • if multiple projects, program lighting plan	• EIS/EIR, Environmental documents • Light fixture cut sheets • Lighting specs • Map showing existing lighting vs. implemented lighting • Mitigation hierarchy form (HDR) • Project lighting plan • Project-specific lighting assessment • Project site map with noted lighting needs and impacts • Site map indicating location and type of each lighting strategy deployed
QL1.6 Minimize Construction Impacts	• Agency management plan or policy related to construction impacts o with guidance re: noise/vibration) o with guidance re: safety and wayfinding) o with guidance re: public space access) o with guidance re: lighting) o with guidance re: monitoring and feedback) • Agency standard construction monitoring programs • Agency/org policy related to construction management • Standard specification with contractor requirements adressign construction impacts o construction lighting (i.e., nighttime work) o maintaining access to public space and amenities during construction o pedestrian and vehicle safety and wayfinding during construction. o minimizing construction noise and vibration (should meet or exceed accepted local practices)		• Construction management plan o addressing lighting during construction o addressing plan for feedback, working with affected neighbors o including noise/vibration sources, mitigation/minimization, monitoring, and corrective action • Information from feedback mechanisms • Project specifications o addressing construction lighting (i.e., nighttime work) o addressing how access to public space and amenities will be maintained during construction. o addressing pedestrian and vehicle safety and wayfinding during construction. • Public communication (e.g., website, emails, presentations, etc.)

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
QL2.1 Improve Community Mobility and Access	• Agency master plan(s) • Agency Complete Streets policy	• Local/regional transportation plans • City Complete Streets policy • Local mobility studies	• Alternatives analysis • Basis of Design report • Diagrams/plans illustrating mobility and access • EIS/EIR/EA, Environmental documents • Reports, memos, meeting minutes of community meetings • Reports, memos, meeting minutes showing discussion of new connections/reconnections • Traffic analysis study (impact/improvement) • Transit/mobility assessment
QL2.2 Encourage Sustainable Transportation	• Agency master plan(s) • Agency/org transportation/transit policies (e.g., transit subsidies, bikeshare, carshare, etc.) • Agency programs related to EV charging	• Info on existing facilities, walkways, trails, and networks • Availability of non-motorized transportation facilities and policies for the users • Public transportation options: service maps/bus stops near project • Local/regional transportation plans	• Alternatives analysis • Basis of Design report • EIS/EIR/EA, Environmental documents • Map showing pedestrian proximity and accessibility to active, shared, or mass transportation • Mobility & Accessibility Map • Plans and specs • Public education plan & associated items (Display boards, social media) • Transit/mobility assessment
QL2.3 Improve Access and Wayfinding	• Agency emergency response policy/procedures • Agency org policy/standard re: universal design principles • Agency signage standards		• Communication examples • EIS/EIR/EA, Environmental documents • Map showing publicly accessible areas • Plans and specification o for signage o showing universal design o showing emergency access • Public meeting responses
QL3.1 Advance Equity and Social Justice	• Agency master plan(s) • Agency/ organizational policies and commitments concerning equity and social justice diversity & inclusion, pay equity, non-discrimination • Agency/org policies on stakeholder engagement	• Community planning documents	• Analysis of stakeholder engagement process • Basis of design • EIS/EIR/EA, Environmental documents • Evidence of key team member policies and commitments concerning equity and social justice diversity & inclusion, pay equity, non-discrimination • Examples of stakeholder communication • Examples of targeting underrepresented communities • Maps showing the key demographic data identified in the assessment of social impacts overlaid with areas likely to receive benefits or impacts of the project. • Meeting minutes • Mitigation Hierarchy form (HDR) • Programs to address equity and social justice • Project specific research on historical context • Project specific social risk and impact assessment • Qualifications of individuals responsible for managing the stakeholder engagement process. • Stakeholder mapping
QL3.2 Preserve Historic and Cultural Resources	• Agency/org policy on cultural resources • Agency master plan(s) • Facility master plan	• Databases and historical records • If multiple projects (program), program EIS/EIR/EA	• Alternatives Analysis • Cultural Resources Technical Report -Project assessment of cultural resources beyond National Registries (i.e. historic neighborhoods, places, events, natural features) • EIS/EIR/EA, Environmental documents • Meeting minutes • Project plans, specs; plans showing changes in plans due to feedback) • Presentations • SHPO letter(s) / communication • Site plan, plans, specs showing mitigation • Stakeholder feedback
QL3.3 Enhance Views and Local Character	• Agency/or design guidelines • Agency/org design/aesthetic guidelines • Agency/org land use and development policies • Agency/org policies and regulations regarding public views • Agency/org policy related to construction management • Standard specification with contractor requirements related to construction impacts	• Public/city policies and regulations regarding public views • Public/city design guidelines • Public/city land use policies	• Agency/Public comment • Alternatives analysis • Basis of Design • Construction management plan -identifies important natural or man-made features deemed important to views or local character and how they will be protected during construction. • EIS/EIR/EA, Environmental documents • Inventory of all natural landscape or manmade features to be protected. • Meeting Minutes • Meeting minutes -with stakeholders • Photos/renderings • Plans and specs; Plans/specifications noting protection of important features; site plan • Public presentations • Reports • Review board presentations • Stakeholder feedback • Tree protection plan
QL3.4 Enhance Public Space and Amenities	• Agency master plan(s) • Facility master plan	• Community plan(s) --showing community needs/goals • Articles	• Alternatives Analysis • EIS/EIR/EA, Environmental documents • Letters, memoranda, and meeting minutes with stakeholders showing stakeholder involvement • Maps • Photos/renderings • Project assessment of public space/amenities • Site plan/ plans showing public space/amenities • Stakeholder engagement plan • Stakeholder feedback/approval • Written approval from officials

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
LD1.1 Provide Effective Leadership and Commitment	• Agency/org Sustainability management policy • Agency/org sustainability commitment/strategy/goals • Agency/Organizational sustainability policies/ reports • Annual Reports • Master Plan(s) • News Releases • Standard RFP language • Strategic Plan • Sustainability reports • Websites		• Agenda, presentation, meeting minutes from chartering session/kickoff • Evidence of commitments to sustainability from each of the key project team members • Meeting minutes • Project charter • Project org chart • RFP (includes sustainability) • Specifications (include sustainability) • Sustainability Management Plan • Sustainability Management Policy • Sustainability reports
LD1.2 Foster Collaboration and Teamwork	• Project control standards/ guidelines • Integrated design standard/ guidelines		• Envision workshop • Kick-off meeting / sustainability kick-off meeting/ chartering session • List of sutainability meetings • Meeting minutes • Meeting Presentations • Org chart • Plans/specifications • Project controls • Project management plan • Project org chart • Sustainability Management Plan
LD1.3 Provide For Stakeholder Involvement	• Agency/org master plan(s)	• Community planning documents	• Comment Reports • Community engagement (communications) plan/Public Participation Plan • Design Element Boards • EIS/EIR/EA, Environmental documents • Examples of design changes, i.e., rendering, plans, etc. before/after • Feedback mechanism documentation • Letters/email of support • Meeting Minutes • Plan Presentations • Presentations • Project Fact Sheets (public/shared) • Public meeting/open house materials • Public outreach summary • Results of collaboration, i.e., reports, program description, etc. • Review board presentations/ feedback/meeting minutes • Social media • Stakeholder engagement plans • Stakeholder mapping exercise
LD1.4 Pursue Byproduct Synergies	• Agency/org processes related to byproduct use	• Internet / Online databases	• Basis of design report • Letters/emails • Meeting minutes • O&M info/manual • Plans/specifications • Research, i.e., websites, meetings, presentations, etc.
LD2.1 Establish A Sustainability Management Plan	• Agency operational processes, monitoring and reporting • Agency/org sustainability policy/ strategy • Project control standards/ guidelines • Some agency or organizational processes would be incorporated into a program or project SMP	• Program-level organizational chart	• Contractor reporting forms • Organizational chart • Sustainability management plan -Assessment of project environmental, economic, and social aspects
LD2.2 Plan For Sustainable Communities	• Agency/org design guidelines • Agency/org sustainability strategy and/or goals • Agency/org master plan	• Community planning documents	• Alternatives analysis • Assessment of project's impacts to broader long-term community or regional sustainability • EIS/EIR/EA, Environmental documents • Project planning documents
LD2.3 Plan For Long-Term Monitoring and Maintenance	• Agency/org budget or capital maintenance program • Agency/org Capital Plan – funding • Employee training information • Established O&M plan or plan standards • Example of maintenance performed at other client-owned facilities • Maintenance Guidelines • Monthly inspection documentation • O&M Certification Forms • Operations and Maintenance (O&M) Plan • Operations Manual • Role description(s) for people tasked with monitoring		• Alternatives analysis • Budget or funding • Long-Term Monitoring & Maintenance Plan • Maintenance Guidelines • Meeting Minutes • Monthly inspection documentation • O&M Certification Forms • O&M org chart • Operations and Maintenance (O&M) Plan • Operations Manual • Planting plan – native and regionally adapted plants • Schedule for re-evaluating the monitoring and maintenance plan • Specifications (noting material durability; training requirements) • Specs/Brochures describing monitoring systems • Training agendas • Training information

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
LD2.4 Plan For End-of-Life	• Agency/org design guidelines that require assessment of TBL end-of-life impacts		• Alternatives Analysis • Assessment of potential social, environmental, and economic end-of-life impacts; analysis of end-of-life costs and salvage value • BODR • End of life plan • Feasibility study for expansion • Feasibility study identifying key areas where increasing investment in extending useful life will offer a reasonable payback • Materials specs/brochures • Meeting minutes • Operations & Maintenance Plan -End of Life Plan • Photos • Potential expansion plans • Research/reports • Site materials for durability map showing materials and locations • Stakeholder engagement plan • Stakeholder feedback, i.e., letter, emails, comment cards
LD3.1 Stimulate Economic Prosperity and Development	• Agency/org master plan • Agency/org policy on DBE, local workers, training and development • Analysis performed regarding types of sustainable employment opportunities created by the project • Annual reports • Award submittals/Awards won • Owner project website	• Community planning documents	• Alternatives analysis • Analysis of jobs created during design, construction, and/or operation that benefit local economy • EIS/EIR/EA, Environmental documents (+Comments/letters) • Growth calculations • Job creation estimate • Letters/emails • Meeting minutes
LD3.2 Develop Local Skills and Capabilities	• Agency/org training policies and/or programs • Community Benefits Agreement • Community Jobs Program • Employment Agreement • Hiring specs directed at the project team	• Community Jobs Program	• Proposed education and training programs to be developed and implemented, and an explanation of the extent to which these programs will address identified community needs and improved community competitiveness, current and future • Job creation estimate • Tiger grant application • Hiring specs directed at the contractor
LD3.3 Conduct a Life-Cycle Economic Evaluation	• Agency/org master plan	• Community planning documents	• Alternatives analysis • Lifecycle cost analysis • Cost benefit analysis

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
RA1.1 Support Sustainable Procurement Practices	• Agency/org Sustainable Procurement Policy/Program • Policies and criteria for supplier identification and selection		• Project Sustainable Procurement Policy/Program • Calculations • Materials inventory • Material/supplier tracking forms and/ or spreadsheets; receipts/ invoices. • Manufacturer documentation • Materials certifications
RA1.2 Use Recycled Materials	• Agency/or design guidelines that require use of recycled materials	• Program goal for using recycled materials	• Calculation • Inventory of materials (reused and recycled content)
RA1.3 Reduce Operational Waste	• Agency/org O&M plan includes standard operational waste reduction measures • Agency/org policies addresing operational waste • Agency/org Operational Waste Management Plan	• Program-level waste management program or diversion goals	• Project operational waste management plan • Inventory of waste streams • Calculation - total waste vs. diversion
RA1.4 Reduce Construction Waste	• Agency/org policy about development and implementation of construction management plans • Agency/org policy about waste diversion rate/target • Standard specifications re: contractor waste diversion		• Construction waste management plan, reports, logs • Specifications, plans • Contractor waste forms • Calculations of total waste reduction measures and percentage of materials diverted to recycling or reuse. • Load tickets/logs • Recycling tickets
RA1.5 Balance Earthwork On Site	• Agency/org policy or standard practices about balancing earthwork		• BODR • Plans, specifications > • Site plan • Grading/drainage plans • Earthwork calculations/ Earthwork balance spreadsheet • Spec sections for site clearing/top soil and finishing • Cut and fill drawing/design • Map showing source/destination of materials brought onsite for fill or transported off-site. Map should indicate distance(s) • Load tickets/logs
RA2.1 Reduce Operational Energy Consumption	• Agency/org policy or standard practices about energy reduction • Baseline information, if based on other agency facility		• Project energy use estimates • Alternatives Analsysis • Meeting minutes • Business case for green funding • Meeting minutes • Electrical Site Plan and Light Fixture Schedule • Spec for LED lighting • Documentation of feasibility and cost analyses and how energy reductions were incorporated in the design • Calculations - Energy consumption and energy reduction • Documentation describing baseline
RA2.2 Reduce Construction Energy Consumption	• Agency/org policy or standard practices about contractor energy consumption, i.e., Tier IV vehicles, reduced idling, prefabrication of design elements	• State mandates related to contractor energy consumption, i.e., Tier IV vehicles, reduced idling	• Meeting minutes • Review report(s) • Construction management plan
RA2.3 Use Renewable Energy	• Agency/owner Energy Plan • Agency/owner renewble energy portfolio • Purchased Power (PPA) Summary	*Project teams cannot attribute latent renewable energy within the grid to the project without a purchase agreement.*	• Project Energy Plan • Project's anticipated annual operational energy consumption broken down by source type • Renewable Energy Breakdown by Source Type • Purchased Power (PPA) Summary
RA2.4 Commission and Monitor Energy Systems	• Agency/owner overall or facility-wide O&M plan(s) • Contract with commissioning agent • O&M Plan" • Scope of services • Testing procedures		• Contract with commissioning agent, team resumes • Network architecture diagram / Piping and Instrumentation Diagram • Plans/Specs for data/control/ monitoring systems • Project O&M Plan • Scope of services • Spec section on start up and commissioning • Spec section on training • Startup and performance testing • Testing procedures
RA3.1 Preserve Water Resources	• Agency/owner master plan(s)	• Regional water plan • Watershed-level or regional water plan	• Calculations • EIS/EIR/EA, Environmental documents • Flow calculations • Geotech reports • Piping plan • Planting plan • Process diagrams • Site master plan • Stormwater drainage study • Surface water analytical results • Surface water sampling proposal • Wastewater Discharge Alternatives Study • Water availability assessment • Water demands spreadsheet • Water quality report • Water reuse plan drawings

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
RA3.2 Reduce Operational Water Consumption			• Alternatives Analysis • BODR • Calculation • Irrigation plan • Landscape Plan • Meeting minutes • Plans and specs • Planting plan • Reports • Spec for plumbing fixtures and equipment
RA3.3 Reduce Construction Water Consumption	• Agency/org policy or standard practices about construction water use		• Construction management plan • Contractor programs and policies • Meeting minutes • Review report(s) • Spec for contractor water management plan
RA3.4 Monitor Water Systems	• Agency/owner overall or facility-wide O&M plan(s) • Agency/owner standard monitoring equipment and/or integration into existing system • Contract with commissioning agent • Operator Contract/RFP • Scope of services • Testing procedures		• Contract with commissioning agent, team resumes • Plans and specs • Project O&M Plan • Scope of services • Spec for data/control/ monitoring/metering systems • Spec section on training • Specs on start up and commissioning • Specs on water system • Specs or cut sheets of monitoring equipment • Startup and performance testing • Testing procedures

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
NW1.1 Preserve Sites of High Ecological Value			• Alternatives Analysis • Construction management plan • Contractor standard operating procedures • Documentation signed by natural resources professional or regulatory body • EIS/EIR/EA, Environmental documents • Land use map • Landscape plan • Landscape planting table • Mitigation Hierarchy Form (HDR) • Mitigation plan • Photos • Site map • Site plan • Site selection study • Specs
NW1.2 Provide Wetlands and Surface Water Buffers			• Alternatives Analysis • BODR • Calculations • EIS/EIR/EA, Environmental documents • Land use map • Maps • Meeting minutes • Photos • Plans/specs • Plan/spec on site clearing • Reports • Site plan • Site selection study • Surface Water Analytical Results • Surface Water Sampling proposal
NW1.3 Preserve Prime Farmland		• USDA Soil Data Explorer Map - Farmland Classification For N/A: show GIS map showing USDA information on prime farmlands in relation to the project site. (or other related map)	• Alternatives Analysis • Calculations • Construction management plan • EIS/EIR/EA, Environmental documents • Grading/site clearing plan • Map • Mitigation Hierarchy Form (HDR) • Photos • Plans/specs • Site plan • Siting analysis
NW1.4 Preserve Undeveloped Land			• EIS/EIR/EA, Environmental documents • Alternatives Analysis • Siting analysis • Plans/specs • Photos
NW2.1 Reclaim Brownfields	• Brownfield designation • Agency/owner monitoring processes	• Brownfield designation • Regulatory agency monitoring processes	• Closure report • Construction management plan • Deed restrictions • EIS/EIR/EA, Environmental documents • Mitigation and remediation plan • O&M Plan • Record of decision (ROD) • Site management, monitoring, and inspection plan
NW2.2 Manage Stormwater	• Agency/owner policy or practice regarding SWPPP or ESCP • Agency/owner/facility stormwater management plan	• City/regional stormwater management plan	• BODR • Calculations • Drainage map • Drainage plan • Drainage reports • EIS/EIR/EA, Environmental documents • Erosion, sedimentation, and pollutant control plan • Plans/specs • Site plan • Stormwater Pollution Prevention Plan (SWPPP) or Erosion and Sedimentation Control Plan (ESCP)
NW2.3 Reduce Pesticide and Fertilizer Impacts	• Agency/owner Integrated Pest Management practices • Agency/owner O&M plans/programs • Agency/owner policy or practice regarding landscape design/plant selection • Agency/owner policy or practice regarding landscape maintenance /fertilizers and pesticides		• Construction management plan • Information on specific plants • Integrated Pest Management plan • Landscape Maintenance Guidelines • Landscape maintenance plan • Organic • Plan/specs • Plant List • Planting plan-native & regionally adapted plants • Product information on pesticides and fertilizers • Project O&M plan • Seeding detail and seeding spec • Specs • Spec re: fertilizer management approach

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
NW2.4 Protect Surface and Groundwater Quality	• Agency/owner/facility O&M plan • Agency/owner-level water quality monitoring program(s) • Environmental Management Program • Photos • Spill Prevention, Control and Countermeasure (SPCC) Plans • Stormwater Pollution Prevention Plan (SWPPP)		• Alternatives Analysis • BODR • Construction Management Plan • Contamination management plan • Discharge permits • EIS/EIR/EA, Environmental documents • Environmental Management Program • Meeting minutes • O&M plan • Permits • Photos • Plans/specs • Potential Impact analysis report • Spill and leak prevention and response plans • Spill Prevention, Control and Countermeasure (SPCC) Plans • Stormwater drainage study • Stormwater Pollution Prevention Plan (SWPPP) • Water quality reports • Water Supply and Wastewater Discharge Alternatives Study
NW3.1 Enhance Functional Habitats		• Conservation easement • Information on native plants • Map showing connectivity to other sites • Protected habitats map • Rare, Threatened, and Endangered Species Lists	• Biologist statement saying this was addressed • Description of preventative measures/changes in design to support biodiversity • EIS/EIR/EA, Environmental documents • Landscaping Plan • List of species in habitat • Maps • Mitigation Hierarchy Form (HDR) • O&M Plan / Monitoring plan • Photos • Planting/seeding plans/ descriptions • Site photos • Site plan • Soil survey/resource report
NW3.2 Enhance Wetland and Surface Water Functions			• BODR • EIS/EIR/EA, Environmental documents • Habitat survey • Map of development • Maps • Mitigation Hierarchy Form (HDR) • Photos • Plans/specs • Pre-and Post-Development Topographic Maps • Pre-Construction Existing Conditions Map • Report(s) from qualified resource professional • Site paving plan • Soil Erosion and Sediment Control Plan • Stormwater management calculations
NW3.3 Maintain Floodplain Functions	• Agency/owner master plan • Agency/owner stormwater management plan	• FEMA floodplain map • External sources of climate change info	• Alternatives Analysis • Calculations • Drainage plan • EIS/EIR/EA, Environmental documents • Emergency plan specific to flooding • Erosion and sediment control plans • Grading Plan • Maps • Plans/specs • See also climate change info related to CR credits • Site map(s) • Site selection study • Stormwater management plan
NW3.4 Control Invasive Species	• Agency/owner environmental policy • Agency/owner landscape maintenance plan • Agency/owner master plans • Agency/owner species removal program • Agency/owner website	• Research/web - information about specified plant species • Status of Invasive Plants in area - university or extension website • Invasive Species of Concern in area	• Construction management plan • EIS/EIR/EA, Environmental documents • Landscape Details • Landscape Plan • Map(s) • Monitoring Plan • O&M Plan(s) • Park Landscape and Grounds Maintenance Plan • Plans/specs • Seeding specs • Site Plan • Species Removal Program • Treatment plan • Tree Protection Plan • Vegetation/Planting Plan
NW3.5 Protect Soil Health	• Agency/owner policy on restoring disturbed soils	• Local soil conservation agency best management practices	• Alternatives Analysis • Calcs showing 100% of disturbed soils have been restored • Construction management plan • Contractor documentation of soil restoration activities, areas of disturbance, and areas restored. • Disturbed Soils Calculations • Disturbed Soils map • Disturbed soils spec • EIS/EIR/EA, Environmental documents • Excavation spec • Landscape plan • Plans/specs • Site clearing spec • Site plans • Soil restoration plan • Topsoiling and finished grading spec

Envision Credit Documentation Examples

Credit	Owner Policy/Standard/Guideline	Other Broad Documentation Types (likely to cover multiple projects -- external or programmatic)	Project Specific
CR1.1 Reduce Net Embodied Carbon			• LCCA • Quantities spreadsheets or index of materials • Index of the embodied carbon calculations
CR1.2 Reduce Greenhouse Gas Emissions	• Baseline based on existing agency/owner facility		• Life-cycle carbon assessment • LCA Carbon Emissions Summary • SROI Study • Calculations • GHG reporting
CR1.3 Reduce Air Pollutant Emissions	• Agency/owner air quality standards/policy	• Local air quality standards and regulations	• Air permit • Air Permit application • EIS/EIR/EA, Environmental documents • Materials information • Monitoring plan • O&M Plan • Operational design document • Plans/specs • Plans/specs (control systems) • PTE Air Emission Calculations
CR2.1 Avoid Unsuitable Development		• Online resources	• Alternatives analysis • BODR • Borings Report • EIS/EIR/EA, Environmental documents • Environmental work plan • Landscape plan • Maps • Meeting minutes • Photos • Plans/specs
CR2.2 Assess Climate Change Vulnerability	• Agency/owner climate assessment • Agency/owner/facility master plan • Articles • Presentations (conference, public) • Evidence of collaboration • Webinar	• City, state, or regional climate impact assessment and adaptation plan • Climate change assessment - statewide - how it affects region around project	• Articles • Conference presentation • EIS/EIR/EA, Environmental documents • Meeting minutes • Project climate assessment • Project resiliency review (HDR) • Webinar
CR2.3 Evaluate Risk and Resilience			• EIS/EIR/EA, Environmental documents • Mapping graphic • Meeting minutes • Project climate assessment • Project resiliency review (HDR)
CR2.4 Establish Resilience Goals and Strategies		• Climate Impact Assessment and Adaptation Plan • Climate action/protection plan • Local/regional area plans/master plans	• EIS/EIR/EA, Environmental documents • Meeting minutes • Project climate assessment • Project resiliency review (HDR)
CR2.5 Maximize Resilience			• Calculations • EIS/EIR/EA, Environmental documents • Matrix of resilience goals and risk management strategies • Meeting minutes • Monitoring plan • O&M Plan(s) • Project climate assessment • Project resiliency review (HDR) • Reports • Risk Evaluation
CR2.6 Improve Infrastructure Integration	• Agency/org Master Plan(s) • Agency/org O&M guidelines • Maps	• Community planning documents • Maps • Related community policies	• Alternatives analysis • BODR • Design documents • Design workshop information • Meeting minutes • Plans/specs • Plans/specs – monitoring systems • Stakeholder comments • Utility plans

Technical Memorandum No. 18

Date:	December 14, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Arlington Re-Gen Program Greenhouse Gas Impact Analysis

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Appendix A. Greenhouse Gas Emission Calculations A-1

1.0 Introduction

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary sludge (PS) and waste activated sludge (WAS) thickening, dewatering, and lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The biosolids management improvements will affect the WPCP's operational greenhouse gas (GHG) emissions. Depending on which future scenario is selected, there are variable outcomes for GHG emissions from this biosolids treatment process, which have been evaluated in this technical memorandum (TM) in two analyses: a project-level GHG impact assessment and an energy use intensity (EUI) calculation for the biosolids facilities.

This TM is structured to provide some introductory information on GHG emissions and calculation protocols in Section 2.0. Project-specific methodology information is presented in Section 3.0, with calculated emissions and energy intensity metrics following in Sections 4.0 and 5.0.

2.0 Greenhouse Gas Fundamentals

A GHG impact assessment represents the GHG emissions associated with the activities of an entity or individual. GHGs are a group of compounds that have significant impacts on global warming and climate change based on their increasing presence in the atmosphere. The United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) has identified the following seven major compounds that contribute to the greenhouse effect in the atmosphere:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)
- Nitrogen trifluoride (NF_3)

The emissions of all of these chemicals are distilled into units of carbon dioxide equivalent (CO_2e) based on their relative level of impact and contribution to climate change and global warming. This variable is defined as the global warming potential (GWP) for each compound. Because these impacts are expressed in terms of CO_2e, they are often referred to as the "carbon footprint" of a project or facility; however, some GHG compounds do not include any carbon (i.e., SF_6), so this term is slightly misleading.

2.1 Global Warming Potential

These GWP values are used as reference factors when calculating the global warming impact for emissions of these identified compounds. GHG emissions are expressed in standardized units of CO_2e, typically as metric tons (MT). Table 1 lists the GHG compounds and their GWP values, as well as the atmospheric lifetime for each compound. These lifetimes can help researchers understand the impact of

reducing emissions of a specific compound and compare strategies to reduce the overall greenhouse effect from these emissions.

Table 1. Global Warming Potentials of Greenhouse Gases

Chemical	Formula	Global Warming Potential (100 years)	Atmospheric Lifetime (years)
Carbon dioxide	CO_2	1	5–200
Methane	CH_4	25	12
Nitrous oxide	N_2O	298	121
Sulfur hexafluoride	SF_6	22,800	3,200
Nitrogen trifluoride	NF_3	17,200	740
Hydrofluorocarbons	HFC	Up to 14,800	Varies
Perfluorocarbons	PFC	Up to 17,340	Varies

Source: 40 CFR Appendix Table A-1 to Subpart A of Part 98: Global Warming Potentials, based on IPCC AR4 findings.[1]

For the Re-Gen Program, calculations were developed in alignment with the Greenhouse Gas Protocol[2] (GHG Protocol). GHG Protocol Guidelines are the standard for developing GHG emission inventories and are broadly applicable to most industries and processes. Several climate reporting frameworks are built on the GHG Protocol or point to the guidelines as a principal resource. Frameworks include:

- Carbon Disclosure Project (CDP)
- U.S. Environmental Protection Agency (EPA) Climate Leaders
- California Climate Action Registry
- Global Reporting Initiative (GRI)
- United States Agency for International Development (USAID) Greenhouse Gas Pollution Prevention Program
- Ceres Sustainable Governance Initiative
- Task Force on Climate-related Financial Disclosures (TCFD)

The GHG Protocol Guidelines are a joint venture between the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD). The guidelines are updated regularly based on the latest climate science and have been used for GHG emissions accounting for more than 20 years. The guidelines consist of multiple guidance publications including the GHG Protocol Corporate Standard (2004), GHG Protocol for Project Accounting (2005), Corporate Value Chain (Scope 3) Standard (2011), and Product Life Cycle Standard (2011). Additional supplements for specific market sectors and industries have continually been added to the guidelines since their initial publication.

[1] 40 CFR Appendix Table A-1 to Subpart A of Part 98: Global Warming Potentials
[2] Greenhouse Gas Protocol Guidelines

2.2 Scopes of GHG Emissions

The GHG Protocol divides emissions into three "scopes" based on where emissions occur and what influences them. Figure 1 shows the following scopes and how they relate to the individual company or facility developing an emissions inventory:

- **Scope 1 emissions** are typically the simplest group of activities to quantify—they are the direct GHG emissions from a site (project or company) that encompass fuel combustion, process emissions, and on-site company vehicles and machinery. The facility directly controls these emissions.
- **Scope 2 emissions** are essentially all emissions that result from the purchase of grid power (or steam)—they are considered indirect because the emissions occur elsewhere from the facility (e.g., at a power plant), but the level of emissions coming from the power plant is driven partly by customer demand (a simple example is if the facility requires more electricity, more electricity would be generated and therefore more emissions). The facility does not directly control these emissions but does control the level of energy purchased.
- **Scope 3 emissions** are the most complex for carbon accounting, because they encompass GHG emissions from activities upstream and downstream of a facility in the supply chain. Emissions are generated by these activities, but varying degrees of data are available to attribute emissions to specific actions of the reporting company. The GHG Protocol considers 15 categories of emissions for Scope 3 evaluations, much of which focus on the supply-chain emissions associated with the production of goods.

For the Re-Gen Program, Scope 1, Scope 2, and the limited categories for Scope 3 that are applicable for analysis are discussed in later sections, with a list of specific activities for each scope presented in Table 3.

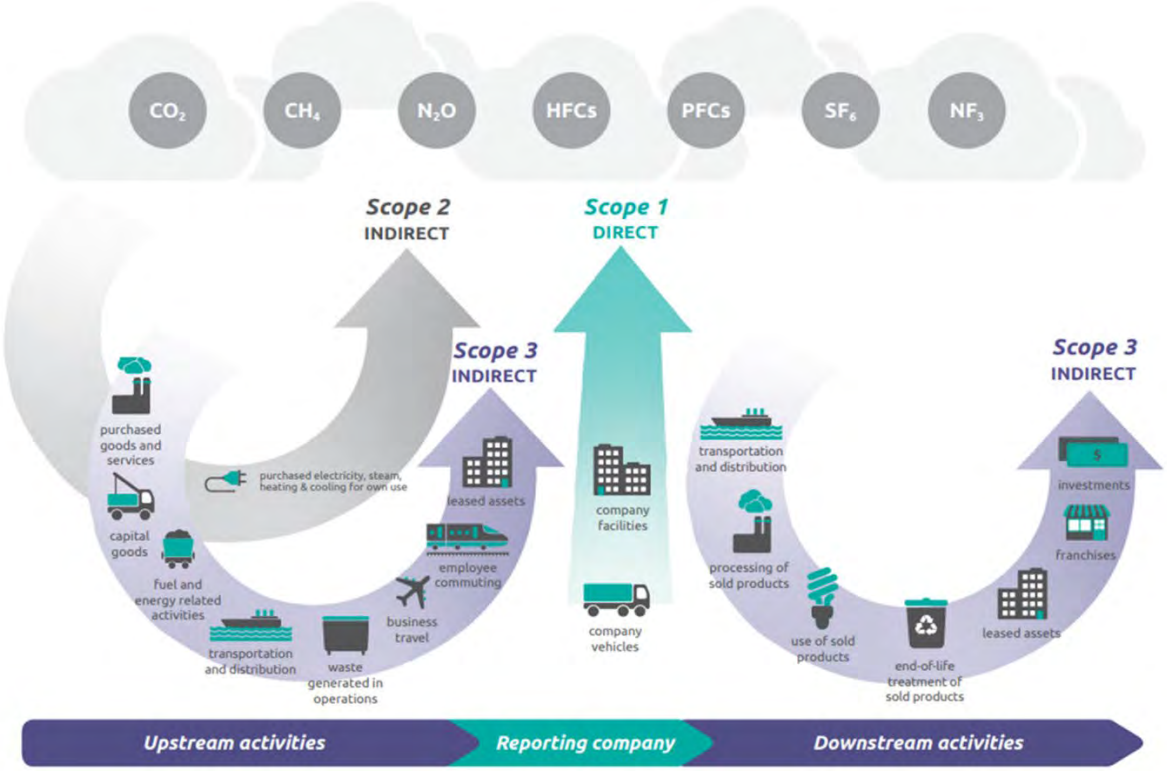

Figure 1. GHG Emission Scopes

Source: GHG Protocol Guidelines.

2.2.1 Carbon Sequestration

Downstream activities in Scope 3 include land application of biosolids. Carbon sequestration benefits from the land application of biosolids is an area of emerging research. The Biosolids Emission Assessment Model (BEAM), which was developed by the Canadian Council of Ministers of the Environment in 2009[3], and recently updated in 2022[4], provides estimates for GHG emissions from Canadian biosolids generators. BEAM was intended to help biosolids managers compare emissions from a range of biosolids management scenarios as agencies seek to become carbon neutral. BEAM includes emissions estimation methodologies for a variety of wastewater treatment activities and emission factors from a variety of sources.

With respect to carbon sequestration, the IPCC does not provide specific factors for carbon accumulation as a result of the use of organic soil amendments. Research is currently limited on the emission offsets for carbon sequestration.

Without more appropriate data for comparison to the local area surrounding the WPCP, no benefits from carbon sequestration should be included in the overall GHG impact calculation that could underrepresent the impacts from the Re-Gen Program.

[3] Canadian Council of Ministers of the Environment - BEAM 2009
[4] BEAM*2022, https://www.BiosolidsGHGs.org. Accessed December 2022.

2.3 Biogenic Emissions

Biogenic emissions are any GHG emission that results from renewable resources or carbon that is already present in the short-term, natural carbon cycle. The assumption is that these biogenic emissions are produced by organic material that would end up in the atmosphere from natural processes (decomposition, off-gassing of organic material, etc.), whereas GHG emissions from fossil fuel–based sources draw carbon out of long-term sinks and add it to the atmosphere, accelerating climate change through increased atmospheric CO_2.

2.3.1 Carbon Cycles

The natural carbon cycle has been a key part of planetary and atmospheric balance throughout the lifespan of Earth. Carbon is present in all life forms, and through natural processes, is moved back and forth between the land, the ocean, and the atmosphere continuously. These various pathways include natural fluxes, human contributions, and long-term storage of carbon.

IPCC distinguishes between the **slow domain** of the carbon cycle, where turnover times exceed 10,000 years, and the **fast domain** (the atmosphere, ocean, vegetation, and soil), where vegetation and soil carbon have turnover times in the magnitude of 1–100 and 10–500 years, respectively. Fossil fuel transfers carbon from the slow domain to the fast domain, while renewable systems such as biogas operate within the fast domain. Historically, a relatively constant amount of carbon has been present in this fast domain cycle, which is responsible for keeping the planetary temperature at a habitable level through the atmospheric greenhouse effect; however, the increasing atmospheric carbon resulting from fossil fuel transfers from the slow domain is shifting the balance of the carbon cycle and increasing the atmospheric greenhouse effect, which increases the average global temperature.

2.3.2 Anthropogenic Global Warming

As the Industrial Revolution accelerated the use of fossil fuels around the globe, combustion of fossil fuels has released into the atmosphere carbon that was previously locked up in long-term carbon sinks in the ground for millions of years. These activities primarily include combustion of oil and coal, as well as natural gas, but also include other human activities like burning of forests and clearing of land. These added emissions increase the amount of carbon in the fast domain, exceeding the offsetting capacity of natural carbon sinks and thus contributing to climate change.

3.0 Calculation Methodology

This section describes the approach to the GHG impact assessment and EUI calculations. GHG calculations can be developed for a wide range of activities and entities, depending on the scale of the analysis. There are several methods, with varying degrees of accuracy, and these methods are divided into tiers based on the level of detail and complexity, as discussed below. EUI calculations focus on expressing energy use per unit of production or operation, which helps understand the balance of expanding business while simultaneously making efforts to increase efficiency, thereby reducing material usage, energy usage, and environmental impact. Both calculations rely on input data and calculation factors to produce a resultant emissions total or energy intensity. The quality of these data is directly correlated to the reliability of the analyses.

3.1 Tiers of Methodology

The IPCC defines three tiers of methodology for GHG emission calculations: Tier 1 is the basic method, Tier 2 is intermediate, and Tier 3 is the most demanding in terms of complexity, precision, and data requirements. These tiers are shown in Table 2.

Wherever possible, site-specific data (highest tier) that include data inputs from actual operations and detailed project outcomes (materials hauled and specific start/end points for that transportation, physical properties of the biosolids, detailed calculations on the composition of the biogas production, etc.) were used in the analysis.

In some areas, a combination of site-specific data and standard emission factors from EPA (i.e., natural gas fuel combustion is calculated with the actual therms of gas used multiplied by EPA's standard conversion for natural gas combustion to CO_2e) were used in the analysis.

No values in the calculations rely on national or regional default values (the lowest calculation tier). The lowest tier is not an invalid method, and often is the best estimate available because of the challenges of collecting data in some parts of the value chain. However, for this analysis, the calculations reflect this site specifically and are more refined than what may be produced with more generic estimation tools.

Table 2. IPCC Methodology Tiers

Tier	Description
3	Direct measurements, local data
2	Combination of some direct measurements, local data, and regional default values
1	National or regional default values

3.2 Emission Factor Sources

Wherever possible, this analysis opted for the highest tier of complexity and specificity for the calculation methodology. All data inputs were sourced from the WPCP's site-specific data (both existing operations data from 2020 and detailed projections of operational loads for the future case of 2037) and used the most detailed emissions factors available. The sources for emission factors include EPA's Emission Factors for GHG Inventories database (standard for items like fuel combustion and transportation), sourced data directly from Dominion Energy about emissions from power generation, and also incorporated factors from accepted best practices for the biosolids industry. Emission factors are all referenced within the calculations, attached to this TM as Appendix A.

3.3 Project Activities

For this GHG calculation, only the biosolids treatment processes and supporting activities were evaluated (see Table 3). This includes the direct and indirect GHG emissions from the project in Scopes 1 and 2 above, and some limited activities from Scope 3.

Table 3. Project Activities and Other Activities

	Biosolids Treatment (Project)	Other WPCP Facilities
Scope 1	• Fuel combustion for Solids Processing Building heat and steam generation • Production of biogas	• Fuel combustion in various other equipment • Other wastewater treatment
Scope 2	• Electricity use for solids-handling processes	• Electricity use not for solids-handling processes
Scope 3	• Transportation and production of chemicals for biosolids processing • Transportation of biosolids for land application	• Transportation and production of chemicals/materials for liquid treatment

3.4 Scope 1 Emissions

For the Re-Gen Program, the Scope 1 emissions that were analyzed include:

- Fuel combustion for building heating (natural gas)
- Fuel combustion for process steam generation (natural gas)

Baseline data for these activities were taken directly from current operational data from 2020 natural gas purchasing records. Default emission factors for natural gas combustion were applied to calculate the GHG emissions from this fuel combustion. For the future use cases, projected natural gas consumption was calculated based on the anticipated steam and building heat demands.

3.5 Scope 2 Emissions

As discussed above, Scope 2 emissions are emissions generated in the production of purchased energy. Scope 2 baseline emissions were calculated directly from electrical meter records for electricity at distribution center (DC) 7 and solids area motor control centers. Future emissions were estimated based on the expected electrical demand for the completed improvements. Multiple grid power scenarios were evaluated, beginning with quantifying the impact of Dominion Energy's projected increase in renewable energy in its portfolio as it targets carbon-free energy by 2050. Calculations were also done to show the impact of the County's goal to procure all purchased power from renewable resources by 2025.

3.6 Scope 3 Emissions

The GHG Protocol Guidelines contain 15 established Scope 3 categories, many of which are not applicable to the Re-Gen Program. Activities that were considered to be material for this analysis and affected by this project included:

- Purchased goods and services:
  - Production of chemicals (lime, polymer) that are used in the biosolids treatment processes or in the liquid treatment process as a result of the biosolids treatment (methanol)
- Fuel- and energy-related activities:
  - Transmission grid losses for purchased electricity
- Transportation and distribution:
  - Upstream transportation emissions for chemical deliveries
  - Downstream transportation emissions for biosolids hauling to land application

The Scope 3 emissions were calculated by evaluating current operational data. Baseline biosolids transportation emissions were calculated based on volumes present on 2020 shipping invoices, and an average round-trip distance to local fields for land application. Chemical delivery invoices were analyzed and baseline hauling emissions were estimated based on the size of the trucks, the number of deliveries, and the distance to the point of origin (including empty backhauling) for each chemical. Future emissions were estimated based on the projected increase or decrease of necessary chemical additives for the new biosolids handling and treatment process, in addition to the future amount of biosolids that would require transportation to land application. Transmission grid losses are roughly 5 percent of the energy transferred[5] (EPA 2021) and this factor is typically applied to Scope 3 emissions in GHG inventories.

Portions of land application activities are considered in the WPCP's Scope 3 emission calculations, including the transport of biosolids to the end point, the tractors that perform the application, and an estimate of emissions from the storage piles of biosolids prior to land application. At this time, the calculations do not quantify the carbon sequestration value of the land-applied biosolids or the potential benefit of offsetting conventional fertilizers. Generic information and emission factors are available through BEAM; however, those particular activities should be investigated locally to assess the applicability of the generic BEAM emission factors and assumptions.

3.7 Natural Gas Offsets

Biogas (a combination of primarily methane and carbon dioxide) will be produced as part of the new biosolids facilities. This biogas production results from the breakdown of organic materials within the wastewater. Carbon dioxide and other impurities will be removed from this biogas through a treatment process to produce pipeline-quality renewable natural gas (RNG). The RNG will likely be injected into the natural gas pipeline and sold to downstream users.

Use of the RNG by the downstream users will displace current use of fossil-fuel based natural gas, resulting in an offset of natural gas use. Emissions resulting from biogas treatment and the combustion of RNG are considered biogenic emissions at the point of combustion. The end user of the biogas would be able to claim a Scope 1 emission reduction for use of the RNG as a renewable fuel. These emission reductions are an important piece of the renewable focus of the Re-Gen Program but would not be reported as part of the WPCP's GHG inventory. The analysis presented below includes these emissions reductions as part of the overall comparison between existing and future GHG assessments.

4.0 Project GHG Assessment

To calculate the GHG impacts for the Re-Gen Program, a detailed assessment of current operational GHG emissions was performed, focusing on biosolids treatment only. The baseline GHG assessment was then expanded and revised to account for changes to the process as a result of the Re-Gen Program. The resulting future GHG impact assessment was then compared to the baseline to show the overall impact of the Re-Gen Program and its effect on GHG emissions.

[5] https://www.epa.gov/egrid/egrid-questions-and-answers#egrid5aa

4.1 Energy Value of Renewable Natural Gas Production

Based on operational projections for the WPCP, the amount of RNG produced at the mid-point of the Re-Gen Program (year 2037) has a heating value of 118,000 million British thermal units (MMBtu) per year (yr), which is roughly equivalent to 115 million standard cubic feet (MMscf) of conventional natural gas. This offset of fossil fuel with a renewable fuel saves 6,150 MT CO_2e from entering the atmosphere from long-term carbon sinks and replaces it with biogenic CO_2e, using carbon that is already present in the short-term (fast domain) carbon cycle. Table 4 below shows the equivalent GHG emissions from RNG produced.

Table 4. Equivalent GHG Emissions from RNG Produced

RNG Produced (2037)	GHG Compound	Emission Factor (kg/MMBtu)	GWP	MT CO_2e
118,000 MMBtu	CO_2	52.07	1	6,120
	CH_4	0.003	25	9
	N_2O	0.0006	298	21
			Total emissions	6,150

The maximum RNG production value of 118,000 MMBtu/yr assumes that all available biogas is refined into pipeline-quality RNG for distribution downstream and none of the biogas is used on site. This value of 6,150 MT CO_2e will be used in comparisons below to illustrate the impact of RNG production on the biosolids treatment facilities' GHG emissions.

4.2 Project Operational Scenarios

A variety of future scenarios were analyzed for year 2037 to show the differences in overall GHG emissions based on factors both within the control of the WPCP and beyond the control of the WPCP, including projections for added renewable energy for purchased power from Dominion Energy:

- **Continuation of current operations in future scenario:** if the Re-Gen Program is not completed and lime treatment continues
- **Future scenario 1:** estimate Scope 2 emissions with no added renewable energy
- **Future scenario 2:** estimate Scope 2 emissions with Dominion Energy projection for increased renewables as they move to carbon-free 2050
- **Future scenario 3:** estimate Scope 2 emissions assuming that Arlington County reaches its goal of 100 percent renewable energy sourcing by 2025
- **Future scenario 4:** estimate Scope 2 emissions with Dominion Energy projection for increased renewables as it moves to carbon-free 2050; use biogas on site for steam production in the boilers to offset conventional natural gas (reduces available biogas sent to pipeline)

Table 5 below presents each of these scenarios side by side for comparison. Note that if the current lime treatment continues, GHG emissions for all three scopes will increase in proportion to the expected increase in overall WPCP flow. There is a significant increase in Scope 1, 2, and 3 emissions for the transition to digestion and RNG production over the current lime treatment process; however, as discussed above, the RNG that is produced will offset conventional natural gas in the pipeline that would

otherwise emit more than 6,000 MT CO_2e as shown in Section 4.1. **When compared with the current operations, this results in a GHG reduction range of 4,290 to 7,560 MT CO_2e per year, depending on the energy source.**

Table 5. Annual GHG Emissions for Future Scenarios (MT CO_2e)

Category	Baseline 2020: Limed Solids	Future 2037: Limed Solids	Future 2037: Digested Solids, Same Grid Power Emission Factors	Future 2037: Digested Solids Dominion Renewable Projection	Future 2037: Digested Solids Arlington County 100% Renewable	Future 2037: Digested Solids, Dominion Renewable Projection, Some RNG Combusted on Site
Scope 1	41	49	1,970	1,970	1,970	0
Scope 2	1,210	1,420	3,300	1,380	0	1,380
Scope 3	3,510	3,860	1,940	1,940	1,940	1,940
Total[a]	**4,760**	**5,340**	**7,210**	**5,290**	**3,910**	**3,320**
RNG offset	--	--	*(6,150)*	*(6,150)*	*(6,150)*	*(4,180)*
Adjusted total	--	--	*1,050*	*(860)*	*(2,240)*	*(860)*
Difference from future—limed	--	--	*(4,290)*	*(6,200)*	*(7,560)*	*(6,200)*

a. Rounded values may not sum consistently.

The benefits of the Re-Gen Program increase depending on the energy sources for the electricity used to produce the biogas. All three future digested solids scenarios have the same Scope 1 and Scope 3 emissions; however, the reductions in GHG emissions from purchased electricity (Scope 2) are included in future scenarios 2, 3, and 4. The result shows that the source of the purchased power does make a difference, and that even when electricity is generated with less-clean fuels, the benefits outweigh the costs when compared with the baseline scenarios.

As a final point of comparison, there is the potential to use the biogas on site to remove the need for purchased conventional natural gas for operating the biosolids treatment process. This beneficial use of the biogas would zero out the Scope 1 emissions for the Re-Gen Program by removing fossil fuel from the process but would also reduce the amount of available RNG to be sold into the pipeline. This scenario is still beneficial but may not provide the greatest financial return for the WPCP depending on market values. Please reference the *Arlington Re-Gen Biogas Utilization Report (HDR, November 2022)* for a detailed comparison of the various biogas utilization options that were considered for the WPCP.

5.0 Project Energy Intensity

To assess the potential energy benefits from the Re-Gen Program, the overall EUI for the production of RNG to offset conventional natural gas and the change from current operational EUI were both calculated. Energy usage was quantified in MMBtu for both the fuel combustion and the equivalent MMBtu in purchased electricity to standardize the amount of energy used for each component of the Re-Gen Program. Using a standard energy unit allows for a direct comparison of different energy sources.

As shown in Table 6 below, the WPCP will increase in flow between the baseline of 2020 and the future scenario in 2037 no matter which strategies are (or are not) implemented. The fuel combustion on site

and electricity demand are projected to increase in proportion to the main WPCP flow increase, accounting for an overall energy increase of 2,800 MMBtu between the baseline and future cases.

The proposed improvements to create pipeline-quality RNG and produce Class A biosolids will require a significant increase in operational energy demand. However, the RNG that is produced has a much higher equivalent heating value than the energy that is required for production. The investment of some traditional energy to produce a larger volume of renewable energy creates a **beneficial energy balance** for the Re-Gen Program.

Table 6. Biosolids Treatment Energy Balance

Energy Source	Baseline 2020 Energy Use (MMBtu)	Future 2037 Limed Energy Use (MMBtu)	Future 2037 Digested Energy Use (MMBtu)
Fuel combustion	780	921	37,000
Purchased power	14,400	17,000	39,500
RNG produced	--	--	*(118,000)*
Total energy use	15,200	18,000	*(41,000)*

Conversion of power usage (kWh) to energy (MMBtu): 293 kWh = 1 MMBtu.

5.1 Energy Use Intensity

When this energy usage is normalized for the projected increase in biosolids that would be produced in the future as WPCP throughput grows, the resultant EUI factor is expressed as energy used over biosolids produced in Table 7, based on the values established in Table 6 above. Note that the limed biosolids EUI remains constant, as no processes would be changed for that scenario.

Table 7. Energy Use Intensity of Biosolids Treatment Options

Energy Source	Baseline 2020	Future 2037 Limed	Future 2037 Digested
Total energy use (MMBtu)	15,200	18,000	*(41,000)*
Produced biosolids (DT/year)	9,920	11,700	11,700
EUI (MMBtu/DT solids)	1.53	1.53	*(3.50)*

The project creates more energy than it consumes and uses the biosolids as a renewable resource. Energy usage does not factor in energy source (renewables or fossil) for grid power, but only shows the energy demand of the facilities. This yields an **overall energy-positive** result, as the **energy required to make the RNG fuel is less than the energy value of the RNG that is produced.**

5.2 EnergyStar Ratings for Comparative EUI

The EnergyStar program provides energy efficiency metrics and ratings for a range of applications. The rating is most commonly found on commercial appliances, which are ranked by ability to save energy by using less electricity and/or water throughout the lifetime of the equipment. The EnergyStar program has also been applied to commercial buildings with the same principles: buildings that are designed to require fewer resources and less energy are rated accordingly.

Some wastewater treatment plants have also been evaluated with the EnergyStar program and given a score based on their relative use of purchased power and other operational metrics. Energy usages are

calculated and compared against other wastewater treatment facilities across the country in a database of survey information that has been compiled by the Water Research Foundation. From there, a facility can be assigned a rank within the database, which then corresponds to an assigned EnergyStar score.

Comparing the energy use of the Re-Gen Program to other wastewater treatment facilities is not recommended, as the EnergyStar rating system is intended to be used for entire wastewater treatment plant operations, rather than specific portions, such as biosolids processing. The rating system also does not account for differences in treatment requirements at various wastewater facilities, which can vary drastically depending on the location and water body to which a plant releases outflow. This difference in treatment requirements can mean that significantly more energy is needed to achieve treatment, and some plant designs inherently are more energy intensive. The rating system also does not account for differences in plant processes such as variations in chemical treatment applications, different biosolids treatment technologies, or different scales of operations. Figure 2 summarizes the differences between these two assessments, which both calculate an energy use metric, but use different methodologies.

Project-specific GHG assessment	EnergyStar rating/score
• Includes Scope 1, Scope 2, and Scope 3 GHG emissions relevant to the Program • Represents only the biosolids processing facilities affected by this Program • Calculated for this specific facility (WPCP) • Expressed as energy usage (kBtu) per dry tons of solids produced per day (tons)	• Energy usage only (no Scope 3), both electricity use (kWh) and combustion on site (kBtu) • Based on average influent flow (plant-wide) • Scores are based on comparisons to National Survey Data from AwwaRF in a lookup table • Expressed as energy usage (kBtu) per influent flow (gpd)

Figure 2. Methodology comparison for EnergyStar

6.0 Conclusions

The current WPCP biosolids treatment process produces solids for land application as a beneficial outcome. The proposed Re-Gen Program to implement a digestion process and create, capture, and clean biogas for sale as RNG provides a greater benefit than land application with lime stabilization alone. The reductions in CO_2e emissions by producing RNG as a renewable fuel offset conventional fossil fuel and reduce the need for extraction of fossil fuel from long-term carbon sinks. The GHG impact assessment of the biosolids treatment facilities at the WPCP shows an energy-positive result, meaning that the facility will generate more energy than it consumes, and this generated energy takes advantage of a renewable resource (wastewater) that will increase over time. The sustainability elements of the Re-Gen Program align with sustainability principles and support the County's larger sustainability goals, including prioritizing renewable fuel sources and reducing EUI for County operations.

Appendix A. Greenhouse Gas Emission Calculations

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

Parameter	Unit	Source/Note	2020	2021	2022	2023	2024	2025
Flow	mgd	TM1	23	23.2	23.5	23.7	24.0	24.2
Existing Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	14,448	14,601	14,754	14,907	15,060	15,213
Power - DC7	kWh/yr	PowerBI (2020), proportion per flow	2,889,785	2,920,410	2,951,036	2,981,661	3,012,287	3,042,912
Power - Solids MCCs	kWh/yr	PowerBI (partial 2021), proportion per flow	1,343,355	1,357,592	1,371,829	1,386,065	1,400,302	1,414,539
Natural Gas	MMBtu/yr	Utility bill	780	788	797	805	813	821
Biosolids Produced	DT/year	TM1, data analysis	9,921	10,027	10,132	10,237	10,342	10,447
Biosolids Hauled	MT/year	Calculation	29,669	29,984	30,298	30,613	30,927	31,241
Polymer - Thickening	MT/year	Polymer deliveries	18	18	18	19	19	19
Polymer - Dewatering	MT/year	Polymer deliveries	42	42	43	43	44	44
Lime	MT/year	Lime tickets	1,484	1,499	1,515	1,531	1,547	1,562
Methanol	gal/yr	Methanol tickets	321,200	324,604	328,008	331,412	334,816	338,220
Existing Facilities GHG Emissions - Scope 1	MT CO2e/year	Baseline Factors	41	42	42	43	43	44
Existing Facilities GHG Emissions - Scope 2	MT CO2e/year	Baseline Factors	1,206	1,219	1,232	1,245	1,258	1,270
Existing Facilities GHG Emissions - Scope 3	MT CO2e/year	Baseline Factors	3,514	3,535	3,555	3,576	3,597	3,617
Existing Facilities GHG Emissions - Total	MT CO2e/year	Baseline Factors	**4,762**	**4,796**	**4,830**	**4,864**	**4,897**	**4,931**
New Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	-	-	-	-	-	-
Power	kWh/yr	Estimate load 2052, proportion per flow						
Natural Gas Consumed	MMBtu/yr	Gas utilization model	31,491	31,817	32,143	32,469	32,795	33,121
Biogas to Flare	MMBtu/yr	Gas utilization model	14,624	14,781	14,936	15,091	15,245	15,403
RNG Generated	MMBtu/yr	Gas utilization model	99,618	100,688	101,739	102,790	103,841	104,911
Biosolids Hauled	MT/year	TM1	14,600	14,755	14,909	15,064	15,219	15,374
Polymer - Pre-dewatering	MT/year	Match existing	42	42	43	43	44	44
Polymer - Final Dewatering	MT/year	Solids model	47	47	48	48	49	49
Lime	MT/year	None	-	-	-	-	-	-
Methanol	gal/yr	Methanol tickets+recycle	2342	2,367	2,392	2,417	2,442	2,467
Biogenic Emissions	*MT CO2e/year*	*Future (2037) Factors*	*765*	*774*	*782*	*790*	*798*	*806*
New Facilities GHG Emissions - Scope 1	MT CO2e/year	Future (2037) Factors	1,673	1,690	1,707	1,725	1,742	1,759
New Facilities GHG Emissions - Scope 2	MT CO2e/year	Future (2037) Factors - assume no grid mix change	-	-	-	-	-	-
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100% carbon-free 2050	-	-	-	-	-	-
		Future (2037) Factors - assume Arlington County meets 100% renewable energy purchasing goal	-	-	-	-	-	-
New Facilities GHG Emissions - Scope 3	MT CO2e/year	Future (2037) Factors	1,795	1,804	1,812	1,821	1,829	1,837
New Facilities GHG Emissions - Total	MT CO2e/year	Future (2037) Factors - assume no grid mix change	**3,468**	**3,494**	**3,519**	**3,545**	**3,571**	**3,597**
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100% carbon-free 2050	**3,468**	**3,494**	**3,519**	**3,545**	**3,571**	**3,597**
		Future (2037) Factors - assume Arlington County meets 100% renewable energy purchasing goal	**3,468**	**3,494**	**3,519**	**3,545**	**3,571**	**3,597**
Equivalent GHG Emissions from RNG Produced	MT CO2e/year	conventional natural gas offset	5,214	5,270	5,325	5,380	5,435	5,491
Energy Demand (Scope 1 and 2)								
Baseline	MMBtu/yr		15,228	15,389	15,550	15,712	15,873	16,034
Future	MMBtu/yr		(68,127)	(68,871)	(69,596)	(70,321)	(71,046)	(71,790)
Energy Intensity (per dry ton solids produced)*								
Baseline	MMBtu/DT produced	*assumes the same amount of biosolids are treated pre- and post-	1.53	1.53	1.53	1.53	1.53	1.53
Future	MMBtu/DT produced	project, scaled proportionally to plant flow	(6.87)	(6.87)	(6.87)	(6.87)	(6.87)	(6.87)

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

Parameter	Unit	Source/Note	2026	2027	2028	2029	2030	2031	2032	2033
Flow	mgd	TM1	24.5	24.7	25.0	25.2	25.4	25.7	25.9	26.2
Existing Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	15,366	15,519	15,672	15,826	15,979	16,132	16,285	16,438
Power - DC7	kWh/yr	PowerBI (2020), proportion per flow	3,073,537	3,104,163	3,134,788	3,165,414	3,196,039	3,226,665	3,257,290	3,287,915
Power - Solids MCCs	kWh/yr	PowerBI (partial 2021), proportion per flow	1,428,775	1,443,012	1,457,249	1,471,485	1,485,722	1,499,959	1,514,195	1,528,432
Natural Gas	MMBtu/yr	Utility bill	830	838	846	854	863	871	879	887
Biosolids Produced	DT/year	TM1, data analysis	10,552	10,657	10,763	10,868	10,973	11,078	11,183	11,288
Biosolids Hauled	MT/year	Calculation	31,556	31,870	32,185	32,499	32,814	33,128	33,442	33,757
Polymer - Thickening	MT/year	Polymer deliveries	19	19	20	20	20	20	20	20
Polymer - Dewatering	MT/year	Polymer deliveries	45	45	46	46	46	47	47	48
Lime	MT/year	Lime tickets	1,578	1,594	1,609	1,625	1,641	1,657	1,672	1,688
Methanol	gal/yr	Methanol tickets	341,624	345,028	348,432	351,836	355,240	358,644	362,048	365,452
Existing Facilities GHG Emissions - Scope 1	MT CO2e/year	Baseline Factors	44	45	45	45	46	46	47	47
Existing Facilities GHG Emissions - Scope 2	MT CO2e/year	Baseline Factors	1,283	1,296	1,309	1,322	1,334	1,347	1,360	1,373
Existing Facilities GHG Emissions - Scope 3	MT CO2e/year	Baseline Factors	3,638	3,658	3,679	3,699	3,720	3,740	3,761	3,781
Existing Facilities GHG Emissions - Total	MT CO2e/year	Baseline Factors	**4,965**	**4,998**	**5,032**	**5,066**	**5,100**	**5,133**	**5,167**	**5,201**
New Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	-	35,974	36,329	36,683	37,038	37,393	37,748	38,103
Power	kWh/yr	Estimate load 2052, proportion per flow		10,540,264	10,644,253	10,748,243	10,852,232	10,956,222	11,060,211	11,164,200
Natural Gas Consumed	MMBtu/yr	Gas utilization model	33,447	33,773	34,099	34,425	34,750	35,076	35,402	35,728
Biogas to Flare	MMBtu/yr	Gas utilization model	15,557	15,712	15,867	16,024	16,179	16,334	16,488	16,646
RNG Generated	MMBtu/yr	Gas utilization model	105,961	107,012	108,063	109,133	110,184	111,235	112,286	113,355
Biosolids Hauled	MT/year	TM1	15,528	15,683	15,838	15,993	16,147	16,302	16,457	16,611
Polymer - Pre-dewatering	MT/year	Match existing	45	45	46	46	46	47	47	48
Polymer - Final Dewatering	MT/year	Solids model	50	50	51	51	52	52	53	53
Lime	MT/year	None	-	-	-	-	-	-	-	-
Methanol	gal/yr	Methanol tickets+recycle	2,491	2,516	2,541	2,566	2,591	2,616	2,640	2,665
Biogenic Emissions	*MT CO2e/year*	*Future (2037) Factors*	*814*	*822*	*830*	*839*	*847*	*855*	*863*	*871*
New Facilities GHG Emissions - Scope 1	MT CO2e/year	Future (2037) Factors	1,777	1,794	1,811	1,828	1,846	1,863	1,880	1,898
New Facilities GHG Emissions - Scope 2	MT CO2e/year	Future (2037) Factors - assume no grid mix change	-	3,004	3,034	3,063	3,093	3,123	3,152	3,182
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100%	-	1,260	1,272	1,285	1,297	1,309	1,322	1,334
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	-	-	-	-	-	-	-	-
New Facilities GHG Emissions - Scope 3	MT CO2e/year	Future (2037) Factors	1,846	1,854	1,863	1,871	1,880	1,888	1,897	1,905
New Facilities GHG Emissions - Total	MT CO2e/year	Future (2037) Factors - assume no grid mix change	**3,622**	**6,652**	**6,708**	**6,763**	**6,818**	**6,874**	**6,929**	**6,985**
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100%	**3,622**	**4,908**	**4,946**	**4,984**	**5,023**	**5,061**	**5,099**	**5,137**
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	**3,622**	**3,648**	**3,674**	**3,700**	**3,726**	**3,751**	**3,777**	**3,803**
Equivalent GHG Emissions from RNG Produced	MT CO2e/year	conventional natural gas offset	5,546	5,601	5,656	5,712	5,767	5,822	5,877	5,933
Energy Demand (Scope 1 and 2)										
Baseline	MMBtu/yr		16,196	16,357	16,519	16,680	16,841	17,003	17,164	17,326
Future	MMBtu/yr		(72,515)	(37,266)	(37,636)	(38,025)	(38,395)	(38,765)	(39,135)	(39,524)
Energy Intensity (per dry ton solids produced)*										
Baseline	MMBtu/DT produced	*assumes the same amount of biosolids are treated pre- and post-	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Future	MMBtu/DT produced	project, scaled proportionally to plant flow	(6.87)	(3.50)	(3.50)	(3.50)	(3.50)	(3.50)	(3.50)	(3.50)

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

Parameter	Unit	Source/Note	2034	2035	2036	2037	2038	2039	2040	2041
Flow	mgd	TM1	26.4	26.7	26.9	27.1	27.4	27.6	27.9	28.1
Existing Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	16,591	16,744	16,897	17,050	17,204	17,357	17,510	17,663
Power - DC7	kWh/yr	PowerBI (2020), proportion per flow	3,318,541	3,349,166	3,379,792	3,410,417	3,441,043	3,471,668	3,502,294	3,532,919
Power - Solids MCCs	kWh/yr	PowerBI (partial 2021), proportion per flow	1,542,669	1,556,905	1,571,142	1,585,378	1,599,615	1,613,852	1,628,088	1,642,325
Natural Gas	MMBtu/yr	Utility bill	896	904	912	921	929	937	945	954
Biosolids Produced	DT/year	TM1, data analysis	11,393	11,499	11,604	11,709	11,814	11,919	12,024	12,129
Biosolids Hauled	MT/year	Calculation	34,071	34,386	34,700	35,015	35,329	35,644	35,958	36,272
Polymer - Thickening	MT/year	Polymer deliveries	21	21	21	21	21	22	22	22
Polymer - Dewatering	MT/year	Polymer deliveries	48	49	49	50	50	50	51	51
Lime	MT/year	Lime tickets	1,704	1,719	1,735	1,751	1,767	1,782	1,798	1,814
Methanol	gal/yr	Methanol tickets	368,856	372,260	375,664	379,068	382,472	385,876	389,280	392,684
Existing Facilities GHG Emissions - Scope 1	MT CO2e/year	Baseline Factors	48	48	48	49	49	50	50	51
Existing Facilities GHG Emissions - Scope 2	MT CO2e/year	Baseline Factors	1,385	1,398	1,411	1,424	1,437	1,449	1,462	1,475
Existing Facilities GHG Emissions - Scope 3	MT CO2e/year	Baseline Factors	3,802	3,822	3,843	3,863	3,884	3,904	3,925	3,945
Existing Facilities GHG Emissions - Total	MT CO2e/year	Baseline Factors	**5,235**	**5,268**	**5,302**	**5,336**	**5,370**	**5,403**	**5,437**	**5,471**
New Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	38,458	38,813	39,168	39,523	39,878	40,233	40,587	40,942
Power	kWh/yr	Estimate load 2052, proportion per flow	11,268,190	11,372,179	11,476,169	11,580,158	11,684,148	11,788,137	11,892,127	11,996,116
Natural Gas Consumed	MMBtu/yr	Gas utilization model	36,054	36,380	36,706	37,032	37,358	37,684	38,010	38,336
Biogas to Flare	MMBtu/yr	Gas utilization model	16,800	16,955	17,110	17,267	17,422	17,576	17,731	17,889
RNG Generated	MMBtu/yr	Gas utilization model	114,406	115,457	116,508	117,578	118,629	119,680	120,730	121,800
Biosolids Hauled	MT/year	TM1	16,766	16,921	17,076	17,230	17,385	17,540	17,695	17,849
Polymer - Pre-dewatering	MT/year	Match existing	48	49	49	50	50	50	51	51
Polymer - Final Dewatering	MT/year	Solids model	54	54	55	55	56	56	57	57
Lime	MT/year	None	-	-	-	-	-	-	-	-
Methanol	gal/yr	Methanol tickets+recycle	2,690	2,715	2,740	2,765	2,789	2,814	2,839	2,864
Biogenic Emissions	*MT CO2e/year*	*Future (2037) Factors*	*879*	*887*	*895*	*904*	*912*	*920*	*928*	*936*
New Facilities GHG Emissions - Scope 1	MT CO2e/year	Future (2037) Factors	1,915	1,932	1,950	1,967	1,984	2,002	2,019	2,036
New Facilities GHG Emissions - Scope 2	MT CO2e/year	Future (2037) Factors - assume no grid mix change	3,211	3,241	3,271	3,300	3,330	3,360	3,389	3,419
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100	1,347	1,359	1,372	1,384	1,396	1,409	1,421	1,434
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	-	-	-	-	-	-	-	-
New Facilities GHG Emissions - Scope 3	MT CO2e/year	Future (2037) Factors	1,914	1,922	1,931	1,939	1,948	1,956	1,965	1,973
New Facilities GHG Emissions - Total	MT CO2e/year	Future (2037) Factors - assume no grid mix change	**7,040**	**7,096**	**7,151**	**7,206**	**7,262**	**7,317**	**7,373**	**7,428**
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100	**5,175**	**5,214**	**5,252**	**5,290**	**5,328**	**5,367**	**5,405**	**5,443**
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	**3,829**	**3,855**	**3,880**	**3,906**	**3,932**	**3,958**	**3,983**	**4,009**
Equivalent GHG Emissions from RNG Produced	MT CO2e/year	conventional natural gas offset	5,988	6,043	6,098	6,154	6,209	6,264	6,319	6,375
Energy Demand (Scope 1 and 2)										
Baseline	MMBtu/yr		17,487	17,648	17,810	17,971	18,132	18,294	18,455	18,617
Future	MMBtu/yr		(39,894)	(40,264)	(40,634)	(41,023)	(41,393)	(41,763)	(42,133)	(42,522)
Energy Intensity (per dry ton solids produced)*										
Baseline	MMBtu/DT produced	*assumes the same amount of biosolids are treated pre- and post-	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Future	MMBtu/DT produced	project, scaled proportionally to plant flow	(3.50)	(3.50)	(3.50)	(3.50)	(3.50)	(3.50)	(3.50)	(3.51)

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

Parameter	Unit	Source/Note	2042	2043	2044	2045	2046	2047	2048	2049
Flow	mgd	TM1	28.4	28.6	28.9	29.1	29.3	29.6	29.8	30.1
Existing Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	17,816	17,969	18,122	18,275	18,429	18,582	18,735	18,888
Power - DC7	kWh/yr	PowerBI (2020), proportion per flow	3,563,544	3,594,170	3,624,795	3,655,421	3,686,046	3,716,672	3,747,297	3,777,922
Power - Solids MCCs	kWh/yr	PowerBI (partial 2021), proportion per flow	1,656,562	1,670,798	1,685,035	1,699,272	1,713,508	1,727,745	1,741,982	1,756,218
Natural Gas	MMBtu/yr	Utility bill	962	970	978	987	995	1,003	1,011	1,020
Biosolids Produced	DT/year	TM1, data analysis	12,235	12,340	12,445	12,550	12,655	12,760	12,865	12,971
Biosolids Hauled	MT/year	Calculation	36,587	36,901	37,216	37,530	37,845	38,159	38,473	38,788
Polymer - Thickening	MT/year	Polymer deliveries	22	22	23	23	23	23	23	24
Polymer - Dewatering	MT/year	Polymer deliveries	52	52	53	53	54	54	54	55
Lime	MT/year	Lime tickets	1,830	1,845	1,861	1,877	1,892	1,908	1,924	1,940
Methanol	gal/yr	Methanol tickets	396,088	399,493	402,897	406,301	409,705	413,109	416,513	419,917
Existing Facilities GHG Emissions - Scope 1	MT CO2e/year	Baseline Factors	51	52	52	52	53	53	54	54
Existing Facilities GHG Emissions - Scope 2	MT CO2e/year	Baseline Factors	1,488	1,501	1,513	1,526	1,539	1,552	1,564	1,577
Existing Facilities GHG Emissions - Scope 3	MT CO2e/year	Baseline Factors	3,966	3,986	4,007	4,027	4,048	4,068	4,089	4,109
Existing Facilities GHG Emissions - Total	MT CO2e/year	Baseline Factors	**5,505**	**5,538**	**5,572**	**5,606**	**5,640**	**5,673**	**5,707**	**5,741**
New Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	41,297	41,652	42,007	42,362	42,717	43,072	43,427	43,782
Power	kWh/yr	Estimate load 2052, proportion per flow	12,100,106	12,204,095	12,308,084	12,412,074	12,516,063	12,620,053	12,724,042	12,828,032
Natural Gas Consumed	MMBtu/yr	Gas utilization model	38,662	38,987	39,313	39,639	39,965	40,291	40,617	40,943
Biogas to Flare	MMBtu/yr	Gas utilization model	18,043	18,198	18,353	18,510	18,665	18,819	18,974	19,132
RNG Generated	MMBtu/yr	Gas utilization model	122,851	123,902	124,953	126,023	127,074	128,124	129,175	130,245
Biosolids Hauled	MT/year	TM1	18,004	18,159	18,313	18,468	18,623	18,778	18,932	19,087
Polymer - Pre-dewatering	MT/year	Match existing	52	52	53	53	54	54	54	55
Polymer - Final Dewatering	MT/year	Solids model	58	58	59	59	60	60	61	61
Lime	MT/year	None	-	-	-	-	-	-	-	-
Methanol	gal/yr	Methanol tickets+recycle	2,889	2,913	2,938	2,963	2,988	3,013	3,038	3,062
Biogenic Emissions	*MT CO2e/year*	*Future (2037) Factors*	*944*	*952*	*961*	*969*	*977*	*985*	*993*	*1,001*
New Facilities GHG Emissions - Scope 1	MT CO2e/year	Future (2037) Factors	2,053	2,071	2,088	2,105	2,123	2,140	2,157	2,175
New Facilities GHG Emissions - Scope 2	MT CO2e/year	Future (2037) Factors - assume no grid mix change	3,449	3,478	3,508	3,537	3,567	3,597	3,626	3,656
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100%	1,446	1,459	1,471	1,483	1,496	1,508	1,521	1,533
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	-	-	-	-	-	-	-	-
New Facilities GHG Emissions - Scope 3	MT CO2e/year	Future (2037) Factors	1,981	1,990	1,998	2,007	2,015	2,024	2,032	2,041
New Facilities GHG Emissions - Total	MT CO2e/year	Future (2037) Factors - assume no grid mix change	**7,484**	**7,539**	**7,594**	**7,650**	**7,705**	**7,761**	**7,816**	**7,871**
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100%	**5,481**	**5,519**	**5,558**	**5,596**	**5,634**	**5,672**	**5,710**	**5,749**
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	**4,035**	**4,061**	**4,087**	**4,112**	**4,138**	**4,164**	**4,190**	**4,215**
Equivalent GHG Emissions from RNG Produced	MT CO2e/year	conventional natural gas offset	6,430	6,485	6,540	6,596	6,651	6,706	6,761	6,817
Energy Demand (Scope 1 and 2)										
Baseline	MMBtu/yr		18,778	18,939	19,101	19,262	19,423	19,585	19,746	19,908
Future	MMBtu/yr		(42,892)	(43,262)	(43,632)	(44,021)	(44,391)	(44,761)	(45,131)	(45,520)
Energy Intensity (per dry ton solids produced)*										
Baseline	MMBtu/DT produced	*assumes the same amount of biosolids are treated pre- and post-	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Future	MMBtu/DT produced	project, scaled proportionally to plant flow	(3.51)	(3.51)	(3.51)	(3.51)	(3.51)	(3.51)	(3.51)	(3.51)

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

Parameter	Unit	Source/Note	2050	2051	2052
Flow	mgd	TM1	30.3	30.6	30.8
Existing Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	19,041	19,194	19,347
Power - DC7	kWh/yr	PowerBI (2020), proportion per flow	3,808,548	3,839,173	3,869,799
Power - Solids MCCs	kWh/yr	PowerBI (partial 2021), proportion per flow	1,770,455	1,784,692	1,798,928
Natural Gas	MMBtu/yr	Utility bill	1,028	1,036	1,045
Biosolids Produced	DT/year	TM1, data analysis	13,076	13,181	13,286
Biosolids Hauled	MT/year	Calculation	39,102	39,417	39,731
Polymer - Thickening	MT/year	Polymer deliveries	24	24	24
Polymer - Dewatering	MT/year	Polymer deliveries	55	56	56
Lime	MT/year	Lime tickets	1,955	1,971	1,987
Methanol	gal/yr	Methanol tickets	423,321	426,725	430,129
Existing Facilities GHG Emissions - Scope 1	MT CO2e/year	Baseline Factors	55	55	55
Existing Facilities GHG Emissions - Scope 2	MT CO2e/year	Baseline Factors	1,590	1,603	1,616
Existing Facilities GHG Emissions - Scope 3	MT CO2e/year	Baseline Factors	4,130	4,150	4,171
Existing Facilities GHG Emissions - Total	MT CO2e/year	Baseline Factors	**5,774**	**5,808**	**5,842**
New Facilities	MMBtu/yr	convert electricity to equivalent energy in MMBtu	44,137	44,492	44,846
Power	kWh/yr	Estimate load 2052, proportion per flow	12,932,021	13,036,011	13,140,000
Natural Gas Consumed	MMBtu/yr	Gas utilization model	41,269	41,595	41,921
Biogas to Flare	MMBtu/yr	Gas utilization model	19,286	19,441	19,599
RNG Generated	MMBtu/yr	Gas utilization model	131,296	132,347	133,417
Biosolids Hauled	MT/year	TM1	19,242	19,397	19,551
Polymer - Pre-dewatering	MT/year	Match existing	62	62	63
Polymer - Final Dewatering	MT/year	Solids model	0	0	0
Lime	MT/year	None	-	-	-
Methanol	gal/yr	Methanol tickets+recycle	3,087	3,112	3,137
Biogenic Emissions	*MT CO2e/year*	*Future (2037) Factors*	*1,009*	*1,017*	*1,026*
New Facilities GHG Emissions - Scope 1	MT CO2e/year	Future (2037) Factors	2,192	2,209	2,227
New Facilities GHG Emissions - Scope 2	MT CO2e/year	Future (2037) Factors - assume no grid mix change	3,686	3,715	3,745
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100%	1,546	1,558	1,570
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	-	-	-
New Facilities GHG Emissions - Scope 3	MT CO2e/year	Future (2037) Factors	1,554	1,558	1,563
New Facilities GHG Emissions - Total	MT CO2e/year	Future (2037) Factors - assume no grid mix change	**7,432**	**7,483**	**7,534**
		Future (2037) Factors - assume grid mix change per Dominion forecast to 100%	**5,292**	**5,326**	**5,360**
		Future (2037) Factors - assume Arlington County meets 100% renewable energ	**3,746**	**3,768**	**3,790**
Equivalent GHG Emissions from RNG Produced	MT CO2e/year	conventional natural gas offset	6,872	6,927	6,983
Energy Demand (Scope 1 and 2)					
Baseline	MMBtu/yr		20,069	20,230	20,392
Future	MMBtu/yr		(45,890)	(46,260)	(46,650)
Energy Intensity (per dry ton solids produced)*					
Baseline	MMBtu/DT produced	*assumes the same amount of biosolids are treated pre- and post-	1.53	1.53	1.53
Future	MMBtu/DT produced	project, scaled proportionally to plant flow	(3.51)	(3.51)	(3.51)

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

FACTOR	UNIT	SOURCE	VALUE
Global Warming Potentials			
CO2	GWP	Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007	1
CH4	GWP	Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007	25
N2O	GWP	Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007	298
Emission Factors - Scope 1			
Stationary Combustion, Natural Gas	kg CO2/MMBtu	EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	53.06
Stationary Combustion, Natural Gas	kg CH4/MMBtu	EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.001
Stationary Combustion, Natural Gas	kg N2O/MMBtu	EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.0001
Stationary Combustion, Biogas (flared)	kg CO2/MMBtu	EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	52.07
Stationary Combustion, Biogas (flared)	kg CH4/MMBtu	EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.003
Stationary Combustion, Biogas (flared)	kg N2O/MMBtu	EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.0006
Emission Factors - Scope 2			
Purchased Power Emissions, 2020	MT CO2e/MWh	https://sustainability.dominionenergy.com/assets/pdf/metrics/dominion-energy-environmental-metrics-2019.pdf	0.285
Purchased Power Emissions, 2037	MT CO2e/MWh	Projected Renewable Grid Mix - Dominion Energy Forecast, targeting 100% Carbon Free by 2050	0.120
Purchased Power Emissions, 2037	MT CO2e/MWh	Arlington County Goal of 100% Renewable Energy Sourcing	0.000
Emission Factors - Scope 3			
2019 Transmission Loss (Virginia)	% Loss	US Energy Information Administration (EIA) State Profile Data; https://www.eia.gov/electricity/state/virginia/	5.14%
Transportation and Distribution, Material Transport (calculated Upstream)	MT CO2e	Assume: diesel medium/heavy duty trucks; EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.211
Transportation and Distribution, Material Transport (calculated Downstream)	MT CO2e	Assume: diesel medium/heavy duty trucks; EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.000002
			0.0000049
Transportation and Distribution, Material Transport (Backhaul)	MT CO2e	Assume: diesel medium/heavy duty trucks; EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	1.407
Transportation and Distribution, Material Transport (Backhaul)	MT CO2e	Assume: diesel medium/heavy duty trucks; EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.000013
		Assume: diesel medium/heavy duty trucks; EPA, Emission Factors for Greenhouse Gas Inventories, April 2021	0.000033
Average Trip Distance, Lime Delivery	miles one-way	Assume: Greer Lime Company, 1088 Germany Valley, Limestone Rd, Riverton, WV 26814	166
Average Trip Distance, Polymer Delivery	miles one-way	Assume: Polydyne, Inc., 1 Chemical Plant Rd, Riceboro, GA 31323	600
Average Trip Distance, Methanol Delivery	miles one-way	Assume: Colonial Chemical Solutions, Inc., 916 West Lathrop Avenue, Savannah, GA 31415	571
Average Trip Distance, Biosolids Land Application, 2020	miles one-way	Biosolids tickets	92.97
Average Trip Distance, Biosolids Land Application, 2037	miles one-way	Estimated reduction of radius	72.91
Polymer Manufacturing	Mg CO2eq/Mg polymer	BEAM v1.3, Carnegie Mellon Green Design Inst. (http://www.eiolca.net/accessed March 2010)	9.0
Lime Manufacturing	Mg CO2eq/Mg lime produced	BEAM v1.3, Carnegie Mellon Green Design Inst. (http://www.eiolca.net/accessed March 2010)	0.9
Land Application			
Applying biosolids to land	MT CO2e/day	Baseline fuel usage, application time, load size	0.15
Applying biosolids to land	MT CO2e/day	Future fuel usage, application time, load size	0.09
CO2 Emissions equivalents from released CH4 (Mg/day)	MT CO2e/day	Baseline limed solids parameters, BEAM v1.3 (Mg CO2e/day)	0.37
CO2 emissions equivalents from released N2O (Mg/day)	MT CO2e/day	Baseline limed solids parameters, BEAM v1.3 (Mg CO2e/day)	0.26
CO2 Emissions equivalents from released CH4 (Mg/day)	MT CO2e/day	Future digested solids parameters, BEAM v1.3 (Mg CO2e/day)	0.37
CO2 emissions equivalents from released N2O (Mg/day)	MT CO2e/day	Future digested solids parameters, BEAM v1.3 (Mg CO2e/day)	0.26

PROJECTED BIOSOLIDS COMPOSITION		UNIT CONVERSIONS	
Lime	15%	kilograms to metric tons	0.001
Existing Cake	32%	kwh per MMBtu	293

ARLINGTON COUNTY WPCP **GREENHOUSE GAS EMISSION CALCULATIONS**

Data from Biosolids Emission Assessment Model (BEAM), 2009

Carbon Sequestration					**Project Estimate**
From biosolids applied to soil (Mg CO_2/day)	MT CO2e/day	Baseline limed solids parameters, BEAM v1.3 (Mg CO2e/day)	-6.50	-2374	*Baseline 2020*
From biosolids applied to soil (Mg CO_2/day)	MT CO2e/day	Future digested solids parameters, BEAM v1.3 (Mg CO2e/day)	-3.89	-1421	*Future 2037*
Fertilizer Off-set Credits					
From nitrogen applied to soil (Mg CO_2/day)	MT CO2e/day	Baseline limed solids parameters, BEAM v1.3 (Mg CO2e/day)	-3.12		
From phosphorus applied to soil (Mg CO_2/day)	MT CO2e/day	Baseline limed solids parameters, BEAM v1.3 (Mg CO2e/day)	-0.62		
From nitrogen applied to soil (Mg CO_2/day)	MT CO2e/day	Future digested solids parameters, BEAM v1.3 (Mg CO2e/day)	-3.12		
From phosphorus applied to soil (Mg CO_2/day)	MT CO2e/day	Future digested solids parameters, BEAM v1.3 (Mg CO2e/day)	-0.59		
Calcium Carbonate Debit					
From $CaCO_3$ applied to soil (Mg CO_2/day)	MT CO2e/day	Baseline limed solids parameters, BEAM v1.3 (Mg CO2e/day)	1.72		
From $CaCO_3$ applied to soil (Mg CO_2/day)	MT CO2e/day	Future digested solids parameters, BEAM v1.3 (Mg CO2e/day)	0		

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Technical Memorandum No. 19

Date:	February 9, 2023
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Centrifuge Equipment Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the centrifuge evaluation, followed by a description of the centrifuge evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary solids (PS) and waste activated solids (WAS) thickening, dewatering, and lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a thermal hydrolysis process (THP) and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this centrifuge evaluation is to further assess and compare centrifuge alternatives. The results of this evaluation will inform and validate a final decision on which centrifuge manufacturer(s) will be chosen to replace the existing centrifuges.

1.2 Evaluation Approach

A suite of alternatives using various centrifuges was developed. Conceptual process sizing, configurations, site layouts, and conceptual costs for centrifuges were prepared. The project team attended 1-hour virtual workshops with each manufacturer to learn about the specific details of each manufacturer and ask questions. Centrifuge options were presented and reviewed at the December 8, 2021, project workshop with the County. Workshop participants screened and selected a short list of preferred centrifuges. In this evaluation, the shortlisted technologies are further evaluated and compared based on conceptual operations and maintenance (O&M) cost estimates and non-cost considerations, site layout, and space requirements.

2.0 Summary of Existing Facilities and Processing

A process flow diagram for existing solids handling at the WPCP is shown in Figure 1. Solids are thickened using gravity thickeners for PS and dissolved air flotation thickeners for WAS. Thickened solids are blended in solids storage tanks and dewatered using centrifuges. Liquid centrate from the centrifuges is returned to the head of the WPCP. Lime is added to the dewatered solids to achieve Class B pathogen and vector attraction reduction. Lime-stabilized biosolids are hauled off site for beneficial use through bulk land application.

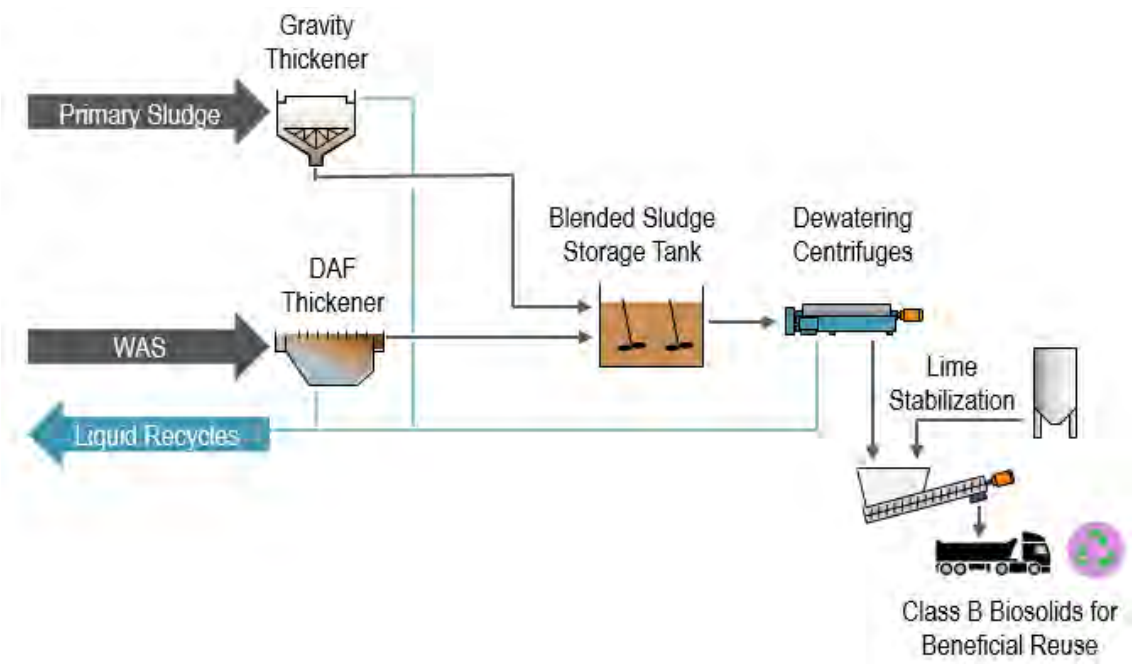

Figure 1. Existing PS and WAS Process Flow Diagram

The new solids handling process will include two dewatering steps, as shown in Figure 2: a pre-dewatering process to provide the appropriate solids concentration to feed the THP and subsequent digestion process, and a final dewatering process for creation of the dewatered cake for beneficial use. The equipment evaluations for both dewatering processes, indicated in the blue dashed area in the figure, were included in the dewatering equipment technical memorandum.

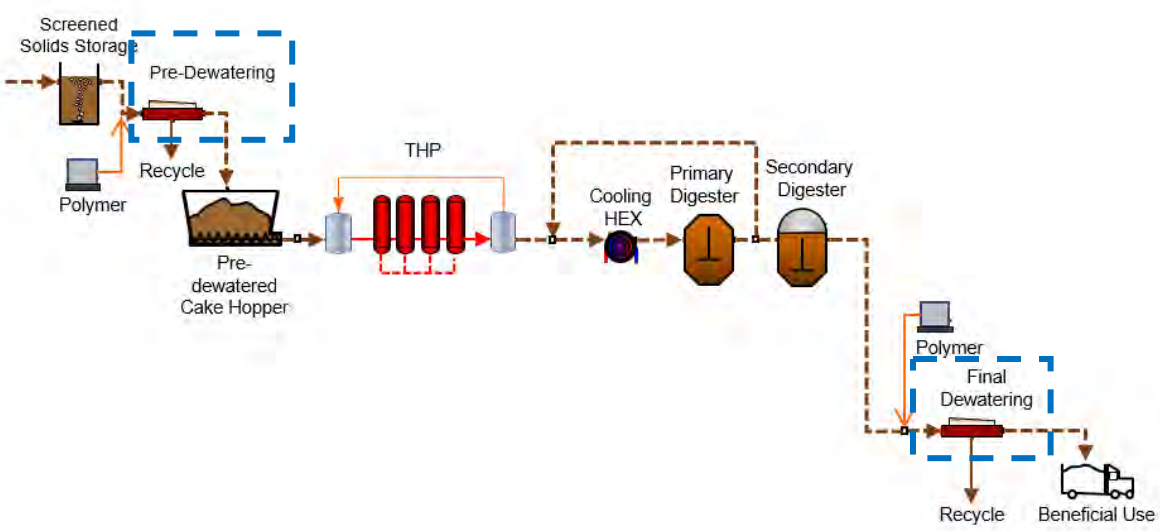

Figure 2. Future Solids Handling Process Dewatering Locations

3.0 Design Criteria

Three design loading conditions were considered for the centrifuge evaluation:

- **23.0 million gallons per day (mgd):** 2020 current conditions
  - Annual average loading was considered for "minimum" operating conditions and as a baseline for annual O&M costs
- **30.8 mgd:** 2052 projected conditions
  - Used as the basis for equipment sizing and number of units required for the Facilities Plan
- **40.0 mgd:** final/buildout conditions
  - Used to establish total footprint requirements and dewatering facility sizing with space reserved for potential future equipment

Process equipment selections and facility concepts were based on a 30.8 mgd design condition for equipment sizing and a 40.0 mgd buildout condition for overall facility sizing.

For ease of maintenance and interchangeability of parts, manufacturers were asked to provide the same model of centrifuge for pre-dewatering and final dewatering. Manufacturers were also asked to provide centrifuges with a 29- to 30-inch-diameter scroll for consistency in comparison. This size machine is appropriate for use in both pre-dewatering and final dewatering applications, where there will be two centrifuges in service and one centrifuge in service, respectively.

3.1 Pre-Dewatering

Peak 3-day solids loadings were used for sizing the pre-dewatering process. The pre-dewatering process is intended to operate 24 hours per day, 7 days per week, to provide a continuous flow of solids to THP. The pre-dewatering feed solids concentration is assumed to be 4.3 percent with a PS:WAS ratio of 70:30. THP is required to be fed at 15 to 18 percent solids; however, it is understood that any of the pre-dewatering systems being evaluated will dewater to a higher solids concentration, and additional dilution will be required prior to feeding THP. The anticipated flows and loads for pre-dewatering are summarized in Table 1.

Table 1. Pre-Dewatering Design Criteria

Design Condition	Average Conditions		Peak 3-Day	
	Flow (gpm)	TSS Load (lb/hr)	Flow (gpm)	TSS Load (lb/hr)
23.0 mgd	120	2,700	210	4,400
30.8 mgd	170	3,600	280	5,900
40.0 mgd	215	4,600	358	7,700

Note: flows are based on an assumed feed concentration of 4.3% solids.
gpm = gallons per minute; lb/hr = pounds per hour.

Three centrifuges are proposed for the pre-dewatering process (two duty, one standby) at the 30.8 mgd design condition. Therefore, to meet the peak 3-day flow and load, the centrifuges' capacity must be at least 140 gallons per minute (gpm) and 2,950 pounds per hour (lb/hr) total suspended solids (TSS).

3.2 Final Dewatering

Peak 14-day solids loadings were used for sizing final dewatering processes because of the equalization capacity provided by the secondary anaerobic digester as well as upstream cake and thickened solids storage. The final dewatering process is sized to operate 24 hours per day, 5.5 days per week at peak 14-day loading conditions. The feed solids concentration is anticipated to be 4.6 percent, and the target solids concentration is 30 percent solids or greater. The anticipated flows and loads to final dewatering are summarized in Table 2.

Table 2. Final Dewatering Design Criteria

	Average Conditions		Peak 14-Day	
Design Condition	Flow (gpm)	TSS Load (lb/hr)	Flow (gpm)	TSS Load (lb/hr)
23.0 mgd	70	1,600	100	2,300
30.8 mgd	100	2,200	140	3,100
40.0 mgd	125	2,900	180	4,000

Note: flows are based on an assumed feed concentration of 4.3% solids.

Two centrifuges are proposed for the final dewatering process (one duty, one standby) at the 30.8 mgd design condition. Therefore, the centrifuges will be sized for a capacity of 140 gpm and 3,100 lb/hr TSS.

4.0 Manufacturer Evaluation

This section describes the results from the following centrifuge manufacturers applicable to the Arlington WPCP:

- Alfa Laval
- Andritz
- Centrisys
- Flottweg
- GEA

For each manufacturer, the following information is presented:

- Technical criteria and survey findings
- Approach for centrifuge replacement in the dewatering building
- Feedback from lunch-and-learns and preferred manufacturers
- Findings from site visits to operating installations

4.1 Specifications

The following criteria were used to evaluate each centrifuge manufacturer:

- Footprint/geometry
- Beach angle

- Throughput capacity
- Manufacturer experience/reliability
- Installation number
- Lubrication system
- Gearbox
- Materials of construction: bowl/scroll
- Drive type
- Controls
- Manufacturer support

Table 3 presents general specifications of the equipment. The existing centrifuges have the solids feed on the centrate end of the unit. If the existing dewatering building is reused, the solids feed piping will have to be rerouted to the opposite side of the centrifuge room for units with solids feed on the solids end (Alfa Laval and Centrisys), because the centrifuge orientation must align with the existing cake discharge location due to the reuse of the cake bins on the floor below. For more details on the orientation and placement of the centrifuges, refer to Section 4.2.

Table 3. General Centrifuge Specifications

Parameter	Alfa Laval	Flottweg	Andritz	Centrisys	GEA
Current Model	G3-125	C8E	D7LL	CS30-4	CF8000
Number of wastewater installations (current model)	21	2	35	0	7
Number of wastewater installations of similar size (older model(s))	16 (G2-125[a] and others)	0	0	0	34 (CA755, CD755[b])
Bowl diameter (in)	29	30	29	30	30
Frame material	Galvanized mild steel	Powdered coated carbon steel	Painted steel	Carbon steel	Epoxy-coated carbon steel
Cover material	316 SST	316 SST	FRP or 316L SST	304 SST	316 SST and duplex
Solids feed location	Solids end	Centrate end	Centrate end	Solids end	Centrate end
Bowl material	Duplex SST	Duplex SST	Cast duplex SST	Cast duplex SST	Duplex SST
Scroll feed location	Mid-scroll	Mid-scroll	Centrate end	Solids end	Mid-scroll

in = inches; SST = stainless steel.

a. The G2-125 centrifuge is an older version of the G3-125 centrifuge.

b. The CA755 and CD755 centrifuges are part of the older CA and CD series, respectively. They use forced-oil lubrication with water-cooled heat exchangers.

Table 4 presents bearing and drive specifications of the equipment.

Table 4. Bearings/Drives Specifications

Parameter	Alfa Laval	Flottweg	Andritz	Centrisys	GEA
Main bearing lubrication	Grease	Oil	Forced oil	Air/oil	Air/oil mist
Scroll bearing lubrication	Grease	Grease	Forced oil	Air/oil	Grease

Main drive type	VFD	VFD	VFD	VFD	VFD
Main drive motor (hp)	125	200	150–200	150	100–150
Scroll drive type	VFD	VFD	VFD	Hydraulic	VFD
Scroll drive motor (hp)	50	60	50	60	50
Gearbox	Multistage planetary	Planetary	Cycloidal (CYCLO®-Sumitomo) and planetary	N/A	Multistage planetary

hp = horsepower; VFD = variable-frequency drive.

Table 5 presents wear protection and beach angle specifications of the equipment.

Table 5. Wear Protection and Beach Angle Specifications

Parameter	Alfa Laval	Flottweg	Andritz	Centrisys	GEA
Beach angle (degrees)	10	15	13	15	15
Full vs. partial length tiles on scroll	Partial length	Both are available	Full	Both are available	Full
Wear strips in bowl	20	18	8	16	24 – as an optional offering (grooves are standard)
Wear part guarantees	8,000 hr/ 1 yr (with extended warranty option)	15,000 hr	15,000 hr	15,000 hr	15,000 hr

yr = years.

Table 6 presents specifications for programmable logic controllers (PLCs) and variable-frequency drives (VFDs).

Table 6. PLC and VFD Specifications

Parameter	Alfa Laval	Flottweg	Andritz	Centrisys	GEA
PLC manufacturer	Allen-Bradley	Customer preference	Allen-Bradley CompactLogix or ControlLogix	Allen-Bradley CompactLogix	Rockwell, Allen-Bradley, Modicon, GE, Siemens
VFD manufacturer	ABB	Customer preference	Allen-Bradley PowerFlex Series 755	ABB	ABB, Danfoss, Schneider, Rockwell
Clean-in-place procedures	Yes	Yes	Yes	Yes	Yes
Power loss ride through	Yes	Yes	Yes	Optional	Yes

4.2 Layouts

The following figures display the existing centrifuges and potential centrifuges in plan and section, with green indicating existing piers and yellow indicating new piers. The layouts are based on the models presented in Table 3 above. Note that figures are relevant only for pre-dewatering centrifuges in the "renovate dewatering building" option. If the "decommission dewatering building" option is chosen, the pre-dewatering centrifuges will be located in a new building.

If the existing dewatering building is reused, the solids feed piping will have to be rerouted to the opposite side of the centrifuge room for units with solids feed on the solids end (Alfa Laval and Centrisys), because the centrifuge orientation must align with the existing cake discharge location. The solids discharge outlet on each centrifuge must align with the existing solids chute location to allow conveyance of solids.

Figure 3, Figure 4, and Figure 5 present the plan and section of the existing centrifuges with the piers and centrate discharge pipe outlined in green.

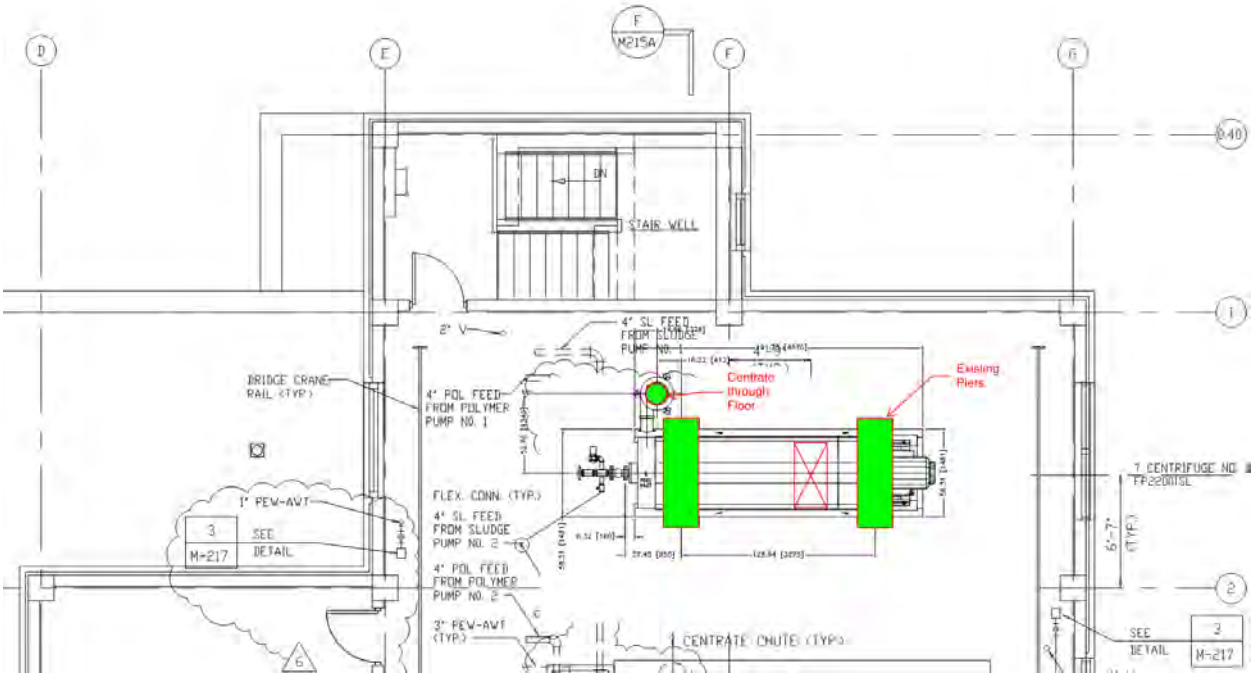

Figure 3. Existing Centrifuges Plan

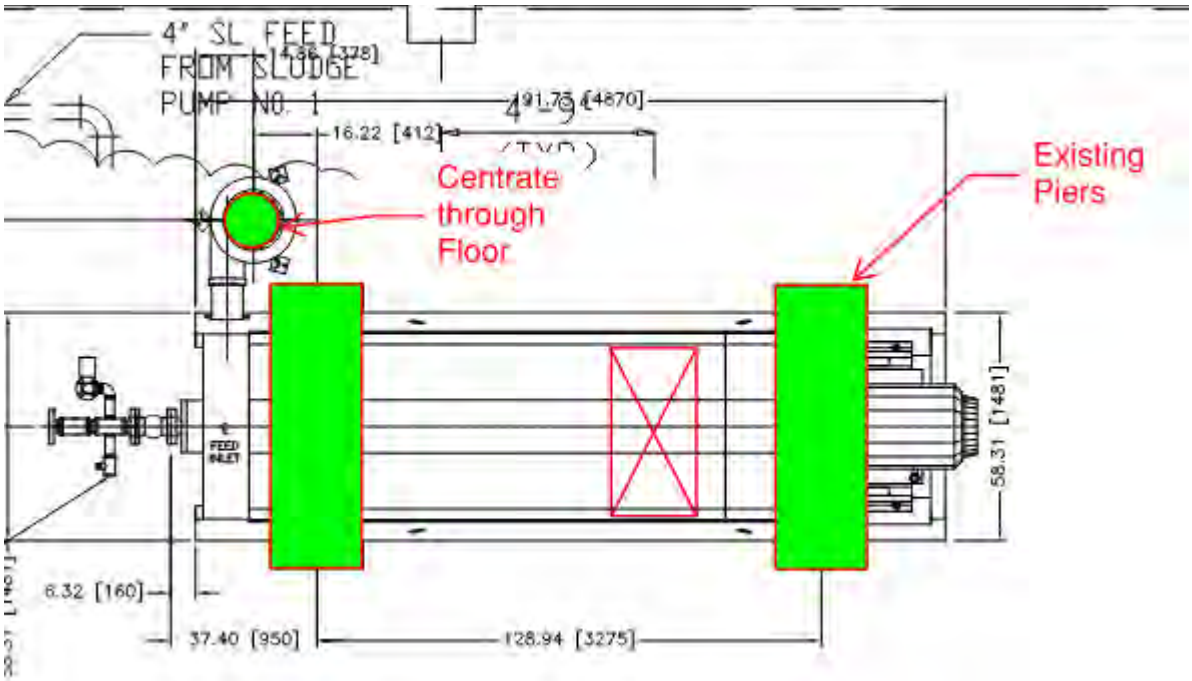

Figure 4. Existing Centrifuges Plan Zoomed

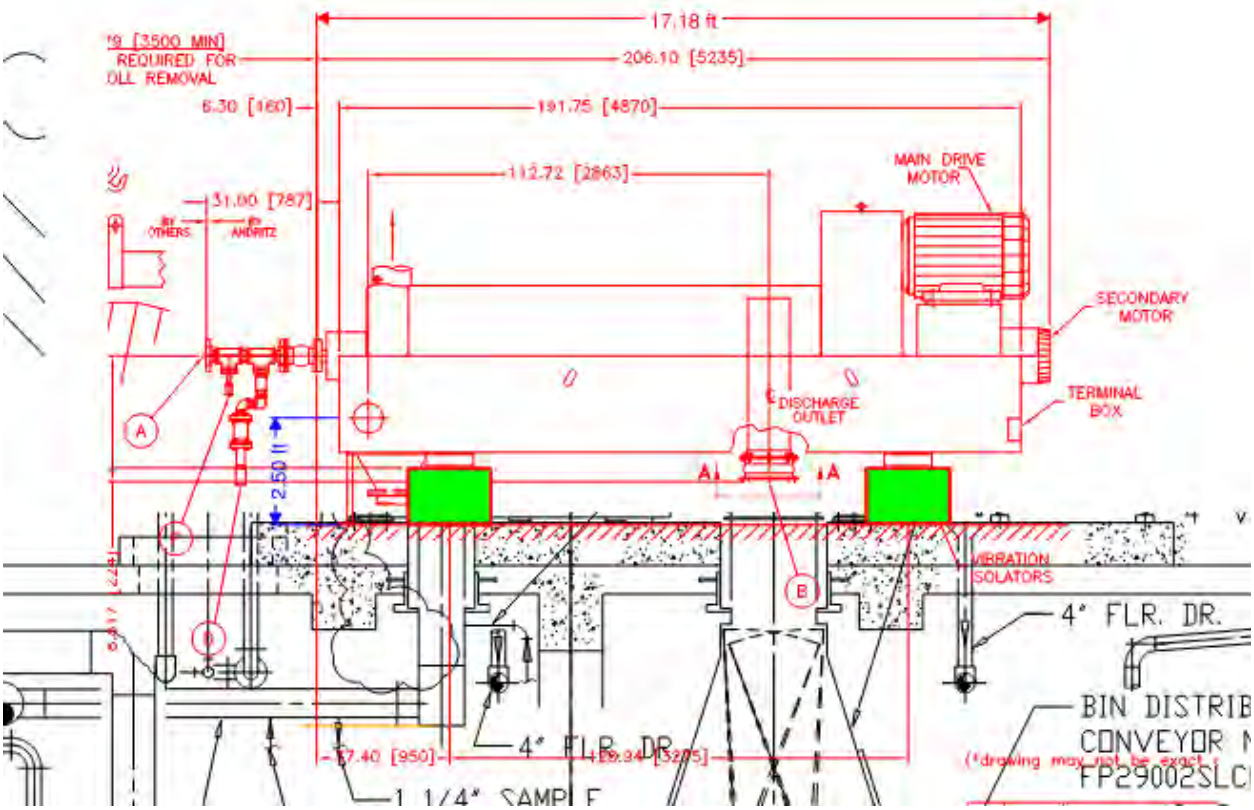

Figure 5. Existing Centrifuges Section

Figure 6, Figure 7 and Figure 8 present the plan and section for the GEA centrifuge. The solids feed is on the same side as the existing centrifuge, so no rerouting is required. New pier locations (in yellow) are required to support this centrifuge.

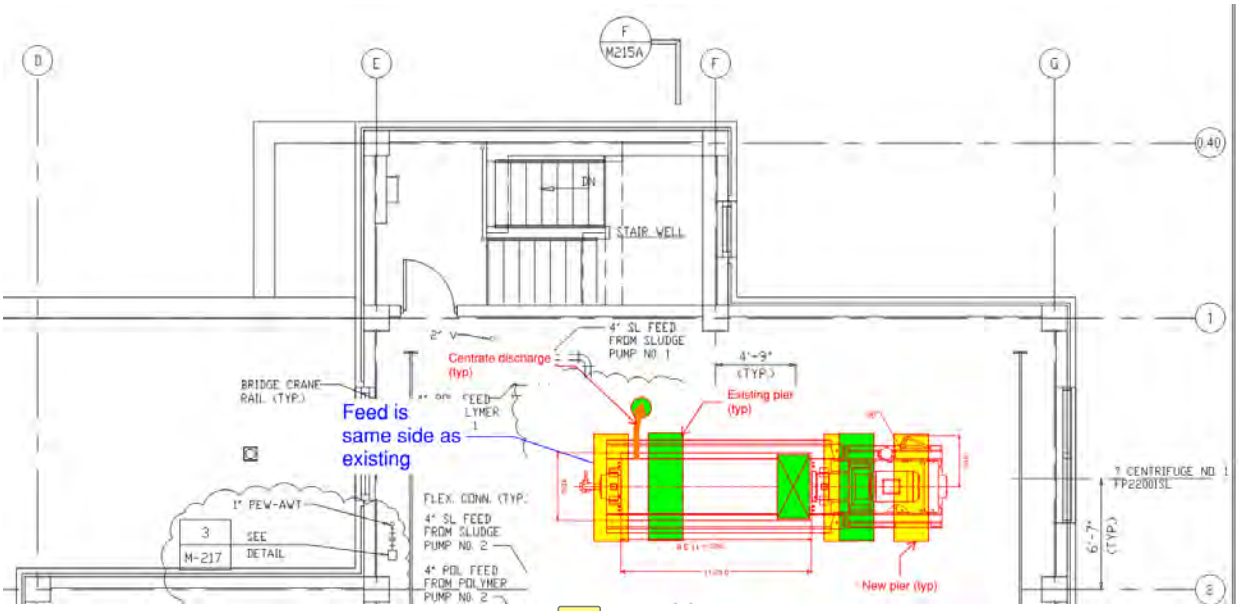

Figure 6. GEA Centrifuges Plan

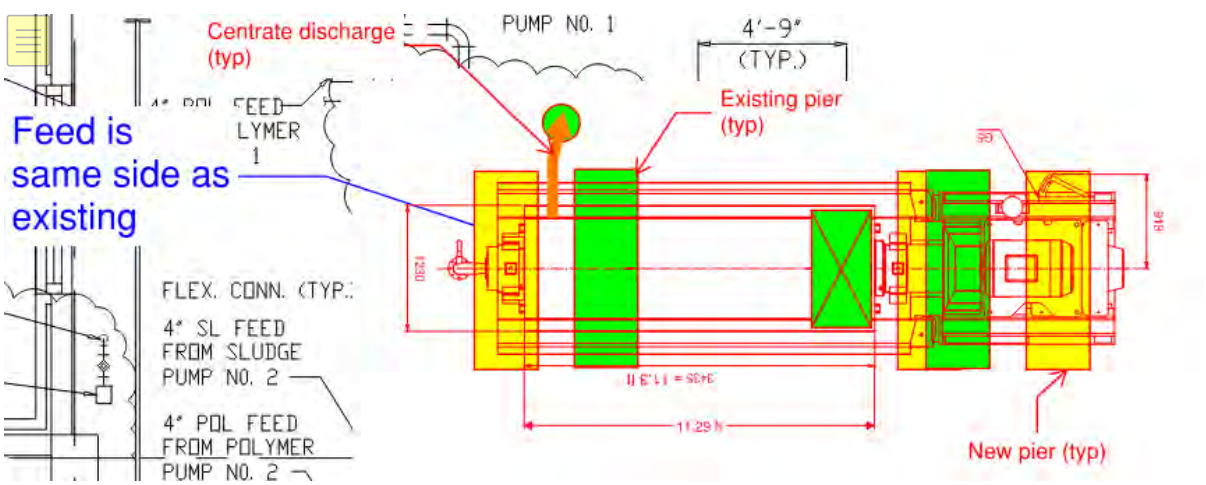

Figure 7. GEA Centrifuges Plan Zoomed

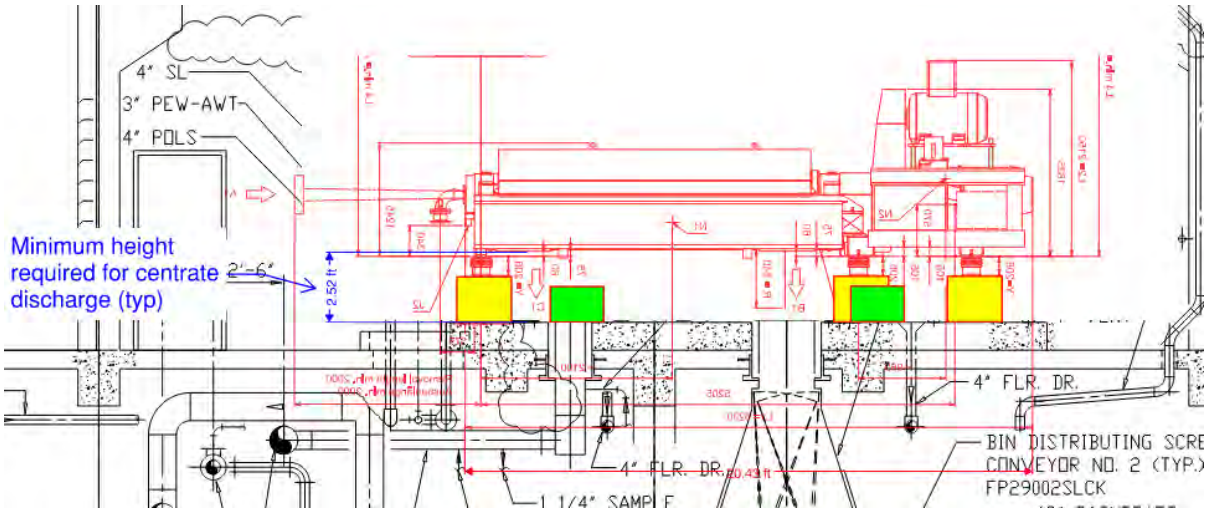

Figure 8. GEA Centrifuges Section

Figure 9, Figure 10, and Figure 11 present the plan and section for the Alfa Laval centrifuge. The solids feed is on the opposite side as the existing centrifuge, so rerouting of the solids feed to the opposite side of the centrifuge is required. New pier locations (in yellow) are required to support this centrifuge.

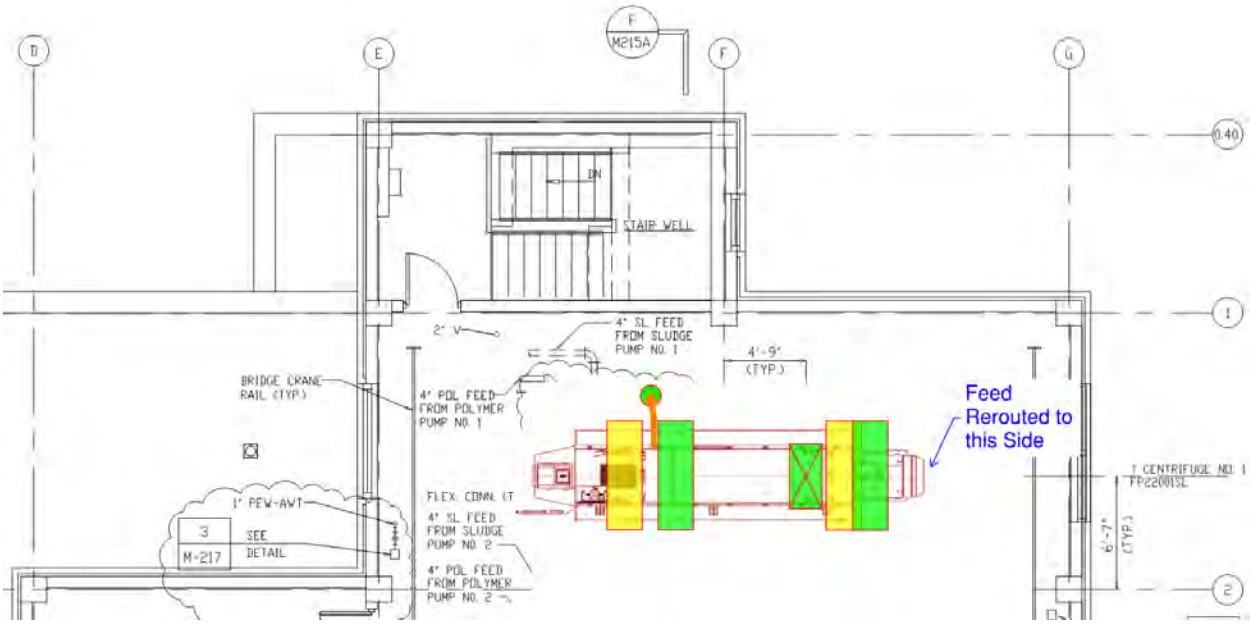

Figure 9. Alfa Laval Centrifuges Plan

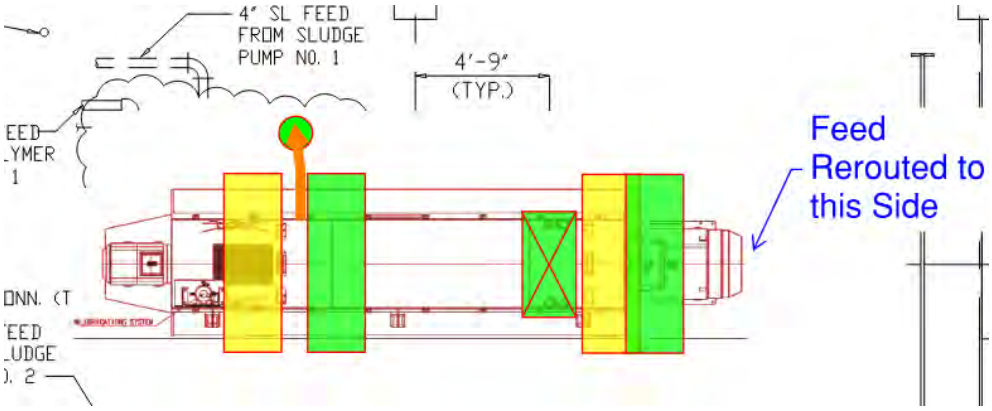

Figure 10. Alfa Laval Centrifuges Plan Zoomed

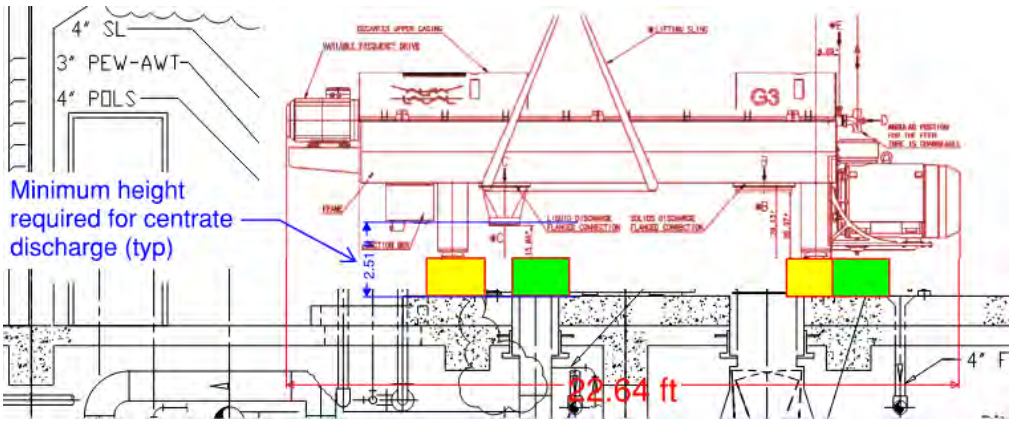

Figure 11. Alfa Laval Centrifuges Section

Figure 12, Figure 13 and Figure 14 present the plan and section for the Andritz centrifuge. The solids feed is on the same side as the existing centrifuge, so no rerouting is required. New pier locations (in yellow) are required to support this centrifuge.

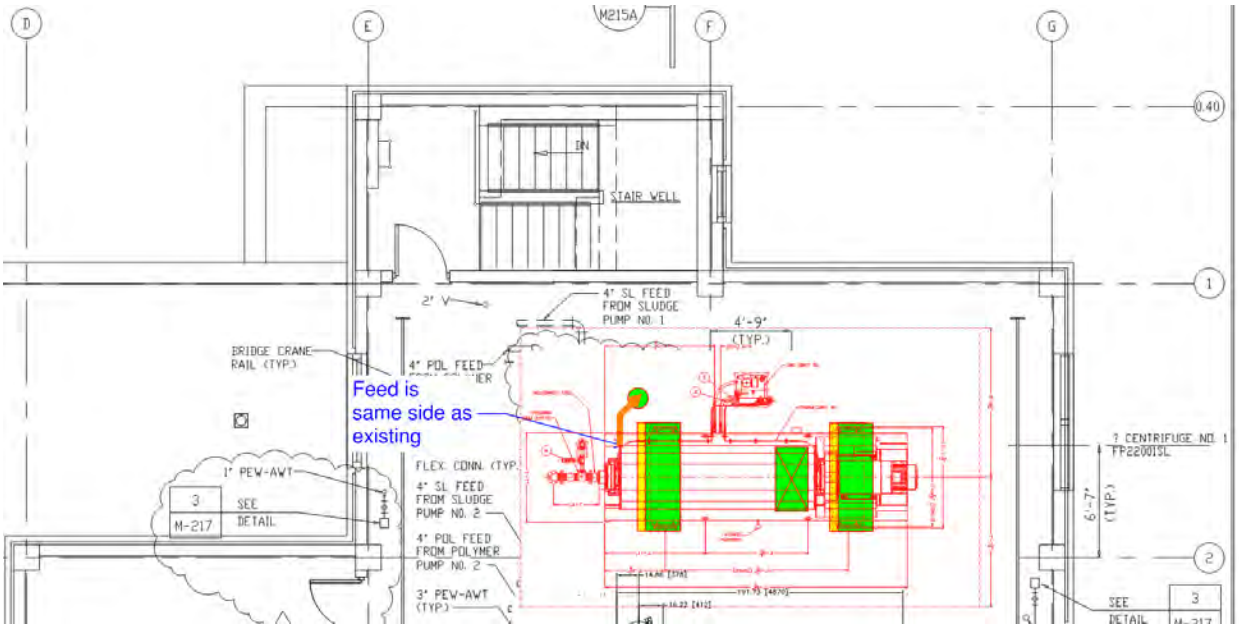

Figure 12. Andritz Centrifuges Plan

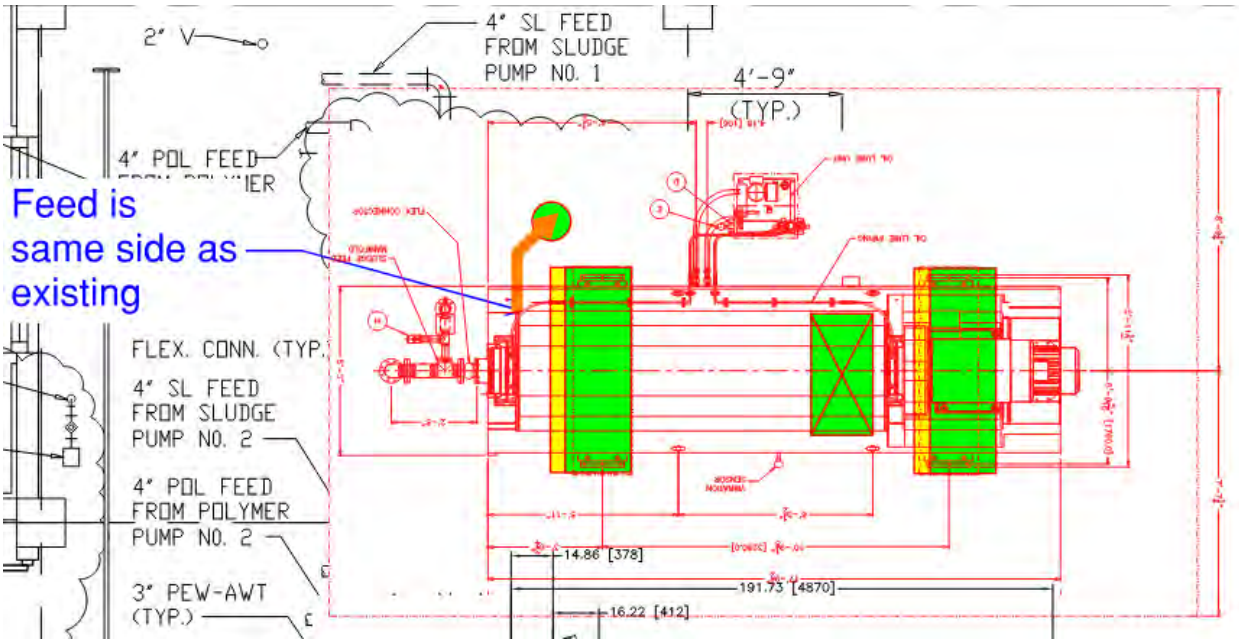

Figure 13. Andritz Centrifuges Plan Zoomed

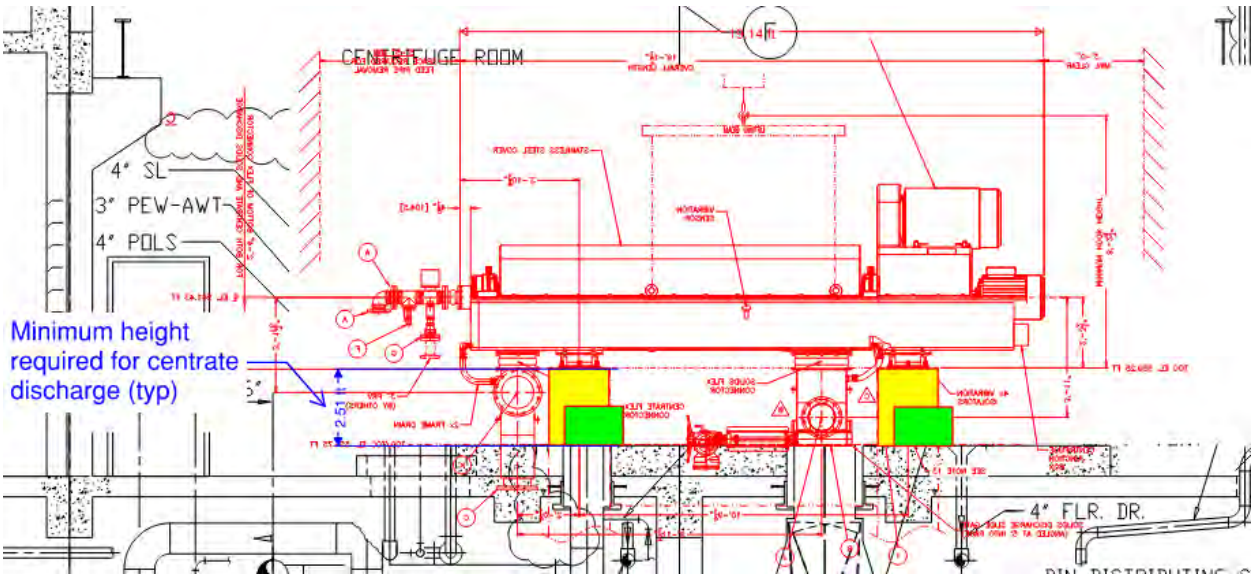

Figure 14. Andritz Centrifuges Section

Figure 15, Figure 16 and Figure 17 present the plan and section for the Centrisys centrifuge. The solids feed is on the opposite side as the existing centrifuge, so rerouting of the solids feed to the opposite side of the centrifuge is required. New pier locations (in yellow) are required to support this centrifuge.

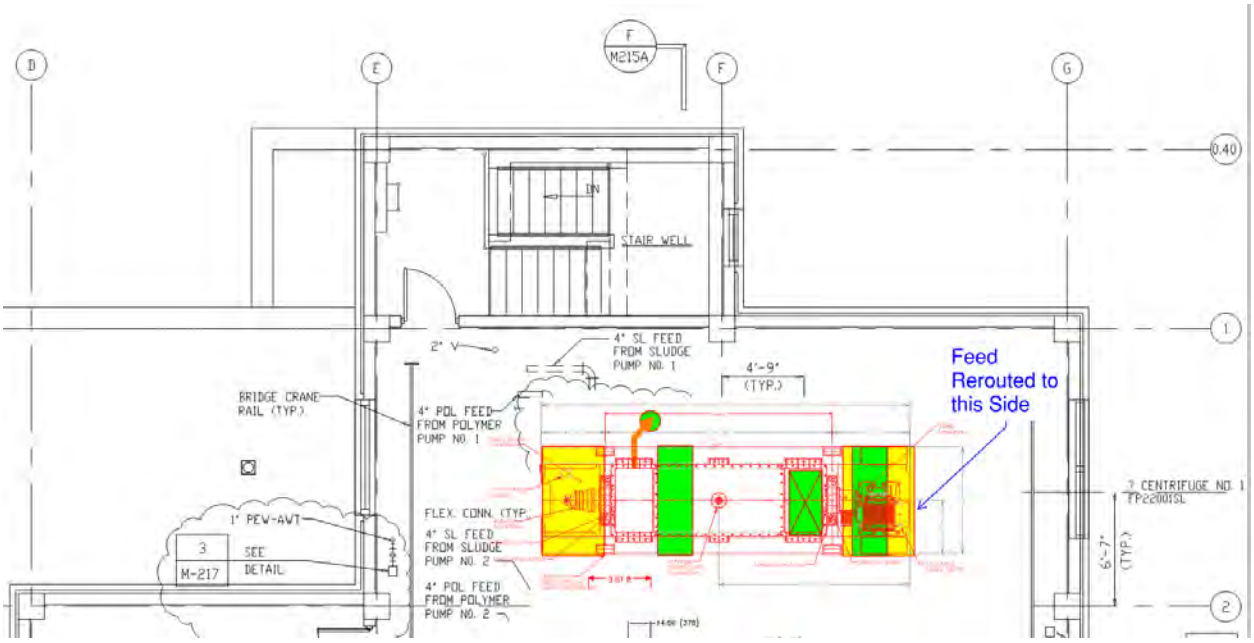

Figure 15. Centrisys Centrifuges Plan

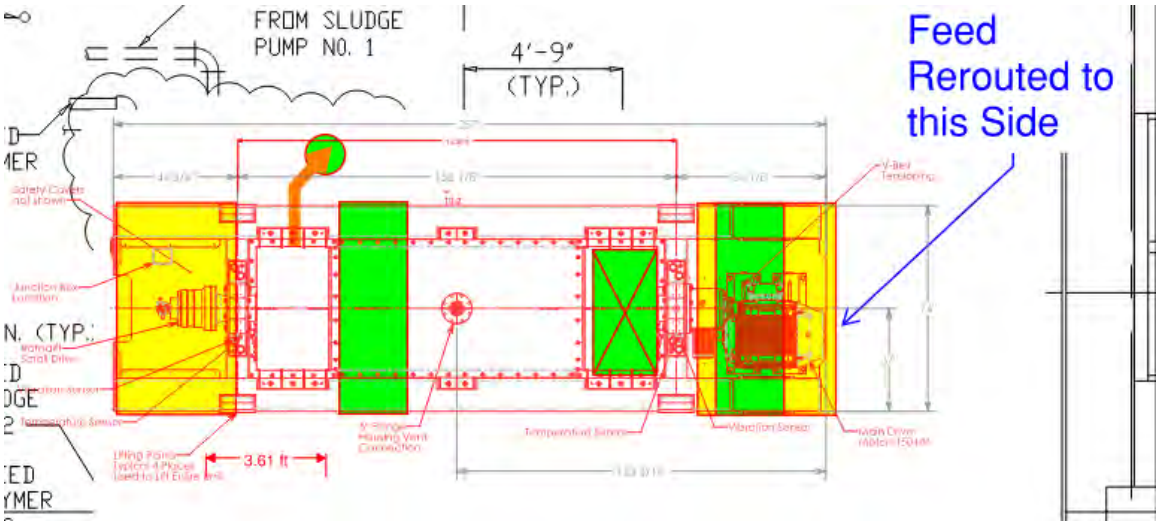

Figure 16. Centrisys Centrifuges Plan Zoomed

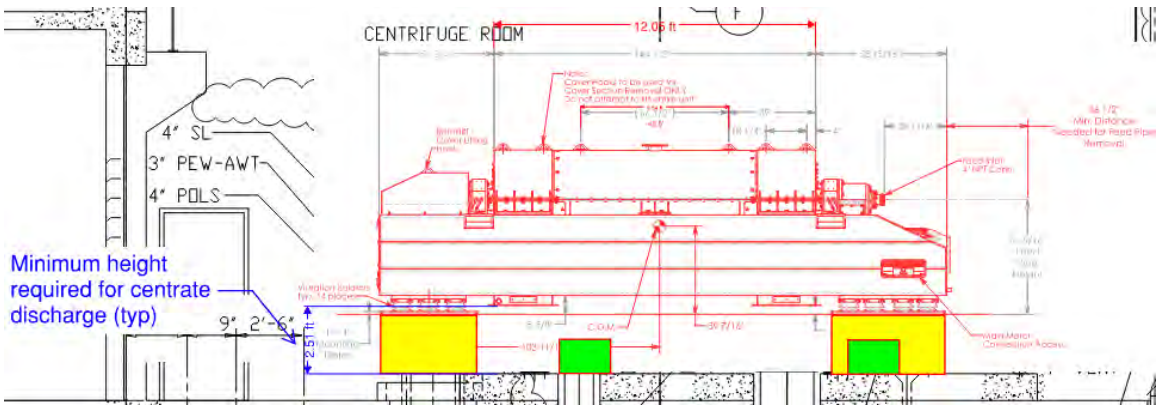

Figure 17. Centrisys Centrifuges Section Zoomed

Figure 18, Figure 19, and Figure 20 present the plan and section for the Flottweg centrifuge. The solids feed is on the same side as the existing centrifuge, so no rerouting is required. New pier locations (in yellow) are required to support this centrifuge.

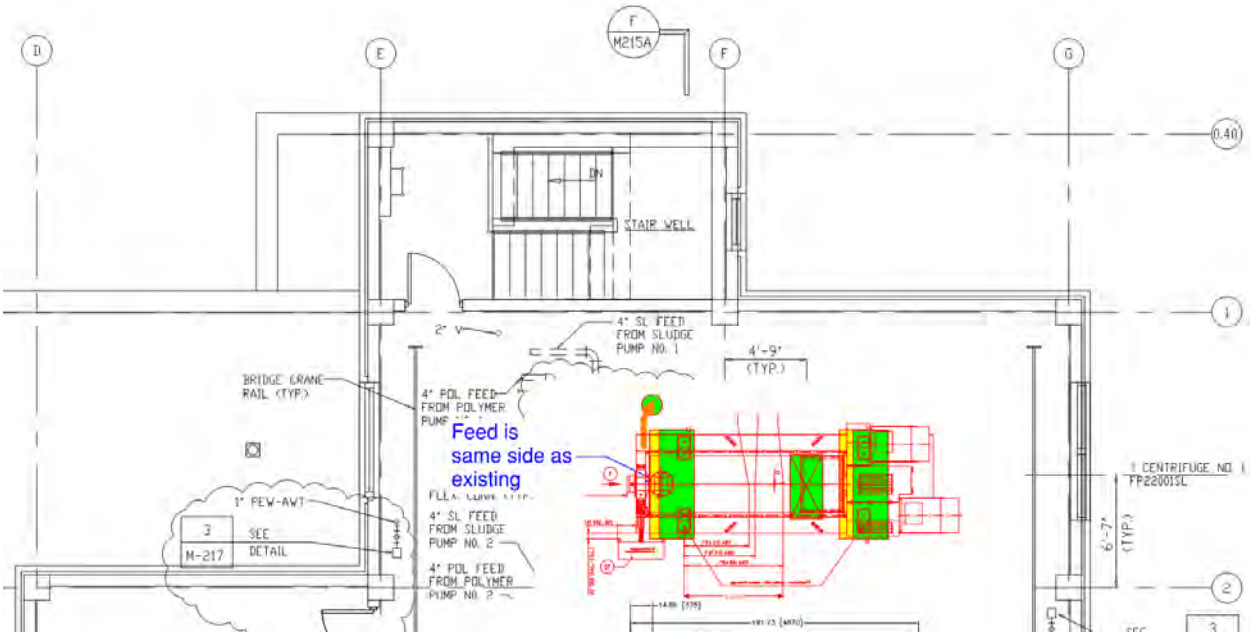

Figure 18. Flottweg Centrifuges Plan

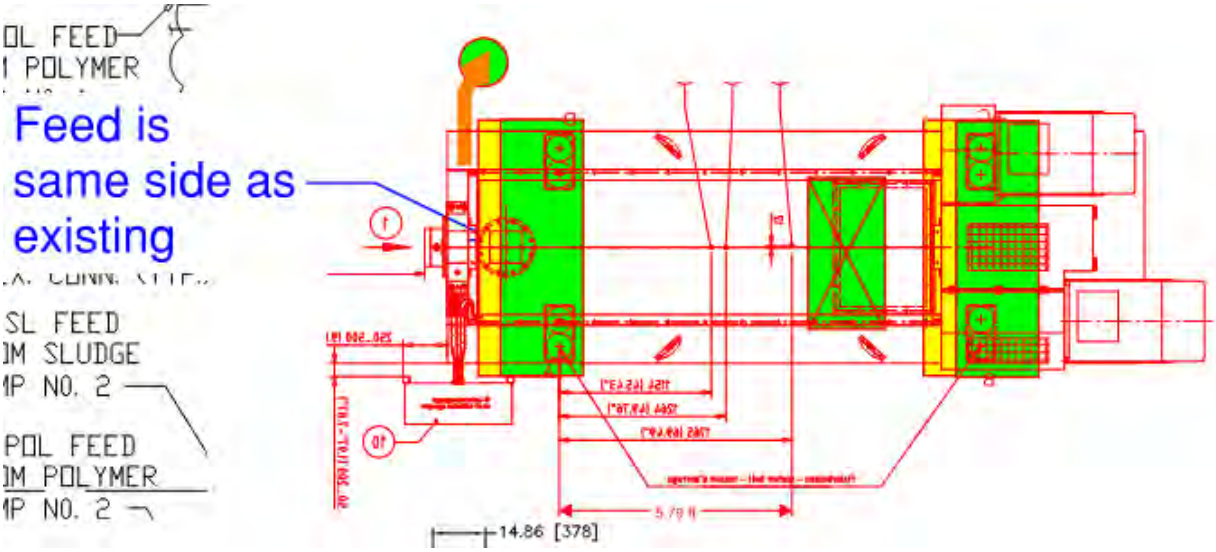

Figure 19. Flottweg Centrifuges Plan Zoomed

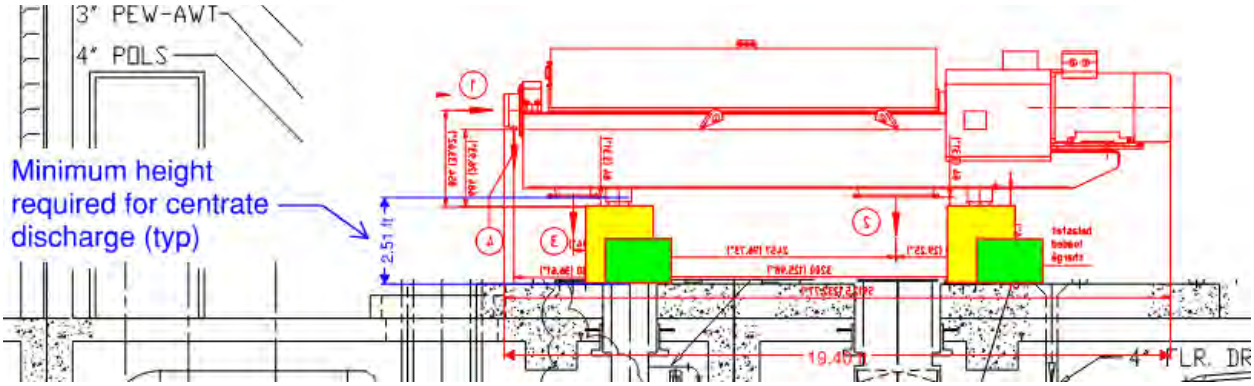

Figure 20. Flottweg Centrifuges Section

4.3 Installation and Service

Table 7 summarizes the municipal installations provided by each centrifuge manufacturer for the models presented in Table 3 above. The installations provided include facilities that process digested sludge (similar to the Arlington WPCP after completing the upgrades) as well as those that process unstabilized sludge. For manufacturers that have an older-generation model of similar size, the number of installations is provided in a separate column. Generally, Alfa Laval, Andritz, and GEA have the most municipal experience for centrifuges with the 29-30-inch-diameter bowl size proposed for this project.

Table 7. Centrifuge Installations

Manufacturer	Current Model	Installations	Comparable Model Installations
Alfa Laval	G3-125	21	16 (G2-125[a])
Flottweg	C8E	2	0
Andritz	D7LL	35	0
Centrisys	CS 30-4	0	0
GEA	CF8000	7	34 (20 of CA755, 14 of CD755[b])

a. The G2-125 centrifuge is an older version of the G3-125 centrifuge.
b. The CA755 and CD755 centrifuges are part of the older CA and CD series, respectively. They use forced-oil lubrication with water-cooled heat exchangers.

Table 8 summarizes each manufacturer's storage location for routine parts and non-routine parts. "Routine parts" are components that are regularly replaced over the life of the unit, including wear bars, scroll tiles, motors, VFDs, and gearboxes. "Non-routine parts" are components that are considered to last several years or the lifetime of a unit, such as frames, covers, bowls, and scrolls. Some manufacturers noted that a local shop typically carries most parts, but some parts might be stocked in a warehouse elsewhere in the United States.

Table 8. Centrifuge Part Locations

Manufacturer	Main Warehouse	Routine Parts at Main Warehouse	Other Routine Parts not at Main Warehouse?	Local Shop	Non-routine Parts
Alfa Laval	Indianapolis, Indiana	All parts		Suffolk, Virginia	Poland
Flottweg	Independence, Kentucky	Wear bars, tiles, gearboxes	Motors, VFDs: U.S.-sourced		Germany
Andritz	Arlington, Texas	Wear bars, tiles	Motors, VFDs, gearboxes: U.S.-sourced	Scott Depot, West Virginia	Austria
Centrisys	Kenosha, Wisconsin	All parts			Kenosha, Wisconsin
GEA	Naperville, Illinois	Wear bars, tiles, gearboxes	Motors, VFDs: job-by-job basis	Northvale, New Jersey	Germany

All manufacturers claim to have all routine maintenance parts available in the United States. With the exception of Centrisys, all manufacturers fabricate and store non-routine parts in Europe.

Rebuild times are summarized in Table 9. These estimates were provided by the manufacturers and have not been verified independently.

Table 9. Centrifuge Rebuild Times

Manufacturer	Rebuild Time
Alfa Laval	6–8 weeks
Flottweg	3–4 weeks offsite
Andritz	8–10 weeks typical 12–16 weeks if beyond normal wear and tear
Centrisys	2–4 weeks (minor) 4–6 weeks (major)
GEA	4–6 weeks

4.4 Reference Installations

Table 10 summarizes the number of contacts for each manufacturer. Manufacturers were asked to provide contact information for centrifuge reference installations.

Table 10. Reference Installation Contact Summary

Manufacturer	Contacts Received	Contacts Attempted	Contact Responses
Alfa Laval	6	6	1
Flottweg	4	4	2
Andritz	5	5	2
Centrisys	4	4	1
GEA	6	6	2

Notable responses from reference plants are listed below for each manufacturer:

- For **Andritz**, one plant that responded indicated that Andritz is slow to respond to maintenance requests. Another plant indicated oil leak issues, AC issues, and communication card issues.

- For **Alfa Laval**, the plant indicated that the G3-125 had much lower power consumption than the old DS-706 machine. The plant had to switch centrifuges because of a catastrophic failure with the old DS-706. The performance was found to be fairly equivalent between the DS-706 and G3-125.
- For **Centrisys**, the one plant that responded indicated loose and corroded connections, but this plant trucks its centrifuge between plants, which may be the cause of the issues. The plant also indicated some human-machine interface (HMI) and computer problems.
- For **Flottweg**, both plants that responded indicated satisfaction with centrifuge performance, but only 22.5-inch machine references were available. Maintenance service was quick and well-regarded. The small pads on the discharge of the cake were the location of the most wear.
- For **GEA**, one plant indicated issues with controls that required a full wipe of programming to reset the system by a technician from Germany. The plant also indicated some premature wear on the feed zone. Another plant experienced maintenance service issues that were slow enough to cause the plant to stop paying invoices to GEA until maintenance was performed.

4.5 Equipment Cost

Table 11 presents the cost per unit of each centrifuge, which includes only the equipment cost without installation or piping costs.

Table 11. Centrifuge Equipment Cost Summary

Manufacturer	Model	Cost per Unit	Cost Expressed as Percentage of Lowest Cost
Alfa Laval	G3-125	$550,000	100%
Flottweg	C8E	$710,000	130%
Andritz	D7LL	$650,000	120%
Centrisys	CS 30-4	$897,200	160%
GEA	CF8000	$650,000	120%

5.0 Analysis

Arlington County and HDR conducted workshops and site visits to further review centrifuge manufacturers and preferences. The following preferences were identified through these workshops and site visits:

- **Number of installations:** several installations of similar-sized units, preferably the exact same model unit
- **PLCs:** Allen-Bradley and ABB preferred because of familiarity with the products
- **VFDs:** Allen-Bradley PowerFlex preferred because of familiarity with the product
- **Scroll tiles:** partial length tiles preferred so that tiles are only installed where necessary.
- **Lubrication:** forced oil lubrication not preferred

6.0 Summary and Conclusions

Table 12 displays a comparison between client preferences and each centrifuge manufacturer's specifications. PLC and VFD specifications were not included in the table because all manufacturers have Allen-Bradley or ABB options.

Table 12. Manufacturer Preference Comparison

Parameter	Client Preference	Alfa **Laval**	Flottweg	Andritz	Centrisys	GEA
Number of municipal installations with same model of unit (installations with similar-sized unit)	Many	21 (16)	**2 (0)**	35 (0)	**0 (0)**	7 (34)
Full vs. partial length tiles on scroll	Partial length	Partial length	Both are available	**Full**	Both are available	**Full**
Main bearing lubrication	Not forced oil	Grease	Oil	**Forced oil**	Air/oil	Air/oil mist
Scroll bearing lubrication	Not forced oil	Grease	Grease	**Forced oil**	Air/oil	Grease
Scroll drive type	None	VFD	VFD	VFD	Hydraulic	VFD
Gearbox	None	Multistage planetary	Planetary	Cycloidal (CYCLO®-Sumitomo) and planetary	N/A (hydraulic drive)	Multistage planetary
Typical rebuild time, weeks	Shorter is better	**6–8**	3–4	**8–10**	4–6	4–6
Routine parts locations	USA	USA	USA	USA	USA	USA
Non-routine parts locations	USA	**Poland**	**Germany**	**Austria**	USA	**Germany**

A centrifuge sole-source selection is not deemed to be necessary. However, based on site visits and discussion with Arlington County engineering, operations, and maintenance staff, the County has expressed a preference for the following centrifuge manufacturers:

- Alfa Laval
- Centrisys
- GEA

ARLINGTON RE-GEN

Appendix B

Biogas Utilization Report

Appendix B Contents

Biogas Utilization Report – Executive Summary

Biogas Utilization Report

ARLINGTON RE-GEN

Arlington County Water Pollution Control Plant

Biogas Utilization

Executive Summary

Updated November 2022

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Introduction

Arlington County (County) is implementing new biosolids management facilities at the Arlington County Water Pollution Control Plant (Plant). Arlington Re-Gen (Program) is part of the Arlington County Water Pollution Control Bureau's commitment to protecting public health and the environment, while recovering valuable resources with innovative processes that will also reduce our carbon footprint. This comprehensive biosolids program, adopted by the County Board in 2018, includes a new thermal hydrolysis process followed by anaerobic digestion as the main treatment processes. Thermal hydrolysis treats the biosolids under high pressures and temperature to break down the solids and remove pathogens. To achieve these high pressures and temperatures, steam boilers are required. Anaerobic digestion uses microbes to digest the solids in the absence of oxygen, which stabilizes and reduces the quantity of the biosolids, while also reducing odors of the finished product. These upgrades will produce a high quality marketable biosolids product.

Biogas, comprised of approximately 60% methane and 40% carbon dioxide, is also a product of the digestion process. Beneficial use of the biogas can have a significant impact on the County's sustainability goals, as it is estimated to have an energy content of 120 billion British thermal units (Btu) per year and the capability to reduce greenhouse gas emissions by up to 3,500 metric tons per year.

The objective of this gas utilization evaluation is to look at all feasible alternatives for the beneficial use of the biogas to assist in meeting Arlington County's sustainability goals while also reliably meeting the Plant's heating (steam generation) and electrical needs. Monetary, non-monetary, and sustainability evaluations were completed to determine the recommended alternative for the County.

Overall Biogas Recommendations

Based on the analyses presented below, the Arlington County Water Pollution Control Bureau recommends proceeding with the production of renewable natural gas (RNG) as the selected biogas utilization approach. The basis for this recommendation is as follows:

- The RNG alternatives have the lowest net present value (i.e., lowest total cost to the County over the life of the equipment) for the baseline conditions using conservative capital and operating costs.
- Injecting RNG into the local utility pipeline scored the highest in the County's non-financial scoring. In particular, the County found that the RNG alternatives would be less complex to maintain and would result in fewer localized impacts

such as noise and emissions than the combined heat and power (CHP) alternatives.

- A sensitivity analysis concluded that when considering multiple variables, including RIN market volatility and changes in electrical rates, injecting RNG into the local utility pipeline had a very high likelihood of being more financially advantageous than generating electricity through CHP.
- The County has the ability to retain greenhouse credits if the biogas is used within Arlington County for transportation purposes.
- Benefits of on-site CHP are limited because the CHP size would not be sufficient to power the entire Plant, which is already protected with two independent power feeds and backup generators. In addition, the use of CHP onsite will generate new, localized air emissions.

Biogas Utilization Alternatives

The range of feasible alternatives includes using the biogas for one or a combination of the following:

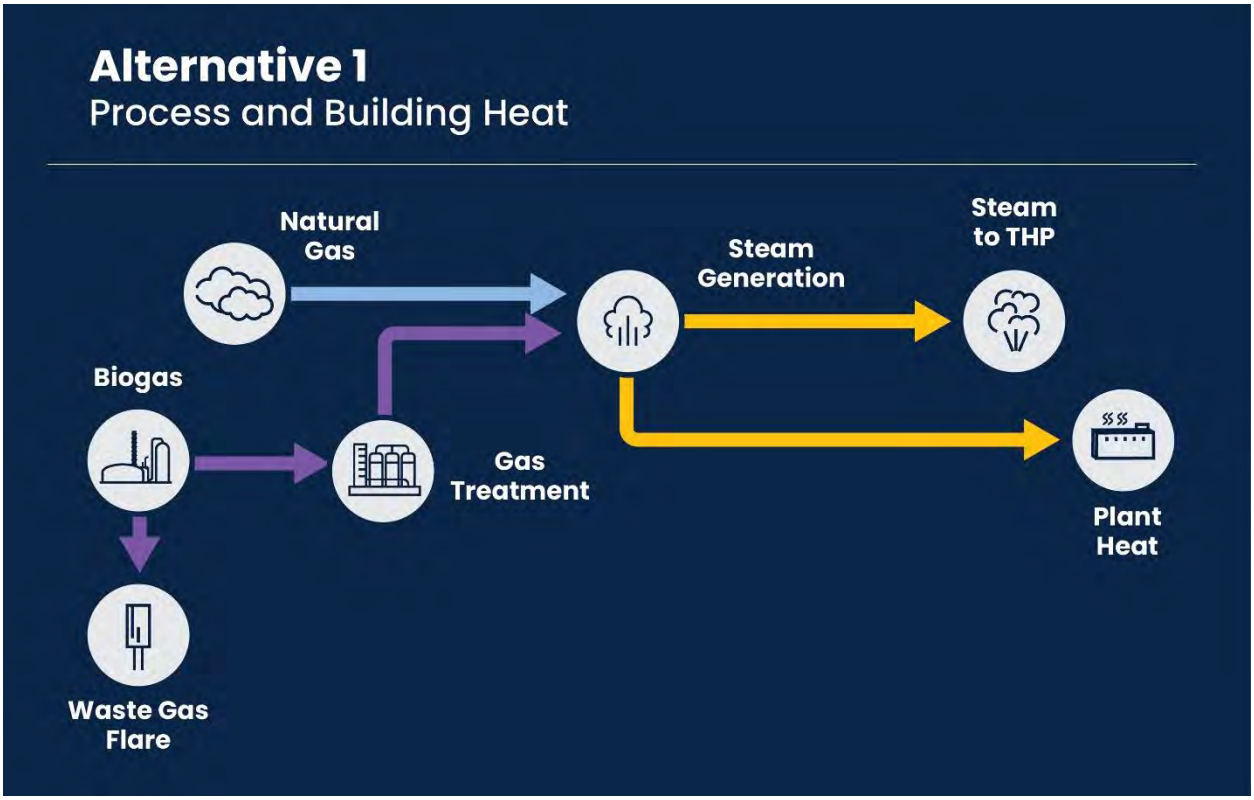
- On-site use for process and building heating
- Production of electrical power and recovery of waste heat (CHP)
- Production of RNG for use offsite through pipeline injection or as CNG for direct use as vehicle fuel.

From these potential biogas uses the following alternatives and sub-alternatives were identified for the evaluation. An energy balance was used to develop preliminary sizing of the equipment and summarize any energy production and heat recovered as well as the energy purchase requirements and biogas flared.

Alternative 1 – Process and Building Heating

In this alternative, shown schematically in Figure 1, the biogas produced during digestion would be used to fuel steam boilers to satisfy the process and building heating requirements. However, the steam demand for the Thermal Hydrolysis Process (THP) would use only about 30 percent of the biogas produced, leaving 70 percent as excess, which would be flared. **Because this alternative does not fully utilize the biogas, it is not a viable biogas utilization option, but it is included in the analysis as the minimum required to meet process needs.**

Figure 1. Alternative 1 – Process and Building Heat

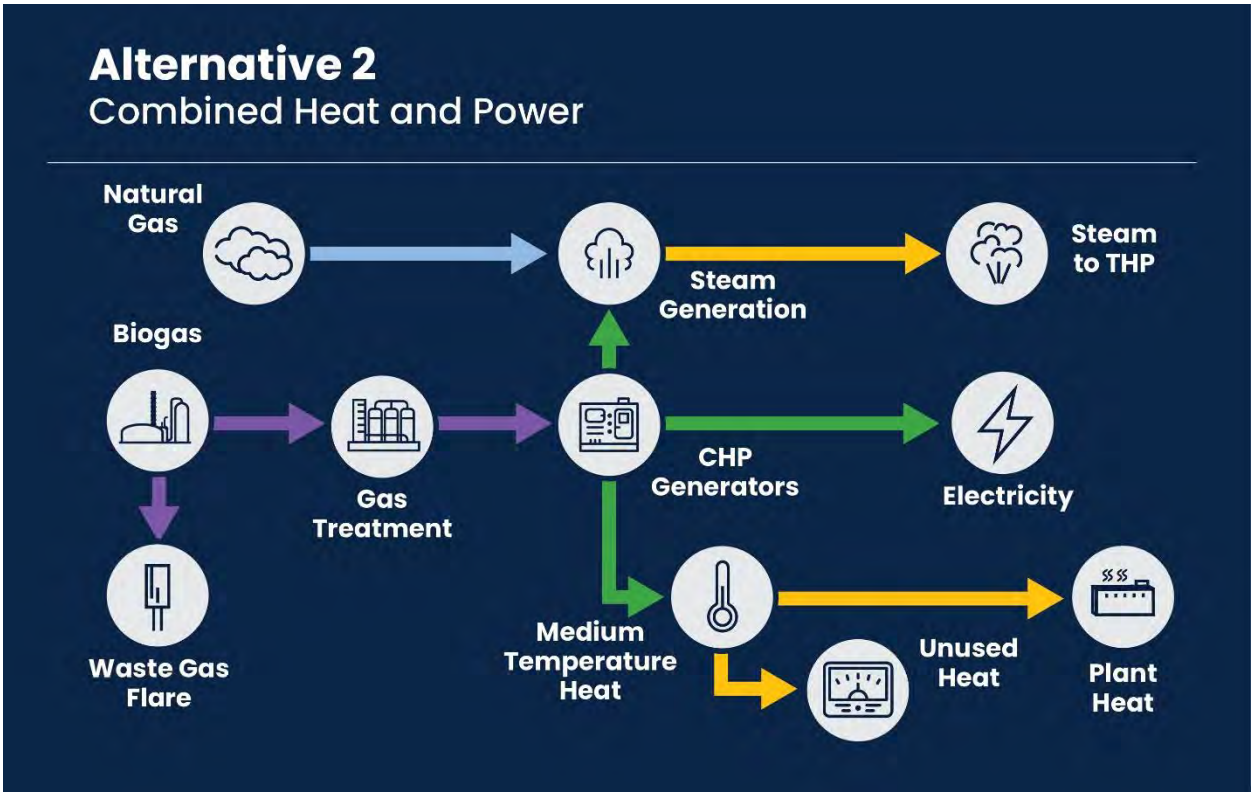


Alternative 2 – CHP

In this alternative, shown schematically in Figure 2, the biogas would be used as fuel for engines to produce electrical power. Recovered heat from the engines would be used for production of steam for process needs and building heat. Multiple types of power generation equipment are available, each with its own electrical and heat transfer efficiencies, so this alternative was divided into the following two sub-alternatives:

- **Alternative 2A – CHP with Engines:** Internal-combustion engines would produce more power at the site but would recover less heat. As supplemental heat would be required to meet process needs, some of the biogas would be bypassed around the engines to fire directly in the boiler and provide the steam for THP.
- **Alternative 2B – CHP with Gas Turbine:** A gas turbine engine would produce less power but would recover more steam. The heat recovered would satisfy process needs.

Figure 2. Alternative 2 – Combined Heat and Power

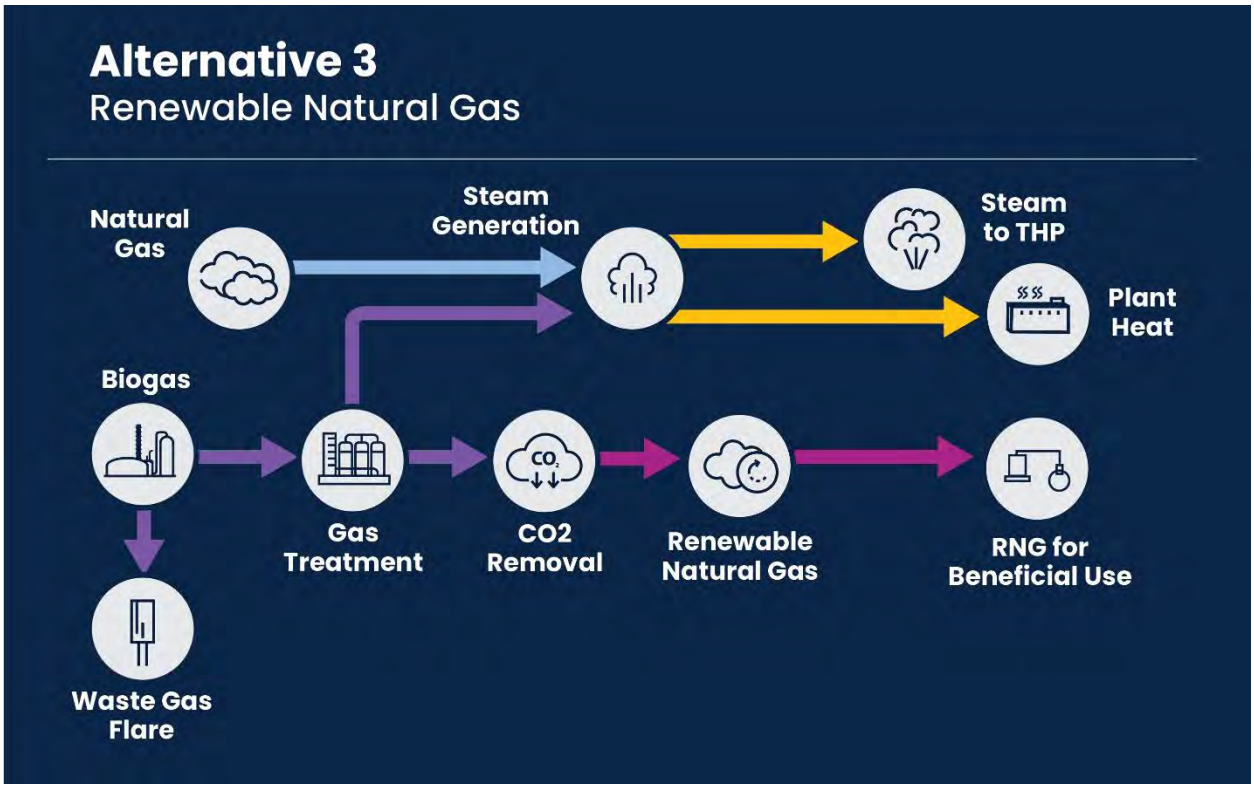


Alternative 3 – RNG

In this alternative, shown schematically in Figure 3, all of the biogas would be conditioned to RNG quality for use off site. The facility heating requirements would be met using steam boilers fueled by natural gas or from biogas onsite. There are two potential points of entry into the natural gas system so this alternative was divided into the following two sub-alternatives:

- **Alternative 3A – RNG Injected into the Natural Gas Pipeline:** In this alternative, all of the RNG would be injected into the local natural gas pipeline for off-site use as vehicle fuel.
- **Alternative 3B – RNG Used as Compressed Natural Gas (CNG):** In this alternative, the RNG would be sent to local CNG stations for use directly at those stations. This alternative is similar to Alternative 3A, but instead of injecting the RNG into the natural gas pipeline, it would be used across the road to fuel CNG buses operated by Arlington Transit and the Washington Metropolitan Area Transit Authority.

Figure 3. Alternative 3 – Renewable Natural Gas

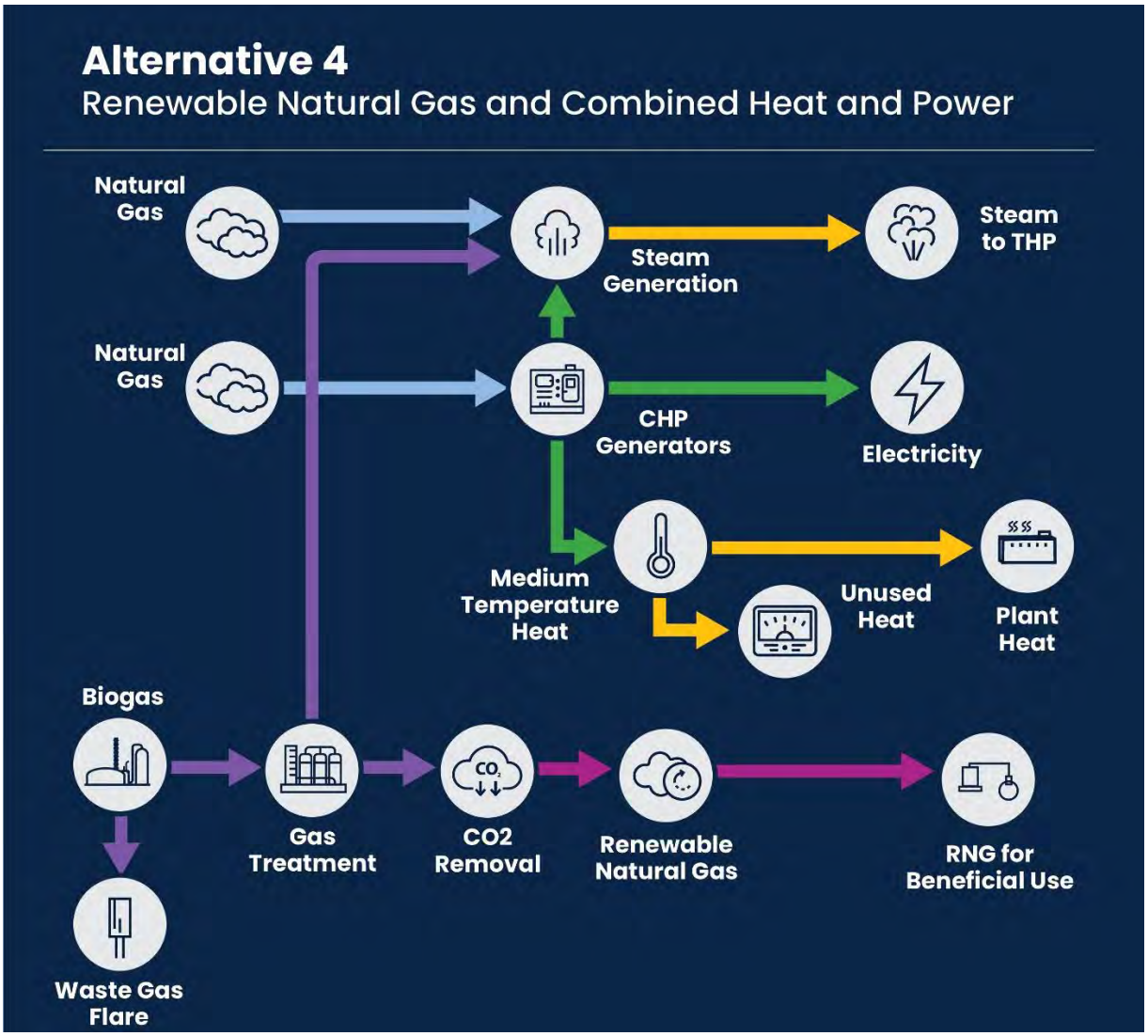


Alternative 4 – RNG and CHP

This alternative, shown schematically in Figure 4, would combine using the biogas to produce RNG as described above with using CHP fueled by natural gas for electricity and heat production. Similar to the CHP Alternative, there are two different engine options, so this alternative was divided into the following two sub-alternatives:

- **Alternative 4A – RNG and CHP with Engines:** Larger internal-combustion engines would be provided to produce all of the supplemental heat required to provide the steam for THP.
- **Alternative 4B – RNG and CHP with Gas Turbine**: Smaller gas turbine engines would produce less power but would recover more steam. The heat recovered would satisfy process needs.

Figure 4. Alternative 4 – Renewable Natural Gas and Combined Heat and Power



Alternatives Evaluations

The alternatives described above were developed and sized using the projected biogas production (approximately 120 billion Btu/year) and steam demands (approximately 35 billion Btu/year) and then evaluated using the following methods:

- **Financial analysis:** A present value of each alternative was developed from conceptual capital costs, operations and maintenance costs, energy production offsets, and RNG revenue.
- **Non-financial analysis:** A non-financial analysis was used to reflect such criteria in the overall alternatives analysis. Examples of non-financial criteria include noise production, facility aesthetics, and Plant safety.
- **Sustainability criteria:** The environmental and sustainability benefits (carbon emissions reductions) were monetized using an industry standard approach.
- **Sensitivity analysis:** To reflect future market and pricing unknowns and risks, multiple approaches were used to illustrate the sensitivity of the major assumptions.

The financial analysis considered the change in solids production and costs of electricity, natural gas, and equipment operations and maintenance over time to develop a net present value for each alternative. Based on discussions with the County, a 25-year planning period following construction was selected. With construction anticipated to finish in 2027, the planning period for this study runs from 2027 to 2052. The target year of 2052 was selected for when the design flows and loads are anticipated to be reached, resulting in a design solids production loading of approximately 40 tons per day. To illustrate the energy balance and economic analysis results presented in the subsequent sections, an evaluation year of 2037 was selected as it is close to the midpoint of the planning period and falls on one of the 5-year increments developed.

Financial Analysis

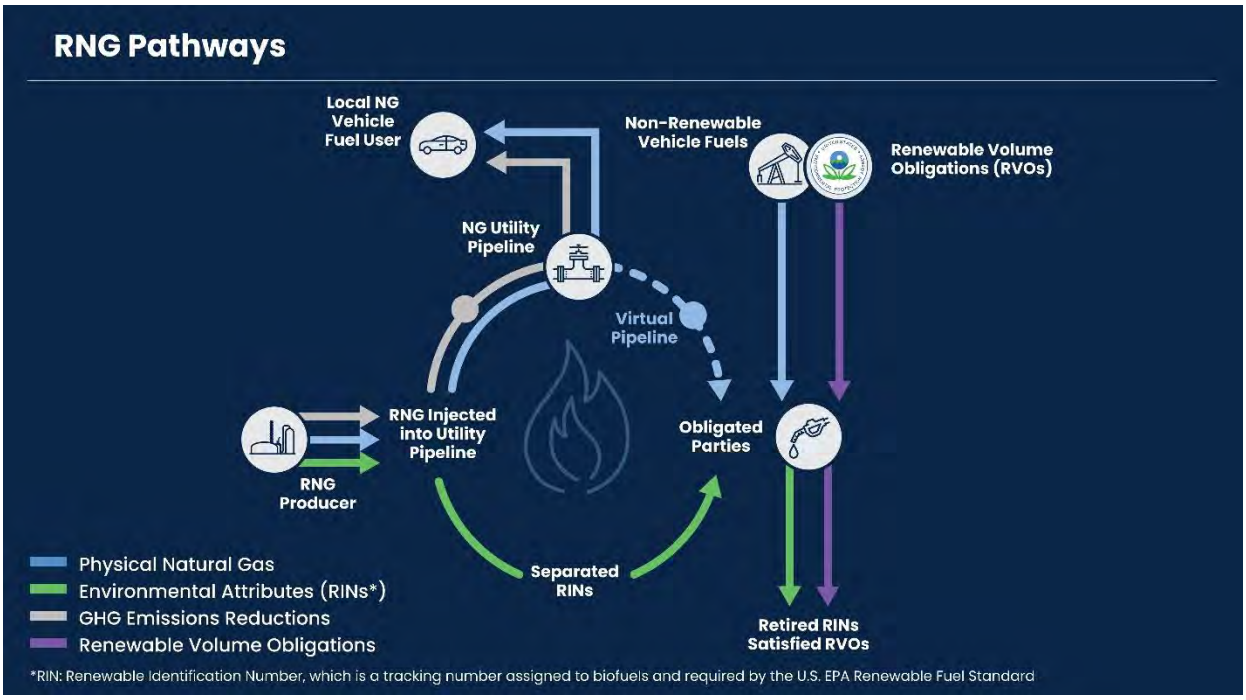
For each alternative, conceptual capital costs of the process heating, CHP, and biogas conditioning systems were developed. In addition, annual operations and maintenance costs and potential energy savings or revenues were summarized and totaled for each year of the 25-year planning period. The present value of each alternative was then developed.

For the alternatives that include CHP, it is likely that the County could either sell Renewable Energy Credits (RECs) for the electricity produced or defer purchase of RECs for other County needs. The County currently purchases RECs at a cost of $4,500/kWh and it is assumed that all CHP alternatives would be able to sell RECs for all of the electricity produced at that value.

For the alternatives that include the off-site sale of RNG, the RNG revenues were developed from the commodity value of natural gas and the historical and anticipated values of the environmental attributes of the RNG in the U.S. Environmental Protection Agency (EPA) Renewable Fuel Standard (RFS). This program is specifically for renewable fuels for transportation programs. Therefore, the fuel must ultimately be used as a transportation fuel for the renewable attribute to be recognized. In addition to the EPA's RFS, similar state programs exist such as the California Low Carbon Fuel Standard (LCFS). These state programs could be pursued by Arlington County but are not currently included in the financial metrics.

The production and sale of RNG and environmental attributes like Renewable Identification Numbers (RINs) through the RFS occurs via two pathways: the physical pathway for the commodity value and the contractual pathway for the attributes. The physical pathway is the sale of the RNG by the producer to an end user of the actual gas via the natural gas grid. The gas can be sold either to the current gas supplier or to another party directly. The contractual pathway for the environmental attributes (RINs) is separate and handled by a third party that verifies that the RNG produced complies with the RFS and markets the attributes to Obligated Parties (any refiner or importer of gasoline or diesel fuel in the United States). Note that these two pathways are independent of carbon credit programs. The County will be able to take credit for the reduction of greenhouse gases (GHGs) in its internal accounting independently of the sale of RINs as long as the gas is used within Arlington County. The valuation of RINs and GHG credits are treated separately in this report. The various physical, contractual, and greenhouse gas pathways are shown schematically on Figure 5.

Figure 5. RNG Pathways



In the RFS, RINs include a "D code" that identifies the type of biofuel based on the feedstock used. Each D code has a different market value in the RFS program. RNG generated from wastewater biosolids qualifies as a D3 RIN (cellulosic biofuel), which have historically traded at the highest value. Historical RIN values are provided in Figure 6. The base RIN value used in the financial analysis was $1.15/RIN or $15 per 1 million British thermal units (MMBtu). This value is also represented on Figure 6. The October 2021 D3 RIN value was approximately $38/MMBtu[1]. The value of the RNG environmental attributes greatly impacts the results of the financial analysis, which is why a sensitivity analysis was performed to further characterize the financial risks associated with RNG. The results of the sensitivity analysis are summarized later in this section.

[1] https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information#regulatory-categories

Figure 6. Historical RIN Pricing

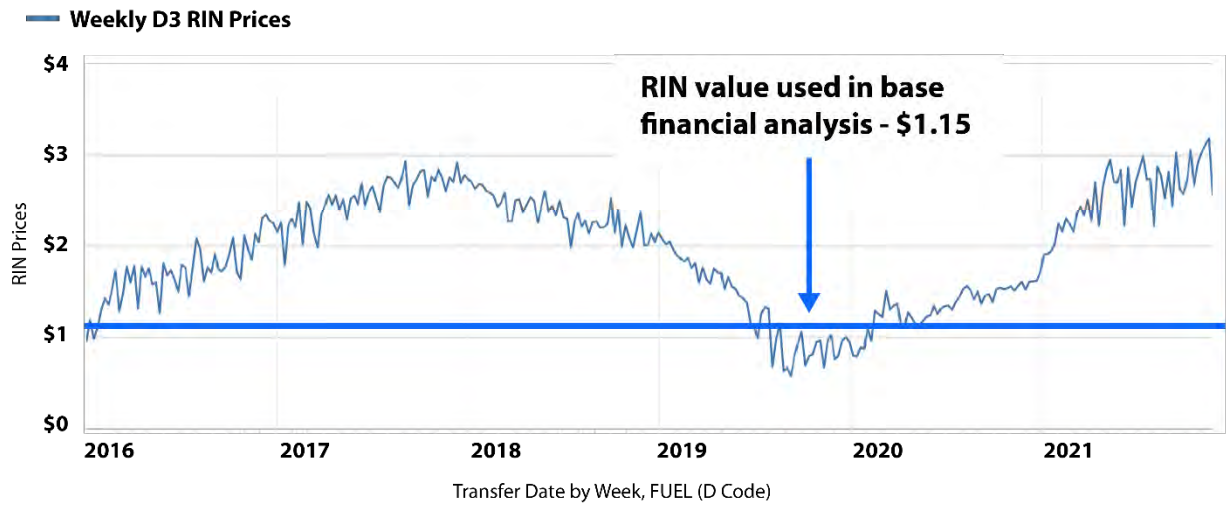
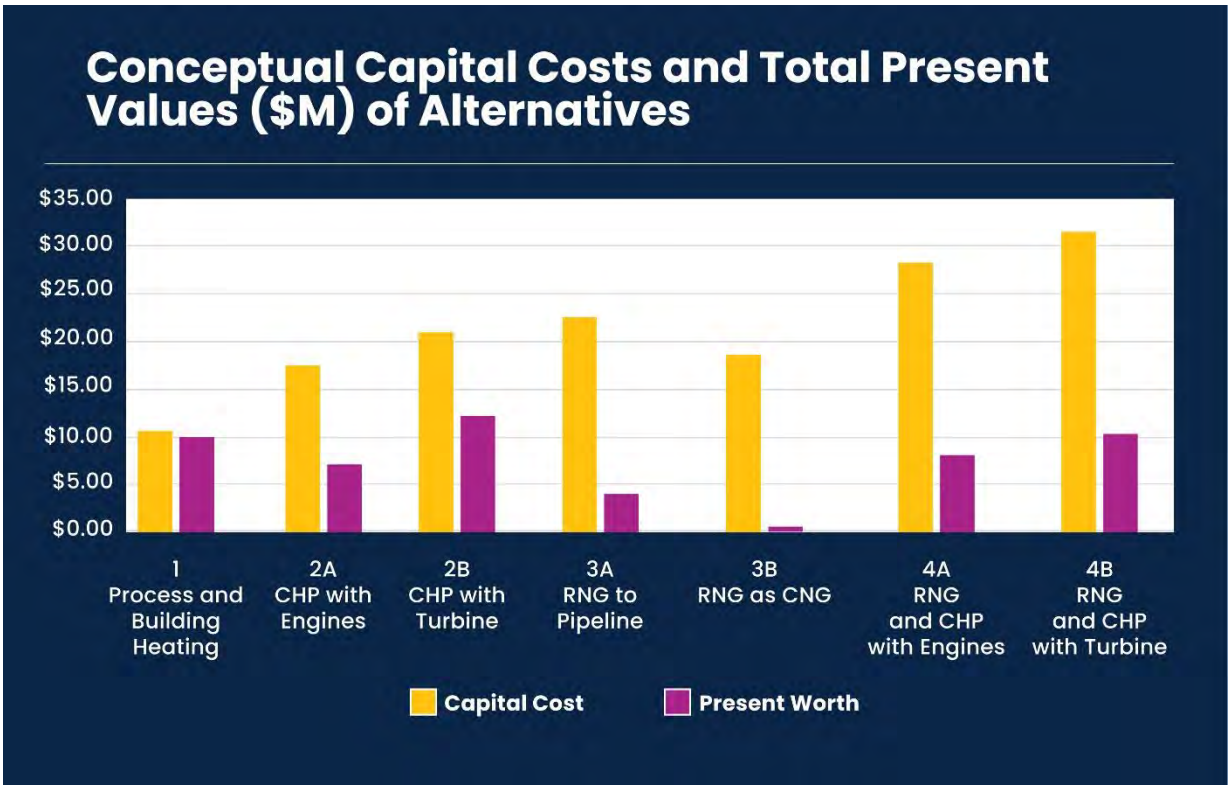


Figure 7 shows the conceptual capital costs and total present value for all alternatives. In this analysis, the cost of electricity was assumed to be $0.077 per kilowatt-hour (kWh) as this is the current average rate paid by Arlington County and energy prices are projected to remain stable.

The base cost analysis indicates that although the RNG alternatives (Alternatives 3A and 3B) do not have the lowest capital cost, they do have the lowest cost when taking into account the entire life cycle of the gas handling equipment to develop a total present-value cost, primarily because the value of the RINs offsets the initial capital investment. In comparison, the RNG and CHP alternatives (Alternatives 4A and 4B) would entail larger capital costs and comparable present-value costs to CHP alternatives (Alternatives 2A and 2B).

Figure 7. Conceptual Capital Costs and Total Present Values ($M) of Alternatives



The initial present-value analysis supported eliminating Alternatives 4A and 4B (RNG and CHP alternatives) from further consideration because of high capital costs, high overall complexity, significant use of natural gas to run the engines, and comparable present financial values to Alternatives 2A and 2B (CHP alternatives). The remaining alternatives were further analyzed for risk and non-financial factors, sustainability, and sensitivity to changing market conditions.

Non-Financial Analysis

Non-financial criteria were developed and weighted using input from County stakeholders. A description of the non-financial criteria and the weights established by the County for those criteria are presented in

Table 1.

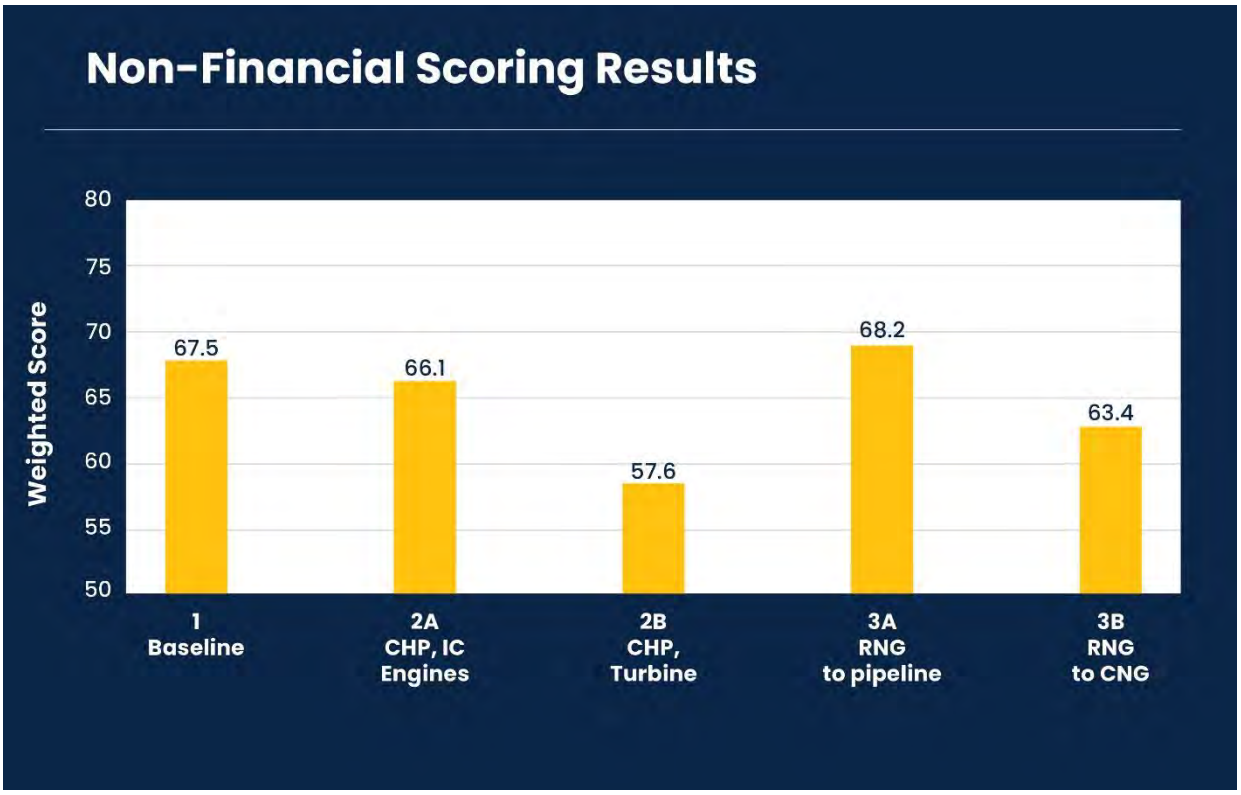
Table 1. Non-Financial Criteria

Criterion	Description	Weight
Localized emissions	Produces emissions at Plant site that may negatively impact air permitting requirements, cause neighborhood issues, or result in poor air quality in immediate area	8.0%
Noise	Generates excess noise that may impact neighbors or result in costly noise reduction measures	8.4%
Visual aesthetics	Is acceptable to the neighbors and general Arlington County community from a visual aesthetics standpoint	4.1%
Footprint	Sufficient space for operations and maintenance; does not take land space from current needs or potential future add-ons	6.9%
Potential for flaring	Provides multiple outlets for use of biogas or redundancy options to minimize the amount of biogas sent to the waste flare	8.4%
Operational complexity	Complexity of equipment and facilities in operation	11.8%
Maintenance complexity and reliability	Reliability of equipment and facilities, ongoing maintenance requirements, annual downtime for maintenance, and number of components that could fail, resulting in failure of system	11.8%
Safety	Risks for operation of system, including leaks, pressures, number of components, etc.	22.5%
Resilience	Provides for additional resilience benefits for the Plant and solids handling systems	8.8%
Future opportunities	Maintains flexibility for modifying approach should market conditions change	9.3%

The remaining alternatives (excluding Alternatives 4A/4B – RNG and CHP) were then scored based on this criteria to develop a non-financial score. With this methodology higher scores are better. Figure 8 presents the average scores for each alternative carried forward. Alternative 3A (RNG into pipeline) had the highest average non-financial score at 68.2, followed by Alternative 1 (Process and Building Heat) at 67.5. As stated previously, Alternative 1 is not a viable biogas utilization option, but it is included in the analysis as the minimum required to meet process needs. Alternative 1 scored well in the non-financial analysis as it is generally less complex than the other

alternatives. Alternative 2B (CHP with Turbines) had the lowest non-financial score of 57.6.

Figure 8. Non-Financial Scoring Results



The main differentiators between the RNG alternatives (Alternatives 3A/3B) and CHP alternatives (Alternatives 2A/2B) were that the RNG alternatives had:

- Lower localized emissions
- Reduced noise
- More outlets for beneficial use of the biogas and ability to reduce flaring
- Lower maintenance complexity and reliability
- Ease of adaptability to other gas utilization alternatives in the future

Sustainability Criteria

Table 2 presents net change in GHG (namely carbon dioxide [CO_2]) emissions for each of the sources of energy for 2037. The net GHG change presented in Table 2 is solely for the gas utilization equipment, not the entire biosolids upgrade program. Alternatives 2A and 2B (CHP alternatives) result in emissions reductions from the offset of purchased power, while Alternatives 3A and 3B (RNG alternatives) result in emissions reductions because of the reduction in use of petroleum-based natural gas. Overall, Alternatives 2A (CHP with Engines) and 3A/B (RNG =alternatives) have greater GHG reductions than Alternative 1 (Process and Building Heating) and Alternative 2B (CHP with Turbines).

GHG reductions for Alternatives 2A and 2B (CHP alternatives) are based on the current Dominion Energy CO_2 emission profile, which includes a combination of fossil-fuel and renewable energy sources. Electricity for Arlington County operations is projected to be 100 percent renewable by 2025 through separate power purchase agreements, in which case the GHG reduction for net electricity production would be zero. However, the generation of renewable power at the Plant may allow for currently forecasted renewable sources to be used elsewhere and the financial analysis assumes that the County would be able to sell RECs for these alternatives.

Table 2. Total Change in Net CO_2 Emissions (Metric Tons) in Year 2037

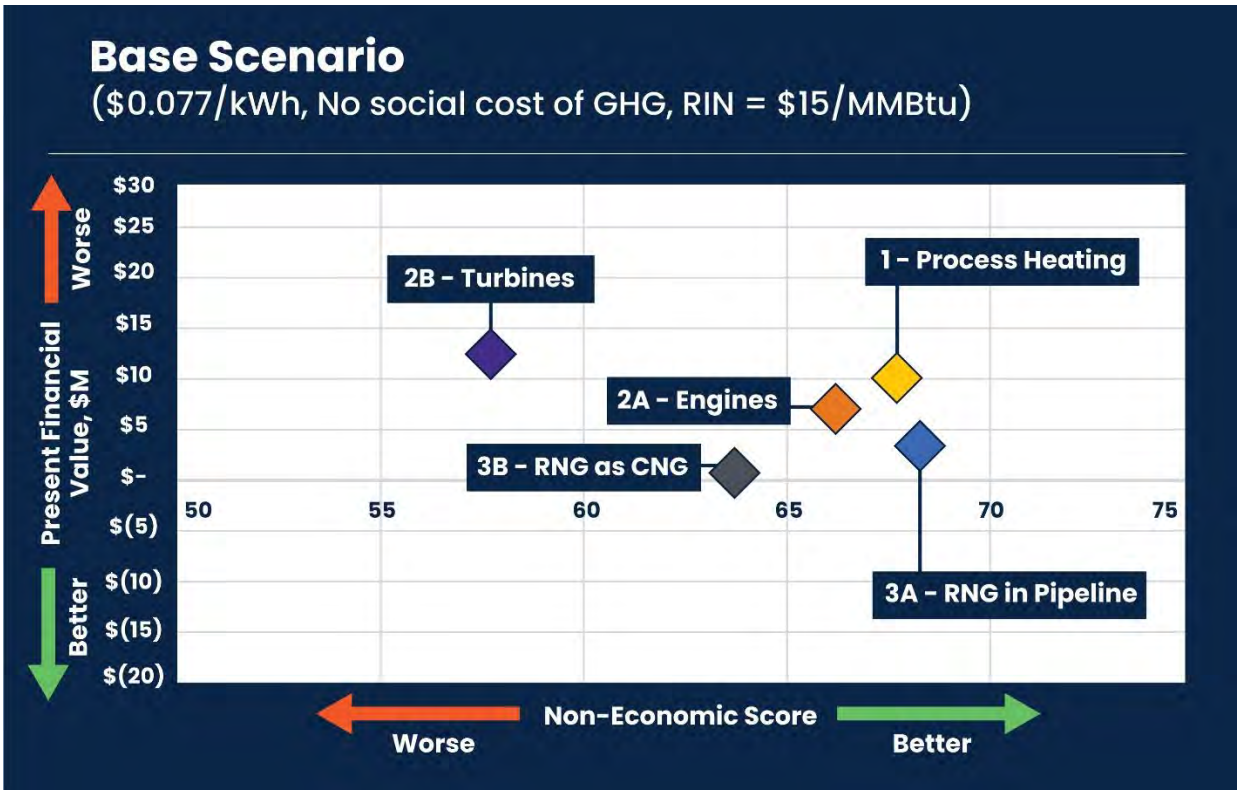
Alternative	Net Electricity Use of Biogas Utilization	Biogas Production (Offsets Natural Gas Purchases)	Natural Gas Purchased	Total Change in Emissions
1: Process and Building Heat	80	-40	0	40
2A: CHP with Engines	-3,330	-40	0	-3,370
2B: CHP with Turbines	-2,310	-40	0	-2,350
3A: RNG to Pipeline	770	-6,240	1,970	-3,500
3B: RNG Used as CNG	770	-6,240	1,970	-3,500

Note: Negative values are emissions reductions and positive values are emissions increases.

Composite Results

Figure 9 presents a composite result of the financial and non-financial scores using the base financial conditions (namely current electrical price of $0.077/kWh and average RIN market value of $15/MMBtu). The non-financial score is presented on the x-axis, the present financial value is presented on the y-axis, and the size of the bubble represents the conceptual capital cost. For this base condition, without considering the social cost of GHG, Alternative 3A (RNG to Pipeline) had the highest non-financial score and the second-lowest present financial value.

Figure 9. Base Scenario ($0.077/kWh, No social cost of GHG, RIN = $15/MMBtu)



Several alternative scenarios were run to test the sensitivity to key parameters.

Figure 10 provides the same analysis including the social cost of GHG and the average RIN value for the past six years of $23.35/MMBtu. This RIN value furthers the financial advantage of the RNG alternatives.

Figure 10. Average RIN Scenario ($0.077/kWh, Includes social cost of GHG, RIN = $23.35/MMBtu)

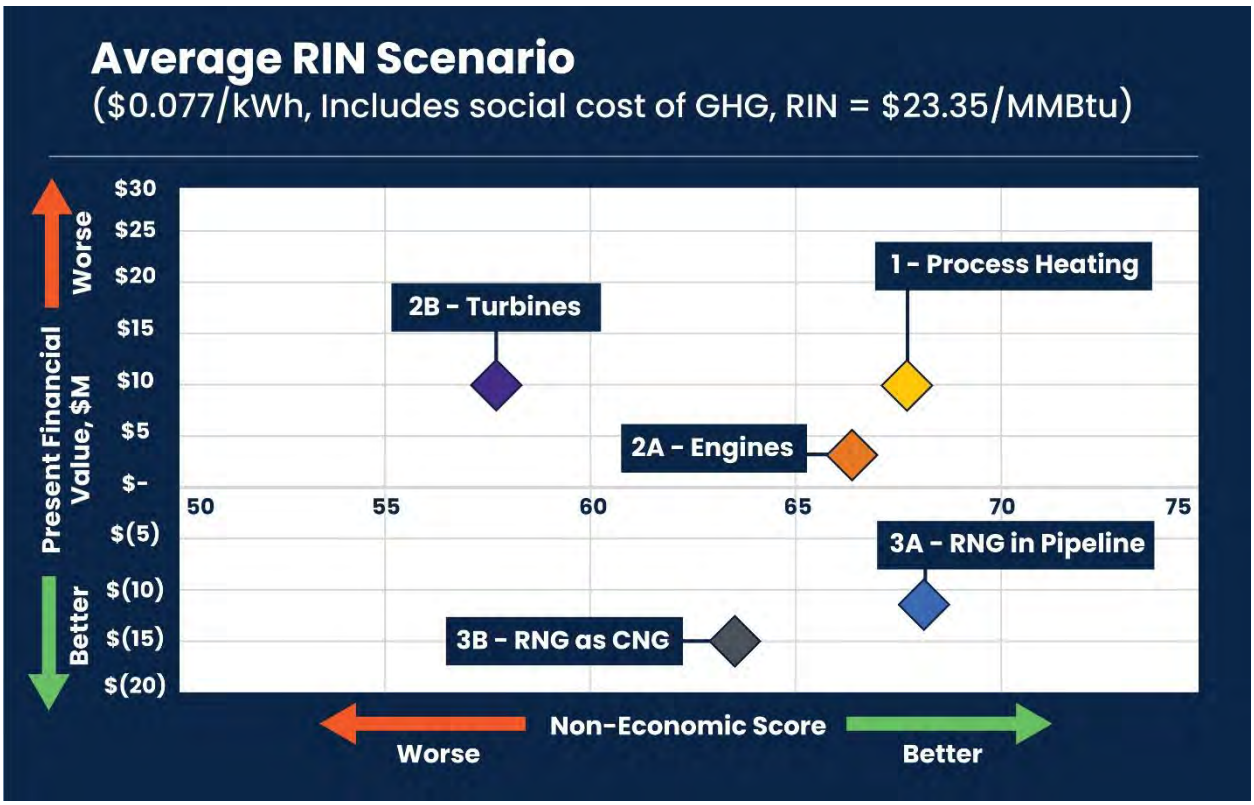


Figure 11 provides the same analysis including the social cost of GHG and the lowest weekly RIN value over the last six years of $6.38/MMBtu. In this scenario, Alternative 2A (CHP with Engines) becomes more financially advantageous.

Figure 11. Lowest RIN Scenario ($0.077/kWh, Includes social cost of GHG, RIN = $6.38/MMBtu)

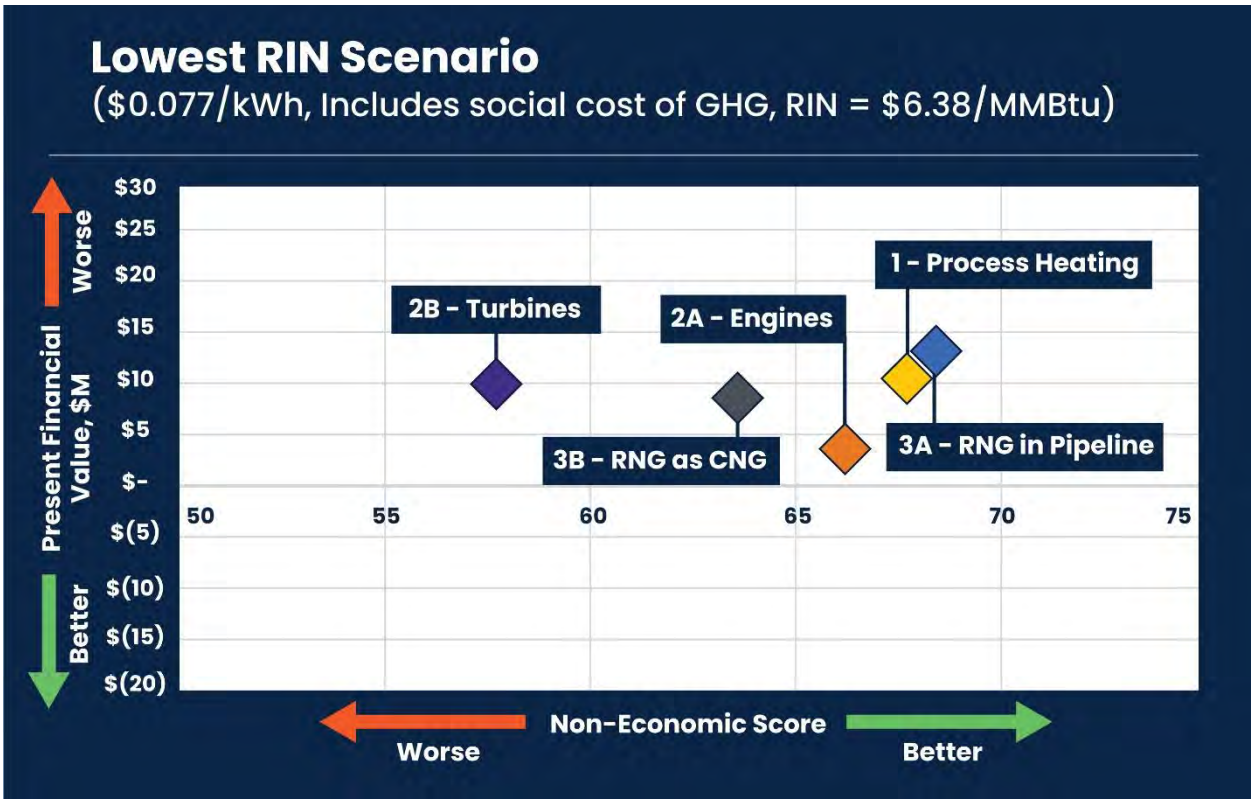
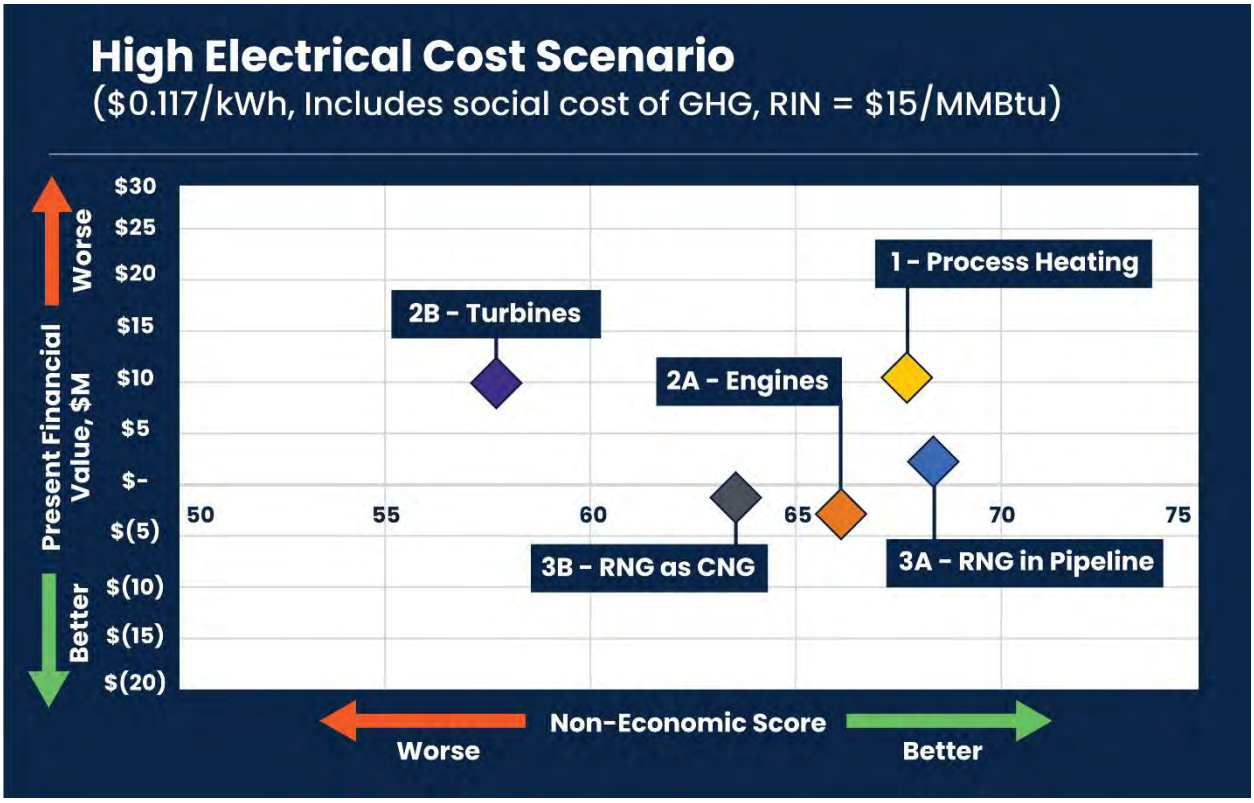


Figure 12 provides the analysis including the social cost of GHG and higher electricity cost of $0.117/kWh. In this scenario, the CHP alternatives become more financially favorable than the RNG alternatives.

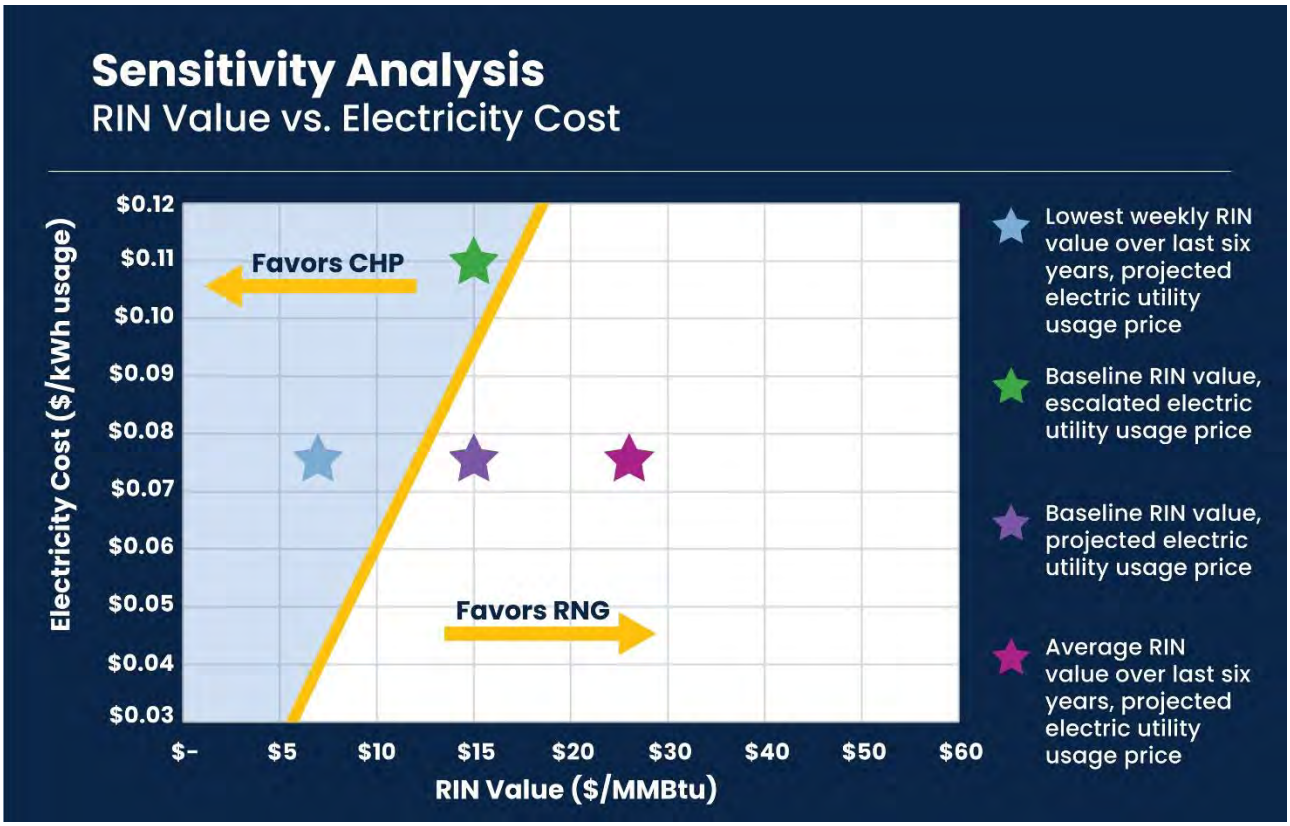
Figure 12. High Electrical Cost Scenario ($0.117/kWh, Includes social cost of GHG, RIN = $15/MMBtu)



Sensitivity Analysis

The financial analysis makes it clear that the main drivers in the comparison are the cost of electricity and the value of the RIN market. A break-even analysis was completed to identify the point at which Alternative 2A (CHP with Engines) is financially equal to Alternative 3A (RNG into Pipeline). This break-even analysis is shown on Figure 13, with the scenarios completed above identified.

Figure 13. Sensitivity Analysis of RIN Value vs. Electricity Cost



Additional detailed computer simulations were completed and these simulations confirmed the very high likelihood (greater than 90%) that the RNG alternatives will be more financially advantageous to Arlington County than the CHP alternatives.

Biogas Utilization Conclusion

Based on the analyses presented, the Arlington County Water Pollution Control Bureau recommends proceeding with Alternative 3 (RNG) as the selected biogas utilization approach. The basis for this recommendation is as follows:

- Alternative 3 (RNG) has the lowest net present value (i.e., lowest total cost to the County over the life of the equipment) for the baseline conditions using conservative capital and operating costs.
- Alternative 3A (RNG into Pipeline) scored the highest in the County's non-financial scoring. In particular, the County found that the RNG alternatives would be less complex to maintain and would result in fewer localized impacts such as noise and emissions than the CHP alternatives.
- A sensitivity analysis concluded that when considering multiple variables, including RIN volatility and changes in electrical rates, Alternative 3A (RNG into Pipeline) had a very high likelihood of being more financially advantageous than Alternative 2A.
- The County has the ability to retain GHG credits if the biogas is used within Arlington County for transportation purposes.
- Benefits of on-site CHP are limited because the CHP size would not be sufficient to power the entire Plant, which is already protected with two independent power feeds and backup generators. In addition, the use of CHP onsite will generate new, localized air emissions.

The County's current preference is for Alternative 3A (RNG into Pipeline) over Alternative 3B (RNG as CNG) due to the uncertain future of Arlington Transit and Washington Metropolitan Area Transit Authority fueling stations and the lack of a match between fueling times and gas production times (resulting in the need for additional storage). However, the final decision to inject RNG into the natural gas utility pipeline or to use CNG will be made in the future as more discussions with the stakeholders are conducted.

ARLINGTON RE-GEN

Biogas Utilization Final Report

HDR

November 18, 2022

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Abbreviations

°F	degree(s) Fahrenheit
AD	anaerobic digestion
ART	Arlington Transit
Btu	British thermal unit(s)
CDF	cumulative density function
CF	cubic foot/feet
CH_4	methane
CHP	combined heat and power
CI	carbon intensity
CIP	Capital Improvement Program
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
County	Arlington County
d	day(s)
Dominion	Dominion Energy
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EQ	Exceptional Quality
Facilities	solids handling processes
FOG	fats, oils, and greases
gCO_2e	gram(s) carbon dioxide equivalent
GHG	greenhouse gas
H_2S	hydrogen sulfide
HDR	HDR Engineering, Inc.
hp	horsepower
hr	hour(s)
HRSG	heat recovery steam generator
IC	internal combustion
IWG	Interagency Working Group
kg	kilogram(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
lb	pound(s)
lbm	pound(s) mass
LCFS	Low Carbon Fuel Standard
LHV	low heating value
MAD	mesophilic anaerobic digestion
MBH	1,000 British thermal units per hour

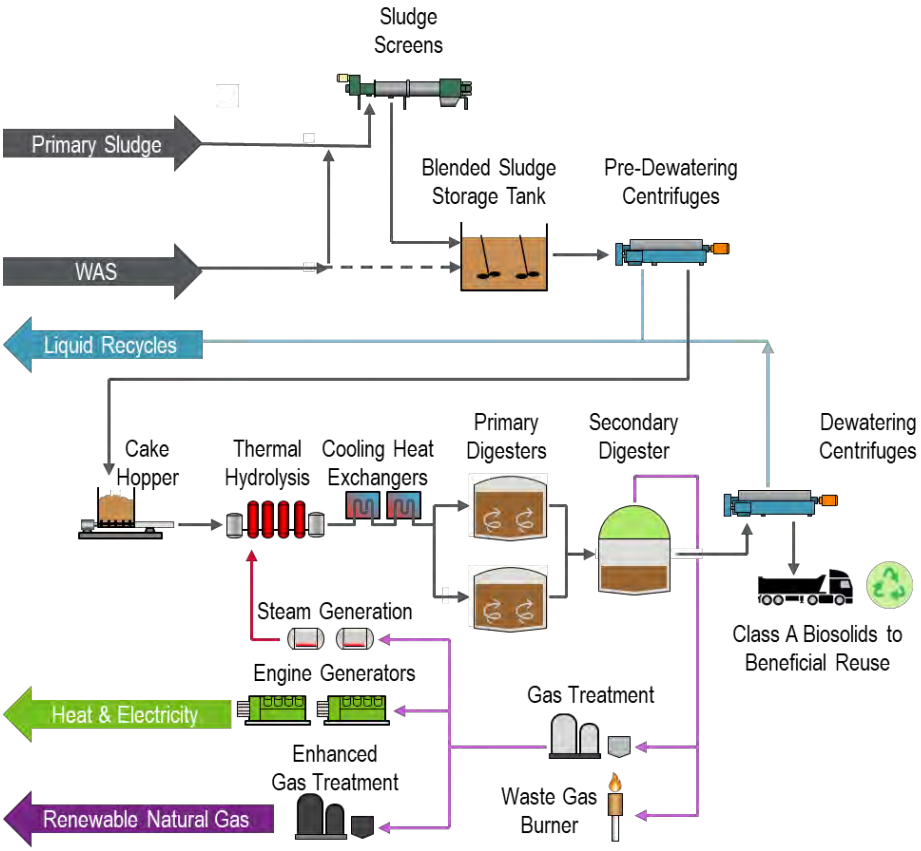
MBtu	1,000 British thermal units
MMBtu	1 million British thermal units
mgd	million gallons per day
MJ	megajoule(s)
MMscf	million standard cubic feet
MT	metric ton(s)
MW	megawatt(s)
MWh	megawatt-hour(s)
N/A	not applicable
N_2	nitrogen
NG	natural gas
O_2	oxygen
O&M	operations and maintenance
O&P	overhead and profit
PDF	probability density function
Plan	Arlington County Water Pollution Control Plant Solids Master Plan
ppm	part(s) per million
Program	Arlington County Water Pollution Control Plant Re-Gen/Biosolids Program
psig	pound(s) per square inch gauge
QA	quality assurance
REC	Renewable Energy Credit
RFP	request for proposals
RFS	Renewable Fuels Standard
RIN	Renewable Identification Number
RNG	renewable natural gas
RTO	regenerative thermal oxidizer
RVO	Renewable Volume Obligation
S	sulfur
scf	standard cubic foot/feet
scfm	standard cubic foot/feet per minute
SF	square foot/feet
THP	thermal hydrolysis process
TM	technical memorandum
VOC	volatile organic compound
WMATA	Washington Metro Area Transit Authority
WPCB	Water Pollution Control Bureau
WPCP	Water Pollution Control Plant
yr	year(s)

1 Introduction and Goals

1.1 Introduction

Arlington County (County) is implementing new biosolids management facilities at the Arlington County Water Pollution Control Plant (WPCP). The Arlington County WPCP Re-Gen/Biosolids Program (Program) is a comprehensive program that will include the engineering, design, construction, maintenance, startup, and operation necessary to add sustainable equipment and systems to effectively recover the County's renewable resources, produce a Class A biosolids product, and most efficiently utilize the biogas. The new solids handling processes (Facilities) will entail upgrades or replacement of nearly all existing solids handling processes. A thermal hydrolysis process (THP) followed by anaerobic digestion (AD) form the backbone of the new treatment train. The THP process uses temperature and pressure to breakdown the solids and remove pathogens, while the AD process stabilizes the solids and generates a methane (CH_4) rich biogas. The solids end product is a marketable Class A biosolids product. The overall process flow diagram for the Facilities is shown in Figure 1.

Figure 1: New Solids Handling Processes Flow Diagram



1.2 Program Mission Statement

A mission statement can be a valuable tool to help set the tone for a program during internal meetings and workshops. The Program's mission statement is as follows:

Upgrade resource recovery facilities to produce Class A biosolids and renewable energy, maximizing sustainability and community acceptance. Collaborate with team members to select and implement processes that are safe, reliable, and financially responsible throughout planning, design, construction, operations and maintenance.

1.3 Program Goals

Building on the mission statement and related drivers for the Program, below are the Program goals developed by the County:

1. **Produce a Class A Exceptional Quality (EQ) end product:** high-quality, low-odor product suitable for beneficial use and reduced risk of regulatory impact for land application
2. **Recover biogas for beneficial use:** recovering and beneficially using renewable resources to help achieve County-wide sustainability goals
3. **Provide ease of maintenance and repairs:** easy to work with equipment, updated technology with high efficiency and long-term ability to find replacement parts
4. **Keep safety in mind:** throughout process, design, construction, and ongoing operations
5. **Apply proper process selection and configuration:** appropriate choice of processes, well-designed and coordinated across the entire system, reliable with adequate redundancy
6. **Implement an open, transparent, and collaborative process between all team members**
7. **Achieve and maintain community acceptance:** maintain "good neighbor" status, including construction, and produce an outcome that is an asset to the community
8. **Implement cost-effective solutions:** make the most out of the investment
9. **Develop operator-friendly solutions:** comprehensive training on reliable and accessible equipment with clear operations and maintenance (O&M) and troubleshooting guidance
10. **Design for long-term reliability:** eliminate nuisance-causing, aging equipment and processes
11. **Actively engage staff throughout process:** during design, construction, startup, and training

12. **Ensure that staff are well prepared to operate and maintain the new processes:** via comprehensive training, ample transition time, and appropriate staffing levels for new systems

This Biogas Utilization Report is intended to provide more clarity on achieving Goal 2 (recover biogas for beneficial use). The following chapters summarize biogas production and energy needs at the WPCP, and evaluate several alternatives based on financial, non-financial, and sustainability criteria to recommend a biogas utilization approach that is consistent with the remaining Program goals listed above.

2 Background

2.1 Previous Reports

Several previously completed Arlington County planning reports and documents serve as a foundation for the Program evaluations:

- Arlington County Community Energy Plan (2019)
- Arlington County WPCP Foul Air Study (2017)
- Arlington County Sanitary Sewer Study (2020)
- Arlington County WPCP Condition Assessment (2019)
- Arlington County WPCP Solids Master Plan (2018)

The most relevant previous report for the biogas utilization analysis is the Arlington County WPCP Solids Master Plan (Plan) authored by CDM Smith. Additional descriptions of the Plan goals and recommendations are provided in the next sections.

2.1.1 Arlington County WPCP Solids Master Plan

The Plan, dated March 2018, evaluated several solids handling alternatives and developed a recommendation that addressed several needs of the WPCP. The overall goals of the Plan are listed below:

- Replace failing and end-of-life equipment
- Mitigate the risk of potential future regulatory changes to the current practice of recycling Class B biosolids through application to agricultural land
- Provide a solution that reduces the energy and greenhouse gas (GHG) footprint of the WPCP
- Achieve additional County-wide sustainability goals
- Develop a solids management strategy that offers long-term reliability
- Establish an implementation plan compatible with County Capital Improvement Program (CIP) funding

The alternatives evaluated in the Plan to achieve these goals included continuing lime stabilization, mesophilic anaerobic digestion (MAD), THP followed by MAD, and MAD followed by heat drying. The evaluation took into consideration 19 criteria, including the energy balance of each alternative. The energy balances are presented in Figures 10-10a, 10-10b, and 10-10c of the Plan.

The recommended alternative from the Plan was THP followed by MAD and a key aspect of the selection of this alternative was the energy value of the biogas produced. Section 12.4 of the Plan discusses the potential for future biogas utilization alternatives, but no formal recommended biogas use was made. Text from Section 12.4 of the Plan is shown below.

12.4 Biogas Utilization

In addition to the equipment and processes described, the County will continue to evaluate opportunities for biogas utilization. Opportunities identified include utilization of the biogas on-site through a combined heat and power system or cleaning and exporting the gas as a biomethane.

A combined heat and power system would include a combustion engine generator that produces electrical power for use on-site or potential metering the electrical utility. A heat recovery system for the engines and exhaust would allow heat to be captured for potential uses in building or process heating (e.g., steam generation). A biogas cleaning system is recommended for the system. The cleaning system would remove contaminants in the biogas such as hydrogen sulfide, siloxanes, and moisture that could impact engine wear and performance.

The opportunity to purify and export biogas as a biomethane may also be considered. Biomethane production involves increasing the energy content of the gas as well as removing contaminants including carbon dioxide, hydrogen sulfide, and moisture. Multiple technologies exist for producing biomethane. Opportunities to inject the biomethane into the natural gas distribution system or pipeline can be explored. The County may also consider a partnership with the Arlington Rapid Transit's CNG (compressed natural gas) fueling station located adjacent to the WPCP.

As the County moves ahead with implementation of thermal hydrolysis and anaerobic digestion, biogas utilization opportunities can be explored.

This Biogas Utilization Report does not seek to revisit the previous Arlington County Board-adopted decision to proceed with THP followed by MAD, but rather to evaluate the biogas utilization alternatives to meet the biogas utilization goal of recovering and beneficially using renewable resources to help achieve County-wide sustainability goals.

2.1.2 Planning Period

The planning period is important for this study as the financial analysis needs to consider the change in solids production and costs of electricity, natural gas (NG), and equipment O&M over time to develop a net present value for each alternative. Based on discussions with the County, a 25-year planning period following construction was selected. With construction anticipated to finish in 2027, the planning period for this study runs from 2027 to 2052. The target year of 2052 was selected for when the design flows and loads are anticipated to be reached, resulting in a design solids production loading of approximately 40 tons per day. Based on the current solids production of 30.7 tons per day, it is anticipated that the solids production will increase linearly by approximately 0.37 ton per year, or roughly 1.0 percent per year based on anticipated population growth. To illustrate the energy balance and economic analysis results presented in the subsequent chapters, an evaluation year of 2037 was selected

as it is close to the midpoint of the planning period and falls on one of the 5-year increments developed.

2.2 Process Requirements

The energy required to achieve the WPCP process requirements was calculated to develop the overall energy balance of the WPCP and determine the best use of the biogas. The sections below summarize the solids production, heating requirements, and biogas production throughout the planning period.

2.2.1 Solids Production

Current and future solids production were determined as part of the review of historical WPCP data and the resulting mass balance as presented in Technical Memorandum (TM) No. 1, *Solids Production and Design Criteria*. The three sizing scenarios are based on loadings in 2020 at 23.0 million gallons per day (mgd), a year 2052 design condition at 30.8 mgd, and ultimate capacity at 40.0 mgd. Solids production and corresponding energy needs and biogas production are assumed to increase at a linear rate between now and the design year. Table 1, Table 2, and Table 3 below present the biosolids total solids; volatile solids; and primary scum and fats, oils, and greases (FOG) volatile solids loadings, respectively, over the planning period in 5-year increments.

Table 1: Biosolids Total Solids Loading to Pre-dewatering, dry lb/d

Parameter	2027	2032	2037	2042	2047	Design 2052
Average	65,872	69,122	72,371	75,621	78,870	82,120
30-day max	86,190	90,442	94,694	98,946	103,197	107,449
14-day max	93,892	98,524	103,156	107,788	112,419	117,051
7-day max	99,391	104,294	109,197	114,099	119,002	123,905
3-day max	109,423	114,821	120,219	125,616	131,014	136,412

Table 2: Biosolids Volatile Solids Loads to Pre-dewatering, dry lb/d

Parameter	2027	2032	2037	2042	2047	Design 2052
Average	50,865	53,374	55,883	58,392	60,901	63,410
30-day max	66,085	69,170	72,400	75,780	79,317	83,020
14-day max	71,980	75,341	78,858	82,539	86,393	90,426
7-day max	76,190	79,747	83,470	87,367	91,446	95,715
3-day max	83,904	87,821	91,921	96,213	100,705	105,406

Table 3: Primary Scum and FOG Volatile Solids Loads to Digestion, dry lb/d

Parameter	2027	2032	2037	2042	2047	Design 2052
Average	4,625	4,854	5,082	5,310	5,538	5,766
30-day max	6,244	6,552	6,860	7,168	7,476	7,784
14-day max	6,752	7,086	7,419	7,752	8,085	8,418
7-day max	7,123	7,474	7,825	8,177	8,528	8,879
3-day max	7,955	8,348	8,740	9,132	9,525	9,917

2.2.2 Biogas Production

Future biogas production is based on the same assumptions as presented in TM No. 1, which included 95 percent solids capture in the pre-dewatering system, 60 percent volatile solids reduction for primary and secondary biosolids, and 90 percent volatile solids reduction of primary scum and FOG. The assumed biogas yield is 17 standard cubic feet (scf) of biogas produced per pound (lb) of volatile solids destroyed.

Table 4 below presents the biogas production values for the planning period in 5-year increments. The average values for each year are used for the financial analysis in Chapter 4.

Table 4: Biogas Production, scfm

Parameter	2027	2032	2037	2042	2047	Design 2052
Average	388	408	428	445	466	486
30-day max	511	536	562	587	612	637
14-day max	556	584	611	639	666	693
7-day max	589	618	647	676	705	734
3-day max	649	681	713	745	777	809

The above biogas production values were used with an energy content of 580 British thermal units (Btu)/scf (low heating value [LHV]) to develop the biogas energy production in thousands of British thermal units (MBtu) per hour (MBH) in Table 5 below. LHV is the energy produced from combustion excluding the latent heat of vaporization. The efficiencies of combustion equipment such as boilers and engines are stated based on the LHV of the fuel inputs.

Table 5: Biogas Production, MBH

Parameter	2027	2032	Used 2037	2042	2047	Design 2052
Average	13,500	14,200	14,900	15,500	16,200	16,900
30-day	17,800	18,700	19,500	20,400	21,300	22,200
14-day	19,400	20,300	21,300	22,200	23,200	24,100
7-day	20,500	21,500	22,500	23,500	24,500	25,500
3-day	22,600	23,700	24,800	25,900	27,100	28,200

2.2.3 Steam Demand

The THP system consumes 1.0 ton of steam for each ton of solids processed. In the 2037 evaluation year that equals an annual average steam demand of 3,020 pounds per hour (lb/hr) or 3,490 MBH. That is an average steam demand, but the batch nature of THP requires higher peak flows of steam reaching more than 10,000 lb/hr. The average demand was used for the financial analysis, whereas the peak demand of 10,000 lb/hr was used for sizing steam boilers. Table 6 below presents the steam required for the planning period in 5-year increments.

Table 6: Steam Required, lb/hr

Parameter	2027	2032	Used 2037	2042	2047	Design 2052
Average	2,740	2,880	3,020	3,150	3,290	3,420
30-day	3,590	3,770	3,950	4,120	4,300	4,480
14-day	3,910	4,110	4,300	4,490	4,680	4,880
7-day	4,140	4,350	4,550	4,750	4,960	5,160
3-day	4,560	4,780	5,010	5,230	5,460	5,680

Table 7 presents the steam requirements above as energy required in MBH.

Table 7: Steam Required, MBH

Parameter	2027	2032	Used 2037	2042	2047	Design 2052
Average	3,170	3,330	3,490	3,640	3,810	3,960
30-day	4,150	4,360	4,570	4,770	4,980	5,180
14-day	4,520	4,760	4,980	5,190	5,410	5,650
7-day	4,790	5,030	5,260	5,500	5,740	5,970
3-day	5,280	5,530	5,800	6,050	6,320	6,570

2.3 Other Energy Requirements

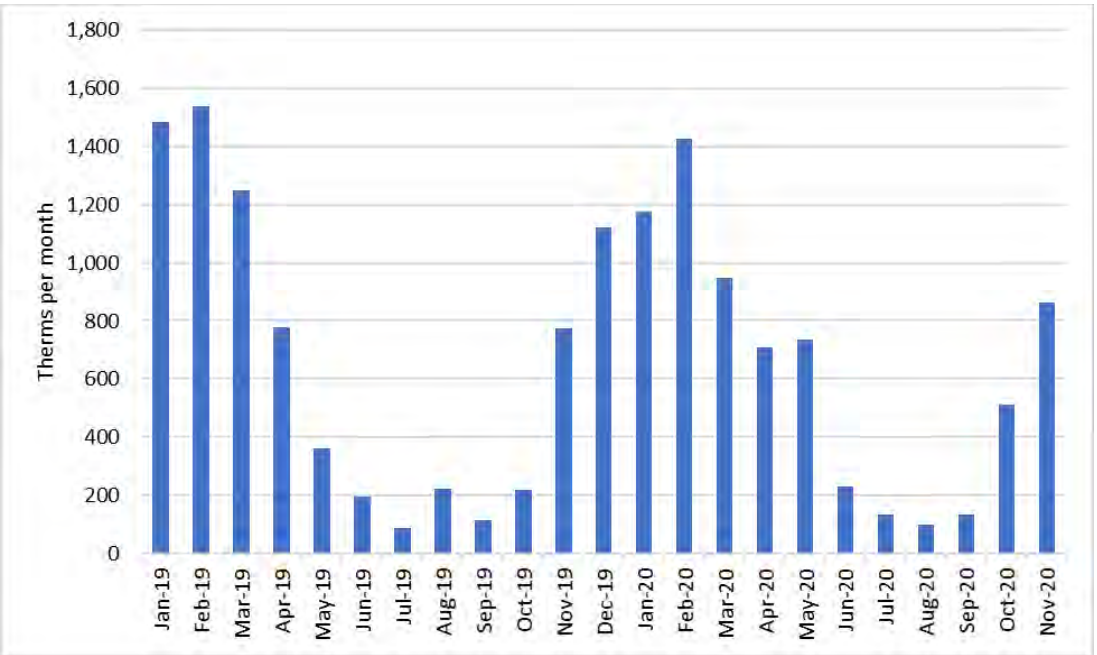
In addition to process heating requirements described above, the Arlington WPCP has other energy requirements, including providing heat for buildings and overall WPCP electrical demands. These energy requirements are summarized in the sections below.

2.3.1 Building Heating

Current building heating requirements were based on existing NG bills for the period between January 2019 and November 2020.

Figure 2 shows the monthly NG usage. Based on these data the average annual NG usage is 7,800 therms per year (780 million British thermal units per year [MMBtu/yr]) or 89 MBH and a heating load of 71 MBH at 80 percent efficiency. Building heating needs will likely change over time and will be refined as the building modifications are refined throughout the Program. For now, building heating needs are assumed to be constant through the duration of the planning period.

Figure 2: Monthly Natural Gas Usage



2.3.2 WPCP Electrical Usage

Similar to natural gas, current and future WPCP electrical requirements were based on existing power bills for the period between January 2019 and November 2020.

Figure 3 shows the monthly power usage in kilowatt-hours (kWh) per month. Based on these data the average annual power usage is approximately 29,624,000 kWh/yr, or a 3.38-megawatt (MW) average load. Assuming a similar usage increase as the flows and loads, the future electrical usage can be developed and is shown in Table 8.

Figure 3: Monthly Electrical Usage

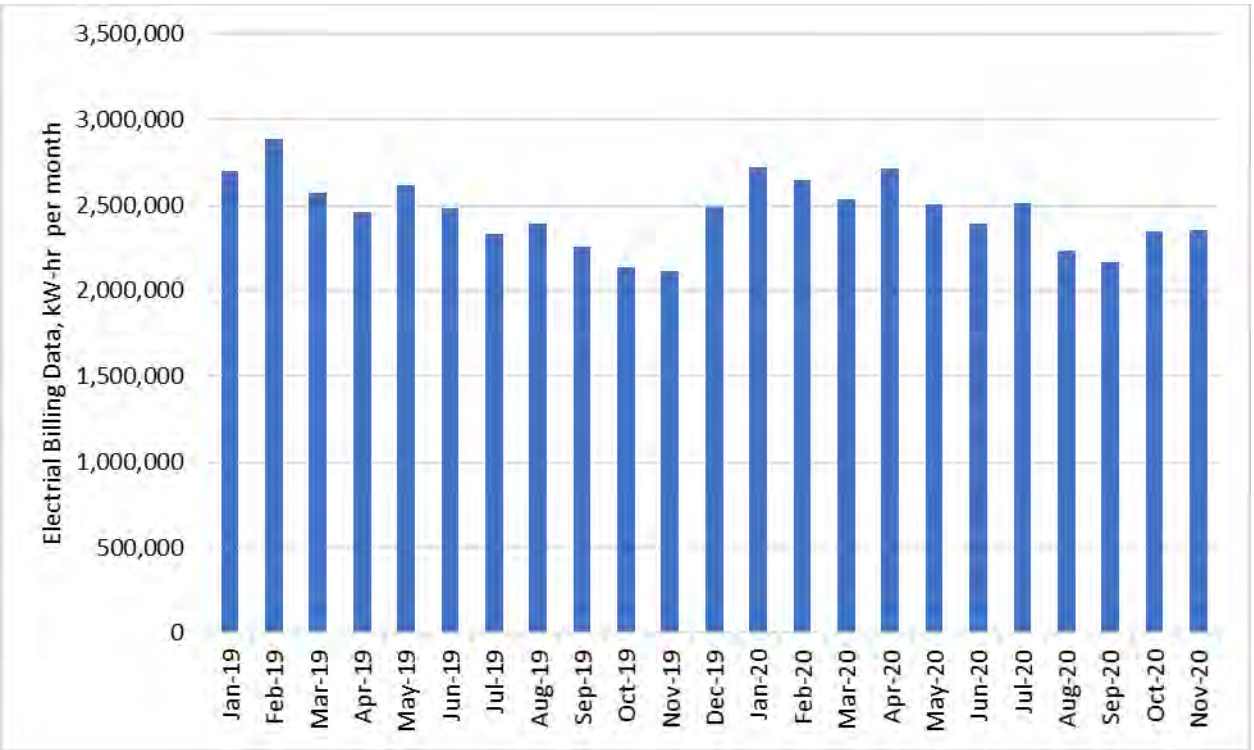


Table 8: Facility's Electrical Usage Forecast

Parameter	Actual 2020	2022	2027	2032	Used 2037	2042	2047	Design 2052
kWh/yr	29,624,000	30,252,000	31,822,000	33,391,000	34,961,000	36,531,000	38,101,000	39,670,400
MBH	11,500	11,800	12,400	13,000	13,600	14,200	14,800	15,500
MW	3.38	3.45	3.63	3.81	3.99	4.17	4.35	4.53

2.4 Renewable Natural Gas Market Summary and Potential Values

Biogas produced from anaerobic digestion has historically been used on site at wastewater facilities to provide fuel for process and building heating or by generating electricity and recovering waste heat for process and building heating. Over the last decade, the option of conditioning the biogas to NG quality and using the renewable natural gas (RNG) off site as vehicle fuel has become a viable third potential use of the biogas. The major drivers of this biogas utilization option are federal programs, like the U.S. Environmental Protection Agency (EPA) Renewable Fuels Standard (RFS), and state incentive programs, like the California Low Carbon Fuel Standard (LCFS), that encourage the use of renewable fuels to lower the use of petroleum products. Summaries of the EPA RFS and California LCFS are provided below.

2.4.1 EPA Renewable Fuels Standard

The United States Congress created the RFS through the Energy Policy Act of 2005 and revised the program with the Energy Independence and Security Act in 2007. The RFS is a renewable-fuels program within the Clean Air Act that mandates that large fossil-fuel producers and blenders (Obligated Parties) must include within their fuel mix a growing portion of renewable fuels. The quotas required of the Obligated Parties are referred to as Renewable Volume Obligations (RVOs) and are established and tracked by EPA through the use of renewable credits, also known as Renewable Identification Numbers (RINs). The original program was designed to increase the RVOs until 2022 and then level off beyond that point unless Congress issued another amendment. EPA can lower or raise the RVOs up to the maximum RVO quota set for 2022 but Congressional action would be required to eliminate the RFS program. The RFS program has pressure against it from the oil and gas industry, but also has strong support from the corn ethanol industry, which represents half of the RIN market.

As part of EPA's RFS, RVOs are developed by categorized RIN types based on their environmental benefit and the production pathway. These categories, D3 through D7, encompass lower-value biofuels like corn-based ethanol (D6) up to high-value biofuels like cellulosic biodiesel or ethanol (D3). Refer to Figure 4 for classifications of the RIN types.

The biogas produced from the digestion of municipal biosolids is considered D3 cellulosic and has the highest market value. However, any biogas produced by the co-digestion of municipal solids with hauled-in or high-strength wastes will be considered D5 advanced, unless each individual feedstock has a 75 percent or higher cellulosic content. Hauled-in wastes are defined as any wastes brought to the WPCP by truck, not the sewer, and these wastes are typically not considered cellulosic as they are not woody or starchy by nature. The exception to this requirement is hauled-in septage, which is still considered cellulosic. At this point the County does not intend to receive any wastes by truck.

Figure 4: EPA RFS Nested RIN Categories and Volumes

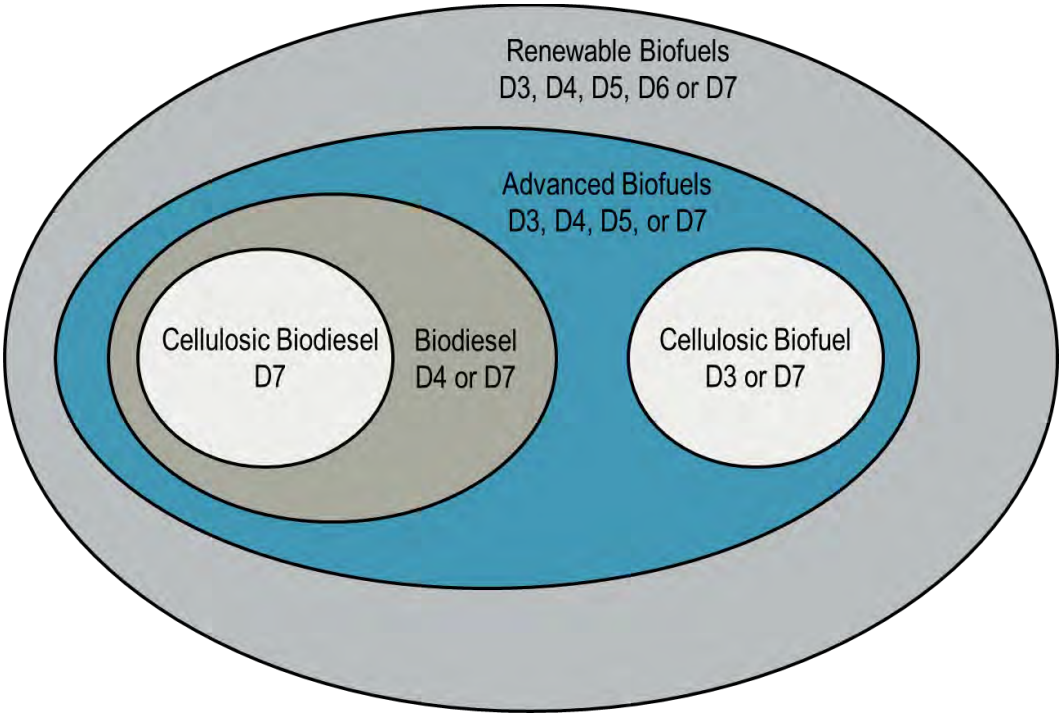
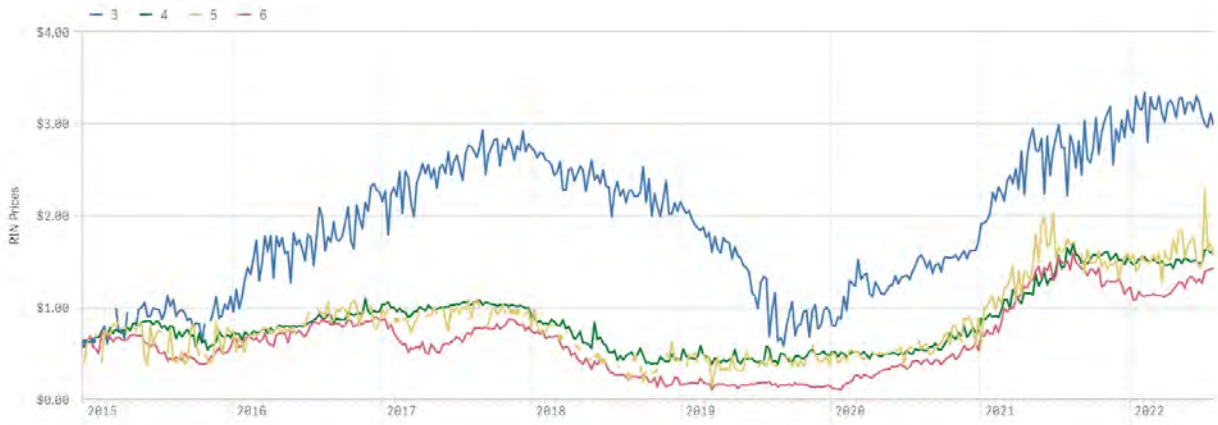


Figure 5 presents the historical RIN values as reported by EPA from 2015 through June 2022 ([https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information).](https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information) Note, there are 13 RINs per 1 MMBtu, so a RIN price of $1.00 equates to $13/MMBtu.

Figure 5: EPA RFS RIN Historical RIN Values



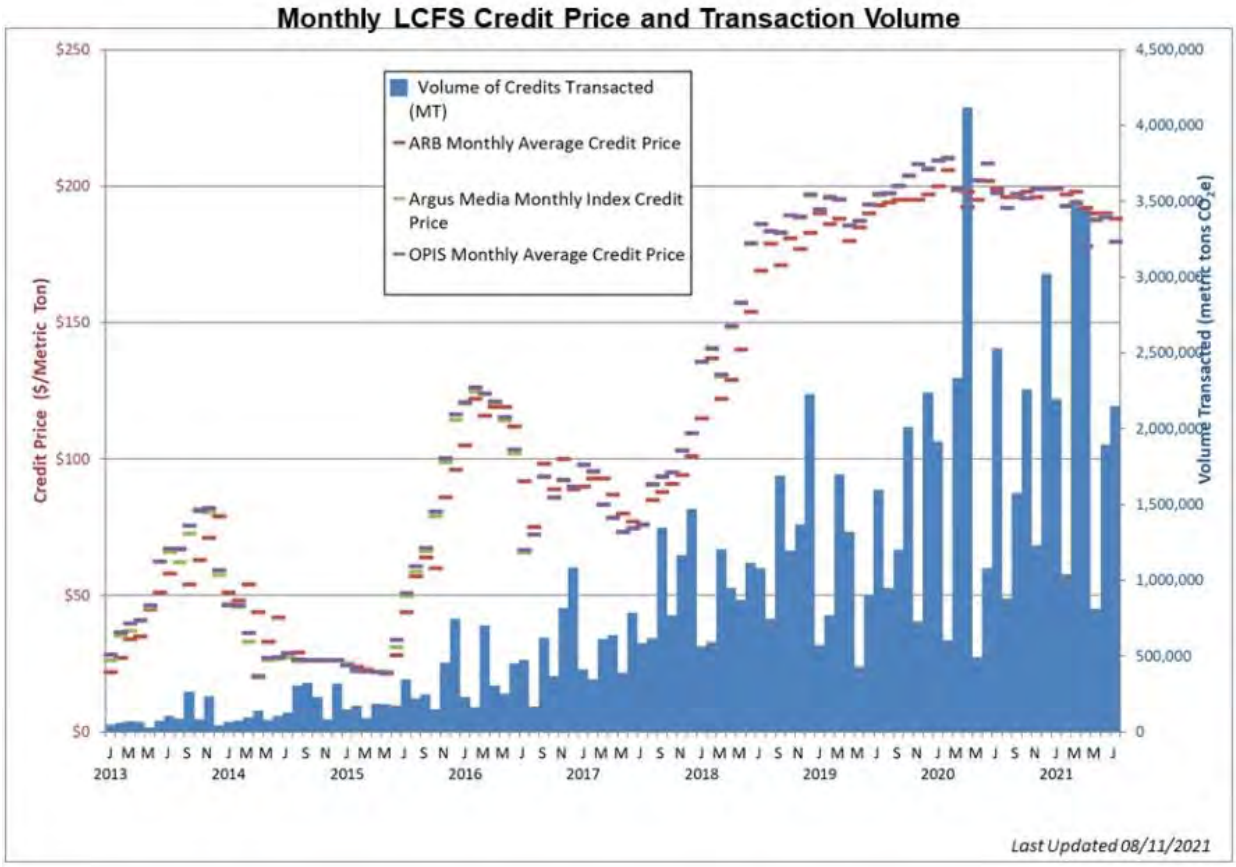
As shown in Figure 5, all RIN market values peaked in late 2017 and continued to fall through 2019 with a market rebound occurring in 2020 through 2022. The drop in market values in 2018 and 2019 was due to two major short-term factors:

- **Small refinery exemptions:** EPA administration at the time was allowing this hardship exemption to be used by large blenders, reducing their obligation for RINs.
- **Carry-over bank:** The program allows Obligated Parties to carry more than 20 percent of their obligation to the next year. In 2018 and 2019 Obligated Parties were using this carry-over allowance, but they are not allowed to do that year over year, so demand for all RINs returned in 2020.

2.4.2 Low Carbon Fuel Standard

In addition to RINs, carbon offset credits are available through California's LCFS program. The LCFS has become a healthy market with more transactions and higher values throughout the last 8 years (see Figure 6) and the program is currently slated to run through 2032. It could be renewed to extend past that date. LCFS credits can be obtained in addition to RIN credits as long as the renewable fuel is contracted for sale to an Obligated Party with end use in California. The value of RNG in the LCFS market is dependent on the carbon intensity (CI) score of the RNG produced as determined by the LCFS program requirements. The CI score takes into account the net carbon reductions achieved by producing the RNG including the energy required for processing and transporting the RNG to the end use. Typical wastewater treatment CI scores are in the range of 20 to 40 grams carbon dioxide equivalent per megajoule (gCO_2e/MJ). The current credit price of $180 per metric ton (MT) is equivalent to $12.30/MMBtu at an average CI score of 30 gCO_2e/MJ. This value can be added to the values of the RINs from the RFS. Arlington County would be eligible to participate in the LCFS program. However, it is a highly competitive program. It is attractive to producers of biogas generated from animal manure, as that biogas has a lower CI score.

Figure 6: California LCFS Market History



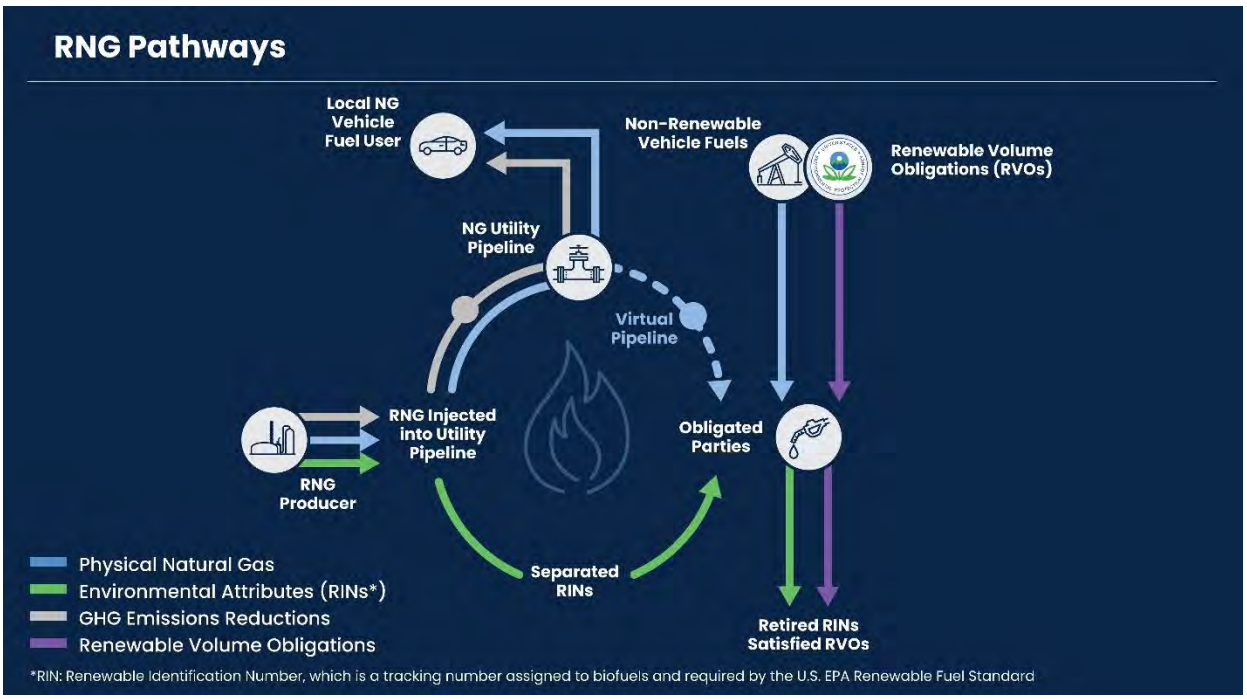
2.4.3 Pathways and Requirements

Both the RFS and LCFS are specifically for renewable fuels for transportation programs. Therefore, the fuel must ultimately be used as a transportation fuel for the renewable attribute to be recognized. A renewable-fuel producer is not required to explicitly find a transportation end user of the fuel it produces; however, at some point along the fuel supply pathway, it must be capable of being used as a transportation fuel so that an Obligated Party can claim the RIN and/or the LCFS credit and meet its obligation with EPA or California.

The production and sale of RNG and environmental attributes, like RINs through the RFS, occurs in two pathways: the physical pathway and the pathway for the separated environmental attributes. The physical pathway is the sale of the RNG by the producer to an end user of the actual gas via the NG Utility. The gas can be sold to the current gas supplier or to another party directly. The pathway for the separated environmental attributes (RINs) is handled by a third party that verifies that the RNG produced complies with the RFS and markets the attributes to Obligated Parties to satisfy their Renewable Volume Obligations (RVOs) in the RFS. Figure 7 illustrates the two

pathways of RNG and RIN/LCFS sales. Note that the molecules of natural gas do not actually have to be used as vehicle fuel, but the physical pathway from the point of injection to the vehicle fueling point needs to be verified by a third-party RIN developer or broker.

Figure 7: Physical and Contractual Pathways for RNG



These two pathways are independent of GHG emissions reductions and local greenhouse gas accounting. The County will be able to take credit for the reduction of GHGs in its internal accounting, independently of the sale of RINs, as long as the gas is used for transportation purposes in Arlington County. The valuations of RINs and carbon credits are treated separately in this report.

2.4.4 RNG Value Considerations

The value of RNG should take the following factors into account:

1. The value of the RNG as natural gas based on the NG commodity market
2. The value of environmental attributes obtained through the RFS (D3 or D5)
3. The value of environmental attributes obtained through the LCFS (CI score)
4. The cost of compliance with the RFS and LCFS
5. The cost of marketing the environmental attributes to Obligated Parties

Items 1 through 3 should be considered as ranges (low, average, high) to account for the variability in future market values. The biogas revenues at the WPCP need to be designated as either D3 (highest market value) or D5 categories. The biogas produced in the anaerobic digesters handling municipal biosolids will produce D3 RNG, but biogas produced from the co-digestion of FOG or other high-strength waste will be D5. Discussions are occurring currently at EPA regarding how to account for the RIN designation of biogas produced at wastewater plants where FOG and high-strength wastes are also digested. For facilities that wish to receive and digest these organics, the recommended approach is that they be sent to one specific D5 digester with the remaining digesters designated as D3 to maintain the high-value biogas designation. Biogas metering is needed on all digesters to quantify the D3 and D5 RNG quantities separately to meet the RFS program requirements. There is the potential that EPA may allow a blended D3/D5 approach in the future where the biogas production from biosolids is designated D3 with the additional biogas produced from hauled-in wastes designated D5, even if these materials are digested together in the same digester. However, there is currently no indication of if, or when, EPA might consider these changes. The current Program does not include facilities to receive and process high-strength wastes in the new digesters, but provisions will be included to add such a facility in the future if it is deemed appropriate by the County.

Items 4 and 5 are included to reflect the cost of bringing the gas to market within the environmental attribute programs. The RFS is highly regulated, so market RIN values are typically reduced by 15 percent and the LCFS values by 15 to 30 percent to account for the third-party cost of compliance and marketing the environmental attributes to Obligated Parties. The third parties are either gas marketing companies or the Obligated Parties themselves and are typically selected by the RNG producer through a request for proposals (RFP) process. The resulting contractual arrangement specifies that the County's share be based on either a fixed price or percentage of total revenue and the term of the agreement. The third party will qualify the RINs with EPA, qualify with California for LCFS credits, develop quality assurance (QA) programs for certification, and administer the program. The County is then paid by the third party for both the NG commodity value and the associated environmental attributes on a monthly or quarterly basis.

Table 9 comparatively presents the range of RNG market values of the RFS program. Cellulosic RINs (D3) have the highest value and have been valued from a minimum of $0.50/RIN to a maximum of $3.26/RIN between January 2016 and July 2021 with an average value of $1.96/RIN over that time frame. The ranges shown in Table 9 are based on a tighter range of values because the markets for RNG are anticipated to become more mature and less variable than they have been over the last 5 years. The statistical distribution of historical RIN prices is discussed below in Section 5.4. The net

D3 RIN values are calculated by converting the $/RIN to $/MMBtu by multiplying by 13 RIN/MMBtu (LHV) and 85 percent to account for the cost of marketing the RINs and regulatory compliance. The RFS value is combined with the commodity price of natural gas, which is currently approximately $2.70/MMBtu (LHV). If the renewable fuels are sold into the California fuels market, LCFS is also available and is worth approximately $12.30/MMBtu (based on CI of 30 gCO_2e/MJ and $180/MT).

Table 9: RINs and Carbon Market Comparative Values: March 29, 2021

RIN and Carbon Market	County Share of Environmental Attributes	Conservative	Moderate	Aggressive
Commodity price of RNG ($/MMBtu)	100%	$2.70	$2.70	$2.70
D3 market value ($/RIN)		$0.55	$1.25	$2.25
D3 market value ($/MMBtu)		$7.15	$16.25	$33.75
Net D3 RIN ($/MMBtu)	85%	$6.10	$13.80	$24.90
Total for D3 + commodity ($/MMBtu)		$8.80	$16.50	$27.60
Net LCFS ($/MMBtu)	70%	$0.00	$4.00	$10.00
Total for D3 + commodity + LCFS ($/MMBtu)		$8.80	$20.50	$37.60

A RIN value of $15/MMBtu has been used in this Biogas Utilization Report for the base financial analyses. This is reflective of a conservative value for RINs only and does not include any potential value from the LCFS. Sensitivity analyses are also included to address potential volatility of the RIN market, and these are described in Section 5.4.

2.4.5 Anticipated RNG Specifications

There are two major ways to use RNG produced at the Arlington WPCP as vehicle fuel, and each method has different RNG quality requirements. The most common method is to inject the RNG into an NG utility pipeline. This allows the environmental attributes of the RNG, the RINs and LCFS credits, to be sold to Obligated Parties across the country, providing the largest market of potential buyers. NG utilities have stringent specifications and monitoring requirements for the RNG injected into their pipelines—with the largest market comes the highest RNG standards. A less common method is to use the RNG in a dedicated fleet fueling station. If an RNG producer is located near, or has access to, a fleet of CNG vehicles, the RNG could be directly used to fuel that fleet without having to be injected into the NG pipeline. This method is less common because of challenges related to matching supply and demand and making sure that all the RNG produced will be used. The benefit of this option is that fleet fueling typically has lower standards for RNG quality as the only limit is what is needed by the vehicles, not other

uses on a pipeline. The Arlington WPCP is located across the street from two transit bus facilities, Arlington Transit (ART) and Washington Metro Area Transit Authority (WMATA), and these fleets currently have the fueling needs necessary to use all the RNG produced. The Arlington County Transit Bureau is currently completing a study for the County bus fleets, including electrification and resiliency alternatives. Supply of RNG to these facilities may be limited or eliminated in the future based on the pace of bus electrification.

2.4.5.1 Pipeline Injection

The American Biogas Council has developed a recommended RNG-quality specification for pipeline injection, which is presented in Table 10 below.

Table 10: Anticipated RNG Pipeline Specification

Parameter Maximum (unless noted otherwise)	Unit	Acceptable Limit	Typical Raw Biogas
Minimum high heating value	Btu/scf	960	580–680
H_2S	ppm	0.0057	300–1,000
Total sulfur	ppm	0.458	300–1,200
CO_2	Percentage by volume	2.0%	32%–42%
O_2	Percentage by volume	0.4%	<1.0%
Total inerts	Percentage by volume	5.0%	33%–45%
Water	lb/MMscf	7.0	~2,000
Siloxanes	ppm	1.0	5–20
Dust, gum, bacteria, and pathogens	Filter microns	Commercially free	N/A
Minimum and maximum limits of acceptable temperature range	°F	50–120	90–110

2.4.5.2 Compressed Natural Gas Bus Fleet Fueling

Preliminary discussions have been conducted with ART to use the RNG produced as fuel for compressed natural gas (CNG) buses within its system. Table 11 below provides a summary of the major parameters for RNG used for bus fueling at the ART facility. The complete anticipated fuel specification for the ART bus facility is included in Appendix A . These limits are less restrictive than the pipeline specification described above. The minimum LHV of 16,100 Btu per pound mass (lbm) is roughly equivalent to an RNG product gas with 89 percent methane, 10 percent carbon dioxide (CO_2), and less than 1 percent oxygen (O_2) and nitrogen (N_2).

Table 11: Anticipated CNG Bus Gas Specification

Parameter Maximum (unless noted otherwise)	Unit	Requirements
Minimum CH_4 number[a]	MN	65/75
Minimum LHV	Btu/lbm	16,100
Hydrogen	ppm	300
H_2S	ppm	6
Sulfur (S)	ppm	10
Siloxanes	ppm	3
CO_2	Percentage by volume	3.0%
N_2	Percentage by volume	4.0%

a. Methane number is the calculated knock resistance of a fuel used by engine manufacturers to ensure that the fuel does not combust automatically on temperature and pressure.

3 Alternatives Development

3.1 Biogas Utilization Alternatives

There are several options for the beneficial use of the biogas produced in anaerobic digestion, each with its own advantages and disadvantages including biogas conditioning requirements, capital cost, O&M requirements, financial benefits, sustainability impacts, and GHG emissions.

The objective of this analysis is to look at all feasible alternatives for the beneficial use of the biogas while reliably meeting the WPCP's heating and electrical needs and then perform monetary, non-monetary, and sustainability evaluations to determine the recommended alternative for the County.

The range of feasible alternatives includes using the biogas for one or a combination of the following:

- On-site use for process and building heating
- Producing electrical power and recovering wasted heat (combined heat and power [CHP])
- Production of RNG for use off site through pipeline injection or as CNG for direct use as vehicle fuel.

From these potential biogas uses the following four major alternatives were developed:

- **Alternative 1:** process and building heating
- **Alternative 2:** CHP
- **Alternative 3:** RNG
- **Alternative 4:** RNG and CHP

For each of the alternatives, Sankey diagrams (depiction of energy balance) were developed to help illustrate the sources and flows of energy purchased and produced. These diagrams show the process and building heating requirements, electrical power requirements and production, equipment efficiencies, NG purchase, and biogas flaring for each alternative. Note the following regarding the Sankey diagrams:

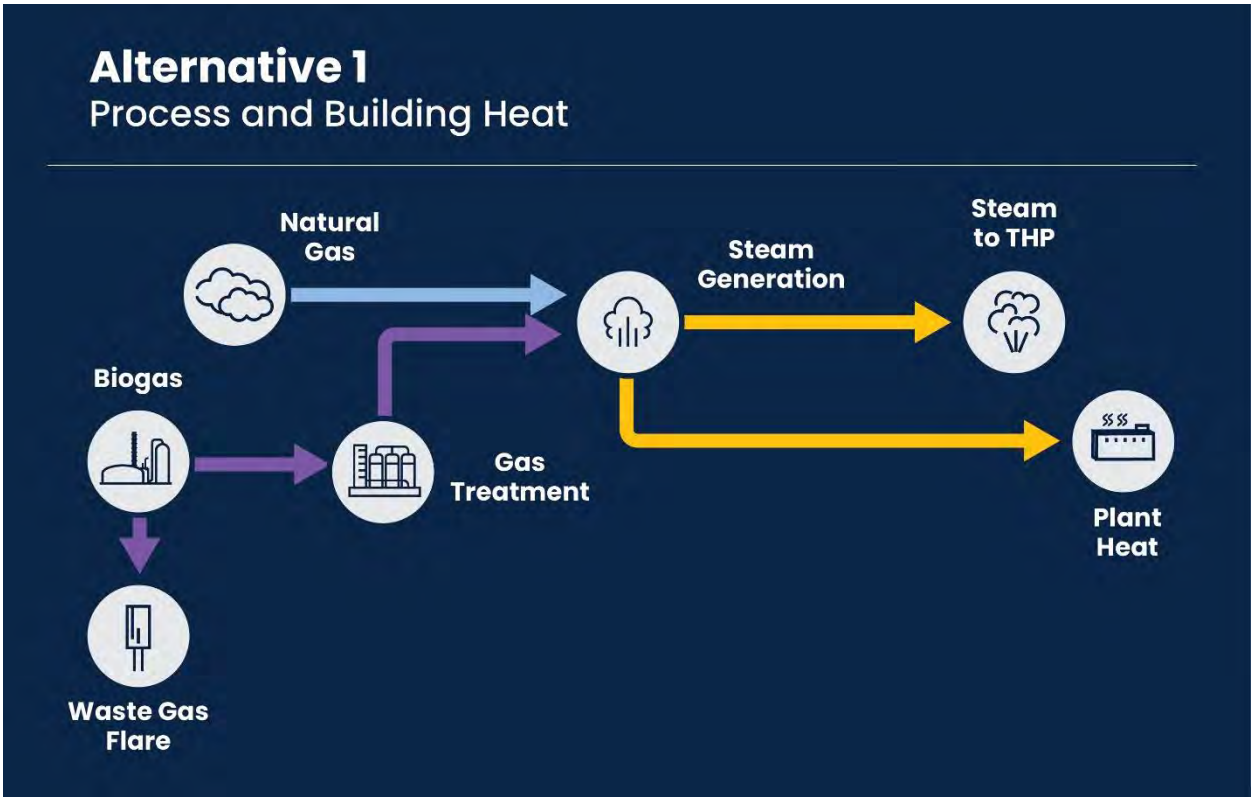
- The diagrams are based on anticipated 2037 operating conditions.
- The diagrams represent the annual average total energy flow, not capacity or peak conditions.
- The units of the diagrams are represented in MBH.

It is assumed that all methane generated at the WPCP is combusted, whether through beneficial use on site, beneficial use off site, or combusted through a flare. A description of each of the alternatives and the corresponding Sankey diagrams are provided in the following sections.

3.1.1 Alternative 1: Process and Building Heating

The simplest and least expensive way to beneficially use the biogas produced in the digesters would be to fuel the boilers that produce steam for the THP system, as shown schematically in Figure 8. The THP steam demand would consume only about 30 percent of the biogas produced, leaving 70 percent as excess, which would be flared in a waste gas flare. Note, all alternatives would require a waste gas flare for flaring during equipment maintenance or downtime. However, Alternative 1 is the only option where biogas would constantly be flared.

Figure 8: Alternative 1: Process and Building Heating

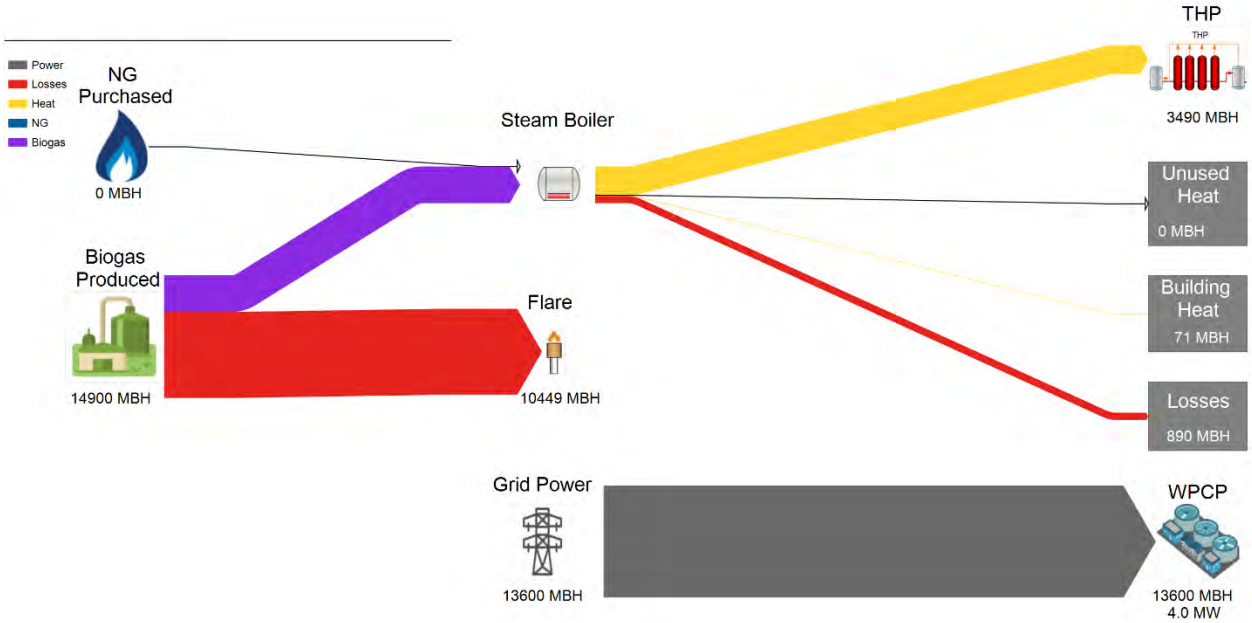


Alternative 1 was developed for comparison against the alternatives that target higher beneficial use of biogas. **Because this alternative does not fully utilize the biogas, it is not a viable biogas utilization option, but it is included in the analysis as the minimum required to meet the process needs.**

For the 2037 condition, the anticipated biogas production is 14,900 MBH and the THP steam requirement is 3,020 lb/hr or 3,490 MBH with 200 pounds per square inch gauge (psig) steam. In addition, the building heating requirement is 71 MBH, which results in a total heating requirement of 3,560 MBH. The assumed boiler heating efficiency for all alternatives is 80 percent, so 4,450 MBH of biogas is needed to produce the steam needed for THP and building heating demands. This leaves 10,450 MBH of biogas

production that must be flared. These values are illustrated graphically in the Sankey diagram for Alternative 1, shown in Figure 9.

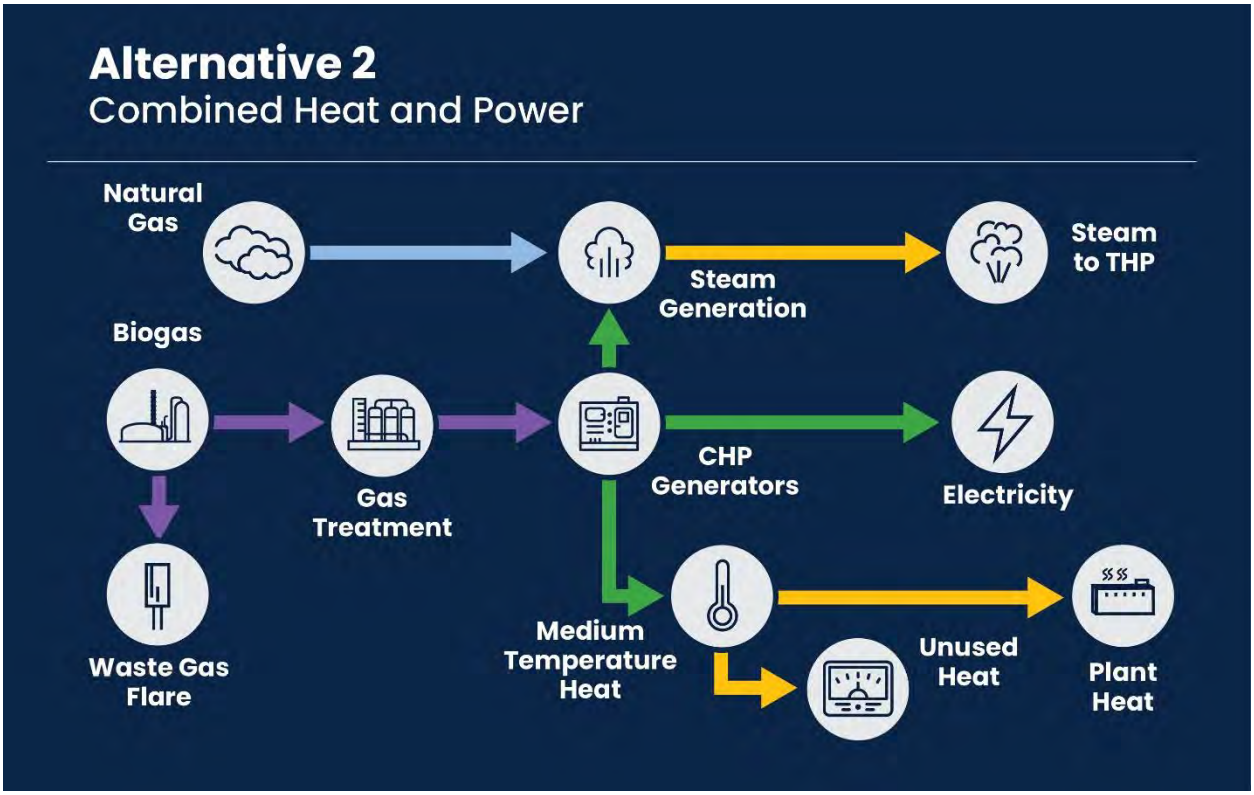
Figure 9: Alternative 1: Process and Building Heating



3.1.2 Alternative 2: Combined Heat and Power

CHP includes any options that use a fuel to produce electrical power and recover the wasted heat from the electrical generating equipment for beneficial use. The goal of the CHP options, shown schematically in Figure 10, is to balance the power produced and heat recovered from the biogas with the heating needs of the WPCP. As discussed previously, the primary heating need for the Facilities is steam production for the THP process.

Figure 10: Alternative 2: Combined Heat and Power



CHP is a popular option for wastewater facilities because it is more efficient than heat production only and more of the biogas can be used while still meeting the heat requirements of the WPCP. There are three major types of CHP combustion equipment for electrical production: internal-combustion (IC) engines, microturbines, and gas turbines. Microturbines were discussed as part of the initial workshops, but a preliminary analysis showed that the electrical and heat recovery efficiencies are similar to internal-combustion engines but at an increased capital and O&M cost. Therefore, microturbines are not presented specifically in the subsequent analysis, but would be considered like the engine options. The sections below describe the engine and gas turbine CHP sub-alternatives in more detail.

3.1.2.1 Alternative 2A: Internal-Combustion Engines

Internal-combustion engines have been standard combustion equipment used in wastewater CHP systems. These engines have a fuel train that blends a stoichiometric ratio of biogas and air prior to entering the cylinders for combustion. Older styles of engines were derived from large marine or locomotive diesels, converted to use spark ignition. These were inefficient, large, and slow, capable of burning raw biogas. However, modern engines need to meet tighter emissions standards, which has resulted in more efficient, smaller engines requiring a higher quality of biogas for fuel with strict standards for hydrogen sulfide (H_2S), moisture, and siloxane content. The

electrical efficiency used for this analysis is 35 percent based on the LHV of methane. New engines may have up to 39 percent electrical efficiency, but an engine's efficiency typically drops as it ages. Figure 11 shows a typical engine installation for a CHP system at a wastewater treatment facility.

Figure 11: Typical Engine Installation

Heat recovered from internal-combustion engines comes from two sources, the exhaust and the engine cooling system. The heat from the exhaust is considered high-value heat (greater than 500 degrees Fahrenheit [°F]) and can be used for steam generation in a composite boiler. The engine cooling system recovers a low-value heat (less than 500°F) that cannot be used for steam generation, but it can produce hot water for other uses at the WPCP, such as building heat. The high- and low-value heat recovery efficiencies for the engines are 18 and 24 percent, respectively, for a total maximum CHP efficiency of 77 percent.

The same 2037 condition was used with a biogas production of 14,900 MBH, 3,490 MBH of steam, and 71 MBH of building heating. If all the biogas was used in the engines 5,215 MBH or 1.53 MW of electricity would be produced, 2,682 MBH of high-value heat would be recovered as steam, and 3,576 MBH of low-value heat would be recovered as hot water. Therefore, the anticipated steam production does not meet the heating values needed by the THP and supplemental heating is required either through

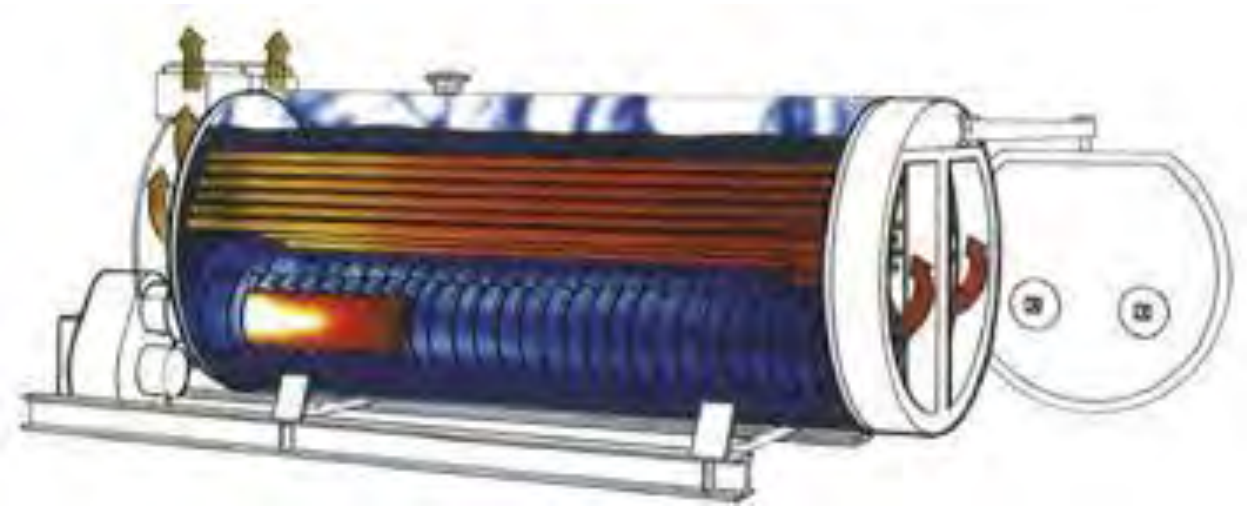
the use of purchased natural gas or diverting some of the biogas from the engine directly to a boiler.

Another factor that should be considered in this analysis is the uptime of engines. For the engine alternative, the uptime was assumed to be 90 percent for each engine and a total 95 percent system uptime based on providing two engines sized to provide 70 percent of the needed capacity. This means that for 10 percent of the time during a typical year, one of the engines is offline and only 70 percent of the biogas can be used in the engine for power production. During these periods the excess biogas would be used in a boiler or flared if necessary. When the downtime is taken into consideration 522 MBH of biogas is flared.

3.1.2.2 Composite Boiler

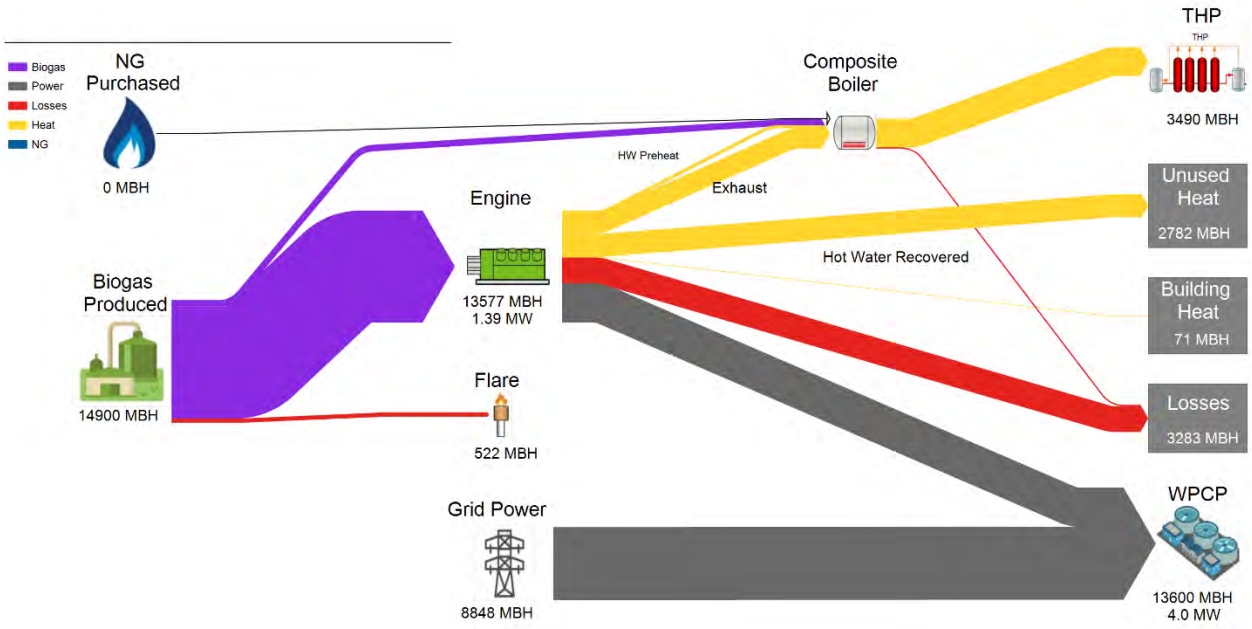
To address the lack of high-value heat recovered, maximize the use of biogas, and minimize flaring, a composite boiler would be used to recover heat from the exhaust and also provide supplemental heating. A composite boiler is a fire tube–style boiler that can recover the heat from the exhaust, but also has a direct-fired burner that can be fueled with biogas or natural gas as shown in Figure 12. To provide the supplemental heating for steam production when both engines are operating, a small percentage of biogas would be sent directly to the burner. Also, when one engine is down for maintenance, additional biogas would be sent to the burner to meet the heat demand and minimize flaring.

Figure 12: Composite Boiler Configuration



The energy balance is presented graphically in Figure 13. This balance takes into consideration the efficiencies of the engine and heat recovery, uptime for the engines, and supplemental heating needed for the steam demand.

Figure 13: Alternative 2A: CHP with Engines



Note: The unused heat is low-value hot water that can be recovered from the engine. If it is not used, the heat produced will be wasted through a radiator.

3.1.2.3 Alternative 2B: Gas Turbines

Gas turbines are the standard combustion equipment in the power generation industry. These turbines combust compressed air-fuel mixtures to produce hot gases that rotate a high-speed turbine to produce power and waste heat. The turbines operate at much higher pressures and speeds than internal-combustion engines and are more similar to a jet engine than a diesel engine. A gas turbine is shown in Figure 14. Gas turbines are often used in high-capacity electrical production applications, but there are suppliers that provide smaller sizes for wastewater treatment plants. Gas turbines are electrically less efficient than engines at only 25 percent electrical efficiency but produce a greater amount of high-value heat at approximately 50 percent efficiency. This heat can be recovered to produce steam for additional electrical production (combined-cycle generator) or process heating.

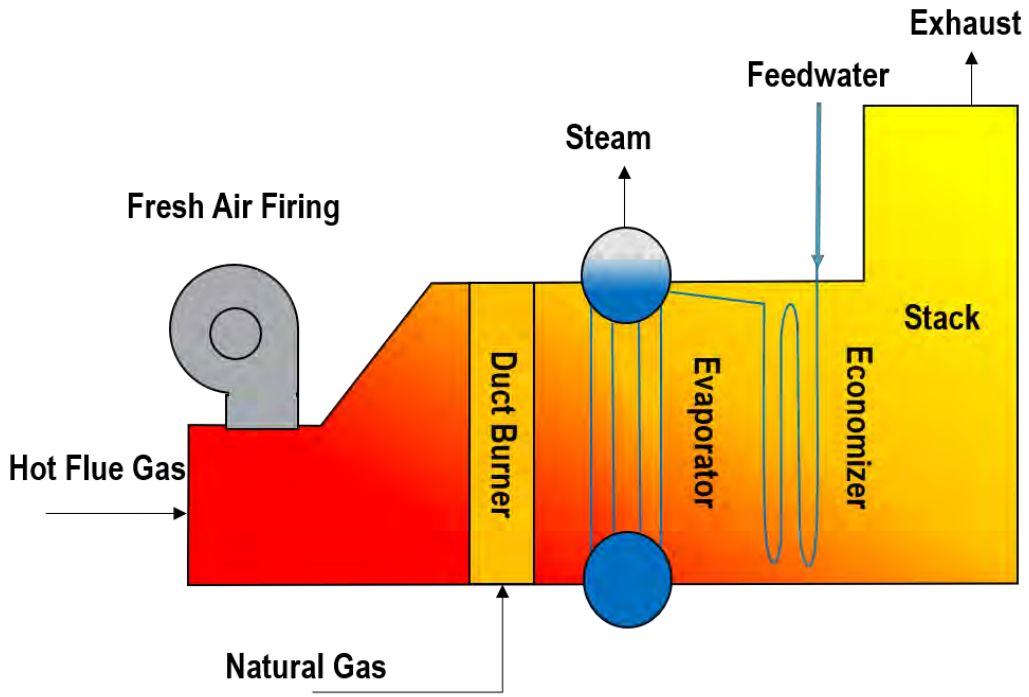
Figure 14: Example Gas Turbine

For the same evaluation condition, if all the biogas was used in the turbine, 3,725 MBH or 1.1 MW of electricity would be produced, and 7,450 MBH of high-value heat would be available, which would meet the steam demand. However, because of their cost, gas turbine systems are usually sized with one turbine sized for the desired capacity. This reduced redundancy is reflected in an assumed uptime of 90 percent. This means that during a typical year 90 percent of the biogas would be directed to the turbine and during the remaining time the biogas would need to go to a boiler or the flare. This reduces the electrical output of the turbine to an annual average production of 0.98 MW.

3.1.2.4 Heat Recovery Steam Generator

Similar to composite boilers, gas turbine systems are often installed with heat recovery steam generators (HRSGs) on the exhaust to recover heat and produce steam. HRSGs are water tube boilers that, like composite boilers, can include a duct burner to supplement heating requirements or bypass the turbine during downtime, as shown in Figure 15.

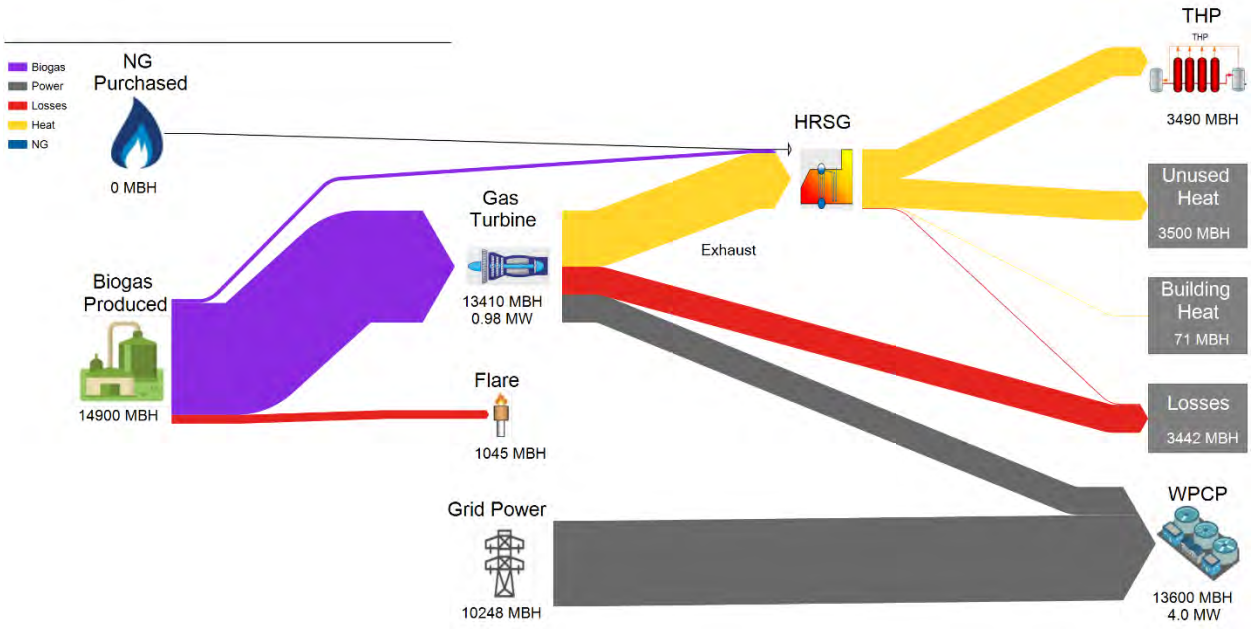
Figure 15: Heat Recovery Steam Generator



To minimize biogas flaring, it was assumed that during gas turbine downtimes, the biogas would be directed to the HRSG to maintain steam production. A summary of the energy balance for the gas turbine option is presented in Figure 16. The gas turbine option produces less electrical power than the engine option, but sufficient high-value heat for steam production without any biogas bypass when the turbine is operating. The biogas bypass shown is only for when the turbine is down for maintenance. However, the significant amount of high-value heat is not entirely used by the THP system, and 2,427 MBH is left unused.

When the downtime is taken into consideration 1,045 MBH of biogas is flared.

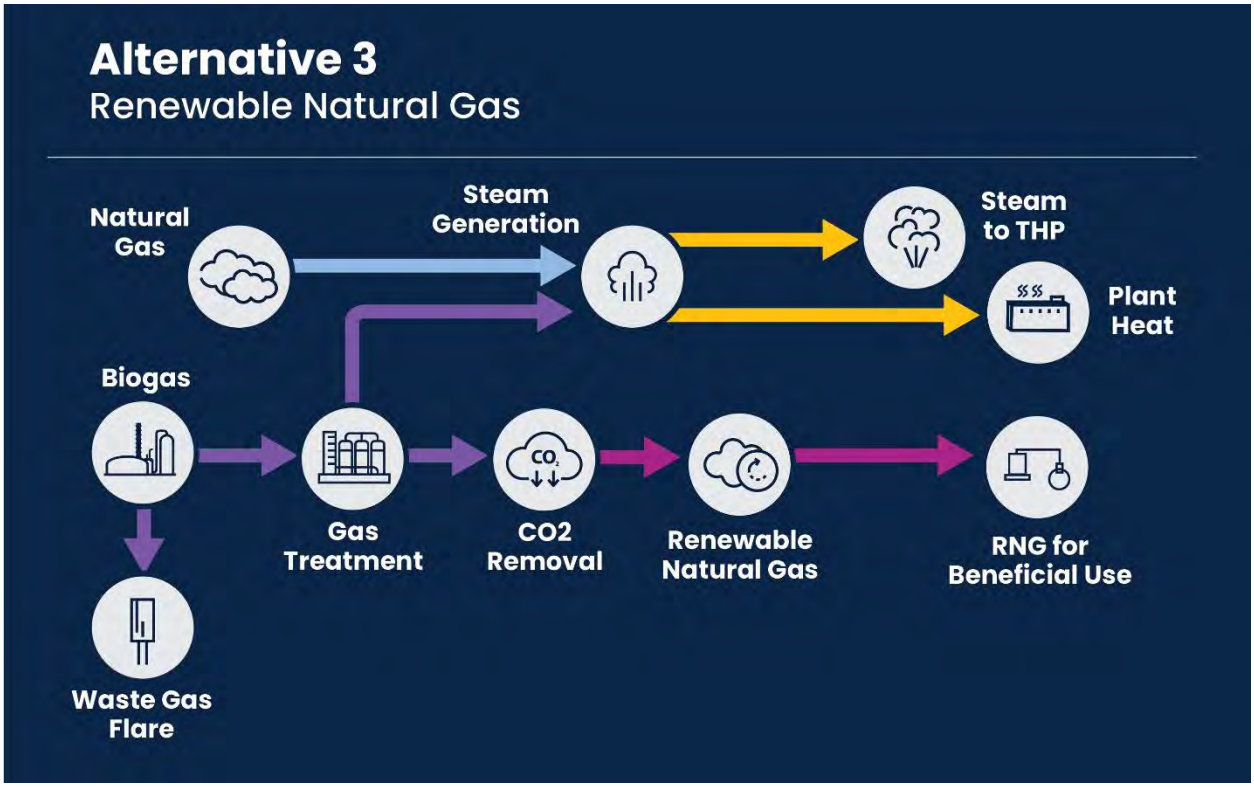
Figure 16: Alternative 2B: CHP with Gas Turbine



3.1.3 Alternative 3: Renewable Natural Gas

For Alternative 3, shown schematically on Figure 17, all the biogas produced would be conditioned to RNG quality for use off site. The production of RNG from biogas requires treatment of the biogas to remove contaminants such as hydrogen sulfide, moisture, siloxanes, volatile organic compounds (VOCs), and carbon dioxide. A discussion on the technologies available to accomplish this treatment is presented in Appendix D . For this alternative, it was assumed that all of the biogas would be conditioned and used off site and natural gas would be purchased and used in boilers to meet the process and building heating needs in order to maximize the amount of RINs.

Figure 17: Alternative 3: Renewable Natural Gas



The energy balance for Alternative 3 does not distinguish between injecting the RNG into the NG utility pipeline or piping the RNG directly to bus fleet fueling. However, these two options will have different costs, risks, and potential future revenues. Therefore, Alternative 3 will have two sub-alternatives. Alternative 3A represents injecting the RNG into the NG utility pipeline and Alternative 3B represents piping the RNG directly for bus fleet fueling.

The removal of contaminants from the raw biogas, regardless of the technology used, results in some loss of methane to the waste biogas stream, or tail gas. The disposal of the tail gas is site-specific and dependent on air quality regulations and sustainability goals as it contains a small amount of methane as well as some hydrogen sulfide and other contaminants. For this evaluation it was assumed that the tail gas was combusted in a regenerative thermal oxidizer (RTO) designed to oxidize low-Btu gas streams, effectively converting methane to carbon dioxide and other contaminants to oxidized states. The overall methane capture is technology-dependent but is generally in the range of 95 to 98 percent. For this evaluation a methane capture rate of 95 percent was used and the 5 percent leaving in the tail gas is oxidized and shown as directed to the RTO.

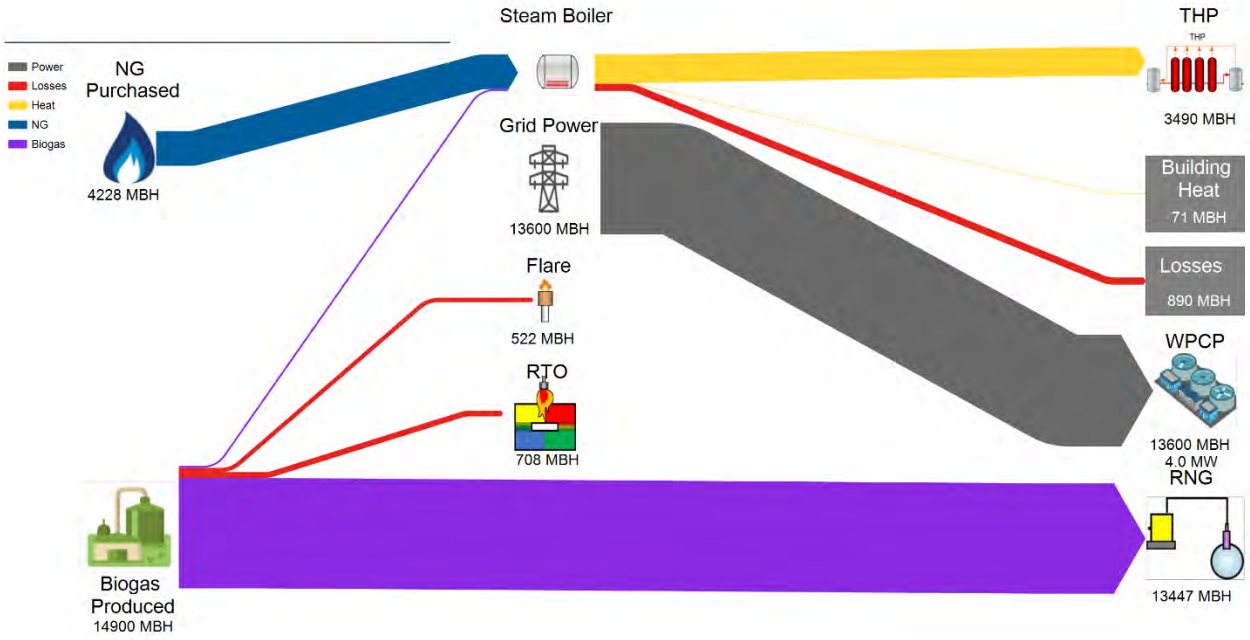
Similar to the CHP alternatives, the RNG conditioning equipment will have downtime for maintenance. During these periods it was assumed that the biogas would be diverted directly to the boilers to minimize flaring. The uptime for the RNG options was assumed to be 95 percent.

For the 2037 evaluation condition, 14,900 MBH of biogas is produced. The biogas conditioning system has a 95 percent uptime and 5 percent downtime. Accounting for the 95 percent methane capture in the conditioning equipment, this results in 708 MBH ending up in the tail gas and combusted in the RTO. During the 5 percent downtime, approximately 30 percent of the biogas or 223 MBH can be diverted and used in the boiler. The remaining 70 percent would go to the flare. On an annual basis, this results in an average 522 MBH flared because of downtime. The total amount not beneficially used is 1,230 MBH.

During RNG production, natural gas is used in the boiler for process and building heating. This heating requires 3,561 MBH of heat production or 4,451 MBH of natural gas. When the 5 percent downtime biogas diversion is subtracted from this amount, an annual amount of 4,228 MBH of natural gas to be purchased results. Figure 18 illustrates the energy balance for the RNG and boiler alternatives.

Note, it is possible to use RNG in the boiler for process and building heating such that no NG purchase is required. However, in this case more biogas would be used on site and less RNG would be sent to others as a replacement for fossil fuel–based natural gas. The production of RNG does not change the quantity or type of uses for natural gas. Because there are economic benefits to sending RNG off site, the analysis presented below assumes that all biogas is being upgraded to RNG. If this alternative is chosen, the system would be piped to use either natural gas or biogas in the boiler.

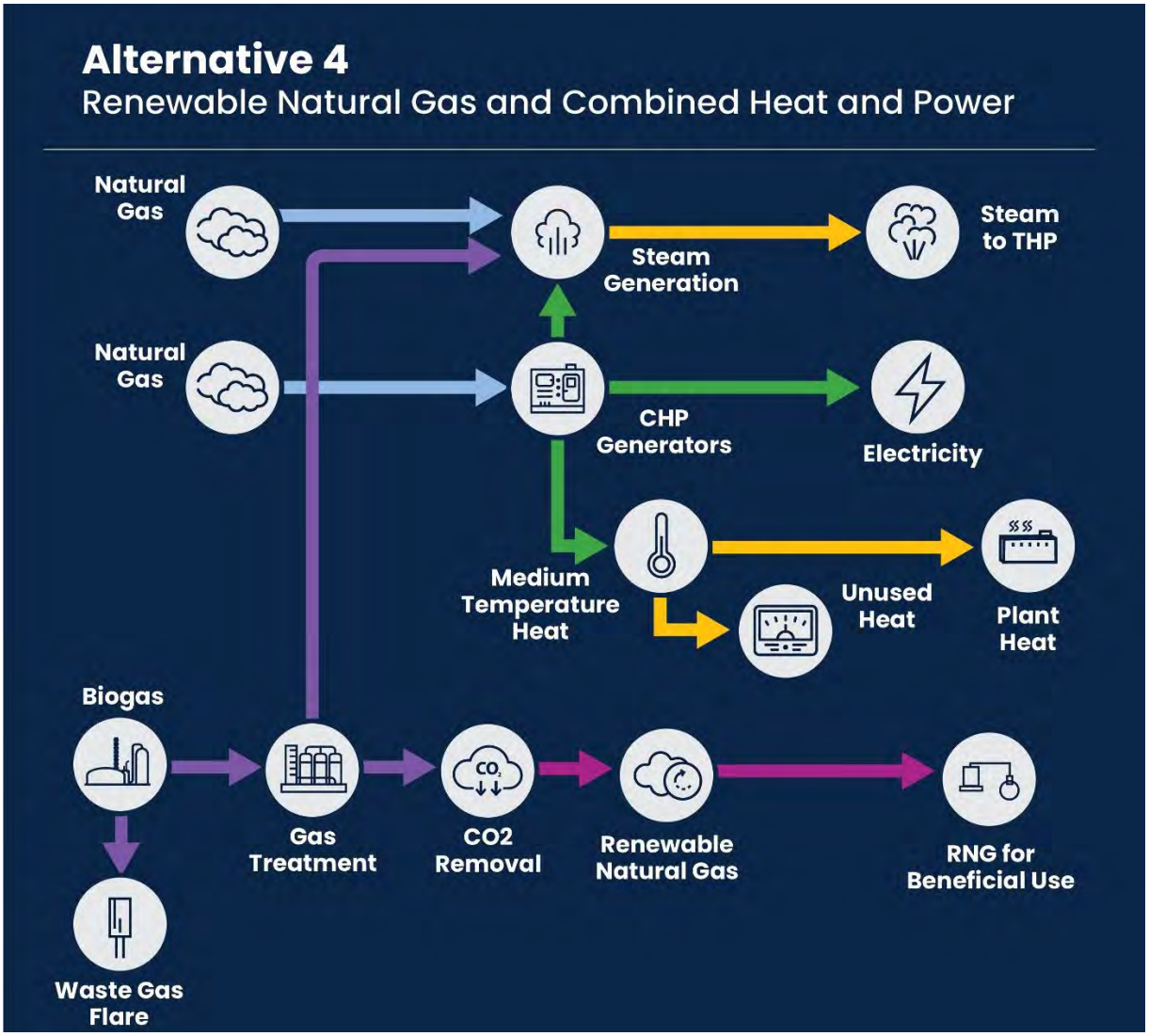
Figure 18: Alternatives 3A and 3B: RNG



3.1.4 Alternative 4: RNG and CHP

Alternative 4, as shown schematically in Figure 19, combines using the biogas as RNG for vehicle fuels with an NG–fueled CHP system to produce power and recover heat. Similar to Alternative 2, the CHP could be provided with internal-combustion engines or gas turbines. The CHP sizing is based on providing the process and building heating necessary. Similar to Alternative 3, during the RNG system downtime, biogas would be diverted to the CHP system to minimize flaring and NG purchases. The downtimes for the CHP are also similar to Alternative 2, so that when the CHP system is down, natural gas is diverted directly to the composite boiler or HRSG depending on the CHP system.

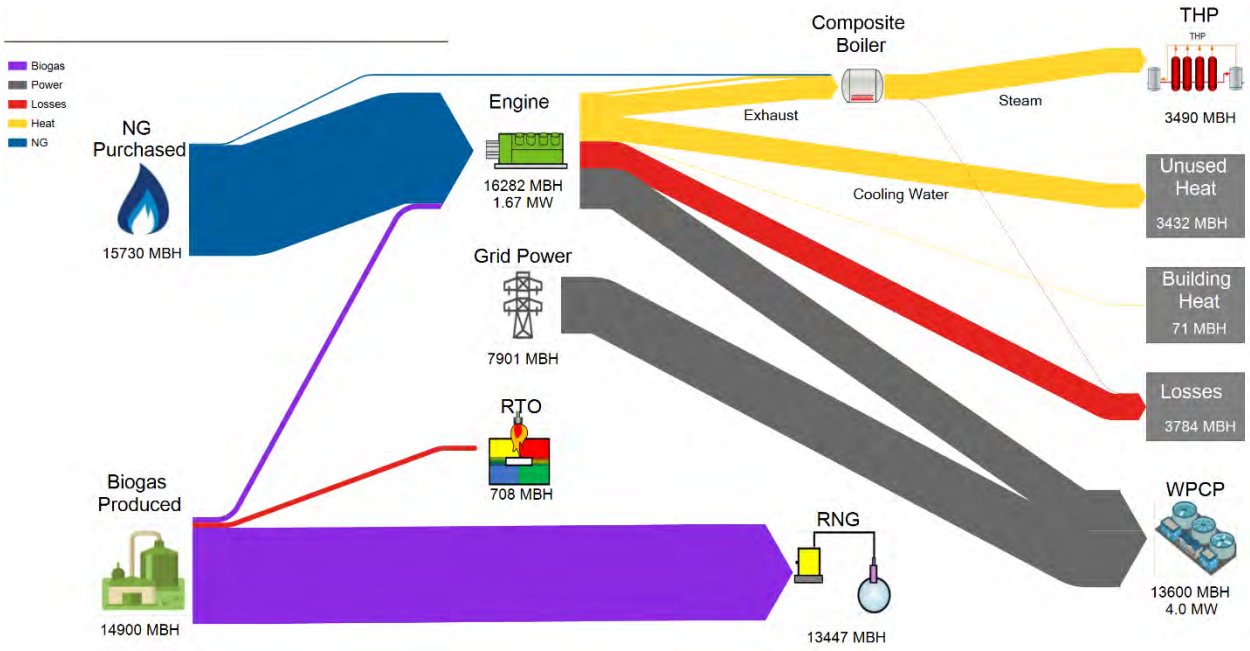
Figure 19: Alternative 4: Renewable Natural Gas and Combined Heat and Power



3.1.4.1 Alternative 4A: RNG with Engines

The energy balance for Alternative 4A is shown in Figure 20 and results in 13,447 MBH of RNG production, similar to Alternative 3. The energy production from the engines is sized to meet the heating requirement and results in 1.67 MW of power production, which is slightly higher than Alternative 2A. The natural gas required to fuel the engines during cogeneration and the composite boiler when an engine is offline is 15,730 MBH.

Figure 20: Alternative 4A: RNG with Engines

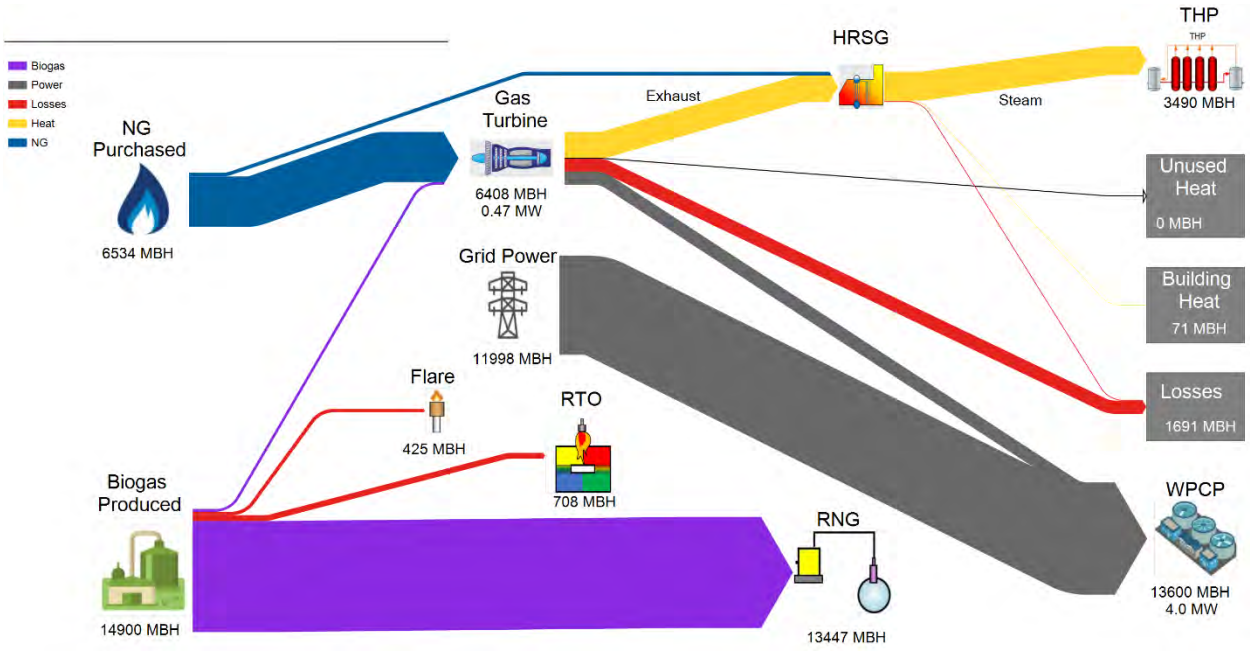


3.1.4.2 Alternative 4B: RNG with Gas Turbine

The energy balance for Alternative 4B is shown in Figure 21 and results in 13,447 MBH of RNG production, similar to Alternative 3. The energy production from the turbines is sized to meet the heating requirement and results in 0.47 MW of power production, which is lower than Alternative 2B because the turbine capacity is reduced to match the heat recovered with the steam production. The natural gas required to fuel the turbine during cogeneration and the HRSG when the turbine is offline is 6,534 MBH.

Biogas is conditioned to RNG quality with an equipment uptime of 95 percent. During periods of downtime biogas is used in the gas turbine. However, the biogas production exceeds the design capacity of the gas turbine and only 43 percent of the biogas diverted during the RNG downtime can be used effectively for CHP. The remaining 57 percent during that 5 percent per year is flared. Therefore, the flared amount due to downtime is 425 MBH and the amount flared in the tail gas is 708 MBH for a total flared amount of 1,133 MBH.

Figure 21: Alternative 4B: RNG with Gas Turbine



3.2 Biogas Utilization Alternative Summary

A summary of the energy balances for each alternative/sub-alternative is presented in Table 12. A more detailed breakdown of the energy balances is provided in Appendix B .

Table 12: Alternatives Energy Summary

Alternative		1	2A	2B	3A/3B	4A	4B
Description		Process and building heating	CHP with engines	CHP with gas turbine	RNG	RNG with engines	RNG with gas turbine
Energy source/use	Unit						
Heat required total	MBH	3,561	3,561	3,561	3,561	3,561	3,561
Steam (hot)	MBH	3,064	3,064	3,064	3,064	3,064	3,064
Hot water							
Building	MBH	71	71	71	71	71	71
Boiler preheat	MBH	427	427	427	427	427	427
Steam total	MBH	3,490	3,490	3,490	3,490	3,490	3,490
Biogas production	MBH	14,900	14,900	14,900	14,900	14,900	14,900
Biogas used							
Boiler total	MBH	4,452	801	445	222	0	0
CHP	MBH	0	13,577	13,410	0	745	320
RNG	MBH	0	0	0	13,447	13,447	13,447
Waste gas flare	MBH	10,449	522	1,045	522	0	426
Tail gas combusted	MBH	0	0	0	708	708	708
Heat production	MBH	3,561	6,343	7,061	3,561	6,993	3,561
Boiler total	MBH	3,561	641	356	3,561	154	357
CHP							
Steam	MBH	0	2,444	6,705	0	2,931	3,204
Hot water	MBH	0	3,258	0	0	3,908	0
Capacity CHP	MBH	0	13,577	13,410	0	16,282	6,408
NG purchased, total	MBH	0	0	0	4,230	15,730	6,534
Boiler	MBH	0	0	0	4,230	193	446
CHP	MBH	0	0	0	0	15,537	6,088
Heating losses, total	MBH	712	3,283	3,442	712	3,783	1,691
Boiler	MBH	712	160	89	712	39	89
CHP	MBH	0	3,123	3,353	0	3,745	1,602
Unused heat	MBH	0	2,782	3,500	0	3,431	0
WPCP Electricity required	MBH	13,600	13,600	13,600	13,600	13,600	13,600
Electricity produced	MBH	0	4,752	3,353	0	5,699	1,602
Equivalent cap. CHP	MW	0.00	1.39	0.98	0.00	1.67	0.47
Electricity purchased	MBH	13,600	8,848	10,248	13,600	7,901	11,998

3.3 Biogas Conditioning

The level of biogas conditioning required is directly related to the end use of the biogas. Using the biogas on site as an NG replacement for building and process heating would likely require treatment for H_2S prior to use in boilers for heating and other uses. The CHP alternatives will require moisture and siloxane removal in addition to H_2S removal, and any of the RNG alternatives will require treatment to NG quality, which includes the treatments above plus CO_2 removal, volatile organic compound (VOC) removal, compression, and tail gas disposal. Finally, all the biogas utilization alternatives will require a waste gas flare to combust the biogas as a backup should all beneficial uses be offline or over capacity. Table 13 presents a summary of the biogas conditioning equipment needed for each of the end uses being considered.

These conditioning technologies were used to develop the capital costs and O&M costs that inform the life-cycle cost analysis presented in this Biogas Utilization Report. Appendix D presents an overview of biogas treatment and conditioning systems available to meet the intended end-use requirements.

Table 13: Biogas Conditioning Equipment Requirements

Alternative/	Removal Equipment						Pressure Boosting	Tail Gas Disposal	Waste Gas Flare
	H_2S[a]	Moisture (Drying)	Siloxanes	VOCs	CO_2	$O_2 + N_2$			
Alternative 1	✓	✓							✓
Alternative 2A	✓	✓	✓				✓		✓
Alternative 2B	✓	✓	✓				✓		✓
Alternative 3A	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alternative 3B	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alternative 4A	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alternative 4B	✓	✓	✓	✓	✓	✓	✓	✓	✓

a. H_2S concentrations at the WPCP are anticipated to be low because of the amount of ferric chloride currently being added for phosphorus removal but could be needed in the future if this practice changes.

4 Financial Analysis

The present financial value analysis presented in this section includes the anticipated capital costs, O&M costs, avoided costs from electricity generation, and RNG revenues for each alternative. These are summarized for each alternative along with the major assumptions in the sections below.

4.1 Conceptual Capital Costs

Conceptual capital cost estimates for the different biogas utilization alternatives are based on a combination of equipment quotes, estimates based on similar projects, building type, and building square footage. The costs are in 2021 dollars. The conceptual capital costs accounted for are not meant to be detailed cost estimates but are meant to capture the relative differences in costs between the alternatives.

4.1.1 Equipment Costs

The development of the capital cost estimates starts with the major equipment costs for each alternative. These costs are summarized below. All the costs reflect providing a redundant steam supply for the THP. This includes a redundant boiler for CHP alternatives as well as redundant deaerators, which preheat and condition the boiler feed water to remove oxygen and prevent corrosion in the boiler and steam piping systems.

4.1.1.1 Alternative 1: Process and Building Heating

The equipment costs for Alternative 1, summarized in Table 14, include two 350-horsepower (hp) steam boilers, two deaerator and feed pump packages, and H_2S and drying biogas treatment.

Table 14: Alternative 1 Equipment Costs

Item	Cost	Quantity	Subtotal
Boiler	$205,000	2	$410,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$2,000,000	1	$2,000,000
Total			**$2,590,000**

4.1.1.2 Alternative 2A: CHP with Engines

The equipment costs for Alternative 2A, summarized in Table 15, include two 847-kilowatt (kW) CHP generators; one 350 hp composite boiler; one 350 hp boiler; two deaerator and feed pump packages; and H_2S, siloxane, and drying biogas treatment.

Table 15: Alternative 2A Equipment Costs

Item	Cost	Quantity	Subtotal
CHP engines	$425,000	2	$851,000
Composite boiler	$690,000	1	$690,000
Boiler	$205,000	1	$205,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$3,000,000	1	$3,000,000
Total			**$4,926,000**

4.1.1.3 Alternative 2B: CHP with Gas Turbine

Alternative 2B equipment, summarized in Table 16, includes one 1,204 kW turbine CHP generator with HRSG; one 350 hp boiler; two deaerators and feed pump package; and H_2S, siloxane, and drying biogas treatment.

Table 16: Alternative 2B Equipment Costs

Item	Cost	Quantity	Subtotal
Turbine with HRSG	$3,810,000	1	$3,810,000
Boiler	$205,000	1	$205,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$3,000,000	1	$3,000,000
Total			**$7,195,000**

4.1.1.4 Alternative 3A: RNG into the NG Pipeline

Alternative 3A equipment, summarized in Table 17, includes two 350 hp steam boilers; two deaerator and feed pump packages; H_2S, siloxane, moisture, and CO_2 removal biogas treatment; and a connection to the NG utility. For this analysis it is assumed that the CO_2 removal is performed with a membrane treatment system, which is likely the most conservative and highest-cost system.

Table 17: Alternative 3A Equipment Costs

Item	Cost	Quantity	Subtotal
NG utility interconnect	$5,000,000	1	$5,000,000
Boiler	$205,000	2	$410,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$5,000,000	1	$5,000,000
Total			**$10,590,000**

4.1.1.5 Alternative 3B: RNG with CNG

Alternative 3B equipment, summarized in Table 18, includes two 350 hp steam boilers; two deaerator and feed pump packages; H_2S, siloxane, moisture, and CO_2 removal biogas treatment; and a connection to ART and/or WMATA. The equipment costs for Alternative 3B are roughly $4 million less expensive than those for Alternative 3A

because of the savings on the interconnect to the NG utility. It is not known at this time what improvements, if any, would be required at the bus depots to effectively use all the RNG, and all such improvements are excluded from this evaluation. Such improvements could include additional fueling stations, compression, and storage.

Table 18: Alternative 3B Equipment Costs

Item	Cost	Quantity	Subtotal
ART/WMATA interconnect	$1,000,000	1	$1,000,000
Boiler	$205,000	2	$410,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$5,000,000	1	$5,000,000
Total			**$6,590,000**

4.1.1.6 Alternative 4A: RNG and CHP with Engines

Alternative 4A equipment, summarized in Table 19, includes two 1,141 kW CHP gensets; one 350 hp composite boiler; one 350 hp steam boiler; two deaerators and feed pump package; H_2S, siloxane, moisture, and CO_2 removal biogas treatment; and a connection to the NG utility.

Table 19: Alternative 4A Equipment Costs

Item	Cost	Quantity	Subtotal
NG utility interconnect	$5,000,000	1	$5,000,000
CHP engines	$502,000	2	$1,004,000
Composite boiler	$690,000	1	$690,000
Boiler	$205,000	1	$205,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$5,000,000	1	$5,000,000
Total			**$12,079,000**

4.1.1.7 Alternative 4B: RNG and CHP with Gas Turbine

Alternative 4B equipment, summarized in Table 20, includes one 1,204 kW turbine CHP genset with HRSG; one 350 hp steam boiler; two deaerators and feed pump package; H_2S, siloxane, moisture, and CO_2 removal biogas treatment; and a connection to the NG utility.

Table 20: Alternative 4B Equipment Costs

Item	Cost	Quantity	Subtotal
NG utility interconnect	$5,000,000	1	$5,000,000
Turbine with HRSG	$3,810,000	1	$3,810,000
Boiler	$205,000	1	$205,000
Deaerator	$90,000	2	$180,000
Biogas conditioning	$5,000,000	1	$5,000,000
Total			**$14,195,000**

4.1.2 Building Costs

Building layouts and footprints were developed for each alternative/sub-alternative. Alternative 1 has the lowest building cost, which consists of a 4,000-square-foot (SF) building to house the boilers, a 288 SF slab on grade for biogas drying and compression, and two 12-foot-diameter slabs on grade for H_2S vessels. Alternative 3 has the same footprint but with the addition of a 500 SF slab on grade for CO_2 removal. The CHP Alternatives 2 and 4 require a larger, 6,000 SF building to house the CHP equipment and standby boilers. Alternatives 2A and 2B have the same biogas treatment footprint as Alternative 1 while Alternatives 4A and 4B have the same biogas treatment footprint as Alternative 3.

For pricing buildings during this planning phase, a simplified price per square foot method was used. For the buildings a price of $1,150/SF was used and is meant to include all building systems. The slabs on grade are assumed to be $50/SF. The building costs for the various alternatives are summarized in Table 21.

Table 21: Summary of Building Costs

Item	Alternative 1	Alternatives 2A and 2B	Alternatives 3A and 3B	Alternatives 4A and 4B
Building structure (SF)	4,000	6,000	4,000	6,000
H_2S and siloxane treatment slab (SF)	226	226	226	226
Biogas drying and compression slab (SF)	288	288	288	288
CO_2 treatment slab (SF)	0	0	504	504
Total cost	**$4.6 million**	**$6.9 million**	**$4.7 million**	**$7.0 million**

4.1.3 Total Conceptual Construction Costs

The multipliers listed in Table 22 were used for total conceptual construction cost.

Table 22: Construction Multiplier Summary

Item	Multiplier
Contractor overhead and profit	15.0%
Contingency	20.0%
Mobilization, staging, bonds, and insurance	8.0%

For each alternative the multipliers are applied to the sum of the building and equipment costs.

Table 23 below shows the conceptual construction costs for each alternative with the multipliers applied. The capital costs in the table are for the equipment for each alternative (CHP, boilers, and biogas treatment equipment) and a building space to house the equipment.

Table 23: Total Conceptual Construction Costs

Alternative	Cost
1: Process and building heating	$10.8 million
2A: CHP with engines	$17.7 million
2B: CHP with gas turbine	$21.1 million
3A: RNG injected into the NG pipeline	$22.7 million
3B: RNG used as CNG	$18.7 million
4A: RNG and CHP with engines	$28.4 million
4B: RNG and CHP with gas turbine	$31.5 million

Alternative 1—using the biogas to generate steam for process and building heating—can be considered the lowest-cost investment to beneficially use a portion of the biogas. However, this alternative uses only 30 percent of the biogas produced by the digesters, while the rest is flared, which does not meet the goals of the Program.

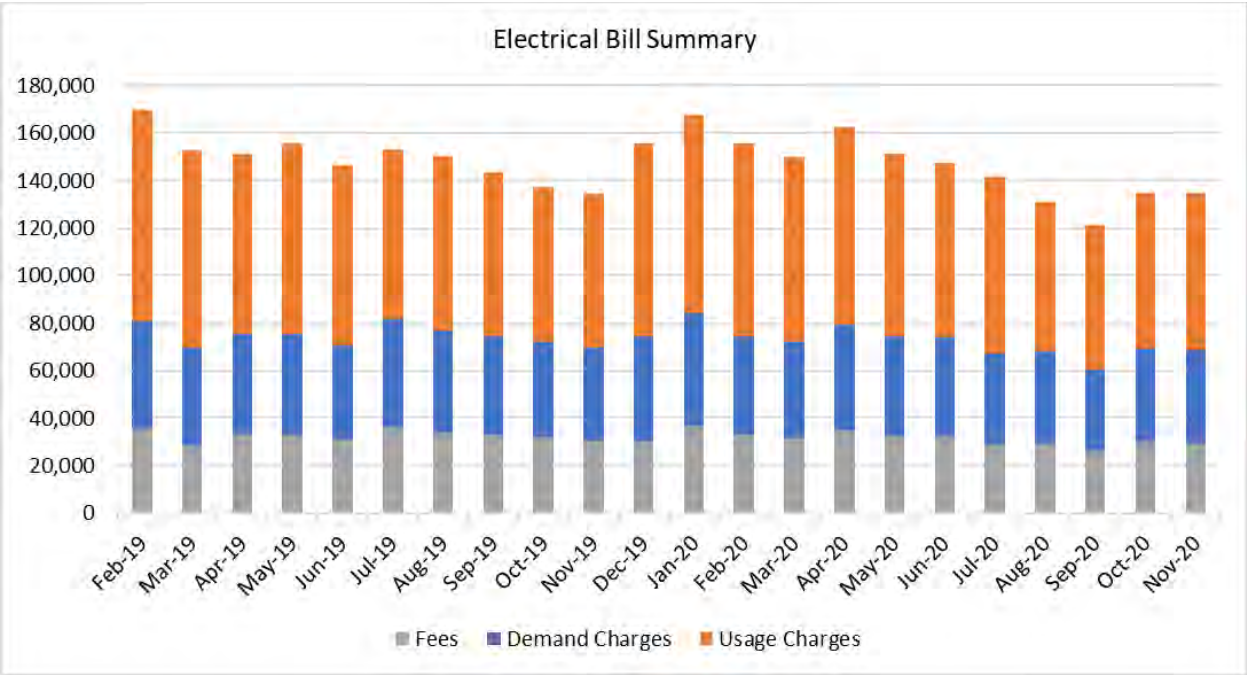
4.2 Electrical Costs

The production of electrical power through CHP will result in a reduction of electricity purchased from the power utility. To adequately account for these reductions, an understanding of the current electrical rate structure is needed.

4.2.1 Electrical Billing Rate Structure

Figure 22 below illustrates the breakdown of the WPCP electrical charges from February 2019 to November 2020. The usage charges, shown in orange, are the portion of the bill that is proportional to consumption. The demand charge, shown in blue, is based on a peak demand during the billing cycle and minimally fluctuates. The fees, shown in gray, are fixed with little variation. The total historical monthly amount paid for electricity divided by the usage comes to $0.06/kWh. Because of the billing rate structure of the existing Dominion Energy (Dominion) service, only about $0.03/kWh is linked to usage.

Figure 22: Electrical Billing Summary



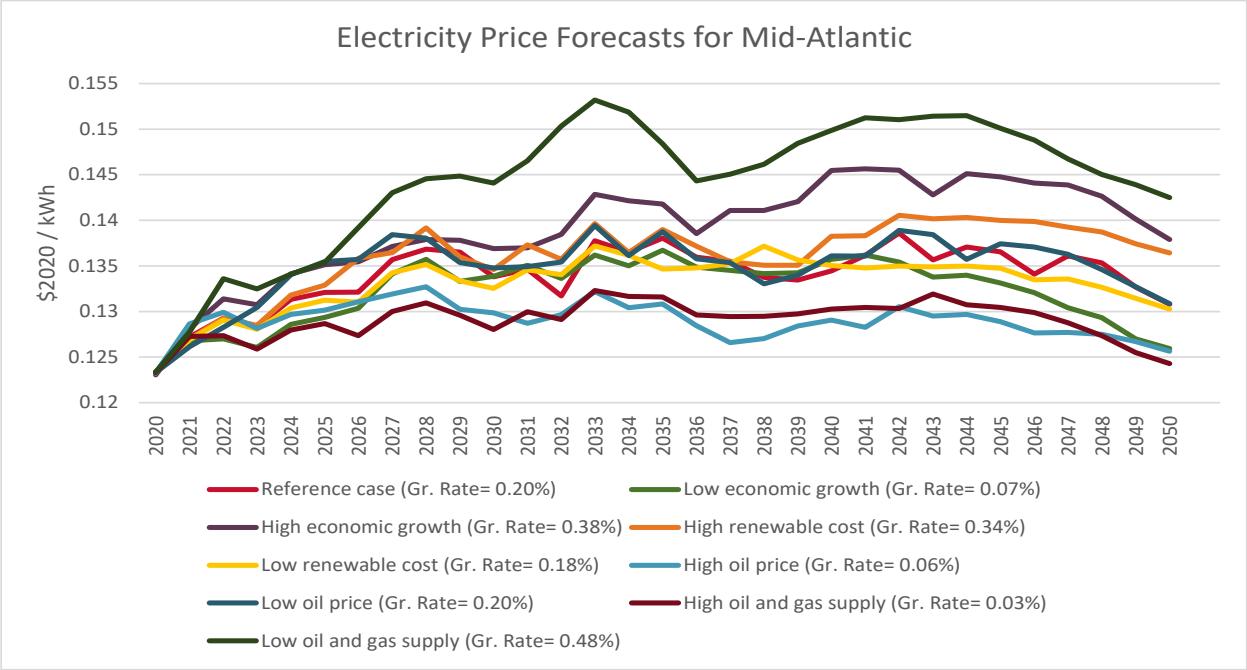
With the current billing rate structure, the CHP alternatives would be offsetting electricity at a rate of $0.03/kWh. To maximize the financial benefit of CHP electrical production the Facilities would want to enter a billing rate structure that is 100 percent based on consumption. Note: in early 2022 the County was notified that there would be an approximately 30 percent increase in total electrical costs from Dominion for Arlington County, which would raise Arlington County's average electrical cost at the WPCP to $0.078/kWh. For purposes of this Report, it is assumed that the rate structure with Dominion could be changed to consumption-only at a rate of $0.078/kWh.

4.2.2 Electricity Price Forecast

Various factors cause electricity prices to vary over time including macroeconomic conditions, fuel stock costs and supplies, technological innovations, and policies. The U.S. Energy Information Administration (EIA) is the key federal source for modeling electricity pricing forecasts. EIA develops alternative forecasts from different scenarios of future conditions, such as high and low economic growth, oil and gas supplies, renewable energy costs, and other factors. Figure 23 presents several of EIA's real price forecasts (in terms of year 2020 dollars per kWh, without adjusting for potential inflation) for the Mid-Atlantic region through 2050. In all scenarios, prices are expected to rise at least through the next 10 years. From that point, prices could rise (e.g., low oil and gas supply), remain flat (e.g., high renewable energy costs), or potentially decline (other scenarios). Through 2050, annualized growth rates could range from 0.03 percent to 0.48 percent, reflecting EIA's high and low oil and gas supply scenarios,

respectively. The prices shown on Figure 23 are average retail pricing. Arlington County benefits from negotiated pricing through the Virginia Energy Purchasing Governmental Association and should expect to pay substantially less than the retail forecasts. As noted above, Arlington County's current electrical rate is assumed to be $0.078/kWh. The projected price escalation forecasts from EIA were used in model simulations starting from the County's current electrical rate.

Figure 23: Forecasts of Real Electricity Prices, EIA



Source: U.S. Energy Information Administration.

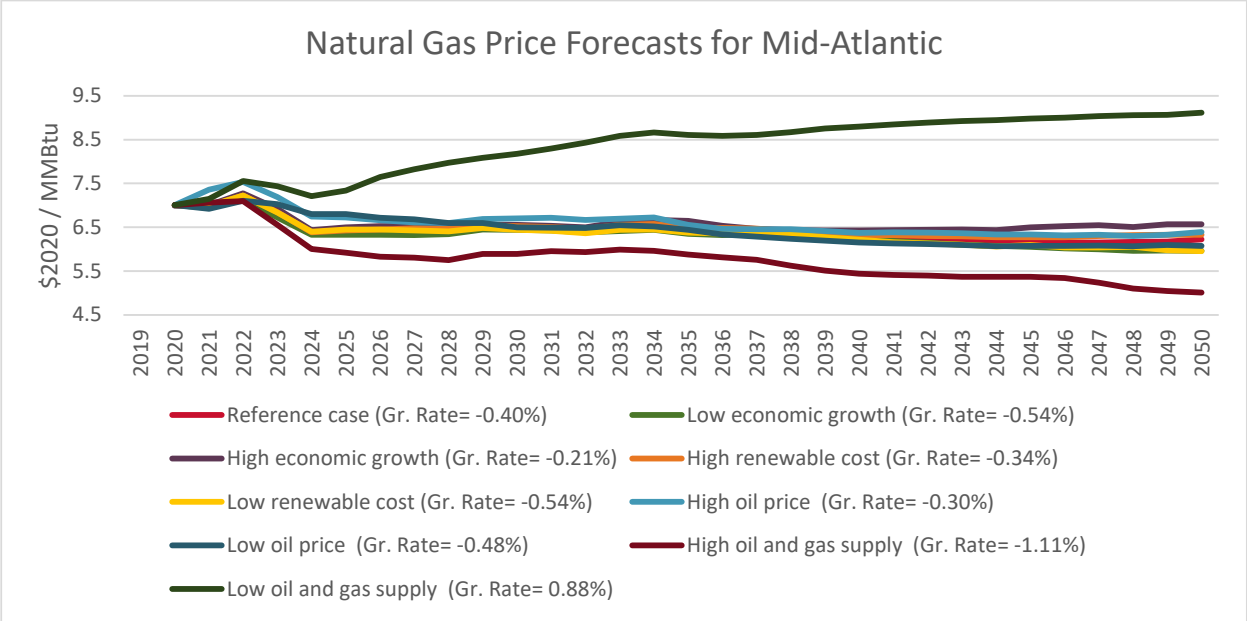
4.3 RNG Revenue

As discussed in Section 2.4.4, the revenues from the sale of RNG will likely be a combination of environmental attributes as well as the commodity value of natural gas. The composite value of the environmental attributes is in the range of $5/MMBtu to $25/MMBtu, with 15 percent deducted for marketing the RNG, plus a commodity value of $2.50/MMBtu.

Similar to electricity prices described above, EIA also produces scenario-based forecasts for gas prices. Figure 24 presents EIA's real gas price forecasts (in year 2020 dollars per MMBtu) for the Mid-Atlantic region through 2050. The price shown reflects commodity and transportation costs (as compared to commodity value only in Table 9). In most scenarios, prices are expected to rise in 2022, then drop significantly through 2024. Real prices would then generally remain flat for at least a decade before potentially declining. However, two extreme cases of low and high oil and gas supply

would tell a different story. Low supplies could directly drive up prices while high supplies would have the opposite effect. Considering these extreme cases in oil and gas supply, real annual price changes through 2050 could range from a 1.11 percent decline to a 0.88 percent increase. Other scenarios are also possible within these boundaries.

Figure 24: Forecasts of Real Gas Prices (EIA)



Source: U.S. Energy Information Administration.

Table 24 shows the RNG revenue for select years through the life of the Program based on the anticipated range of RNG values. This revenue uses an RNG inflation rate of 0.0 percent and an NG inflation rate of -0.3 percent.

Table 24: Anticipated Range of RNG Revenues at Various Environmental Attribute (RIN) Values

Parameter	2028	2037	2052
RNG produced, MBH	12,400	13,400	15,200
RNG produced, MMBtu/yr	108,000	118,000	133,000
$5/MMBtu	$730,000	$800,000	$900,000
$10/MMBtu	$1,190,000	$1,300,000	$1,470,000
$15/MMBtu	$1,650,000	$1,800,000	$2,040,000
$20/MMBtu	$2,110,000	$2,300,000	$2,600,000
$25/MMBtu	$2,570,000	$2,800,000	$3,170,000

4.4 Renewable Energy Credits

For the alternatives that include CHP (Alternatives 2 and 4), it is likely that the County could either sell Renewable Energy Credits (RECs) for the electricity produced or defer purchase of RECs for other County needs. The County currently purchases RECs at a cost of $4,500/kWh and it is assumed that all CHP alternatives would be able to sell RECs for all of the electricity produced at that value.

4.5 O&M Costs

Each alternative has a cost to operate and maintain. Generally, the simpler a system is, the less it costs to maintain. Factoring in the O&M cost and comparing for each alternative is important for a thorough comparison. The annual O&M costs presented in this section are all expressed in 2020 dollars. These O&M costs are based on historical trends in the industry normalized to capacity. The electrical demand and other O&M costs all scale proportionally with the biosolids production. The Monte Carlo analysis in Section 5.4.1 illustrates how different inflation and discount rates affect the O&M costs. In this case, the discount rate refers to the interest rate used in a discounted cash flow analysis to determine the present value of future cash flows. Each yearly cash flow is discounted by this rate compounded annually by the number of years from present.

4.5.1 Alternative 1: Process and Building Heating

Alternative 1, which would use biogas to fuel boilers to produce steam for THP, has the lowest O&M cost. The key assumptions used for the O&M costs of Alternative 1 are as follows:

- Maintenance costs averaged year to year of $15,000/year in 2020 dollars. This cost includes periodic fire tube replacement.
- Operating costs are based on boiler electrical usage (burners and feed water pumps).
- Biogas conditioning cost for boilers of $0.63/MMBtu for operations, and maintenance and $0.15/MMBtu for electricity.

The O&M breakdown for Alternative 1 for select years is shown in Table 25.

Table 25: Alternative 1: Boiler and Process Heat Annual O&M

Item	2028	2037	2052
Natural gas	N/A	N/A	N/A
Electrical	$20,000	$23,000	$26,000
Boiler maintenance	$15,000	$15,000	$15,000
Biogas conditioning	$23,000	$25,000	$28,000
Total	**$58,000**	**$63,000**	**$69,000**

4.5.2 Alternatives 2A/B: CHP

Engine and turbine CHP systems are complex with high-speed, moving components that wear out and require periodic replacement and overhauls. For engines this maintenance would occur on site and would include removal of the heads, replacement of the cylinder liners, and new piston rings. Turbine overhaul would occur off site in a shop certified by the manufacturer and without a redundant turbine the facility would flare 70 percent of the biogas produced during this exercise. The following assumptions were used for CHP O&M costs:

- Maintenance costs for engines of $0.025/kWh in 2020 dollars.
- Avoided electrical costs are credited at $0.06/kWh assuming a consumption-based rate structure.
- Biogas conditioning cost for boilers of $0.63/MMBtu for operations, and maintenance and $0.15/MMBtu for electricity.
- Natural gas is $0.85/therm in 2020 dollars. For Alternative 2A, it is assumed that a fraction of the biogas bypasses CHP to fire the boiler directly instead of purchasing natural gas to supplement the CHP heat.

Table 26 and Table 27 present Alternative 2A engine O&M costs and Alternative 2B gas turbine O&M costs, respectively.

Table 26: Alternative 2A: CHP with Engine Annual O&M

Item	2028	2037	2052
Natural gas	N/A	N/A	N/A
Electrical offset	($844,000)	($937,000)	($1,098,000)
Electrical RECs	($48,000)	($52,000)	($59,000)
Electrical usage	$36,000	$40,000	$47,000
Engine maintenance	$266,000	$289,000	$328,000
Boiler maintenance	$15,000	$15,000	$15,000
Biogas conditioning	$72,000	$78,000	$89,000
Total	**($503,000)**	**($567,000)**	**($678,000)**

Table 27: Alternative 2B: CHP with Gas Turbine Annual O&M

Item	2028	2037	2052
Natural gas	N/A	N/A	N/A
Electrical offset	($627,000)	($696,000)	($815,000)
Electrical RECs	($32,000)	($36,000)	(40,000)
Electrical usage	$36,000	$40,000	$47,000
Turbine maintenance	$178,000	$193,000	$219,000
Boiler maintenance	$15,000	$15,000	$15,000
Biogas conditioning	$68,000	$74,000	$84,000
Total	**($362,000)**	**($408,000)**	**($490,000)**

4.5.3 Alternatives 3A/B: RNG

Removal of carbon dioxide from the raw biogas is required to create RNG. The removal of carbon dioxide increases the concentration of methane, thus increasing the specific energy of the biogas from 580 Btu per cubic foot (CF) to a near-NG level of 1,000 Btu/CF. The financial analysis assumes that this step is performed by a membrane treatment system. A more detailed analysis of different treatment options is provided in Appendix D .

The main O&M costs for an RNG membrane biogas upgrading system are electricity, natural gas, and the NG upgrading. The breakdown of the biogas upgrading O&M cost is shown below in Table 28.

Table 28: RNG Equipment Annual O&M

Item	O&M Cost
H_2S, siloxane, and drying treatment excluding electricity	$0.63/MMBtu
Electricity for H_2S, siloxane, and drying treatment	$0.15/MMBtu
Electricity for boosting	$1.07/MMBtu
Other	$0.73/MMBtu

The total H_2S, siloxane, and drying O&M cost is the same $0.78/MMBtu used for the boiler and CHP treatment alternatives. The comparatively high $1.07/MMBtu additional cost for electricity reflects the energy-intensive biogas compression required for CO_2 removal and pipeline injection. The $0.73/MMBtu other cost represents the cost for labor, general maintenance, and media replacement. Note that these costs are represented per MMBtu of biogas processed.

The following additional assumptions were used for RNG O&M costs:

- Natural gas purchased is $0.85/therm ($8.50/MMBtu) in 2020 dollars
- RNG commodity (sale) price of $2.50/MMBtu
- RNG environmental attributes of $15.00/MMBtu
- County share of environmental attribute of 85 percent to account for broker assistance

Table 29 shows the breakdown of the revenue for Alternatives 3A and 3B.

Table 29: Alternatives 3A and 3B: RNG Annual O&M

Item	2028	2037	2052
Natural gas	$282,000	$298,000	$320,000
Electrical used	$207,000	$230,000	$269,000
Boiler maintenance	$15,000	$15,000	$15,000
Biogas conditioning	$140,000	$152,000	$172,000
RNG revenue	($1,642,000)	($1,778,000)	($2,002,000)
Total	**($998,000)**	**($1,083,000)**	**($1,226,000)**

4.5.4 Alternative 4A/B: RNG with CHP

The O&M costs for Alternatives 4A/B include purchase of natural gas for running the engines, electricity offsets for the generation of electricity, and other O&M costs included in Alternatives 2 and 3, as appropriate.

Table 30 shows the breakdown of the revenue for Alternative 4A.

Table 30: Alternative 4A: RNG and Engine Annual O&M

Item	2028	2037	2052
Natural gas	$1,049,000	$1,106,000	$1,194,000
Electrical offset	($1,058,000)	($1,174,000)	($1,376,000)
Electrical RECs	($60,000)	($66,000)	($74,000)
Electricity used	$207,000	$230,000	$269,000
Engine maintenance	$333,000	$363,000	$412,000
Boiler maintenance	$15,000	$15,000	$15,000
Biogas conditioning	$140,000	$152,000	$172,000
RNG revenue	($1,642,000)	($1,778,000)	($2,002,000)
Total	**($1,016,000)**	**($1,151,000)**	**($1,390,000)**

Table 31 shows the breakdown of the revenue for Alternative 4B. Alternative 4B would generate less power than Alternative 4A but also would use less natural gas.

Table 31: Alternative 4B: RNG and Gas Turbine O&M

Item	2028	2037	2052
Natural gas	$427,000	$460,000	$486,000
Electrical offset	($294,000)	($333,000)	($382,000)
Electrical RECs	($17,000)	($18,000)	($21,000)
Electricity used	$207,000	$230,000	$269,000
Turbine maintenance	$93,000	$103,000	$114,000
Boiler maintenance	$15,000	$15,000	$15,000
Biogas conditioning	$140,000	$152,000	$172,000
RNG revenue	($1,642,000)	($1,778,000)	($2,002,000)
Total	**($1,071,000)**	**($1,169,000)**	**($1,349,000)**

4.6 Results of Analysis

A first-stage analysis of all alternatives focuses on the financial costs only over a 6-year period of construction and 25-year period of subsequent operations. Table 32 presents the original conceptual construction cost (inclusive of contractor overhead and profit [O&P], mobilization and other preliminary costs, and contingency), and total present value of all capital and net operating costs through 2052, assuming a 3 percent discount rate.

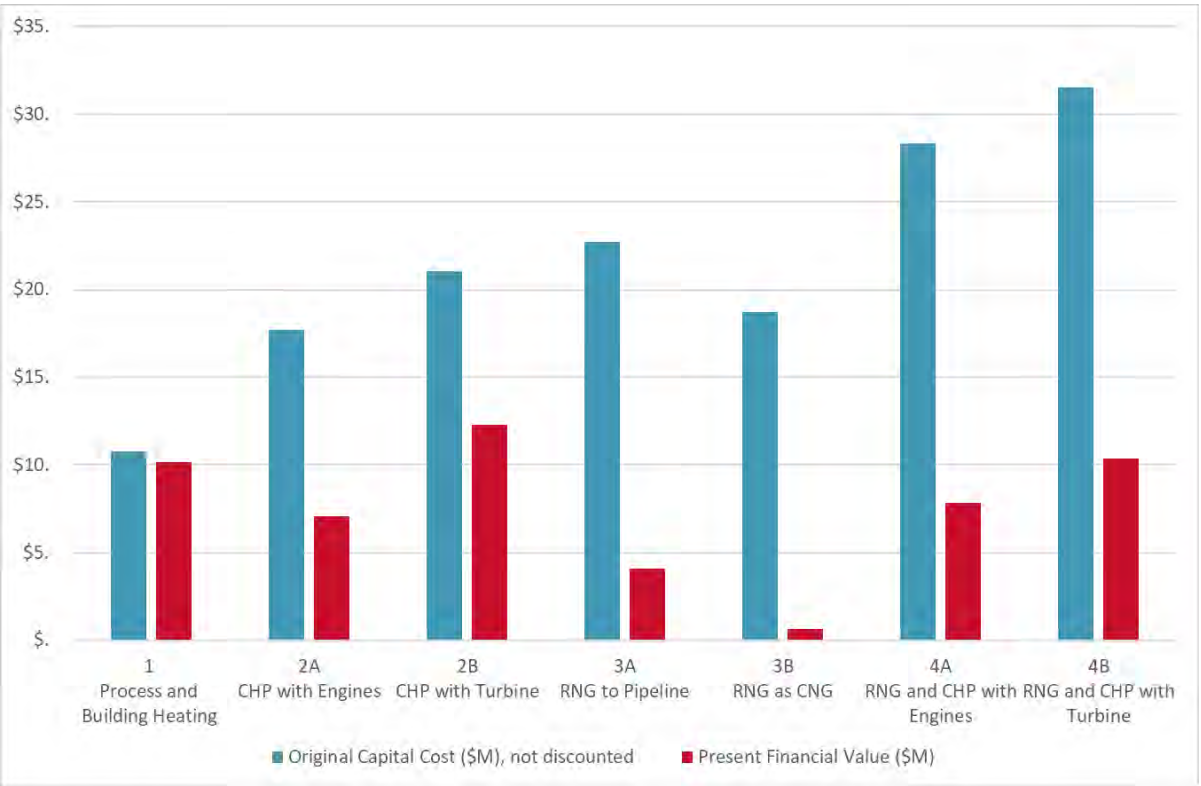
Table 32: Financial Analysis Results

Alternative	1 Process and Building Heating	2A CHP with Engines	2B CHP with Turbine	3A RNG into the NG Pipeline	3B RNG with CNG	4A RNG and CHP with Engines	4B RNG and CHP with Turbine
Conceptual construction cost, $M	$10.8	$17.7	$21.1	$22.7	$18.7	$28.4	$31.5
	Present Financial Value ($M)						
Capital cost	$9.3	$15.3	$18.2	$19.6	$16.2	$24.5	$27.2
Equipment O&M	$0.8	$6.1	$4.6	$5.7	$5.7	$10.9	$7.1
NG cost	$0.0	$0.0	$0.0	$4.2	$4.2	$15.8	$6.4
Electrical offset and RECs	$0.0	($14.2)	($10.5)	$0.0	$0.0	($17.8)	($5.0)
RNG revenue	$0.0	$0.0	$0.0	($25.5)	($25.5)	($25.5)	($25.5)
Total present value	$10.1	$7.1	$12.3	$4.1	$0.6	$7.9	$10.3

Figure 25 shows a comparison of these results graphically.

The base cost analysis indicates that although Alternatives 3A and 3B (RNG alternatives) do not have the lowest capital cost, they do have the lowest total present-value cost due to the anticipated value of the RNGs. In comparison, Alternatives 4A and 4B (RNG and CHP alternatives) would entail larger capital costs and comparable present-value costs when compared to Alternatives 2A and 2B (CHP alternatives).

Figure 25: Capital Costs and Total Present Values ($M) of Alternatives



4.7 Alternatives Selected for Further Review

The initial present-value financial analysis supports eliminating Alternatives 4A and 4B for future consideration because of high capital costs, high overall complexity, significant use of natural gas, and comparable present financial values to Alternatives 2A and 2B. Alternatives 2A, 2B, 3A, and 3B are further analyzed for risk and non-financial factors in the following sections.

5 Shortlisted Alternatives Analyses

5.1 Non-Financial Analysis

The selection of a biogas utilization option is not driven solely by the financial analysis, as the new facilities will need to be operated and maintained by the County. In addition, the facilities could impact local stakeholders in different ways. To account for these factors, a comprehensive non-financial analysis was completed, as described in this section for the shortlisted alternatives.

5.1.1 Evaluation Criteria

The evaluation criteria for the non-financial analysis were developed in conjunction with County staff as part of Workshop 3.2 on May 10, 2021.

Table 33 presents the criteria and descriptions that were used in the subsequent weighting and scoring of the biogas utilization alternatives.

Table 33: Non-Financial Criteria Descriptions

Criterion	Description
Localized emissions	Produces emissions at WPCP site that may negatively impact air permitting requirements, cause neighborhood issues, or result in poor air quality in immediate area
Noise	Generates excess noise that may impact neighbors or result in costly noise reduction measures
Visual aesthetics	Is acceptable to the neighbors and general Arlington County community from a visual aesthetics standpoint
Footprint	Sufficient space for operations and maintenance; does not take land space from current needs or potential future add-ons
Potential for flaring	Provides multiple outlets for use of biogas or redundancy options to minimize the amount of biogas sent to the waste flare
Operational complexity	Complexity of equipment and facilities in operation
Maintenance complexity and reliability	Reliability of equipment and facilities, ongoing maintenance requirements, annual downtime for maintenance, number of components that could fail resulting in failure of system
Safety	Risks for operation of system, including leaks, pressures, number of components, etc.
Resilience	Provides for additional resilience benefits for the WPCP and solids handling systems

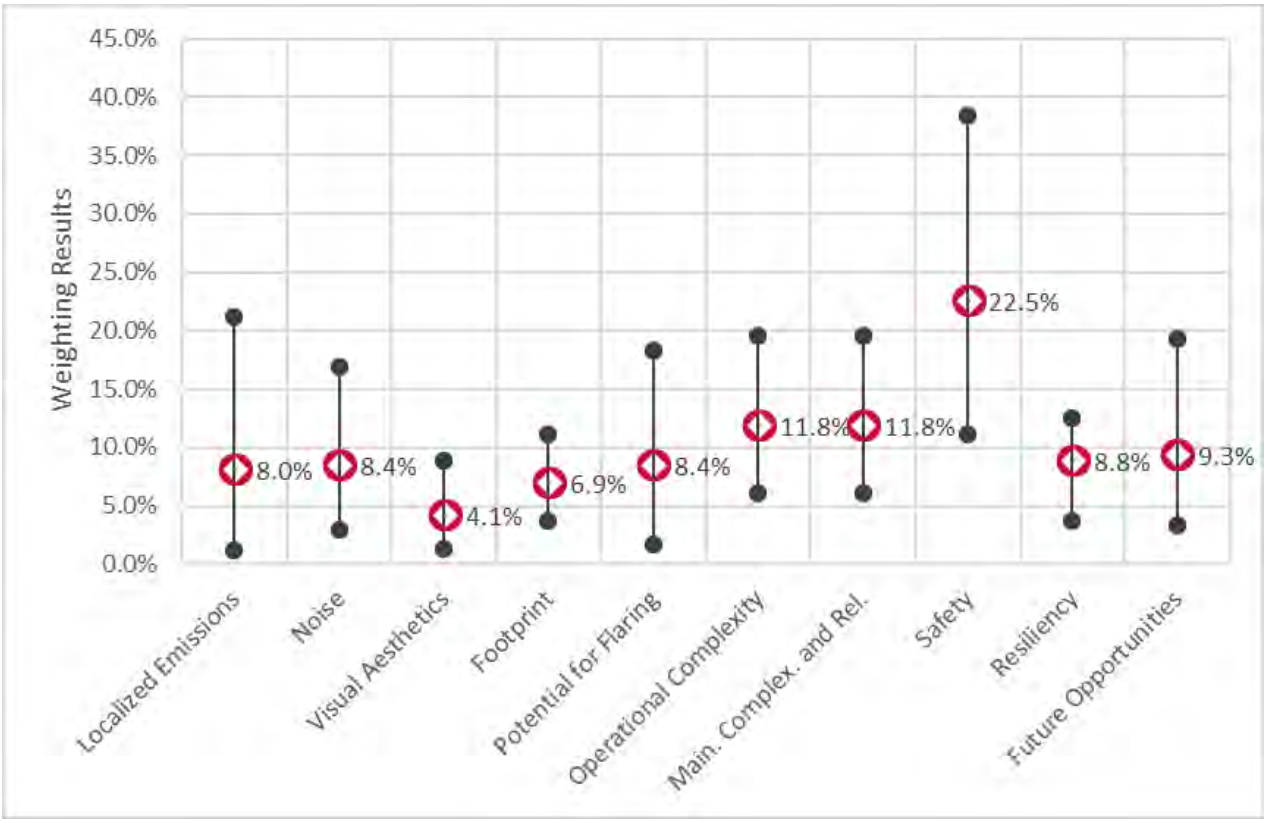
Criterion	Description
Future opportunities	Maintains flexibility for modifying approach should market conditions change

5.1.1.1 Weighting

During Workshop 3.2 on May 10, 2021, the HDR team introduced the alternatives summary sheets and scoring worksheets and provided instructions for completing a pairwise scoring comparison. In the pairwise analysis, participants compared "pairs" of criteria and selected which of those criteria was more important. For example, for evaluating biogas utilization alternatives, is "safety" more important than "operational complexity"? Each participant made a subjective selection, and then compared the remaining pairs. For this exercise, 14 County employees participated in the scoring exercise.

The results of the non-financial criteria weighting are presented in Figure 26. The percentage listed represents the geometric mean for that criterion of all the participants scores. The range bars represent the range of individual weights for each criterion.

Figure 26: Non-Financial Criteria Weighting



5.1.1.2 Alternatives Scoring

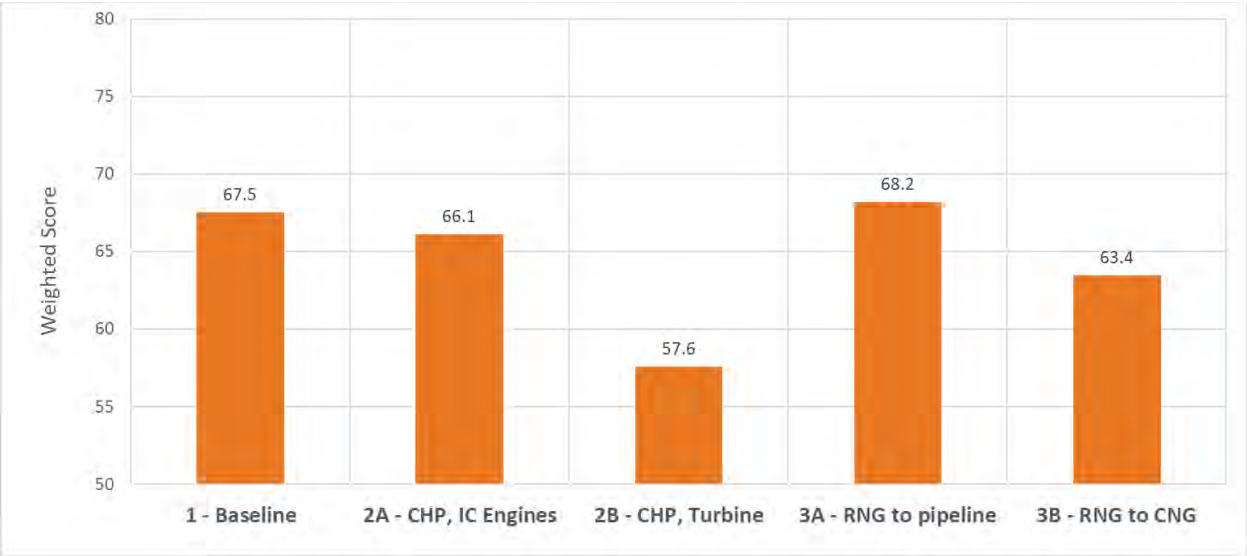
Participants were then asked to weight each biogas utilization alternative for effectiveness in achieving a particular evaluation criterion. For example, is Alternative 2A, CHP with engines, more effective than Alternative 3B, RNG sent to ART/WMATA, for achieving “long-term resilience?” Scoring values, from a scale of 1 (very low) to 5 (very high), were made for all five alternatives and for each evaluation criterion. The summary sheets were distributed electronically to all participants, with guidance for each scoring value listed for each criterion, to assist them in making a subjective selection. Guidance for the scoring of the criteria is presented in Table 34.

Table 34: Non-Financial Criteria Scoring Guidelines

Title	Characteristics	1 - Very Low	2 - Low	3 - Moderate	4 - High	5 - Very High
Localized Emissions	Produces emissions at plant site that may negatively impact air permitting requirements, cause neighborhood issues, or result in poor air quality in immediate area.	Visual emissions impact to existing communities, puts project at risk.	Known emissions are modeled with some impacts to surrounding areas but permitable.	Community understanding of approach and emissions.	Minimal increase in local emissions.	No increase in local emissions.
Noise	Generates excess noise that may impact neighbors or result in costly noise reduction measures	Noise leaving plant site 24/7.	Increase in noise leaving plant site intermittently.	Noise impacts are mittigatable through additional cost. May be periodic excess noise during maintenance activities.	No mitigation impacts required. May be periodic excess noise during maintenance activities.	No excess noise leaving plant site.
Visual Aesthetics	Is acceptable to the neighbors and general Arlington County community from a visual aesthetics standpoint.	Industrial nature, seen as factory with visible emissions.	Industrial nature, but no visible emissions.	Screened from one side but industrial from Route 1. Exposed piping throughout.	All new facilities are screened. Exposed piping throughout.	All facilities inside and/or enclosed. No exposed visible piping.
Footprint	Sufficient space for operations and maintenance, does not take land space from current needs or potential future add ons.	Overly constrained site, not adaptable to other site requirements, prevents future add ons.	Tight site for operations and maintenance, not adaptable to other site requirements and limits future opportunities.	Adequate space for operations and maintenance but still constrains site for future opportunities and lacks site synergies.	Adequate space for all new facilities and takes advantages of site synergies, but limited space for future opportunities.	Small footprint, able to take advantages of site synergies, allows for future opportunities.
Potential for Flaring	Provides multiple outlets for use of biogas or redundancy options to minimize the amount of biogas sent to the waste flare.	All biogas except that used for boiler is flared.	Biogas is benefically used in areas other than boiler but equipment failures and lack of redundancy result in significant flaring.	Biogas is beneficially used in areas other than boiler with flaring for offspec gas and systems offline. No additional outlets.	Biogas is beneficially used with flaring for offspec gas but is minimized through equipment redundancy.	Biogas has multiple outlets and only is flared when all outlets fail.
Operational Complexity	Complexity of equipment and facilities in operation.	Highly complex systems with multiple control points and sensors. Requires external resources to operate.	Complex systems with multiple control points and sensors with some annual downtime and/or Requires specialized training and some reliance on external resources to maintain operation.	Complex systems with multiple control points and sensors with some annual downtime. Requires specialized training but no external resources to maintain operation.	Less complex operational systemswith fewer control points. Minimal training and current staff can operate.	Standard systems with standard operational requirements. Current staff have the skillsets to operate all equipment.
Maintenance Complexity and Reliability	Reliability of equipment and facilities, ongoing maintenance requirements, annual downtime for maintenance, number of components that could fail resulting in failure of system.	Systems with non-standard maintenance requirements and limited redundancy, leading to downtime and system failures.	Non-standard maintenance requirements and some annual downtime. Requires external resources to operate and/or maintain all new gas handling systems.	Non-standard maintenance and some annual downtime. Systems other than boiler requires specialized staff to operate and maintain but no external resources.	Generally standard maintenance requirements. Systems other than boilers require some specialized training that current staff can take to operate and maintain.	Standard maintenance requirements. Current staff have the skillsets to operate and maintain all equipment.
Safety	Risks for operation of system, including leaks, pressures, number of components, etc.	Multiple high pressure systems(>100 psi) with multiple locations of potential failures.	Single high pressure system (>100 psi) with fewer locations for potential failures.	Single high pressure system with limited length of pressurized lines.	Lower pressure gas system with fewer components and potential leakage points.	Standard gas systems with safety components in place.
Resiliency	Provides for additional resiliency benefits for the WPCP and solids handling systems.	No change in gas or electrical resiliency.	Provides only natural gas resiliency to Solids Area	Provides only electrical resiliency to Solids area	Provides natural gas resiliency to multiple areas or both electric and natural gas resiliency to solids area	Provides electrical resiliency to multiple areas.
Future Opportunities	Maintains flexibility for modifying approach should market conditions change.	Locks-in treatment and biogas utilization options with no ability to adapt in the future	Provides limited treatment and biogas utilization flexibility in the future - may be possible but would require significant rework of infrastructure put in place.	Flexibility to add new end uses but at significant cost beyond the new technology.	Flexibility to add new end uses without paying a premium	Has multiple end uses now and flexibility to pivot should markets change.

At Workshop 4.2 on June 24, 2021, the scoring of each alternative was discussed to develop consensus. The participants discussed each criterion and their perspective on scores to develop the consensus. Figure 27 presents the average scores for each alternative. The average score is represented by multiplying the consensus score by the average weighting results presented in Figure 26. Alternative 3A had the highest non-financial score at 68.2, followed by Alternative 1 at 67.5. Alternative 2B had the lowest non-financial score of 57.6.

Figure 27: Non-Financial Scoring Results



The main differentiators between the RNG alternatives (Alternatives 3A/3B) and CHP alternatives (Alternatives 2A/2B) were that the RNG alternatives had:

- Lower localized emissions
- Reduced noise
- More outlets for beneficial use of the biogas and ability to reduce flaring
- Lower maintenance complexity and reliability
- Adaptability to future opportunities

5.2 Sustainability Criteria

In addition to financial and non-financial considerations, the Program is tasked with reviewing the sustainability, or environmental impact, of the alternatives identified. This was accomplished using the anticipated reductions of GHG emissions (namely CO_2) for each alternative and using a social cost of GHG approach to monetize the reductions. Note, this social cost of GHG is a monetization of the social impacts of the GHG emissions based on economic loss over time—it does not represent a true financial value to the County. However, by monetizing the value of the GHG offsets, the results

can be combined with the financial and non-financial results to develop a composite comparison for each.

5.2.1 Basis of Greenhouse Gas Evaluation

A comparative greenhouse gas summary was developed for the biogas utilization alternatives. The summary in the sections below includes only the emissions from electricity and NG utilization associated with the biogas portion of the Program (regardless of where the end user of the biogas is located) including reductions from avoided electricity purchase or avoided fossil fuel-based NG usage. A complete comprehensive GHG emissions evaluation including biosolids hauling and chemical usage will be provided in a separate TM.

5.2.1.1 Electrical Use

The Arlington WPCP buys its electrical power from Dominion. From Dominion's Sustainability Report, included in Appendix C , the GHG emissions (expressed as MT carbon dioxide equivalent [CO_2e] per net MWh) from Dominion-provided power in Virginia has been steadily decreasing from 0.637 MT/net megawatt-hours (MWh) in 2000 to 0.285 MT/net MWh in 2019, as shown in Figure 28. This is due to the gradual reduction in power production from coal to more renewable sources and natural gas. The breakdown of Dominion's energy sources in 2019 is presented in Figure 29.

Figure 28: Dominion Emissions Trend

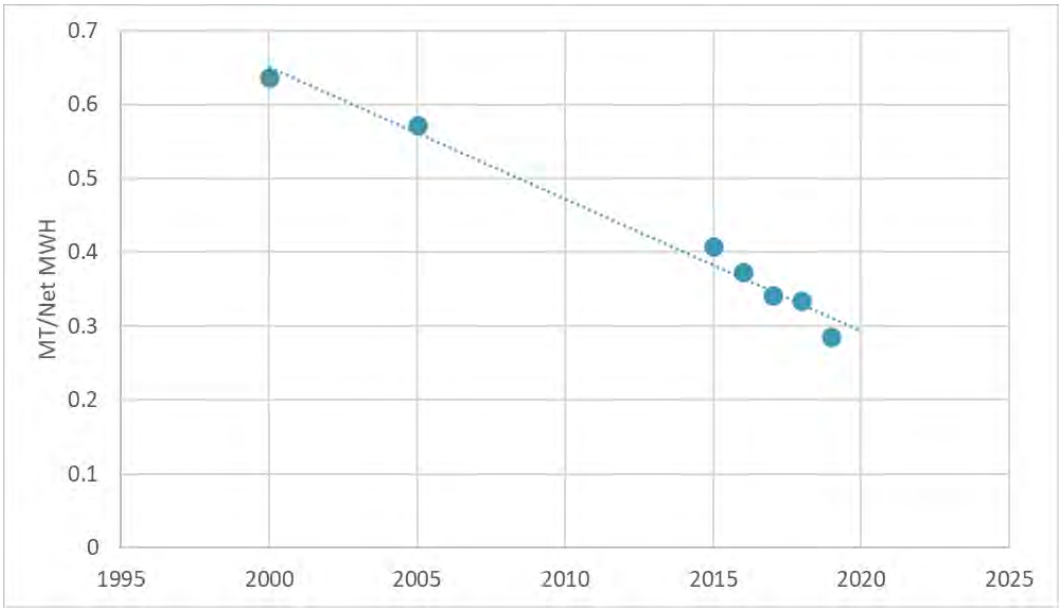
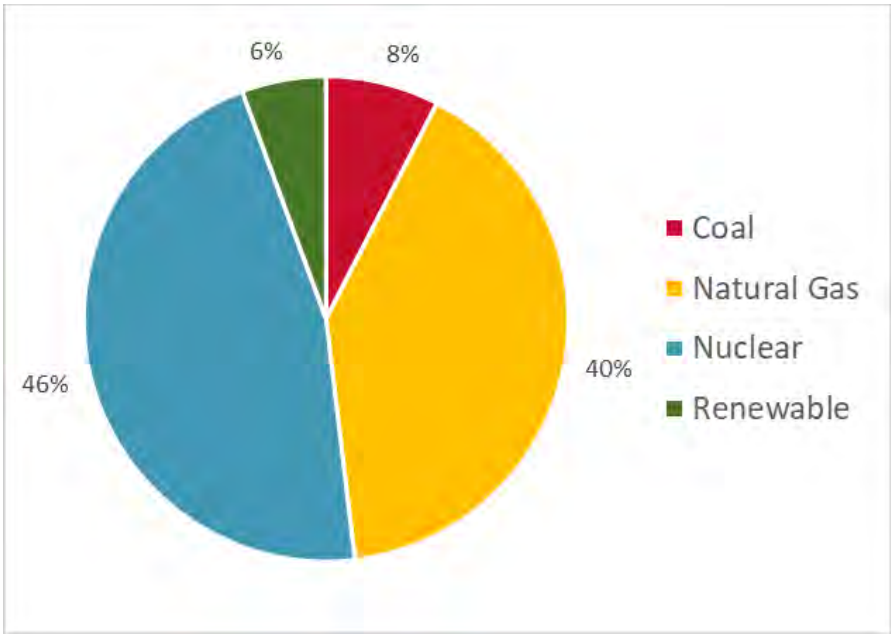


Figure 29: Dominion Energy Sources, 2019



5.2.1.2 Natural Gas Use

As summarized in Section 2.3.1, the WPCP currently uses approximately 7,800 therms or 780 MMBtu of natural gas per year. From EIA, the combustion of natural gas results in 53.07 kilograms (kg) of carbon dioxide per MMBtu. Therefore, the GHG emissions from NG use at the WPCP are approximately 40 MT/yr.

5.2.2 Changes in GHG Emissions

In addition to differences in energy production and costs, each biogas utilization alternative results in a different amount of total net GHG emissions. The net GHG change presented herein is solely for the biogas utilization equipment, not the entire Re-Gen/Biosolids Program. Table 35 below provides a breakdown of what areas contribute to GHG additions and offsets for the various components of each alternative:

Table 35: Impacts of Alternatives on Net GHG Emissions

Alternative	Electricity Use	Electricity Production	NG Used On Site for Steam Production	Biogas Displaces Fossil Fuel-Based NG On Site	Biogas Displaces Fossil Fuel-Based NG Off Site
1: Process and building heat	+			-	
2A: CHP with IC engines	+	-		-	
2B: CHP with turbines	+	-		-	
3A: RNG to pipeline	+		+		-
3B: RNG used as CNG	+		+		-

GHG emissions from removal of carbon dioxide in the biogas, combustion of biogas on site for steam generation, combustion on site in CHP, or flaring are not included, as the carbon dioxide being emitted is biogenic.

With Alternative 1, steam generation would be solely through using biogas in boilers. This would also eliminate current combustion of fossil fuel-based NG and thus reduce emissions by 40 MT/yr. However, this alternative also would require an increase in electricity use over current usage, which would lead to 80 MT/yr of additional GHG emissions. Therefore, a net increase over current emissions of 40 MT/yr would result.

For Alternative 2A the biogas would be used to produce 1.39 MW of electricity or 12,185 MWh/yr. Combined with additional electricity use for this alternative, GHG emissions for electricity would be reduced by 3,330 MT/yr based on the current Dominion Energy CO_2 emission profile. Steam generation for THP will come solely from heat recovery from the engines or biogas combustion. In addition, the heat recovery from the engines would eliminate current fossil fuel-based NG consumption and the corresponding emissions of 40 MT/yr. Therefore, the total GHG emissions reduction of 3,370 MT/yr.

Because of the lower efficiency of the gas turbine, Alternative 2B would produce only 0.98 MW of electricity or 8,585 MWh/yr, reducing GHG emissions by 2,310 MT/yr. Similar to Alternative 2A, the heat recovery from the turbine would reduce NG purchases by another 40 MMBtu/yr, resulting in a total net GHG emission reduction of 2,350 MT/yr.

Alternatives 3A and 3B, which involve selling all the biogas produced as RNG, would generate the most emissions reductions, even though some natural gas would be purchased for the steam boiler. Alternatives 3A and 3B result in an emissions reduction of 6,240 MT/yr from the displacement of fossil-fuel based NG off site. The use of NG on site in steam boilers would result in an additional 1,970 MT/yr of emissions. The

additional electrical usage for the biogas conditioning system results in 770 MT/yr of additional emissions. When these are added together, the total net GHG emissions reductions for these alternatives amount to 3,500 MT/yr in 2037.Table 36 presents net change in GHG emissions for each of the sources of energy for 2037. Overall, Alternatives 2A, 3A, and 3B have greater emissions reductions than Alternatives 1 and 2B.

Table 36: Total Change in Net GHG Emissions (MT CO_2e) in Year = 2037

Alternative	Net Electricity Use	Biogas Production (Offsets NG Purchases)	NG Purchased	Total Change in Emissions
1: process and building heat	80	-40	0	40
2A: CHP with IC engines	-3,330	-40	0	-3,370
2B: CHP with turbines	-2,310	-40	0	-2,350
3A: RNG to pipeline	770	-6,240	1,970	-3,500
3B: RNG used as CNG	770	-6,240	1,970	-3,500

Note: Negative values are reductions and positive values are increases in emissions.

Note, GHG reductions for Alternatives 2A and 2B are based on the current Dominion Energy emission profile, which includes a combination of fossil-fuel and renewable energy sources described above. Electricity usage for Arlington County operations is projected to be 100 percent renewable by 2025, in which case the GHG reduction for net electricity production would be zero. However, the generation of renewable power at the WPCP may allow for currently forecast renewable sources to be used elsewhere.

5.2.3 Environmental Value of Greenhouse Gas Emission Savings

Annual GHG emissions reductions can be converted into monetary terms by applying the dollar values per metric ton that have been established by the Interagency Working Group (IWG) on Social Cost of Greenhouse Gases of the U.S. government.[1] The IWG analysis accounts for a wide range of climate change impact studies that assess losses to the U.S. and world economies over time. These future losses are discounted to the present and normalized on a per metric ton of CO_2 emissions basis.

Results of the analysis are formalized in tables and charts. Because of uncertainty in future impacts and uses of the results, several dollar values are produced. Generally, monetary values can be combined with a change in GHG emissions to reveal the benefits of a change.[2] Table 37 presents two sets of dollars per ton by year to illustrate the range of values. The “most likely” value represents the best estimate for potential

[1] Interagency Working Group on Social Cost of Greenhouse Gases (IWG). February 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. United States Government Publication. (Link)
[2] Note that if emissions increase, the monetary value would be considered a loss or “negative” benefit.

damage caused by GHG emissions, given the analyses considered by the IWG. A high value is also computed and represents a much more significant level of future economic damage from GHG emissions.[3] The analysis of emissions reduction for the Program applies the most likely values.

Table 37: Social Cost of GHG, per Metric Ton of CO_2, by Year, at a 3% Discount Rate

Year	$/MT (Most Likely Value)	$/MT (High Value)
2020	$51	$152
2025	$56	$169
2030	$62	$187
2035	$67	$206
2040	$73	$225
2045	$79	$242
2050	$85	$260

The value of net GHG emissions reductions is presented in Table 38. The first column shows the same forecast value of GHG emissions reductions from Table 37 above. Next to it on the right is the corresponding monetary value of these reductions for year 2037, which have an estimated value of $69.34/MT for that year. The second set of columns to the right show the discounted total value of all GHG emissions reductions over a 25-year period of operations. These results show that reductions from Alternatives 3A, 3B, and 2A are all similar in total value with Alternatives 3A and 3B, with the highest at $3.62 million. The total discounted monetary value of emissions reductions can be combined with capital and financial costs to determine a total project value.

Table 38: Total Net CO_2 Emissions Reductions Value, $Millions

Alternative	Tons Reduced, Year 2037 Only	Most Likely Value Reduced, Year 2037 Only	Total Value, 25-Year Total (Discounted at 3%)
1	40	-$0.003	-$0.04
2A	-3,370	$0.23	$3.5
2B	-2,350	$0.16	$2.4
3A	-3,500	$0.24	$3.6
3B	-3,500	$0.24	$3.6

[3] Technically, this high value characterizes damage levels for which there is only a 5% chance that the future could be any worse. At this more extreme level of potential damage, the dollar value is correspondingly higher than an average damage condition in the future.

5.2.4 GHG Offsets

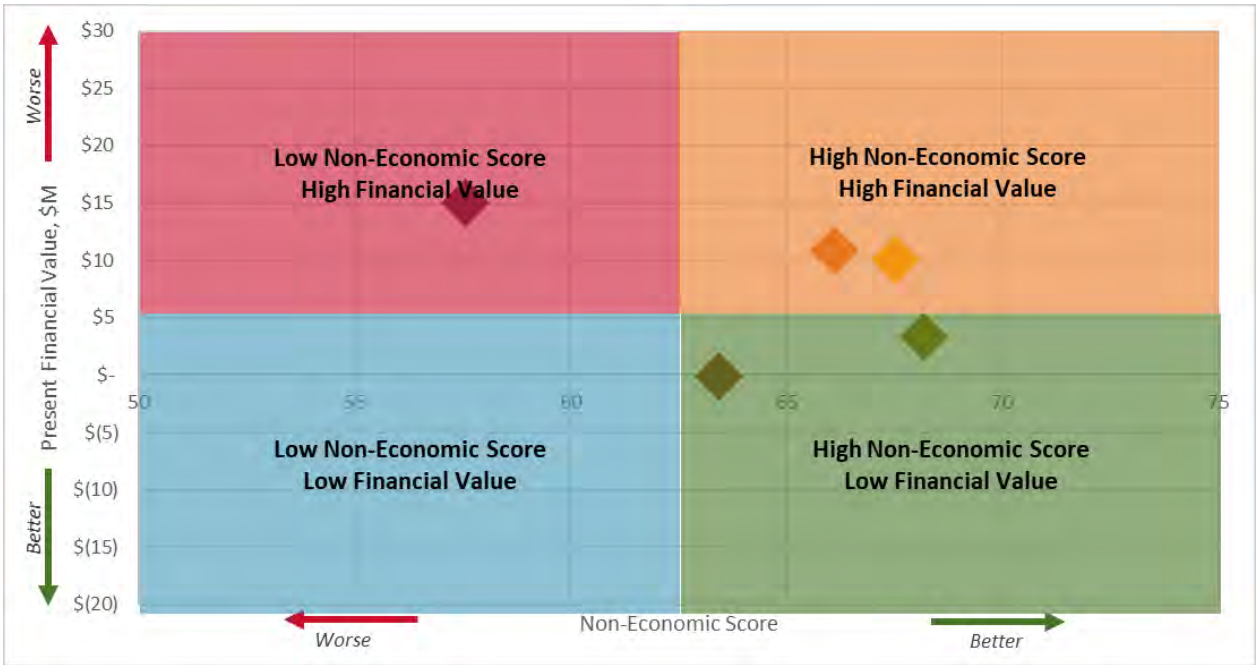
As discussed in Section 2.4.3, the GHG emission reductions associated with RNG will likely be realized by the ultimate purchaser of the RNG for use as transportation fuel. If that purchaser is within Arlington County, these emission reductions could be counted toward Arlington County's Carbon Neutrality goals.

However, if that purchaser is outside of Arlington County, the County might want to consider using some of the revenue brought in from RNG to purchase carbon credits on the open market. At the current market rate of approximately $15/MT of CO_2e, it would cost Arlington approximately $100,000 per year to purchase GHG credits equivalent to those attributable to the RNG. This purchase would not materially impact the financial evaluations presented.

5.3 Composite Results

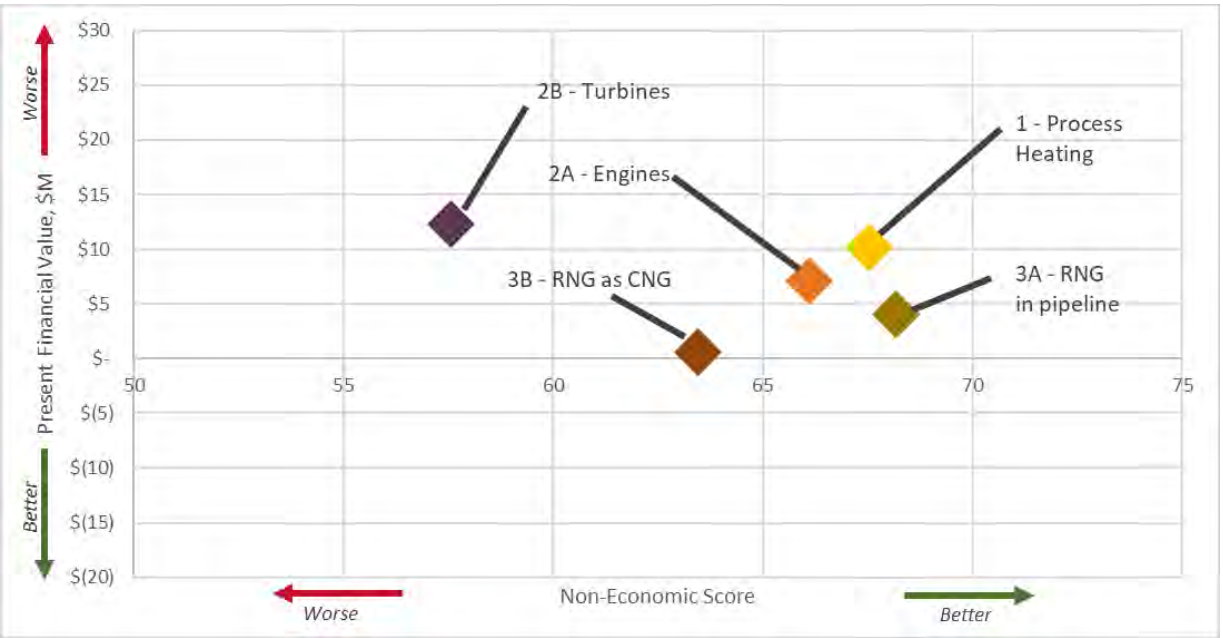
To further evaluate the financial results and non-financial scoring, the results of both efforts are combined into plots to illustrate the composite results for each alternative. By plotting the non-financial scores on the x-axis and the present financial values on the y-axis, a clearer picture of the most beneficial alternative can be achieved. With this approach alternatives that are located in the lower-right quadrant have higher non-financial scores and lower present financial values (better). Conversely, alternatives in the upper left quadrant have lower non-financial scores and higher present financial values (worse). Figure 30 illustrates this methodology.

Figure 30: Composite Scoring Methodology



When the non-financial scores from Figure 27 above are combined with the present financial values from Figure 25, the composite results can be developed; see Figure 31. These results represent the current electrical price of $0.078/kWh and an average RIN market value of $15/MMBtu, and do not include any social cost of carbon.

Figure 31: Base Scenario ($0.078/kWh, No GHG, RIN = $15/MMBtu)



For this base scenario, without considering the social cost of carbon, Alternative 3A had the highest non-financial score and the second lowest present financial value.

The results of several other scenarios were developed to help illustrate the potential impact of electrical costs, social cost of carbon, and RNG pricing on the composite results. The conditions and present financial values for each of these scenarios are presented in Table 39. The low RIN value represents the lowest weekly RIN value seen in the market over the last 6 years. The high RIN value represents the average weekly RIN value seen in the market over the last 6 years. The RIN market value as of October 2021 was $38/MMBtu. A high electrical scenario, with electricity at $0.117/kWh (50% over current), was also developed to reflect the impact of potential higher electric prices, although no such jump increase is forecast by the EIA projections.

Table 39: Present Financial Values for Other Scenarios

Condition	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Original Capital Cost ($M), Not Discounted
Electrical, $/kWh	$0.078	$0.078	$0.078	$0.078	$0.117	
GHG value	0	Most-Likely	Most-Likely	Most-Likely	Most-Likely	
RIN market value, $/MMBtu	$15	$15	$23.35 (average)	$6.38 (min)	$15	
Alternative	Present Financial Value ($M)					
1	$10.2	$10.2	$10.2	$10.2	$10.3	$10.8
2A	$7.1	$3.6	$3.6	$3.6	$1.6	$17.7
2B	$12.3	$9.9	$9.9	$9.9	$8.4	$21.1
3A	$4.1	$0.5	($11.5)	$12.8	$1.0	$22.7
3B	$0.6	($3.0)	($15.0)	$9.4	($2.5)	$18.7

Figure 32 shows the Scenario 1 composite results when the most-likely value for the social cost of carbon (GHG value) is included. The main impact is that Alternative 1 becomes less attractive because of the present value of the other alternatives being lowered. The relative differences between the other alternatives remain the same.

Figure 32: Scenario 1 ($0.078/kWh, Most-Likely GHG, RIN = $15/MMBtu)

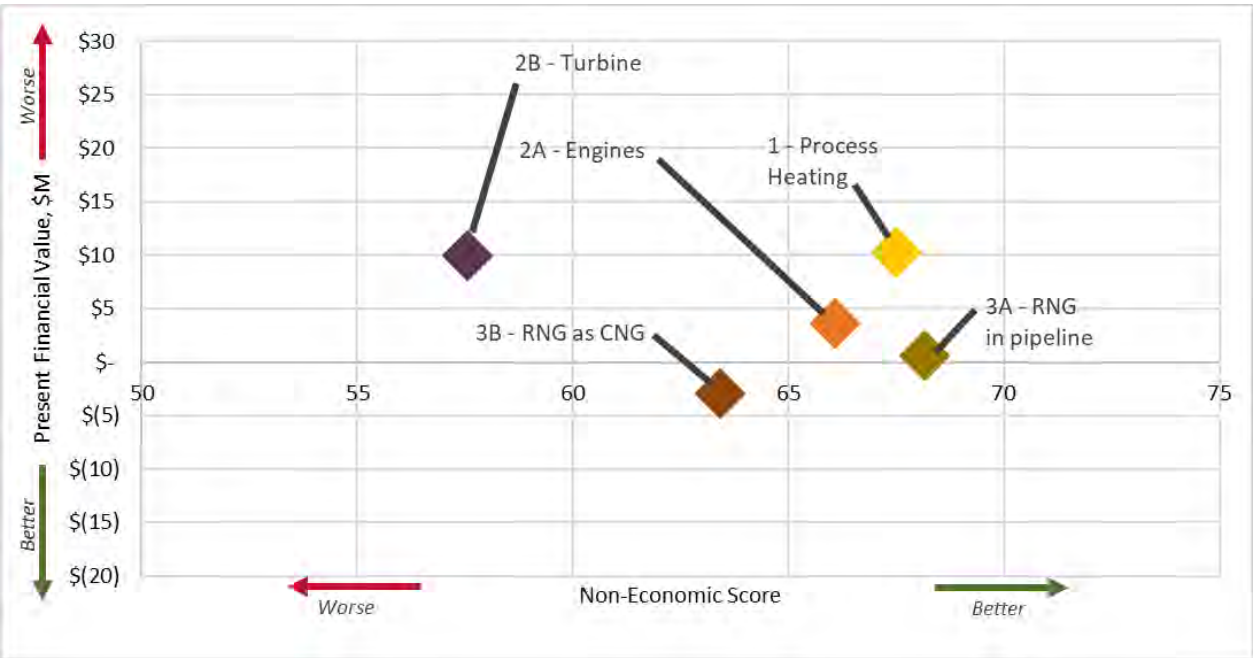


Figure 33 shows the Scenario 2 results including the social cost of GHG and the average RIN value for the past 6 years of $23.35/MMBtu. This RIN value furthers the financial advantage of the RNG alternatives.

Figure 33: Scenario 2 ($0.078/kWh, Most-Likely GHG, RIN = $23.35/MMBtu)

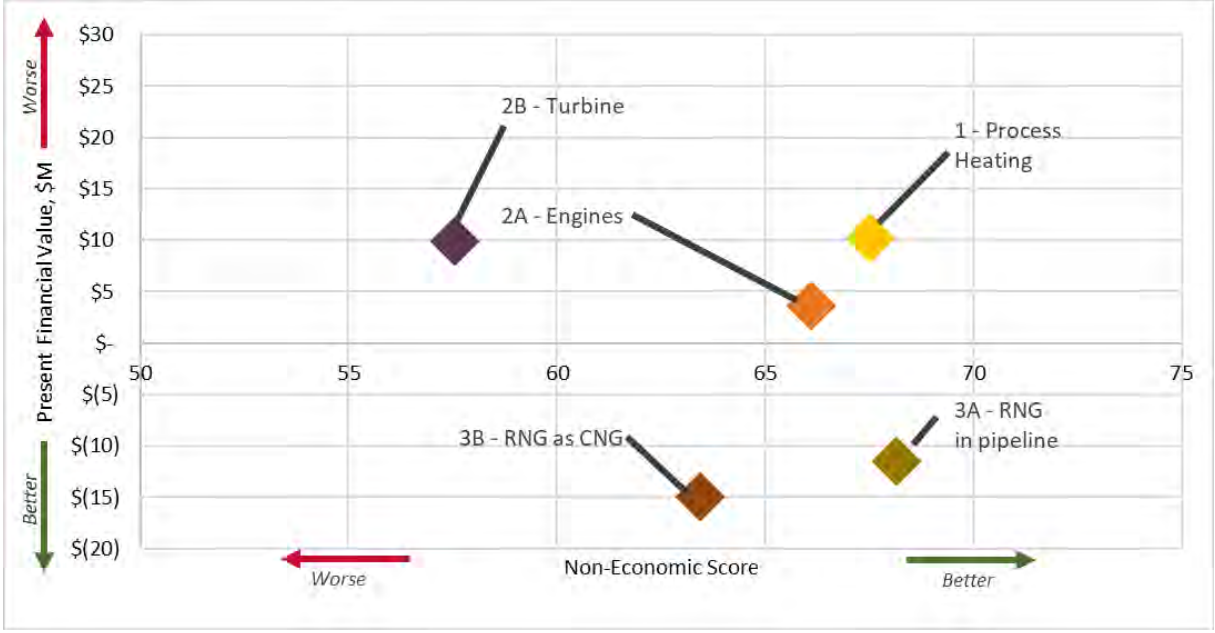
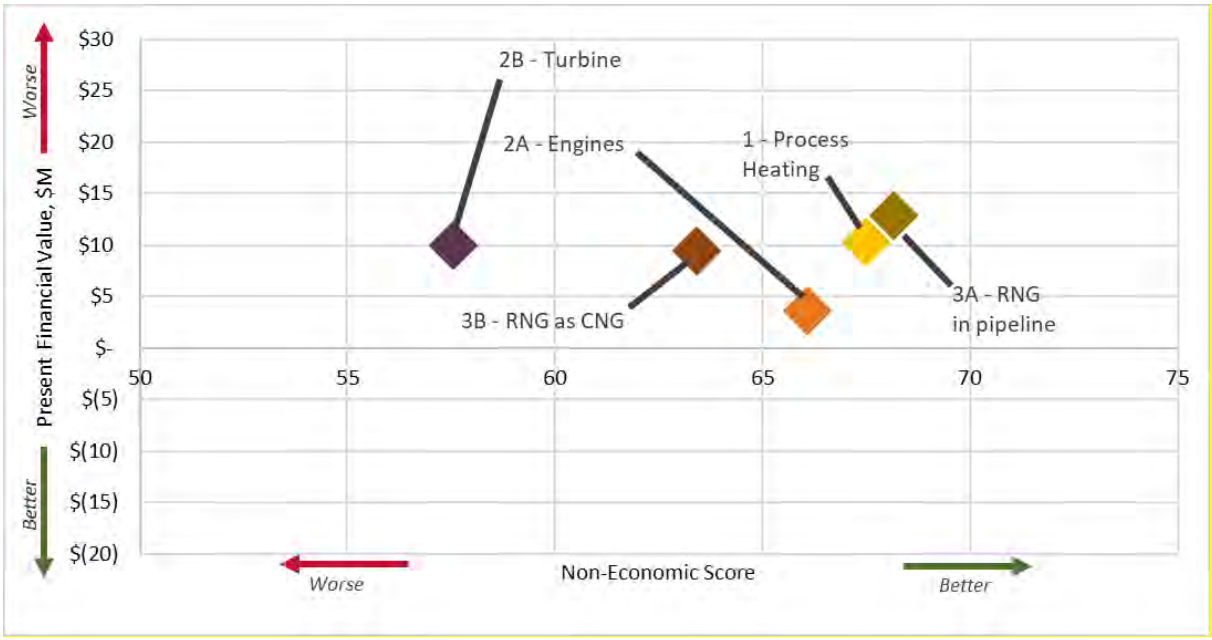


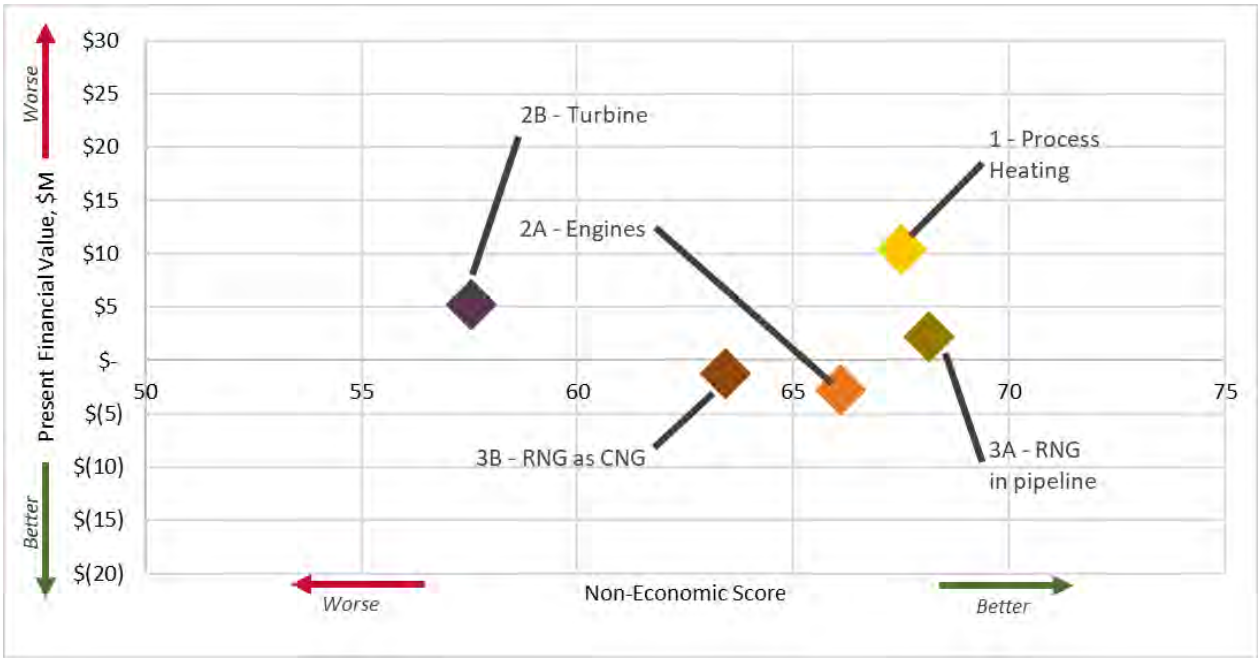
Figure 34 provides the same analysis including the social cost of GHG and the lowest weekly RIN value over the last 6 years of $6.38/MMBtu. In this scenario, Alternative 2A (CHP with engines) becomes more financially advantageous than Alternative 3A (RNG in pipeline). Note that this represents the RIN value averaging the minimum value for the entire 25-year analysis.

Figure 34: Scenario 3 ($0.078/kWh, Most-Likely GHG, RIN = $6.38/MMBtu)



Finally, when the electrical cost is increased to $0.117/kWh, the composite score of the CHP alternatives becomes more favorable than the RNG alternatives (see Figure 35).

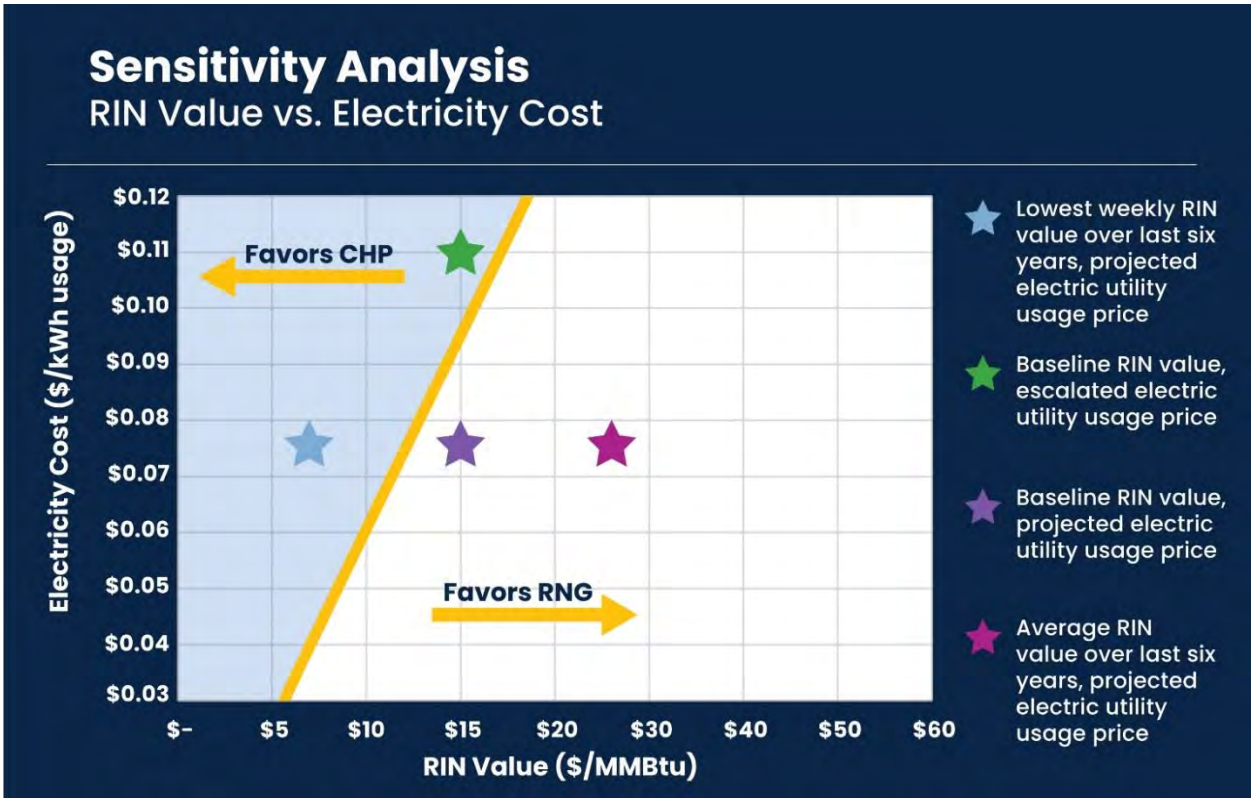
Figure 35: Scenario 4 ($0.117/kWh, Most-Likely GHG, RIN = $15/MMBtu)



5.4 Sensitivity Analysis

The financial analysis makes it clear that the main drivers in the comparison are the cost of electricity and the value of the RIN market. A break-even analysis was completed to identify the point at which Alternative 2A (CHP with engines) is financially equal to Alternative 3A (RNG into pipeline). This break-even analysis is shown on Figure 36, with the scenarios completed above identified.

Figure 36: Sensitivity Analysis of RIN Value vs. Electricity Cost



In addition to the sensitivity analysis described above, a more computationally rigorous approach, using Monte Carlo simulation methods, was completed to assess the combined impact of changing several factors at once.

5.4.1 Simulation Assumptions

Monte Carlo simulation involves defining input parameters as probability distributions of possible values, instead of one or several possible scenario values. For example, Figure 37 shows the probability distribution of annual growth rates (in percentage terms) for real electricity prices in the Mid-Atlantic region. This probability distribution was obtained by examining a variety of forecast scenarios produced by EIA (Figure 23) and identifying the lowest, baseline, and highest annual growth rates over a 30-year period.[4]

[4] The distribution was formed using a "Pert" distribution, a reasonable distributional form for engineering and economic analyses such as this.

Figure 37: Probability Distribution of Annual Growth Rates in Real Electricity Prices

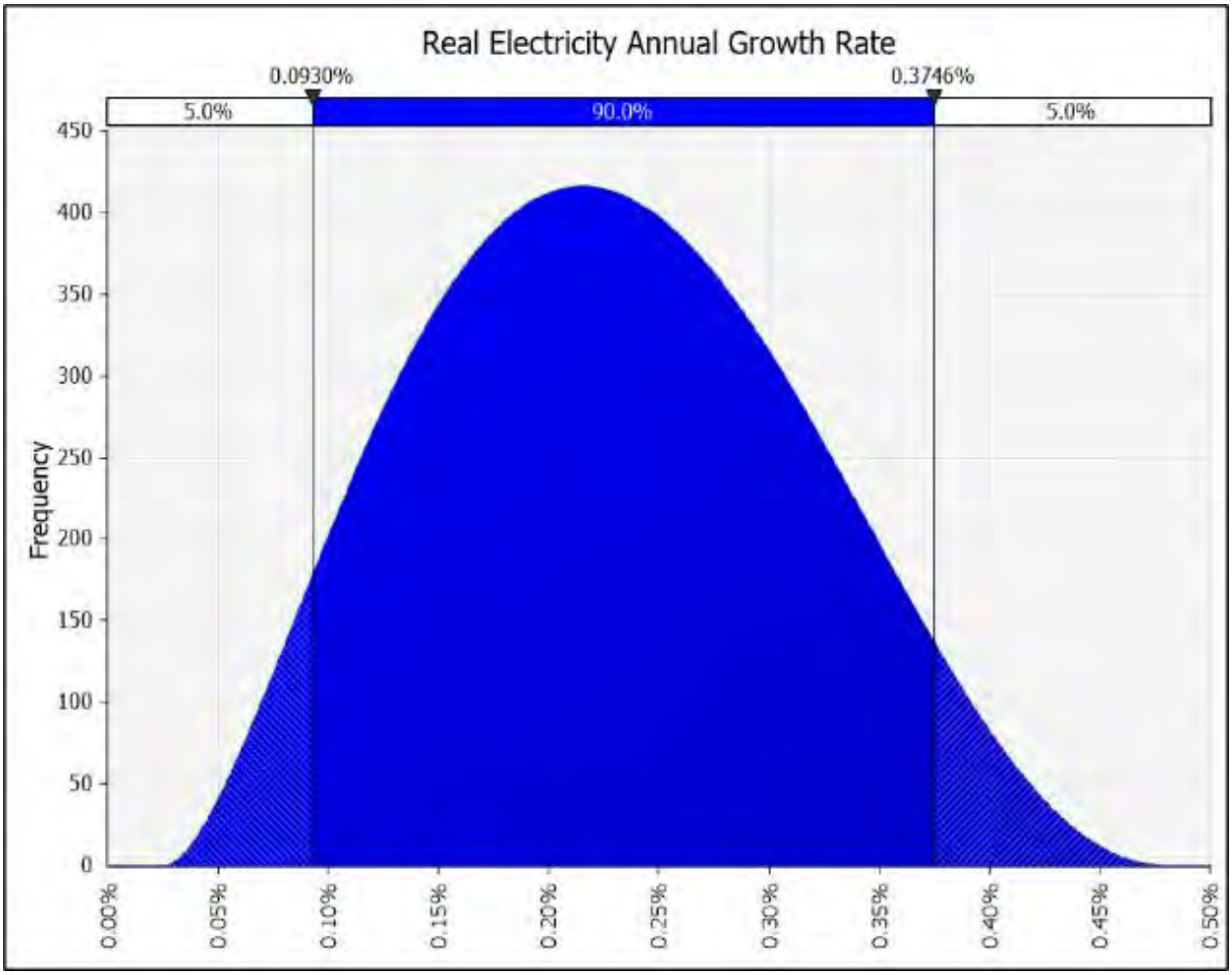


Table 40 presents the lower limit, estimated, and upper limit for the uncertain factors that are included in the model. Separate probability distributions are formed for each of these factors, using the same functional form as electricity price growth rates. The sources for these distributions include HDR assumptions and existing data.

Table 40: Monte Carlo Probability Distribution Parameter Values

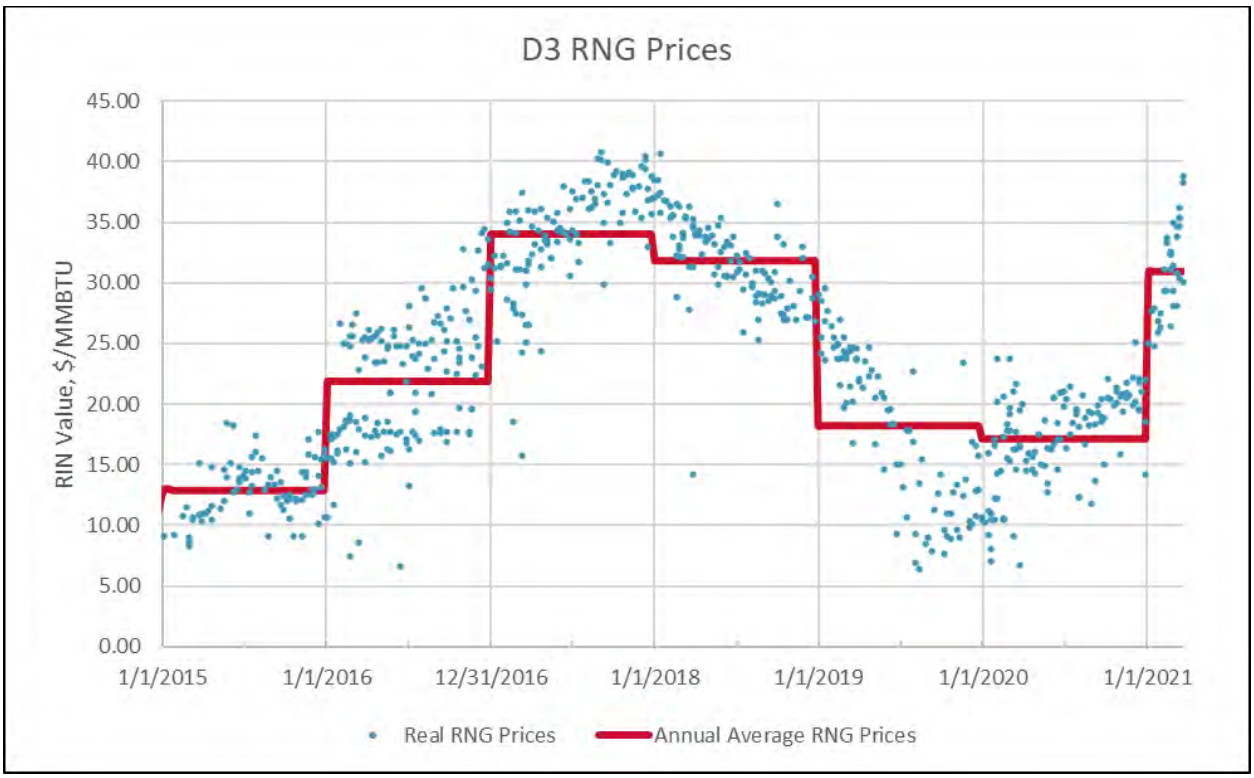
Uncertain Parameter	Lower Limit	Estimated Value	Upper Limit	Data Source
Energy Prices				
Electricity inflation (annual real rate)	0.03%	0.22%	0.48%	EIA
NG inflation (annual real rate)	-1.11%	-0.34%	0.88%	EIA
RIN price inflation (annual real rate)	0.00%	0.00%	2.18%	EPA
RIN market value (distribution for simulation)	$3	$22.36	$47	EPA
Capital Costs				
Contractor O&P (percentage of estimated cost)	12%	15%	18%	HDR
Contingency (percentage of estimated cost)	15%	20%	30%	HDR
Mobilization, bonds, and insurance (percentage of estimated cost)	6%	8%	10%	HDR
Building price, $/SF	$1,000	$1,150	$1,300	HDR
Slab-on-grade price, $/SF	$40	$50	$60	HDR
Performance				
Engine availability (annual probability)	90%	95%	97%	HDR
Turbine availability (annual probability)	85%	90%	95%	HDR
RNG treatment availability (annual probability)	85%	95%	95%	HDR

With a probability distribution of potential parameter values, such as the one shown in Figure 37 above, the model produces a full range of outcomes along with the likelihood that those values could occur.[5] When a model includes several uncertain parameters and each one is defined by its own independent probability distribution, the results will have fully accounted-for possible outcomes.

[5] A full range of model outcomes is achieved by the simulation process. Monte Carlo simulation methods involve performing thousands of iterations of model solutions whereby each iteration applies random draws of parameters from each probability distribution to solve the model.

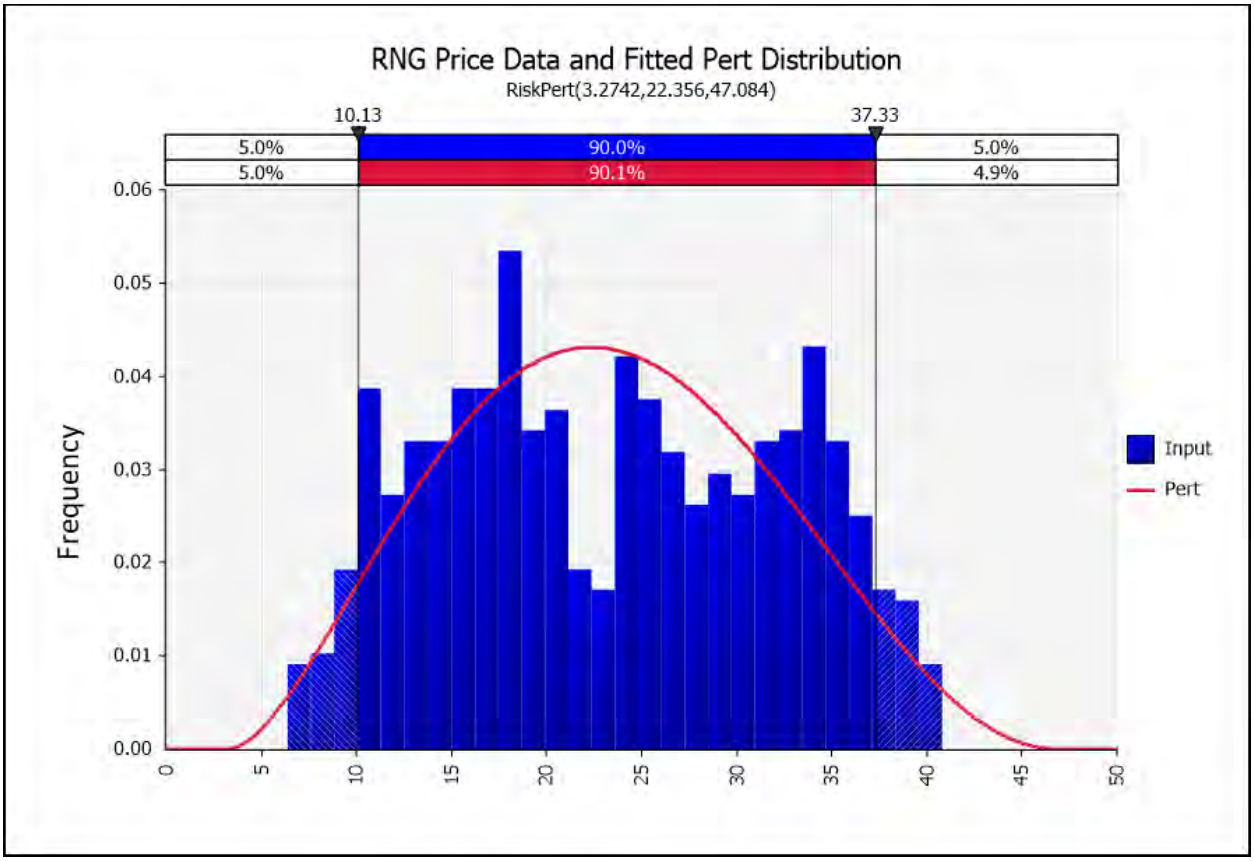
The parameter with the most significant influence on model results is RIN growth rates. The RIN distribution was estimated with a curve-fitting tool using the Palisade company's commercial @Risk software employed with Microsoft Excel. RIN prices for the past several years obtained from EPA records are shown in Figure 38. The curve-fitting approach assumes that all instances of RIN prices are independent of each other, as a group.[6] The resulting distribution is shown in Figure 39. The model uses the distribution to select a single annual price.

Figure 38: D3 RIN Prices (EPA)



[6] While trends may exist in the data, these were not evaluated at this stage. In fact, this approach is wider than the range of average annual values, which is how the data are used in the model.

Figure 39: Curve-fitted Probability Distribution of D3 RIN Prices



5.4.2 Simulation Results

Results from a Monte Carlo simulation are a probability distribution of possible outcomes, given the range of possible inputs of uncertain parameters. Figure 40 shows the distributions of possible present values of total financial and social outcomes for all five alternatives, in both probability density function (PDF) and cumulative density function (CDF).[7] The CDF has a useful interpretation for decision making because it can clearly indicate the probability that a condition holds, such as having a total present value of benefits exceeding costs.

[7] A PDF often appears to be bell-shaped; a CDF adds probabilities together for each value and appears as an S-curve.

Figure 40: Monte Carlo Simulation Results: Present Financial and Environmental Values of Alternatives

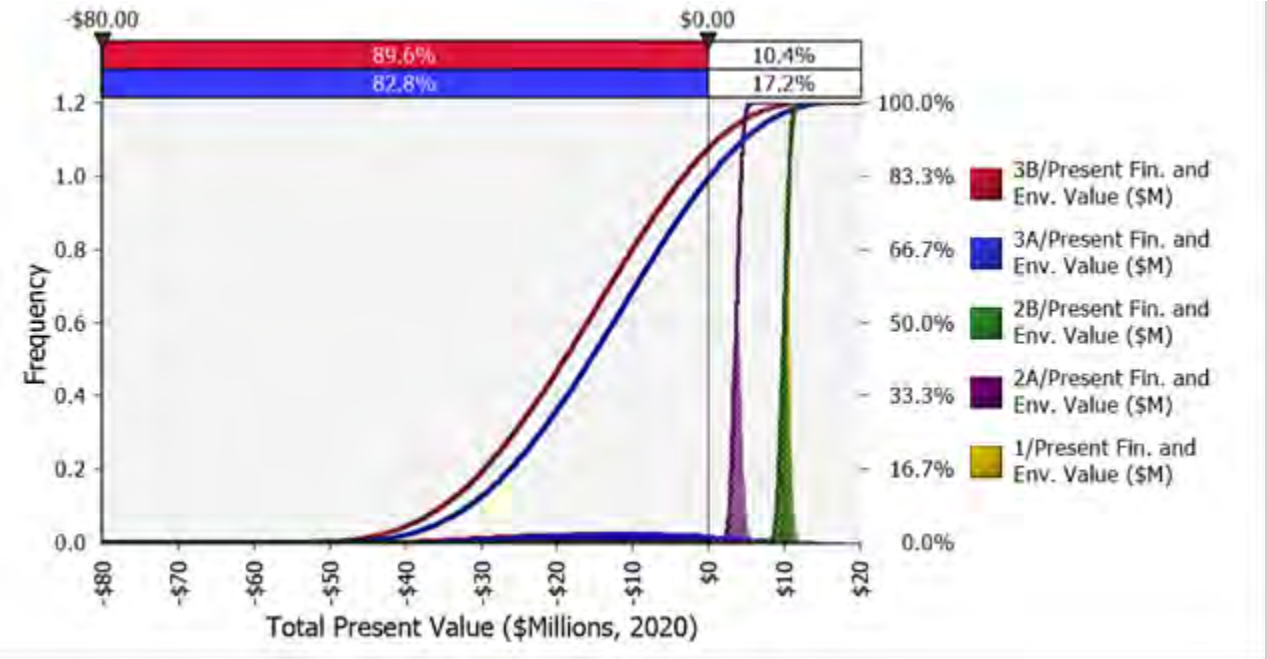
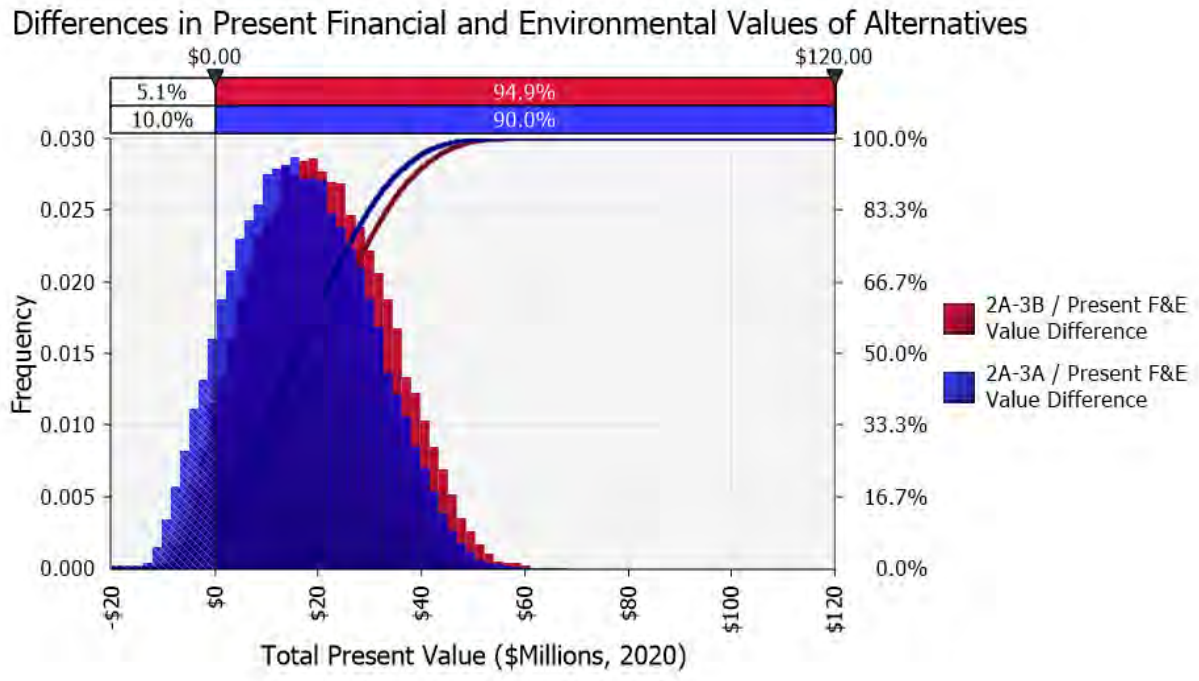


Figure 40 shows that Alternatives 1, 2A and 2B all have a very narrow range of potential financial values, and that these financial values are always positive (i.e., costs exceed benefits for the modeled parameters). Alternatives 3A and 3B have a wide range of potential financial values, which is a function of the uncertainty in the RNG market. However, even with the wide range, a majority of the model runs indicate a negative financial value (i.e., benefits exceed costs for the modeled parameters). Note, it is not a stated goal of the Program to be “cash positive” and many additional factors impact the overall Program cost. The analysis completed here is for the biogas utilization portion of the Program only.

A more direct comparison between alternatives can be performed by evaluating a distribution of the difference in present financial and social values. Figure 41 shows the results of the PDFs and CDFs of differences between Alternatives 2A and 3A, as well as Alternatives 2A and 3B. In both cases, there is a very low probability that the value of Alternative 2A would exceed that of Alternative 3A or 3B as shown on the top bar of Figure 41. For example, Alternative 2A has only a 5.1 percent chance of being a better value than Alternative 3B given the range of possible input values. Alternative 2A has a slightly better chance of being a better value than Alternative 3A, at 10 percent.

Figure 41: Monte Carlo Simulation Results: Differences in Present Financial and Environmental Values



6 Biogas Utilization Recommendation

Based on the analyses presented, the Water Pollution Control Bureau (WPCB) recommends proceeding with Alternative 3 (RNG) as the selected biogas utilization approach. The basis for this recommendation is as follows:

- The RNG alternatives have the lowest net present value (i.e., lowest total cost to the County) for the baseline conditions using conservative capital and operating costs.
- Alternative 3A (RNG into pipeline) scored the highest in the County's non-financial scoring. In particular, the County found that the RNG alternatives would be less complex and result in fewer localized impacts (noise and emissions) than the CHP alternatives.
- A sensitivity analysis concluded that when considering multiple variables, including RIN volatility and changes to electrical rates, Alternative 3A (RNG into pipeline) had a very high likelihood of being more financially advantageous than Alternative 2A.
- The County has the ability to retain GHG credits if the biogas is used within Arlington County for transportation purposes. Should the biogas be used outside of Arlington County, the revenue from the RINs could be used to purchase an equivalent amount of GHG credits on the open market.
- Biogas can be used on site for generation of steam in lieu of natural gas. This would slightly impact the financial analysis, as it would reduce the RNG being produced and the RINs generated. However, it would also eliminate the purchase of natural gas for the steam boilers and allow for effective use of the biogas if the RNG system is out of service.
- Benefits of on-site CHP are limited because the CHP size would not be sufficient to power the entire WPCP and the existing WPCP is already protected with two independent power feeds and backup generators.

Should the RFS program be terminated, CHP could be added at the WPCP in the future. In addition, the County is monitoring other programs - such as eRINs through the RFS and novel technologies that recover hydrogen and sequester carbon - that could be implemented in the future. The eRINs program could allow for the use of RNG off site for electrical generation to provide energy to electric vehicle fleets.

The County's current preference is for Alternative 3A (RNG into pipeline) over Alternative 3B (RNG as CNG) due to the uncertain future of ART and WMATA fueling stations and the lack of a match between fueling times and gas production times (resulting in the need for additional storage). However, the final decision to inject RNG into the NG utility pipeline or use CNG will be made in the future as more discussions with the stakeholders are conducted. Issues that need to be reviewed as the Program is further defined include the following:

- **Additional negotiations with the NG utility regarding offtake agreements, monitoring requirements, and cost of interconnection facilities:** The analysis

made some assumptions regarding these items based on what is known today about the required gas specification and anticipated interconnection costs. These items need to be refined as the Program proceeds.

- **RNG market values:** While a sensitivity analysis was performed on the RNG market values based on historical values, these markets should be monitored closely in the future as they are impacted by political and regulatory pressures.
- **The long-term viability of ART and WMATA using RNG (as CNG) for fleet fueling:** Based on preliminary discussions, both transit systems have decarbonization goals, which adds risk to the CNG options. The NG utility has indicated that RNG can be part of its portfolio at the WPCP regardless of the ultimate decision for the CNG stations.

In addition to these items, a biogas conditioning technology needs to be selected for implementation. The financial analysis performed as part of Chapter 4 assumed the cost of membrane treatment, which is the most conservative capital cost. A detailed life-cycle cost, site visits, and discussions with equipment vendors are needed to make a final recommendation of the selected technology (refer to Appendix D for additional information on biogas conditioning).

APPENDICES

Appendix A

ART Fuel Specification

(/qs3/pubsys2/xml/en/manual/4021650/4021650-titlepage.html)

General Information

Cummins® natural gas engines provide a low emission alternative for various applications. In order for the engines to continually provide extremely low emission levels and provide the best durability and reliability, Cummins Inc. has developed several fuel standards. Operators of Cummins® natural gas engines should provide the standard or specification to the potential suppliers and request confirmation as to local availability.

For all Cummins® natural gas engines, the methane number based on Society of Automotive Engineers (SAE) 922359, and the higher or lower heating value (as appropriate) **must** equal or exceed those shown in the table below. As new ratings are developed and released, these values may change based on engine ratings.

These specifications apply to fuel as it is delivered to the engine, regardless of whether its origin was liquid or gaseous. Liquefied Natural Gas (LNG) is an acceptable fuel, provided the on-board fuel storage and supply system delivers proper pressure, temperature, and complete vaporization to the engine fuel system inlet. These specifications are **not** intended to cover certification requirements. The fuel **must not** contain water, dust, sand, dirt, oils, or any other substance or component in an amount that is detrimental to the operation of the engine. More specifications and test methods are detailed in these standards.

Cummins® natural gas engines are designed and adjusted to meet performance and emissions standards with fuel meeting these specifications. The engine may operate on fuels possessing a wide range of properties, but performance and emissions will be affected. In extreme cases, fuel with characteristics outside of these specifications can cause engine reliability or durability issues. Cummins Inc. assumes no responsibility for the use of fuels that do **not** meet these specifications. Engine damage caused by fuel **not** meeting these specifications is **not** covered by warranty.

Operators **must** be alert for sudden changes in engine operation, power levels, or the presence of knock. Each of these issues can be a sign of substandard fuel. If an issue related to fuel quality is suspected, ask the fuel supplier to sample and analyze the fuel in the vehicle. Contact a Cummins® Authorized Repair Location for information regarding calculating methane numbers, higher heating values, and lower heating values.

Fuel Standards for Cummins® Natural Gas Engines			
Standard	**Engine Family**		
	B5.9 G, C8.3 G	**ISB5.9 G B Gas International, B Gas Plus, C Gas Plus, L Gas Plus**	**ISL G ISX12 G**
Cummins® Engineering Standards (CES) 14604 Minimum Methane Number: 80 Minimum Higher Heating Value: 975 British Thermal Unit (BTU)/Standard Cubic Feet	Yes		
CES 14624 Minimum Methane Number: 75 Minimum Lower Heating Value: 37448.6 kJ/kg (16100 BTU/lbm)			Units 5054-5257 and 5281-5299 Yes
CES 14608 Minimum Methane Number: 65 Minimum Lower Heating Value: 37448.6 kJ/kg (16100 BTU/lbm)		Units 5258 - 5279 Yes	

The table below shows the basic chemical composition for CES 14604, CES14624, and CES 14608. More information for each standard will follow the chart.

Table 9: CES 14604, CES 14624, and CES 14608 Chemical Composition	
Constituents	**Test Method**
Methane (CH_4)	American Society of Testing and Materials (ASTM) D1945
Ethane (C_2H_6)	ASTM D1945

Table 9: CES 14604, CES 14624, and CES 14608 Chemical Composition	
Constituents	**Test Method**
Propane (C_3H_8)	ASTM D1945
Butane and Heavier (C_4H_{10}+)	ASTM D1945
Carbon Dioxide and Nitrogen (CO_2 + N_2)	ASTM D1945
Hydrogen (H_2)	ASTM D2650
Carbon Monoxide (CO)	ASTM D2650
Oxygen (O_2)	ASTM D1945
Sulfur (S)	Title 17 CCR Section 94112 Method 16

CES 14604 applies to B5.9 G and C8.3 G. For CES 14604, the methane number shall **not** be below 80 and the higher heating value shall **not** be below 975 BTU/Standard Cubic Foot. The methane number and higher heating value are calculated values. For more detail on CES 14604, contact an approved Cummins® authorized repair location.

CES 14624 applies to ISL G and ISX12 G. For CES 14624, the methane number shall **not** be below 75 and the lower heating value should **not** be below 16,100 BTU/lbm. The methane number and lower heating value are calculated values. For more detail on CES 14624, contact an approved Cummins® authorized repair location. The table below specifies the four constitutes in the natural gas mixture that **must** meet certain requirements to be used in the ISL G and ISX12 G engines.

CES 14608 applies to ISB5.9 G, B Gas International, B Gas Plus, C Gas Plus, and L Gas Plus engines. For CES 14608, the methane number shall **not** be below 65 and the lower heating value should **not** be below 16,100 BTU/lbm. The methane number and lower heating value are calculated values. For more detail on CES 14608, contact an approved Cummins® authorized repair location. The table below specifies the four constitutes in the natural gas mixture that **must** meet certain requirements to be used in ISB5.9 G, B Gas International, B Gas Plus, C Gas Plus, and L Gas Plus engines.

CES 14608 and CES 14624 Maximum Allowable Hydrogen, Hydrogen Sulfide, Sulfur, and Siloxanes		
Constituents	**Requirements**	**Test Method**
Hydrogen (H_2)	0.03 percent volume maximum	ASTM D2650
Hydrogen Sulfide (H_2S)	0.0006 percent volume maximum	ASTM D4084
Siloxanes	0.0003 percent volume maximum	Environmental Protection Agency (EPA) TO-14, 15 GC/ELCD,GC/AED, GC/MS

CES 14608 and CES 14624 Maximum Allowable Hydrogen, Hydrogen Sulfide, Sulfur, and Siloxanes		
Constituents	**Requirements**	**Test Method**
Sulfur (S)	0.001 percent weight maximum	Title 17 CCR Section 94112 Method 16

This table is an example using CES 14604 to determine if the fuel meets the fuel standards.

Test Fuel Data Input (See Notes at Right)			
Location (Description)		**Certified Fuel**	**Notes**
Methane	CH_4	90.20 percent	Fuel requirements for automotive spark-ignited gas engines **only**.
Ethane	C_2H_6	4.03 percent	Fuel as delivered to engine, regardless if liquid or gaseous.
Propane	C_3H_8	1.76 percent	The maximum allowable sulfur content is equal to 0.001 percent of the weight.
Butane	C_4H_{10}	0.01 percent	Fuel **must not** contain water, dust, sand, dirt, oils, or any substance that can harm the engine.
Pentane	C_5H_{12}	0.01 percent	
Hexane	C_6H_{14}	0.00 percent	
Heptane	C_7H_{16}	0.00 percent	
Octane	C_8H_{18}	0.00 percent	
Carbon Dioxide	CO_2	0.00 percent	
Nitrogen	N_2	3.99 percent	
Oxygen	O_2	0.00 percent	
Sum of Components		100 percent	
Methane Number:		89.76	**PASS** (Minimum Methane Number: 80)

Test Fuel Data Input (See Notes at Right)		
Location (Description)	**Certified Fuel**	**Notes**
Higher Heating Value (BTU/Standard Cubic Feet)	1024.50	**PASS** (Minimum Higher Heating Value is equal to 975 BTU/Standard Cubic Feet)

Note : Both the methane number and higher heating value criteria **must** be met to pass a given fuel.

L10 G		
CES 20067 Chemical Composition of Fuel		
Constituents	**Requirements**	**Test Method**
Methane (CH_4)	90.0 percent volume minimum	ASTM D1945
Ethane (C_2H_6)	4.0 percent volume maximum	ASTM D1945
Propane (C_3H_8)	1.7 percent volume maximum	ASTM D1945
Butane and Heavier (C_4H_{10}+)	0.7 percent volume maximum	ASTM D1945
Carbon Dioxide (CO_2)	3.0 percent volume maximum	ASTM D1945
Nitrogen (N_2)	3.0 percent volume maximum	ASTM D1945
Hydrogen (H_2)	0.1 percent volume maximum	ASTM D2650
Carbon Monoxide (CO)	0.1 percent volume maximum	ASTM D2650
Oxygen (O_2)	0.5 percent volume maximum	ASTM D1945
Sulfur (S)	0.001 percent weight maximum	Title 17 CCR, Section 94112, Method 16
Wobbe Index	1300 to 1377	ASTM D3588

For further details and discussion of fuels for Cummins® engines, refer to Fuels for Cummins® Engines, Bulletin 3379001 (/qs3/pubsys2/xml/en/bulletin/3379001.html).

This section presents the specifications for liquefied petroleum gas (LPG) engines.

CES 14612 and 14613 have been developed as a specification for LPG fueled engines. Operators of Cummins® LPG engines **must** refer the standard/specification to the potential fuel suppliers and request confirmation as to the local availability.

The requirements apply to fuel as it is delivered to the engine. This specification is **not** intended to cover certification requirements. The fuel **must not** contain water, dust, sand, dirt, oils, or any other substance or component in an amount that is detrimental to the operation of the engine. More specifications and testing methods are detailed in the standard.

- B5.9 LPG engines require fuels which conform to CES 14612.
- B LPG Plus engines include knock sensing and control. Fuels conforming to CES 14612 or CES 14613 can be used with these engines.

CES 14612 Chemical Composition		
Constituents	**Requirements**	**Test Method**
Propane (C_3H_8)	90.0 percent volume minimum	ASTM D 2163
Propylene (C_3H_6)	5.0 percent volume maximum	ASTM D 2163
Butane and Heavier (C_4H_{10}+)	2.5 percent volume maximum	ASTM D 2163
Hydrogen Sulfide (H_2S)	Pass	ASTM D 2420
Sulfur (S)	123 parts per million weight (ppmw)	ASTM D 2784
Oxygen (O_2)	0.5 percent weight maximum	ASTM D 1945
Carbon Dioxide and Nitrogen (CO_2 + N_2)	3.0 percent volume maximum	ASTM D 1945
Vapor Pressure with a gas temperature of 38°C [100°F]	1430 kPa [208 psig] maximum	ASTM D1267
Volatile residue temperature at 95% evaporation	-38.3°C [-37°F] maximum	ASTM D1837
Moisture Content	Pass	ASTM D2713
Copper corrosion strip test	Number 1 maximum	ASTM D1838

CES 14613 Chemical Composition		
Constituents	**Requirements**	**Test Method**
Propane (C_3H_8)	85.0 percent volume minimum	ASTM D 2163
Propylene (C_3H_6)	10.0 percent volume maximum	ASTM D 2163
Butane and Heavier (C_4H_{10}+)	5.0 percent volume maximum	ASTM D 2163
Hydrogen Sulfide (H_2S)	Pass	ASTM D 2420
Sulfur (S)	80 parts per million weight (ppmw)	ASTM D 2784

CES 14613 Chemical Composition		
Constituents	**Requirements**	**Test Method**
Vapor Pressure with a gas temperature of 38°C [100°F]	1430 kPa [208 psig] maximum	ASTM D1267
Volatile residue temperature at 95% evaporation	-38.3°C [-37°F] maximum	ASTM D1837
Moisture Content	Pass	ASTM D2713
Copper corrosion strip test	Number 1 maximum	ASTM D1838

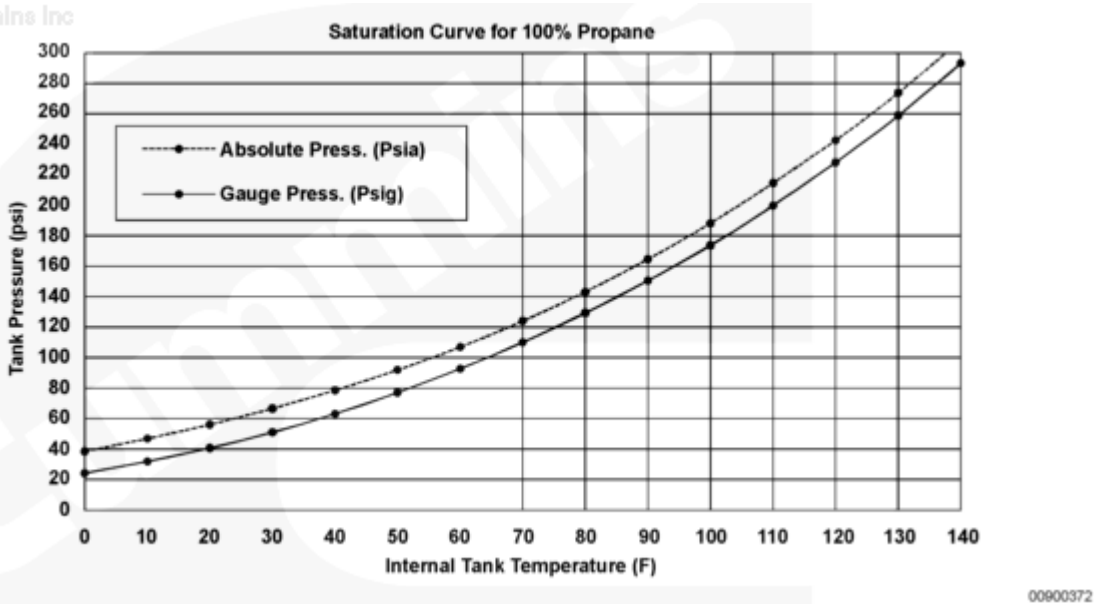
Cummins® LPG engines are designed and adjusted to meet performance and emissions standards with fuel meeting these specifications. The engine may be able to operate on fuels possessing a wide range of properties, but performance and emissions will be affected, and in extreme cases, fuel with characteristics outside of these specifications can cause engine reliability or durability issues. Cummins Inc. assumes no responsibility for the use of fuels that do **not** meet this specification. Engine damage caused by fuel **not** meeting this specification is **not** covered under warranty.

The vehicle supply hose to the engine **must** be approved for use with liquid phase propane (CGA Type III Approved). Engine damage, service issues, or performance issues that occur due to the use of other products are **not** considered a defect in workmanship or material as supplied by Cummins Inc. and can **not** be compensated under the Cummins Inc. warranty.

Operators **must** be alert for sudden changes in engine operation, power levels, or pre-ignition. Each of these can be a sign of substandard fuel. If you suspect an issue related to fuel quality, ask your fuel supplier to sample and analyze the fuel in the vehicle, or contact a Cummins® Authorized Repair Location for assistance.

Fuel pressure control is vital to proper engine operation. Liquid phase propane **must** be supplied to the engine at a steady pressure (+/- 5 psi) under all conditions (temperature and fuel flow rates). Fuel pressure will vary as a function of temperature. Fluctuations can **not** occur rapidly. Reference the engine data sheet for pressure and flow requirements.

For cold weather operation (less than 2°C [35°F]), a pressure assist fuel system may be needed to meet the fuel pressure requirements. The figure: Vehicle LPG Tank - Cold Ambient Effects, shows the pressure/temperature correlation for 100 percent propane.



Vehicle LPG Tank - Cold Ambient Effects

Last Modified: 18-Feb-2016

Appendix B

Detailed Energy Balance

Alternative		1	2A	2B	3A/3B	4A	4B
Description		Process and building heating	CHP with engines	CHP with gas turbine	RNG	RNG with engines	RNG with gas turbine
Thermal Efficiency							
Boilers		80%	80%	80%	80%	80%	80%
CHP							
Steam		0%	18%	50%	0%	18%	50%
Hot Water		0%	24%	0%	0%	24%	0%
Electrical Efficiency		0%	35%	25%	0%	35%	25%
Downtime							
CHP		0%	5%	10%	0%	5%	10%
RNG		0%	0%	0%	5%	5%	5%
RNG % Methane Use		0%	0%	0%	5%	5%	5%
Energy source/use	Unit						
Heat required total	MBH	3,560	3,560	3,560	3,560	3,560	3,560
Steam (hot)	MBH	3,060	3,060	3,060	3,060	3,060	3,060
Hot water							
Building	MBH	70	70	70	70	70	70
Boiler preheat	MBH	430	430	430	430	430	430
Steam total	MBH	3,490	3,490	3,490	3,490	3,490	3,490
Biogas production	MBH	14,870	14,870	14,870	14,870	14,870	14,870
Biogas used							
Boiler total	MBH	4,450	800	450	220	0	0
CHP	MBH	0	13,550	13,410	0	740	320
RNG	MBH	0	0	0	13,420	13,420	13,420
Waste gas flare	MBH	10,420	520	1,010	520	0	420
Tail gas combusted	MBH	0	0	0	710	710	710
Heat production	MBH	3,560	6,330	7,070	3,560	6,990	3,560
Boiler total	MBH	3,560	640	360	3,560	150	360
CHP							
Steam	MBH	0	2,440	6,710	0	2,930	3,200
Hot water	MBH	0	3,250	0	0	3,910	0
Capacity CHP	MBH	0	13,580	13,410	0	16,280	6,410
NG purchased, total	MBH	0	0	0	4,230	15,730	6,540
Boiler	MBH	0	0	0	4,230	340	450
CHP	MBH	0	0	0	0	15,390	6,090
Heating losses, total	MBH	890	3,280	3,440	44	3,745	1,602
Boiler	MBH	890	160	90	44	0	0
CHP	MBH	0	3,120	3,350	0	3,745	1,602
Unused heat	MBH	0	2,750	3,510	0	3,430	0
WPCP Electricity required	MBH	13,600	13,600	13,600	13,600	13,600	13,600
Electricity produced	MBH	0	4,740	3,350	0	5,699	1,602
Equivalent cap. CHP	MW	0	1.39	0.98	0	1.67	0.47
Electricity purchased	MBH	13,600	8,860	10,250	13,600	7,901	11,998

Appendix C

Dominion Energy Sustainability Report

Dominion Energy

Our Company

Metrics

Our story in numbers.

Environmental

Dominion Energy Portfolio

YEAR Baseline	2000 Baseline	2005	2015	2016	2017	2018	2019
Dominion Energy Virginia and Contracted Generation Owned Nameplate Generation Capacity at end of year (MW)	15,147	25,910	22,774	24,604	25,101	25,117	23,768
Coal	5,992	7,937	4,406	4,406	4,402	4,406	3,684
Natural Gas	1,800	7,107	7,836	9,256	9,297	9,187	8,413
Nuclear	3,253	5,726	5,349	5,349	5,349	5,349	5,349
Petroleum	2,476	3,219	2,171	2,171	2,168	2,155	2,143
Total Renewable Energy Resources	1,587	1,921	2,997	3,407	3,870	4,005	4,179
Biomass/Biogas		80	236	236	236	236	153
Geothermal							
Hydroelectric	1,587	1,841	2,120	2,126	2,126	2,124	2,124
Solar			359	763	1,226	1,363	1,752
Wind			282	282	282	282	150
Other	39		15	15	15	15	

Metrics

YEAR Baseline	2000 Baseline	2005	2015	2016	2017	2018	2019
Dominion Energy South Carolina Owned Nameplate Generation Capacity at end of year (MW)	4,483	5,776	5,240	5,239	5,239	5,708	5,651
Coal	2,720	2,590	1,789	1,789	1,789	1,789	1,704
Natural Gas	372	1,719	2,004	2,003	2,003	2,507	2,513
Nuclear	635	644	647	647	647	647	650
Petroleum							
Total Renewable Energy Resources	756	823	800	800	800	765	784
Biomass/Biogas							
Geothermal							
Hydroelectric	756	823	800	800	800	765	784
Solar							
Wind							
Other							
Combined Owned Nameplate Generation Capacity at end of year (MW)	19,630	31,686	28,014	29,843	30,340	30,825	29,419
Coal	8,712	10,527	6,195	6,195	6,191	6,195	5,388
Natural Gas	2,172	8,826	9,840	11,259	11,300	11,694	10,926
Nuclear	3,888	6,370	5,996	5,996	5,996	5,996	5,999
Petroleum	2,476	3,219	2,171	2,171	2,168	2,155	2,143
Total Renewable Energy Resources	2,343	2,744	3,797	4,207	4,670	4,770	4,963
Biomass/Biogas		80	236	236	236	236	153
Geothermal							
Hydroelectric	2,343	2,664	2,920	2,926	2,926	2,889	2,908
Solar			359	763	1,226	1,363	1,752
Wind			282	282	282	282	150
Other	39		15	15	15	15	

Metrics

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017	2018	2019
Dominion Energy Virginia and Contracted Net Generation Production for the data year (MWH)	71,536,133	109,328,723	98,455,046	108,368,094	102,060,029	100,659,937	94,855,233
Coal	37,772,810	51,607,246	22,613,052	21,947,757	15,376,307	12,302,427	7,177,447
Natural Gas	3,698,671	7,728,873	28,858,084	38,370,996	37,654,007	38,838,261	38,386,925
Nuclear	26,552,901	44,164,092	42,888,281	43,951,909	44,548,239	43,541,335	43,833,345
Petroleum	3,021,949	4,710,344	847,768	459,162	271,644	626,111	123,323
Total Renewable Energy Resources	489,802	1,118,168	3,247,861	3,638,270	4,209,832	5,351,803	5,334,193
Biomass/Biogas		540,007	1,193,180	1,266,746	1,163,454	1,196,101	1,007,679
Geothermal							
Hydroelectric	489,802	578,161	613,069	771,100	488,627	850,529	690,754
Solar			747,748	934,322	1,983,498	2,686,996	3,037,885
Wind			693,864	666,103	574,253	618,177	597,876
Other							
Dominion Energy South Carolina Net Generation Production for the data year (MWH)	22,459,240	25,493,722	23,282,862	22,793,374	22,016,656	23,523,302	23,223,220
Coal	17,501,201	17,867,835	10,352,062	8,565,143	8,760,962	8,580,257	6,481,671
Natural Gas	90,882	2,063,550	7,477,292	7,892,092	8,178,640	9,519,949	10,970,384
Nuclear	4,240,198	4,979,600	4,743,582	5,772,294	4,610,254	4,910,880	5,483,003
Petroleum							
Total Renewable Energy Resources	626,959	582,737	709,926	563,845	466,800	512,217	288,162
Biomass/Biogas	382,880	154,836	321,718	312,548	305,081	150,181	
Geothermal							
Hydroelectric	244,079	427,901	388,208	251,297	161,719	362,036	288,162
Solar							
Wind							
Other							

Metrics

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017	2018	2019
Combined Net Generation Production for the data year (MWH)	93,995,373	134,822,445	121,737,908	131,161,469	124,076,685	124,183,240	118,078,453
Coal	55,274,011	69,475,081	32,965,114	30,512,900	24,137,269	20,882,684	13,659,118
Natural Gas	3,789,553	9,792,423	36,335,376	46,263,088	45,832,647	48,358,209	49,357,309
Nuclear	30,793,099	49,143,692	47,631,863	49,724,203	49,158,493	48,452,215	49,316,348
Petroleum	3,021,949	4,710,344	847,768	459,162	271,644	626,111	123,323
Total Renewable Energy Resources	1,116,761	1,700,905	3,957,788	4,202,116	4,676,632	5,864,020	5,622,355
Biomass/Biogas	382,880	694,843	1,514,898	1,579,294	1,468,535	1,346,282	1,007,679
Geothermal							
Hydroelectric	733,881	1,006,062	1,001,277	1,022,397	650,346	1,212,565	978,916
Solar			747,748	934,322	1,983,498	2,686,996	3,037,885
Wind			693,864	666,103	574,253	618,177	597,876
Other							

YEAR	2017	2018	2019
Miles Distribution Lines-Electric (regulated utility)	58,277	58,300	85,000
Miles Transmission Lines-Electric (regulated utility) Includes circuit miles, including overhead and underground lines	6,600	6,700	10,400

Air[1]

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017[2]	2018[3]	2019
Carbon Emissions Dominion Energy Virginia & Contracted Generation							
Total generation (net MWh) (by ownership)	71,536,133	109,328,723	98,455,046	108,368,094	102,060,029	100,659,937	94,855,233
Total CO_2 emissions (MT) (by ownership)	41,989,458	57,262,200	33,761,475	36,659,419	29,945,097	27,659,008	21,854,373
CO_2 intensity rate (MT/net MWh) (by ownership)	0.587	0.524	0.343	0.338	0.293	0.275	0.230
Total CO_2e emissions (MT) (by ownership)	42,298,827	58,025,709	34,253,305	37,186,655	30,155,246	27,763,387	21,982,856
CO_2e intensity rate (MT/net MWh) (by ownership)	0.591	0.531	0.348	0.343	0.295	0.276	0.232

[1] Reported carbon emissions (CO_2) includes emissions from electric generating units (EGUs). Carbon equivalent emissions (CO_2e) includes emissions from EGUs and other minor combustion sources, such as ancillary and auxiliary equipment, associated with electric generation operations. Note: This excludes sulfur hexafluoride reported as CO_2e, which includes emissions from power delivery transmission and delivery operations.

[2] By way of clarification and transparency, the company is restating its 2017 emissions as a result of a calculation update.

[3] By way of clarification and transparency, the company is restating its 2018 intensity rate as a result of updated MWhs.

Air[1] (continued)

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017[2]	2018[3]	2019
Carbon Emissions Dominion Energy South Carolina							
Total generation (net MWh) (by ownership)	22,459,240	25,493,722	23,282,862	22,793,374	22,016,656	23,523,302	23,223,220
Total CO_2 emissions (MT) (by ownership)	16,115,664	17,035,669	12,008,478	11,081,704	11,426,554	11,522,827	9,820,746
CO_2 intensity rate (MT/net MWh) (by ownership)	0.718	0.668	0.516	0.486	0.519	0.490	0.423
Total CO_2e emissions (MT) (by ownership)	17,727,230	18,739,236	12,087,352	10,930,629	11,494,249	11,644,685	9,907,987
CO_2e intensity rate (MT/net MWh) (by ownership)	0.789	0.735	0.519	0.480	0.522	0.495	0.427
Carbon Emissions Combined							
Total generation (net MWh) (by ownership)	93,995,373	134,822,445	121,737,908	131,161,469	124,076,685	124,183,240	118,078,453
Total CO_2 emissions (MT) (by ownership)	58,105,122	74,297,869	45,769,953	47,741,123	41,371,652	39,181,835	31,675,119
CO_2 intensity rate (MT/net MWh) (by ownership)	0.618	0.551	0.376	0.364	0.333	0.316	0.268
Total CO_2e emissions (MT) (by ownership)	60,026,057	76,764,945	46,340,656	48,117,284	41,649,495	39,408,072	31,890,844
CO_2e intensity rate (MT/net MWh) (by ownership)	0.639	0.569	0.381	0.367	0.336	0.317	0.270

Air[1] (continued)

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017[2]	2018[3]	2019
Purchased Power[4] Emissions (Net MWH) Dominion Energy Virginia	16,753,741	18,987,726	14,656,975	7,486,404	13,419,239	18,600,961	15,607,678
Total Purchased Generation CO_2 Emissions (MT)	12,159,115	13,780,442	10,637,376	5,443,297	8,399,959	10,968,543	8,637,107
Total Purchased Generation CO_2 Emissions Intensity (MT/Net MWH)	0.73	0.73	0.73	0.73	0.63	0.59	0.55
Carbon Dioxide Equivalent (CO_2e)							
Total Purchased Generation CO_2e Emissions (MT)	13,604,038	15,418,034	11,901,464	6,078,960	9,239,955	12,065,397	9,500,818
Total Purchased Generation CO_2e Emissions Intensity (MT/Net MWH)	0.812	0.812	0.812	0.812	0.69	0.65	0.61
Purchased Power[5] Emissions (Net MWH) Dominion Energy South Carolina	2,338,904	831,683	1,219,892	1,986,931	2,195,328	1,332,503	1,144,067
Total Purchased Generation CO_2 Emissions (MT)	1,547,978	478,330	535,759	942,564	971,451	161,986	114,343
Total Purchased Generation CO_2 Emissions Intensity (MT/Net MWH)	0.662	0.575	0.439	0.474	0.443	0.122	0.100
Carbon Dioxide Equivalent (CO_2e)							
Total Purchased Generation CO_2e Emissions (MT)	1,702,776	526,163	589,335	1,036,821	1,068,596	178,185	114,974
Total Purchased Generation CO_2e Emissions Intensity (MT/Net MWH)	0.73	0.63	0.48	0.52	0.49	0.13	0.10
Purchased Power Emissions (Net MWH) Combined	19,092,645	19,819,409	15,876,867	9,473,335	15,614,567	19,933,464	16,751,745
Total Purchased Generation CO_2 Emissions (MT)	13,707,093	14,258,772	11,173,135	6,385,861	9,371,410	11,130,529	8,751,450
Total Purchased Generation CO_2 Emissions Intensity (MT/Net MWH)	0.72	0.72	0.70	0.67	0.60	0.56	0.52
Carbon Dioxide Equivalent (CO_2e)							
Total Purchased Generation CO_2e Emissions (MT)	15,306,814	15,944,197	12,490,799	7,115,781	10,308,551	12,243,582	9,615,792
Total Purchased Generation CO_2e Emissions Intensity (MT/Net MWH)	0.80	0.80	0.79	0.75	0.66	0.61	0.57

[4]DEVA Purchased power and non-utility generators (NUGs) emissions are calculated based on PJM's CO_2 Emissions Intensity Factor published annually. CO_2e calculated using a conversion factor.

[5]DESC Purchased power emissions are calculated using EPA's eGRID (https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid) factors for the North American Electric Reliability Corporation (NERC) subregion. CO_2e calculated using a conversion factor.

Air[1] (continued)

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017[2]	2018[3]	2019
Owned Generation + Purchased Power[4] Emissions (Net MWH) Dominion Energy Virginia & Contracted Generation	88,289,874	128,316,449	113,112,021	115,854,498	115,479,268	119,260,898	110,462,911
Total Owned + Purchased Generation CO_2 Emissions (MT)	54,148,573	71,042,641	44,398,851	42,102,716	38,345,056	38,627,551	30,491,480
Total Owned + Purchased Generation CO_2 Emissions Intensity (MT/Net MWH)	0.613	0.554	0.393	0.363	0.332	0.324	0.276
Carbon Dioxide Equivalent (CO_2e)							
Total Owned + Purchased Generation CO_2e Emissions (MT)	56,223,338	73,443,743	46,154,769	43,265,615	39,395,201	39,828,784	31,483,674
Total Owned + Purchased Generation CO_2e Emissions Intensity (MT/Net MWH)	0.637	0.572	0.408	0.373	0.341	0.334	0.285
Owned Generation + Purchased Power[5] Emissions (Net MWH) Dominion Energy South Carolina	24,798,144	26,325,405	24,502,754	24,780,305	24,211,984	24,855,805	24,367,287
Total Owned + Purchased Generation CO_2 Emissions (MT)	17,663,642	17,513,999	12,544,237	12,024,268	12,398,005	11,684,813	9,935,089
Total Owned + Purchased Generation CO_2 Emissions Intensity (MT/Net MWH)	0.712	0.665	0.512	0.485	0.512	0.470	0.408
Carbon Dioxide Equivalent (CO_2e)							
Total Owned + Purchased Generation CO_2e Emissions (MT)	31,331,268	19,265,399	12,676,687	11,967,450	12,562,845	11,822,870	10,022,961
Total Owned + Purchased Generation CO_2e Emissions Intensity (MT/Net MWH)	1.263	0.732	0.517	0.483	0.519	0.476	0.411
Owned Generation + Purchased Power[2] Emissions (Net MWH) Combined	113,088,018	154,641,854	137,614,775	140,634,804	139,691,252	144,116,704	134,830,198
Total Owned + Purchased Generation CO_2 Emissions (MT)	71,812,215	88,556,641	56,943,089	54,126,984	50,743,062	50,312,364	40,426,569
Total Owned + Purchased Generation CO_2 Emissions Intensity (MT/Net MWH)	0.635	0.573	0.414	0.385	0.363	0.349	0.300
Carbon Dioxide Equivalent (CO_2e)							
Total Owned + Purchased Generation CO_2e Emissions (MT)	87,554,606	92,709,142	58,831,455	55,233,064	51,958,046	51,651,654	41,506,635
Total Owned + Purchased Generation CO_2e Emissions Intensity (MT/Net MWH)	0.774	0.600	0.428	0.393	0.372	0.358	0.308

[4]DEVA Purchased power and non-utility generators (NUGs) emissions are calculated based on PJM's CO_2 Emissions Intensity Factor published annually. CO_2e calculated using a conversion factor.

[5]DESC Purchased power emissions are calculated using EPA's eGRID (https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid) factors for the North American Electric Reliability Corporation (NERC) subregion. CO_2e calculated using a conversion factor.

Air[1] (continued)

YEAR	2015	2016	2017[2]	2018[3]	2019
Methane Emissions Dominion Energy					
Methane Emissions from Gas Operations* (MT)	53,328	60,838	62,625	63,543	59,996
Methane Emissions Dominion Energy South Carolina					
Methane Emissions from Gas Operations* (MT)	3,621	3,771	3,958	3,905	3,910
Methane Emissions Combined					
Methane Emissions from Gas Operations* (MT)	56,949	64,609	66,583	67,448	63,906

*As reported in EPA's GHG reporting program. In 2016, Dominion Energy began reporting additional emissions from pipeline blowdowns, gathering and boosting as part of EPA's reporting program.

YEAR	2000 Basline	2005 Baseline	2015	2016	2017[2]	2018[3]	2019
Other Air Emissions Dominion Energy Virginia & Contracted Generation							
Nitrogen oxide, sulfur dioxide and mercury generation basis for calculation (MWH)	71,421,615	108,511,203	97,958,771	108,050,001	101,775,887	100,374,893	94,710,520
Nitrogen oxide emissions (MT) (by ownership)	132,895	101,106	15,361	13,883	10,559	10,621	7,121
Nitogen oxide emissions intensity (MT/net MWH) (by ownership)	0.001861	0.000932	0.000157	0.000128	0.000104	0.000106	0.000075
Sulfur dioxide emissions (MT) (by ownership)	372,732	283,213	12,921	9,665	5,490	7,439	2,956
Sulfur dioxide emissions intensity (MT/net MWH) (by ownership)	0.005219	0.002610	0.000132	0.000089	0.000054	0.000074	0.000031
Mercury emissions (kg) (by ownership)	2,194	931	54	52	32	31	33
Mercury emissions intensity (kg/net MWH) (by ownership)	0.0000307	0.0000086	0.0000006	0.0000005	0.0000003	0.0000003	0.0000004
Sulfur hexafluoride (MT)			2.36	1.9	1.66	1.75	1.68
CO_2e of sulfur hexafluoride (MT)			53,819	42,847	37,841	39,900	38,338

Air[1] (continued)

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017[2]	2018[3]	2019
Other Air Emissions Dominion Energy South Carolina							
Nitrogen oxide, sulfur dioxide and mercury generation basis for calculation (MWH)	22,459,240	25,493,722	23,282,862	22,793,374	22,016,656	23,523,302	23,223,220
Nitrogen oxide emissions (MT) (by ownership)	165,190	125,517	20,582	18,795	15,743	15,749	12,094
Nitogen oxide emissions intensity (MT/net MWH) (by ownership)	0.007355	0.004923	0.000884	0.000825	0.000715	0.000670	0.000521
Sulfur dioxide emissions (MT) (by ownership)	432,702	354,976	16,309	11,181	7,449	9,031	4,326
Sulfur dioxide emissions intensity (MT/net MWH) (by ownership)	0.019266	0.013924	0.000700	0.000491	0.000338	0.000384	0.000186
Mercury emissions (kg) (by ownership)	1,253	1,034	63	59	40	42	42
Mercury emissions intensity (kg/net MWH) (by ownership)	0.0000558	0.0000406	0.0000027	0.0000026	0.0000018	0.0000018	0.0000018
Sulfur hexafluoride (MT)			0.521	0.457	0.167	0.542	0.467
CO_2e of sulfur hexafluoride (MT)			11,455	10,049	3,678	11,914	10,265
Other Air Emissions Combined							
Nitrogen oxide, sulfur dioxide and mercury generation basis for calculation (MWH)	93,880,855	134,004,925	121,241,633	130,843,375	123,792,543	123,898,196	117,933,740
Nitrogen oxide emissions (MT) (by ownership)	298,085	226,623	35,943	32,678	26,302	26,370	19,214
Nitogen oxide emissions intensity (MT/net MWH) (by ownership)	0.003175	0.001691	0.000296	0.000250	0.000212	0.000213	0.000163
Sulfur dioxide emissions (MT) (by ownership)	805,434	638,189	29,230	20,846	12,939	16,470	7,282
Sulfur dioxide emissions intensity (MT/net MWH) (by ownership)	0.008579	0.004762	0.000241	0.000159	0.000105	0.000133	0.000062
Mercury emissions (kg) (by ownership)	3,447	1,965	117	111	72	73	76
Mercury emissions intensity (kg/net MWH) (by ownership)	0.0000367	0.0000147	0.0000010	0.0000008	0.0000006	0.0000006	0.0000006
Sulfur hexafluoride (MT)			2.881	2.357	1.827	2.292	2.148
CO_2e of sulfur hexafluoride (MT)			65,274	52,896	41,519	51,814	48,604

Water

YEAR	2000 Baseline	2005 Baseline	2015	2016	2017	2018	2019
Dominion Energy Virginia							
Water reused/recycled (million liters) (by ownership)			2,097	5,598	5,066	4,194,700	3,139,995
Water reused/recycled (million liters/net MWH) (by ownership)			0.00002	0.00005	0.00005	0.041	0.033
Fresh water withdrawn (billion liters)			7,984	7,760	7,625	6,885	6,815
Fresh water consumed (billion liters)			33.2	38	29	16.7	20
Water withdrawals - consumptive (billion liters/net MWH)	0.0000006	0.00000007	0.00000026	0.0000004	0.00000003	0.00000017	0.00000021
Water withdrawals - non-consumptive (billion liters/net MWH)	0.000142	0.000133	0.000082	0.0000703	0.000074	0.000068	0.000072
Dominion Energy South Carolina							
Water reused/recycled (million liters) (by ownership)			3,186,805	6,193,075	4,997,274	5,457,708	5,804,755
Water reused/recycled (million liters/net MWH) (by ownership)			0.27	0.62	0.48	0.47	0.59
Fresh water withdrawn (billion liters)			1,896	1,770	1,435	1,777	1,807
Fresh water consumed (billion liters)			18.1	17.7	18.9	16.2	5.3
Water withdrawals - consumptive (billion liters/net MWH)			0.00000074	0.00000071	0.00000078	0.00000069	0.00000023
Water withdrawals - non-consumptive (billion liters/net MWH)			0.000077	0.000071	0.000059	0.000071	0.000078
Combined							
Water reused/recycled (million liters) (by ownership)			3,188,902	6,198,673	5,002,340	9,652,408	8,944,750
Water reused/recycled (million liters/net MWH) (by ownership)			0.27	0.62	0.48	0.51	0.62
Fresh water withdrawn (billion liters)			9,880	9,530	9,060	8,662	8,622
Fresh water consumed (billion liters)			51.3	55.7	47.9	32.9	25.3
Water withdrawals - consumptive (billion liters/net MWH)			0.00000042	0.00000042	0.00000039	0.00000026	0.00000021
Water withdrawals - non-consumptive (billion liters/net MWH)			0.000081	0.000073	0.000073	0.000069	0.000073

*The significant increase is due to the inclusion of Bath County Pumped Storage and the Nuclear facilities that withdrawal/discharge water from the same source as reused/recycled water, in addition to improved accounting.

Recycled and Reused Materials

YEAR	2015	2016	2017	2018	2019
Dominion Energy					
Coal combustion byproducts (tons)*	776,765	718,257	433,927	340,695	399,901
Gypsum (tons)	193,747	191,071	110,503	97,157	319,516
Biomass combustion products (tons)	13,896	7,473	7,110	6,564	13,066
Oils, fluids for reclamation/recovery (tons)	10,241	12,335	11,151	10,481	832
Scrap metals (tons)	8,145	20,553	17,661	18,973	15,431
Paper, cardboard, plastic, glass (tons)	721	495	528	724	4,543
E-waste (tons)	14	34	50	54	4.41
Dominion Energy South Carolina					
Coal combustion byproducts (tons)*	474,139	538,330	507,294	377,973	387,769
Gypsum (tons)	135,481	129,626	129,835	48,851	159,401
Biomass combustion products (tons)	0	0	0	0	0
Oils, fluids for reclamation/recovery (tons)	1,071	916	787	861	564
Scrap metals (tons)	11,694	17,273	5,273	3,415	4,911
Paper, cardboard, plastic, glass (tons)	499	544	540	493	614
E-waste (tons)	22.26	17.06	12.14	16.25	41.90
Combined					
Coal combustion byproducts (tons)*	1,250,904	1,256,587	941,221	718,668	787,670
Gypsum (tons)	329,228	320,697	240,338	146,008	478,917
Biomass combustion products (tons)	13,896	7,473	7,110	6,564	13,066
Oils, fluids for reclamation/recovery (tons)	11,312	13,251	11,938	11,342	1,397
Scrap metals (tons)	19,839	37,826	22,934	22,388	20,342
Paper, cardboard, plastic, glass (tons)	1,220	1,039	1,068	1,217	5,157
E-waste (tons)	36.26	51.06	62.14	70.25	46.31

*The amount of CCB material recycled includes material from newly generated CCB, reuse of deposited material, and material from storage unit closures.

Other

YEAR	2015	2016	2017	2018	2019
Dominion Energy					
Coal ash produced / reused (million tons) (by ownership)	3.3/0.6	3.2/0.5	2.53/0.5	2.21/0.34	1.2/0.08
Coal combustion byproducts produced / reused (million tons) (by ownership)	3.4/0.8	3.4/0.7	2.53/0.5	2.31/0.44	1.62/0.4
Percent of coal combustion byproducts reused / recycled (by ownership)	24%	21%	20%	19%	25%
Hazardous waste produced (million lbs) (by ownership)	2.39	3.67	3.56	3.72	11.1
Notices of violation (NOVs)	12	11	15	18	19
Environmental penalties paid	$447,732	$404,415	$175,124	$485,111	$168,200
Dominion Energy South Carolina					
Coal ash produced / reused (million tons) (by ownership)	0.42/0.34	0.38/0.4	0.44/0.37	0.43/0.33	0.29/0.23
Coal combustion byproducts produced / reused (million tons) (by ownership)	0.59/0.47	0.53/0.54	0.59/0.51	0.61/0.38	0.4/0.39
Percent of coal combustion byproducts reused / recycled (by ownership)	81%	101%*	86%	62%	98%
Hazardous waste produced (million lbs) (by ownership)	< 0.05	0.015	0.044	0.016	0.005
Notices of violation (NOVs)	2	1	2	0	1
Environmental penalties paid	$0	$0	$3,200	$0	$10,000
Combined					
Coal ash produced / reused (million tons) (by ownership)	3.7/0.9	3.5/0.9	2.9/0.8	2.6/0.6	1.5/0.3
Coal combustion byproducts produced / reused (million tons) (by ownership)	3.99/1.27	3.9/1.2	3.1/1.0	2.9/0.78	2.01/0.79
Percent of coal combustion byproducts reused / recycled (by ownership)	32%	31%	32%	27%	39%
Hazardous waste produced (million lbs) (by ownership)	2.39	3.69	3.60	3.74	11.10
Notices of violation (NOVs)	14	12	17	18	20
Environmental penalties paid	$447,732	$404,415	$178,324	$485,111	$178,200

*The amount of CCB material recycled includes material from newly generated CCB, reuse of deposited material, and material from storage unit closures.

Appendix D

Biogas Conditioning Technical Memo

Technical Memorandum No. 16

Date:	November 30, 2022
Project:	Arlington County Biosolids Program Management Services
To:	Mary Strawn Lisa Racey
From:	HDR
Subject:	Biogas Conditioning Evaluation

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1.0 Introduction

This introductory section presents the background and purpose of this project and the biogas conditioning evaluation, followed by a description of the evaluation approach.

1.1 Background and Purpose

Arlington County (County) is implementing a program of biosolids management improvements at the Arlington Water Pollution Control Plant (WPCP). Currently, solids handling includes primary sludge (PS) and waste activated sludge (WAS) thickening, dewatering, and Class B lime stabilization of undigested solids. Planned improvements will replace the existing lime stabilization process with a Class A THP and anaerobic digestion, as recommended in the 2018 Solids Master Plan report (Master Plan) for the WPCP.

The purpose of this biogas conditioning evaluation is to further assess requirements and technologies for biogas conditioning. The results of this evaluation will inform a final decision on which technology will be chosen for biogas conditioning.

1.2 Evaluation Approach

A suite of alternatives using various biogas conditioning technologies was developed. Conceptual process conditions, configurations, cooling technology sizing, and conceptual operation costs were prepared and then presented and reviewed at the July 22, 2021 and August 30, 2021 project workshops with the County. In this evaluation, the technologies are evaluated and compared based on budgetary capital equipment costs, conceptual operating cost estimates, and non-cost considerations including space requirements and noise. A 20-year life-cycle cost analysis was also completed.

2.0 Biogas Conditioning

The level of biogas conditioning required is directly related to the end use of the biogas. With the recommended alternative of upgrading the biogas to renewable natural gas, the required biogas conditioning will include H_2S, moisture, siloxane, carbon dioxide, and volatile organic compound (VOC) removal with compression and tail gas disposal. Emergency biogas disposal will be through a waste gas flare.

2.1 Hydrogen Sulfide Removal

Hydrogen sulfide removal would be required for any of the gas utilization alternatives considered. When hydrogen sulfide (H_2S) is combusted (either onsite in boilers or engines or offsite as RNG), sulfur dioxide forms. This can condense into sulfuric acid with the presence of water vapor and cause significant corrosion issues. Removing H_2S prior to combustion reduces the likelihood of corrosion. Hydrogen sulfide is typically removed by precipitating the dissolved sulfide in the anaerobic digesters (thus preventing its formation in the biogas) or by directly removing the hydrogen sulfide from the biogas in a biogas scrubber. Removal with biogas scrubbers requires the gas to be fully saturated with moisture to reduce safety concerns (fires) associated with the exothermic nature of the treatment process. Therefore, hydrogen sulfide is normally the first constituent removed from raw biogas in traditional biogas uses as the raw biogas is fully saturated,

The Arlington WPCP currently uses iron salt addition, in the form of ferric chloride ($FeCl_3$), to provide chemical phosphorus removal in the liquid stream process. $FeCl_3$ is added at multiple locations in the process including the primary clarifiers and secondary clarifiers to precipitate dissolved orthophosphate, which ends up in the solids treatment train. At the current high dosage levels, it is anticipated that a significant amount of dissolved hydrogen sulfide in the digesters will also be precipitated along with the phosphate, which will

significantly lower the H_2S concentrations in the biogas. If this practice continues, the H_2S concentrations in the biogas may be below 200 ppm, in which case no further removal would be required for any of the alternatives. However, if the facility were to move away from chemical phosphorus removal to an enhanced biological phosphorus removal (EBPR) approach, hydrogen sulfide concentrations would increase and additional treatment would be required. For the purposes of this alternative, H_2S removal is retained in all alternatives. Pilot testing currently being conducted by Virginia Tech will provide data on potential H_2S concentrations in the biogas and ultimately inform the final design.

2.1.1 Precipitation with Iron Salt Addition

Iron salts combine chemically with dissolved sulfide to form relatively insoluble metal sulfides that precipitate from the wastewater, thus preventing the release of H_2S gas. Iron sulfide precipitates exist as soft, black, or reddish-brown flocs that usually do not settle well in the collection system but are easily removed at treatment plants. Sulfur precipitation with iron salts has the following advantages and disadvantages:

- Advantages:
    - Long residuals can be maintained to precipitate sulfides as they are generated.
    - Iron salts Iron salts can be used to treat sludge or full wastewater flows.
    - Reaction by-products are harmless.
    - The precipitates are beneficial to downstream treatment processes because they help increase settling and remove phosphorus.
- Disadvantages:
    - Precipitates can dissociate at lower pH levels (less than 6.5), allowing sulfides to release back into the wastewater.
    - Dissolved sulfide cannot be decreased to much lower than 0.2 to 0.5 milligram per liter (mg/L) using iron salts.
    - Iron salts can form a film on pipe walls, instrument sensors, and ultraviolet treatment equipment.
    - Precipitates increase sludge production.

As stated previously, the Arlington WPCP currently uses iron salt addition, in the form of FeCl3, to provide chemical phosphorus removal in the liquid stream process. A stoichiometric dose of 3.3 to 4.9 pounds of FeCl3 is required per pound of sulfide. However, field and laboratory experiments indicate that the typical required dose to remove sulfide in domestic wastewater is between 3 and 7 pounds of FeCl3 per pound of sulfide removed. In the near term, it is anticipated that the WPCP will continue to utilize FeCl3 optimized for phosphorus (not sulfide removal). Impacts of this $FeCl_3$ dosing strategy on biogas H_2S removal will be evaluated in on-going pilot tests with Virginia Tech.

2.1.2 Adsorptive Media

Adsorptive media is commonly used to remove hydrogen sulfide from biogas ahead of downstream unit processes. Hydrogen sulfide is removed by chemical adsorption in the fixed-media vessel using metal oxides. Common media types include iron sponge, Sulfatreat™, and other proprietary products.

Iron sponge media is typically wood chips impregnated with iron oxide. The iron oxide reacts with the hydrogen sulfide and binds to the media as iron sulfide and water. The metal sulfides are contained within the media. Once the media is spent, it must be replaced. Engineered iron oxide media, such as Sulfatreat™, is also available for H_2S removal. This media is typically more expensive than iron sponge but is easier to

remove once the media is exhausted. The primary advantages of the solid media technology are the passive operation, simple use, and reliability. If the $FeCl_3$ addition continues, the County's low H_2S concentrations will likely require infrequent media replacement.

Several companies manufacture the adsorptive media treatment systems for installation in the United States. Common iron sponge providers for installation at wastewater treatment plants include Unison Solutions, Marcab, Varec Biogas, and DMT Clear Gas Solutions. Figure 1 shows a photo of an adsorptive media system installation.

Figure 1. Adsorptive Media Installation Example

Table 1 below presents the advantages and disadvantages of the H_2S removal technologies.

Table 1. Advantages and Disadvantages of H_2S Removal Technologies

Alternative	Advantages	Disadvantages
Iron salt addition	• Already used at WPCP • Improves phosphorus removals and odor control • Can achieve good H_2S removal with high doses	• Safety considerations with storage and feed facilities • May not be used in the future if WPCP switches to biological phosphorus removal • High costs of chemicals
Adsorptive media (iron sponge)	• Proven technology with many installations • Simple configuration with no moving parts • Removes sulfur from the system • Lower media replacement costs at concentrations anticipated with iron salt addition	• Higher media replacement costs at anticipated H_2S levels without iron salt addition • Media can combust

2.2 Moisture Removal

Biogas is saturated with moisture as it leaves the digester and nearly all end uses require at least some level of moisture removal. For RNG, moisture must be nearly completely removed to meet injection specifications. It is recommended that a two-step process be used for moisture removal, where the first step is mechanical

refrigeration for the bulk of the moisture, followed by an adsorption technology for final biogas drying. Figure 2 presents an example of a moisture removal installation.

Figure 2. Moisture Removal Installation Example

2.3 Siloxane and VOC Removal

Siloxanes and VOCs are typically removed following moisture removal and initial compression, as the vessels have higher head loss and require a dry gas environment to work properly. Siloxanes and VOCs at normal levels within biogas (between 1 and 5 parts per million by volume [ppmv]) are removed using similar solid sorptive media as with hydrogen sulfide, described above. The most common media choice is activated carbon. In addition to siloxane removal, the media also serves as polishing to remove residual hydrogen sulfide and VOCs that may be in the biogas. Because of this polishing, the media is exhausted as much by residual hydrogen sulfide and VOCs as it is by siloxanes. Figure 3 presents an example of siloxane removal equipment and media.

Figure 3. Siloxane Removal Equipment and Media

Caution should be used with media selection because gas flow is very important for effective removal. If the media size is too large, at lower gas flow rates the flow will channelize, resulting in breakthrough occurring because media is exhausted in a concentrated area, while the overall bed is in good condition. Small media size will distribute flow better. However, if flows are higher, small media size will result in high pressure drops and potentially fluidizing the bed, leading to carry-over of media out of the treatment vessel. Careful coordination between the engineers and vendors on the range of gas flows is important for selection of media size.

2.4 Carbon Dioxide Removal

Biogas treatment to natural gas quality requires the removal of carbon dioxide from the biogas stream. Several technologies are available to condition the biogas to RNG quality, including water wash, pressure swing adsorption (PSA), and membranes. These technologies are described in more detail later in this Chapter, but Table 2 provides a summary of the advantages and disadvantages of each.

Table 2. Biogas Storage Scenarios

Alternative	Advantages	Disadvantages
Water wash	• Proven technology with many installations • No media to be replaced • High CH_4 recovery (98%) at design efficiency point	• More appropriate for larger installations (>750 scfm) • Requires high-pressure water (~150 psig) and water cooling • Requires post-scrubbing drying • Reduction in CH_4 recovery efficiency at turndown • Moderate energy use
PSA	• Proven technology with many installations • Regenerative adsorbent has long media life	• Lowest CH_4 recovery (95%) • Continuous actuation of vessel valves during operation is loud and causes mechanical wear of equipment • Moderate energy use
Membrane	• Proven technology with many installations • Highest CH_4 recovery (99%) with three-pass system • Fewer moving parts • Modular design • Good for smaller installations (<600 scfm)	• Requires separate upstream treatment of H_2S, VOCs, and siloxanes • Requires multiple passes to get higher CH_4 recovery • Higher energy use

2.5 Waste Gas Management

In addition to biogas treatment options, there are alternatives for how to properly dispose of waste gas generated at the WPCP. Below are the viable options for waste gas management at Arlington County WPCP.

2.5.1 Enclosed Waste Gas Flares

The most common method of waste gas disposal is with a waste gas flare. Waste gas flares are mostly used to combust raw biogas or off-spec RNG that is higher in heating value, or Btu content, and can provide self-sustaining direct combustion. Waste gas flares are always provided at anaerobic digestion facilities as a safety provision to be able to dispose of the flammable biogas during system downtime regardless of the biogas utilization method. Because of the visibility of the WPCP and footprint constraints an enclosed waste gas flare is recommended for the Arlington WPCP. An example of an enclosed flare is shown in Figure 4.

Figure 4. Enclosed Waste Gas Flare

2.5.2 Regenerative Thermal Oxidizers

For lower-Btu waste gases, or tail gas, produced as a by-product from the processing of RNG, RTOs are often used. RTOs provide higher efficiencies than regular thermal oxidizers when the waste gas does not have the Btu content to provide self-sustaining combustion. They provide this efficiency with a common combustion chamber and two sets of ceramic media with switching valves to capture and reuse the heat provided by the combustion to preheat the incoming waste gas. Once the heat is recovered from one combustion cycle the waste gas flow is reversed with the valves to recover heat from the recently combusted gas. An RTO is shown in Figure 5 and Figure 6.

Like any other form of thermal oxidation, a startup burner (fueled by natural gas) is employed to raise the temperature of the unit to proper destruction conditions. Once at the proper temperature, the process gas can be introduced and blended with the correct amount of dilution/combustion air, and the RTO cycles through the combustion sequence. The burner provides supplemental fuel to maintain the combustion chamber temperature should the heat content fall below that required for self-sustaining operation. Using a hot-gas bypass can expand the range of possible operating conditions by diverting some of the combusted air directly to atmosphere, rather than sending it through the heat-recovery media.

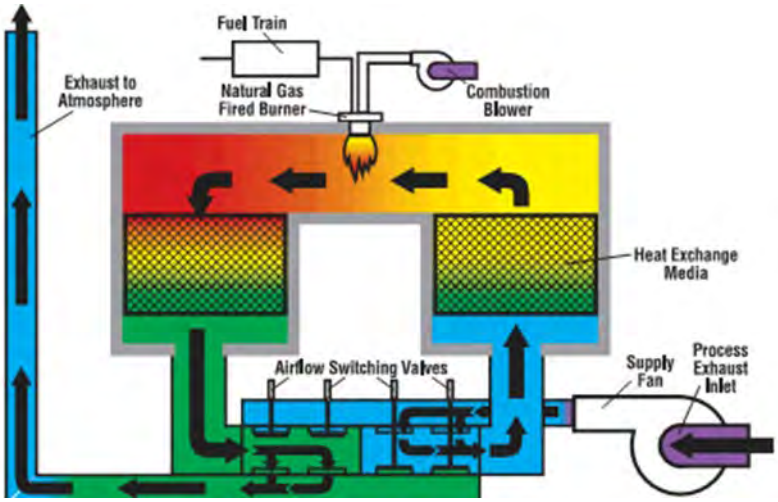

Figure 5. Regenerative Thermal Oxidizer

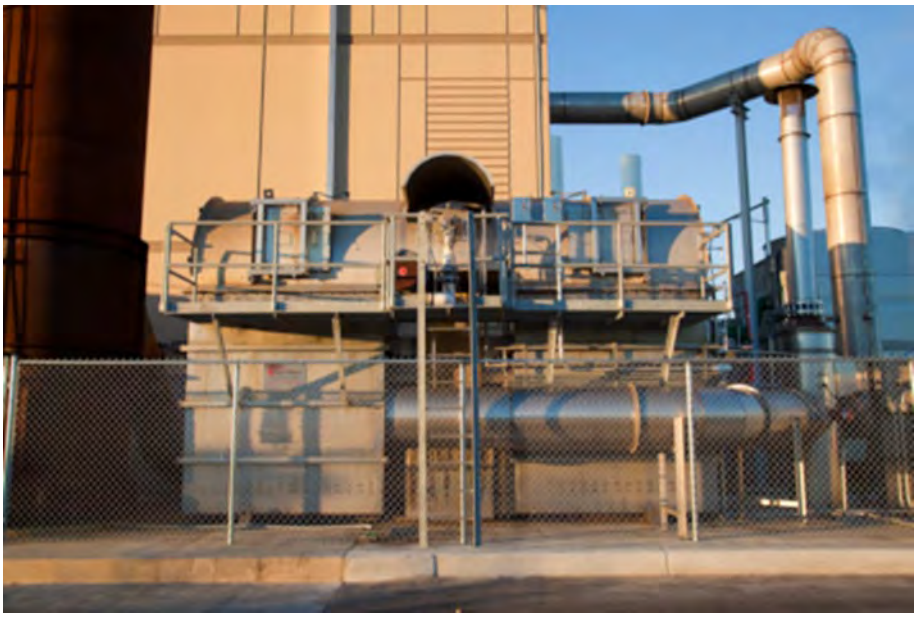

Figure 6. Regenerative Thermal Oxidizer

2.6 Pressure Boosting

Digester pressure is typically around 6 to as much as 20 inches of water column (in WC) or 0.2 to 0.7 psig. There are a wide range of pressure requirements for end use and for the associated treatment requirements described above that must be considered as part of a project. Depending on the technology used for biogas upgrading, a large range of pressure requirements are necessary to account for pressure losses through pipelines and the treatment system and achieve the required delivery pressure of the biogas equipment. Different RNG upgrading equipment technologies require a range between 100 and 250 psig for CO_2 removal. Typically, the upgrading equipment includes a compressor that can increase pressure necessary to the full requirement of that system. If there is pipeline injection, then it is also possible that an additional compressor would be needed to meet the requirement of the natural gas pipeline pressure for injection. Figure 7 shows an example of a biogas compression skid.

Figure 7. Biogas Compression Equipment Example

3.0 Biogas Upgrading Alternatives

With the recommended alternative of conditioning the biogas to be used as RNG off site, an additional analysis is needed to select the most appropriate carbon dioxide removal conditioning technology. There are three main types of biogas conditioning to produce RNG: membrane separation, pressure swing adsorption, and water wash scrubbing. The following sections provide additional descriptions of each technology followed by a life-cycle cost analysis to compare the three types and make a recommended selection for the Arlington WPCP.

3.1 Membrane Treatment

Membrane treatment systems consist of bundles of hollow membrane fibers fashioned together in canisters to remove carbon dioxide and other contaminants from the methane. The pores in the membrane fibers are sized to allow CO_2 molecules to pass through, while retaining the CH_4 molecules, as shown in Figure 8. Biogas is pressurized to 150 to 200 psig and conveyed through a series of canisters in a multi-pass configuration to improve CH_4 recovery and maintain a high CH_4 content in the product gas.

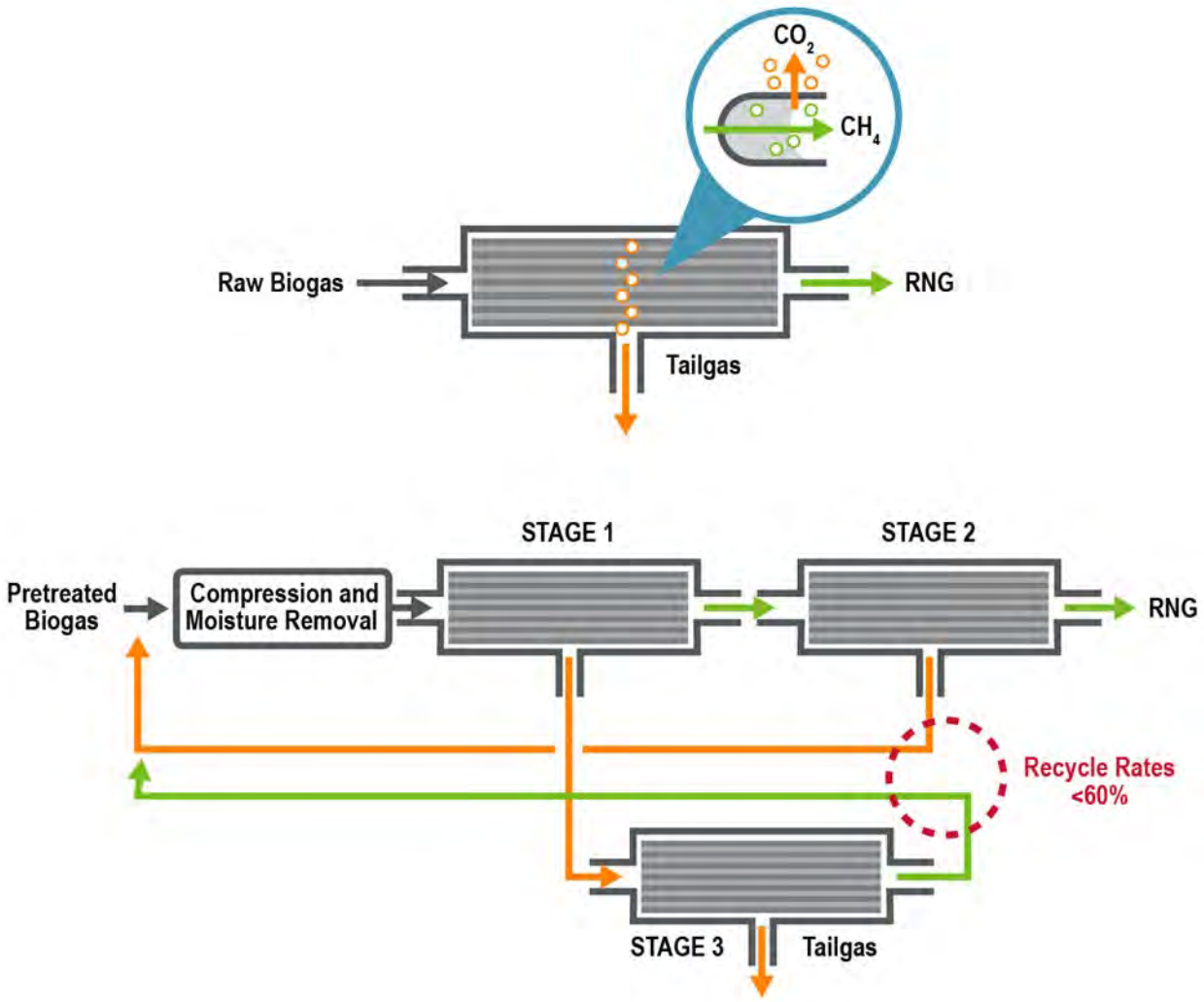

Figure 8. Membrane Treatment Schematic

Membrane systems must be used in combination with other technologies to remove hydrogen sulfide, siloxanes, moisture, and VOCs ahead of the membranes to protect the integrity of the fibers. The number of membrane filtration steps, or passes, determines the quality of the RNG and the methane recovery of the system. With additional membrane steps, higher finished gas quality is produced and/or more methane is captured from the waste tail gas stream. Gas typically passes through the membranes two to three times.

Currently, several companies manufacture membrane systems for installation in the United States: Unison Solutions, DMT Clear Gas Solutions, Greenlane Biogas, Air Liquide, and Pentair. A simplified schematic of a typical membrane system with mass balance is shown Figure 9. Figure 10 shows a photo of a typical membrane system installation.

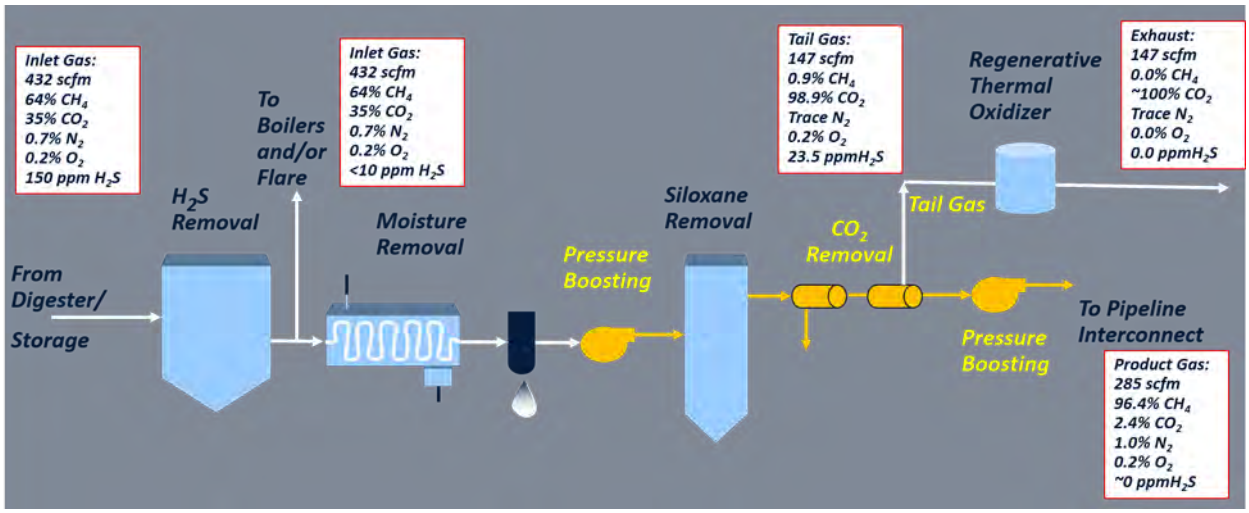

Figure 9. Membrane Treatment Process Flow Diagram

Figure 10. Typical Membrane Treatment Installation

3.2 Pressure Swing Adsorption

PSA systems remove hydrogen sulfide, carbon dioxide, and siloxanes in a single vessel by the adsorption of contaminants onto media under pressure (approximately 100 psig) and then regenerating the media under a vacuum. The systems operate with multiple pressure vessels so that the batch process of pressurizing the vessel, treating, and vacuum regeneration can be done while allowing for continuous operation. Figure 11 shows a schematic of the PSA treatment process. The systems are cost-effective; however, they typically have lower methane recovery rates (95 percent) compared to other gas upgrading systems being considered.

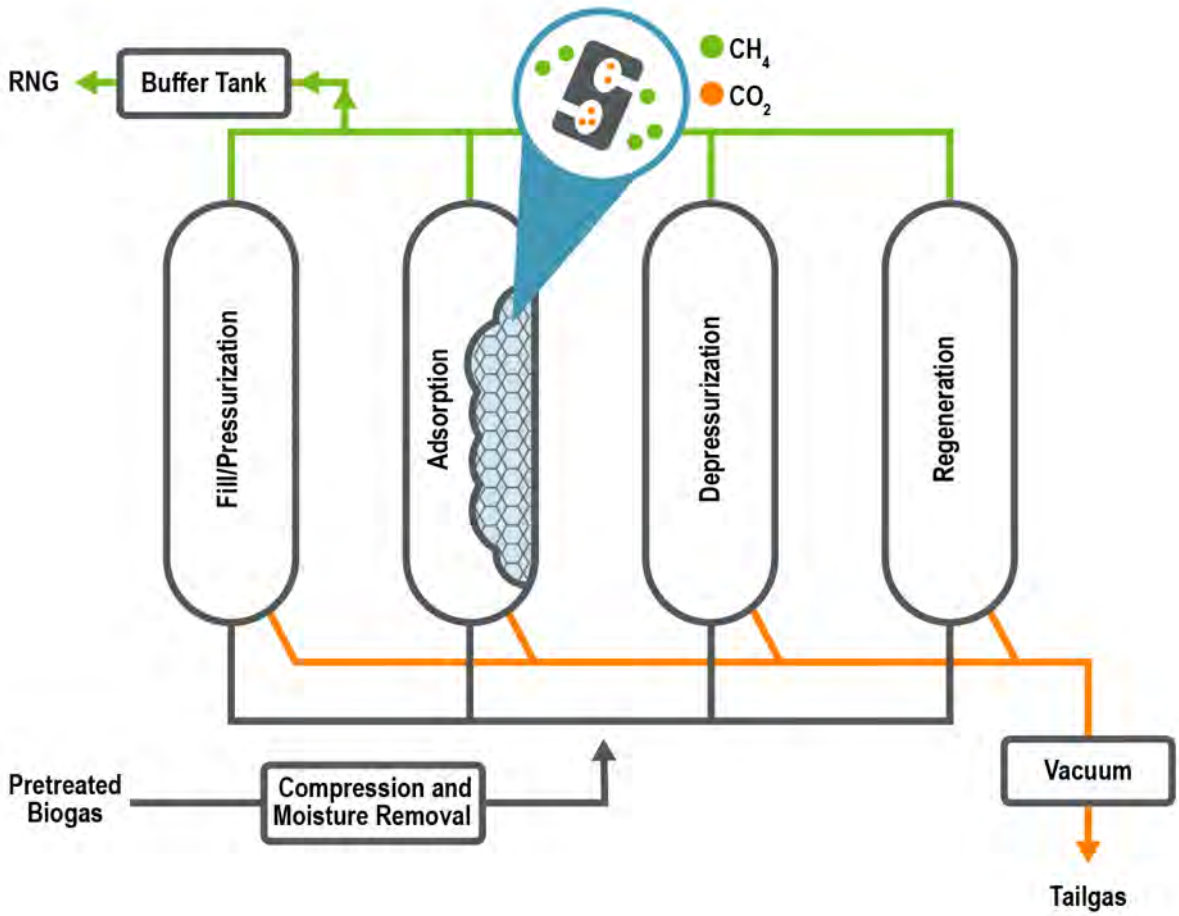

Figure 11. PSA Treatment Schematic

H_2S removal could occur upstream of the PSA or on the waste tail gas stream. The level of treatment provided will determine if an RTO or flare on the tail gas stream is needed to convert remaining hydrogen sulfide to sulfur oxides or if the stream can be vented to the atmosphere.

Currently, four companies manufacture PSAs for installation in the United States: Greenlane Biogas, Guild Associates, Xebec, and BioFERM. A simplified process flow diagram of a typical PSA system with mass balance is shown in Figure 12. Figure 13 shows a photo of a PSA system installation.

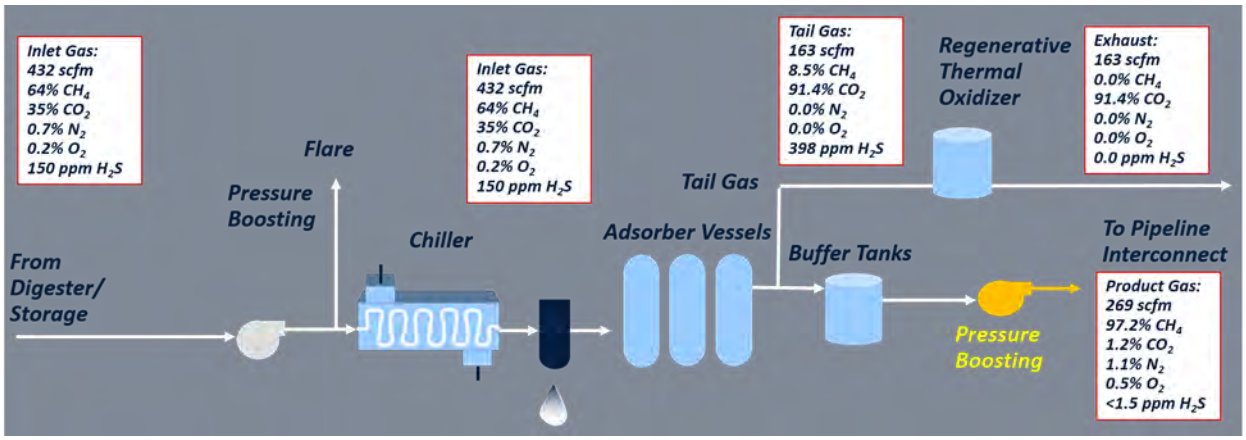

Figure 12. PSA Treatment Schematic

Figure 13. Typical PSA Installation

3.3 Water Wash Scrubber

The water wash, or water scrubber, treatment system dissolves carbon dioxide and other impurities in water to separate the CH_4 gas stream. Biogas compressed to approximately 150 psig enters the bottom of the scrubber vessel and flows upward through packing media as chilled water sprays downward. The carbon dioxide and other gas impurities (hydrogen sulfide, siloxanes, and VOCs) are dissolved in the water, the methane exits through the top of the scrubbing tower, and moisture is removed with a drier. The water, now saturated with carbon dioxide, is then depressurized in the flash tank, which operates as an intermediate step to release and recycle any methane that may have been absorbed in the water. The flash tank water is sent to the stripper vessel where pressure is lowest within the system. Lowering the pressure releases the carbon dioxide and contaminants into the tail gas waste stream. A schematic of the water wash treatment

process is shown in Figure 14. A defoaming, antimicrobial, and pH adjustment solution may be fed to the water wash system to improve performance.

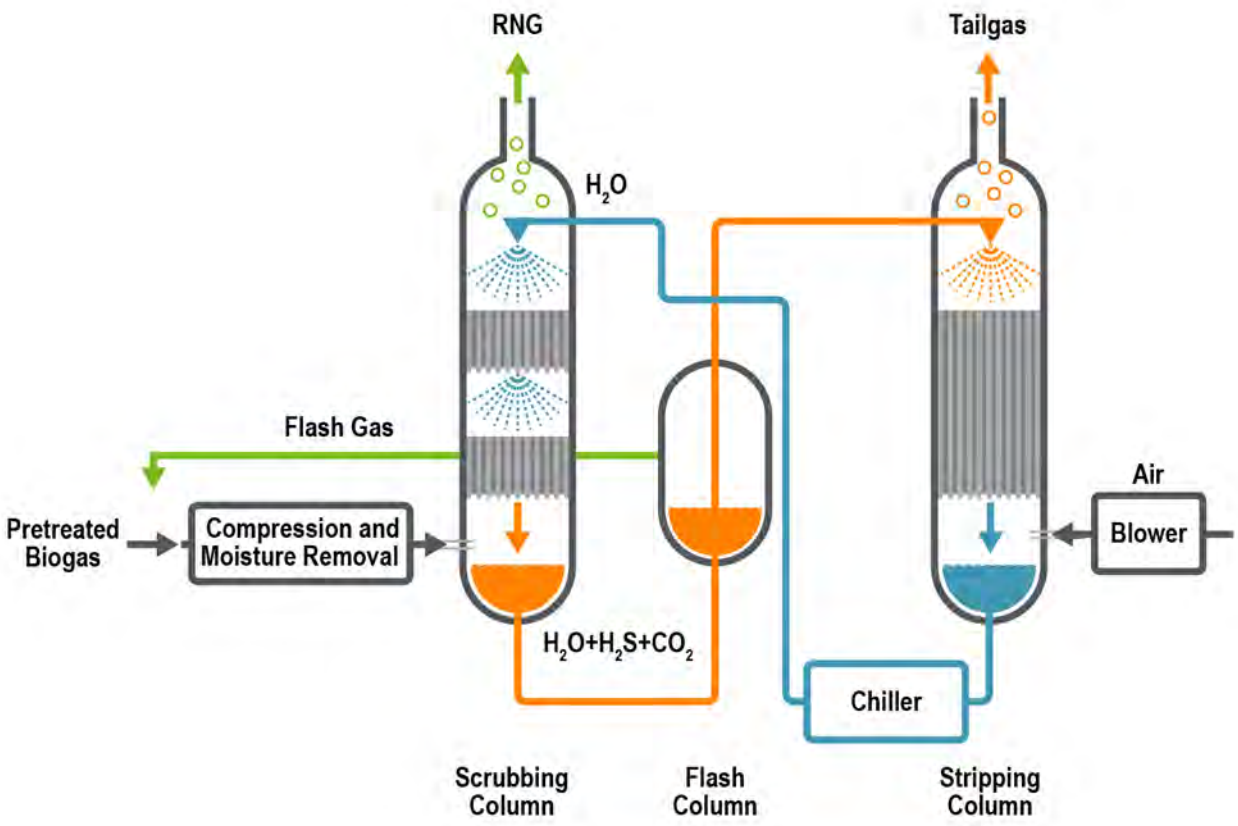

Figure 14. Water Wash Treatment

It should be noted that while the water wash systems remove hydrogen sulfide from the methane stream, the process does not actually treat it to a final product. The H_2S removal could occur upstream of the water wash process or on the waste tail gas stream. The level of treatment provided will determine if an RTO on the tail gas stream is needed to convert remaining hydrogen sulfide to sulfur oxides or if the stream can be vented to the atmosphere.

Water wash systems can achieve CH_4 recovery rates of up to 98 percent. However, this recovery rate drops when the system is operating below the designed best efficiency point.

Currently, two companies manufacture water wash systems for installation in the United States: Greenlane Biogas and Dürr Megtec. A simplified schematic of a typical water wash system with mass balance is shown in Figure 15. Figure 16 shows a photo of a water wash system installation.

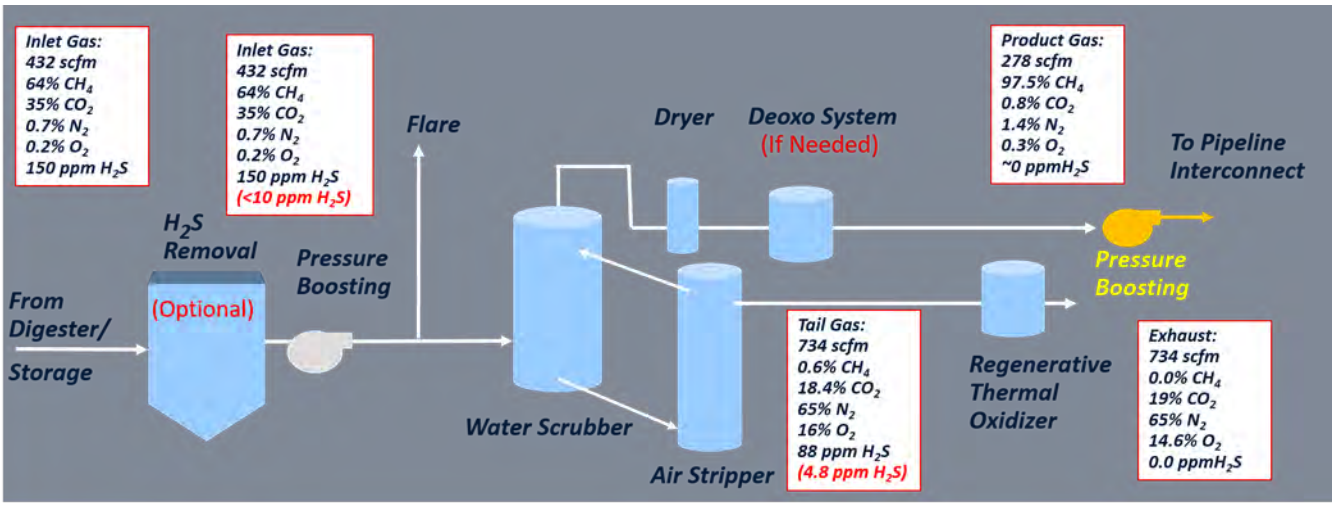

Figure 15. Water Wash System Process Flow Diagram

Figure 16. Typical Water Wash systems Installation
Source: HDR, Portland, Oregon.

4.0 Life-Cycle Cost Comparison

Similar to the gas utilization alternatives analysis, a life-cycle cost comparison was developed to evaluate and compare the three technologies from a capital and O&M cost basis.

4.1.1 Conceptual Capital Costs

Conceptual capital costs have been developed for each biogas conditioning alternative. Manufacturers for each equipment type were contacted for budgetary equipment pricing. The following multiplier percentages were used in the capital cost development:

- Electrical and instrumentation/controls: 28 percent
- Sitework/general civil: 15 percent
- Specialty piping: 5 percent
- Contractor general requirements (O&P, mobilization, etc.): 23 percent
- Contingency: 20 percent

No salvage or deep foundation costs or engineering, legal, and administrative costs are included in the cost estimates.

Capital costs are associated with the interconnection to the natural gas utility pipeline injection. These costs typically include the custody transfer station and the pipeline to the tie-in location. An estimated cost of $5 million is applied to all RNG injection alternatives and is based on preliminary feedback from the gas utility. This cost will be confirmed as additional discussions with the natural gas utility are conducted.

It is assumed that the natural gas pipeline will require post-treatment compression to 600 psig to inject RNG into the pipeline. Each pipeline injection alternative includes capital cost for this pressure increase. Each CO_2 removal technology discharges RNG at a different pressure, between 80 and 190 psig, so the compression needs vary for each alternative.

Capital costs for the conditioning alternatives are summarized in Table 3. The vendor quotes for each alternative are included in Appendix D.

Table 3. Biogas Conditioning Conceptual Capital Costs

Item		Membrane	PSA	Water Wash
Boilers		$0.60M	$0.60M	$0.60M
Building requirements		$2.45M	$2.45M	$2.45M
Pretreatment H_2S and siloxane removal		$0.50M	$0.00M	$0.00M
Inlet conditioning		$0.27M	$0.27M	$0.27M
CO_2 removal		$3.53M	$3.39M	$3.86M
Tail gas handling		$0.15M	$0.15M	$0.25M
Compression to delivery		$0.49M	$0.49M	$0.49M
Custody transfer station and pipeline		$5.00M	$5.00M	$5.00M
Total direct costs		$7.98M	$7.34M	$7.92M
Markups				
Electrical, instrumentation/controls	28%	$2.24M	$2.06M	$2.22M
Sitework	15%	$1.20M	$1.10M	$1.19M
Specialty piping	5%	$0.40M	$0.37M	$0.40M
Contingency	20%	$2.36M	$2.17M	$2.34M
Contractor general requirements	23%	$3.26M	$3.00M	$3.23M
Conceptual Capital costs		**$22.44M**	**$21.04M**	**$22.30M**
Compared to minimum		107%	100%	106%

4.2 O&M Costs

Similar to the capital costs, O&M costs have been estimated from vendor proposals, reference project experience, and the County's historical cost information. Anticipated O&M costs were developed and are presented in Table 4. Assumptions include costs related to operations labor, maintenance labor, labor parts, power requirements, water use, media replacement, and chemical costs. The common values used across all alternatives include the following:

- Power cost: $0.06/kWh
- Natural gas cost: $0.85/therm
- Operations labor: $80/hr
- Maintenance labor: $60/hr

Annual O&M cost summaries for the conditioning alternatives are provided in Table 4.

Table 4. Annual Biogas Conditioning O&M Costs at Start-up

Item	Membrane	PSA	Water Wash
Pretreatment H_2S and siloxane removal	$29,700	$0	$0
Inlet conditioning	$25,900	$25,900	$25,900
CO_2 removal	$237,500	$197,000	$252,600
Tail gas H_2S treatment	$0	$0	$0
Tail gas handling	$12,000	$12,000	$12,900
Compression to delivery	$17,900	$17,900	$17,900
Total O&M	**$323,000**	**$252,800**	**$309,300**
Total O&M $/MMBtu	**$2.45**	**$1.91**	**$2.34**

The membrane system has the highest annual O&M cost of the three options because of the higher power requirements and also media costs associated with H_2S and siloxane removal systems.

4.3 Present Values

The net present financial values for each technology option were calculated using the same heating requirements, biogas production quantities, annual costs, and financial assumptions as Alternatives 3A and 3B presented in Chapters 04 and 05 of the Arlington Re-Gen Biogas Utilization Report. These included the same WPCP energy costs for electricity and natural gas, O&M inflation, discount rate, and planning period.

Table 5 presents the present financial values for Alternatives 1, 3A, and 3B for each of the biogas conditioning technologies. The present financial values are presented for a range of RIN market values from $5/RIN to $35/RIN. The main differences between the options are the specific capital and O&M costs presented above as well as the methane capture for each of the technologies.

This analysis shows that the PSA technology has the lowest net present financial value as compared to the membrane and water wash system. This is mostly due to the difference in capital costs and slightly lower O&M costs for the PSA system. Even with the higher percentage methane capture for membranes and water wash, the difference in capital and O&M cannot be overcome through RNG revenue.

Table 5. Net Financial Values, $M

Item	Membrane	PSA	Water Wash
Conceptual Capital Cost	$22.4M	$21.0M	$22,3M
Annual Operating and Maintenance Costs	($0.32M)	($0.25M)	($0.31M)
Annual RIN Revenue at $15/MMBtu	$1.85M	$1.78M	$1.84M
Total Net Present Value	$3.46M	$1.92M	$3.32M

4.4 Summary

Overall, the three biogas conditioning technologies are very comparable in present value and performance; however, some differences should be discussed before the final decision is made.

Table 6 presents these differences graphically. The membrane system has the highest capital and O&M costs, but also the highest methane capture while the PSA has the lowest capital and O&M costs and the lowest methane capture. From an uptime perspective, all the technologies are similar. The PSA equipment will likely by louder and will not have the flexibility to simply add CHP in the future (additional pre-treatment would be required). The noise production of the PSA will be evaluated as part of the future site visits. Water wash has similar challenges and also will be less aesthetically pleasing because of its height, and tail gas management would be more costly because of higher gas flows. Membranes will be similar to or better than PSA and water wash in all of these categories.

Table 6. Technology Comparison

Criterion	Membranes	PSA	Water Wash
Capital cost	↑	↓	↑
O&M cost	↑	↓	↓
Methane capture	↑	↓	↑
Uptime	↔	↔	↔
Noise	↓	↑	↓
Aesthetics	↑	↑	↓
Flexibility for future CHP	↑	↓	↓
Tail gas management	↑	↑	↓

5.0 Recommended Alternative

Based on the analysis presented, it was recommended that the Program continue to pursue all three biogas treatment technologies until more understanding of the day-to-day operations and maintenance can be obtained. This was accomplished with additional discussions with the equipment vendors and site visits to existing installations to see the equipment in person and talk to O&M staff who have experience with the equipment options. Recommended next steps for the biogas utilization equipment selection included:

- Schedule technical brown bag sessions with equipment suppliers for the membrane, water wash, and PSA conditioning systems. This next step is currently in progress and potential dates and times are being discussed. *These technical brown bag sessions were conducted over three lunch and learn sessions in October 2021.*
- Identify potential facilities to perform in-person site visits. The equipment suppliers have provided lists of relevant installations, but additional facilities are currently being identified. A preliminary list of facilities that are being considered is shown in Table 7. The site visits should have relevance to the Arlington WPCP

where biogas from domestic wastewater digestion is conditioned to natural gas quality. Facilities of similar size and biogas conditioning capacity will be preferred.

- Schedule and perform site visits. It is anticipated that this will occur sometime in late 2021 or early 2022 depending on COVID-19 protocols. *Site visits to representative installations were conducted in October 2022.*
- Select a technology for implementation based on the results of the vendor discussions, site visits, and further refinement of the WPCP requirements as part of the Program.

Based on the results of this analysis, lessons learned from vendor presentations and discussions with operations and maintenance staff during site visits at representative installations, the preferred biogas treatment technology for implementation at the WPCP is membrane separation. The final technology and manufacturer selection will be determined during the detailed design phase of the Program.

Table 7. Technology Installation Lists

Water Wash (Greenlane)	PSA (Guild)	Membrane (Unison/Air Liquide)
Fair Oaks, Indiana (manure)	San Antonio, Texas (muni)	Atlanta, Georgia (LFG)
Perris, California	Dayton, Ohio (muni)	Pittsburgh, Pennsylvania (LFG)
Canton, Michigan	Newark, Ohio (muni)	Waste Management (LFG: multiple locations)
Weld County, Colorado (manure, food waste)	Des Moines, Iowa (muni)	Avondale, Louisiana (LFG)
Portland, Oregon (muni) startup end of 2021		Lincoln, Nebraska (muni)

ARLINGTON RE-GEN

Appendix C

Draft Sustainability Management Plan Outline

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DRAFT SUSTAINABILITY MANAGEMENT PLAN

HDR

April 25, 2022

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